Envisat MIPAS measurements of CFC-11 and CFC-12: an add-on to ESA operational data

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Motivation

Why monitor chlorofluorocarbons (CFCs)? They are involved in polar ozone destruction, contribute to the greenhouse effect, but...

...are also useful to study transport processes and to validate atmospheric models.

Satellites allow for continuous, global monitoring of CFCs, but provide large amounts of data. Hence, efficient algorithms are required for data analysis!
Part I

Forward model and retrieval processor
Forward model: line-by-line example (RFM)

⇒ computations most exact, but require CPU-time
Forward model: EGA example (JURASSIC)

⇒ computations very fast, but loss of accuracy
Forward model: validation

JURASSIC compared to MIPAS Reference Forward Model:
Forward model: optimization

Dependence of CPU-time on ray path segment length:

\[ t[\text{msec}] = \frac{4.89}{ds[\text{km}]} \]

(mid latitudes)

(CPU-time line-by-line evaluation: 100 \ldots 1000 \text{ msec})
A 'typical' CFC-11 retrieval:

**Optimal estimate of atmospheric state:** Minimize deviations between
(1) measurements and simulated observations as well as
(2) estimate and a priori state.
Retrieval: How to handle systematic errors?

offset calibration

- $c_z = 0.1$ km
- $c_z = 1$ km
- $c_z = 5$ km
- $c_z = 10$ km
- $c_z = 50$ km
- $c_z = 100$ km
- $c_z = 1000$ km
- $c_z = 10000$ km

CFC-11 retrieval error [ppt]

Tangent height [km]
A priori mean and standard deviations from climatology [Remedios, 1999].

Modifications: Minimum uncertainty 5%. Scaling factor 300% for standard deviations. Correlation length 10 km.
Part II

Global data sets of CFCs in 2002–2004
Differences due to: cross-section data (bias in CFC-11), temperature data and Level 1B data (scattering)
CFCs: comparison to in-situ measurements (HAGAR)

02–MAR–2003 / Kiruna (68°N / 21°O)

- Pressure [hPa]
- CFC–11 volume mixing ratio [ppt]

HAGAR
MIPAS

12–MAR–2003 / Kiruna (68°N / 21°O)

- Pressure [hPa]
- CFC–12 volume mixing ratio [ppt]

HAGAR
MIPAS
CFCs: comparison space experiments

CFC-11 mean profiles at mid latitudes:

(trend not corrected for)
CFCs: comparison space experiments

CFC-12 mean profiles at mid latitudes:

- ATMOS/SL3 (APR–1985)
- CIRRIS–1A (APR–1991)
- CRISTA–1 (NOV–1994)

(trend not corrected for)
CFCs: Seasonal variability

- troposphere: chemically stable, well mixed
- tropics: tropical pipe, photolysis
- mid latitudes: residual circulation, planetary waves, surf-zone
- polar regions: down-welling (winter!)

**JUN-2003 to AUG-2003**

- winter
- summer

**Height (log-p) [km]**

**Latitude [°]**

**CFC-11 volume mixing ratio [ppt]**
CFCs: seasonal variability

Time series for CFC-11, 20 km height (log-p):

(based on ≈ 430 000 vertical profiles)
CFCs: seasonal variability

Time series for CFC-11, 20 km height (log-p):

(variance mainly due to planetary waves)
CFCs: comparison to CTM simulation (CLaMS)

Antarctic vortex-split, CFC-11, 500 K:

⇒ Kalman-filter module for quantitative comparisons
We could provide...

- A **fast forward model** and an accompanying **retrieval processor** suitable to derive trace gas concentrations from Envisat MIPAS measurements.
  (system suited for comprehensive retrievals, i.e. typically 2–3 weeks effort to process a new trace gas for whole mission)

- Global data sets of **CFC-11 and CFC-12** for the time period July 2002 to March 2004.
  (data validated, approx. 500 000 scans per species)

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