Data evaluation

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OUTLINE

- **Introduction**
- **Basic data evaluation for remote sensing**
- **Data evaluation in chemical data assimilation**
- **Data evaluation using chemical data assimilation**

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Introduction

- **Usage of remote sensing chemical observations**
  - Scientific issues
  - Chemical data assimilation
  - …
- **'National Bureau of Standards' : non-existing, non-applicable**
- **Best effort is required, but least rewarding**

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Basic data evaluation

- **Basic data evaluation: comparing with ground based observations**
  - J.-C. Lambert at BIRA-IASB
- **Scientific objectives of validation:**
  - To test general soundness of ENVISAT data.
  - To better understand what comes from the measurement.
  - To test error bars provided by retrieval teams.
  - To assess whether and to what extent ENVISAT data can be used for aimed scientific application.

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Basic data evaluation

Contributors

Analysis

BIRA-IASB, Belgium
CNRS/SA, France
FMI/Sodankylä, Finland
IAP/Berne, Switzerland
IMK/FZK, Germany
INTA, Spain
ISAC/CNR, Italy
IUP/Bremen, Germany
IUP/Heidelberg, Germany
KMI-IRM, Belgium
KNMI, The Netherlands
NILU, Norway
NIWA, New Zealand
RIVM, The Netherlands
SPbSU, Russia
U. Bonn, Germany

Data Acquisition

Analysis teams +
AWI, Germany
BAS, UK
CAO, Russia
DMI, Denmark
DWD, Germany
ETH-Zurich, Switzerland
FHG, Germany
IAP, Russia
IFU, Germany
IRF, Sweden
JPL/Caltech, CA
KSNU, Kyrgyzstan
KTSU, Ukraine
MCH, Switzerland
MGO, Russia
MSC, Canada
NASA/LaRC, VA
NOAA/CMDL, CO
SAAI, Canada
STEL, Japan
U. Athens, Greece
U. Bordeaux, France
U. Chalmers, Sweden
U. Denver, CO
U. L'Aquila, Italy
U. La Sapienza, Italy
U. Liège, Belgium
U. Nagoya, Japan
U. Reims, France
U. Réunion, France
U. Sao Paulo, Brazil
U. Thessaloniki, Greece
U. Toronto, Canada
U. Tor Vergata, Italy
U. Wales, UK
U. Wollongong, Australia

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Basic data evaluation

Ground-based Capabilities for ENVISAT Geophysical Validation

- ✓ **Low cost, easily deployable**
- ✓ **Independent correlative data**
- ✓ **Well controlled, well documented**
- ✓ **Network operation and infrastructure (WMO, NDSC)**
- ✓ **High quality standard, certification**
- ✓ **Continuous, long-term time-series**
- ✓ **Many geophysical states**
- ✓ **Ancillary parameters**
- ✓ **Know-how**

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Basic data evaluation

Ground-based Validation : General Issues

- **Geophysics :**
  - •Atmospheric fields are highly structured and variable.
  - •High accuracy/precision/stability often are required.
- **Remote sensing :**
  - •Every observation technique has its own uncertainties and limitations.
  - •Remote sensing often is site-dependent.
- **Comparison : What does 'coincidence' really mean?**
  - • Two different sensors have different 4D resolution.
    - ➢ 3D weighting functions + time effects

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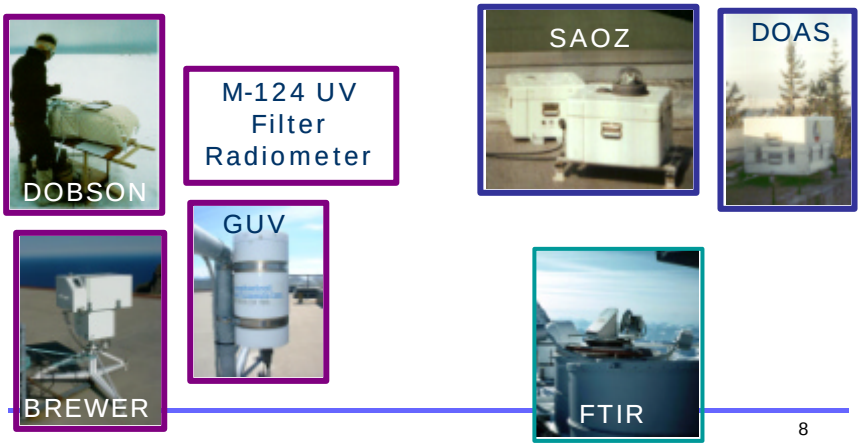
Basic data evaluation

Ozone Vertical Column

➢ **Networks of complementary instruments**



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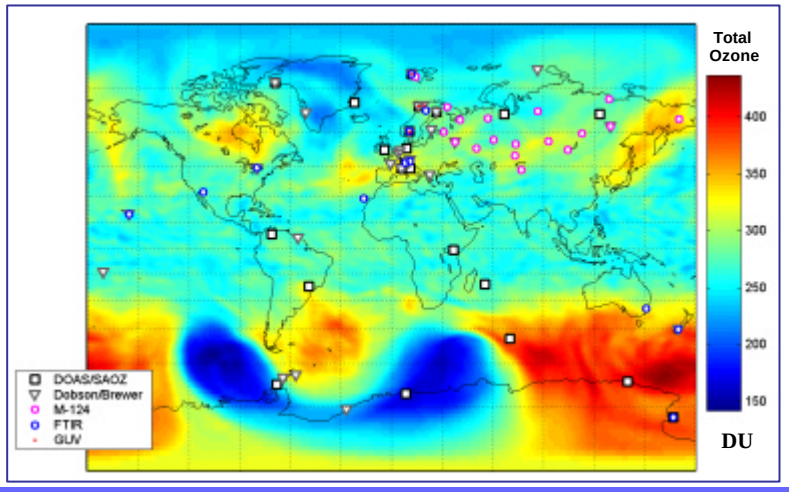
Basic data evaluation

