Airborne and Satellite Investigation of Asian Air Quality (ASIA-AQ): An Opportunity for International Collaboration

United States: *James H. Crawford, Katherine Travis, Laura Judd, NASA Langley Research Center*
Barry Lefer, NASA Headquarters; Jack Dibb, University of New Hampshire

South Korea: *Jhoon Kim, Yonsei University; Rokjin Park, Seoul National University*
Gangwoong Lee, Hankuk University of Foreign Studies; Limseok Chang, NIER

Philippines: *James Simpas, Maria Obiminda Cambaliza, Ateneo de Manila University*

Thailand: *Ronald Macatangay, Vanisa Surapipith, National Astronomical Research Institute of Thailand*
Narisara Thongboonchoo, King Mongkut's Institute of Technology; Kim Oanh, Asia Institute of Technology

Vietnam: *To Thi Hien, Vietnam National University Ho Chi Minh City-University of Science*
Ly Bich Thuy, Hanoi University of Science and Technology

Bangladesh: *Abdus Salam, Dhaka University*

India: *Sachin Ghude, Indian Institute of Tropical Meteorology, Pune*

Malaysia: *Mohd Talib Latif, Universiti Kebangsaan Malaysia*

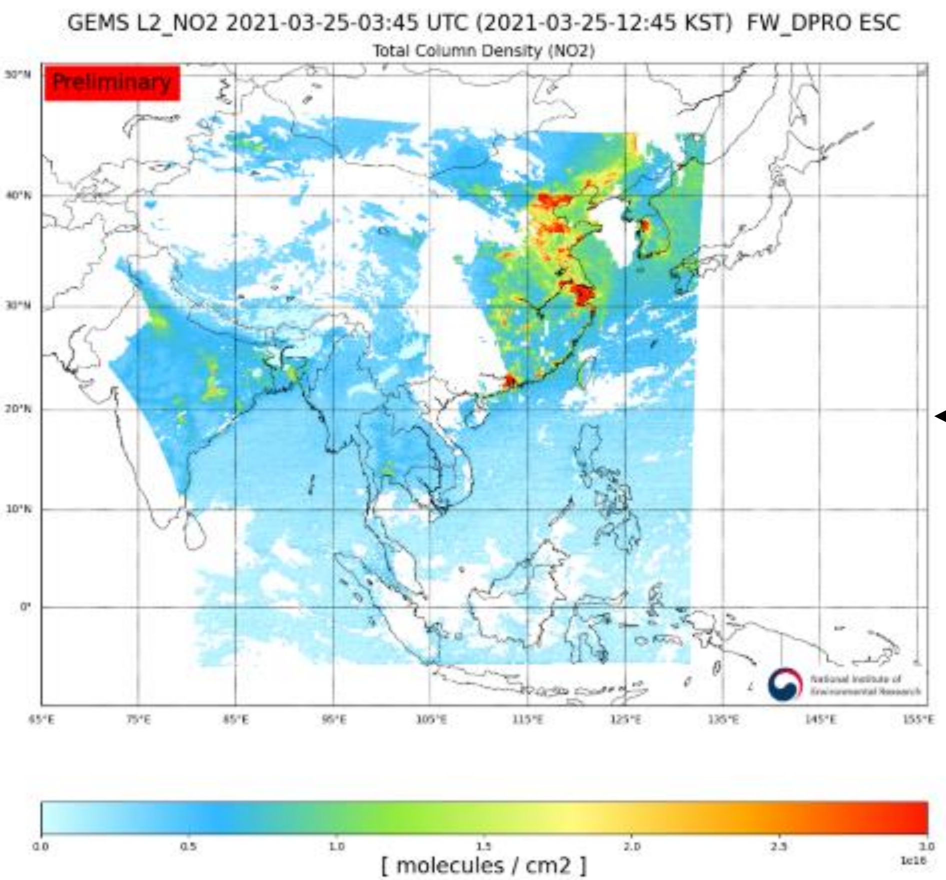
Singapore: *Liya Yu, National University of Singapore*

Japan: *Hiroshi Tanimoto, NIES; Yugo Kanaya, JAMSTEC*

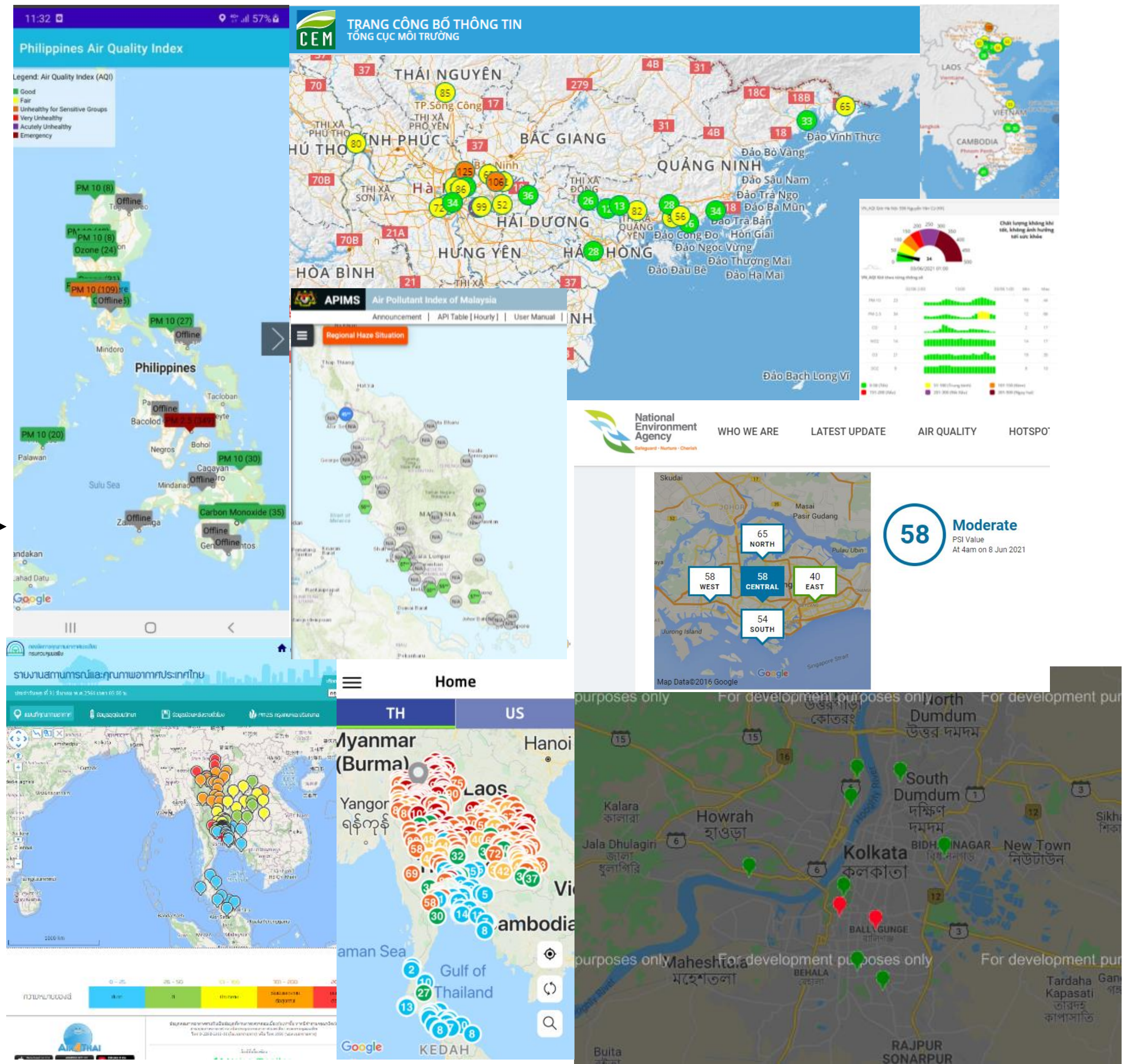
White paper at https://espo.nasa.gov/asia-aq

ASIA-AQ will contribute to reconciling the view of air quality from space with what is observed on the ground…

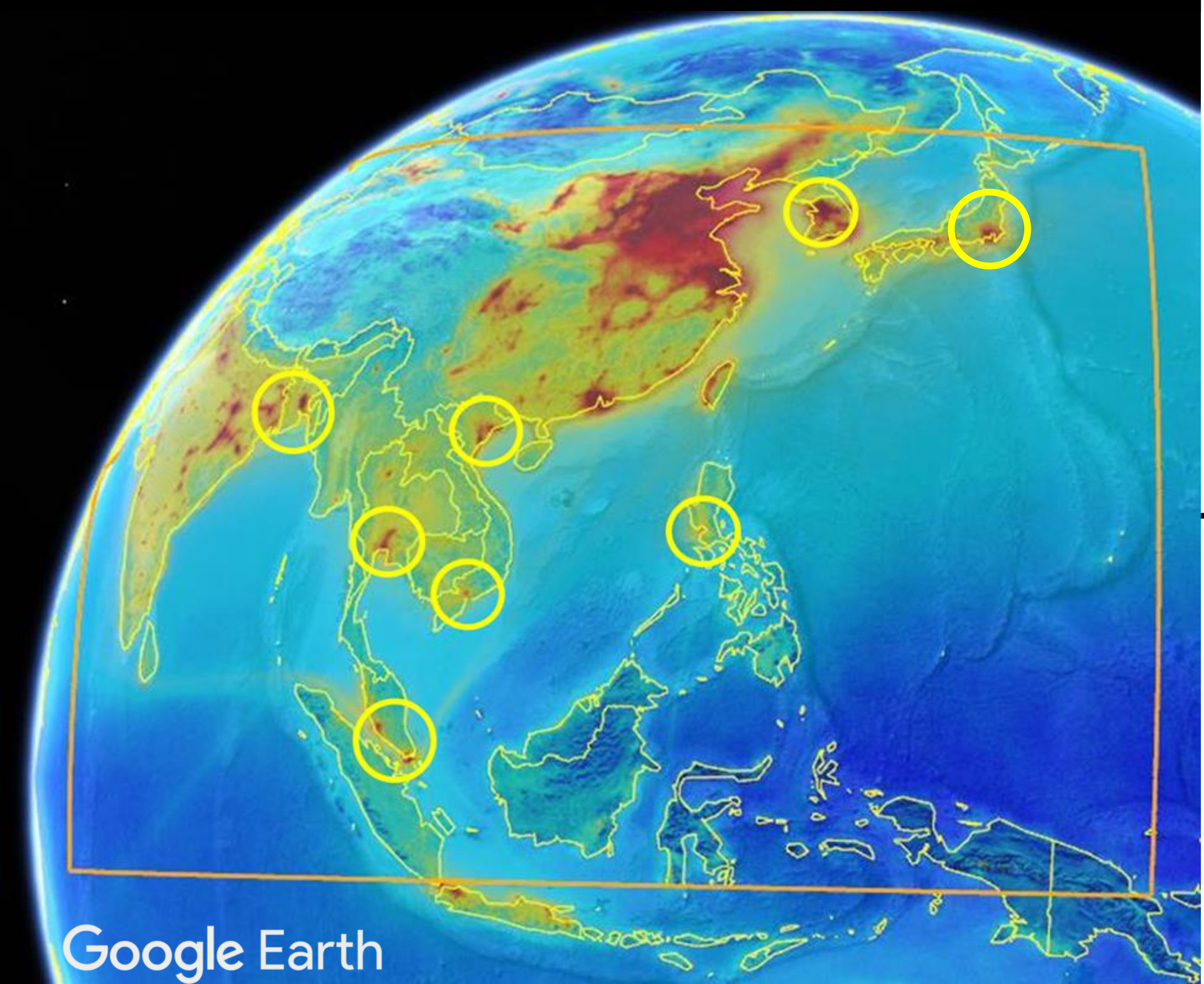
GEMS Satellite Observations



Monitoring Data



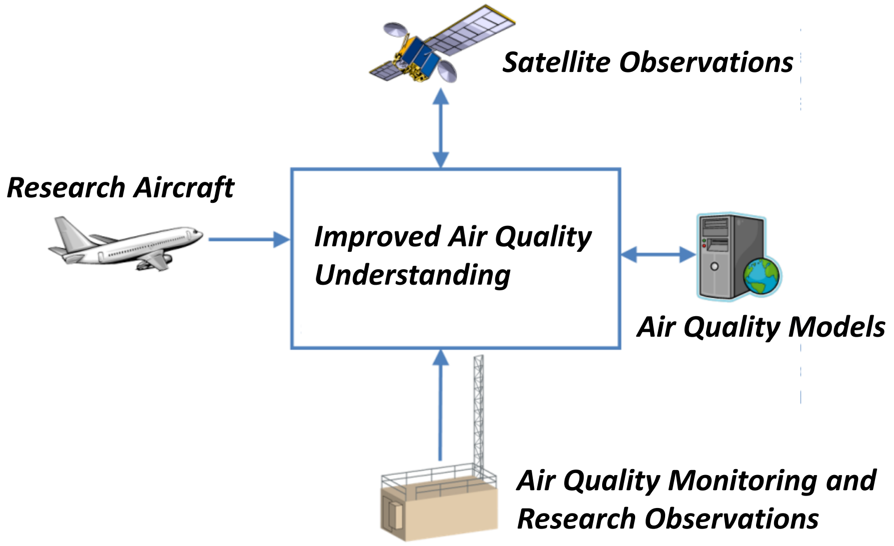
Airborne and Satellite Investigation of Asian Air Quality (ASIA-AQ)



