An Improved Retrieval Algorithm for NO_2 and Other Tracers
&
A Novel Model System to Integrate Multiple Geostationary Satellite Measurements

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in collaboration with

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http://www.atmos.pku.edu.cn/acm/index.html

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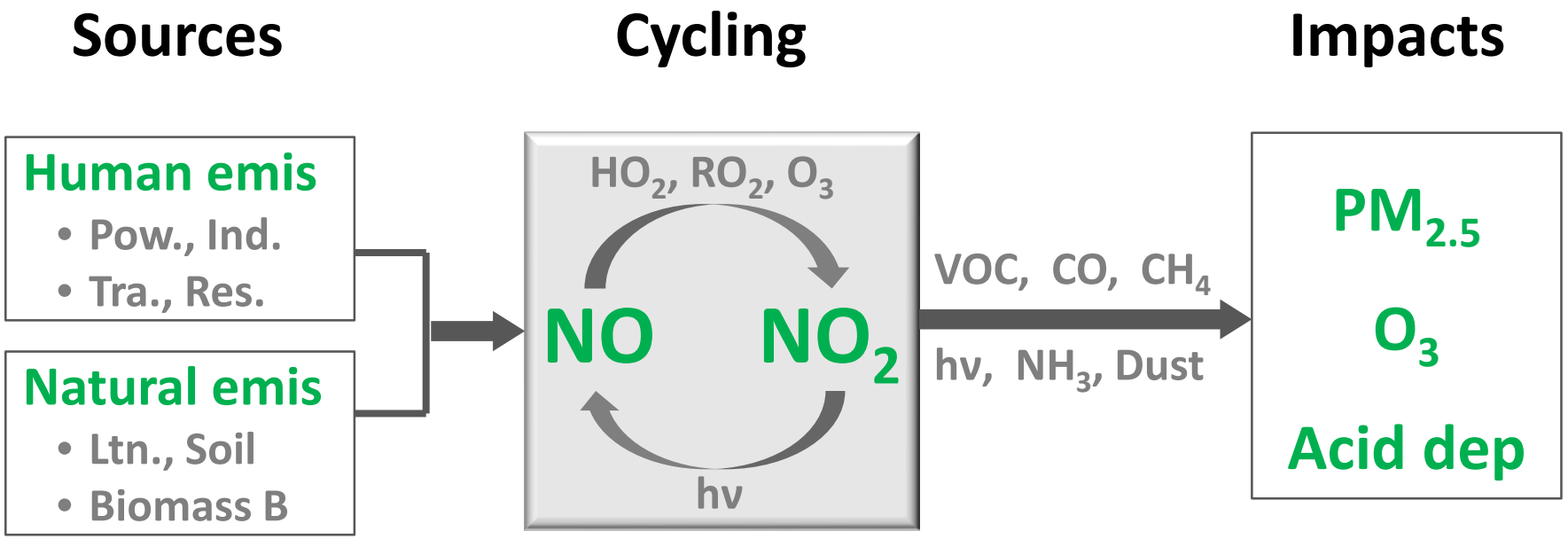
NOx = NO + NO_2 as Critical Pollution

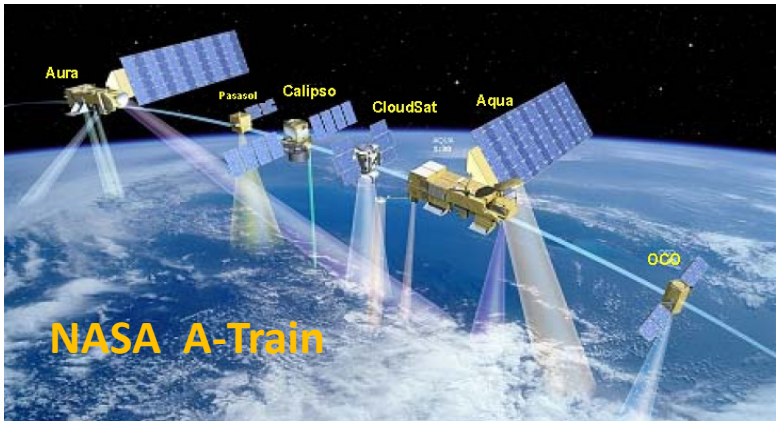


Lifetime of NOx = hours to 1 day

Satellite Remote Sensing: Present and Future

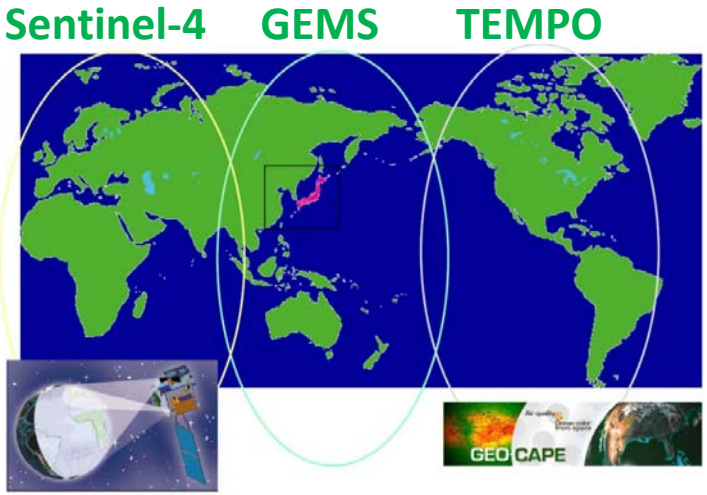
To date:

- Polar orbiting
  - GOME, SCIA
  - GOME-2, OMI, OMPS
  - 10 + products



Future (2017–2021):

- Polar orbiting
  - TropOMI, Chinese sensors…
- Geostationary
  - TEMPO, Sentinel-4, GEMS



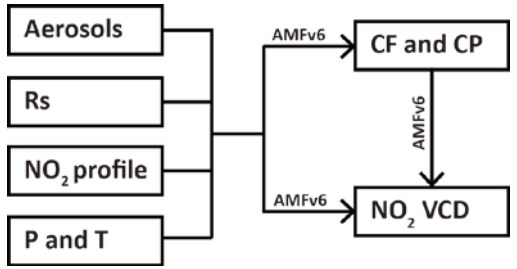
Source: H. Irie

Improving NO_2 Retrieval from OMI

http://www.atmos.pku.edu.cn/acm/satellite_no2.html

Step 1: SCD from DOAS calc.
Step 2: Tropospheric and stratospheric SCD
Step 3: Tropospheric AMF – *most important*
- Surface albedo; Surface air pressure
- Aerosol absorption and scattering
- Eff. cloud fraction and cloud top pressure
- Vertical profile of NO_2

