Coupled chemical-dynamical data assimilation

ESA/ESTEC Contract

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SPARC Data Assimilation Workshop, Toronto, September 4 2007

Environment Canada Environnement Canada

Canada

General Study Program

"*Can chemical observations improve numerical weather prediction through data assimilation*"

- Context: - Stratosphere (simpler problem – no sources)
  - ENVISAT observations
  - Limb sounders (vertical information)

- Objectives:
  - ➢ Develop GCCM from state-of-the-art GCM and CTM
  - ➢ Analysis of benefits/drawbacks of GCCM-DAS

Outline

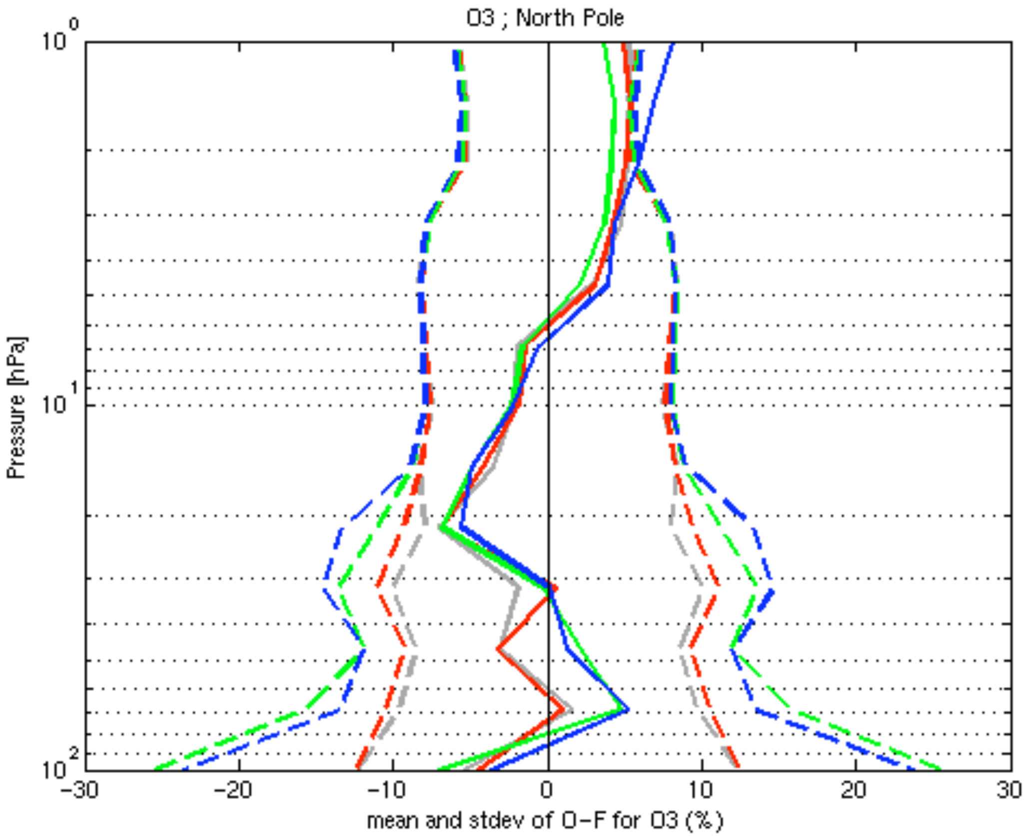
- Coupled model – ozone forecast
- Error statistics derived from polar orbiting satellite data
- Ozone-radiation interaction – impact on temperature forecast skill
- Deducing winds from chemical observations: a simplified 4D-Var approach
- Can we assimilate in presence of bias: Case of decent of mesospheric NOx in the polar vortex produced by geomagnetic events

Model description

- **GEM:** the operational NWP model of Environment Canada
- Dyn and phys modules used operationally since June 2009
- Vertical grid: 80 s-p hybrid levels from surface to 0.1 hPa.
- Here horizontal grid is 240x120 (1.5°x1.5°)

- **BASCOE** stratospheric chemistry module
- **57 chemical species**, all advected (S-L)
- Ox, HOx, NOx, ClOx, BrOx and few hydrocarbons
- Source species: N2O, CH4, H2O, CFCs, HCFCs and Halons
- 52 photodissociation reactions, *J* interp from tables
- 142 gas-phase reactions, 7 heterogeneous reactions
- **Heterogeneous chemistry is fully resolved**, with simplified parameterizations for PSC surface area densities

GCCM (GEM-BACH) *vs* CTM (BASCOE)