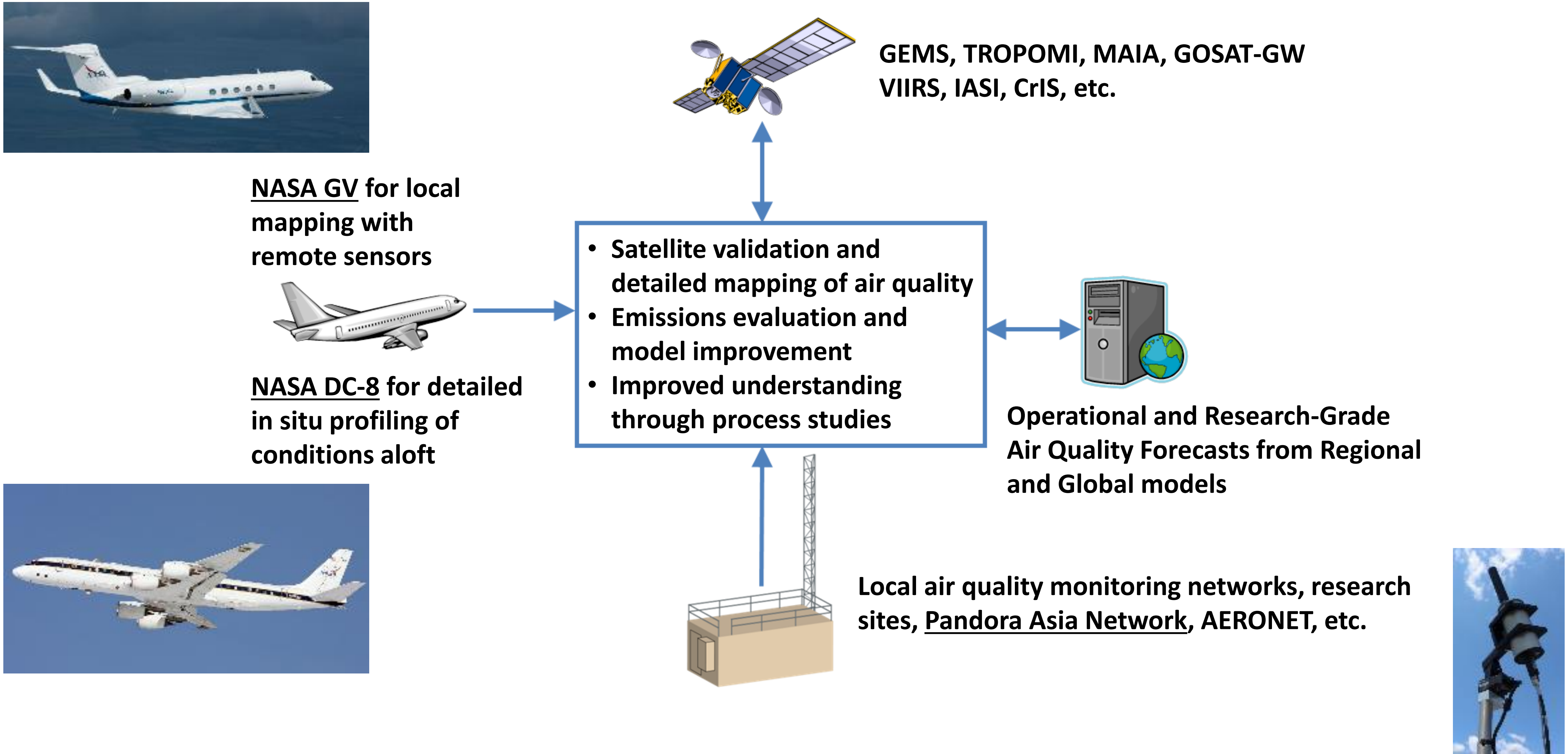
Purpose: Improve understanding of the factors controlling local air quality across Asia through multi-perspective observations and modeling

Approach: Conduct airborne sampling across three to five locations in collaboration with local scientists, air quality agencies, and other relevant government partners.

Philosophy: Openly share data during all phases, conduct joint analysis with local scientists and air quality agencies, and report findings to local governments



An integrated observing strategy is needed to bridge between satellite and ground measurements and to improve air quality models.



ASIA-AQ Scientific Goals

Satellite Validation and Interpretation:
Detailed vertical structure to assess retrievals throughout the day
Aerosol corrections to trace gas retrievals
Pollutant distributions relative to sources
Satellite proxies for secondary aerosol (e.g., $CH_2O/NO_2/SO_2$ versus SOA/nitrate/sulfate)
Satellite proxies for ozone (e.g., CH_2O versus surface O_3)

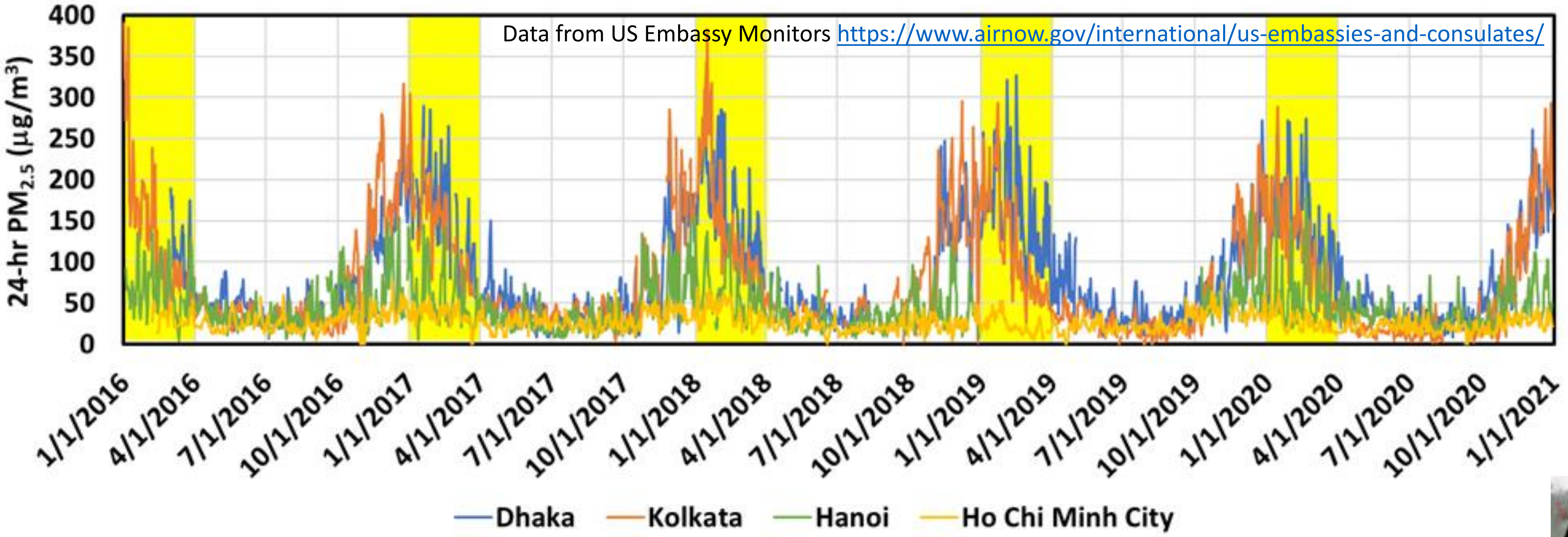
Emissions Quantification and Verification:
Observation-based assessment through comparison with models
Comparison of bottom-up inventories versus top-down assessments
Source apportionment based on detailed composition analysis

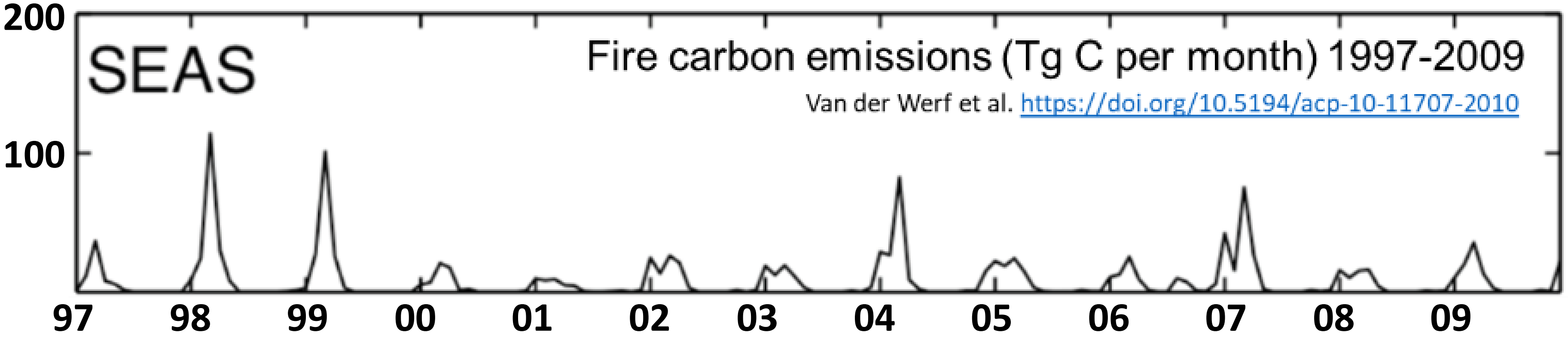
Model Evaluation:
Observation-based evaluation of model forecasting ability
Representation of chemistry and processes affecting the production of secondary pollutants
Assessment of local versus transboundary impacts

Aerosol/Haze and Ozone Chemistry:
Deeper understanding of the factors governing the conversion of precursor gases into fine particle pollution and ozone
Primary versus secondary sources of fine particle pollution
Detailed aerosol composition and impacts on meteorology and remote sensing.

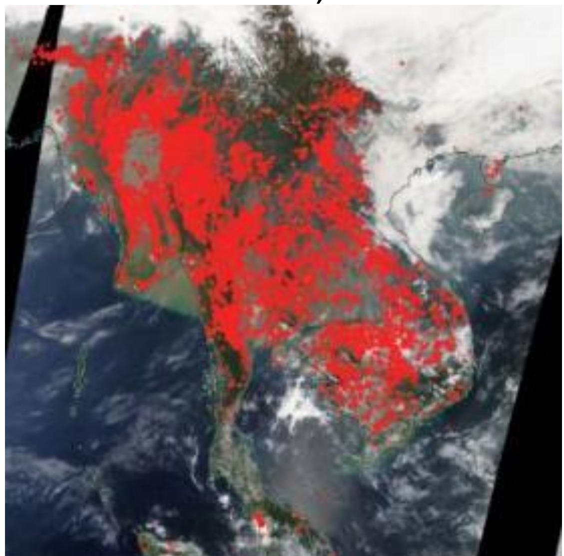
ASIA-AQ Campaign Window: January-March 2024 timeframe

- **Dry Season, peak particulate pollution**
- **Widespread agricultural burning in SE Asia**