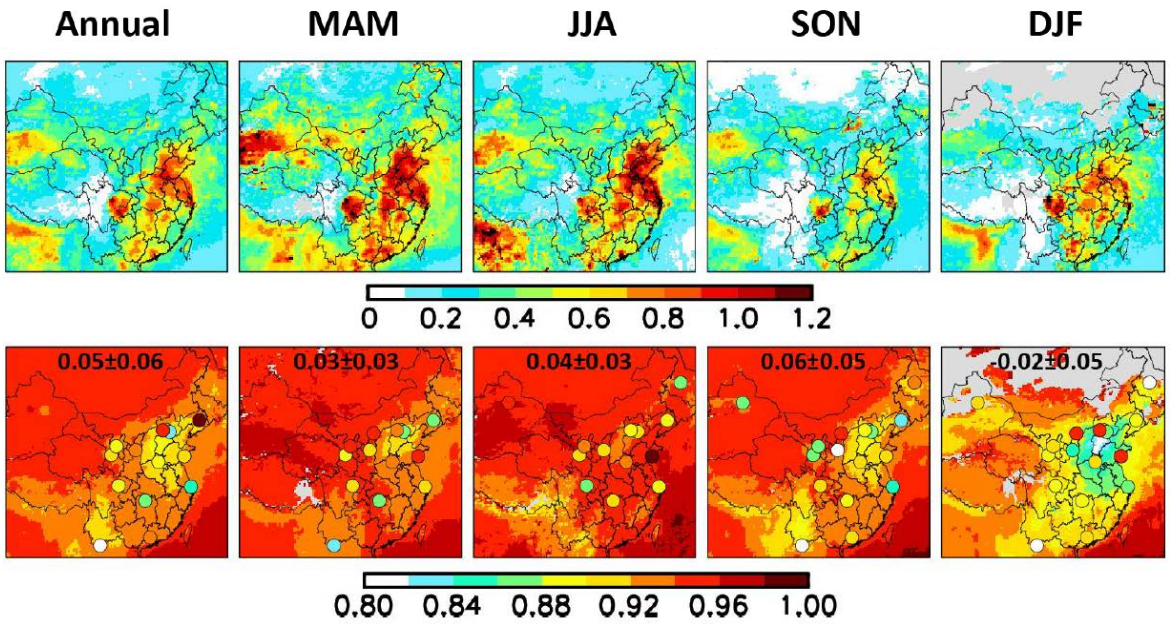
- SCD = F(radiance)
- SCD_T = SCD – SCD_S
- VCD_T = SCD_T / AMF



Issues in current NO_2 products:
- Not fully accounting for aerosol optics
- Inconsistent ancillary assumptions between NO_2 and cloud products
- No geometric dependence of surface reflectance
- Coarse-resolution NO_2 profile (200 km)
- Use of look-up table

*Improvements in our **POMINO**:*
- **Explicitly accounting for aerosols**
- **Same ancillary assumptions in retrieving NO_2 and clouds**
- **Accounting for surface reflectance anisotropy**
- **High-resolution NO_2 profile (50 km)**
- **Parallelized RTM calc. for each pixel**

Aerosol Treatment is Critical over China



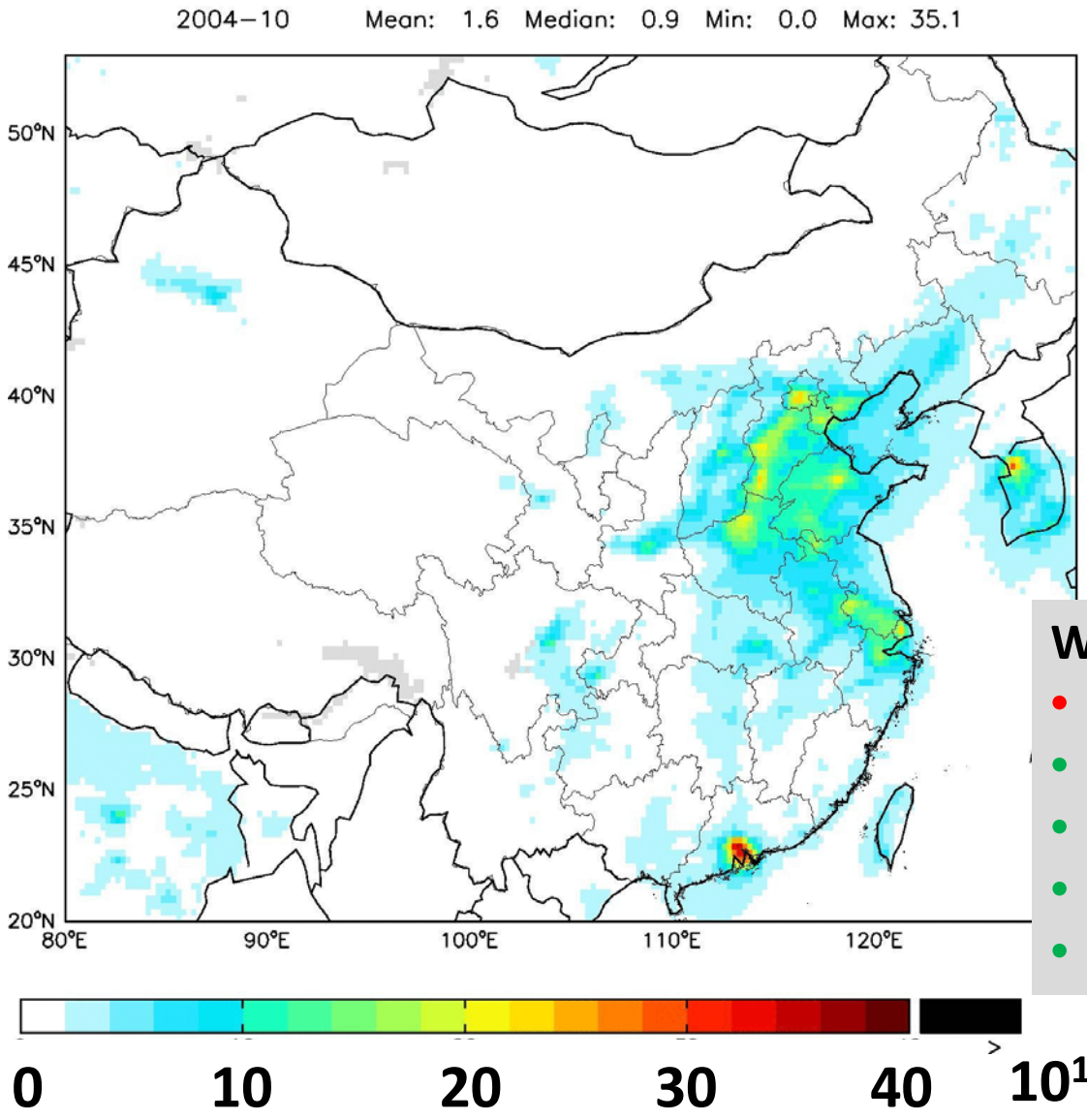
Characteristics of Chinese aerosols:

- Large amounts in key areas
- Highly absorbing in many areas
- Considerable spatiotemporal variability