Validation with MIPAS OFL
20030825-20030904, 60°N-90°N

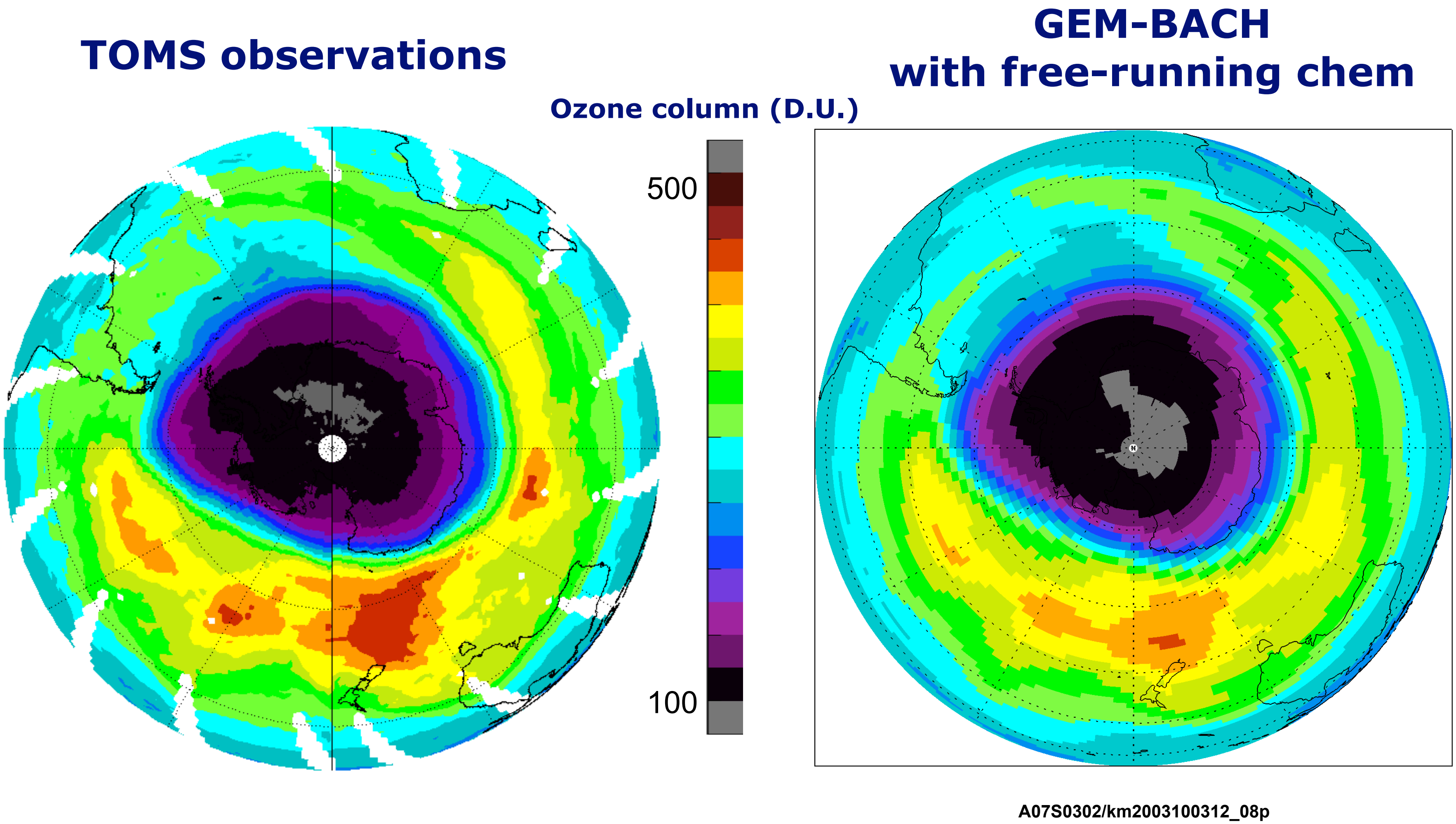
GEM-BACH, 4D-VAR dyn (K4BCS304)

GEM-BACH, 3D-VAR dyn (K3BCS304)

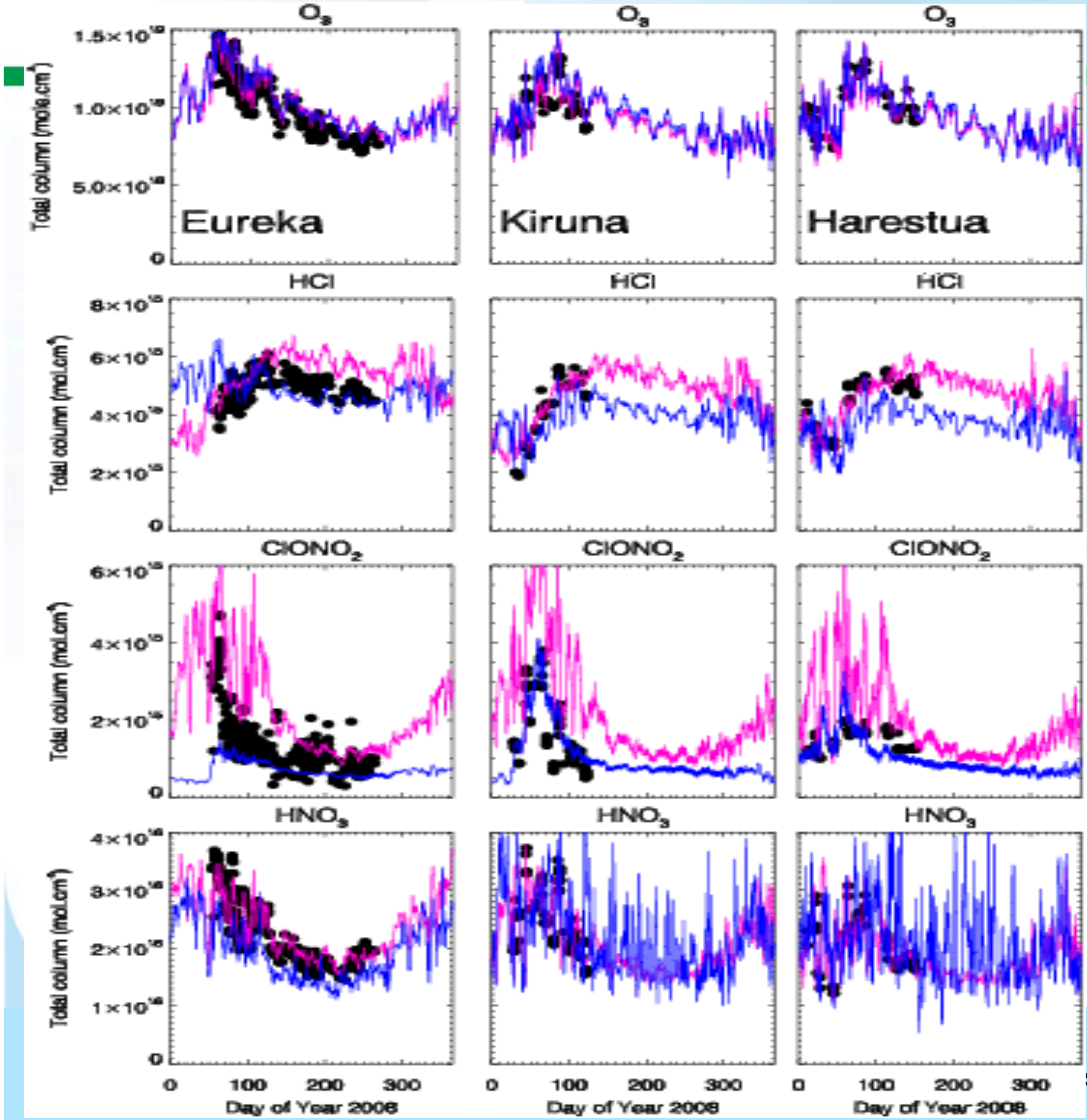
BASCOE CTM, 3D-VAR dyn (v3s85)

