Inferring NOx emissions from GEMS data

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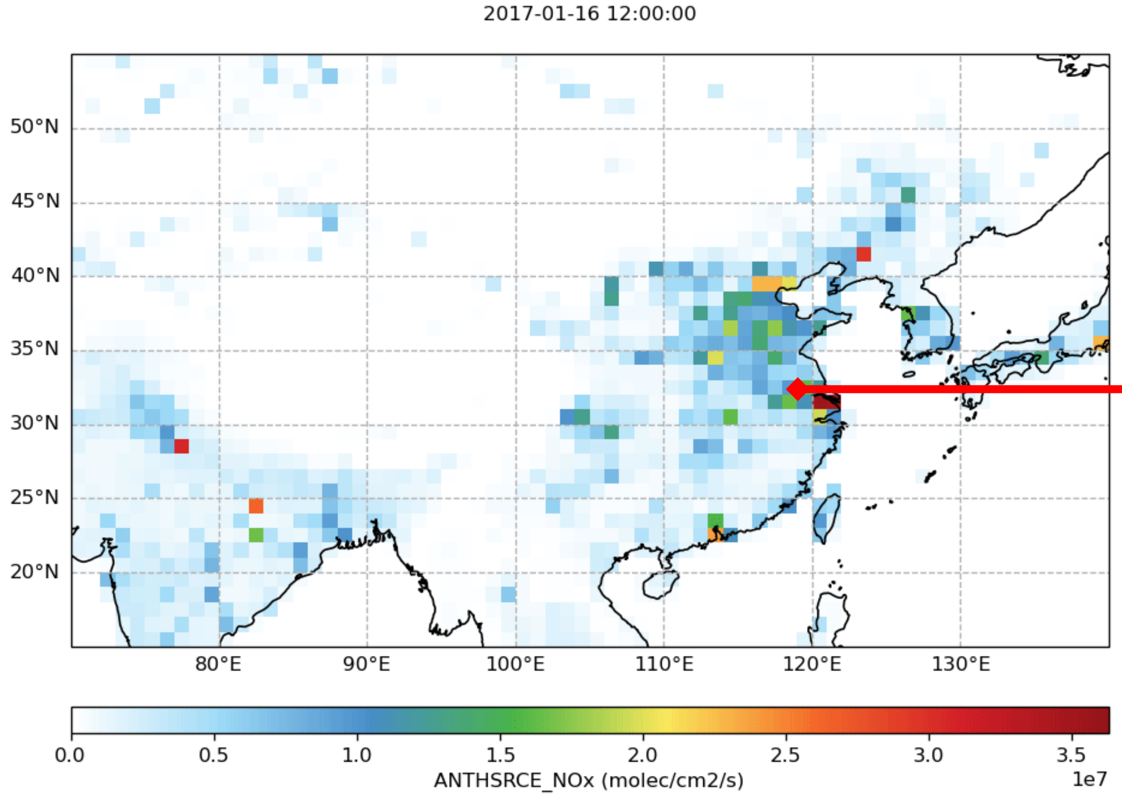
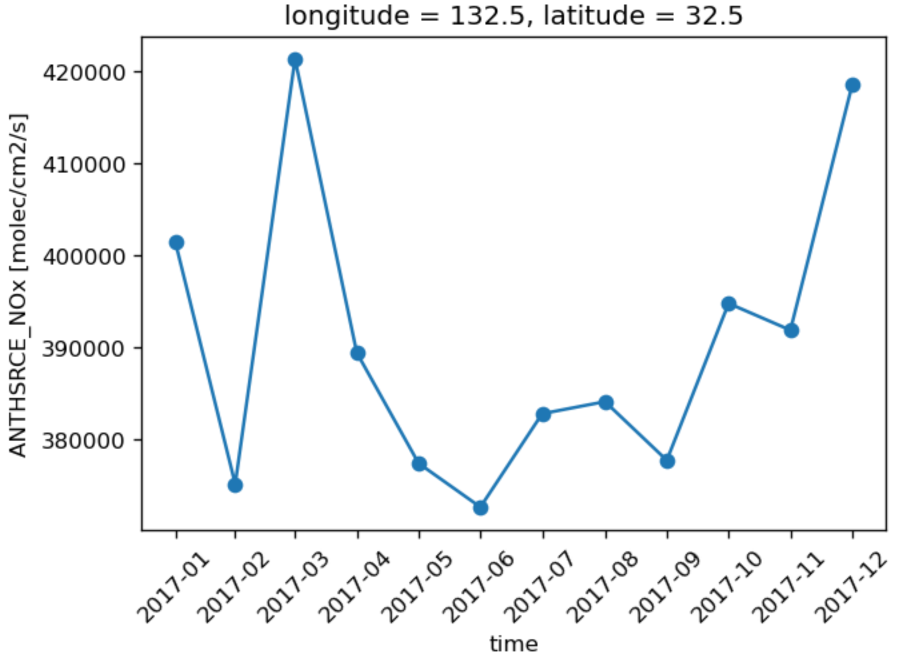
Conventional bottom-up emission inventories for atmospheric pollutants suffer from infrequent updates

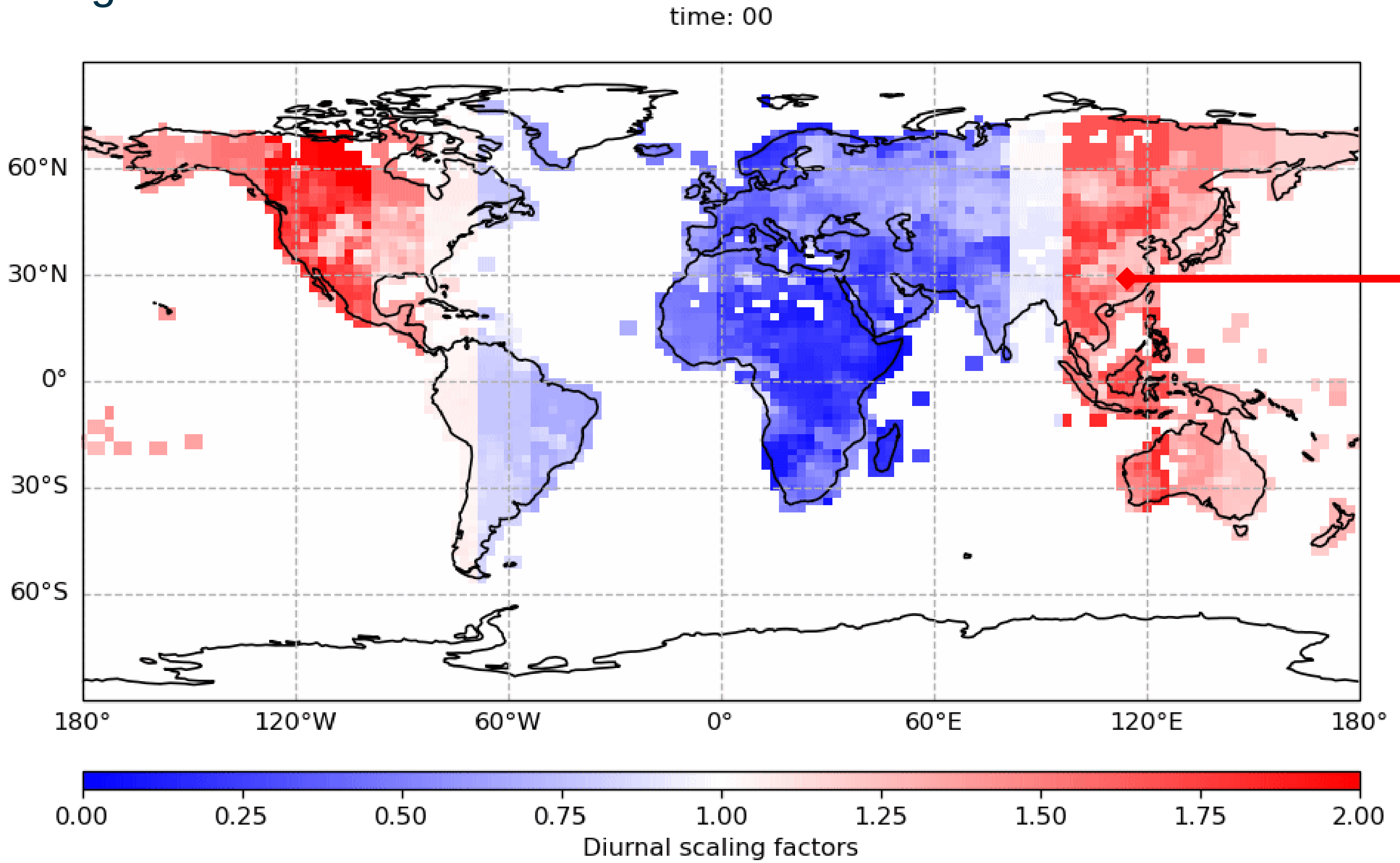
For instance, a harmonised, publicly available emission inventory for the whole of Asia is current only up to 2017 and provides data only at a monthly scale.

