Trace Gas Measurements from Space

Christian Frankenberg
(and numerous others providing input)
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Spectral Ranges

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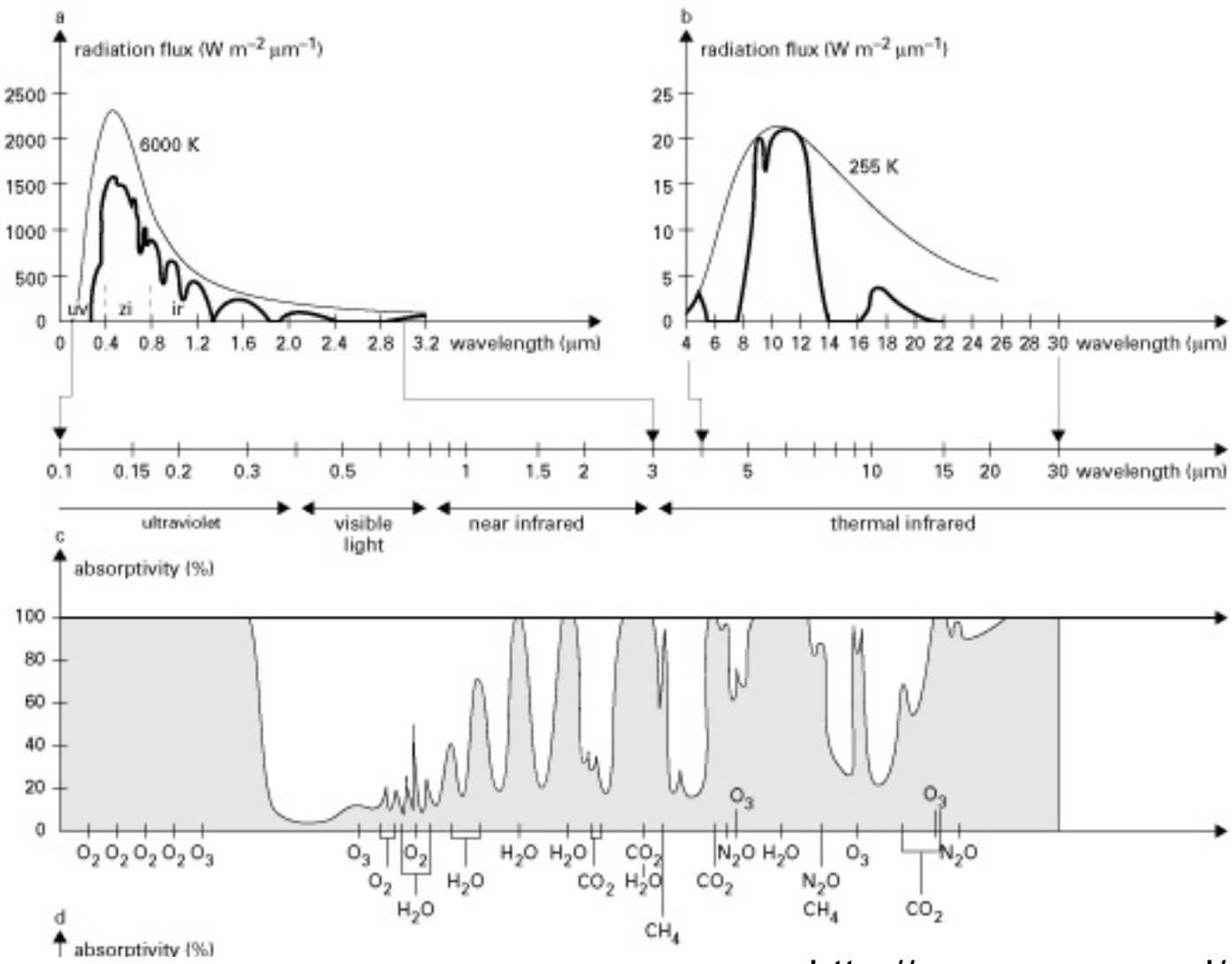
California Institute of Technology

Sun as light-source

Earth thermal radiation as light-source



http://www.open.ou.nl/dja/Klimaat/

Spectral Ranges

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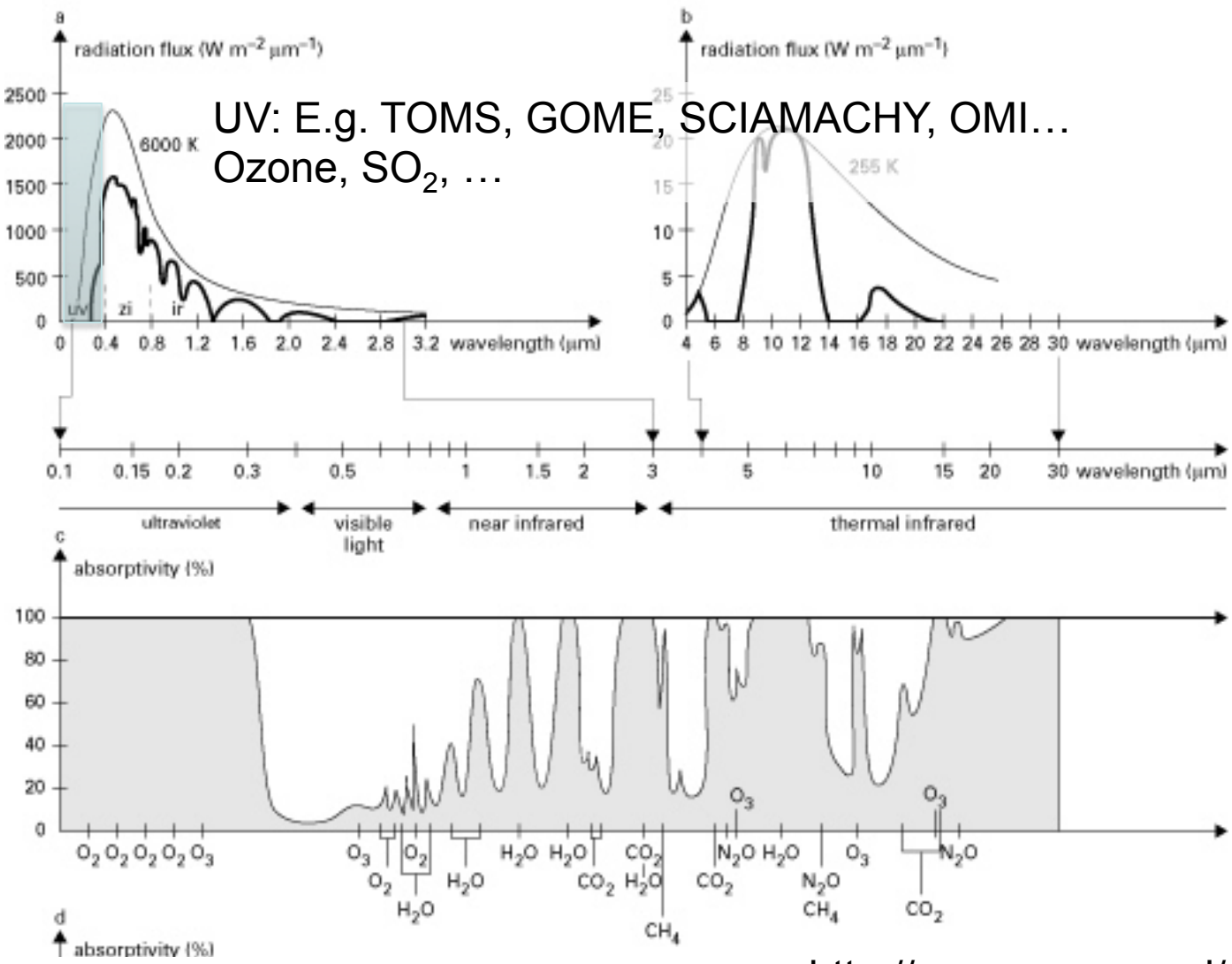
UV: E.g. TOMS, GOME, SCIAMACHY, OMI…
Ozone, SO_2, …