Lin et al., 2015, ACP

POMINO – Peking University OMI NO_2 Product

http://www.atmos.pku.edu.cn/acm/satellite_no2.html

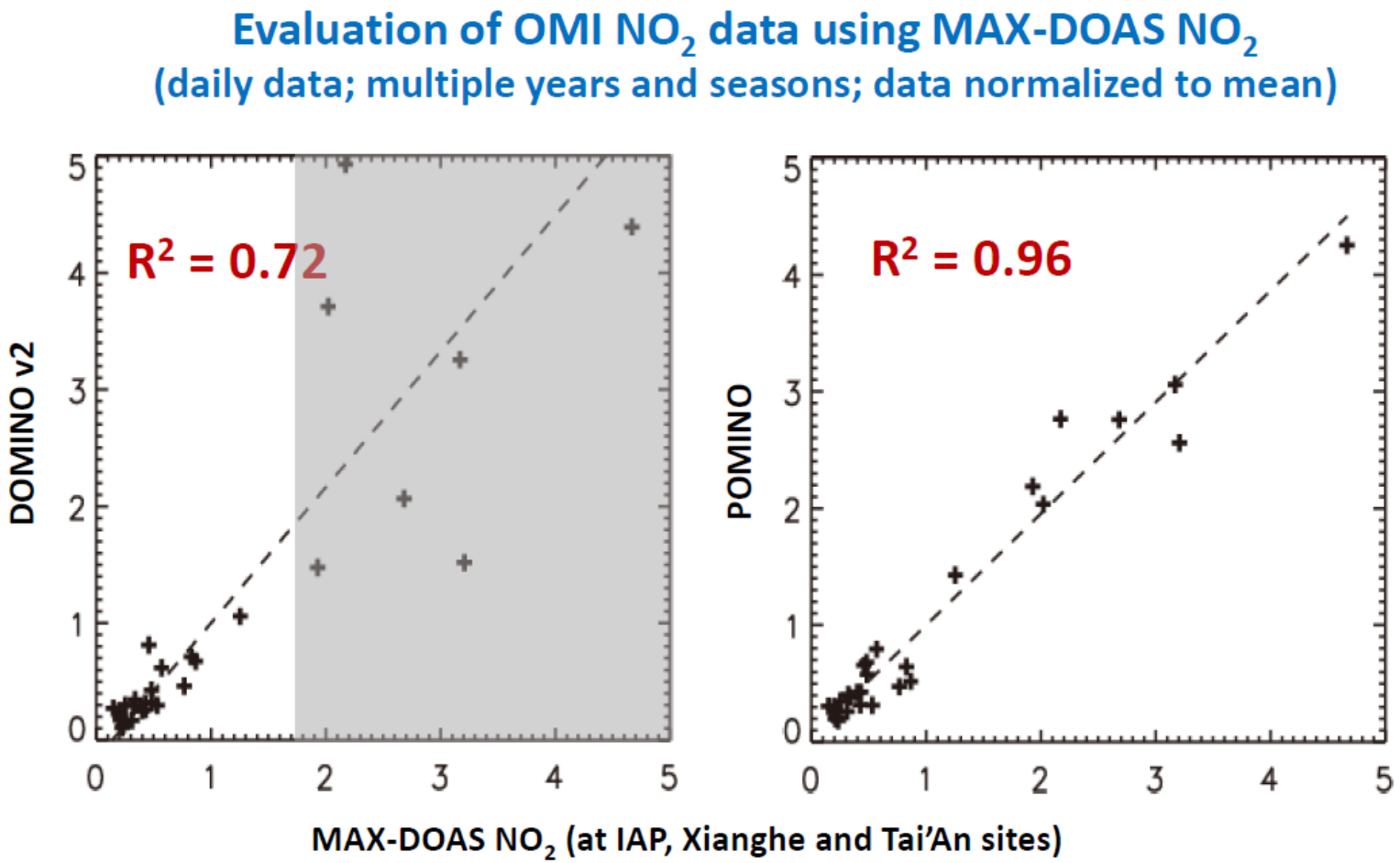


Lin et al., 2015 ACPD

What's new:

- Explicit aerosols
- Anisotropic Rs
- Coherent clouds
- High-res NO_2 prof.
- Pixel-specific RTM

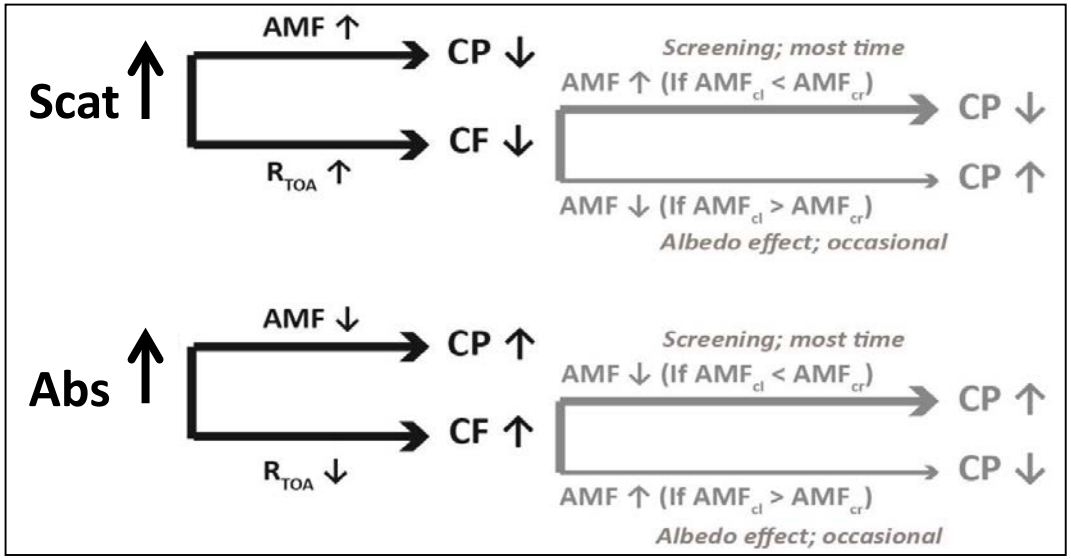
POMINO: Improved NO_2 Retrieval from OMI



Lin et al., 2014 ACP

Aerosols Complexly Affect Cloud & NO_2 Retrieval

- **Effects on Cloud**



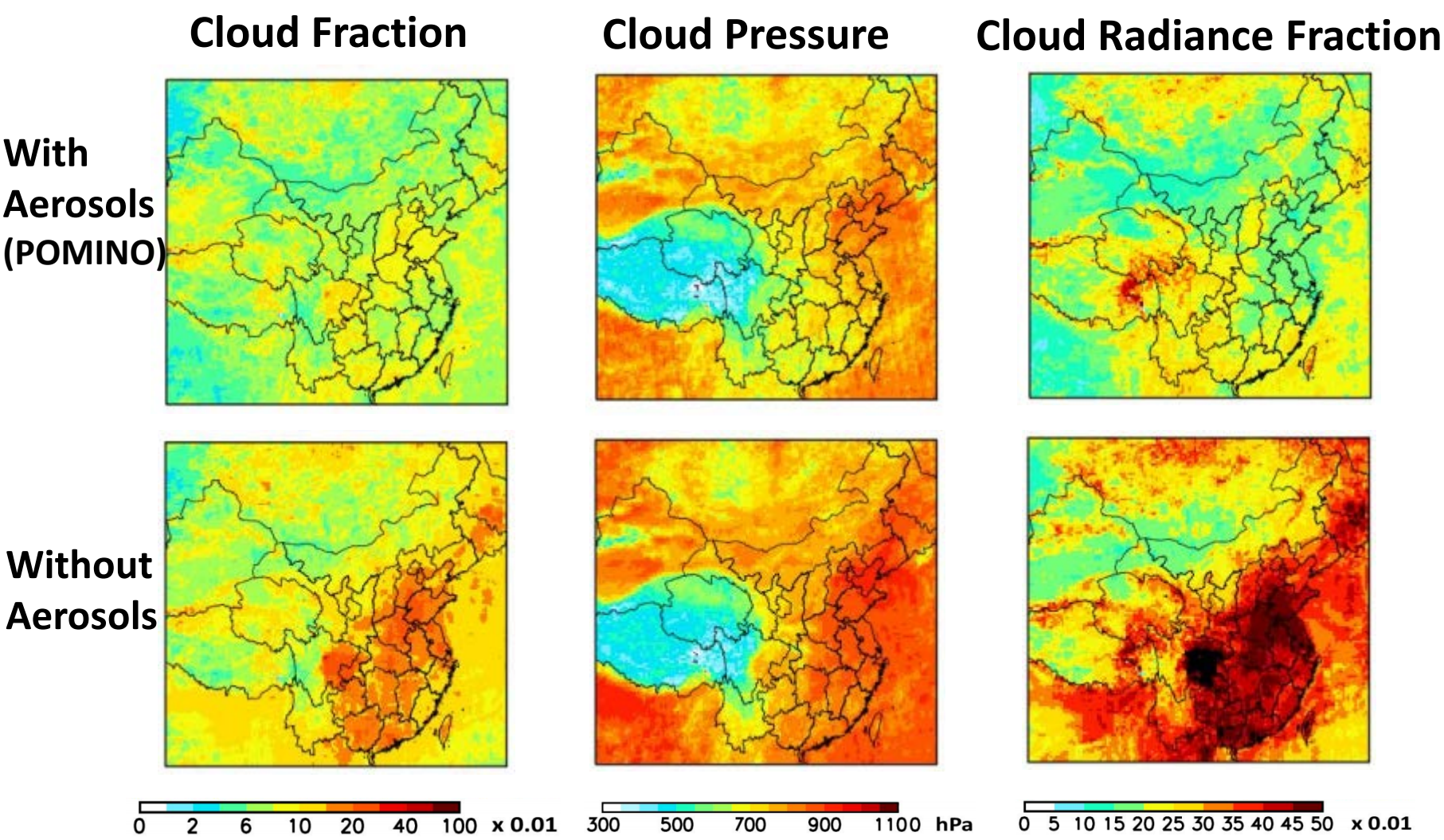
- **Effects on NO_2**

$$AMF = AMFcl \cdot CRF + AMFcr \cdot (1 - CRF) \quad \Leftrightarrow \quad VCD = \frac{1}{1/VCDcl \cdot CRF + 1/VCDcr \cdot (1 - CRF)}$$

