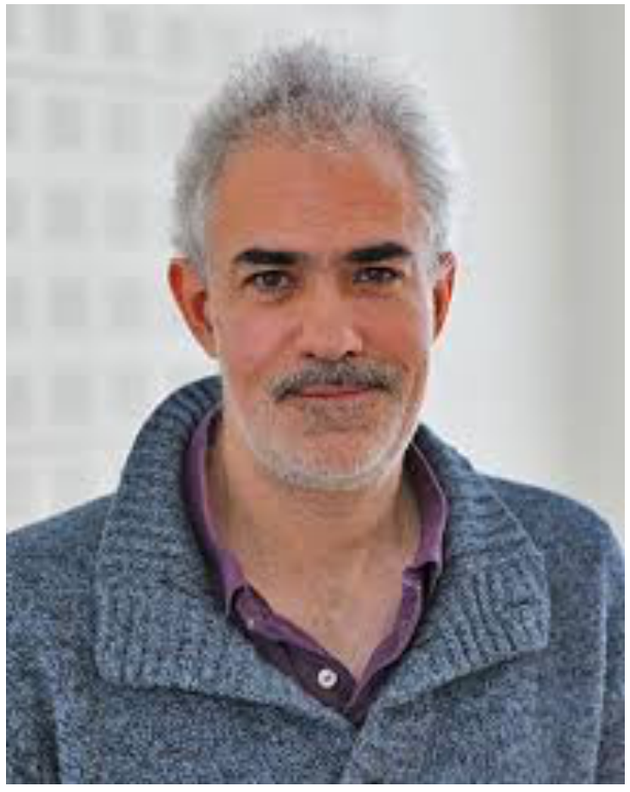
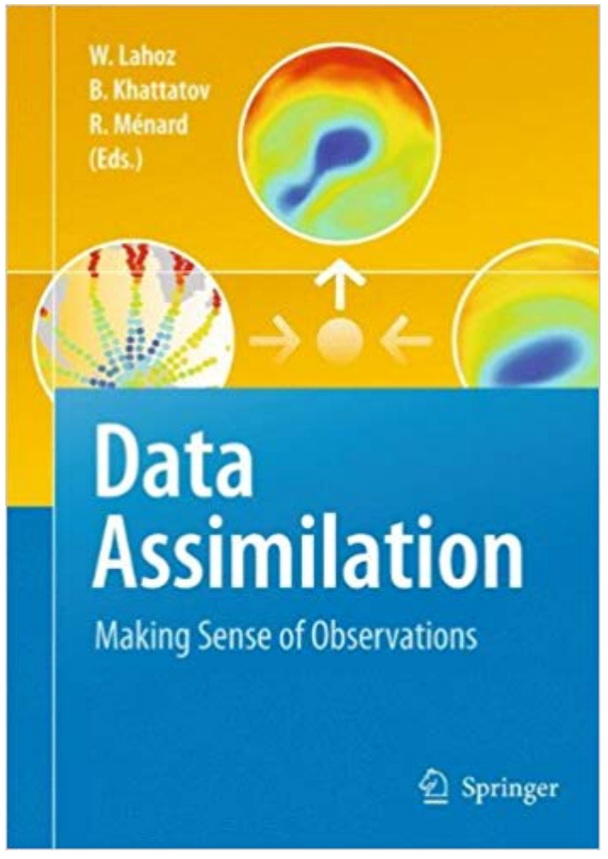
Predicting FF CO_2 fluxes using top-down NOx and CO emissions estimated from multi-constituent chemical data assimilation

Air quality + **GHG**

Kazuyuki Miyazaki, Kevin Bowman

Jet Propulsion Laboratory, California Institute of Technology





Dr. William Lahoz

1960-2019

Edo Bridge
東都江戸橋日本橋
(歌川広重 1797-1858)

Air quality

Edo Bridge
東都江戸橋日本橋
(歌川広重 1797-1858)

GHG

- OH coupling (CH_4)
- Combustion process (NOx, CO, CO_2)
- Joint emission optimization

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Reuter et al., 2019

- The use of proxy species (NO_2, CO) for FF CO_2 flux estimates: Contain a strong signal associated with human activities

Silva and Arellano, 2017, Tang et al., 2019

- AQ-GHG emission ratios are used to understand emission processes (combustion type, new technology and regulation)

Konovalov et al., 2016

- Emission ratios can be used in hybrid emission estimations (e.g., from top-down NOx to CO_2)

Air quality

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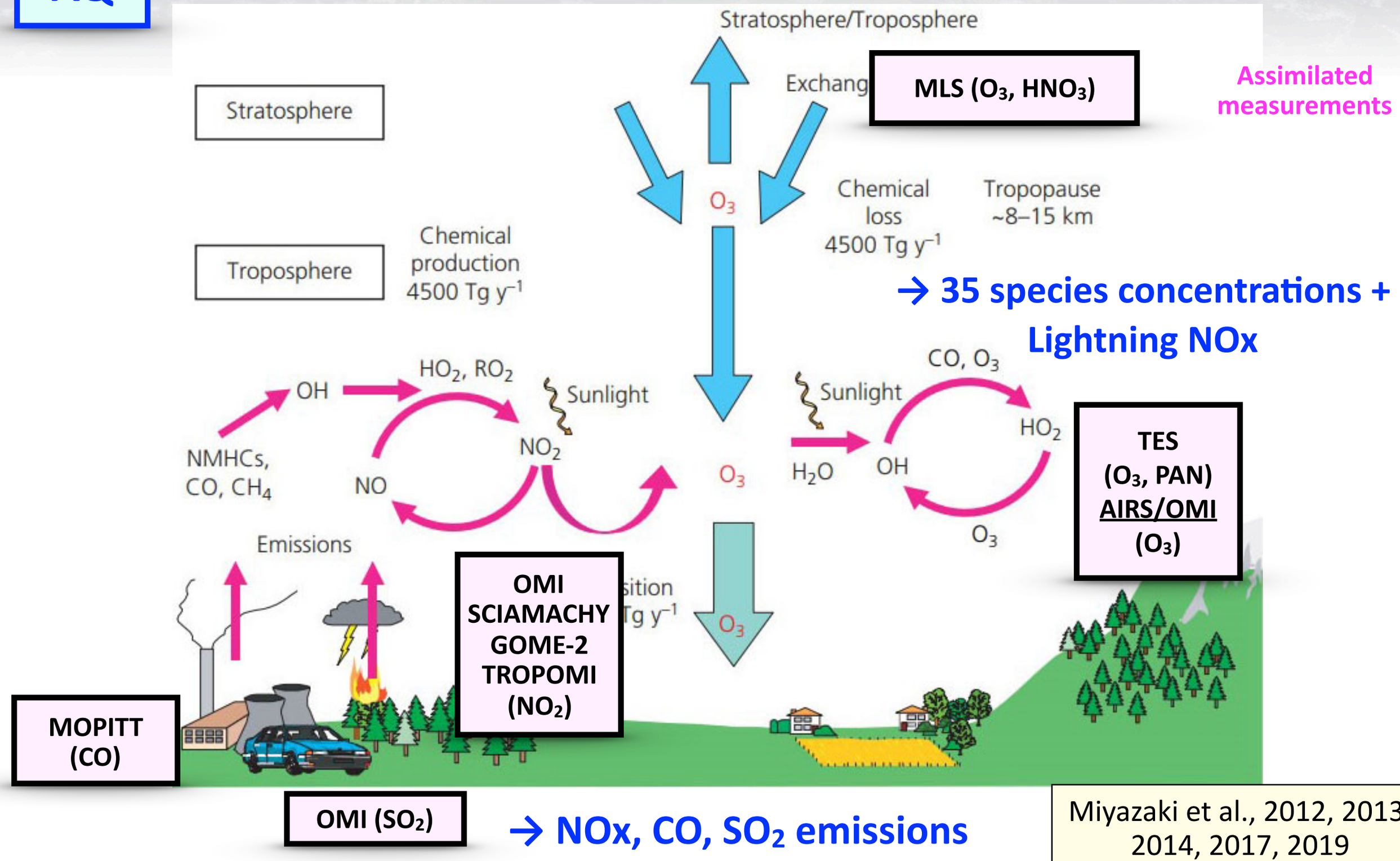
Multi-constituent chemical reanalyses + **GHG inventories**

Multi-constituent chemical data assimilation

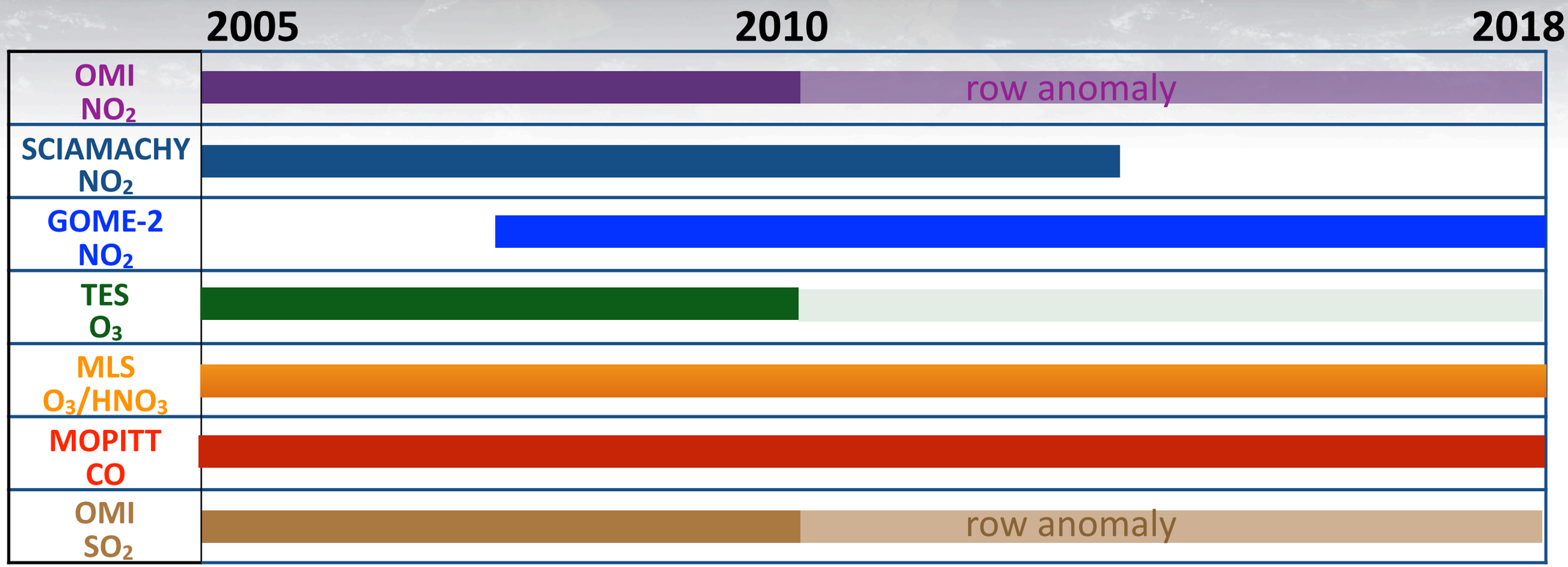
AQ

through ingestion of a suite of measurements from multiple satellite sensors



Miyazaki et al., 2012, 2013, 2014, 2017, 2019

Tropospheric chemistry reanalysis (TCR-2)



Two-hourly, 1.1°x1.1° resolution, up to 70 hPa level

(1) understand the processes controlling the atmospheric environment
(2) provide initial/boundary conditions for climate/chemical simulations
(3) evaluate climate models and bottom-up emission inventories
(4) suggest developments of models/observations (e.g., satellite concepts)