Contributing Total Ozone Sensors



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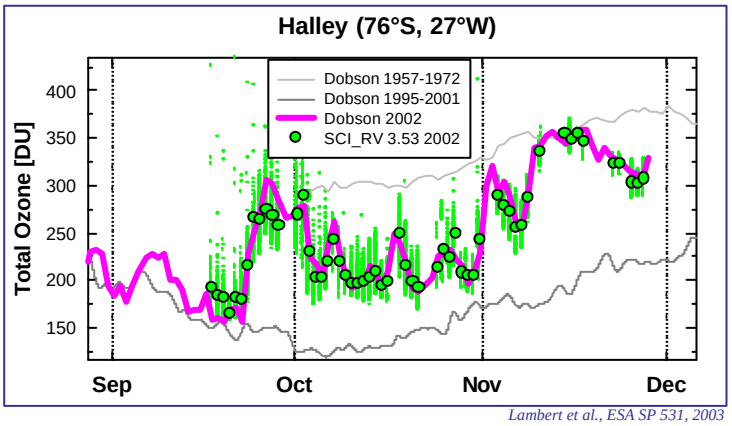
Basic data evaluation

SCIAMACHY Ozone Column: Antarctic Ozone 'Hole' 2002



Lambert et al., ESA SP 531, 2003

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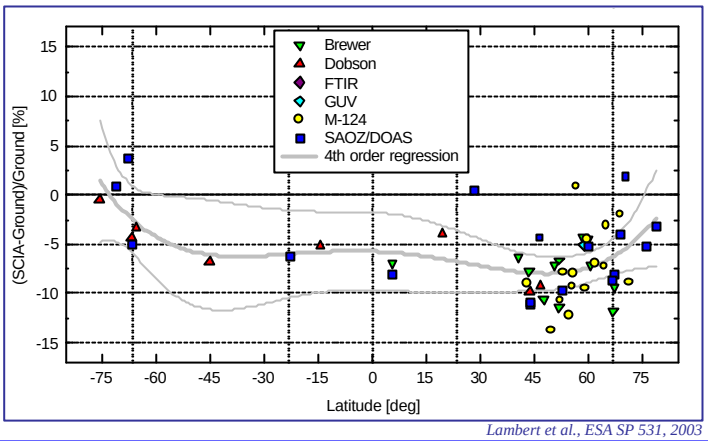
Basic data evaluation

SCIAMACHY Ozone Column Meridian Structure vs. Ground-based networks



Lambert et al., ESA SP 531, 2003

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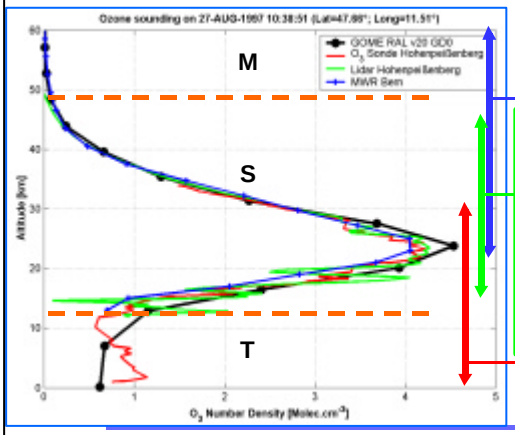
Basic data evaluation

Ozone Vertical Distribution: information content



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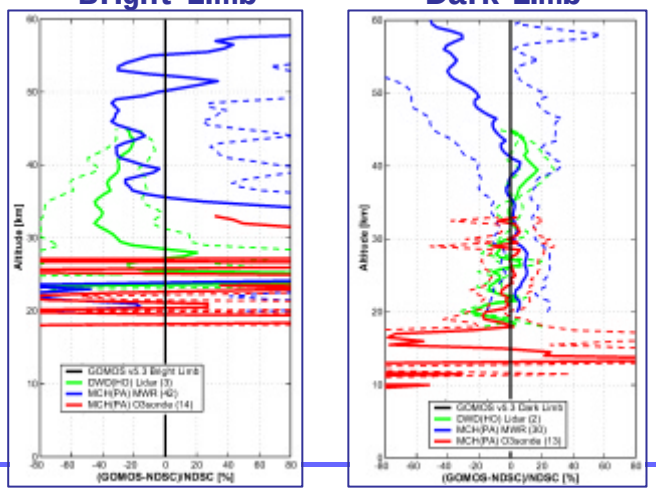
Basic data evaluation

GOMOS vs. Ground-based Ozone Profile

MeteoSwiss

Bright Limb | **Dark Limb**



Lambert et al., ESA SP 531, 2003

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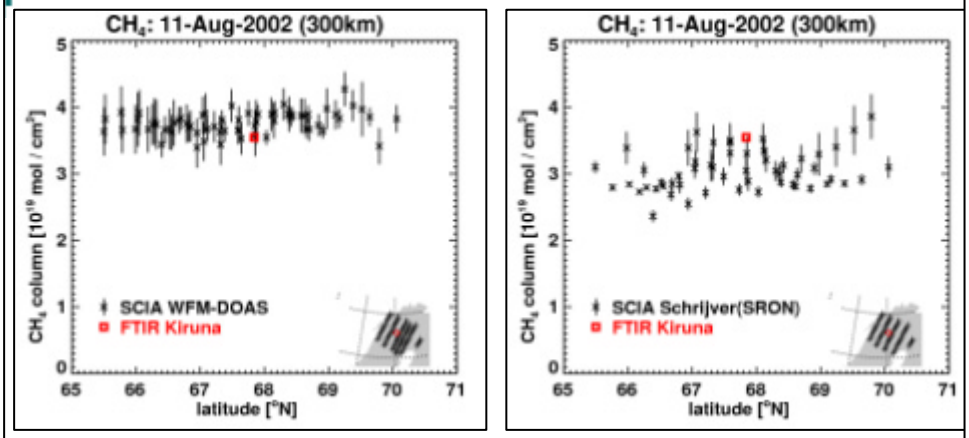
Basic data evaluation