- **Changes in CRF (CF) affect weights of AMFcl v.s. AMFcr**
- **Changes in CP affect the value of AMFcl**
- **Aerosols also affect the value of AMFcr**

Lin et al., 2015, ACP

Aerosols Complexly Affect Cloud Retrieval



Lin et al., 2015, ACP

Aerosols Complexly Affect NO_2 Retrieval

$$VCD = \frac{1}{1/VCDcl \cdot CRF + 1/VCDcr \cdot (1 - CRF)}$$

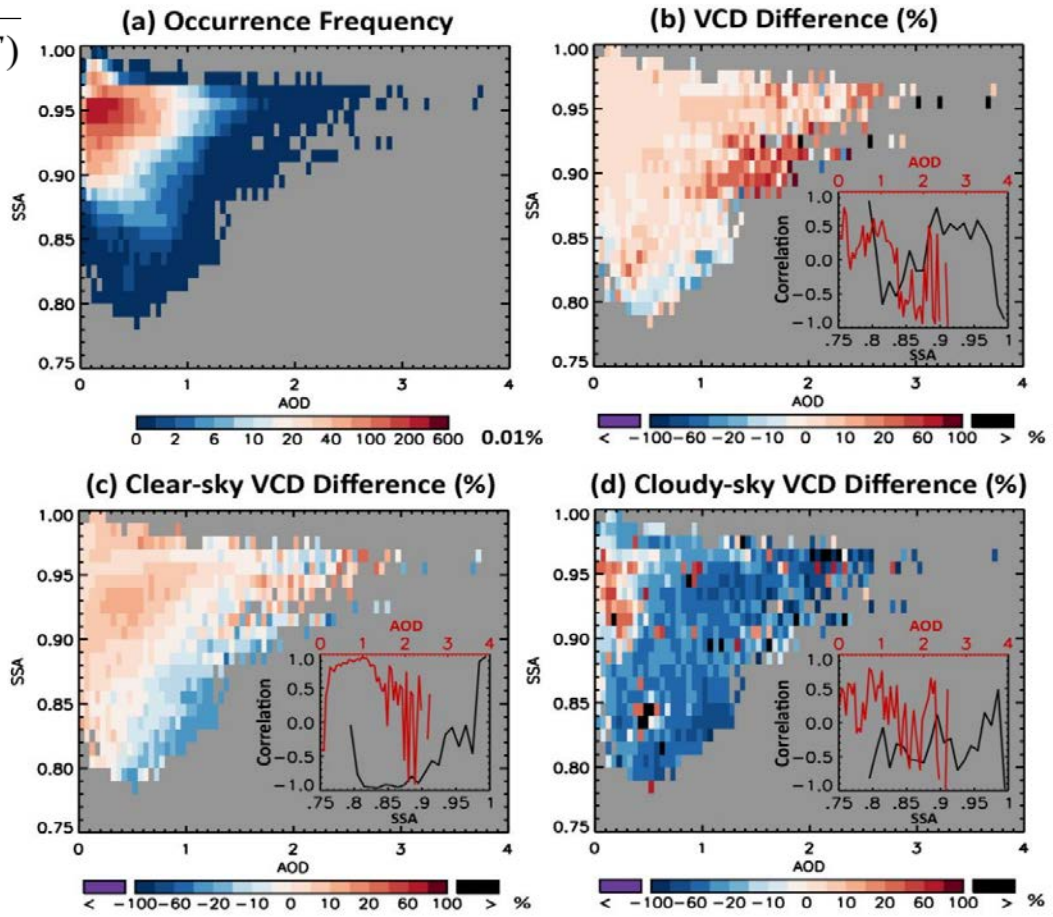
$VCD_{cl} = SCD/AMF_{cl}$

$VCD_{cr} = SCD/AMF_{cr}$

$VCD_{cl} > VCD_{cr}$

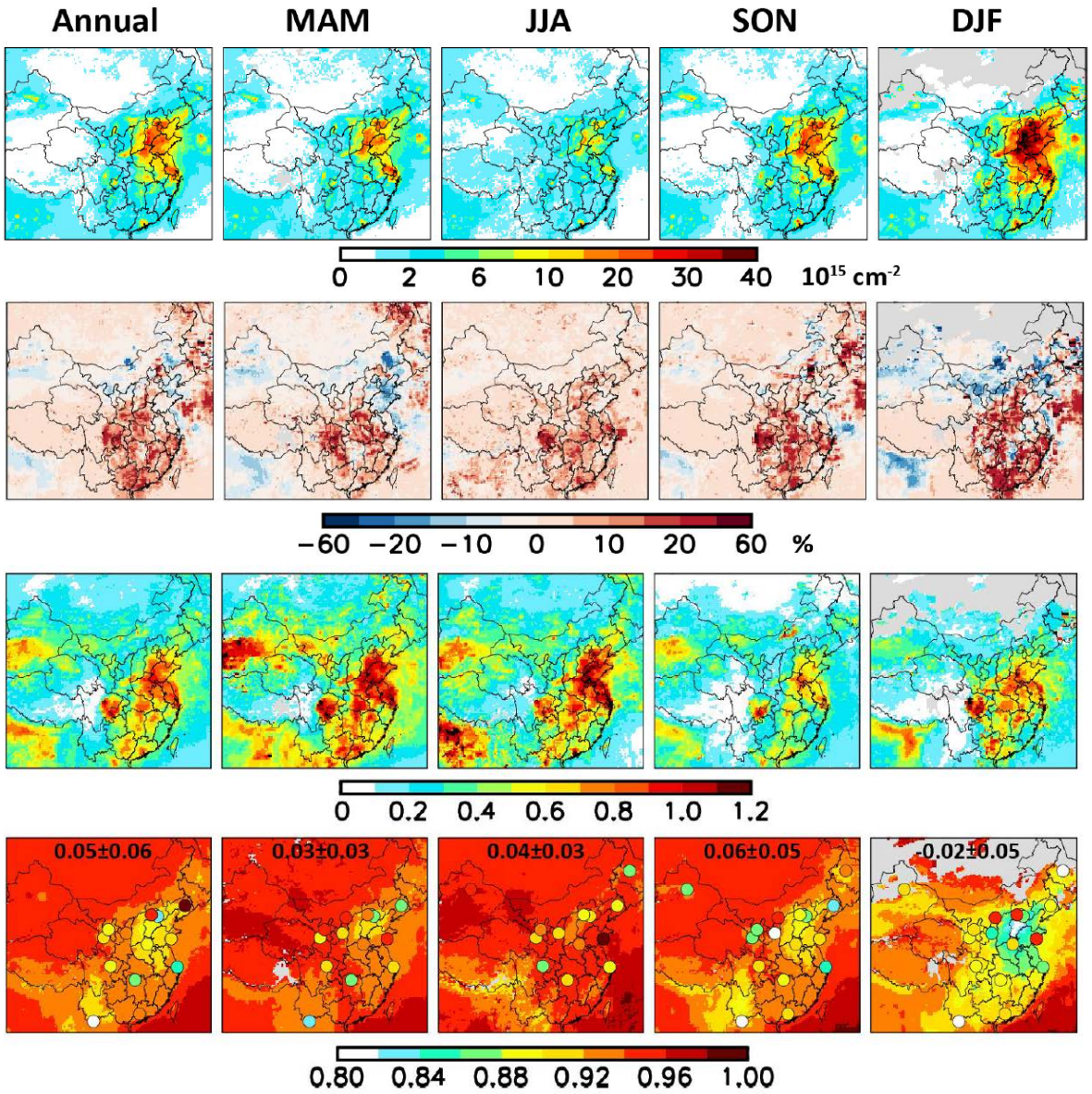
$CRF < 50\%$ (20% on avearge)

