Trace Gas Measurements from Space

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(and numerous others providing input)
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Spectral Ranges

Sun as light-source

Earth thermal radiation as light-source
Spectral Ranges

UV: E.g. TOMS, GOME, SCIAMACHY, OMI…
Ozone, SO$_2$, …
Spectral Ranges

Vis: e.g. GOME, SCIAMACHY, OMI… NO₂, H₂O, CH₂O, …

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

SWIR/NIR: e.g. SCIAMACHY, GOSAT, OCO-2…
CH$_4$, CO$_2$, HDO, H$_2$O, …

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

TIR: e.g. AIRS, IASI, TES, CH$_4$, CO$_2$, HDO, H$_2$O, ...
Trace Gas examples (UV/Vis): TOMS/GOME: $O_3$

http://envisat.esa.int/support-docs/atmospheric-absorption/atmospheric-absorption.html
Trace Gas examples (UV/Vis):
GOME/SCIAMACHY/OMI: NO$_2$

From the SCIAMACHY book
Trace Gas examples (UV/Vis): GOME/SCIAMACHY: NO₂

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

- 7 years of GOME data
- DOAS retrieval
- Seasonal and local AMF based on 1997 MOART-2 run
- Cloud screening
- NO₂ reductions in Europe and parts of the US
- Strong increase over China
- Consistent with significant NOₓ emission changes

From Andreas Richter, Bremen
Trace Gas examples (NIR): SCIAMACHY CH$_4$

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Deuterium depletion, indicative of water vapor history (as phase changes change the isotopic composition)
Trace Gas examples (NIR): CO$_2$: GOSAT (now), OCO-2 (future)

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) \( \rightarrow \) Ideal test-bed for the OCO-2 mission
Exotic example (NIR-fluorescence): GOSAT (now), OCO-2 (future)

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
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.

• 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 sunlight.
• 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?