

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

**EVALUATION OF IASI NH₃ LEVELS IN THE EASTERN MEDITERRANEAN
REGION**



M.Sc. THESIS

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Department of Environmental Engineering

Environmental Sciences Engineering and Management Programme

JULY 2025

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

**DOĞU AKDENİZ BÖLGESİNDE İAŞI NH₃ SEVİYELERİNİN
DEĞERLENDİRİLMESİ**

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To all who lit my way...



FOREWORD

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ABBREVIATIONS

AQMSs	: Air Quality Monitoring Stations
CALIOP	: Cloud-Aerosol Lidar with Orthogonal Polarization
CALIPSO	: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CLC	: CORINE Land Cover
CO	: Carbon monoxide
DEM	: Digital Elevation Map
DEM	: Digital Elevation Map
EPA	: Environmental Protection Agency
ESA	: European Space Agency
FRP	: Fire Radiative Power
ha	: Hectare
HCHO	: Formaldehyde
IASI	: Infrared Atmospheric Sounding Interferometer
km	: Kilometer
METOP	: Meteorological Operational Satellite
MoEUCC	: Ministry of Environment, Urbanization and Climate Change
MS	: Meteorological Station
MW	: MegaWatt
NH₃	: Ammonia
NO	: Nitrogen oxide
NO₂	: Nitrogen dioxide
NO_x	: Nitrogen oxides
HNO₃	: Nitric Acid
H₂SO₄	: Sulfuric Acid
(NH₄)₂SO₄	: Ammonium Sulphate
NH₄NO₃	: Ammonium Nitrate
UV	: Ultraviolet
VIS	: Visible
NIR	: Near-Infrared
SWIR	: Shortwave Infrared
O₃	: Ozone
P	: Precipitation

PM	: Particulate Matter
RB	: Residue Burning
WF	: Wildfire
RH	: Relative Humidity
T	: Temperature
CrIS	: Cross-track Infrared Sounder
EMEP	: the European Monitoring and Evaluation Programme
SCR	: Selective Catalytic Reduction
SNCR	: Selective non-Catalytic Reduction
BB	: Biomass Burning
TFIM	: Trajectory-fire interception method
TROPOMI	: TROPOspheric Monitoring Instrument
TSMS	: Turkish State Meteorological Service
TUIK	: Türkiye Statistical Institute
VIIRS	: Visible Infrared Imaging Radiometer Suite
VOC	: Volatile Organic Compound
WD	: Wind Direction
WS	: Wind Speed
VFM	: Vertical Feature Mask

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EVALUATION OF IASI NH₃ LEVELS IN THE EASTERN MEDITERRANEAN REGION

SUMMARY

Air pollution is a growing environmental problem due to its impact on both climate change and public health with increasing population, industrial activity, and agricultural intensification, atmospheric pollutants continue to rise, making effective monitoring more critical than ever. Among these pollutants, ammonia (NH₃) remains under-regulated despite its substantial role in air quality degradation and secondary particulate matter (PM) formation. NH₃ is an alkaline gas that reacts with atmospheric acids such as nitric acid (HNO₃) and sulfuric acid (H₂SO₄) which can contribute to the formation of ammonium nitrate (NH₄NO₃) and ammonium sulfate ((NH₄)₂SO₄) contributing to secondary inorganic aerosols (SIA). These compounds make up a significant portion of secondary fine particulate matter (PM_{2.5}) in atmosphere, which is associated with adverse health effects and contributes to radiative forcing.

Agriculture is known as the leading contributor to global atmospheric NH₃ emissions, primarily from agricultural activities and animal husbandry, such as livestock housing, manure handling, application of manure and synthetic nitrogen-based fertilizers to land. Beyond agriculture, industrial activities such as fertilizer and soda ash production, as well as NO_x reduction processes, also emit NH₃. Furthermore, waste management and wastewater treatment systems are additional contributors as well. Biomass burning (BB), which includes wildfires and agricultural residue burning, is another notable source, especially during the smoldering stage of combustion, where NH₃ is released alongside CO and other fire-related pollutants.

NH₃ has been studied using both ground-based and satellite-based approaches. While ground-based measurements provide detailed temporal analyses, satellite retrievals from Infrared Atmospheric Sounding Interferometer (IASI) made it possible to identify global NH₃ hotspots and major point sources, especially those related to agricultural and industrial activities. Beyond these well-known sources, BB has been recognized as an important episodic contributor to atmospheric NH₃ levels. Several global studies have identified increases in NH₃ levels during wildfire events, along with other co-emitted air pollutants such as CO. These studies have reported NH₃ peaks via satellite observations, fire-period enhancement ratios, and short-term increases in total column concentrations.

However, although BB-related NH₃ emissions have been investigated in global studies, research specific to Türkiye remains limited. While some national and regional studies have addressed NH₃ pollution using satellite observations, the link between BB and NH₃ has not yet been comprehensively examined. This gap is particularly important for the Eastern Mediterranean Region, where BB is a common event due to both the increasing frequency of wildfires driven by climate change, and the widespread practice of agricultural residue burning, despite being officially banned. Therefore, this region represents a critical area for investigating NH₃ enhancements associated with BB.

In this thesis, satellite-based retrievals of NH_3 and CO from IASI and NO_2 , HCHO, and CO from TROPOMI, and the Fire Radiative Power (FRP) product from Visible Infrared Imaging Radiometer Suite (VIIRS) were used to investigate the relationship between BB events and atmospheric NH_3 in the Eastern Mediterranean Region of Türkiye. The study focused on quantifying NH_3 enhancement ratios during selected BB episodes and sub-regions via fire-related co-emitted pollutants, including IASI-CO and TROPospheric Monitoring Instrument (TROPOMI) TROP- NO_2 , TROP-CO, and TROP-HCHO. Additionally, potential marine impacts were assessed through chlorophyll-a retrievals from (Global Change Observation Mission) GCOM-C over the Mediterranean Sea to investigate the influence of BB-related smoke deposition.

The analysis of IASI- NH_3 retrievals from 2012 to 2023 over the Eastern Mediterranean region showed consistently high concentrations in coastal provinces such as Mersin and Adana, and relatively elevated levels in Antalya. Seasonal distributions revealed NH_3 peaks during spring and summer ($>2 \times 10^{16}$ molecules/ cm^2), particularly in agricultural areas such as Silifke, Karatas, and central Mersin, suggesting strong links to seasonal agricultural activity. In fall, elevated NH_3 levels were also observed, which were further investigated in relation to BB events. Both spatial distributions and time series analysis showed increasing NH_3 levels over the years, and Mann Kendall trend analysis confirmed these patterns with statistically significant increases in all provinces. This long-term trend analysis revealed that NH_3 levels increased more rapidly in agricultural zones compared to overall region. Adana showed the highest trend slope in agricultural areas (1.74×10^{14} molecules/ cm^2 /year). Similar trends were detected in Antalya, Hatay, and Mersin and the slope for agricultural areas nearly twice the overall trend. Further, to understand the relationship between NH_3 and meteorological parameters, correlation analyses were conducted for monthly average temperature (T) and total precipitation (P) in study area ($p < 0.001 = ***$, $p < 0.01 = **$, $p < 0.05 = *$). The results showed strong positive correlations between NH_3 and T in both land types. In agricultural areas, the correlation was $r = 0.93***$ for Mersin, $r = 0.87***$ for Adana, and $r = 0.96***$ for Antalya. Over artificial surfaces, similarly strong correlations were observed: $r = 0.93***$ for Mersin, $r = 0.93***$ for Adana, and $r = 0.96***$ for Antalya. Further, NH_3 and P was negatively correlated. In agricultural areas, the correlation was $r = -0.91***$ for Mersin, $r = -0.84***$ for Adana, and $r = -0.86***$ for Antalya. In artificial surfaces, the negative correlation remained strong: $r = -0.92***$ for Mersin, $r = -0.84***$ for Adana, and $r = -0.87***$ for Antalya. These negative correlations with P were likely mostly related to NH_3 removal via wet deposition or impact on partitioning of NH_3 in soil, while the strong positive correlations with T highlight the role of NH_3 volatilization.

In 2021, when large-scale wildfires occurred in Mersin, Antalya, and Mugla, NH_3 concentrations during the defined fire period (28 July-7 August) were 94% higher than the pre-fire (18-27 July) period and 146% higher than the post-fire (08-17 August) period which this indicates an enhancement of NH_3 related to BB. Then, subregions were selected for wildfire regions (WF) based on total grid-based FRP according to 2021 wildfire time interval. In the study area, 2 subregions for Antalya-AN (AN-1 and AN-2) and Mersin-ME (ME-1 and ME-2) and 4 subregions for Mugla (MU-1 to MU-4) selected. Based on the sub-regional analysis for the wildfire regions, NH_3 enhancements were observed in all selected region especially in AN-1 and AN-2 regions which NH_3 levels during the fire period increased by 308% and 594% compared to the pre-fire and post-fire periods, respectively. Similar patterns were also found in co-emitted pollutants, especially TROP- NO_2 and TROP-HCHO, with increases exceeding 100% in most regions. For instance, in AN-1, NO_2 rose by 77% (pre-fire) and 103% (post-fire), while HCHO increased by 105% and 128%. The enhancement ratios of NH_3 to co-emitted pollutants during the fire period were notably higher than pre-fire and post-fire periods in most WF region, especially in AN-1, AN-2, and MU-3. For instance, in AN-1, the NH_3/NO_2 ratio increased from 7.51 (pre-fire)

to 16.96 (fire), and in MU-3, it rose sharply from 11.08 to 56.04 which these results indicated a significant contribution of BB event to NH_3 emissions relative to other pollutants. For NH_3 to CO ratios, a similar pattern was observed. In AN-1, the $\text{NH}_3/\text{IASI-CO}$ ratio increased from 0.0041 to 0.0094, and the $\text{NH}_3/\text{TROP-CO}$ ratio increased from 0.0042 to 0.0104, which both doubled during the fire period.

For the analysis of residue burning (RB) subregions were determined based on the cumulative grid-based FRP levels over a five-year period (2019-2023). Sub-regional analyses were conducted for Adana-Osmaniye (Ad-Os), Mersin-Adana (Me-Ad), and Hatay (Ha) with focused on two different fire-affected time intervals. For the Ad-Os region (RB-1), a longer fire period was defined from 15 August to 15 November 2020, with pre-fire and post-fire periods define as 5-14 August and 16-25 November 2020, respectively. For Me-Ad and Ha (RB-2), the fire period was defined as 15 August-30 September 2020, with pre-fire and post-fire periods define as 5-14 August and 1-10 October 2020, respectively. In Ad-Os region, noticeable NH_3 increases were detected during the RB-1 fire period, with a 43% rise compared to the post-fire period. In Me-Ad, although overall enhancements were not as strong as in wildfire regions, NH_3 increased by 20% during the RB-2 fire period compared to post-fire. In Ha region, NH_3 showed a 56% increase from pre to fire RB-2 period which mostly Ha did not stand out in NH_3 distribution. These increases highlight the importance of fire-related NH_3 enhancements in local areas. These results indicated that even in the absence of intense wildfire activity, agricultural residue burning could elevate NH_3 levels in the region.

Further, when the impact of the 2021 wildfires on the marine environment was examined during the wildfire period, a significant increase in chlorophyll-a concentrations was observed in the downwind direction of the wildfire plume over the Mediterranean Sea. The maximum enhancement reached 553.6% from the pre-fire to fire period, with a mean increase of 98.5% and from the post-fire to fire period, the maximum increase was 568.9%, and the mean increase was 87.5%. These findings suggest that nitrogen deposition from wildfire smoke may have influenced phytoplankton growth in the Mediterranean. Further, the same analyses were conducted for the RB regions. However, unlike the WF regions, no clear increases were observed, except for localized enhancements along the coastal areas of the Me-Ad RB region.

Overall, this thesis showed that BB-related NH_3 enhancements are evident across the Eastern Mediterranean with co-emitted pollutants, especially during the 2021 wildfires. Moreover, the observed changes in chlorophyll-a concentrations highlight that large-scale BB events not only affect air quality but may also have broader environmental impacts through atmospheric deposition to the Mediterranean Sea.



DOĞU AKDENİZ BÖLGESİNDE İASI NH₃ SEVİYELERİNİN DEĞERLENDİRİLMESİ

ÖZET

Hava kirliliği, artan nüfus, sanayi faaliyetleri ve tarımsal aktivelerin artması nedeniyle hem iklim değişikliği hem de halk sağlığı üzerindeki etkileriyle büyüyen bir çevresel sorun haline gelmiştir. Atmosferik kirleticilerin seviyeleri yükselmeye devam etmekte olup, bu durum etkin izlemeyi her zamankinden daha kritik hale getirmektedir. Bu kirleticiler arasında, amonyak (NH₃), hava kalitesinin bozulması ve ikincil partikül madde (PM) oluşumundaki önemli rolüne rağmen hala yeterince düzenlenmemektedir. NH₃, nitrik asit (HNO₃) ve sülfürik asit (H₂SO₄) gibi atmosferik asitlerle reaksiyona giren alkali bir gazdır ve bu reaksiyonlar sonucunda amonyum nitrat (NH₄NO₃) ve amonyum sülfat ((NH₄)₂SO₄) gibi ikincil inorganik aerosol (SIA) bileşikleri oluşur. Bu bileşikler, atmosferdeki ikincil ince partikül maddelerin (PM_{2.5}) önemli bir kısmını oluşturarak sağlık üzerinde olumsuz etkilere ve radyatif zorlamaya katkıda bulunmaktadır.

Gübre yönetimi, organik ve sentetik azot bazlı gübrelerin araziye uygulanması gibi tarımsal faaliyetler ve hayvancılık faaliyetleri küresel atmosferik NH₃ emisyonlarının başlıca kaynağıdır. Tarımın ötesinde, gübre ve soda üretimi gibi endüstriyel faaliyetler ile NOX emisyon azaltım teknolojileri de NH₃ salımına neden olmaktadır. Ayrıca, atık yönetimi ve atık su arıtma sistemleri de NH₃'ün diğer kaynaklarındandır. Biyokütle yanması (BKY) orman yangınları ve tarımsal artık yakımı dahil özellikle yanmanın korlaşma evresinde CO ve diğer yangın kaynaklı kirleticilerle birlikte NH₃ salımına neden olan bir başka önemli kaynaktır.

NH₃ kirleticisi hem yer tabanlı hem de uydu tabanlı yöntemlerle araştırılmıştır. Yer tabanlı ölçümler zamansal analizlerde ayrıntılı bilgi sağlarken, Kızılötesi Atmosferik Sesleme Interferometresi (IASI) aracılığıyla elde edilen uydu verileri, küresel NH₃ yoğunluk bölgelerinin ve büyük noktasal kaynakların, özellikle tarım ve sanayi kaynaklı olanların, tespit edilmesine imkan sağlamıştır. Bu iyi bilinen kaynakların yanı sıra, BKY atmosferik NH₃ seviyelerine önemli bir epizodik katkı sağlayan bir unsur olarak tanımlanmıştır. Birçok küresel çalışma, yangın dönemlerinde NH₃ seviyelerinde artış ve beraber yayılan CO gibi diğer kirleticilerle birlikte uydu verileriyle zirve değerleri, yangın dönemi artış oranları ve kısa süreli toplam kolon konsantrasyonu artışlarını raporlamıştır.

Ancak BKY kaynaklı NH₃ emisyonları küresel düzeyde çalışılmış olmasına rağmen, Türkiye özelinde yapılan araştırmalar sınırlıdır. Uydu verileriyle NH₃ kirliliğini inceleyen bazı ulusal ve bölgesel çalışmalar bulunsa da BKY ile NH₃ arasındaki ilişki henüz kapsamlı şekilde incelenmemiştir. Bu, özellikle iklim değişikliğine bağlı olarak artan orman yangınları ve yasak olmasına rağmen yaygın olarak uygulanan tarımsal artık yakımı nedeniyle BKY'nin sık görüldüğü Doğu Akdeniz Bölgesi için kritik önem taşımaktadır. Bu nedenle, bölge BKY kaynaklı NH₃ artışlarının incelenmesi açısından önemli bir bölgedir.

Bu tezde, Türkiye'nin Doğu Akdeniz Bölgesi'nde BKY olayları ile atmosferik NH_3 arasındaki ilişkiyi araştırmak amacıyla, IASI'den elde edilen NH_3 ve CO ile TROPOMI'den elde edilen NO_2 , HCHO ve CO uydu verileri ile birlikte VIIRS (Visible Infrared Imaging Radiometer Suite) kaynaklı Yangın Radyatif Gücü (FRP) verisi kullanılmıştır. Seçilen yangın olayları ve alt bölgeler için NH_3 artış oranları, IASI-CO ve TROPOMI-TROP- NO_2 , TROP-CO ve TROP-HCHO gibi beraber yayılan kirleticiler üzerinden incelenmiştir. Ayrıca, yangın dumanının denize taşınmasının potansiyel etkisini değerlendirmek üzere, Akdeniz üzerinde Global Change Observation Mission (GCOM-C) uydusundan elde edilen klorofil-a verileri kullanılarak deniz ortamına etkileri analiz edilmiştir.

2019-2023 yılları arasındaki IASI NH_3 verilerinin analizi, Mersin ve Adana gibi kıyı illerinde sürekli yüksek NH_3 konsantrasyonları ve Antalya'da göreceli olarak yüksek seviyeler gözlemlenmiştir. Mevsimsel dağılımlar özellikle tarımsal alanlarda (örneğin Silifke, Karataş ve Mersin merkezi) ilkbahar ve yaz aylarında ($>2 \times 10^{16}$ molekül/ cm^2) yüksek NH_3 seviyeleri olduğunu ortaya koymuştur. Sonbaharda da yüksek NH_3 seviyeleri gözlemlenmiş ve bunlar BKY olaylarıyla ilişkilendirilmiştir. Hem mekansal dağılımlar hem de zaman serisi analizleri, yıllar içinde NH_3 seviyelerinde bir artış olduğunu göstermiştir ve Mann Kendall trend analiz sonuçları bu artışların tüm illerde istatistiksel olarak anlamlı ve artan eğilimde olduğunu doğrulamıştır. Bu trend analizi, NH_3 seviyelerinin tarım alanlarında genel bölgeye kıyasla daha çok arttığını ortaya koymuştur. Adana ili, tarımsal alanlar içinde en yüksek trend eğimine sahip olup bu değer 1.74×10^{14} molekül/ cm^2 /yıl olarak hesaplanmıştır. Benzer eğilimler Antalya, Hatay ve Mersin'de de gözlemlenmiştir ve tarım alanlarındaki eğim genel eğimin neredeyse iki katı olduğu bulunmuştur. Ayrıca, NH_3 ile meteorolojik parametreler arasındaki ilişkiyi anlamak amacıyla çalışma alanında aylık ortalama sıcaklık (T) ve toplam yağış (P) için korelasyon analizleri yapılmıştır ($p < 0.001=***$, $p < 0.01=**$, $p < 0.05=*$). Sonuçlar, NH_3 ile T arasında tüm arazi türlerinde güçlü pozitif ilişki olduğunu göstermiştir. Tarım alanlarında bu ilişki Mersin için $r = 0.93***$, Adana için $r = 0.87***$, Antalya için $r = 0.96***$ olarak bulunmuştur. Yapay alanlarda da benzer şekilde güçlü korelasyonlar gözlemlenmiştir. Mersin için $r = 0.93***$, Adana için $r = 0.93***$, Antalya için $r = 0.96***$. Buna ek olarak, NH_3 ile P arasında negatif ilişki tespit edilmiştir. Tarım alanlarında bu korelasyon Mersin için $r = -0.91***$, Adana için $r = -0.84***$, Antalya için $r = -0.86***$ şeklinde belirlenmiştir. Yapay alanlarda da negatif güçlü bir ilişki olduğu görülmüştür. Mersin için $r = -0.92***$, Adana için $r = -0.84***$, Antalya için $r = -0.87***$. P ile olan bu negatif korelasyonların büyük ölçüde NH_3 'ün ıslak çökeltme yoluyla atmosferden uzaklaştırılması ya da toprakta faz dağılımı üzerindeki etkisiyle ilişkili olduğu düşünülmektedir. Öte yandan, T ile olan güçlü pozitif ilişki gaz fazına geçiş etkisini vurgulamaktadır.

2021 yılında Mersin, Antalya ve Muğla'da meydana gelen büyük ölçekli orman yangınlarında, yangın dönemindeki (28 Temmuz-7 Ağustos) NH_3 seviyeleri, yangın öncesi döneme (18-27 Temmuz) göre %94, yangın sonrası döneme (8-17 Ağustos) göre ise %146 daha yüksekti. Bu da BKY ile ilişkili bir NH_3 artışına işaret etmektedir. Ardından, 2021 yılı yangın zaman aralığına göre toplam grid tabanlı FRP'ye dayanarak yangın bölgeleri (WF) için alt bölgeler seçildi. Çalışma alanında, Antalya (AN-1 ve AN-2) için 2, Mersin (ME-1 ve ME-2) için 2 ve Muğla (MU-1'den MU-4'e) için 4 alt bölge belirlendi. Yangın alt bölgelerinde yapılan analizlerde, özellikle AN-1 ve AN-2 bölgelerinde yangın döneminde NH_3 seviyelerinde sırasıyla %308 ve %594'lük artışlar gözlemlenmiştir. Benzer şekilde, TROP- NO_2 ve TROP-HCHO gibi yangınla birlikte salımı gerçekleşen kirleticilerde de çoğu bölgede %100'ü aşan artışlar kaydedilmiştir. Örneğin, AN-1'de NO_2 seviyesi yangın öncesine göre %77, yangın sonrasına göre %103 artarken HCHO %105 ve %128 artmıştır. NH_3 'ün birlikte salımı gerçekleşen kirleticilere oranı yangın döneminde belirgin şekilde artmıştır. Örneğin, AN-1 bölgesinde NH_3/NO_2 oranı yangın öncesinde 7.51 iken yangın döneminde 16.96'ya, MU-3'te ise 11.08'den 56.04'e yükselmiştir. Bu da NH_3 emisyonlarına

BKY'nin görece katkısını açıkça göstermektedir. NH_3/CO oranları için benzer bir oran gözlemlenmiştir. AN-1 bölgesinde, $\text{NH}_3/\text{IASI-CO}$ oranı 0.0041'den 0.0094'e, $\text{NH}_3/\text{TROP-CO}$ oranı ise 0.0042'den 0.0104'e yükselmiştir ki her iki oran da yangın döneminde yangın öncesine göre iki katına çıkmıştır.

Anız yakılması analizleri kapsamında, 2019-2023 yılları arasındaki beş yıllık dönemdeki kümülatif grid bazlı FRP seviyelerine göre alt bölgeler tanımlanmış ve Adana-Osmaniye (Ad-Os), Mersin-Adana (Me-Ad) ile Hatay (Ha) bölgeleri özelinde değerlendirmeler yapılmıştır. Her bir bölge için yangından etkilenmiş iki farklı zaman aralığına odaklanılmıştır. Ad-Os bölgesi (RB-1) için yangın dönemi 15 Ağustos-15 Kasım 2020 olarak tanımlanmış, yangın öncesi dönem 5-4 Ağustos 2020, yangın sonrası dönem ise 16-25 Kasım 2020 olarak belirlenmiştir. Me-Ad ve Ha bölgeleri (RB-2) için yangın dönemi 15 Ağustos-30 Eylül 2020, yangın öncesi dönem 5-14 Ağustos 2020, yangın sonrası dönem ise 1-10 Ekim 2020 olarak tanımlanmıştır. Ad-Os bölgesinde, RB-1 yangın döneminde NH_3 seviyelerinde dikkat çekici artışlar gözlemlenmiştir ve yangın sonrası döneme kıyasla %43'lük bir artış tespit edilmiştir. Me-Ad bölgesinde ise genel artışlar orman yangını bölgelerinde gözlenen kadar belirgin olmasa da, NH_3 seviyeleri RB-2 yangın döneminde yangın sonrasına göre %20 artış göstermiştir. Ha bölgesinde ise NH_3 , RB-2 yangın döneminde yangın öncesine göre %56 oranında artmıştır, bu durum Ha bölgesinin NH_3 dağılımında genellikle öne çıkmamasına rağmen dikkat çekmiştir. Bu artışlar, yangına bağlı NH_3 artışlarının yerel ölçekteki önemini vurgulamaktadır. Elde edilen sonuçlar, yoğun orman yangını faaliyetleri olmasa dahi, tarımsal atık yakılmasının bölgedeki NH_3 seviyelerini yükseltebileceğini göstermektedir.

Ayrıca, 2021 yangınlarının deniz ortamına etkisi değerlendirildiğinde, yangın dumanının rüzgar altı yönünde Akdeniz üzerinde klorofil-a konsantrasyonlarında belirgin artışlar gözlenmiştir. Yangın öncesine göre maksimum artış %554, ortalama artış %99; yangın sonrasına göre maksimum artış %569, ortalama artış %55 olarak belirlenmiştir. Bu bulgular, yangın kaynaklı duman yoluyla taşınan azotun fitoplankton büyümesini etkilemiş olabileceğini göstermektedir. Ayrıca, aynı analizler RB bölgeleri için de gerçekleştirilmiştir. Ancak, WF bölgelerinin aksine, belirgin artışlar gözlemlenmemiştir, yalnızca Me-Ad RB bölgesinin kıyıya yakın kesimlerinde yerel artışlar tespit edilmiştir.

Genel olarak, bu tez BKY ile ilişkili NH_3 artışlarının Doğu Akdeniz genelinde diğer yangın kaynaklı hava kirleticileri ile birlikte arttığını ortaya koymuştur. Ayrıca, klorofil-a konsantrasyonlarındaki değişimler büyük ölçekli BKY olaylarının yalnızca hava kalitesini değil, aynı zamanda Akdeniz'e atmosferik çökeltme yoluyla daha geniş çevresel etkiler yaratabileceğini göstermektedir.

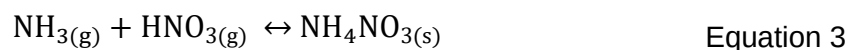
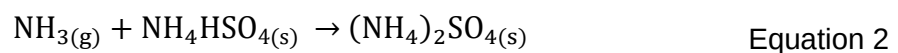
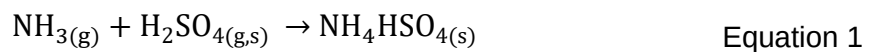


1. INTRODUCTION

Air pollution is a growing environmental problem due to its impact on both climate change and public health. With the rise in population, industrial production, and agricultural activities due to increasing demand, atmospheric pollutants continue to increase, which makes effective monitoring more crucial than ever.

Among the various air pollutants that negatively affect air quality, some are more closely monitored and regulated than others. While pollutants such as particulate matter (PM), nitrogen oxides (NO_x), and sulphur oxides (SO_x) are classified as major criteria air pollutants, ammonia (NH₃) is not included in this category although, it plays a significant role in atmospheric chemistry and contributes to air pollution. In addition to its contribution to eutrophication and acidification by the nitrogen deposition into terrestrial and aquatic ecosystems which negatively affects biodiversity and ecosystem quality, NH₃ is an important alkaline gas and primary air pollutant. NH₃ is one of the key contributors to the formation of secondary PM with NO_x (nitrogen oxide (NO) and nitrogen dioxide (NO₂)) and SO_x (Sutton and Fowler, 2002).

NO_x and SO_x are first oxidized in the atmosphere, which this step leading to the formation of strong acids, primarily nitric acid (HNO₃) and sulfuric acid (H₂SO₄) and NH₃ reacts with these acids through neutralization reactions. As a result of this chemical reactions, ammonium sulphate ((NH₄)₂SO₄) and ammonium nitrate (NH₄NO₃), also known as ammonium salts are formed. These ammonium salts form a substantial fraction of fine particulate matter (PM_{2.5}) in the atmosphere. The representative chemical reactions are given in Equations 1-3:



In addition to degrading air quality and reducing visibility, these aerosols affect atmospheric radiative forcing by scattering and absorbing solar radiation (Xu and Penner, 2012) and also influence cloud properties through aerosol-cloud interactions

(Sorooshian et al., 2008). Hence, NH_3 indirectly influences climate change. Furthermore, they cause serious health risks, including respiratory irritation and distress, and may contribute to broader respiratory and cardiovascular problems through PM formation. Therefore, detecting NH_3 sources is necessary to mitigate its adverse impact on human health, environment, and climate. A simplified schematic overview of NH_3 major sources, atmospheric transformations, deposition pathways, and associated effects is illustrated in Figure 1.1.

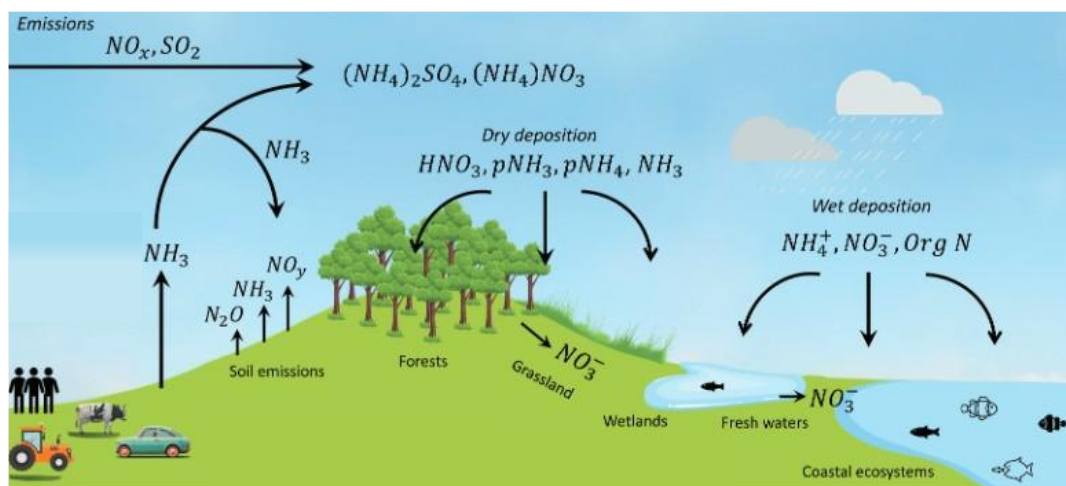


Figure 1.1 : Sources and Pathways of atmospheric NH_3 (adapted from Driscoll et al., 2024).

1.1 Key Sources of NH_3 Pollution

NH_3 is a reduced form of nitrogen which is emitted into the atmosphere from various sources. NH_3 mainly emitted from agricultural activities and animal husbandry, such as livestock farming, manure handling, and application of manure and synthetic nitrogen-based fertilizers to land (Sutton et al., 2000). Through various biological and chemical processes, NH_3 is volatilized from livestock manure and synthetic fertilizers, contributing to atmospheric emissions (Mikkelsen, 2009).

Additionally, non-agricultural sources waste management, wastewater, (Chen et al., 2022) and several industries such as fertilizer, soda ash, and iron and steel production, are also notably significant contributors to NH_3 emissions (Van Damme et al., 2018). NH_3 emissions from non-agricultural sources emitted either from nitrogen-containing raw materials, as in fertilizer and soda ash production, or from air pollution control technologies in iron and steel, and cement industries. In these industries, NH_3 can be used as absorbent but can escape as a byproduct, such as in selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) systems, which are designed to reduce NO_x emission.

Moreover, biomass burning, whether from forest fires or agricultural stubble burning, is another atmospheric NH_3 sources. NH_3 is emitted alongside CO , primarily during the smoldering stage of combustion while NO_x and CO_2 are more dominant during the flaming stage (Andreae & Merlet, 2001; Lobert et al., 1990). The transition between smoldering and flaming stages depends on the fuel, especially its moisture content and this change can vary during the day, with stronger flaming typically seen in the daytime, and across the fire region.

Despite its emission from various sources and crucial role in atmospheric chemistry and air quality, NH_3 concentrations are not currently measured at any Air Quality Monitoring Station (AQMS) in Türkiye. The lack of ground-based observations makes it difficult to evaluate spatio-temporal distribution and trends of NH_3 over any region in Türkiye. Since NH_3 has a short atmospheric lifetime which ranges from a few hours to a day and undergoes a rapid transformation in the atmosphere, NH_3 monitoring requires frequent and widespread measurements. In the absence of in-situ measurements, remote sensing is the only available method to track NH_3 concentrations for Türkiye.

1.2 Satellite-based Remote Sensing

Remote sensing technologies are increasingly recognized as important tools for air quality monitoring, as they provide wide spatial and temporal coverage of atmospheric pollutants. While ground-based can measure at fine temporal resolutions, such as hourly or even sub-hourly, they are spatially limited. In contrast, remote sensing technologies, enables large-scale and continuous spatial observations, though typically with lower temporal resolution. This makes satellite-based monitoring particularly important for assessing pollutant distribution across vast or inaccessible areas, especially where ground-based monitoring is lacking.

In this scope, several missions and instruments have been developed to monitor atmospheric composition and support air quality assessments. These satellites onboard specific instruments that detect and measure trace gases and aerosols based on their unique absorption features in different parts of the electromagnetic spectrum. Such as the Infrared Atmospheric Sounding Interferometer (IASI), onboard the MetOp series of satellites operated by EUMETSAT, provides global observations of NH_3 and CO using thermal-infrared (TIR) measurements, with observations made during morning and evening overpasses. Meanwhile, the TROPOspheric Monitoring Instrument (TROPOMI) on Sentinel-5P, operated by the European Space Agency (ESA), operates across a wide spectral range, including the ultraviolet (UV), visible

(VIS), near-infrared (NIR), and shortwave infrared (SWIR) regions of the electromagnetic spectrum and retrieves various pollutants such as NO₂, HCHO, SO₂, and CO during early afternoon overpasses. Overall, each instrument provides distinct spatial and temporal resolutions, which contributes to a better understanding of various pollution distribution across various spatio-temporal scales.

Beyond monitoring atmospheric pollutants, remote sensing also plays an important role in assessing various environmental parameters. Satellite-derived products such as land cover classifications, vegetation indices, surface temperature, and elevation models provide valuable insights into land use dynamics. For instance, the Copernicus programme provides CORINE Land Cover (CLC) (*Copernicus Land Monitoring Service*, 2018) product for land use mapping and Digital Elevation Model (DEM) products for analyzing topography and hydrological processes. Integrating atmospheric measurements with these products allows for more comprehensive environmental assessments by linking pollutant patterns with land use, topographic context, and potential emission sources

1.3 Aim and Scope

Although numerous satellite-based studies have examined NH₃ distributions, trends, and its major region-specific sources such as agriculture and industry at global or regional scales, its spatio-temporal distribution and fire-related enhancements have not yet been investigated in the Eastern Mediterranean region of Türkiye. Biomass burning, including wildfires and agricultural residue burning, represents an episodic yet potentially significant source of NH₃ emissions. Since the Eastern Mediterranean experiences frequent and intense biomass burning events, it is essential to investigate NH₃ emissions from such fire-episodes, given its critical role in air pollution and the formation of secondary PM.

Within this scope, the study focuses on examining NH₃ levels associated with selected fire episodes in the region, with specific attention to their spatial distribution, NH₃ enhancement ratios, and its relationship with other fire-related air pollutants.

The scope of this study involved the following key tasks:

- The spatio-temporal distribution of NH₃ over the Eastern Mediterranean region was analyzed using IASI retrievals, with a special focus on annual, seasonal, and monthly variations. In addition, the influence of meteorological parameters on NH₃ levels was examined to better understand the underlying drivers of its variability.

- Selected major wildfire event were evaluated to quantify NH_3 enhancements and examine their relationship with other fire-related air pollutants. NH_3 and CO retrievals from IASI, along with NO_2 , CO, and HCHO retrievals from TROPOMI, were used to assess pollutant enhancement ratios over region.
- Similarly, agricultural residue burning was investigated to assess NH_3 enhancements and associated pollutant ratios, with a focus on periods and regions dominated by stubble burning.

Although fire-related NH_3 and other air pollutants have been examined in several global studies, this thesis represents one of the first to investigate the relationship between different biomass burning events and NH_3 pollution in the Eastern Mediterranean region. By quantifying NH_3 enhancement ratios relative to other biomass burning pollutants during selected fire episodes and sub-regions, the study aims to fill a critical regional gap and improve the understanding of fire-related NH_3 dynamics.



2. LITERATURE REVIEW

Agricultural NH_3 emissions have been a widely studied topic (Li et al., 2017; Lovarelli et al., 2020; Saravia & Trachte, 2025; Warner et al., 2017), as agriculture is recognized as the dominant global source. Ground-based measurement techniques, which including both passive and active in-situ measurements, are among the commonly used approaches to monitor atmospheric NH_3 concentrations. For instance, Puchalski et al. (2015) conducted an annual intercomparison at rural CASTNET sites influenced by agriculture and observed distinct seasonal trends aligned with fertilizer application and livestock activity. In addition to in-situ methods, ground-based remote sensing techniques, such as Fourier Transform Infrared (FTIR) spectrometry, have been utilized to retrieve NH_3 total column concentrations (molecules/cm^2) with high temporal resolution, as demonstrated in the study by Dammers et al. (2015) which also reported maximum concentrations around April consistent with manure application periods, and highlighted elevated summer levels which linked to increased volatilization from livestock housing driven by temperature and animal activity. Similarly, the study by Wang et al. (2022), which combined FTIR and satellite-based remote sensing, identified agriculture as the dominant source of NH_3 with elevated summer concentrations driven by fertilizer application and livestock activity.

In addition to agricultural sources, non-agricultural point sources have also been recognized as important contributors in recent studies (Clarisse et al., 2019; Dammers et al., 2019; Van Damme et al., 2018). For instance, Van Damme et al. (2018) identified global NH_3 hotspots using satellite retrievals from IASI, revealing that many of these hotspots are linked to industrial activities, which are mostly related to fertilizer production, but also including soda ash, coal processing, and mining sectors. Dammers et al. (2019) quantified NH_3 emissions from major point sources using Cross-track Infrared Sounder (CrIS) retrievals and results show significant underreporting in inventories and highlighting industrial contributions, while Clarisse et al. (2019) applied wind-adjusted superresolution techniques to IASI retrievals, which making it possible to accurately detect over 500-point sources and showing emission patterns in much greater detail than before.

Beyond agricultural and industrial emissions, biomass burning (BB) events are also emerged as a significant contributor to atmospheric NH_3 , especially during large-scale fires. BB events are episodic but important sources, with wildfire events drawing particular attention due to their increasing frequency and intensity under a changing climate. While NH_3 emissions from BB have received growing attention in recent years, most of the wildfire-related studies in the literature have focused on pollutants such as $\text{PM}_{2.5}$, NO_2 , CO , and O_3 using a combination of satellite observations, in-situ measurements, and air quality models. For instance, (Schneider et al., 2021) investigated wildfire episodes in Western Canada between 2001 and 2019 using air quality station data, MODIS FRP product, HYSPLIT trajectories, and the trajectory-fire interception method (TFIM). Similarly, Jin et al. (2023) combined TROPOMI NO_2 and HCHO retrievals and GEOS-Chem simulations to assess the impact of wildfires on tropospheric NO_x and VOC levels across California, demonstrating increased precursor concentrations and enhanced ozone production linked to fires.

As with other wildfire-related atmospheric pollutants, BB-related NH_3 has been investigated through various methods such as aircraft campaigns (Lindaas et al., 2021; Tomsche et al., 2023), ground-based in-situ monitoring (Benedict et al., 2017), laboratory-simulated studies (McMeeking et al., 2009), satellite-based remote sensing techniques (Chang et al., 2021; Hickman et al., 2021; Whitburn et al., 2017) and combination of ground-based remote sensing and atmospheric transport modeling approaches (Lutsch et al., 2016).

Among these, the study reported in-situ measurements of NH_3 and ammonium (NH_4) conducted using the NASA DC-8 aircraft in smoke plumes from wildfires and small agricultural fires in the Western United States (Tomsche et al., 2023). Measurements were done during multiple flight transects with wildfire plumes sampled at higher altitudes while agricultural fire plumes sampled at lower. The results showed that NH_3 levels, in downwind direction of fire plume which emitted during Williams Flats Fire event in August 2019, ranged from 110 to 200 ppb, while NH_4 levels ranged 42 to 65 ppb. NH_4 levels suggested that it was either directly emitted or formed through NH_3 conversion into particulate NH_4 within a few hours after emitted. Also, CO showed the similar trend as NH_3 with some tailing during the downwind measurement of fire plume which reach up to 6000 ppb. Same study also examined agricultural residue fires, which showed similar NH_3 peaks but declined more rapidly than those from wildfires which likely due to faster conversion of NH_3 to particulate NH_4 , as explained in the study.

Benedict et al. (2017) studied ground-based in-situ measurements of NH_3 and other reactive nitrogen species during the 2012 Hewlett Gulch and High Park wildfires in Colorado and they measured background NH_3 concentrations around 5 ppb. However, during fire periods hourly concentrations increased by a factor of 20 (>100 ppb). To quantify the relative enhancement of NH_3 , the study calculated average NH_3/CO emission ratio, where represented the difference in the pollutant before and during the fire period and the respective their background levels. This ratio found to be 0.0274 to 0.002 (ppb/ppb) and this ratio shows how much NH_3 increased compared to CO in the smoke plume, and it is a commonly used ratio to compare emissions from the fires. Additionally, the NO_x/CO ratio was determined as 0.0057 to 0.0007 (ppb/ppb). Another key finding of this study is the elevated $\text{NH}_3\text{-NO}_x$ ratio, along with this ratio's diurnal pattern, which showed higher values during early morning and evening hours compared to the non-fire period. In this context, all these ratio observations suggest that smoldering stage of combustion was the main phase during these fire events. Lastly, Benedict et al. (2017) suggested that the limited increase in NH_4 concentrations, despite high NH_3 levels, was likely due to the fresh nature of the smoke and warm conditions that limited the formation of ammonium nitrate. Similarly, Hu et al. (2022) conducted online measurements of NH_3 at a rural site in North China Plain and background NH_3 concentrations generally remained below 65 ppb, however a nearby BB event occurred approximately 100 meters away from the selected site which caused a significant increase with elevated concentration of 145.6 to 139.9 ppb. To quantify the impact of the BB event, the authors employed a machine learning technique to simulate a scenario without BB. Based on this approach, they estimated that the BB event led to a 411% increase in NH_3 concentrations. Additionally, the NH_3/CO emission ratio during the burning period was calculated as 0.016, which reported as this value falls within the typical range reported for BB emissions.

Lutsch et al. (2016) presented ground-based FTIR measurements of NH_3 in the high Arctic and investigated the long-range transport of BB event from the 2014 Northwest Territories wildfires. FTIR measurements from Eureka and Toronto sites revealed that NH_3 total column concentration exhibited strong seasonal variability and episodic increase, with maximum monthly averages recorded in summer (2.79×10^{14} molecules/ cm^2 at Eureka and 9.80×10^{15} molecules/ cm^2 at Toronto), and notable increases during July-August period were attributed to long-range transport from boreal wildfires via FLEXPART Lagrangian dispersion model. Their analysis at sites revealed enhancements in NH_3 levels during the fire period by 2-5 times above their

background. Furthermore, they reported an NH_3 -CO enhancement ratio and derived an estimated NH_3 emission factor of 1.40 ± 0.72 g/kg based on observed fire-periods.

Some studies, such as Clarisse et al. (2009) and Van Damme et al. (2015) identified short-term NH_3 peaks in their results, which they suggested might be associated with BB events; however, these findings were not supported by further investigation. In contrast, a number of studies have specifically focused on the NH_3 -fire relationship and many of them utilized IASI retrievals similar to the point source studies by Van Damme et al. (2018) and Clarisse et al. (2019). For instance, Whitburn et al. (2016) quantified the emissions from the 2015 Indonesian peat fires using IASI retrievals and reported exceptionally high NH_3 concentrations over the main fire regions of Sumatra and Borneo during the 2015 Indonesian peat fires, with daily average for NH_3 concentration reaching 1.6×10^{17} molecules/cm². They determined NH_3/CO ratio from slope of the linear regression and the results were significantly higher in Sumatra (17.3×10^{-3}) compared to Borneo (8.4×10^{-3}). Based on these observations, the study estimated daily NH_3 emissions up to 0.33 Tg and total annual emissions ranging from 1.4 to 8.2 Tg for the peat fires. Similarly, another study by Whitburn et al. (2017) analyzed NH_3/CO ratios over tropical biomass burning regions for the different biome type, and found ratio ranging from 6.5 to 15.3×10^{-3} depending on biome type, with the highest ratios observed in evergreen broadleaf forests. This variability was attributed to differences in combustion characteristics and fuel types according to the different biomes. Moreover, R'Honi et al. (2013) captured exceptional NH_3 increase during the 2010 Russian wildfires, with total column concentrations exceeded more than 300 times the background levels for NH_3 and 40 times for CO compared to the pre-fire period results. Based on IASI observations, they estimated maximum daily emissions of 0.04 to 0.15 Tg for NH_3 and 1.41 to 1.87 Tg for CO, with all fire-period emissions reaching 0.7 to 2.6 Tg and 19 to 33 Tg, NH_3 and CO, respectively. Furthermore, Hickman et al. (2021) reported dry-season NH_3 increases exceeding 6% annually in West Africa, with CO increases attributed to BB influence, while Chang et al. (2021) found that BB accounted for 9.6 to 21.0% of ambient NH_3 in Southeast Asia based on IASI retrievals combined with ground-based and isotopic analyses.

Despite the number of studies that investigating the relationship between BB and NH_3 at regional or sub-regional scales, no study to date has not been examined this topic within Türkiye. Nonetheless, there are a few studies that focusing on NH_3 pollution in the Türkiye. The first ever satellite-based study on NH_3 in Türkiye by Tokgoz & Kaynak (2021) provided a national-scale assessment of spatio-temporal distribution via utilized IASI retrievals for 2018. Further, there are some sub-regional studies have

focused on specific regions, including Iğdır (Tokgoz et al., 2024), Konya (Mehmet Alban et al., 2024) and the Eastern Mediterranean (Saracoglu et al., 2024a) (Saracoglu et al., 2024b). In addition, a few global satellite-based studies have identified NH_3 point sources in Türkiye, mostly related to agricultural activity. For instance, Van Damme et al. (2018) reported a hotspot from poultry emissions in Afyonkarahisar, while Clarisse et al. (2019) detected agricultural hotspots in Konya and İzmir, as well as a potential industrial hotspot in Mersin linked to a soda ash facility. Furthermore, Akyuz et al. (2024) applied the Community Multiscale Air Quality (CMAQ) model in Türkiye using an improved bottom-up agricultural inventory alongside the European Monitoring and Evaluation Programme (EMEP) inventory. The model results revealed discrepancies with IASI-derived NH_3 , which these differences indicated that non-agricultural sources, in addition to agricultural ones, may significantly contribute to observed NH_3 levels.

Despite the lack of studies related to NH_3 in Türkiye, there are some BB focused studies have investigated in terms of fire activity, emissions, and air quality impacts across the country. For example, Coskuner (2022) reported that most fires between 2015 and 2019 occurred in agricultural lands (78.9%). Eke and Kaynak (2021) showed that agricultural burning during the summer of 2018 via using satellite-based data showed that 34% and 58% of annual fires in Adana and Osmaniye, respectively, were attributed to agricultural areas. Bahşı et al. (2024) estimated emissions from crop residue burning in southeastern Türkiye using Sentinel-2 imagery, though without assessing air quality impacts. In response to the intense 2021 wildfires in southwestern Türkiye, several studies have examined BB-related pollution. İban and Şahin (2022) assessed burned areas and pollutants in Mersin, while Tariq et al. (2022) reported increased Aerosol Optical Depth (AOD), which is a satellite-based parameter that indicates the amount of aerosols in a vertical column, over Antalya. More comprehensively, Eke et al. (2024) analyzed pre-fire, during-fire, and post-fire pollutant levels (HCHO , CO and NO_2) via using TROPOMI retrievals and ground-based measurements.

As mentioned, there are global studies where fire related NH_3 and other pollutant were investigated however, the relationship between BB events and NH_3 remains largely unaddressed in the Eastern Mediterranean region of Türkiye. Therefore, this study aims to fill this gap by quantifying NH_3 enhancements ratio to other BB emitted air pollutants during the selected fire events and regions. Moreover, considering that many of the BB events occur near coastal areas in the region, potential transport of smoke plumes over the Mediterranean has also been taken into account. Atmospheric

deposition of BB plumes represents a key pathway for the transfer of nutrient-rich particles to marine environments. Since wildfire ash is rich in biogenic nutrients such as nitrogen which can fertilize surface waters and stimulate phytoplankton growth (Kramer et al., 2020; Nguyen et al., 2024). In this scope, studies have reported a positive relationship between wildfires and phytoplankton production in both marine and freshwater systems (Charette & Prepas, 2003; Liu et al., 2022). Accordingly, this study also examines chlorophyll-a over the Mediterranean to investigate the potential effects of BB events on the marine environment in the region.



3. METHODOLOGY

In this chapter, the study area and the data sources used in this thesis are presented, followed by a detailed explanation of each chapter, along with the methodology used to analyze NH_3 sources.

3.1 Study Area

The Eastern Mediterranean is an important region characterized by extensive forested areas, agricultural lands, and residential-industrial areas. It also hosts major ports with heavy maritime traffic along its coastline. The region includes five provinces: Antalya, Mersin, Adana, Osmaniye, and Hatay. The CORINE Land Cover (CLC) data (Copernicus Land Monitoring Service, 2018) was utilized to classify and visualize land use patterns across the study domain as shown in Figure 3.1 with Meteorological stations (MS). The CLC product has a 100m spatial resolution. In this study, since satellite retrievals were primarily utilized, the CLC product remains relatively fine compared to the study's grid resolution. While CLC product is important for understanding detailed land use in the region, it was simplified to a 1x1 km² grid resolution to conduct more detailed analyses on the relationship between land use and pollutants in Chapters 4 and 5.

The elevation map clearly shows the sharp topographic contrast between the low coastal plains and the rise of the Taurus Mountains in the north. This variation plays a significant role in shaping land use and local wind patterns, which this topography has an influence on pollutant transport and air quality across the region, as illustrated in Figure 3.2. The population map reveals that settlement density is highest along the coastal area, particularly around major urban centers such as Adana, Mersin, and Antalya (Luminocity3D, 2025). This spatial pattern highlights the concentration of anthropogenic activities near the coast, which is critical when evaluating emission sources in the region (Figure 3.3).

According to the Köppen-Geiger climate classification, the coastal zone predominantly falls under the hot-summer Mediterranean climate (Csa), characterized by dry, hot summers and mild, mostly wet winters. However, as elevation increases toward the north, the climate transitions into a humid continental type (Dsa), marked

by more pronounced temperature variations and drier summers. This classification is mapped for the study area based on the 0.1°x0.1° resolution Köppen-Geiger data as shown in Figure 3.4 (Beck et al., 2023).

The region includes large agricultural areas, distributed industrial zones, and relatively high population density, all of which contribute to NH₃ emissions from multiple sources. In addition, the wide coverage of forests and agricultural areas makes the region important for analyzing BB influence. The varied topography, from low coastal plains to high mountains, together with the region's general climate, also affects the fate and transport of pollutants in the atmosphere.

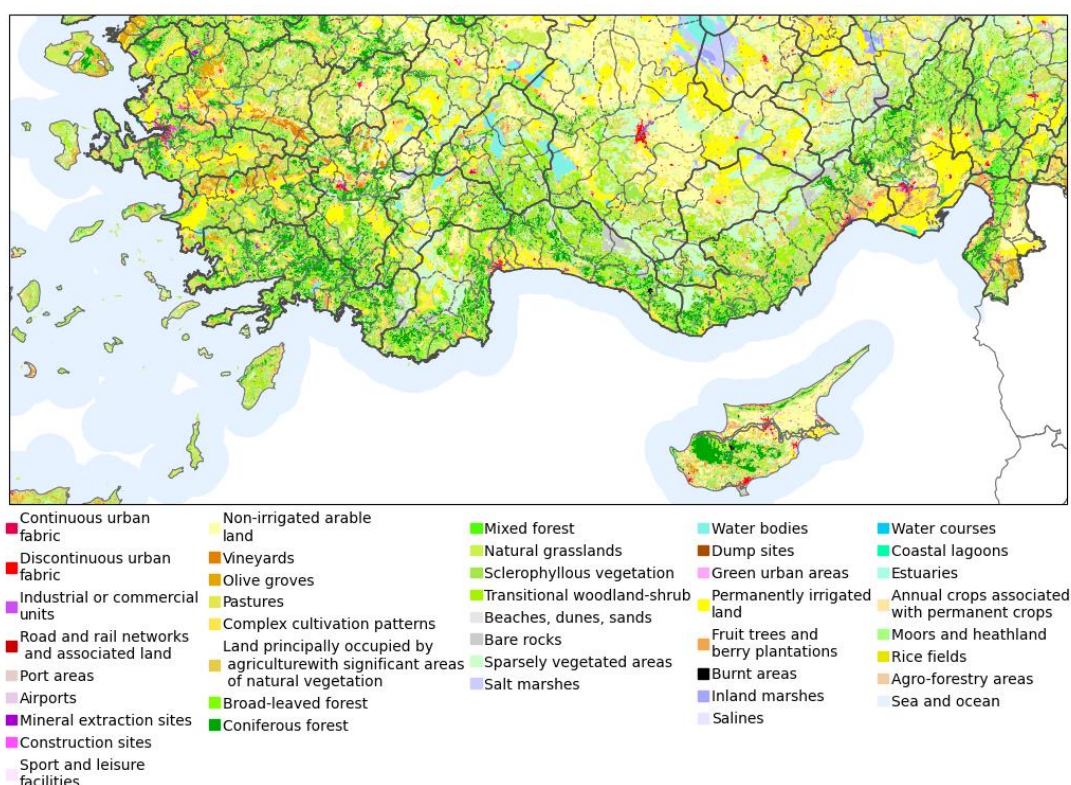


Figure 3.1 : Study area with CLC data.

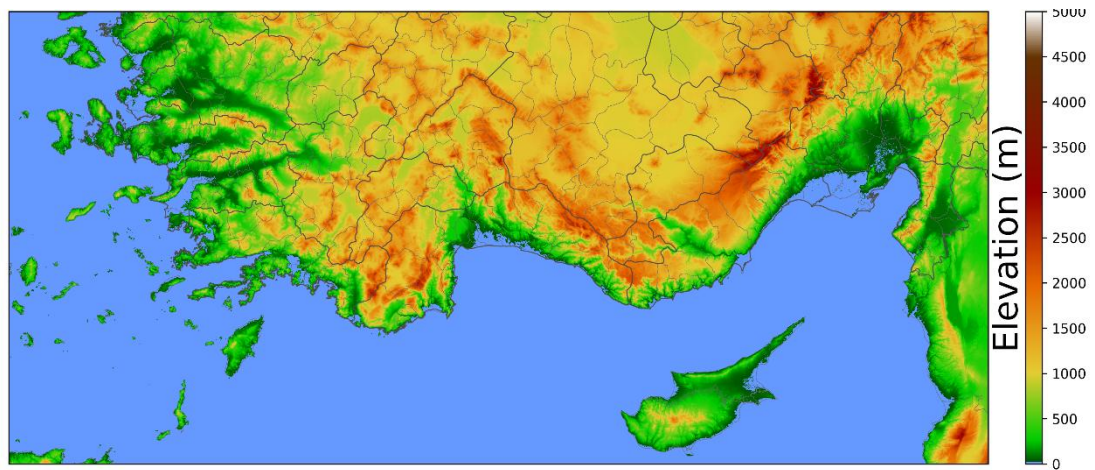


Figure 3.2 : DEM map for the study area.

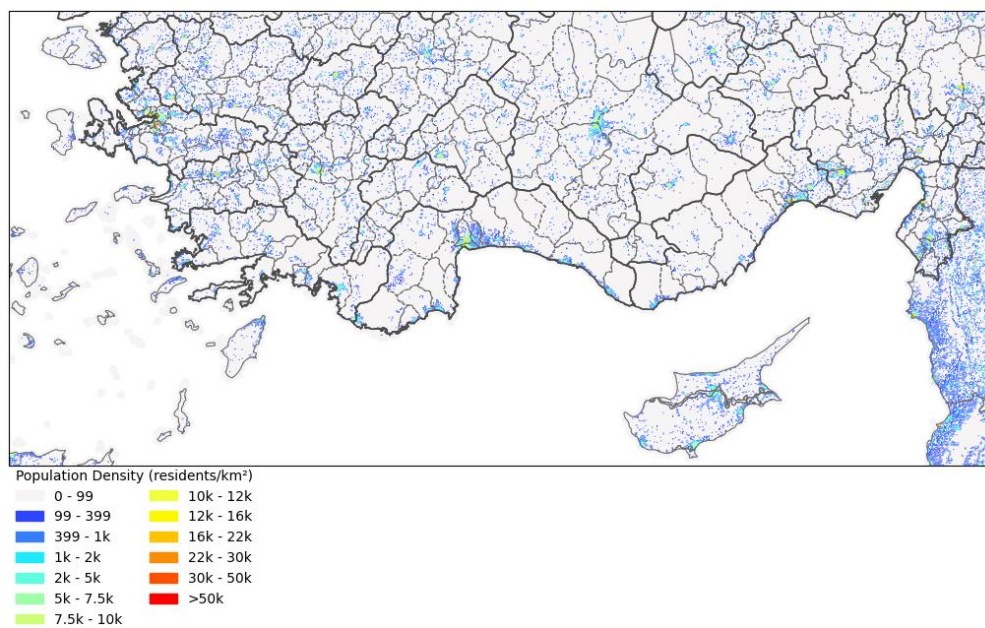


Figure 3.3 : Population density in the study area.

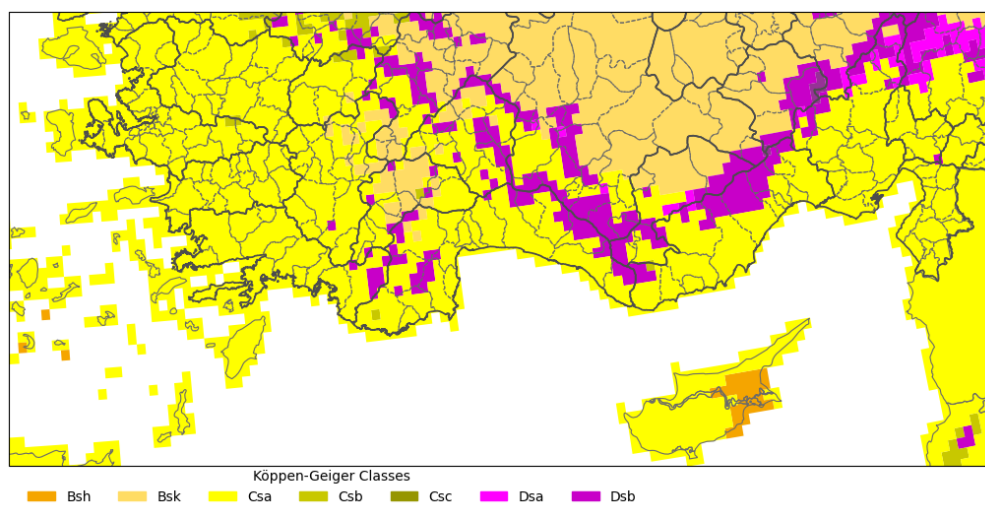


Figure 3.4 : Köppen-Geiger climate classification in the study area.

3.2 Multi-Satellite Pollutant Retrievals

NH₃ retrievals from the Infrared Atmospheric Sounding Interferometer (IASI) onboard the METOP series (Metop-A, Metop-B, and Metop-C) satellites, operated under the European Space Agency (ESA), were used in this study. IASI provides measurements with a spatial resolution of 12 km (circular footprint at nadir) and a temporal resolution of twice a day morning and afternoon overpass (9:30 AM and 9:30 PM). Level-2 (L2) NH₃ retrievals, which represent geolocated atmospheric NH₃ concentrations, were processed for five years (2019-2023) to analyze spatio-temporal variations in the study area. Retrievals were filtered according to quality criteria (pre and post filter =1) and processed over 4x4 km² and 1x1 km² gridded resolution as vertical column concentrations (molecules/cm²) (AERIS, 2025). While processing over gridded resolution, oversampling method was applied to NH₃ L2 retrievals with a 6 km radius search distance for reduce noise. This method has been widely used in satellite-based studies, especially short-lived species such as NH₃, to improve spatial resolution and detect localized sources. Such as, Van Damme et al. (2018) applied oversampling to IASI-NH₃ L2 retrievals to identify NH₃ emission hotspots globally. Additionally, CO retrievals from IASI were also processed within the scope of this thesis to further investigate BB events. CO retrievals filtered based on quality assurance (QA) flag (retrieval_quality_flag>=1) and same oversampling method was applied with 6 km radius search distance over same gridded domain.

TROPOspheric Monitoring Instrument (TROPOMI), part of the Sentinel-5 Precursor mission under the Copernicus program, provides measurements of NO₂ (v02.04) and HCHO (v02.04) at a spatial resolution of 3.5 x 5.5 km² and CO (v02.04) at 5.5 x 7 km² at nadir observation with an overpass at 13:30 at local time. The data used in this study were obtained from its L2 retrievals available in NASA GES DISC archive (Earthdata NASA, 2025). All retrievals were filtered based on their Quality Assurance (QA) flag, with NO₂, CO, and HCHO products retained only when QA > 0.5 and processed as total vertical column concentration. The same oversampling method used for the IASI product was applied, with a 6 km radius search distance over the same gridded domain.

Since this thesis aims to investigate the relationship between NH₃ and other fire-related air pollutants during BB event, direct geolocated and time-synchronized comparisons could not be performed due to the differences in the spatial and temporal resolutions of the IASI and TROPOMI instruments. Therefore, the analysis was

conducted by spatially matching the averaged concentration of each gridded product over the domain.

Here, only the morning overpass of IASI was used for analyses with TROPOMI retrievals, as evening observations from IASI may reflect different atmospheric conditions and are not suitable for consistent temporal alignment with TROPOMI. This approach allowed for the investigation of the relationships and enhancement ratios between IASI derived NH_3 and other fire-related air pollutants, in this case IASI derived CO (hereafter referred to as IASI-CO) and TROPOMI derived NO_2 , CO and HCHO (hereafter referred to as TROP- NO_2 , TROP-CO, and TROP-HCHO), making it possible to calculate NH_3 to pollutant ratios for specific regions and periods.

Additionally, Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) instrument onboard the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) L2 Vertical Feature Mask (VFM) product retrievals (V4.21) were used to investigate fire-affected areas which these products provide information on aerosol layers and their vertical distribution (NASA, 2018). Therefore, VFM retrievals were examined for specific periods and regions to investigate biomass burning-related aerosol pollution in Chapter 5.

This thesis primarily focuses on the atmospheric impacts of BB events, with particularly focus on NH_3 , although their influence is not limited to the atmosphere. In coastal regions such as the study area, BB smoke containing nitrogen compounds and nutrient-rich ash can be transported and deposited into nearby sea surfaces which this input enhances phytoplankton growth by supplying additional nutrients. To examine this potential effect, chlorophyll-a (hereafter referred as Chl-a) concentrations were analyzed as a representation of phytoplankton activity, which also contributes to a broader understanding of wildfire impacts beyond the atmosphere. Chl-a product for the study were obtained from the GCOM-C satellite, developed by the Japan Aerospace Exploration Agency (JAXA), and launched in December 2017 to monitor climate-related parameters using its Second-generation Global Imager (SGLI) which is a multi-spectral sensor that can captures data from near-ultraviolet to thermal infrared wavelengths. The 250-meter spatial resolution L2 Chl-a (mg/m^3) (JAXA, 2018; G-PORTAL, 2025), with a local overpass time of 10:30, retrievals were processed over $1 \times 1 \text{ km}^2$ Mediterranean Sea grids, which obtain from The European Marine Observation and Data Network (EMODnet) (EMODnet, 2025), for selected time interval. Unlike other pollutants, due to the high spatial resolution of Chl-a product, oversampling method was not conducted.

All satellite-based retrievals mentioned in this chapter, including their parameters, units, spatial and temporal resolutions, are summarized in Table 3.1.

Table 3.1 : Summary of satellite-based data used in this study.

Instrument / Satellite	Parameters	Units	Spatial Resolution	Temporal Resolution	Reference
IASI Metop-A, B and C	NH ₃ , CO	molecules/cm ²	12 km (Circular nadir)	09:30 and 21:30	AERIS, 2025
TROPOMI Sentinel-5P	NO ₂ , CO, HCHO	molecules/cm ²	NO ₂ and HCHO: 3.5x5.5 km ² CO: 5.5x7 km ²	13:30	NASA, 2025
SGLI GCOM-C	Chl-a	mg/m ³	250 m	10:30	GCOM-C, 2025

3.3 Meteorological Observations

Meteorological parameters are important factors for air pollutants, as wind patterns play a crucial role in the dispersion and transport of pollutants, while parameters such as temperature, relative humidity, and precipitation influence their chemical transformations, formation, and deposition from the atmosphere. Several studies have indicated that local meteorological conditions have a significant impact on NH₃ levels (Bouwman, Boumans, & Batjes, 2002). To investigate the influence of these meteorological factors on pollutant levels in the study region, hourly meteorological data for wind speed (WS; unit in m/sec), wind direction (WD; unit in degree), relative humidity (RH; unit in %) and temperature (T; unit in C°) were obtained from the Turkish State Meteorological Service (TSMS). In this study, MSs were selected based on data completeness and spatial relevance to the selected sites, which allowing flexibility for future region-specific evaluation (Figure 3.1).

Since satellite overpasses do not match exactly with the hourly timestamps of meteorological data, the satellite observation times were first rounded to the nearest hour. Then, based on the geolocation of each retrieval around MSs within a 12 km radius were utilized. This radius was selected based on the spatial resolution of IASI's circular footprint at nadir observations which this distance ensures that the meteorological data used are representative of the area covered by each observation. Then, further analyses were conducted with the matching retrievals and hourly meteorological data.

In addition to using exact time-matched measurements, which reflected the real-time conditions during satellite overpasses, hourly data were also included. This way helps to understand the overall meteorological background that might influence pollutant levels throughout the day. Based on that, hourly measurements of T and RH were

also analyzed for selected MSs, and WS and WD were utilized for wind roses to understand the wind pattern.

Additionally, other hourly meteorological dataset was used in this study since precipitation (P; units in mm) measurements were not available at any of the MSs. The additional hourly data for T and P for the study years were obtained from the NOAA Global Surface Hourly Dataset (Integrated Surface Dataset, NCEI DSI 3505_03) provided by the National Centers for Environmental Information (NOAA National Centers for Environmental Information, 2001).

3.4 Air Quality Monitoring

Hourly ground-based measurements of NO₂, PM₁₀, and CO were obtained from the Ministry of Environment, Urbanization, and Climate Change (MoEUCC) for the period 2019-2023 (MoEUCC, 2025). Together with satellite retrievals, these measurements were used to investigate the impacts of biomass burning events in detail. In particular, pollutant increases during periods associated with residue burning were examined in this scope.

3.5 Fire Monitoring Using Remote Sensing

Remote sensing is a suitable approach for monitoring not only air quality but also fire events, and some proper instruments onboard satellites can capture thermal anomalies. Thus, the intensity of the fires, known as Fire Radiative Power (FRP) in units of MegaWatt (MW), can be determined by the magnitude of these anomalies.

The Moderate Resolution Imaging Spectroradiometer (MODIS), onboard NASA's Terra and Aqua satellites, has been widely used for global fire monitoring. MODIS provides FRP at 1 km resolution, allowing long-term detection of fire activity. Another instrument is the Visible Infrared Imaging Radiometer Suite (VIIRS), launched onboard the Suomi National Polar-orbiting Partnership (NPP) satellite, provides an improved active fire product with a finer spatial resolution of 375 m.

In this study, VIIRS active fire data were used to monitor fire activity and derive FRP values over the selected region, as its higher spatial resolution was more suitable for detecting detailed fire dynamics within the study area (FIRMS, 2025). Further, the VIIRS fire product was processed over a 1x1 km² grid based on its geolocated information, using the same approach as applied to TROPOMI and IASI products, as described in Chapter 3.2.

Grid-based total values of FNR and fire counts were used to conduct a detailed analysis of BB events and associated pollutant levels. In addition to daily and period-based analyses, cumulative FRP mapping were also performed. This approach was used to create a 5-year which 2019 to 2023 cumulative FRP-sum map for the study area, as shown in Figure 3.5.