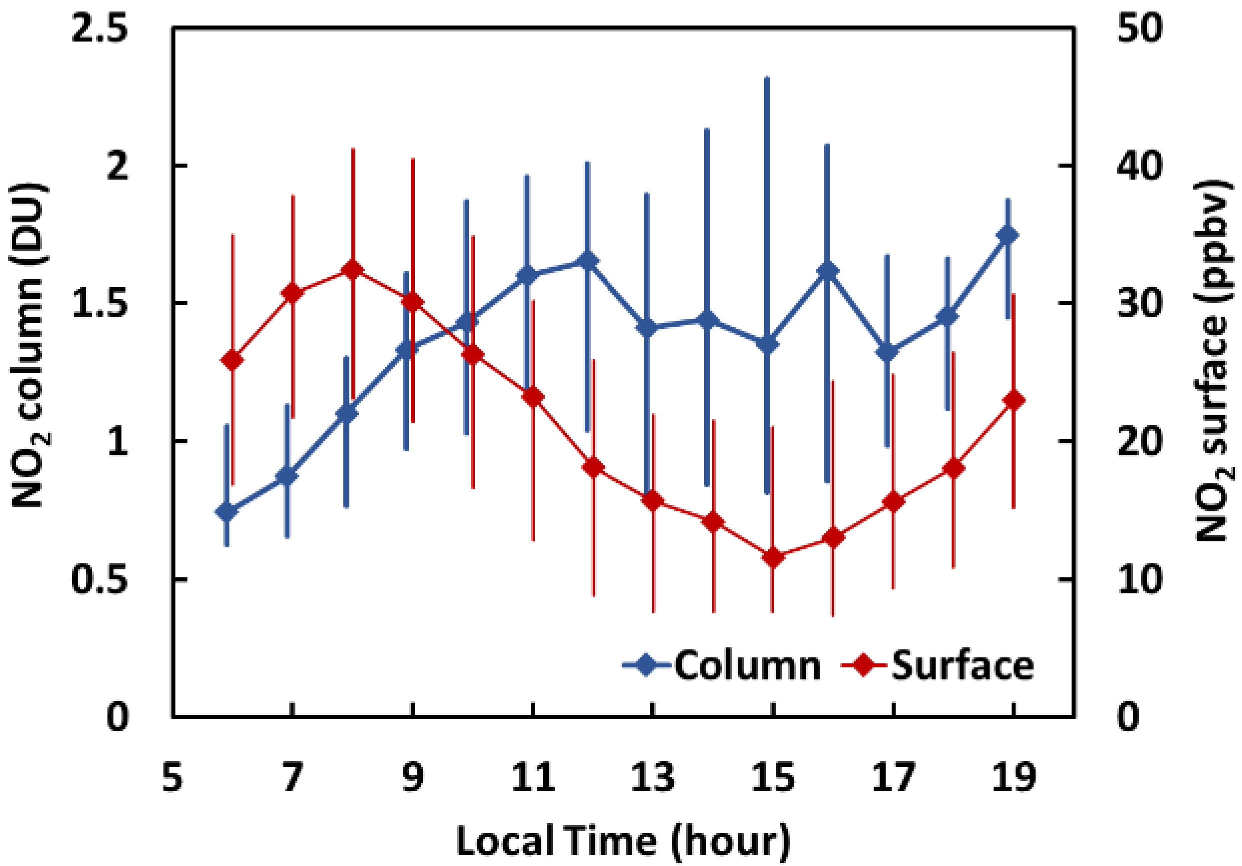


NASA Worldview, 1 Mar 2021

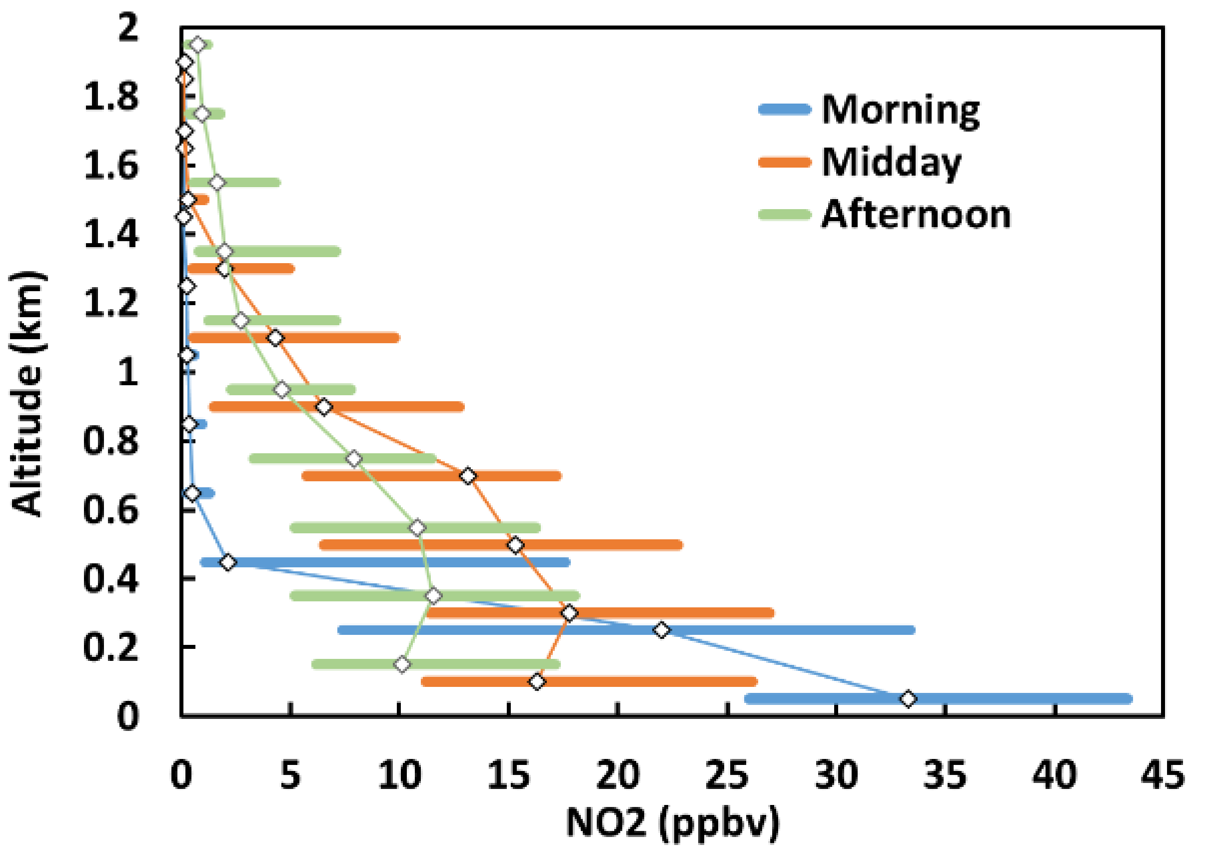


Diurnal statistics for NO_2 demonstrate the difference between surface and column behavior calling for integrated observations

Surface and Column NO_2

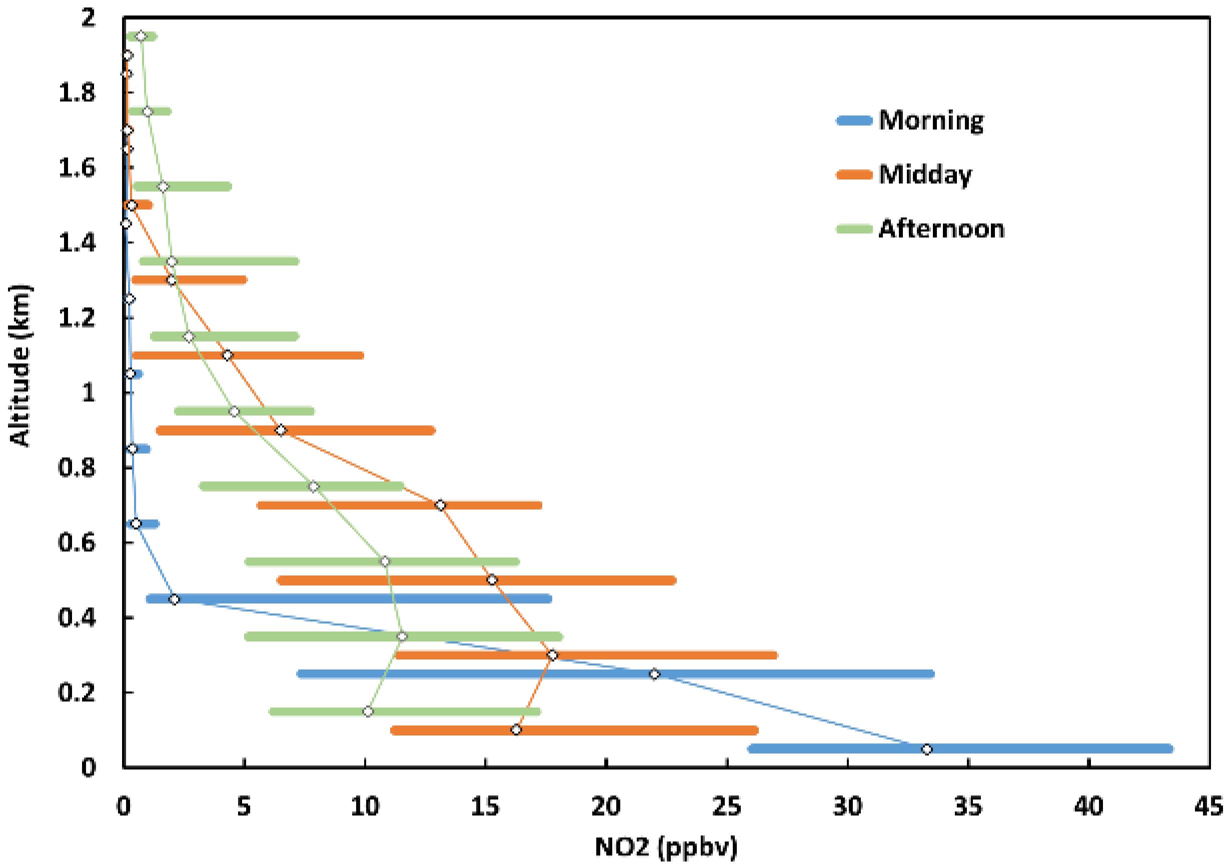


Aircraft Profiles of NO_2

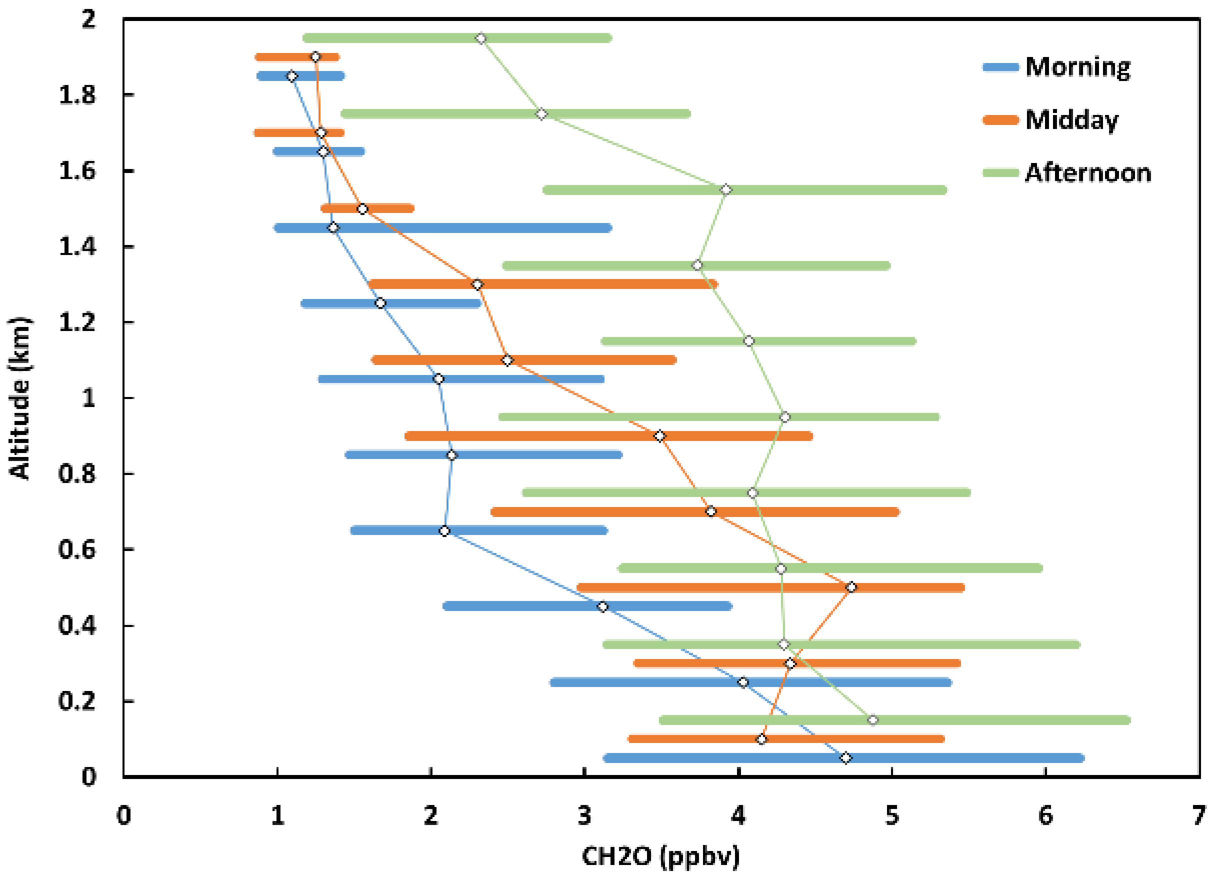


Differences in key ozone precursors demonstrate the complexity of the surface-column relationship