AIRS Atmospheric Infrared Sounder — O_3 (AIRS/OMI)

OMI — NO_2 (QA4ECV), SO_2 (NASA PCA)

GOME-2 Global Ozone Monitoring Experiment — NO_2 (QA4ECV)

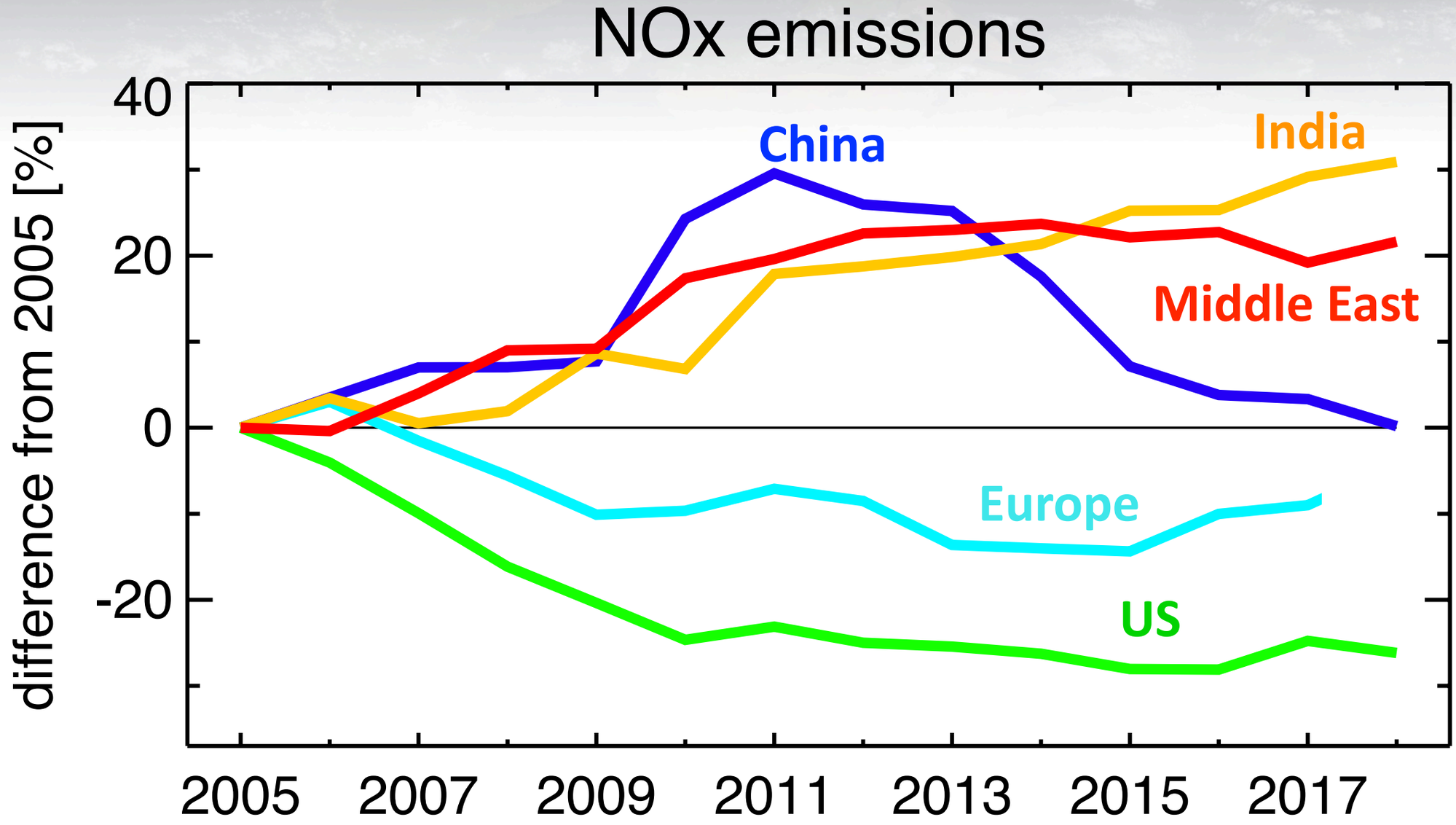
SCIAMACHY Scanning Imaging Absorption Spectrometer for Atmospheric Cartography — NO_2 (QA4ECV)

O_3 (v6)

MEASUREMENTS OF POLLUTION IN THE TROPOSPHERE — MOPITT — CO (v7J)

EOS MLS — to study Earth's ozone and climate — O_3,HNO_3 (v4.2)

Global NOx emission trends (2005-2018)



TCR-2 performance has been evaluated using various independent data (Miyazaki et al., in prep)

IAGOS

DISCOVER-AO

KORUS-AQ

ARCTAS

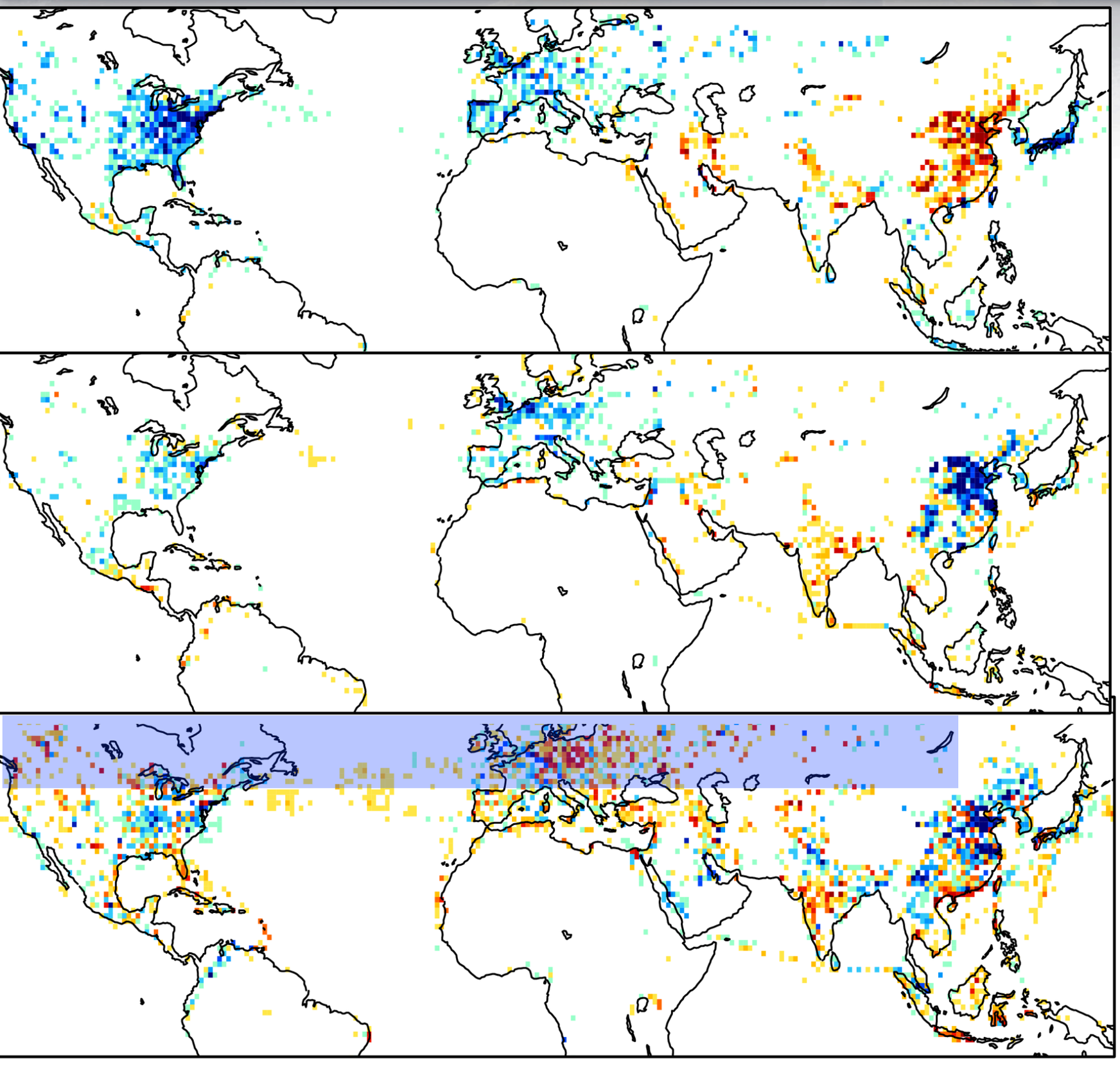
SEAC4RS

INTEX-B

SHADOZ

ATOM

Global NOx emission trends (2005-2018)



2005-2010

2010-2015

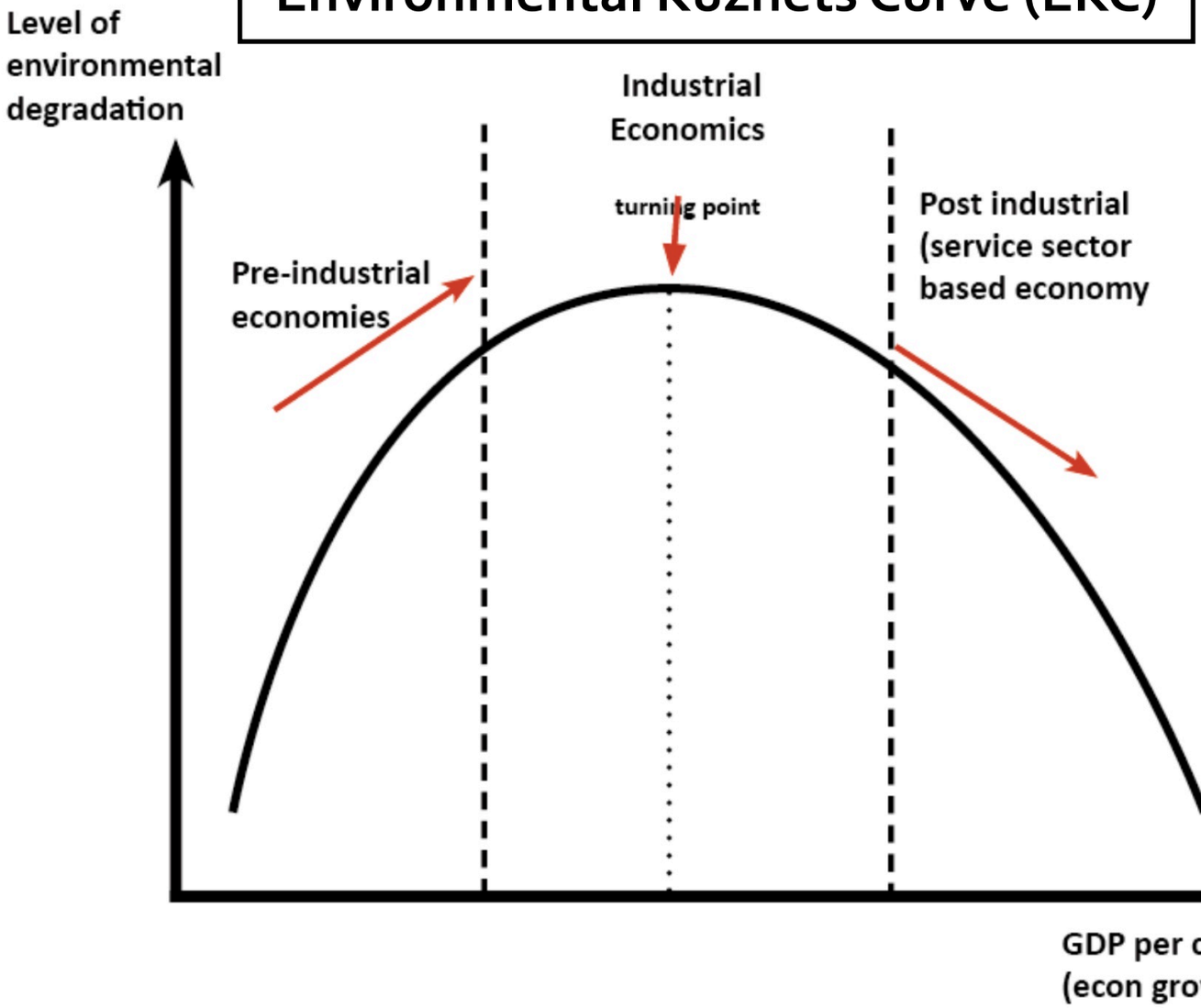
Insufficient constraints at NH high latitudes for 2017-2018 (unhealthy OMI only). Will be revised using OMI+GOME-2.