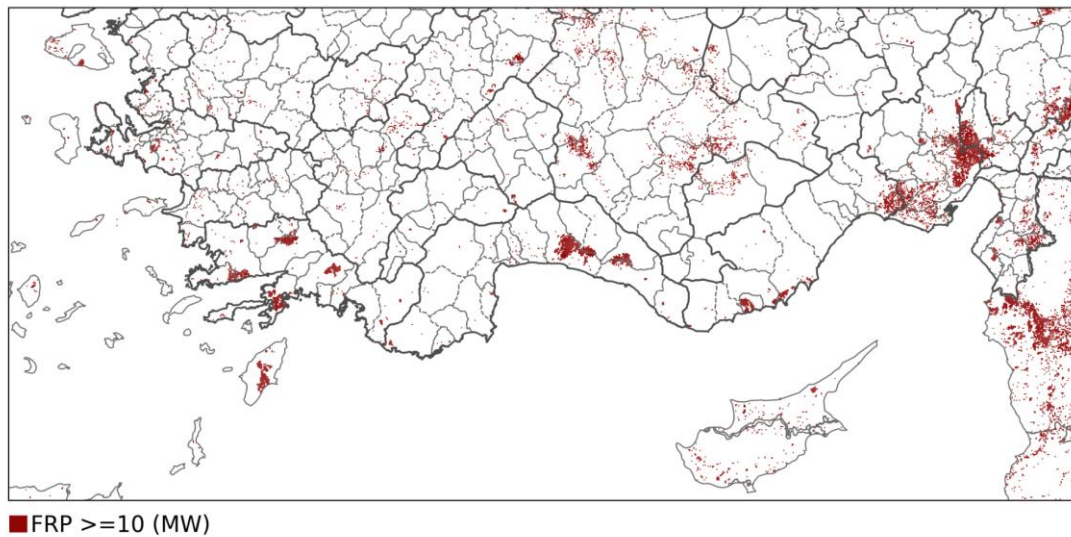


Figure 3.5 : Five-year (2019-2023) FRP-sum distribution for the study area.

4. SPATIO-TEMPORAL DISTRIBUTION OF NH₃ POLLUTION IN THE REGION

To understand the long-term trends of NH₃, spatial and temporal distribution maps were compiled for the 12-year period (2012 to 2023) using IASI-NH₃ only morning overpass retrievals. Morning observations were preferred due to the generally better sensitivity of IASI during daytime conditions, which is associated with stronger thermal contrast in the lower atmosphere, as also emphasized and utilized in various studies (Van Damme et al., 2014; Whitburn et al., 2017). To capture finer spatial details and better identify and represent local sources, the distribution maps were primarily generated at 1x1 km² gridded finer resolution.

Firstly, to evaluate the spatial changes in NH₃ levels across Türkiye over the study period, annual distribution maps for the starting and ending years, 2012 and 2023, respectively, were compiled (Figure 4.1). A comparison of these two years was used to investigate and understand the long-term changes and the regions that showed high NH₃ levels. In 2012, NH₃ levels remained relatively low in most regions, whereas in 2023 several hotspots (referred to as the area where high NH₃ concentrations were observed) became more noticeable. These included parts of the western region such as Izmir and its surrounding provinces, the southern part of Central Anatolia including Konya and Karaman, the eastern Mediterranean coastal region covering Adana and Mersin, and the northeastern part of Türkiye, particularly around Agri and Igdir.

Further, some sub-regional studies have specifically focused on these areas, including studies conducted as part of the present research of ours. These include our investigations in Agri and Igdir (Tokgoz et al., 2024), Konya and its surroundings (Alban et al., 2024), and the Eastern Mediterranean region (Saracoglu et al., 2024a; Saracoglu et al., 2024b).

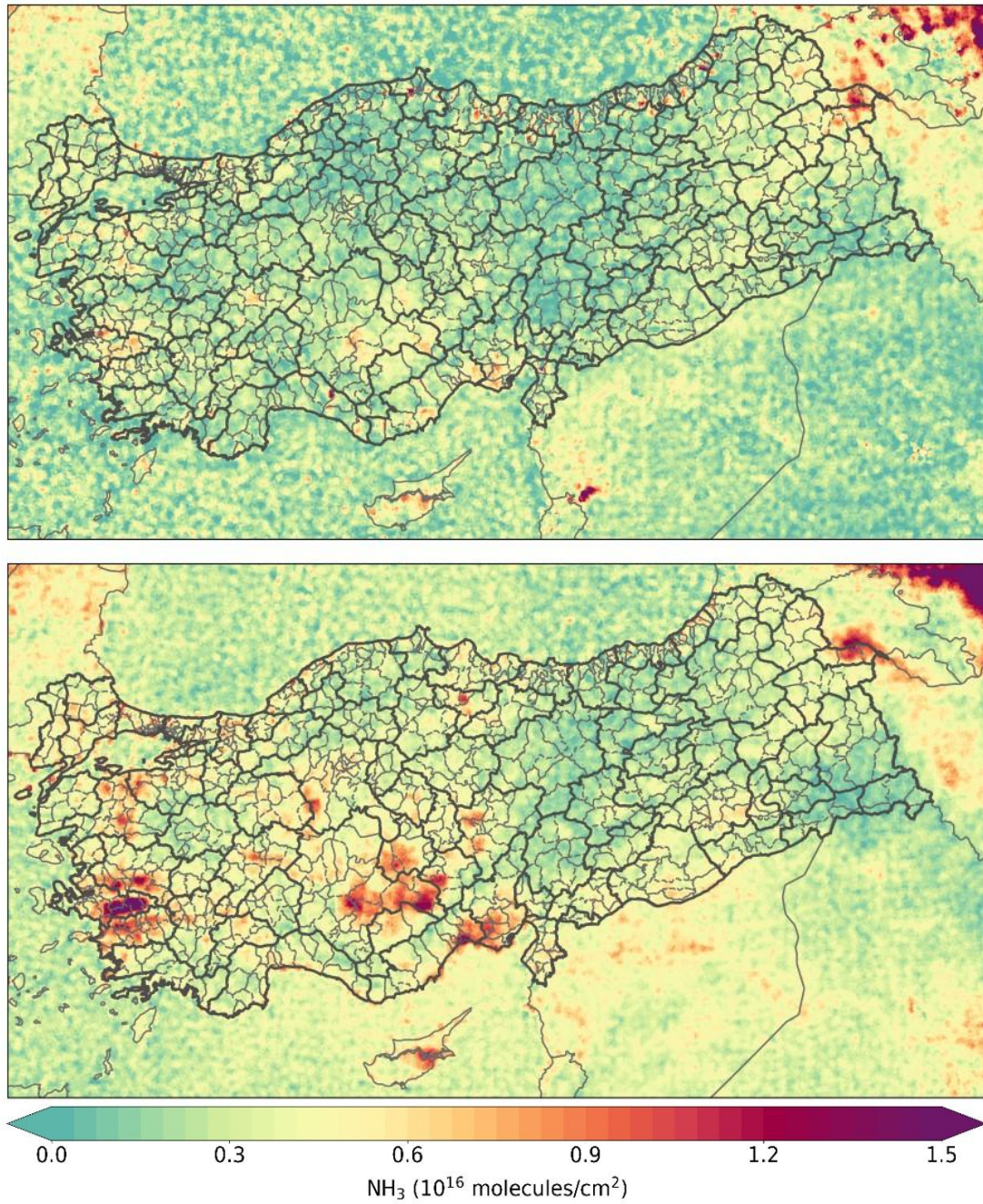


Figure 4.1 : Annual average NH₃ distributions (molecules/cm²) for 2012 (top), and 2023 (bottom).

Figure 4.2 showed the annual NH₃ distribution (10¹⁶ molecules/cm²) in the study area for the years 2012 to 2023 over 1x1 km² grid resolution. When the annual distributions were examined, several regions were more notable and persistently high over the years. One of the most prominent hotspots is consistently observed in all study domain, particularly over the region surrounding Izmir, as well as around Konya and its surroundings, and in the Mersin-Adana region.

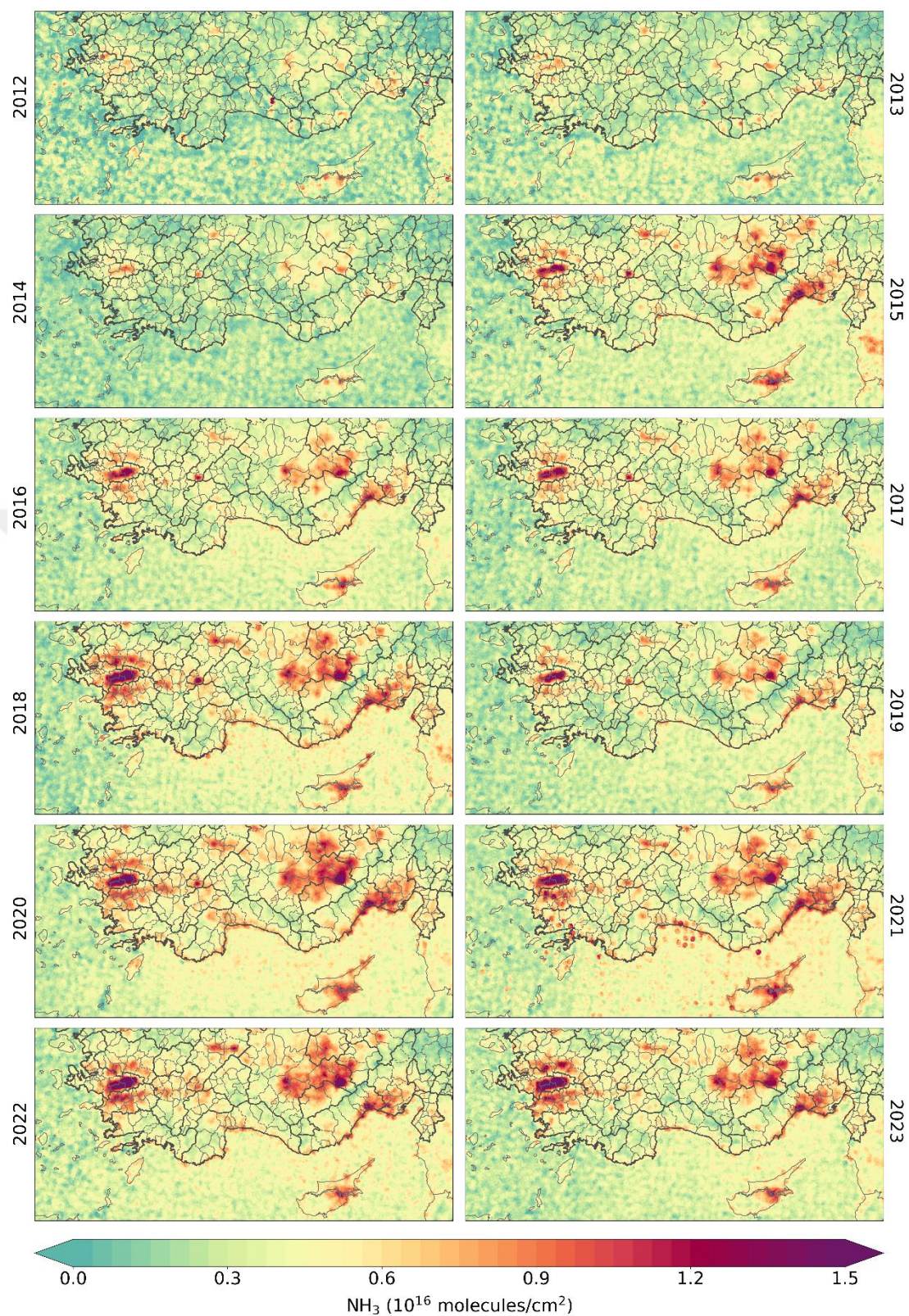


Figure 4.2 : Annual average NH_3 distributions (molecules/ cm^2) for 2012-2023.

While NH_3 enhancements were observed in various regions, the focus of this thesis is the coastal provinces of the Eastern Mediterranean. A clear increasing trend in NH_3 levels were observed from annual distributions, which mainly began in 2015, and NH_3 concentrations became significantly higher in the later years, particularly between 2017 and 2023.

Spatial distributions showed the general qualitative trend of NH_3 across the study area. In contrast, the annual time series analysis by province (Figure 4.3), conducted based on the simplified CLC land cover types which provides a more clear and quantitative assessment of temporal variations based on the provinces. From the time series analysis NH_3 levels showed an increasing trend across all provinces from 2012 to 2023, with noticeable fluctuations. Particularly decreases in 2014 and 2019, and increases in 2018 and 2021 were observed. These results suggested that emission changes, specific events, or meteorological conditions may have contributed to the observed variation in NH_3 concentrations in those years.

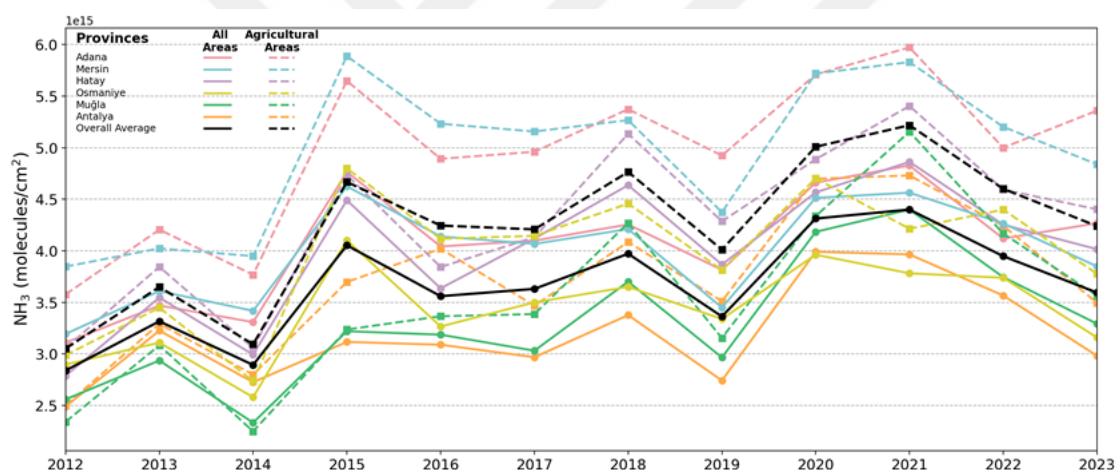


Figure 4.3 : Annual average NH_3 (molecules/cm²) for the selected provinces according to all and agricultural land types.

In all selected provinces, NH_3 concentrations were consistently higher in agricultural areas compared to overall areas, highlighting the significant contribution of agricultural activities over province-based NH_3 levels. Across all provinces and CLC types, NH_3 concentrations showed an average increase of approximately 20-50% over the long-term period, except for agricultural areas in Osmaniye (analysis statistics are summarized in Table C.1). The most pronounced increase was observed in Adana, where average NH_3 levels in agricultural areas rose by 49.8% (from 3.58 to 5.36×10^{15} molecules/cm²) and in total areas by 37.3% (from 3.11 to 4.27×10^{15} molecules/cm²). Substantial increases were also recorded in Antalya and Hatay provinces, particularly in agricultural areas, with increases of 39.8% (from 2.50 to 3.50×10^{15} molecules/cm²) and 44.0% (from 3.06 to 4.40×10^{15} molecules/cm²),

although their overall average NH_3 levels remained relatively low compared to other provinces. In Mersin, while the increase was more moderate 25.8% in agricultural areas (from 3.85 to 4.84×10^{15} molecules/ cm^2) and 20.5% (from 3.19 to 3.85×10^{15} molecules/ cm^2) in all areas the province already showed high NH_3 concentrations at the beginning of the period, which might have explained the smaller relative change. Moreover, both Adana and Mersin provinces consistently exhibited higher average NH_3 levels in all land areas compared to other provinces throughout the long-term period, which may be attributed to the influence of NH_3 -emitting industrial activities concentrated in these regions. When the overall average across all provinces was considered, NH_3 concentrations increased by 41.6% in agricultural areas (from 3.16 to 4.47×10^{15} molecules/ cm^2) and by 27.2% in all areas (from 2.82 to 3.59×10^{15} molecules/ cm^2) which these results showed a consistent increasing trend across the study area and indicated the important role of agriculture activity influence NH_3 emissions.

To better identify the spatial distribution of NH_3 hotspots, annual percentile maps were generated for the long-term period (Figure 4.4). This analysis was based on ranking annual average NH_3 concentrations from lowest to highest for each grid, which allowed for a clear visualization of the most polluted areas, previously identified as hotspots, and their changes within the years. By this analysis, spatial NH_3 hotspots became more apparent. For instance, in the annual distribution maps (Figure 4.2), NH_3 levels in the Adana and Mersin provinces appeared relatively low during the years 2012, 2013, and 2014 compared to other years. However, when examined the percentile maps, it became clear that this region still represented a hotspot within those years. This showed that percentile-based maps were useful for identifying local hotspots regardless of the absolute value differences between years. Further, when evaluated overall percentiles for Türkiye, it was evident that although NH_3 concentrations were generally low in 2012 (Figure 4.1), these regions still exhibited relatively high percentile scores. By 2023, these hotspot areas became even more pronounced in both concentration levels and percentiles (Figure B. 1).

Specifically, Adana, the southern coastal area of Mersin and central districts of Antalya, and their surrounding areas consistently emerged as hotspots throughout the entire study period. To understand the province-based hotspot distribution in detail, the average NH_3 percentile scores were calculated for each district by averaging the percentile score of all grids located within its boundaries, as presented in Table C.4. This analysis showed that several districts in Adana consistently exhibited high average NH_3 percentile scores over the long-term period. Notably,

Seyhan (96.5) and Yüreğir (92.7) in Adana had the highest scores, followed by Karatas (89.7), Sarıcam (87.7), Çukurova (87.3), and Ceyhan (83.5). Similarly, Akdeniz (98.7) and Yenişehir (95.0) districts in Mersin had particularly high long-term score, while Tarsus (80.8) and Mezitli (78.0) also had relatively elevated scores.

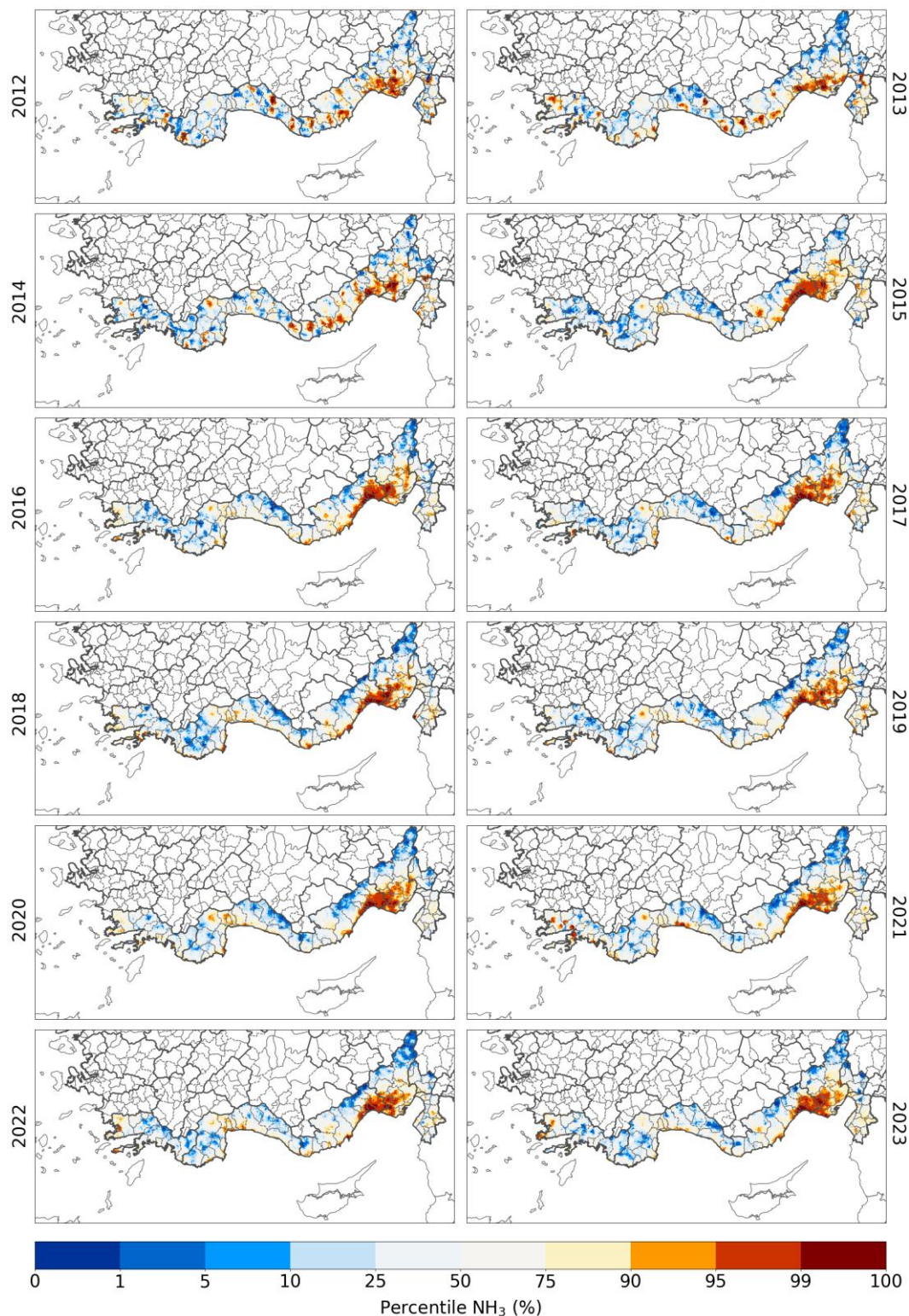


Figure 4.4 : Annual NH_3 percentile distributions (%) for 2012-2023 for the selected provinces.

The district-based average NH_3 percentile scores in Antalya, Hatay, and Osmaniye were relatively lower compared to Adana and Mersin, but still some districts exhibited elevated long-term scores, particularly in Antalya. For instance, Muratpasa (82.9) and Kepez (80.6) had the highest scores in the province, followed by Aksu (73.7) and Döşemealtı (72.1). In Hatay, Kumlu (79.7), Reyhanlı (78.2), Erzin (75.7), and Antakya (75.6) showed relatively higher scores, in Osmaniye, Toprakkale (73.2) recorded a relatively high average, whereas Kadirli (56.2) and other districts remained noticeably lower.

In addition to annual distributions and trend, seasonal and monthly analysis of NH_3 was also important to better understand temporal patterns and identify periods of elevated levels. Thus, seasonal, and monthly NH_3 distributions were compiled. From the seasonal maps, it was clearly observed that NH_3 levels are highest in summer, followed by spring and fall, with the lowest levels consistently occurring in winter across all years (Figure 4.5). This seasonal trend was also clearly illustrated in the seasonal average NH_3 concentrations by province (Figure 4.6), where both agricultural and total area average NH_3 levels showed a significant increase from spring to summer with reaching their peak in summer across all provinces. Seasonal statistics for the provinces and overall study area are presented in Table C.2 and the seasonal average NH_3 levels are presented in Figure 4.6. Average NH_3 concentrations in agricultural areas during summer were highest in Mersin at 7.68×10^{15} molecules/cm², followed by Adana (6.99×10^{15} molecules/cm²), Muğla (5.94×10^{15} molecules/cm²), Antalya (5.78×10^{15} molecules/cm²), Osmaniye (5.08×10^{15} molecules/cm²), and Hatay (4.95×10^{15} molecules/cm²) (Figure 4.6). In terms of all land areas, Mersin again recorded the highest average with 6.07×10^{15} molecules/cm², followed by Adana (5.56×10^{15} molecules/cm²), Muğla (5.49×10^{15} molecules/cm²), Antalya (4.94×10^{15} molecules/cm²), Hatay (4.86×10^{15} molecules/cm²), and Osmaniye (4.23×10^{15} molecules/cm²). The high average NH_3 concentrations observed in Mersin and Adana across all areas can be attributed to two main factors here, large proportion of agricultural land within the grids and additional contributions from non-agricultural sources. Although simplified CLC classification had been applied in this analysis, when CLC map was examined (Figure 3.1) agricultural and urban/industrial areas are often spatially intertwined, especially in Mersin and Adana. Such mixed-use grids were primarily categorized based on the dominant land cover in the simplified CLC, but still can include substantial agricultural or industrial influence within the same grid.

This spatial overlap can lead to elevated NH_3 levels in areas where classified as non-agricultural due to the presence of agricultural activity or otherwise.

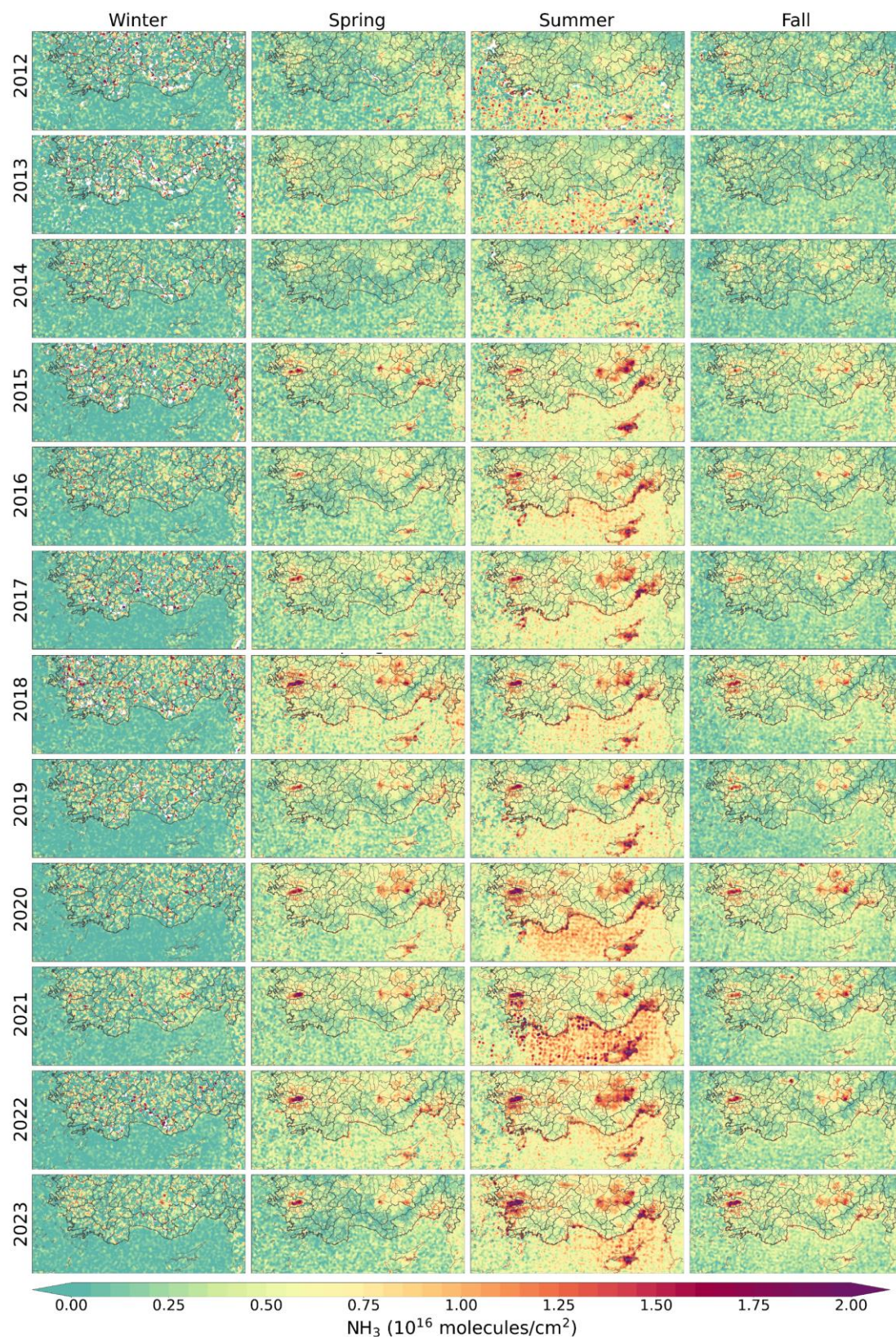


Figure 4.5 : Seasonal average NH_3 distributions for 2012-2023 (molecules/ cm^2).

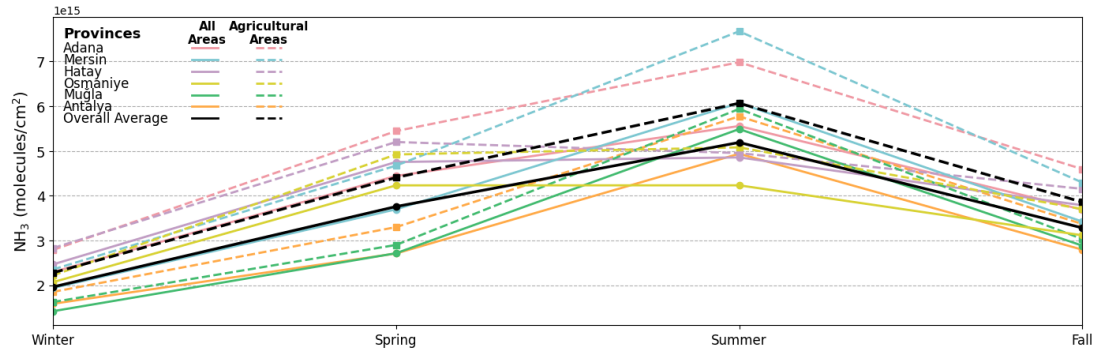


Figure 4.6 : Seasonal average NH_3 (molecules/cm²) according to all and agricultural land type for the selected provinces.

During spring, the highest average NH_3 concentrations were again observed in Adana, both in agricultural areas (5.45×10^{15} molecules/cm²) and across all land areas (4.44×10^{15} molecules/cm²). However, unlike summer, Mersin did not rank second highest in spring. Instead, Hatay (5.20×10^{15} molecules/cm²), Osmaniye (4.92×10^{15} molecules/cm²), and Mersin (4.67×10^{15} molecules/cm²) followed Adana in agricultural areas. In terms of all land areas, Hatay again ranked second one (4.76×10^{15} molecules/cm²), followed by Osmaniye (4.23×10^{15} molecules/cm²), Mersin (3.70×10^{15} molecules/cm²), and Antalya (2.71×10^{15} molecules/cm²). As emphasized earlier, NH_3 concentrations were generally high during spring and summer. However, in the seasonal distributions, relatively elevated NH_3 levels were also observed in fall season. Particularly in the eastern part of the study area, mainly in the provinces of Adana and Mersin, and moderately high levels were recorded in Osmaniye and Hatay (Figure 4.5).

During the fall, average NH_3 concentrations were again relatively high in Adana (4.60×10^{15} molecules/cm² in agricultural areas and 3.69×10^{15} molecules/cm² in all land areas) and Mersin (4.30×10^{15} molecules/cm² in agricultural areas and 3.42×10^{15} molecules/cm² in all areas). Hatay (4.16×10^{15} molecules/cm² in agricultural areas and 3.79×10^{15} molecules/cm²) and Osmaniye (3.70×10^{15} molecules/cm² in agricultural areas and 3.12×10^{15} molecules/cm² in all areas) also observed above-average concentrations compared to the overall regional mean (Table C.2). When evaluated together with the seasonal percentile maps, this observation became more evident; although overall NH_3 levels were lower compared to other seasons, these regions still appeared as seasonal NH_3 hotspots (Figure 4.7 and Table C.5).

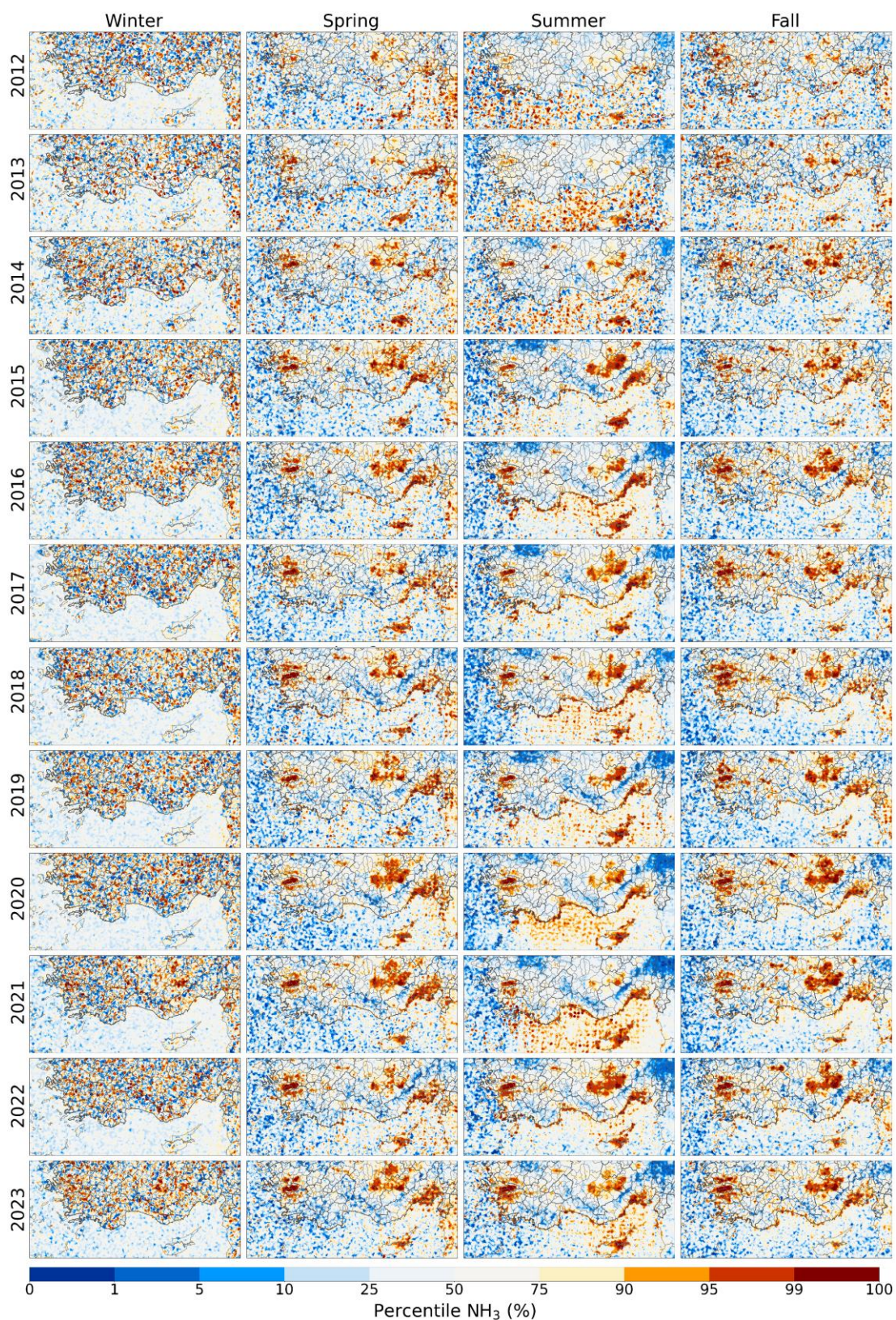


Figure 4.7 : Seasonal percentile NH_3 distributions (%) for 2012-2023.

In Adana province, Seyhan consistently had the highest percentile score across all three seasons which were 92.8 in spring, 94.0 in summer, and 89.4 in fall. Yuregir also showed strong score, ranging from 87.7 in spring to 80.0 in fall. Other districts such as Karatas, Cukurova, and Saricam remained above the 70th percentile in all three seasons.

In Mersin, Akdeniz recorded extremely high percentile score with reaching 98.6 in summer and 94.2 in fall. Yenisehir district also showed a similar trend with score over 87 in all seasons. Tarsus and Mezitli showed moderately high percentiles which mostly above 70th percentile while in Antalya, Muratpasa and Kepez district show the highest percentile score in summer (80.9 and 78.8, respectively).

For Osmaniye, although spring values for Toprakkale (79.6) and Kadirli (65.8) were notable, fall percentiles dropped slightly but remained moderate with Toprakkale reaching 61.4. In Hatay, unlike the other provinces where observed high during NH₃ percentiles summer, relatively higher values were observed in spring and fall. For instance, Reyhanlı and Kumlu had spring percentile scores of 80.6 and 80.0, respectively, and remained elevated in fall with 72.5 and 73.5.

During winter, the spatial distributions appeared relatively noisy, which this problem likely due to the limitations of satellite observations under unfavorable weather conditions. Despite this, elevated NH₃ levels were occasionally observed, particularly in Adana and Mersin (Figure 4.5). When considered together with the percentile-based distributions (Figure 4.7), these regions became relatively more evident.

In addition to seasonal patterns, monthly NH₃ distributions were also examined to better understand variations on a monthly basis (Figure B. 2 and Figure B. 3). In 2021, particularly high NH₃ levels were observed during July and August, which significantly contributed to the overall peak seen in the summer months. These elevated concentrations were observed across the southern and southeastern part of the regions. In addition, during spring months, especially April and May, and throughout the summer months a southward transport trend toward the Mediterranean Sea were particularly noticeable in almost every year. Even, relatively high NH₃ concentrations were occasionally detected during winter months as well.

Furthermore, relatively high NH₃ levels were also evident in September and October, especially over Adana and Mersin provinces. This pattern supports the seasonal findings where these areas appeared as hotspots during the fall. Even in monthly percentile maps (Figure B.4 and Figure B.5) it became more evident after 2015.

All these findings indicated that despite the decrease in agricultural activities after summer months elevated NH_3 levels in these areas may be attributed to the influence of other sources, such as NH_3 -emitting industries and agricultural residue burning and also meteorological conditions.

The study area was examined with considering the CLC (Figure 3.1), with particular attention to agricultural lands in Aksu, Serik, and Manavgat districts in Antalya; Seyhan, Yüreğir, Karatas, and Ceyhan districts in Adana; and Tarsus, Akdeniz, Yenisehir, Mezitli and Erdemli districts near the center of Mersin, as well as the southern coastal areas around Silifke. In these regions, NH_3 levels became especially prominent during spring and summer, which particularly corresponds to periods of intense agricultural activity. Further, livestock and agricultural production from the Turkish Statistical Institute (TUIK) were analyzed together with considering NH_3 hotspots and CLC (APPENDIX A: Livestock and crop statistics).

Vegetable production was highest in Antalya, exceeding 4×10^6 tons, particularly in the Serik and Aksu districts (Figure A.2). In Mersin, more than 1.5×10^6 tons were recorded, mainly in Tarsus, Erdemli, Akdeniz, and Silifke (Figure A.3), while in Adana, over 1×10^6 tons were reported in Karatas, Yüreğir, and Seyhan (Figure A.1). For cereal production, Adana (Figure A.1) recorded more than 150×10^4 tons, particularly in Ceyhan, Yüreğir, and Karatas, and Milas, Seydikemer, and Yatagan, respectively.

In terms of fruit production, Mersin recorded the highest values, exceeding 3×10^6 tons (Figure A.3), mainly in Tarsus, Erdemli, and Anamur. Adana followed with over 2×10^6 tons, especially in Yüreğir, Karatas, Seyhan, Kozan, Ceyhan, and Yumurtalık (Figure A.1), while Antalya recorded more than 1×10^6 tons, particularly in Elmalı and Manavgat (Figure A.2). In contrast, Hatay (Figure A.4) and Osmaniye (Figure A.5) had lower production values for cereals, vegetables, and fruits compared to the other provinces.

When seasonal NH_3 distributions and crop production were considered together, a strong spatial overlap was observed between NH_3 hotspots and districts with intensive agricultural activity. Specifically, areas such as Serik and Aksu in Antalya, Tarsus, Erdemli, Akdeniz, and Silifke in Mersin, and Karatas, Yüreğir, Seyhan, and Ceyhan in Adana, which recorded the mostly highest crop production according to TUIK statistics, also consistently appeared as NH_3 hotspots during spring and summer, which is mostly known as peak agricultural growing seasons.

This spatial alignment strengthens the crop production role in contributing to elevated NH_3 levels in these provinces. However, crop production itself did not fully explain the observed high NH_3 levels. Additional factors such as the type and amount of fertilizer used, application timing and frequency, and the specific crop types played a significant role in this context. Furthermore, climatic conditions may have influenced the volatilization processes, further affecting NH_3 emission levels. When livestock statistics were examined, Mersin stood out with more than 1500,000 animals (Figure 4.8), particularly concentrated in districts such as Tarsus, Erdemli, and Silifke (Figure A.8). Notably, poultry revealed that Tarsus alone hosted approximately 800,000 representing the highest poultry population in the entire region. This substantial livestock presence, especially in Tarsus, aligns with the observed NH_3 hotspots and indicated that emissions from animal husbandry might be significant contributor to elevated NH_3 concentrations in the area.

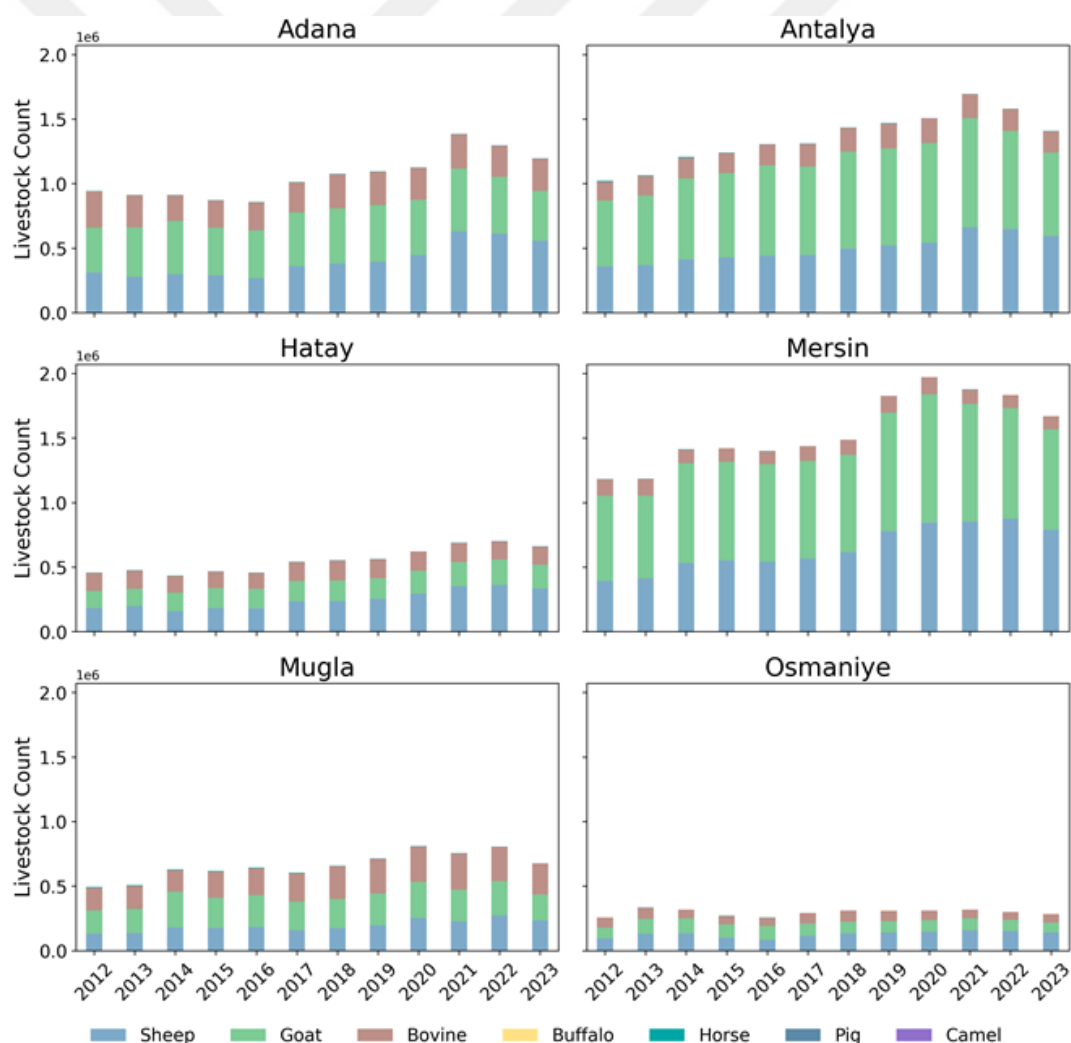


Figure 4.8 : Annual livestock count for the province (Adana, Antalya, Hatay, Mersin, Mugla, Osmaniye, respectively).

Considering the potential link between NH_3 levels and agricultural activities, NH_3 concentrations were analyzed separately for agricultural areas and for all land types. In this context, both daily average time series analyses for agricultural lands and all land cover types (Figure 4.9) were conducted.

Daily average analyses showed that the overall study area exhibited high NH_3 levels across all land types. However, average concentrations were higher over agricultural lands compared to all land type areas. Agricultural areas also showed a clear seasonal trend, with concentrations starting to increase in spring, peaking in summer, and then decreasing towards fall and winter. When evaluated at the province-based time series, the seasonal trend in agricultural lands was especially evident in Adana, Mersin, and Antalya. In these provinces, agricultural areas showed significantly higher daily average NH_3 levels compared to all land types. In contrast, a distinct seasonal pattern was not observed in Osmaniye and Hatay.

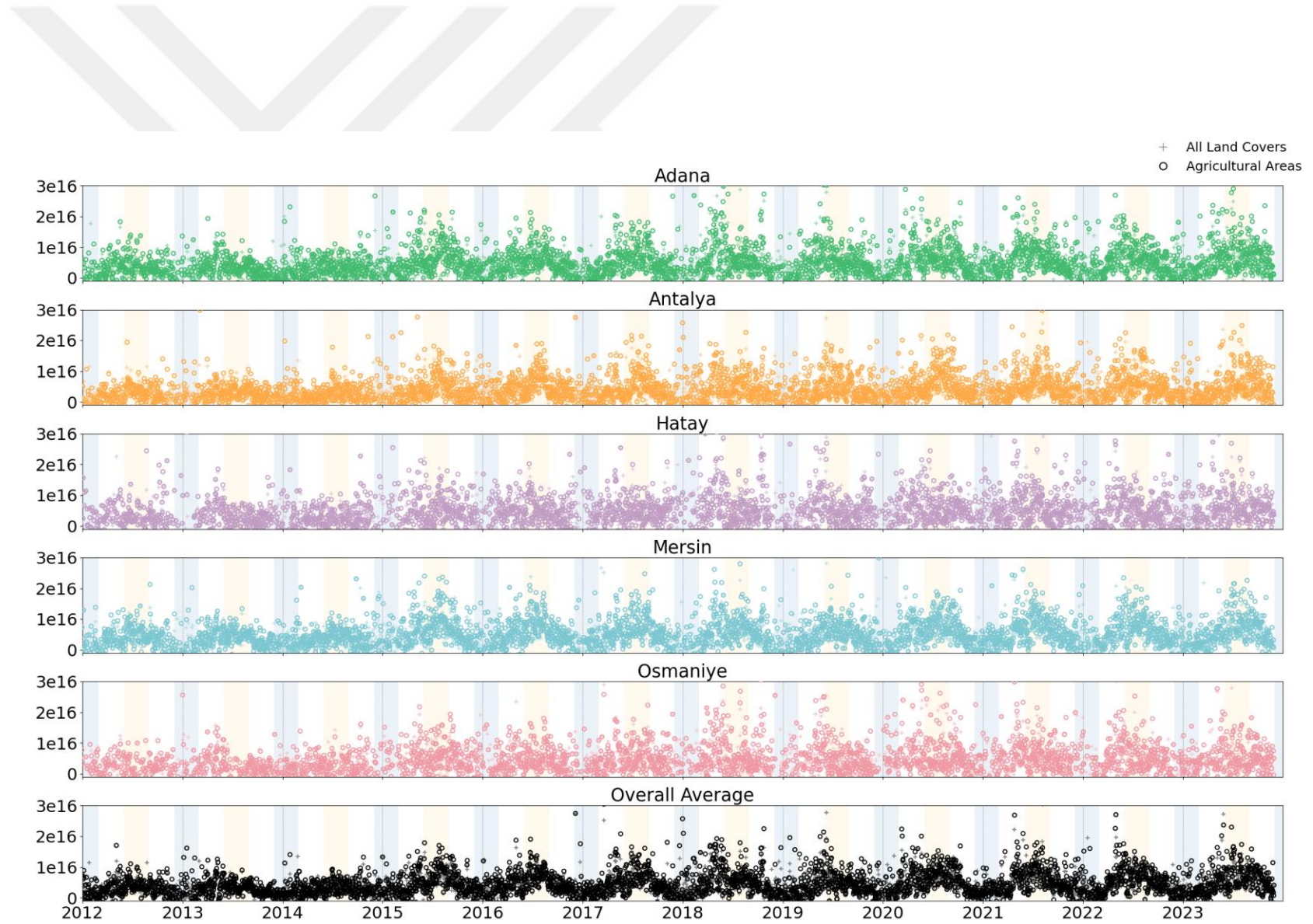


Figure 4.9 : Daily average time series of NH_3 according to the land type and each provinces and overall study area.

In addition, an annual increase in NH₃ levels was observed from 2012 to 2023 in most provinces. However, to statistically examine whether these increases reflect a consistent trend or not, Mann-Kendall trend analysis was performed at both the province (Table 4.1) and district level (Table C.6).

Table 4.1 : Mann Kendall Trend analysis results for provinces.

Province	Agricultural Areas				All Areas			
	Intercept	Trend	p	Slope	Intercept	Trend	p	Slope
Adana	3.26 x10 ¹⁵	↑	*	1.74 x10 ¹⁴	2.87 x10 ¹⁵	↑	*	8.75 x10 ¹³
Antalya	2.27 x10 ¹⁵	↑	*	1.24 x10 ¹⁴	2.10 x10 ¹⁵	↑	*	5.16 x10 ¹³
Hatay	2.92 x10 ¹⁵	↑	*	1.42 x10 ¹⁴	2.69 x10 ¹⁵	↑	*	1.27 x10 ¹⁴
Mersin	3.49 x10 ¹⁵	↑	*	1.21 x10 ¹⁴	2.85 x10 ¹⁵	↑	*	6.26 x10 ¹³
Mugla	2.06 x10 ¹⁵	↑	*	1.53 x10 ¹⁴	1.86 x10 ¹⁵	↑	*	9.77 x10 ¹³
Osmaniye	2.87 x10 ¹⁵	↑	*	1.24 x10 ¹⁴	2.50 x10 ¹⁵	↑	*	9.00 x10 ¹³

According to the trend analysis results all provinces showed statistically significant increasing trends (* represent $p < 0.05$ ↑ represent increasing trend, and slope in unit of molecules/cm²/year) in NH₃ concentrations over the study period. This trend was observed in both agricultural areas and overall land areas. Among these provinces, Adana showed the highest trend slope in agricultural areas (1.74x10¹⁴ molecules/cm²/year). This slope indicates the average annual increase in concentrations which basically means that NH₃ levels in agricultural areas of Adana increased by this amount each year during the study period. For overall areas, although the trend slopes were lower than agricultural areas, the increasing trend remained consistent across all provinces.

Further district-based Mann-Kendall result showed (Table C.6) that many districts across the study region exhibited statistically significant increasing trends in both agricultural and overall land areas. For instance, Cukurova district in Adana showed a strong upward trend with a slope of 8.58x10¹⁴ molecules/cm²/year in agricultural areas and 5.85x10¹⁴ molecules/cm²/year in all land areas. Similarly, Aydıncık in Mersin showed one of the highest trend slopes, with 5.06x10¹⁵ molecules/cm²/year in agricultural areas and 4.13x10¹⁴ molecules/cm²/year in all areas. In contrast, there were also districts where an increasing trend was observed only in agricultural areas but not in all land types. For example, Akseki showed an increasing trend only in agricultural areas (7.48x10¹⁴ molecules/cm²/year), while no statistically significant trend was observed in all land areas (3.90x10¹² molecules/cm²/year). On the other hand, there were also few districts that showed both decreasing trend such as Toroslar district in Mersin with slopes of -1.20x10¹⁴ molecules/cm²/year in agricultural

areas and -4.50×10^{13} molecules/cm²/year in all areas. Overall, most of the district show upward trend with few districts with consistent downward trends.

In addition to the seasonal trend that observed in daily average analyses, monthly boxplots revealed notably high NH₃ concentrations over artificial surfaces, particularly in the Mersin and Adana provinces (Figure 4.10). Even these concentrations exceeded the overall regional average. As mentioned earlier, this might indicate industrial NH₃-emitting sources in these areas. Moreover, due to the spatial overlap of industrial and agricultural zones in Mersin and Adana, agricultural activities taking place within these urbanized areas may also contribute to the elevated NH₃ levels observed over artificial surfaces.

For forest and semi-natural areas remained relatively low and stable throughout the year with a slight seasonal pattern can be observed but still seasonal variation was limited compared to agricultural and artificial surfaces. The district-level analyses further support these findings (Figure 4.10). Such as elevated NH₃ concentrations in Seyhan (Adana) and Akdeniz (Mersin) both of which contain dense industrial and agricultural zones. In contrast, lower NH₃ levels in districts such as Reyhanlı (Hatay) and Kadirli (Osmaniye) showed comparatively weaker concentrations despite following a similar seasonal trend.

So far, all these findings showed that elevated NH₃ levels could be related to agricultural and industrial sources, as well as additional sources such as biomass burning, and meteorological conditions that might influence the observed concentrations. Therefore, the potential impact of agricultural residue burning in this region was further investigated in Chapter 5, and NH₃ levels and selected MSs were examined in detail here.

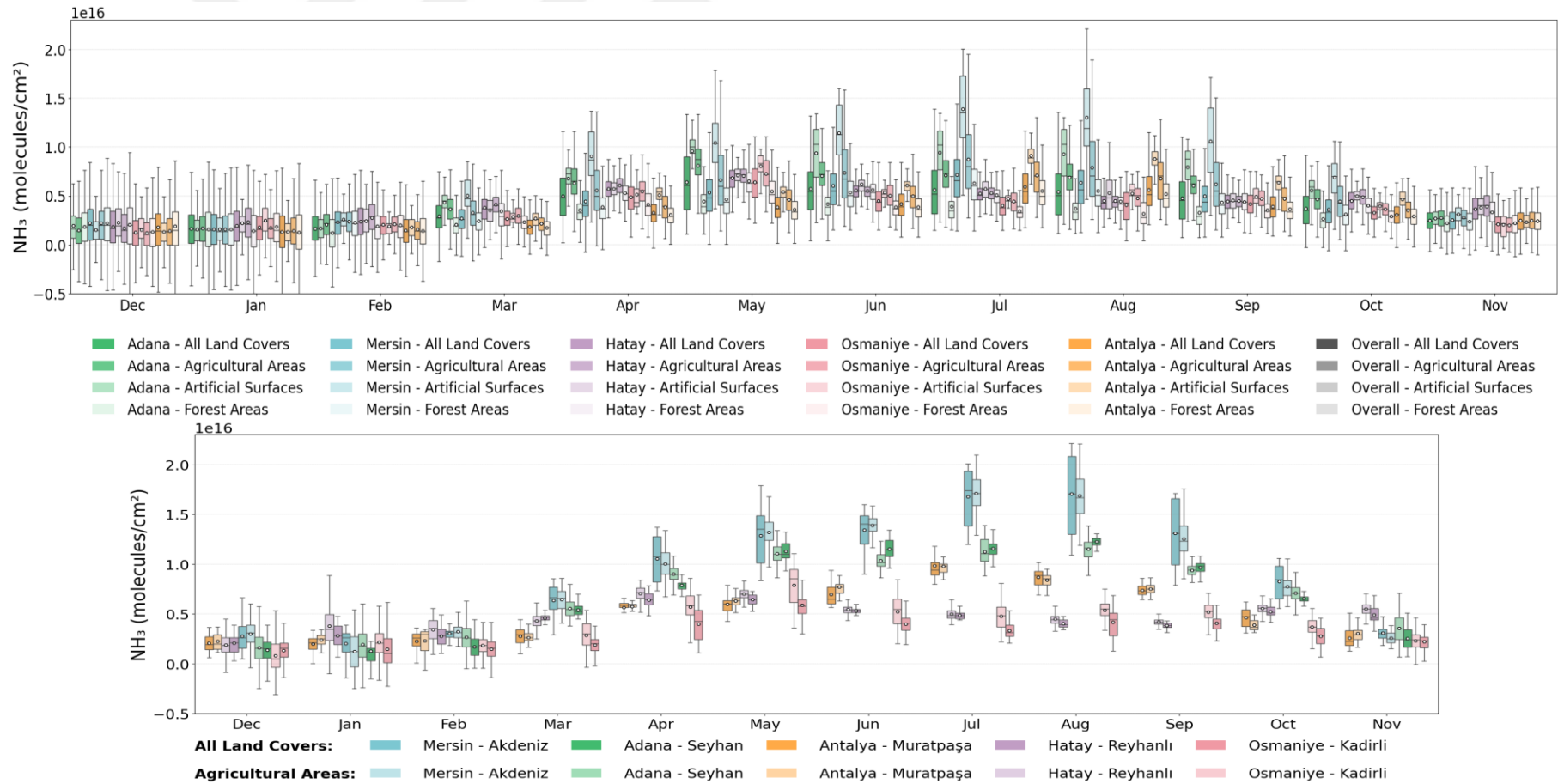


Figure 4.10 : Monthly distribution of NH_3 concentrations by province and land cover type (top), and by selected districts within each province (bottom).

To investigate the possible influence of meteorology on NH_3 levels, data from TSMS and NOAA were used. TSMS data were utilized for understand the periodic-pollution distribution and hourly evaluations of T, RH, WS, and WD, whereas NH_3 levels according to land type were evaluated alongside daily average T and daily total P for provinces using the NOAA meteorological dataset. When NH_3 distributions were examined together with the CLC and TSMS data for Adana, the elevated NH_3 levels observed particularly during summer and spring can be attributed to the presence of nearby agricultural areas. For fall, and even winter, the high concentrations detected toward the north may reflect the possible contribution of point source emissions, especially from fertilizer production facilities known to be concentrated in that area (Figure 4.11). Similar to Adana, Mersin MS showed higher NH_3 levels during summer and spring, which aligns with the presence of intensively cultivated agricultural areas surrounding the MS.

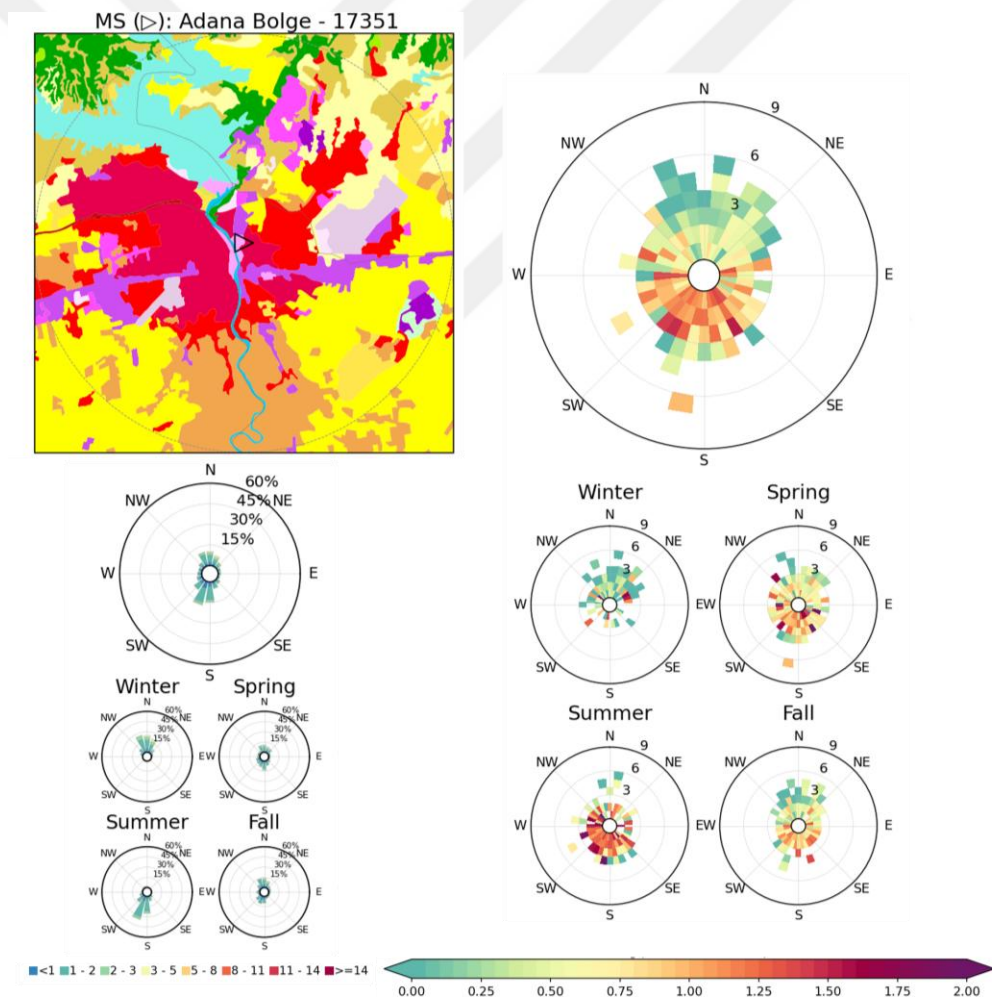


Figure 4.11 : CLC data near MS (top left), wind roses (bottom left; long-term (top) and seasonal (bottom)), NH_3 distribution (right; long-term (top) and seasonal (bottom)) for Adana.

Moreover, elevated NH_3 concentrations detected in the other seasons were also likely influenced by point sources situated along the highway corridor to the north of the MS (Figure E. 1). This particular pattern is also detected in the selected Antalya and Osmaniye MSs, where similar spatial relationships between NH_3 levels and agricultural emissions were observed (Figure E. 1 and Figure E. 2). In contrast, for Hatay, the absence of elevated NH_3 levels in spring and summer may be explained by the lack of intensive agricultural land use around the MS, as can be seen in the CLC data (Figure E. 2). Instead, the consistently high NH_3 concentrations observed throughout all seasons were attributed to the influence of point source emissions.

To further investigate the potential meteorological drivers of NH_3 , time series analyses were conducted for the same MSs. Based on the analyses that conducted for Adana showed high NH_3 levels with increasing T overtime (Figure 4.12). This trend was more noticeably between spring and summer. Moreover, in summer most the extreme levels were detected under the influence of extreme T observations such as in spring of 2020, elevated high concentrations overlap with high T. Further, year-specific correlation analyses showed that NH_3 -T pair had the most positive strong and statistically significant relationship. Other than that RH and WS relationship between NH_3 mostly showed fluctuations.

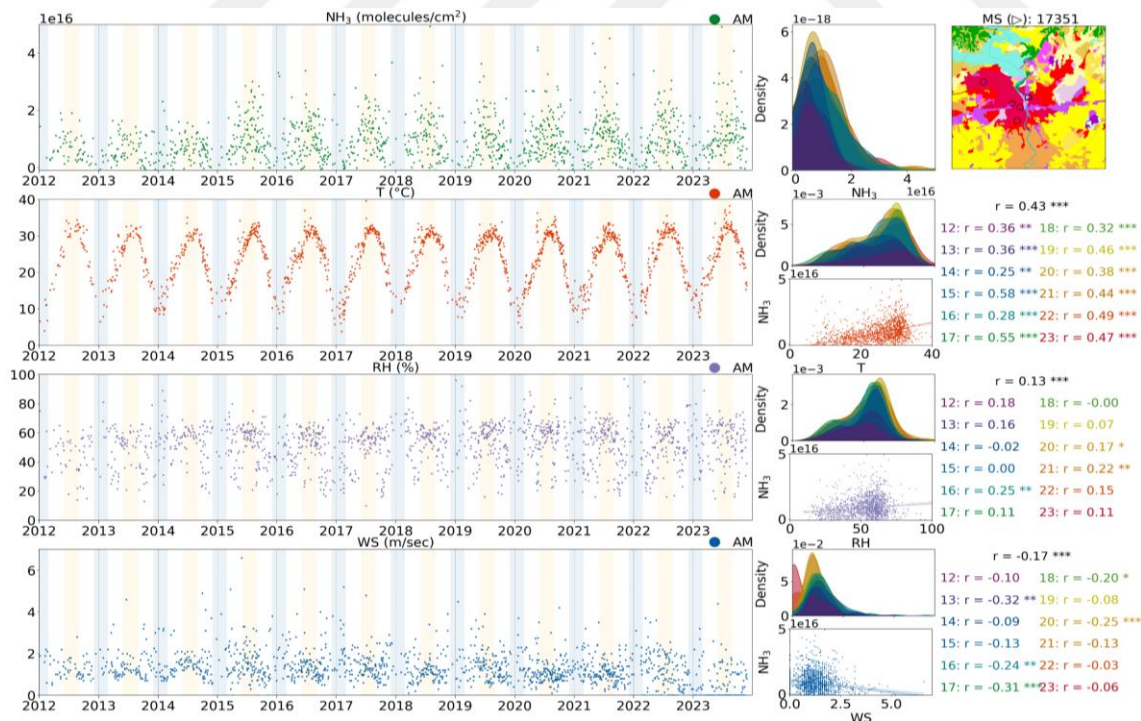


Figure 4.12 : Time series of NH_3 , T, RH, and WS from 2012 to 2023 (left), along with corresponding density plots and year-specific correlation analyses (right) for Adana.

For the other MSs results basically showed the similar trend in Antalya, Mersin and Osmaniye MSs mostly high relationship between NH_3 -T except Hatay (Figure F. 1 to Figure F. 4). In Hatay, there was no significant relationship between NH_3 and any other meteorological parameter except a few exceptions in T in year 2017 and 2021 to 2023.

For RH- NH_3 relationship most of the MSs observed fluctuated relationship or showed no statistical relation at all. Except Antalya which showed quite high and statistically significant year-specific correlation. For WD in all provinces, there were no correlation at all.

When NOAA meteorological dataset used for additional analyses showed that high NH_3 concentrations across provinces were generally matched with the seasonal T trend and lowest levels typically matched with periods of higher P, except in Osmaniye, where the precipitation data were limited (Figure 4.13).

This pattern was especially notable in Adana, Antalya, and Mersin. In these provinces, NH_3 levels started to increase with rising T in spring, reached their highest values in summer, which also detected early with TSMS data, and decreased again in autumn as T dropped. Periods with more P, especially in early spring and late autumn, were linked to clear decrease in NH_3 , which could be showed the possible effect of wet removal of NH_3 . In Osmaniye, the lack of P data made it hard to evaluate this relationship, while Hatay showed a similar seasonal pattern but with slightly lower NH_3 levels.

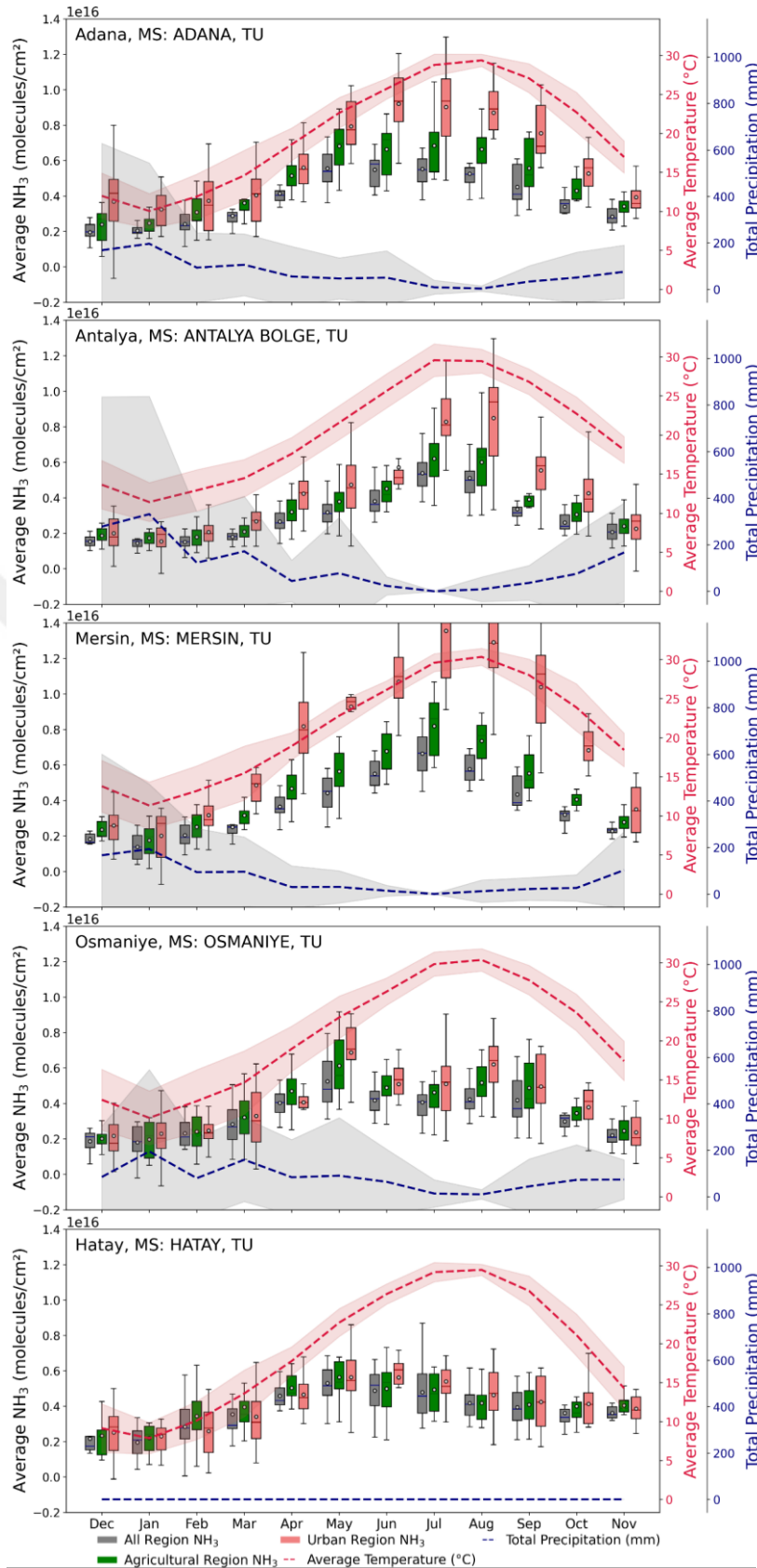


Figure 4.13 : Monthly boxplots of NH_3 concentrations in different land types with daily average T, and daily total P (Adana, Antalya, Mersin, Osmaniye and Hatay, respectively).