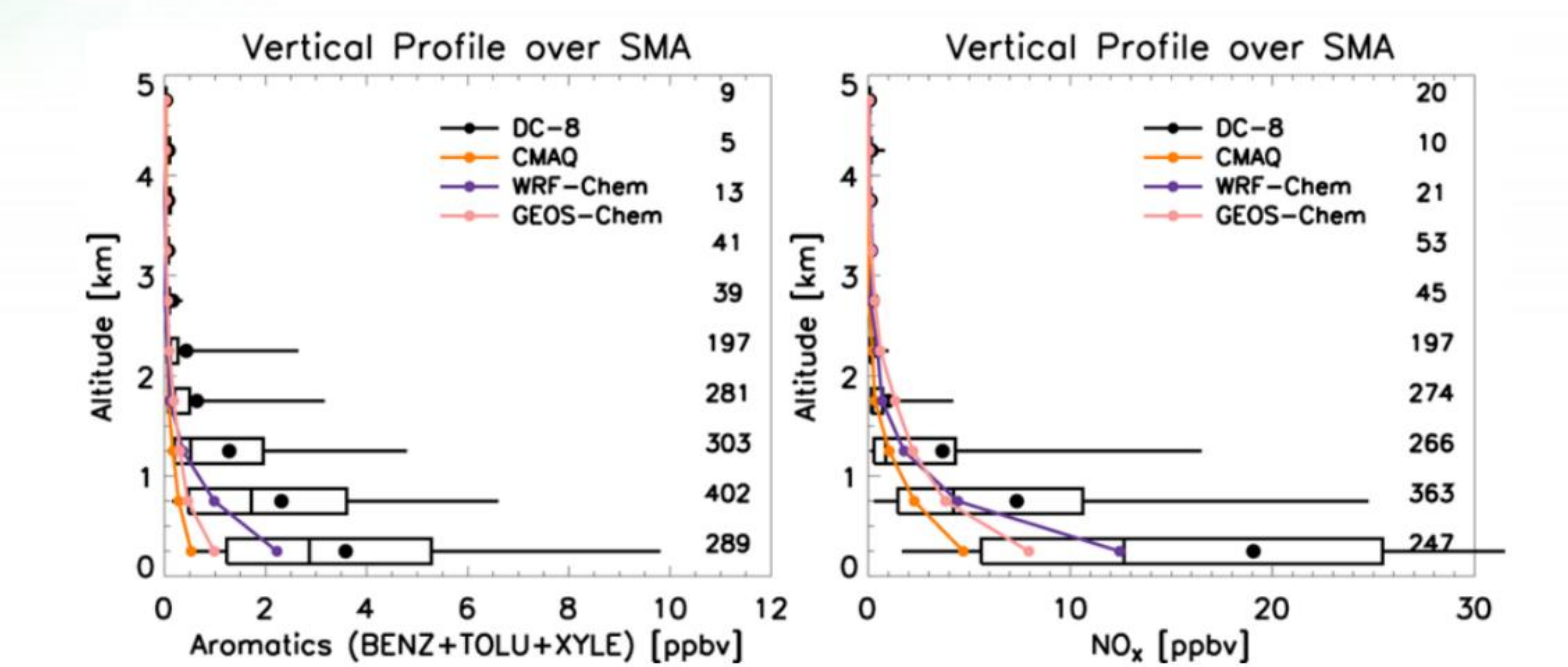
Olympic Park NO_2 vertical profiles



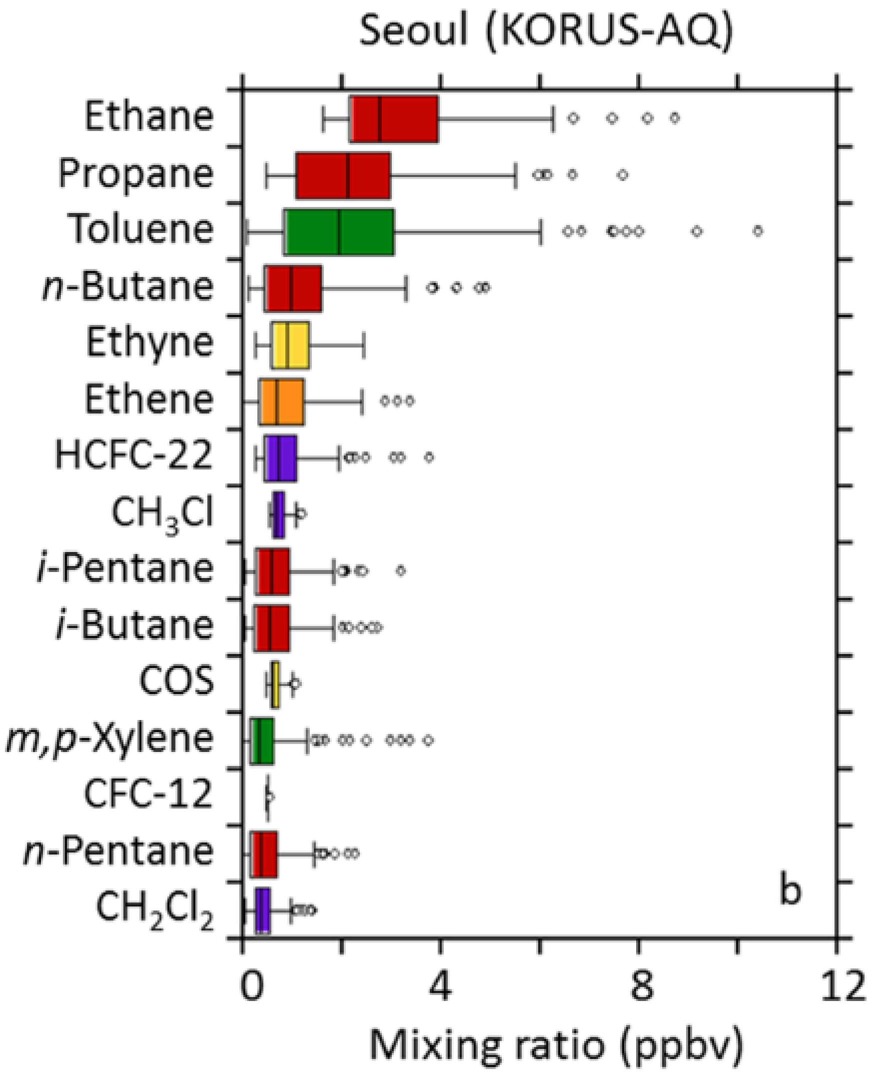
Olympic Park CH_2O vertical profiles

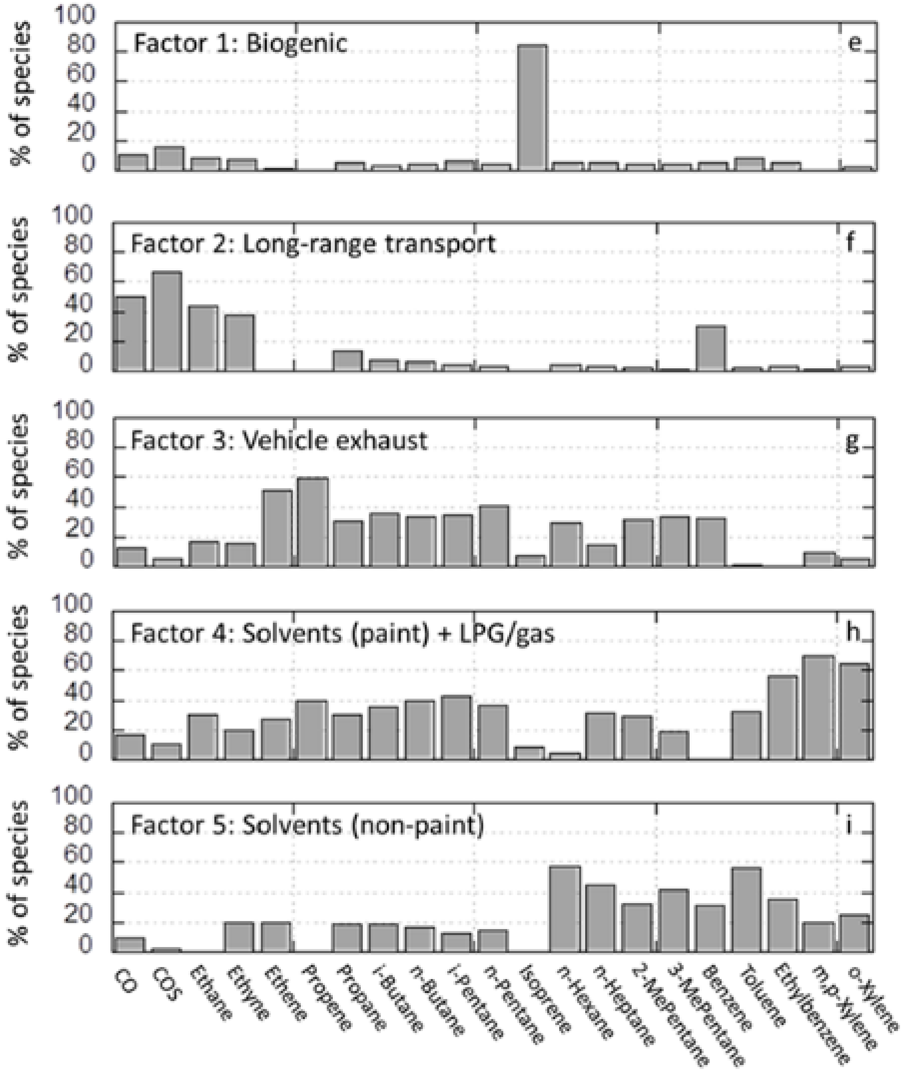


Model-measurement comparisons over urban areas provide an important test of emissions



Detailed measurements of speciated VOCs and other tracer compounds enables source apportionment analysis to better understand emissions





Next Steps:

- **Solicit feedback from the community. Much more detail than could be provided in this short talk is available from the white paper. We would like to hear from you if you are interested and have thoughts to share.**

- **Visit candidate locations to engage local governments, gain support, encourage local funding, and secure flight permissions (starting in Summer 2022)**

- **Assemble the science team through a NASA solicitation (proposals due October 2022) and local funding opportunities in each country.**

- **Identify opportunities for young scientists to participate in ASIA-AQ through post-doctoral or visiting scientist roles with measurement and modeling groups.**

White paper at https://espo.nasa.gov/asia-aq

BACKUP SLIDES

NASA GV instrument payload for ASIA-AQ

The GV payload will consist of two remote sensing instruments. Flying at 28,000 ft, the aircraft can map an area of 135 x 50 km three times during a flight of eight hours.

1) GEO-CAPE Airborne Simulator (GCAS): This UV spectrometer with fly at high altitude over the predetermined region to map trace gas columns beneath the aircraft for NO2 and HCHO with 250x550m resolution. These measurements will provide valuable insight on NOx and VOC emissions.

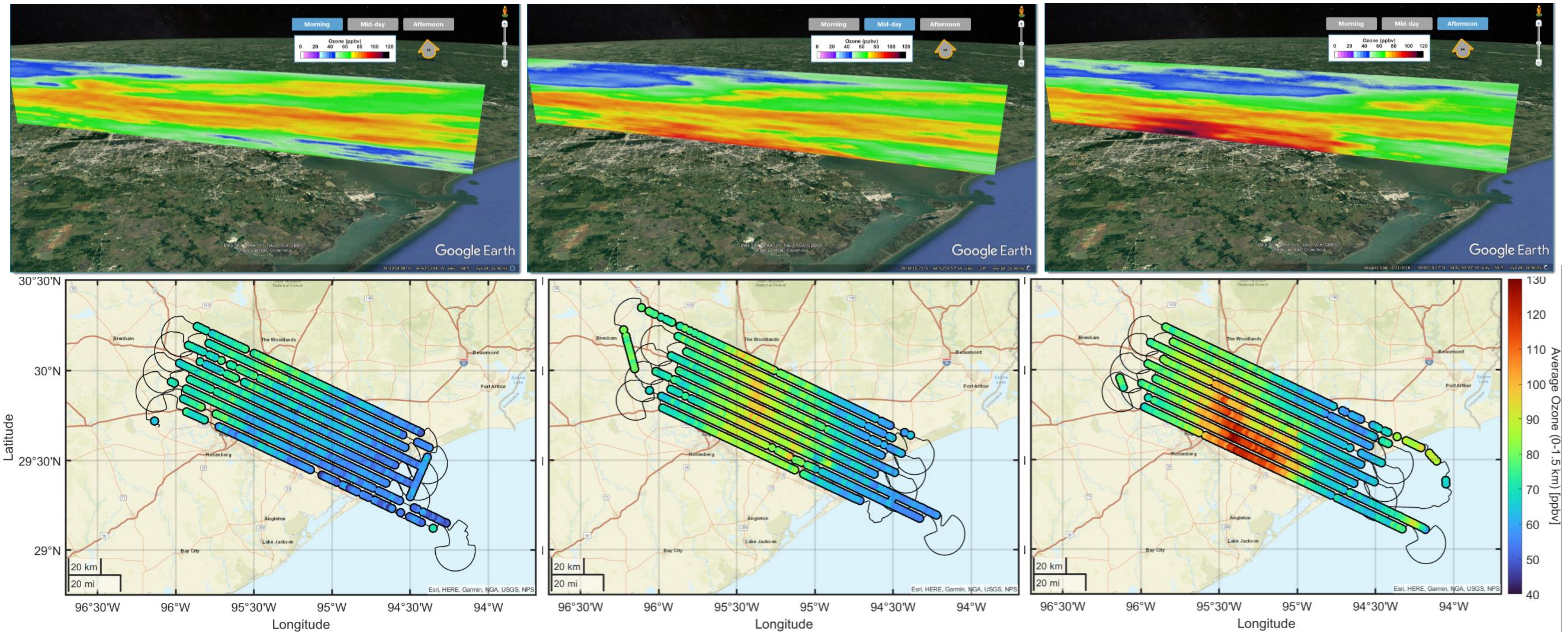
2) High Spectral Resolution Lidar/Differential Absorption Lidar (HSRL/DIAL) – This combined lidar system will provide information on aerosols (HSRL) and ozone (DIAL). HSRL provides a wealth of detail with respect to aerosol properties that include backscatter, extinction, depolarization, and intensive aerosol properties.

