

Space-based constraints on Chinese NMVOC emissions and impacts on regional air quality

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4 BIRA; 5 Tsinghua U; 6 IAP / CAS; 7 South China U of Tech

The 1st Regional GEOS-Chem Asia Meeting

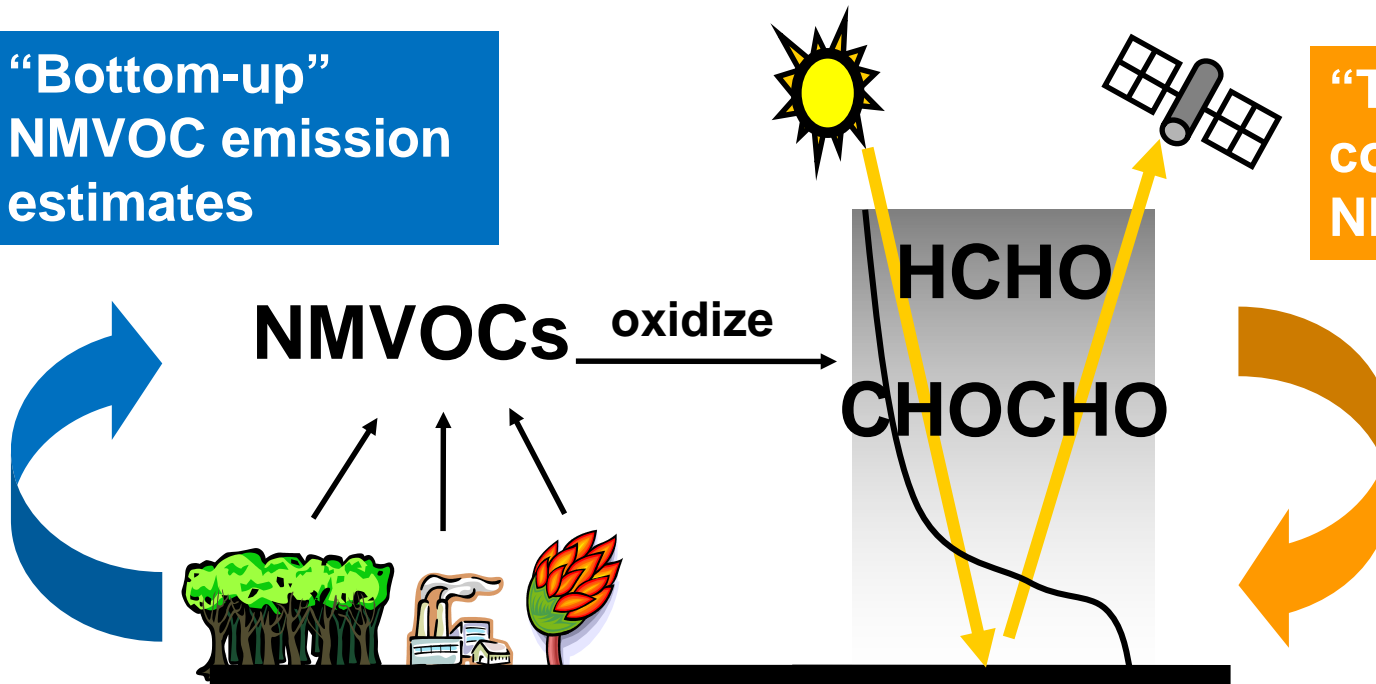


Atmospheric Chemistry & Climate @ Peking University
www.phy.pku.edu.cn/atmoschem/

Formaldehyde and glyoxal observed by satellites provide “top-down” constraints on NMVOC emissions

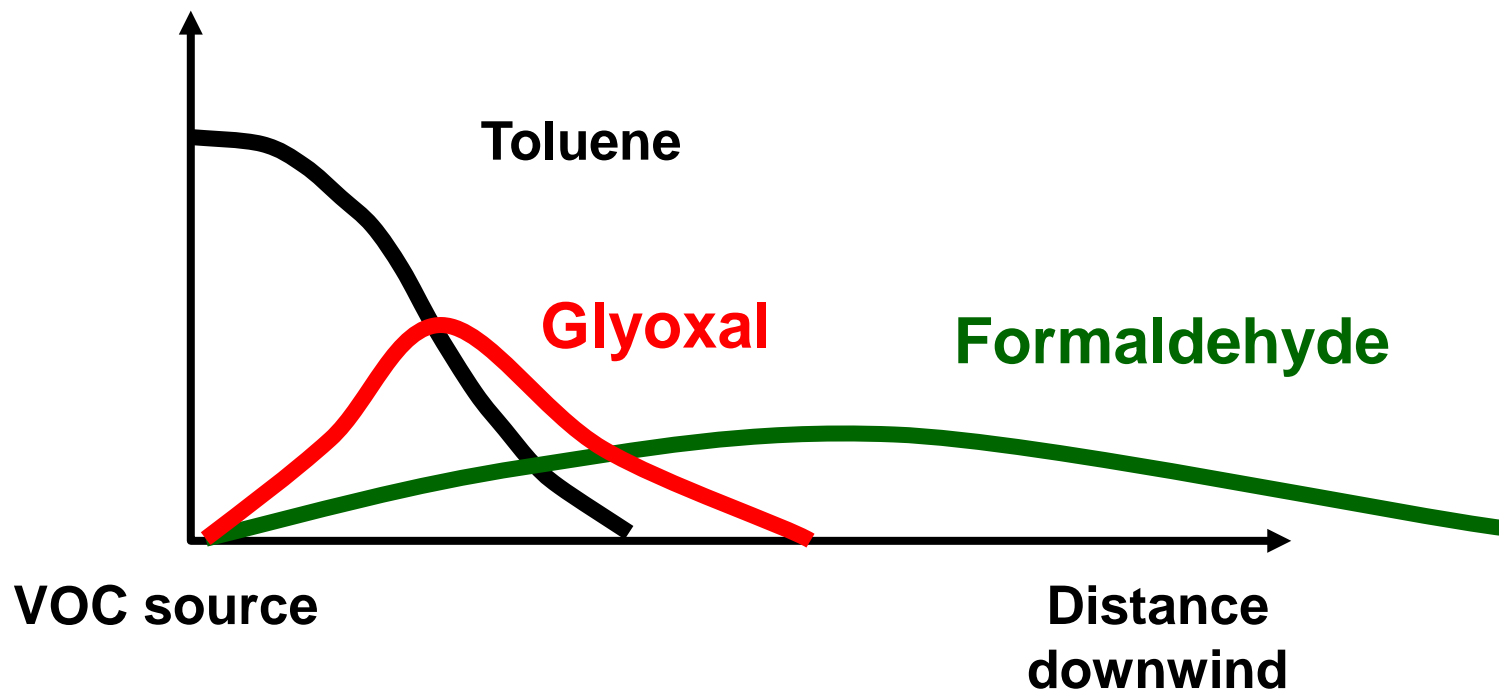
“Bottom-up”
NMVOC emission
estimates

“Top-down”
constraints on
NMVOC emissions

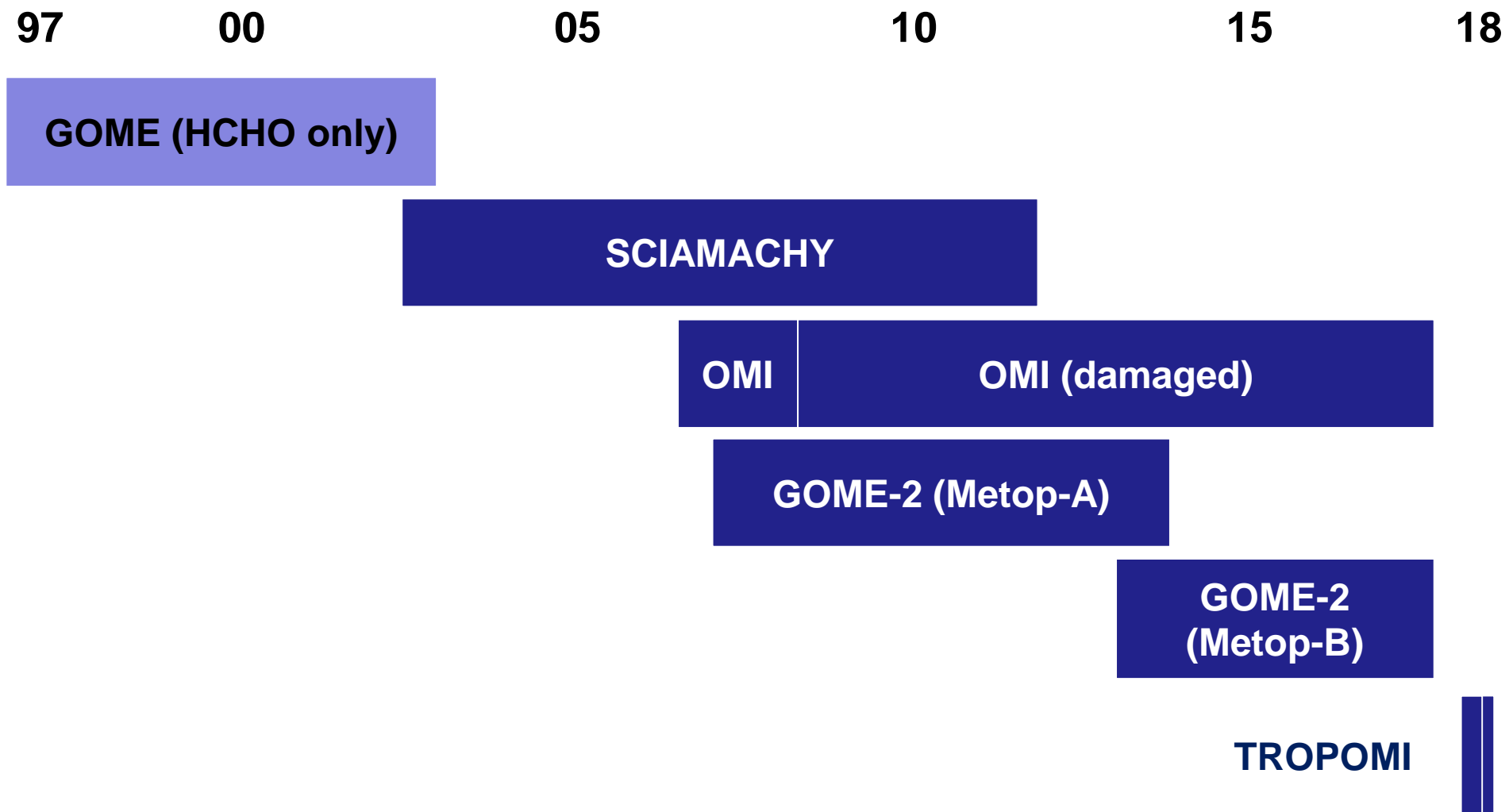


- Good where local data are scarce
- Not so good for chemical speciation
- Subject to a different set of uncertainties associated with satellite and model
- Validation of satellite observations difficult