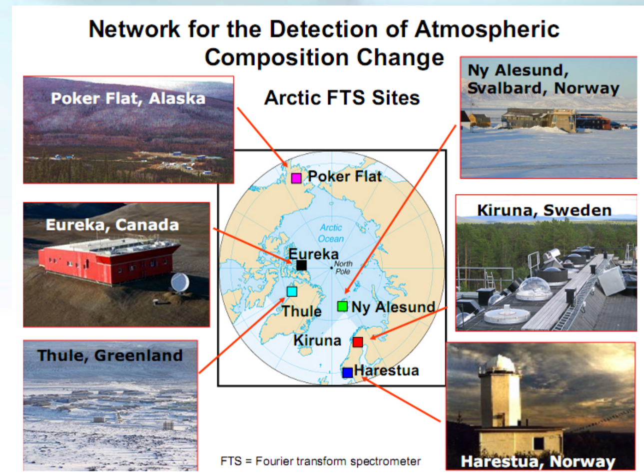
BASCOE CTM, ECMWF dyn (d2003G)

Ozone column, 3 Oct 2003



Validation of polar chemistry with NDACC FTIR





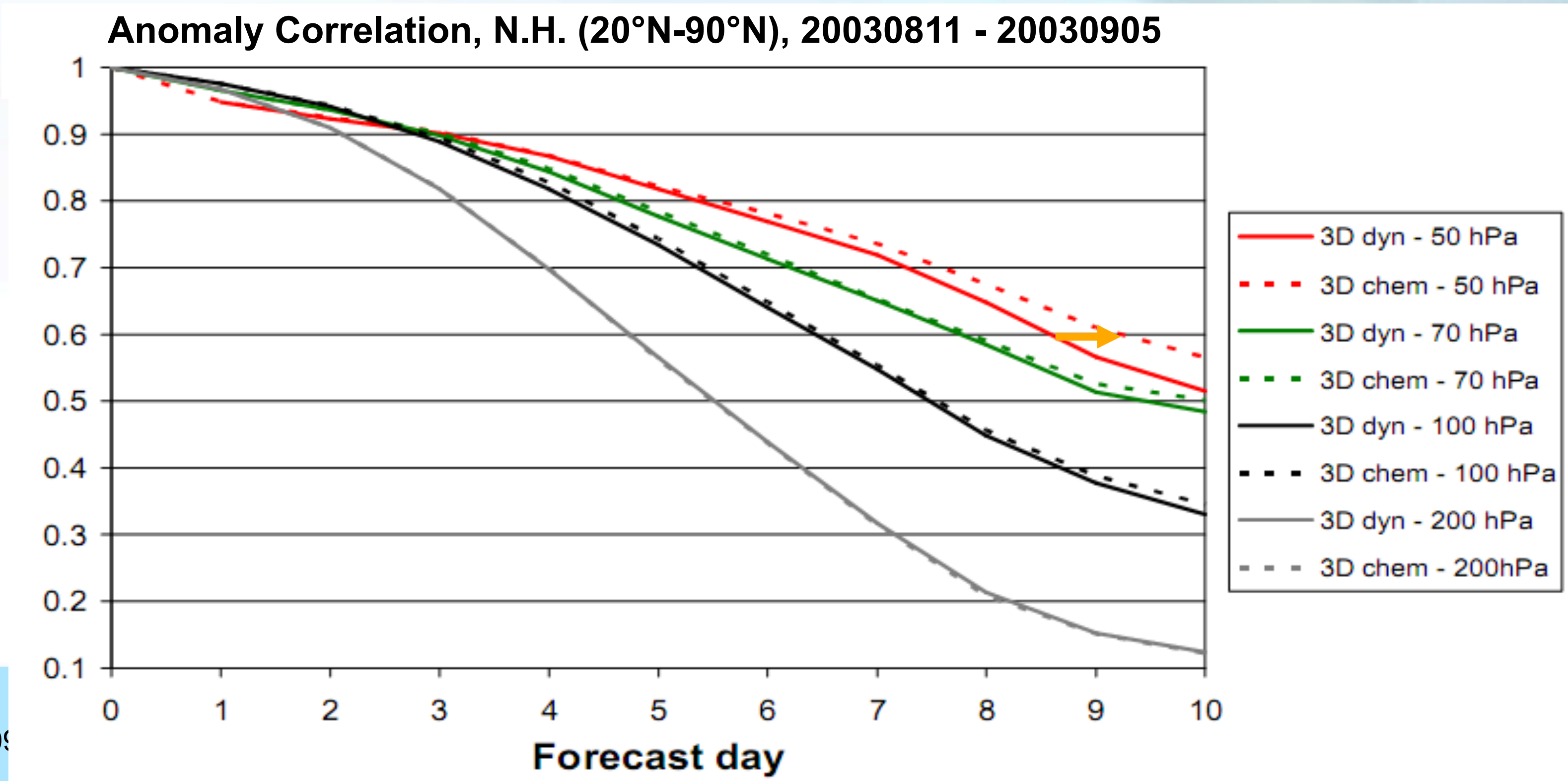
Acknowledgements:
- *CMAM-DA team*
- *NDACC Arctic FTIR team*

