Sequential and Four-Dimensional Variational Data Assimilation for Reanalyses of MIPAS Observations: (First) Comparison and Evaluation

F. Baier, J. Meyer-Arnek, T. Erbertseder, M. Bittner; DLR
H. Elbern, J. Schwinger; University of Cologne
R. Bochorishvili; Fraunhofer Institute for Scientific Computing

frank.baier@dlr.de
SPARC DA-Workshop, October 4, 2006

Outline

- Motivation: SPARC CCMval
- Assimilation Systems ROSE/SACADA
- Case Study: Winter 2003/2004
- Results:
  - Mean Characteristics
  - PDF analyses
  - Comparisons to HALOE
- Summary and Outlook

Multi-year assimilated 3D stratospheric ozone

Contribution for GSE PROMOTE

Joined effort of BIRA and DLR

- Best affordable description of chemical state by combination of satellite data, meteorological data and chemistry-transport models
- Synoptic 3D ozone analyses and long-term analyses of trends in reactive trace gases and inorganic reservoir species

Parameters:

- O3 and related (destructive) species (ClOx, NOx, BrOx)
- Polar-stratospheric clouds (PSCs)
- Reservoir species: Cly,Bry
- Quantification of chemical ozone loss

Geographic coverage: global, stratosphere

Temporal coverage: 1992-2010

PROMOTE Assimilation tools

- **ROSE/OI:** optimal interpolation based sequential assimilation providing analyses and error estimates by ensemble approach

- **SACADA/4Dvar**: four-dimensional variational assimilation of ERS2, ENVISAT and MeTop instruments

- **BASCOE/4Dvar**: four-dimensional variational assimilation of ENVISAT, EOS and UARS instruments

=> Combine different instruments and models for optimum results and better error characterization

Service implementation plan

Phase 1

- Derive data record for 1995-2005 from ENVISAT MIPAS/SCIAMACHY and ERS-2/GOME-NNORSY using ROSE/OI
- Second data record for 1992-1999 from ENVISAT MIPAS/SCIAMACHY and UARS/MLS data to derive using BASCOE

Phase 2

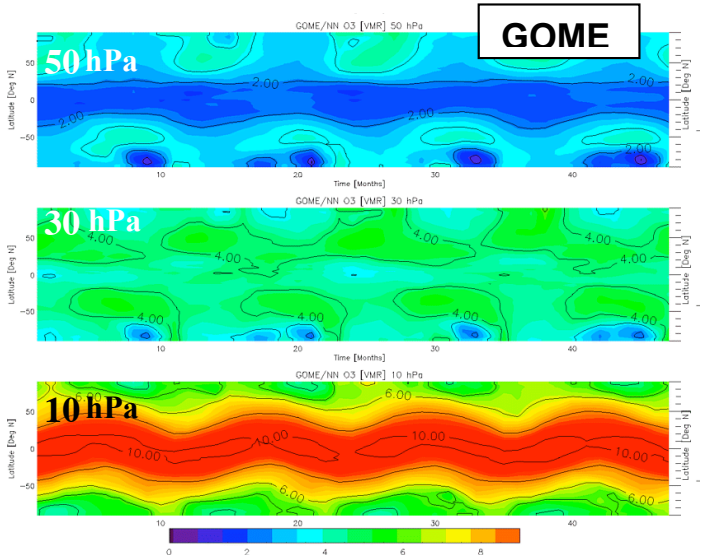
- Migration from ROSE/OI to SACADA/4Dvar
- RIU sensitivity study to improve modelling of PSCs
- Service d'Aeronomie provides GOMOS data on O3, NO2 and NO3
- Adaptation of BASCOE for inorganic reservoir species
- Joined validation of DLR and BIRA data records

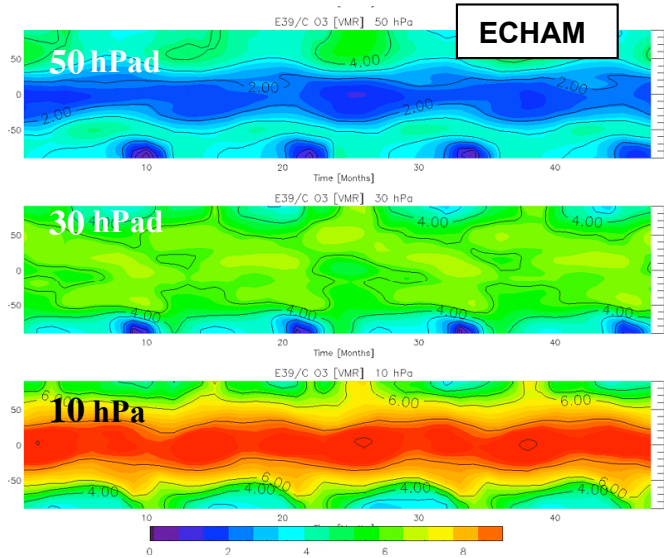
Phase 3

- Provision of improved ensemble data record from all available sensors
- Operational processing of actual ENVISAT data (foreseen until 2010)