Further correlation analysis supported these observations (Table 4.2). From the analyses strong positive relationships were found between NH_3 and T, and strong negative relationships with P as indicated by correlation coefficients (r) and significance levels (** for $p < 0.01$, and * for $p < 0.05$). For instance, in Mersin, NH_3 levels in agricultural areas showed a strong correlation with T of 0.93***, while a clear negative correlation was found with P with $r = -0.91$ ***. Similar trends were observed in Adana, where the correlation with T was $r = 0.87$ *** and with P was $r = -0.84$ ***. Provinces that showed strong positive correlations between NH_3 and T, along with strong negative correlations with P, such as Adana and Mersin, were more likely influenced by agricultural NH_3 emissions. In contrast, provinces like Hatay, where the correlations were slightly weaker, could reflect a much lower contribution from agricultural sources.

Table 4.2 : Correlation analysis of NH_3 according to land type and meteorological variables (A: All Areas NH_3 ; S: Artificial Surfaces NH_3 ; G: Agricultural NH_3 ; T: Daily average T; P: Daily total P).

Parameters	Adana	Antalya	Hatay	Mersin	Osmaniye
A NH_3 - G NH_3	0.99***	0.998***	0.99***	0.99***	0.99***
A NH_3 - S NH_3	0.99***	0.99***	0.98***	0.99***	0.98***
A NH_3 - T	0.87***	0.96***	0.72**	0.92***	0.70*
A NH_3 - P	-0.82**	-0.84***	-0.8**	-0.89***	-0.42
G NH_3 - S NH_3	0.98***	0.99***	0.97***	0.99***	0.99***
G NH_3 - T	0.87***	0.96***	0.67*	0.93***	0.71**
G NH_3 - P	-0.84***	-0.86***	-0.74**	-0.91***	-0.43
S NH_3 - T	0.92***	0.96***	0.79**	0.93***	0.71*
S NH_3 - P	-0.84***	-0.87***	-0.86***	-0.92***	-0.41
T-P	-0.91***	-0.85***	-0.90***	-0.89***	-0.83***



5. IMPACT OF BIOMASS BURNING EVENTS ON NH₃ POLLUTION

Based on the NH₃ distributions in Chapter 4, noticeable increases were observed in certain years and regions. These enhancements may indicate a potential link to BB events. Therefore, further analysis was conducted to investigate the relationship between fire activity and NH₃ pollution, as discussed here for wildfires in Chapter 5.2 and for agricultural residue burning in Chapter 5.3.

5.1 Fire Periods and Regions

Firstly, VIIRS FRP product were used to understand fire characteristics and periods, and to define fire-regions based on the fire data over the study domain. FRP-sums were generally elevated during the summer and fall seasons across the study area (Figure 5.1 and Figure 5.2). The most intense FRP signals were observed in the summer of 2021, particularly in July and August months. In fact, much of the elevated FRP levels observed at Türkiye for 2021 FRP were caused by the fires originated from the study area.

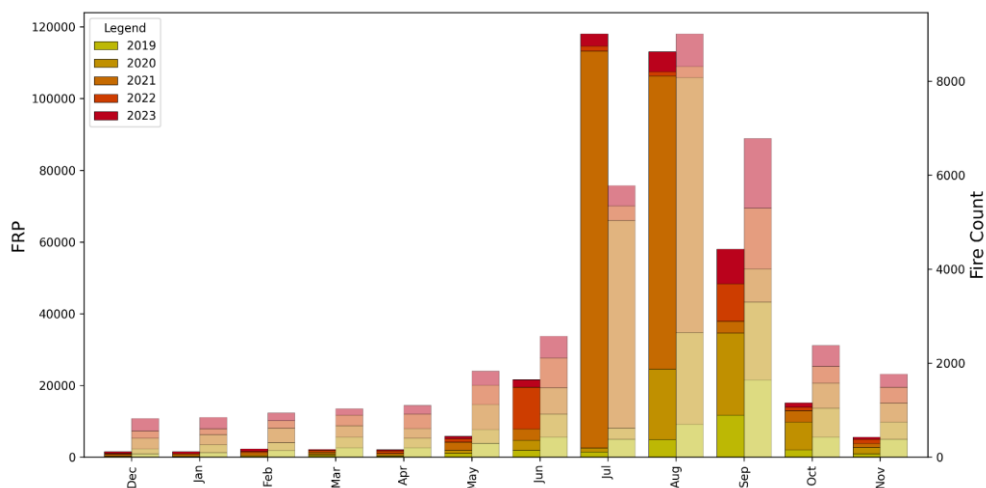


Figure 5.1 : Monthly total FRP (right) and fire counts (left) for the study area.

When the seasonal spatial distribution of FRP was examined, these high FRP levels for 2021 summer were mostly concentrated over Antalya, Mersin, and Mugla, which corresponding to the large-scale wildfires (WF) that occurred in these provinces (Figure 5.2).

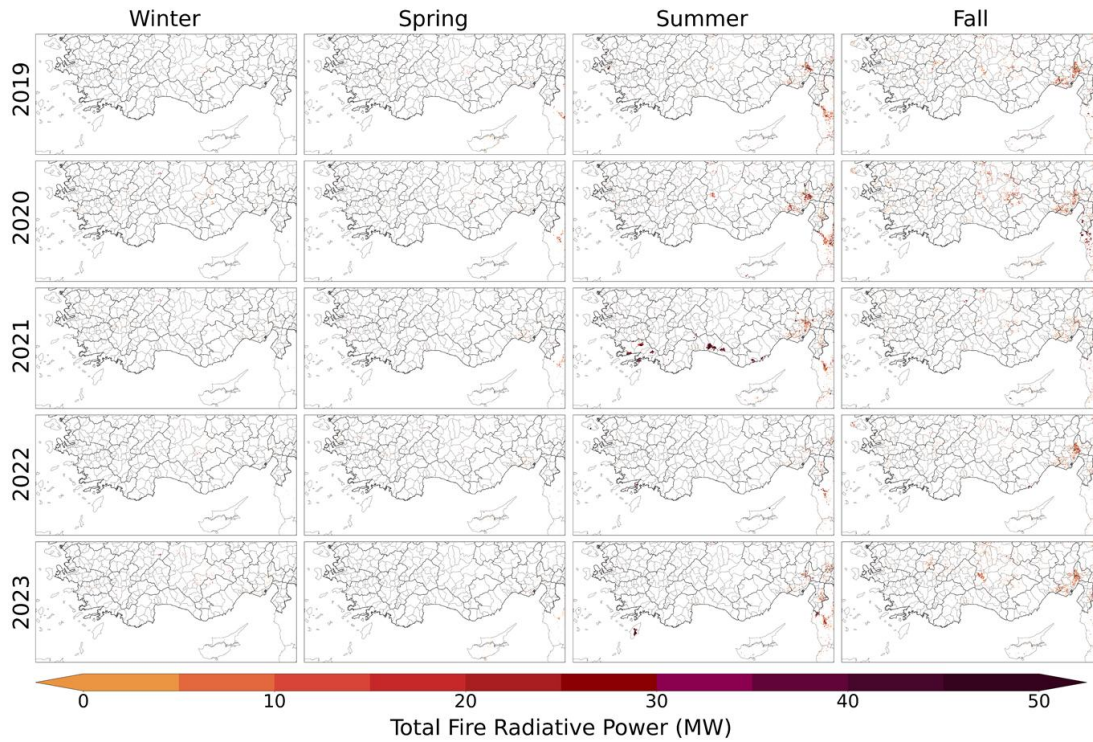


Figure 5.2 : Seasonal FRP distribution for study area.

To investigate fire-NH₃ relationship during WF event, the analysis focused on these intense wildfires that occurred in 2021, and specific fire-regions were defined based on FRP hotspots. As shown in Figure 5.3, the selected WF regions included multiple areas in Antalya (AN: AN-1, AN-2), Mersin (ME: ME-1, ME-2), and Mugla (MU: MU-1 to MU-4).

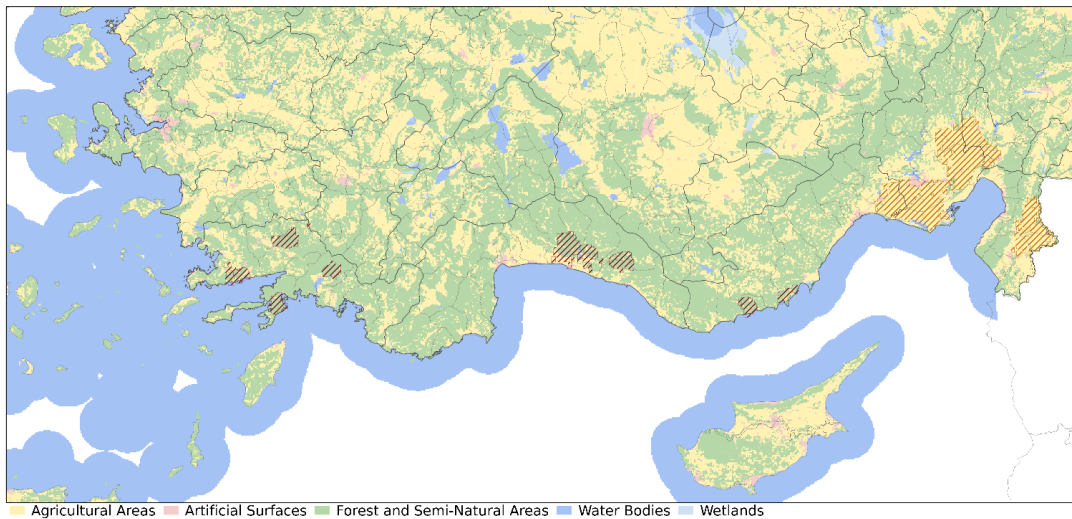


Figure 5.3 : Study area with fire region with simplified CLC (red hatched regions represent wildfire while orange hatched regions represent residue burning).

As shown in the FRP time series based on these WF regions (Figure 5.4, Table 5.1), the highest FRP levels were observed in the AN and MU regions compared to ME regions. Within these, AN-1 and MU-1 showed particularly intense activity. A sharp increase in FRP was observed at different times within each region. For instance, AN-1 peaked on 28 July with 24,743 MW, while ME-2 and MU-3 showed its highest FRP on 29 July with 5,315 MW and 6,212 MW, respectively. In the MU-1 and MU-2 regions, peaks were observed later, such as 12,017 MW in MU-1 on 1 August, 8,741 in MU-2 on 5 August and 2,609 in MU-4 on 3 August. Although peak timings and magnitudes varied across WF-regions, a common temporal interval was defined to ensure consistent spatial-temporal comparison.

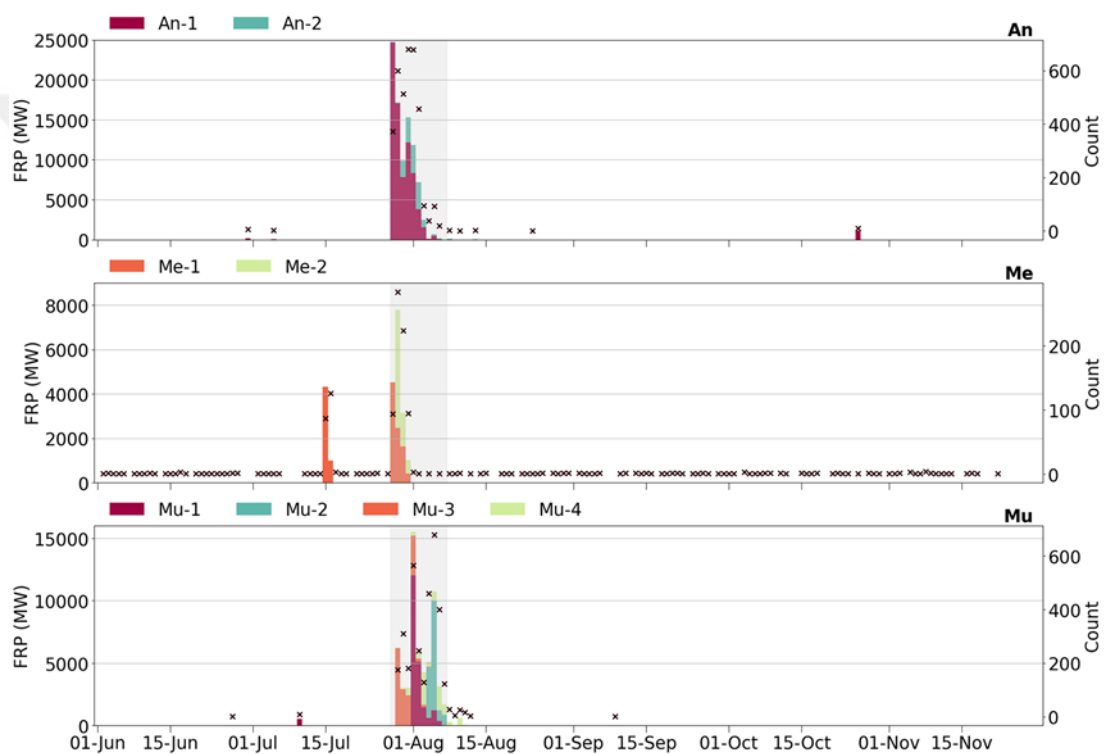


Figure 5.4 : Time series of FRP-sum (right, bars) and fire count (left, crosses) for selected wildfire region.

The main fire period was defined as 28 July-07 August based on these observed high FRP and count levels thought the WF-regions. The 10 days before the fire (18-27 July) was selected as **pre-fire** to represent unaffected time period while following 10 days after fires (08-17 August) were defined as **post-fire** to assess changes after the fire events. Selected fire period is emphasized as the gray shaded in Figure 5.4. These time intervals were then used to compare pollutant concentrations before and after the fire events to further analyze their variations in detail across different periods in Chapter 5.2.

Table 5.1 : Fire period FRP (MW) and fire count (C) for each WF-region.

Date	AN				ME				MU							
	AN-1		AN-2		ME-1		ME-2		MU-1		MU-2		MU-3		MU-4	
	FRP	C	FRP	Count	FRP	C	FRP	C	FRP	C	FRP	C	FRP	C	FRP	C
7/28	24,743	373	0	-	4,529	93	3	1	-	-	-	-	-	-	-	-
7/29	17,069	594	141	6	2,467	162	5,315	122	-	-	-	-	6,212	174	13	2
7/30	7,858	416	2,054	98	1,620	114	1,516	110	-	-	-	-	2,909	294	115	15
7/31	12,186	468	3,110	213	415	43	593	52	-	-	-	-	2,436	129	601	52
8/1	8,351	398	3,519	281	11	3	-	-	12,017	345	-	-	3,163	180	324	40
8/2	3,807	229	3,399	227	-	-	3	1	5,133	166	-	-	216	29	537	52
8/3	1,550	70	966	24	-	-	-	-	1,453	68	-	-	201	19	2,609	42
8/4	96	28	44	10	-	-	2	1	624	46	4,040	363	28	5	435	46
8/5	463	64	230	29	-	-	-	-	1,235	90	8,741	507	43	10	711	71
8/6	25	8	139	11	-	-	1	1	356	73	863	154	-	-	1,937	172
8/7	-	-	-	-	-	-	-	-	17	8	820	30	-	-	866	84

When considering the intensity of fire activity in summer and fall, a six-month period analysis (June-November) was performed and presented in Figure 5.5. Monthly spatial distributions of FRP that August and September stand out with notably high levels. During these months, fire activity mostly observed over the eastern part of the region, particularly Mersin, Adana, and Osmaniye, and slightly in Hatay province. When these areas were examined together with the CLC map (Figure 3.1), they mostly overlapped with agricultural lands. Therefore, these regions were selected for detailed analysis of agricultural residue burning (RB) regions.

However, unlike WF regions, it was not possible to define a specific grid for RB regions with only considering one year, season, or time period. This is primarily because RB practices are more diffuse, and vary considerably in timing and location across regions. Therefore, instead of selecting a single fire period and regions, grid selections were made based on cumulative FRP levels over the entire study period. The five-year cumulative FRP distribution (Figure 3.5) along with monthly distributions (Figure 5.5) were used to identify the agricultural regions with the highest FRP activity. The purpose of this selection was to focus on areas where consistently high fire activity (higher than 10 MW) occurred over the five year period. These regions were representative of continuous RB events due to high fire activity rather than short-term anomalies. Based on this, three RB regions were selected for the detailed analysis (Figure 5.3). An area between eastern Mersin and western Adana was defined as Me-Ad. Similarly, the area between eastern Adana and western Osmaniye was defined as Ad-Os. Lastly, a region in southwestern Hatay was also included as Ha. While monthly FRP distributions did not show high levels as in Ad-Me or Ad-Os, this region was detected within the 5-year cumulative analysis and was included for comparison purposes

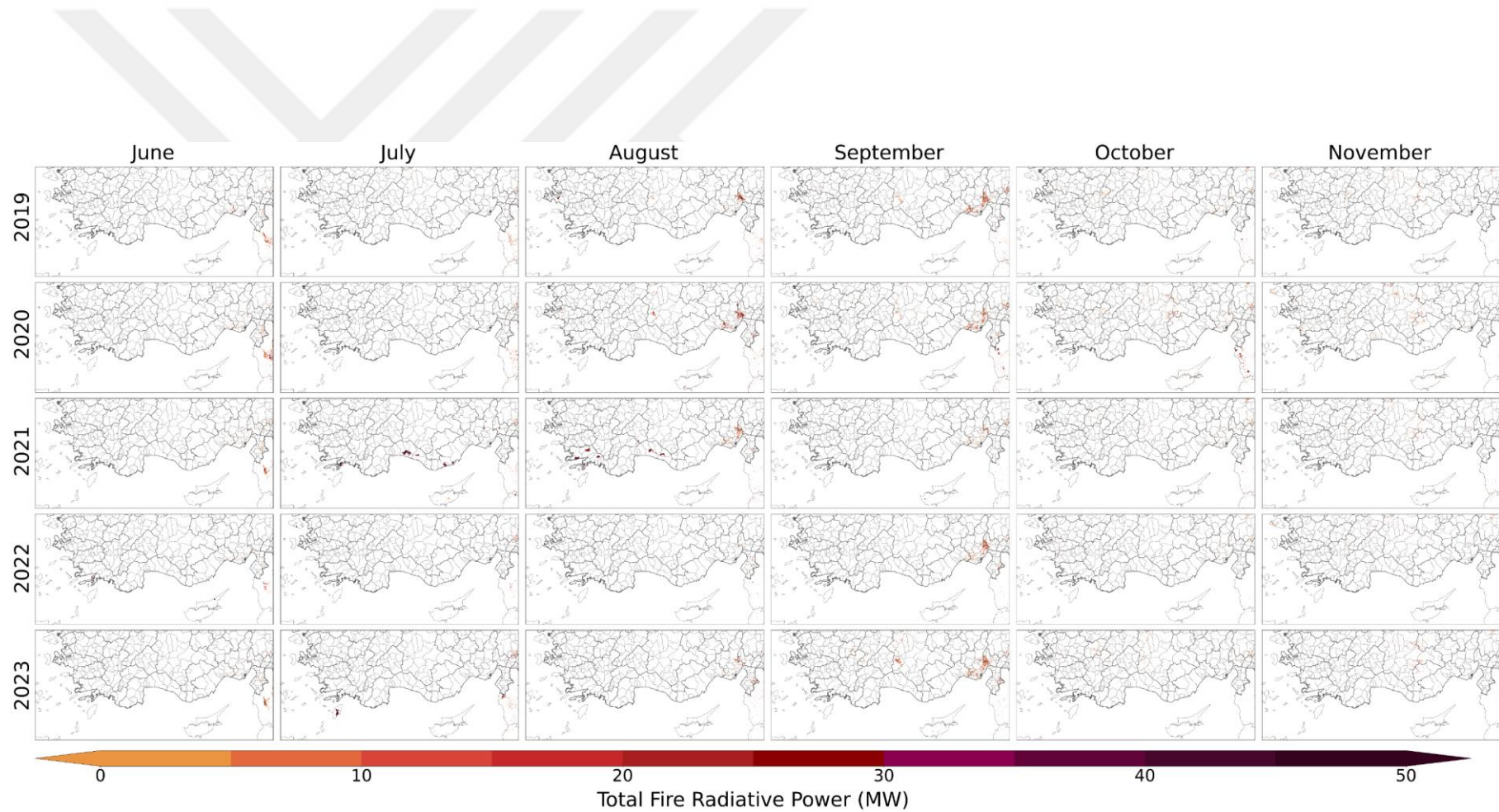


Figure 5.5 : Monthly FRP distribution map for study area.

The time series of FRP showed a similar trend across all RB regions (Figure 5.6). A notable increase was observed from mid-August, then observed their peak levels during late August and early September. After that, FRP gradually decreased toward the end of November.

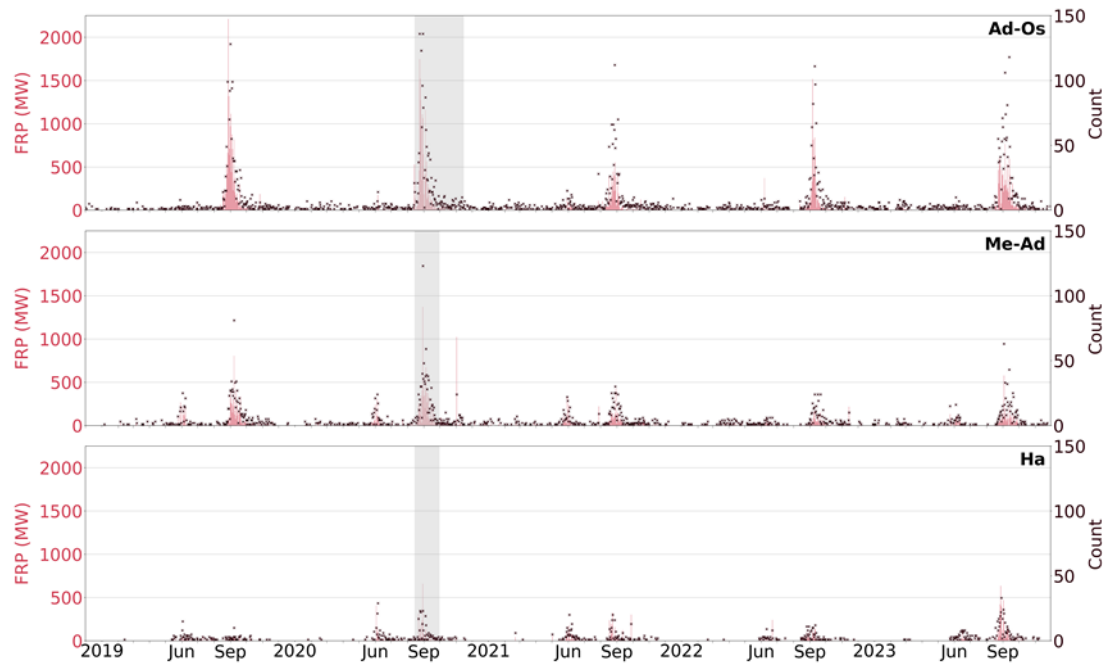


Figure 5.6 : Time series of FRP-sum for selected agricultural region (right, bars) and fire count (left, crosses).

Among all RB regions, Ad-Os recorded much higher FRP levels compared to the others, with the most intense peaks reaching 2212 MW in August 2019 and 1516 MW in September 2022. The Me-Ad region also experienced significant peaks, notably 1371 MW in August 2020 and 1023 MW in November 2020. In comparison, the Ha region remained consistently lower, with a maximum FRP of 660 MW in August 2020. Therefore, two different time intervals were selected for further analysis based on the temporal distribution of FRP across the regions. Although elevated FRP levels were also detected in 2019 and 2022, particularly in the Ad-Os region, the other ones showed limited fire activity during those years. In contrast, 2020 stood out as the only year when all three RB regions experienced significant BB events. As a result, year of 2020 was selected as the common reference year for agricultural burning analysis.

Ad-Os region exhibited much longer fire activity that extended into November. Thus, a longer interval from 15 August to 15 November 2020 was defined for this RB region (hereafter referred as RB-1 fire period). For Me-Ad and Ha RB regions, 15 August and 30 September 2020 were selected as time intervals (hereafter referred as RB-2 fire period). To examine fire-related changes, same as WF regions, 10-day interval

for pre and post periods were defined for each region. For Ad-Os, the pre-fire period was defined as 5-14 August 2020, and the post-fire period as 16-25 November 2020 (hereafter referred as RB-1 pre-fire and RB-1 post-fire, respectively). For Me-Ad and Ha, the pre-fire period was also defined as 5-14 August 2020, while the post-fire period was defined 1-10 October 2020 (hereafter referred as RB-2 pre-fire and RB-2 post-fire, respectively).

5.2 Impact of Wildfires on NH₃ Pollution

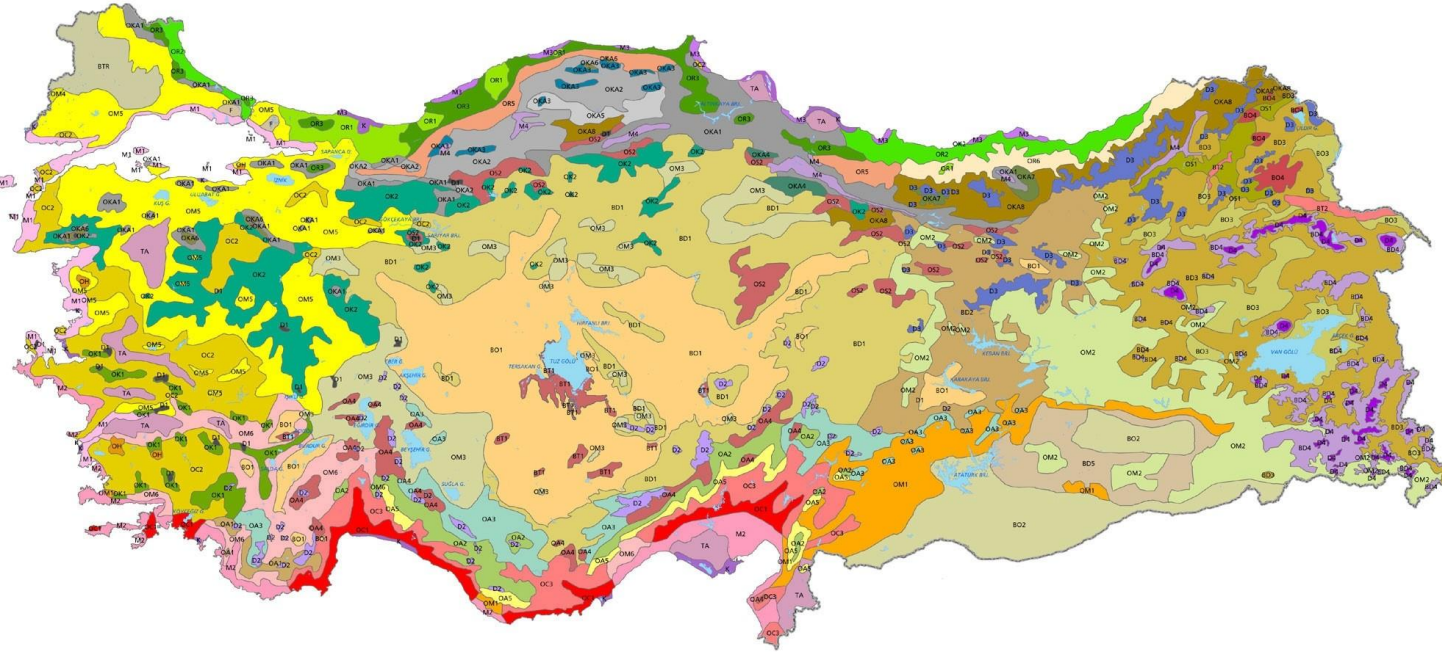
Eastern Mediterranean contains forested lands and natural vegetation, along with its hot and dry climate in summers which makes the region particularly vulnerable to wildfires (Figure 3.1 and Figure 3.4). According to the biome classification of Türkiye (Figure 5.7), one of the most common biome type in this region is the red pine forest type (OC), mostly found near the coast at lower elevations. Specifically, Mediterranean mixed red pine forest (OC1) and Mediterranean red pine forest (OC3) are the dominant biome types in Antalya and Mersin provinces. On the other hand, OC1 is only found in a limited area in the southern part of Mugla, where Aegean red pine forest (OC2) and Aegean black pine forest (OK1) are more prevalent. Additionally, Taurus Mountain forests (TO) are also present in the upper elevation areas of Antalya and Mersin. This combination of extensive forest coverage and climate conditions resulted in notable wildfire activity within the region increasing over the recent years.

According to General Directorate of Forestry (OGM) official record for wildfires (Forestry Statistics, 2025), between 2019 and 2023, a total 200,125.02 hectares (ha) of land in Türkiye were affected by wildfires. Of this amount, 151,534.58 ha of burned area were recorded within the study region, accounting for 75.7% of the national total (Table C.7). The highest contribution from this area occurred in 2021, accounting for 92.5% of the overall national burned ha area and 33.5% of the total recorded fire count. In 2021, a total of 129,034.36 ha of burned area and 935 fire were recorded within the study region. Among the provinces, Antalya was the most affected one with 60,366.56 ha burned area, followed by Mugla with 50,602.92 ha and Mersin with 9,661.20 ha. These recorded values largely reflect the exceptional wildfires that broke out in late July and early August 2021, particularly in these provinces.

Snapshots from MODIS True Color Corrected Reflectance on 2 August July 2021 (Worldview Snapshots, 2025) and CALIOP aerosol type retrievals for the same event illustrated the scale and atmospheric impact of the 2021 wildfires in the region (Figure 5.8). Intense smoke plumes over Antalya and Mugla where transport over the

Mediterranean Sea were observed (Figure 5.8, top) and CALIOP retrievals also indicated the smoke aerosols reaching up to 5-6 km altitude over the same region (Figure 5.8, bottom). These figures revealed both horizontal and vertical transport during the event. To assess the impact of these extreme 2021 wildfire events on air quality, changes in atmospheric pollutant levels were examined in detail, across different periods.





ORMANLAR

Çam ormanları

- OK1 Akdeniz kızılçam karışık ormanı
- OK2 Ege kızılçam ormanı
- OK3 Akdeniz kızılçam ormanı
- OK4 Halap çamı ormanı
- OK5 Ege karaçam ormanı
- OK6 Batı Anadolu karaçam ormanı
- OK7 Doğu Karadeniz ardı sarıçam ormanı
- OK8 Orta Karadeniz ardı sarıçam ormanı

Meşe ormanları

- OM1 Kermes meşesi ormanı (yer yer ağaçlı bozkır şeklinde)
- OM2 Doğu Anadolu meşe ormanı (yer yer ağaçlı bozkır şeklinde)
- OM3 Orta Anadolu meşe ormanı (yer yer ağaçlı bozkır şeklinde)
- OM4 Trakya meşe-gürgen karışık ormanı
- OM5 Batı Anadolu meşe ormanı
- OM6 Akdeniz meşe ormanı

Karadeniz ormanları

- OKA1 Karadeniz ardı meşe ormanı
- OKA2 Batı Karadeniz göknar ormanı
- OKA3 Batı Karadeniz ardı kayın ormanı
- OKA4 Orta Karadeniz ardı kayın ormanı
- OKA5 Orta Karadeniz ardı meşe-ığneyaşlı karışık ormanı
- OKA6 Batı Anadolu yüksek dağ göknar ormanı
- OKA7 Doğu Karadeniz göknar ormanı
- OKA8 Doğu Karadeniz yüksek dağ ığneyaşlı ormanı
- OKR1 Karadeniz nemli meşe ormanı
- OKR2 Doğu Karadeniz yaprakdökme ormanı
- OKR3 Batı Karadeniz kayın ormanı
- OKR4 Karadeniz göknar-kayın karışık ormanı
- OKR5 Orta Karadeniz kayın ormanı
- OKR6 Doğu Karadeniz ığneyaşlı-yaprakdökme karışık ormanı

Toros ormanları

- OA1 Toros sedir ormanı
- OA2 Toros sedir-göknar karışık ormanı
- OA3 Toros ardıç ormanı
- OA4 Toros ığneyaşlı dağ ormanı
- OA5 Toros ığneyaşlı-yaprakdökme karışık ormanı

BOZKIRLAR

Dağ bozkırları

- BD1 Orta Anadolu dağ bozkırı
- BD2 İ. Doğu Anadolu dağ bozkırı
- BD3 Doğu Anadolu dağ bozkırı
- BD4 Doğu Anadolu yüksek dağ bozkırı
- BD5 Güneydoğu Anadolu dağ bozkırı

Ova bozkırları

- BO1 Orta Anadolu ova bozkırı
- BO2 Güneydoğu Anadolu ova bozkırı
- BO3 Doğu Anadolu ova bozkırı
- BO4 Kuzeydoğu Anadolu yüksek plato bozkırı
- BO5 Toros ova bozkırı

Tuzcul bozkırlar

- BT1 Orta Anadolu tuzcul bozkırı
- BT2 Doğu Anadolu tuzcul bozkırı

YÜKSEK DAĞ ÇAYIRLARI

- D1 Batı Anadolu yüksek dağ çayırı
- D2 Akdeniz yüksek dağ çayırı
- D3 Kuzeydoğu Anadolu yüksek dağ çayırı
- D4 Doğu Anadolu yüksek dağ çayırı

MAKİ

- M1 Pınar meşesi maki topluluğu
- M2 Doğu Akdeniz tipi maki topluluğu
- M3 Karadeniz kıyısı yalancı maki topluluğu
- M4 Karadeniz ardı kıt Akdeniz birli topluluğu
- F Kuru fundaklar

DİĞER ALANLAR

- K Delta ekosistemi
- TA Doğal yapım-tümüyle kaybetmiş alanlar

Figure 5.7 : Biome type distribution for Türkiye.

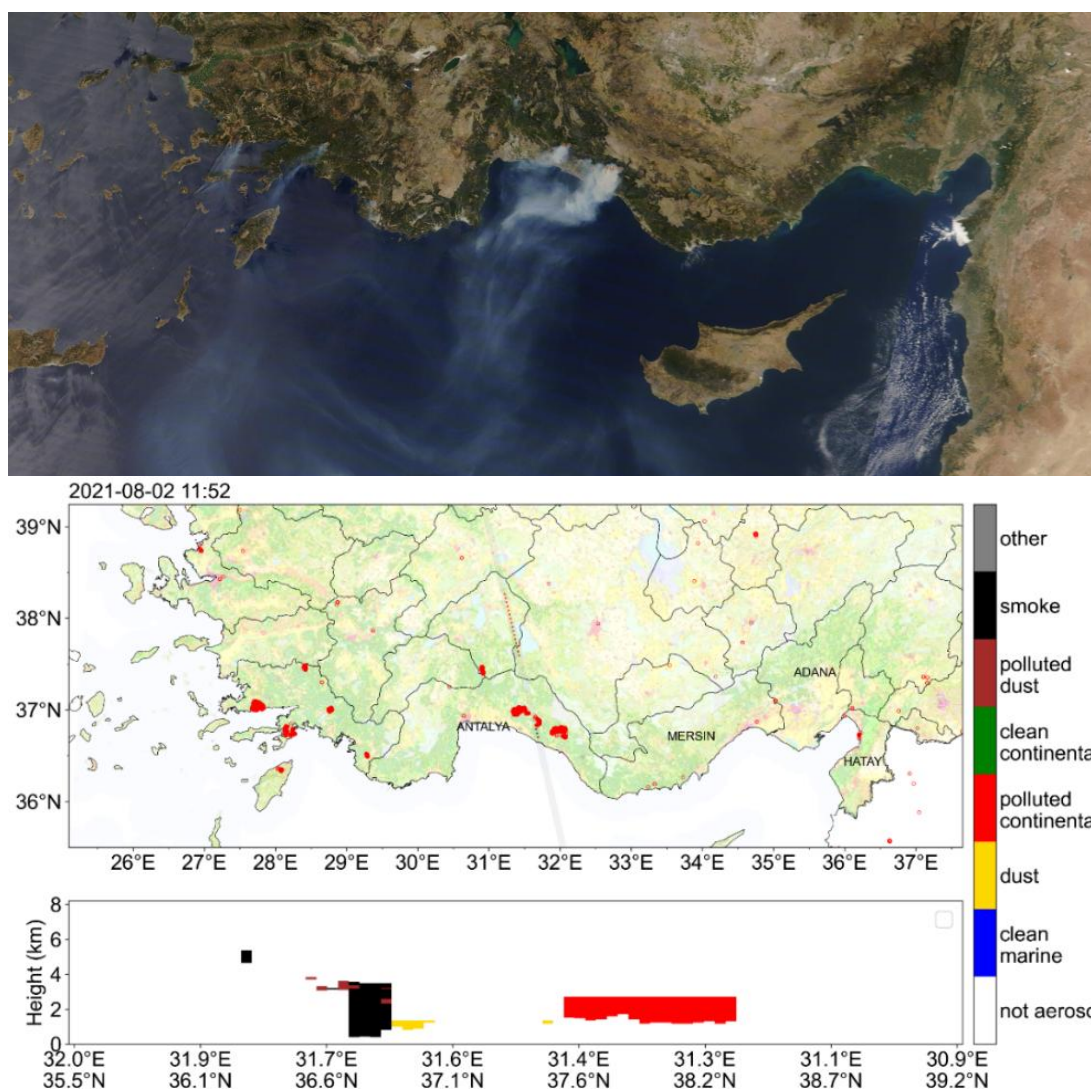


Figure 5.8 : Worldview snapshots of MODIS True Color Corrected Reflectance on 2 August 2021 (top) and aerosol types retrieved from the CALIOP L2 VFM product on the same day over the study region (bottom).

As defined in Chapter 5.1 and illustrated in Figure 5.4, the pre-fire, fire, and post-fire periods were determined based on FRP and temporal patterns observed in 2021. Accordingly, NH_3 distributions across the study domain during these periods were presented (Figure 5.9).

A clear enhancement in NH_3 concentrations was evident during the fire period where average NH_3 concentration over study area was 1.40×10^{16} molecules/ cm^2 which showed a 94.5% increase compared to the pre-fire average (0.72×10^{16} molecules/ cm^2) and 146.5% times than the post-fire level (0.57×10^{16} molecules/ cm^2) (Table C.9). While, maximum NH_3 levels increased dramatically to 6.21×10^{17} molecules/ cm^2 , which was more than 1000% higher than both the pre-fire and post-fire intervals (5.47×10^{16} molecules/ cm^2 and 5.17×10^{16} molecules/ cm^2 , respectively).

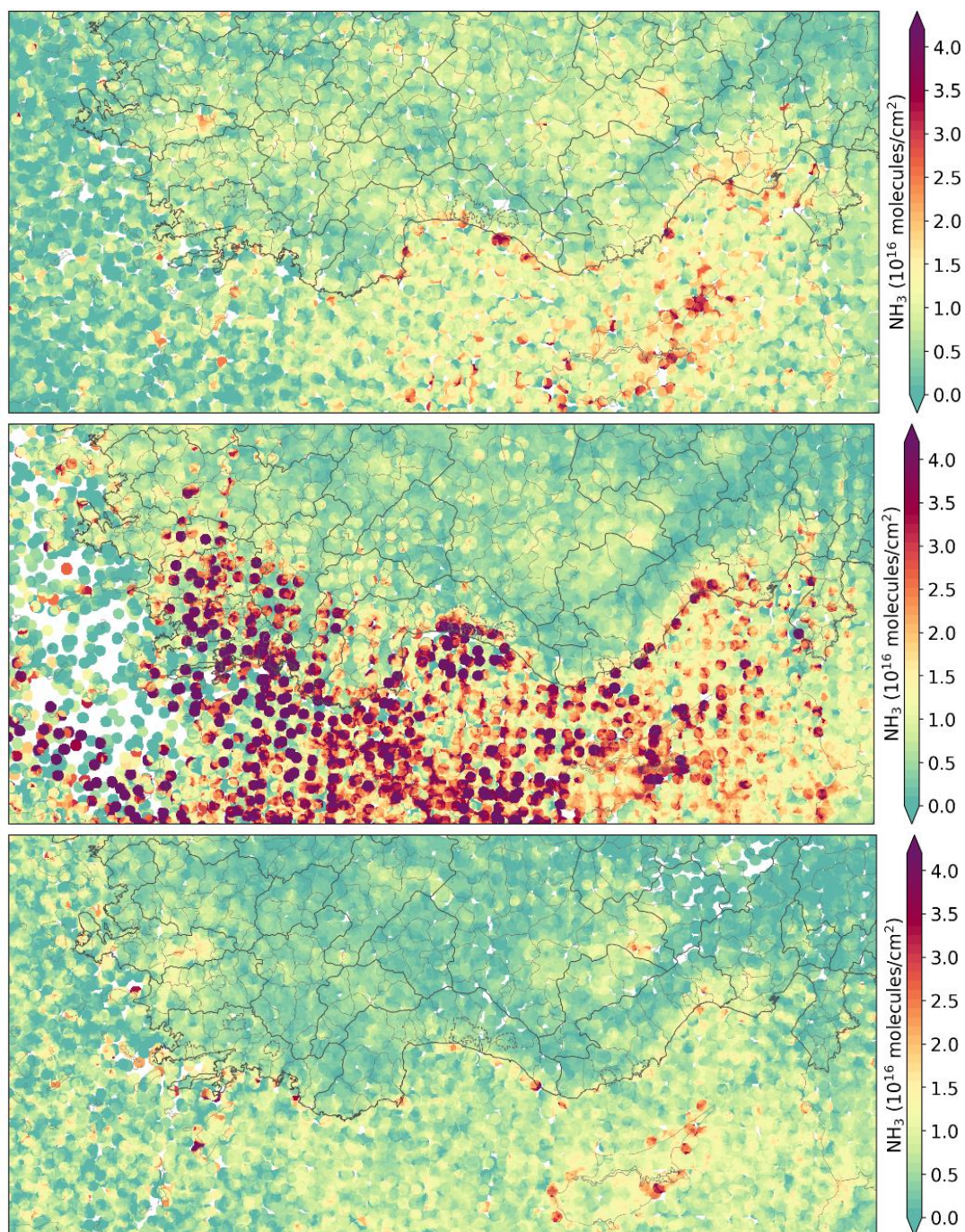


Figure 5.9 : NH_3 distribution (molecules/ cm^2) for pre-fire (top), fire (middle), post-fire (bottom) period.

Compared this enhancement to pre-fire and post-fire periods, the fire period showed a clear increase in NH_3 levels over the Mediterranean Sea (Figure 5.9). The highest concentrations were not located directly over the WF regions of AN, MU and ME, but slightly to the south (grey line represent WF regions). This strongly indicated a possible transport toward the Mediterranean which is consistent with other studies (Eke et al., 2024). To further investigate this transport, wind roses were analyzed for selected MSs that were representative for these WF region (Figure D.1).

In the AN, northeasterly winds were dominant throughout all periods. At regions AN-1 (MS-18047) and AN-2 (MS-18012), moderately strong northeasterly winds observed during the fire period were found to support the transport and dispersion of NH_3 toward the Mediterranean Sea. In contrast to AN, the ME region exhibited more variation in wind patterns across periods. During the fire period, strong northerly winds were observed at ME-1 (MS-18061), indicating pollutant transport. However, at ME-2 (MS-18870), both northeasterly and southwesterly winds were observed, and this mixed pattern might have affected NH_3 transport, which might make it less clear compared to the more consistent pattern in AN-1. In addition, the relatively lower FRP levels in ME-1 and ME-2, compared to AN-1, further supported this difference (Figure 5.4). In the MU region, stations over MU-2 (MS-17292) and MU-4 (MS-18019) were influenced by northerly and northeasterly winds during the fire period. This wind pattern indicated a possible transport from land to the Mediterranean. At MU-1 (MS-17921) and MU-3 (MS-17470) this northerly wind pattern was less dominant which might have influenced pollution transport towards the south might have played a role in the observed levels. However, when FRP levels were considered in MU regions, they were not as high as in AN-1 region, only in MU-1 FRP levels close to AN-1, but still greater than in ME regions. Therefore, this might have contributed to enhanced NH_3 transport in this area.

To further investigate NH_3 pollution and determine its possible relation with BB, NH_3 retrievals around selected MSs were examined in more detail. As described in Chapter 3.3, these MSs were selected based on their proximity to regions with considering retrievals within a 12 km radius. Due to low temporal resolution, seasonal distributions were used instead of fire-periods to better characterize the overall pollutant distribution. Based on that, Figure 5.10 and Figure G. 1 to Figure G. 5 present the time series of daily morning NH_3 concentrations from 2019 to 2023, along with seasonal NH_3 pollution roses and wind roses for each selected MSs. When temporal NH_3 levels were examined at MS-17917 (south of AN-1), 2021 stood out with an exceptionally high concentration peak of 2.38×10^{-17} molecules/ cm^2 , which was far exceeding the maximum of other years (Figure 5.10). During the summer months, monthly average NH_3 levels reached 2.02×10^{-16} in July and 2.04×10^{-16} molecules/ cm^2 in August 2021. These observed concentrations were significantly higher than the monthly averages recorded during the same months in other years, which ranged from 6.53×10^{-15} to 1.30×10^{-16} molecules/ cm^2 between 2019 to 2023. In addition, since MS was located south of AN-1, high NH_3 levels were observed only in 2021 under the influence of dominant northerly winds that strengthens the BB- NH_3 relationship.

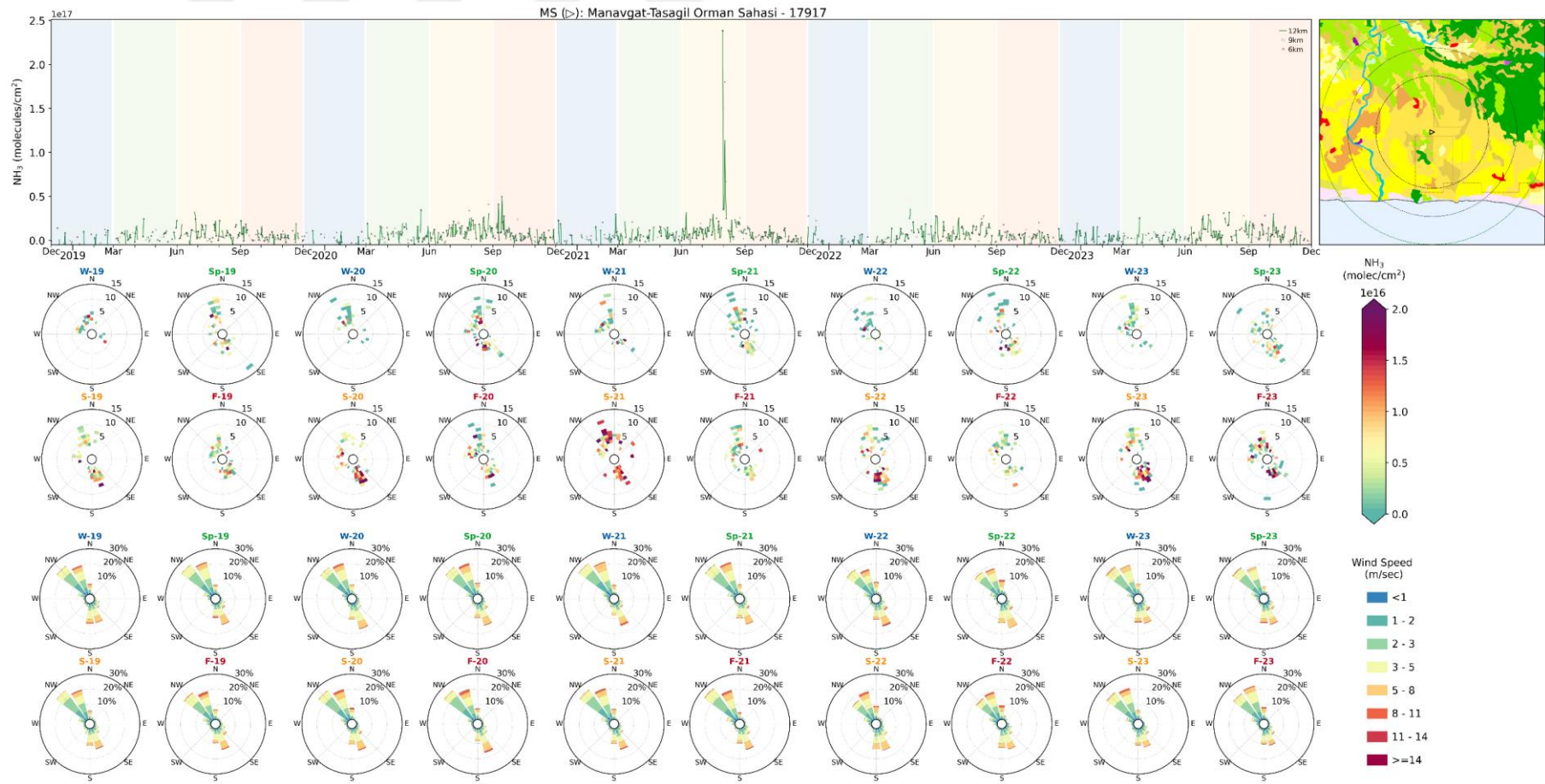


Figure 5.10 : NH_3 daily averages (top left), 12 km surroundings of MS-17917 with CLC (top right), seasonal pollution roses (middle), and wind roses (bottom).

At MS-18012 (located north of AN-2), NH_3 concentrations in 2021 reached a maximum of 1.88×10^{16} molecules/ cm^2 , with summer monthly averages of 0.54×10^{16} in July and 0.64×10^{16} molecules/ cm^2 in August (Figure G. 1). These observed levels were notably lower than those at MS-17917. This situation was mostly related to FRP levels and the time interval of AN-2, which were clearly lower than those of AN-1 (Figure 5.4). Given the MS location and dominant northeasterly winds, NH_3 transport may have occurred in the opposite direction. However, the southerly winds during the summer of 2021, matching with elevated NH_3 levels which indicated a possible influence from WF regions. Unlike the other MSs located in the AN region, no extreme increase in NH_3 levels was observed at MS-18047 (located north of AN-1) (Figure G. 2). This is likely due to location of MS and dominant northerly winds observed both during the fire period (Figure D. 1) and across seasonal wind roses.

In the ME region, ME-1 (MS-18061) also showed elevated NH_3 levels during the fire, similar to those observed at AN regions (MS-17917 and MS-18012) (Figure G. 3). The maximum NH_3 concentration reached 1.21×10^{17} molecules/ cm^2 , and the elevated values observed under southerly winds suggest a potential BB-related influence. At ME-2 (MS-18870), NH_3 peaks were also observed though they were relatively lower (Figure G. 4). This was likely due to lower FRP levels recorded in ME-2 fires compared to ME-1 (Figure 5.4). Additionally, same as ME-1, the NH_3 peaks under easterly winds coincided with nearby WF regions, further supporting the influence of fire. In the MU region, MU-3 (MS-17470) reached a maximum NH_3 concentration of 2.38×10^{17} molecules/ cm^2 (Figure G. 5). The elevated NH_3 levels observed under southwesterly winds aligned well with the spatial location of MU-3 WF regions occurring to the southwest of the MS further indicated a potential relation between BB and NH_3 levels.

In addition to NH_3 , other co-emitted pollutants from BB event present in IASI-CO and TROP-CO (Figure 5.11), and TROP- NO_2 and TROP-HCHO (Figure 5.12). Their distributions were examined across pre-fire, fire, and post-fire periods, same as NH_3 , to identify potential WF-related impacts. During the fire, IASI-CO showed elevated concentrations only around the WF-regions, particularly near the AN regions, with limited evidence of transport. Relatively high levels were also observed over the MU and ME WF-regions. In contrast, TROP-CO showed a clear southward transport over the Mediterranean, particularly from the AN WF-regions. This TROP-CO transport was similar to NH_3 and aligned with the examined wind patterns. Although this signal was weaker over the ME regions, a southward extension of the plume was still evident. However, pollutant transport was much less evident in the MU regions.

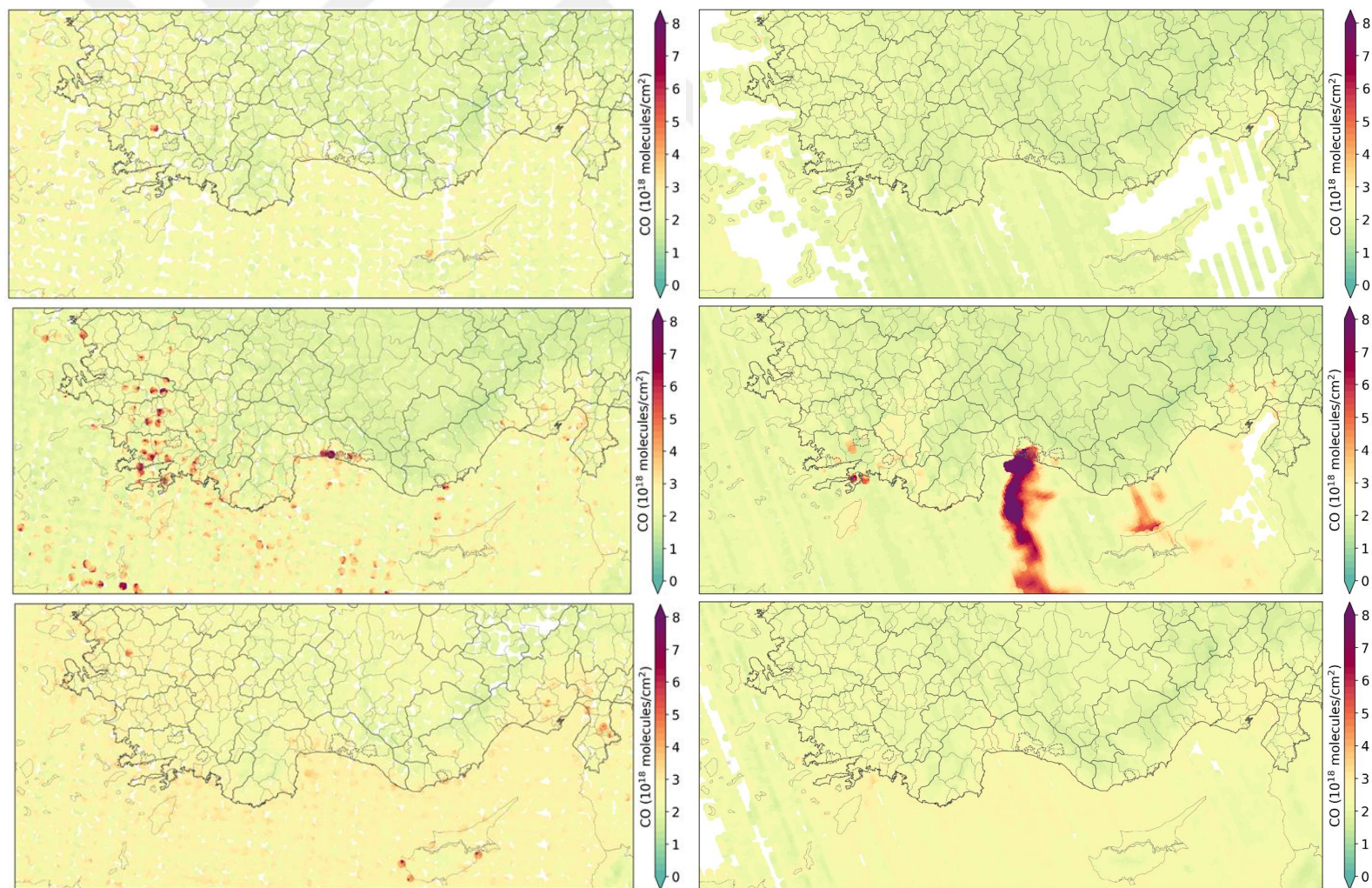


Figure 5.11 : IASI-CO distribution (left) and TROP-CO (right) (molecules/cm²) for pre-fire (top), fire (middle), and post-fire (bottom) periods.

These CO distribution differences might be related to characteristics of the instruments. When comparing the instruments together, IASI has a coarser spatial resolution, and this study only utilized early morning overpass time, while TROPOMI provides finer spatial resolution with an early afternoon overpass. Therefore, these two instruments might capture different phases of fire activity and pollutant transport during the day.

Based on that, in addition to the 0.0 to 8×10^{18} molecules/cm² distribution, IASI-CO was also examined additional within the 1.5×10^{18} to 4.5×10^{18} molecules/cm² (Figure B.6). In this range, IASI-CO enhancements became clearer, especially around the WF-regions, particularly near the AN and MU. Even in ME-1, transport toward the Mediterranean was observed. This scale allowed much clearer presentation of the spatial distribution that had been less apparent in the higher scale (Figure 5.11). Overall, CO concentrations were relatively lower in IASI-CO compared to TROPOMI-CO, and this difference might be attributed to differences in spatial resolution and satellite overpass, as previously discussed. Also, since CO had a relatively long atmospheric lifetime, background levels were more clear due to much lower scale, particularly during the pre-fire and post-fire periods.

During the fire period, increases in NO₂ and HCHO concentrations were clearly observed, particularly over the AN-1 wildfire region (Figure 5.12). Similar to other pollutants, both showed transport toward the Mediterranean Sea. However, the extent of this transport was more limited compared to CO, likely due to the shorter atmospheric lifetimes of NO₂ and HCHO. While NO₂ levels remained relatively low in the MU WF-regions, HCHO concentrations were more pronounced in these areas. Additionally, HCHO enhancements extended further downwind, reflecting its secondary formation. To better understand region-specific pollutant changes, the analysis was further narrowed down to each WF-region, with changes in concentrations across the pre-fire, fire, and post-fire periods examined within the gridded areas.

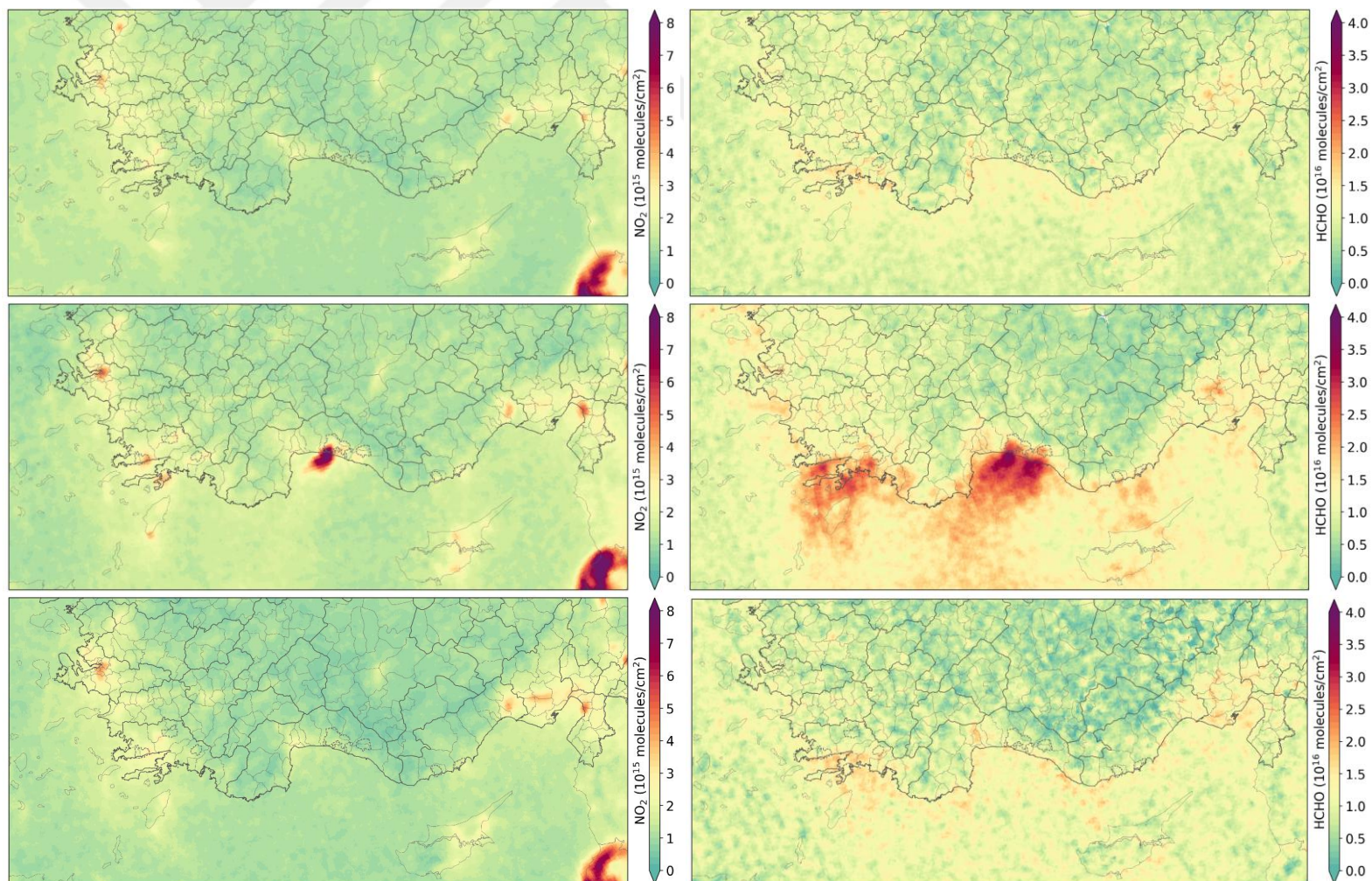


Figure 5.12 : TROP-NO₂ distribution (left) and TROP-HCHO (right) (molecules/cm²) for pre-fire (top), fire (middle), and post-fire (bottom) periods.

NH₃ levels showed clear increases during fire period in all WF-regions (Figure 5.13). The highest averages were observed in MU-3 (4.17×10^{16} molecules/cm²), AN-1 (3.81×10^{16} molecules/cm²), and MU-4 (3.74×10^{16} molecules/cm²), while the rest of the WF-regions remained below 3.15×10^{16} molecules/cm² (Table C.10). Pre-fire to fire increases were particularly observed in MU-3 (777.6%) and MU-4 (765.8%), followed by MU-1 (354.6%) and AN-1 (307.6%). In these WF-regions, high NH₃ difference between two periods were likely driven by direct BB event which considering the WF-regions forest cover and higher fire intensity. In contrast, ME-1 and ME-2 exhibited much smaller increases (14.3% and 183.4%, respectively), which may be attributed to both the lower fire activity (Figure 5.4) and the influence of agricultural activities over closet agricultural lands (Figure 5.3). After the fire period, NH₃ levels were decreased across all regions.

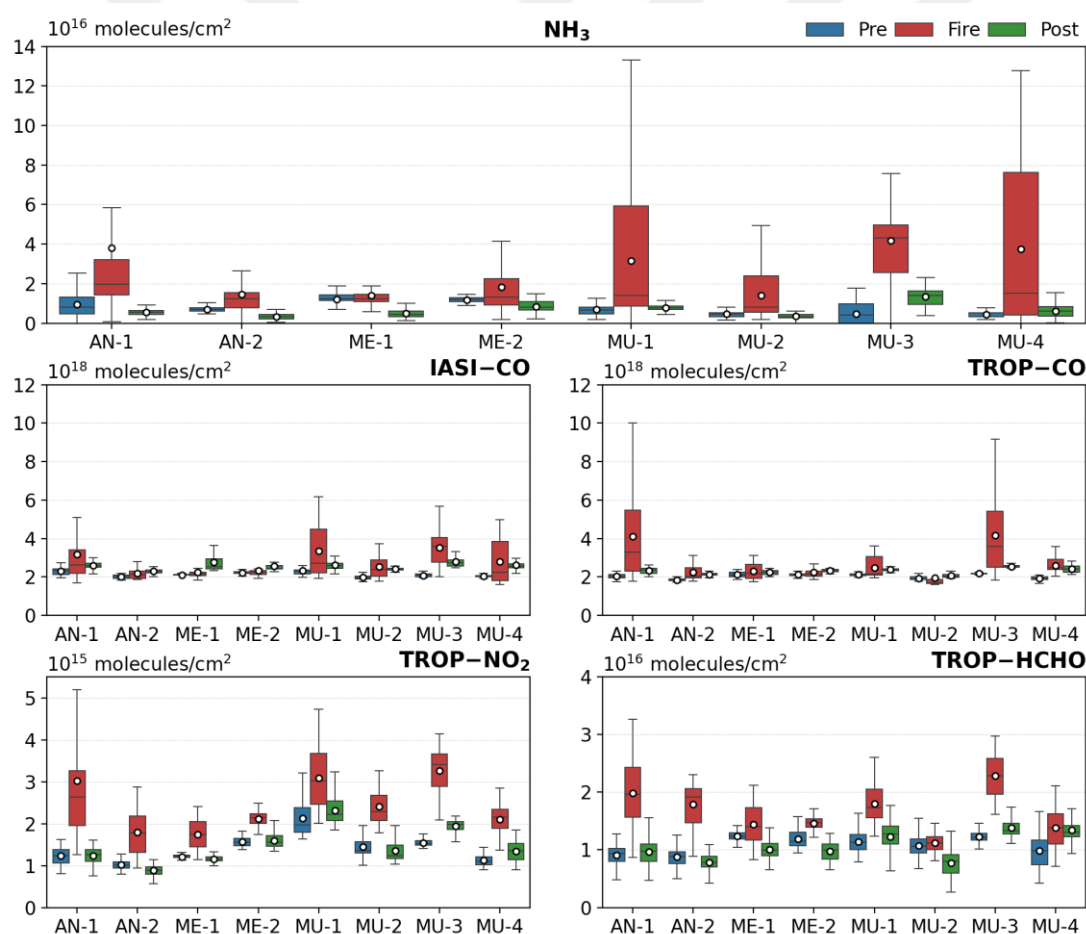


Figure 5.13 : Boxplots of NH₃ and co-emitted pollutant concentrations (IASI-CO, TROP-CO, TROP-NO₂ and TROP-HCHO, respectively) across WF-region for pre-fire, fire, and post-fire periods.

In fire period, both IASI-CO and TROP-CO showed increases in most WF-regions, however the percentage changes were generally smaller than those observed for NH₃. In regions such as ME-2, slight decreases were observed where remaining below -20%. The highest fire-period levels were recorded in MU-3 and AN-1, reaching 3.51×10^{18} and 3.17×10^{18} molecules/cm² for IASI-CO, and 4.17×10^{18} and 4.10×10^{18} molecules/cm² for TROP-CO, respectively. However, post-fire decreases were not as evident as NH₃. Most of the WF-regions, CO concentrations remained close or even above pre-fire concentrations. Hence, this trend was mostly attributed to longer atmospheric lifetime of CO, which causes background levels to remain elevated or even increase after the fire event. As also seen in the CO distribution maps (Figure 5.11), TROP-CO levels were generally higher than IASI-CO during the fire period. Especially, over AN-1 and MU-3 WF-regions recorded significantly higher CO peaks compared to IASI.

TROP-NO₂ increases were observed in all regions, where the highest ones were AN-1 (144.8%), MU-3 (112.2%), and AN-2 (76.8%) from pre-fire to fire period. In these regions, concentrations peaked from 1.23 to 3.02×10^{15} molecules/cm², 1.54 to 3.27×10^{15} molecules/cm² and 1.01 to 1.79×10^{15} molecules/cm², respectively. The strong NO₂ difference, such as in AN-1 and AN-2 likely reflected direct BB impact. Because when the location of these two WF-regions were considered other NO₂ sources nearby were limited, such as traffic or industrial.