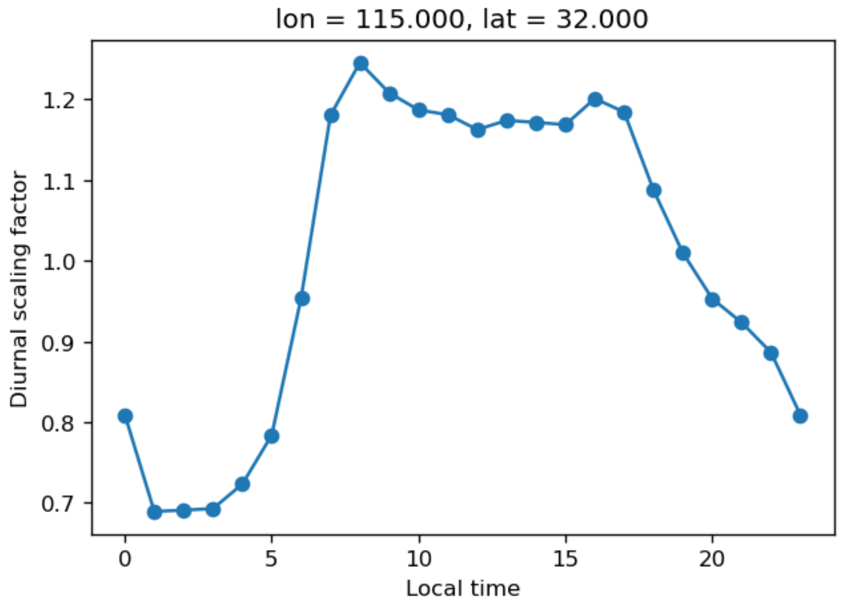




Conventional bottom-up emission inventories for atmospheric pollutants suffer from large uncertainties

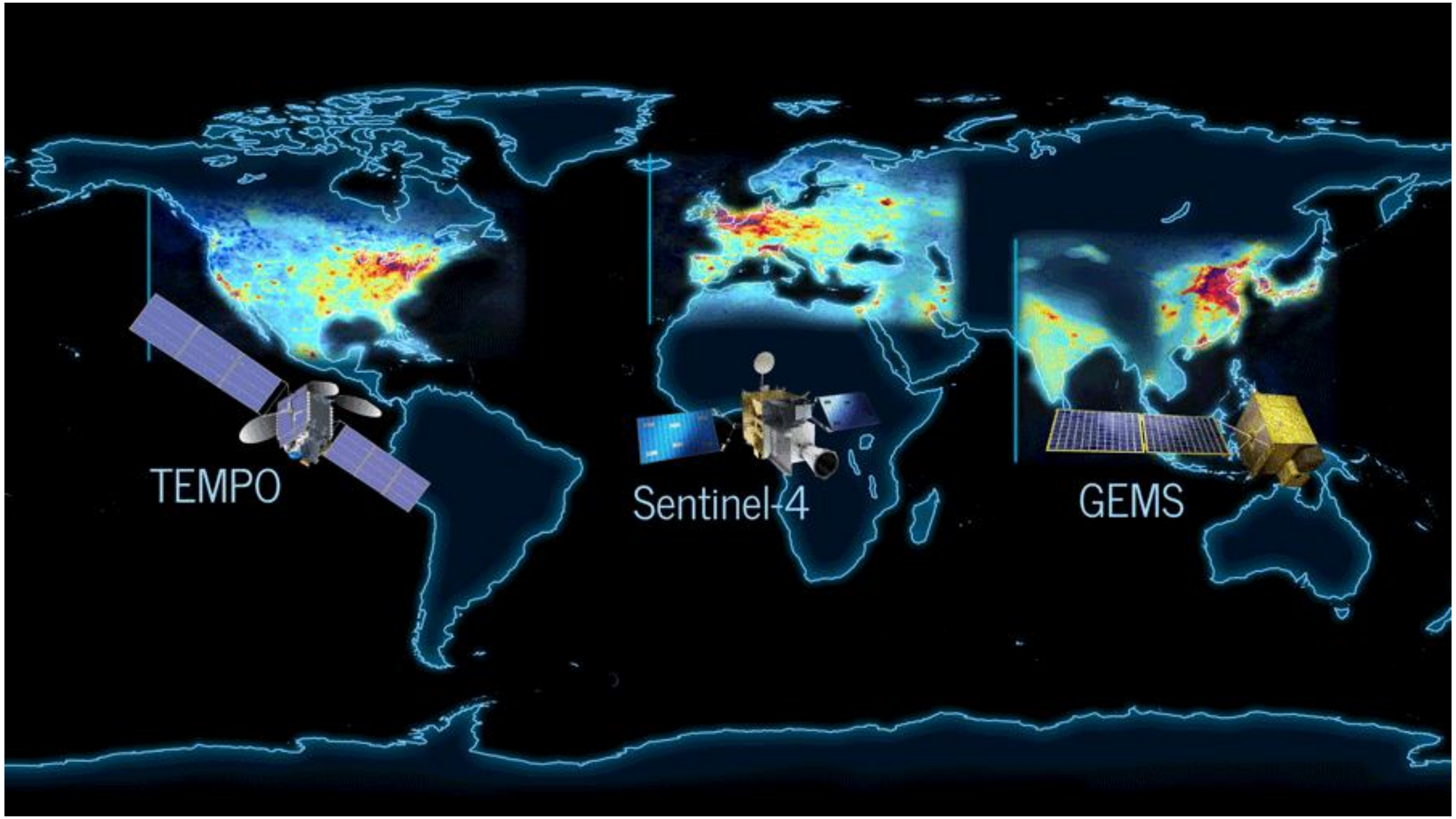
Monthly emissions are converted to hourly emissions in the model only by applying some prescribed diurnal scaling factors.