Motivation -1- Long-Term Ozone Fields

Zonal mean ozone mixing ratios for 1996-1999



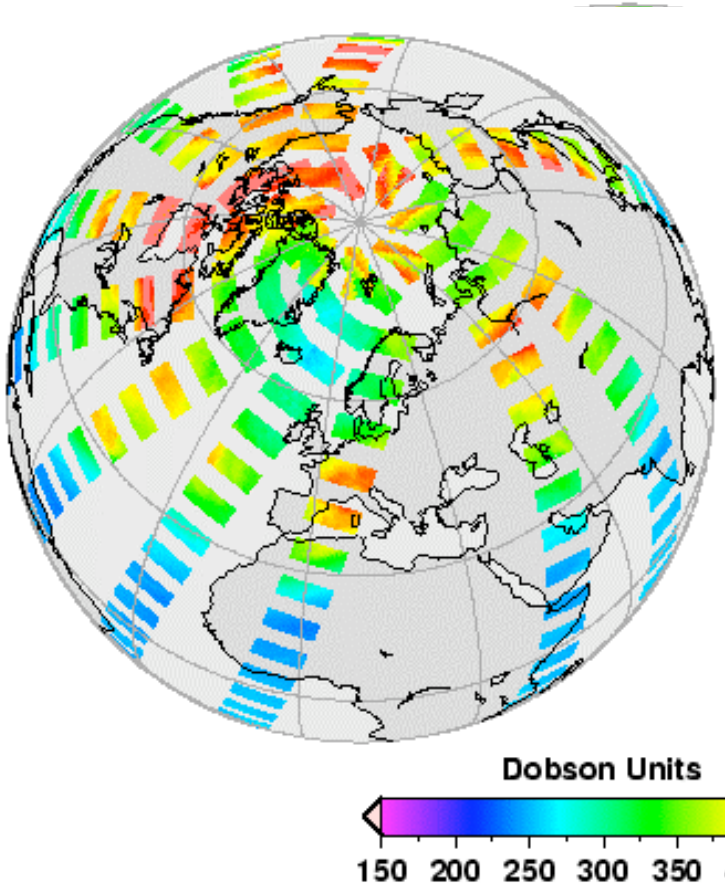


ERS2-GOME **ECHAM E39/C**

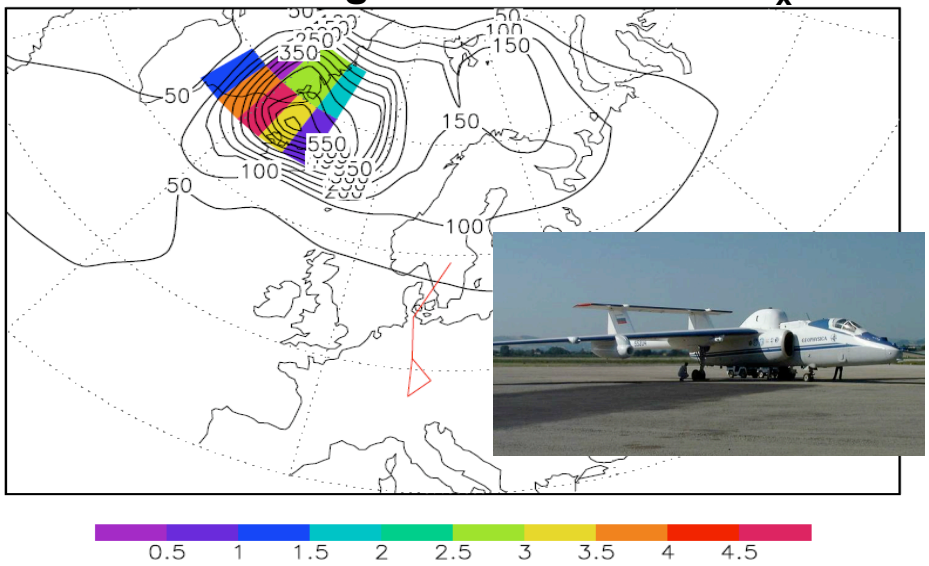
Motivation -2- Near-Real Time Analysis

ENVISAT SCIAMACHY **Mar 07, 2005**

Ozone Vertical Column DOAS_0 **Northern Hemisphere**



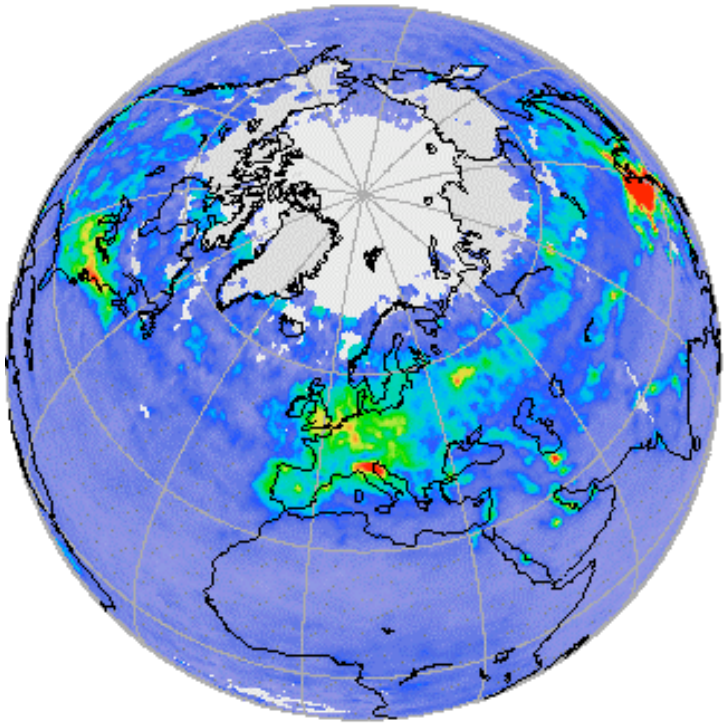
Forecasting PScC Area and ClO_x



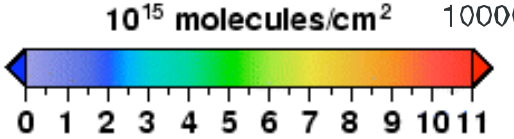
Motivation -3- Tropospheric Retrieval

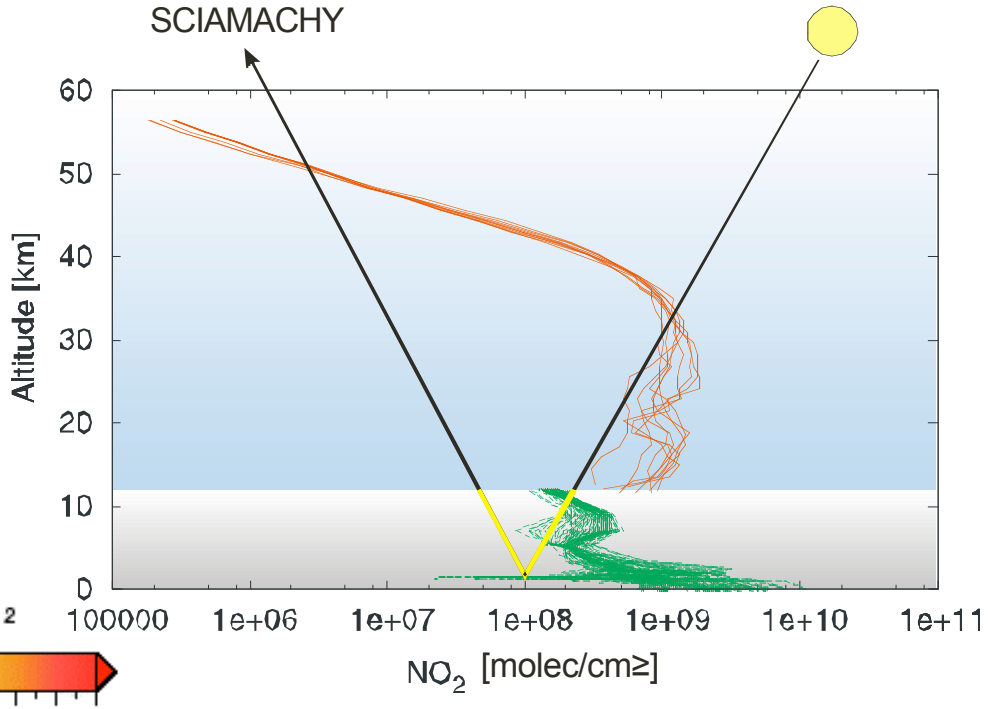