$[VCD_{noAER} - VCD_{POMINO}] / VCD_{POMINO}$ as a function of AOD and SSA



Lin et al., 2015, ACP

Explicit Aerosol Treatment Improves NO_2 Retrieval

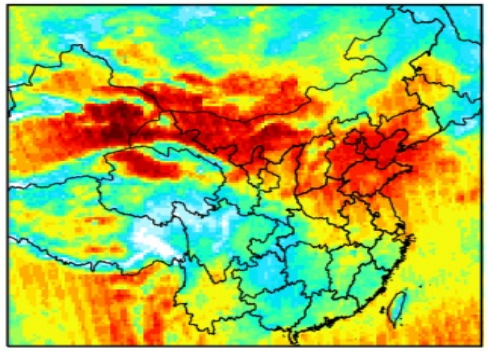


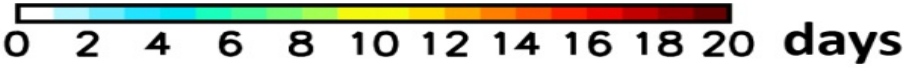
Lin et al., 2015, ACP

Explicit Aerosol Treatment Reduces Sampling Low Bias

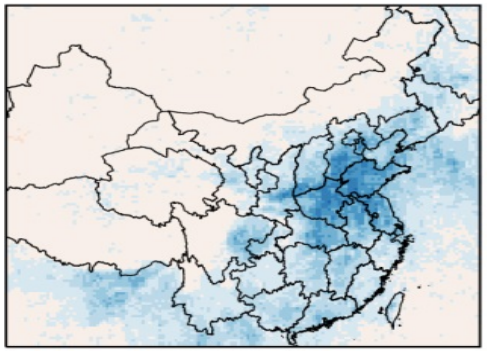
Valid pixels:
CRF ≤ 50%

Days per month w/ valid data in POMINO

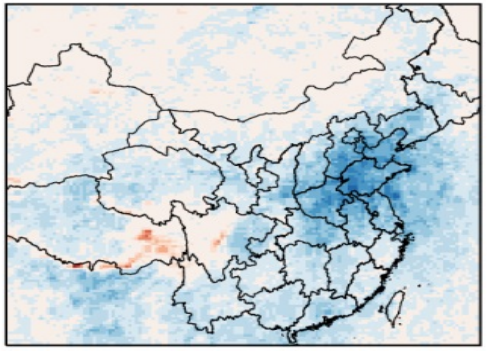




noAER – POMINO



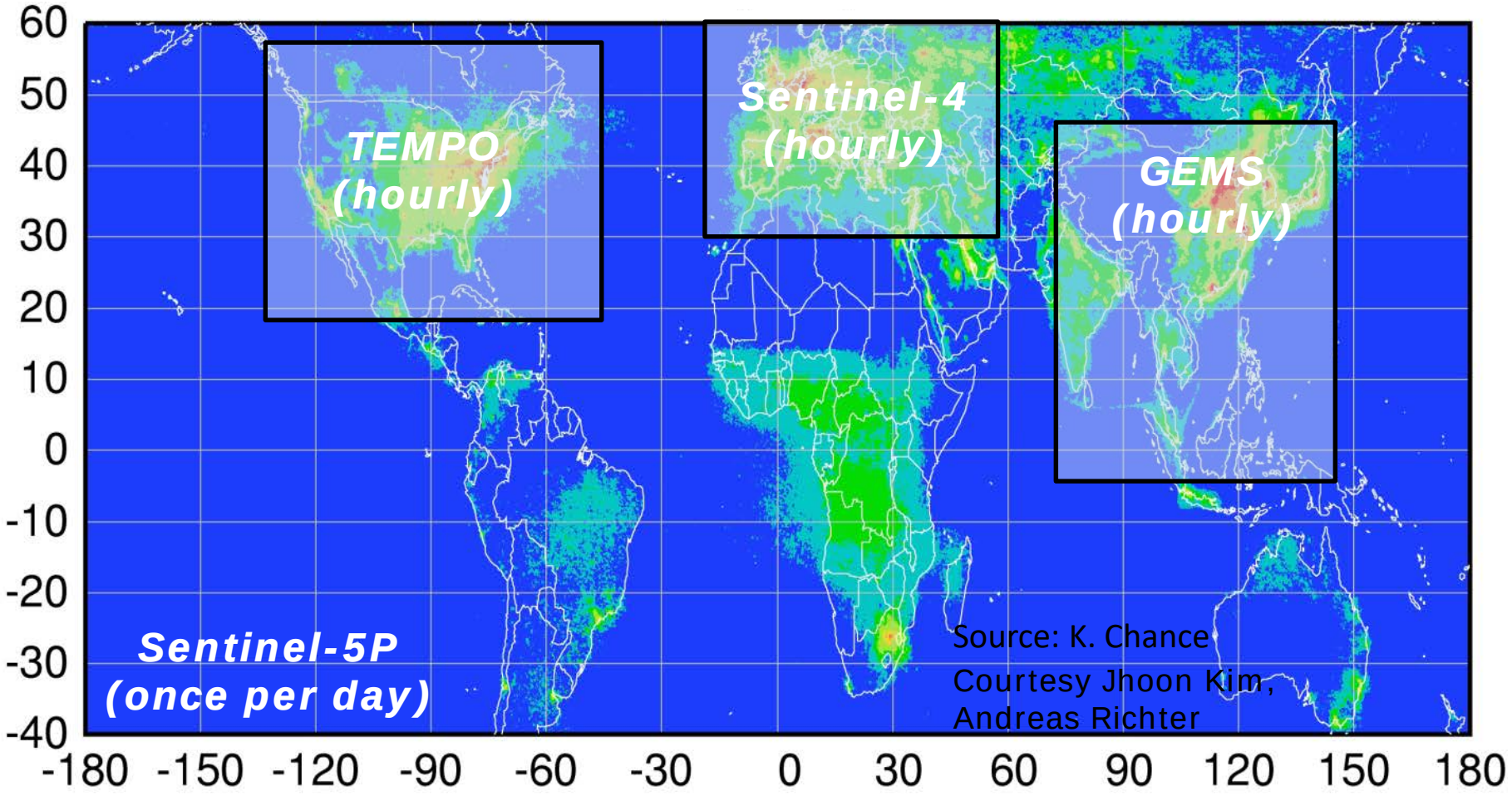
DOMINO – POMINO



- **An explicit treatment better accounts for high-pollution days**

Lin et al., 2015, ACP

