Tropospheric Composition Change observed from Space

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Why from Space?
- atmospheric composition is changing, mainly as result of anthropogenic activities
- consistent global long-term measurements are needed to monitor and understand these changes
- surface in-situ measurements provide local long-term data sets but lack spatial coverage
- air-borne in-situ measurements provide vertical resolution but also lack coverage
- satellite measurements lack vertical and spatial resolution but provide good coverage

How to measure from Space?
- Measurement Technique:
  - Differential Optical Absorption Spectroscopy on UV/visible sun light scattered back and reflected from the atmosphere and surface
  - use of Lambert-Beer’s law to determine the absorption along the effective light path
  - use of radiative transfer simulations to determine the effective light path
  - separation of tropospheric and stratospheric components by making assumptions on zonal homogeneity of the stratospheric fields

Some Examples

NOx Increase above China
- NOx, is mainly emitted from cars, power plants and cement industry
- rapid industrialisation leads to rapid increase in emissions
- increase seen by satellite is slightly larger than in recent emission estimates
- winter increase much larger in satellite data but only moderately larger in emission estimate

SO2 Increase above China
- SO2 is mainly emitted from power plants and domestic heating
- increased coal use in power plants increases emissions
- reduced household use decreases emissions
- improved emission controls reduce emissions
- change in viewing conditions might contribute to satellite signal (see Fig. 6)

El Nino and NOx above Indonesia and Australia
- dryness during El Nino years such as 2006 lead to large scale wild fires in Indonesia and Australia
- air quality is affected in large region
- smoke and haze from fires reduces number of good satellite measurements (see gaps in SCIAMACHY, September 2006 map)

Problems and possible Solutions

Instrument Changes
- any instrument may change over time introducing artificial changes
- long-term data sets rely on data from different sensors which may differ for several reasons:
  - instrument characteristics
  - spatial resolution differences
  - local time of measurement differences
  - verification using overlapping time series (see Figure 5)

Viewing Condition Changes
- over a longer time series, the observation conditions may change, e.g.
  - systematic cloud changes
  - changes in surface albedo (e.g. deforestation)
  - changes in aerosol loading, possibly linked to emission changes (e.g. SOx)
  - changes in emission height (see figure)
  - validation with external data needed

Separation of Effects
- the measurements provide atmospheric column amounts, which have to be transferred to emission strengths or local concentrations
- external information or models are often needed to make the link
- selection of appropriate case studies can also help (e.g.: only power plant emissions change, see Figure 7)
- data are best used synergistically

Conclusions
- UV/visible satellite measurements of tropospheric species provide valuable long-term data sets
- the data can be used to monitor emission changes
- examples are increases in anthropogenic emissions of NOx and SOx in China, reductions in NOx emissions in power plants in the US, as well as NOx emissions from fires in Indonesia
- use of multi-sensor time series necessitates careful instrument cross-verification
- possible changes in observation conditions (e.g. change in vertical profile) have to be considered

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Selected References

see also: www.iup.physik.uni-bremen.de/doas