ENVISAT SCIAMACHY **Nov+Dec 2005**

Tropospheric NO_2 Slant Column

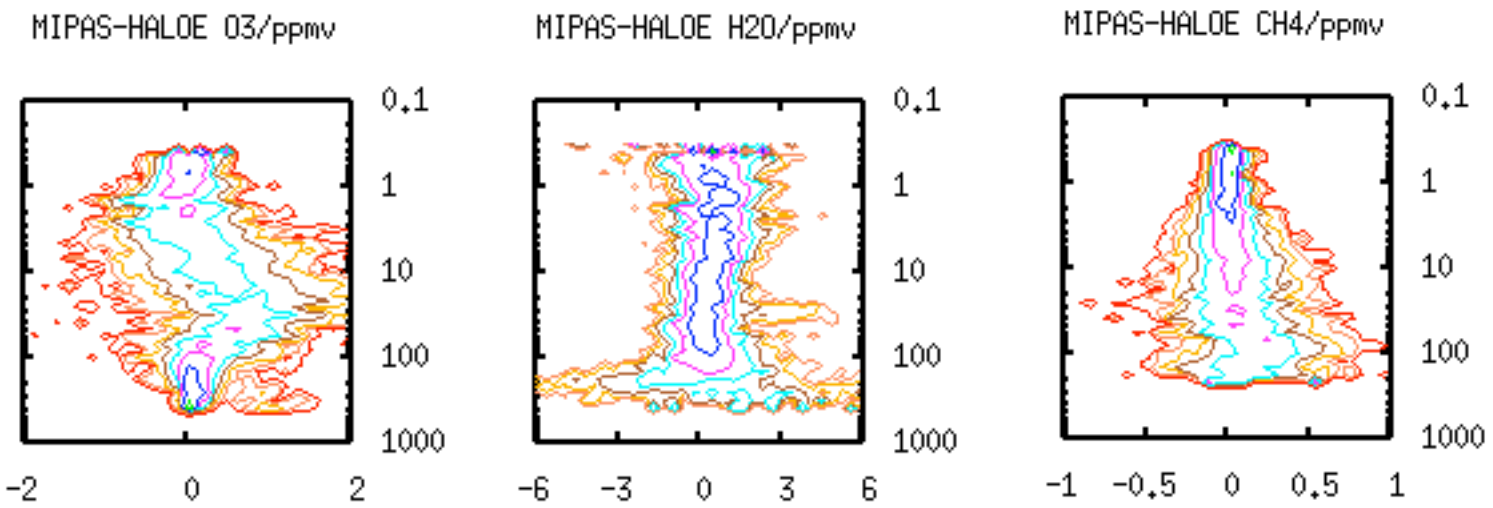


Version 5.04 ESA



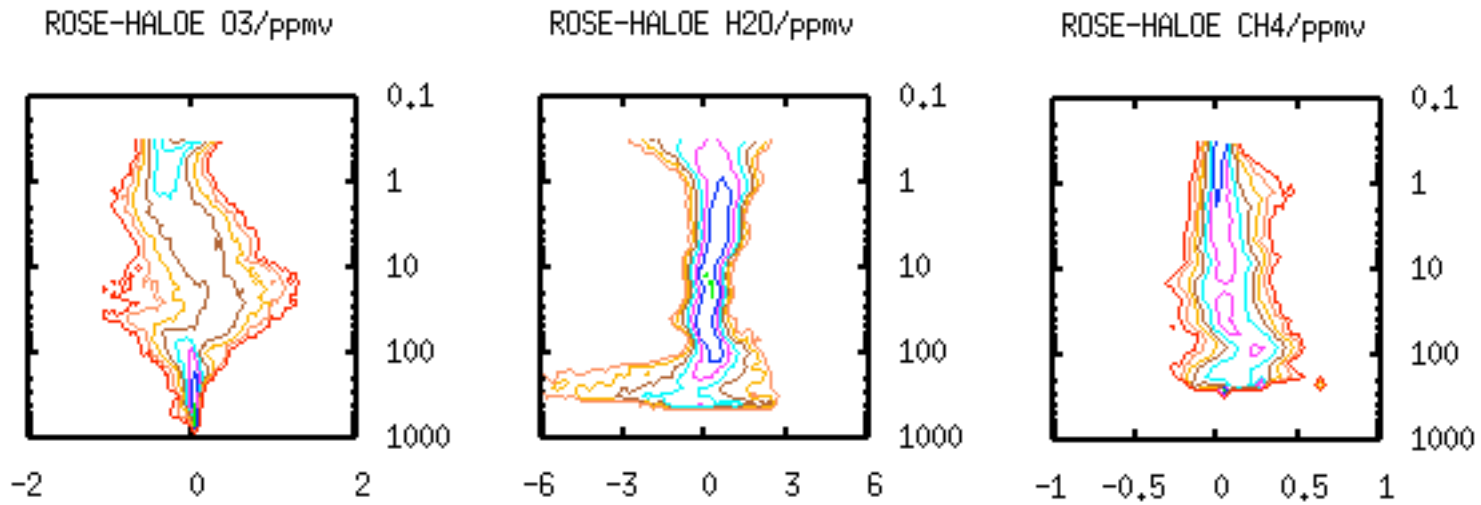


The Benefit of Data Assimilation?



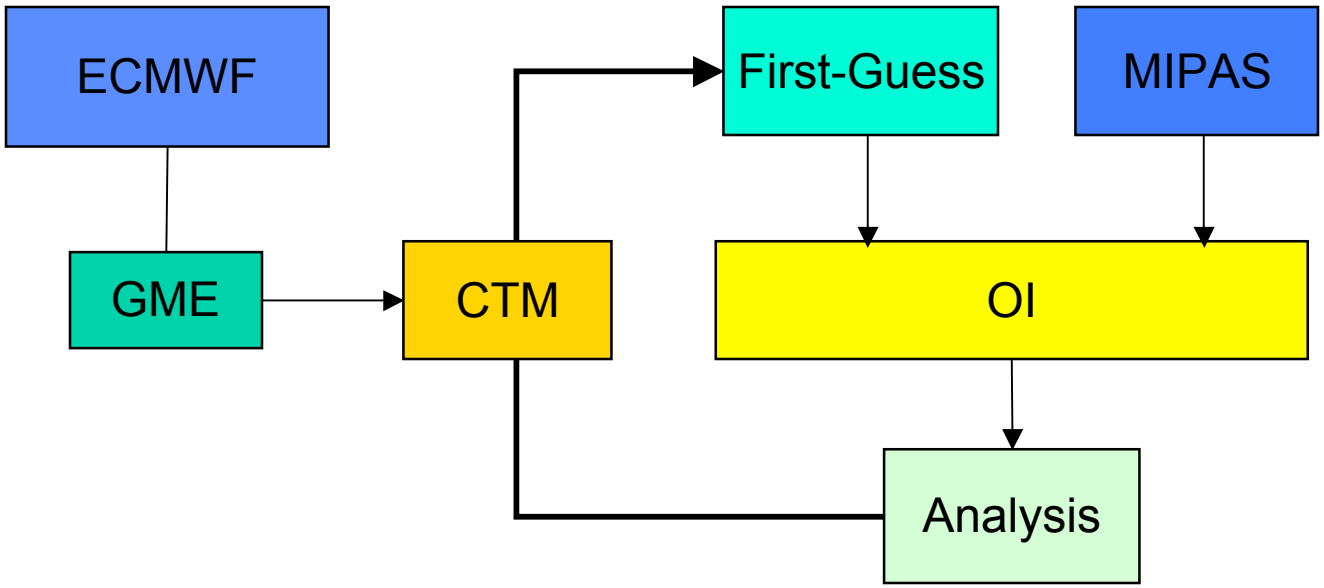
MIPAS-HALOE PDF analysis for winter 2003/2004

The Benefit of Data Assimilation?

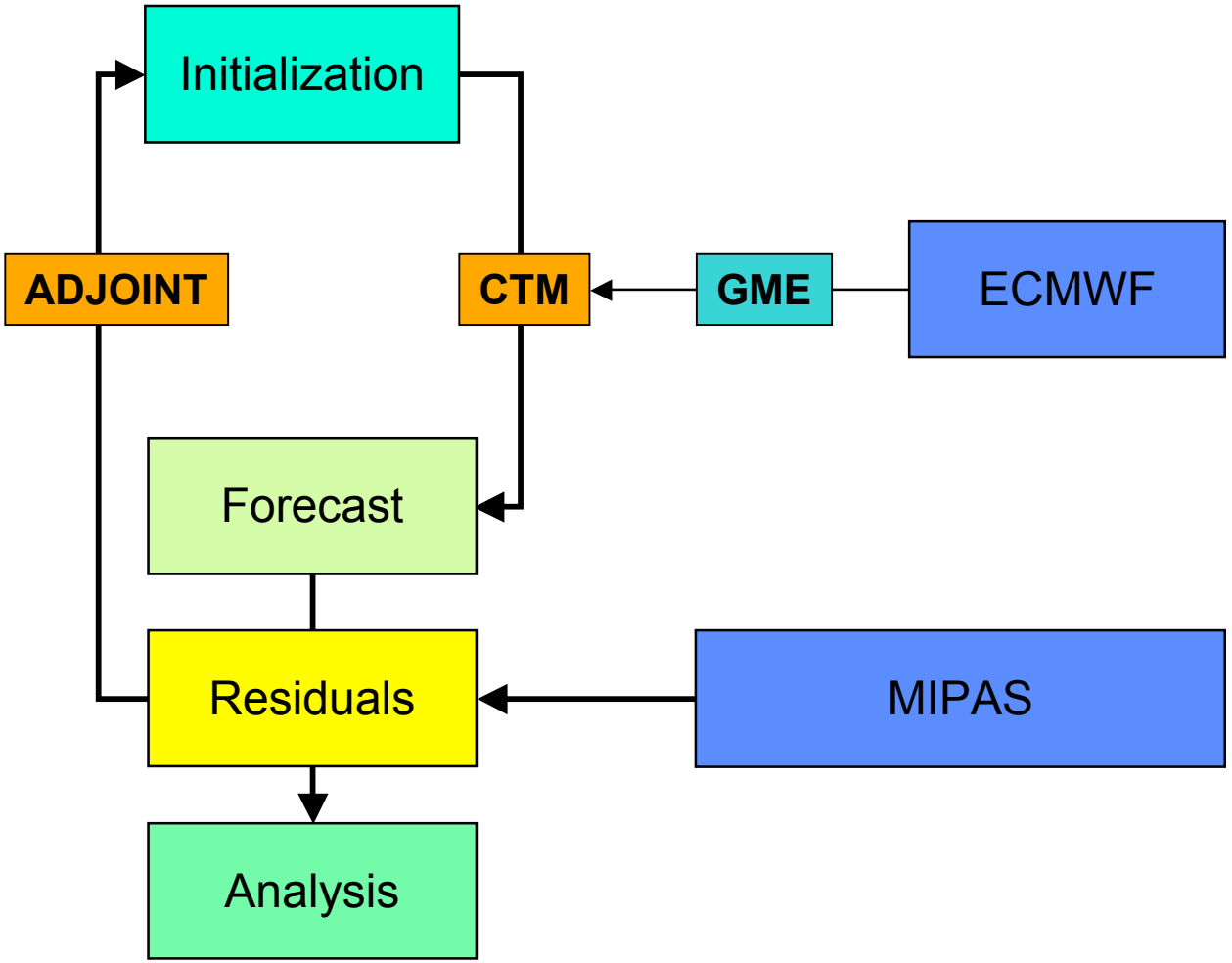


ROSE-HALOE PDF analysis for winter 2003/2004

ROSE OI



SACADA 4DVAR



ROSE/DLR v3.0

Resolution = 2.5°x 3.7° x 1.3km (0-57km)