Impact of *interactive* ozone assimilation on T predictability

de Grandpré *et al.*, Monthly Weather Review, 2009 :

- Taking the ozone-radiation into account
  (in calculation of heating rates)
- MIPAS assimilation of ozone

big improvement of *T* forecast skill in lower strato:

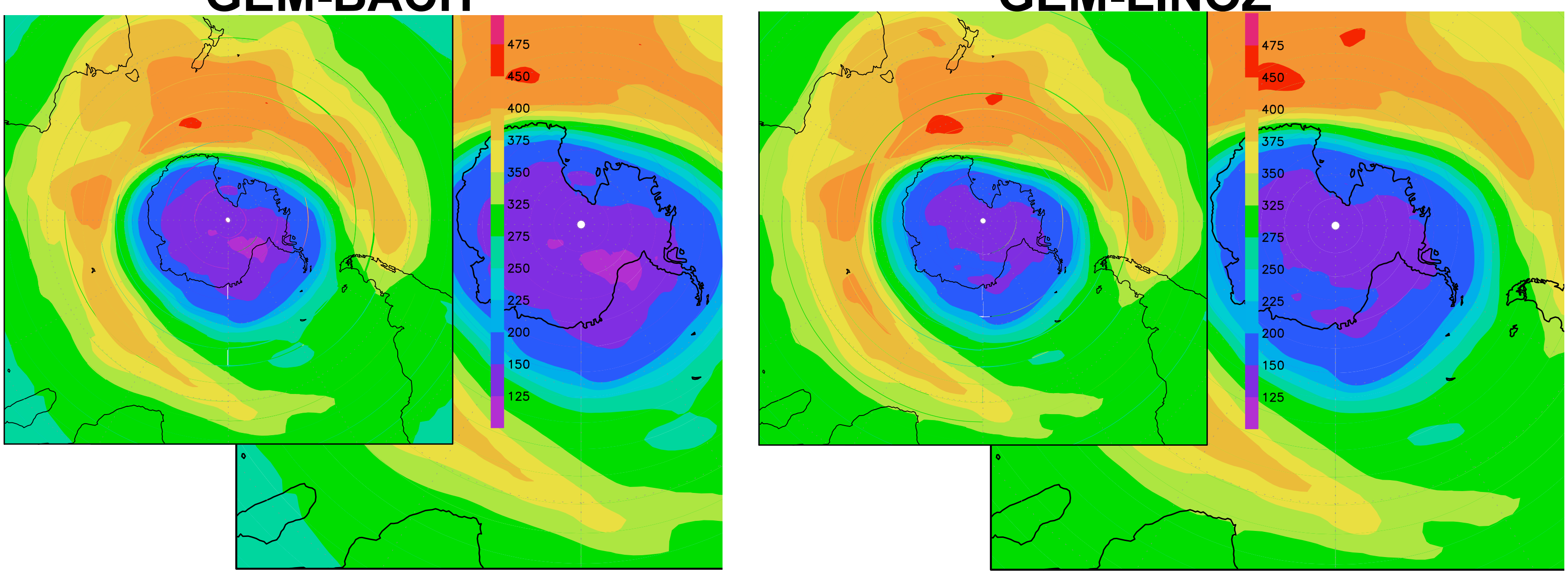


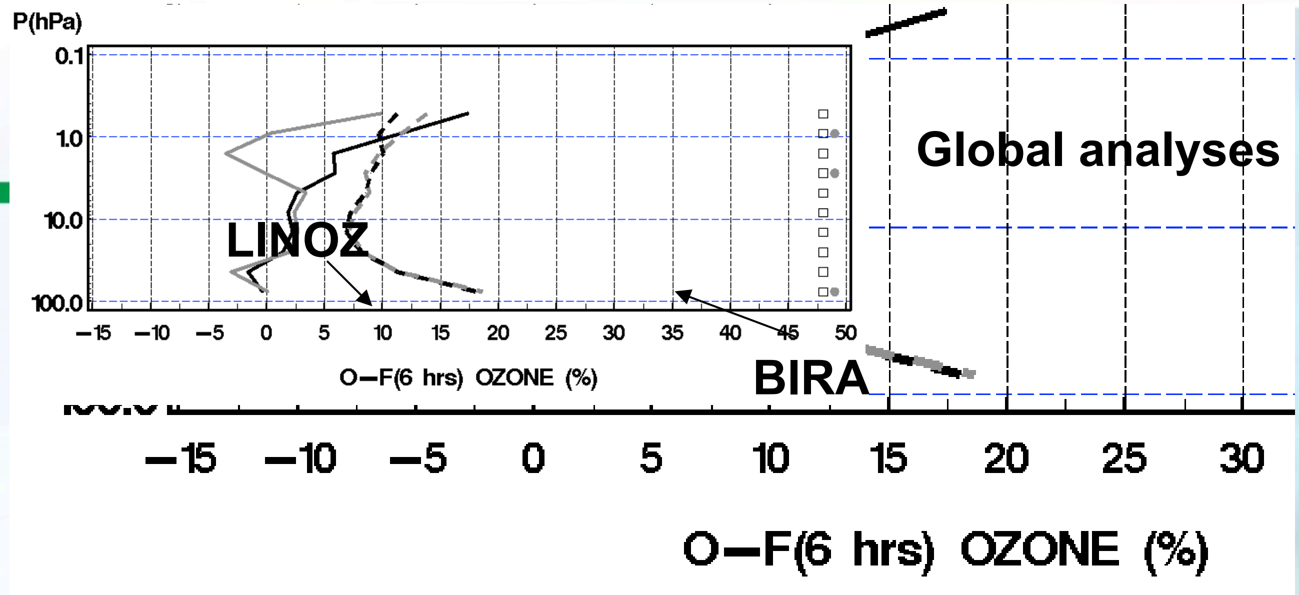
Assimilation of MIPAS with GEM-BACH *or* GEM-LINOZ