Example of DIAL measurements of ozone over Houston, Texas on 8 September 2021

The top three panels show selected vertical cross-sections (surface to 7 km) of ozone below the aircraft

The bottom three panels show average ozone over the lowest 1.5 km

Morning | Mid-day | Afternoon

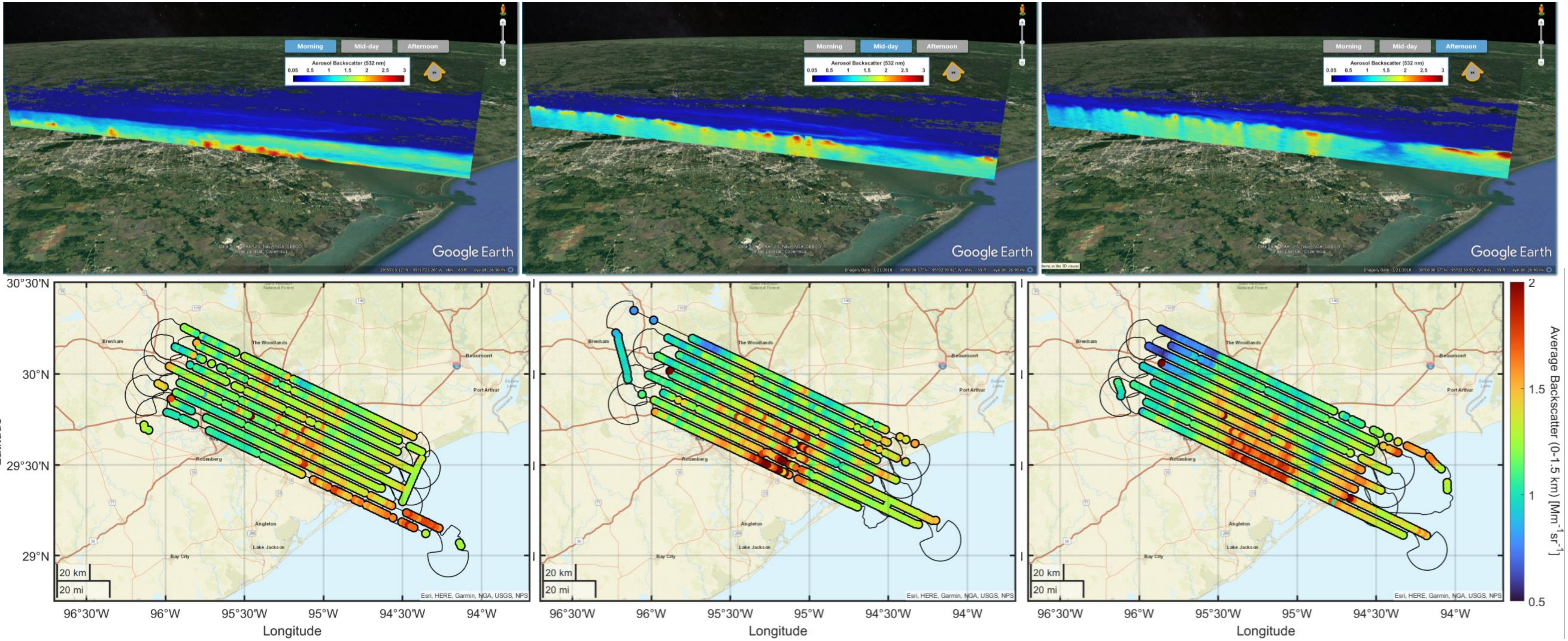


Example of HSRL measurements of aerosol backscatter over Houston, Texas on 8 September 2021

The top three panels show selected vertical cross-sections of aerosol backscatter below the aircraft (note increasing boundary layer depth from morning to afternoon)

The bottom three panels show average aerosol backscatter over the lowest 1.5 km

Morning | Mid-day | Afternoon



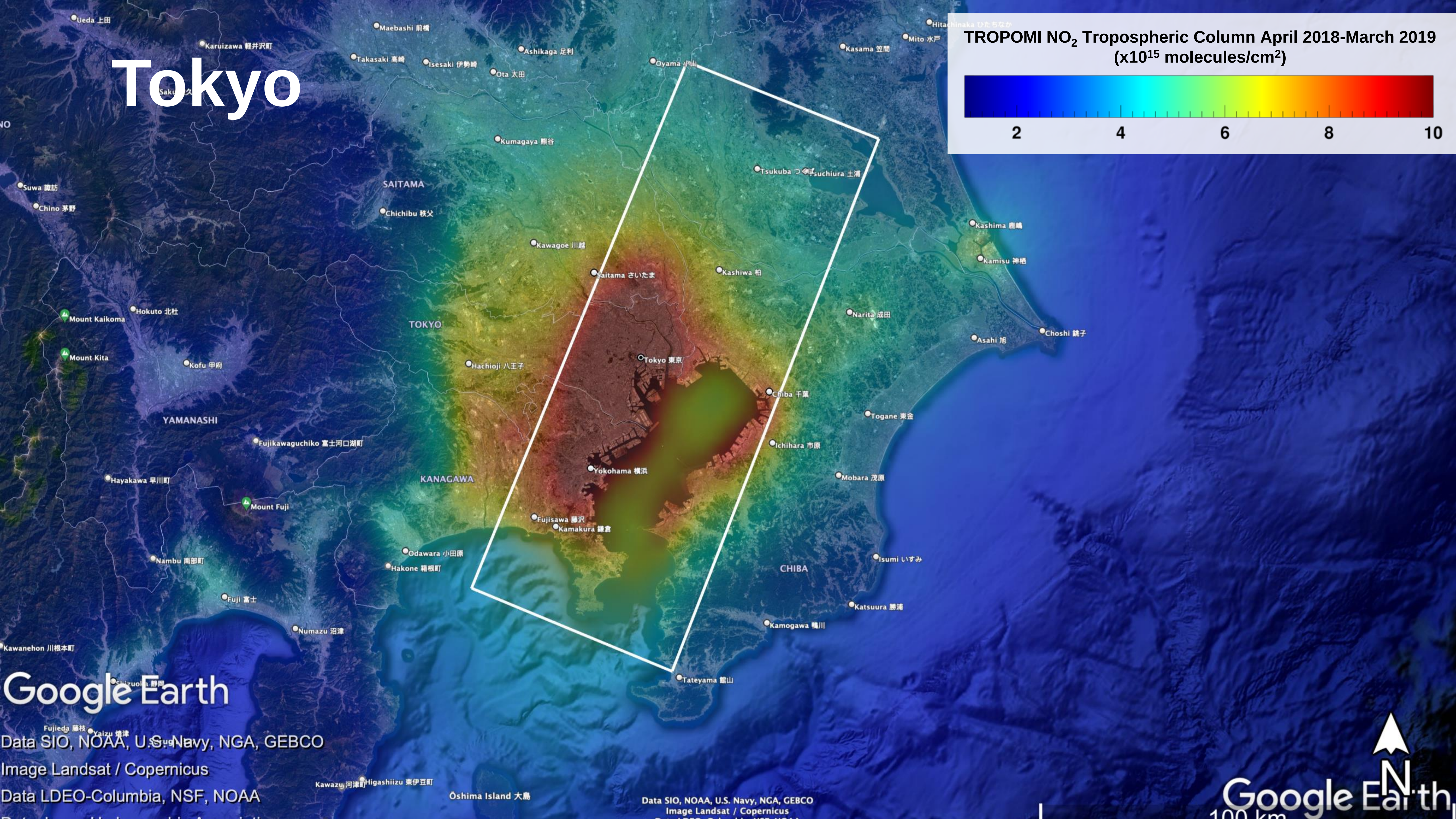
NASA DC-8 instrument payload for ASIA-AQ

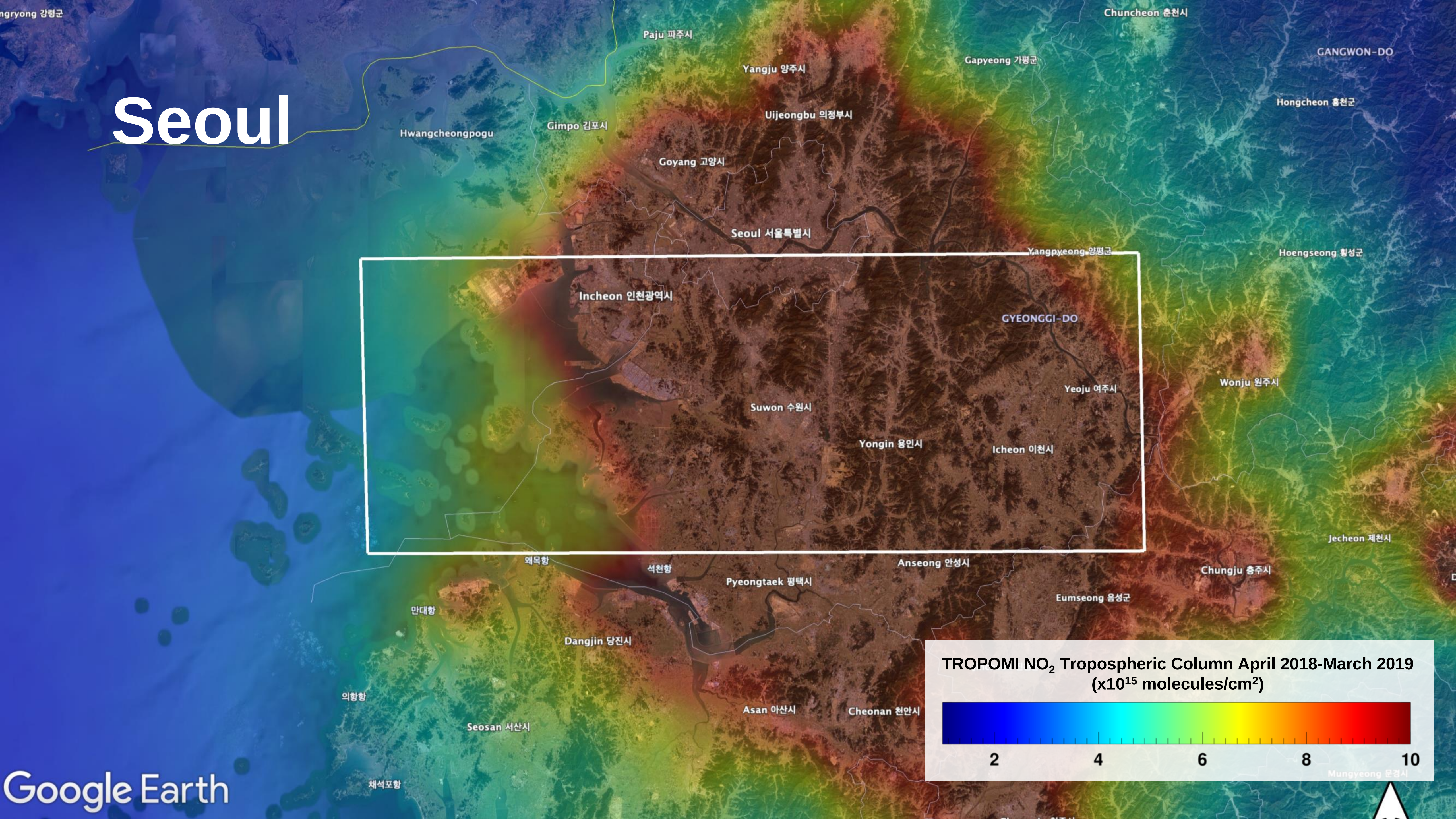
While the specific instrument payload is still to be competed later this year, the variables listed below represent the minimum DC-8 measurement suite.

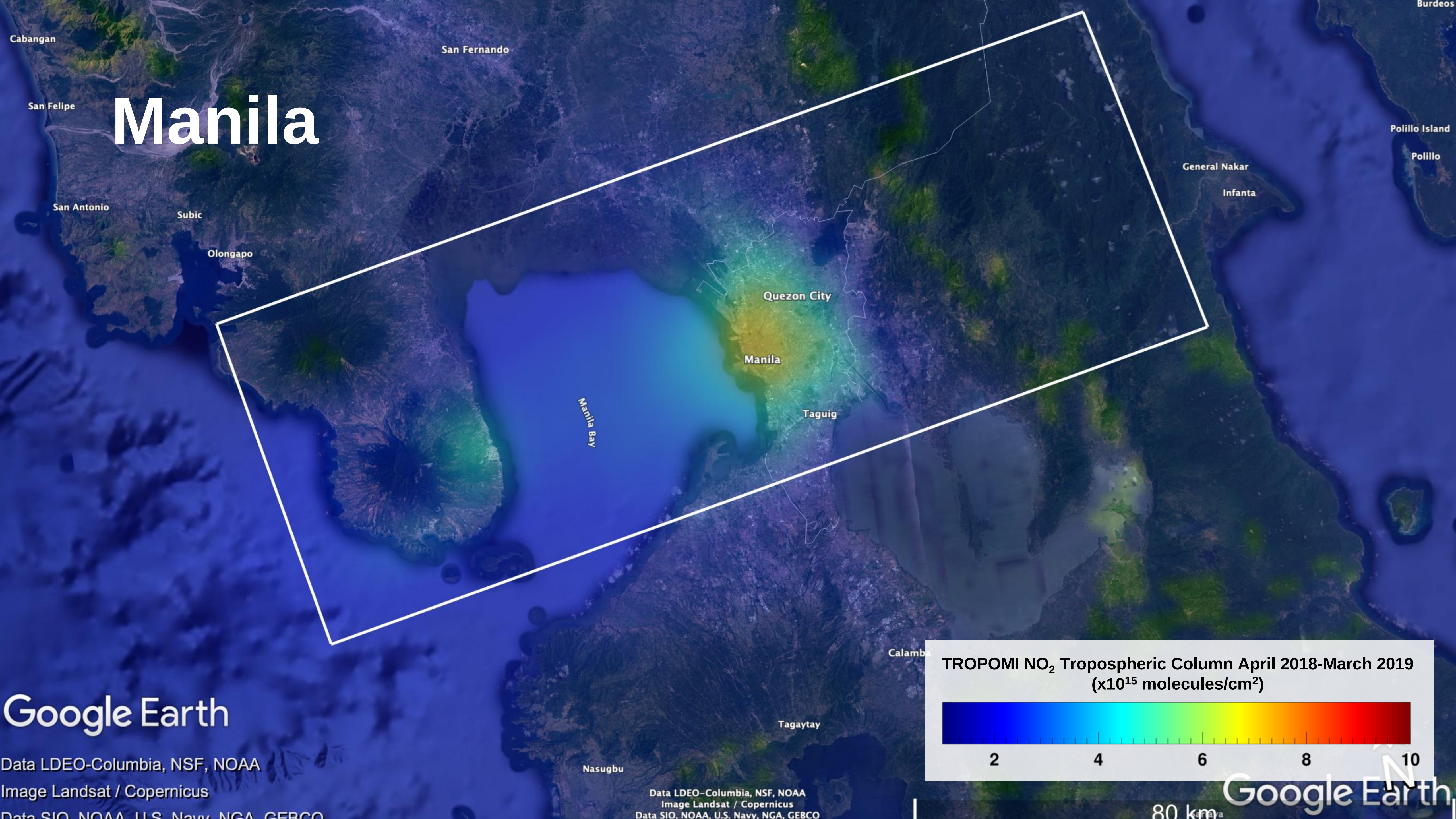
Trace Gas Observations
O_3, H_2O, CO, CH_4, CO_2, SO_2, H_2O_2, ROOH
NO, NO_2, HNO_3, HONO, PANs, $RONO_2$, NH_3
Speciated hydrocarbons (alkanes, alkenes, aromatics, oxygenated VOCs, etc.), HCN, CH_3CN
Aerosol Observations
Aerosol number and size distribution
Aerosol properties (volatility, scattering, absorption, hygroscopicity)
Aerosol composition (ionic composition, organic composition, black carbon)
Radiation and Meteorology
UV spectral actinic flux
High resolution meteorology (temperature, pressure, winds)