UKMO/ECMWF meteorology
3D Lin-Rood transport scheme
non-QSSA, NAT, ICE, aerosols

Basic time step = 1h
Initial model error = 30%
Instrument error + 10%
AVK interpolation to MIPAS level
Diagnostic analysis error

OI analysis subgrid = 50° x 45°

24h analysis = 30min on 1xCPU

SACADA/DFD v1.5

Mean resolution = 250km x 2km (0-65km)

ECMWF-GME meteorology
Semi-Lagrange transport
non-QSSA, NAT, ICE, aerosols

Basic time step = 10min
Initial model error = 30%
Instrument error + 10%
Linear interpolation to MIPAS level
Diffusive approach for background covariances

4Dvar global, 24h-window, 5-10 iterations

24h analysis = 90min on 16xCPU

Data for case study winter 2003/2004

ENVISAT/MIPAS ESA Level 2 data v4.61:

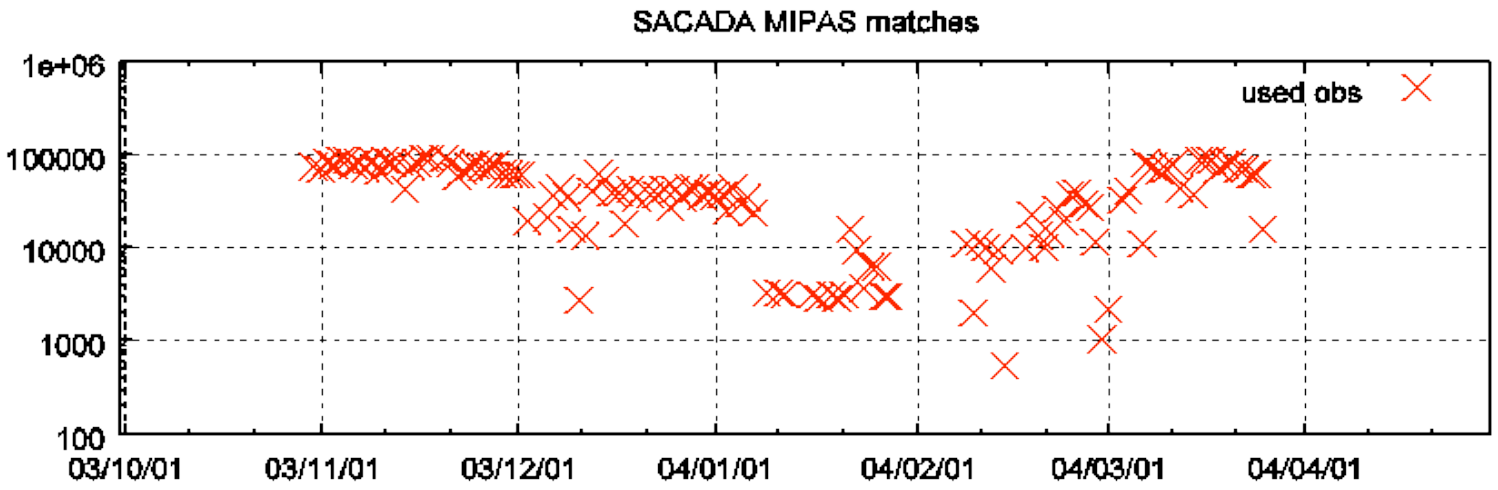
O3, H2O, CH4, N2O, NO2, HNO3

Best resolution: 400km x 3km

Errors (different studies)	O3	5-15%
	H2O, CH4, NO2	25-35%

Rapid degradation < 15km
Bias ~ 10%

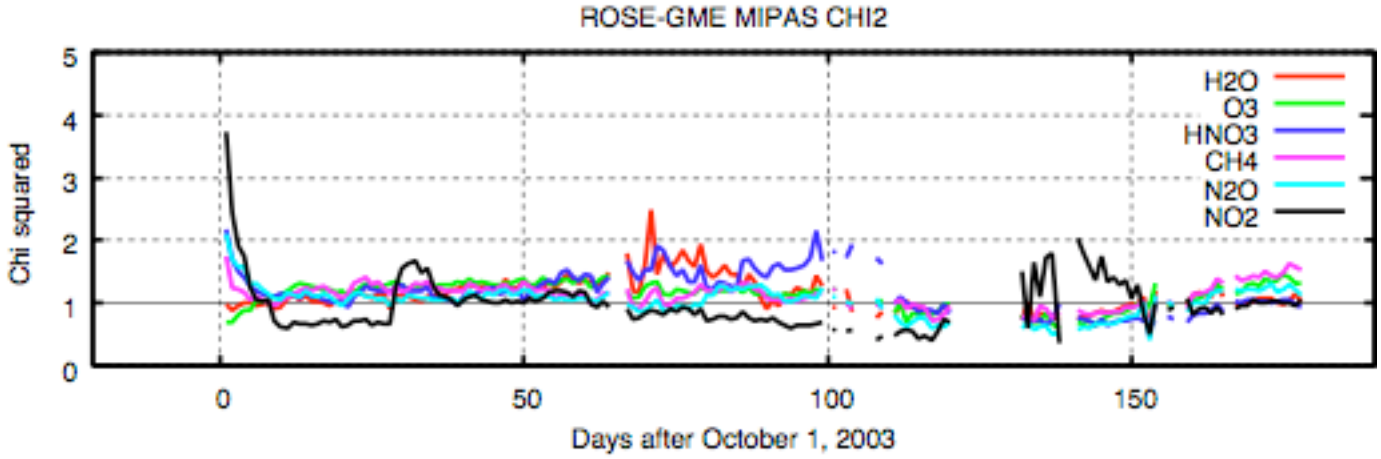
MIPAS data coverage winter 2003/2004



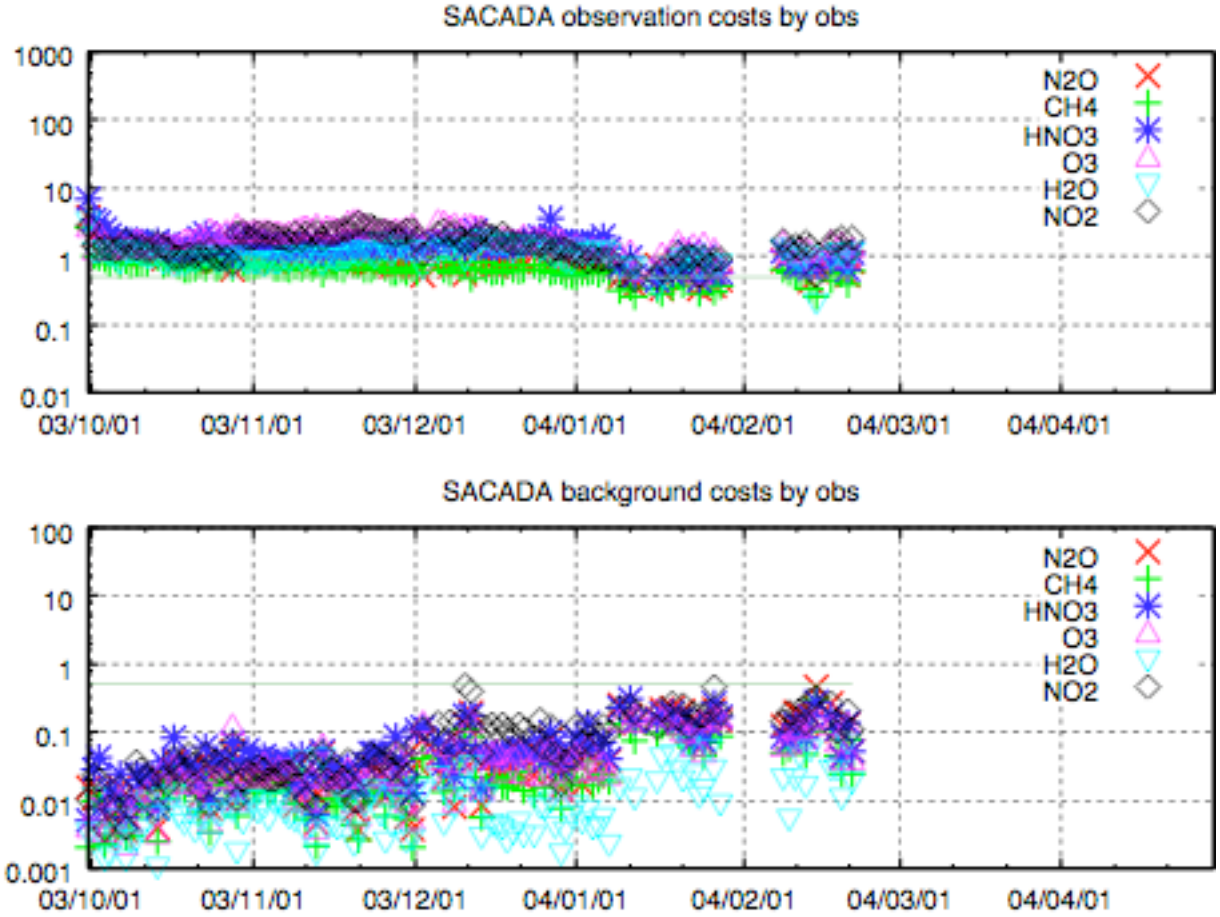
Init. October 1st, 2003

March 31st, 2004

Performance Analysis: ROSE/OI



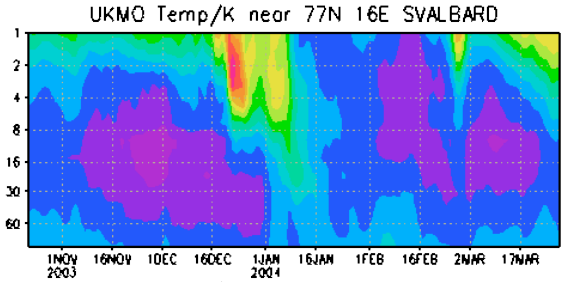
Performance Analysis: SACADA/4Dvar

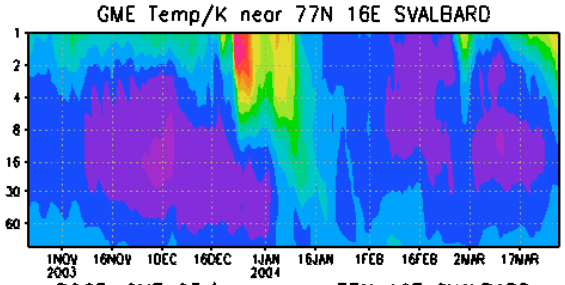


2003/2004 Stratospheric Analysis: Svalbard Station

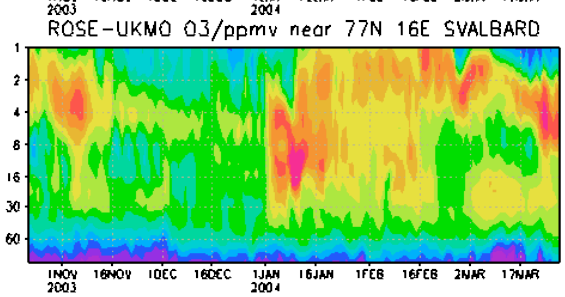
UKMO **ECMWF**

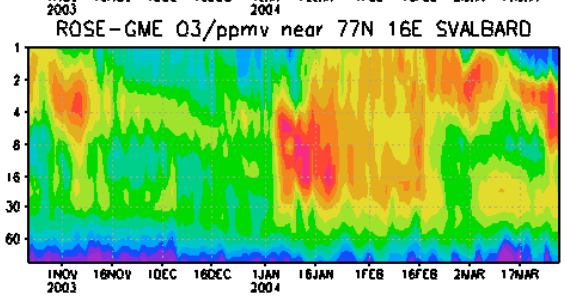
Temp.