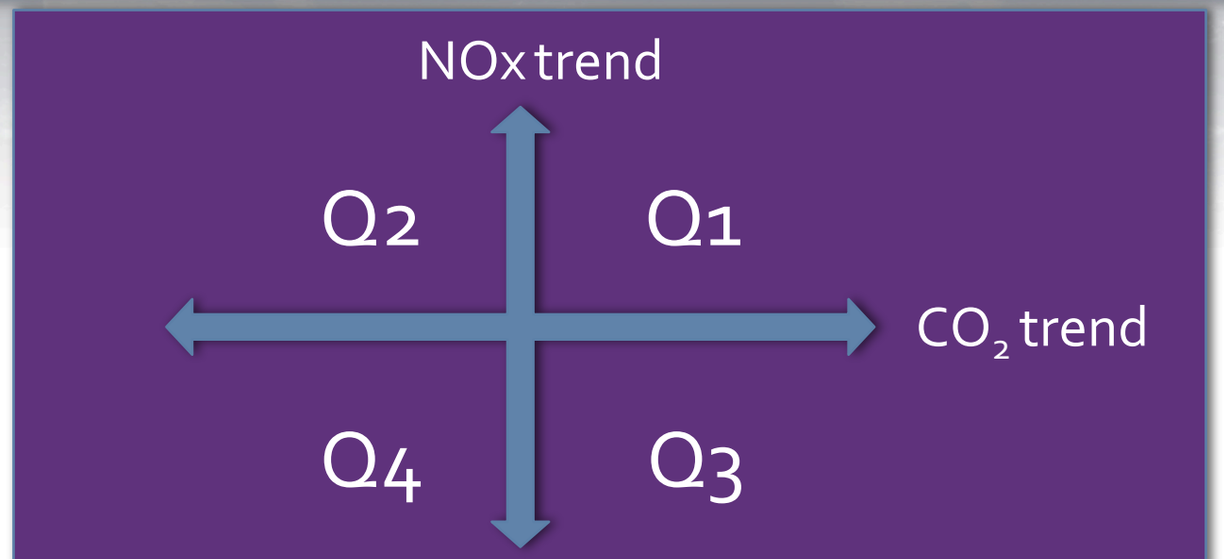
2015-2018

AQ/Carbon co-evolution

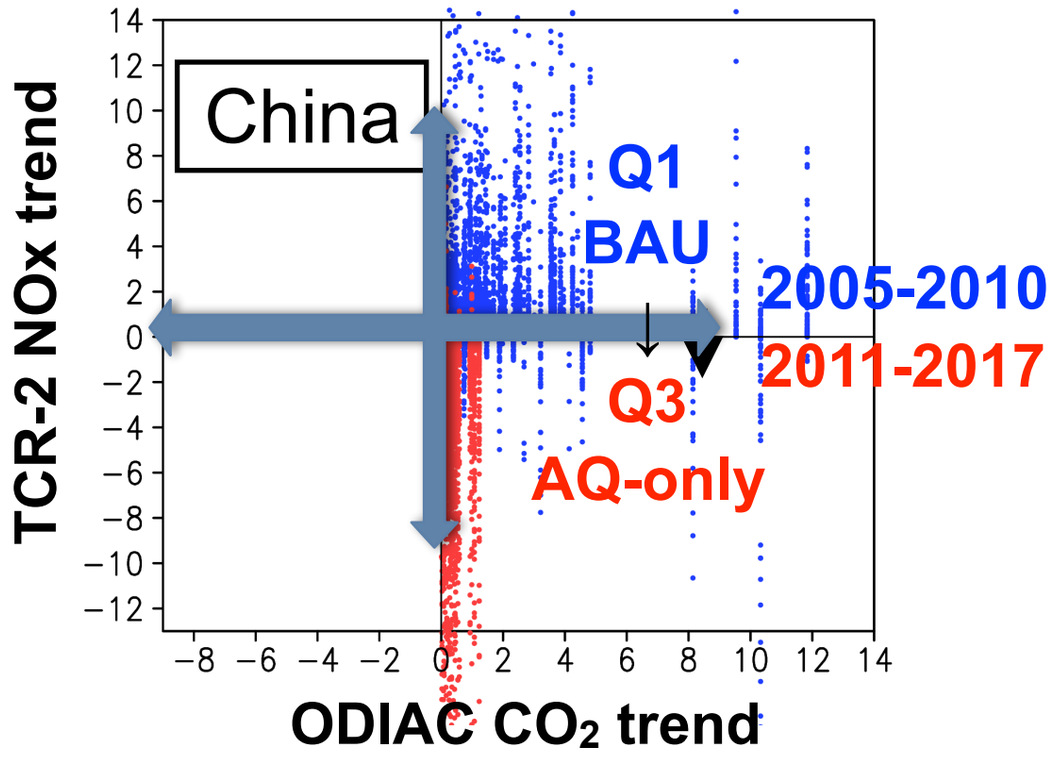
How will changes in air quality mitigation impact carbon emissions?

Environmental Kuznets Curve (EKC)

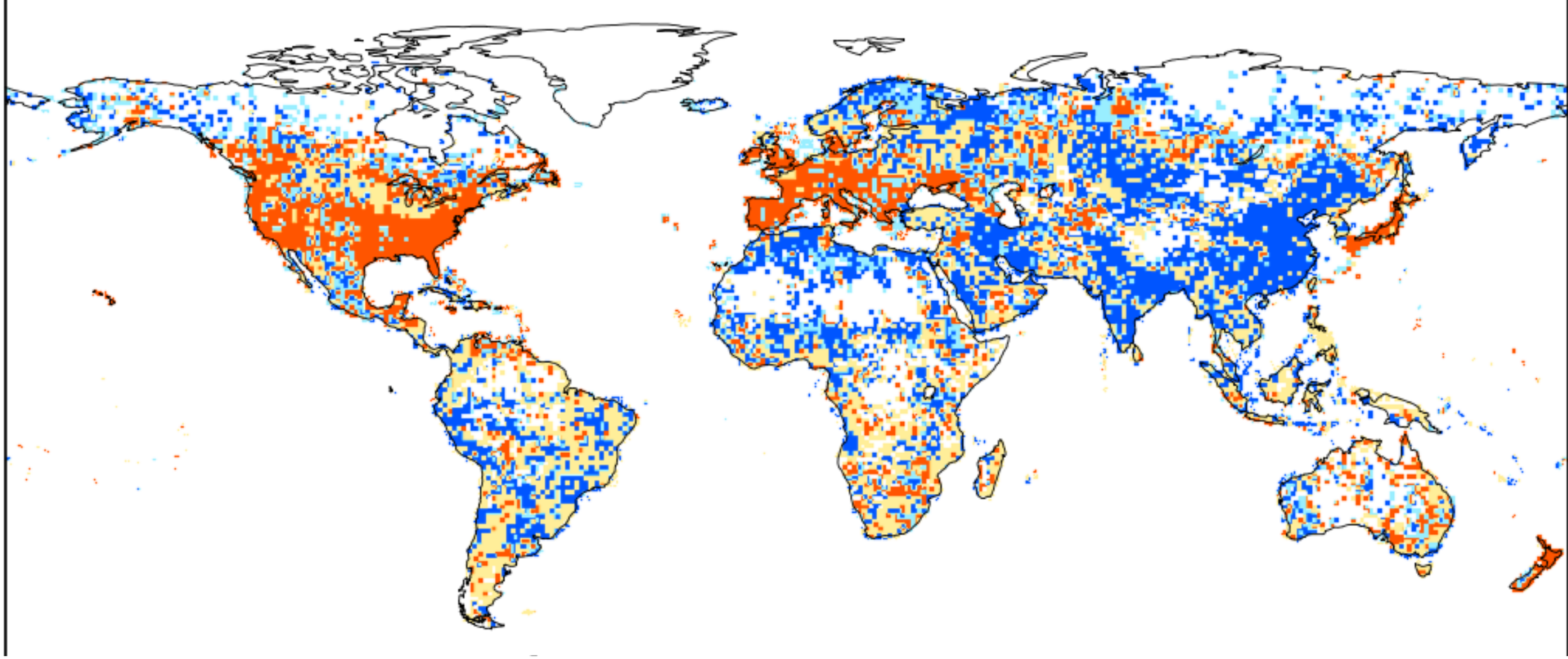




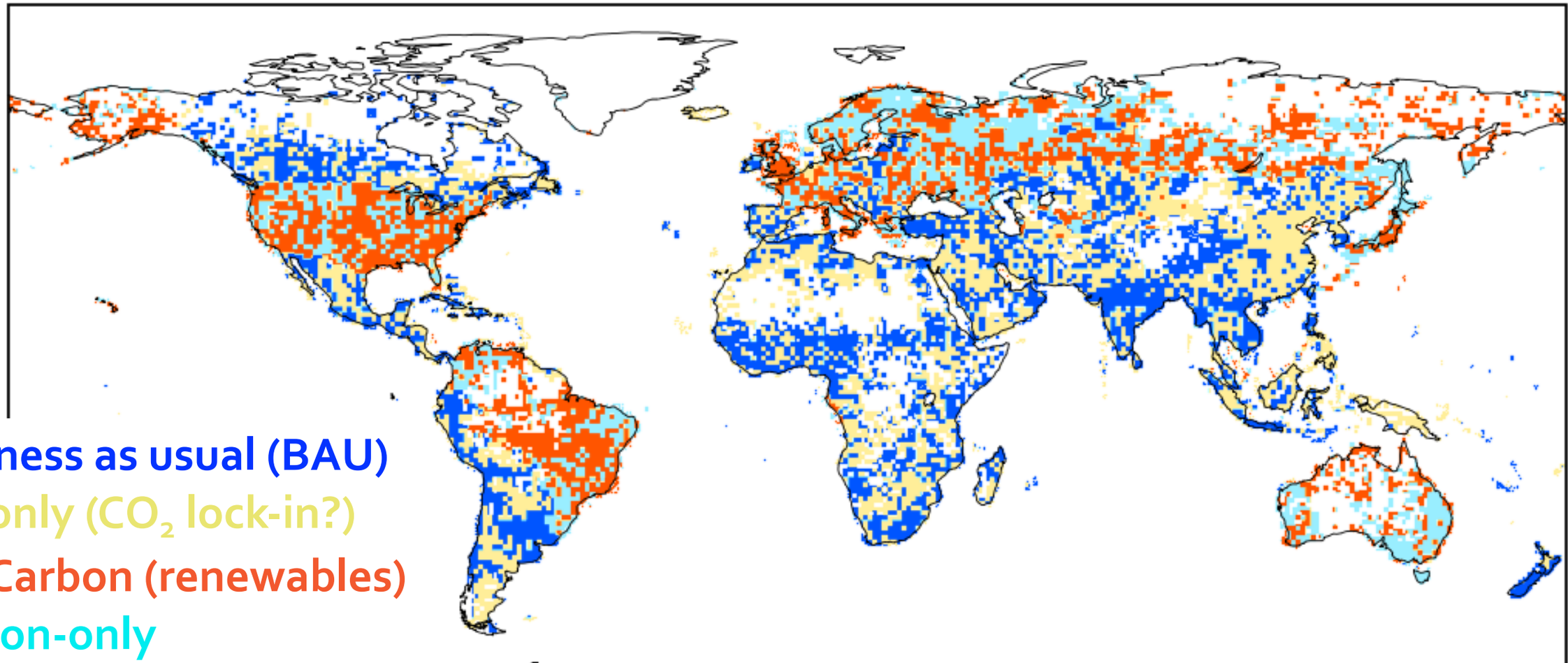
Q1: Business as usual (BAU)
Q2: Carbon-only
Q3: AQ-only (CO_2 lock-in?)
Q4: AQ/Carbon co-reduction (renewables)



2005-2010



2011-2017



Q1: Business as usual (BAU)

Q3: AQ-only (CO_2 lock-in?)