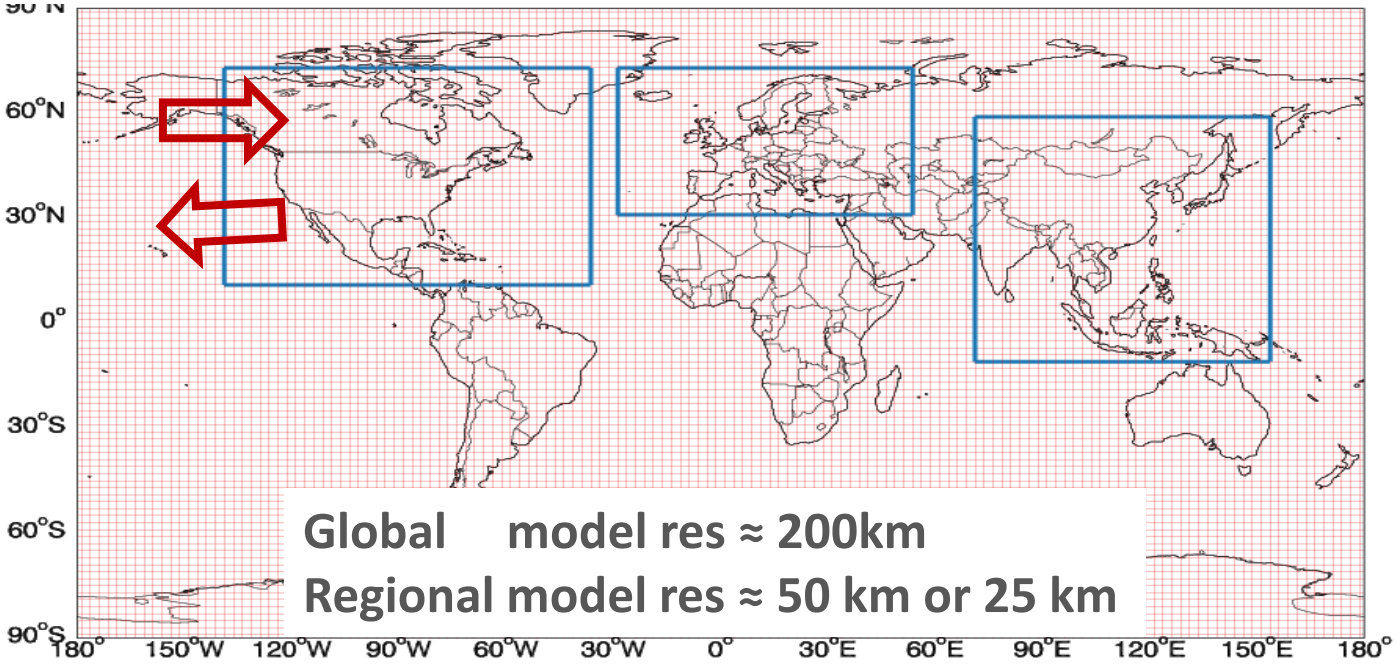
A Fast and High-res Global Modeling System is Needed to Interpret Geostationary Satellite Measurements



- Most global models are too coarse (200 km) to simulate fine processes

Based on GEOS-Chem

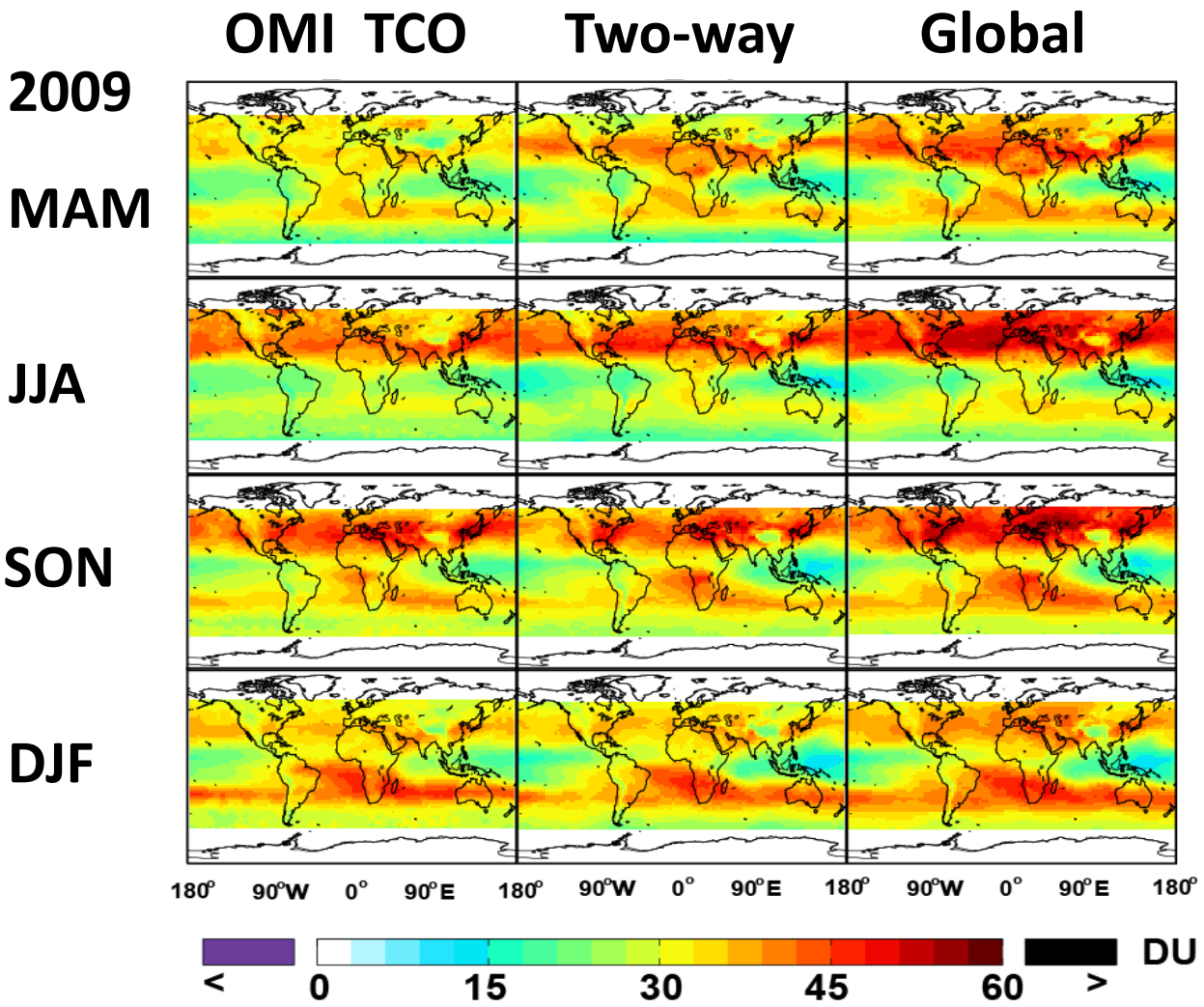
Global-multi-regional Two-way Coupled Modeling



- Global model provides LBCs for nested models
- Nested models provide simulation to 'correct' global model
- All models run simultaneously, with low system complexity

Yan Y.-Y. et al., 2014, ACP

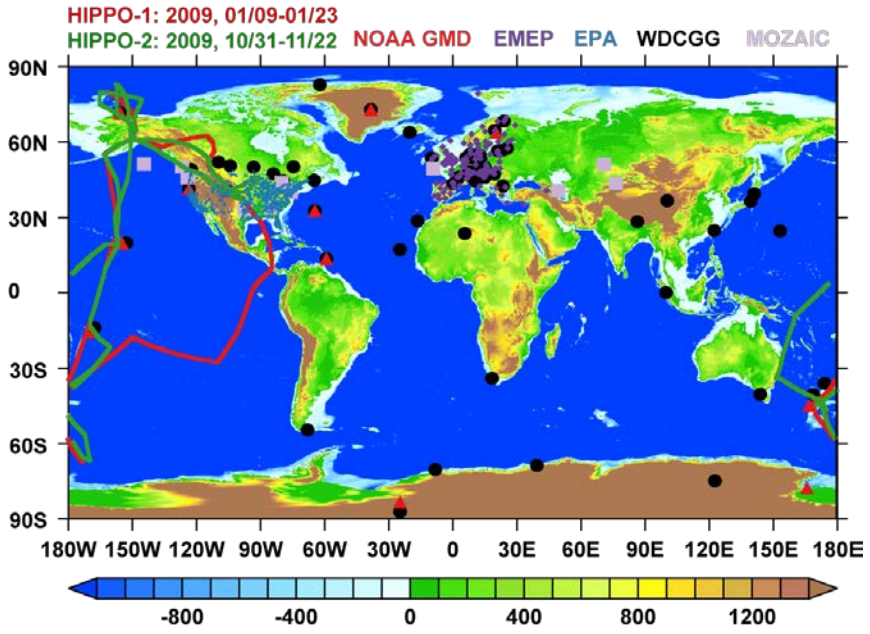
2-way Model Better Simulates Tropospheric O_3