Infrared Products: SCIAMACHY CH4 Column



Bramstedt et al., ESA SP 531, 2003

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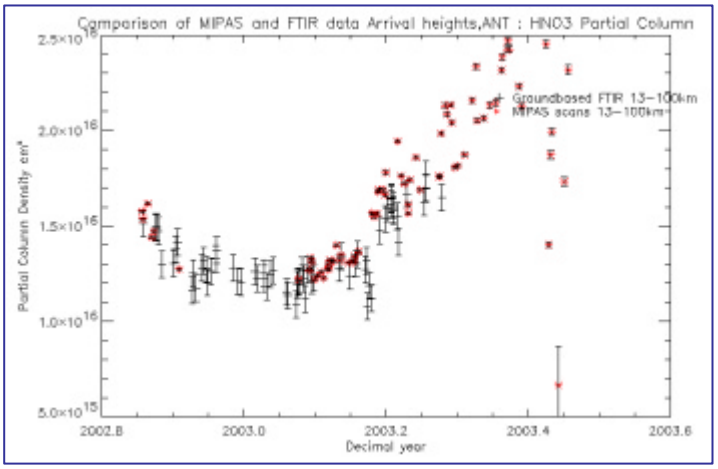
Basic data evaluation

Infrared Products: MIPAS HNO3 vs. FTIR



Courtesy S. Wood, NIWA

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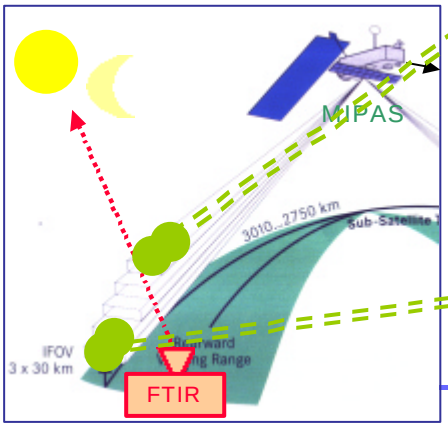
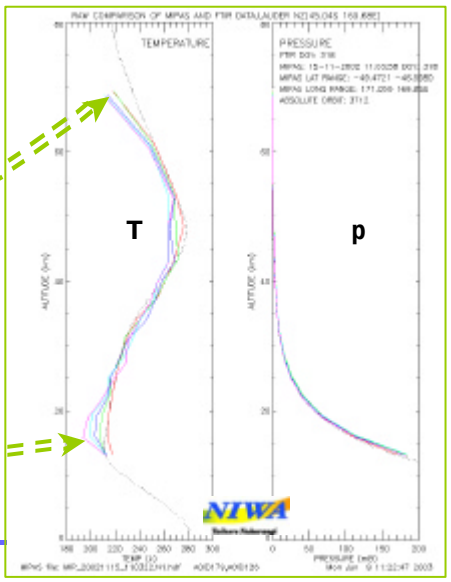
Basic data evaluation

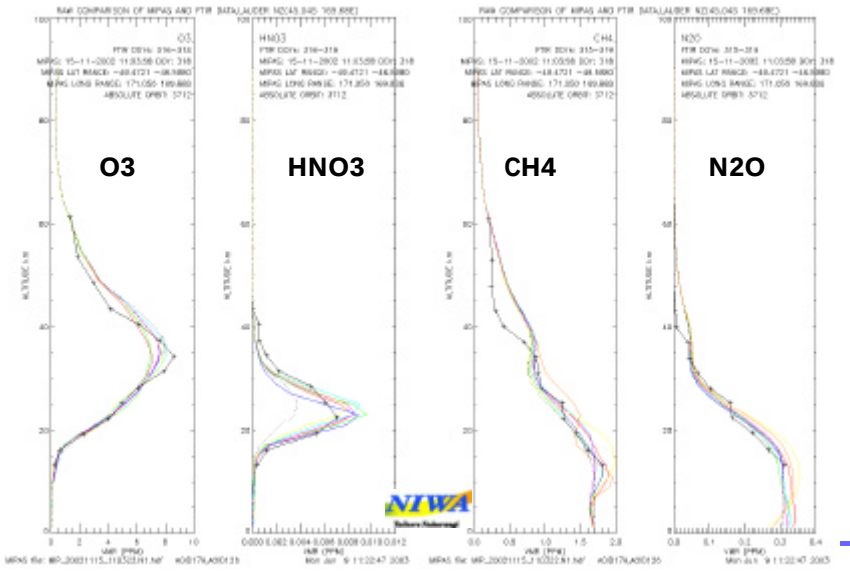
Infrared Products:
Atmospheric Variability
Within Scan/Line-of-sight