Ozone

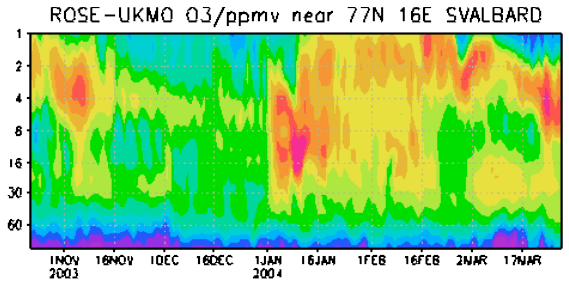


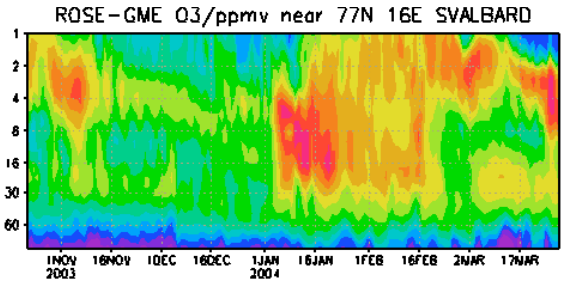


Influence of Model and Location

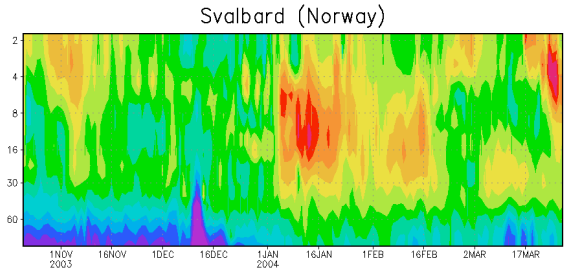
Svalbard (77°N) **Copenhagen (55°N)**

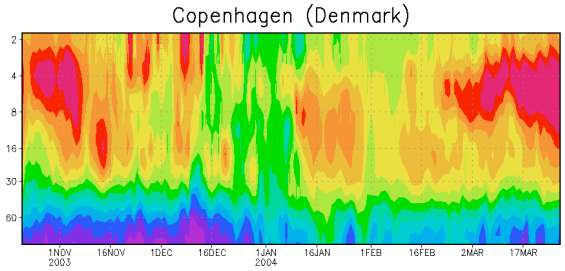
ROSE





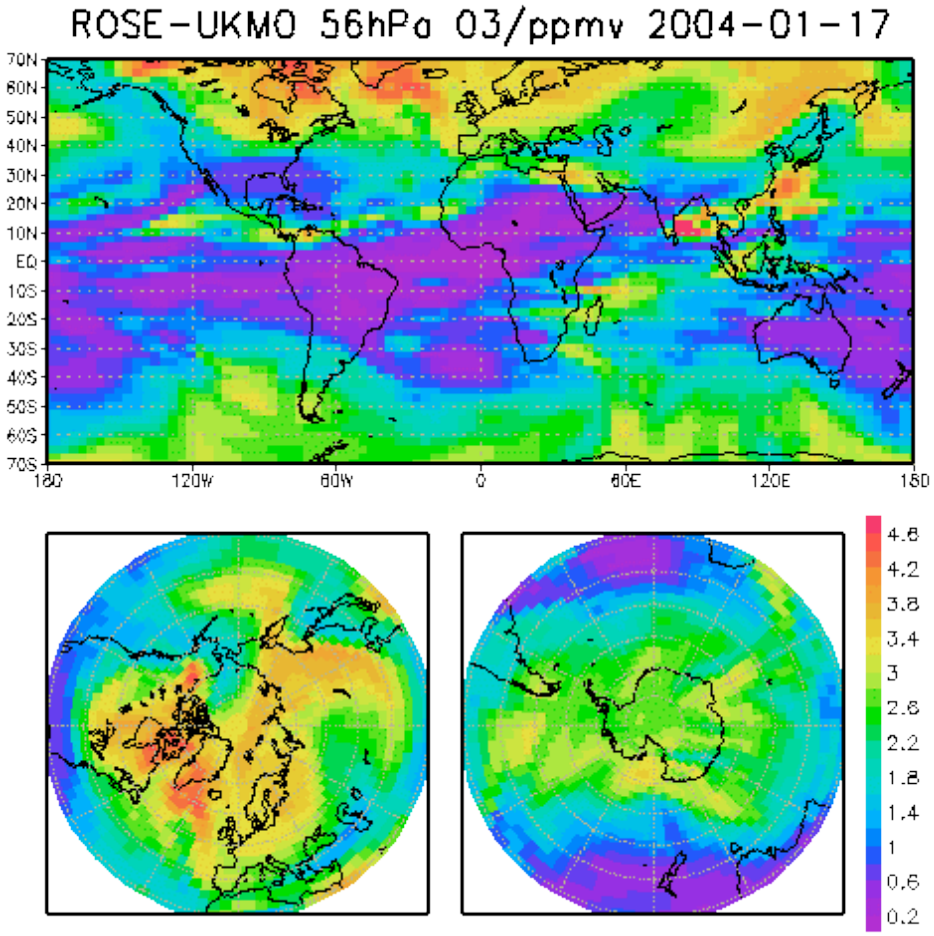
SACADA





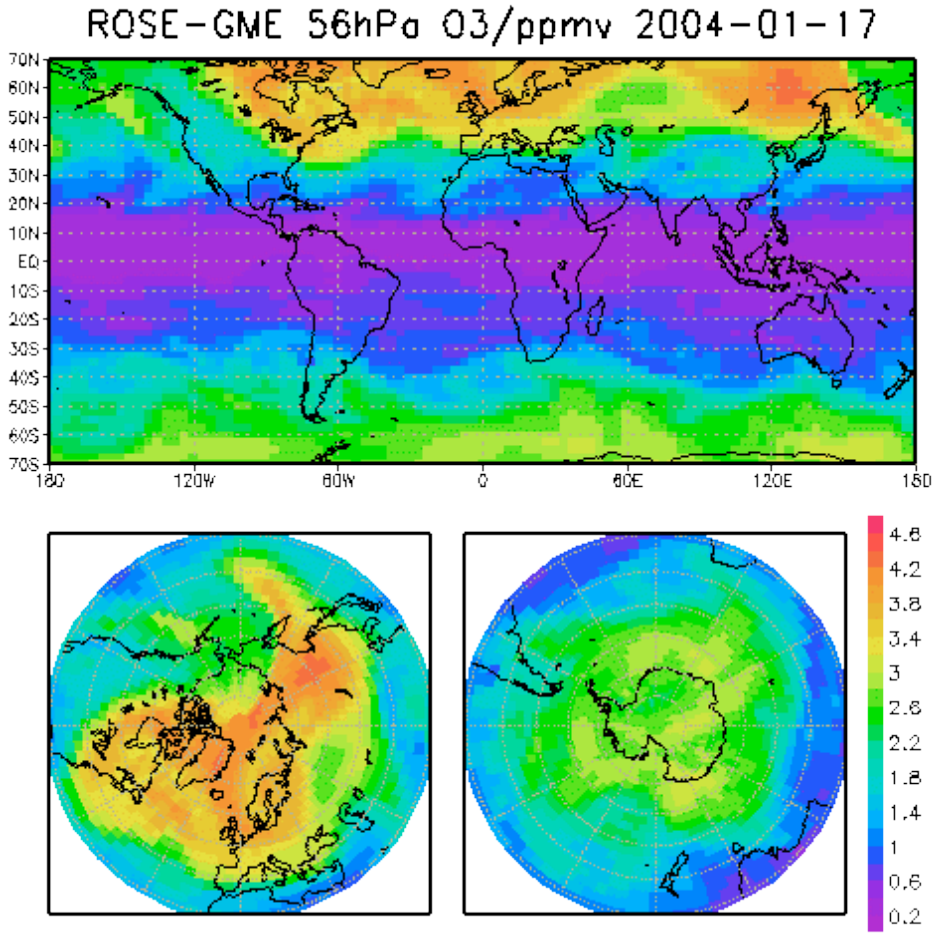
56 hPa Sample Ozone Distribution

ROSE/ UKMO



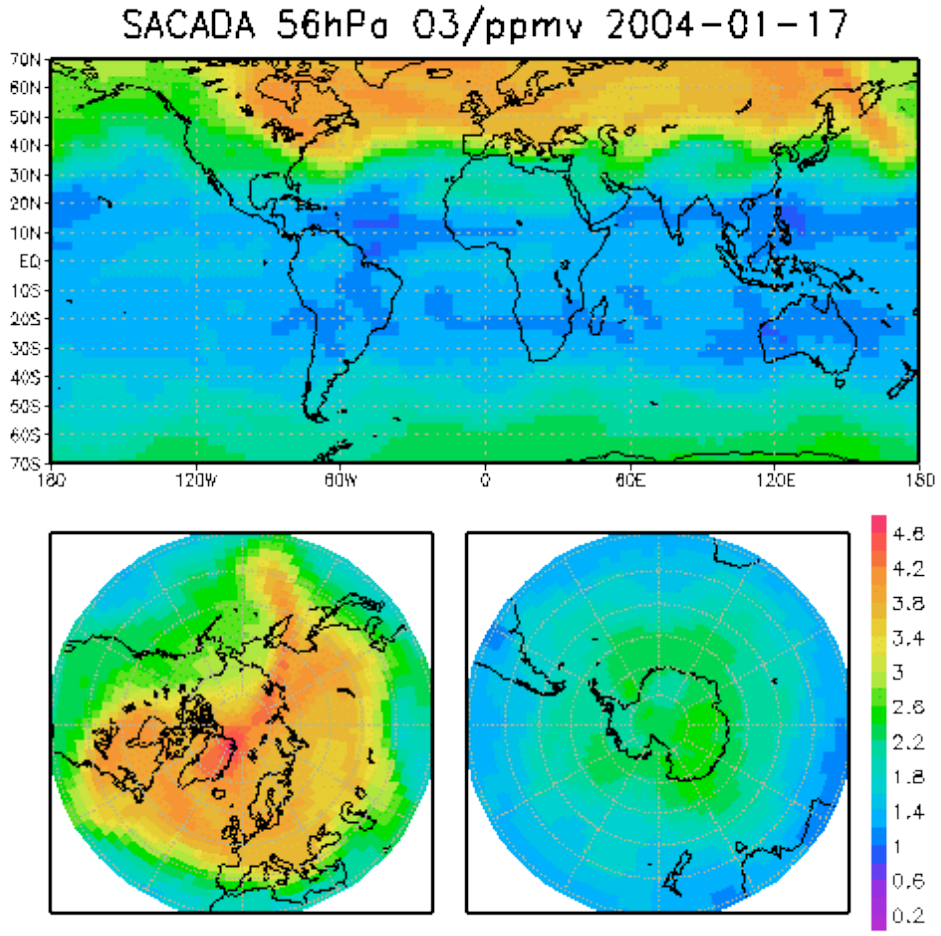
Influence of meteorological analysis

ROSE/ ECMWF

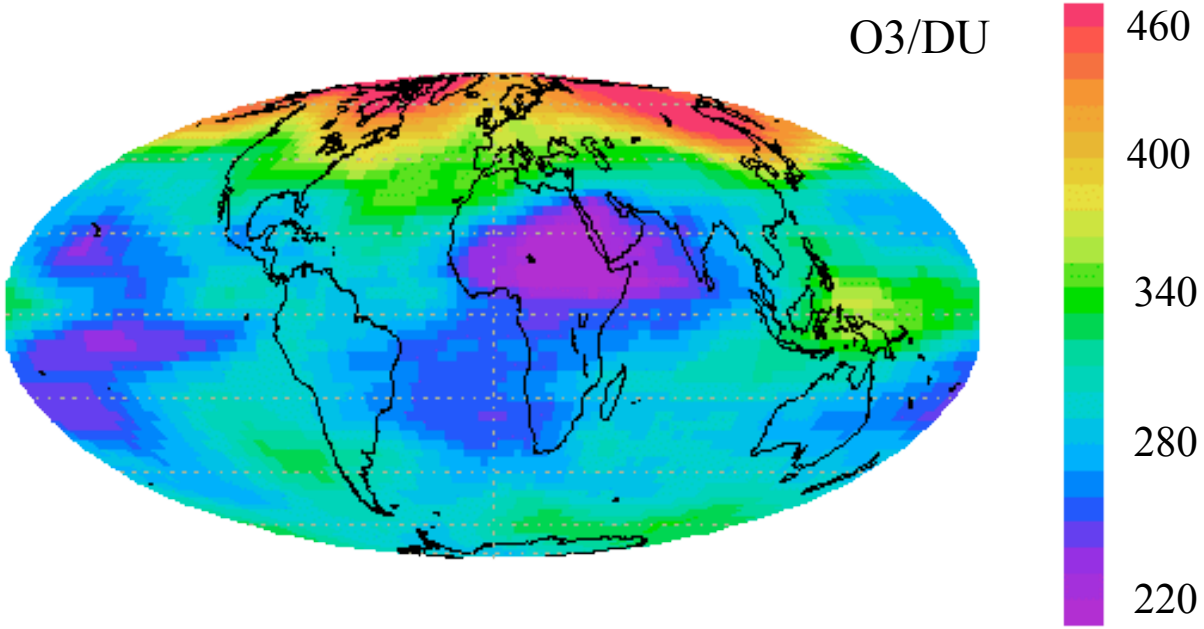


Influence of model and assimilation scheme

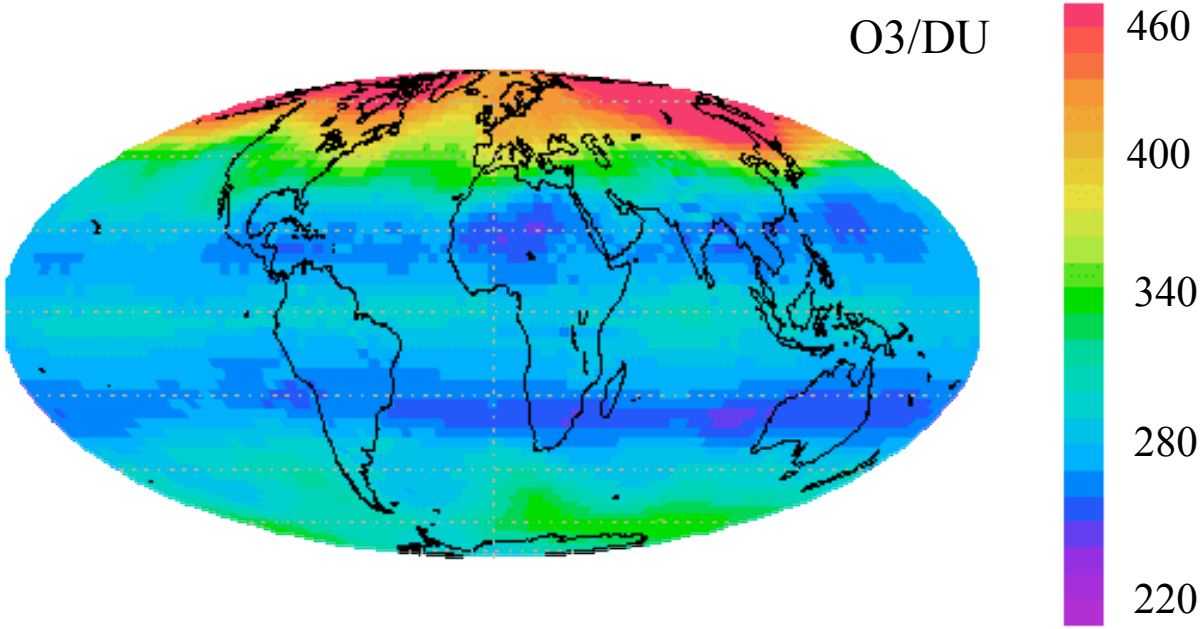
SACADA



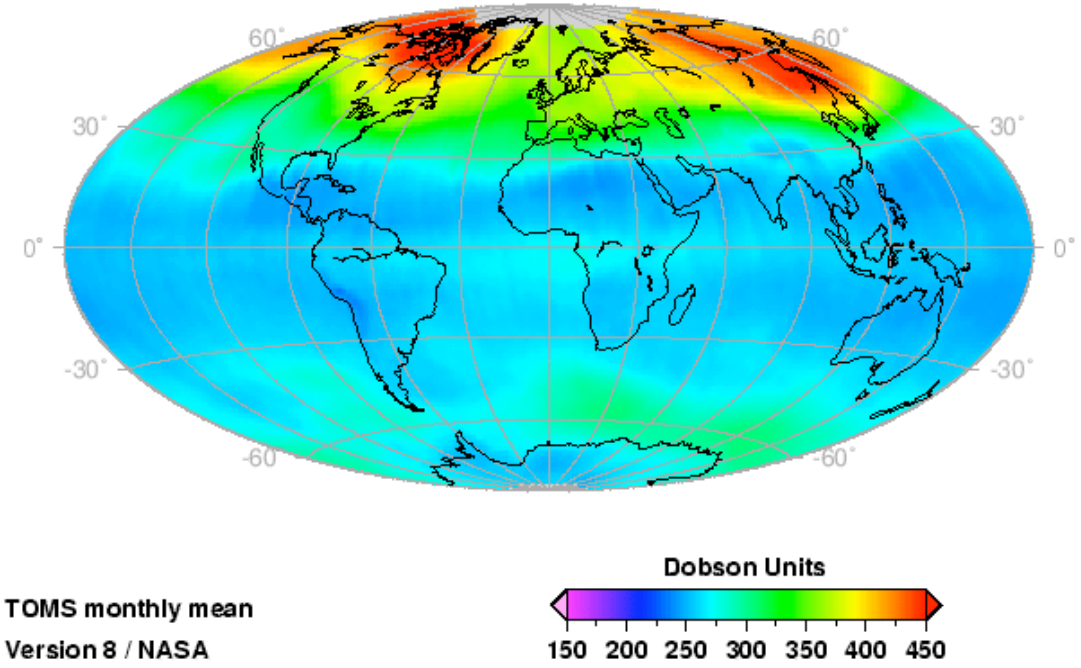
Total Global Ozone: ROSE/UKMO March 2004