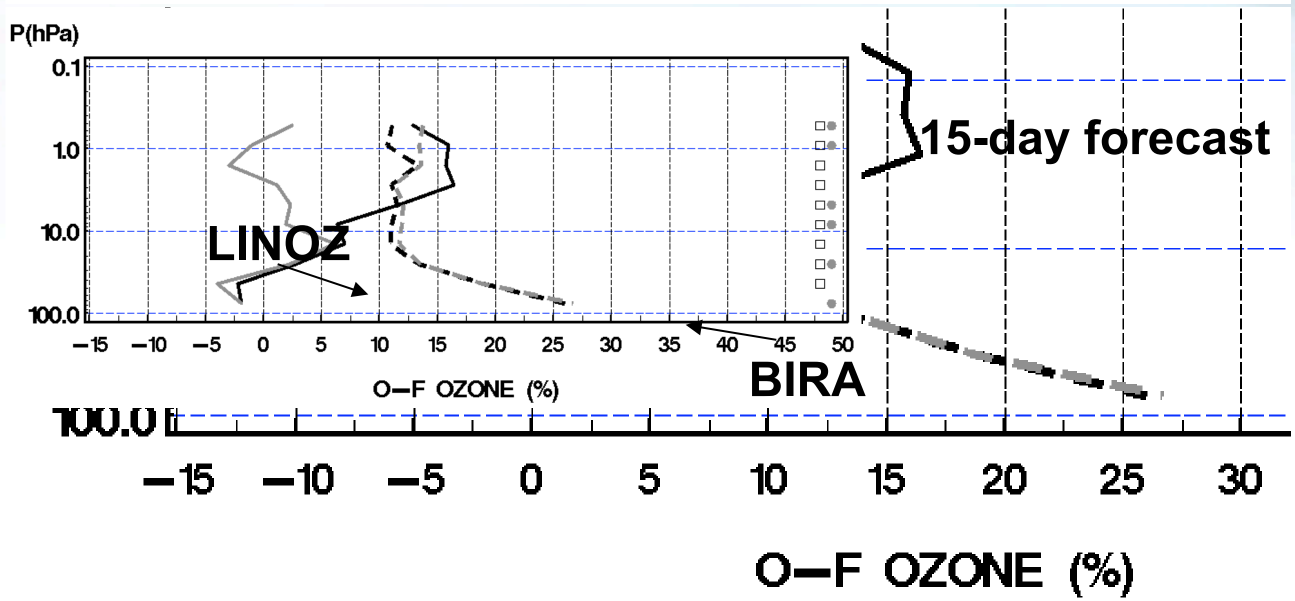
LINOZ: Linearized scheme (ozone only) that does *not* take heterogeneous chemistry into account
(Mclinden et al. JGR, 2000).

analyses of MIPAS: ozone column, 3 October 2003

GEM-BACH **GEM-LINOZ**



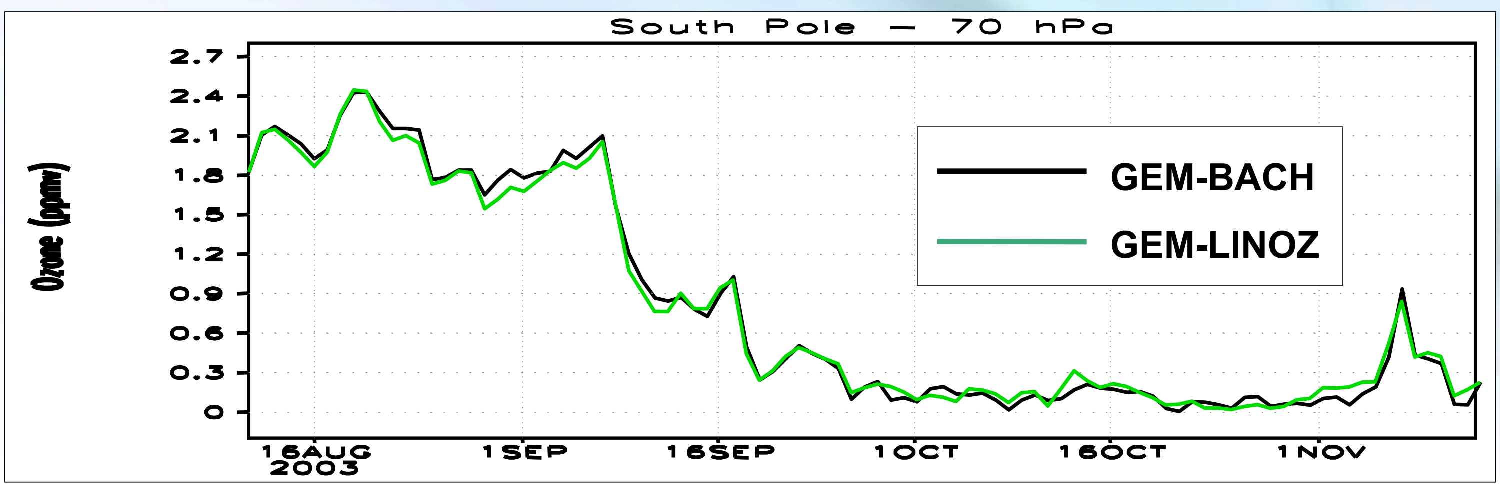

P(hPa)
0.1
1.0
10.0
100.0
−15 −10 −5 0 5 10 15 20 25 30 35 40 45 50
O−F(6 hrs) OZONE (%)
LINOZ
BIRA
Global analyses
−15 −10 −5 0 5 10 15 20 25 30
O−F(6 hrs) OZONE (%)