Courtesy S. Wood, NIWA

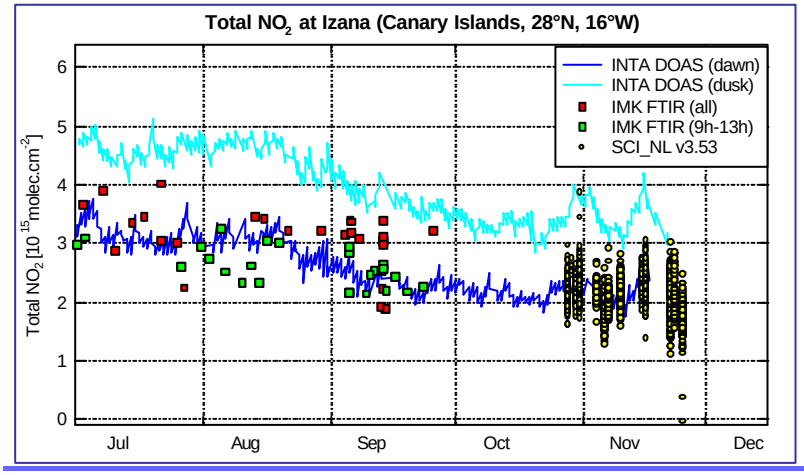
Basic data evaluation



Courtesy S. Wood, NIWA

Basic data evaluation

SCIAMACHY NO2 Column



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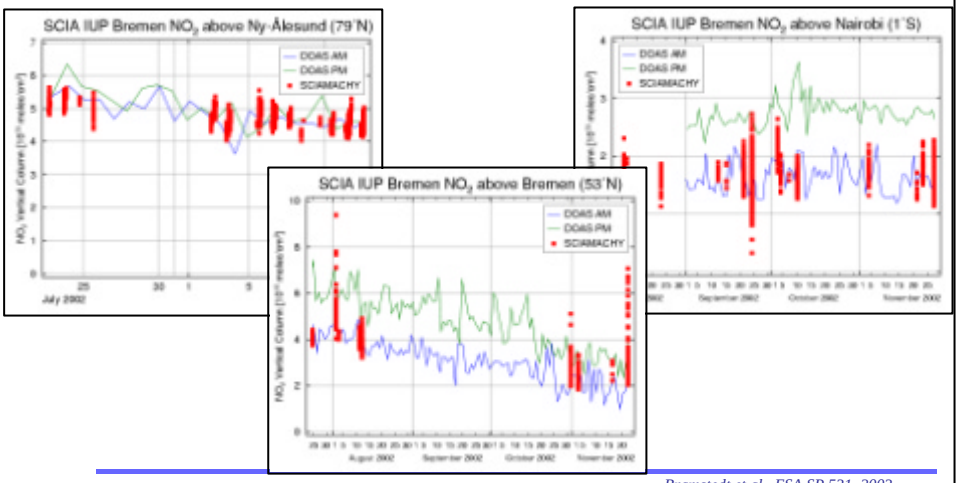
Basic data evaluation

SCIAMACHY NO2 Column



Bramstedt et al., ESA SP 531, 2003

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Basic data evaluation

- **Basic data evaluation: crucial element**
- **Different types of information: co-location, averaging kernels, …**

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Data evaluation in chemical data assimilation

- Evaluation of data assimilation:
  - Comparison with constraining observations
    ↓
  - Test of data assimilation or "quality"
  - Comparison with independent unbiased observations
    ↓
  - 4D-VAR "analysis error"
  - Comparison with independent observations
    ↓
  - Final quality assessment

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Data evaluation in chemical data assimilation

- Examples from BASCOE (and its precursor):
  - 4D-VAR chemical data assimilation
  - 3D CTM and adjoint
  - 57 chemical species
  - Polar Stratospheric Cloud microphysical module (N.Larsen, DMI)
  - Team: S. Bonjean, S. Chabrillat, F. Daerden, Q. Errera & T. Steegmans
  - Site: bascoe.oma.be back online shortly (~ weeks)
- Observations:
  - **CRISTA I (1 week 1994)**
  - MLS (past N.H. winters)
  - **ENVISAT: up to now MIPAS**

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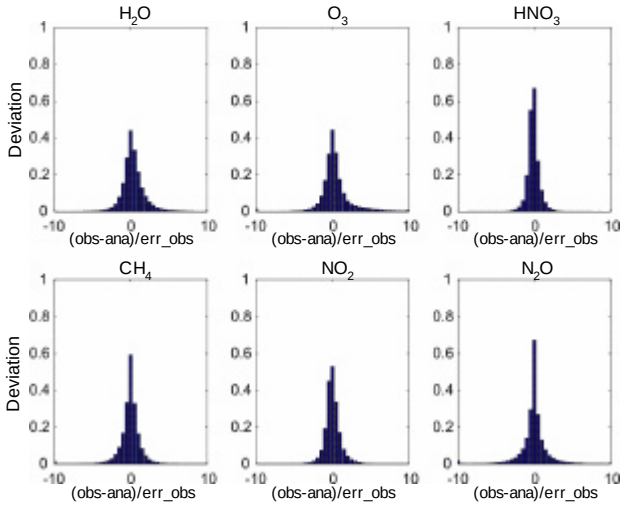
Data evaluation in chemical data assimilation

How are assimilated MIPAS obs. reproduced by the model?

- obs. with small errors (eg. O_3, H_2O) are not reproduced into their error bars.
- similar finding by DARC



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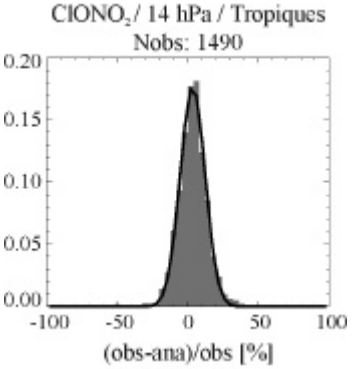
Data evaluation in chemical data assimilation

Estimation of the analysis uncertainty with the help of the non assimilated observations: **unbiased independent observations** (not provided by 4D-VAR)

- only possible for observed species
- assumptions:
  - errors are gaussian
  - non assimilated observations error are independent of assimilated observations error



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Data evaluation in chemical data assimilation

Estimation of the analysis uncertainty with the help of the non-assimilated observations

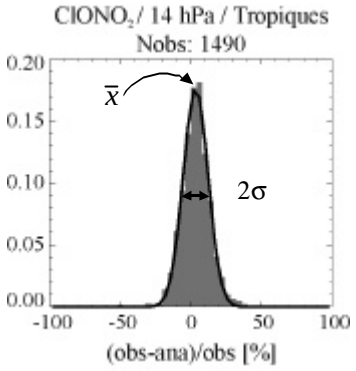
1. Estimation of the bias between CRISTA & analysis

if $\bar{x} > \sigma_{obs} \Rightarrow$ significant bias

2. Estimation of the random uncertainties of the analysis

$$\sigma^2 = \sigma_{ana}^2 + \sigma_{obs}^2$$

Results:
- analysis random error ≅ 3*CRISTA random error
- Generaly, bias are non significant
- When concentrations uncertainties



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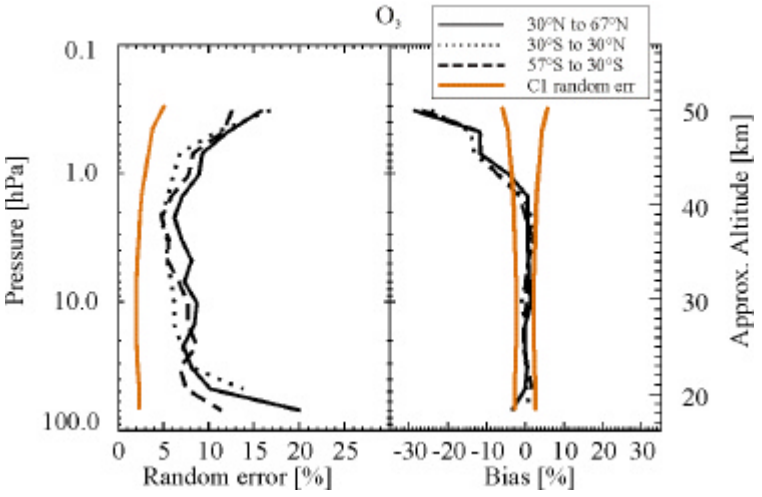
Data evaluation in chemical data assimilation