Total Global Ozone: ROSE/ECMWF March 2004

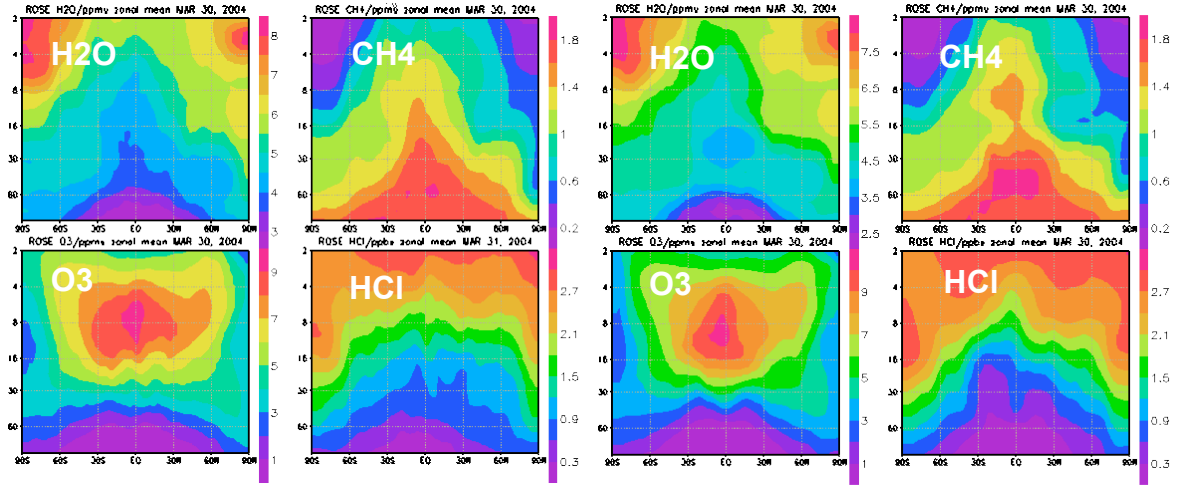


Total Global Ozone: TOMS



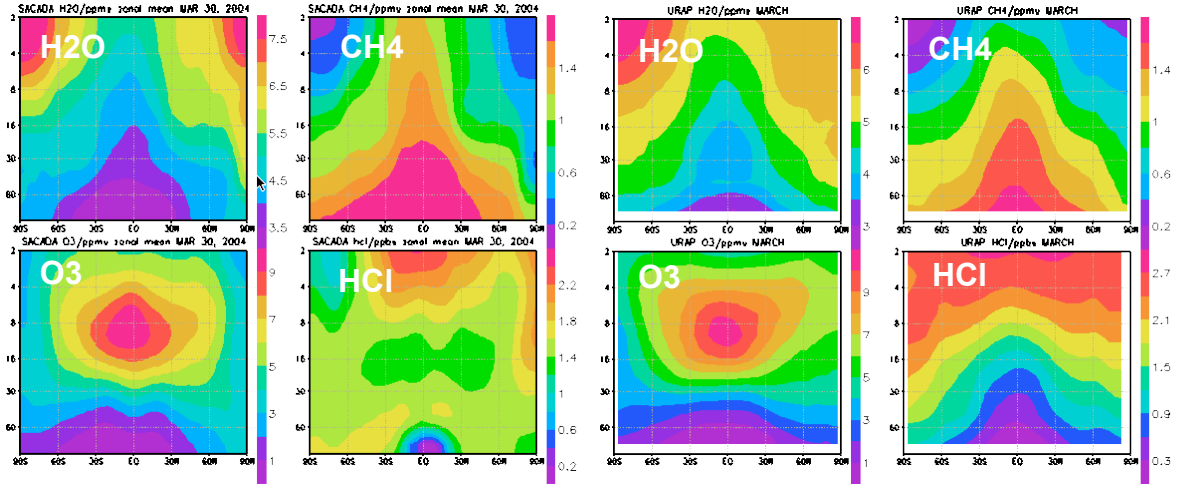
Long-lived species: March 30, 2004

ROSE/ UKMO



ROSE/ ECMWF

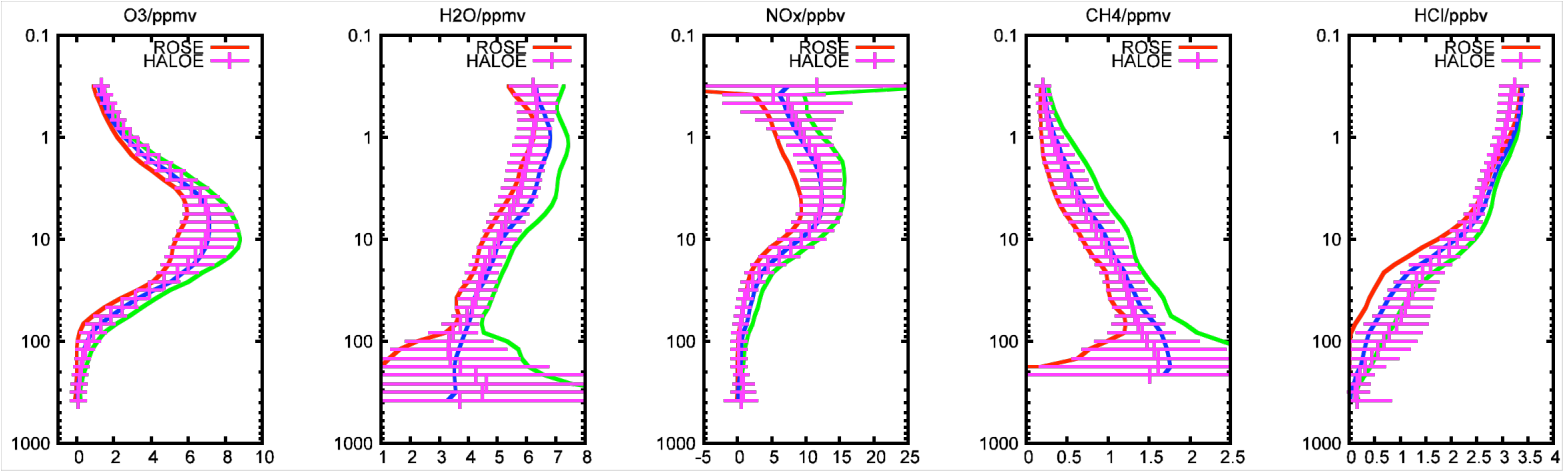
SACADA



URAP

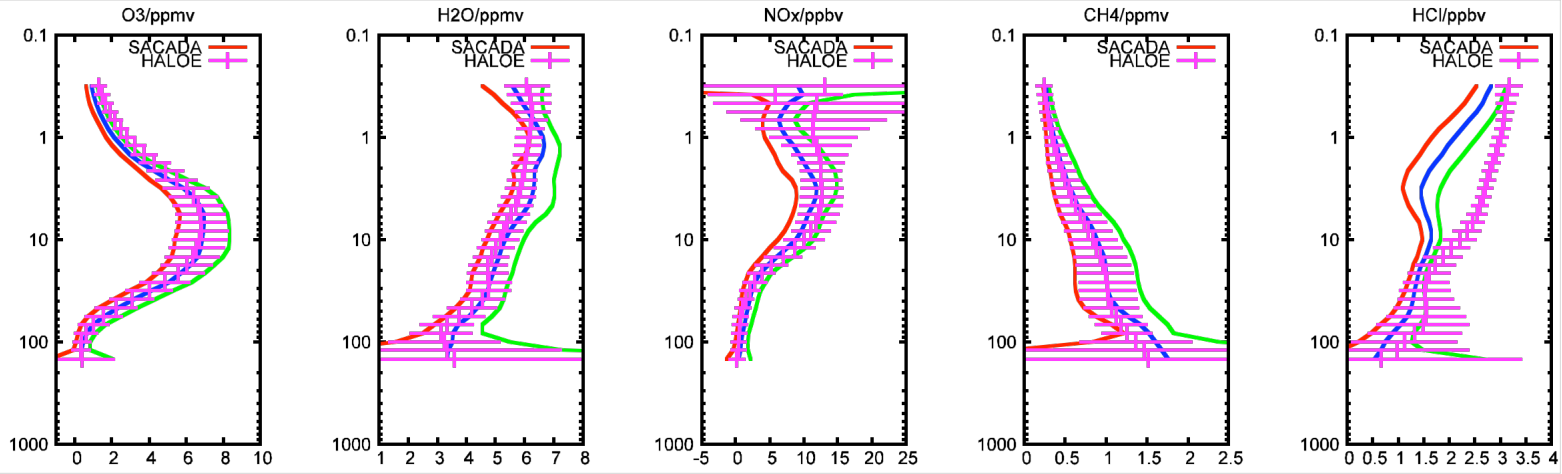
Comparisons to UARS/HALOE

ROSE



Comparisons to UARS/HALOE

SACADA

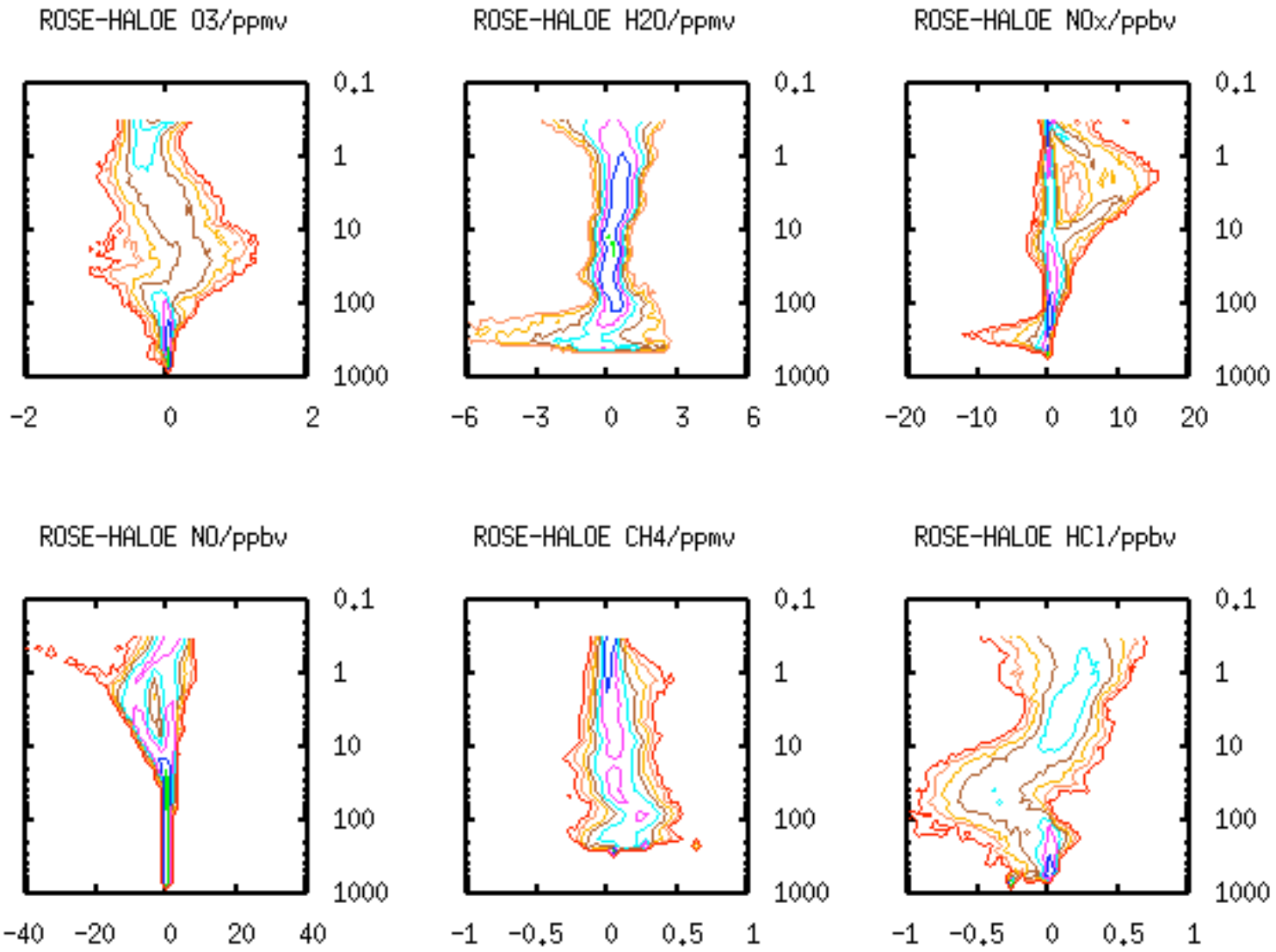


PDF analysis using HALOE data

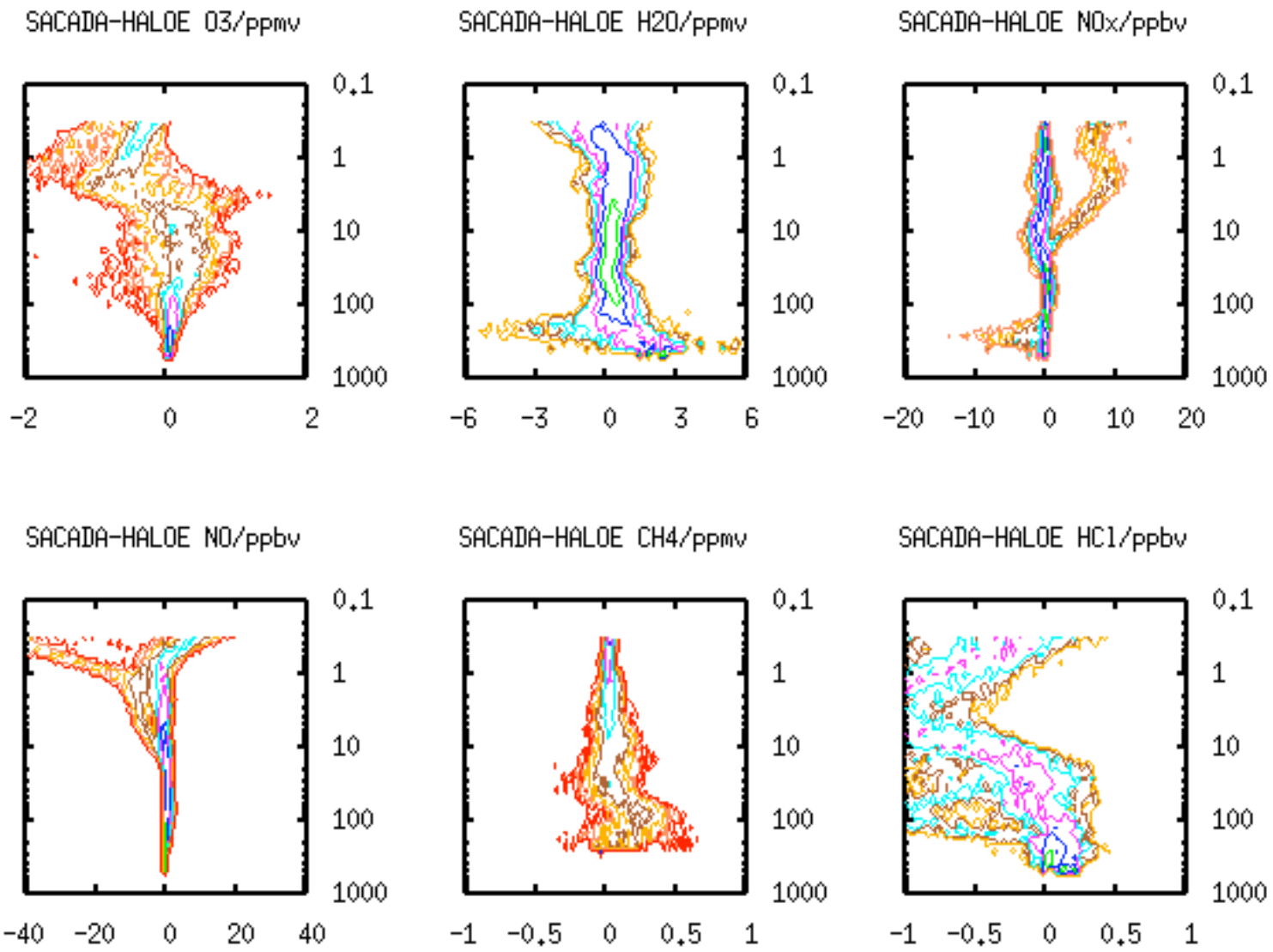
$$0 < \mathrm{PDF} < 1$$

0.005 0.01 0.02 0.04 0.08 0.16 0.32 0.64

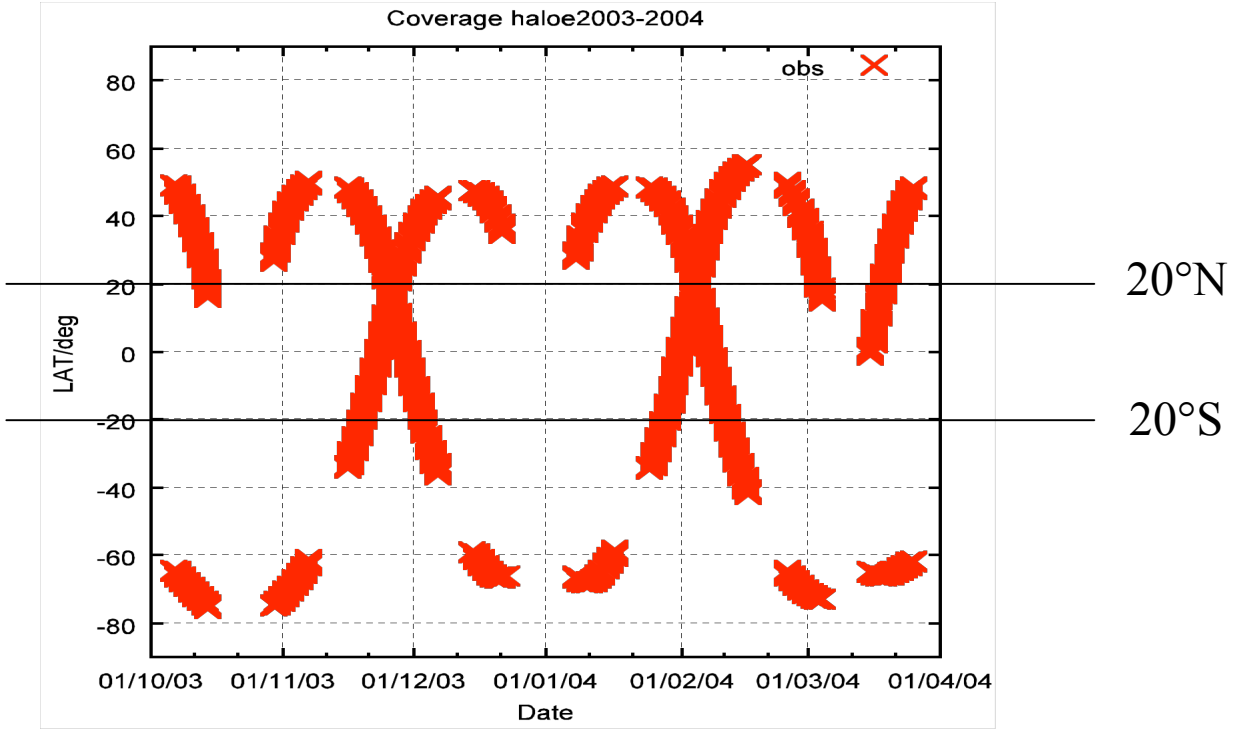
PDFs ROSE/EC-HALOE: global



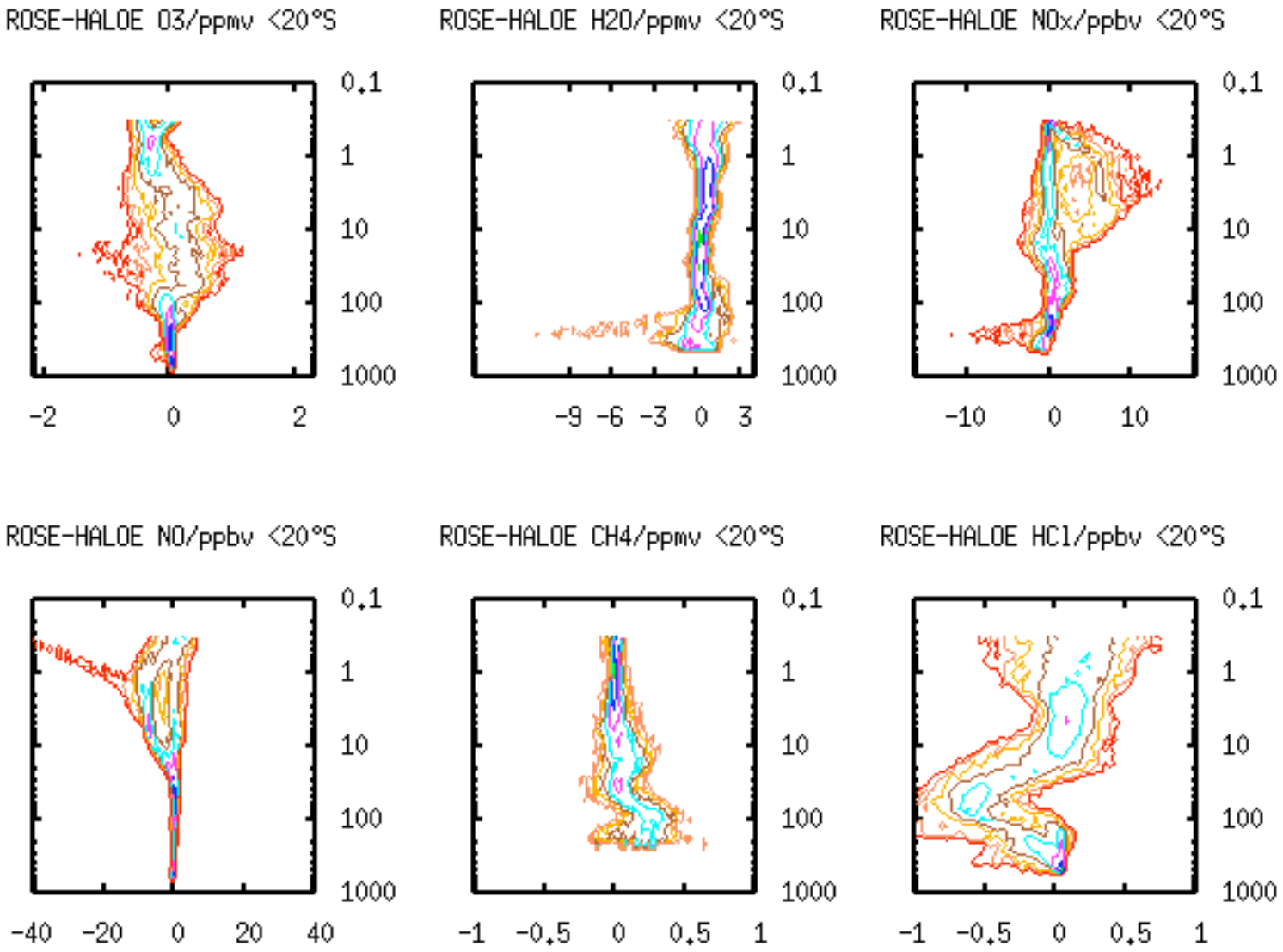
PDFs SACADA-HALOE: global



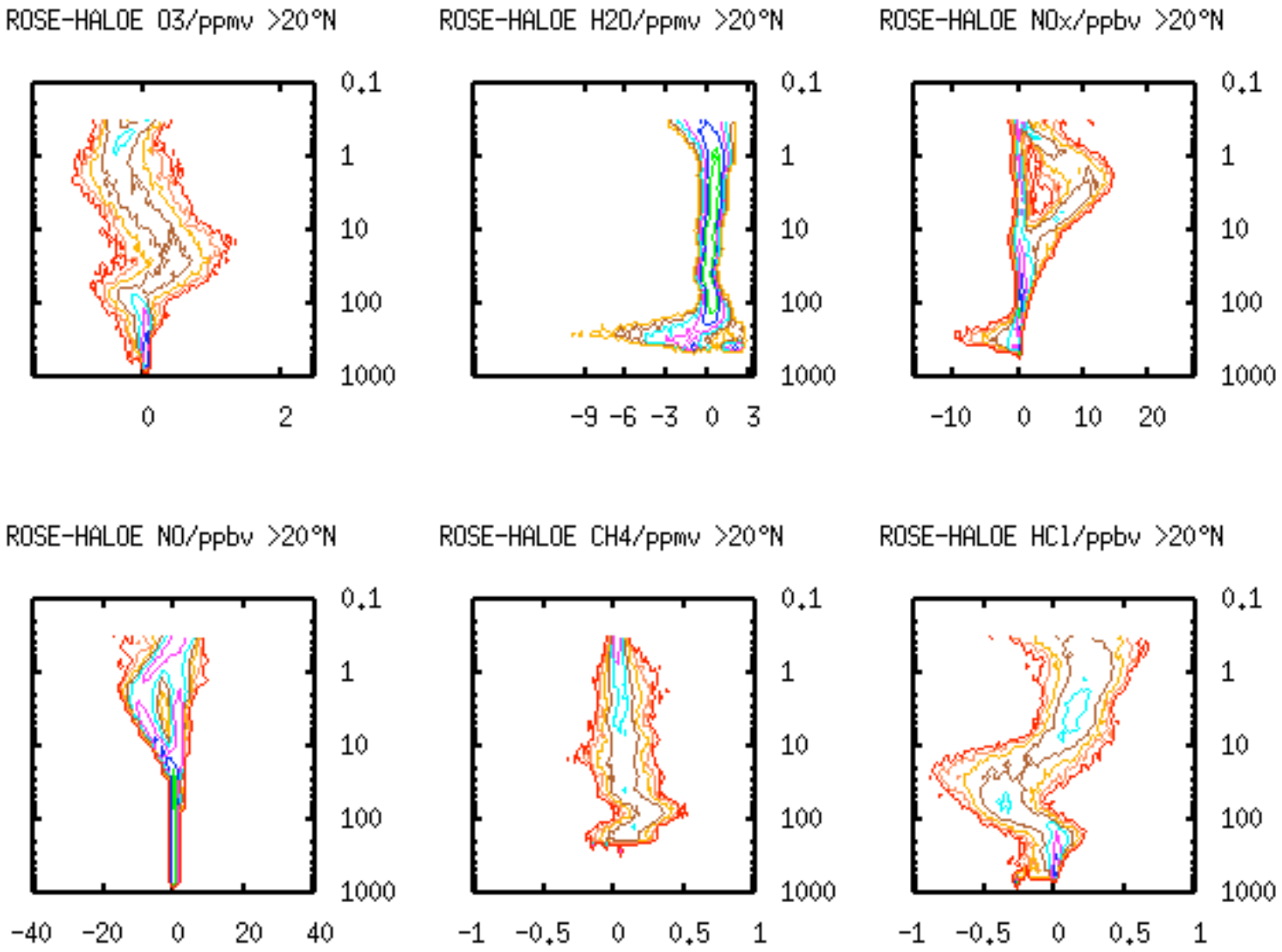
PDFs wrt latitude band



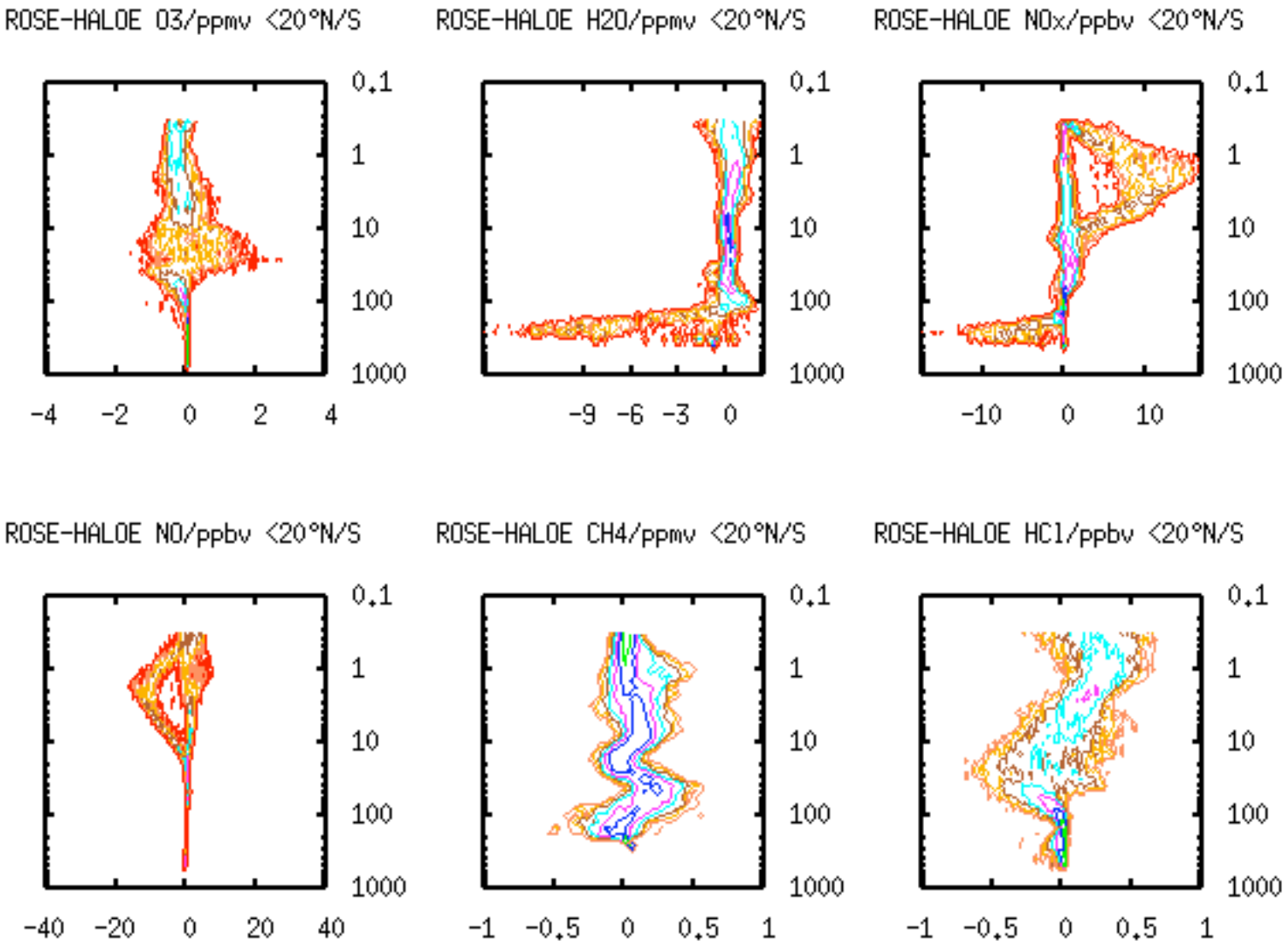
PDFs ROSE/EC-HALOE: SH