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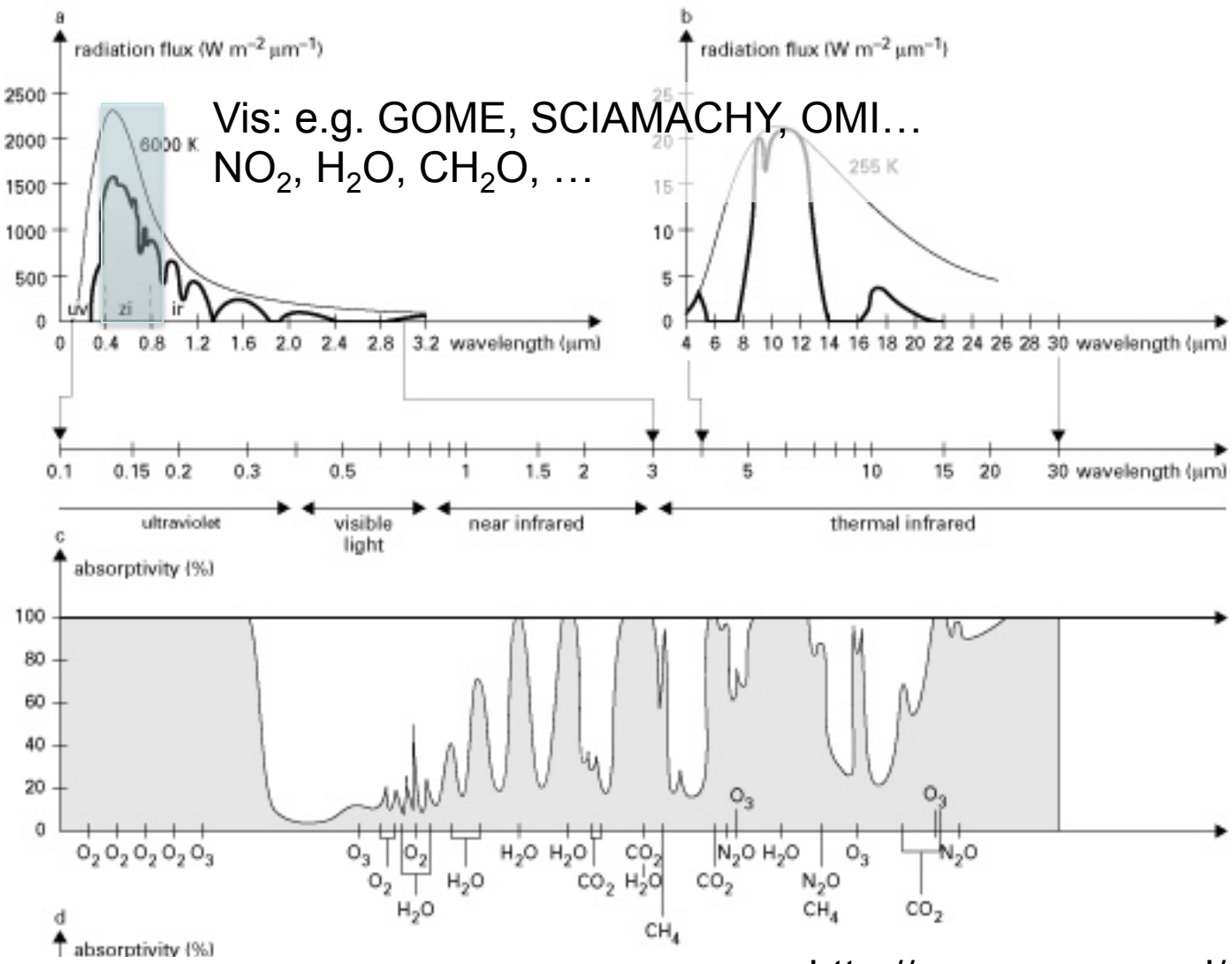
Spectral Ranges



Vis: e.g. GOME, SCIAMACHY, OMI…
NO_2, H_2O, CH_2O, …

http://www.open.ou.nl/dja/Klimaat/

Spectral Ranges

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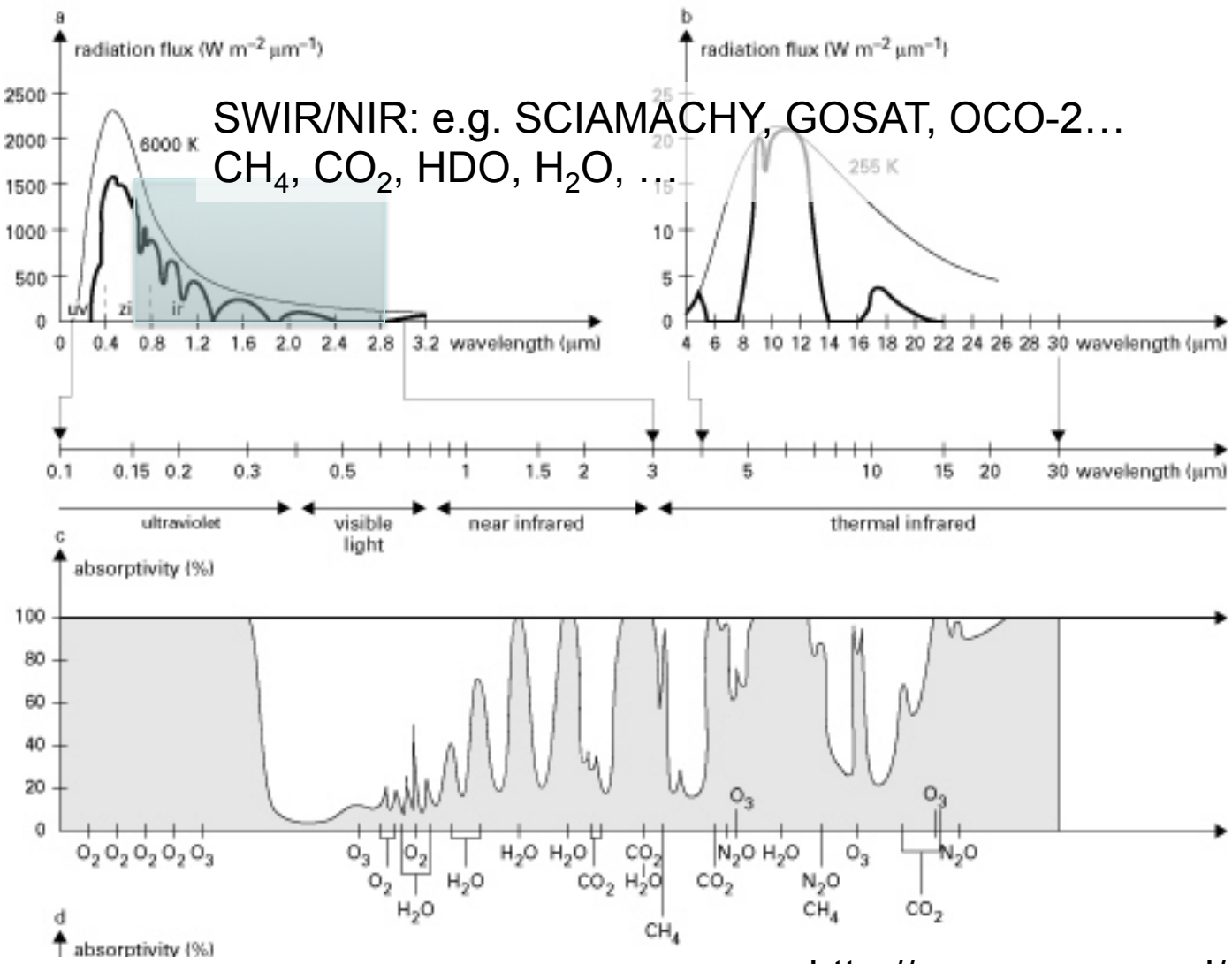
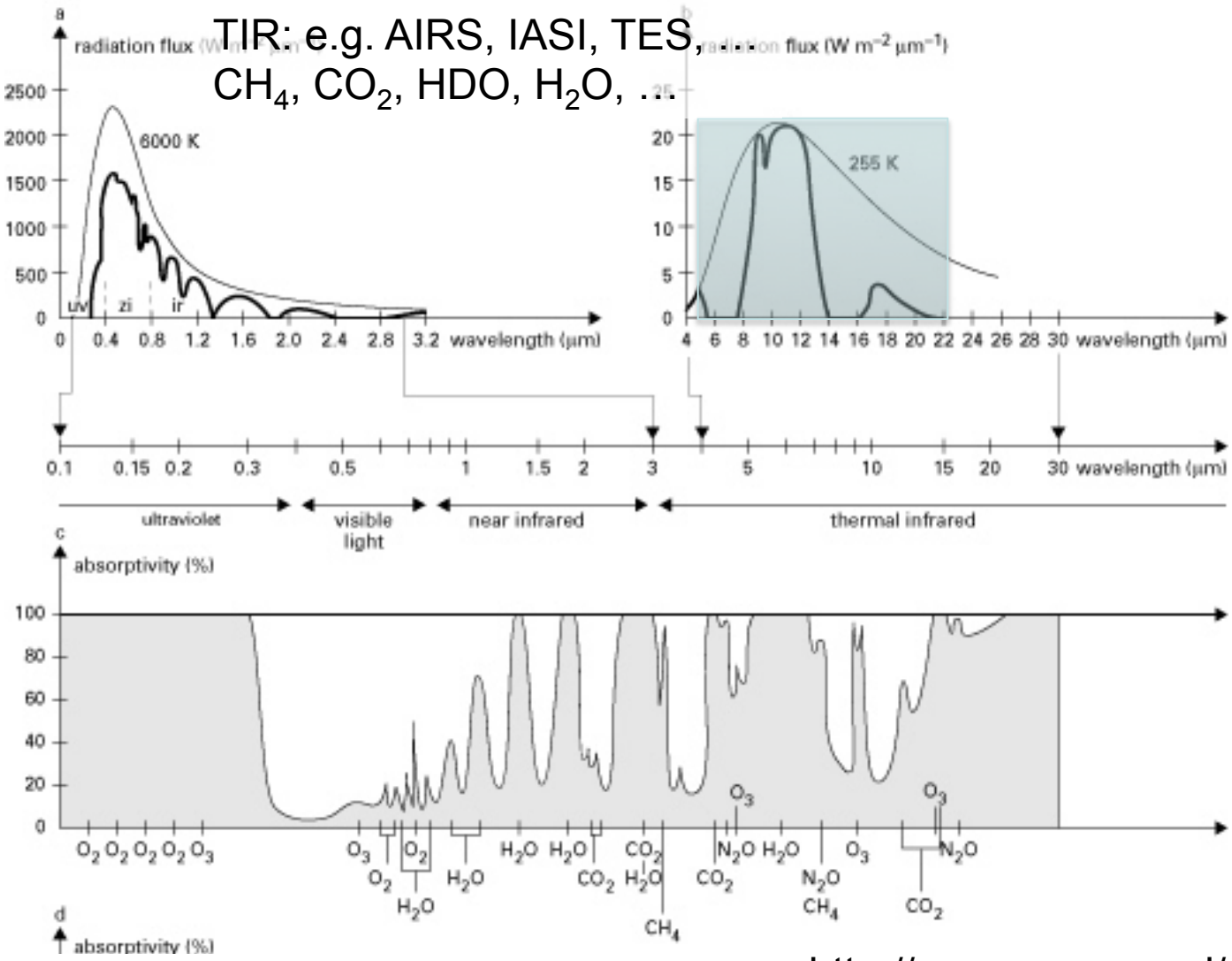
SWIR/NIR: e.g. SCIAMACHY, GOSAT, OCO-2…
CH_4, CO_2, HDO, H_2O, …