Repetitive sampling over the Seoul Metropolitan Area serves as a model for the feasibility

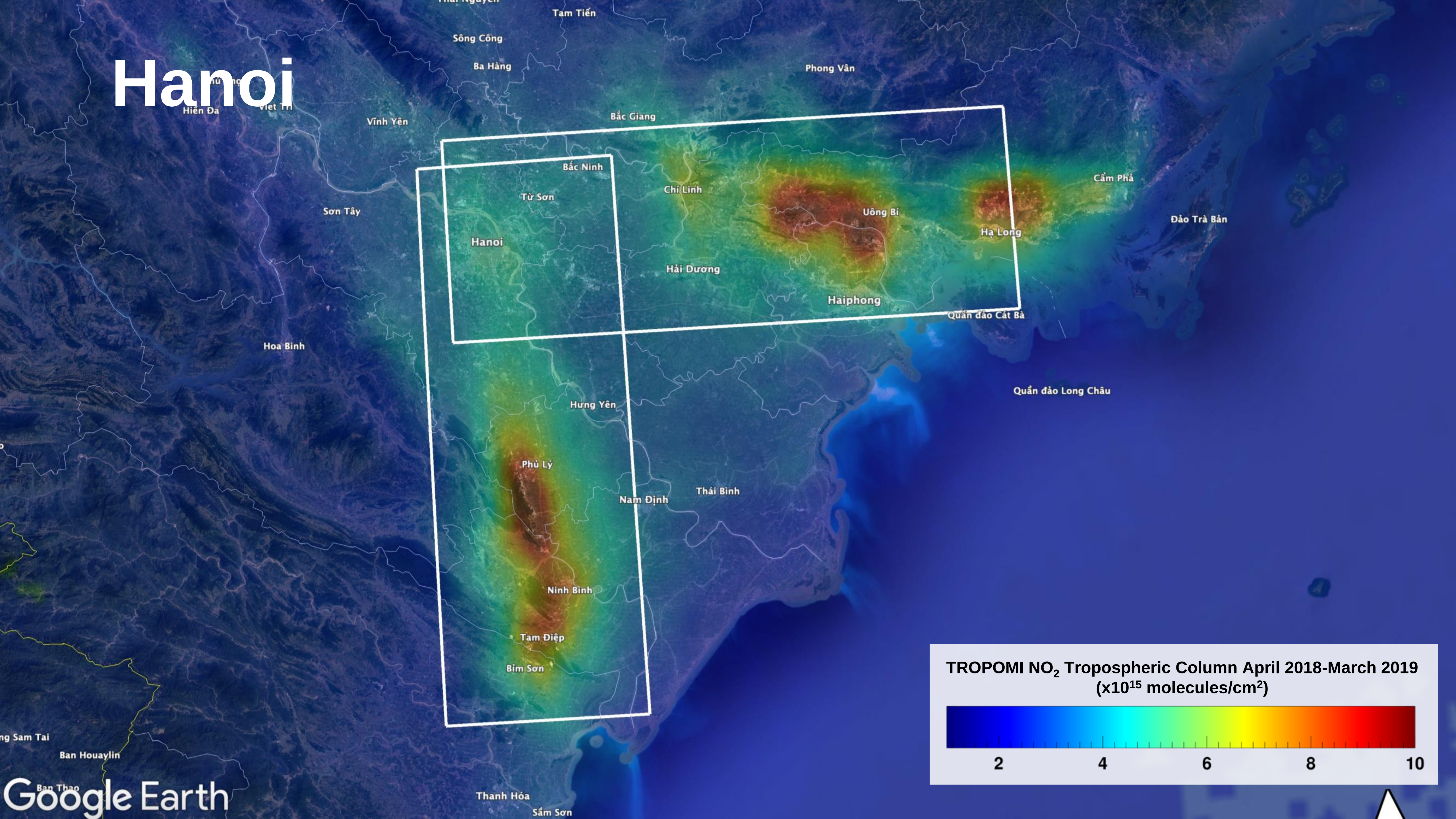
Repetitive sampling over the Seoul Metropolitan Area serves as a model for the feasibility AND the challenge


Tokyo
TROPOMI NO_2 Tropospheric Column April 2018-March 2019
($x10^{15}$ molecules/cm^2)
2
4
6
8
10
SAITAMA
TOKYO
KANAGAWA
YAMANASHI
CHIBA
Ueda 上田
Maebashi 前橋
Karuizawa 軽井沢町
Takasaki 高崎
Isesaki 伊勢崎
Ashikaga 足利
Ota 太田
Oyama 小山
Mito 水戸
Kasama 笠間
Kumagaya 熊谷
Tsukuba つくば
Tsuchiura 土浦
Suwa 諏訪
Chino 茅野
Chichibu 秩父
Kawagoe 川越
Saitama さいたま
Kashiwa 柏
Kashima 鹿嶋
Kamisu 神栖
Narita 成田
Choshi 銚子
Asahi 旭
Hokuto 北杜
Mount Kaikoma
Mount Kita
Kofu 甲府
Hachioji 八王子
Tokyo 東京
Chiba 千葉
Togane 東金
Ichihara 市原
Fujikawaguchiko 富士河口湖町
Yokohama 横浜
Mobara 茂原
Hayakawa 早川町
Mount Fuji
Fujisawa 藤沢
Kamakura 鎌倉
Odawara 小田原
Hakone 箱根町
Isumi いすみ
Nambu 南部町
Fuji 富士
Katsuura 勝浦
Kamogawa 鴨川
Numazu 沼津
Kawanehon 川根本町
Tateyama 館山
Higashiizu 東伊豆町
Ōshima Island 大島
Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Data LDEO-Columbia, NSF, NOAA
N


Seoul
Paju 파주시
Chuncheon 춘천시
Yangju 양주시
Gapyeong 가평군
GANGWON-DO
Hongcheon 홍천군
Uijeongbu 의정부시
Hwangcheongpogu
Gimpo 김포시
Goyang 고양시
Seoul 서울특별시
Yangpyeong 양평군
Hoengseong 횡성군
Incheon 인천광역시
GYEONGGI-DO
Wonju 원주시
Yeoju 여주시
Suwon 수원시
Yongin 용인시
Icheon 이천시
Jecheon 제천시
왜목항
석천항
Anseong 안성시
Chungju 충주시
Pyeongtaek 평택시
Eumseong 음성군
만대항
Dangjin 당진시
의항항
Asan 아산시
Cheonan 천안시
Seosan 서산시
채석포항
Google Earth
TROPOMI NO_2 Tropospheric Column April 2018-March 2019
($x10^{15}$ molecules/cm^2)
2
4
6
8
10

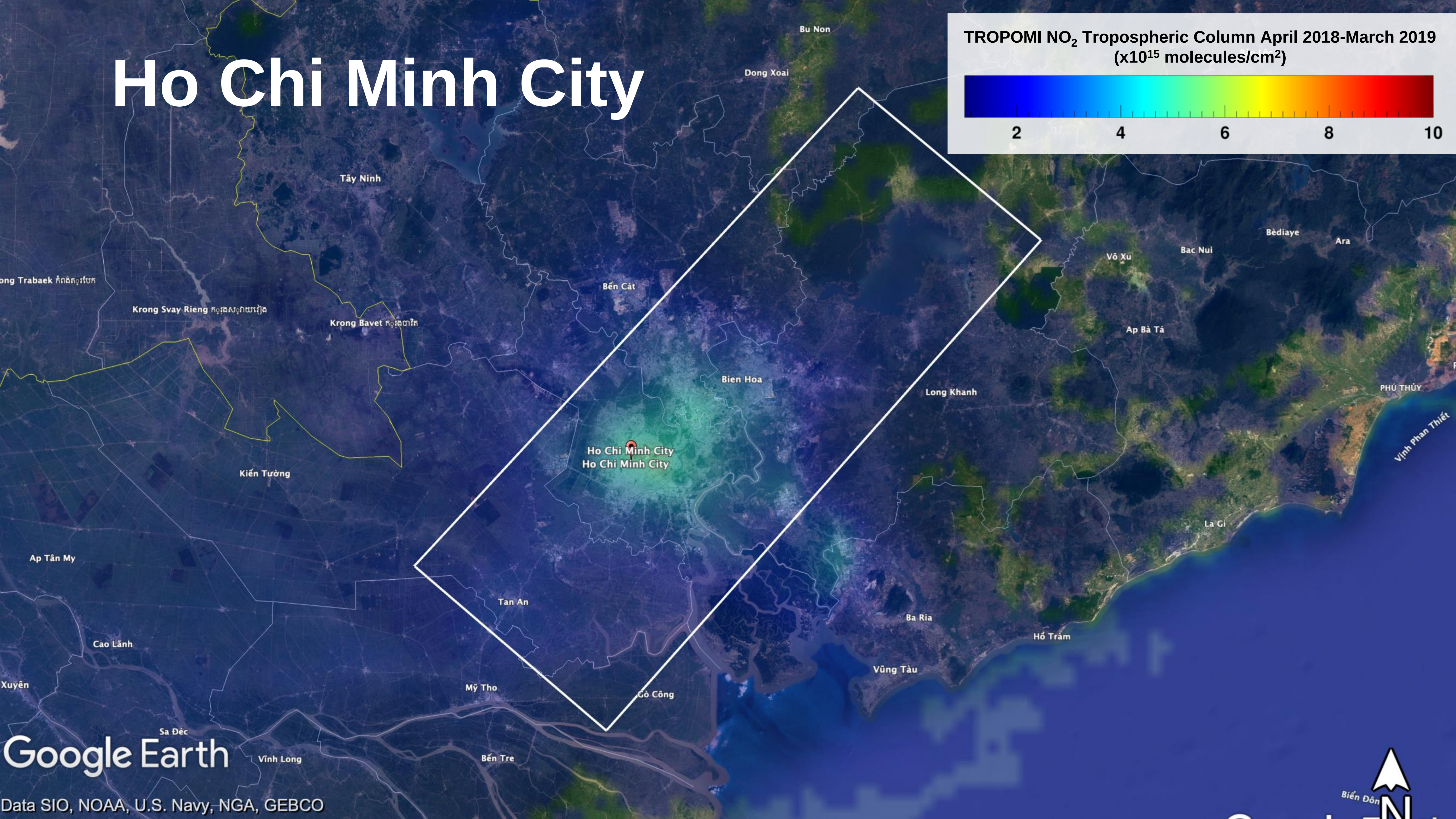

Manila
Cabangan
San Fernando
San Felipe
San Antonio
Subic
Olongapo
Quezon City
Manila
Manila Bay
Taguig
General Nakar
Infanta
Polillo Island
Polillo
Burdeos
Calamba
Tagaytay
Nasugbu
TROPOMI NO2 Tropospheric Column April 2018-March 2019
(x10^15 molecules/cm^2)
2
4
6
8
10
Google Earth
Data LDEO-Columbia, NSF, NOAA
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
80 km