Geostationary satellite data can complement bottom-up emission inventories by providing top-down estimates of air pollutant emissions

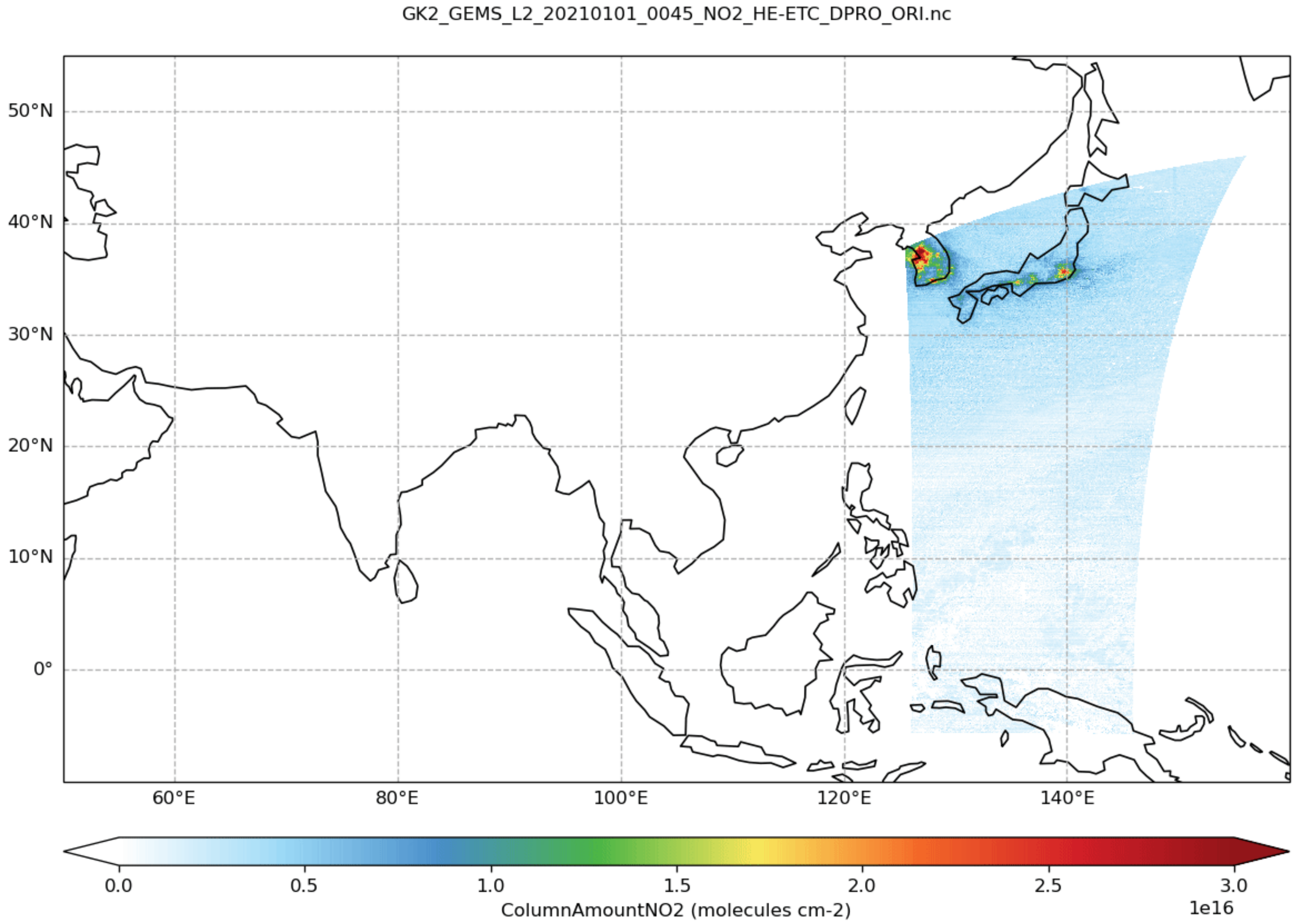
Pollution-monitoring instruments from NASA, the European Space Agency (ESA), and the Korea Aerospace Research Institute (KARI) will together form a geostationary air quality constellation.



c/o Tim Marvel

GEMS is the first environmental monitoring satellite in geostationary Earth orbit (GEO)

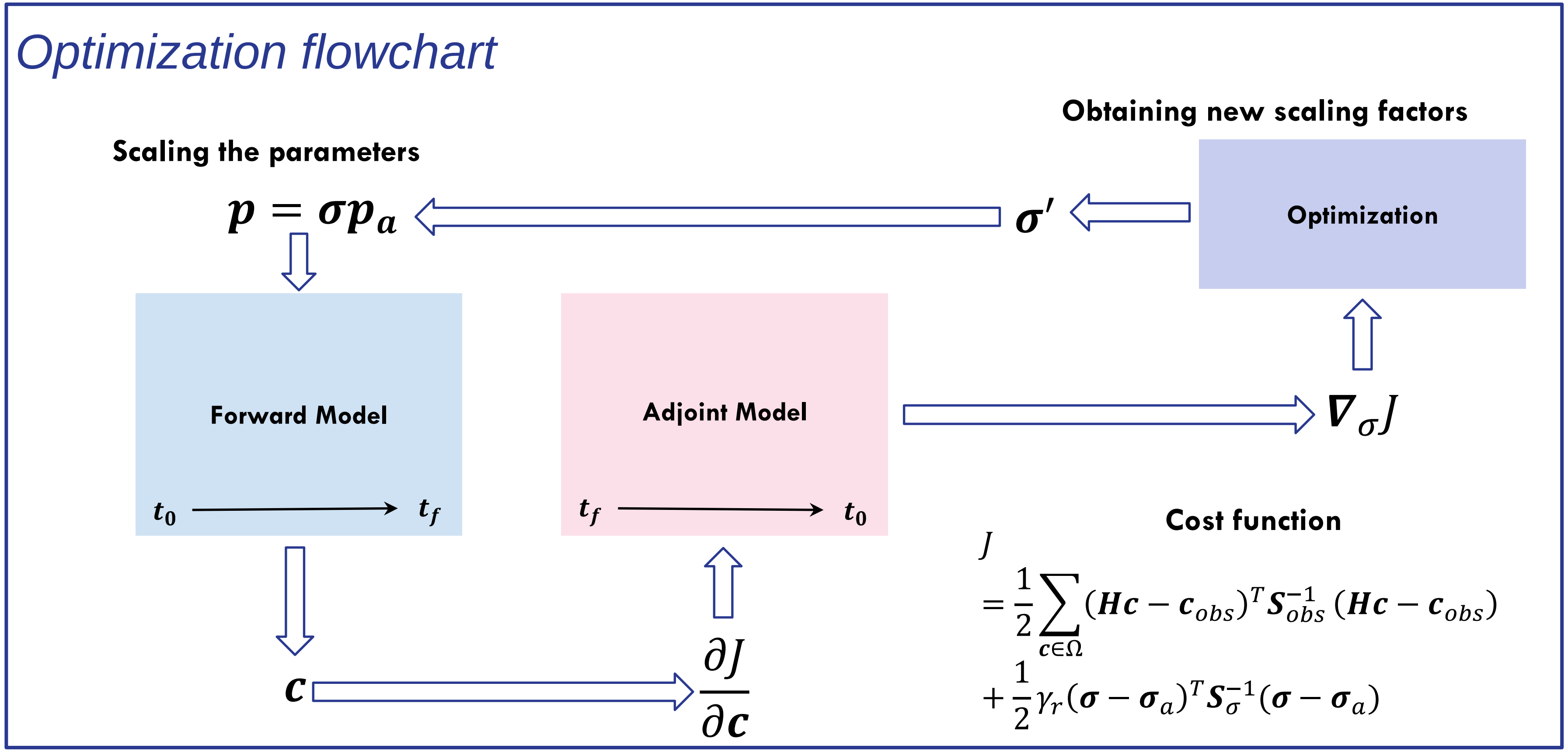
The Geostationary Environmental Monitoring Spectrometer (GEMS) now provides **columnar** measurements for key atmospheric pollutants, including tropospheric ozone (O_3), aerosols, and their precursors (NO_2, SO_2, HCHO, and glyoxal), on an hourly basis throughout the sunlit day.