P(hPa)
0.1
1.0
10.0
100.0
−15 −10 −5 0 5 10 15 20 25 30 35 40 45 50
O−F OZONE (%)
LINOZ
BIRA
15-day forecast
−15 −10 −5 0 5 10 15 20 25 30
O−F OZONE (%)

Assimilation of MIPAS with GEM-BACH *or* GEM-LINOZ

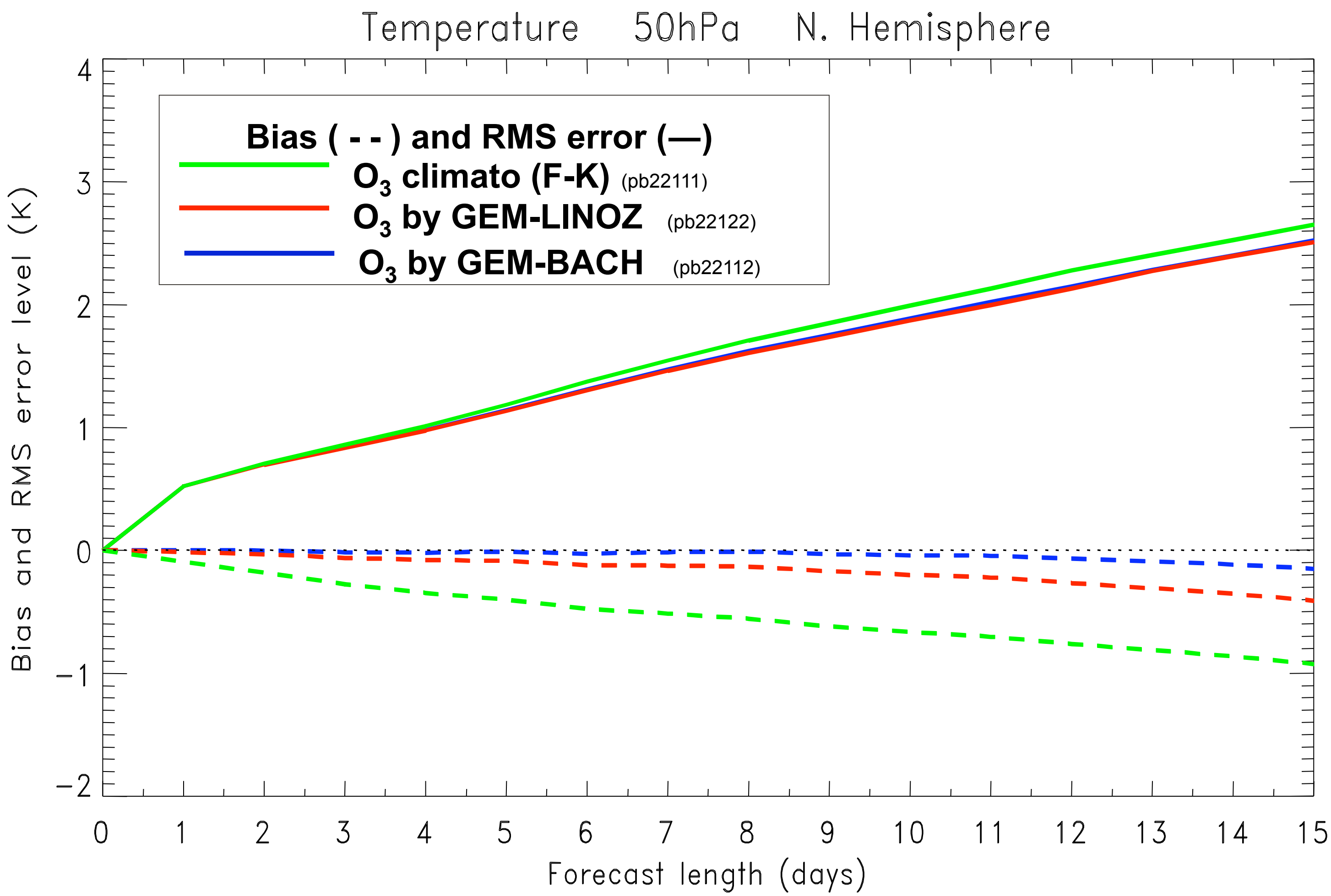
Time series of ozone analyses by assimilation of MIPAS