Q4: AQ/Carbon (renewables)

Q2: Carbon-only

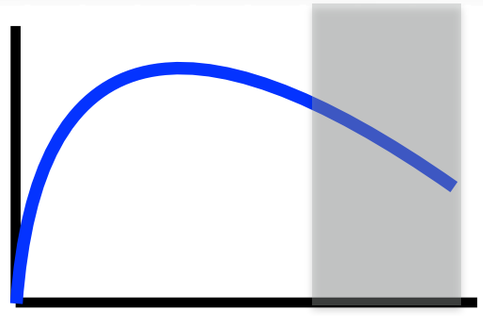
CO_2 flux prediction using top-down NOx emissions

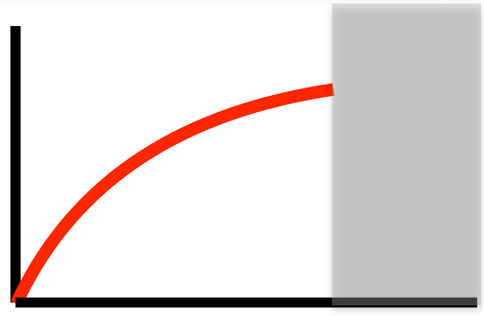
Air quality (NOx)

GHG (CO_2)

Top-Down

quick update





Bottom-up

slower update

Time

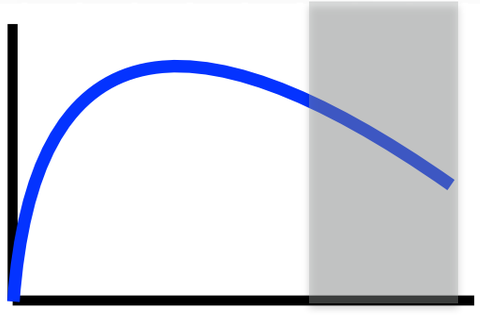
CO_2 flux prediction using top-down NOx emissions

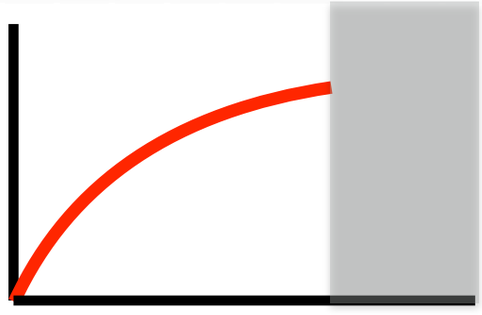
Air quality (NOx)

GHG (CO_2)

Top-Down

quick update





Bottom-up

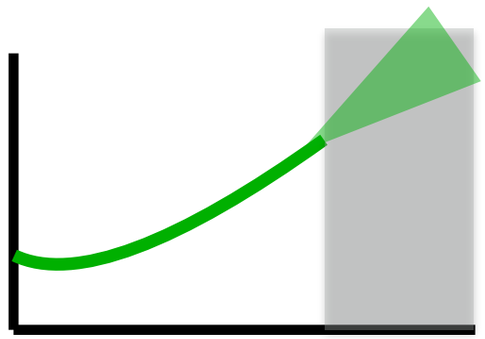
slower update

Time

Variations in emission ratios (CO_2/NOx)

(gradual changes in technology and regulation)

Kalman filter prediction and error estimation

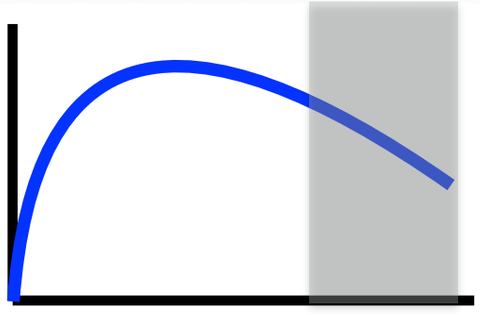


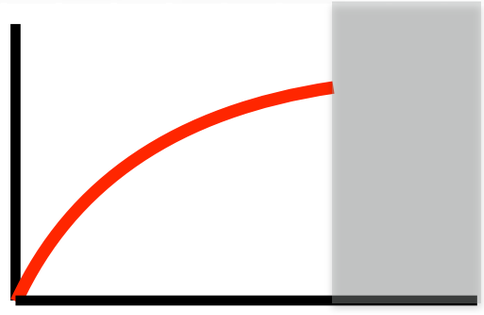
CO_2 flux prediction using top-down NOx emissions

Air quality (NOx)

GHG (CO_2)

Top-Down
quick update





Bottom-up
slower update

Time

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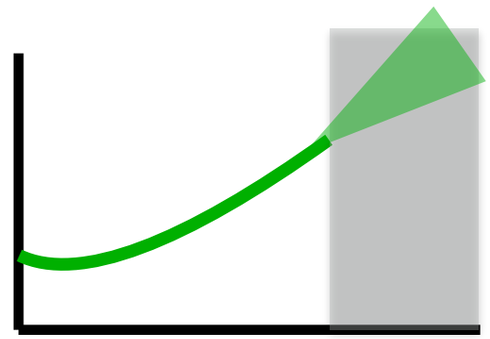
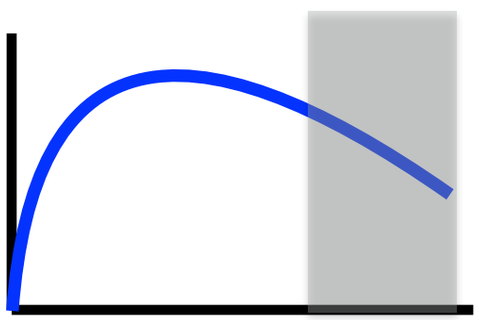
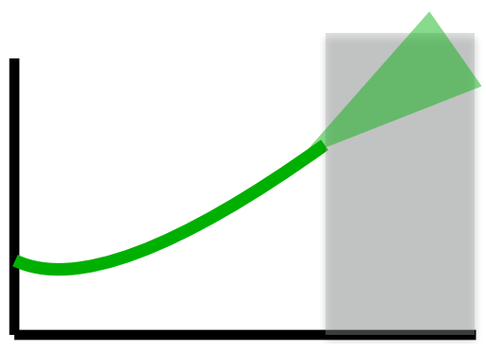