http://www.open.ou.nl/dja/Klimaat/

Spectral Ranges

TIR: e.g. AIRS, IASI, TES, …
CH_4, CO_2, HDO, H_2O, …



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Trace Gas examples (UV/Vis): TOMS/GOME: O_3

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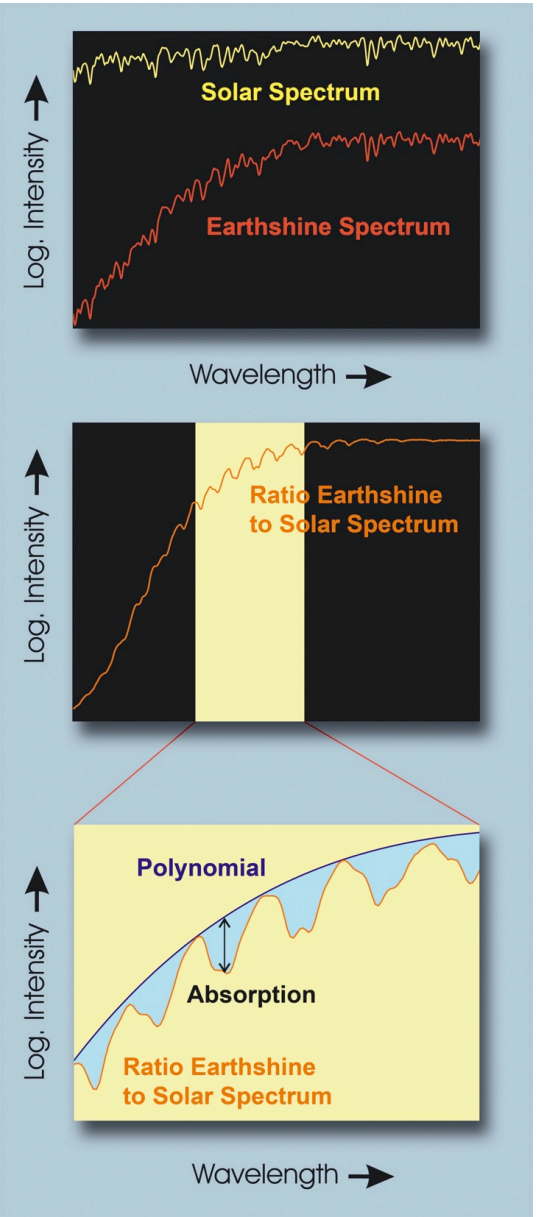