TROP-HCHO also increased notably in AN-1 from 0.91 to 1.99×10^{16} molecules/cm², AN-2 from 0.87 to 1.79 molecules/cm² and MU-3 from 1.23 to 2.28×10^{16} molecules/cm², while ME regions showed only minor changes which less than 25%. Post-fire concentrations remained elevated in some regions, particularly in MU-3 (1.38×10^{16} molecules/cm²) and MU-4 (1.34×10^{16} molecules/cm²), compared to their pre-fire levels (1.23×10^{16} molecules/cm² and 0.99×10^{16} molecules/cm², respectively). As seen in the distribution maps (Figure 5.12), NO₂ and HCHO enhancements were strongest over AN and MU WF-regions during the fire period, with HCHO increases were clearer over MU, while NO₂ enhancements were evident in both. During the pre-fire and post-fire periods, relatively high concentrations were consistently observed around MU regions, whereas levels over the AN region remained comparatively lower. The consistently and relatively high HCHO concentrations observed over MU WF-regions during all periods might be influenced by the local biome type or VOC-related emissions. Unlike AN and ME, MU were dominated by OC2 and OK1 biome type while Antalya and Mersin mostly dominated by OC1 and OC3, which might emitted different VOC profiles.

The spatial distribution of NH_3 enhancement ratios to other co-emitted pollutants were investigated (Figure 5.14). These ratios basically indicate how strongly NH_3 were elevated compared to the other pollutants during the fire period. Then examining the NH_3/CO ratios, both IASI-CO and TROP-CO maps show elevated ratios across the WF-regions. However, the $\text{NH}_3/\text{TROP-CO}$ ratio was more scattered compared to the $\text{NH}_3/\text{IASI-CO}$ which likely due to early mentioned differences of these two instruments.

$\text{NH}_3/\text{IASI-CO}$ ratios showed much higher ratios near the WF-regions. Ratios were likely matched with fire plume directions, similar to the pollution distributions, across these areas. This may indicate that NH_3 was not only elevated near WF-regions but also remained relatively high along the fire smoke. The relative decrease in $\text{NH}_3/\text{IASI-CO}$ ratios along downwind directions were observed. This is further supported by the NH_3 (Figure 5.9) and CO distribution itself (Figure B.6 was more evident than Figure 5.11), where concentrations were high over AN regions but gradually declined over southward direction.

Similar to the $\text{NH}_3/\text{IASI-CO}$ ratios, elevated NH_3/NO_2 ratios were mostly observed near WF-regions and along smoke downwind directions. However, unlike $\text{NH}_3/\text{IASI-CO}$, these high NH_3/NO_2 ratios were observed only over Mugla, coastal parts of Antalya and relatively lower ratios over the coast of Mersin. This may be attributed to elevated NH_3 levels during summer due to agricultural activity, in contrast to relatively low NO_2 emissions in these areas. Therefore, high NH_3/NO_2 ratios close to WF-regions suggested that strong contribution from BB events. Similar to NH_3/NO_2 ratios, higher NH_3/HCHO ratios were observed over Mugla, while in AN and ME WF-regions, elevated ratios appeared mostly along the downwind directions.

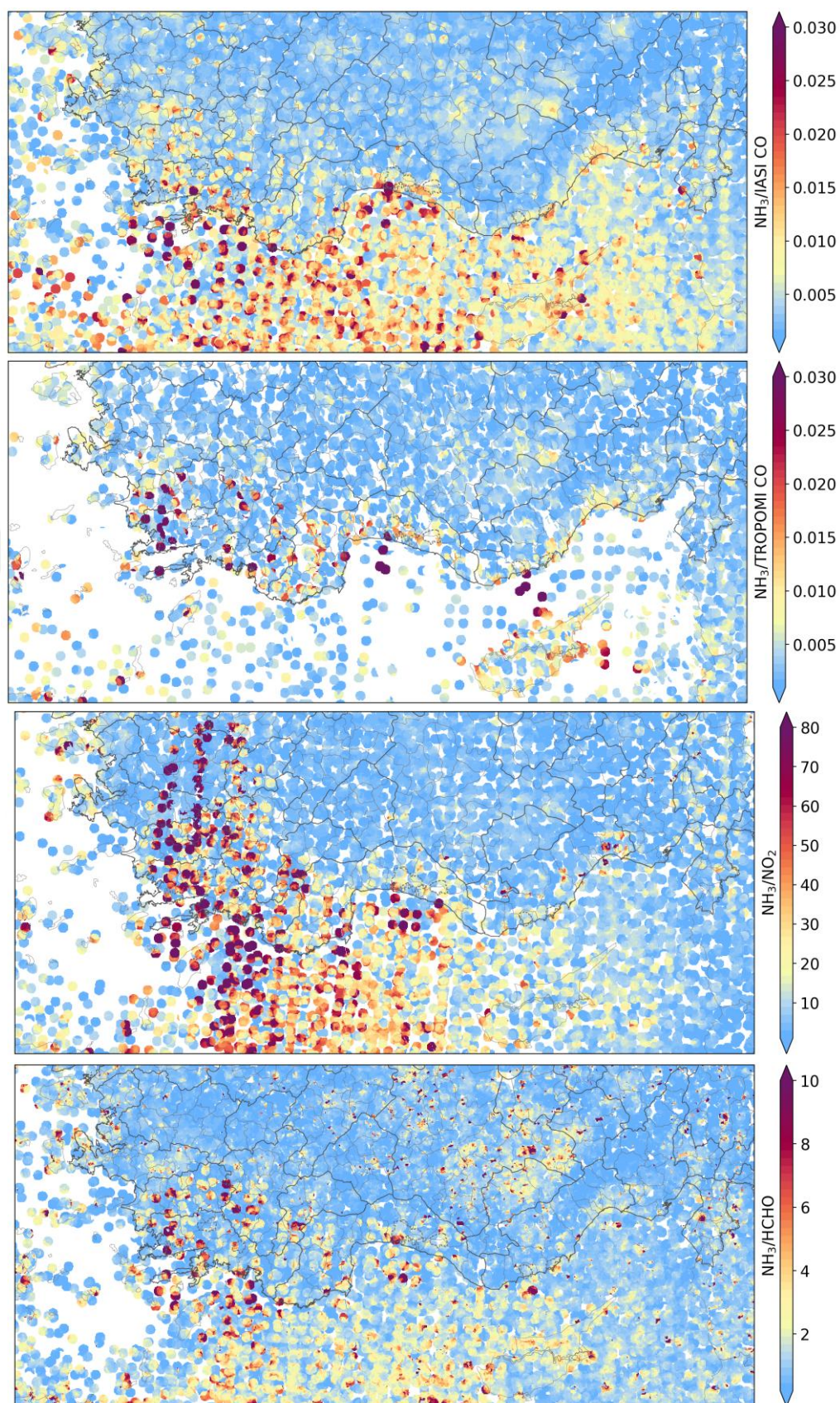


Figure 5.14 : Distribution maps of NH_3 enhancement ratio to other pollutants (IASI-CO, TROP-CO, TROP- NO_2 , TROP-HCHO, respectively).

Similar to the pollutant concentration analysis, NH_3 enhancement ratios were also analyzed across WF-regions to understand the region-specific and period differences (Figure 5.15). The results show clear increases in ratios during the fire period, particularly for $\text{NH}_3/\text{IASI-CO}$ and $\text{NH}_3/\text{TROP-CO}$ (Table 5.2). For $\text{NH}_3/\text{IASI-CO}$, the most notable increases were observed in MU-3 (0.0169) and AN-1 (0.0094). The highest fire-period ratio was found in MU-1 (0.0278), despite this region having the lowest baseline ratio (0.0046) in the pre-fire period. This was followed by MU-4 (0.0105) and AN-1 (0.0104).

NH_3/NO_2 and NH_3/HCHO ratios also showed notable enhancements, especially in the MU WF-regions. In MU regions, NH_3/NO_2 ratios during the fire period ranged approximately from 20 to 60 across regions, followed by AN-1 regions showed a fire-period ratio of 16.96. As for NH_3/HCHO , MU-1 exhibited the highest ratio (6.21), followed by MU-3 (3.67), MU-4 (2.24), AN-1 (2.12), and AN-2 (1.58). Overall, the ME WF-regions showed relatively lower enhancement ratios across all of the calculated ratios.

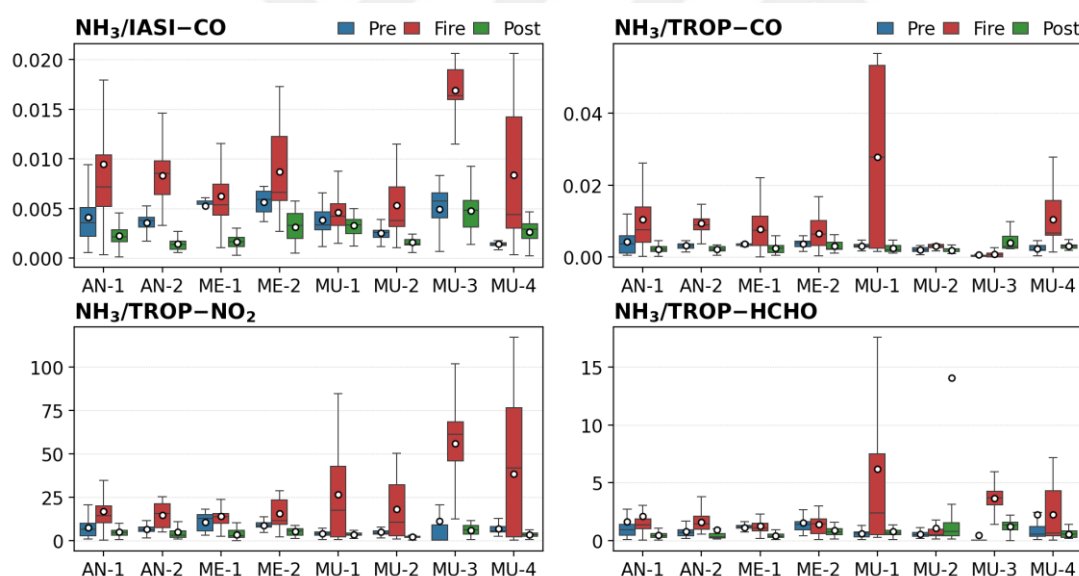


Figure 5.15 : Boxplots of NH_3 to co-emitted pollutant ratios ($\text{NH}_3/\text{IASI-CO}$, $\text{NH}_3/\text{TROP-CO}$, $\text{NH}_3/\text{TROP-NO}_2$ and $\text{NH}_3/\text{TROP-HCHO}$, respectively) across WF-region for pre-fire, fire, and post-fire periods.

Table C.11 shows the fold of NH_3 enhancements ratio to co-emitted pollutant during the fire compared to the pre-fire and post-fire periods. From the statistics determined that the average of all NH_3 enhancements ratio increased during the fire period. The increases in NH_3/CO ratio generally showed a higher fold in AN and MU WF-regions, except MU-3 post-period for $\text{NH}_3/\text{TROP-CO}$, 1.2 to 9.0 times increase. Similarly, the increases in $\text{NH}_3/\text{TROP-NO}_2$ and $\text{NH}_3/\text{TROP-HCHO}$ were particularly noticeable in these regions which ranging from 2.2 to 7.9, except for MU-2.

Table 5.2 : NH₃ to co-emitted pollutants ratio for WF-regions.

WF-Regions		NH ₃ /IASI-CO			NH ₃ /TROP-CO			NH ₃ /TROP-NO ₂			NH ₃ /TROP-HCHO		
		Pre	Fire	Post	Pre	Fire	Post	Pre	Fire	Post	Pre	Fire	Post
Average	AN-1	0.0041	0.0094	0.0023	0.0042	0.0104	0.0022	7.51	16.96	5.09	1.64	2.12	0.48
	AN-2	0.0035	0.0083	0.0014	0.0033	0.0093	0.0022	6.56	14.64	4.86	0.78	1.58	0.95
	ME-1	0.0053	0.0063	0.0017	0.0036	0.0077	0.0025	10.73	13.99	3.38	1.10	1.26	0.44
	ME-2	0.0056	0.0087	0.0031	0.0036	0.0066	0.0031	8.81	15.47	5.22	1.52	1.40	0.88
	MU-1	0.0038	0.0046	0.0033	0.0031	0.0278	0.0024	4.09	26.41	3.49	0.62	6.21	0.79
	MU-2	0.0025	0.0053	0.0016	0.0020	0.0030	0.0018	4.90	18.19	2.11	0.57	1.07	14.08
	MU-3	0.0049	0.0169	0.0048	0.0007	0.0009	0.0040	11.08	56.04	5.83	0.48	3.67	1.22
	MU-4	0.0015	0.0084	0.0026	0.0024	0.0105	0.0031	6.78	38.46	3.46	2.25	2.24	0.57
Median	AN-1	0.0035	0.0072	0.0022	0.0038	0.0076	0.0022	6.63	14.35	4.49	0.92	1.35	0.41
	AN-2	0.0038	0.0085	0.0014	0.0032	0.0090	0.0021	6.11	15.7001	3.06	0.70	1.46	0.31
	ME-1	0.0057	0.0054	0.0016	0.0037	0.0075	0.0024	12.89	13.73	2.65	1.21	1.08	0.37
	ME-2	0.0059	0.0066	0.0033	0.0040	0.0064	0.0024	8.70	11.38	5.60	1.41	1.43	0.76
	MU-1	0.0033	0.0042	0.0034	0.0031	0.0278	0.0021	3.95	17.40	3.42	0.67	2.37	0.66
	MU-2	0.0026	0.0038	0.0014	0.0020	0.0031	0.0016	4.42	10.55	2.10	0.51	0.52	0.81
	MU-3	0.0058	0.0164	0.0048	0.0004	0.0007	0.0030	0.25	61.14	6.17	0.03	3.71	1.37
	MU-4	0.0014	0.0044	0.0029	0.0021	0.0068	0.0030	5.70	41.74	3.26	0.57	0.65	0.55
Max	AN-1	0.0111	0.0461	0.0051	0.0120	0.0739	0.0046	29.09	83.35	29.45	169.10	16.71	9.58
	AN-2	0.0053	0.0146	0.0032	0.0059	0.0147	0.0034	16.42	25.28	33.95	3.09	3.80	15.75
	ME-1	0.0065	0.0143	0.0041	0.0054	0.0220	0.0060	18.05	30.41	10.17	1.66	5.09	1.90
	ME-2	0.0073	0.0173	0.0057	0.0059	0.0168	0.0075	14.83	28.86	8.61	11.72	4.64	3.78
	MU-1	0.0066	0.0128	0.0066	0.0053	0.0565	0.0047	13.57	84.67	5.80	2.41	94.63	4.21
	MU-2	0.0040	0.0175	0.0031	0.0033	0.0036	0.0034	14.46	82.56	6.01	1.67	81.54	686.58
	MU-3	0.0083	0.0238	0.0092	0.0071	0.0026	0.0099	421.17	101.78	11.42	7.70	8.00	2.22
	MU-4	0.0061	0.0334	0.0047	0.0046	0.0414	0.0074	17.38	117.30	7.57	253.36	29.77	1.42

In this study, NH_3 enhancement ratios to other co-emitted pollutants calculated for the fire period could not be directly compared with those reported in the literature (Table 5.3). Firstly, studies that focused on NH_3/NO_2 and NH_3/HCHO ratios are limited. For NH_3/CO ratios, most of the studies classify ratios based on general biome types such as savanna, tropical forest, and cropland. However, the study region is predominantly covered by pine forests (Figure 5.7). Therefore, a direct comparison with literature was not possible. Additionally, most previous studies were based on ground-based or airborne measurements, whereas Whitburn et al. (2017) used satellite-based IASI observations, which were more directly comparable with the IASI-based NH_3 enhancement ratios calculated in this study.

Table 5.3 : Reported NH_3/CO ratios in the literature.

Source	Savanna	Tropical Forest	Cropland
Andreae and Merlet (2001)	0.0152	0.0205	0.0233
Bertschi et al. (2003)	0.0199	-	-
Sinha et al. (2003)	0.007	-	-
Yokelson et al. (2003)	0.0065-0.007	-	-
Christian et al. (2007)	0.0128	-	-
Akagi et al. (2011)	0.0136	0.0236	0.035
Wooster et al. (2011)	0.008-0.035	-	-
Yokelson et al. (2011)	0.0099	0.0468	0.0291
Kaiser et al. (2012)	0.0243	0.0152	0.0286
Smith et al. (2014)	0.0133	-	-
Whitburn et al. (2017)	0.007-0.019	0.014-0.023	0.011-0.014

When compared with the ranges reported by Whitburn et al. (2017), the $\text{NH}_3/\text{IASI-CO}$ enhancement ratios calculated in this study mostly fall within the range defined for savanna fires (0.007-0.019). Regions such as AN-1, AN-2, ME-2, and MU-4 showed fire-period averages that align well with this category. An exception is MU-3, where the fire-period $\text{NH}_3/\text{IASI-CO}$ ratio reached 0.0169 which was closer to the tropical forest range (0.014-0.023). When examining $\text{NH}_3/\text{TROP-CO}$ ratios, the alignment with these biome-defined ranges. For example, although MU-3 showed a high $\text{NH}_3/\text{IASI-CO}$ ratio, the corresponding $\text{NH}_3/\text{TROP-CO}$ ratio was significantly lower which falling below the tropical forest range. Most other regions could be classified within the savanna range, with a few exceptions such as MU-2 and MU-3, which showed much lower ratios. These differences could show variations in WF conditions or, as mentioned earlier, could be related to differences in the resolution of the instruments.

When the periods analyzed for relationship between the pollutants, it is observed that in all three main WF regions, overall NH_3 -CO correlations were stronger and statistically significant during the fire period (Figure 5.16). In overall correlation coefficient for WF-region was 0.79*** for AN, 0.76*** for ME and 0.89*** for MU. Especially during the fire period, showed much higher r values than the overall period. Which during the fire r values were 0.88*** for AN, 0.95*** for ME and 0.92*** for MU. These high and statistically significant levels indicate a direct relationship between NH_3 and IASI-CO during the fire period. However, for overall WF-regions NH_3 and TROP-CO did not show high correlation as IASI- NH_3 but still in MU both overall ($r=0.72$ ***) and fire period showed high correlation ($r=0.68$ ***). On the other hand, examining the other NH_3 -based ratios, it is observed that only in the MU region, the NH_3 -HCHO correlation during the fire period was statistically significant ($r=0.59$ ***). Which might relate with the biome type of the region as mentioned earlier (Figure 5.7). Although higher NH_3 correlations with other pollutants were generally observed during the fire periods across regions, they were not statistically significant in most case. All of these analyses were conducted in a region-specific manner. Considering the chemical characteristics and formation mechanisms of the pollutants further studies could also take into account the downwind transport of the fire plume.

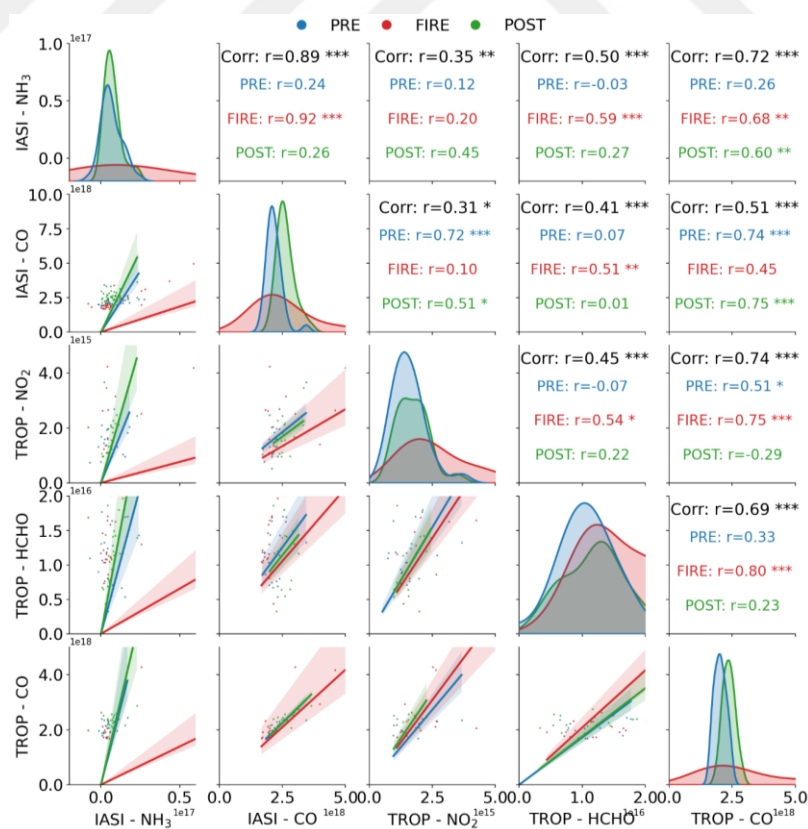


Figure 5.16 : Periodic-correlation analysis of overall WF-regions (MU).

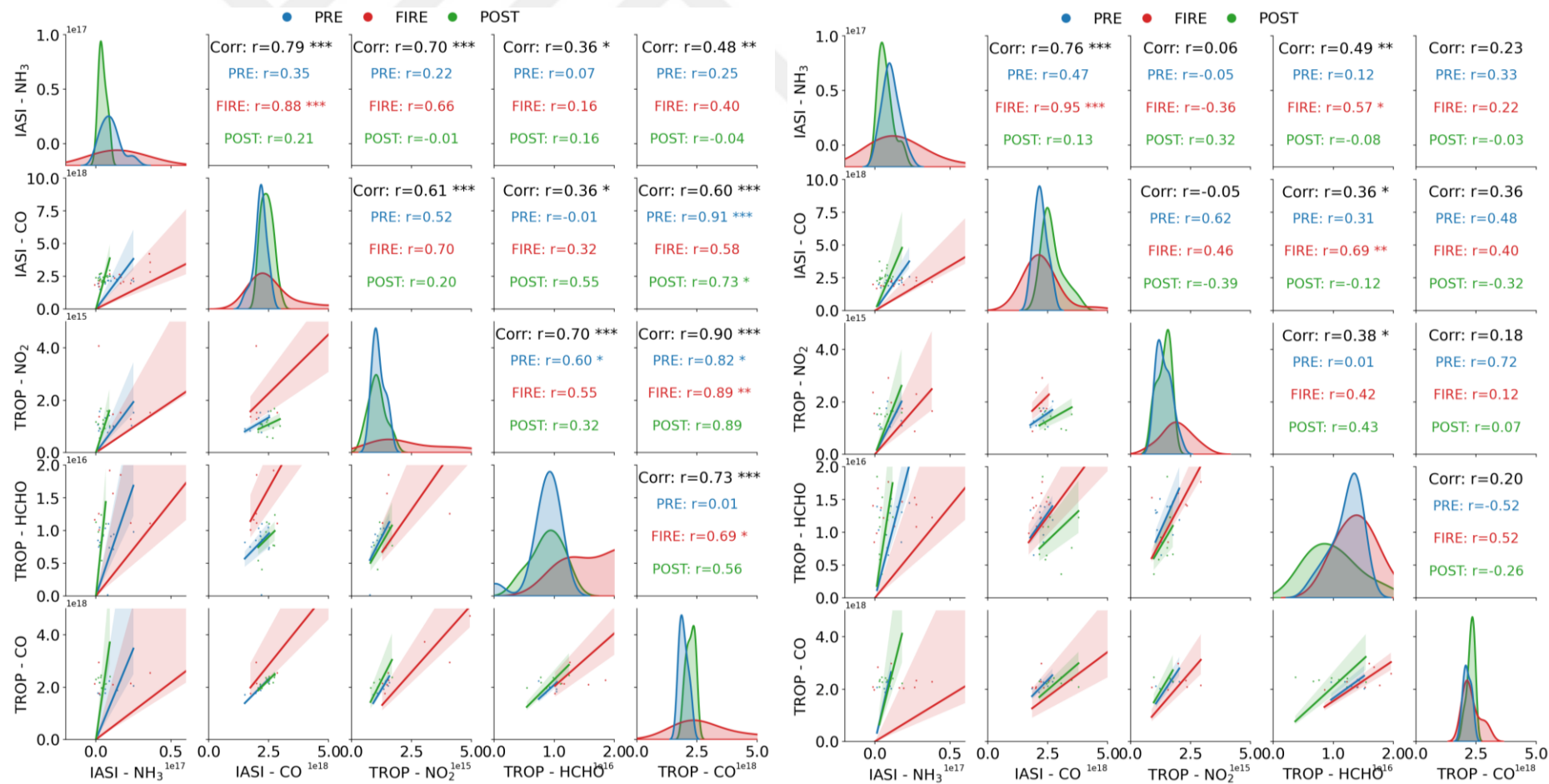


Figure 5.16 (continue) : Periodic-correlation analysis of overall WF-regions (left: AN and right: ME).

During the fire period, Chl-a concentrations increased notably along the southern coastline, particularly in areas close to the smoke plume where the WF regions were shown as red hatched areas in Figure 5.17.

Compared to the pre-fire period, Chl-a levels were clearly higher in the near offshore of the Eastern Mediterranean, especially over Antalya coast. In the post-fire period, Chl-a levels then decreased. This enhancement was only observed in the fire period, strongly suggesting WF-related impact. Notably, this increase aligned spatially with the AN region's downwind of the plume direction (Figure 5.8), where FRP levels were highest (Figure 5.4), and nitrogen compounds of BB smoke such as NH₃ and NO₂ also showed elevated concentrations. These overlapping patterns further supported the WF-influence in Mediterranean.

To evaluate this enhancement more clearly the difference maps were compiled, with considering Equations 4 for pre-fire and in Equations 5 for post fire (Figure 5.17).

$$\Delta\text{Fire (\%)} = \left[\frac{(\text{fire} - \text{pre-fire})}{\text{pre-fire}} \right] \times 100 \quad \text{Equation 4}$$

$$\Delta\text{Fire (\%)} = \left[\frac{(\text{fire} - \text{post-fire})}{\text{post-fire}} \right] \times 100 \quad \text{Equation 5}$$

Analysis based on the difference maps indicated significant enhancements, with maximum increases exceeding 500%. (Table C.12.). The grey-line shown in differences map represents the subdomain region where Chl-a concentrations were quantitatively evaluated. This region was selected to better understand the potential impact of WF smoke plumes, as it is located directly downwind of the main WFs. According to results, the mean Chl-a concentration during the fire period (0.134 mg/m³) was 98.5% higher than the pre-fire mean concentration (0.068 mg/m³), and 87.5% higher than the post-fire mean (0.071 mg/m³). The maximum value reached 0.935 mg/m³ in the fire period with 553.6% increase compared to the pre-fire maximum. These concentrations increase indicate a sharp and temporary Chl-a enhancement likely associated with BB events and suggesting that nitrogen deposition of smoke plume might influenced phytoplankton growth in the Mediterranean Sea.

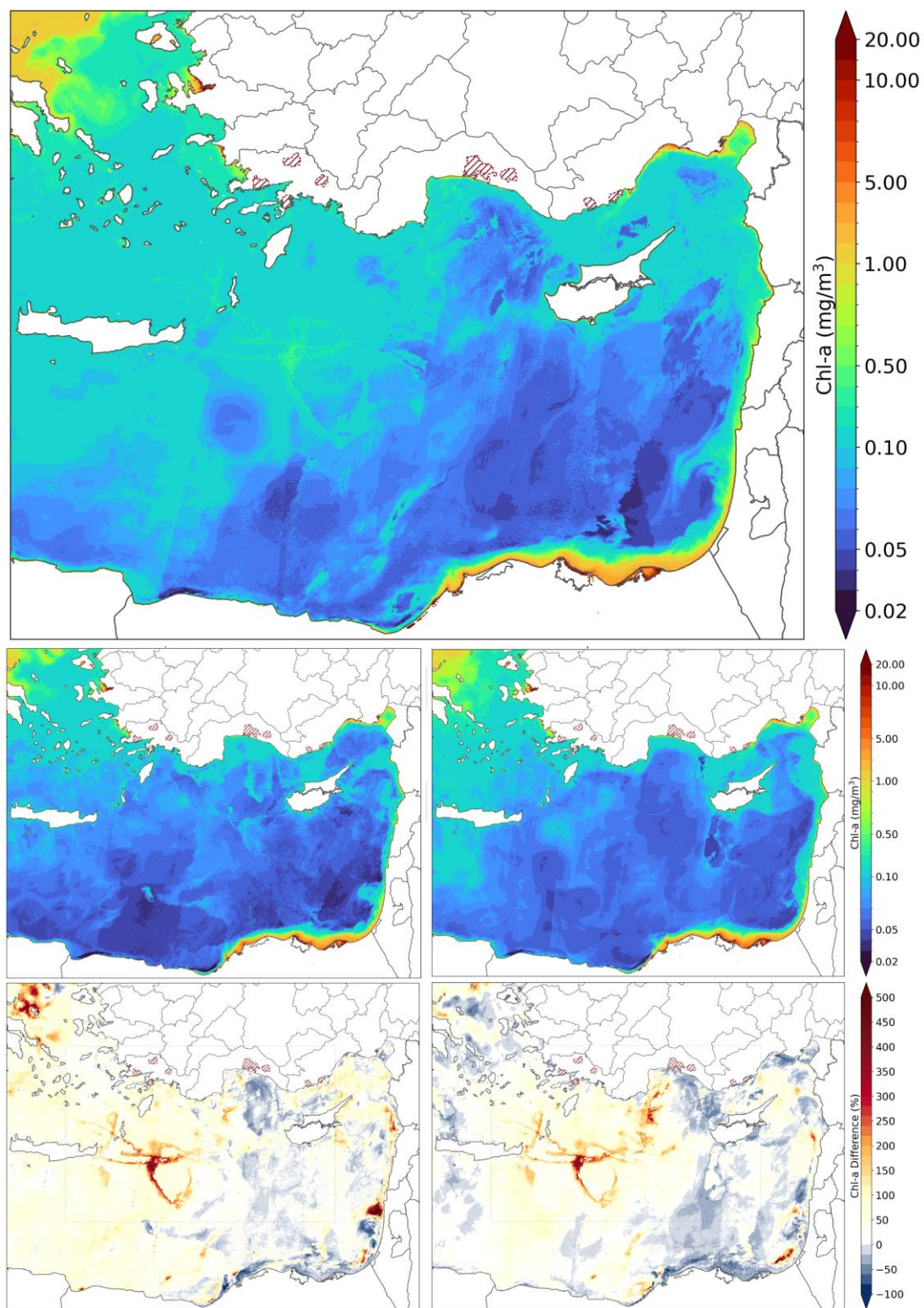


Figure 5.17 : Chl-a distribution (mg/m³) fire period (top), pre-fire (center left), post-fire (center right), changes over fire to pre-fire (bottom left) and fire to post-fire (bottom right).

5.3 Impact of Agri-Fires on NH₃ Pollution

Although less intense than WF events, agricultural residue burning is a widespread practice in the Eastern Mediterranean. Unlike WF, which occur suddenly and spread uncontrollably, residue burning (RB) is usually a planned activity. These practices follow seasonal harvest cycles and are repeated almost every year. Although their timing and extent may vary depending on crop and harvest conditions of that year. These practices are commonly observed toward the end of summer, starting in August, and continuing through with September and October in the study region (Figure 5.6).

Even though, large-scale smoke plumes were not as clearly observed as in WF events (Figure 5.8), the MODIS True Color Corrected Reflectance snapshot for 22 September 2020 showed more localized smoke signals over parts of Osmaniye and Adana which were likely associated with residue burning (Figure 5.18). On the same day, CALIOP aerosol retrievals indicated that aerosols from these events reached up to 2 km altitude and also transported toward the Mediterranean Sea. This indicated both vertical and horizontal aerosol transport despite their smaller scale compared to WFs (Figure 5.18).

RB practices may also trigger much larger fire events if not properly controlled and especially when conducted near forested areas. The MODIS image from 24 August 2020 (Figure 5.18) showed fire activity within forested areas might potentially one of the example for this risk. According to General Directorate of Forestry (OGM) record for the reason of the WF causes, RB accepted as contributing factor. Particularly in Adana and Mersin, where 2.02% to 11.25% of WF were associated with such practices (Table C.8). Therefore, RB is not only a source of local air pollution and other environmental issues but also a broader threat, as RB could lead to larger and uncontrollable WFs.

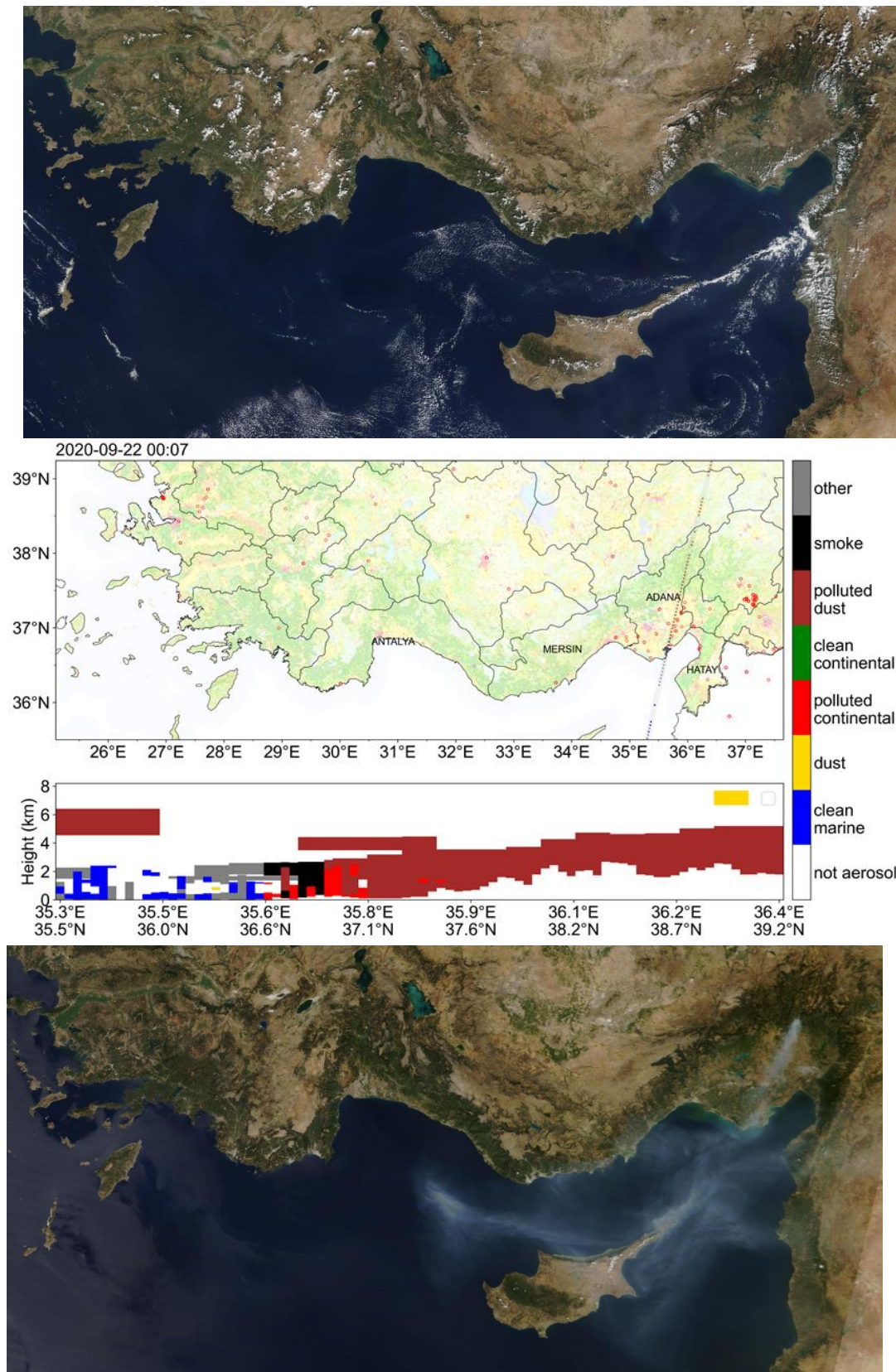


Figure 5.18 : Worldview snapshots of MODIS True Color Corrected Reflectance on 22 September 2020 (top), aerosol types retrieved from the CALIOP L2 VFM product on the same day over the study region (middle) and MODIS True Color Corrected Reflectance on 24 August 2020 (bottom).

As discussed in Chapter 4, even though seasonal NH_3 distributions were lower compared to spring and summer (Figure 4.5), high percentile scores observed over parts of Adana, Mersin, Osmaniye, and relatively Hatay as seasonal NH_3 hotspot (Figure 4.7). When the scope was narrowed to monthly basis NH_3 (Figure B. 2 and Figure B. 3) and percentile (Figure B.4 and Figure B.5) distributions, spatial enhancements became more evident, especially in September and October which these spatial patterns mostly matched the previously selected RB regions (Figure 5.3). For the RB fire periods defined in Chapter 5.1, distribution maps of NH_3 and other co-emitted BB pollutant were compiled over the study region to examine spatial changes during these intervals.

During the fire period for RB-1, NH_3 levels over the Ad-Os region (outlined in dark grey lines) were relatively moderate (Figure 5.19). Unlike the WF regions, high NH_3 levels were not observed over the Ad-Os RB region during the fire period however, higher concentrations were detected toward the southern part of the region. Therefore, RB-1 fire period wind patterns were examined to better understand this spatial distribution (Figure D.2). In this scope, two MSs were examined for Ad-Os region. At MS-17907, located north of Ad-Os, northeasterly winds were dominant during the fire period.

At MS-17960, situated to the south, northerly winds were clearly prevailing. Considering both the MSs location and observed northerly wind patterns, it might indicate a possible southward transport of NH_3 within the region. During the same time interval, Me-Ad RB region recorded fires as well. Therefore, the elevated NH_3 levels may be attributed not only to transport but also to local emissions within the region. To assess this, MS-17978 and MS-18054 were examined for the RB region. Both MSs showed dominant northerly winds which supports the southward NH_3 transport observed in the distribution maps. As noted in Chapter 4, this RB region includes districts with intensive agricultural activity. Considering the selected fire period agricultural activities were likely still ongoing in this region which have contributed to the observed NH_3 levels. In addition, NH_3 -emitting point sources in the area might also have played a role. In contrast, such elevated NH_3 levels were not observed in the Ha region which most likely related to significantly low FRP levels and fire count for the RB-1 fire period.

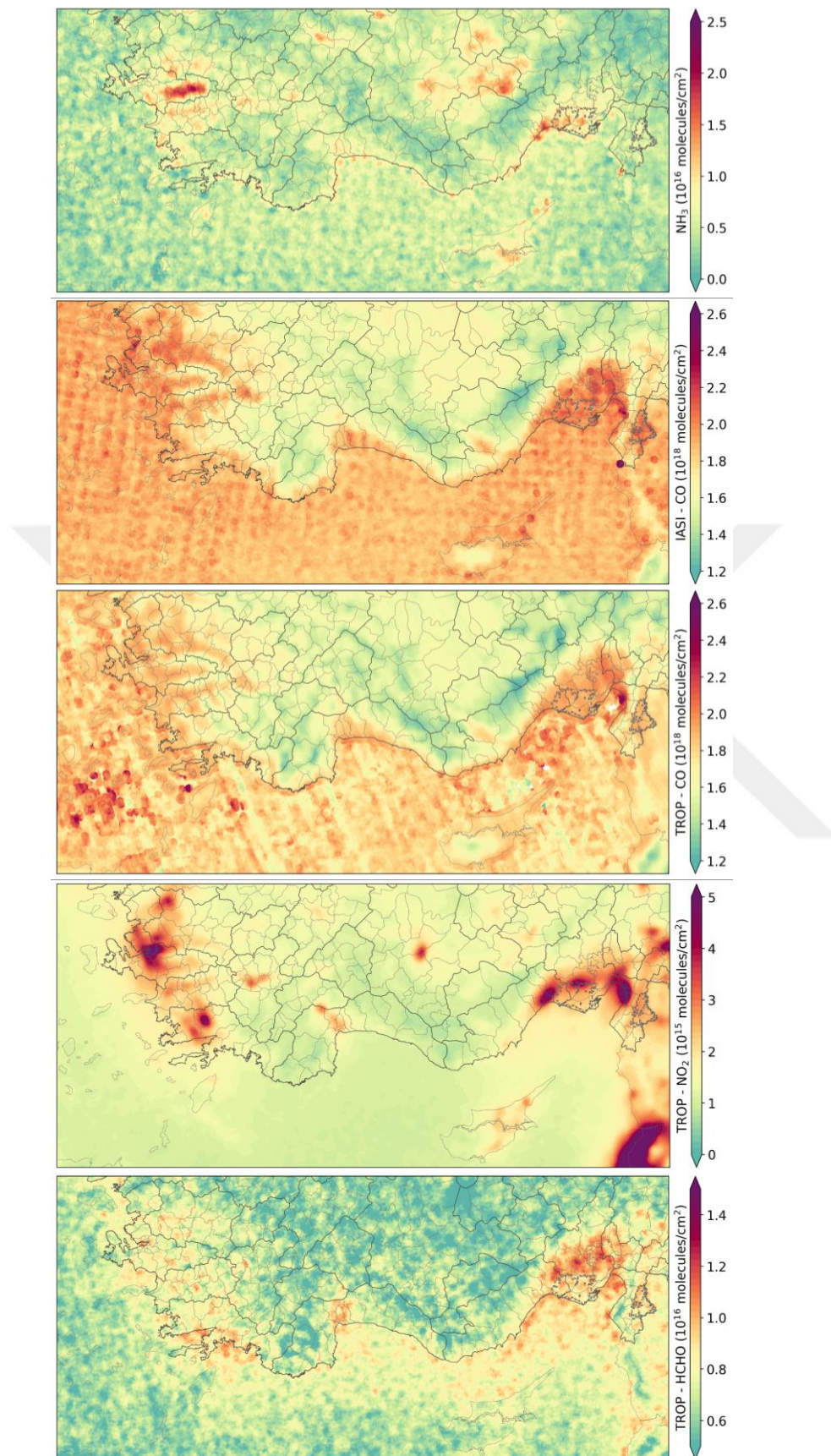


Figure 5.19 : RB-1 period pollutant distributions (molecules/cm²), NH₃, IASI-CO, TROP-CO, TROP-NO₂, TROP-HCHO, respectively.

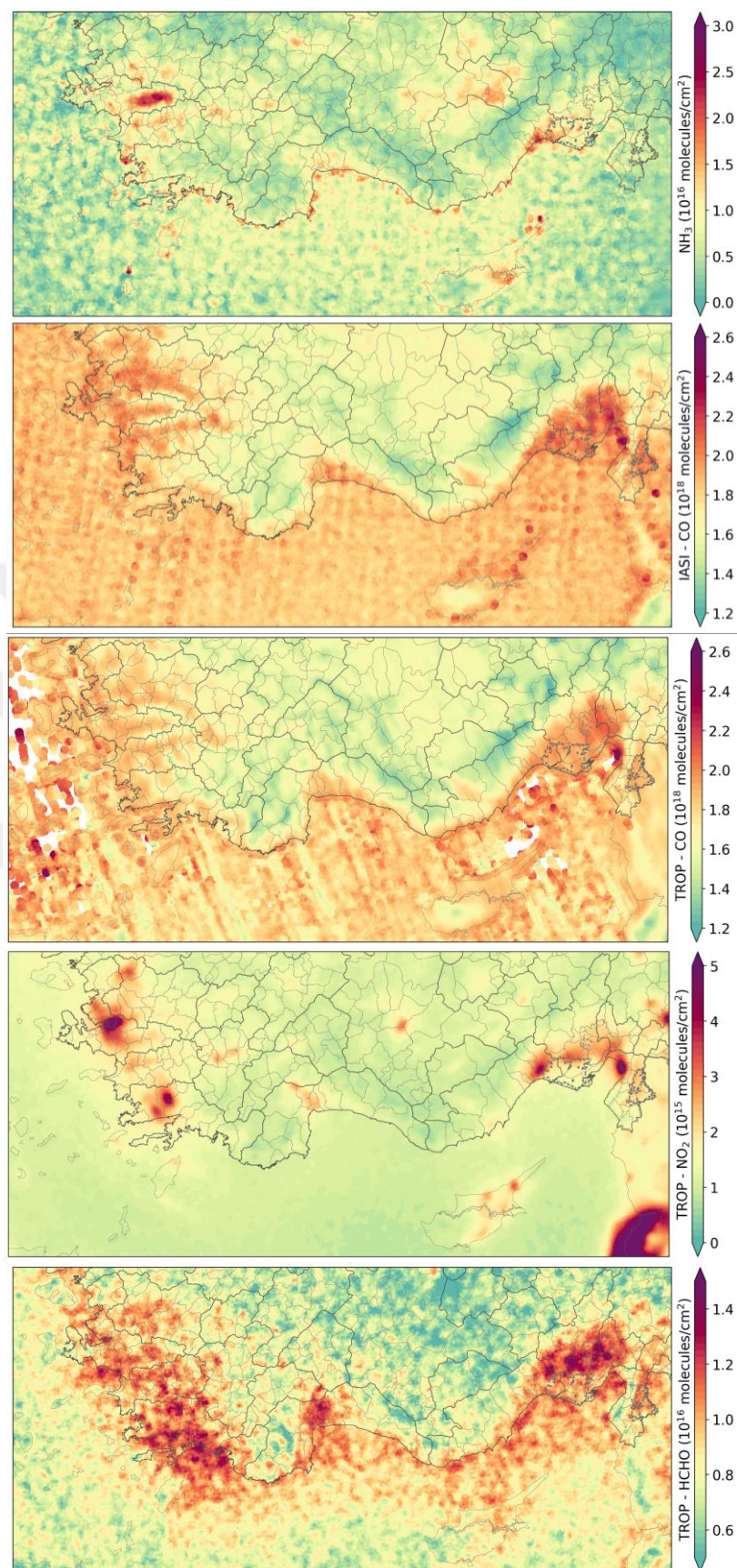


Figure 5.20 : RB-2 period pollutant distributions (molecules/cm²), NH₃, IASI-CO, TROP-CO, TROP-NO₂, TROP-HCHO, respectively.

When the pre-fire and post-fire periods were examined for RB-1 period (Figure B.7), relatively high NH_3 levels were observed particularly over central Mersin and the Me-Ad RB region. In contrast, such elevated levels were not observed over the Ad-Os RB region. These enhancements in Me-Ad RB region were observed without any major FRP peaks during that time. These high NH_3 levels might be related to ongoing agricultural activities, especially considering the timing of the pre-fire period. In addition, coastal parts of the region showed a general transport pattern toward the Mediterranean Sea. Mostly, northerly winds were dominant at coastal MSs in both Antalya and Mersin which indicating possible NH_3 transport toward to Mediterranean. However, as shown in Figure D.2, during the pre-fire period, moderately southwesterly winds were also observed in the Me-Ad RB region, alongside the northerly winds. Therefore, NH_3 transport might not have been as clearly detected as in the coastal areas of Antalya and Mersin. In contrast, during post-fire period moderately strong northerly winds were dominate which likely contributed to the observed high NH_3 levels towards to Mediterranean.

When the same RB regions were examined for the RB-2 fire period (Figure 5.20), more pronounced NH_3 levels were observed compared to RB-1. This difference might be attributed to the seasonal influence of the RB-1 period. RB-1 fire period which included November, a month typically associated with lower NH_3 concentrations due to minor agricultural influence. In contrast, such an effect was not present during the RB-2 fire period. During both RB-1 and RB-2 fire periods, IASI-CO and TROP-CO showed elevated background concentrations. These elevated levels were especially prominent over the Me-Ad and Ad-Os areas.

For TROP- NO_2 , high concentrations were observed particularly over highly populated central districts of Hatay, Adana, and Mersin (Figure 3.3). However, relatively elevated levels were also detected across all RB regions. When comparing the pre-fire and post-fire periods for both RB-1 and RB-2, the strong enhancements observed during the post-fire period were attributed to increased emissions from residential heating due to decreasing temperatures. This pattern was particularly more evident during the RB-1 post period, which, as previously mentioned, included November month.

In summary, although both RB-1 and RB-2 fire periods did not show increases in pollutant levels or FRP levels as strong as those in WF events, they still contributed to noticeable changes, especially over regions like Ad-Os and Me-Ad, where both FRP levels and agricultural activity were relatively higher. In contrast, this effect was much weaker in the Ha region, where FRP levels remained low.

To evaluate RB region-specific pollutant changes, grid-based analysis of concentration differences and NH_3 enhancement ratio across RB-1 and RB-2 pre-fire, fire, and post-fire periods which previously applied to WF regions was also conducted for each RB region (Figure 5.21).

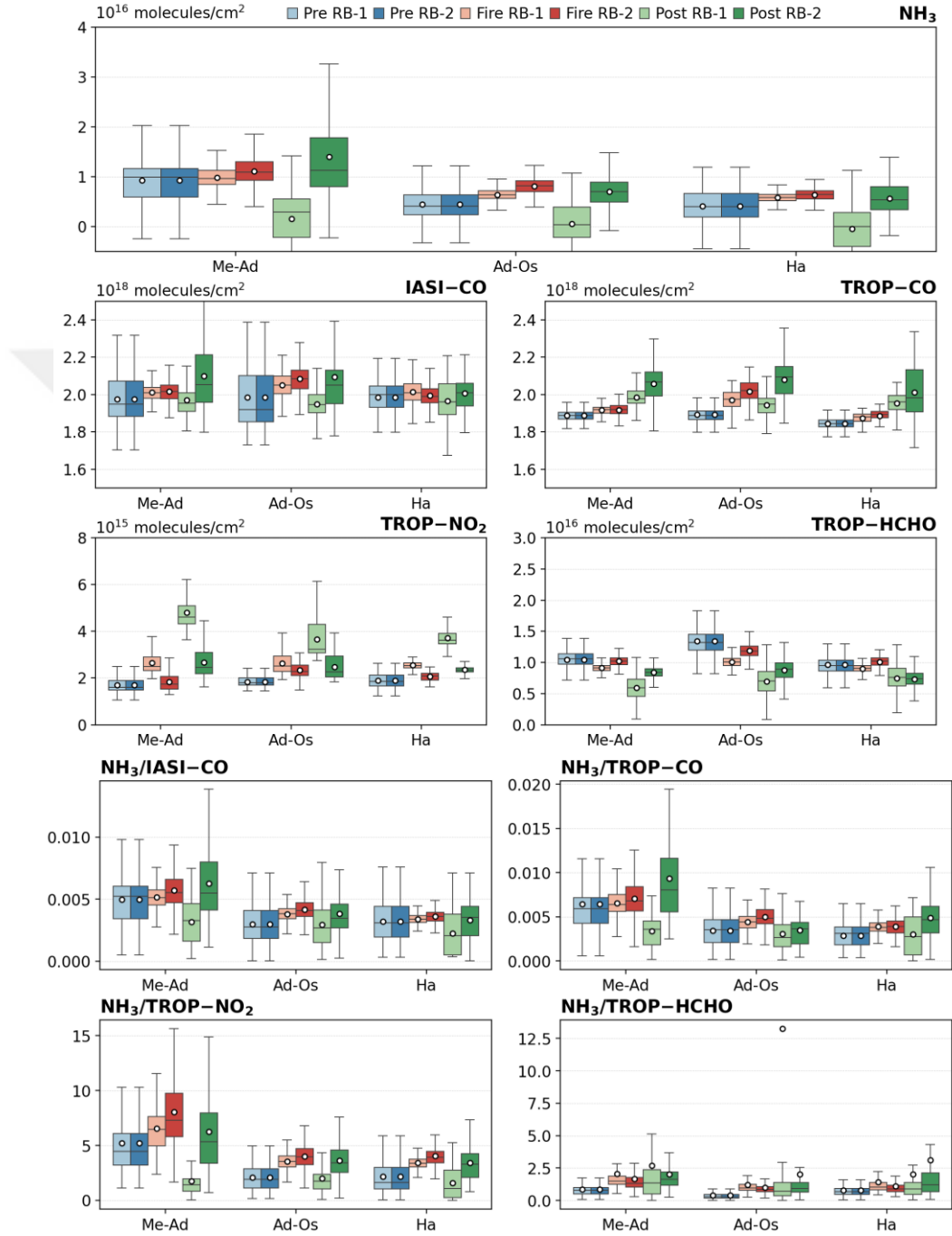


Figure 5.21 : Boxplot of NH_3 and co-emitted pollutant concentrations (NH_3 , IASI-CO, TROP-CO, TROP-NO₂ and TROP-HCHO, respectively) at upper-panel; and NH_3 to co-emitted pollutant ratios ($\text{NH}_3/\text{IASI-CO}$, $\text{NH}_3/\text{TROP-CO}$, $\text{NH}_3/\text{TROP-NO}_2$ and $\text{NH}_3/\text{TROP-HCHO}$, respectively) at lower-panel across RB-1 (light-color) and RB-2 (dark-color) time intervals for the pre-fire, fire, and post-fire periods.

For RB-1, pre-fire NH_3 concentrations were 0.44×10^{16} molecules/ cm^2 in Ad-Os, 0.92×10^{16} molecules/ cm^2 in Me-Ad, and 0.41×10^{16} molecules/ cm^2 in Ha (Table C.13). Since RB-2 had the same pre-fire period (5-14 August 2020), the NH_3 concentrations for Ad-Os, Me-Ad and Ha were also the same. Within the RB-1 fire period, NH_3 levels reached 0.64×10^{16} molecules/ cm^2 in Ad-Os, with an increase of 43.3% compared to the pre-fire period, 0.98×10^{16} molecules/ cm^2 in Me-Ad, with an increase of 5.6%, and 0.58×10^{16} molecules/ cm^2 in Ha, with an increase of 41.4%. Similarly, during the RB-2 fire period, NH_3 levels reached 0.80×10^{16} molecules/ cm^2 in Ad-Os, with an increase of 81.0%, 1.11×10^{16} molecules/ cm^2 in Me-Ad, with an increase of 19.9%, and 0.64×10^{16} molecules/ cm^2 in Ha, with an increase of 55.9%. Fire-period levels in RB-2 were generally higher than those in RB-1, which attributed to the shorter duration of the RB-2 fire period itself. While NH_3 levels did increase during the RB periods, however did not reach the exceptional levels observed in WF regions. In WF regions, average NH_3 levels often exceeded 3×10^{16} molecules/ cm^2 , with peak levels reaching above 10×10^{16} molecules/ cm^2 in several WF regions (Figure 5.15). In contrast, NH_3 concentrations in RB regions generally remained around 1×10^{16} molecules/ cm^2 , which indicated a much lower magnitude of enhancement. This outcome further supports the relationship between extreme NH_3 enhancements and the more intense WF events. Due to the lower intensity of RB events and their timing outside peak agricultural activity, NH_3 concentrations were lower than those observed during WF events. In the post-fire periods, NH_3 concentrations showed clear declines across all regions.

Overall, CO concentrations remained relatively stable throughout the for both RB-1 and RB-2 periods due to its longer atmospheric lifetime and high background levels, with only slight increases observed during the fire period. In RB-1 fire period IASI-CO concentrations reached 2.05×10^{18} molecules/ cm^2 in Ad-Os with a 3.3% increase from the pre-fire level of 1.98×10^{18} molecules/ cm^2 . In Me-Ad and Ha, fire-period levels rose slightly to 2.01×10^{18} molecules/ cm^2 , with increases of 1.8% and 1.4%, respectively. In RB-2, slightly higher changes were recorded, with IASI-CO reaching 2.08×10^{18} molecules/ cm^2 in Ad-Os with 5.0% increase, 2.02×10^{18} molecules/ cm^2 in Me-Ad with 2.0%, and 1.99×10^{18} molecules/ cm^2 in Ha with 0.4%. TROP-CO exhibited similar trends. In RB-1, fire-period values increased to 1.97×10^{18} molecules/ cm^2 Ad-Os, 1.92×10^{18} molecules/ cm^2 in Me-Ad, and 1.87×10^{18} molecules/ cm^2 in Ha which corresponded to increases of 4.1%, 1.5%, and 1.5%, respectively. During RB-2, TROP-CO reached 2.02×10^{18} molecules/ cm^2 in Ad-Os with 6.5% increase, 1.92×10^{18} molecules/ cm^2 in Me-Ad with 1.6%, and 1.89×10^{18} molecules/ cm^2 in Ha with 2.2%.

Unlike CO, TROP-NO₂ showed much sharper variation. In RB-1 fire period NO₂ concentrations in Me-Ad increased by 55.2%, rose from 1.70 to 2.65x10¹⁵ molecules/cm² and continued to increase to 4.81x10¹⁵ molecules/cm² in the post period. A similar post-fire rise was observed in Ad-Os, where average concentration increased from 2.63 to 3.66x10¹⁵ molecules/cm² by 39.1%, and in Ha from 2.54 to 3.71x10¹⁵ molecules/cm² by 45.8%. These post-fire enhancements, as previously mentioned and as could be seen in the distribution maps, were likely linked to increased residential heating and local emissions (for RB-1 and RB-2 fire period Figure 5.19 and Figure 5.20 respectively; for pre-fire and post-fire Figure B.7).

TROP-HCHO showed a pattern during the RB periods. In most regions, HCHO concentrations decreased from the pre-fire to fire period and remained low in the post period. In RB-1, Ad-Os showed a decrease from 1.34 to 1.01x10¹⁶ molecules/cm², followed by a further decline to 0.70x10¹⁶ molecules/cm² in the post period. Me-Ad dropped from 1.05 to 0.91 and then to 0.59x10¹⁶ molecules/cm². In RB-2, HCHO levels were slightly less variable, although the overall trend was similar. These patterns, with significantly lower HCHO levels, were mostly related to seasonal influences rather than fire-related effects, since HCHO formation is also linked to biogenic emissions and photochemical activity.

In RB regions, NH₃/IASI-CO ratios showed moderate but consistent increases during the fire periods in both RB-1 and RB-2 (Table 5.4). In RB-1, this ratio increased from 0.0030 to 0.0038 in Ad-Os, from 0.0050 to 0.0052 in Me-Ad, and from 0.0032 to 0.0034 in Ha. Similar increases were observed during RB-2, fire as well, with the ratio rising from 0.0030 to 0.0042 in Ad-Os, 0.0050 to 0.0057 in Me-Ad, and 0.0032 to 0.0036 in Ha. NH₃/TROP-CO ratios also increased moderately during both fire periods. In RB-1, the ratio rose from 0.0035 to 0.0044 in Ad-Os, 0.0064 to 0.0066 in Me-Ad, and 0.0028 to 0.0039 in Ha. In RB-2, the increase continued with rising ratios, which from 0.0035 to 0.0050 in Ad-Os, 0.0064 to 0.0071 in Me-Ad, and 0.0028 to 0.0039 in Ha. In all WF regions except MU-1 for NH₃/IASI-CO and MU-2 and MU-3 for NH₃/TROP-CO ratios during the fire periods were generally higher than those observed in RB regions. While this may indicate that more NH₃ could be emitted during WF events compared to RB, it should also be considered that low NH₃/CO ratios in some cases may result from rising CO concentrations, such as during the fall and winter with increasing residential heating. These seasonal CO increases may suppress the ratio, even if NH₃ levels remain elevated.

Table 5.4 : NH₃ ratio to co-emitted pollutants for RB regions and periods.

RB-Regions			NH ₃ /IASI-CO			NH ₃ /TROP-CO			NH ₃ /TROP-NO ₂			NH ₃ /TROP-HCHO		
			Pre	Fire	Post	Pre	Fire	Post	Pre	Fire	Post	Pre	Fire	Post
Average	RB-1	Ad-Os	0.0030	0.0038	0.0029	0.0035	0.0044	0.0031	2.09	3.55	2.01	0.41	1.22	13.27
		Me-Ad	0.0050	0.0052	0.0032	0.0064	0.0066	0.0034	5.20	6.56	1.76	0.84	2.05	2.70
		Ha	0.0032	0.0034	0.0022	0.0028	0.0039	0.0030	2.16	3.43	1.59	0.78	1.44	2.01
	RB-2	Ad-Os	0.0030	0.0042	0.0038	0.0035	0.0050	0.0035	2.09	4.02	3.63	0.41	1.00	2.03
		Me-Ad	0.0050	0.0057	0.0062	0.0064	0.0071	0.0093	5.20	8.03	6.25	0.84	1.67	2.02
		Ha	0.0032	0.0036	0.0033	0.0028	0.0039	0.0049	2.16	4.03	3.41	0.78	1.09	3.12
Median	RB-1	Ad-Os	0.0027	0.0038	0.0027	0.0035	0.0044	0.0027	1.91	3.54	1.74	0.30	0.96	0.71
		Me-Ad	0.0052	0.0051	0.0033	0.0059	0.0064	0.0036	4.45	6.45	1.41	0.80	1.50	1.37
		Ha	0.0031	0.0034	0.0021	0.0031	0.0038	0.0028	1.62	3.37	1.08	0.68	1.03	0.89
	RB-2	Ad-Os	0.0027	0.0041	0.0035	0.0035	0.0049	0.0036	1.91	3.96	3.43	0.30	0.86	0.94
		Me-Ad	0.0052	0.0055	0.0055	0.0059	0.0068	0.0080	4.45	7.29	5.33	0.80	1.30	1.65
		Ha	0.0031	0.0036	0.0035	0.0031	0.0039	0.0047	1.62	3.91	3.30	0.68	0.89	1.21
Max	RB-1	Ad-Os	0.0076	0.0054	0.0084	0.0083	0.0069	0.0096	4.95	7.53	8.80	10.99	19.50	1891.81
		Me-Ad	0.0212	0.0081	0.0075	0.0253	0.0129	0.0074	45.18	233.64	9.53	7.32	40.93	239.05
		Ha	0.0076	0.0047	0.0071	0.0065	0.0066	0.0072	7.14	6.79	5.24	11.09	23.31	60.65
	RB-2	Ad-Os	0.0076	0.0070	0.0132	0.0083	0.0092	0.0067	4.95	9.76	16.89	10.99	11.40	82.11
		Me-Ad	0.0212	0.0097	0.0205	0.0253	0.0157	0.0290	45.18	347.14	35.79	7.32	29.28	100.42
		Ha	0.0076	0.0050	0.0071	0.0065	0.0062	0.0106	7.14	9.73	11.44	11.09	9.22	135.25

NH₃/NO₂ ratios showed a clear increase during the fire periods across all RB regions and periods, which ranging from 3.43 to 8.03. However still significantly lower than WF regions. Even the highest ratio observed in RB periods, which detected over Me-Ad region and 6.56 and 8.03 for RB-1 and RB-2 respectively, remained nearly half of the lowest fire-period ratio reported in WF which is 13.99 in ME-1. Although NH₃/HCHO ratios increased during the fire periods in RB regions, these ratios were relatively comparable to those observed in WF regions. In general, ratios in RB regions were within 1 to 2 range, while most WF regions also showed ratios within the 1.5 to 2.5. Notable exceptions were MU-1 and MU-3, where higher ratios were detected which reaching 6.21 and 3.67, respectively.

The NH₃/CO ratios calculated for regions associated with RB-1 and RB-2 were considerably lower than the values typically reported for cropland fires in the literature (Table 5.3). While Whitburn et al. (2017) report NH₃/CO ratios ranging from 0.011 to 0.014 for cropland biomes, the fire-period averages in this study are much lower, ranging from 0.0034 to 0.0057 for NH₃/IASI-CO and 0.0039 to 0.0071 for NH₃/TROP-CO. These values fall below the cropland category reported in the literature, which could be related to lower NH₃ emissions due to differences in fuel characteristics because the ratios reported by Whitburn et al. (2017) were derived from regions with more intense and extensive fire activity.

Hourly correlation analyses were conducted between NH₃ and co-emitted pollutants for each RB region, Ad-Os, Me-Ad, and Ha, and for each RB-1 and RB-2 fire period, across pre-fire, fire, and post-fire intervals (Figure H. 1 to Figure H.3) In Ad-Os, during the RB-1 period, not high but statistically significant correlations were observed between NH₃ and other co-emitted pollutants, except for NO₂. Period-specific analysis showed notable correlations such as $r = 0.35^{***}$ for NH₃ and IASI-CO and $r = 0.43^{**}$ for NH₃ and TROP-CO (Figure H. 1).

However, in the same region during RB-2 period, a significant correlation was only observed with NH₃ and IASI-CO ($r = 0.44^{**}$). A similar analysis for Me-Ad region showed high correlations in RB-1 between NH₃ and both CO and HCHO. Statistically significant values were found as $r = 0.40^{***}$ for NH₃ and IASI-CO, $r = 0.49^{***}$ for NH₃ and TROP-CO, and $r = 0.52^{***}$ for NH₃ and TROP-HCHO (Figure H. 2).

For RB-2, correlations were generally lower, similar to the pattern in Ad-Os. However, a remarkably high and significant correlation of $r = 0.93^*$ was found between NH₃ and HCHO. When considered alongside the HCHO distribution patterns, this indicated not an increase but rather a simultaneous decline in both pollutants.

In Ha, no strong correlations were observed between NH_3 and CO products or HCHO during either RB-1 or RB-2 (Figure H.3). Only a weak NH_3 and NO_2 correlation ($r = 0.27^*$) was detected during the fire period in RB-1.

In order to understand the monthly relationship in 2020 and to investigate BB impact on pollution in the fire-affected months, monthly-based correlation analyses were conducted to for these RB regions (Figure 5.22).

As in the fire periodic analyses, only relatively high but statistically significant correlation were found, especially between the NH_3 and CO products. These was 0.38^{***} and 0.36^{***} in the Ad-Os region and 0.31^{***} and 0.33^{***} for Me-Ad region, IASI-CO, and TROP-CO, respectively. Monthly based analysis for the Ad-Os region revealed that September and October generally showed much stronger correlations between NH_3 and CO products. In particular, the correlation between NH_3 and IASI-CO was 0.48^{**} , 0.38^* , and 0.45^* from August to October, respectively, which these months matched the selected fire-intensified periods in the region. Even in June ($r = 0.66^{***}$) and July ($r = 0.44^*$), relatively strong correlations were observed.

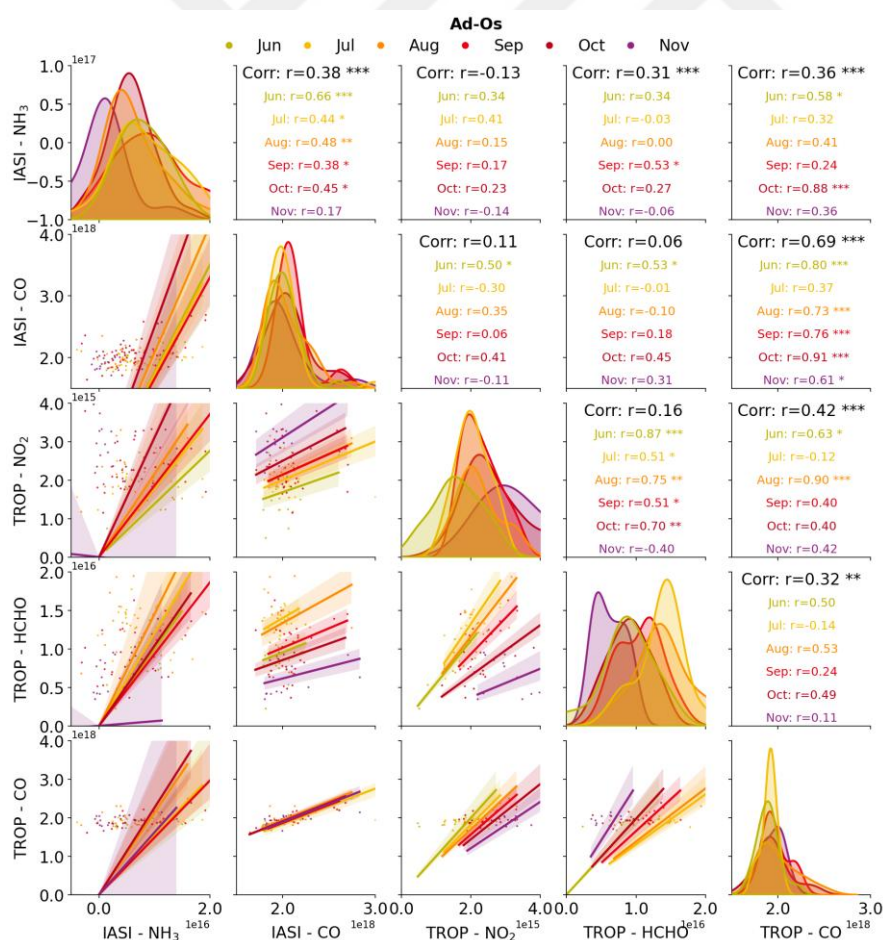


Figure 5.22 : Monthly correlation analysis for RB-regions (Ad-Os).