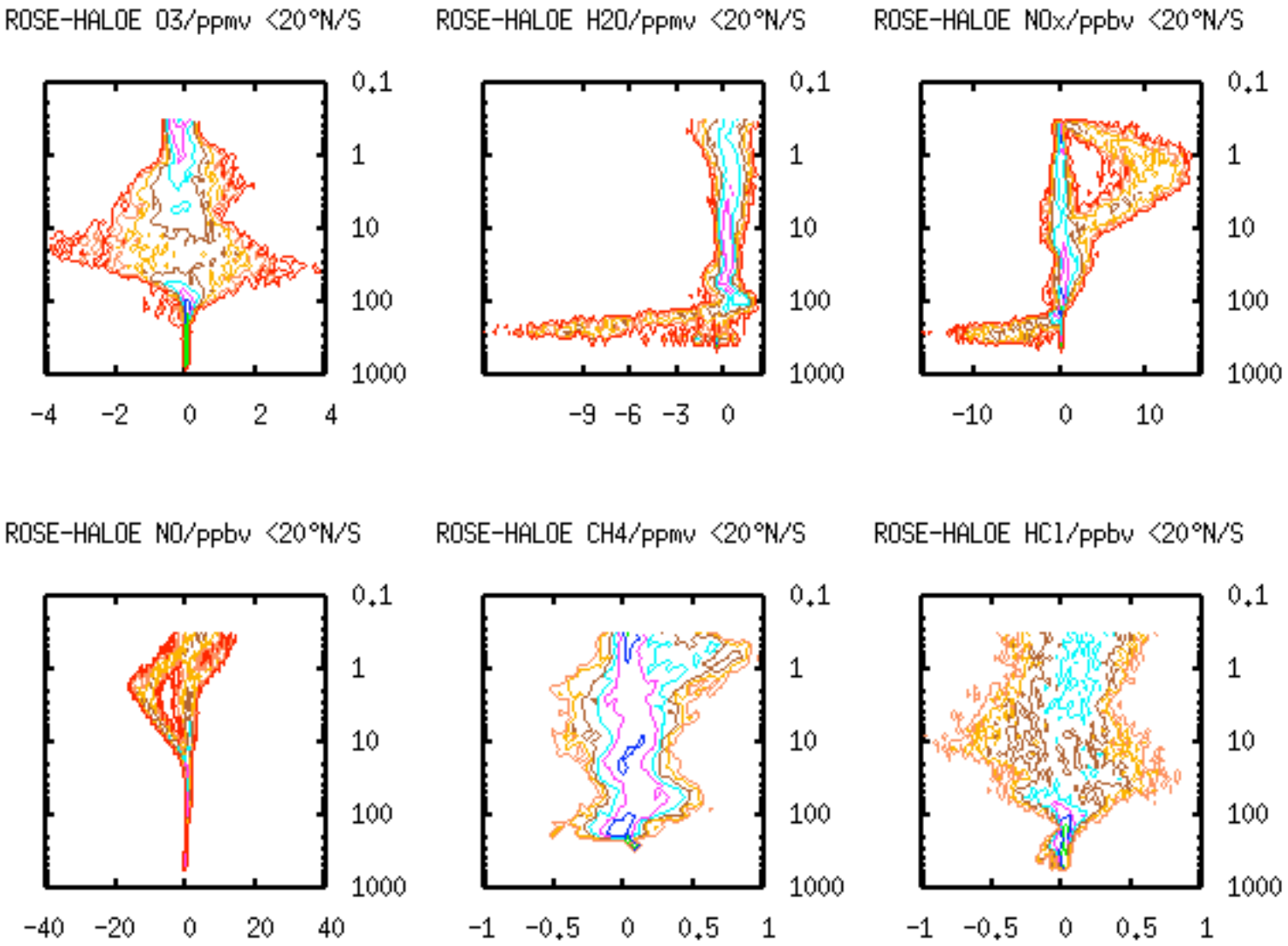
PDFs ROSE/EC-HALOE: NH



PDFs ROSE/EC-HALOE: Eq



PDFs ROSE/UKMO-HALOE: Eq



HALOE Summary

ROSE/EC c.t. HALOE (100-2 hPa)

obs		mean	bias/%	rms/%
O3	46335	5.11	0.37	10.82
H2O	46337	4.97	4.06	13.63
NOx	46127	6.58	3.29	28.14
CH4	46135	1.09	7.76	15.18
HCl	46133	1.57	-12.75	12.95

SACADA c.t. HALOE (100–2 hPa)

obs		mean	bias/%	rms/%
O3	9197	4.86	-1.66	12.11
H2O	9197	4.62	2.93	8.29
NOx	9150	5.95	-0.91	25.56
CH4	9149	1.07	7.53	12.06
HCl	9149	1.36	-21.92	46.41

HALOE Summary

ROSE/EC c.t. HALOE (100-2 hPa)

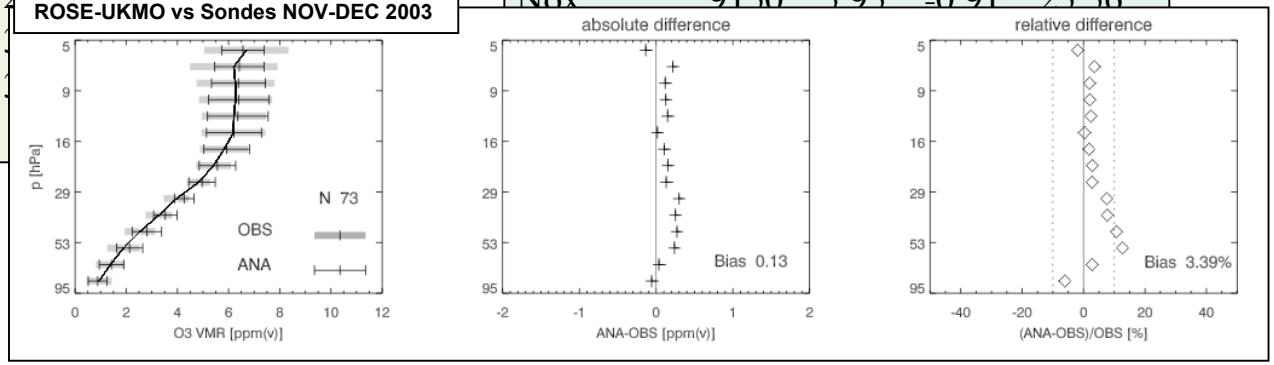
obs		mean	bias/%	rms/%
O3	46335	5.11	0.37	10.82
H2O	46337	4.97	4.06	13.63
Nox	461			
CH4	461			
HCl	461			

SACADA c.t. HALOE (100–2 hPa)

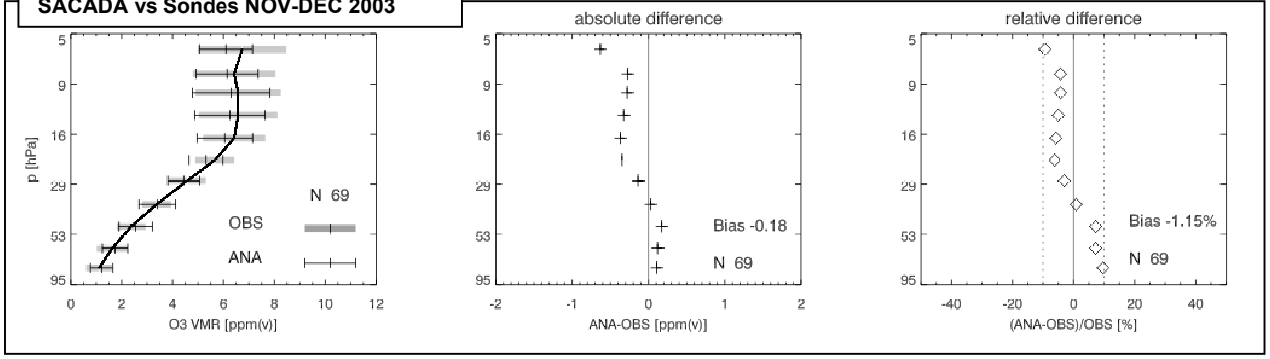
obs		mean	bias/%	rms/%
O3	9197	4.86	-1.66	12.11