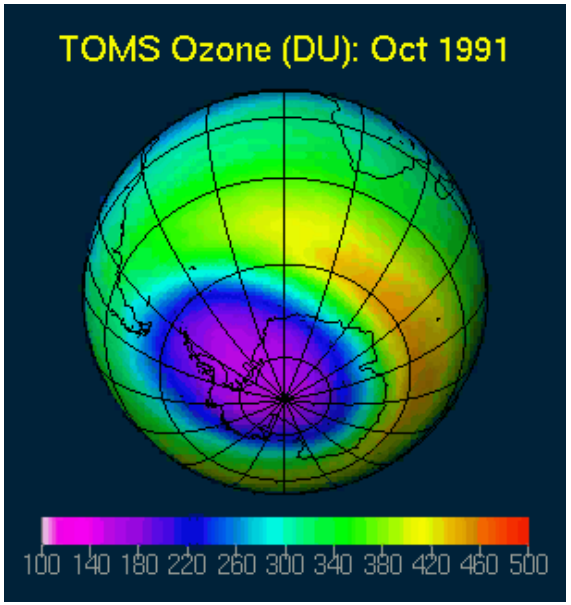

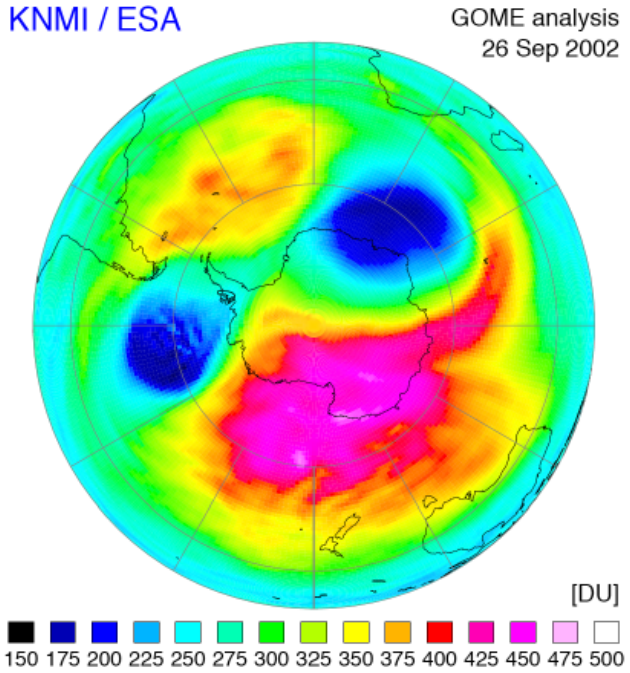

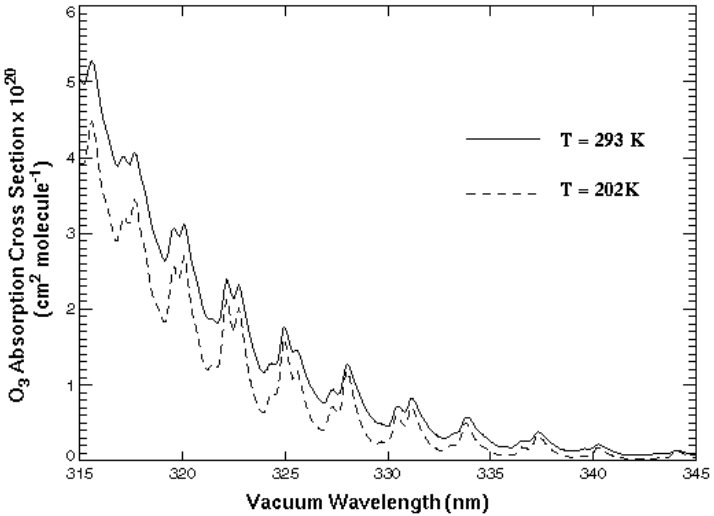

http://envisat.esa.int/support-docs/atmospheric-absorption/atmospheric-absorption.html

Trace Gas examples (UV/Vis): GOME/SCIAMACHY/OMI: NO_2

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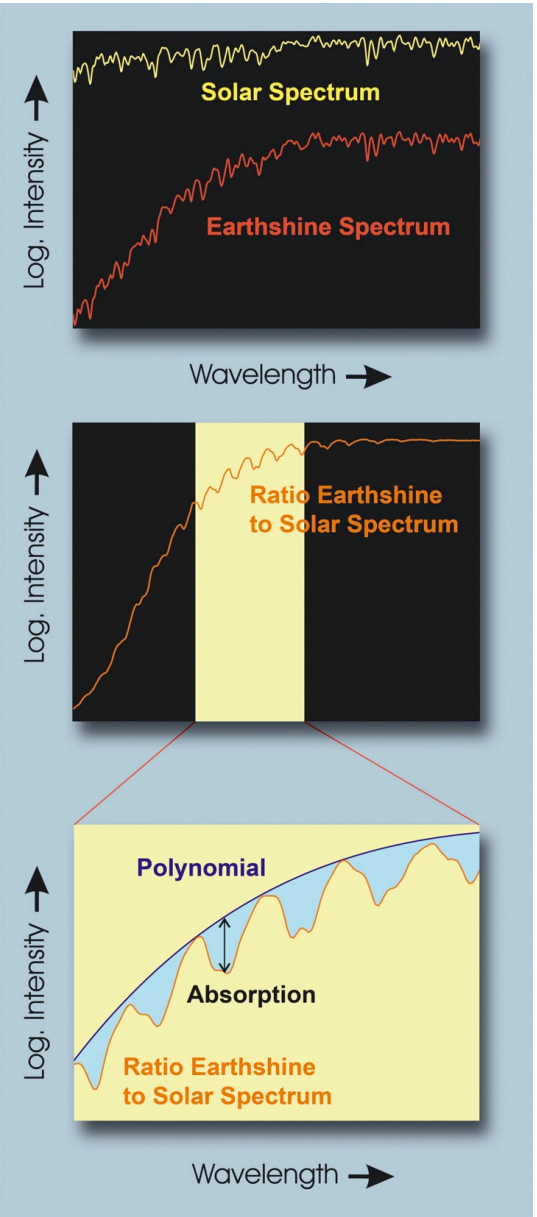