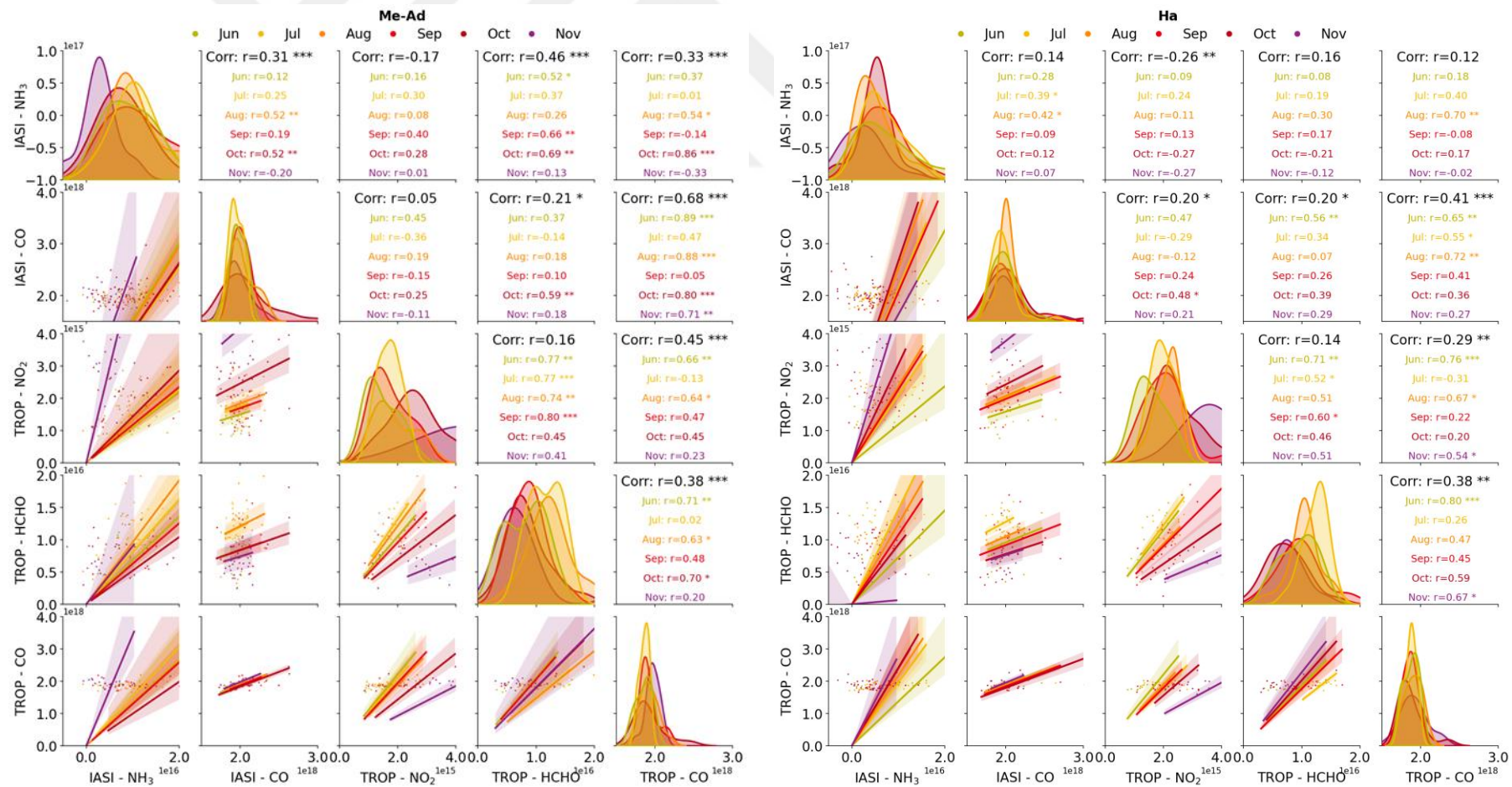


Figure 5.22 (continue) : Monthly correlation analysis for RB-regions (left: Me-Ad and right: Ha).

These relationships may be attributed to another fire trend that occurs in the area during early summer with relatively low FRP activity (Figure 5.6). Additionally, considering the region's agricultural activity and the presence of industrial sources, these factors are also likely to contribute to NH_3 and CO levels observed during this time. The correlation with NH_3 and TROP-CO reached its highest record in October ($r = 0.88^{***}$). This indicated a very strong relationship likely associated with peak fire activity during this period, further supported by a notably steeper slope that NH_3 and CO increase alongside each other.

Similarly, when the same analysis was applied to the Me-Ad region, statistically significant correlations were again found between NH_3 and both CO products, with 0.31^{***} for IASI-CO and 0.33^{***} for TROP-CO. Notably, in both August and October, the correlation between NH_3 and IASI-CO was relatively high ($r = 0.52^{**}$), while the strongest NH_3 and TROP-CO relationship appeared in October ($r = 0.86^{***}$) again.

To further investigate RB-related impacts, AQMS measurements for CO, NO_2 , and PM_{10} were analyzed. CO and NO_2 which were evaluated using satellite retrievals, were examined again here to capture variations that may not be detected by satellite observations. PM_{10} was also included as RB is a well-known source for PM.

In this scope, during the RB-1 and RB-2 periods, daily average time series, periodic pollutant roses and wind roses for understand the pollution distribution of PM_{10} , CO, and NO_2 from AQMS were analyzed. However, any AQMS located near the RB regions did not provide measurements with data completeness for analysis in 2020. Therefore, since RB events occurred during similar time intervals each year in the region (Figure 5.6), the same periods in other years were examined. Additionally, the spatial distribution of grid-based FRP levels was examined within these periods to understand whether the region was affected by fire or not.

Yakapinar AQMS located in the east part the Me-Ad RB region and the west of the Ad-Os region while the closest MS-17350, is located slightly to its west. Therefore, this AQMS were representative to investigated in detail here that can reflect influences from both RB regions. As shown in for 2021 Figure I. 1 and Figure 5.23 for 2022, during the fire period (highlighted in red), daily peaks in PM₁₀ and CO concentrations were observed, particularly from September toward to end of the period.

Notably, NO₂, CO, and PM₁₀ all showed similar peak in the period which further supported the common source related to BB. In 2022, this fire period was also evaluated together with pollution distribution patterns which revealed that only in fire period except PM₁₀ relatively high levels in all pollutants under the influence of prevailing northerly winds. When considered alongside the FRP distribution, which showed concentrated high fire activity north of the region, these findings indicate a likely increase in pollutant levels attributable to nearby BB events.

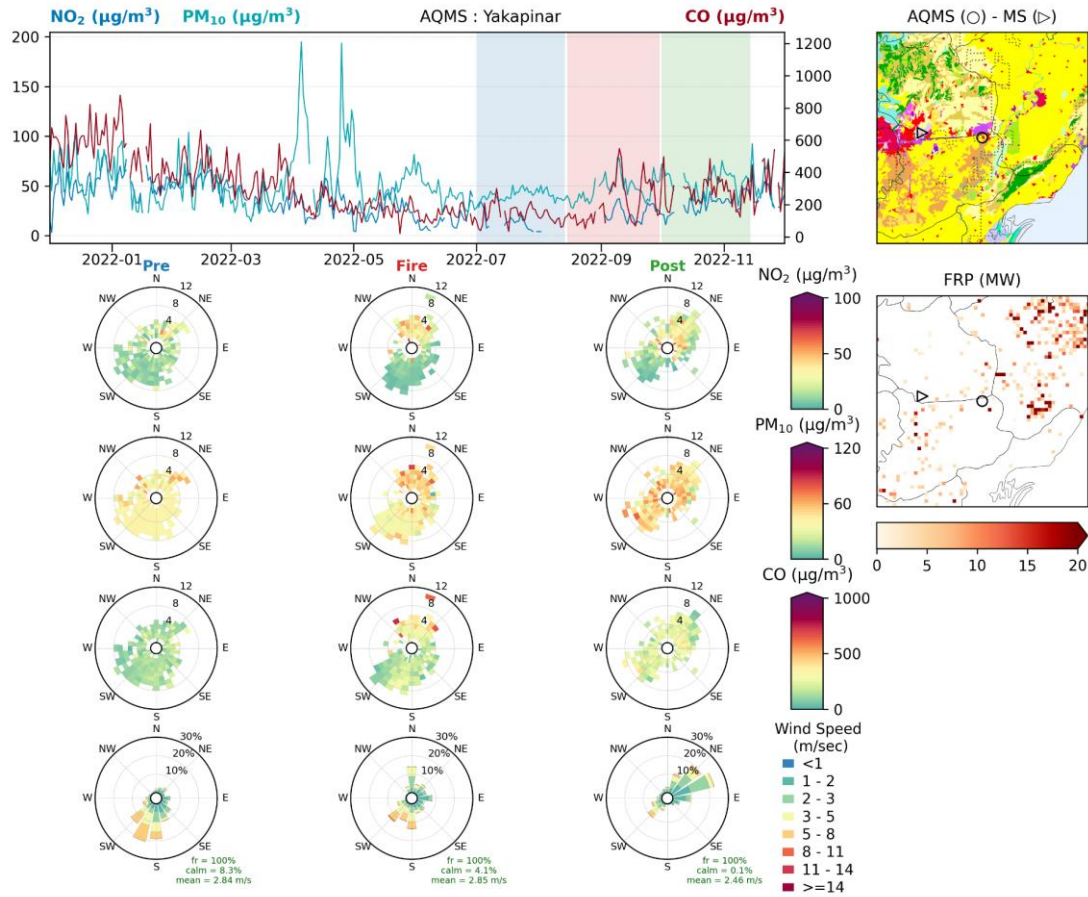


Figure 5.23 : Yakapinar AQMS and MS-17350 daily average time series of NO₂, PM₁₀ and CO (in units of µg/m³) (top left), CLC with AQMS and MS location (top right), periodic pollutant rose (middle left), along with wind rose (bottom left) and FRP for the period.

Kadirli AQMS, located in the northern part of Osmaniye, is situated within the Ad-Os RB region and was evaluated together with MS-19184. As shown in Figure I.2 for 2021 and Figure 5.24 for 2022 similar to Yakapinar AQMS, CO and PM₁₀ levels showed high daily average concentration within the fire period. As in previous observations, all pollutants peaked around the same time. When pollutant distributions were examined, it was observed that fires were predominantly concentrated to the south of the AQMS, and elevated PM₁₀ and CO concentrations were detected under the influence of southerly winds. Unlike Yakapinar, where noticeable increases were mostly limited to the fire period, Kadirli AQMS showed elevated levels not only during the fire period but also in the pre-fire and post-fire periods as well. As seen in the CLC, station located in urban area which might be the reason for the consistently high pollutant levels due to urban activities.

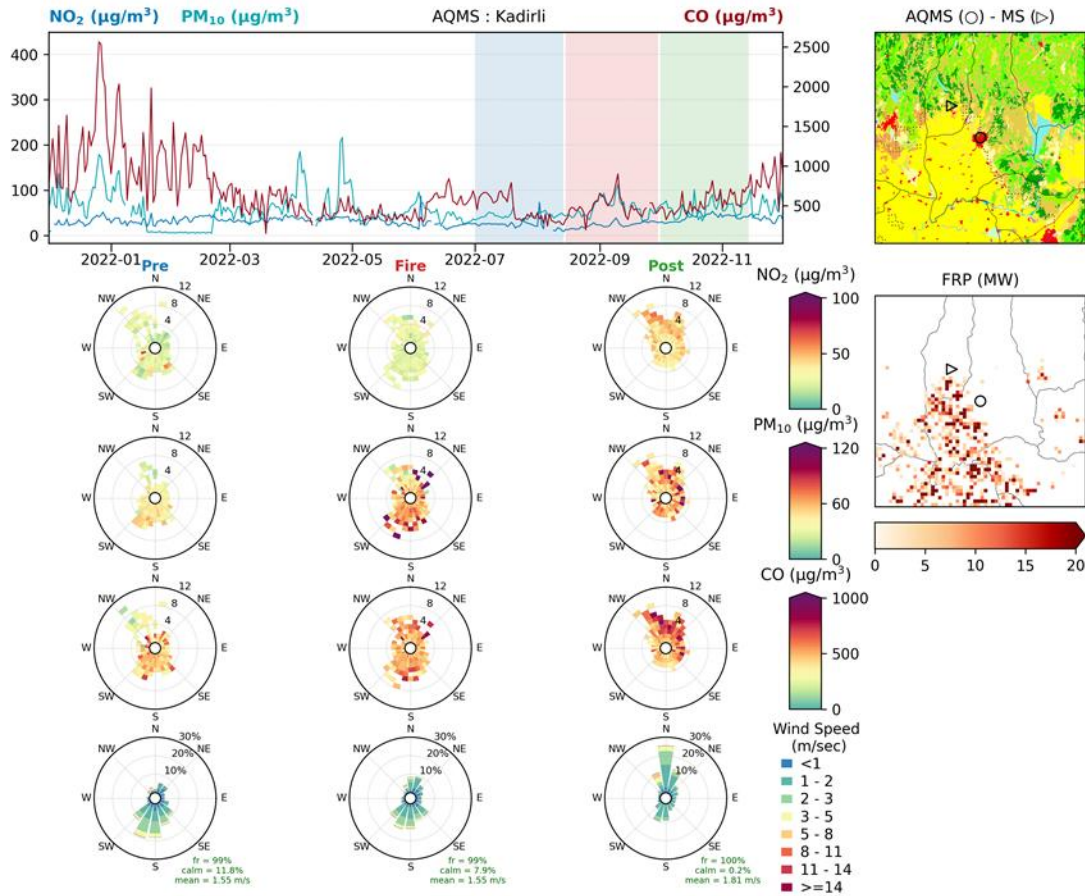


Figure 5.24 : Kadirli AQMS and MS-19184 daily average time series of NO₂, PM₁₀ and CO (in units of µg/m³) (top left), CLC with AQMS and MS location (top right), periodic pollutant rose (middle left), along with wind rose (bottom left) and FRP for the period (middle right).

A similar Chl-a analysis, which was applied to WF events, was also conducted for the RB-1 and RB-2 periods to assess whether RB events had a comparable impact in Eastern Mediterranean or not (Figure 5.25 and Figure 5.26).

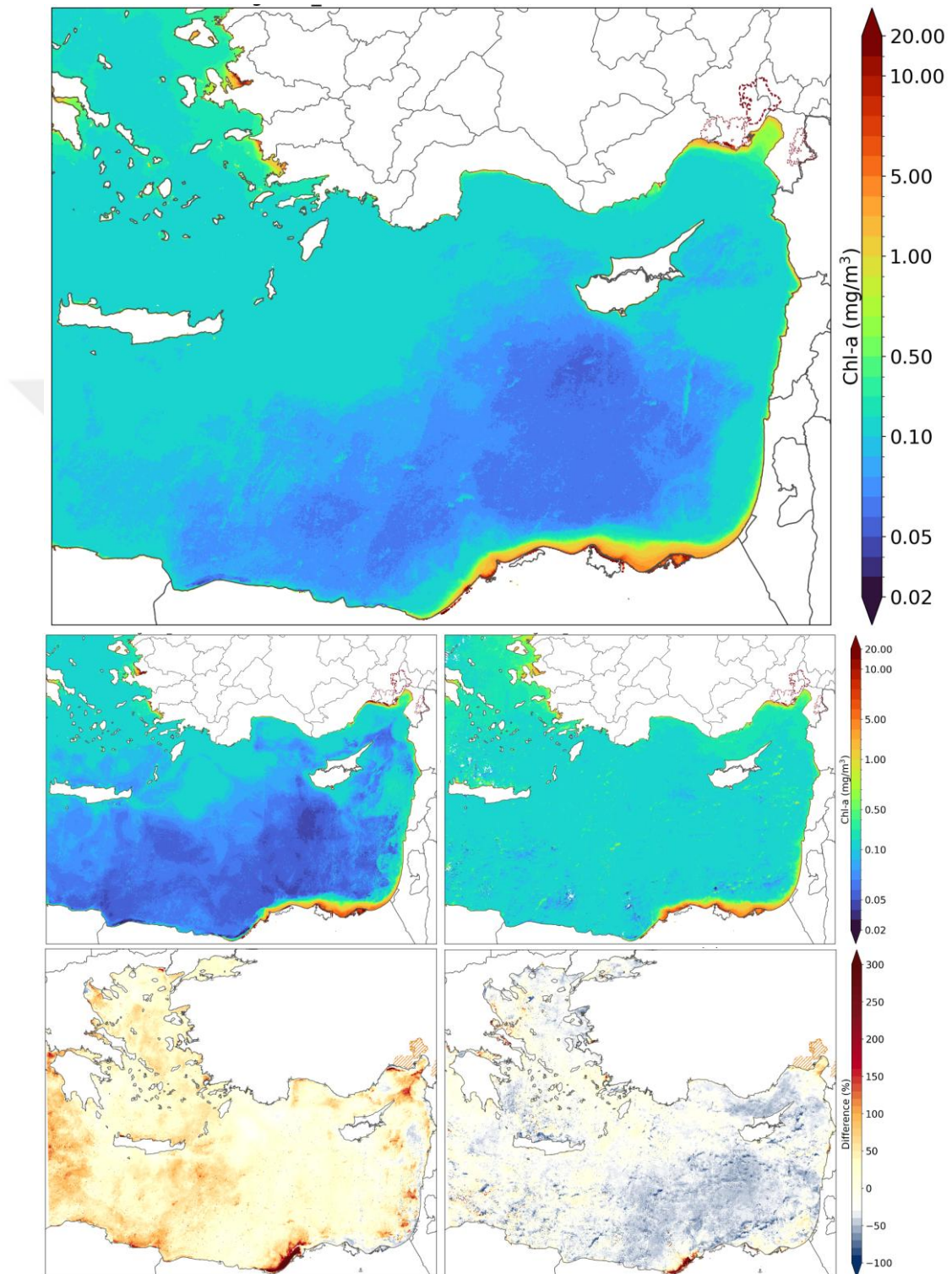


Figure 5.25 : Chl-a distribution (mg/m^3) for RB-1 fire period (top), pre-fire (center left), post-fire (center right), changes over fire to pre-fire (bottom left) and fire to post-fire (bottom right).

During the RB-1 fire period (with RB regions hatched in red and representative RB for the period marked in dark red), elevated Chl-a concentrations were observed in the Hatay Gulf and along the coast of Adana. However, high Chl-a levels were also observed along the Adana coast during both the pre-fire and post-fire periods. Therefore, when the difference maps were examined regional enhancements in the fire period compared to the pre-fire and post-fire periods were detected. However, these increases were not as evident as those observed during the WF event (Figure 5.17). Unlike WF event, which were observed further offshore, the RB-related enhancements appeared to be close to nearshore areas. Notably, in the pre-difference, Chl-a concentrations along the Adana coast increased by more than 300%. As in the WF, this could indicate the influence of smoke plume deposition. But it could also indicate the contribution of regional discharges or other local sources since observed high levels were closed to coast.

When the RB-2 period was examined, the Chl-a increases observed in the difference maps were lower compared to those in the RB-1 period (Figure 5.26). Although enhancement was still can be detected near the coastal areas. However, increases along the Ad-Me region coastline that were observed during RB-1 were not observed during RB-2. Overall, the impact of RB events on Chl-a concentrations was less clear than that of WF event. However, the periodic increases detected in both RB periods indicated BB events may still have had a potential influence over Mediterranean.

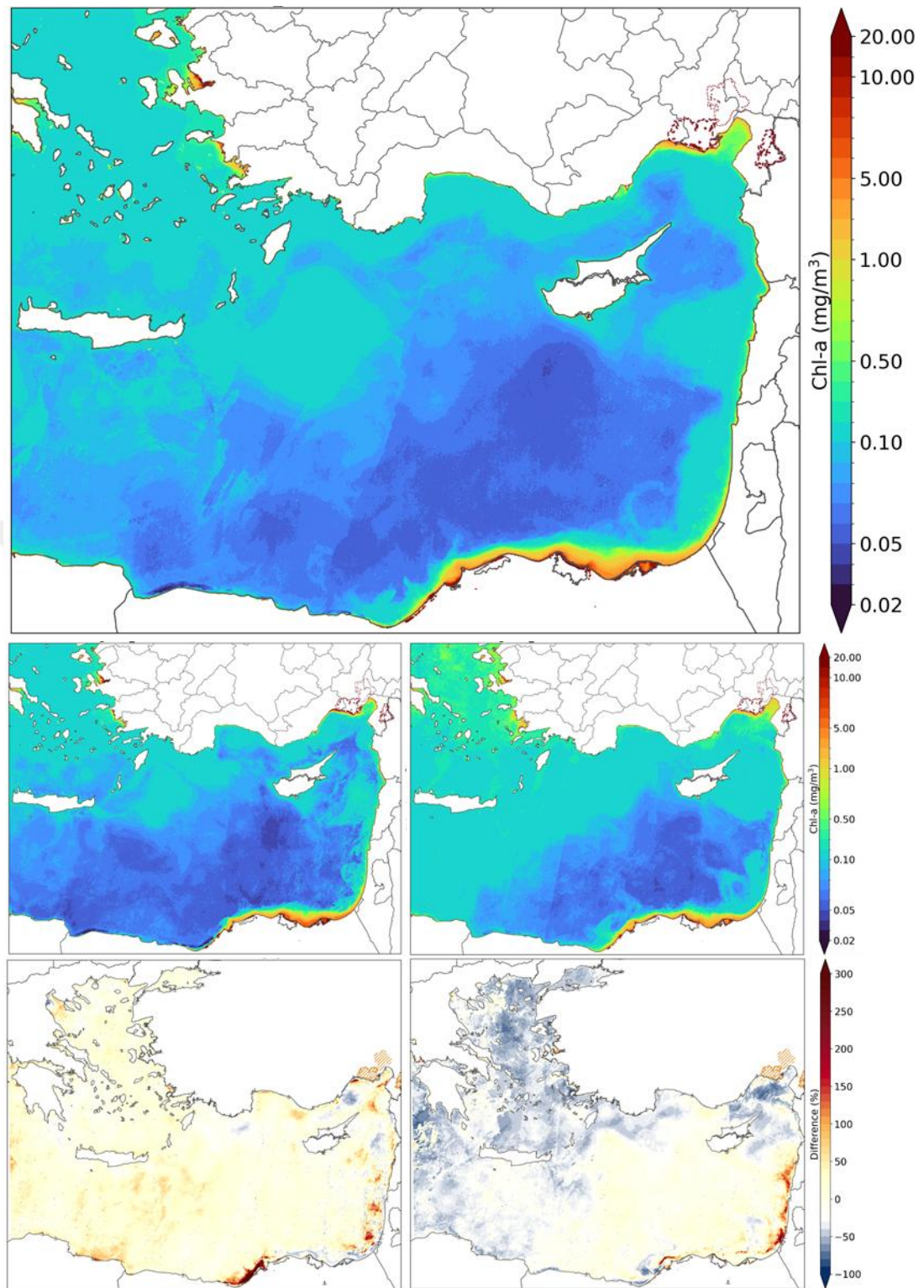


Figure 5.26 : Chla distribution (mg/m³) for RB-2 fire period (top), pre-fire (center left), post-fire (center right), changer over fire to pre-fire (bottom left) and fire to post-fire (bottom right).



6. CONCLUSIONS AND FUTURE WORK

The results derived from IASI NH₃ morning overpass retrievals showed that the Eastern Mediterranean Region recorded relatively high NH₃ levels, with a clear increase from 2012 to 2023, which stood out as one of the most evident hotspot regions across Türkiye. To investigate this change, spatial and temporal distributions of NH₃ were analyzed over 1x1 km² grid Eastern Mediterranean domain. Annual distributions showed that NH₃ concentrations increased in the coastal provinces of the region notably Adana and Mersin and relatively in Antalya and especially after 2015 this increase became more evident. Time series analyses supported this trend which showed increases in overall study area with temporary decreases in 2019 and marked peaks in 2021. Further, annual average NH₃ levels were consistently higher over agricultural areas compared to total land areas across all years which attributed to important role of agricultural activities in the region. Among the provinces, Adana and Mersin stood out not only with consistent upward trends but also with significantly higher annual average concentrations compared to the overall region average throughout the study period. In Adana, NH₃ levels in agricultural areas increased by 49.8%, rising from 3.58×10^{15} to 5.36×10^{15} molecules/cm², while the increase over total land areas was 37.3% (from 3.11×10^{15} to 4.27×10^{15} molecules/cm²). In Mersin, although the increase was more moderate which was 25.8% in agricultural areas (from 3.85×10^{15} to 4.84×10^{15} molecules/cm²) and 20.5% in total areas (from 3.19×10^{15} to 3.85×10^{15} molecules/cm²) which the province already exhibited high NH₃ levels at the beginning of the period, which may explain the smaller relative change. To better detect NH₃ hotspots, a percentile-based analysis was conducted. This analyses confirmed that Adana and Mersin consistently ranked among the highest percentile regions, with districts such as Seyhan, Yüreğir, and Akdeniz showed long-term hotspot characteristics. Both spatial distribution and time series analyses demonstrated a consistent increase in NH₃ levels over the years, which was further confirmed by Mann-Kendall trend analysis which showed statistically significant upward trends across all provinces. The increase was more pronounced in agricultural zones, where annual trend slopes were nearly twice as high as those calculated for overall areas.

To further explore the drivers of these trends, correlation analyses were conducted using monthly-based using daily average T and daily total P. Strong positive and statistically significant correlations were found between NH_3 and T in both agricultural and artificial surfaces with most with the highest observed in Antalya agricultural areas ($r = 0.959^{***}$) and Adana artificial surfaces ($r = 0.932^{***}$). While strong negative and statistically significant correlations were detected between NH_3 and P in all provinces except Osmaniye due to lack of P data. Seasonal based analysis further showed that the summer had the highest average NH_3 levels ($>2 \times 10^{16}$ molecules/cm²), followed by spring and fall, with the lowest levels occurring in winter. The high levels observed during 2021 in summer, particularly in July and August months were noteworthy both for their exceptional levels and for coinciding with the intense wildfire recorded in the region which this leading to an investigation of the BB and NH_3 relationship. Therefore, large-scale wildfires occurred in 2021 Mersin, Antalya, and Mugla were investigated in detail. The results showed that, NH_3 concentrations during the defined fire period (28 July-7 August) were 94% higher than the pre-fire (18-27 July) period and 146% higher than the post-fire (08-17 August) period which this indicates an enhancement of NH_3 related to BB. Then, subregions were selected for WF based on total grid-based FRP according to 2021 wildfire time interval. Based on the sub-regional analysis for the wildfire regions, NH_3 enhancements were observed in all selected region especially in AN-1 and AN-2 regions which NH_3 levels during the fire period increased by 308% and 594% compared to the pre-fire and post-fire periods, respectively. Similar patterns were also found in co-emitted pollutants, especially TROP- NO_2 and TROP-HCHO, with increases exceeding 100% in most regions. These substantial increases in NH_3 and co-emitted pollutant levels and notably higher NH_3 ratios to other pollutants indicated that BB was an important episodic contributor to NH_3 emissions during the fire period. For instance, NH_3/NO_2 ratio in AN-1 increased from 7.51 to 16.96 while $\text{NH}_3/\text{IASI-CO}$ ratio doubled from 0.0041 to 0.0094 and $\text{NH}_3/\text{TROP-CO}$ from 0.0042 to 0.0104.

Further, the impact of the 2021 wildfires on the marine environment was examined during the WF period and a significant increase in Chl-a concentrations was observed in the downwind direction of the wildfire plume over the Mediterranean Sea. The maximum enhancement reached more than 500% from the pre-fire to fire period, which these results might indicated that nitrogen deposition from wildfire smoke may have influenced phytoplankton growth in the Mediterranean.

Sub-regional analyses of RB regions based on cumulative FRP data from 2019 to 2023 showed more lower NH_3 enhancements compared to WF regions during defined two fire periods RB-1 and RB-2. For Ad-Os region, NH_3 concentrations increased by 43.3% during the RB-1 fire period compared to post-fire levels. For the Me-Ad and Ha regions, NH_3 concentrations increased by 19.9% and 55.9%, respectively, during the RB-2 fire period. Although overall NH_3 levels in Hatay remained relatively low throughout the study period. These findings suggest that, even in the absence of large-scale wildfire activity, agricultural residue burning could still caused to notable short-term NH_3 enhancements. Further, unlike the WF, no significant increases in Chl-a were detected in RB periods over Mediterranean Sea, except for minor localized changes near the Me-Ad coastal area which might be related to contribution of regional discharges or other local sources or same as WF could be related to RB smoke plume.

Overall, findings of this study reveal a clear increasing trend in NH_3 levels across the Eastern Mediterranean, particularly over agricultural areas. This is especially important for the region where NH_3 is not measured in any AQMS, and no regulation at all. Due to considering the critical role of in air pollution, climate, and ecosystem and human health, this upward trend highlights the NH_3 monitoring and control, particularly in regions where high levels were observed. In addition to this long-term trend, the results also demonstrate that BB events significantly contributed to NH_3 enhancements in the Eastern Mediterranean, particularly during the large-scale WF event, in parallel with increases in co-emitted pollutants. Additionally, variations in Chl-a concentrations suggest that such events may also trigger broader environmental effects through atmospheric nitrogen deposition over the Mediterranean Sea.



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APPENDICES

APPENDIX A: Livestock and crop statistics.

APPENDIX B: Distribution maps.

APPENDIX C: Statistics tables.

APPENDIX D: Wind rose for study area, wildfire and agricultural residue burning regions and for selected periods.

APPENDIX E: Long-Term annual and seasonal NH₃ distributions and wind pattern analyses.

APPENDIX F: Long-Term time series analyses of NH₃, T, RH, and WS and year-specific correlation analyses.

APPENDIX G: Pollution distribution analyses of NH₃ for study period.

APPENDIX H: Correlation analyses for NH₃ and co-emitting pollutants.

APPENDIX I: Periodic-time series analyses and pollution distribution for AQMS measurements.

APPENDIX A: Livestock and crop statistics.



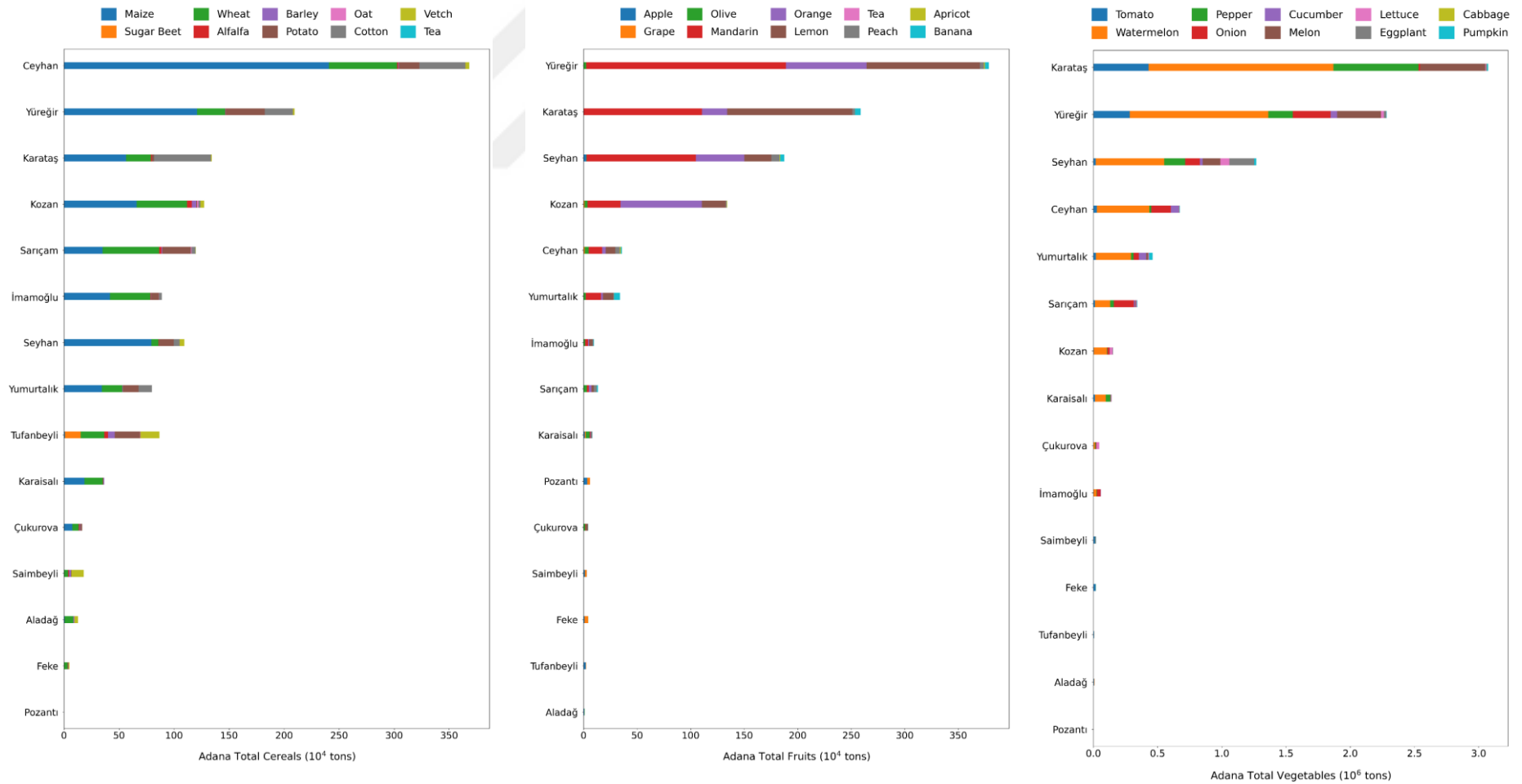


Figure A.1 : Crop for Adana cereals (left), fruits (middle) and vegetables in unit tons (right).

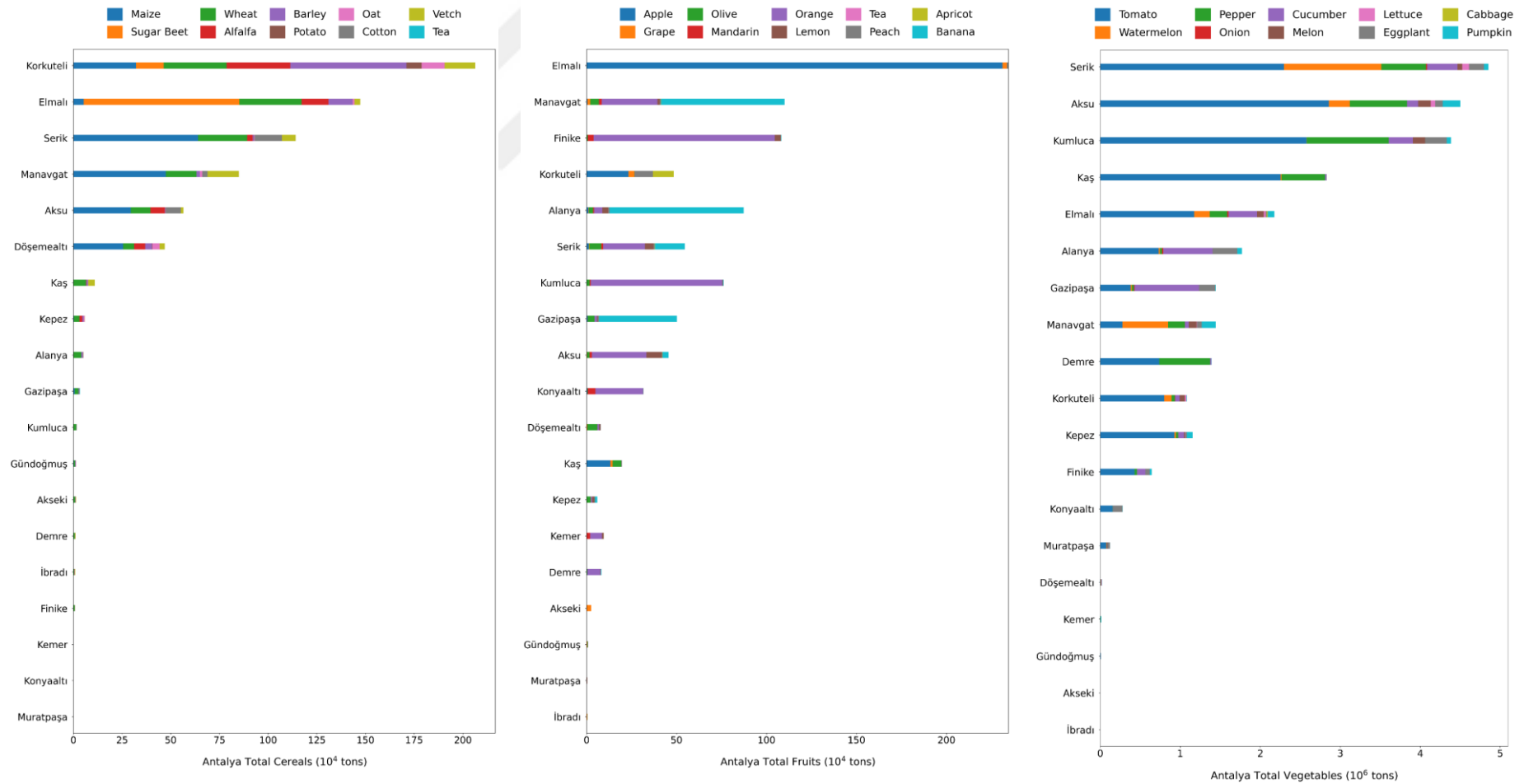


Figure A.2 : Crop for Antalya cereals (left), fruits (middle) and vegetables in unit tons (right).

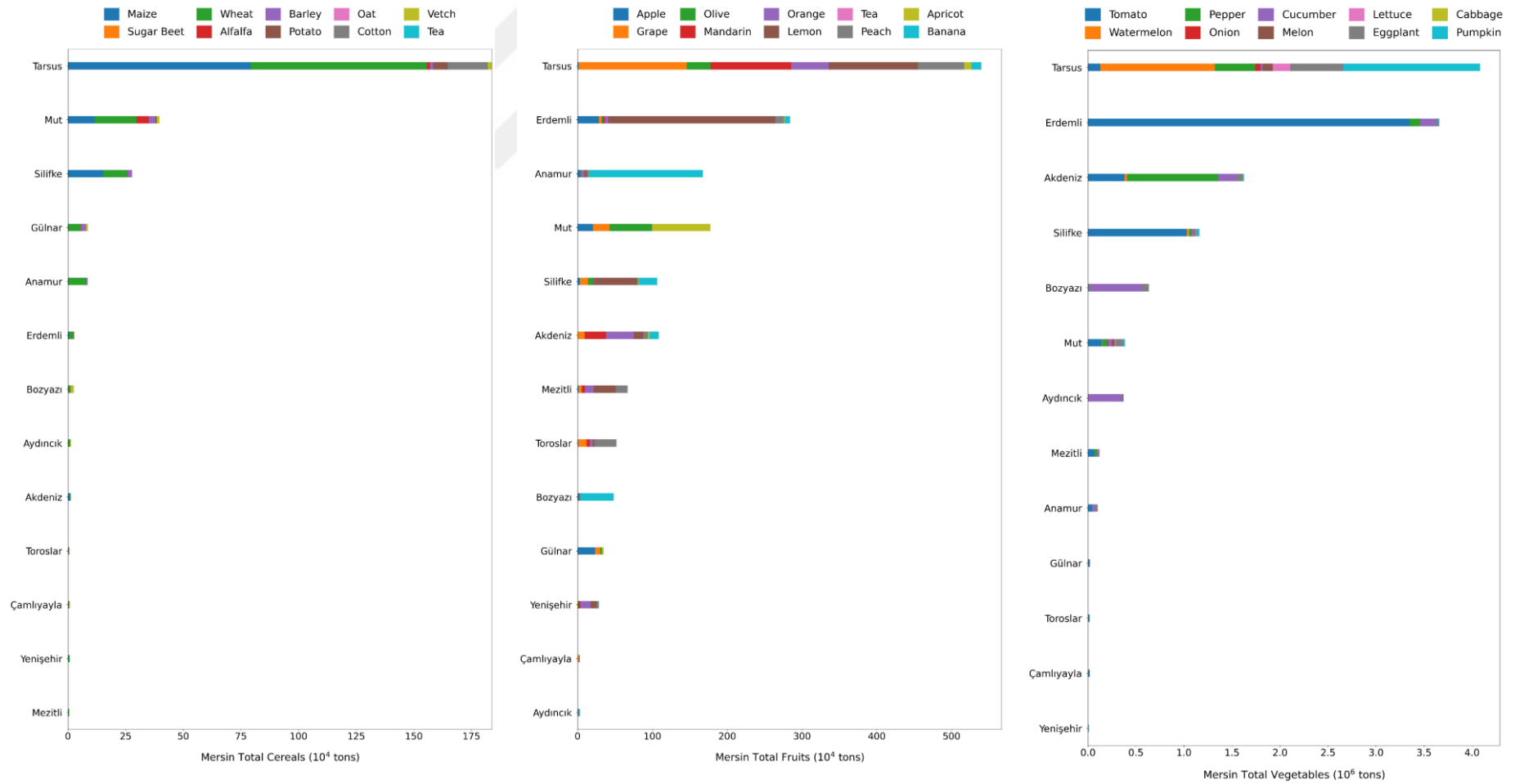
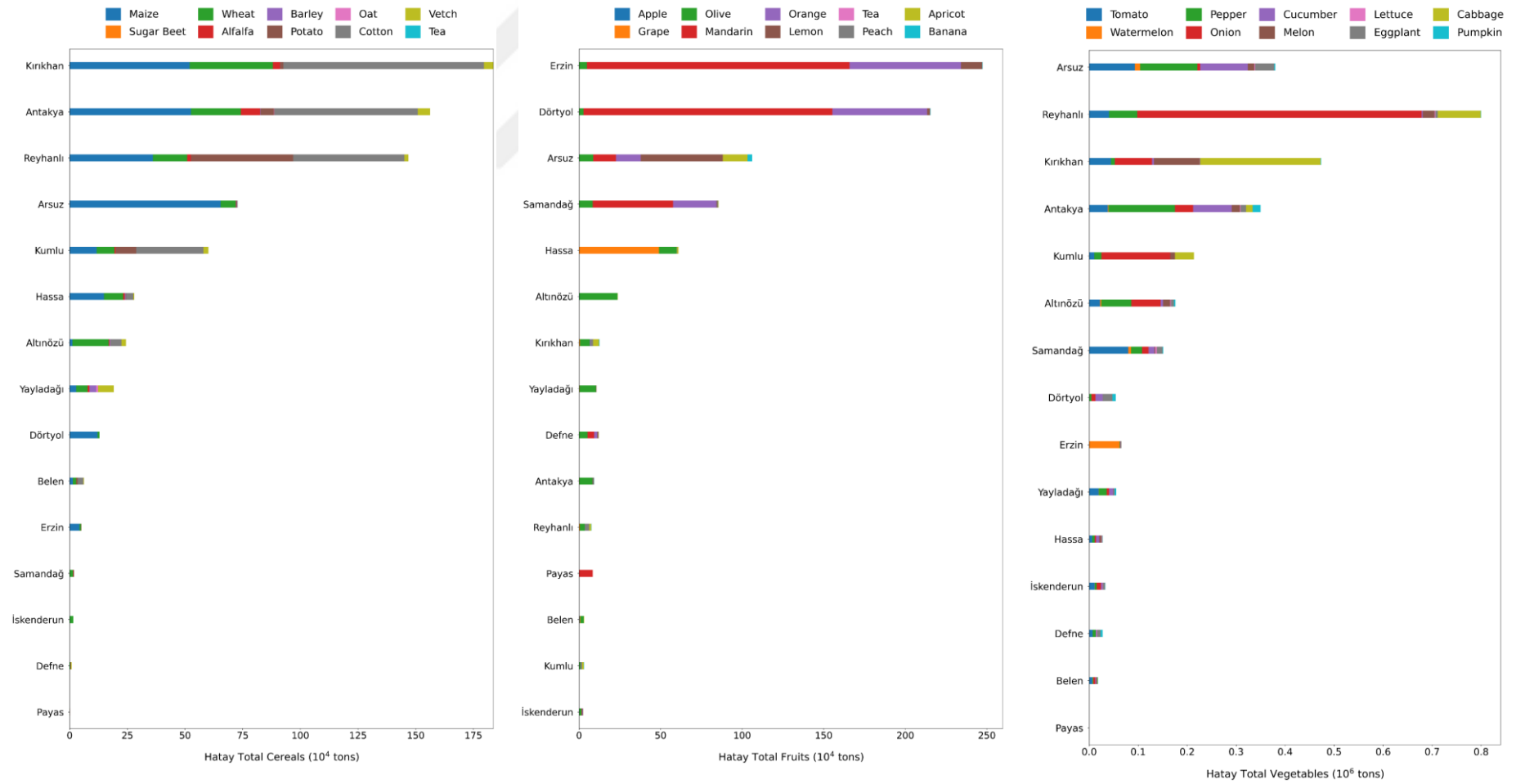


Figure A.3 : Crop for Mersin cereals (left), fruits (middle) and vegetables (right).



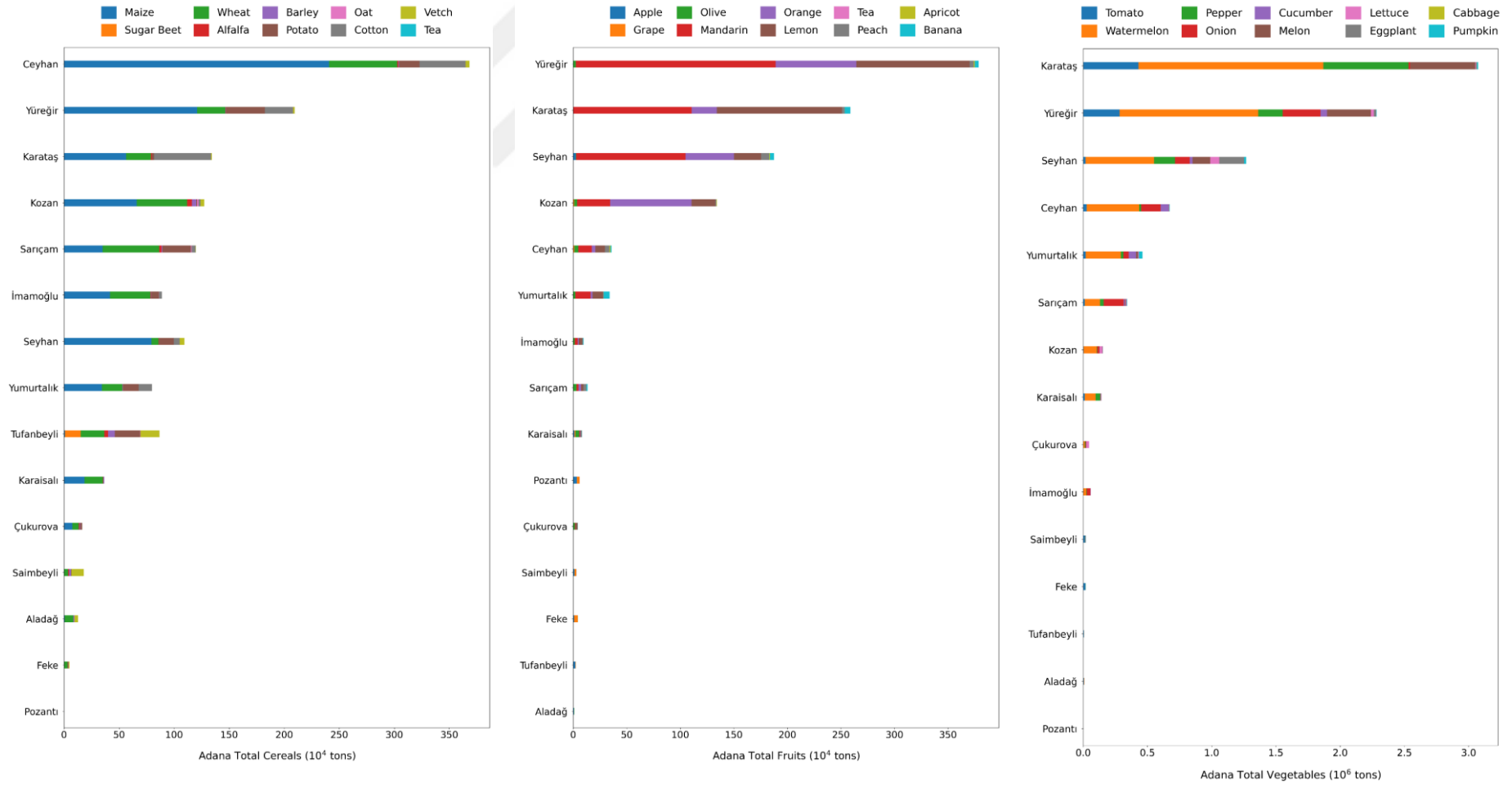


Figure A.5 : Crop for Osmaniye cereals (left), fruits (middle) and vegetables in unit tons (right).

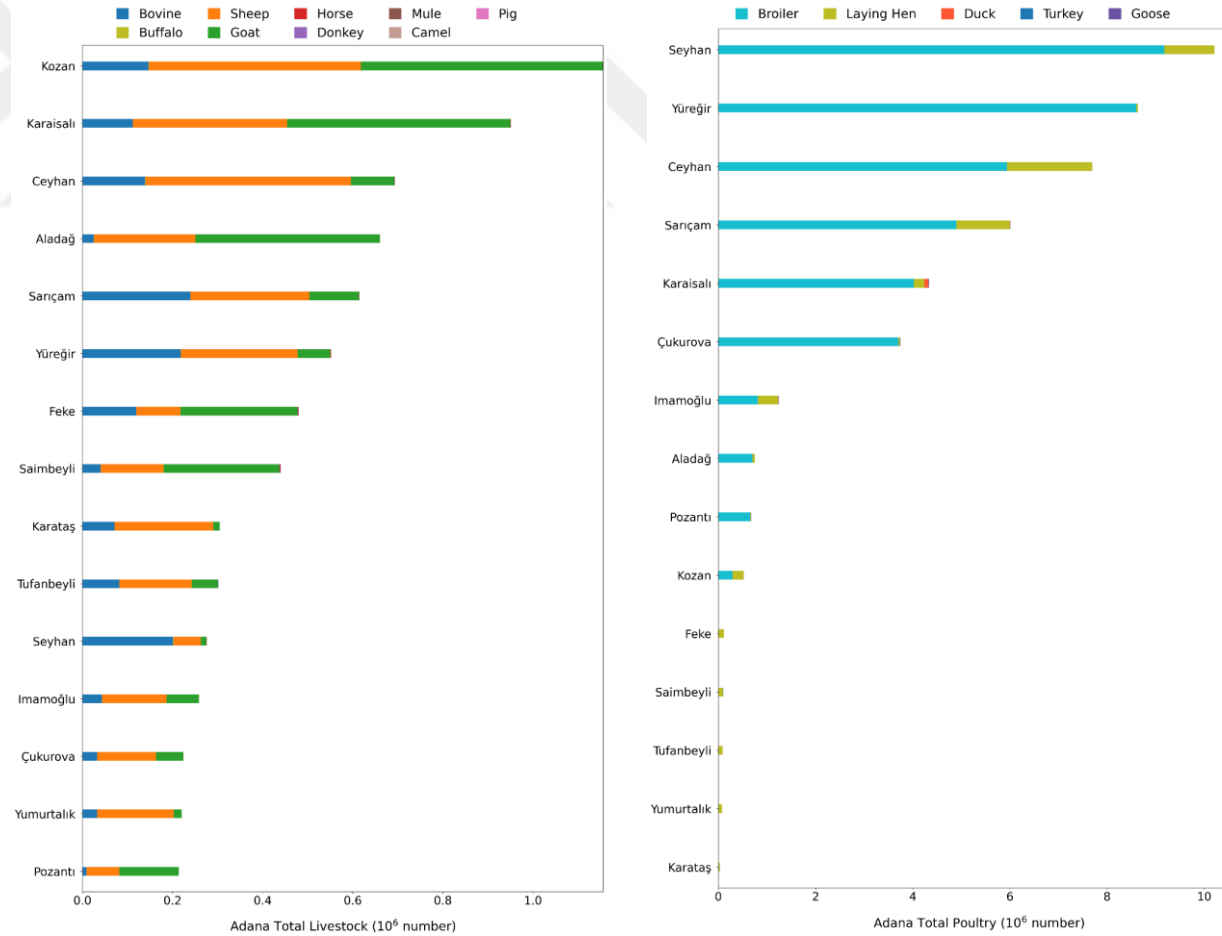


Figure A.6 : Adana livestock (left) and poultry count (right).

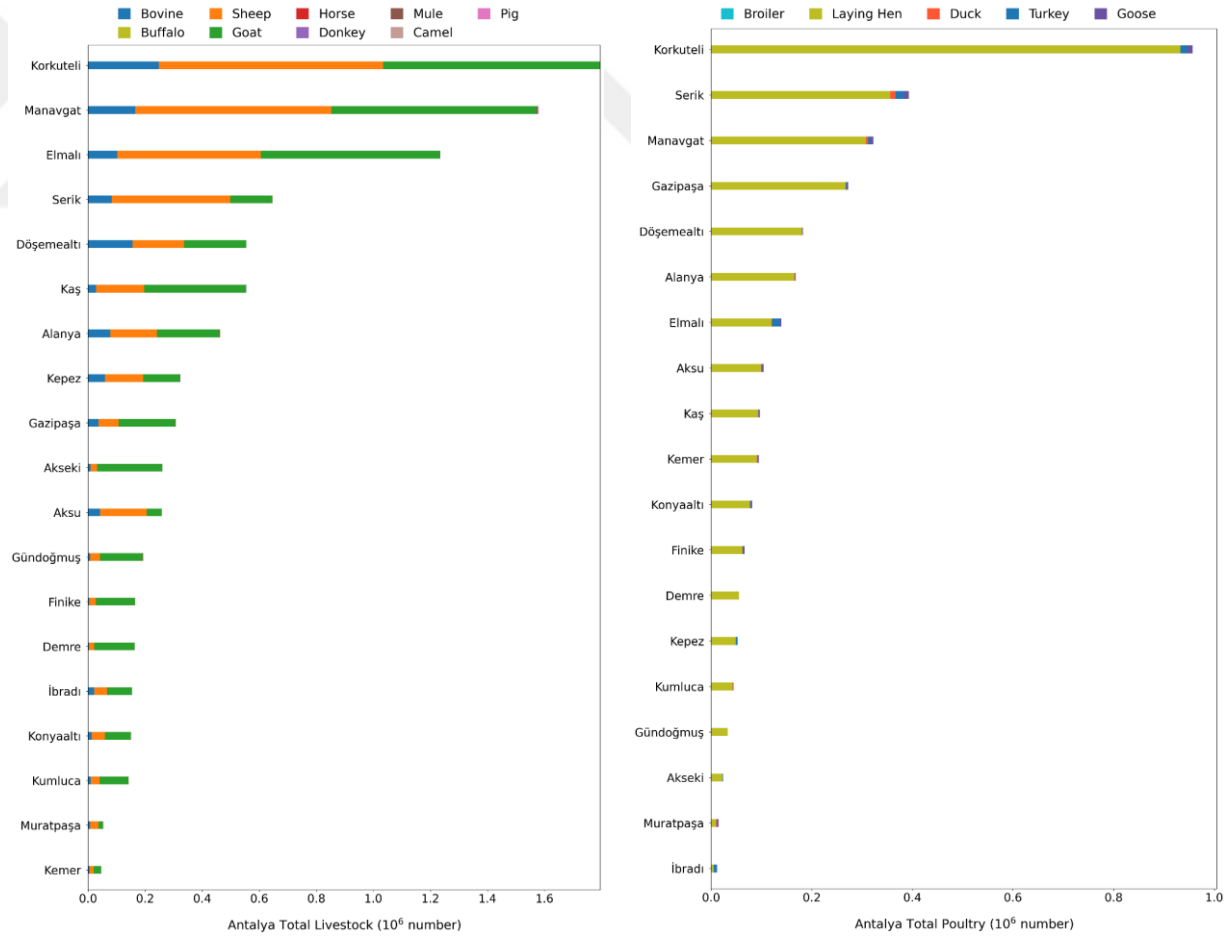


Figure A.7 : Antalya livestock (left) and poultry count (right).

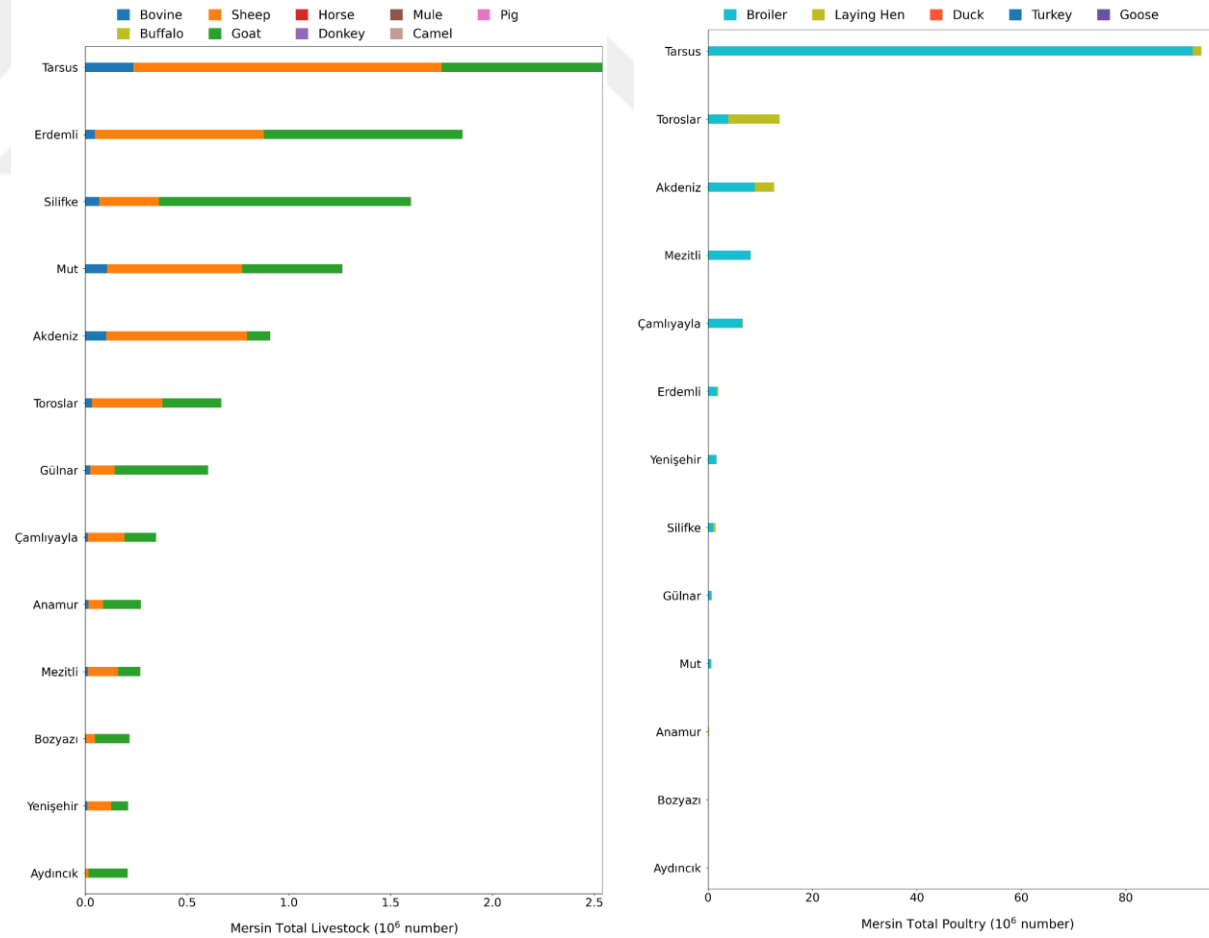
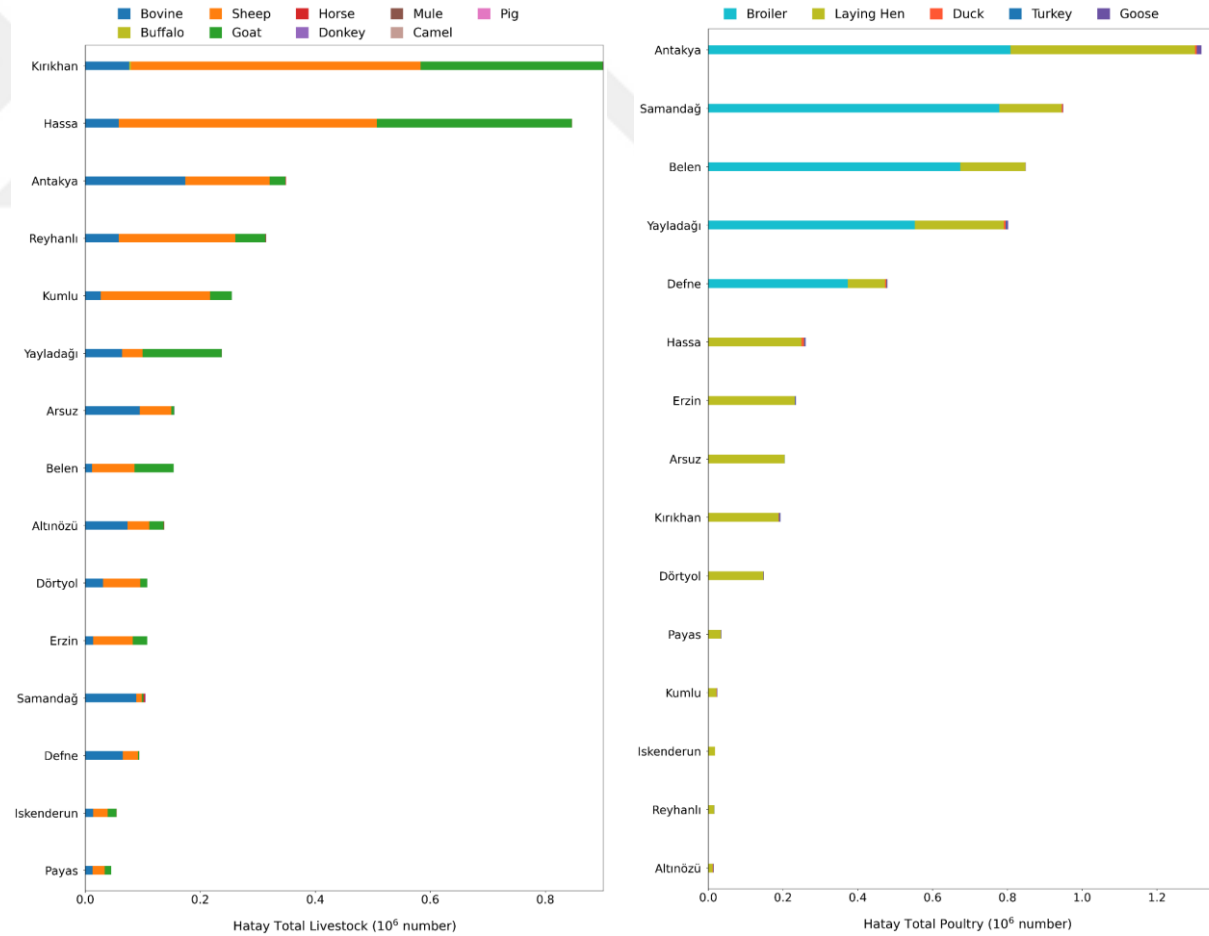


Figure A.8 : Mersin livestock (left) and poultry count (right).



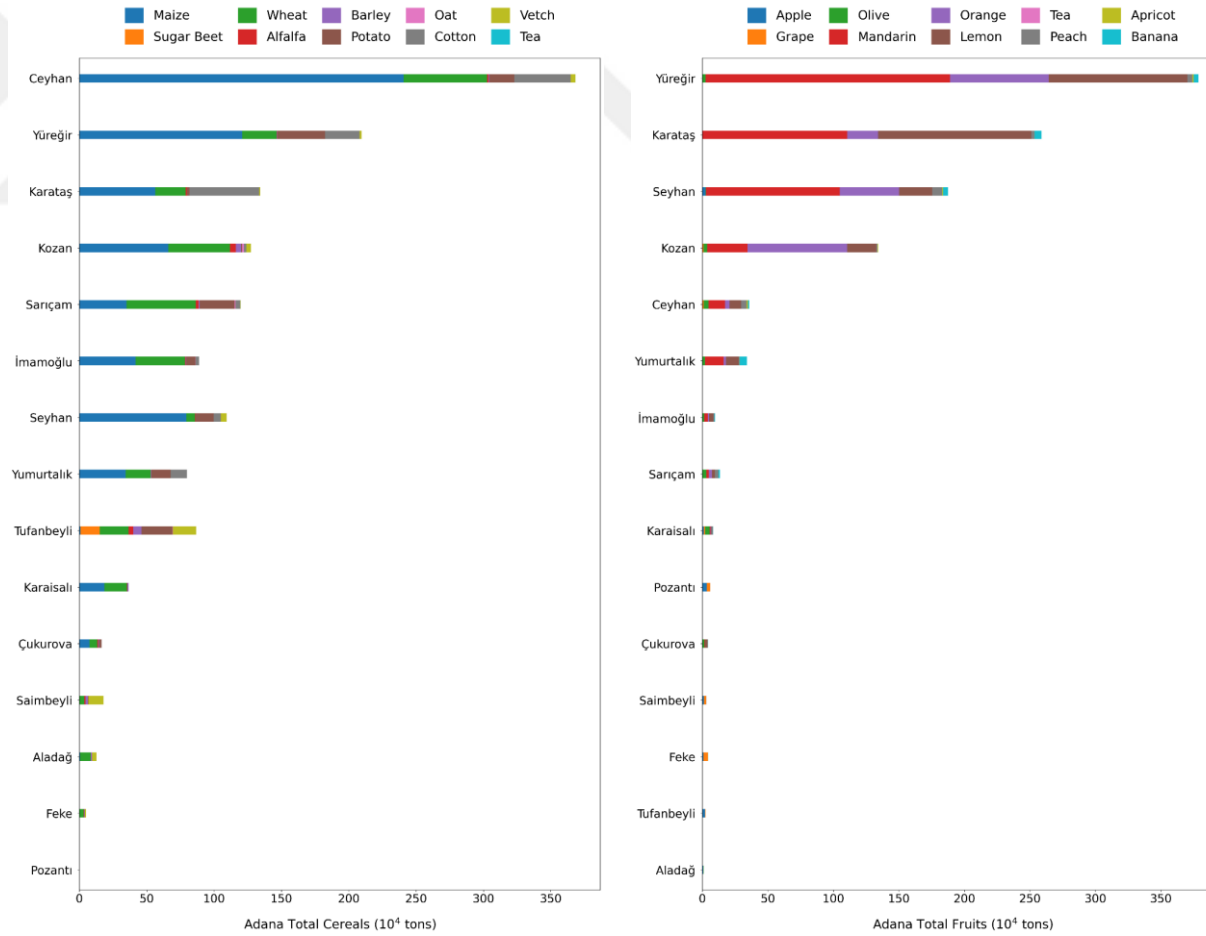


Figure A.10 : Osmaniye livestock (left) and poultry (right).

APPENDIX B: Distribution maps.



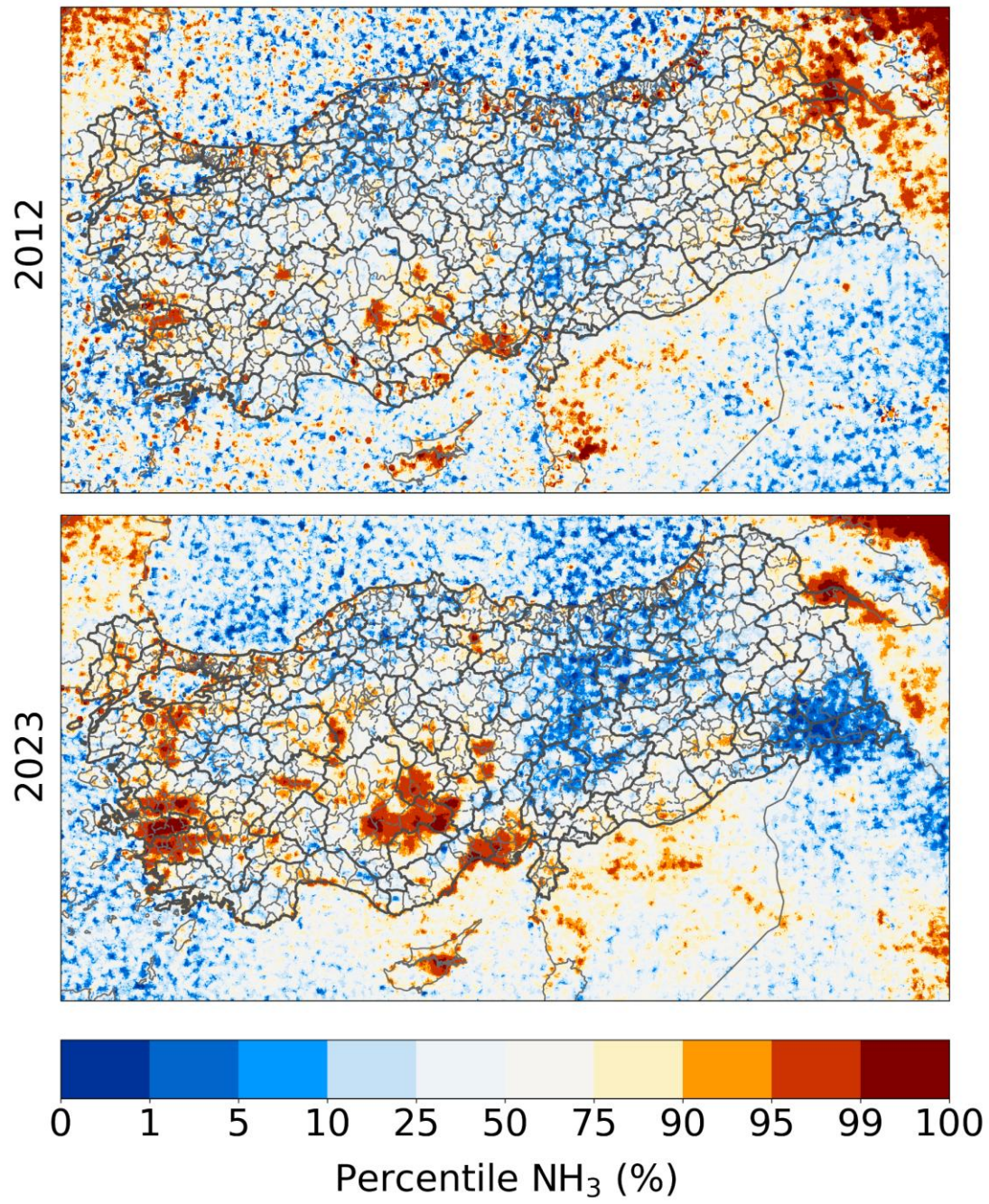


Figure B. 1 : Annual percentile NH_3 distributions over Türkiye (%) for 2012 (top) and 2023 (bottom).