An efficient inverse modelling approach is essential to analyse these large volumes of geostationary data

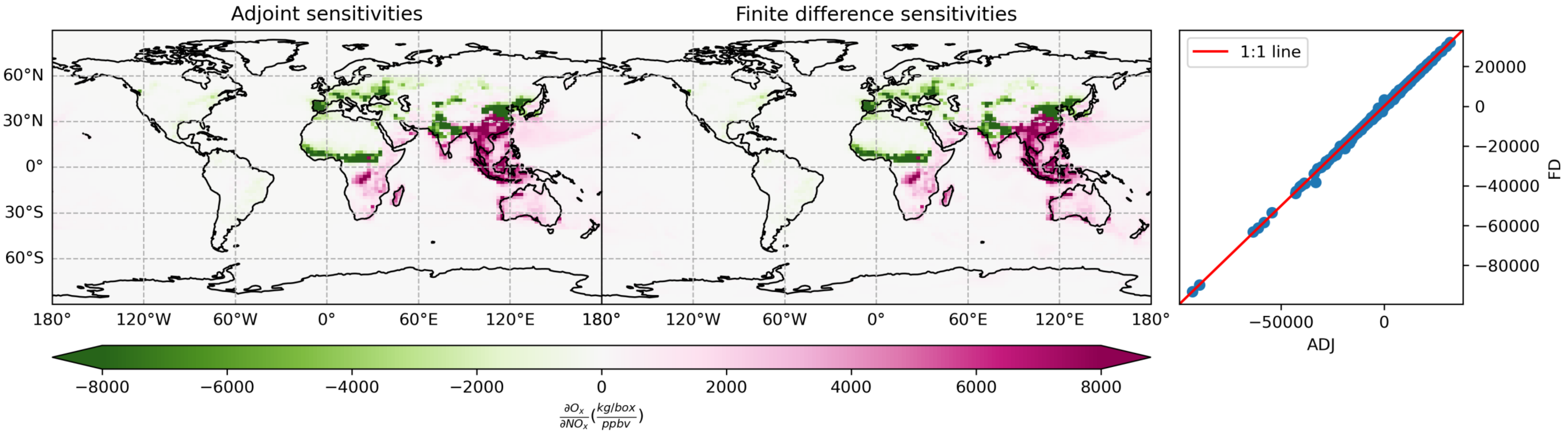
The GEOS-Chem Adjoint model is a strong candidate for such a task. The adjoint model only requires an additional 2x CPU time. The optimisation will generally form within 40 iterations of forward and backward runs.

However, each application requires extra code development, some of which involves code validation, e.g., new emission inventories, chemistry, etc.



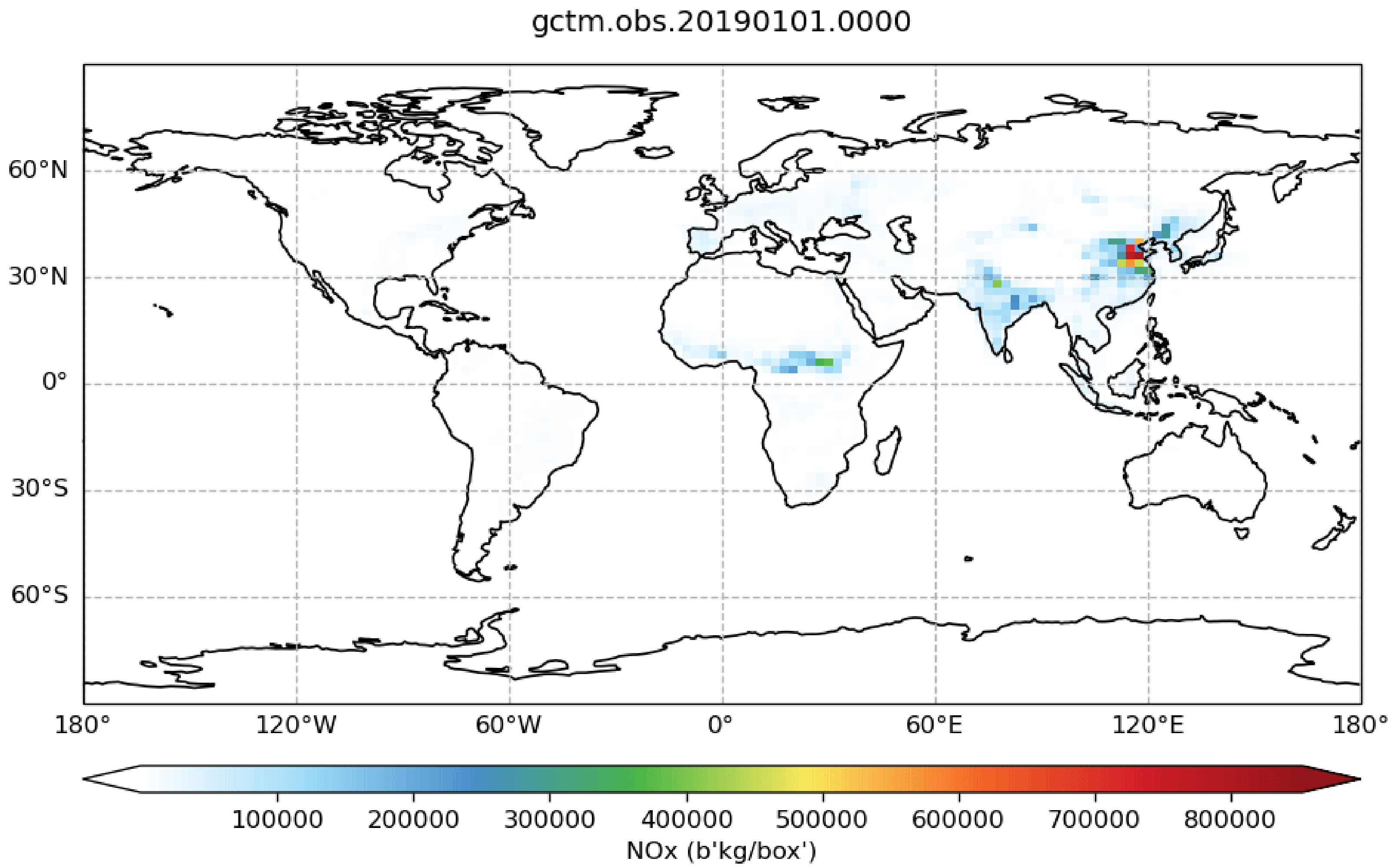
Global tests of a subset of the adjoint model