Formaldehyde + glyoxal obs differentiate precursors



>20 years of satellite obs of HCHO and CHOCHO



Satellite observes NMVOC oxidation products: formaldehyde and glyoxal

GOME-2A

Onboard MetOpA, 2007 – 2014

Overpasses at 9:30 LT

DOAS retrieval (BIRA)

Global coverage in 1 day

Resolution 80 km x 40 km

OMI

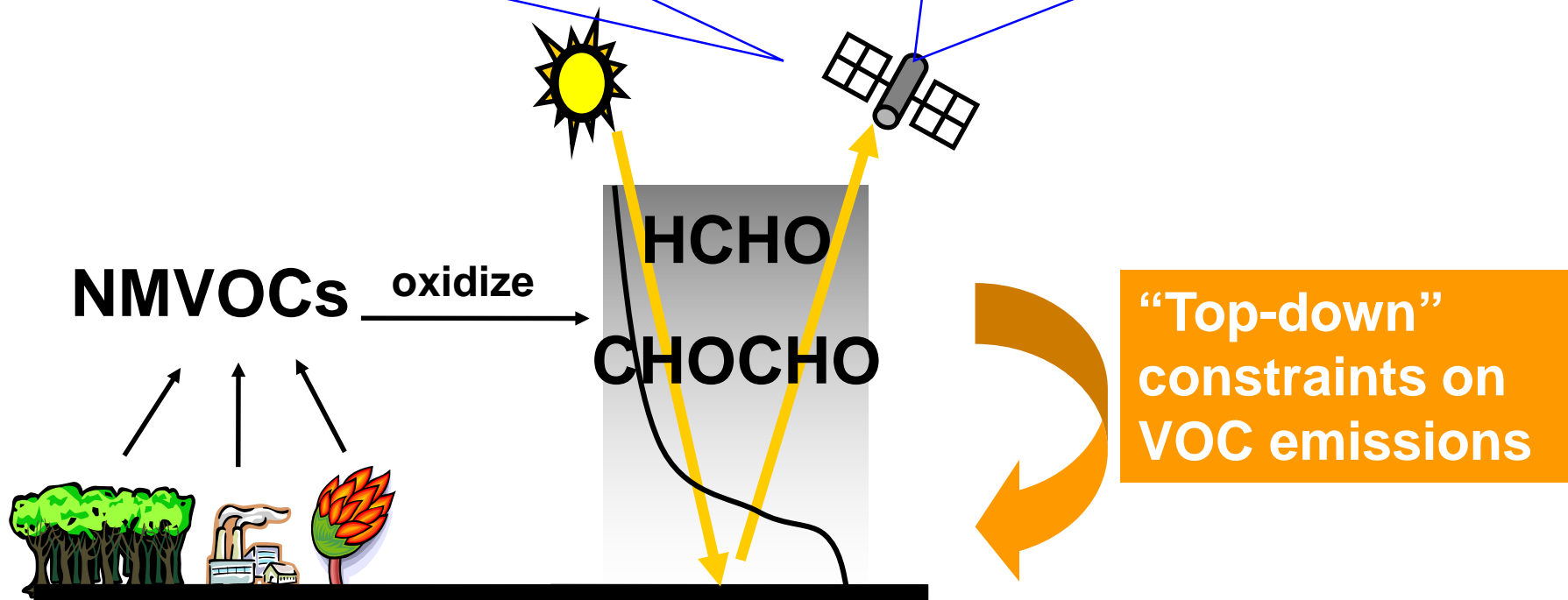
Onboard Aura, 2004 – 2008

Overpasses at 13:30 LT

Direct spectral fitting (Harvard / SAO)

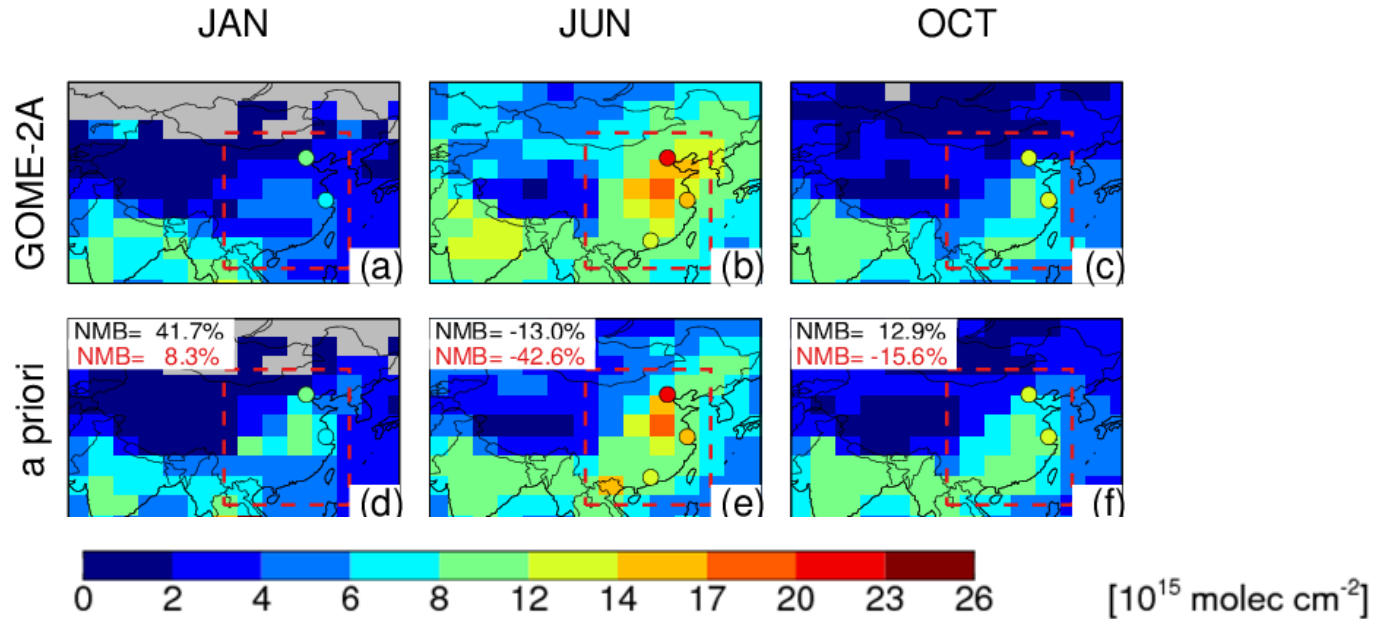
Global coverage in 1 day

Resolution 24 km x 13 km

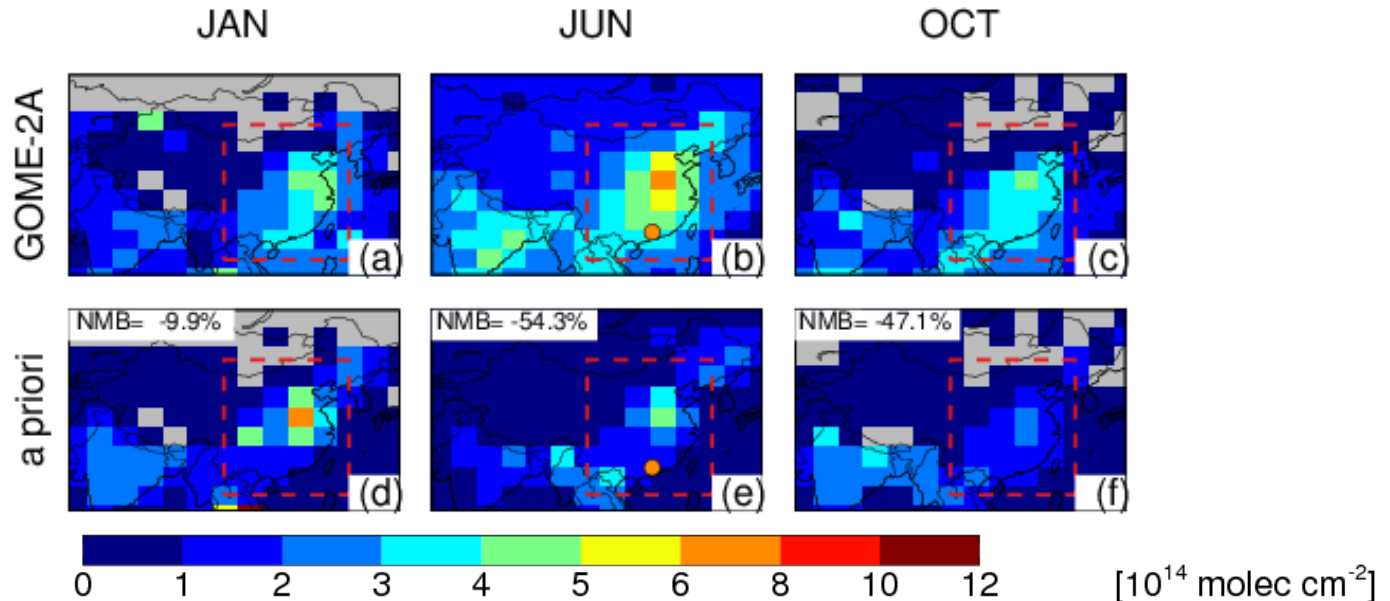


GOME-2A: model *a priori* over-est anthropogenic NMVOC in winter Under-est biogenic/biomass burning NMVOC in summer