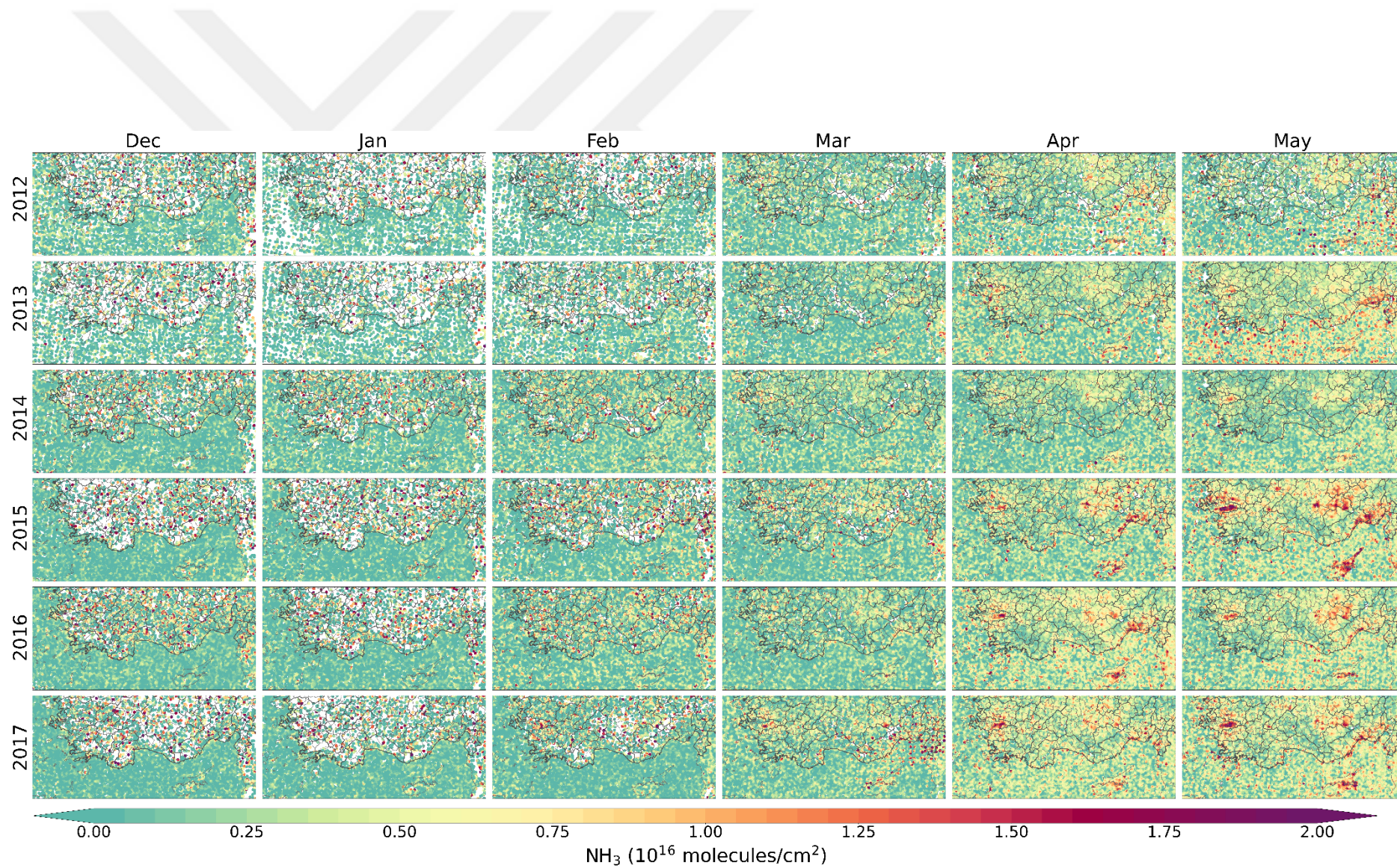


Figure B. 2 : Monthly average NH_3 distributions (molecules/cm²) for 2012-2017 over 1x1 km² domain.

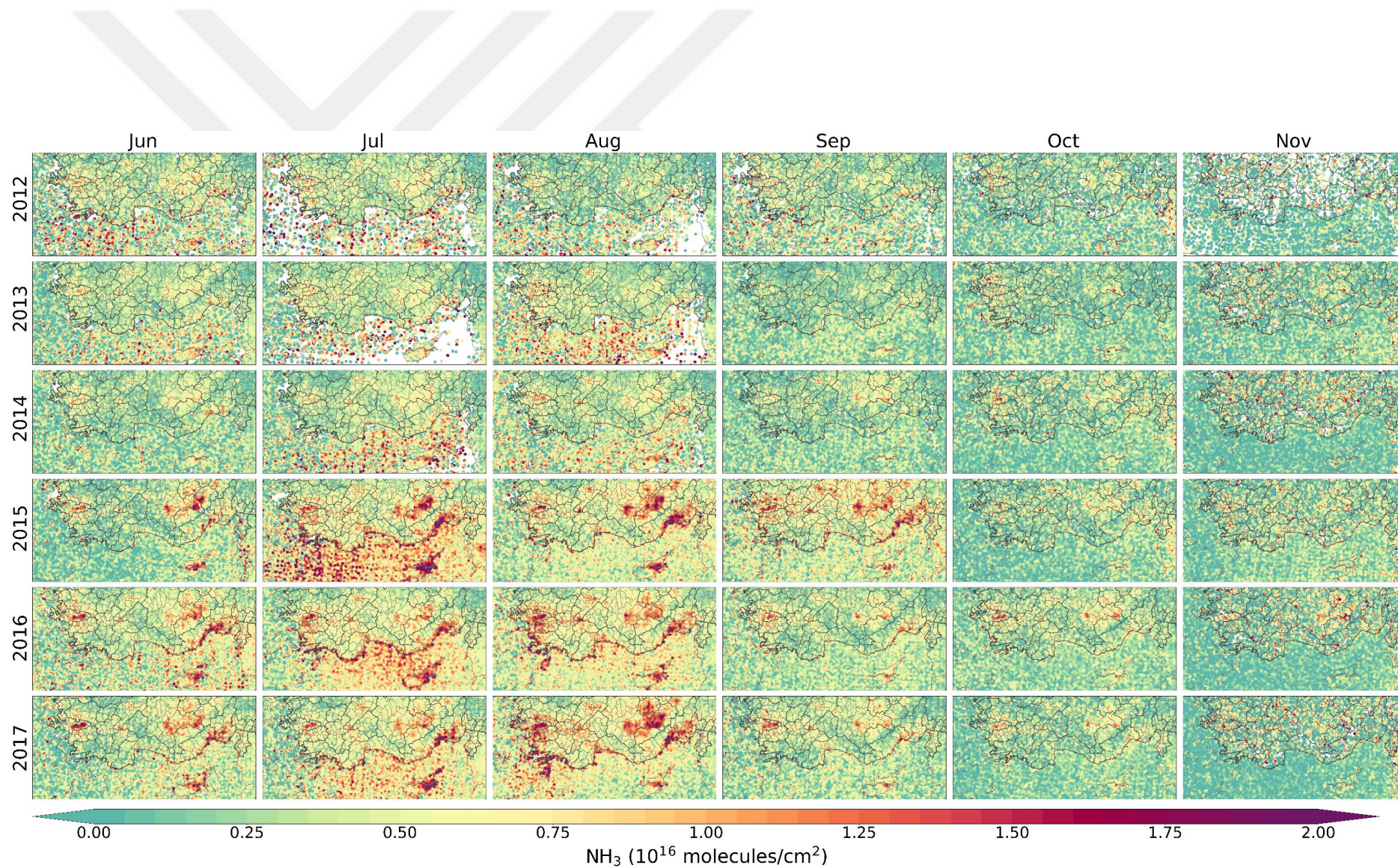


Figure B.2 (continue) : Monthly average NH_3 distributions (molecules/ cm^2) for 2012-2017 over $1 \times 1 \text{ km}^2$ domain.

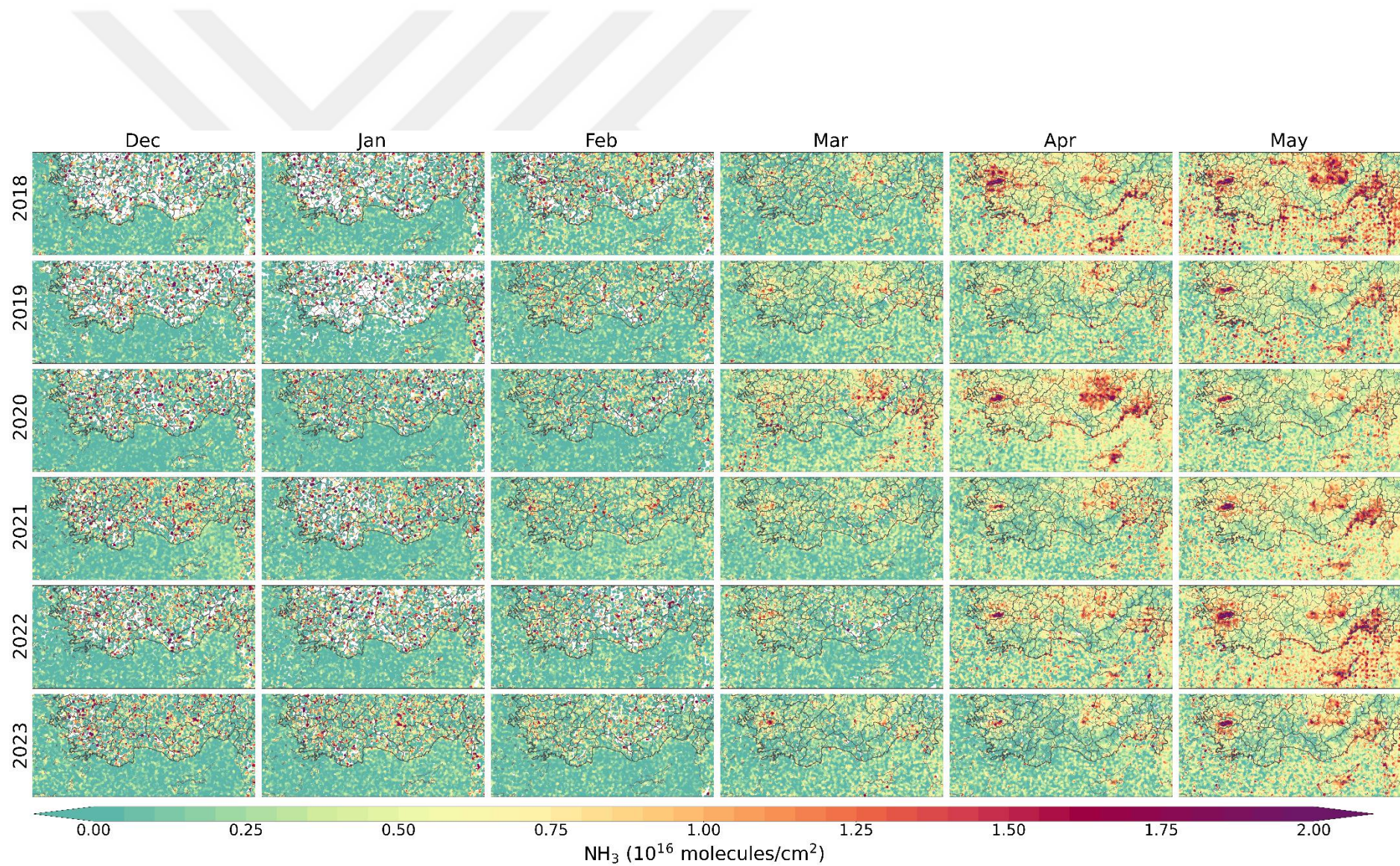


Figure B. 3 : Monthly average NH_3 distributions (molecules/ cm^2) for 2018-2023 over $1 \times 1 \text{ km}^2$ domain.

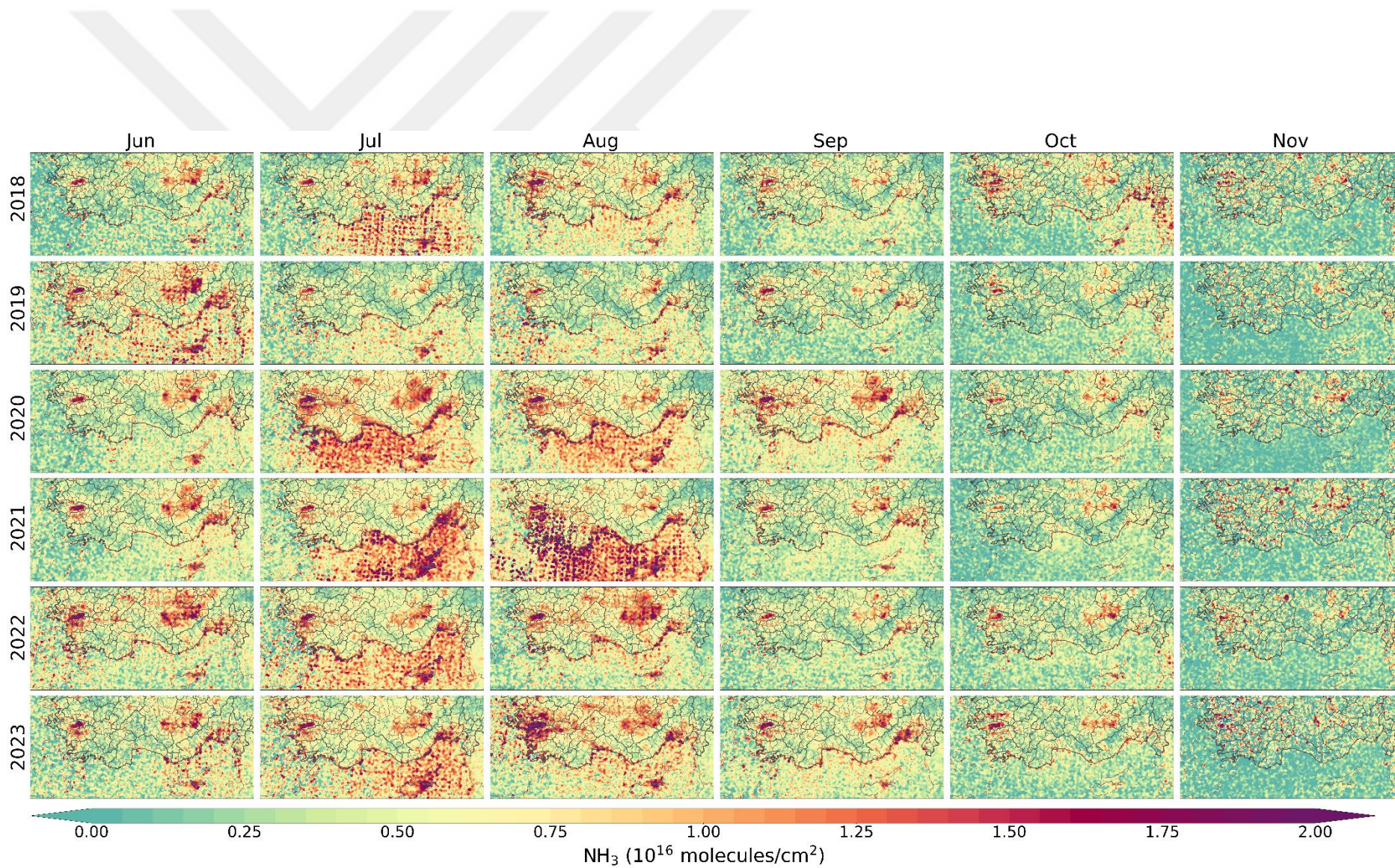


Figure B. 3 (continue) : Monthly average NH_3 distributions (molecules/cm²) for 2018-2023 over 1x1 km² domain.

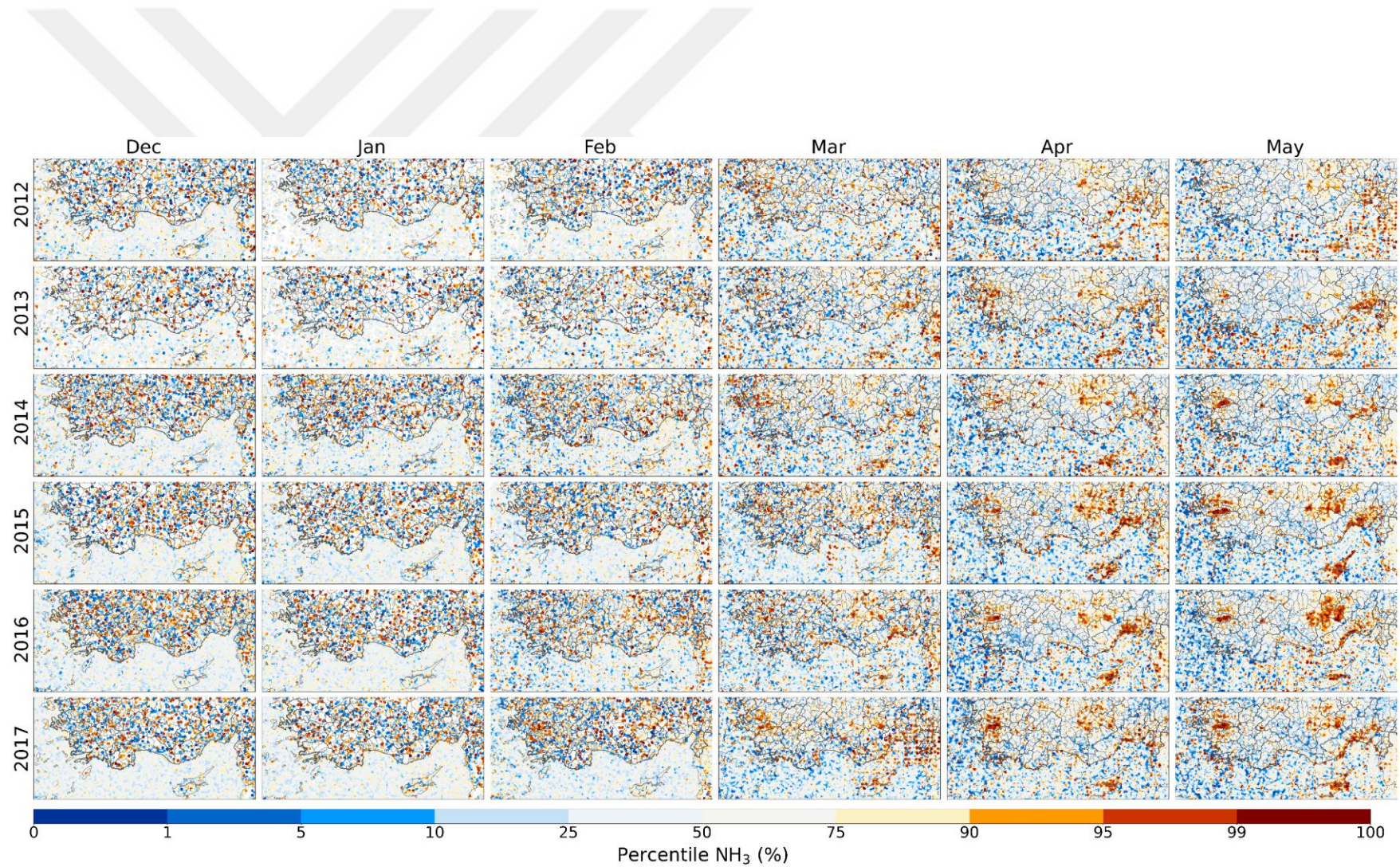


Figure B.4 : Monthly percentile NH_3 distributions (%) for 2012-2017 over 1x1 km² domain.

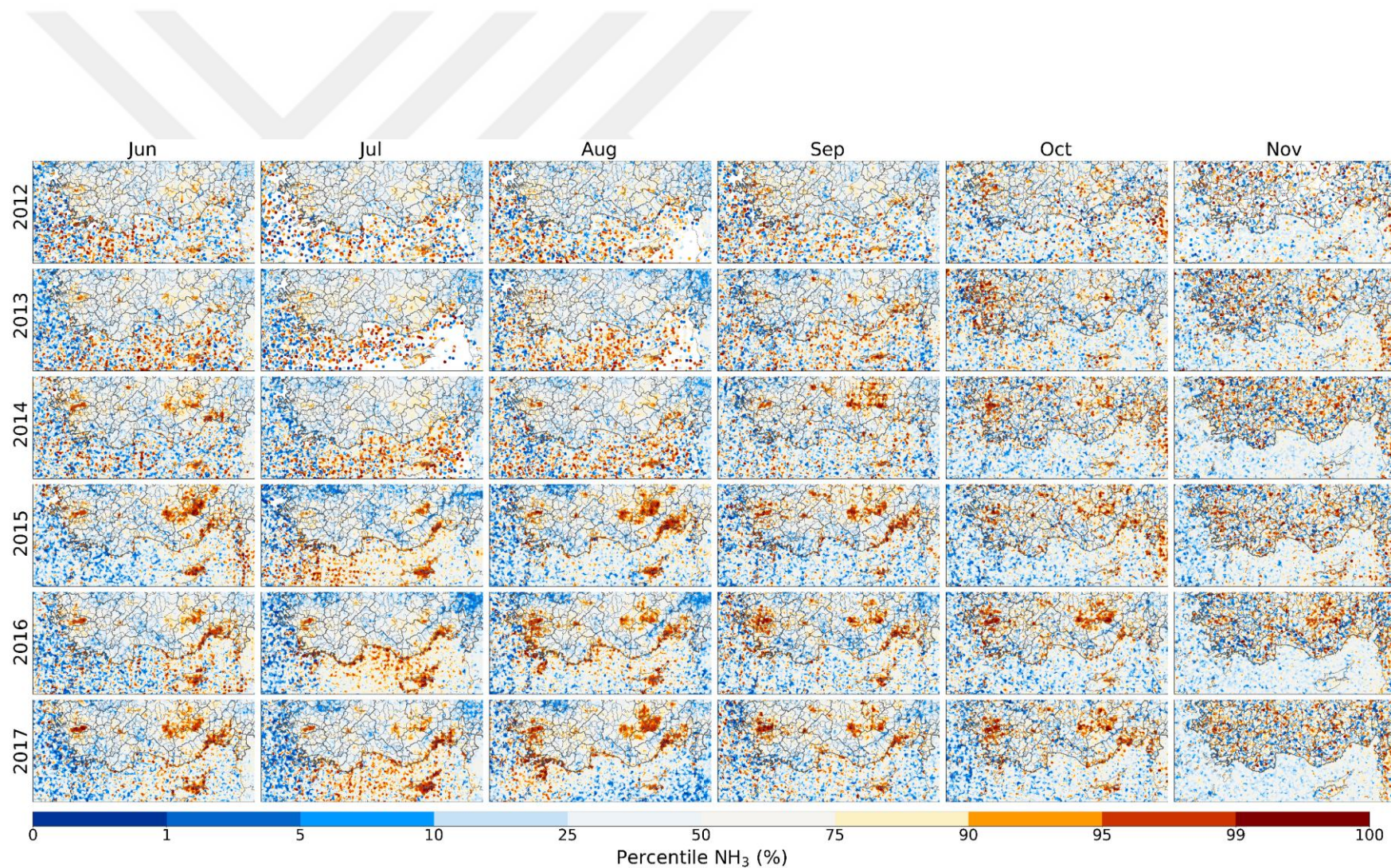


Figure B.4 (continue) : Monthly percentile NH_3 distributions (%) for 2012-2017 over 1x1 km² domain.

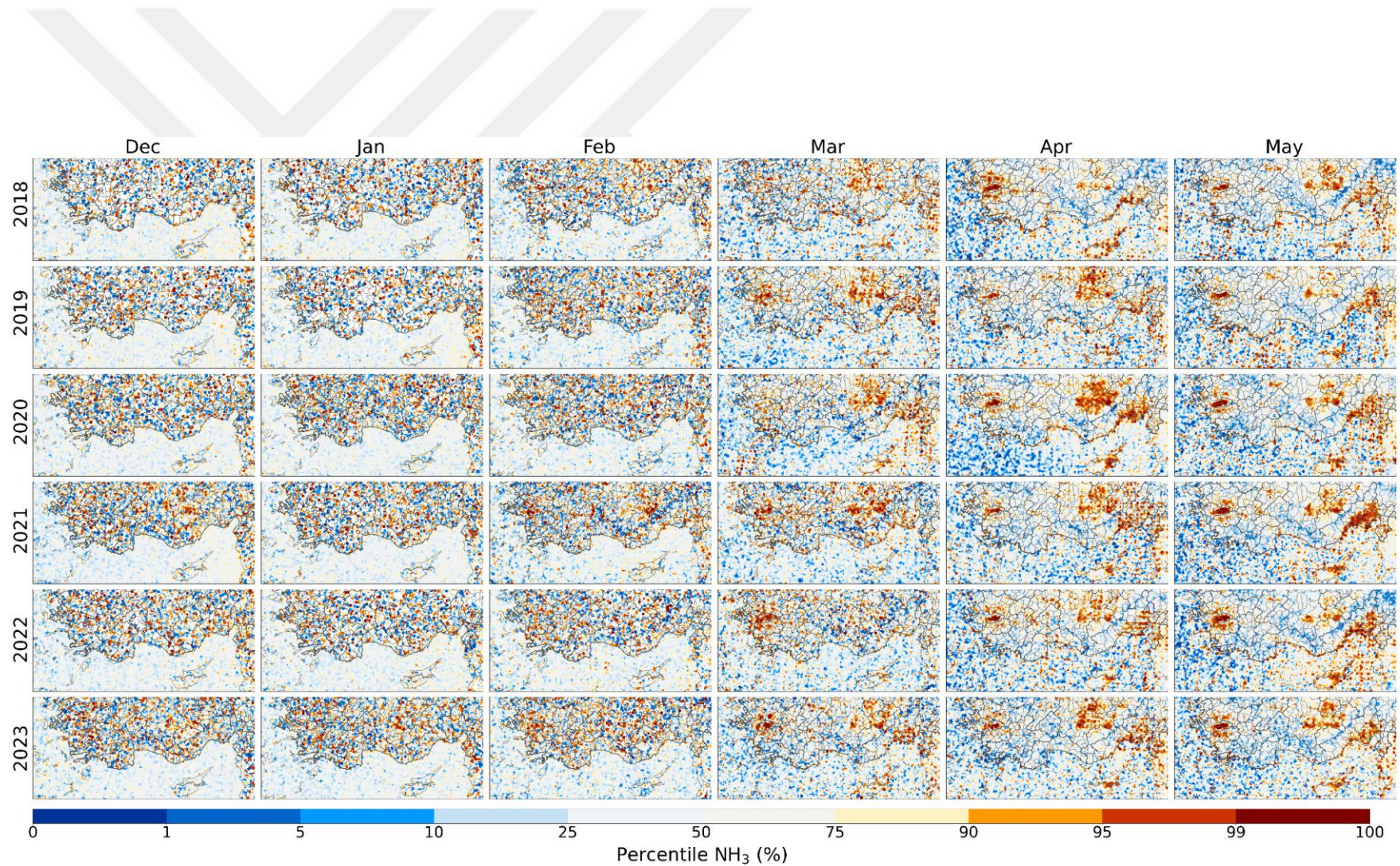


Figure B.5 : Monthly percentile NH_3 distributions (%) for 2018-2023 over 1x1 km² domain.

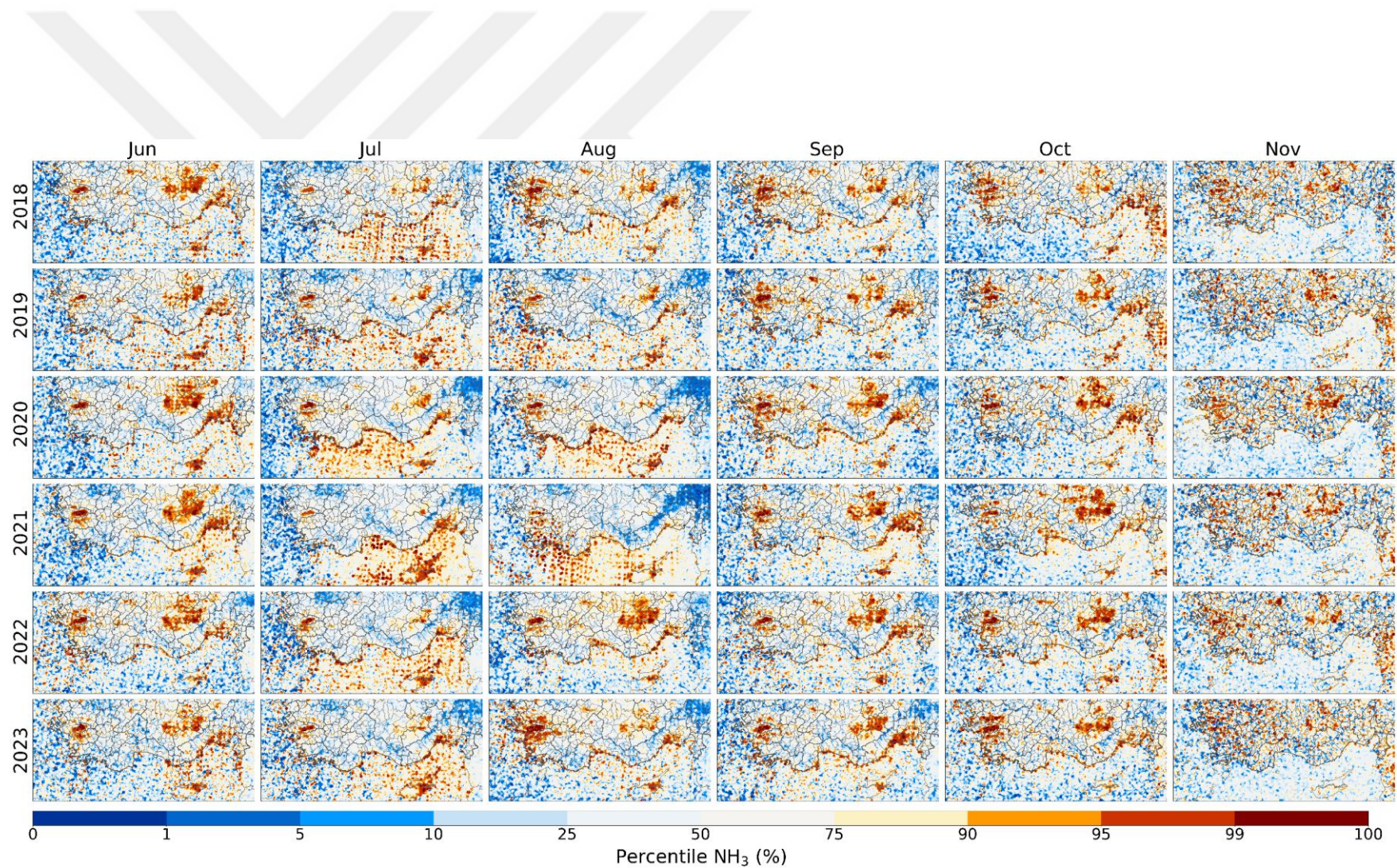


Figure B.5 (continue) : Monthly percentile NH_3 distributions (%) for 2018-2023 over 1x1 km² domain.

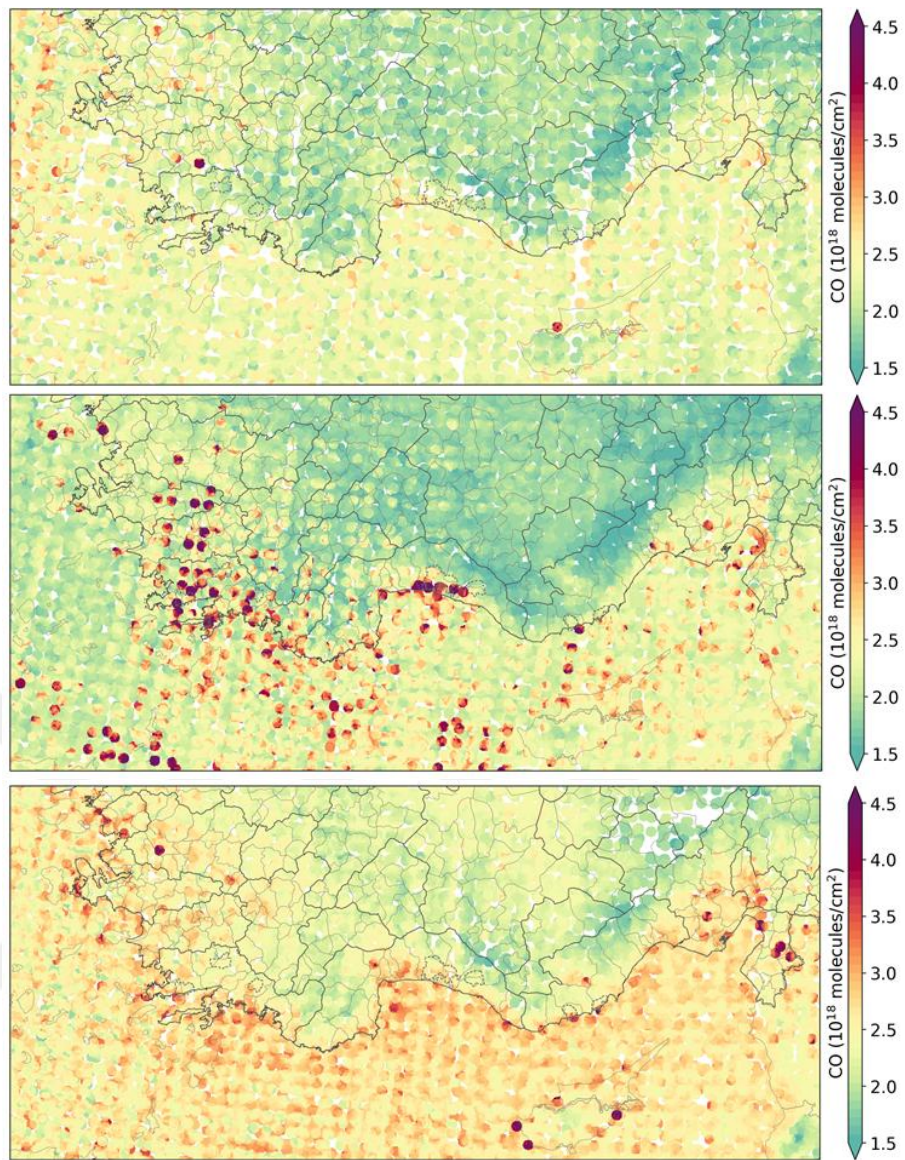


Figure B.6 : IASI-CO distribution (molecules/cm²) for pre-fire (top), fire (middle), post-fire (bottom) period.

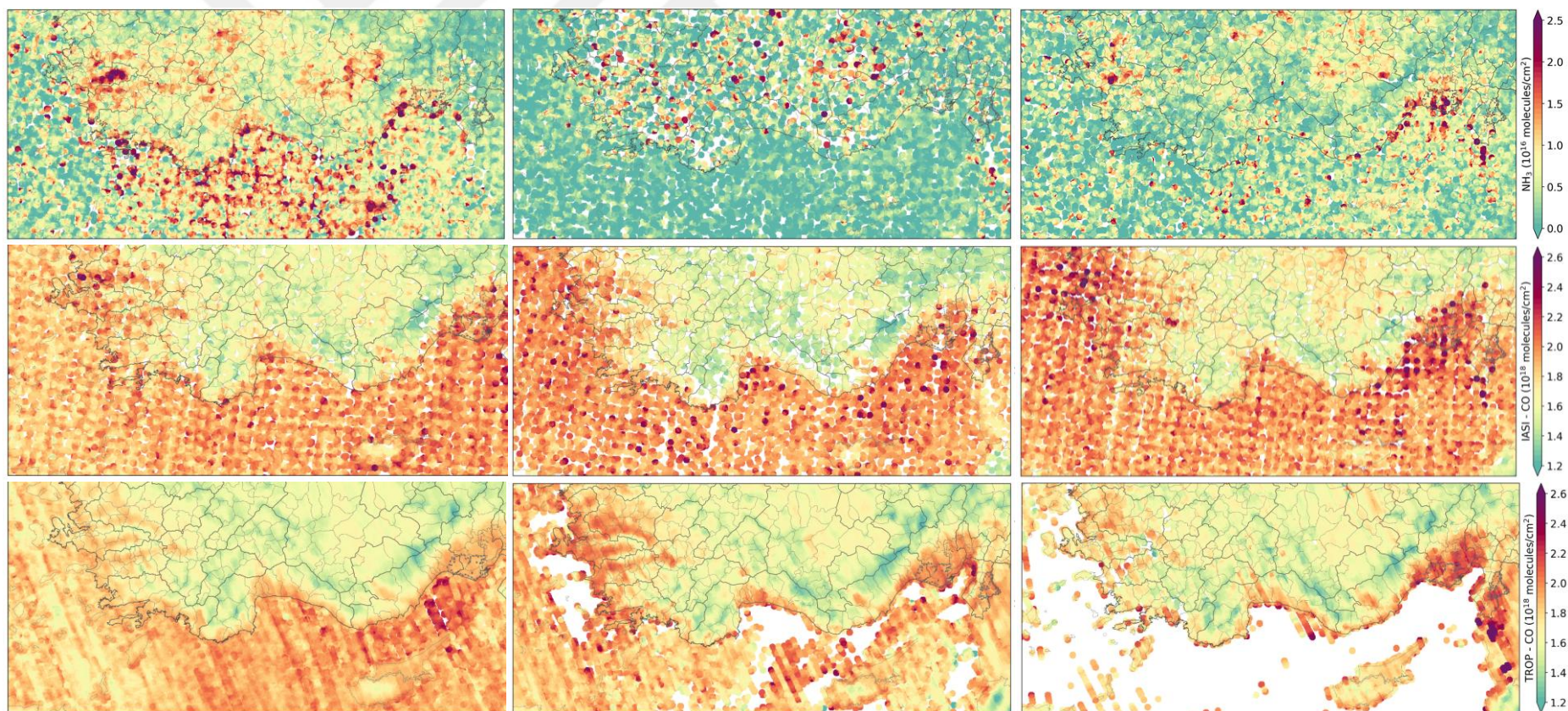


Figure B.7 : Pollution distribution maps (molecules/cm²) for RB-1 and RB-2 pre-fire period (left), post-fire period for RB-1 (middle) and post-fire period for RB-2 (right) (NH₃, IASI-CO, TROP-CO, TROP-NO₂, TROP-HCHO, respectively).

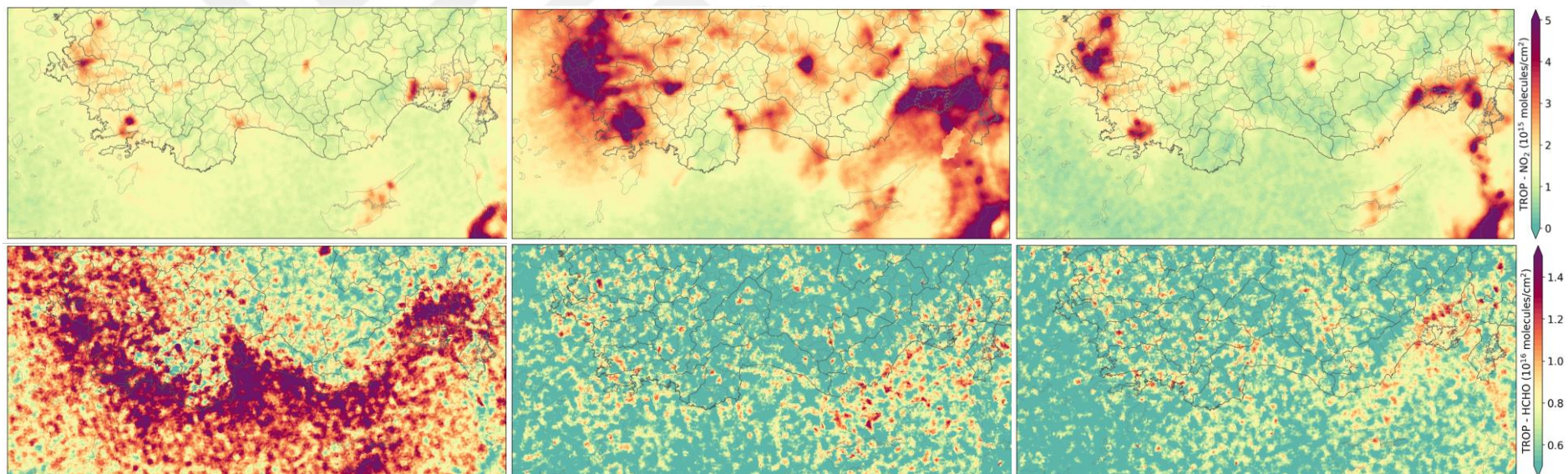


Figure B.7 (continue) : Pollution distribution maps (molecules/cm²) for RB-1 and RB-2 pre-fire period (left), post-fire period for RB-1 (middle) and post-fire period for RB-2 (right) (NH₃, IASI-CO, TROP-CO, TROP-NO₂, TROP-HCHO, respectively).

APPENDIX C: Statistics tables.



Table C.1 : Annual statistics for NH₃ concentration (x10¹⁵ molecules/cm²) according to land type for provinces and overall study area.

Province		2012		2013		2014		2015		2016		2017		2018		2019		2020		2021		2022		2023		2012-2023 Difference (%)	
		Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All
Adana	Mean	3.58	3.11	4.21	3.47	3.77	3.31	5.65	4.76	4.89	4.04	4.96	4.10	5.37	4.26	4.92	3.82	5.71	4.26	5.97	4.83	5.00	4.12	5.36	4.27		
	25th	-0.16	-0.60	0.10	-0.39	-0.41	-0.62	0.81	0.26	0.43	-0.06	0.14	-0.32	0.14	-0.47	0.02	-0.58	0.60	-0.47	0.65	0.14	0.13	-0.24	0.16	-0.42		
	50th	3.10	2.53	3.30	2.74	3.11	2.65	5.26	4.33	4.45	3.63	4.44	3.61	4.64	3.51	4.30	3.25	5.14	3.51	5.41	4.10	4.69	3.63	4.97	3.73	49.8	37.3
	75th	6.87	6.18	7.32	6.41	7.14	6.54	10.03	8.85	8.97	7.85	9.23	8.11	10.00	8.33	9.40	7.86	10.41	8.33	10.77	9.03	9.47	8.14	10.32	8.84		
	Max	48.71	48.71	65.12	65.12	52.01	62.47	44.80	47.14	56.33	56.33	74.14	74.14	63.97	63.97	68.75	68.75	85.26	63.97	101.71	101.71	80.58	80.58	56.14	56.14		
Antalya	Mean	2.50	2.49	3.29	3.23	2.80	2.73	3.70	3.12	4.02	3.09	3.47	2.97	4.09	3.38	3.51	2.74	4.70	3.38	4.73	3.97	4.24	3.57	3.50	2.98		
	25th	-0.85	-0.92	-0.07	-0.30	-0.84	-0.91	-0.78	-0.96	-0.19	-0.91	-0.69	-1.05	-0.62	-0.92	-1.06	-1.33	-0.10	-0.92	0.04	-0.43	-0.16	-0.44	-1.11	-1.22		
	50th	2.22	2.13	2.81	2.61	2.13	2.16	3.21	2.80	3.62	2.88	3.20	2.72	3.70	2.96	3.14	2.53	4.46	2.96	4.10	3.41	4.05	3.38	3.24	2.83	39.8	19.8
	75th	5.34	5.35	5.90	5.80	5.70	5.63	7.56	6.79	8.02	6.94	7.27	6.65	8.34	7.15	7.47	6.42	9.22	7.15	8.54	7.60	8.13	7.47	7.72	7.04		
	Max	44.84	48.89	59.67	59.67	68.72	68.72	87.29	87.29	47.33	50.80	70.31	70.31	78.86	120.00	43.29	85.14	41.52	120.00	475.58	475.58	46.11	77.77	53.33	68.68		
Hatay	Mean	3.06	2.79	3.85	3.55	3.06	2.99	4.74	4.49	3.84	3.64	4.13	4.12	5.13	4.64	4.29	3.87	4.89	4.64	5.40	4.86	4.59	4.25	4.40	4.02		
	25th	-0.35	-0.68	0.13	-0.16	-0.60	-0.79	0.13	-0.26	0.02	-0.54	-0.26	-0.61	0.10	-0.35	-0.63	-0.97	0.01	-0.35	0.47	-0.06	0.02	-0.32	-0.25	-0.63		
	50th	2.43	2.42	3.27	3.16	2.46	2.42	4.42	4.22	3.87	3.64	3.91	3.85	4.54	4.00	3.85	3.36	4.32	4.00	5.00	4.46	4.46	4.01	4.21	3.81	44.0	44.0
	75th	5.83	5.81	7.08	6.98	6.09	6.25	8.96	8.86	7.80	7.92	8.12	8.26	9.47	8.95	8.88	8.28	9.29	8.95	9.87	9.31	9.12	8.70	8.85	8.50		
	Max	35.81	42.10	35.22	35.22	67.44	67.44	37.74	37.74	42.92	42.92	76.01	139.56	46.75	78.87	37.14	46.26	60.84	78.87	65.37	66.23	48.13	49.37	51.73	51.73		
Mersin	Mean	3.85	3.19	4.02	3.61	3.95	3.42	5.89	4.63	5.23	4.14	5.16	4.07	5.27	4.21	4.37	3.45	5.72	4.21	5.83	4.56	5.20	4.27	4.84	3.85		
	25th	-0.18	-0.59	0.24	-0.01	-0.08	-0.39	0.49	0.12	0.46	-0.20	0.46	-0.27	0.17	-0.32	-0.21	-0.60	0.75	-0.32	0.53	0.09	0.30	0.07	0.04	-0.49		
	50th	3.36	2.78	3.60	3.18	3.40	2.88	5.06	4.05	4.63	3.77	4.40	3.64	4.58	3.58	4.04	3.19	5.29	3.58	5.05	4.05	4.64	3.83	4.29	3.47	25.8	20.5
	75th	7.19	6.51	7.22	6.66	7.20	6.63	10.31	8.50	9.34	8.09	9.15	7.95	9.74	8.28	8.85	7.17	10.18	8.28	10.36	8.61	9.71	8.24	9.11	7.79		
	Max	39.38	41.25	45.71	50.44	52.40	59.18	61.82	62.89	94.78	97.32	48.30	58.91	122.17	122.17	79.79	79.79	73.40	122.17	102.88	102.88	61.51	74.74	55.46	55.46		

Table C.1 (continue) : Annual statistics for NH₃ concentration (x10¹⁵ molecules/cm²) according to land type for provinces and overall study area.

Province		2012		2013		2014		2015		2016		2017		2018		2019		2020		2021		2022		2023		2012-2023 Difference (%)	
		Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All
Mugla	Mean	2.34	2.56	3.08	2.94	2.25	2.33	3.24	3.22	3.37	3.19	3.39	3.03	4.27	3.70	3.15	2.97	4.34	3.70	5.15	4.40	4.17	3.74	3.56	3.29		
	25th	-1.14	-1.24	-0.43	-0.69	-1.07	-1.28	-0.66	-1.04	-0.47	-0.86	-0.80	-1.20	-0.12	-0.84	-1.25	-1.34	-0.47	-0.84	-0.15	-0.52	0.01	-0.38	-0.69	-1.08		
	50th	2.26	2.12	2.80	2.52	1.96	1.94	2.90	2.81	3.23	2.89	2.95	2.69	3.57	3.01	2.75	2.47	3.91	3.01	3.79	3.22	3.91	3.46	3.43	2.96	52.2	28.6
	75th	5.55	5.72	5.71	5.72	5.12	5.33	7.01	7.01	7.46	6.98	7.24	6.82	7.81	7.45	7.01	6.77	8.77	7.45	7.92	7.49	8.22	7.56	7.62	7.35		
	Max	33.93	47.23	38.96	56.66	31.47	56.02	38.72	73.76	44.84	62.94	70.66	70.66	48.90	57.43	48.00	65.07	50.02	57.43	550.73	552.58	36.44	81.48	42.99	61.77		
Osmaniye	Mean	2.99	2.90	3.45	3.11	2.74	2.58	4.80	4.10	4.12	3.27	4.15	3.50	4.46	3.65	3.81	3.34	4.70	3.65	4.21	3.78	4.40	3.74	3.78	3.16		
	25th	-0.64	-0.78	-0.22	-0.51	-1.15	-1.50	0.46	-0.23	-0.10	-0.87	0.08	-0.63	-0.29	-0.97	-0.79	-1.16	-0.21	-0.97	-0.73	-0.92	0.13	-0.58	-0.85	-1.16		
	50th	2.79	2.48	2.62	2.27	2.18	2.00	4.49	3.87	3.48	2.97	3.77	3.12	3.89	3.15	3.27	2.86	4.16	3.15	3.70	3.43	4.07	3.42	3.57	3.07	26.4	9.1
	75th	5.82	5.63	6.41	6.15	6.05	5.92	8.83	8.28	8.06	7.14	8.06	7.64	8.25	7.67	7.85	7.41	8.79	7.67	8.69	8.09	8.33	7.74	8.03	7.43		
	Max	36.98	36.98	59.09	59.09	35.02	44.38	39.72	45.56	37.72	51.48	35.33	41.78	40.47	40.47	43.74	43.74	50.14	40.47	49.92	49.92	39.51	43.87	38.87	38.87		
Overall	Mean	3.16	2.82	3.74	3.32	3.26	2.94	4.88	3.96	4.43	3.59	4.37	3.57	4.87	3.90	4.17	3.27	5.18	3.90	5.41	4.41	4.71	3.93	4.47	3.59		
	25th	-0.51	-0.82	0.01	-0.32	-0.63	-0.81	0.10	-0.41	0.13	-0.56	-0.14	-0.69	-0.13	-0.66	-0.56	-0.98	0.24	-0.66	0.28	-0.21	0.06	-0.27	-0.32	-0.82		
	50th	2.72	2.38	3.10	2.75	2.67	2.37	4.32	3.46	4.06	3.29	3.90	3.19	4.21	3.31	3.72	2.88	4.71	3.31	4.67	3.74	4.34	3.59	4.08	3.27	41.6	27.2
	75th	6.24	5.83	6.74	6.20	6.40	6.04	9.15	7.87	8.46	7.47	8.42	7.47	9.16	7.86	8.48	7.12	9.69	7.86	9.66	8.25	9.04	7.88	8.96	7.75		
	Max	48.71	48.89	65.12	65.12	68.72	68.72	87.29	87.29	94.78	97.32	76.01	139.56	122.17	122.17	79.79	85.14	85.26	122.17	550.73	552.58	80.58	81.48	56.14	68.68		

Table C.2 : Seasonal statistics of NH₃ concentrations (x10¹⁵ molecules/cm²) according to land type for provinces and overall study area.

Province		Winter		Spring		Summer		Fall	
		Agri	All	Agri	All	Agri	All	Agri	All
Adana	Mean	2.79	2.30	5.45	4.44	6.99	5.56	4.60	3.69
	25th	-2.87	-3.46	0.40	-0.15	2.18	1.34	-0.02	-0.66
	50th	2.20	1.69	4.76	3.76	6.02	4.48	4.04	3.15
	75th	7.74	7.32	9.73	8.40	11.07	8.91	8.76	7.64
	Max	68.75	68.75	85.26	85.26	101.71	101.71	65.76	72.09
Antalya	Mean	1.85	1.59	3.30	2.71	5.78	4.94	3.37	2.80
	25th	-3.46	-3.83	-0.66	-1.06	1.57	1.13	-0.95	-1.29
	50th	1.28	1.00	2.82	2.35	4.90	4.21	3.03	2.54
	75th	6.52	6.25	6.79	6.09	9.15	8.07	7.27	6.52
	Max	47.33	48.28	87.29	87.29	475.58	475.58	42.08	51.04
Hatay	Mean	2.83	2.47	5.20	4.76	4.95	4.86	4.16	3.79
	25th	-3.00	-3.38	0.55	-0.03	0.93	0.78	-0.33	-0.83
	50th	2.44	2.02	4.56	4.25	4.40	4.33	3.73	3.48
	75th	8.05	7.69	9.42	9.09	8.35	8.35	8.25	8.03
	Max	48.13	48.13	76.01	139.56	65.37	66.23	48.39	52.57
Mersin	Mean	2.35	1.94	4.67	3.70	7.68	6.07	4.30	3.42
	25th	-3.29	-3.46	0.10	-0.38	2.72	1.91	-0.16	-0.67
	50th	1.66	1.32	4.07	3.23	6.53	5.19	3.81	3.07
	75th	7.20	6.47	8.69	7.35	11.62	9.41	8.30	7.12
	Max	46.93	46.93	66.64	97.32	122.17	122.17	61.82	61.82
Mugla	Mean	1.63	1.42	2.90	2.72	5.94	5.49	3.04	2.89
	25th	-4.03	-4.04	-1.05	-1.35	1.65	1.20	-1.27	-1.52
	50th	1.16	0.89	2.42	2.19	4.76	4.36	2.64	2.41
	75th	6.37	6.15	6.24	6.11	8.63	8.33	7.02	6.77
	Max	43.31	45.40	40.43	77.44	550.73	552.58	48.00	59.89
Osmaniye	Mean	2.22	2.07	4.92	4.23	5.08	4.23	3.70	3.12
	25th	-3.18	-3.44	0.25	-0.39	0.96	0.45	-0.56	-1.11
	50th	1.75	1.47	4.27	3.65	4.44	3.66	3.16	2.75
	75th	6.98	6.96	8.99	8.27	8.42	7.50	7.44	7.03
	Max	35.63	51.48	59.09	59.09	49.92	49.92	50.14	50.14
Overall	Mean	2.37	1.88	4.51	3.50	6.38	5.39	4.01	3.23
	25th	-3.21	-3.66	-0.10	-0.70	1.85	1.32	-0.48	-1.01
	50th	1.79	1.31	3.84	2.95	5.36	4.50	3.54	2.84
	75th	7.31	6.66	8.50	7.16	9.93	8.60	8.07	7.06
	Max	68.75	68.75	87.29	139.56	550.73	552.58	65.76	72.09

Table C.3 : Monthly statistics for NH₃ concentration (x10¹⁵ molecules/cm²) according to land type for provinces and overall study area.

Province		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov	
		Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All
Adana	Mean	2.71	2.20	2.42	2.10	3.13	2.53	3.83	3.09	5.25	4.25	6.93	5.68	6.77	5.58	7.28	5.79	6.90	5.32	5.83	4.64	4.45	3.50	3.44	2.86
	25th	-3.19	-3.74	-3.61	-3.93	-2.28	-2.87	-0.95	-1.49	0.56	-0.09	1.58	0.96	1.99	1.28	2.37	1.51	2.19	1.23	1.42	0.64	-0.14	-0.78	-1.69	-2.29
	50th	2.24	1.63	1.74	1.43	2.48	1.91	3.01	2.41	4.72	3.74	6.38	4.91	5.83	4.57	6.22	4.54	6.01	4.35	5.13	3.83	3.85	2.97	3.00	2.42
	75th	7.98	7.53	7.36	7.17	7.70	7.27	7.44	6.69	9.56	8.19	11.48	9.71	10.98	9.12	11.36	9.03	10.79	8.60	9.76	8.15	8.47	7.37	7.92	7.40
	Max	43.10	47.43	51.86	51.86	68.75	68.75	85.26	85.26	49.31	50.79	80.58	80.58	56.33	56.33	63.97	63.97	101.71	101.71	46.92	72.09	65.76	65.76	44.65	45.05
Antalya	Mean	2.03	1.61	1.49	1.47	1.98	1.66	2.23	1.82	3.39	2.78	4.07	3.32	4.39	3.78	6.61	5.54	6.21	5.36	4.11	3.46	3.18	2.66	2.69	2.14
	25th	-3.49	-4.13	-4.02	-3.85	-3.03	-3.57	-1.91	-2.28	-0.49	-0.95	0.21	-0.15	0.53	0.25	2.41	1.86	1.75	1.32	0.34	-0.04	-0.95	-1.33	-2.47	-2.93
	50th	1.44	1.05	0.81	0.77	1.44	1.12	1.80	1.37	2.90	2.39	3.56	2.92	3.80	3.21	5.66	4.81	5.27	4.53	3.84	3.09	2.83	2.41	2.13	1.67
	75th	7.04	6.52	6.14	6.09	6.48	6.15	5.70	5.28	7.04	6.21	7.34	6.55	7.41	6.63	10.01	8.74	9.94	8.62	7.74	6.72	6.98	6.32	7.05	6.51
	Max	47.33	48.28	36.18	41.08	41.52	43.01	87.29	87.29	40.88	47.97	52.32	69.79	70.31	72.23	475.58	475.58	179.52	201.54	36.34	51.04	35.05	44.16	42.08	44.49
Hatay	Mean	2.27	2.07	2.54	2.23	3.42	2.90	4.32	3.86	5.35	4.76	5.66	5.33	5.09	5.03	5.44	5.26	4.36	4.31	4.40	4.20	3.90	3.54	4.23	3.68
	25th	-3.53	-3.77	-4.03	-4.17	-2.08	-2.75	-0.47	-1.24	0.77	0.20	0.87	0.61	0.74	0.68	1.62	1.34	0.60	0.48	0.55	0.31	-0.56	-0.99	-1.27	-2.18
	50th	2.08	1.76	1.85	1.47	3.10	2.51	3.44	2.93	4.85	4.39	5.24	4.92	4.44	4.36	4.99	4.89	3.84	3.70	3.95	3.87	3.58	3.36	3.61	2.95
	75th	7.43	7.42	8.66	8.01	8.28	7.82	8.21	7.85	9.58	9.17	9.98	9.72	9.03	8.89	8.72	8.68	7.30	7.31	7.78	7.77	8.06	7.84	9.30	8.84
	Max	48.13	48.13	35.89	35.89	38.48	38.48	76.01	139.56	67.44	67.44	51.73	78.87	49.47	49.47	55.53	55.53	65.37	66.23	48.39	52.57	46.75	46.75	42.92	42.92
Mersin	Mean	2.32	1.94	2.03	1.67	2.63	2.15	3.22	2.61	4.67	3.67	5.83	4.51	6.80	5.57	8.56	6.82	7.63	5.81	5.72	4.43	4.07	3.22	2.74	2.33
	25th	-3.75	-3.73	-4.01	-3.87	-2.47	-2.92	-1.06	-1.52	0.22	-0.38	1.19	0.45	1.88	1.41	3.58	2.70	2.71	1.68	1.35	0.58	-0.10	-0.66	-2.01	-2.49
	50th	1.46	1.24	1.23	0.97	1.96	1.62	2.74	2.19	4.09	3.22	5.17	3.97	5.70	4.68	7.44	5.85	6.45	5.03	5.00	3.92	3.68	2.87	2.11	1.85
	75th	7.78	6.86	6.90	6.19	6.99	6.35	6.99	6.10	8.68	7.34	9.95	8.19	10.49	8.94	12.47	10.11	11.52	9.20	9.67	7.85	7.96	6.75	6.95	6.47
	Max	46.93	46.93	35.48	44.10	46.18	46.18	42.30	42.30	60.00	73.92	66.64	97.32	102.88	102.88	122.17	122.17	74.04	74.04	61.82	61.82	54.84	54.84	52.14	52.14

Table C.3 (continue) : Monthly statistics for NH₃ concentration (x10¹⁵ molecules/cm²) according to land type for provinces and overall study area.

Province		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov	
		Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All	Agri	All
Mugla	Mean	1.42	1.27	1.65	1.27	1.79	1.68	1.92	1.92	3.01	2.77	3.49	3.24	4.00	3.68	6.07	5.82	7.54	6.77	3.90	3.62	2.81	2.58	2.17	2.32
	25th	-4.66	-4.43	-3.73	-4.20	-3.59	-3.60	-2.14	-2.43	-0.98	-1.30	-0.29	-0.57	0.52	0.15	2.38	1.89	2.19	1.72	0.25	-0.19	-1.51	-1.84	-3.47	-3.18
	50th	0.73	0.69	1.28	0.71	1.50	1.21	1.37	1.31	2.61	2.20	2.86	2.68	3.30	3.03	5.37	4.94	5.39	4.98	3.24	2.96	2.29	2.15	1.59	1.73
	75th	6.28	6.14	6.11	6.02	6.47	6.26	5.42	5.51	6.34	6.10	6.67	6.52	6.76	6.42	9.27	8.87	9.56	9.28	7.10	6.69	6.86	6.54	7.11	7.22
	Max	31.46	41.50	43.31	45.40	33.46	38.11	40.43	77.44	30.91	50.32	38.19	65.07	45.96	61.87	46.45	106.05	550.73	552.58	42.99	59.89	44.84	44.84	48.00	51.44
Osmaniye	Mean	2.01	1.83	1.97	1.79	2.61	2.50	3.59	2.96	5.00	4.20	5.93	5.25	4.84	4.19	4.87	4.22	5.53	4.29	4.95	4.32	3.62	2.98	2.60	2.11
	25th	-4.15	-4.12	-3.39	-3.79	-2.10	-2.60	-0.92	-1.64	0.69	-0.17	1.20	0.65	0.53	0.36	1.16	0.59	1.23	0.37	0.94	0.52	-0.65	-1.16	-1.93	-2.93
	50th	1.61	1.24	1.14	1.04	2.03	1.84	2.55	2.20	4.54	3.84	5.13	4.61	4.47	3.76	4.26	3.73	4.51	3.35	4.13	3.68	3.14	2.68	2.13	1.60
	75th	7.33	7.21	6.76	6.65	6.87	6.98	7.14	6.75	9.09	8.32	10.14	9.38	8.51	7.73	8.15	7.47	8.65	7.39	8.20	7.65	7.33	6.94	6.65	6.40
	Max	35.63	37.70	32.19	35.34	30.41	51.48	42.89	42.89	43.74	44.38	59.09	59.09	41.76	41.76	34.47	45.56	49.92	49.92	39.72	39.72	50.14	50.14	37.20	37.20
Overall	Mean	2.27	1.80	2.05	1.69	2.69	2.11	3.22	2.47	4.49	3.48	5.51	4.28	5.61	4.63	6.90	5.87	6.60	5.60	5.00	4.04	3.83	3.04	3.06	2.48
	25th	-3.56	-3.96	-3.81	-3.95	-2.53	-3.18	-1.25	-1.90	0.06	-0.61	0.82	0.15	1.14	0.70	2.44	1.89	1.94	1.36	0.86	0.25	-0.55	-1.12	-2.05	-2.67
	50th	1.71	1.24	1.38	1.00	2.08	1.56	2.52	1.88	3.94	3.00	4.81	3.66	4.68	3.85	5.90	4.98	5.44	4.60	4.37	3.48	3.40	2.66	2.53	1.96
	75th	7.55	6.85	7.02	6.47	7.30	6.63	6.83	6.01	8.53	7.17	9.58	7.90	9.13	7.82	10.55	9.08	10.08	8.75	8.69	7.37	7.81	6.82	7.55	6.97
	Max	48.13	48.28	51.86	51.86	68.75	68.75	87.29	139.56	67.44	73.92	80.58	97.32	102.88	102.88	475.58	475.58	550.73	552.58	61.82	72.09	65.76	65.76	52.14	52.14

Table C.4 : Annual NH₃ percentile (%) by province, district, and overall average (2012-2023).

Province	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Average	
Adana	Aladag	43.0	23.5	35.9	52.1	36.9	44.0	38.4	32.2	28.8	29.5	32.3	32.6	35.8
	Ceyhan	70.3	74.9	70.0	88.0	87.5	85.1	86.1	90.3	90.8	87.1	82.8	89.1	83.5
	Feke	35.7	29.4	45.3	44.2	26.6	37.0	18.1	20.1	22.5	14.5	14.8	19.7	27.3
	Karaisali	48.9	40.5	58.0	79.2	77.7	68.3	63.0	58.1	77.8	69.1	67.1	63.3	64.2
	Karataş	93.6	74.9	74.6	87.9	91.1	91.5	92.9	93.8	94.4	96.0	91.4	93.8	89.7
	Kozan	41.1	41.2	55.0	73.4	63.5	65.4	57.8	55.8	54.9	50.6	49.3	63.5	55.9
	Pozanti	38.7	24.9	36.4	52.6	43.0	56.3	29.6	26.3	39.5	29.7	29.4	42.5	37.4
	Saimbeyli	35.3	15.6	34.3	27.1	20.3	18.6	15.9	17.9	16.1	11.9	9.2	15.4	19.8
	Sarıcam	79.8	73.7	85.1	91.1	87.9	93.8	89.9	93.7	93.1	91.3	81.8	91.7	87.7
	Seyhan	90.9	95.1	94.8	98.0	98.7	95.3	97.4	97.2	98.0	98.0	96.7	98.2	96.5
	Tufanbeyli	18.2	9.3	17.9	46.2	13.8	14.2	20.7	14.8	14.1	8.9	7.6	13.8	16.6
	Yumurtalık	68.8	80.1	64.3	85.8	83.4	79.4	87.1	92.0	87.5	91.3	87.0	82.6	82.5
	Yüreğir	96.1	94.7	86.3	93.9	91.9	89.1	88.4	94.5	94.7	95.7	92.8	94.2	92.7
Cukurova	68.3	61.9	77.8	94.9	92.4	93.9	92.8	91.7	93.7	94.9	91.2	93.7	87.3	
İmamoglu	61.1	69.8	69.9	85.7	89.7	83.6	77.1	80.3	82.4	85.1	76.2	82.4	78.6	
Antalya	Akseki	48.5	34.5	43.6	27.2	31.4	32.5	38.8	31.7	28.6	28.8	31.8	34.0	34.3
	Aksu	49.4	61.9	57.5	79.1	82.5	72.0	81.9	82.3	86.1	76.4	76.0	78.8	73.7
	Alanya	46.0	43.2	46.1	56.6	60.7	60.0	59.3	42.4	55.5	56.9	57.4	58.9	53.6
	Demre	74.9	71.1	76.9	72.6	67.6	57.2	56.3	51.7	73.3	64.1	67.2	54.3	65.6
	Dosemealti	45.7	49.4	65.6	79.4	83.7	76.8	79.4	77.8	84.6	72.3	81.5	68.6	72.1
	Elmali	41.3	41.8	39.9	33.4	32.7	41.2	26.0	32.6	38.1	31.3	26.0	31.6	34.7
	Finike	43.6	77.3	61.2	52.4	51.4	53.4	41.2	40.3	49.8	45.7	43.0	46.5	50.5
	Gazipasa	63.4	65.6	72.7	48.2	68.7	64.0	55.2	49.0	48.0	48.9	52.2	54.3	57.5
	Gundogmus	58.4	47.8	38.8	27.5	21.2	26.1	19.8	16.0	20.0	20.0	26.7	22.5	28.7
	Kas	45.9	52.6	45.5	42.4	46.2	53.5	42.8	42.6	50.8	55.9	42.6	41.8	46.9
	Kemer	38.9	71.6	48.8	72.6	83.2	88.0	75.7	72.0	77.5	78.2	66.7	68.7	70.2
	Kepez	52.1	69.4	68.3	89.2	82.2	85.1	88.9	84.0	91.3	86.0	87.6	83.0	80.6
	Konyaalti	41.9	47.4	44.0	64.2	73.6	80.7	60.5	61.3	66.3	57.9	54.9	59.9	59.4
	Korkuteli	52.9	52.3	52.3	54.1	53.8	59.0	53.6	55.9	59.2	54.8	55.4	53.7	54.8
	Kumluca	40.5	69.1	48.1	58.7	58.4	65.9	52.1	53.2	56.7	56.6	44.3	43.8	53.9
	Manavgat	46.9	43.4	50.7	60.6	58.3	55.4	60.9	53.3	56.9	56.7	58.9	55.2	54.8
	Muratpasa	66.9	59.5	70.0	89.9	78.6	85.7	87.3	93.4	89.5	94.0	93.6	86.7	82.9
	Serik	34.3	37.7	37.5	57.8	63.5	66.3	72.5	65.5	71.4	64.5	69.0	56.5	58.0
	İbradi	44.9	31.4	52.1	31.5	42.6	34.7	28.9	27.9	26.3	29.7	31.0	44.5	35.5

Table C.4 (continue) : Annual NH3 percentile (%) by province, district, and overall average (2012-2023).