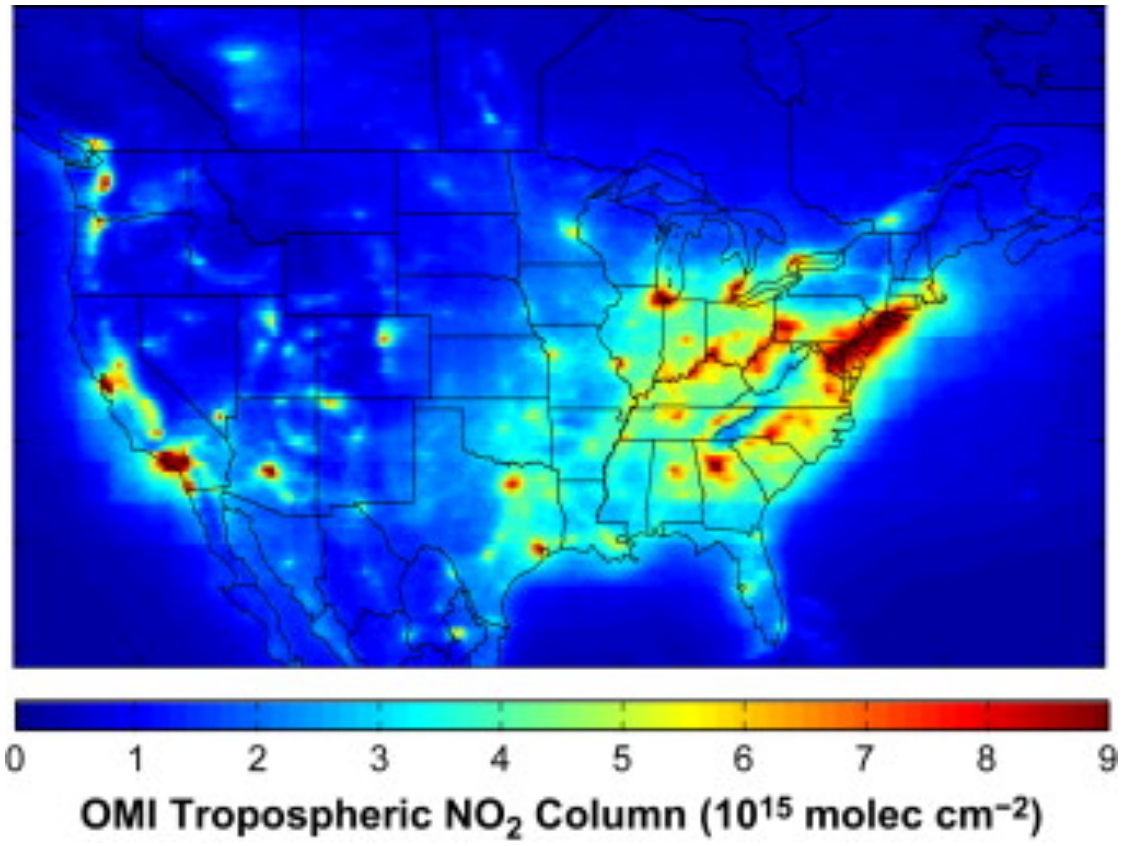

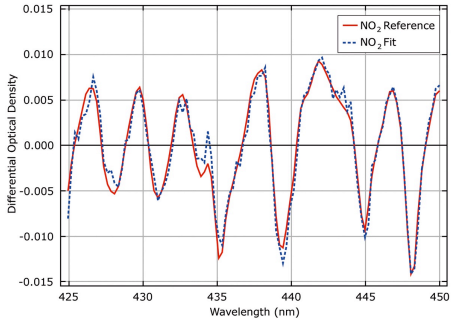

From the SCIAMACHY book

Trace Gas examples (UV/Vis): GOME/SCIAMACHY: NO_2

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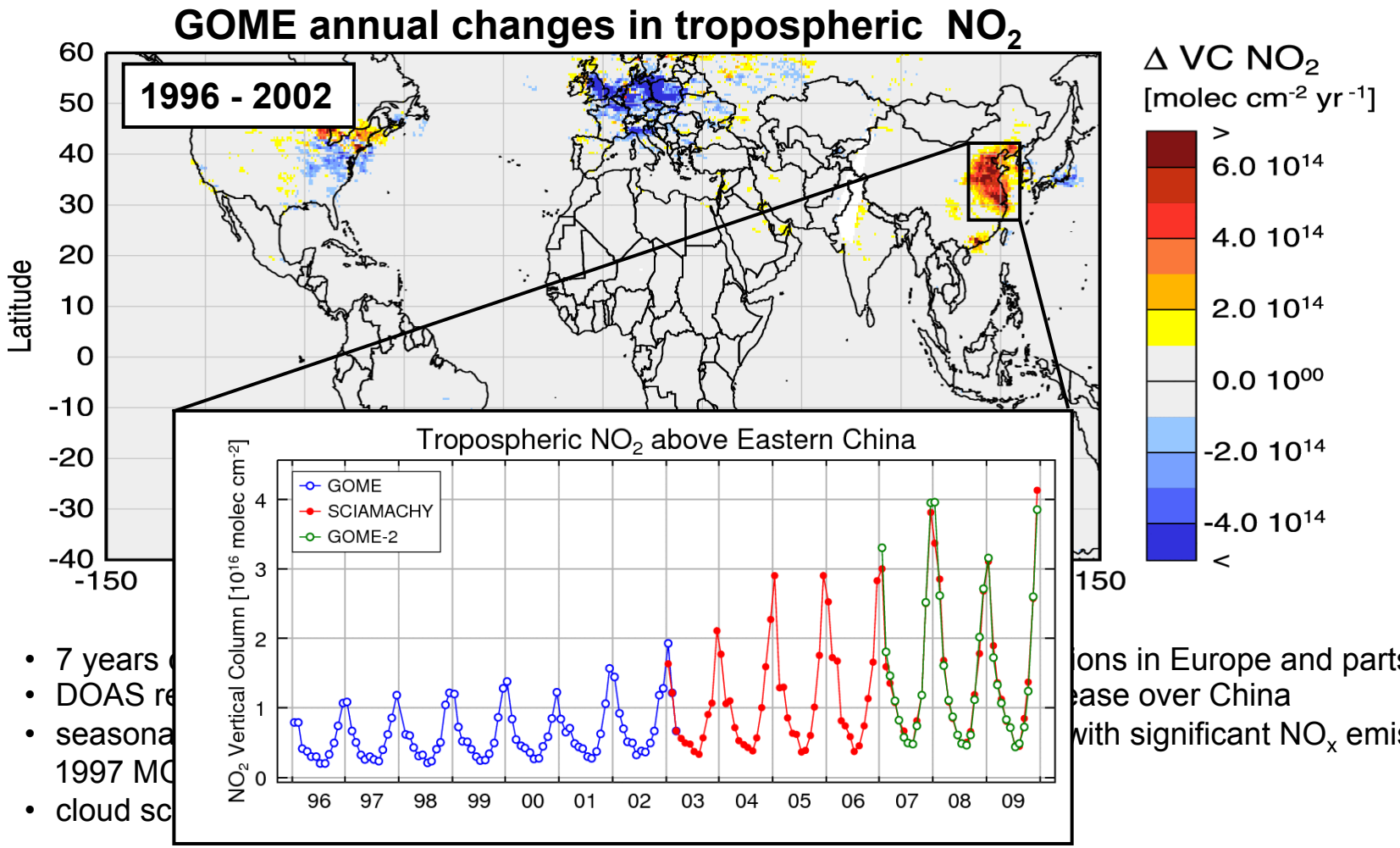
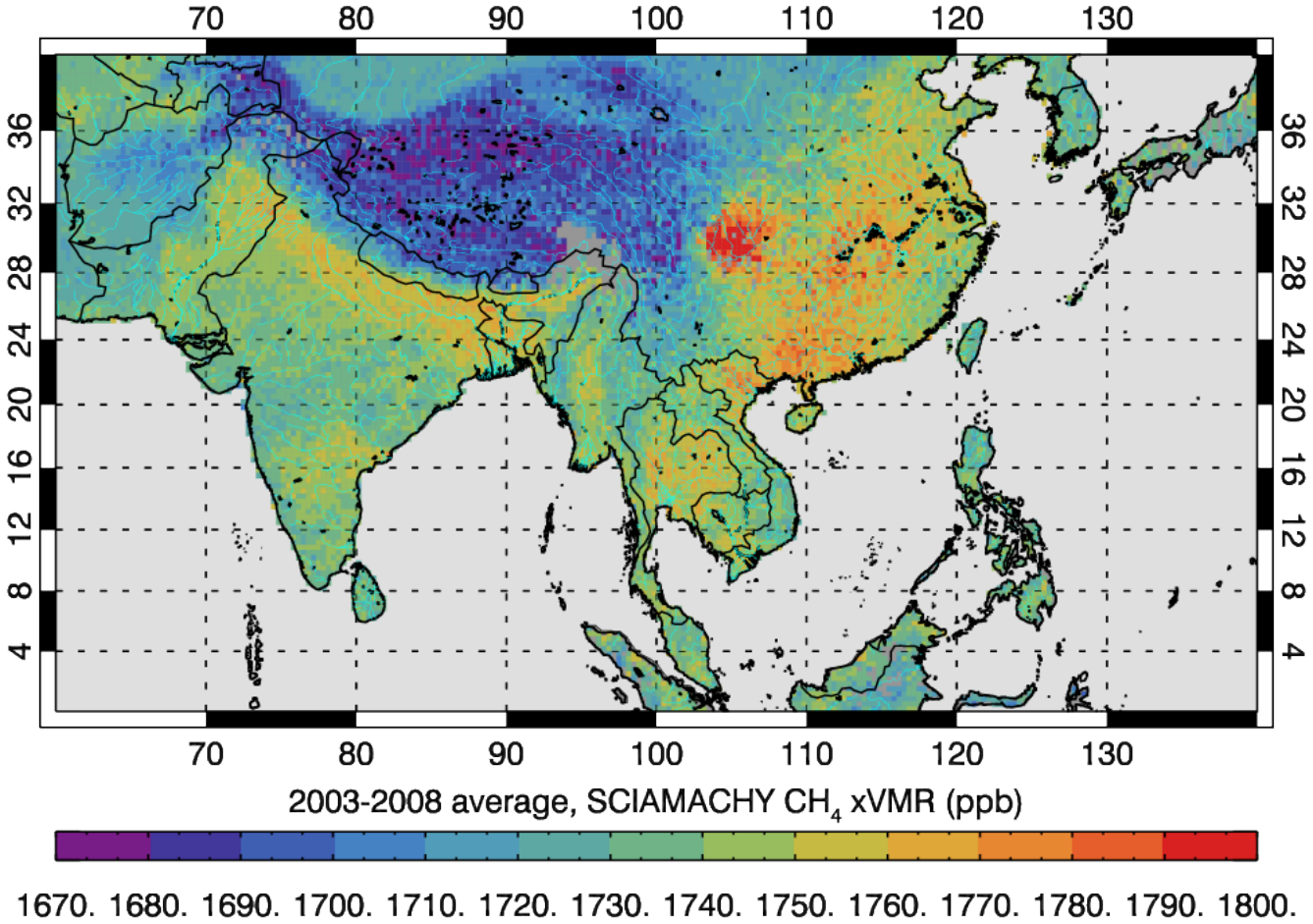


- 7 years (…ions in Europe and parts of the US
- DOAS re…ease over China
- seasona…with significant NO_x emission 1997 MC…
- cloud sc…