Hanoi

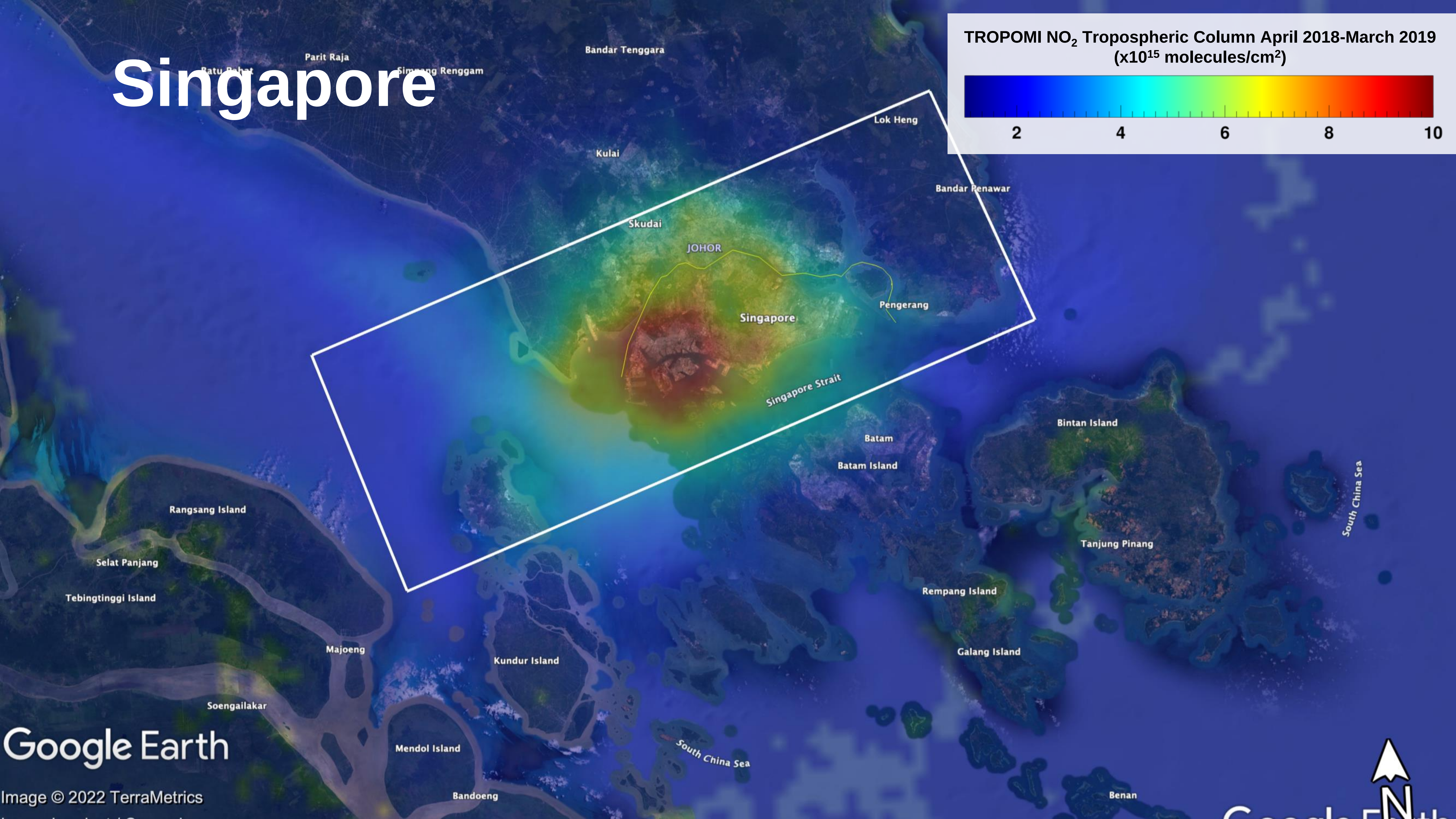


Tam Tiến
Sông Công
Ba Hàng
Phong Vân
Hiền Đa
Vĩnh Yên
Bắc Giang
Bắc Ninh
Từ Sơn
Chí Linh
Uông Bí
Cẩm Phả
Hạ Long
Đảo Trà Bản
Sơn Tây
Hanoi
Hải Dương
Haiphong
Quần đảo Cát Bà
Hoa Binh
Quần đảo Long Châu
Hưng Yên
Phủ Lý
Nam Định
Thái Bình
Ninh Bình
Tam Điệp
Bỉm Sơn
Ban Houaylin
Thanh Hóa
Sầm Sơn
Google Earth
TROPOMI NO_2 Tropospheric Column April 2018-March 2019
($x10^{15}$ molecules/cm^2)
2
4
6
8
10

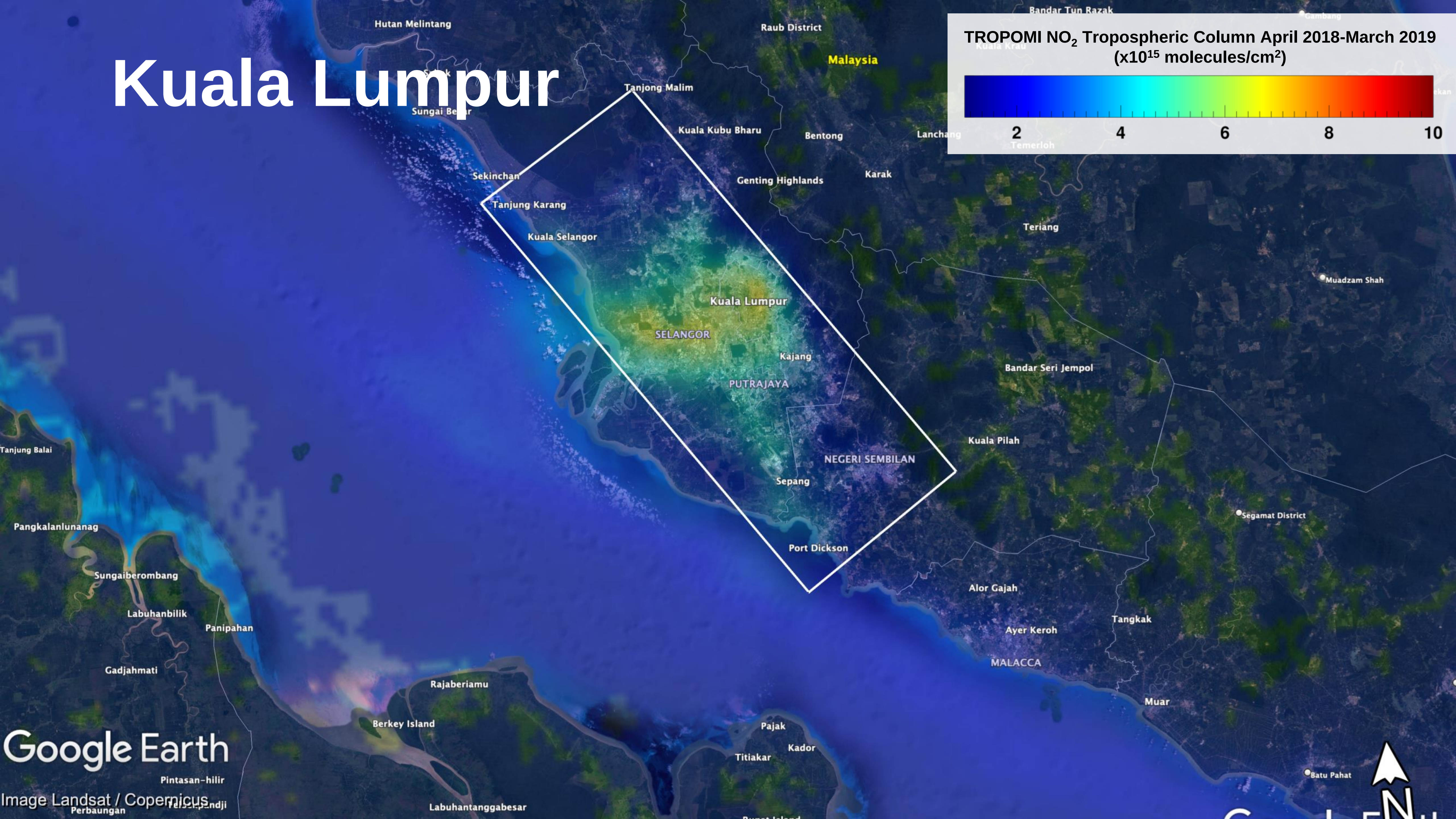
Ho Chi Minh City



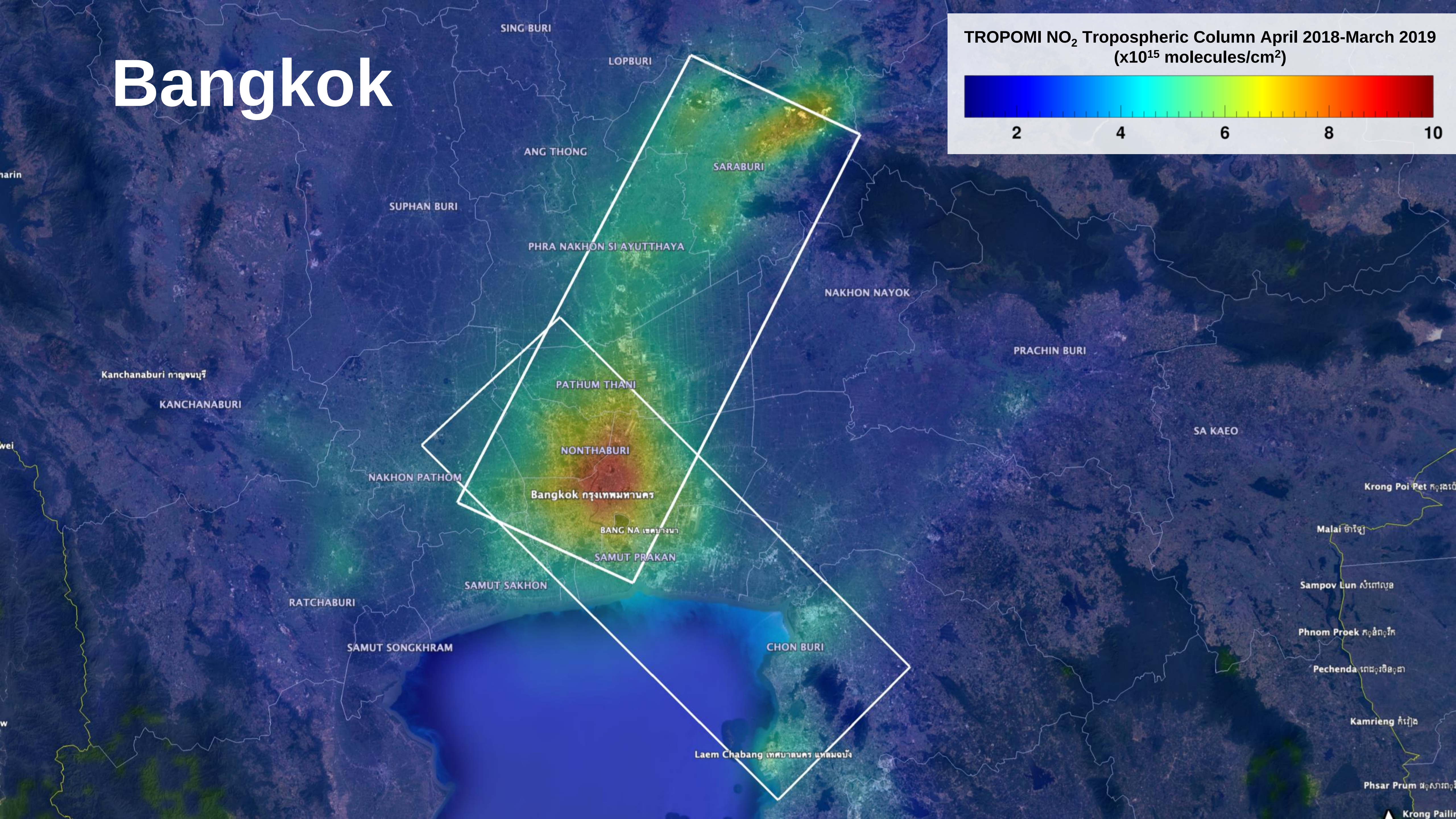
Singapore


TROPOMI NO_2 Tropospheric Column April 2018-March 2019
($x10^{15}$ molecules/cm^2)
2
4
6
8
10
Parit Raja
Simpang Renggam
Bandar Tenggara
Lok Heng
Kulai
Bandar Penawar
Skudai
JOHOR
Pengerang
Singapore
Singapore Strait
Batam
Batam Island
Bintan Island
Tanjung Pinang
South China Sea
Rangsang Island
Selat Panjang
Tebingtinggi Island
Rempang Island
Majoeng
Kundur Island
Galang Island
Soengailakar
Mendol Island
South China Sea
Bandoeng
Benan
Google Earth
Image © 2022 TerraMetrics
N