Hatay	Altinozu	75.5	80.9	49.0	78.0	72.9	75.4	72.6	76.5	62.7	77.1	55.7	74.5	70.9
	Antakya	70.4	80.9	72.3	71.1	77.0	81.3	79.0	80.2	77.0	76.8	65.8	75.5	75.6
	Arsuz	48.7	42.4	50.0	61.4	51.0	75.6	81.9	76.1	73.5	77.8	71.1	70.4	65.0
	Belen	61.2	70.4	73.4	69.9	67.1	77.1	82.8	65.7	64.9	83.8	47.1	73.7	69.8
	Defne	72.7	62.9	68.1	63.5	77.0	62.9	81.0	65.1	81.0	76.7	63.2	84.4	71.5
	Dortyol	59.8	73.9	65.8	58.8	32.8	53.9	63.8	63.0	62.1	65.1	58.4	49.0	58.9
	Erzin	63.1	80.7	71.3	78.6	59.4	70.8	83.7	80.5	75.1	85.4	78.7	81.6	75.7
	Hassa	62.0	68.5	58.2	81.9	63.4	78.3	50.8	59.4	57.2	61.2	44.2	49.4	61.2
	Kumlu	61.2	82.3	68.1	80.7	79.1	82.5	84.4	86.5	81.1	83.7	84.3	82.2	79.7
	Kirikhan	55.7	72.4	67.5	84.5	78.1	84.7	72.9	83.2	79.3	76.9	77.6	72.6	75.4
	Payas	87.9	67.1	73.4	87.2	41.1	84.1	65.2	43.5	73.4	51.2	52.0	44.9	64.3
	Reyhanli	75.4	78.8	52.8	74.1	76.6	83.3	81.6	85.3	76.6	88.4	82.0	83.6	78.2
	Samandag	49.7	48.6	73.5	69.6	64.2	82.9	63.7	82.5	77.4	67.7	59.1	76.6	67.9
	Yayladagi	61.6	66.6	62.2	51.4	52.1	57.2	62.9	70.3	56.2	61.4	53.3	62.7	59.8
	İskenderun	35.6	45.7	60.0	86.5	63.5	78.3	61.9	68.9	75.6	63.6	56.0	66.7	63.5
Mersin	Akdeniz	93.5	97.8	97.5	99.8	99.7	99.8	98.9	99.6	99.6	99.4	99.5	99.2	98.7
	Anamur	48.8	59.6	65.8	49.7	63.4	67.5	57.3	51.3	46.4	47.0	46.0	48.5	54.3
	Aydincik	43.1	73.4	68.4	84.8	67.6	82.8	65.2	76.1	59.8	72.0	69.0	62.3	68.7
	Bozyazi	61.7	69.6	46.3	61.1	70.7	69.6	59.3	59.9	55.5	57.8	53.0	45.9	59.2
	Erdemli	61.3	59.2	63.6	62.7	52.0	57.6	44.7	44.4	43.5	45.2	44.8	47.5	52.2
	Gulnar	71.7	73.3	75.8	62.7	73.5	75.6	72.1	61.1	61.5	56.0	60.3	56.5	66.7
	Mezitli	70.2	79.0	87.1	82.5	76.1	87.4	79.0	76.5	71.8	75.1	71.7	79.8	78.0
	Mut	51.5	50.1	55.7	71.1	64.1	70.0	61.0	57.8	58.9	60.5	60.7	59.8	60.1
	Silifke	75.4	67.6	74.0	69.0	70.3	73.1	59.7	55.8	58.8	59.2	60.8	59.8	65.3
	Tarsus	79.3	75.1	80.7	86.5	87.1	88.1	77.2	78.0	81.0	79.5	76.6	81.0	80.8
	Toroslar	57.1	50.9	68.4	67.2	60.6	65.9	50.5	56.2	48.5	48.3	46.3	50.0	55.8
	Yenisehir	90.0	93.7	91.3	99.3	97.3	98.6	95.6	96.9	95.4	95.5	92.5	94.2	95.0
	Camliyayla	39.7	41.5	40.0	58.5	46.4	55.6	44.5	26.0	38.9	33.1	34.7	50.1	42.4
Osmaniye	Bahce	64.7	29.9	22.1	50.7	29.0	43.0	28.7	33.3	29.5	27.3	30.3	25.5	34.5
	Duzici	55.0	38.0	21.8	61.3	34.1	53.4	40.9	43.0	30.5	43.4	34.3	33.6	40.8
	Hasanbeyli	31.6	43.7	7.2	32.5	16.5	55.2	20.2	45.1	24.9	18.2	23.6	24.5	28.6
	Kadirli	52.2	45.0	36.4	71.3	56.3	56.9	63.1	72.5	61.3	54.9	54.1	49.9	56.2
	Merkez	43.2	35.1	45.6	69.7	52.8	67.4	61.6	53.1	54.3	57.6	62.6	52.6	54.6
	Sumbas	37.4	41.1	36.0	67.2	36.4	67.0	63.8	56.3	57.2	54.3	42.3	46.5	50.5
	Toprakkale	31.9	34.4	40.2	91.2	90.5	83.3	79.6	91.7	75.0	88.3	84.5	87.8	73.2

Table C.5 : Seasonal NH₃ percentile (%) by province, district, and overall average (AVG) between 2012-2023.

Province		Winter													Spring												
		12	13	14	15	16	17	18	19	20	21	22	23	AVG	12	13	14	15	16	17	18	19	20	21	22	23	AVG
Adana	Aladag	42.6	50.1	38.2	56.2	39.7	50.3	51.0	56.4	48.4	30.6	58.6	40.4	46.9	42.4	31.0	54.6	45.0	37.7	35.4	29.6	42.5	42.1	56.4	31.8	53.0	41.8
	Ceyhan	46.9	57.5	43.9	42.1	67.6	49.6	52.5	50.2	65.0	51.7	57.8	41.9	52.2	73.4	84.3	81.8	82.8	80.8	77.0	84.8	90.6	88.4	88.5	86.1	92.6	84.3
	Feke	53.3	42.3	54.4	61.1	58.7	66.0	45.6	41.2	41.9	36.0	47.4	47.6	49.6	48.4	31.5	38.6	36.5	41.5	37.3	26.3	35.7	41.5	45.9	20.1	42.1	37.1
	Karaisali	49.7	36.9	57.2	37.9	49.9	38.7	47.2	50.8	58.2	50.7	63.8	37.1	48.2	49.9	54.7	36.6	68.0	67.3	59.9	58.3	61.9	76.2	74.2	60.1	68.1	61.3
	Karatas	60.1	49.3	50.5	54.7	37.4	54.5	57.1	56.4	52.5	41.0	58.5	48.2	51.7	86.4	73.5	71.9	81.1	85.0	80.5	84.9	89.3	91.9	88.8	89.6	92.0	84.6
	Kozan	47.1	55.6	53.3	55.5	57.6	56.8	53.8	46.1	41.2	42.5	45.5	60.6	51.3	54.5	48.6	54.0	61.8	58.3	47.2	58.2	65.3	67.3	70.1	55.0	68.7	59.1
	Pozanti	47.1	44.0	45.6	51.7	40.1	42.2	59.6	51.4	75.7	33.8	23.2	41.1	46.3	41.4	39.2	30.0	30.4	38.6	46.4	23.9	42.9	51.9	55.6	28.8	45.0	39.5
	Saimbeyli	64.3	66.4	57.6	39.0	67.6	40.1	34.3	53.5	32.6	37.2	34.6	63.5	49.2	37.1	24.2	45.7	38.2	34.7	21.6	23.9	28.6	39.4	44.4	27.0	31.4	33.0
	Saricam	57.1	49.4	55.3	49.3	62.5	48.3	62.0	45.5	45.9	42.2	48.3	45.9	51.0	81.8	70.6	80.4	76.2	73.9	77.7	75.7	84.9	89.5	89.8	71.8	91.7	80.3
	Seyhan	40.1	43.5	73.2	58.0	66.9	46.6	56.1	29.0	60.3	58.6	50.0	70.1	54.4	87.6	89.5	90.5	94.2	97.2	91.6	93.1	90.2	96.1	95.6	91.8	95.9	92.8
	Tufanbeyli	40.3	39.5	39.4	51.1	61.8	38.6	54.8	44.8	59.3	49.1	35.9	52.6	47.3	42.2	27.0	25.1	53.9	19.9	21.1	19.9	33.7	40.2	24.7	21.3	29.5	29.9
	Yumurtalik	38.4	61.1	45.4	64.6	48.6	32.7	63.8	63.8	49.1	73.0	65.7	42.1	54.0	75.9	83.2	72.3	67.2	72.4	76.7	77.2	86.2	89.1	82.6	91.1	87.0	80.1
	Yuregir	40.2	56.2	62.7	59.4	48.5	51.6	51.4	56.7	44.2	56.3	68.5	53.4	54.1	89.4	91.3	91.7	84.3	84.5	81.8	76.9	91.7	90.9	88.7	88.7	92.7	87.7
	Cukurova	60.6	51.6	43.8	39.3	63.5	53.9	28.9	39.5	38.8	58.6	75.6	50.1	50.3	63.8	67.0	76.4	76.3	83.0	80.0	88.6	73.4	88.5	93.9	89.6	86.5	80.6
	İmamoglu	41.2	46.1	42.0	49.1	73.3	56.3	48.0	33.9	31.5	56.7	49.9	29.8	46.5	72.9	73.7	71.9	67.5	81.0	64.4	70.4	87.4	74.8	84.6	77.8	87.1	76.1
Antalya	Akseki	70.1	33.7	43.9	41.2	47.6	53.6	53.8	37.8	41.6	46.8	41.8	60.4	47.7	39.4	35.7	36.7	29.7	19.8	29.7	29.2	26.5	24.6	19.5	38.5	34.2	30.3
	Aksu	50.8	54.5	39.3	34.6	53.5	57.3	45.8	50.1	61.9	49.7	44.5	64.0	50.5	38.2	49.3	52.9	60.4	69.6	42.5	75.3	55.4	67.4	66.2	63.6	45.9	57.2
	Alanya	55.0	58.1	49.2	47.2	46.8	43.3	45.8	34.3	43.7	48.7	60.4	60.6	49.4	37.9	41.5	29.6	39.6	48.2	38.0	46.0	36.6	41.5	35.7	47.1	35.8	39.8
	Demre	67.3	38.5	48.6	43.1	54.9	39.5	37.0	45.8	52.7	54.3	62.4	48.3	49.4	47.6	35.3	57.0	50.6	37.6	31.3	39.4	35.7	56.1	19.4	33.7	43.2	40.6
	Dosemealti	46.4	59.9	63.4	46.0	59.1	55.9	36.7	74.5	57.5	41.0	39.6	46.0	52.2	34.5	36.4	50.7	62.5	66.1	42.7	69.4	39.7	58.5	63.5	76.9	47.9	54.1
	Elmali	36.6	59.5	60.3	29.1	42.8	60.6	45.9	55.8	58.0	53.8	37.1	44.9	48.7	39.6	30.8	30.6	32.1	29.0	35.6	23.7	28.8	25.9	18.8	27.7	37.0	30.0
	Finike	56.9	66.1	68.4	47.6	58.5	63.2	41.5	44.5	71.1	51.1	63.1	62.4	57.9	31.0	53.6	44.8	33.8	25.5	37.1	41.3	34.0	27.3	33.9	35.8	28.6	35.6
	Gazipasa	67.4	71.1	50.7	35.3	40.5	42.8	61.0	24.9	33.9	46.6	66.8	46.4	49.0	48.0	62.2	55.9	36.3	44.3	51.7	35.1	37.1	27.3	41.7	41.0	27.9	42.4
	Gundogmus	51.6	60.2	43.0	47.2	40.3	19.9	47.5	34.7	45.8	35.9	40.3	42.9	42.5	57.4	35.8	35.2	24.6	26.0	14.4	17.3	27.4	17.6	20.9	27.1	17.4	26.8
	Kas	38.7	39.8	52.4	46.7	41.0	53.9	42.5	54.7	41.5	42.7	54.6	46.8	46.3	34.8	46.4	34.4	34.7	29.5	43.1	38.1	42.0	25.3	30.9	33.0	32.0	35.4
	Kemer	59.7	55.5	48.9	39.3	45.8	60.0	58.0	58.2	48.0	52.1	42.7	46.0	51.2	56.2	53.6	47.9	41.2	66.0	68.3	62.5	48.2	42.9	47.2	52.7	32.3	51.6
	Kepez	45.2	54.6	52.7	44.3	36.4	55.1	41.2	51.5	38.3	58.9	49.3	59.4	48.9	52.2	55.6	59.4	76.1	72.3	48.6	76.1	61.5	73.1	61.9	78.2	46.5	63.5
	Konyaalti	49.0	44.1	31.7	48.8	64.4	61.8	53.5	75.3	66.3	33.6	44.3	55.2	52.3	41.6	35.0	58.5	63.5	56.3	60.6	53.4	33.7	31.0	48.1	48.6	37.3	47.3
	Korkuteli	58.6	48.9	46.9	47.6	56.7	52.0	61.6	66.2	61.1	40.9	54.3	56.6	54.3	45.6	38.0	44.3	46.3	42.3	43.0	43.2	41.0	38.8	45.4	48.8	38.6	42.9
	Kumluca	43.0	65.8	48.0	51.4	37.8	56.4	67.5	51.2	36.4	44.6	40.6	55.2	49.8	42.5	51.8	39.3	36.8	42.7	50.8	40.1	44.1	39.0	39.6	41.9	28.4	41.4
	Manavgat	47.2	47.2	53.0	54.4	49.8	39.0	41.4	56.9	43.3	40.3	41.6	48.2	46.9	42.0	38.1	39.3	43.2	50.6	42.5	50.9	38.9	46.3	39.9	50.9	35.8	43.2
	Muratpasa	69.0	63.8	61.5	39.2	39.9	71.3	58.2	46.0	47.2	63.6	51.6	80.3	57.6	35.4	42.2	65.0	77.0	43.9	41.2	70.2	82.9	73.4	85.4	88.2	76.7	65.1
	Serik	42.9	46.3	43.9	41.1	55.7	48.0	54.7	47.6	50.1	47.0	44.1	33.2	46.2	27.2	24.8	40.5	42.5	52.2	44.3	59.3	43.0	52.5	47.6	53.9	39.8	44.0
	İbradi	62.4	48.3	57.8	39.0	47.5	43.6	48.2	30.8	41.0	38.2	21.3	64.1	45.2	29.4	35.5	57.2	19.2	39.0	24.3	21.4	25.0	21.1	24.2	17.5	28.0	28.5

Table C.5 (continue) : Seasonal NH₃ percentile (%) by province, district, and overall average (AVG) between 2012-2023.

Hatay	Altinozu	56.1	47.5	64.8	86.3	77.5	38.7	35.8	62.6	33.6	79.6	29.6	53.8	55.5	73.7	82.2	61.7	72.9	70.1	78.9	70.7	77.8	67.9	77.5	70.2	82.4	73.8
	Antakya	44.4	55.6	67.3	77.9	74.7	55.9	46.6	46.2	47.4	72.2	61.5	67.0	59.7	80.8	83.9	74.7	57.4	68.6	75.4	77.8	72.6	83.2	80.9	72.7	72.7	75.1
	Arsuz	45.5	33.3	44.1	52.8	40.0	52.7	48.7	41.7	41.5	47.0	36.6	46.2	44.2	79.0	63.6	69.0	50.0	50.6	67.9	78.9	48.0	68.2	60.2	79.5	63.3	64.8
	Belen	42.3	81.0	57.6	36.0	29.2	46.3	55.2	60.0	25.3	64.9	44.6	56.1	49.9	75.7	71.7	75.9	66.8	67.6	85.2	69.4	36.8	79.4	77.1	75.7	68.7	70.8
	Defne	35.8	69.1	50.7	66.0	65.2	73.0	50.4	33.7	68.4	79.8	71.3	70.4	61.2	92.4	62.3	76.7	62.1	78.0	84.6	80.1	51.0	89.1	77.1	78.6	87.8	76.6
	Dortyol	75.8	45.9	76.5	31.0	49.0	54.0	51.5	18.8	52.4	88.9	40.4	46.2	52.5	39.5	63.8	45.2	65.3	31.1	62.2	69.5	71.6	71.3	60.5	82.3	70.9	61.1
	Erzin	49.8	16.6	63.2	65.9	28.2	64.7	63.8	31.0	57.1	78.3	65.6	37.8	51.8	63.8	89.9	79.5	71.7	56.8	75.0	77.0	85.9	79.2	79.3	80.8	92.7	77.6
	Hassa	36.5	51.5	37.5	83.2	47.4	71.8	35.3	41.9	60.3	67.9	40.1	37.0	50.9	68.5	72.0	60.7	67.9	69.6	56.1	64.7	71.3	66.7	66.4	64.3	65.4	66.1
	Kumlu	55.2	71.9	52.3	76.2	68.4	71.1	67.5	70.3	64.1	51.1	67.5	64.2	65.0	76.3	78.1	75.9	71.5	75.5	79.0	81.5	90.0	80.3	78.2	86.4	86.7	80.0
	Kirikhan	32.9	53.6	47.2	45.4	54.0	63.0	48.5	61.4	62.0	64.1	56.3	42.4	52.6	75.8	79.0	79.5	69.8	76.4	77.7	80.4	82.6	79.2	75.9	83.5	79.1	78.2
	Payas	87.3	17.7	66.7	53.5	23.1	27.2	8.4	19.2	41.5	55.9	56.5	54.5	42.6	72.1	54.5	56.4	77.2	63.4	53.2	71.2	59.1	75.1	59.5	69.8	39.6	62.6
	Reyhanli	72.6	57.9	35.9	70.7	55.0	71.1	57.1	58.4	61.2	74.5	76.6	59.5	62.5	74.0	81.6	70.2	71.5	74.7	83.3	89.4	86.9	76.7	91.2	82.7	84.6	80.6
	Samandag	70.9	47.3	68.6	47.0	37.3	45.3	32.6	71.2	46.9	79.5	55.2	63.2	55.4	77.9	60.4	75.6	68.6	68.4	84.5	68.8	57.2	87.1	64.7	74.4	81.6	72.4
	Yayladagi	43.3	39.0	55.1	47.1	45.4	46.9	50.7	43.9	34.2	43.2	51.8	43.7	45.4	64.6	60.0	75.1	40.6	64.9	51.2	63.7	62.2	77.4	63.8	70.6	77.6	64.3
	İskenderun	31.8	44.1	34.3	57.4	32.0	47.6	33.4	56.2	58.5	76.9	55.0	55.1	48.5	73.0	56.0	49.0	83.3	56.7	70.8	68.1	64.7	81.7	60.5	56.8	64.6	65.5
Mersin	Akdeniz	56.9	53.7	50.7	47.7	50.3	59.2	60.9	47.8	87.0	63.1	69.6	53.6	58.4	78.8	92.7	94.4	98.4	98.4	98.6	96.5	96.0	98.2	97.8	98.0	95.1	95.2
	Anamur	43.6	47.6	53.5	37.8	57.9	64.4	46.1	46.0	41.2	61.1	57.0	47.4	50.3	49.1	44.5	54.2	42.8	43.8	38.5	53.2	48.3	32.5	29.3	39.0	35.3	42.5
	Aydincik	27.4	24.3	53.9	59.4	28.9	58.5	34.6	42.7	48.7	58.8	47.4	47.5	44.3	56.6	50.4	47.0	66.3	50.5	49.4	55.8	53.2	43.2	45.5	62.3	66.5	53.9
	Bozyazi	56.6	24.7	18.9	54.6	47.1	47.4	45.3	64.6	44.6	61.5	68.1	54.2	49.0	60.5	55.9	53.2	45.5	53.8	46.3	37.6	54.1	45.5	53.3	40.9	32.6	48.3
	Erdemli	45.8	47.1	49.9	58.9	48.3	48.2	36.9	60.9	52.4	56.4	53.5	57.6	51.3	53.2	54.9	48.5	52.3	49.7	50.1	36.6	40.9	44.9	42.9	43.6	46.6	47.0
	Gulnar	57.1	40.3	57.9	45.5	50.5	58.4	71.2	49.7	56.5	56.2	61.9	48.8	54.5	53.7	55.3	43.6	40.5	52.9	52.1	52.4	46.4	38.8	45.8	41.1	52.7	48.0
	Mezitli	38.1	38.0	68.3	44.8	41.7	42.3	68.2	49.6	66.4	60.6	36.8	60.7	51.3	75.8	70.0	63.0	68.9	78.2	81.7	57.4	76.0	70.8	79.2	78.8	73.2	72.8
	Mut	50.0	52.9	53.4	55.6	42.7	55.0	43.0	42.0	48.7	65.6	48.9	47.0	50.4	46.6	41.7	44.8	52.4	66.6	49.4	46.9	42.3	43.9	52.9	38.7	52.6	48.2
	Silifke	49.5	46.7	58.7	72.2	49.0	50.3	46.4	40.9	43.8	65.7	56.9	53.8	52.8	54.1	52.4	58.3	51.6	59.8	60.3	48.9	44.8	43.3	50.8	53.2	48.9	52.2
	Tarsus	56.0	56.9	55.7	53.9	48.9	60.5	40.8	41.6	55.6	47.1	49.3	55.8	51.8	74.4	67.4	73.2	82.2	80.3	72.4	70.9	72.7	78.2	79.5	73.5	76.6	75.1
	Toroslar	53.6	56.0	46.3	64.3	56.1	48.2	59.1	58.0	47.2	57.7	58.6	53.6	54.9	57.5	48.7	54.7	59.1	60.2	60.8	36.0	52.4	46.8	49.7	42.8	60.8	52.5
	Yenisehir	41.3	19.6	42.5	56.9	41.6	76.0	64.1	63.2	43.9	76.0	29.8	47.8	50.2	79.8	84.6	80.1	97.6	97.3	92.3	77.3	92.5	94.5	92.8	87.9	85.8	88.5
	Camliyayla	50.4	71.1	33.0	43.1	57.4	47.9	58.1	33.4	45.0	29.8	33.1	78.7	48.4	58.7	32.0	28.4	47.8	50.2	48.2	31.5	46.4	52.2	52.9	32.7	53.8	44.6
Osmaniye	Bahce	82.1	35.1	44.6	65.9	52.5	62.9	46.3	69.1	60.6	62.9	77.6	35.9	58.0	72.1	61.3	36.6	60.6	31.0	51.9	42.5	60.3	50.9	48.1	42.0	53.8	50.9
	Duzici	64.9	54.6	47.5	48.7	48.4	55.8	57.9	56.5	38.3	48.7	50.3	43.3	51.2	54.3	54.7	28.3	74.4	44.5	63.7	53.0	65.7	62.9	56.1	56.2	61.3	56.3
	Hasanbeyli	71.6	61.8	44.6	33.3	17.1	52.6	42.4	39.3	76.9	35.7	70.8	57.4	50.3	43.2	66.5	50.0	31.8	19.9	70.6	29.1	65.4	47.2	46.0	33.0	58.8	46.8
	Kadirli	60.2	60.7	38.7	50.6	54.0	46.5	54.3	56.3	53.9	37.9	45.2	38.6	49.7	51.0	62.9	58.2	59.6	66.7	51.4	61.5	84.6	74.7	75.6	69.7	73.5	65.8
	Merkez	52.8	43.6	39.2	48.5	47.4	48.5	57.4	48.4	79.6	61.5	58.0	35.2	51.7	42.7	65.6	50.1	57.5	62.1	66.0	62.3	62.7	71.3	62.6	74.8	73.6	62.6
	Sumbas	63.9	66.1	25.5	55.2	36.6	61.7	49.9	38.4	50.7	38.3	56.6	53.3	49.7	43.6	51.3	51.3	63.3	62.4	66.1	67.3	70.8	71.8	82.3	65.5	64.1	63.3
	Toprakkale	54.6	52.0	37.7	68.1	35.4	41.0	50.8	69.9	77.1	60.3	68.5	47.4	55.2	50.1	75.7	62.6	85.7	84.9	90.4	91.2	91.6	56.2	94.0	83.3	89.8	79.6

Table C.5 (continue) : Seasonal NH₃ percentile (%) by province, district, and overall average (AVG) between 2012-2023.

Province		Summer													Fall												
		12	13	14	15	16	17	18	19	20	21	22	23	AVG	12	13	14	15	16	17	18	19	20	21	22	23	AVG
Adana	Aladag	43.1	26.7	33.2	38.6	26.5	32.4	38.1	23.6	18.3	21.1	26.9	24.5	29.4	42.3	30.8	38.3	38.0	42.0	26.6	35.2	33.0	27.7	31.2	31.3	32.0	34.0
	Ceyhan	69.0	44.5	59.7	75.8	71.0	75.5	71.9	73.0	73.5	64.3	65.3	78.3	68.5	61.9	52.3	62.5	75.6	72.3	66.3	72.3	81.1	78.1	82.7	72.5	84.1	71.8
	Feke	23.4	22.0	36.7	30.3	9.9	20.5	13.0	15.1	7.0	7.4	11.8	14.3	17.6	33.4	46.8	48.6	30.1	31.4	25.6	18.4	26.0	31.9	18.7	24.8	18.3	29.5
	Karaisali	51.3	41.0	63.9	73.4	62.3	61.2	56.4	47.7	54.7	55.4	59.6	60.1	57.3	51.5	47.0	55.0	68.3	68.7	61.4	50.7	61.0	71.9	60.6	64.4	62.5	60.3
	Karatas	73.2	67.5	66.7	79.5	85.1	85.8	84.3	78.9	82.8	89.3	82.5	90.4	80.5	87.7	61.0	72.6	72.3	80.0	69.3	78.8	84.1	84.3	93.3	72.5	79.7	78.0
	Kozan	41.2	37.7	45.6	57.0	46.2	59.2	48.5	47.7	40.1	36.9	38.4	45.6	45.3	35.3	37.8	57.8	64.8	57.0	41.5	46.6	44.2	41.0	47.2	52.3	58.5	48.7
	Pozanti	36.1	14.7	37.2	39.5	27.3	32.6	29.5	15.7	19.6	22.0	34.7	41.3	29.2	33.6	35.3	46.6	39.0	51.5	44.3	23.2	30.3	26.9	33.2	25.0	37.3	35.5
	Saimbeyli	19.0	13.2	20.5	16.0	4.9	9.7	14.2	10.6	4.2	4.0	4.9	6.3	10.6	38.6	21.4	34.6	24.3	26.9	21.1	18.3	32.9	22.8	19.0	18.3	18.8	24.8
	Saricam	74.9	77.7	79.6	85.5	77.6	91.7	86.7	88.3	82.4	78.4	84.0	86.9	82.8	57.1	55.9	75.7	76.2	70.2	75.4	75.9	85.4	81.8	86.0	79.4	79.1	74.8
	Seyhan	89.3	92.8	93.0	92.2	97.6	92.2	95.6	95.3	95.7	94.1	94.5	95.4	94.0	80.0	89.4	79.6	96.7	87.1	86.7	81.4	96.2	90.9	93.9	93.6	96.9	89.4
	Tufanbeyli	11.5	7.1	14.5	26.5	2.8	8.1	9.4	10.2	5.5	3.0	6.1	5.1	9.2	23.8	19.9	27.2	30.9	30.8	29.4	31.3	21.2	11.7	21.4	10.9	18.8	23.1
	Yumurtalik	62.9	60.8	63.6	71.1	71.6	69.5	67.6	66.3	67.7	76.4	68.0	75.1	68.4	63.4	47.1	52.4	72.3	70.6	71.1	79.7	88.6	65.6	86.3	64.5	67.9	69.1
	Yuregir	88.8	87.1	84.3	84.3	82.7	86.5	72.4	82.3	83.4	87.5	85.8	89.1	84.5	71.3	72.4	59.8	84.0	85.0	72.5	82.0	84.8	92.0	91.2	82.8	82.0	80.0
Cukurova	69.9	55.4	82.1	91.8	89.8	90.2	93.6	92.8	88.0	82.9	83.6	89.2	84.1	45.9	53.3	65.4	93.3	71.2	89.9	75.5	84.8	91.7	92.2	73.7	93.7	77.6	
İmamoglu	52.1	59.0	73.6	79.0	75.2	84.9	78.9	70.9	73.3	72.1	68.2	81.3	72.4	47.9	57.0	65.5	73.8	69.6	57.8	66.6	72.9	67.7	78.9	52.7	70.2	65.1	
Antalya	Akseki	30.6	35.9	31.0	15.9	24.4	21.0	39.7	27.4	23.9	27.1	30.1	25.8	27.7	36.2	31.6	51.0	37.4	39.4	25.4	32.3	43.8	32.8	46.9	30.1	28.8	36.3
	Aksu	53.9	63.2	65.1	77.7	70.4	70.1	76.7	87.0	87.5	66.6	82.3	76.6	73.1	46.4	53.0	46.4	59.0	66.3	59.3	67.8	61.1	70.7	63.7	58.9	64.1	59.7
	Alanya	42.4	40.4	47.0	44.9	58.4	49.7	60.4	50.6	55.5	57.6	57.6	51.3	51.3	42.8	43.7	52.8	48.1	40.2	44.6	46.1	40.9	43.3	40.2	42.1	54.6	44.9
	Demre	72.1	73.4	60.0	73.3	66.8	71.7	54.8	65.0	74.1	70.9	61.9	50.8	66.2	71.4	71.0	78.6	38.6	53.4	23.7	59.0	48.6	53.3	45.6	79.3	48.5	55.9
	Dosemealti	54.8	48.3	63.6	64.9	70.1	65.7	73.1	70.4	79.8	60.4	76.3	67.7	66.3	53.9	55.2	51.1	67.1	74.5	75.9	67.0	69.4	78.6	68.9	78.8	63.8	67.0
	Elmali	42.1	44.2	41.6	29.8	26.3	22.7	26.2	35.3	39.2	31.6	28.3	25.9	32.7	46.6	36.8	33.6	29.9	37.4	34.0	26.6	29.5	26.4	35.1	30.5	30.9	33.1
	Finike	36.3	60.5	46.0	40.1	43.8	42.4	39.9	45.6	54.6	43.4	38.8	42.4	44.5	60.5	72.4	57.0	43.9	54.9	42.7	29.8	42.7	34.0	46.7	47.0	42.2	47.8
	Gazipasa	62.7	59.7	63.2	45.1	64.0	56.7	53.1	58.8	48.4	50.7	51.7	55.3	55.8	37.0	49.5	68.2	38.3	55.5	46.2	54.5	36.8	50.6	36.2	38.0	51.2	46.8
	Gundogmus	43.4	39.0	34.8	17.1	17.5	23.2	18.4	17.1	18.4	19.8	25.6	20.9	24.6	51.0	54.5	41.2	28.6	21.0	33.5	20.2	20.6	16.2	23.7	31.9	23.2	30.5
	Kas	52.3	50.3	42.9	39.4	47.2	41.6	46.8	45.3	56.6	54.1	42.4	35.8	46.2	42.5	45.8	40.4	28.1	39.3	32.5	31.5	30.1	37.1	51.3	43.5	38.0	38.3
	Kemer	27.4	79.5	72.3	65.8	78.6	75.2	63.0	74.5	78.8	75.6	72.3	80.5	70.3	38.2	66.9	31.3	54.1	76.4	78.9	66.4	61.8	64.3	60.3	71.6	65.0	61.3
	Kepez	53.6	58.2	74.3	85.4	79.4	84.5	86.7	88.8	91.1	74.7	86.8	82.1	78.8	56.7	71.0	43.2	79.4	72.8	75.9	81.7	65.0	85.1	87.1	83.6	76.1	73.1
	Konyaalti	48.8	48.7	57.0	43.5	61.9	56.2	51.5	57.3	66.9	52.7	55.7	55.1	54.6	50.8	57.4	38.4	47.3	56.5	64.8	51.8	53.2	56.2	62.5	60.0	60.9	55.0
	Korkuteli	47.0	54.5	51.6	44.0	43.4	45.9	46.4	49.9	58.3	50.6	52.0	46.4	49.2	45.0	54.2	51.7	44.1	51.5	51.1	45.7	51.6	47.5	48.3	50.1	49.0	49.2
	Kumluca	45.3	62.0	54.7	41.7	56.4	52.1	53.1	45.5	58.3	50.6	46.2	45.0	50.9	43.4	55.6	40.5	60.5	56.2	44.3	35.1	53.0	46.2	60.0	40.8	42.2	48.1
	Manavgat	46.5	40.5	42.6	47.2	50.1	45.0	58.0	51.5	55.0	56.6	59.7	57.0	50.8	46.7	48.6	48.1	51.7	43.2	43.0	55.1	52.8	47.2	56.2	51.7	52.6	49.7
	Muratpasa	71.4	56.0	71.1	90.4	81.7	77.4	85.7	92.4	91.2	89.0	92.9	72.0	80.9	49.1	57.2	41.2	73.6	75.8	82.9	80.5	82.6	84.4	73.0	86.4	80.4	72.2
	Serik	35.9	36.0	45.1	55.5	57.6	54.3	67.9	70.6	67.4	57.9	70.7	60.7	56.6	53.7	58.6	30.4	45.1	44.3	54.5	61.5	44.4	62.6	68.5	69.6	60.2	54.5
	İbradi	39.5	35.4	29.1	21.8	24.1	20.6	28.0	28.8	23.4	25.4	37.4	30.1	28.6	27.6	30.3	44.8	37.4	49.2	28.7	35.5	31.4	28.6	46.5	29.2	39.0	35.7

Table C.5 (continue) : Seasonal NH₃ percentile (%) by province, district, and overall average (AVG) between 2012-2023.

Hatay	Altinozu	65.1	42.1	30.4	38.0	36.5	36.5	31.5	38.3	31.1	45.3	19.8	50.8	38.8	57.0	71.2	38.8	60.1	52.7	74.4	80.7	67.3	61.4	60.9	71.8	46.5	61.9
	Antakya	39.7	38.2	42.8	42.2	47.2	52.3	42.9	49.2	42.4	50.2	30.3	49.5	43.9	72.8	61.8	63.6	57.5	60.4	70.6	77.1	80.1	60.9	51.3	69.8	63.6	65.8
	Arsuz	21.6	25.4	50.2	40.0	45.0	45.5	49.0	66.0	54.4	74.0	53.6	68.5	49.4	45.4	28.6	40.6	55.2	54.6	67.4	80.1	75.5	68.7	62.6	61.6	56.9	58.1
	Belen	26.7	26.9	32.7	63.6	51.8	29.1	46.1	32.5	46.7	62.5	26.5	50.5	41.3	84.9	56.7	68.5	38.2	56.9	76.7	86.7	79.6	47.7	78.9	49.9	68.1	66.1
	Defne	24.1	36.1	63.5	48.2	34.0	11.0	62.7	33.6	36.0	52.3	30.8	62.9	41.3	48.0	65.5	48.4	32.6	62.5	51.4	53.5	84.3	61.7	38.7	47.4	35.3	52.4
	Dortyol	55.3	58.3	59.0	51.5	28.1	42.9	12.5	47.8	17.9	32.9	44.4	42.0	41.1	54.2	60.6	48.3	34.3	49.2	38.0	54.5	71.4	60.2	54.8	43.8	39.0	50.7
	Erzin	55.8	41.7	53.1	68.5	57.1	41.4	50.1	53.1	25.3	66.5	49.1	70.2	52.7	67.1	62.3	60.8	47.7	54.1	49.3	80.2	77.2	76.1	61.5	75.9	67.7	65.0
	Hassa	43.3	38.2	31.1	60.9	36.9	42.8	35.3	42.6	29.3	41.3	31.5	41.2	39.5	61.7	60.2	78.5	58.4	58.8	83.2	30.7	46.5	43.2	40.8	41.9	46.2	54.2
	Kumlu	23.9	45.8	39.3	44.0	44.0	43.4	32.6	57.3	49.4	65.7	50.8	47.9	45.3	55.9	69.5	66.9	73.9	71.9	76.3	91.5	66.3	70.5	74.5	88.5	75.8	73.5
	Kirikhan	36.1	32.8	39.6	67.2	44.3	54.9	38.6	56.0	50.5	56.9	44.4	55.5	48.1	53.8	66.1	61.3	73.0	76.2	79.1	67.5	69.0	65.4	61.6	79.2	68.9	68.4
	Payas	45.4	53.8	34.2	85.5	35.4	64.6	38.3	28.0	48.1	33.4	39.2	53.9	46.6	64.3	83.3	81.5	55.7	34.2	90.3	54.4	78.8	61.0	63.2	27.6	44.1	61.5
	Reyhanli	32.0	40.1	31.5	33.0	46.6	47.0	45.5	58.4	45.0	56.1	49.8	60.7	45.5	73.5	69.2	64.4	69.4	73.8	69.5	72.6	79.3	67.1	78.1	78.5	74.5	72.5
	Samandag	16.9	50.1	61.7	38.8	54.3	53.4	48.4	55.2	43.1	51.7	44.4	69.4	48.9	13.6	41.3	47.1	63.1	50.9	71.5	45.3	85.2	46.7	29.2	44.4	39.2	48.1
	Yayladagi	47.0	38.1	29.6	44.5	47.0	30.0	45.0	49.2	24.0	47.3	26.2	56.5	40.4	69.6	68.3	57.5	38.8	26.3	51.4	55.2	68.2	44.1	53.2	52.8	28.1	51.1
	Iskenderun	19.5	37.9	52.7	89.0	56.8	41.4	44.6	46.3	49.7	49.8	33.5	59.8	48.4	66.3	56.9	81.1	37.9	68.6	86.8	50.3	64.7	60.2	41.4	75.2	71.5	63.4
Mersin	Akdeniz	91.9	98.3	98.9	99.6	99.5	99.4	98.9	99.5	99.2	98.6	99.6	99.4	98.6	85.8	86.5	88.9	95.8	99.1	96.9	91.1	97.9	98.4	97.5	96.1	96.3	94.2
	Anamur	39.9	62.5	53.5	40.7	54.9	50.1	50.6	40.0	41.2	45.4	44.6	47.3	47.5	45.4	57.6	57.2	36.7	46.9	53.3	40.3	48.3	41.1	35.6	39.0	38.7	45.0
	Aydincik	61.3	66.3	75.0	63.7	68.0	68.0	66.0	59.1	50.8	70.9	55.9	50.8	63.0	42.1	83.2	61.2	78.2	59.9	77.2	56.6	81.0	60.8	58.8	75.9	57.0	66.0
	Bozyazi	62.8	74.2	60.1	48.1	60.5	50.3	60.6	57.3	48.1	48.9	47.9	49.9	55.7	31.4	62.4	46.4	49.2	56.2	59.7	52.7	44.0	58.0	42.8	46.2	37.4	48.8
	Erdemli	59.9	57.5	69.5	56.7	48.1	48.0	51.0	44.4	40.4	39.9	47.5	45.3	50.7	49.3	53.0	51.8	49.0	46.0	45.0	36.7	42.3	36.4	43.8	33.5	40.4	43.9
	Gulnar	64.9	69.8	76.4	49.5	58.8	55.6	64.4	53.1	48.9	46.4	56.4	51.5	58.0	55.6	67.8	59.2	52.8	58.3	56.6	62.2	54.8	58.9	47.4	51.1	43.8	55.7
	Mezitli	65.8	72.1	85.2	74.8	76.5	80.0	76.7	73.2	66.4	66.7	71.2	75.8	73.7	64.7	75.5	73.9	83.6	64.7	69.7	66.1	63.3	52.0	68.7	63.7	68.3	67.8
	Mut	47.7	52.1	48.9	59.7	54.2	57.7	60.6	57.1	50.0	45.9	65.1	57.3	54.7	50.1	48.5	52.3	57.7	42.3	45.7	50.4	53.5	56.4	56.3	53.8	52.9	51.7
	Silifke	75.1	70.5	71.5	57.1	62.1	59.4	57.6	54.6	55.5	51.4	61.3	55.8	61.0	63.6	59.5	50.4	52.3	55.3	57.6	50.3	53.7	50.6	46.8	47.9	53.1	53.4
	Tarsus	73.7	73.5	83.1	81.5	80.9	83.4	77.8	74.9	74.9	73.0	78.8	78.7	77.9	72.6	66.2	63.9	77.0	83.0	78.3	69.5	73.5	75.1	78.1	70.6	79.2	73.9
	Toroslar	50.4	59.3	71.4	58.4	49.7	49.2	46.7	49.5	42.6	39.1	49.2	48.1	51.1	52.0	44.1	58.4	48.8	48.9	60.6	47.4	52.0	47.5	43.0	33.2	38.0	47.8
	Yenisehir	94.2	87.6	95.8	97.5	95.5	99.4	97.7	85.9	92.7	86.2	94.3	93.7	93.4	71.2	93.7	82.6	96.3	93.5	83.8	76.9	92.6	88.3	91.8	83.0	95.5	87.4
	Camliyayla	45.1	47.8	60.7	48.4	39.3	45.2	41.5	32.8	30.0	25.4	41.6	31.1	40.7	31.0	34.1	44.3	54.2	32.3	42.6	31.0	21.0	28.6	37.6	32.6	42.5	36.0
Osmaniye	Bahce	18.1	16.9	8.4	17.4	11.7	19.1	11.1	6.4	12.4	12.1	4.6	19.1	13.1	57.5	29.1	47.3	37.3	49.8	32.1	32.0	42.1	31.7	29.2	35.7	36.1	38.3
	Duzici	26.2	24.7	18.0	40.8	18.8	32.6	20.1	21.5	13.5	29.9	21.0	16.5	23.6	55.8	29.9	41.4	39.4	40.5	33.5	35.5	41.8	30.9	46.1	32.0	36.6	38.6
	Hasanbeyli	12.0	12.1	13.5	31.3	22.8	15.1	3.1	7.9	8.2	14.1	12.6	5.0	13.1	44.4	39.5	6.2	34.3	39.9	41.2	43.9	65.2	19.8	15.5	27.2	34.6	34.3
	Kadirli	38.9	28.3	44.8	48.4	45.1	51.9	51.8	49.2	38.3	37.0	28.5	36.5	41.6	56.4	36.0	42.1	70.6	37.9	50.2	50.1	58.5	55.1	56.6	62.4	52.1	52.3
	Merkez	28.1	26.4	38.4	57.7	39.2	43.3	34.4	41.7	23.4	42.0	33.8	45.8	37.9	54.1	33.9	59.3	59.8	38.2	60.1	54.0	45.1	39.0	50.1	59.9	47.8	50.1
	Sumbas	23.5	23.8	44.2	38.2	35.0	42.6	55.0	45.5	26.0	26.4	22.8	26.6	34.1	36.5	38.4	50.0	62.5	19.4	49.1	46.2	44.9	53.4	64.3	30.4	44.5	45.0
	Toprakkale	27.1	10.7	26.3	75.9	70.2	72.8	48.7	73.9	58.3	56.9	47.4	74.8	53.6	25.7	34.7	51.8	76.1	75.8	44.6	59.2	80.0	65.2	56.5	86.8	80.4	61.4

Table C.6 : Mann Kendall trend analysis for district (*/- significant/no significant, slope in units of $\times 10^{14}$ molecules/cm²/year).

Province	District	Agricultural Areas			All Areas		
		Trend	p	Slope	Trend	p	Slope
Adana	Tufanbeyli	-	-	0.55	-	-	0.42
	Saimbeyli	-	-	-1.00	-	-	-0.27
	Feke	-	*	-4.00	-	-	-0.37
	Kozan	↑	*	1.41	↑	*	0.72
	Aladag	↑	*	5.19	-	-	0.04
	Ceyhan	↑	*	2.64	↑	*	2.64
	Karaisali	↑	*	2.22	↑	*	1.40
	Pozanti	↑	*	10.50	↑	*	0.81
	Karatas	↑	*	4.41	↑	*	3.51
	Yuregir	↑	*	3.46	↑	*	3.17
	Cukurova	↑	*	8.58	↑	*	5.85
	Saricam	↑	*	2.82	↑	*	2.64
	Imamoglu	↑	*	2.45	↑	*	2.25
	Seyhan	↑	*	5.01	↑	*	4.37
	Yumurtalik	↑	*	5.04	↑	*	3.75
Mersin	Camliyayla	-	-	10.20	-	-	-0.11
	Toroslar	-	-	-1.20	-	-	-0.45
	Akdeniz	↑	*	11.10	↑	*	9.49
	Erdemli	-	-	0.91	↑	*	0.44
	Mut	↑	*	1.40	↑	*	1.00
	Silifke	-	-	0.25	↑	*	0.84
	Gulnar	-	-	-0.06	-	-	0.21
	Anamur	↑	*	3.53	↑	*	0.74
	Tarsus	↑	*	3.51	↑	*	2.48
	Aydincik	↑	*	50.60	↑	*	4.13
	Mezitli	↑	*	12.20	↑	*	3.20
	Bozyazi	-	-	-0.91	↑	*	0.97
	Yenisehir	-	-	8.28	-	-	2.97
Osmaniye	Kadirli	↑	*	1.71	↑	*	1.53
	Merkez	↑	*	2.90	↑	*	1.68
	Duzici	-	-	1.93	-	-	0.31
	Hasanbeyli	-	-	1.83	-	-	0.22
	Sumbas	-	-	1.78	↑	*	1.89
	Bahce	-	-	4.50	-	-	1.10
	Toprakkale	-	-	10.30	↑	*	13.90
Hatay	Antakya	-	-	0.93	-	-	0.52
	Arsuz	↑	*	7.92	↑	*	3.53
	Reyhanli	↑	*	4.14	↑	*	3.94
	Kirikhan	↑	*	2.98	↑	*	2.47
	Dortyol	-	-	12.60	-	-	3.43
	Hassa	-	-	3.92	↑	*	1.17
	Samandag	-	-	15.30	-	-	3.09
	Yayladagi	-	-	2.58	↑	*	3.04
	Altinozu	↑	*	1.97	↑	*	1.98
	Defne	-	-	7.33	-	-	1.20
	Kumlu	↑	*	4.98	↑	*	4.72
	Iskenderun	-	-	-13.00	-	-	3.30
	Erzin	↑	*	11.90	↑	*	5.02
	Payas	-	-	83.70	-	-	2.21
	Belen	↑	*	28.40	-	*	5.74

Table C.6 (continue) : Mann Kendall trend analysis for district (*/- significant/no significant, slope in units of $\times 10^{14}$ molecules/cm²/year.

Province	District	Agricultural Areas			All Areas		
		Trend	p	Slope	Trend	p	Slope
Antalya	Akseki	-	-	7.48	-	-	-0.04
	Gundogmus	-	-	4.17	-	-	-0.16
	Manavgat	↑	*	2.62	↑	*	1.26
	Konyaalti	-	-	5.71	↑	*	1.56
	Kumluca	-	*	3.20	↑	*	0.73
	Kas	-	-	2.11	↑	*	0.72
	Alanya	↑	*	3.89	↑	*	1.63
	Korkuteli	↑	*	1.68	↑	*	0.91
	Elmali	↑	*	0.98	-	*	0.42
	Aksu	-	*	2.60	↑	*	2.27
	Dosemealti	↑	*	6.94	↑	*	2.27
	Kemer	-	-	13.20	↑	*	2.28
	Finike	↑	*	11.00	-	-	0.58
	İbradi	-	-	-3.40	-	-	0.09
	Gazipasa	↑	*	4.93	-	-	0.84
	Kepez	↑	*	4.81	↑	*	3.39
	Demre	↑	*	52.80	-	*	2.52
	Muratpasa	↑	*	60.50	↑	*	16.70
	Serik	↑	*	2.53	↑	*	1.96

Table C.7 : Comparison of annual burnt hectare area (ha) and fire counts between Türkiye and study region.

Year	Total		Province			Ratio			
	Total Hectare	Total Number	Province	Hectare	Number	Total Hectare	Total Number	Hectare (%)	Number (%)
2019	11332.44	2688	Adana	52.82	132	1765.97	806	15.6	30.0
			Antalya	234.86	199				
			Hatay	71.95	79				
			Mersin	360.78	90				
			Mugla	939.29	264				
			Osmaniye	106.27	42				
2020	20970.66	3399	Adana	2644.81	125	9167.09	894	43.7	26.3
			Antalya	399.58	260				
			Hatay	4978.61	100				
			Mersin	509.15	87				
			Mugla	478.22	260				
			Osmaniye	156.72	62				
2021	139503.16	2793	Adana	4919.26	126	129034.36	935	92.5	33.5
			Antalya	60366.56	294				
			Hatay	334.63	64				
			Mersin	9661.20	89				
			Mugla	50602.9	296				
			Osmaniye	3149.79	66				
2022	12798.66	2160	Adana	58.43	78	8443.34	680	66.0	31.5
			Antalya	194.45	189				
			Hatay	121.18	50				
			Mersin	2118.13	99				
			Mugla	5523.09	234				
			Osmaniye	428.06	30				
2023	15520.10	2579	Adana	255.20	89	3123.82	687	20.1	26.6
			Antalya	786.07	171				
			Hatay	723.80	43				
			Mersin	898.12	82				
			Mugla	369.78	261				
			Osmaniye	90.85	41				
Total	200125.02	13619	Total Study Area			151534.58	4002	75.7	29.4

Table C.8 : Annual wildfires those caused by residue burning (RB) by province (2019–2023).

Year	Province	RB (Count)	Total (Count)	RB/Total (%)	RB (Hectare)	Total (Hectare)	RB/Total (% Hectare)
2019	Adana	4	174	2.30	2.06	159.08	1.29
2020	Adana	4	186	2.15	0.80	2775.54	0.03
2021	Adana	10	190	5.26	109.79	7698.6	1.43
2022	Adana	5	108	4.63	2.79	486.50	0.57
2023	Adana	4	132	3.03	1	346	0.31
2019	Antalya	1	199	0.50	0.70	234.86	0.30
2020	Antalya	4	258	1.55	1.16	399.58	0.29
2021	Antalya	5	278	1.80	2.25	60357.96	0.00
2022	Antalya	3	179	1.68	1.83	200.69	0.91
2023	Antalya	11	162	6.79	4	386	0.91
2022	Hatay	2	56	3.57	0.30	121.64	0.25
2023	Hatay	1	49	2.04	664	732	90.66
2019	Mersin	5	90	5.56	53.87	360.79	14.93
2020	Mersin	9	80	11.25	26.35	509.15	5.18
2021	Mersin	2	89	2.25	2.60	9662.2	0.03
2022	Mersin	2	99	2.02	0.08	2118.12	0.00
2023	Mersin	5	82	6.10	2	898	0.17

Table C.9 : NH₃ concentration (10¹⁶ molecules/cm²) and differences during pre-fire and post-fire in the domain.

Statistics	Pre	Pre-Fire Difference (%)	Fire	Post-Fire Difference (%)	Post
5th	-0.01	-386.6	0.04	888.3	0.00
25th	0.39	6.5	0.42	50.1	0.28
50th	0.67	23.4	0.83	60.9	0.51
Mean	0.72	94.5	1.40	146.5	0.57
75th	0.99	71.9	1.71	111.4	0.81
95th	1.64	175.7	4.52	242.2	1.32
Max	5.47	1035.1	62.14	1100.9	5.17

Table C.10 : Average pollution concentration for each wildfire region and differences during pre-fire and post-fire.

Pollutants	WF-Region	Pre	Pre-Fire Difference (%)	Fire	Post-Fire Difference (%)	Post
NH ₃ (x10 ¹⁶ molecules/cm ²)	AN-1	0.94	307.6	3.81	594.0	0.55
	AN-2	0.69	112.7	1.47	336.0	0.34
	ME-1	1.21	14.3	1.39	183.4	0.49
	ME-2	1.19	54.8	1.84	119.8	0.84
	MU-1	0.69	354.6	3.15	309.3	0.77
	MU-2	0.45	210.6	1.41	310.4	0.34
	MU-3	0.48	777.6	4.17	208.3	1.35
	MU-4	0.43	765.8	3.74	517.2	0.61
IASI-CO (x10 ¹⁸ molecules/cm ²)	AN-1	2.30	37.9	3.17	23.1	2.58
	AN-2	2.01	9.6	2.20	-4.0	2.29
	ME-1	2.10	7.0	2.25	-18.7	2.77
	ME-2	2.21	5.2	2.32	-9.6	2.57
	MU-1	2.32	44.5	3.35	28.2	2.61
	MU-2	1.98	27.7	2.53	4.7	2.41
	MU-3	2.07	69.2	3.51	25.3	2.80
	MU-4	2.04	37.5	2.80	7.6	2.61
TROP-CO (x10 ¹⁸ molecules/cm ²)	AN-1	2.04	101.3	4.10	76.6	2.32
	AN-2	1.84	22.4	2.26	5.6	2.14
	ME-1	2.12	8.2	2.29	3.0	2.23
	ME-2	2.12	5.2	2.23	-4.1	2.33
	MU-1	2.12	16.2	2.46	3.3	2.38
	MU-2	1.93	0.7	1.94	-6.2	2.07
	MU-3	2.17	92.0	4.17	64.0	2.55
	MU-4	1.91	35.0	2.58	7.0	2.41
TROP-NO ₂ (x10 ¹⁵ molecules/cm ²)	AN-1	1.23	144.8	3.02	144.5	1.23
	AN-2	1.01	76.8	1.79	103.3	0.88
	ME-1	1.21	44.2	1.74	50.4	1.16
	ME-2	1.56	34.8	2.11	32.0	1.60
	MU-1	2.12	45.2	3.08	33.4	2.31
	MU-2	1.44	66.9	2.41	78.7	1.35
	MU-3	1.54	112.2	3.27	68.1	1.94
	MU-4	1.12	87.6	2.10	56.4	1.35
TROP-HCHO (x10 ¹⁶ molecules/cm ²)	AN-1	0.91	118.2	1.99	105.0	0.97
	AN-2	0.87	104.6	1.79	127.7	0.79
	ME-1	1.24	16.4	1.44	43.0	1.01
	ME-2	1.19	22.7	1.46	50.7	0.97
	MU-1	1.14	57.9	1.79	46.7	1.22
	MU-2	1.07	4.4	1.12	44.1	0.78
	MU-3	1.23	85.5	2.28	65.2	1.38
	MU-4	0.99	40.4	1.38	2.9	1.34

Table C.11 : Factor of NH₃ ratio to co-emitted pollutants for WF-regions and periods.

WF-Regions		NH ₃ /IASI-CO			NH ₃ /TROP-CO			NH ₃ /TROP-NO ₂			NH ₃ /TROP-HCHO		
		Pre	Fire	Post	Pre	Fire	Post	Pre	Fire	Post	Pre	Fire	Post
Average	AN-1	2.3	-	4.2	2.5	-	4.7	2.3	-	3.3	1.3	-	4.4
	AN-2	2.3	-	5.8	2.9	-	4.3	2.2	-	3.0	2.0	-	1.7
	ME-1	1.2	-	3.8	2.1	-	3.0	1.3	-	4.1	1.1	-	2.9
	ME-2	1.6	-	2.8	1.8	-	2.2	1.8	-	3.0	0.9	-	1.6
	MU-1	1.2	-	1.4	9.0	-	11.5	6.5	-	7.6	9.9	-	7.9
	MU-2	2.1	-	3.4	1.5	-	1.7	3.7	-	8.6	1.9	-	0.1
	MU-3	3.4	-	3.5	1.2	-	0.2	5.1	-	9.6	7.6	-	3.0
	MU-4	5.7	-	3.2	4.5	-	3.4	5.7	-	11.1	1.0	-	3.9
Median	AN-1	2.0	-	3.3	2.0	-	3.4	2.2	-	3.2	1.5	-	3.3
	AN-2	2.3	-	6.2	2.8	-	4.2	2.6	-	5.1	2.1	-	4.7
	ME-1	0.9	-	3.3	2.0	-	3.1	1.1	-	5.2	0.9	-	3.0
	ME-2	1.1	-	2.0	1.6	-	2.7	1.3	-	2.0	1.0	-	1.9
	MU-1	1.3	-	1.3	8.8	-	13.3	4.4	-	5.1	3.5	-	3.6
	MU-2	1.5	-	2.7	1.5	-	1.9	2.4	-	5.0	1.0	-	0.6
	MU-3	2.8	-	3.4	1.6	-	0.2	246.8	-	9.9	132.8	-	2.7
	MU-4	3.2	-	1.5	3.3	-	2.2	7.3	-	12.8	1.1	-	1.2
Max	AN-1	4.2	-	9.1	6.2	-	16.0	2.9	-	2.8	0.1	-	1.7
	AN-2	2.8	-	4.6	2.5	-	4.3	1.5	-	0.7	1.2	-	0.2
	ME-1	2.2	-	3.5	4.1	-	3.7	1.7	-	3.0	3.1	-	2.7
	ME-2	2.4	-	3.0	2.8	-	2.2	1.9	-	3.4	0.4	-	1.2
	MU-1	1.9	-	2.0	10.8	-	12.1	6.2	-	14.6	39.3	-	22.5
	MU-2	4.3	-	5.7	1.1	-	1.1	5.7	-	13.7	48.7	-	0.1
	MU-3	2.9	-	2.6	0.4	-	0.3	0.2	-	8.9	1.0	-	3.6
	MU-4	5.5	-	7.2	9.0	-	5.6	6.8	-	15.5	0.1	-	21.0

Table C.12 : Chl-a concentration (mg/m³) and differences during pre-fire and post-fire in the domain.

Statistics	Pre	Pre-Fire Difference (%)	Fire	Post-Fire Difference (%)	Post
25th	0.061	52.7	0.096	39.7	0.064
50th	0.067	69.3	0.108	55.0	0.069
Mean	0.068	98.5	0.134	87.5	0.071
75th	0.074	119.6	0.147	111.6	0.076
Max	0.935	553.6	0.497	568.9	0.14

Table C.13 : Average pollution concentration for each RB region and period and their differences during pre-fire and post-fire.

Pollutants	RB-Region	RB-Region	Pre	Pre-Fire Difference (%)	Fire	Post-Fire Difference (%)	Post
NH ₃ (x10 ¹⁶ molecules/cm ²)	RB-1	Ad-Os	0.44	43.3	0.64	1191.1	0.05
		Me-Ad	0.92	5.6	0.98	549.8	0.15
		Ha	0.41	41.4	0.58	-1215.8	-0.05
	RB-2	Ad-Os	0.44	81.0	0.80	15.2	0.70
		Me-Ad	0.92	19.9	1.11	-20.6	1.40
		Ha	0.41	55.9	0.64	13.7	0.56
IASI-CO (x10 ¹⁸ molecules/cm ²)	RB-1	Ad-Os	1.98	3.3	2.05	5.2	1.95
		Me-Ad	1.98	1.8	2.01	2.1	1.97
		Ha	1.99	1.4	2.01	2.4	1.97
	RB-2	Ad-Os	1.98	5.0	2.08	-0.4	2.09
		Me-Ad	1.98	2.0	2.02	-4.0	2.10
		Ha	1.99	0.4	1.99	-0.6	2.01
TROP-CO (x10 ¹⁸ molecules/cm ²)	RB-1	Ad-Os	1.89	4.1	1.97	1.4	1.94
		Me-Ad	1.89	1.5	1.92	-3.5	1.99
		Ha	1.85	1.5	1.87	-4.1	1.95
	RB-2	Ad-Os	1.89	6.5	2.02	-3.0	2.08
		Me-Ad	1.89	1.6	1.92	-6.8	2.06
		Ha	1.85	2.2	1.89	-6.2	2.01
TROP-NO ₂ (x10 ¹⁵ molecules/cm ²)	RB-1	Ad-Os	1.84	43.0	2.63	-28.1	3.66
		Me-Ad	1.70	55.2	2.65	-45.0	4.81
		Ha	1.88	34.9	2.54	-31.4	3.71
	RB-2	Ad-Os	1.84	26.7	2.33	-5.6	2.47
		Me-Ad	1.70	7.6	1.83	-31.4	2.68
		Ha	1.88	10.1	2.07	-11.8	2.35
TROP-HCHO (x10 ¹⁶ molecules/cm ²)	RB-1	Ad-Os	1.34	-24.7	1.01	44.7	0.70
		Me-Ad	1.05	-12.6	0.91	54.9	0.59
		Ha	0.96	-6.3	0.90	20.6	0.75
	RB-2	Ad-Os	1.34	-11.4	1.19	35.7	0.87
		Me-Ad	1.05	-2.2	1.02	21.6	0.84
		Ha	0.96	5.1	1.01	37.5	0.73

APPENDIX D: Wind rose for study area, wildfire and agricultural residue burning regions and for selected periods.



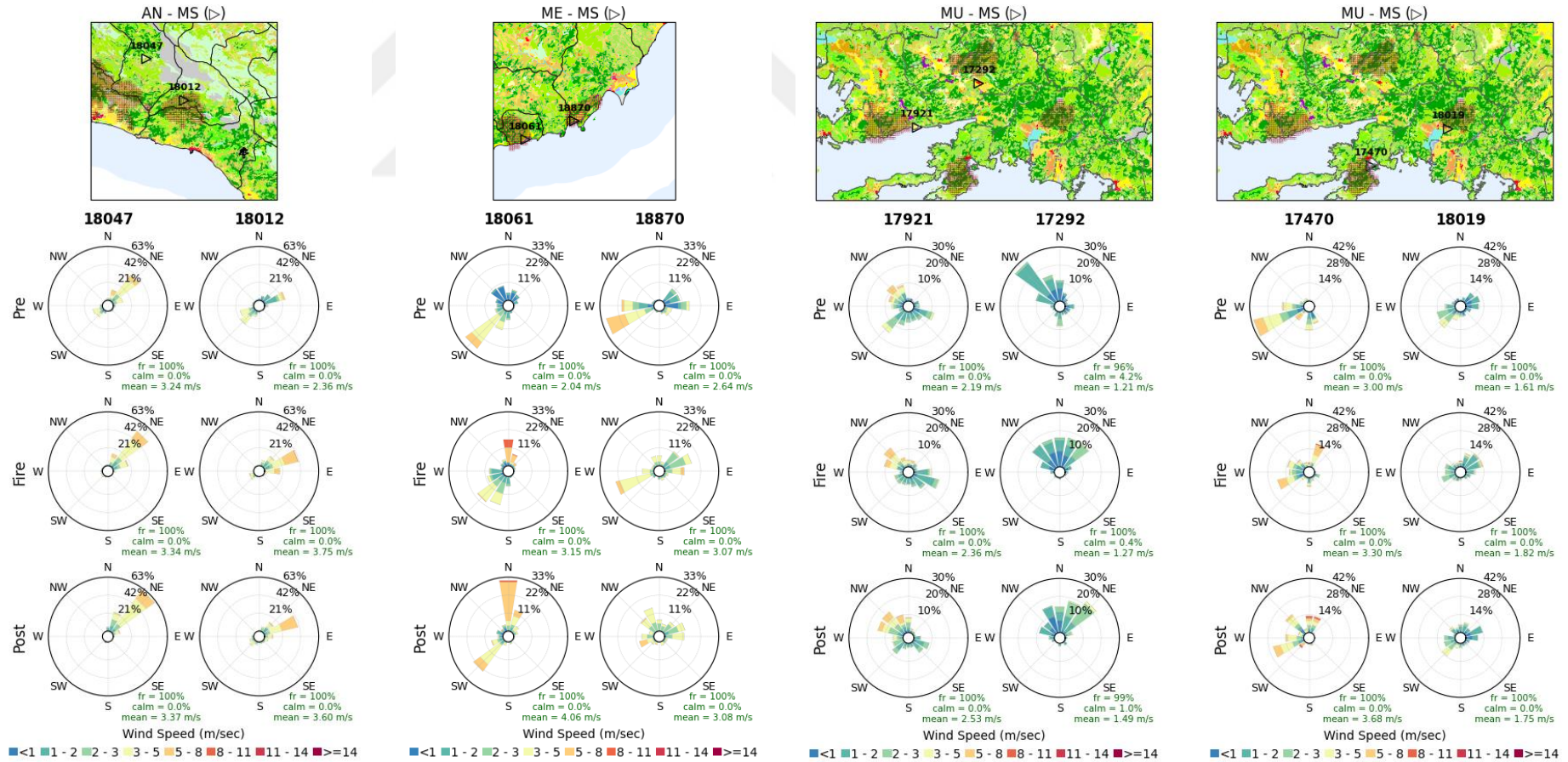


Figure D. 1 : Wind roses of Antalya (AN; AN-1: MS-18047; AN-2:MS-18012), Mersin (ME; ME-1:MS-18061, and ME-2:MS-18870) and Mugla (MU; MU1:MS-17921, MU-2:MS-17292, MU-3:MS-17470 and MU-4:MS-18019) for pre-fire, fire, and post-fire period.

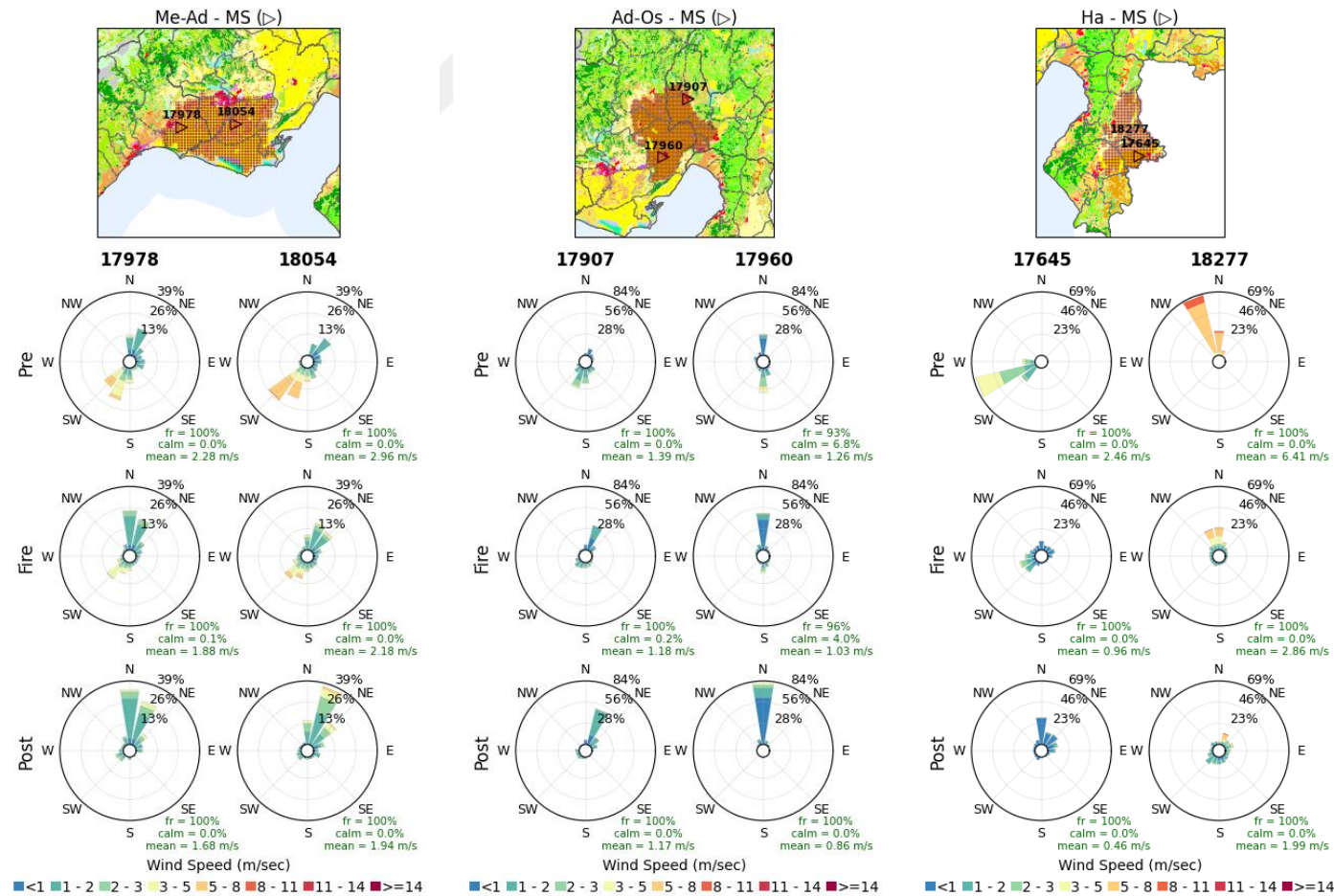


Figure D.2 : Wind roses of Me-Ad (MS-17978 and MS-18054), Ad-Os (MS-17907 and MS-17960) and Ha (MS-17645 and MS-18277) for RB-1 pre-fire, fire, and post fire period.