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Data evaluation in chemical data assimilation

$$J = \frac{1}{2}\left[\mathbf{x}(t_0) - \mathbf{x}^b(t_0)\right]^T \mathbf{B}_0^{-1}\left[\mathbf{x}(t_0) - \mathbf{x}^b(t_0)\right] + \frac{1}{2}\sum_{i=1}^{N}\left(\mathbf{y}^o(t_i) - H[\mathbf{x}(t_i)]\right)^T \mathbf{R}_i^{-1}\left(\mathbf{y}^o(t_i) - H[\mathbf{x}(t_i)]\right)$$

O. Talagrand: $J_{solution}$ @ 0.5

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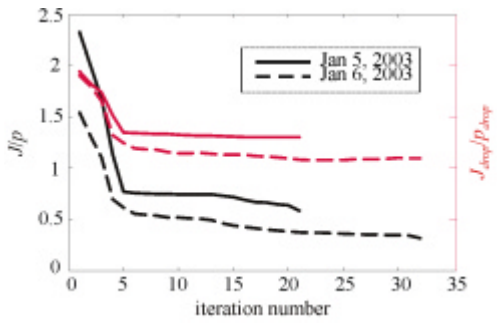
Data evaluation in chemical data assimilation

BASCOE assimilation of MIPAS NRT O_3, NO_2, N_2O, CH_4, H_2O (1/12/2002 until now)



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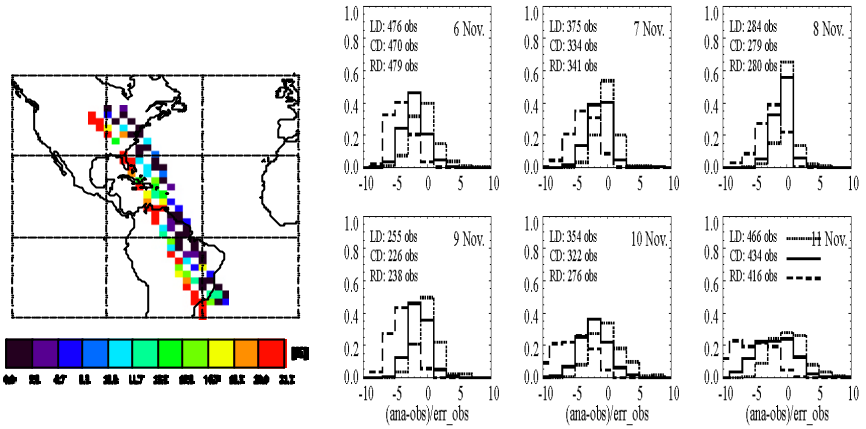
Data evaluation in CDA: highlight problems

Analysis does not reproduce with the same accuracy the CRISTA N_2O_5 observations following their originating detectors.



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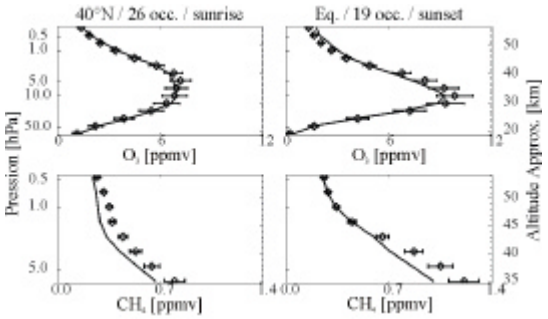
Data evaluation in chemical data assimilation

Comparison with independent observations, well documented errors

- Ground-based observations, sondes, lidars
- Other remote sensing, mostly HALOE

- Analysis/HALOE CH_4 bias ⇒ CRISTA/HALOE CH_4 bias



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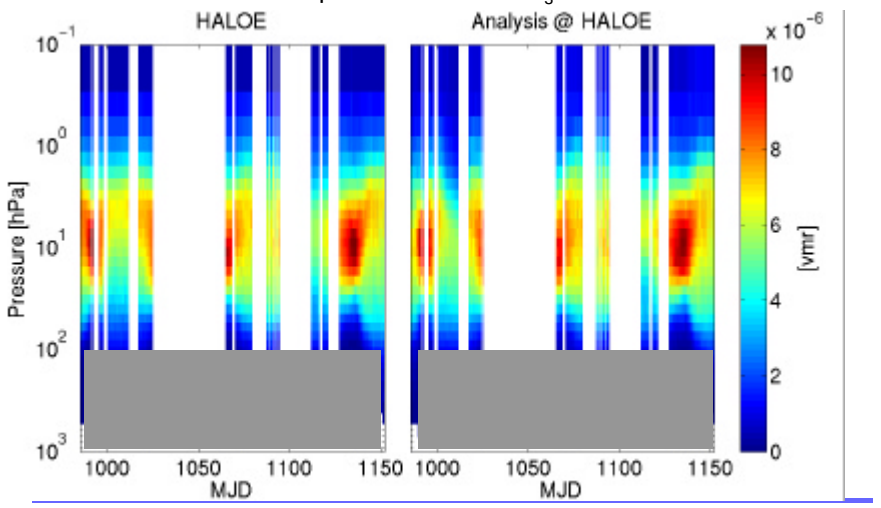
Data evaluation in chemical data assimilation

Comparison to HALOE: O_3



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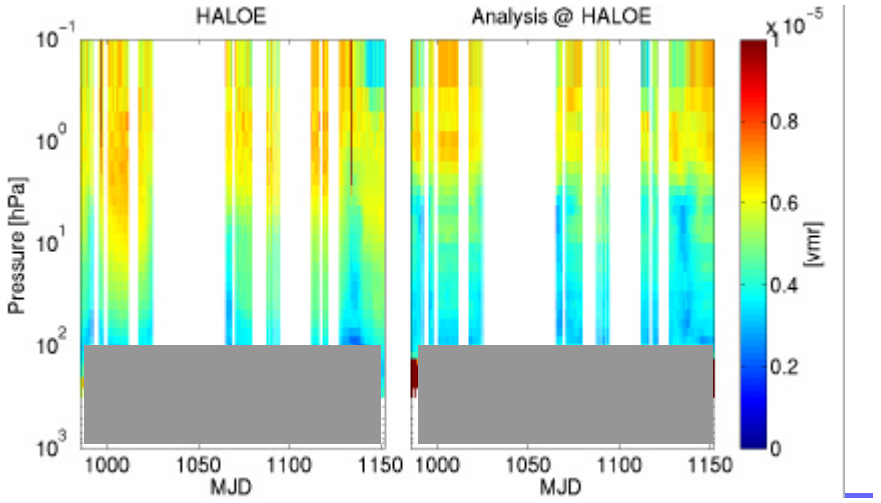
Data evaluation in chemical data assimilation