70 hPa, 90°S-60°S

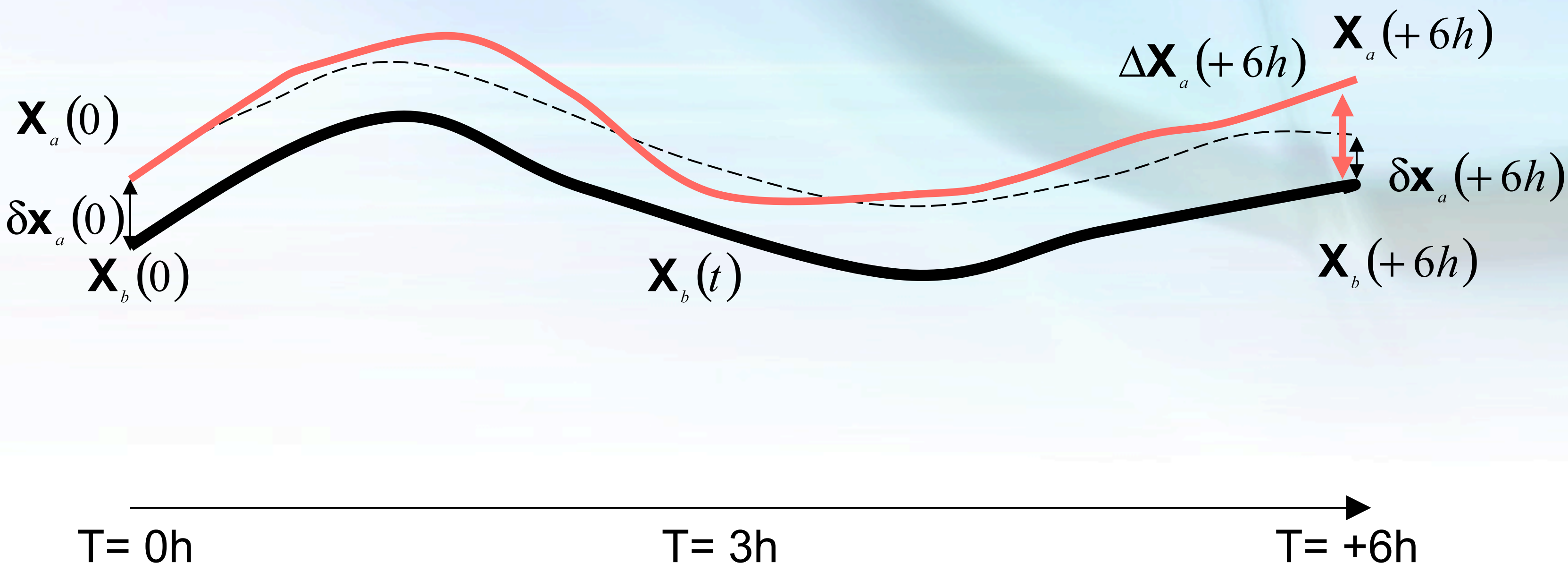


- MIPAS obs are dense enough, and ozone depletion is slow enough, that assimilation with LINOZ works as well as with full chemistry. Interesting when ozone is the only chemical target, e.g. to improve the meteorological forecast:

Impact of *interactive* ozone assimilation on T predictability: ensemble of 15-day forecasts