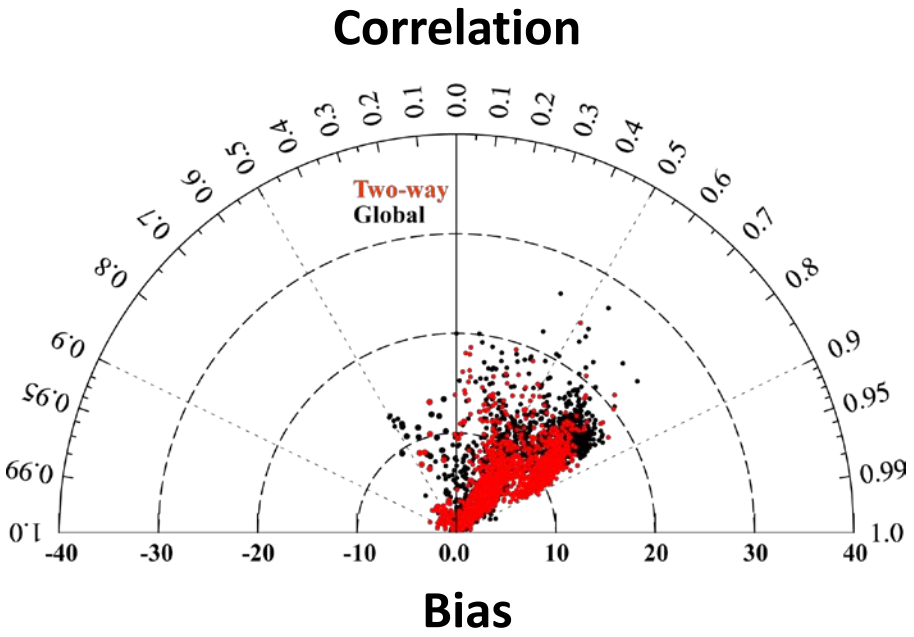


Yan Y.-Y. et al., 2015, ACPD

2-way Model Better Simulates Surface O_3

# of ground sites = 1420





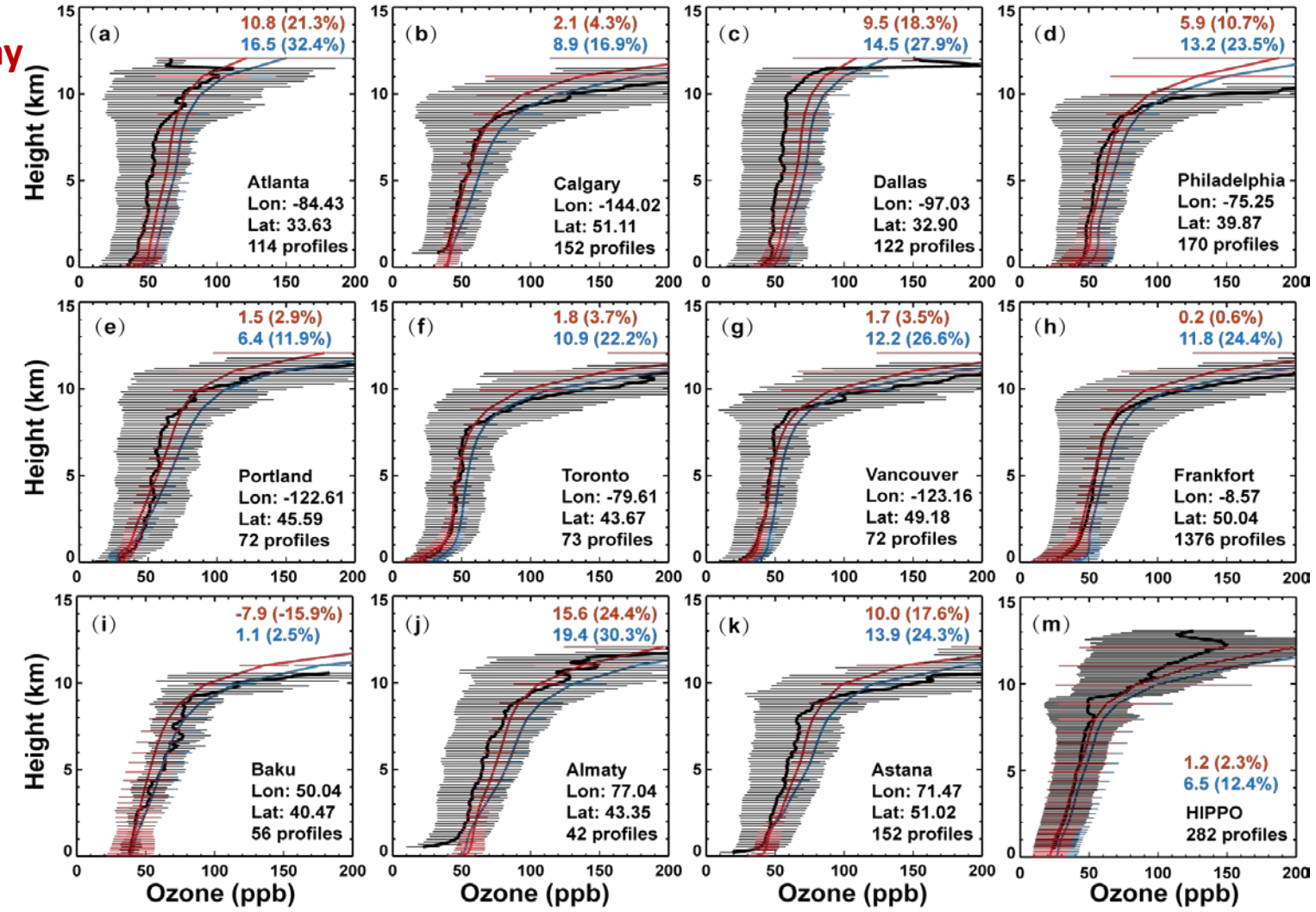
- Mean R increases from 0.51 to 0.65
- Mean bias decreases by 4.8 ppb