From Andreas Richter, Bremen

A. Richter et al., Increase in tropospheric nitrogen dioxide over China observed from space, *Nature*, **437** 2005

Trace Gas examples (NIR): SCIAMACHY CH_4



Frankenberg, C., Aben, I., Bergamaschi, P., Dlugokencky, E. J., van Hees, R., Houweling, S., van der Meer, P., et al. (2011). Global column-averaged methane mixing ratios from 2003 to 2009 as derived from SCIAMACHY: Trends and variability. Journal Of Geophysical Research-Atmospheres, 116, D04302. doi:10.1029/2010JD014849

Trace Gas examples (NIR): SCIAMACHY CH_4

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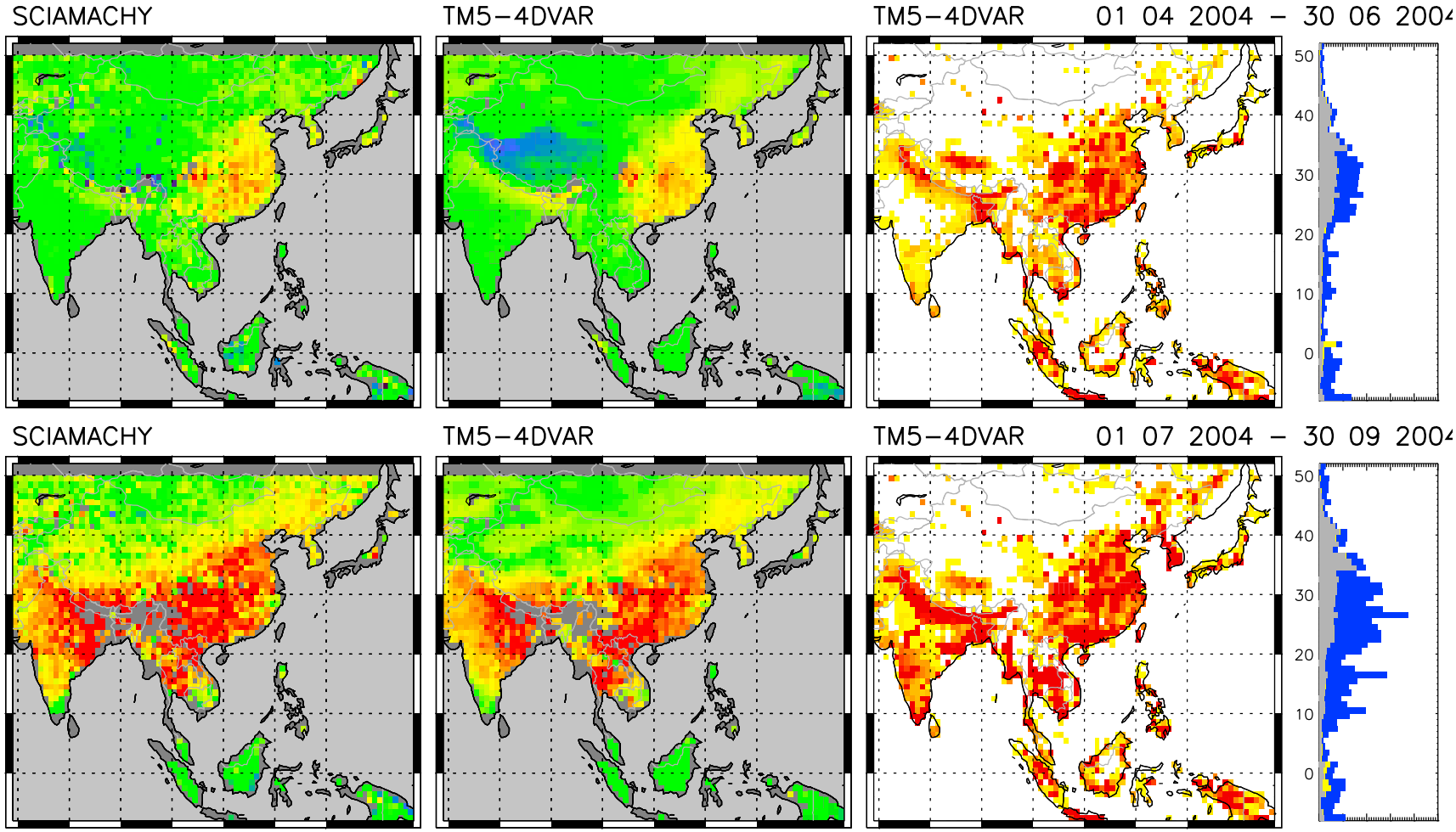

Bergamaschi, P., Frankenberg, C., Meirink, J. F., Krol, M., Villani, M. G., Houweling, S., Dentener, F., et al. (2009). Inverse modeling of global and regional CH_4 emissions using SCIAMACHY satellite retrievals. Journal Of Geophysical Research-Atmospheres, 114, D22301. doi:10.1029/2009JD012287

Trace Gas examples (NIR): SCIAMACHY HDO/H_2O

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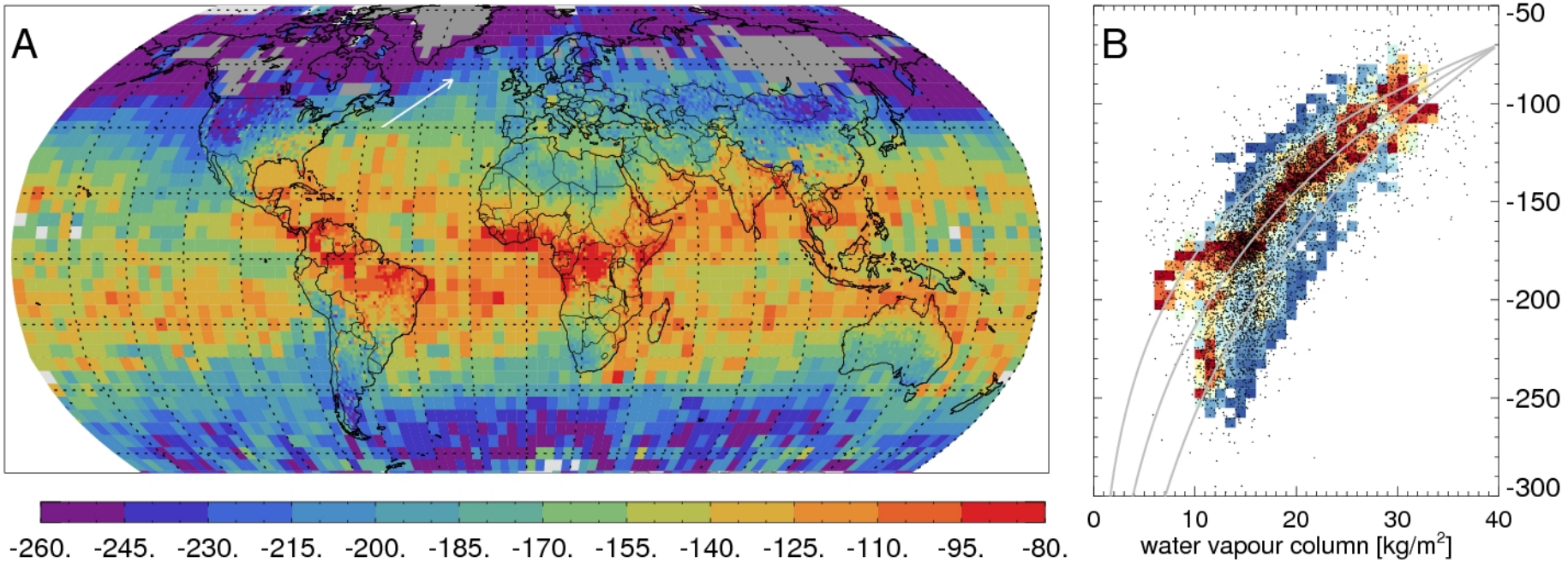
Deuterium depletion, indicative of water vapor history (as phase changes change the isotopic composition)