Top-Down NOx emission



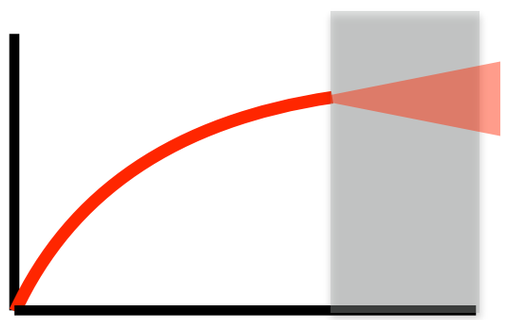
x

Emission ratio

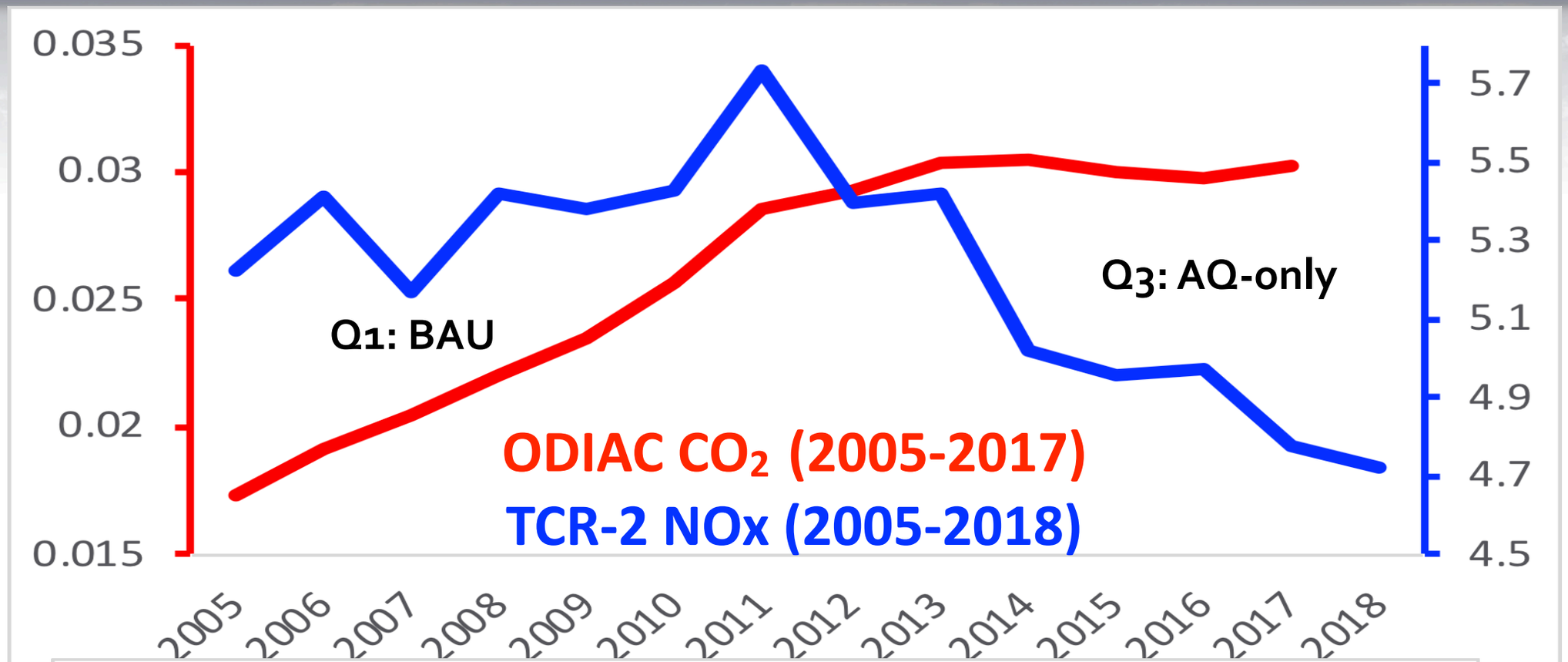


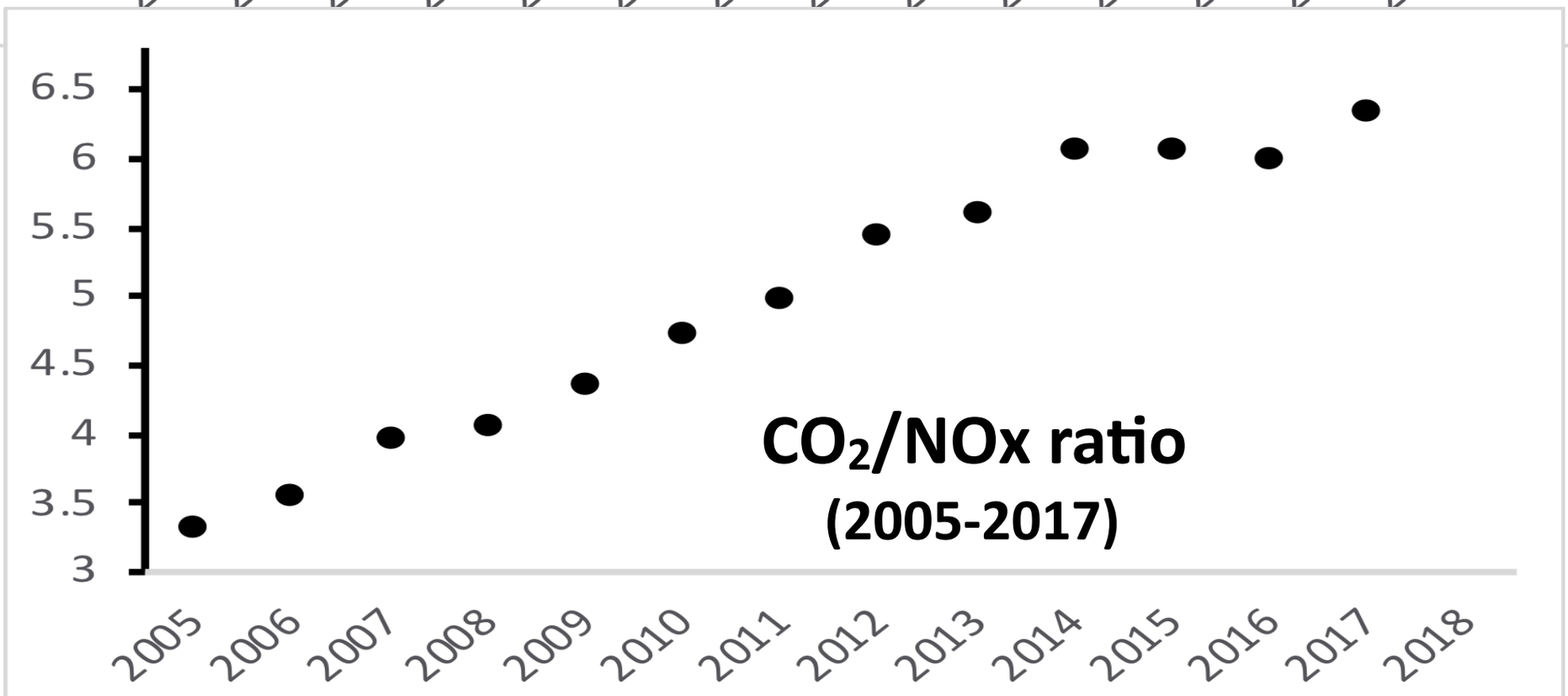
=

CO_2 flux prediction



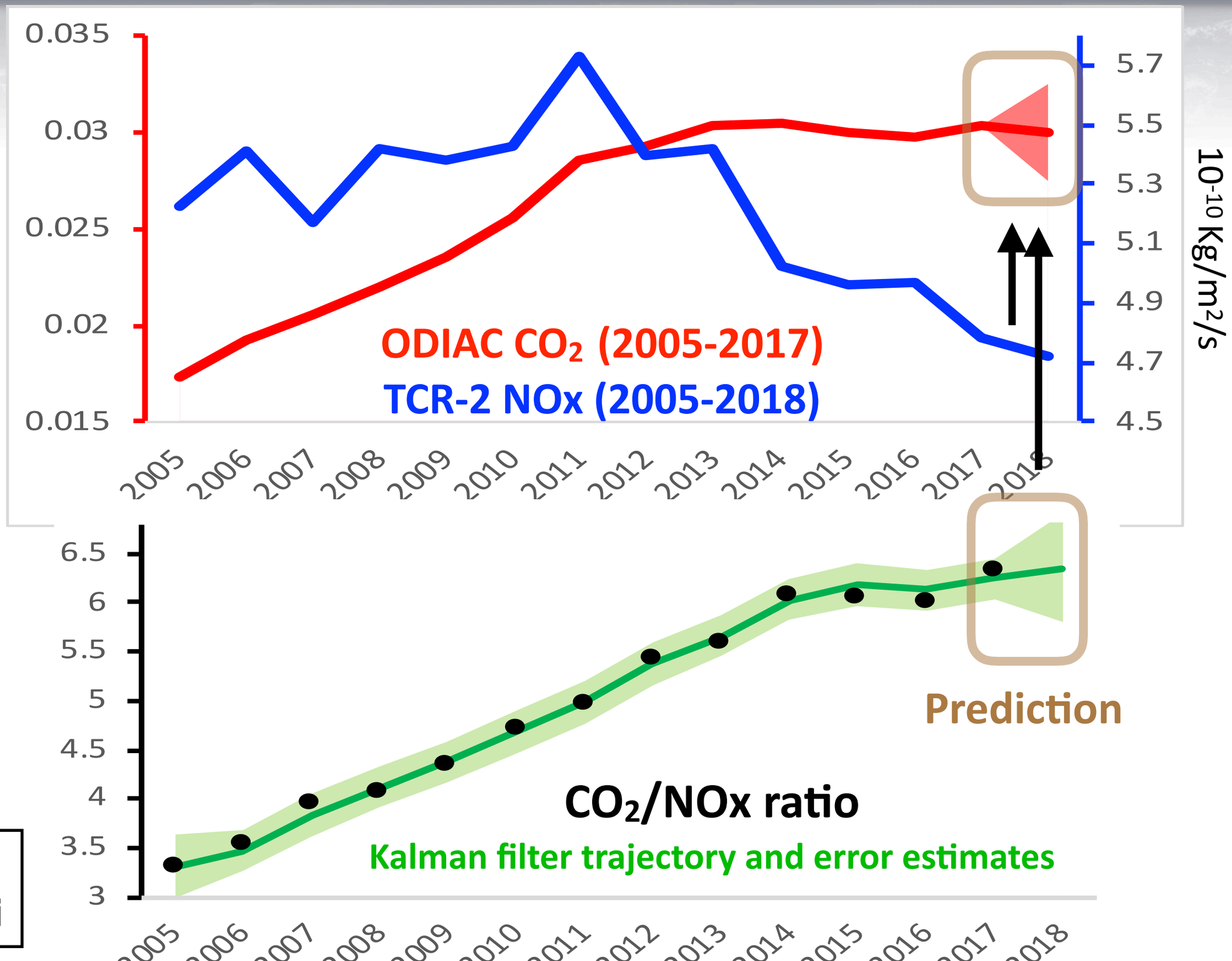
CO_2 flux prediction using top-down NOx emissions





Near Shanghai

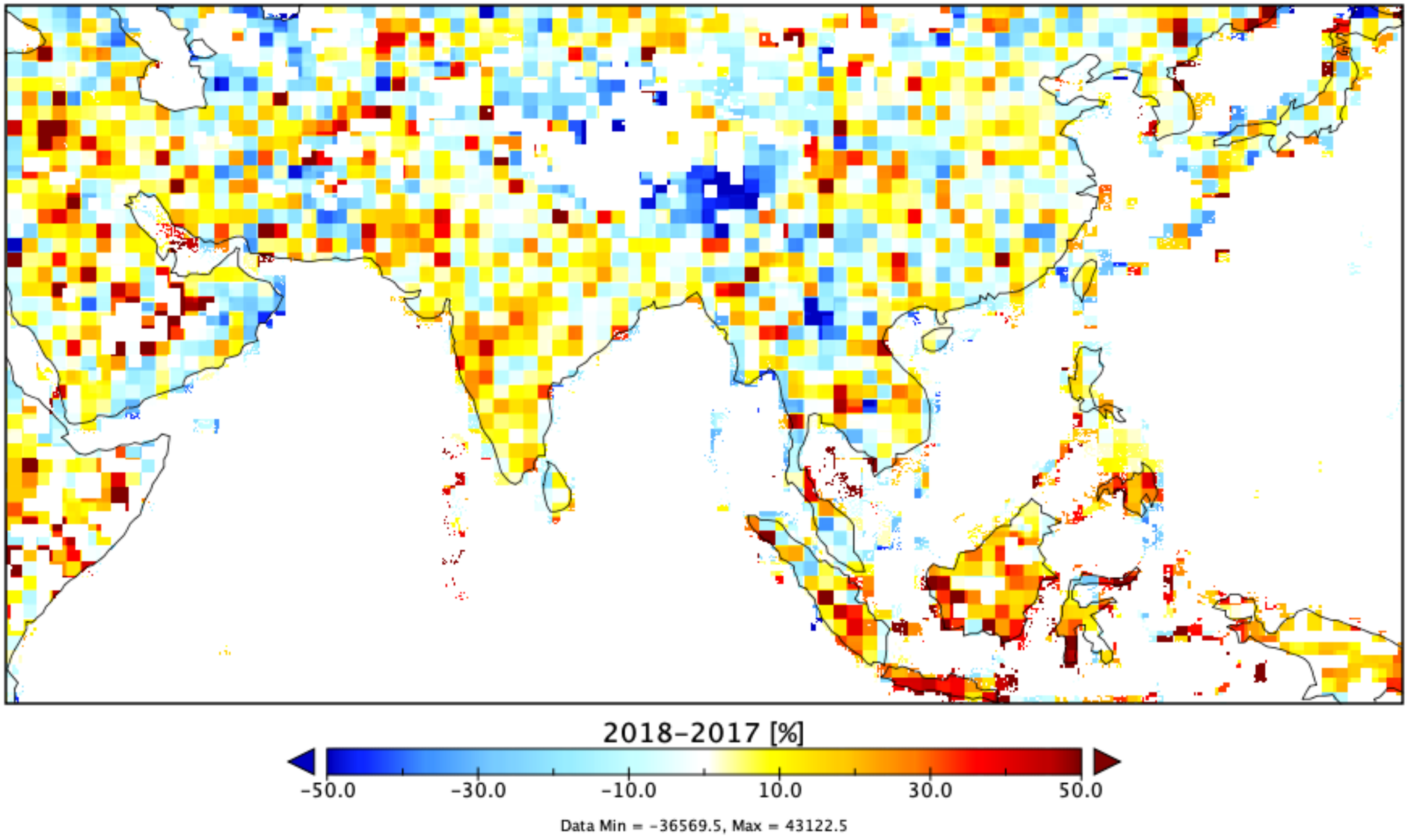
CO_2 flux prediction using top-down NOx emissions



Near Shanghai

FF CO2 fluxes: 2018 (predicted) - 2017 (ODIAC)