The adjoint sensitivities from the updated code are strictly comparable to those from finite differences.



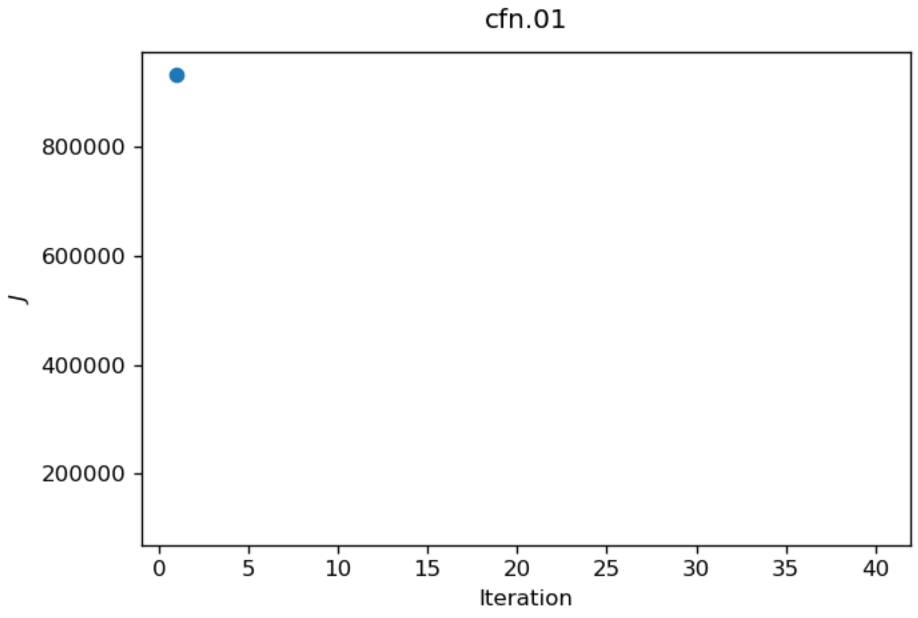
Observing system simulation experiments (OSSEs) for evaluating the model performance in 4D variational (4D-Var) assimilations

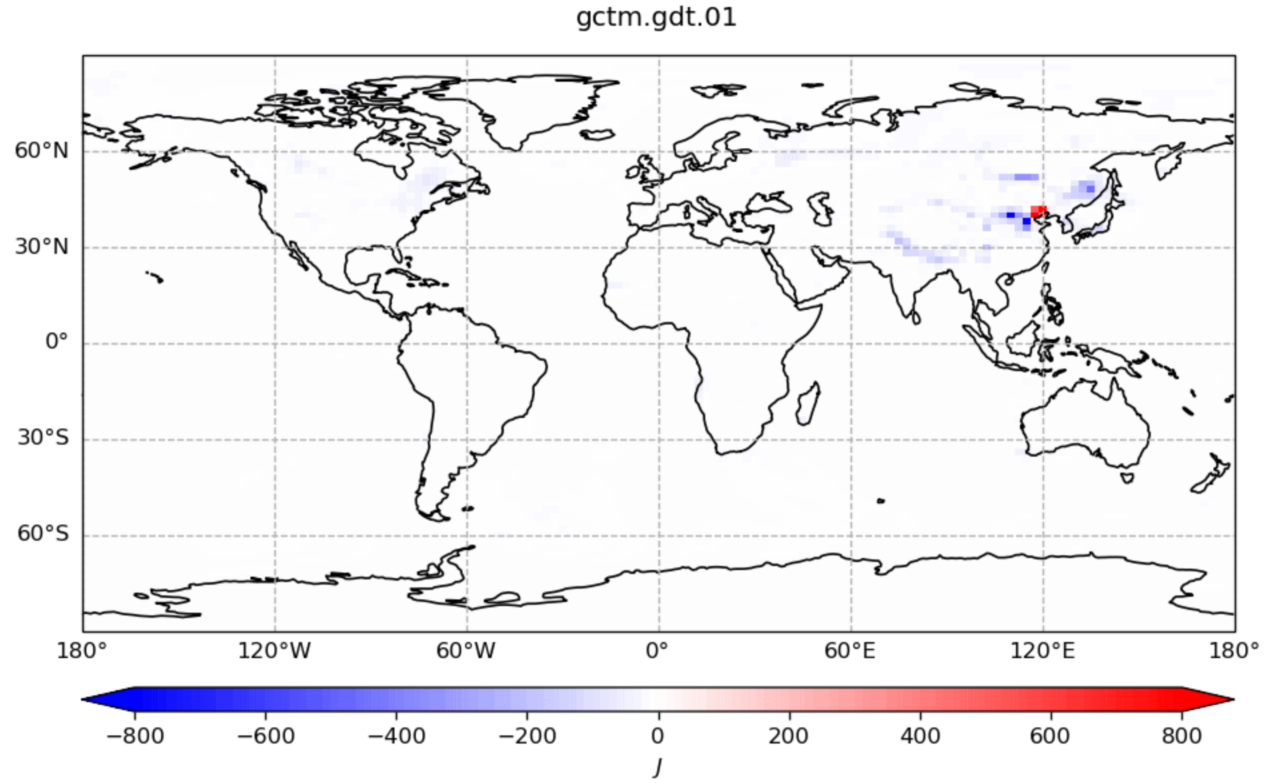
Pseudo-observations of NOx, which will ultimately be replaced by GEMS NO_2 data in 4D-Var, are generated from the forward GEOS-Chem model with controlled initial conditions and emissions.



Observing system simulation experiments (OSSEs) for evaluating the model performance in 4D variational (4D-Var) assimilations

Intentionally set the “initial guess” of scaling factors to be some value other than one and then try to converge to values of one, guided by the gradients of the cost function with respect to model parameters.