Comparison to HALOE: H_2O



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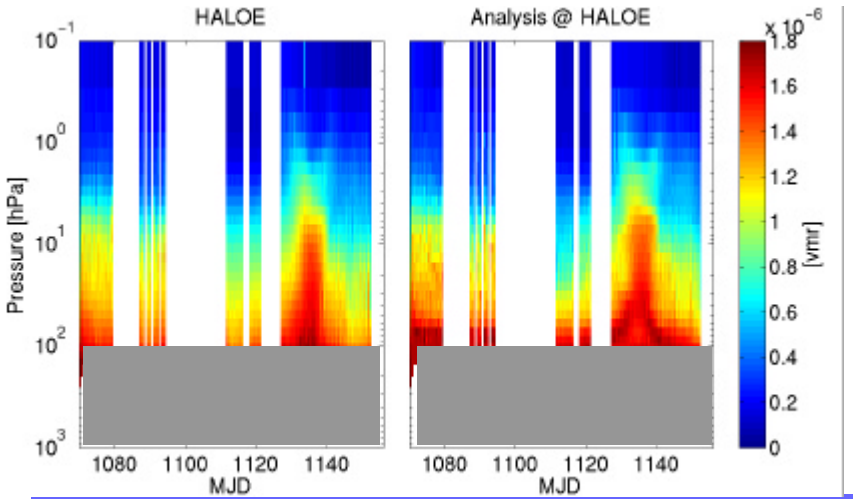
Data evaluation in chemical data assimilation

Comparison to HALOE: CH_4



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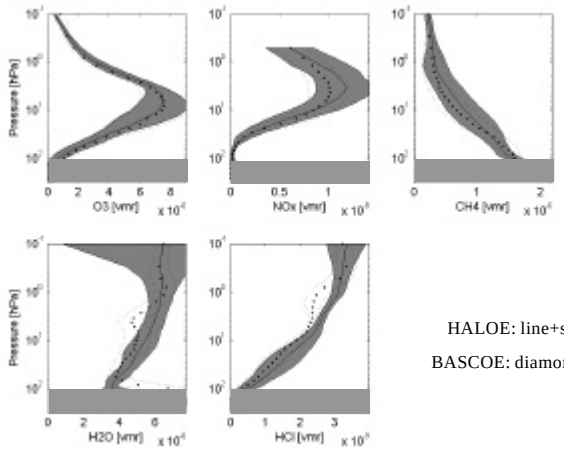
Data evaluation in chemical data assimilation



HALOE: line+shaded

BASCOE: diamonds+dots

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Data evaluation using chemical data assimilation

- **Data assimilation of chemical atmospheric observations:**
  - Model + observations:
  - Analysis representative of real world (constraining observations)
    - ECMWF: ozone, water vapour (4D-VAR)
    - GMAO: ozone (PSAS)
    - KNMI: ozone (Kalman)
    - DARC: ozone, water vapour (3D-VAR)
    - ACRI: chemical species (Kalman)
    - BASCOE: chemical species (4D-VAR)
- GCM
- CTM

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Data evaluation using chemical data assimilation

- **Validation**
  - **Comparison with independent observations**

• **Application: constraining**	**independent observations**
– ECMWF: (SBUV, GOME)	analysis
– GMAO: (SBUV, TOMS)	analysis
– KNMI: (GOME)	analysis
– DARC: (MIPAS)	HALOE, GOMOS
– ACRI: (GOMOS)	HALOE
– BASCOE: (MIPAS)	HALOE

- **Passive and active assimilation**

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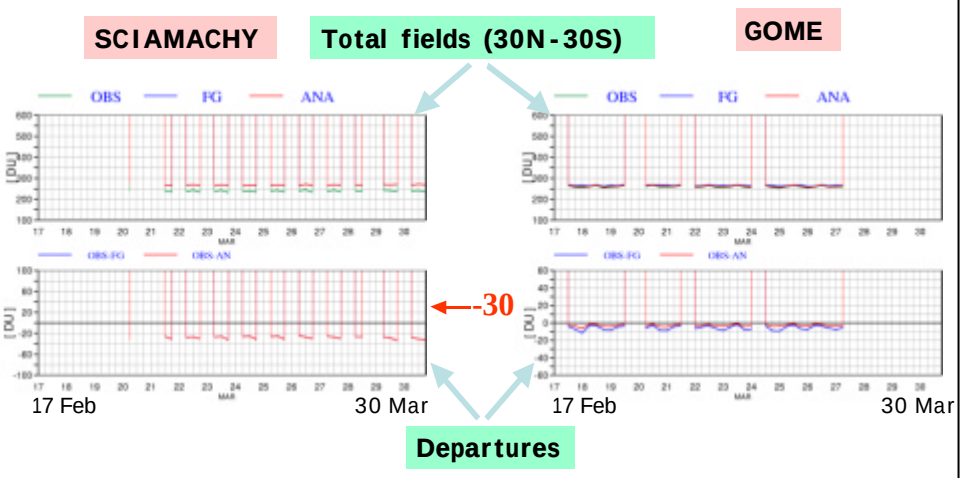
Data evaluation using chemical data assimilation