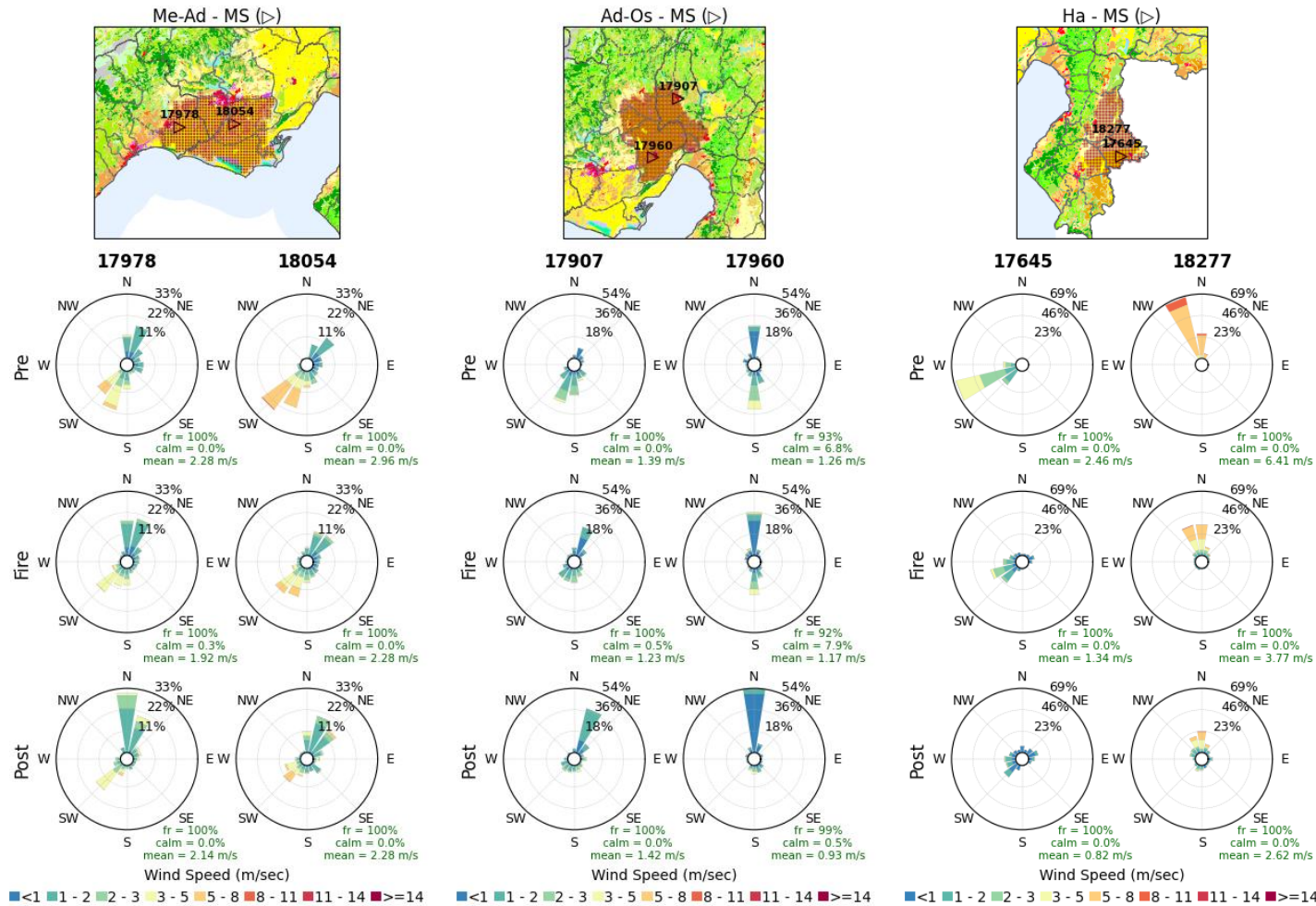


Figure D.3 : Wind roses of Me-Ad (MS-17978 and MS-18054), Ad-Os (MS-17907 and MS-17960) and Ha (MS-17645 and MS-18277) for RB-2 pre-fire, fire, and post fire period.

APPENDIX E: Long-Term annual and seasonal NH₃ distributions and wind pattern analyses.



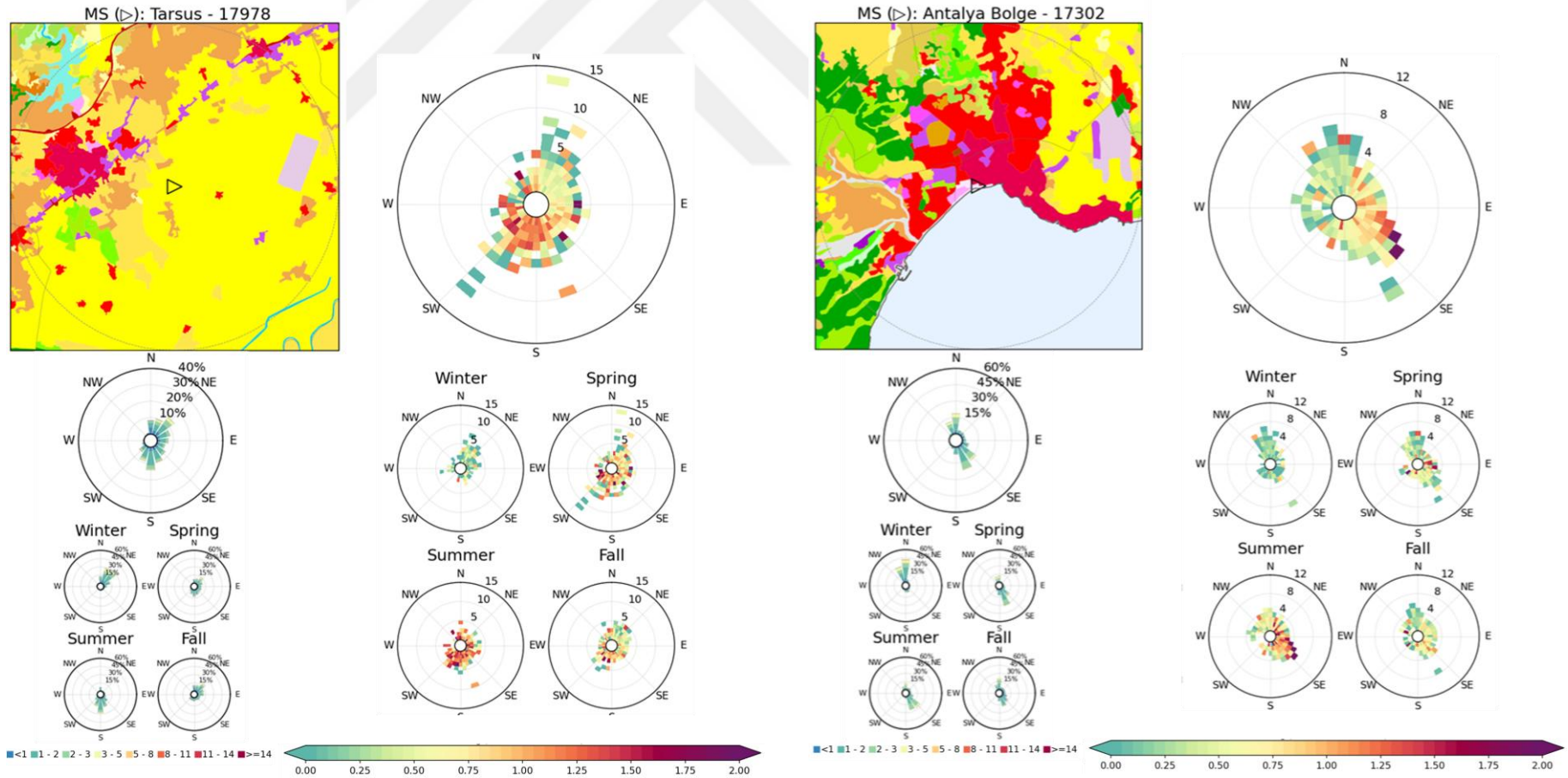


Figure E. 1 : CLC data near MS (top left), wind roses (bottom left: long-term (top) and seasonal (bottom)), and NH₃ distribution (right: long-term (top) and seasonal (bottom)) for Tarsus, Mersin (left) and Antalya (right).

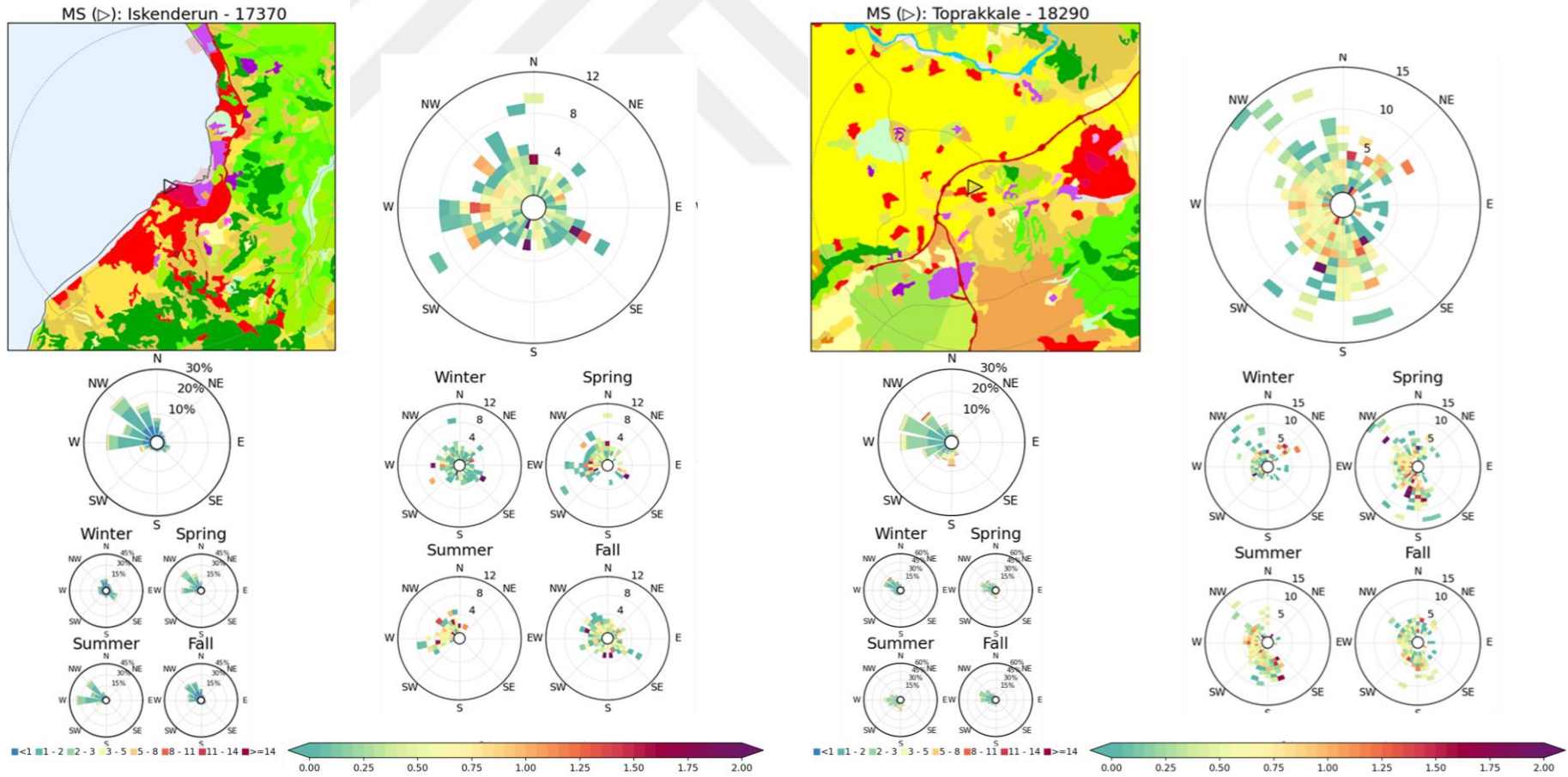


Figure E. 2 : CLC data near MS (top left), wind roses (bottom left: long-term (top) and seasonal (bottom)), and NH_3 distribution (right: long-term (top) and seasonal (bottom)) for Tarsus, Hatay (left) and Osmaniye (right).

APPENDIX F: Long-Term time series analyses of NH₃, T, RH, and WS and year-specific correlation analyses.



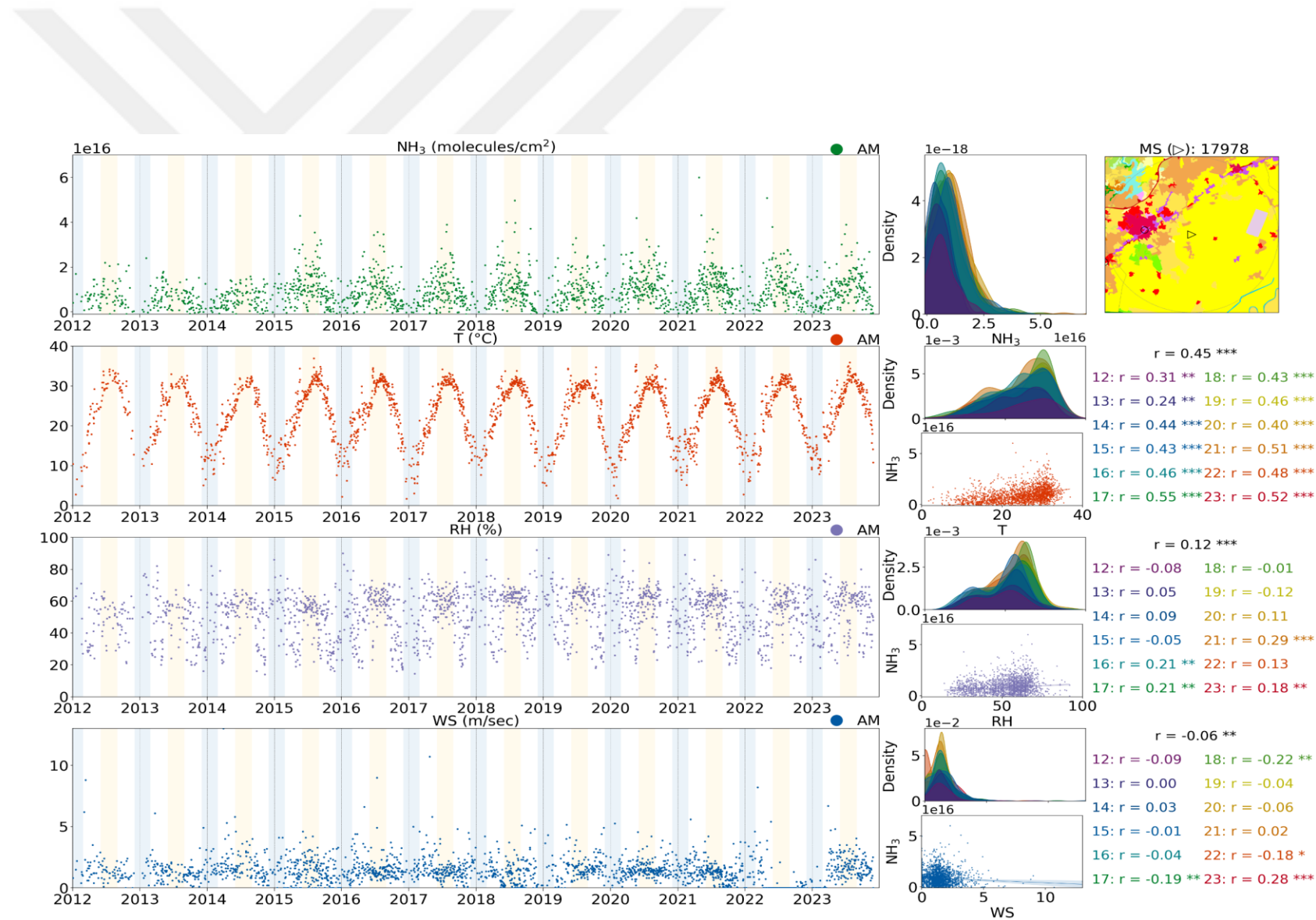


Figure F. 1 : Time series of NH₃, T, RH, and WS from 2012 to 2023 (left), along with corresponding density plots and year-specific correlation analyses (right) for Mersin.

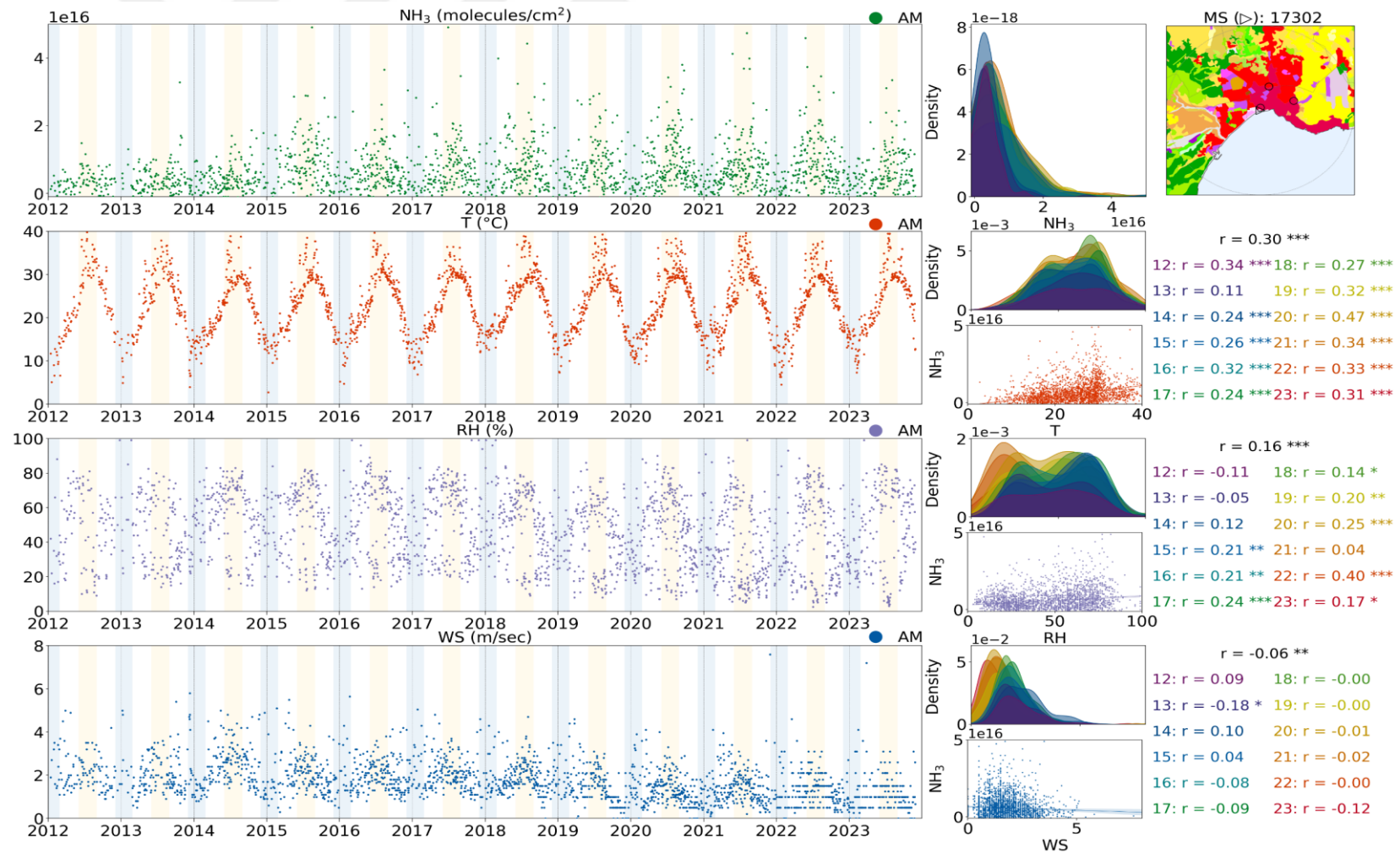


Figure F. 2 : Time series of NH₃, T, RH, and WS from 2012 to 2023 (left), along with corresponding density plots and year-specific correlation analyses (right) for Antalya.

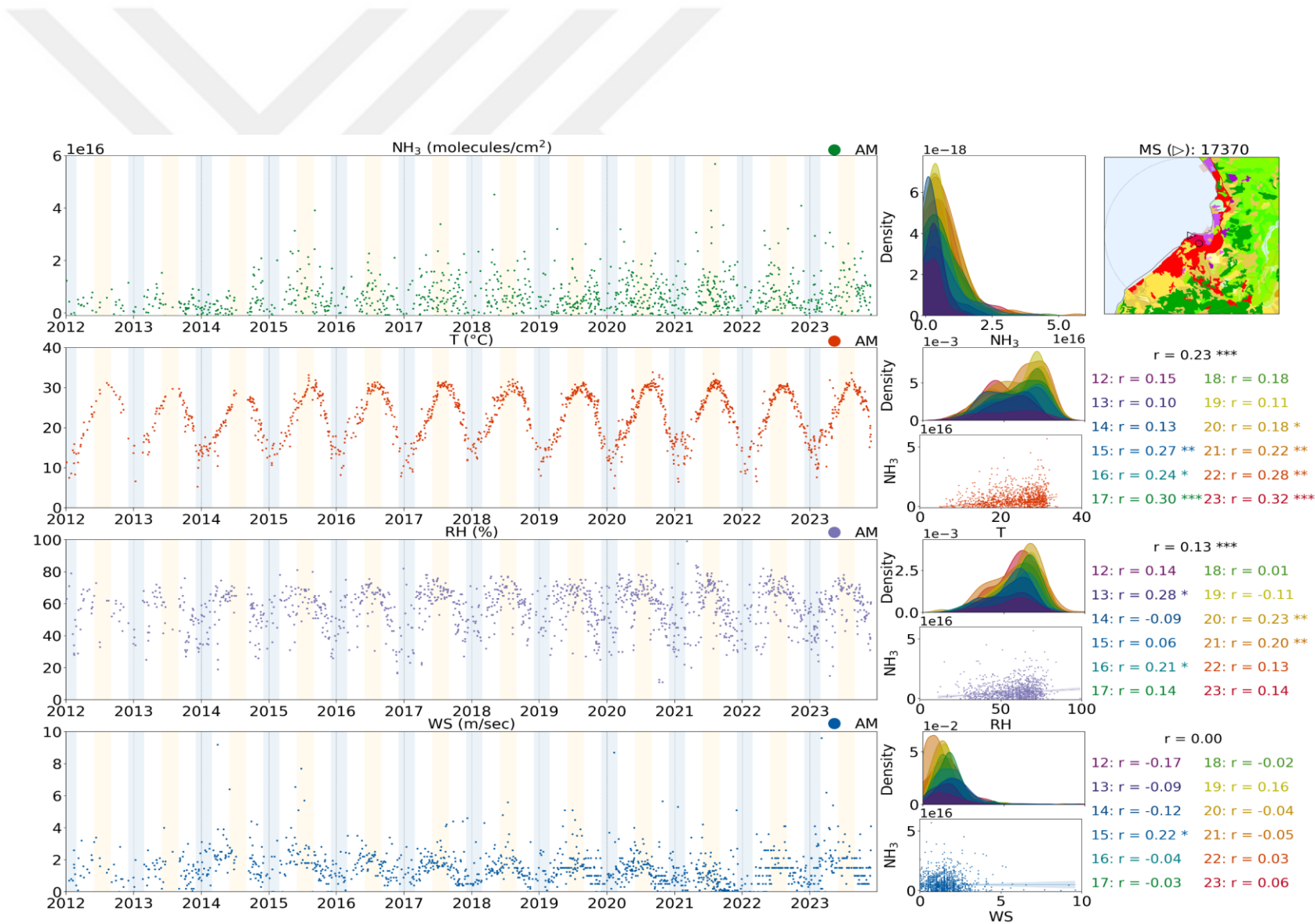


Figure F. 3 : Time series of NH₃, T, RH, and WS from 2012 to 2023 (left), along with corresponding density plots and year-specific correlation analyses (right) for Hatay.

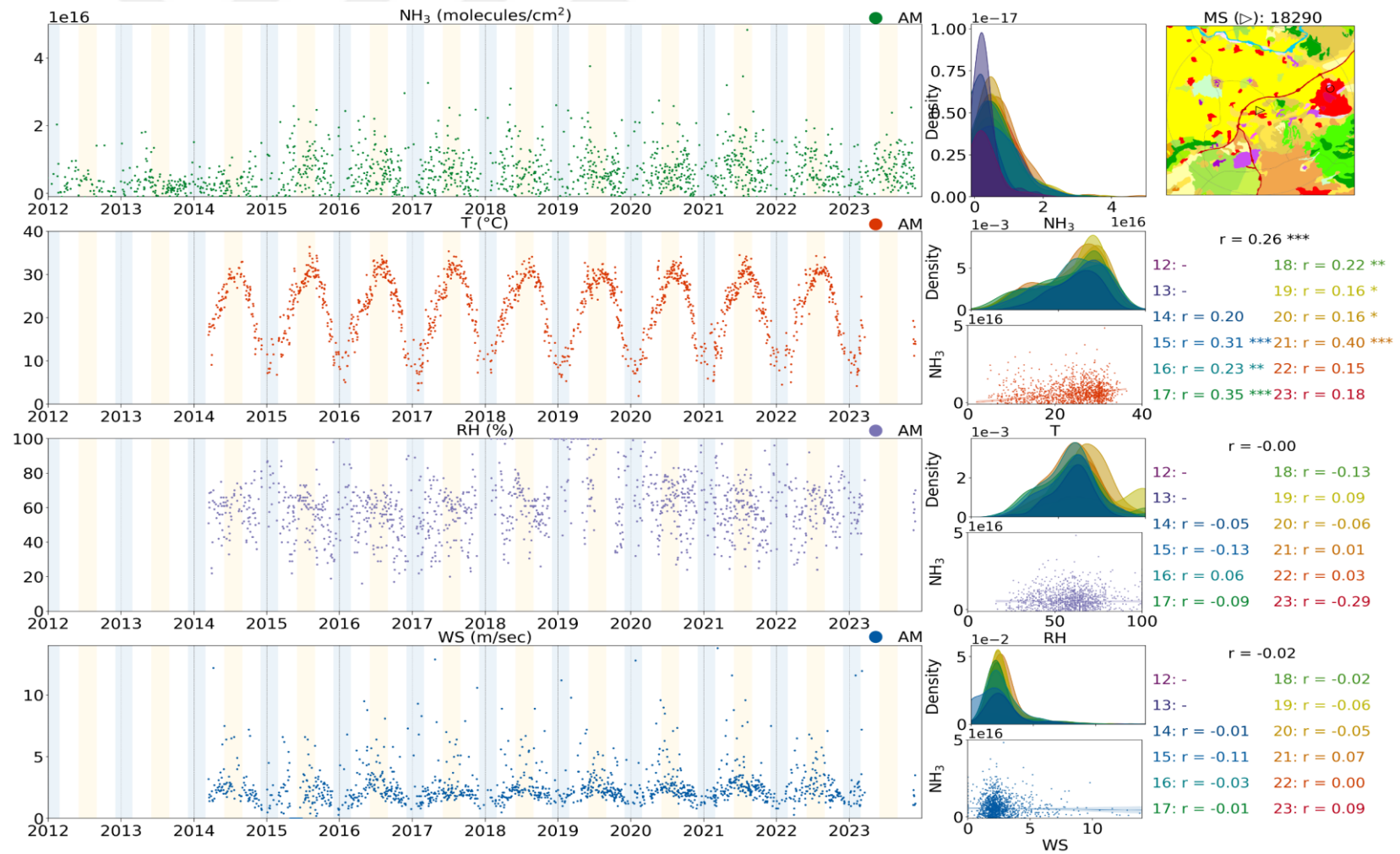


Figure F. 4 : Time series of NH_3 , T, RH, and WS from 2012 to 2023 (left), along with corresponding density plots and year-specific correlation analyses (right) for Osmaniye.

APPENDIX G: Pollution distribution analyses of NH₃ for study period.



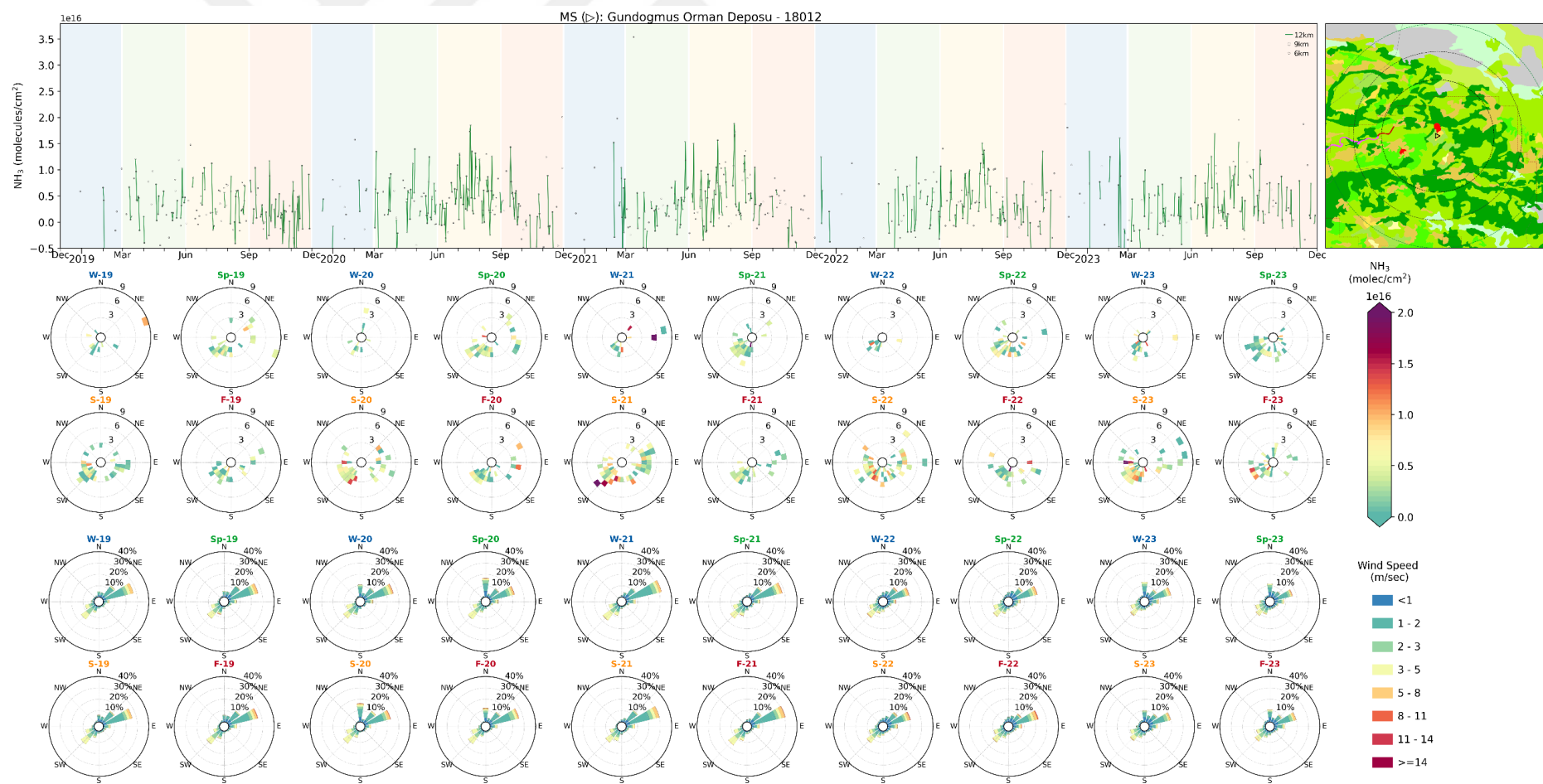


Figure G. 1 : NH_3 daily averages (top left), 12 km surroundings of MS-18012 with CLC (top right), seasonal pollution roses (middle), and wind roses (bottom).

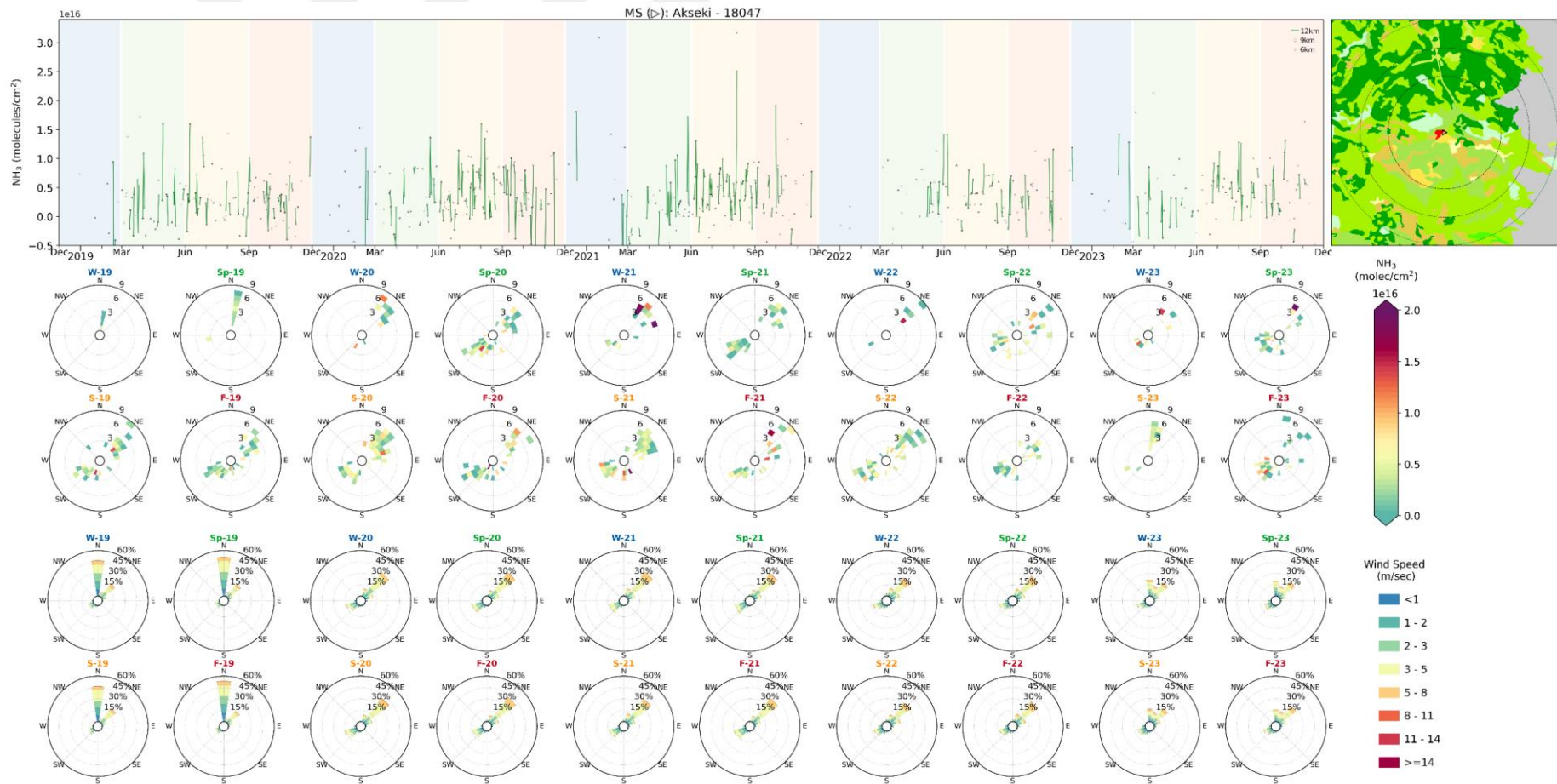


Figure G. 2 : NH₃ daily averages (top left), 12 km surroundings of MS-18047 with CLC (top right), seasonal pollution roses (middle), and wind roses (bottom).

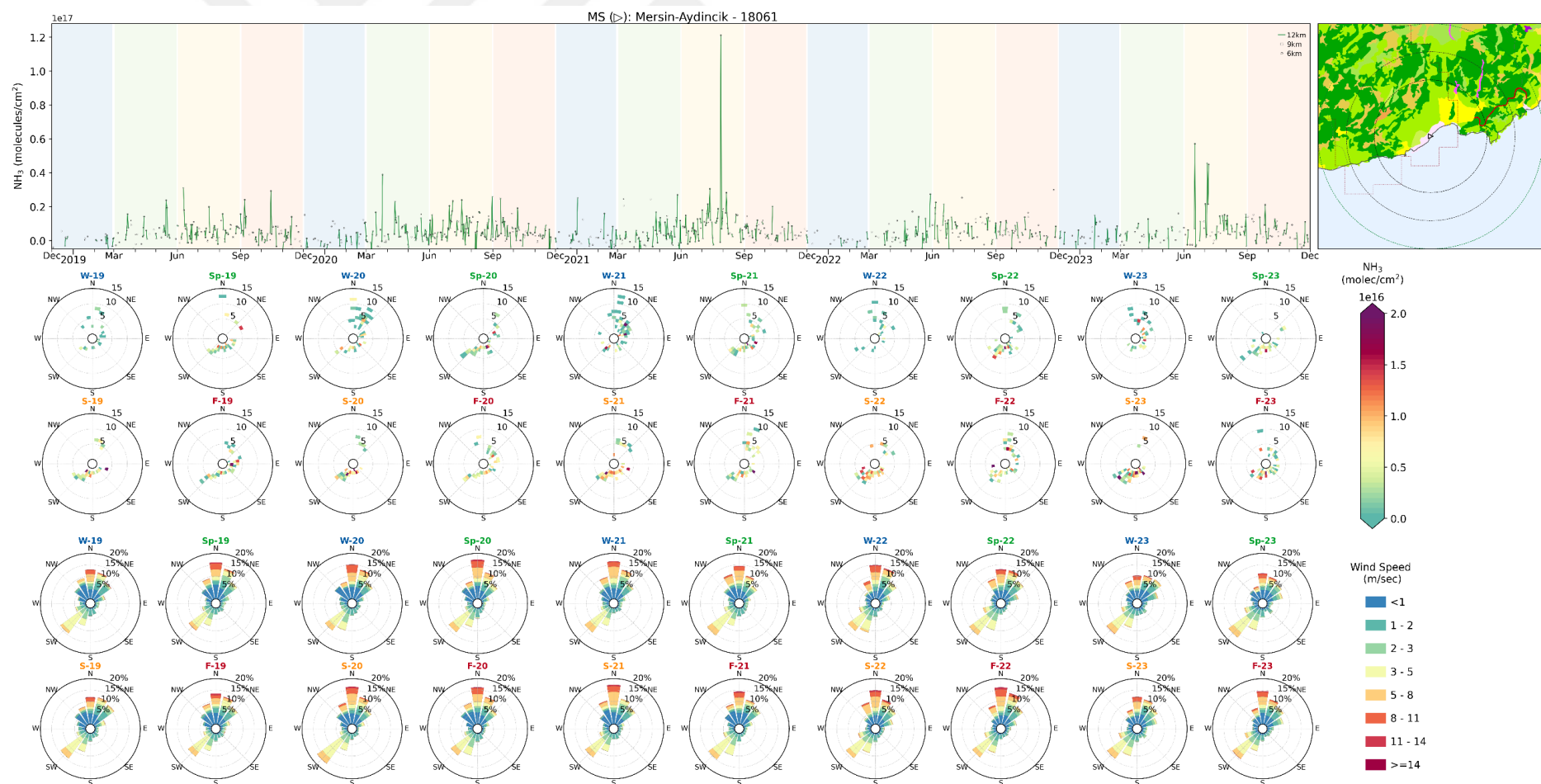


Figure G. 3 : NH₃ daily averages (top left), 12 km surroundings of MS-18061 with CLC (top right), seasonal pollution roses (middle), and wind roses (bottom).

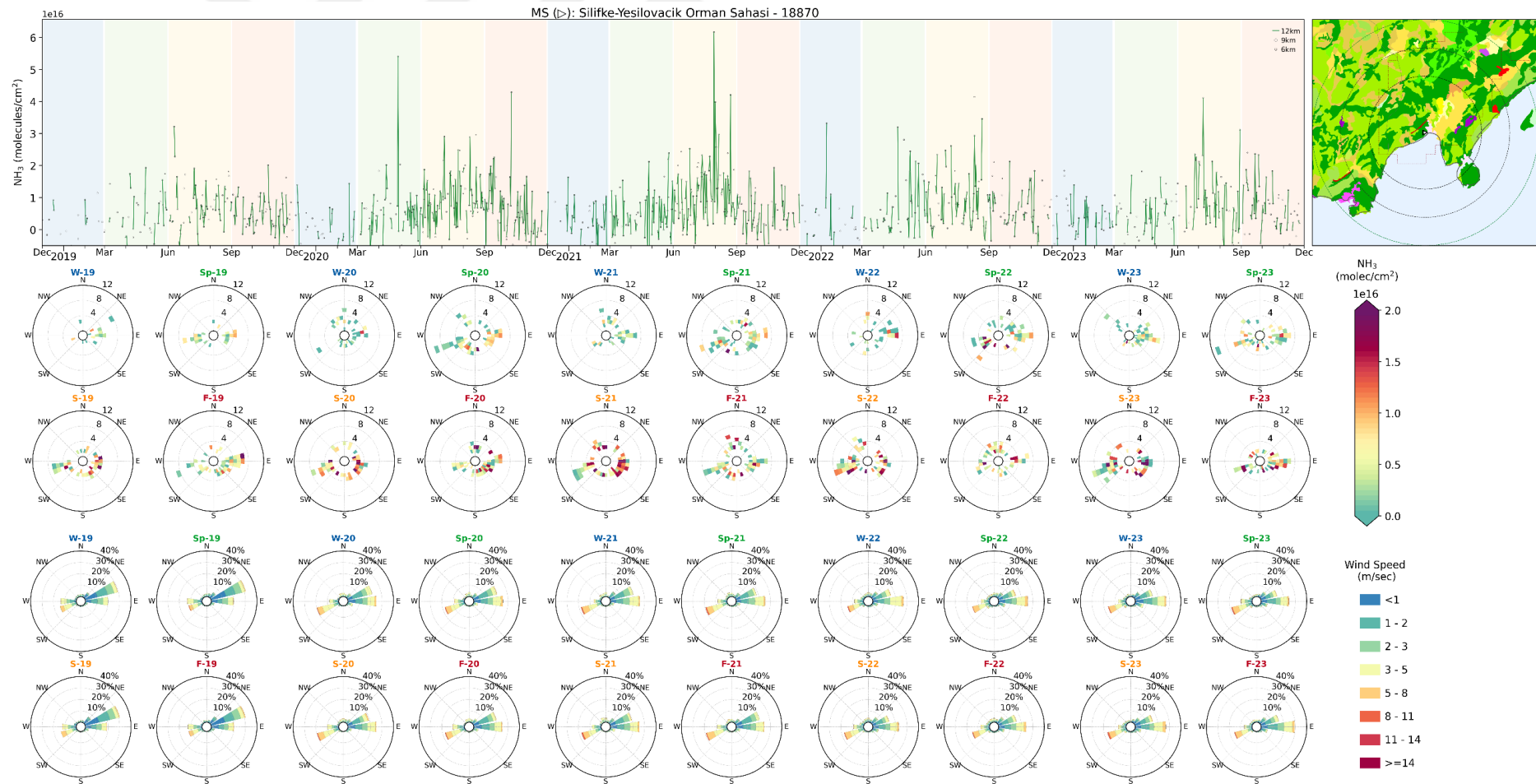


Figure G. 4 : NH₃ daily averages (top left), 12 km surroundings of MS-18870 with CLC (top right), seasonal pollution roses (middle), and wind roses (bottom).

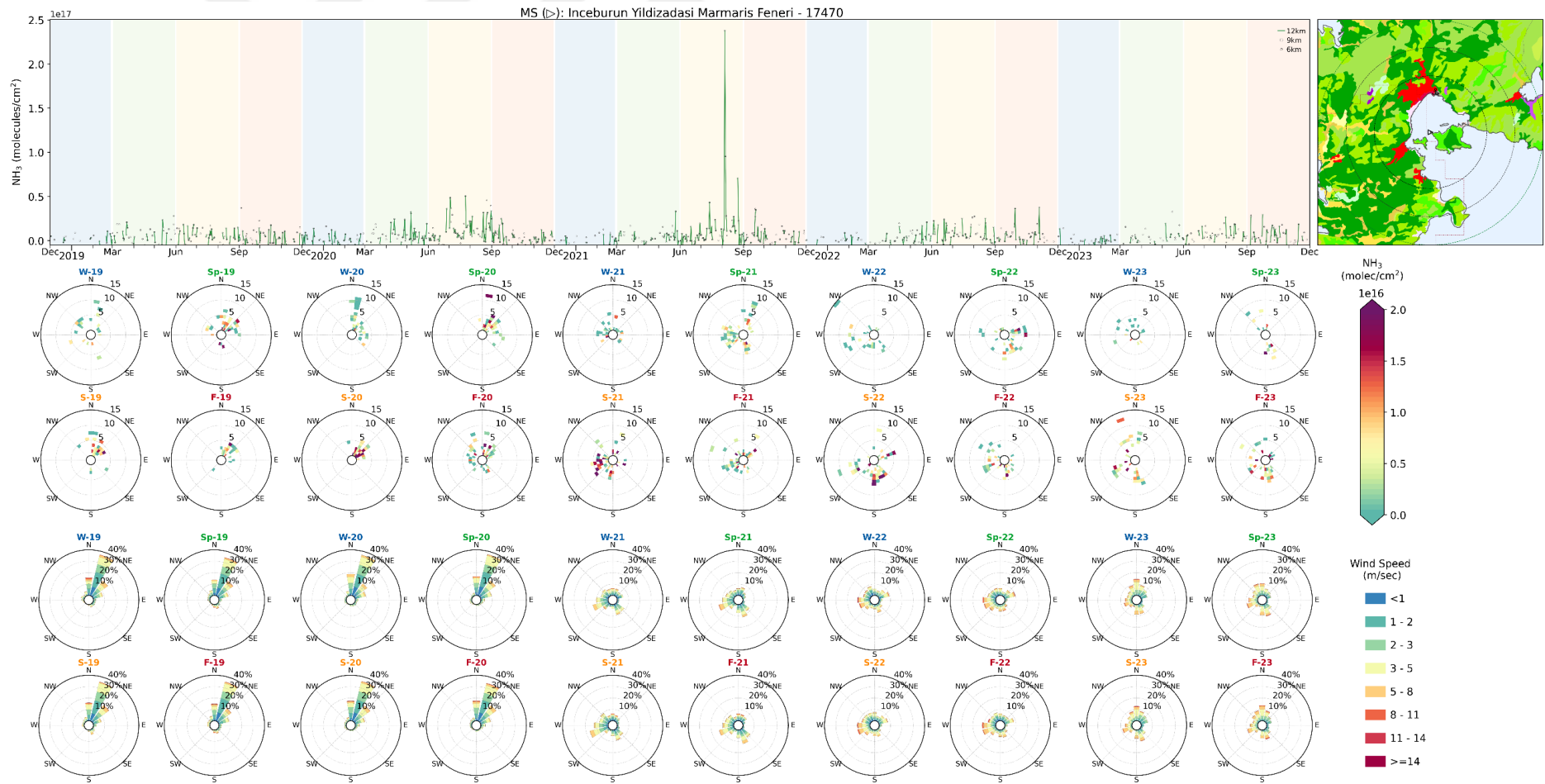


Figure G. 5 : NH₃ daily averages (top left), 12 km surroundings of MS-17470 with CLC (top right), seasonal pollution roses (middle), and wind roses (bottom).

APPENDIX H: Correlation analyses for NH₃ and co-emitting pollutants.



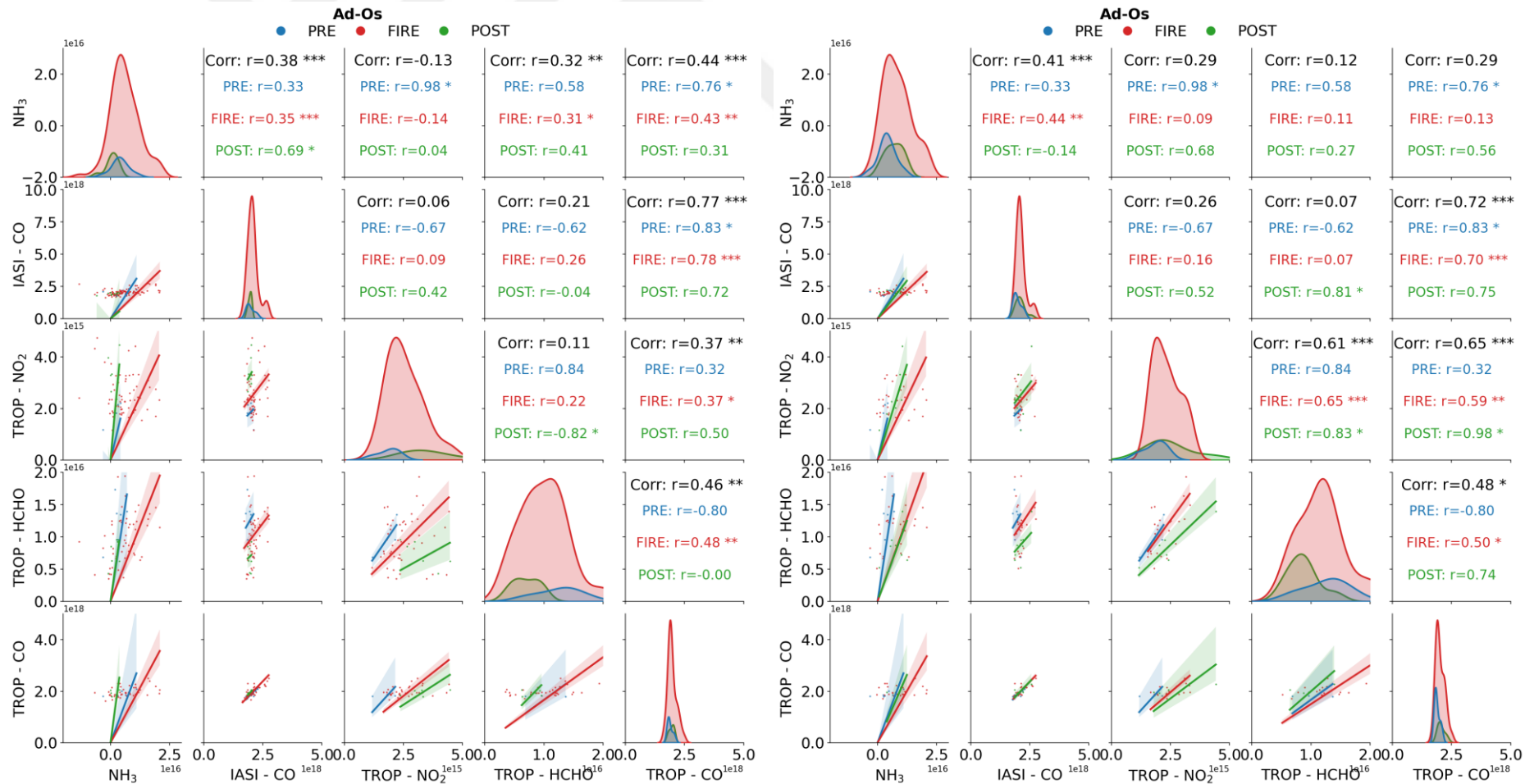


Figure H. 1 : Correlation analysis of Ad-Os region for RB-1 (left) and RB-2 (right) periods.

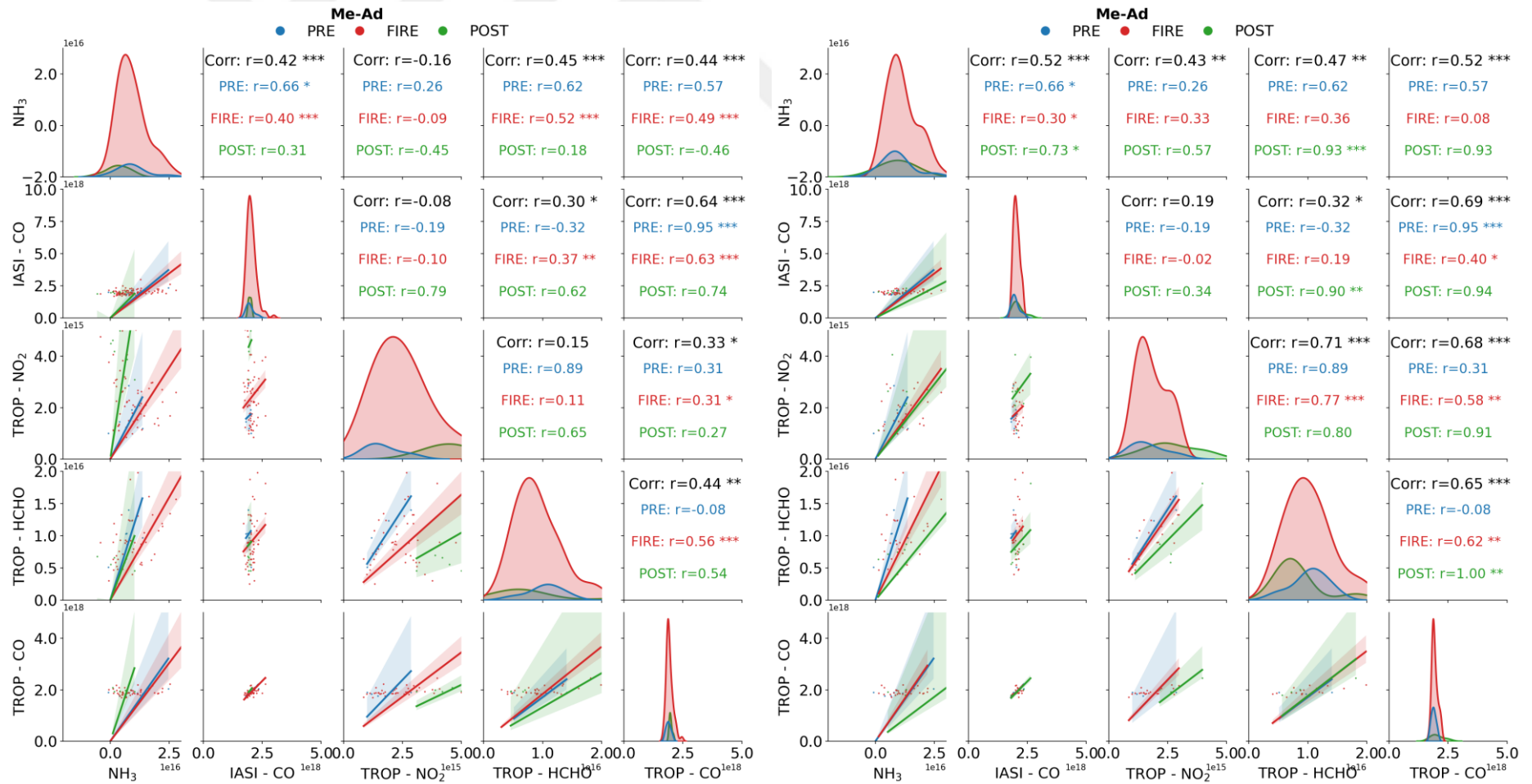


Figure H. 2 : Correlation analysis of Me-Ad region for RB-1 (left) and RB-2 (right) periods.

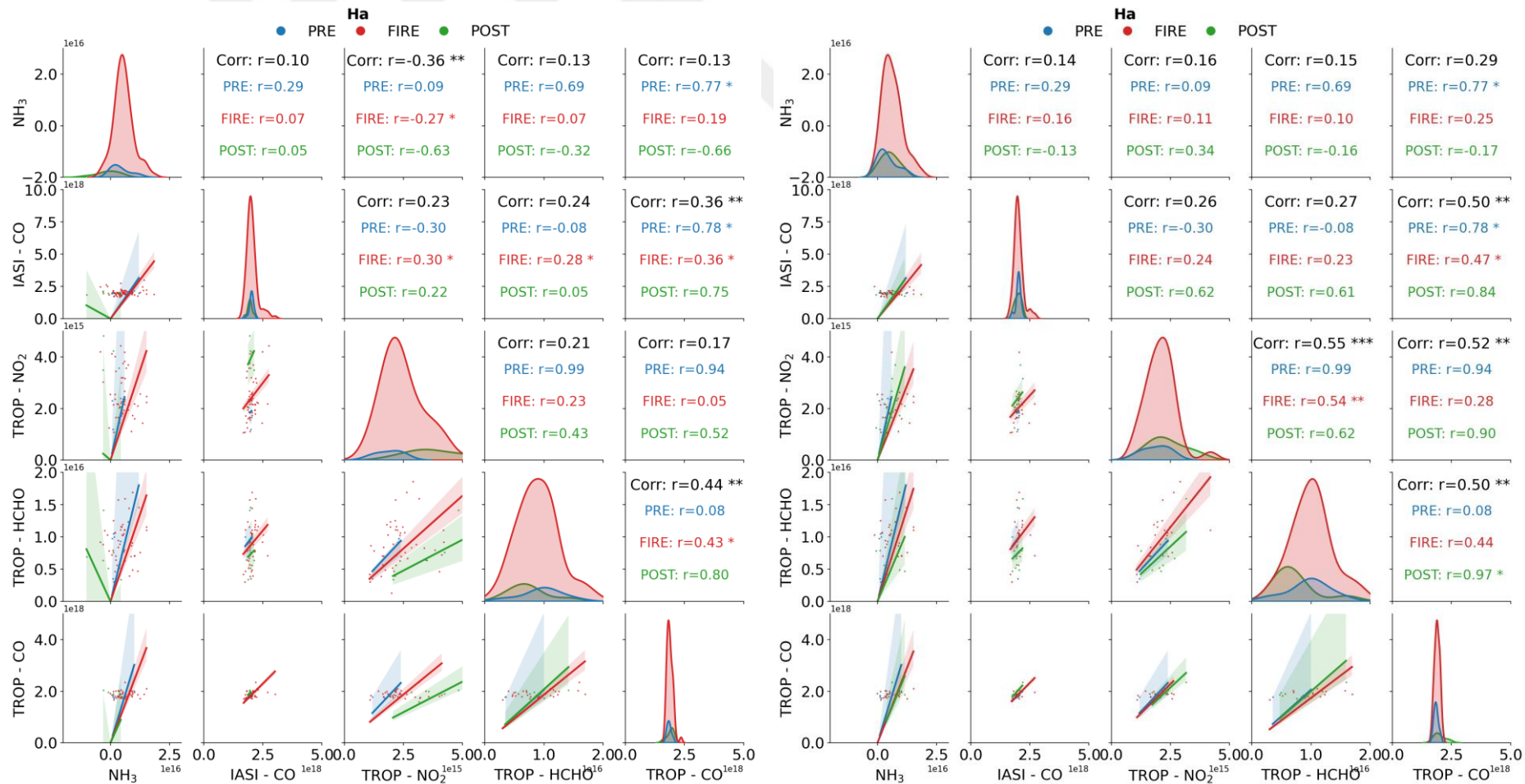


Figure H. 3 : Correlation analysis of Ha region for RB-1 (left) and RB-2 (right) periods.

APPENDIX I: Periodic-time series analyses and pollution distribution for AQMS measurements.



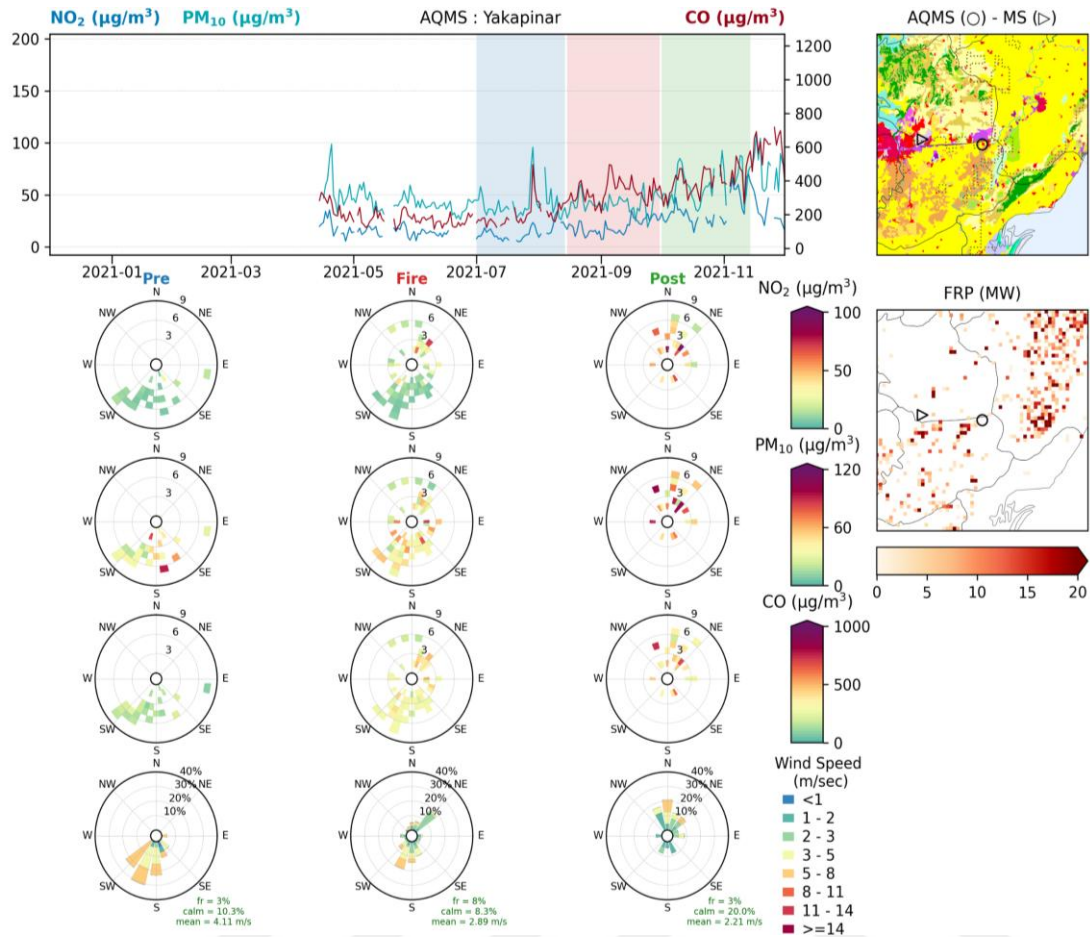


Figure I. 1 : Yakapinar AQMS and MS-17350 daily average time series of NO_2 , PM_{10} and CO (in units of $\mu\text{g}/\text{m}^3$) (top left), CLC with AQMS and MS location (top right), periodic pollutant rose (middle left), along with wind rose (bottom left) and FRP for the 2021 period (middle right).

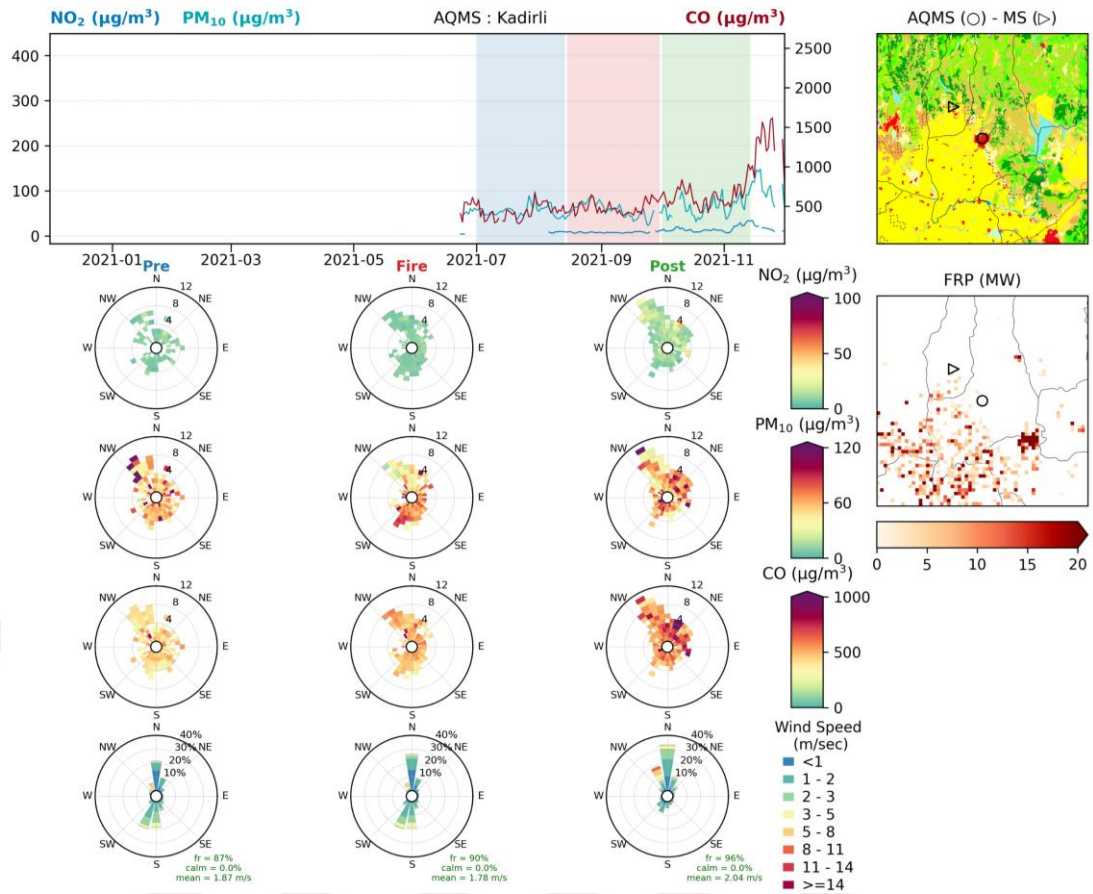


Figure I. 2 : Kadirli AQMS and MS-19184 daily average time series of NO_2 , PM_{10} and CO (in units of $\mu\text{g}/\text{m}^3$) (top left), CLC with AQMS and MS location (top right), periodic pollutant rose (middle left), along with wind rose (bottom left) and FRP for the 2021 period (middle right).



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PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

- **Saracoglu S.**, Alban A. M., Tokgoz S., Kaynak B., 2025. “Investigation of the intense wildfire events and NH₃ levels over the Eastern Mediterranean”, European Geosciences Union (EGU25), 27 April–2 May 2025, Vienna/Austria. (Oral Presentation)
- **Saracoglu, S.**, Tokgoz, S., Uzunyayla S., Onay M. G., Kaynak, B., 2024. “Investigation of high NH₃ levels over Eastern Mediterranean using remote sensing”, 11th International Symposium on Atmospheric Sciences (ATMOS’24), 23-25 October 2024, Istanbul, Türkiye. (Oral Presentation)
- **Saracoglu S.**, Tokgoz S., Aydin M. D., Bayram S., Kaynak B., 2024. “Investigation of High IASI Ammonia Levels in the Eastern Mediterranean Region and Their Relationship with Meteorology and Possible Sources”, 2nd International Symposium on Remote Sensing in Meteorology (METEOIRS 2024), 11–13 June 2024, Istanbul/Türkiye. (Oral Presentation)

OTHER PUBLICATIONS, PRESENTATIONS AND PATENTS:

- Tokgoz S., Alban A. M., **Saracoglu S.**, Kaynak B., 2025. "Long-Term NH₃ Assessment with Meteorological Parameters to Obtain Temporal Profiles in Agricultural Regions", European Geosciences Union (EGU25), 27 April–2 May 2025, Vienna/Austria. (Oral Presentation)
- Alban A. M., Tokgoz S., **Saracoglu S.**, Kaynak B., 2024. "Agricultural sources impact on NH₃ and PM levels in the South- Central Anatolia", European Geosciences Union (EGU25), 27 April–2 May 2025, Vienna/Austria. (Poster Presentation)
- Alban A. M., Tokgoz S., **Saracoglu S.**, Kaynak B., 2024. "Investigation of high NH₃ and PM levels around Konya", 11th International Symposium on Atmospheric Sciences (ATMOS'24), 23-25 October 2024, Istanbul, Türkiye. (Oral Presentation)
- Tokgoz S., **Saracoglu S.**, Aydin M. D., Bayram S., Kaynak B., 2024. "Evaluation of High IASI NH₃ Levels in Iğdir Province with the Measurements of Other Air Pollutants and Meteorological Parameters", 2nd International Symposium on Remote Sensing in Meteorology (METEOIRS 2024), 11–13 June 2024, Istanbul/Türkiye. (Oral Presentation)
- Onay M. G., **Saracoglu S.**, Pehlivanoglu E., Kaynak B., 2025. "Impacts of Russia-Ukraine War on air pollution over the Black Sea Region due to changes in maritime transport", Atmospheric Pollution Research, Volume 16, Issue 10, October 2025, 102613. <https://doi.org/10.1016/j.apr.2025.102613>