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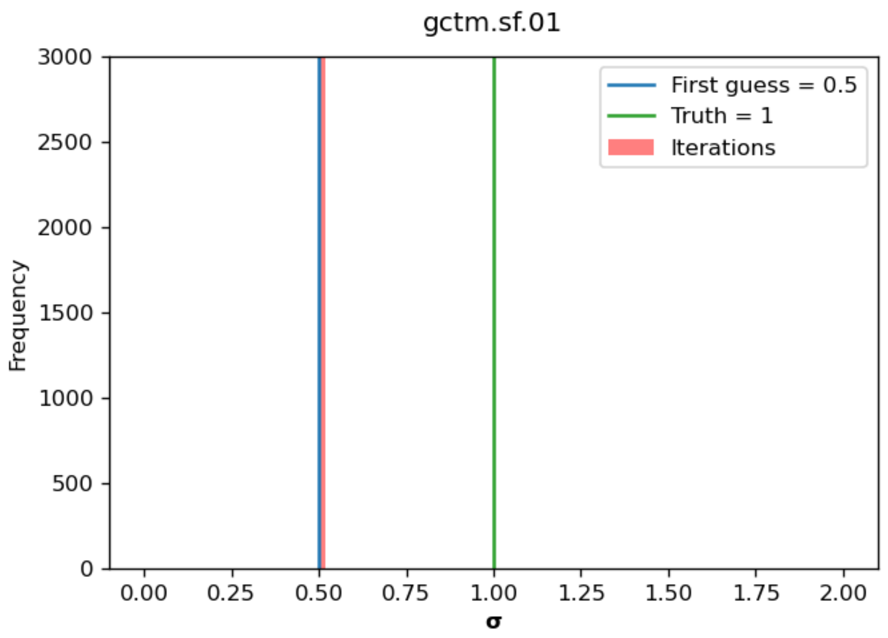
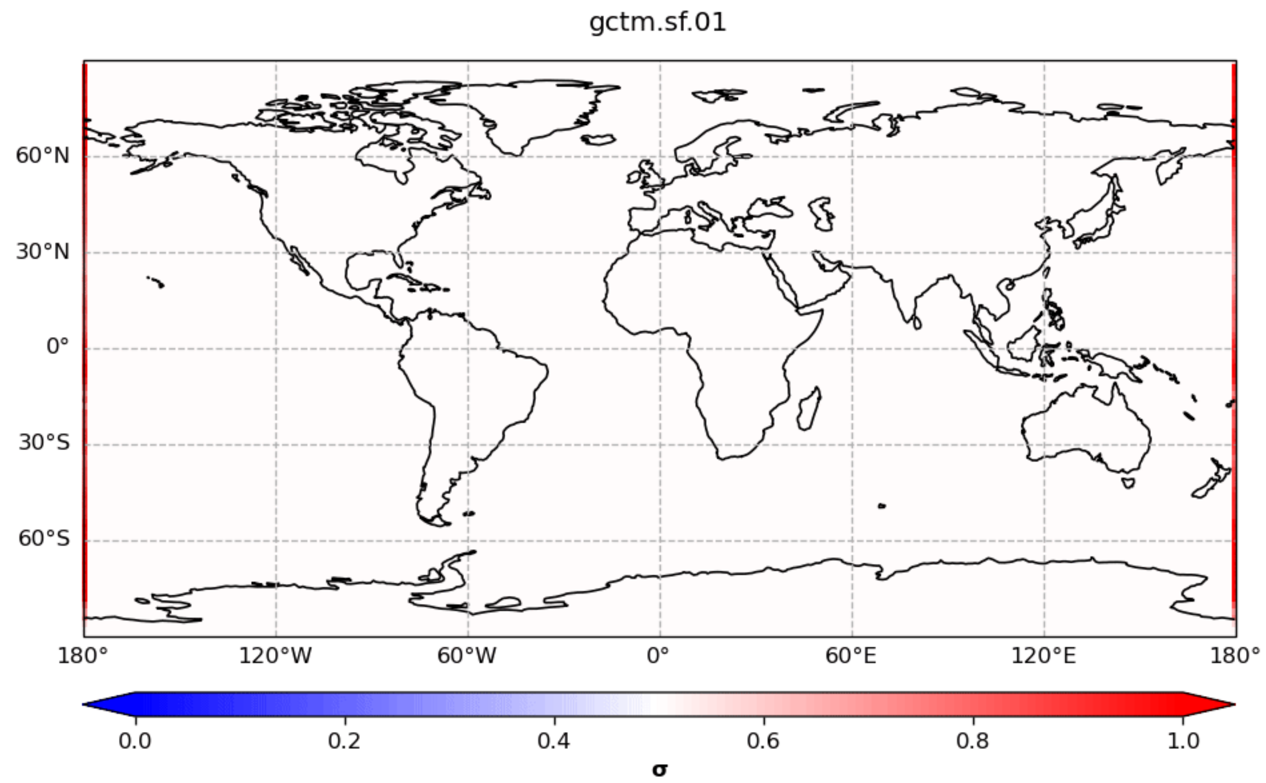




$$\gamma_r = 1$$

Concluding remarks and next steps

- The GEOS-Chem Adjoint full chemistry code has been updated to support recent emission inventories (including MEIC+MIX and GFED4) and chemistry (e.g., aromatics). These updates have been strictly verified to ensure that the model remains as good as the original code in computing sensitivities/gradients as well as in OSSEs.
- New code to interface GEMS data ($V2.0 \rightarrow V3.0$) is in progress.
- The work can be easily expanded to interpret data from TEMPO and Sentinel-4 once these data are available.

Additional slides

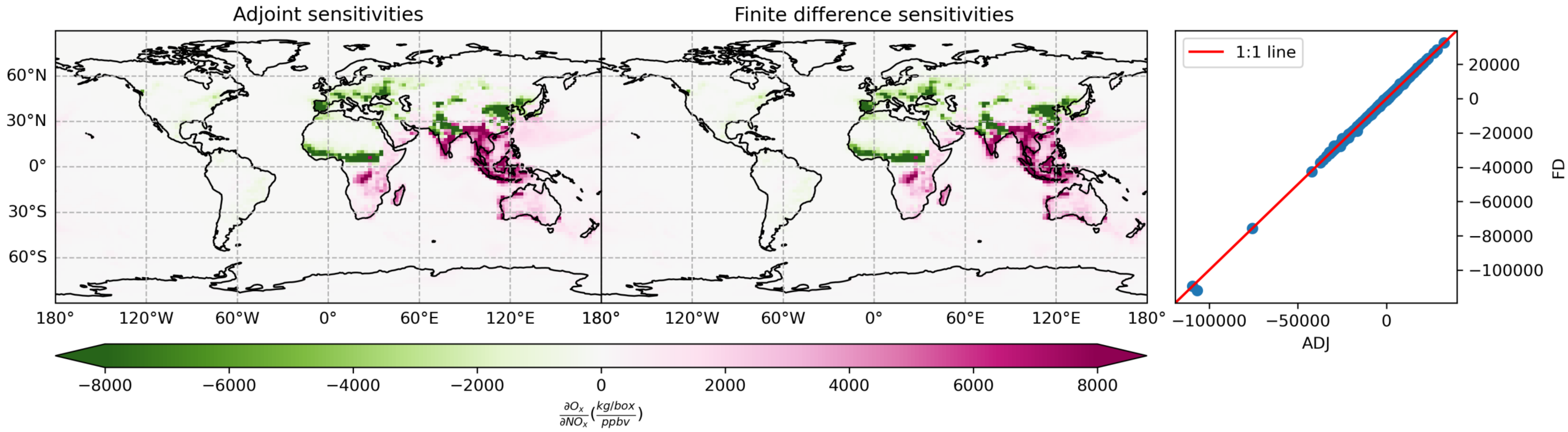
- What is an adjoint model and why you should care about it?
- Comparative results from the original GEOS-Chem Adjoint model
- Tropospheric NO_x chemistry

What is an adjoint model and why you should care about it?