Envisat observed species: total ozone 1/4



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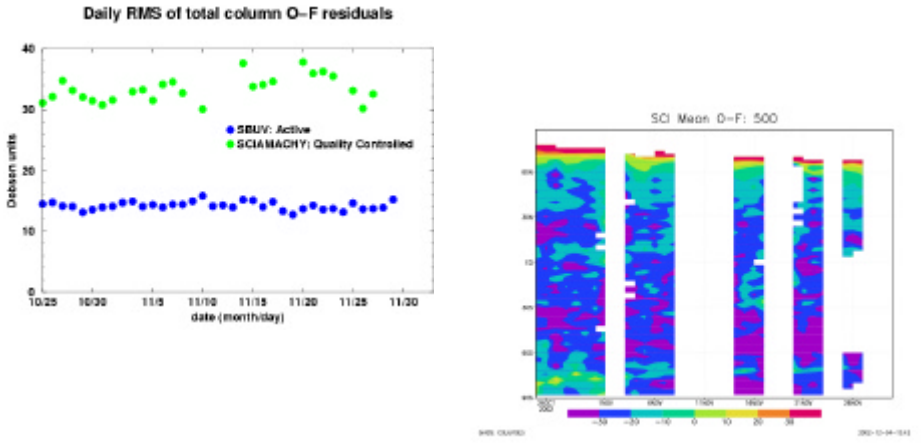
Data evaluation using chemical data assimilation

Envisat observed species: total ozone 2/4



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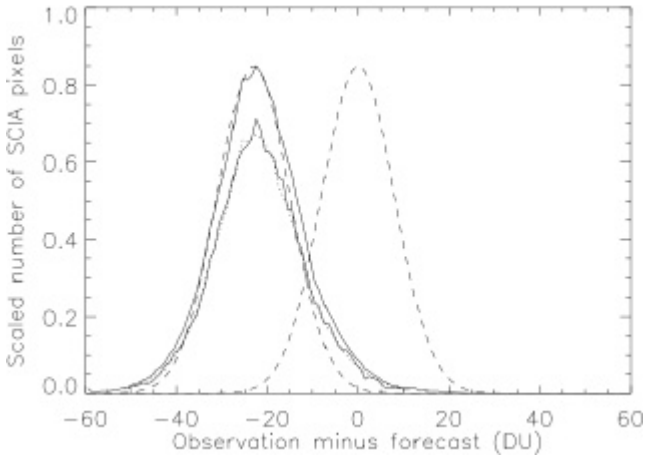
Data evaluation using chemical data assimilation

Envisat observed species: total ozone 3/4



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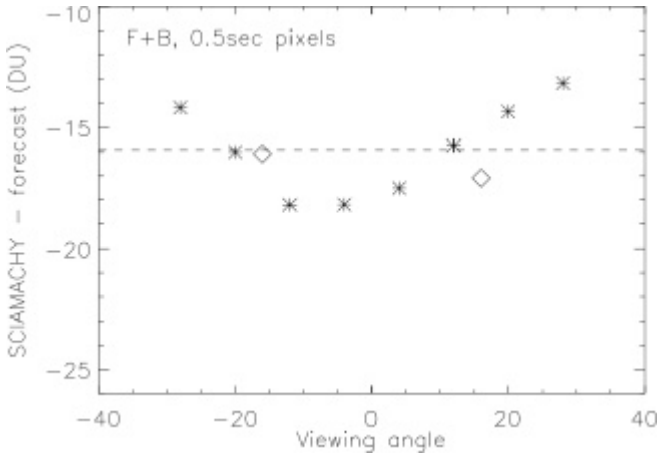
Data evaluation using chemical data assimilation

Envisat observed species: total ozone 4/4



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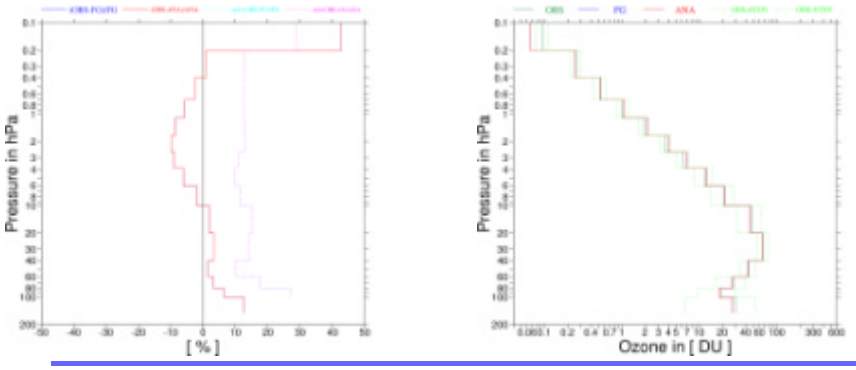
Data evaluation using chemical data assimilation

Envisat observed species: ozone 1/4

MIPAS ozone data

Departures **Obs and Ana**



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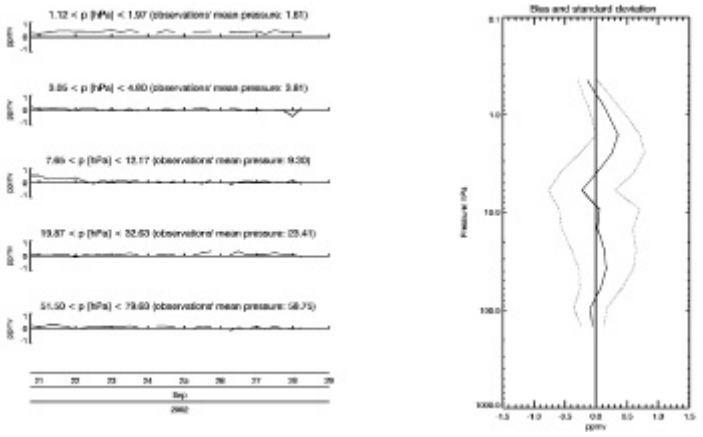
Data evaluation using chemical data assimilation

Envisat observed species: ozone 2/4



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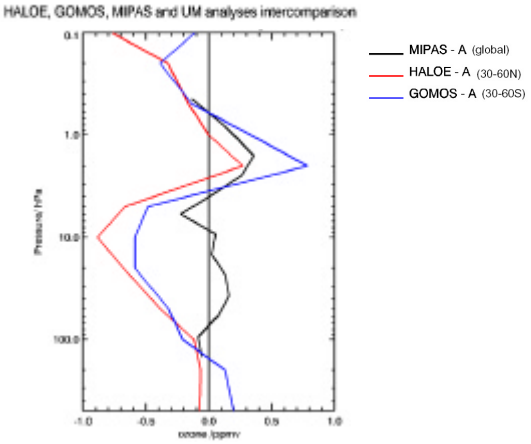
Data evaluation using chemical data assimilation