Frankenberg, C., Yoshimura, K., Warneke, T., Aben, I., Butz, A., Deutscher, N. M., Griffith, D., et al. (2009). Dynamic Processes Governing Lower-Tropospheric HDO/H2O Ratios as Observed from Space and Ground. Science, 325(5946), 1374–1377. doi:10.1126/science.1173791

Trace Gas examples (NIR): CO_2: GOSAT (now), OCO-2 (future)

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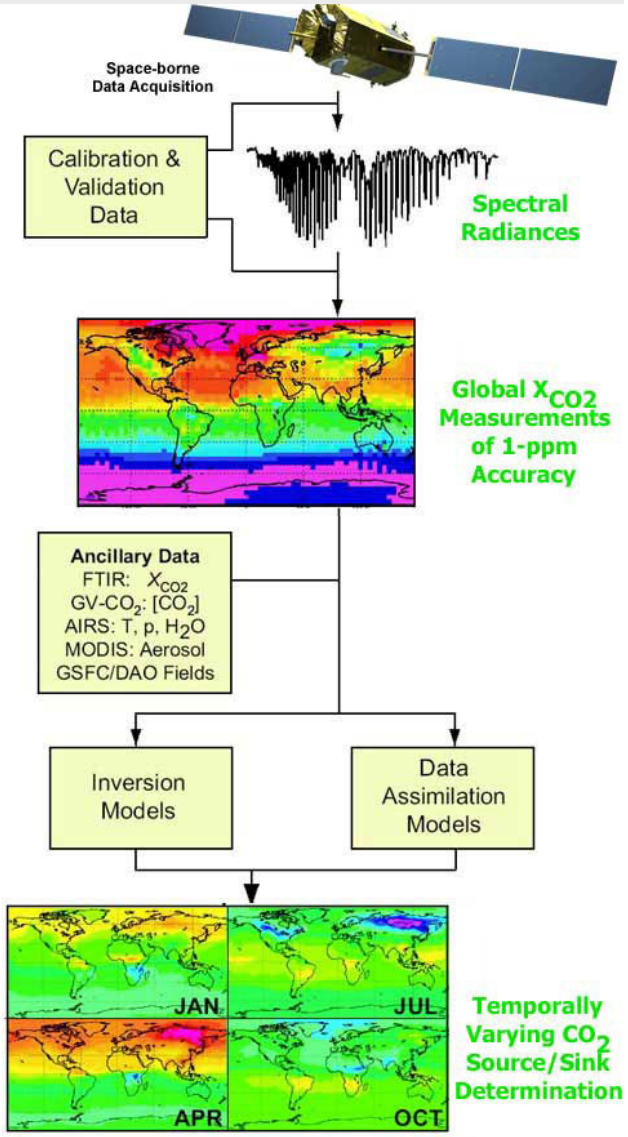
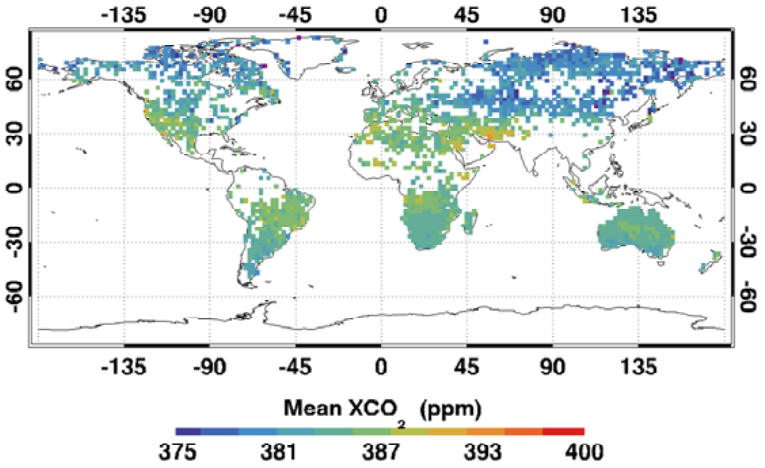
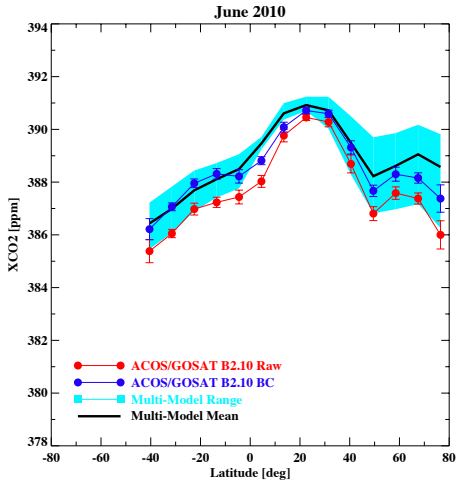
Idea behind OCO-2



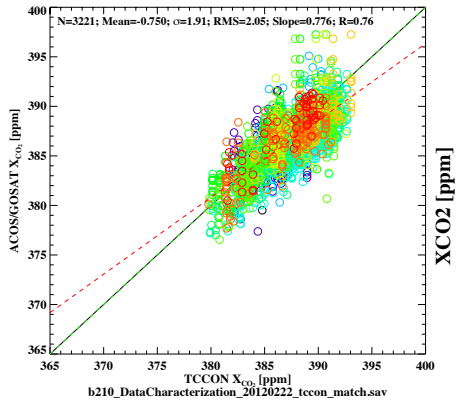
Real GOSAT results

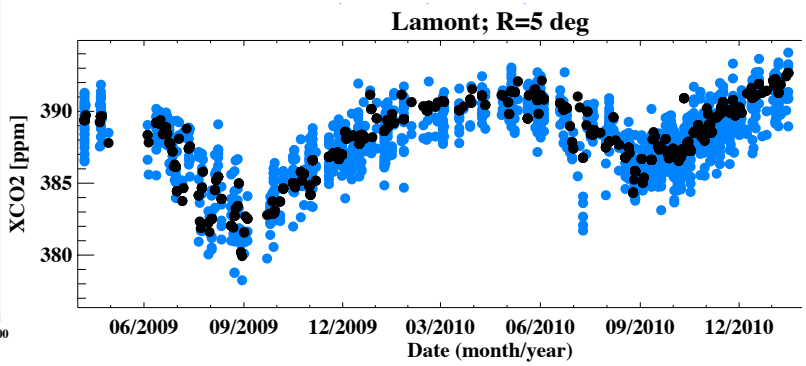
The Japanese GOSAT satellite is a Fourier Transform Spectrometer with bands and spectral resolution similar to OCO-2 (but 50 times less soundings and 30 times larger ground-pixels) → Ideal test-bed for the OCO-2 mission





Validation against TCCON





Exotic example (NIR-fluorescence): GOSAT (now), OCO-2 (future)