Refer to the separate slides

Comparative results from the original GEOS-Chem Adjoint model

Global tests of a subset of the adjoint model



Comparative results from the original GEOS-Chem Adjoint model

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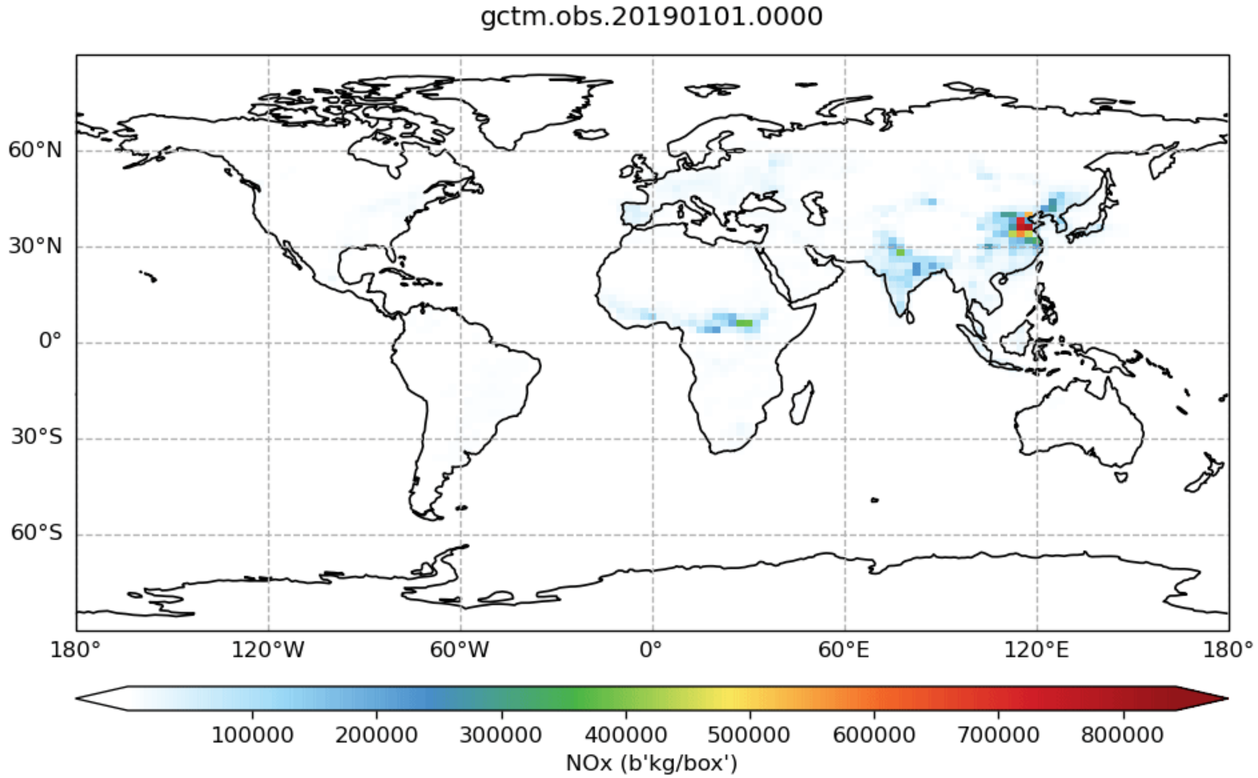

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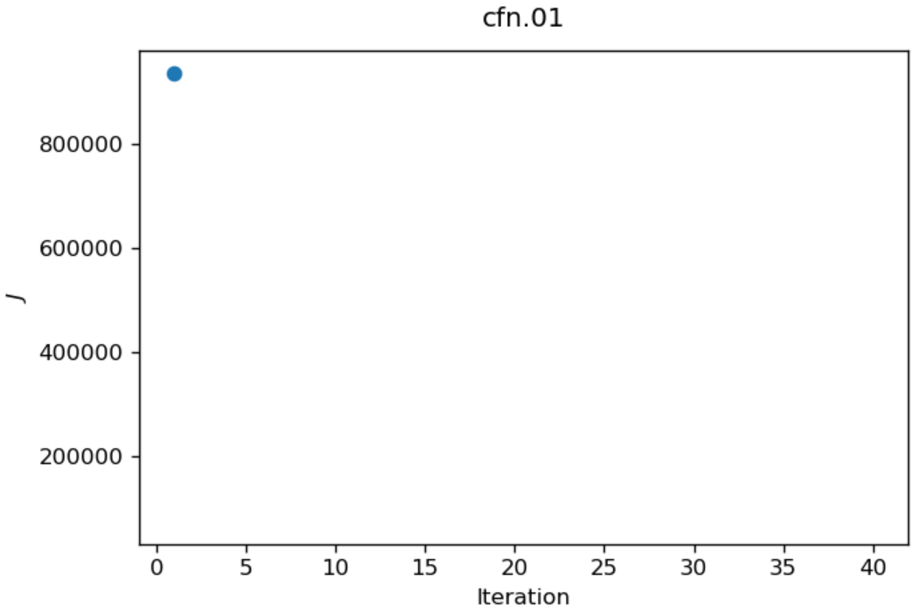