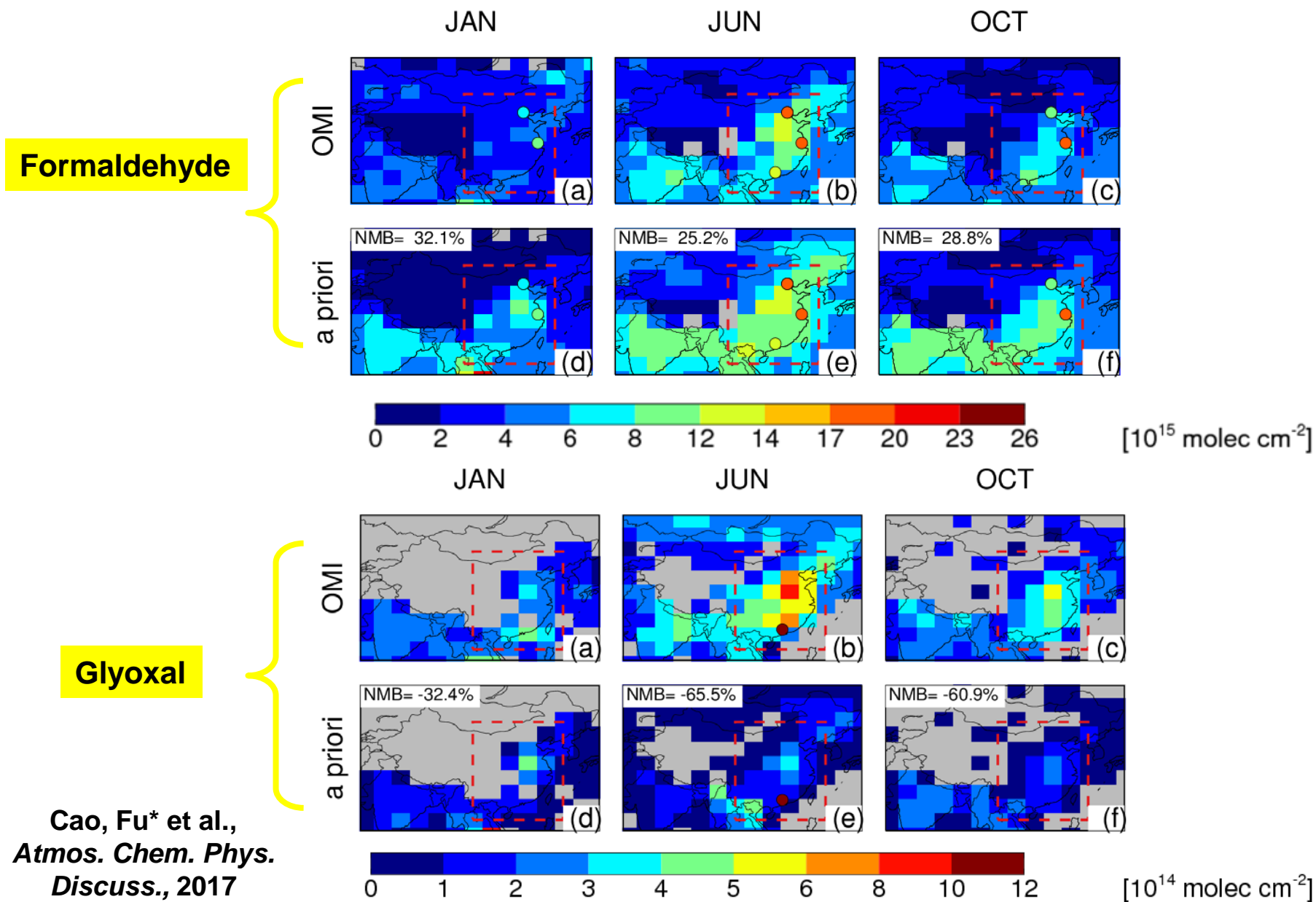
Formaldehyde



Glyoxal



OMI: model *a priori* over-est HCHO but under-est glyoxal in winter and in summer



Using model adjoint to invert for emissions

Cost function:

$$J(X) = \gamma(X - X_a)S_a^{-1}(X - X_a) \\ + (K_H X - H_o)S_{oH}^{-1}(K_H X - H_o) + (K_G X - G_o)S_{oG}^{-1}(K_G X - G_o)$$

X_a and X : a priori emission and model emission vectors

H_o and G_o : formaldehyde and glyoxal observation vectors

K_H and K_G : simulated sensitivity of formaldehyde and glyoxal to emissions

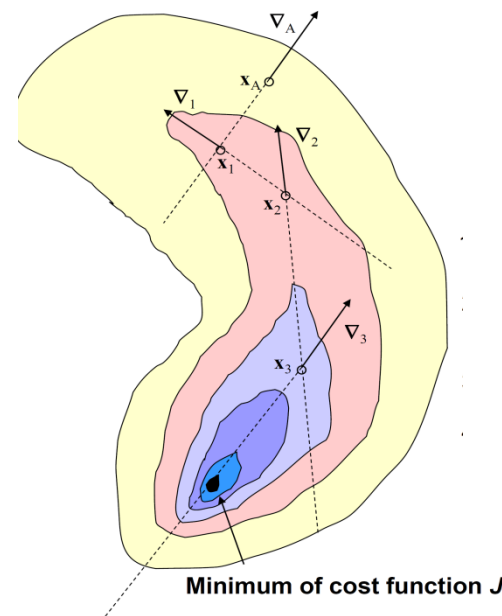
S_a and S_o : covariance matrices of the a priori emission and the observation

To solve the inverse problem is to find the minimum of J :

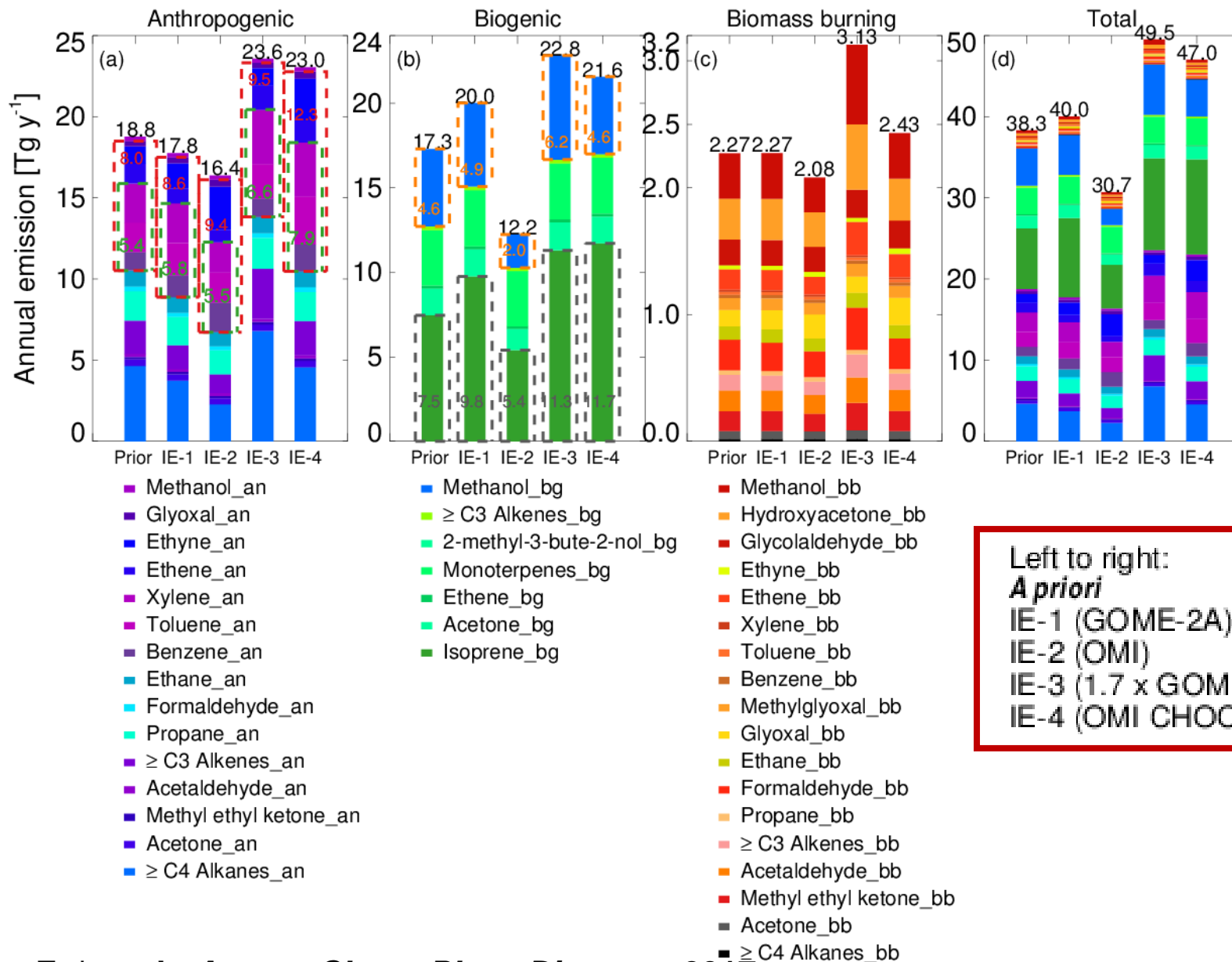
$$\nabla_x J = S_a(X - X_a) + \mathbf{K}^T S_o^{-1}(F(X) - Y) = 0$$