Kuala Lumpur

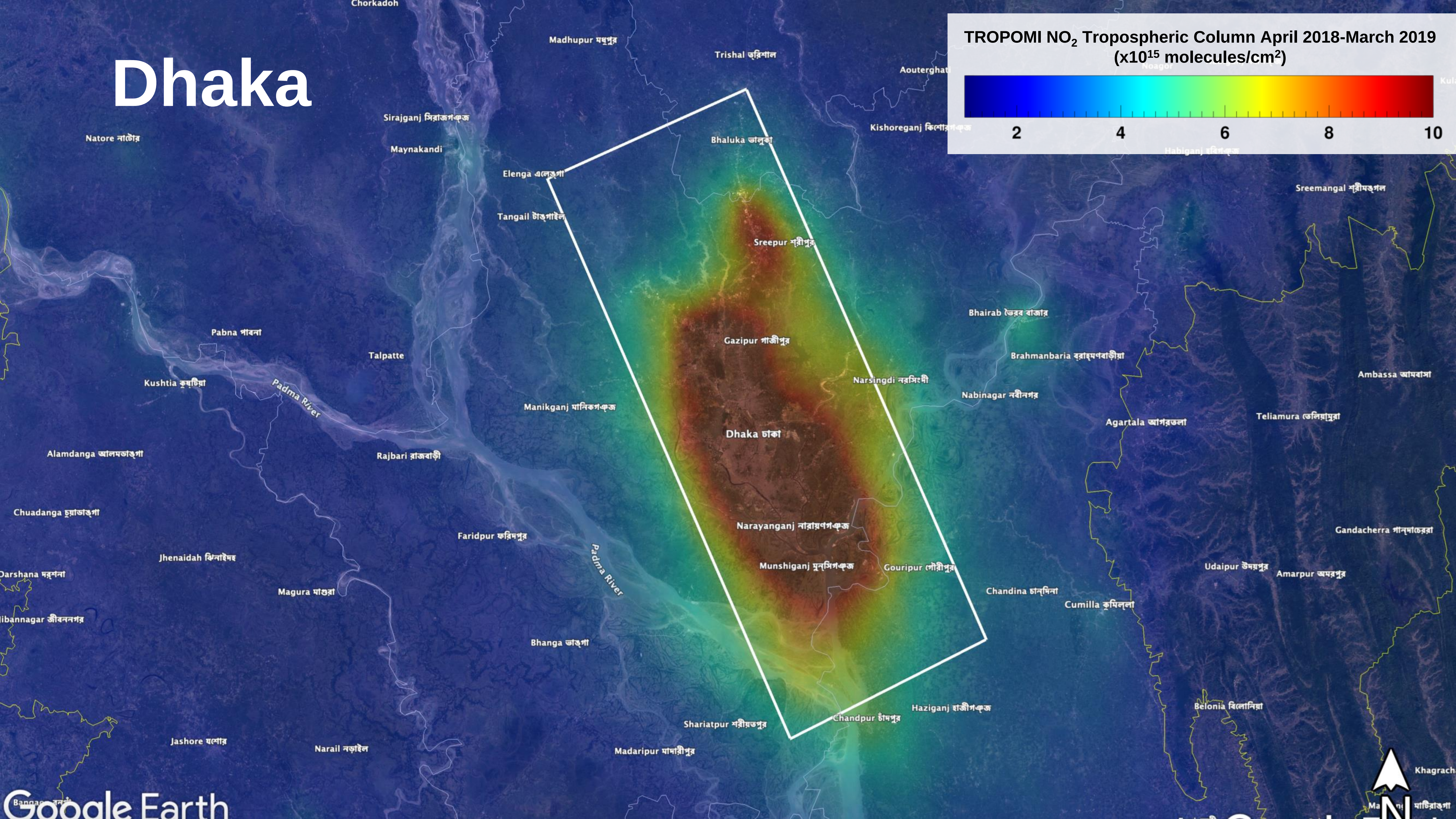


Bangkok

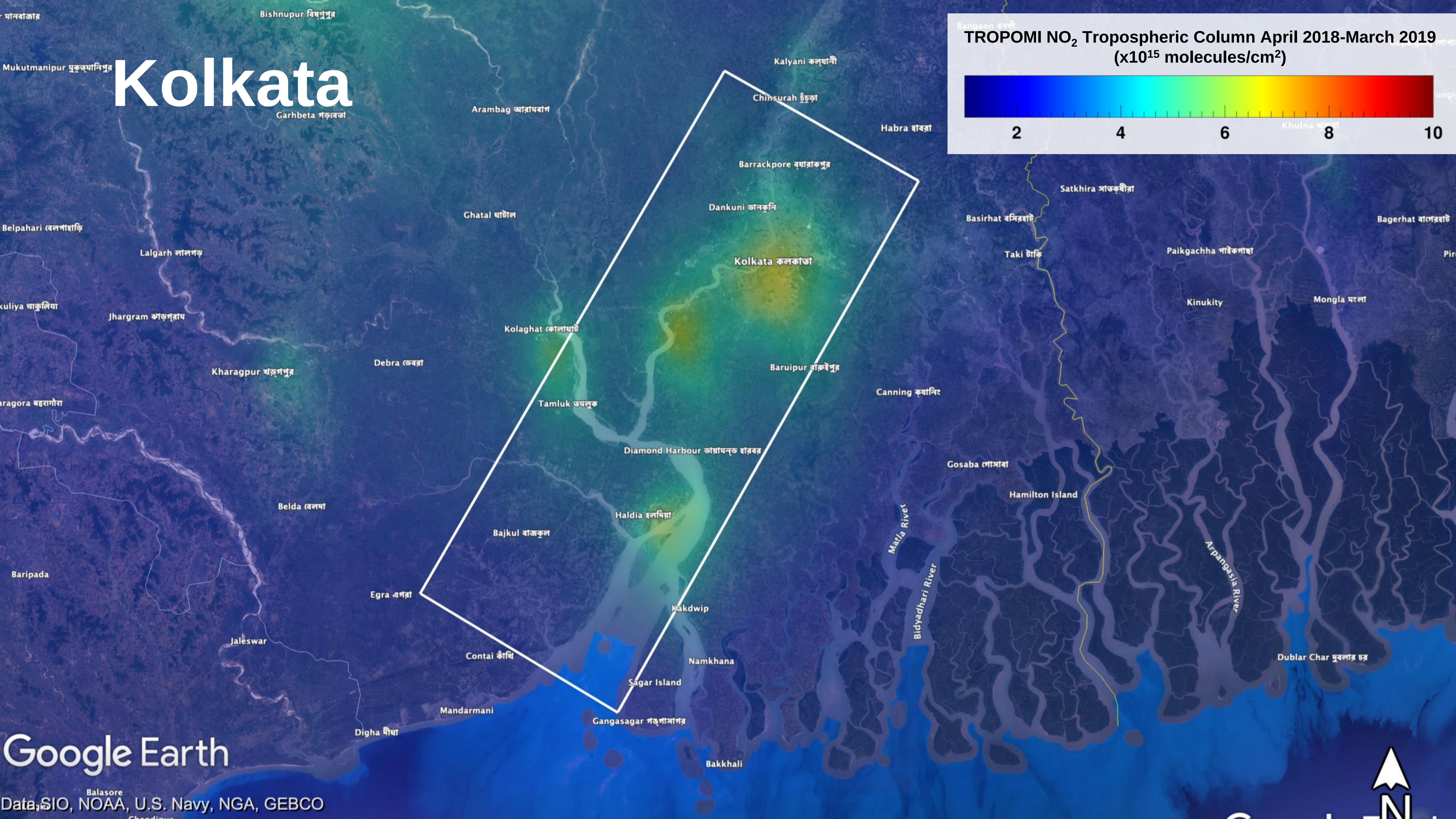


TROPOMI NO_2 Tropospheric Column April 2018-March 2019
($x10^{15}$ molecules/cm^2)
2
4
6
8
10
SING BURI
LOPBURI
ANG THONG
SARABURI
SUPHAN BURI
PHRA NAKHON SI AYUTTHAYA
NAKHON NAYOK
PRACHIN BURI
Kanchanaburi
KANCHANABURI
PATHUM THANI
NONTHABURI
NAKHON PATHOM
Bangkok กรุงเทพมหานคร
BANG NA
SAMUT PRAKAN
SAMUT SAKHON
RATCHABURI
SAMUT SONGKHRAM
CHON BURI
Laem Chabang
SA KAEO
Krong Poi Pet
Malai
Sampov Lun
Phnom Proek
Pechenda
Kamrieng
Phsar Prum
Krong Pailin

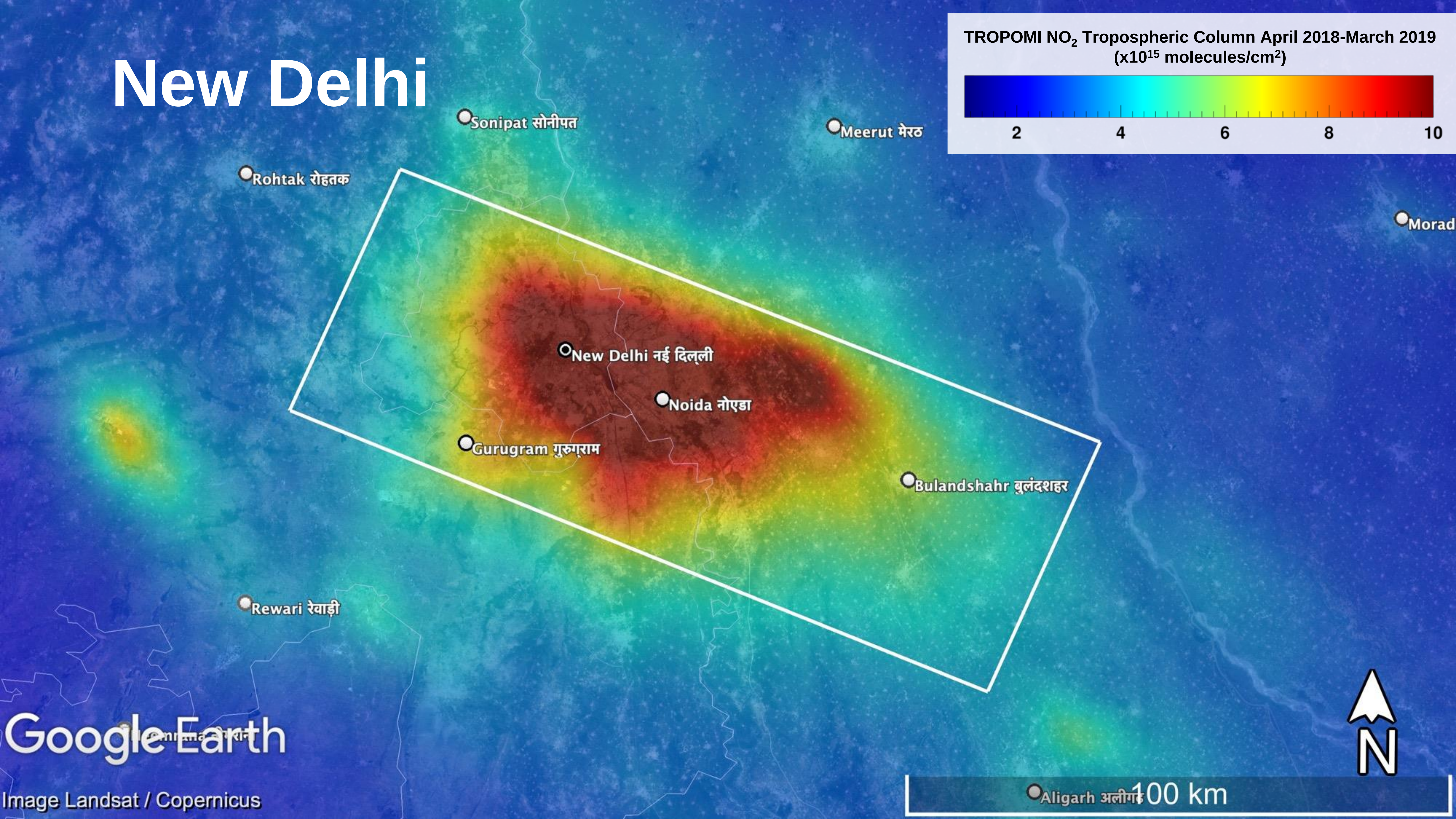
Dhaka



TROPOMI NO_2 Tropospheric Column April 2018-March 2019
($x10^{15}$ molecules/cm^2)
2
4
6
8
10
Madhupur
Trishal
Aouterghat
Kishoreganj
Sirajganj
Natore
Maynakandi
Bhaluka
Elenga
Tangail
Sreepur
Sreemangal
Bhairab
Gazipur
Brahmanbaria
Pabna
Talpatte
Narsingdi
Ambassa
Kushtia
Padma River
Nabinagar
Manikganj
Agartala
Teliamura
Dhaka
Alamdanga
Rajbari
Chuadanga
Narayanganj
Gandacherra
Faridpur
Padma River
Jhenaidah
Munshiganj
Gouripur
Udaipur
Amarpur
Magura
Chandina
Cumilla
Bhanga
Haziganj
Belonia
Chandpur
Shariatpur
Jashore
Narail
Madaripur
Khagrach
Google Earth
N



Kolkata
TROPOMI NO_2 Tropospheric Column April 2018-March 2019
($x10^{15}$ molecules/cm^2)
2
4
6
8
10
Bishnupur
Mukutmanipur
Garhbeta
Arambag
Kalyani
Chinsurah
Habra
Barrackpore
Satkhira
Dankuni
Ghatal
Basirhat
Bagerhat
Belpahari
Lalgarh
Kolkata
Taki
Paikgachha
Kinukity
Mongla
Jhargram
Kolaghat
Debra
Kharagpur
Baruipur
Canning
Tamluk
Diamond Harbour
Gosaba
Hamilton Island
Belda
Haldia
Bajkul
Matla River
Arpangasia River
Baripada
Egra
Bidyadhari River
Kakdwip
Jaleswar
Contai
Namkhana
Dublar Char
Sagar Island
Mandarmani
Gangasagar
Digha
Bakkhali
Google Earth
Balasore
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N


New Delhi
TROPOMI NO_2 Tropospheric Column April 2018-March 2019
($x10^{15}$ molecules/cm^2)
2
4
6
8
10
Sonipat सोनीपत
Meerut मेरठ
Rohtak रोहतक
Morad
New Delhi नई दिल्ली
Noida नोएडा
Gurugram गुरुग्राम
Bulandshahr बुलंदशहर
Rewari रेवाड़ी
Aligarh
100 km
N
Google Earth
Image Landsat / Copernicus