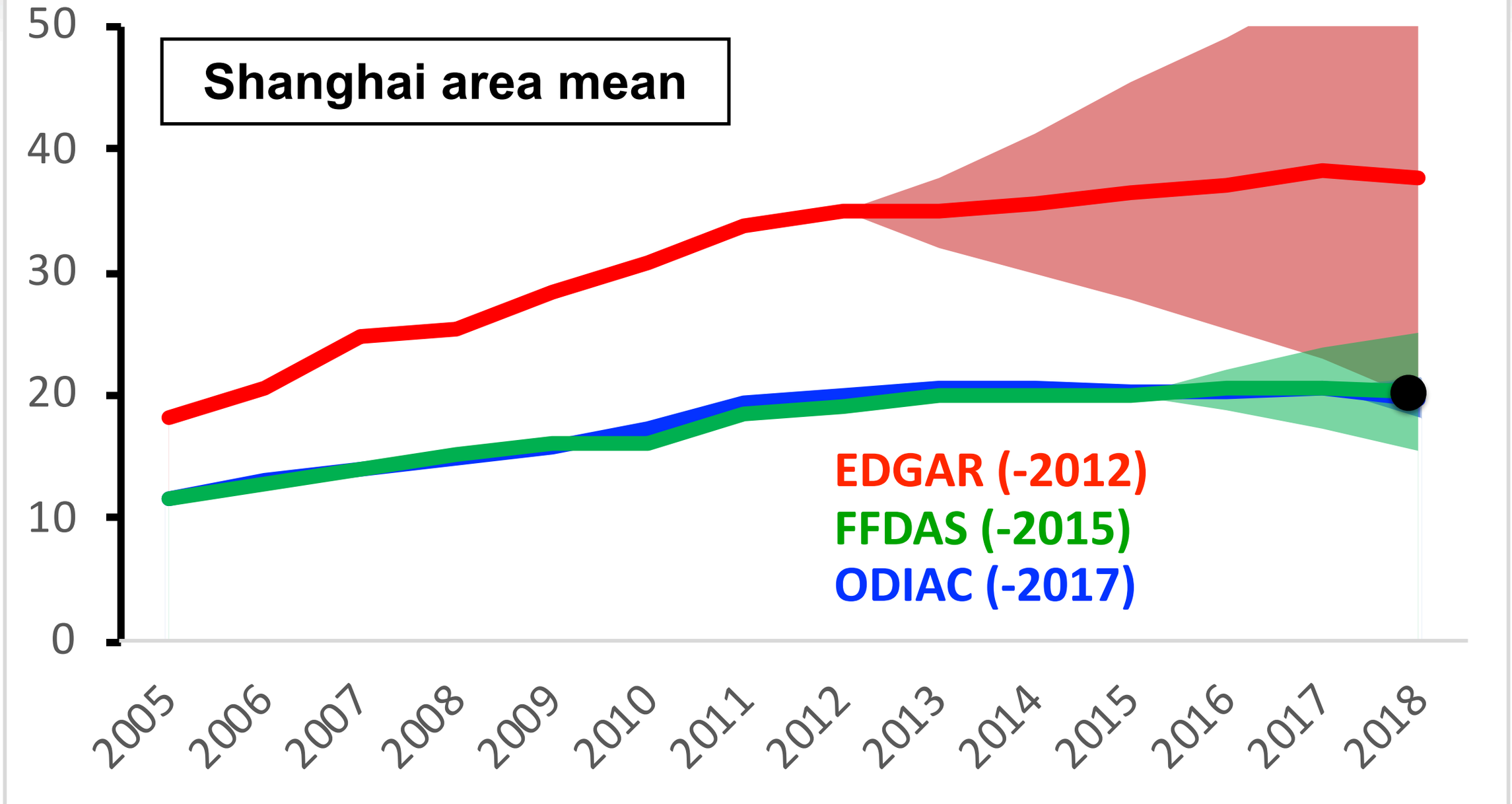
How will ODIAC 2018 look like? 😏



Strong variations in emission ratios for India, SE Asia, and the Middle east

→ ***evaluate multi-species emission inventories, understand emission processes***

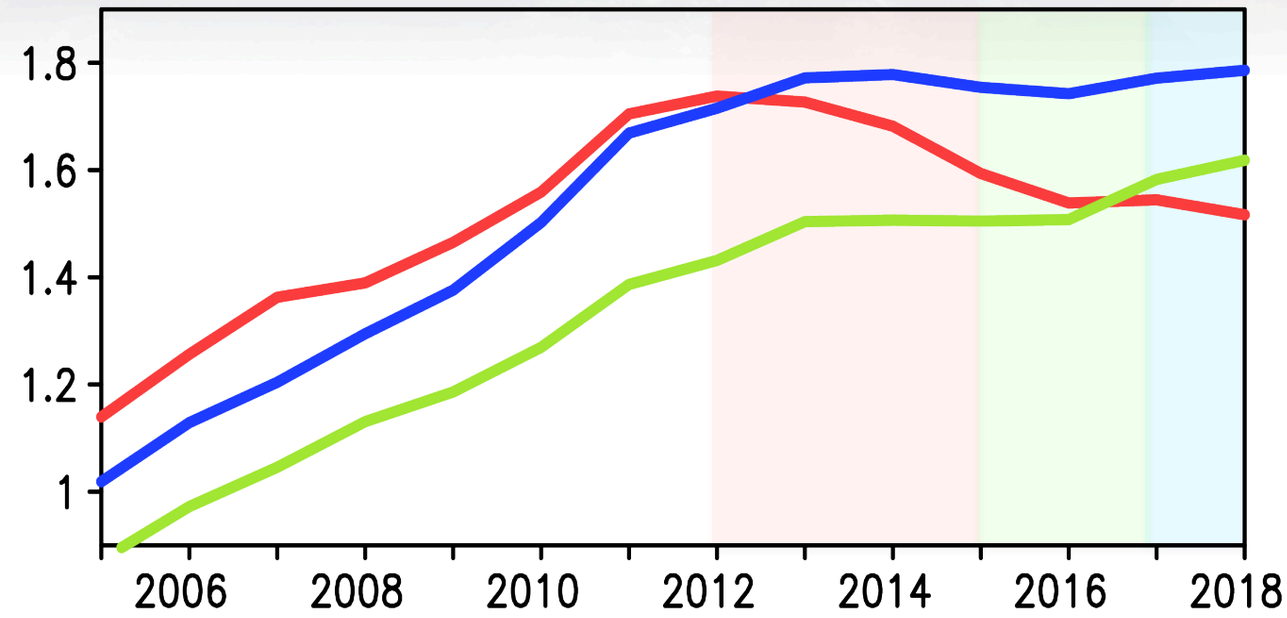
CO_2 flux estimations: Multi-inventories integration



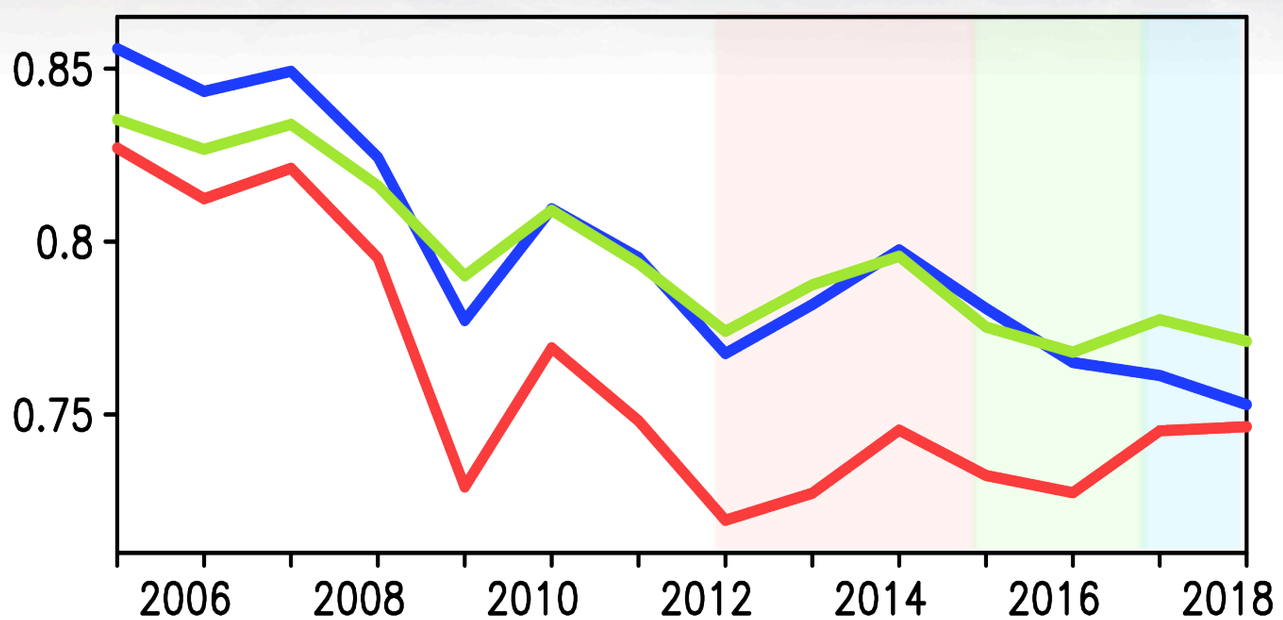
Multi-inventories mean (uncertainty-weighted) for 2018 : <u>19.9±1.5 gC/m²/d</u>