Envisat observed species: ozone 3/4



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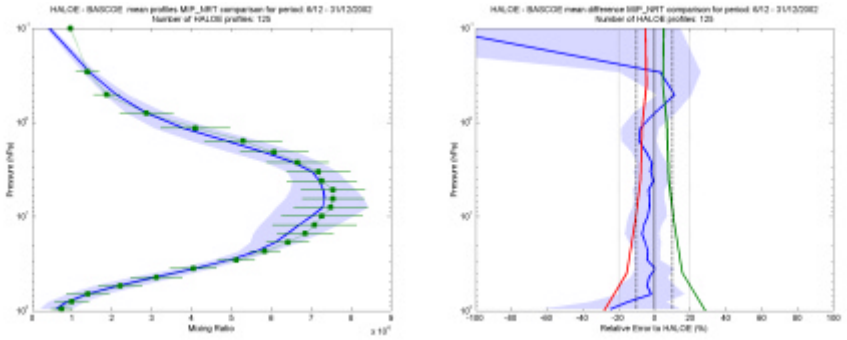
Data evaluation using chemical data assimilation

Envisat observed species: ozone 4/4



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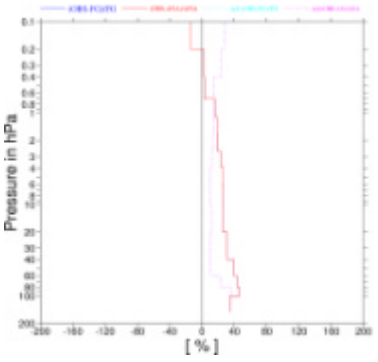
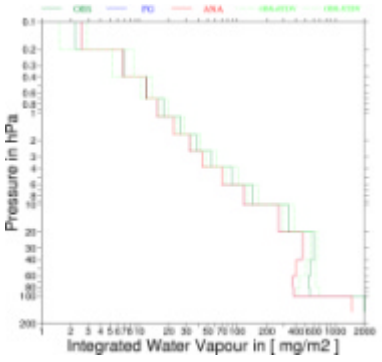
Data evaluation using chemical data assimilation

Envisat observed species: water vapour 1/2

Departures



Obs and Ana



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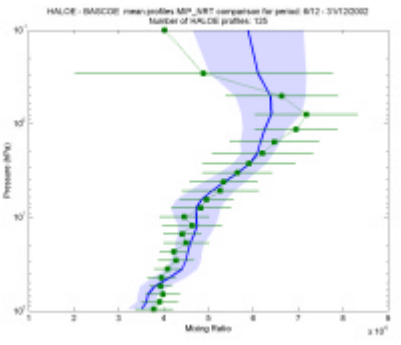
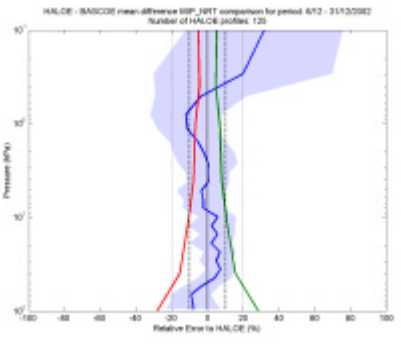
Data evaluation using chemical data assimilation

Envisat observed species: water vapour 1/2





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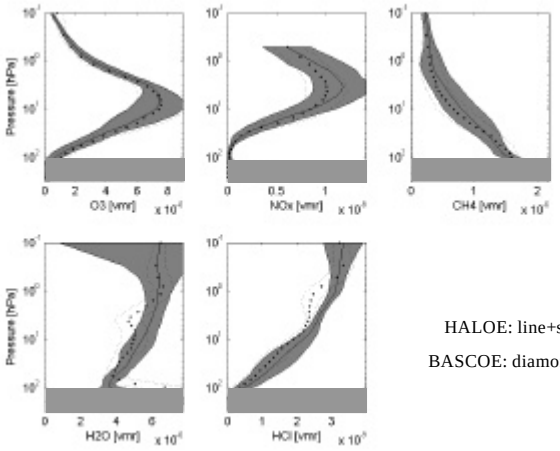
Data evaluation using chemical data assimilation

Envisat observed species: other chemical



HALOE: line+shaded

BASCOE: diamonds+dots

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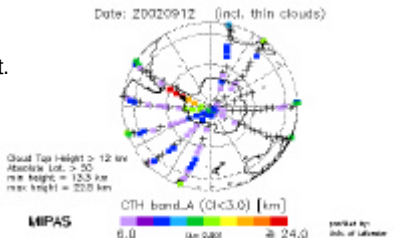
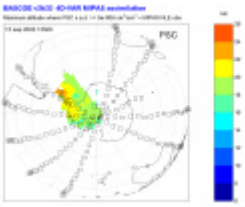
Data evaluation using chemical data assimilation

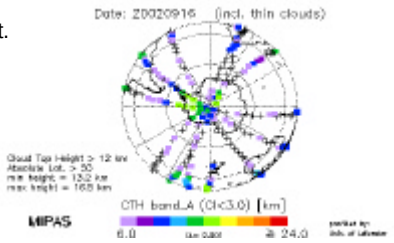
Envisat observed species: other chemical: PSCs Univ. Leicester

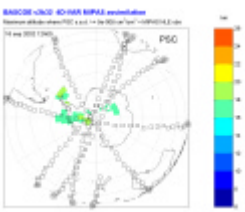
12 Sept.





16 Sept.





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Data evaluation using chemical data assimilation

Conclusion

- **Basic data evaluation, & well understood Chemical Data Assimilation**

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- **Successful in the validation: first time for chemical observations**
- **Observational operator: less constraints on co-location**
- **All methods ☻ consistent results (wherever possible)**
- **Passive mode / active mode**
  - Long time series
  - Data quality
  - Biases
  - Instrument and algorithm stability (for example, viewing angle)

- **"Easy comparison with independent observations"**

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