Model adjoint

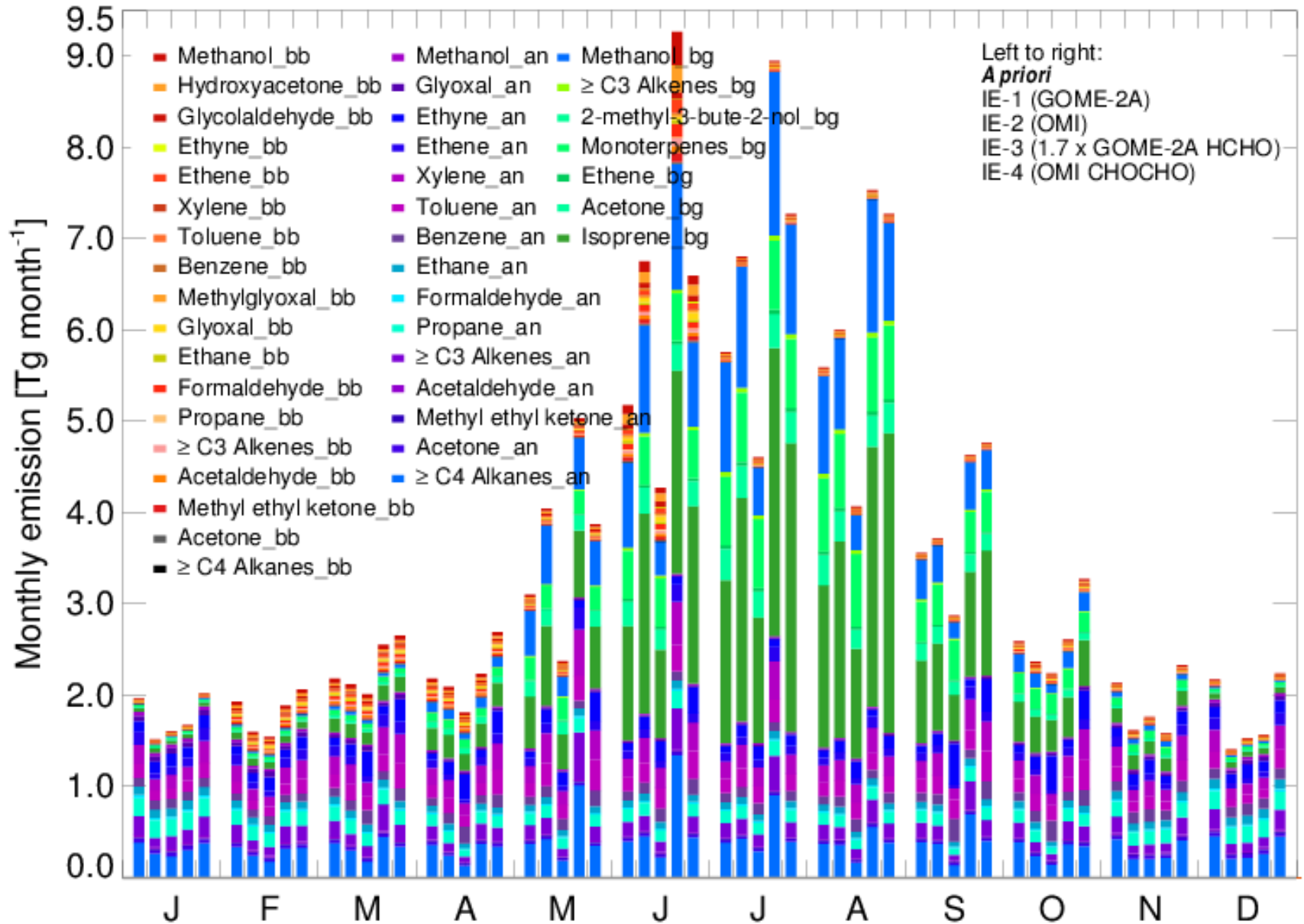


Top-down constraints on Chinese VOC emissions in 2007

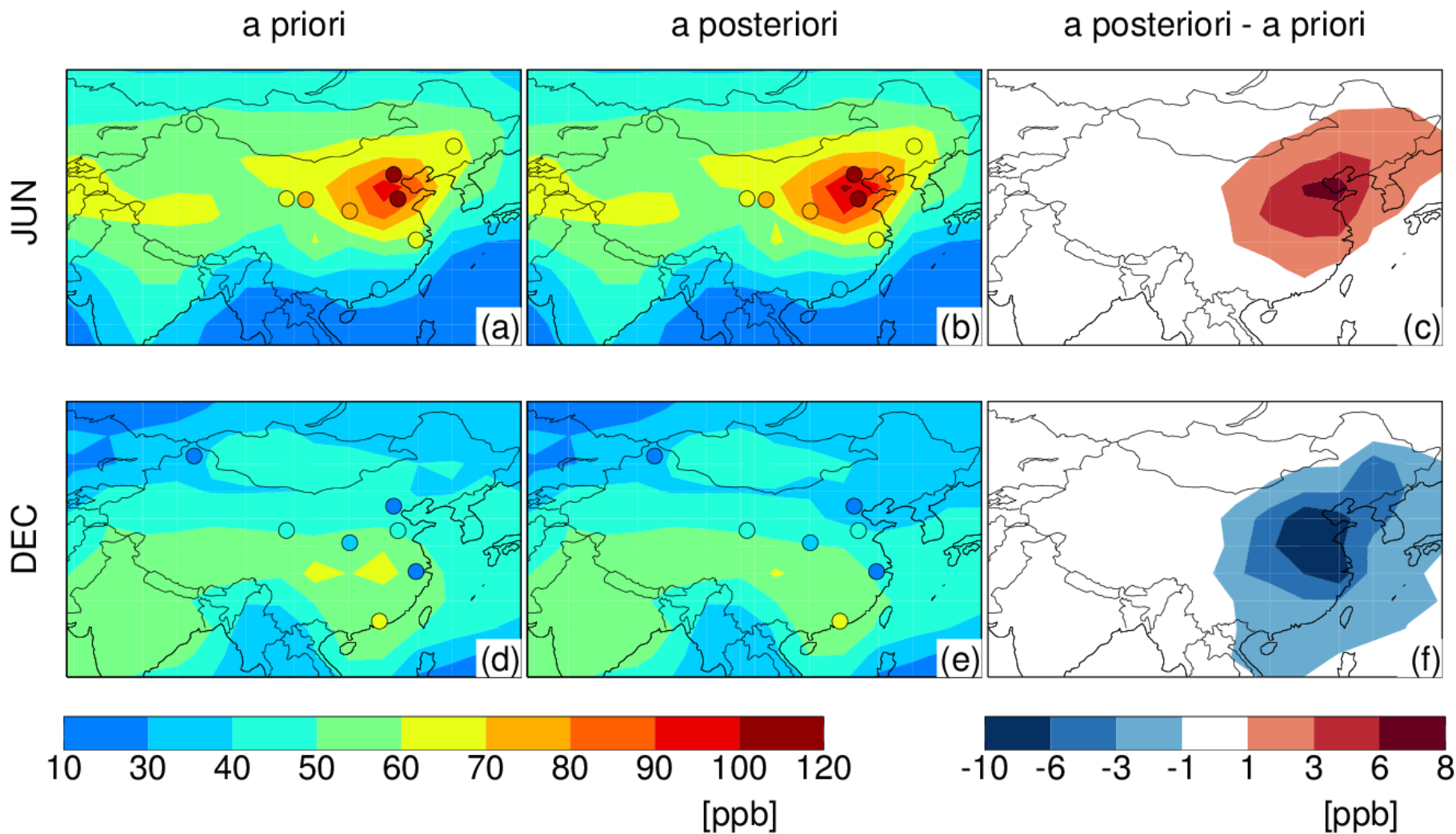


Left to right:
A priori
 IE-1 (GOME-2A)
 IE-2 (OMI)
 IE-3 (1.7 x GOME-2A HCHO)
 IE-4 (OMI CHOCHO)

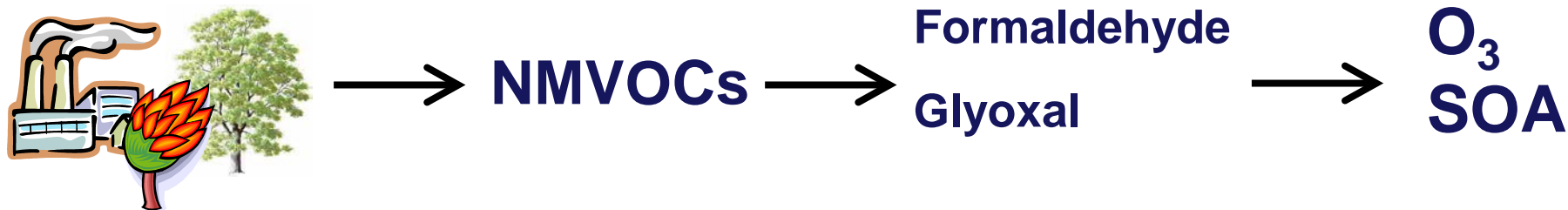
Top-down constraints on Chinese VOC emissions in 2007



Change in seasonal NMVOC emissions have large impacts on surface O_3



Summary



- Our top-down estimates for Chinese annual total NMVOC emission ranged from 30.7 to 49.5 Tg y⁻¹. The average was 41.8 Tg y⁻¹, including 55% from anthropogenic sources, 41% from biogenic sources, and 4% from biomass burning.
- The simultaneous use of glyoxal and formaldehyde observations helped distinguish the NMVOC species from different sources.
- Simulated surface ozone levels using our top-down emission estimates were in better agreement with measurements.