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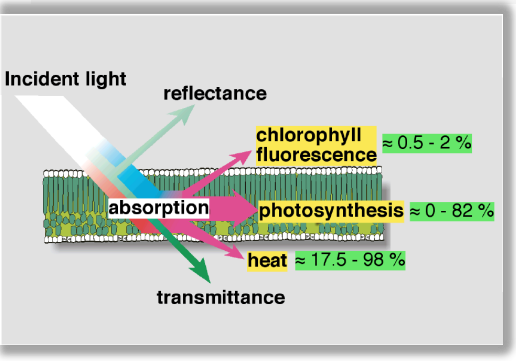
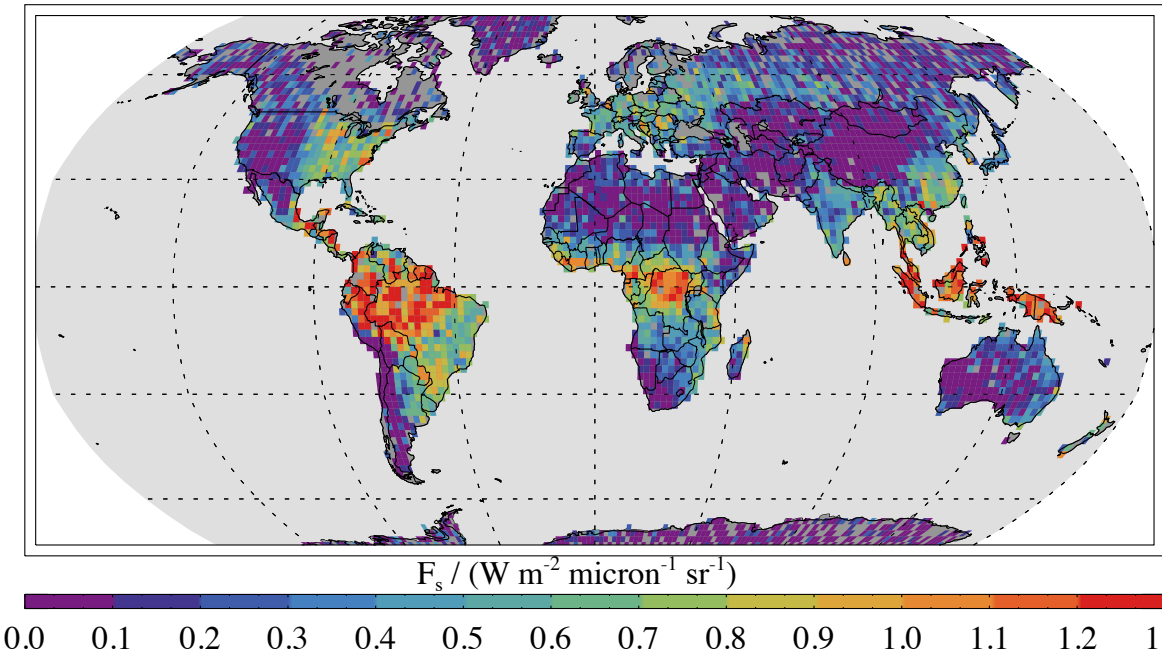
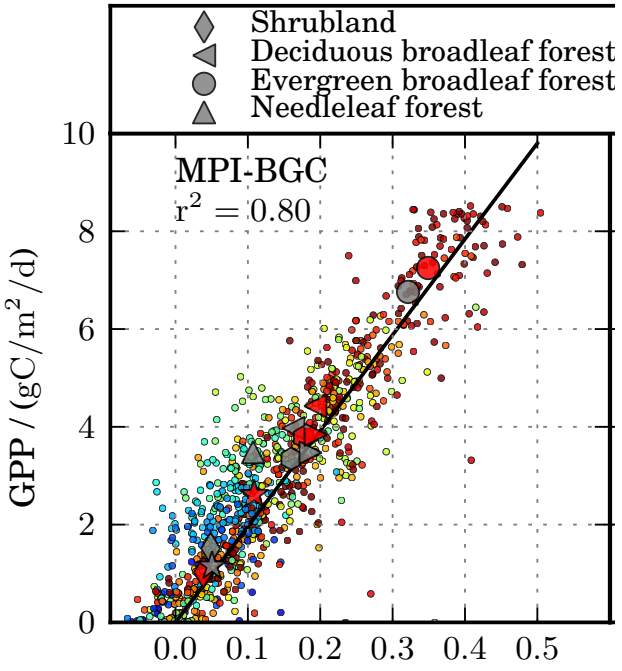
Frankenberg, Fisher et al, GRL (2011)
New global observations of the terrestrial carbon cycle from GOSAT: Patterns of plant fluorescence with gross primary productivity



- Patterns of retrieved chlorophyll **fluorescence linked to photosynthetic activity** via chlorophyll quenching.
- First direct **physiological proxy for gross primary production** (GPP) from space.

A Chlorophyll a fluorescence at 755 nm, June 2009 through May 2010 average





- **Linear correlation** between fluorescence and current best GPP estimates observed using GOSAT data.
- **Better GPP predictor** than EVI/LAI

Trace Gas examples (TIR): TES, O_3 radiative forcing

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In the thermal infrared, the “greenhouse effect” is the reason we can actually measure the trace gases. Example for ozone, where radiative kernels actually come “for free” from the measurements and Jacobian calculation.

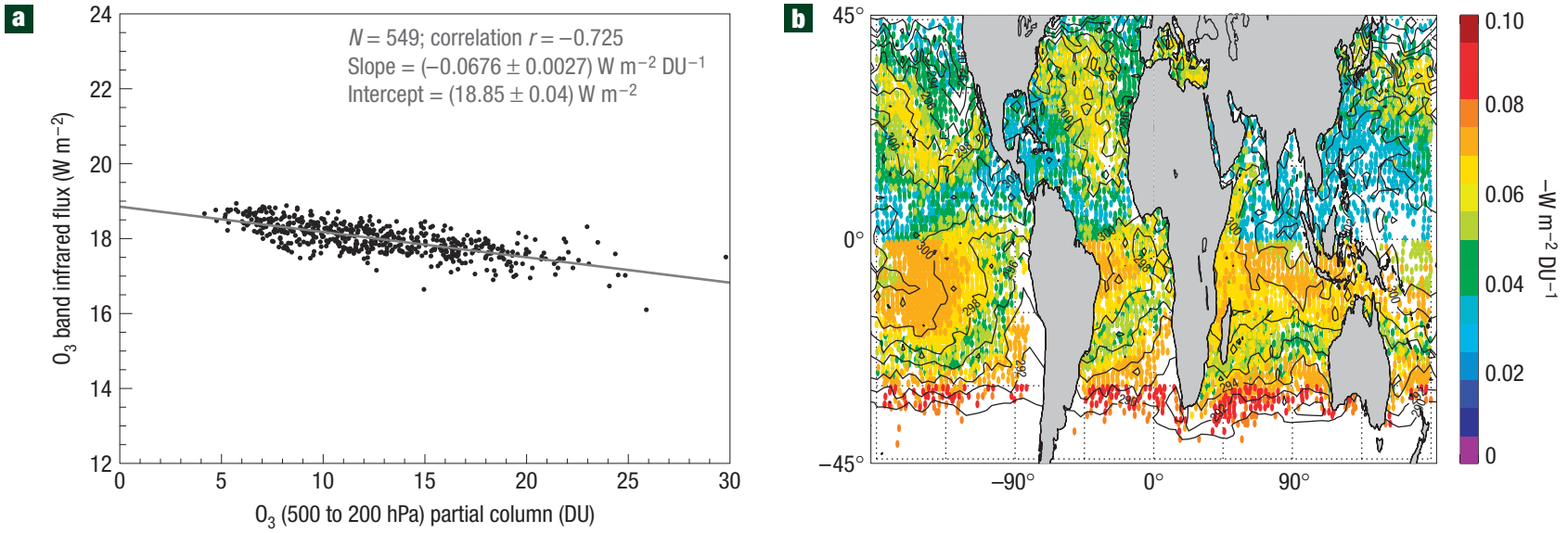

Figure 1 TES ensemble sensitivities of TOA infrared flux to upper tropospheric ozone. a, Example of linear fit of TOA infrared flux to upper tropospheric ozone (partial column ozone from 500 to 200 hPa). The case shown is for JJA 2006 northern hemisphere SSTs between 298 and 299 K. **b**, Map of JJA 2006 ensemble sensitivities in negative W m^{-2} DU^{-1}. 2 K SST contours are overplotted to show the spatial dependence on SST binning.

Worden, H. M., Bowman, K. W., Worden, J. R., Eldering, A., & Beer, R. (2008). Satellite measurements of the clear-sky greenhouse effect from tropospheric ozone. Nature Geoscience, 1(5), 305–308. doi:10.1038/ngeo182

Conclusions

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California Institute of Technology

- Satellites can provide a wealth of information regarding global trace gas abundances (of various long and short-lived species).
- Spectrometers in the UV/Vis/NIR spectral range use the sun as light source, more sensitivity towards the surface but dependent on sun-light
- Spectrometers in the TIR (+ above) use thermal emission from the earth surface and atmosphere → day and night measurements and profiling possible but reduced sensitivity to the surface (relies on thermal contrast).
- Lidar systems are active, use lasers (usually at few wavelengths) as light source.
- Questions?