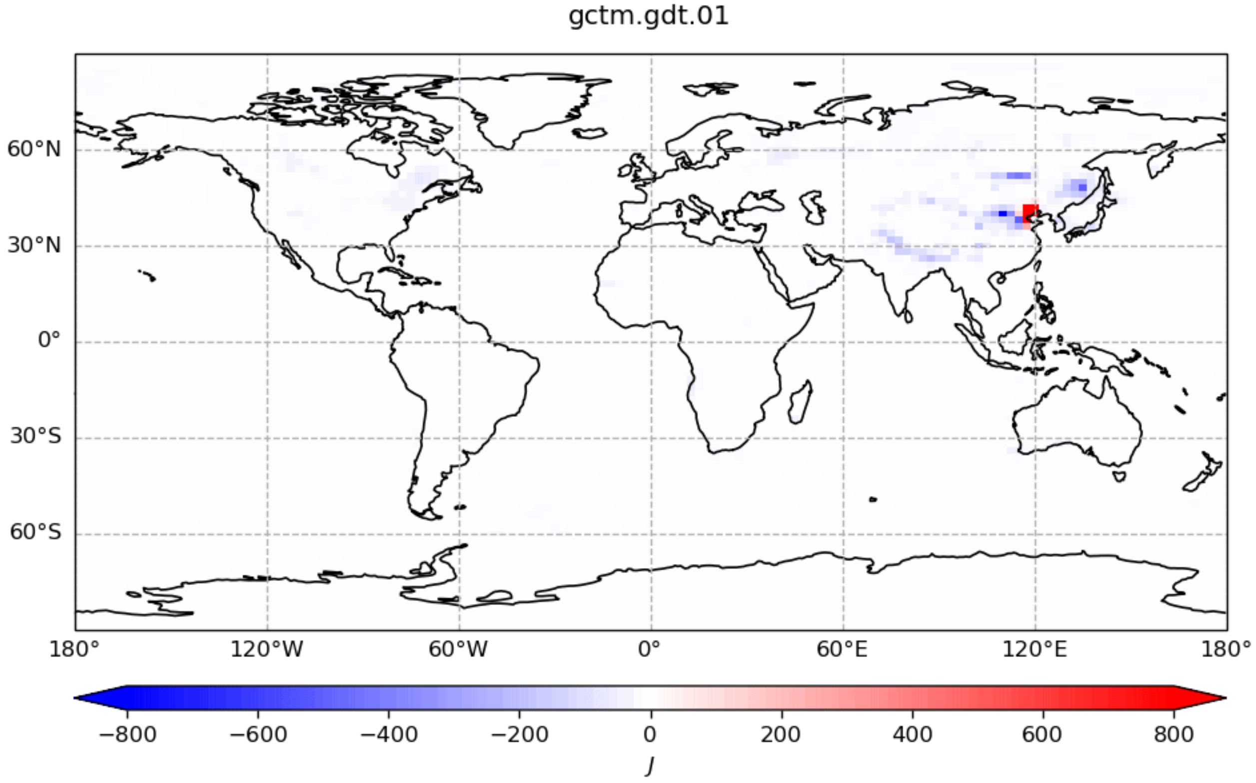

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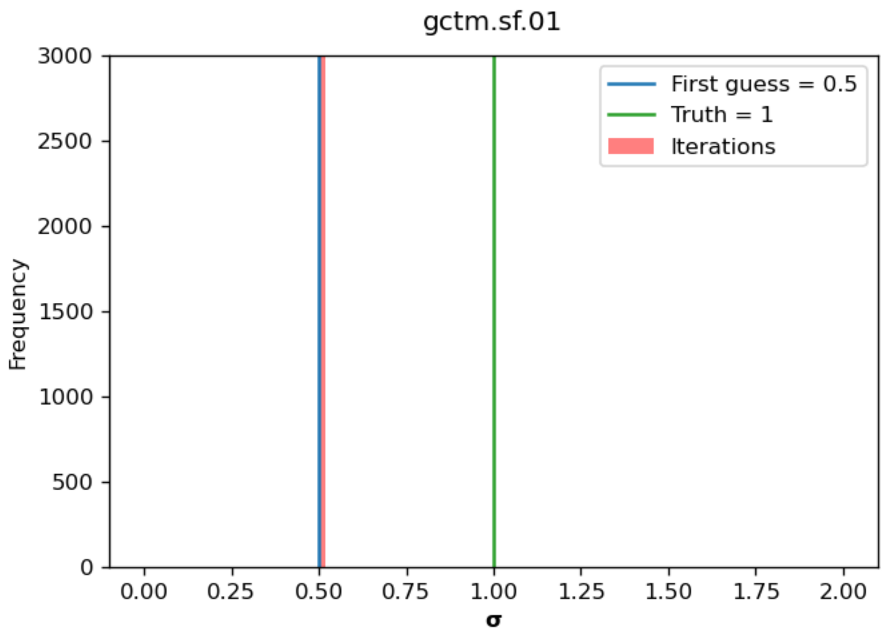

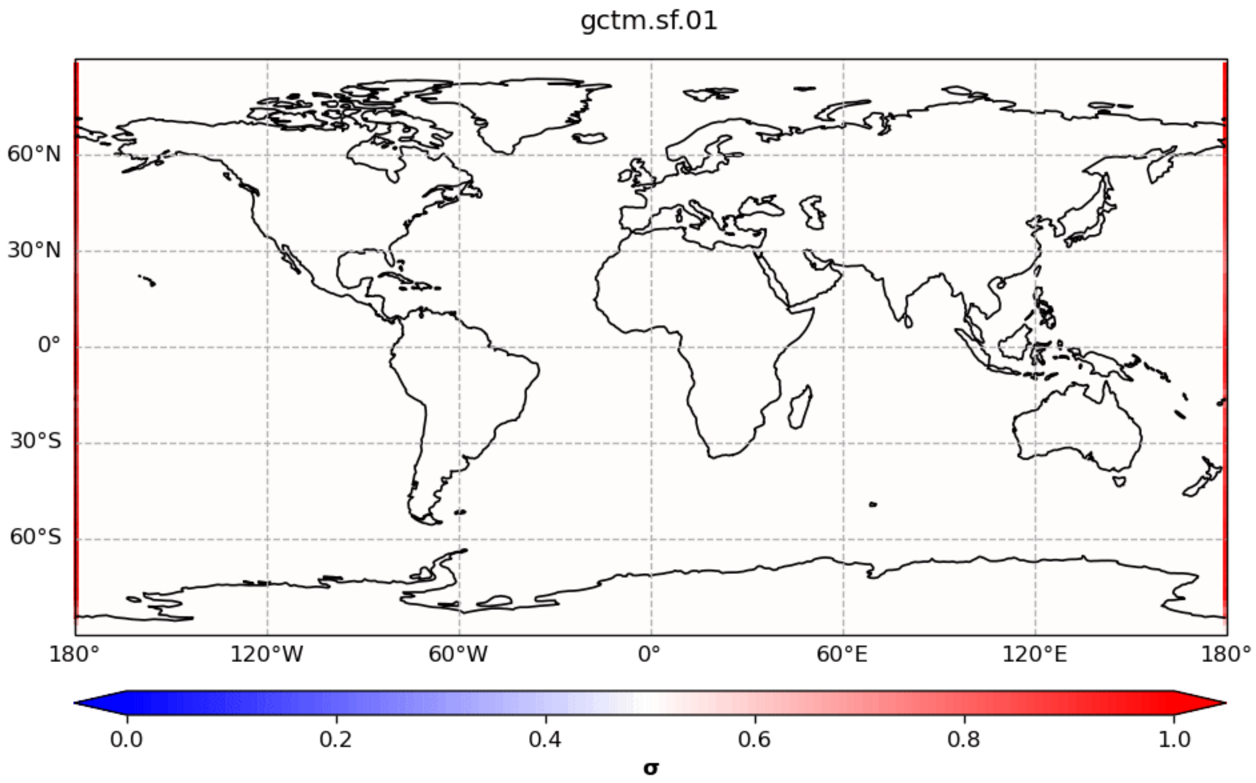

Why do we care about NOx?

NOx ≡ NO+NO_2 are important precursors of ozone (O_3) and particulate matter pollution, and NO_2 itself is harmful to public health.