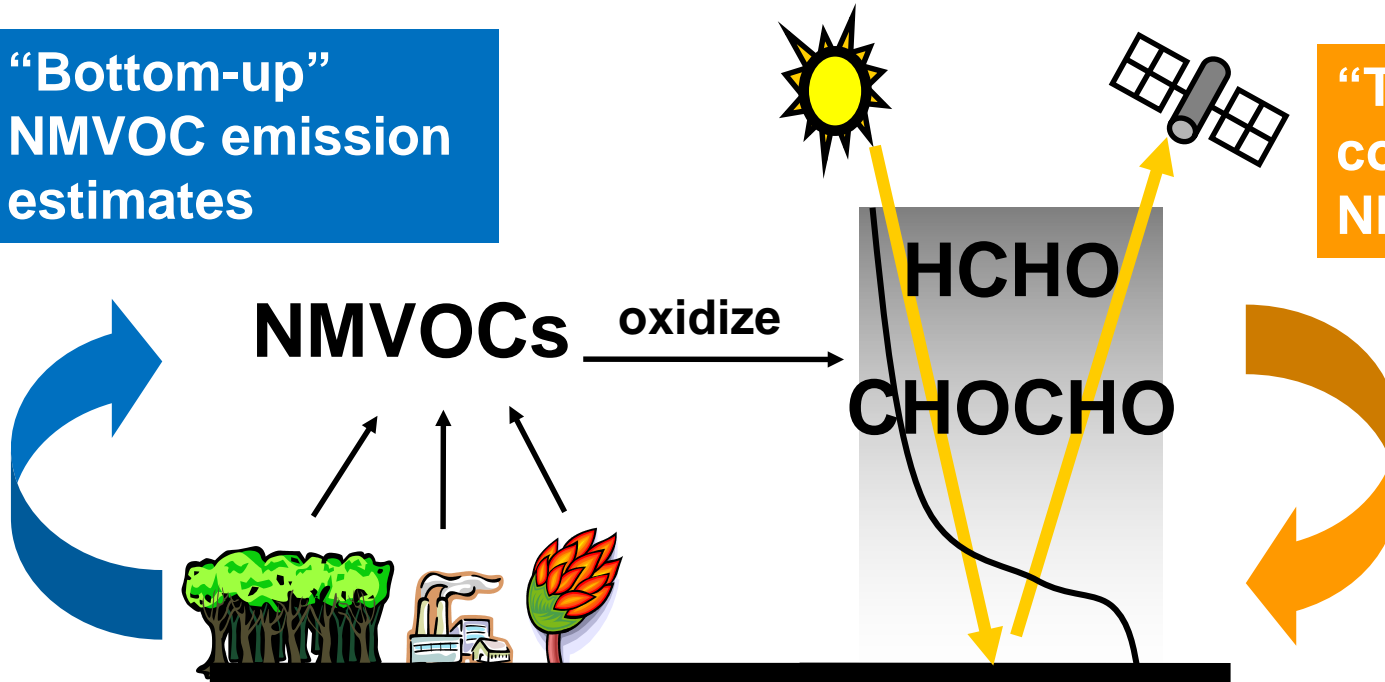
Advertisement

- Hansen CAO (poster today): Adjoint inversion of Chinese NMVOC emissions using satellite observations
- Heng TIAN (poster today): Impacts of emission and climate changes on air quality in China
- Lijuan ZHANG (poster today): Impacts of anthropogenic aerosols on meso-scale convective systems in South China
- Yaping MA (poster today): Evaluation of emergency emission reduction measures in BTH
- Xu FENG (talk this afternoon): Neural network forecasts of agricultural waste burning
- Haipeng LIN (poster yesterday): WRF-GEOS-Chem: a new online coupled regional weather – chemistry model

Formaldehyde and glyoxal observed by satellites provide “top-down” constraints on NMVOC emissions

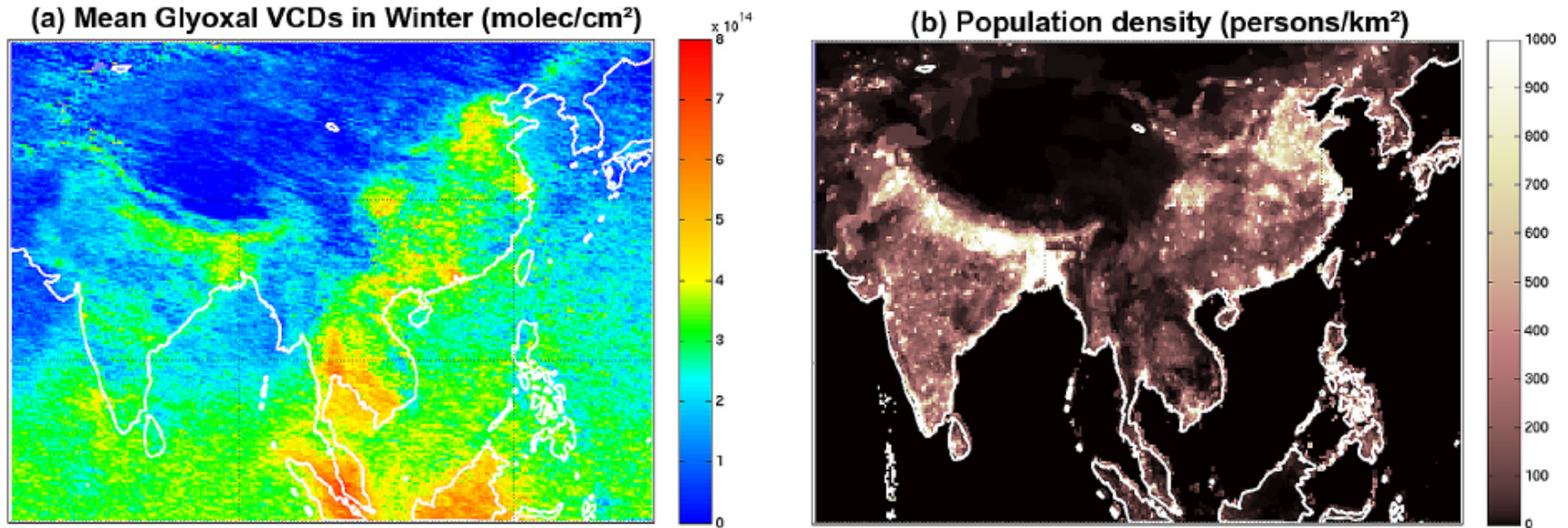
“Bottom-up”
NMVOC emission
estimates

“Top-down”
constraints on
NMVOC emissions



- Good for chemical speciation
- Large uncertainties associated with activity data and emission factors

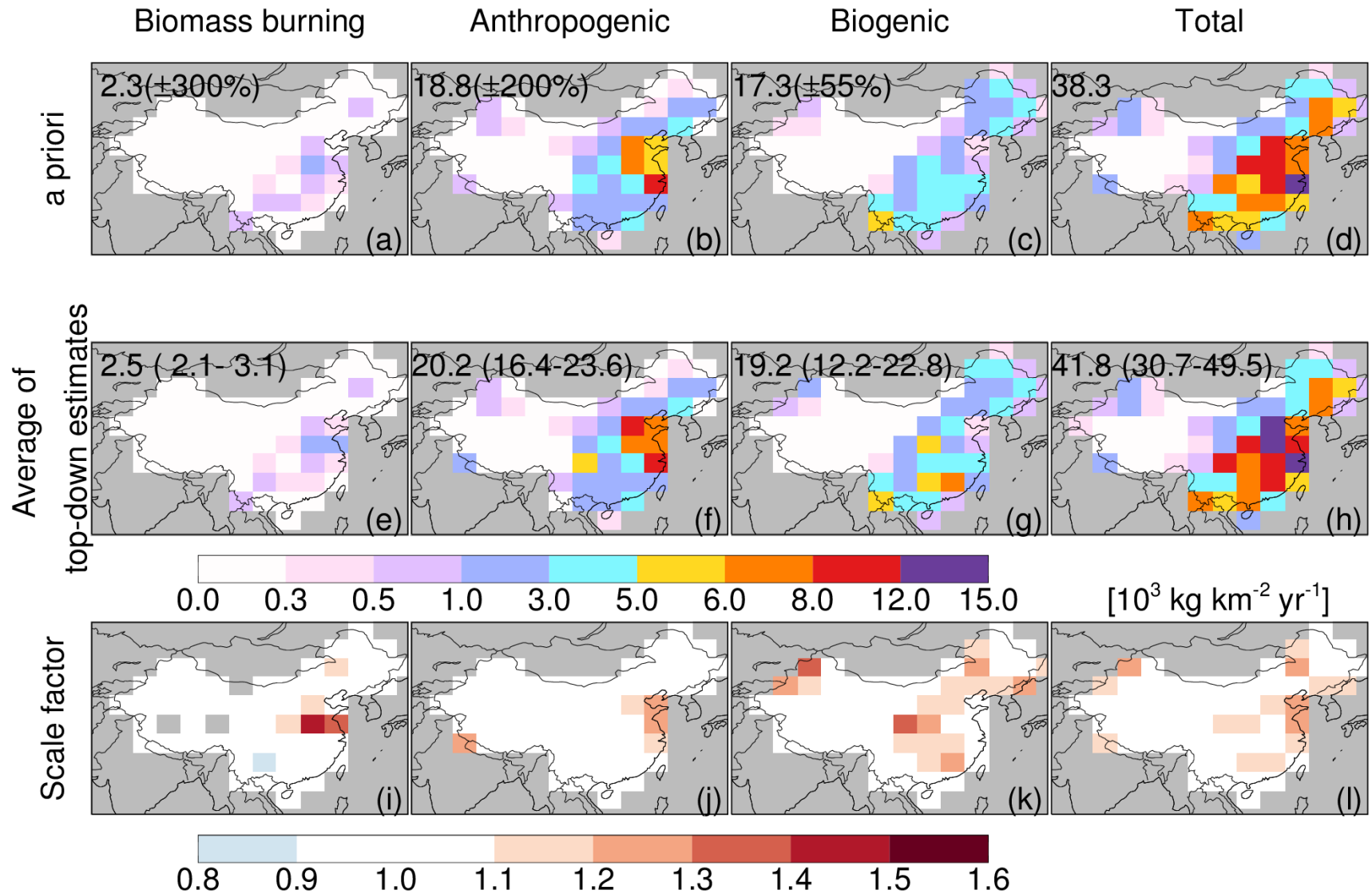
Glyoxal is more sensitive to anthropogenic emissions