H2O	9197	4.62	2.93	8.29
Nox	9150	5.95	-0.91	25.56

Ozone Soundings

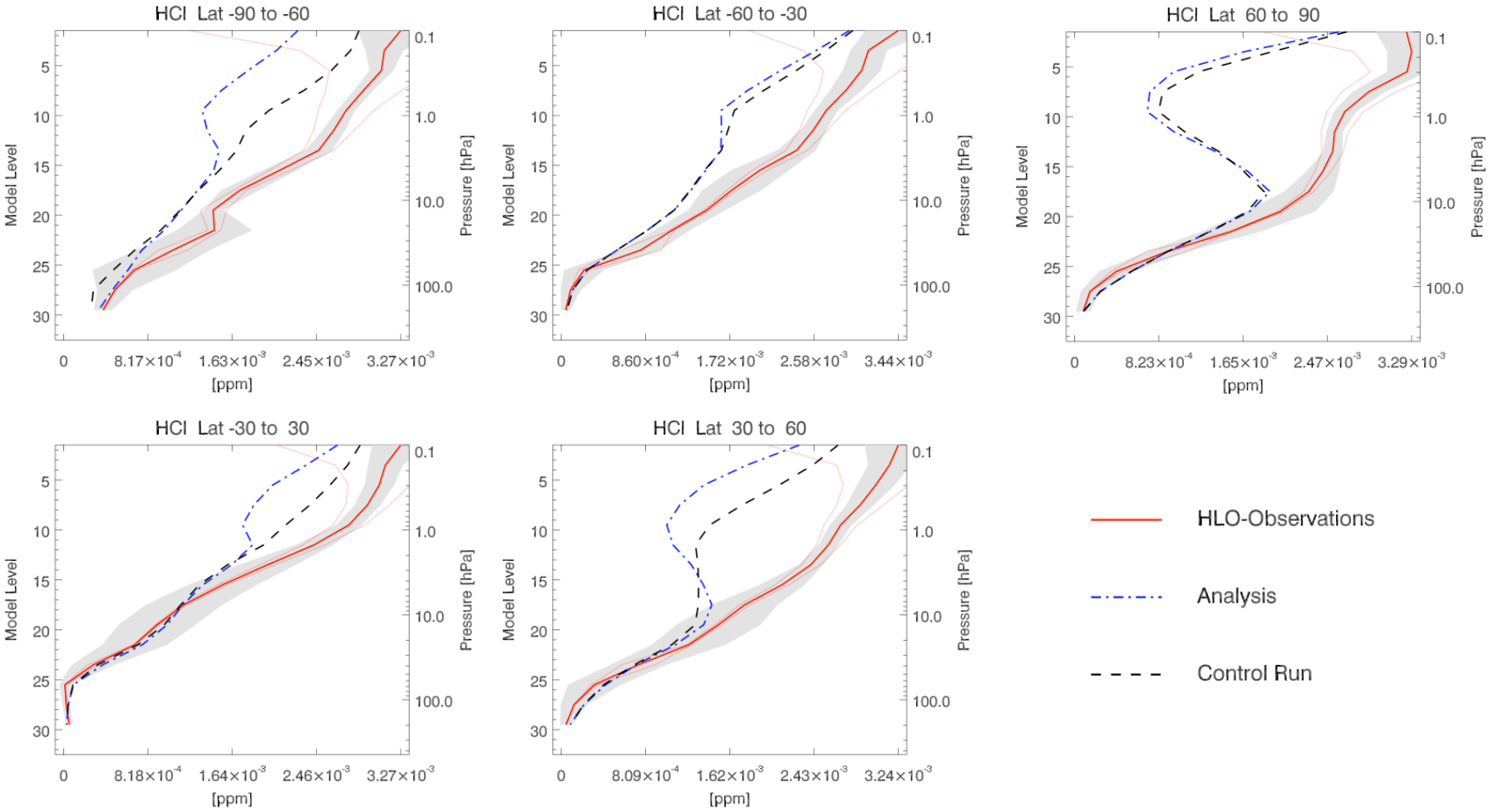
ROSE-UKMO vs Sondes NOV-DEC 2003



SACADA vs Sondes NOV-DEC 2003



HCl Deficit: Episode 2002 day 251-288



Summary

- Initial long-term assimilation of MIPAS ESA data using SACADA 4Dvar
- I.g. good comparison to ROSE/OI for 2003/2004 winter
- Differences hint to different biases and issues, e.g. transport
- Comparisons to HALOE show improvements for H2O, NOx and CH4
- Strong influence of Meteorology on CTM ozone results
- Upper SACADA level show run-away HCl deficit
  (? sources, reaction rates, transport-chemistry coupling, etc.)

Outlook

- Improved boundary conditions wrt source compounds
- Evaluation of PSC parameterization
- Extent analysis to full MIPAS data coverage
- Application to SCIA nadir ozone for daily analysis