Yan Y.-Y. et al., 2015, ACPD

2-way Model Better Simulates O_3 Profiles

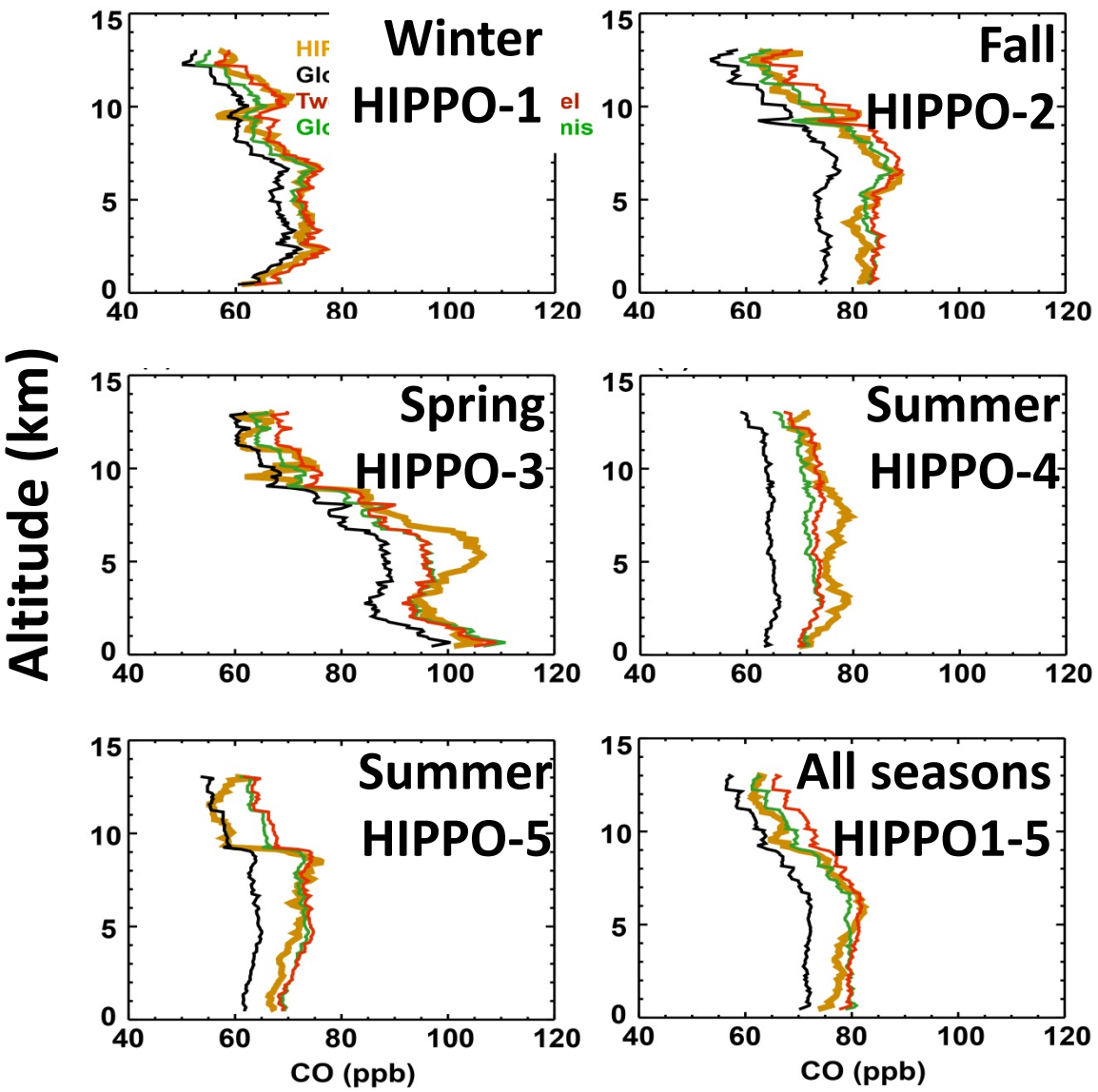
Comparisons with MOZIAC and HIPPO profiles

Obs
Two-way
Global



Yan Y.-Y. et al., 2015, ACPD

2-way Coupling Improves CO Simulation over the Pacific



- HIPPO data
- Global model
- Two-way model
- Global + CO emis
  - HIPPO-1: + 15%
  - HIPPO-2: + 25%
  - HIPPO-3: + 15%
  - HIPPO-4: + 25%
  - HIPPO-5: + 35%
  - Mean : + 25%

Yan Y.-Y. et al., 2014, ACP

Summary

- **POMINO: Our improved OMI NO_2 product**
  - **Fully account for aerosol optical effects**
  - **Fully account for surface reflectance anisotropy**
  - **Account for high-res vertical profile of NO_2**
  - **Consistent retrievals of cloud properties and NO_2**
  - **Line-by-line radiative transfer calculation (no LUT)**
- **POMINO data notably affect NOx emis variability estimate**
- **Our retrieval can apply to SO_2, HCHO, CHOCHO, etc.**
- **A high-res model system to integrate global satellite data**

More analyses can be found at
http://www.atmos.pku.edu.cn/acm/acmProduct.html

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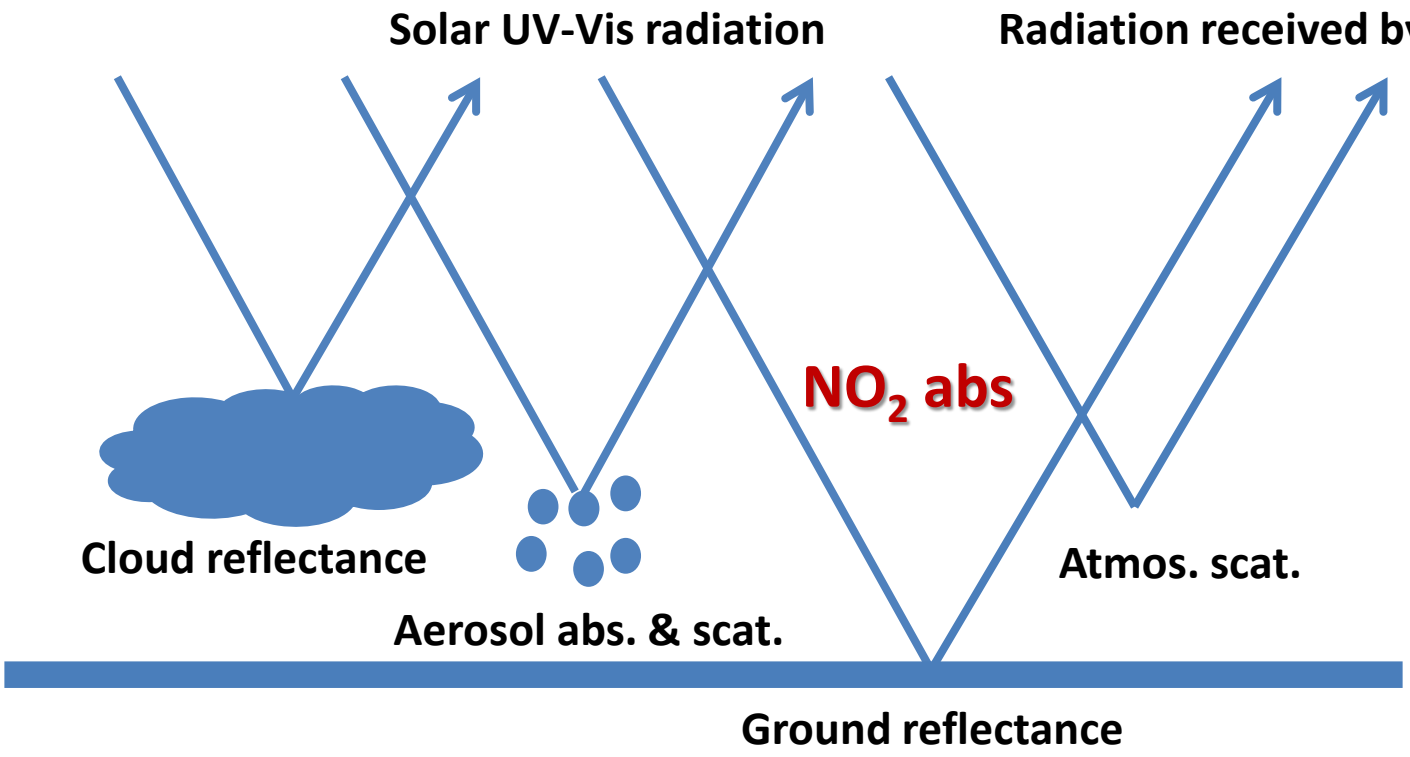
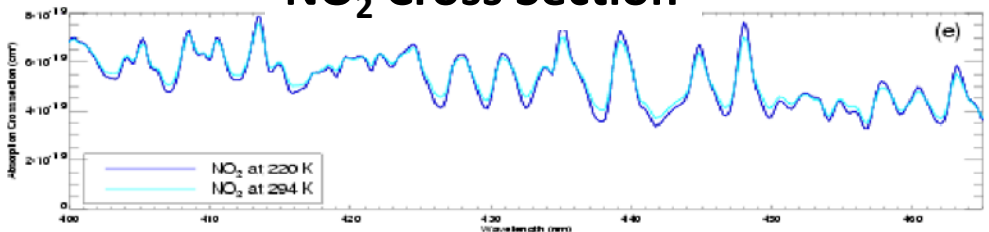
Satellite Remote Sensing to Retrieve NO_2



NO_2 Cross Section



400 nm 430nm 460 nm

$0.001 < OD < 0.05$