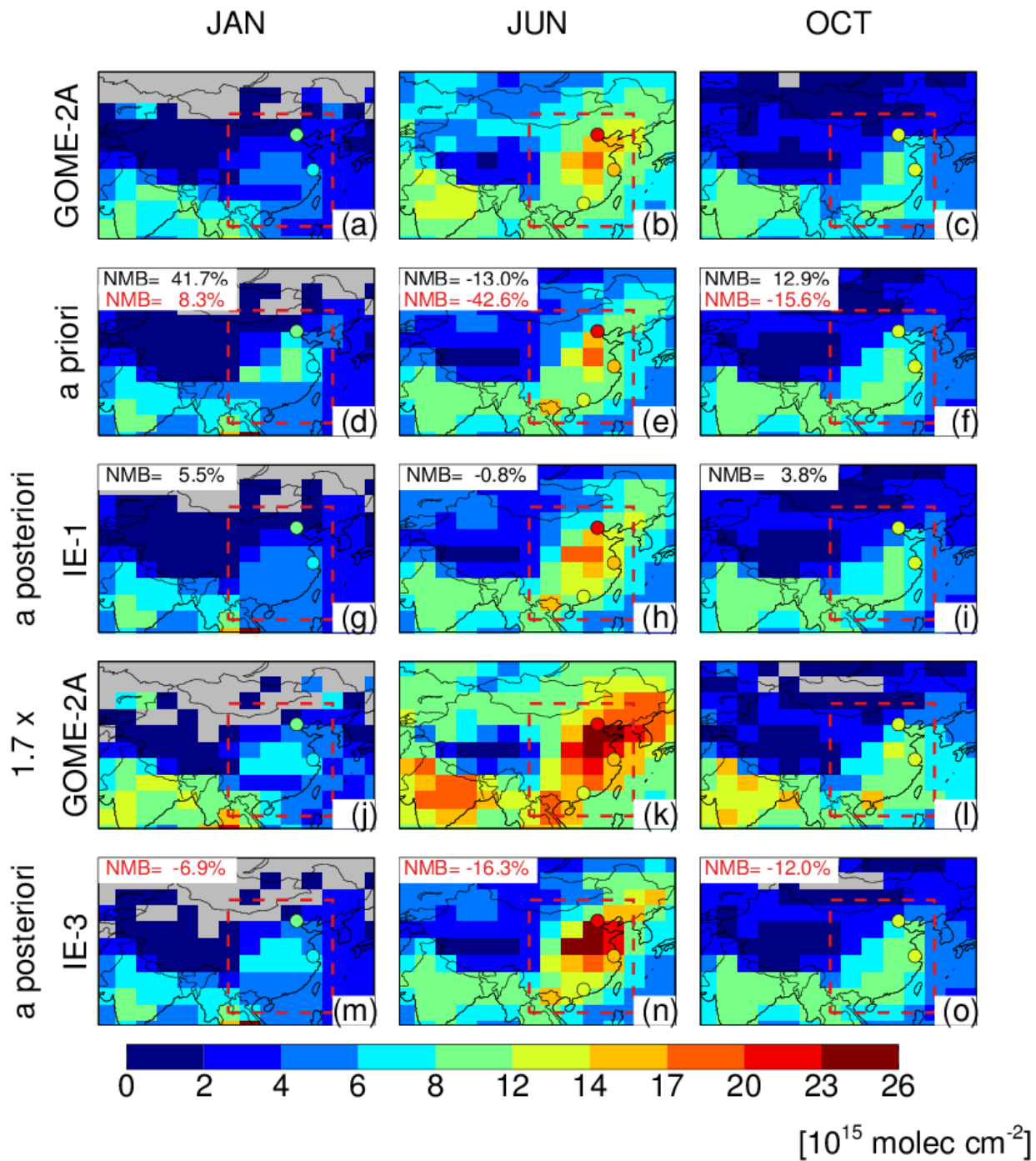


[Lerot et al., *ACP*, 2008]

Fig. 11. Illustration of the mean glyoxal VCDs in winter (December-January-February) (upper panel) and the population density (lower panel) in southeastern Asian regions. The population density data are taken from the GPW v3 data set (Balk and Yetman, 2005).

“Top-down” constraints on Chinese NMVOC emissions



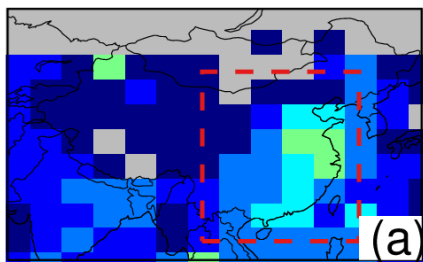


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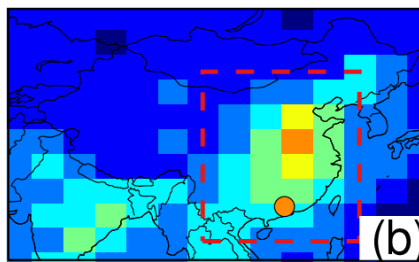
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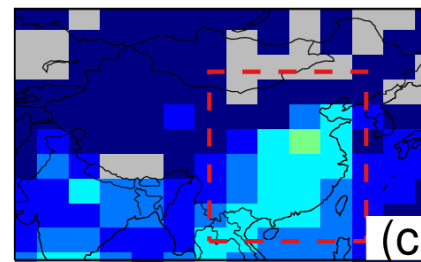
GOME-2A



(a)

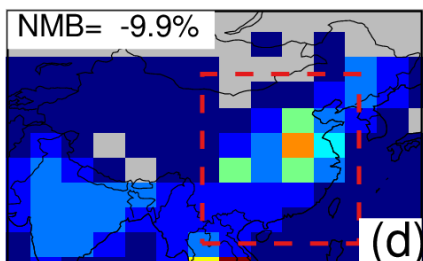


(b)

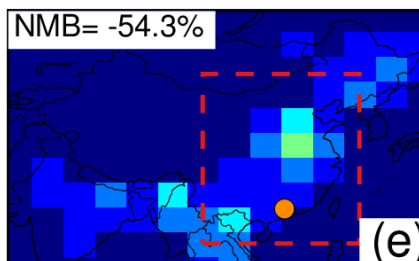


(c)

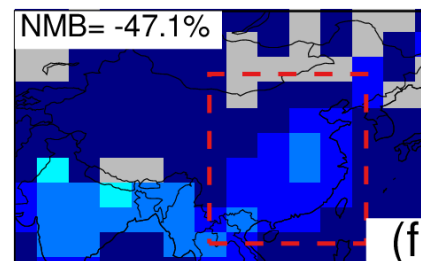
a priori



(d)



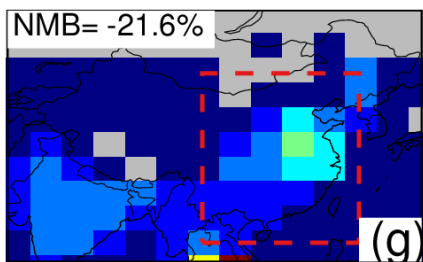
(e)



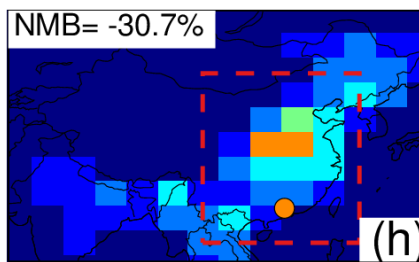
(f)

a posteriori

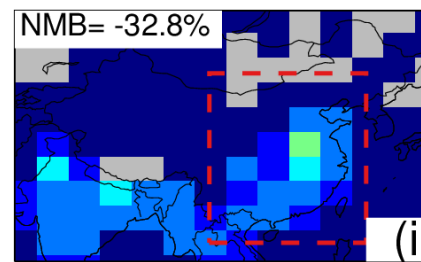
IE-1



(g)

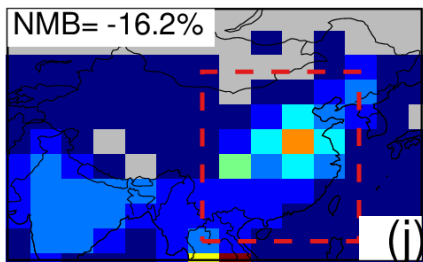


(h)

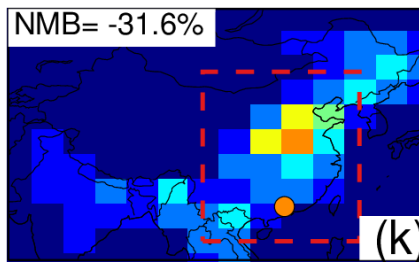


(i)

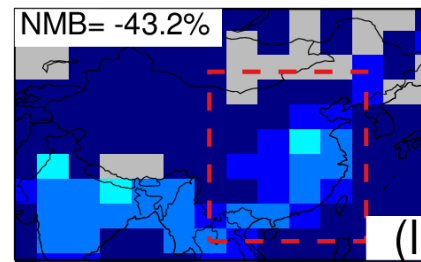
IE-3



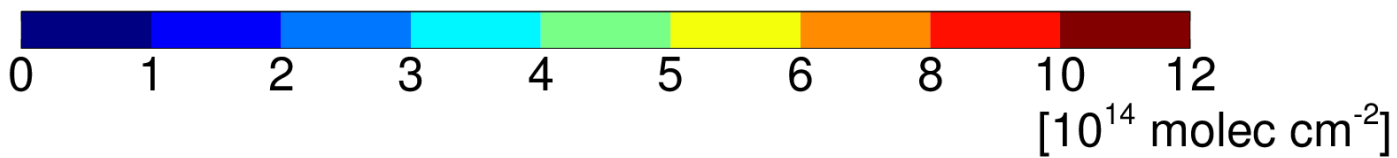
(j)



(k)



(l)

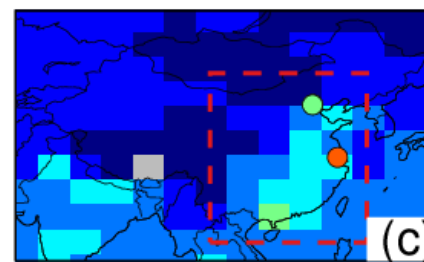
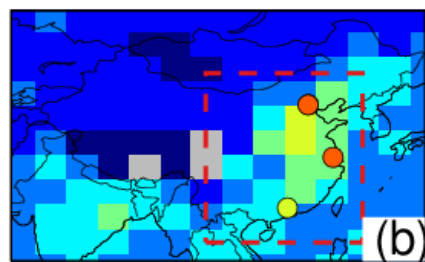
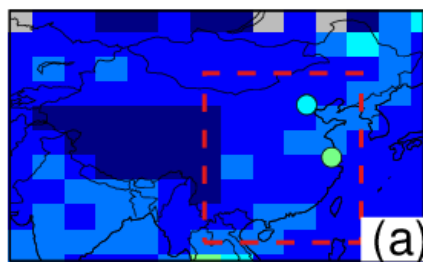


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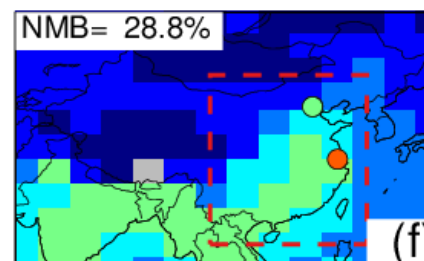
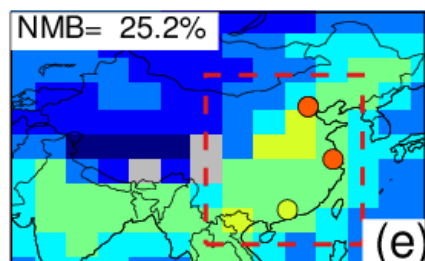
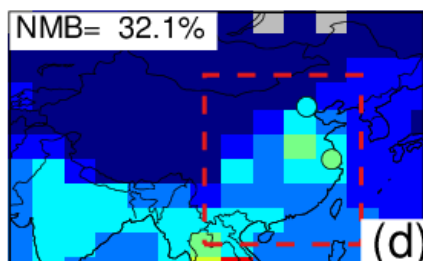
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OMI