CO_2 flux estimations: Multi-inventories integration

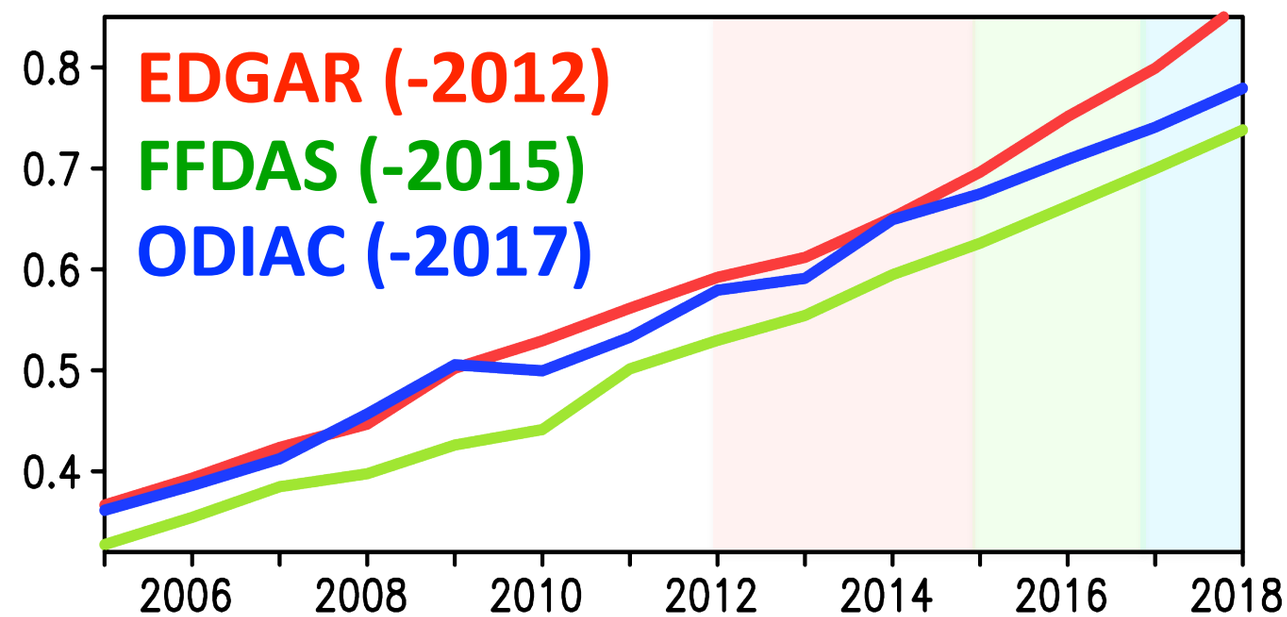
Eastern China



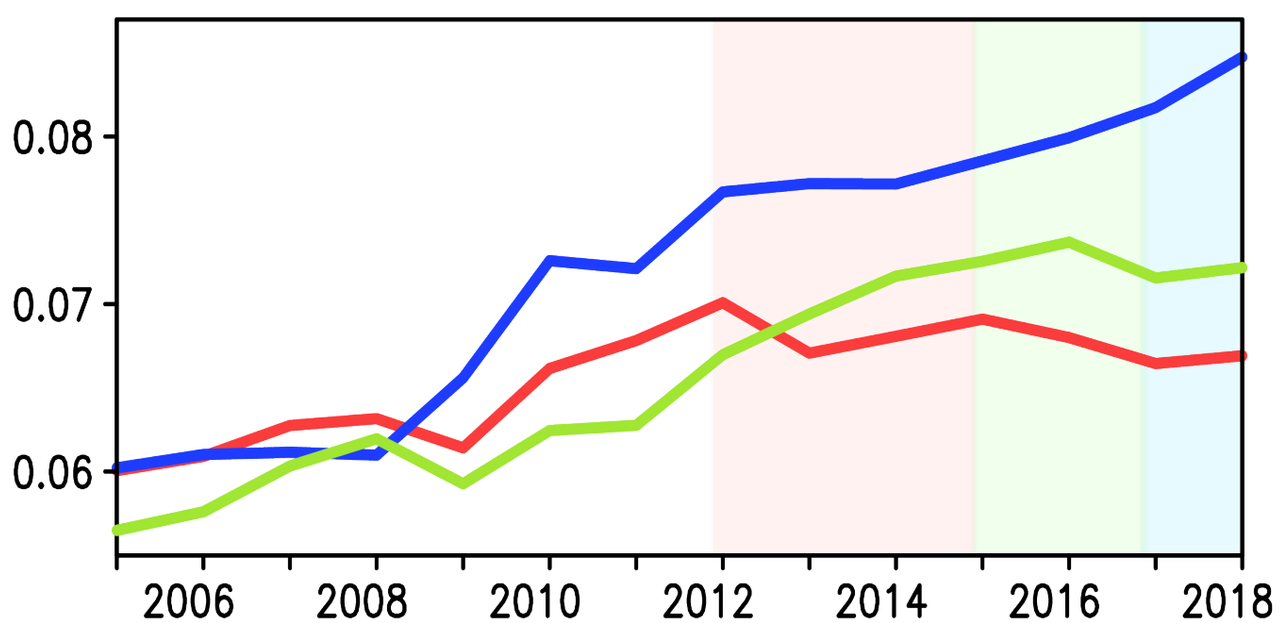
Eastern US



India



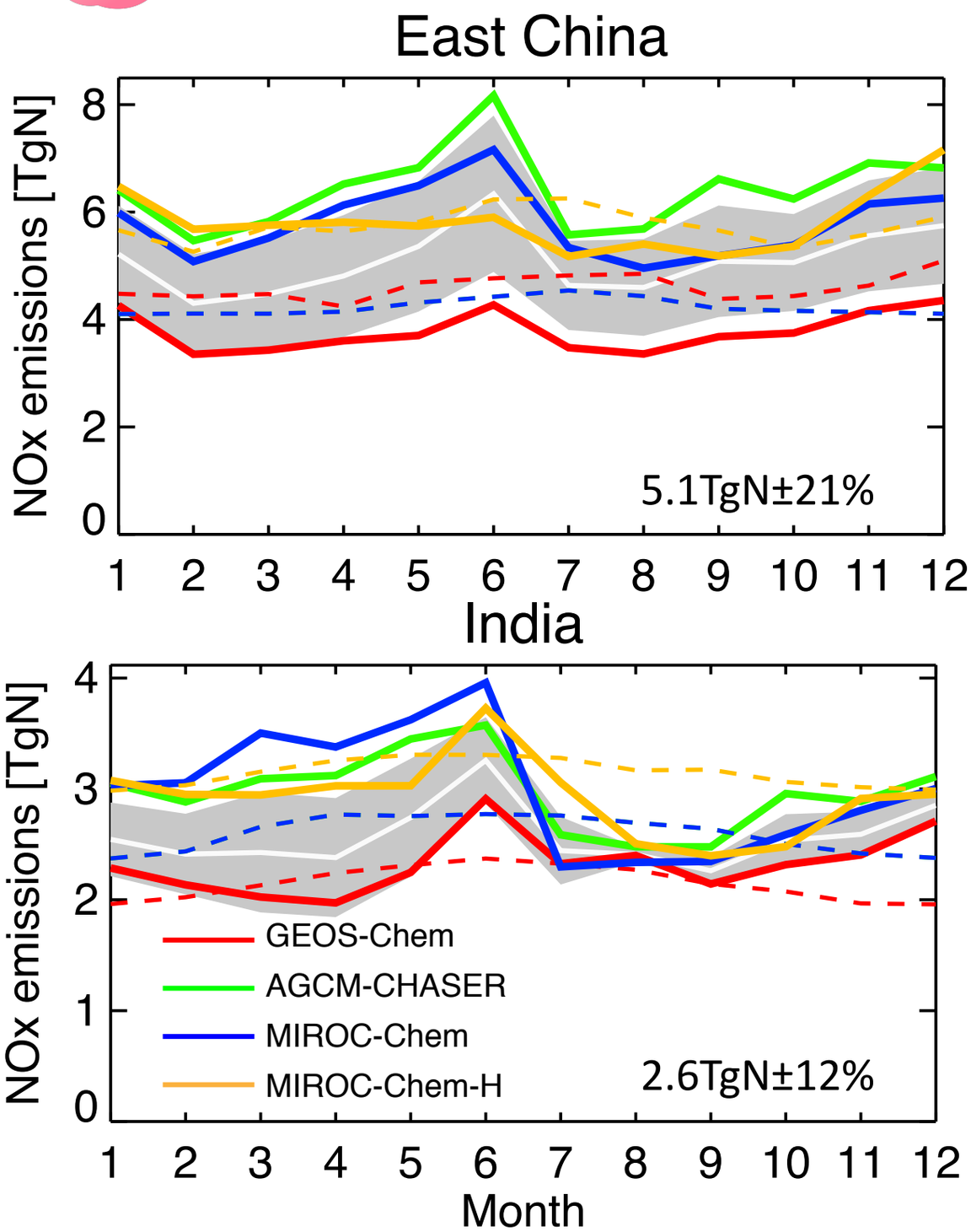
Southeast Asia

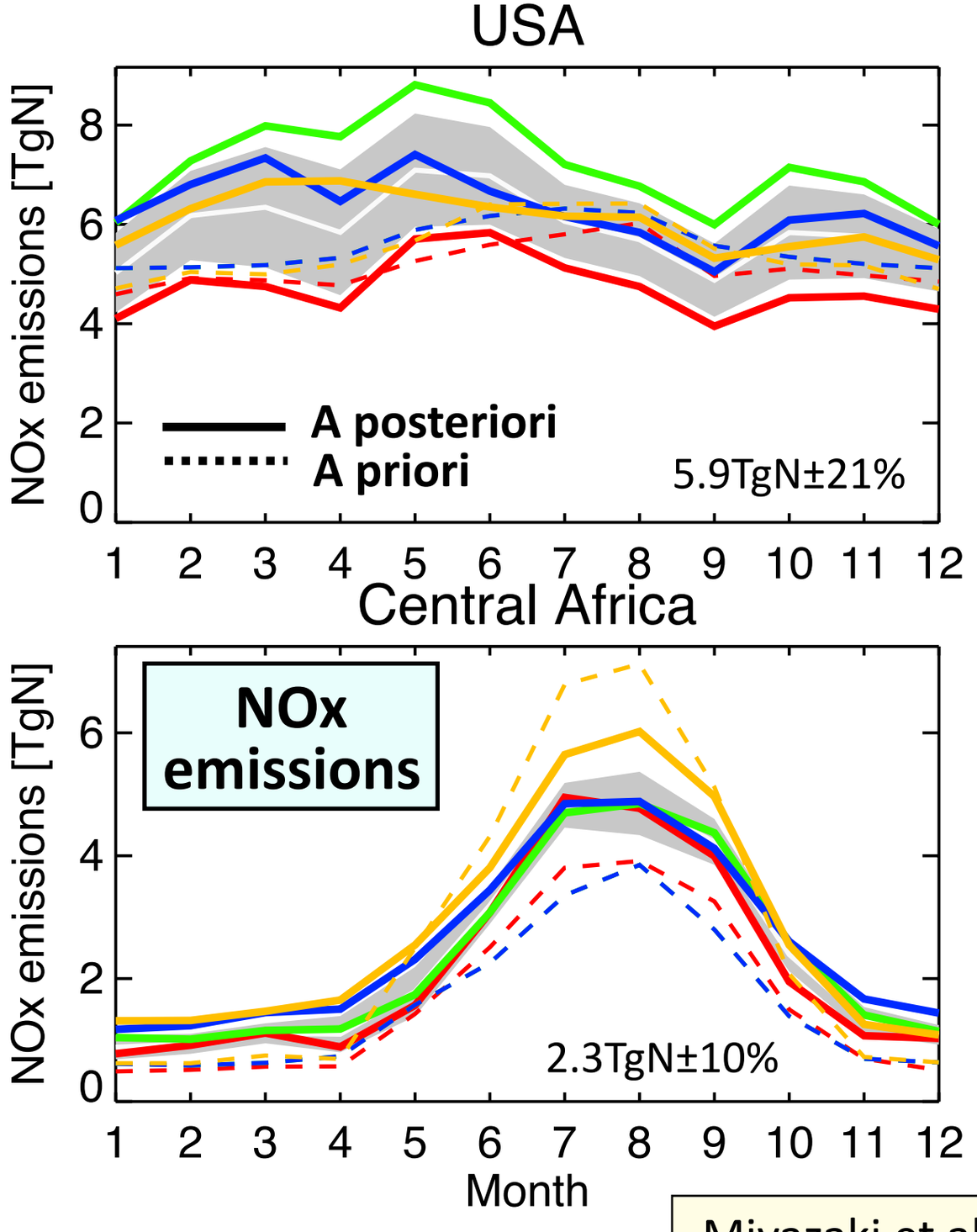


(TgC/yr)

NOx emission uncertainty → CO_2 flux uncertainty

MOMO-Chem : Multi-mOdel, Multi-cOnstituent CHEMical DA





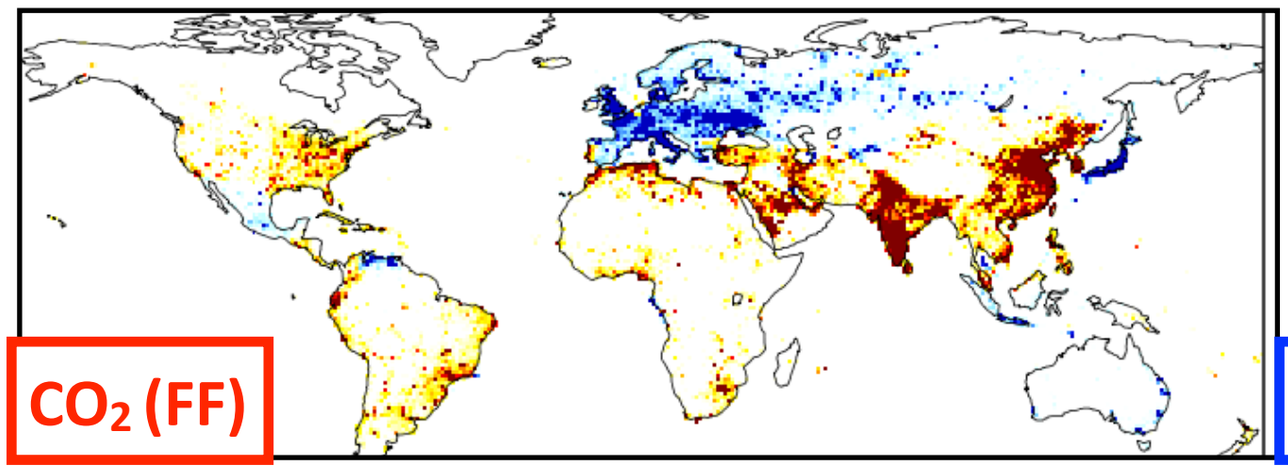
Multi-model Stdev: *13–31% for industrialized areas and 4–21% for BB areas*