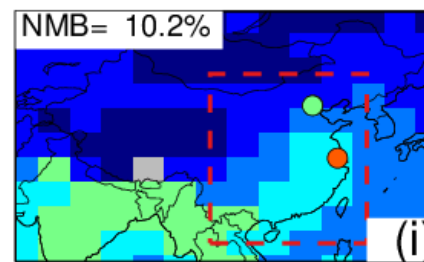
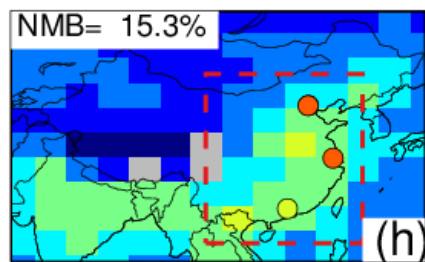
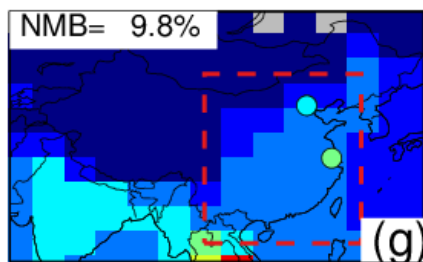


a priori



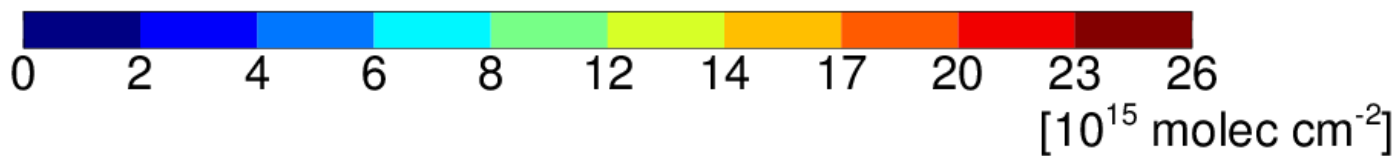
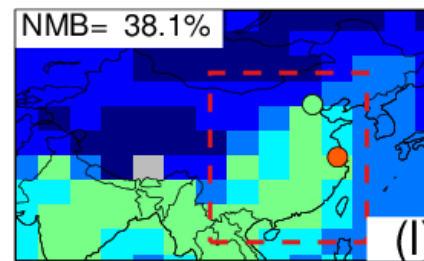
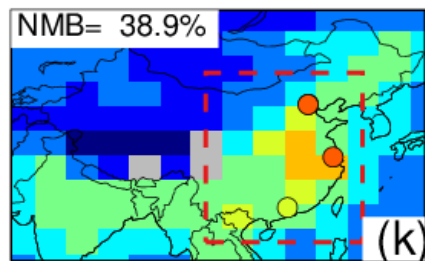
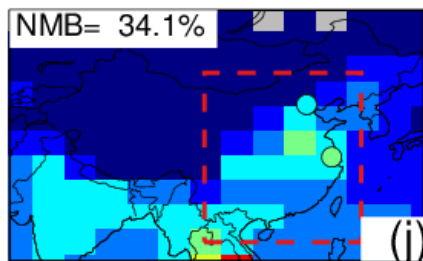
a posteriori

IE-2



a posteriori

IE-4

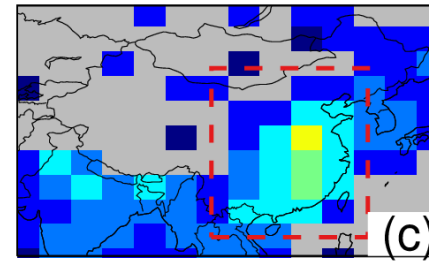
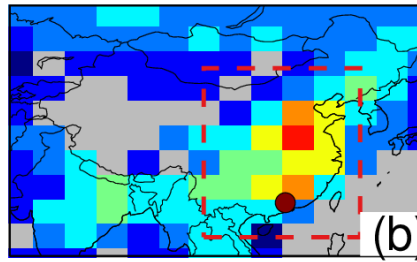
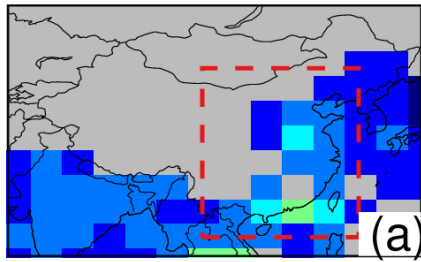


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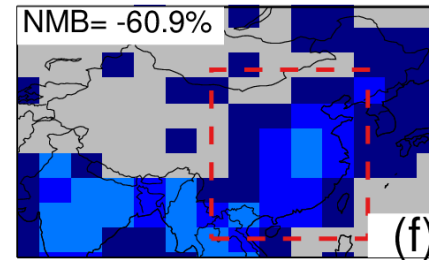
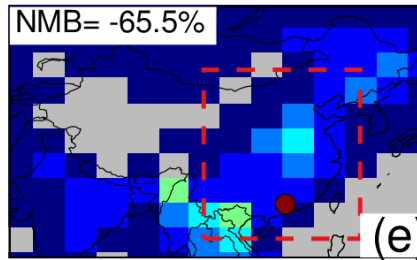
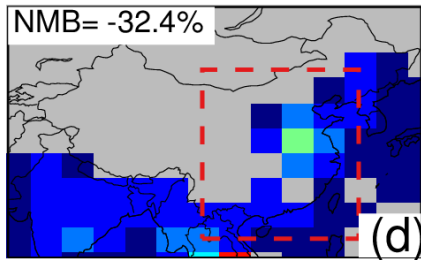
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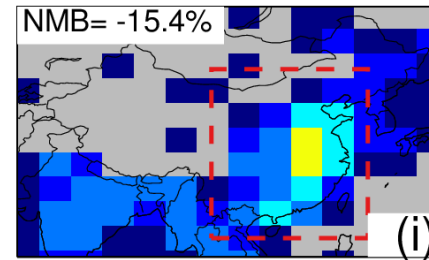
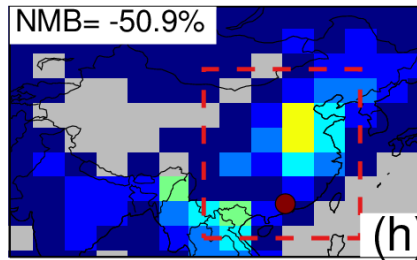
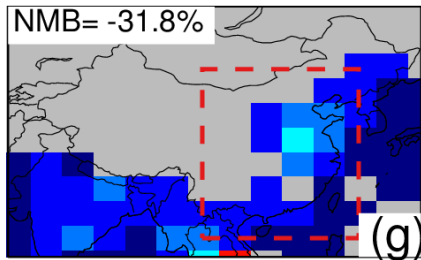


a priori



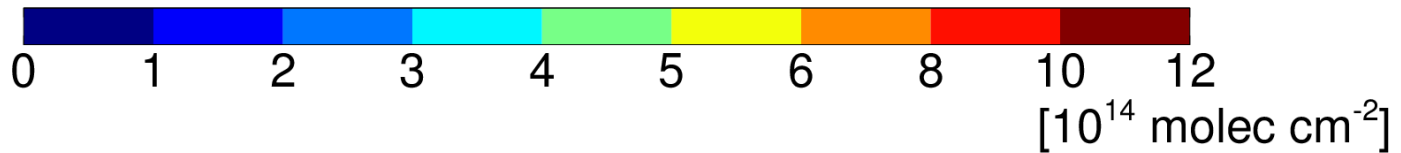
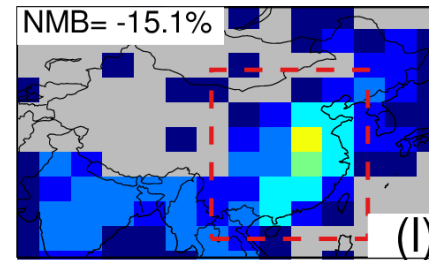
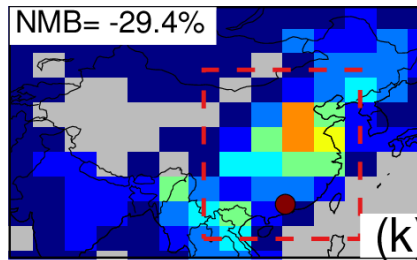
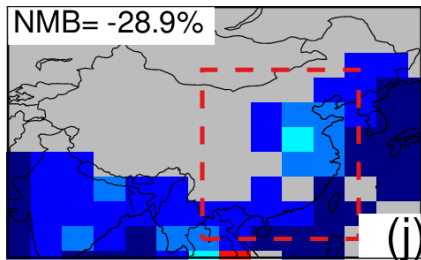
a posteriori