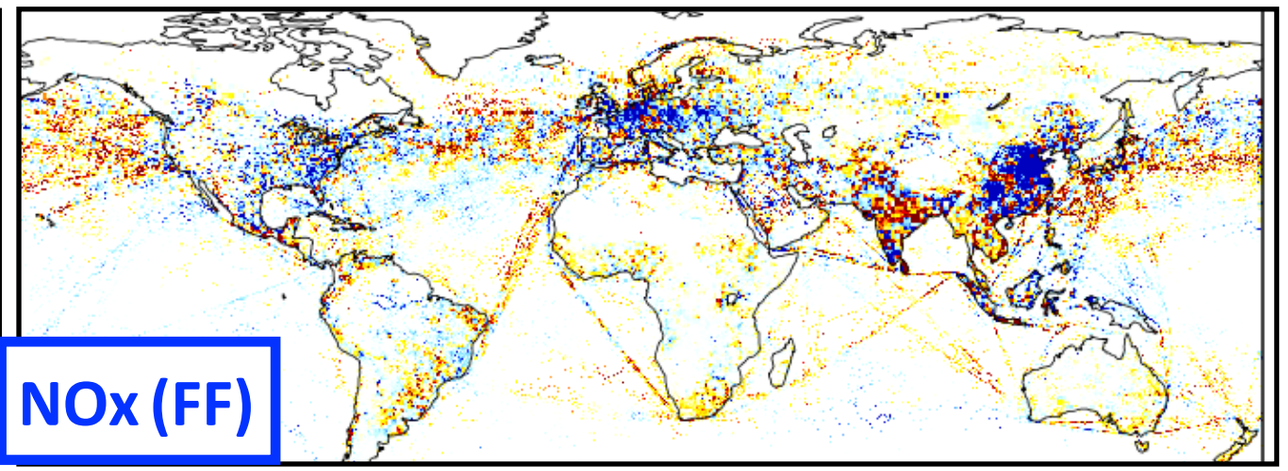
Miyazaki et al., to be submitted

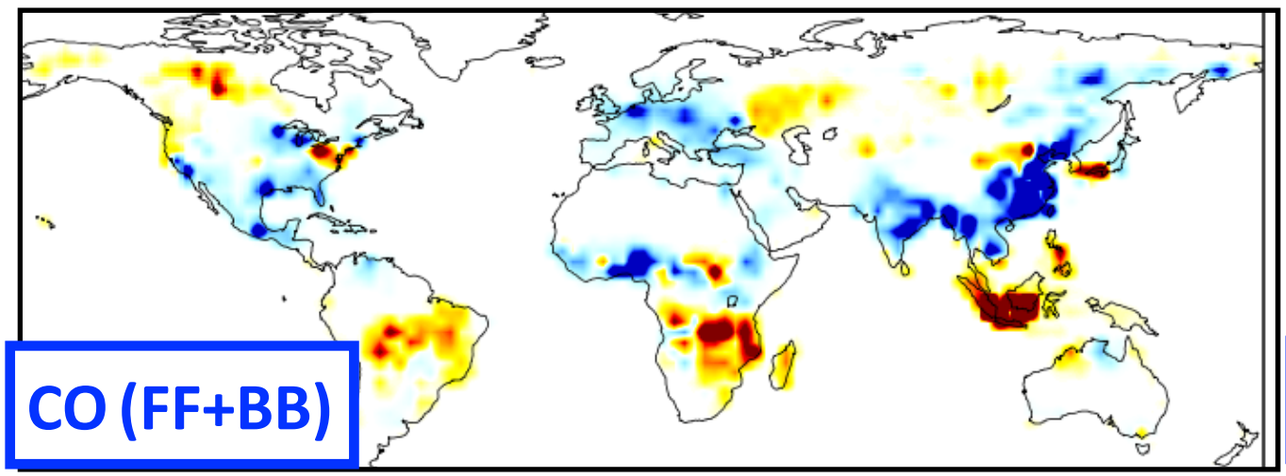
Multi-species constraints on FF CO_2 flux

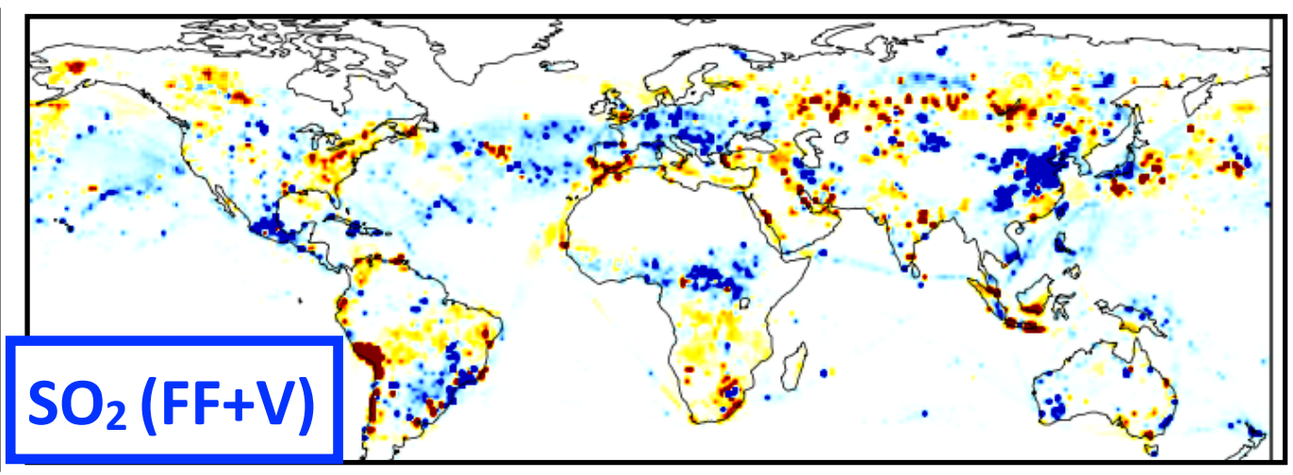
Different aspects of the combustion technology are expected to affect those emissions

- **NOx**: strongly depend on the temperature of combustion (more NOx at high T)
- **CO**: can be regarded as a measure of the incompleteness of combustion processes
- **SO_2**: Linked to the burning of fossil fuels. Also, strong emissions from volcanic eruptions.







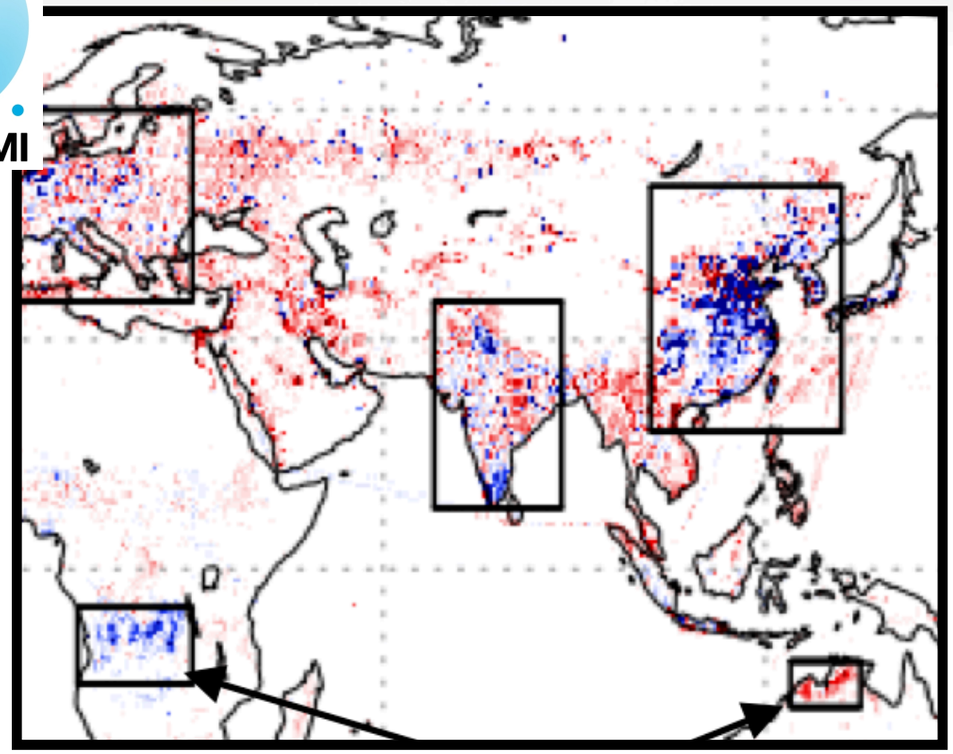


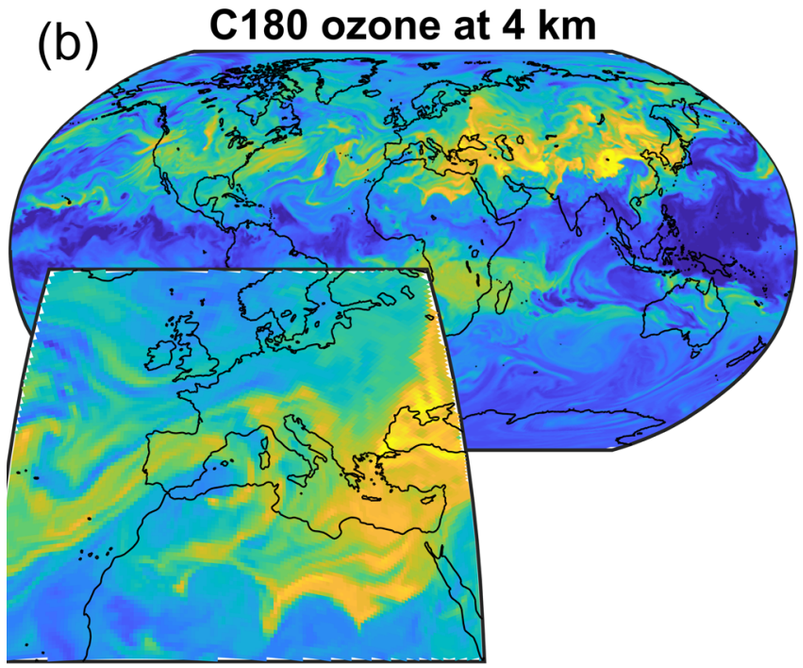
2011-2015 trends

Multi-species information from chemical reanalysis products will provide comprehensive constraints on FF CO_2 fluxes and to improve bottom-up inventories

High-resolution multi-species joint emission analysis

Global TROPOMI NO_2 DA at 0.56 deg resolution
(Sekiya et al., poster)





GCHP-EnKF developments at JPL

Committee on Earth Observation Satellites

OCO-3 | GOSAT-2,3 | GeoCarb | Sentinel-7 | TROPOMI | CrIS | OMPS | TEMPO | GEMS | Sentinel-4

AQ/GHG joint DA analysis and emission estimation

Bottom-up inventories

Conclusions

- FF CO_2 fluxes can be predicted based on Kalman filter trajectories of emission ratios, by combining bottom-up GHG inventories with top-down estimate of proxy species from chemical reanalysis, which extend GHG inventories.
- The multi-GHG inventories and multi-model chemical reanalyses (MOMO-Chem) provide integrated information on GHG/AQ variations/uncertainty.
- The obtained long-term changes in emission ratios could suggest developments of multi-species bottom-up inventories, such as REAS and EDGAR.

Future works

- Multi-species constraints and AQ-GHG joint emission optimizations though high-resolution DA of the existing and future satellites
- Emergent constraints on the chemistry-climate system and carbon cycle

Air quality

GHG