IE-2

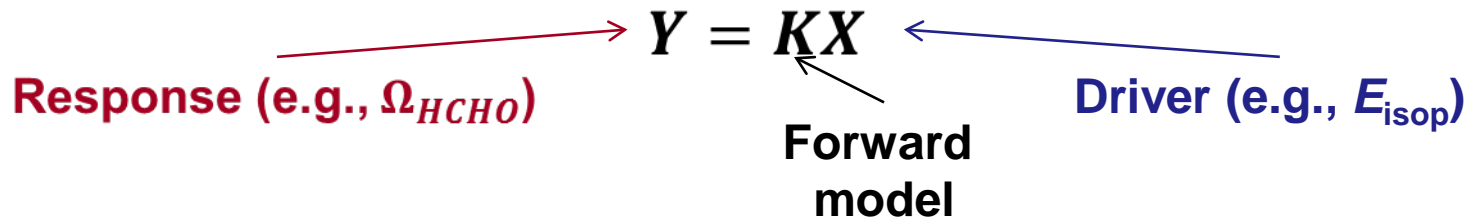


a posteriori

IE-4



Inverse modeling is a tug of war

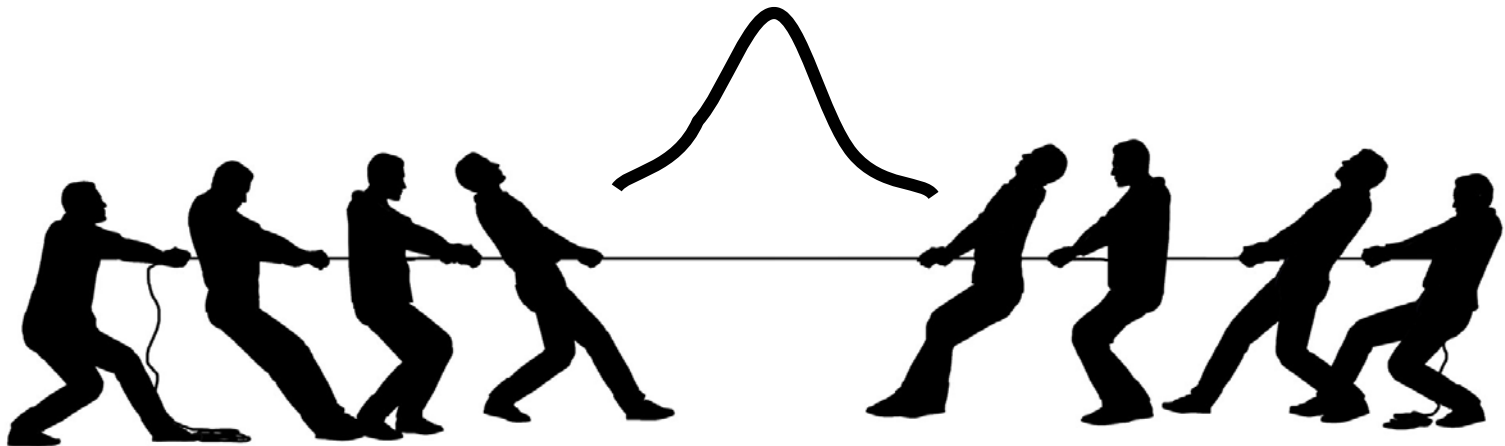


$$\frac{(Y - Y_{Obs})^2}{S_{Obs}}$$

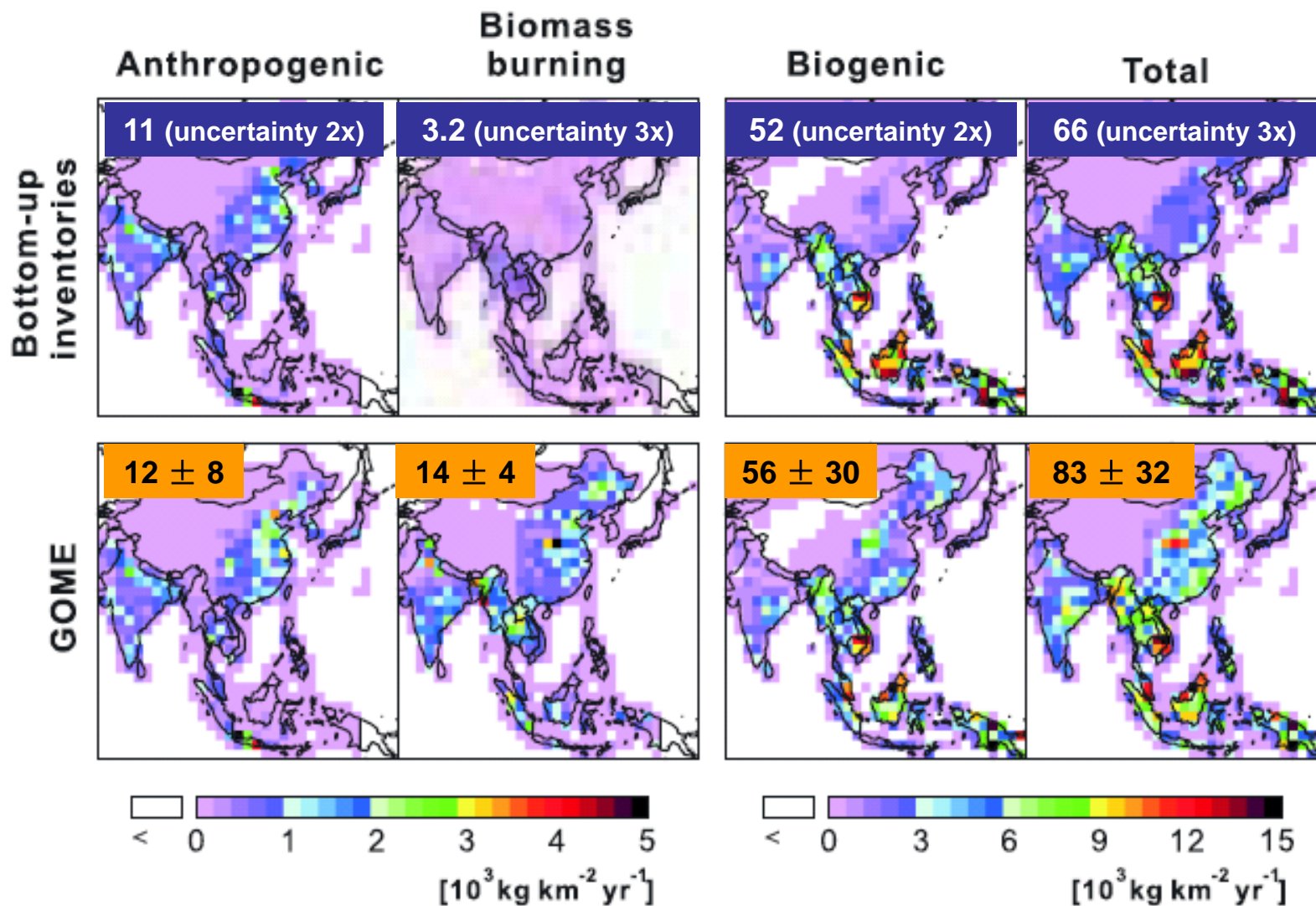
Observational evidence
and associated uncertainties

$$\frac{(X - X_{a\ priori})^2}{S_{a\ priori}}$$

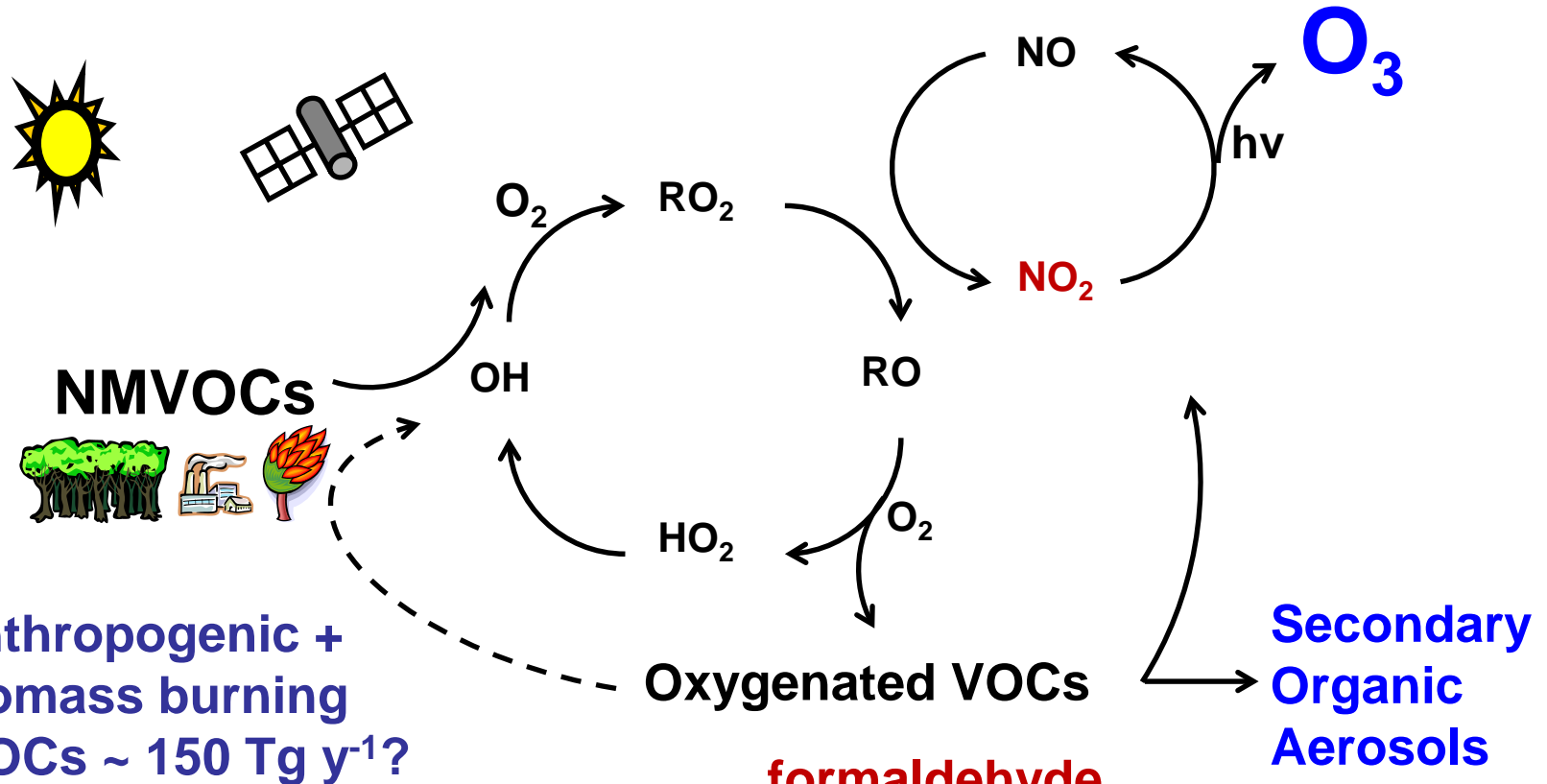
A priori emission
and associated uncertainties



Top-down constraints from GOME on Asian VOC [Tg y⁻¹]



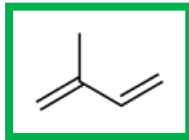
Non-methane volatile organic compounds (NMVOC): precursors to tropospheric pollutants



Anthropogenic +
Biomass burning
NMVOCs ~ 150 Tg y⁻¹?

Biogenic NMVOCs 500~1200 Tg y⁻¹?

Isoprene 280 ~ 850 Tg y⁻¹?



formaldehyde
glyoxal