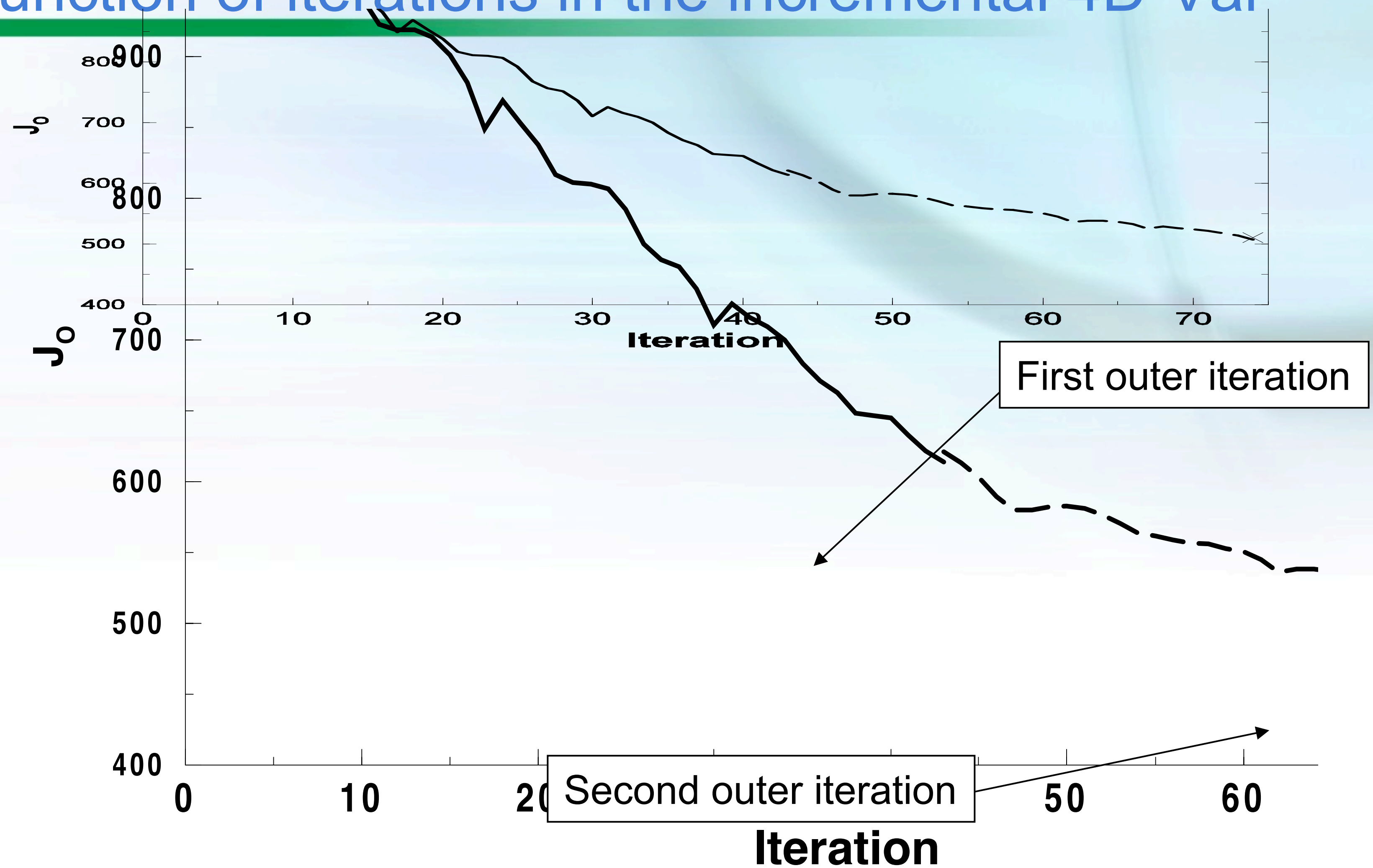


Schematic of the incremental 4D-Var



Assimilation window

J_o cost function for ozone observations as a function of iterations in the incremental 4D-Var

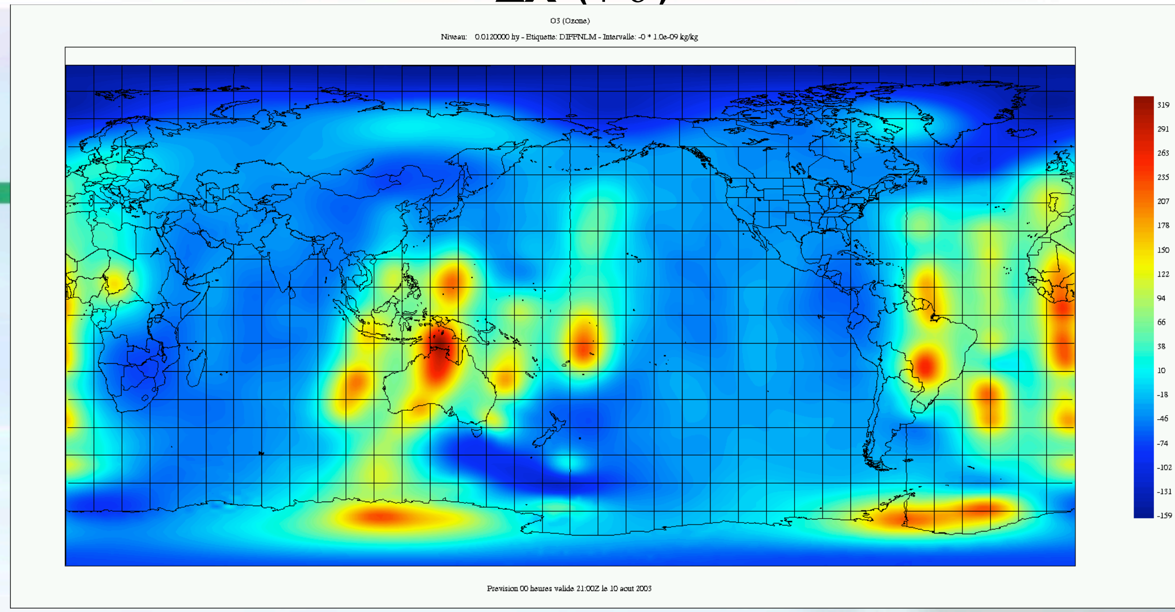


O_3 Increment at final time

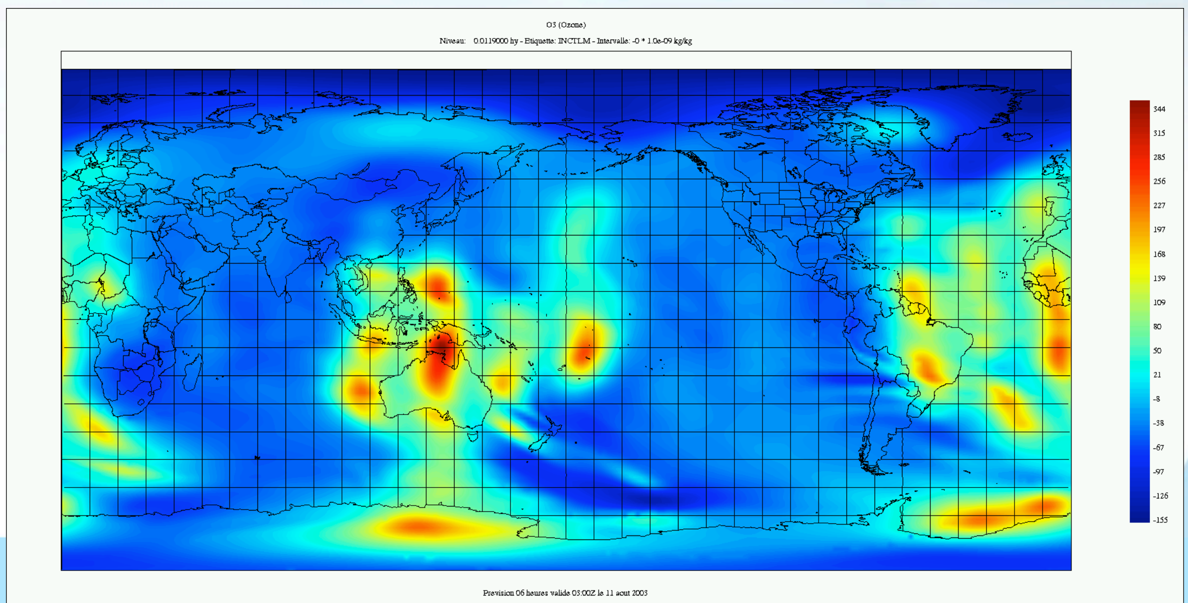
10 hPa

August 11, 2003

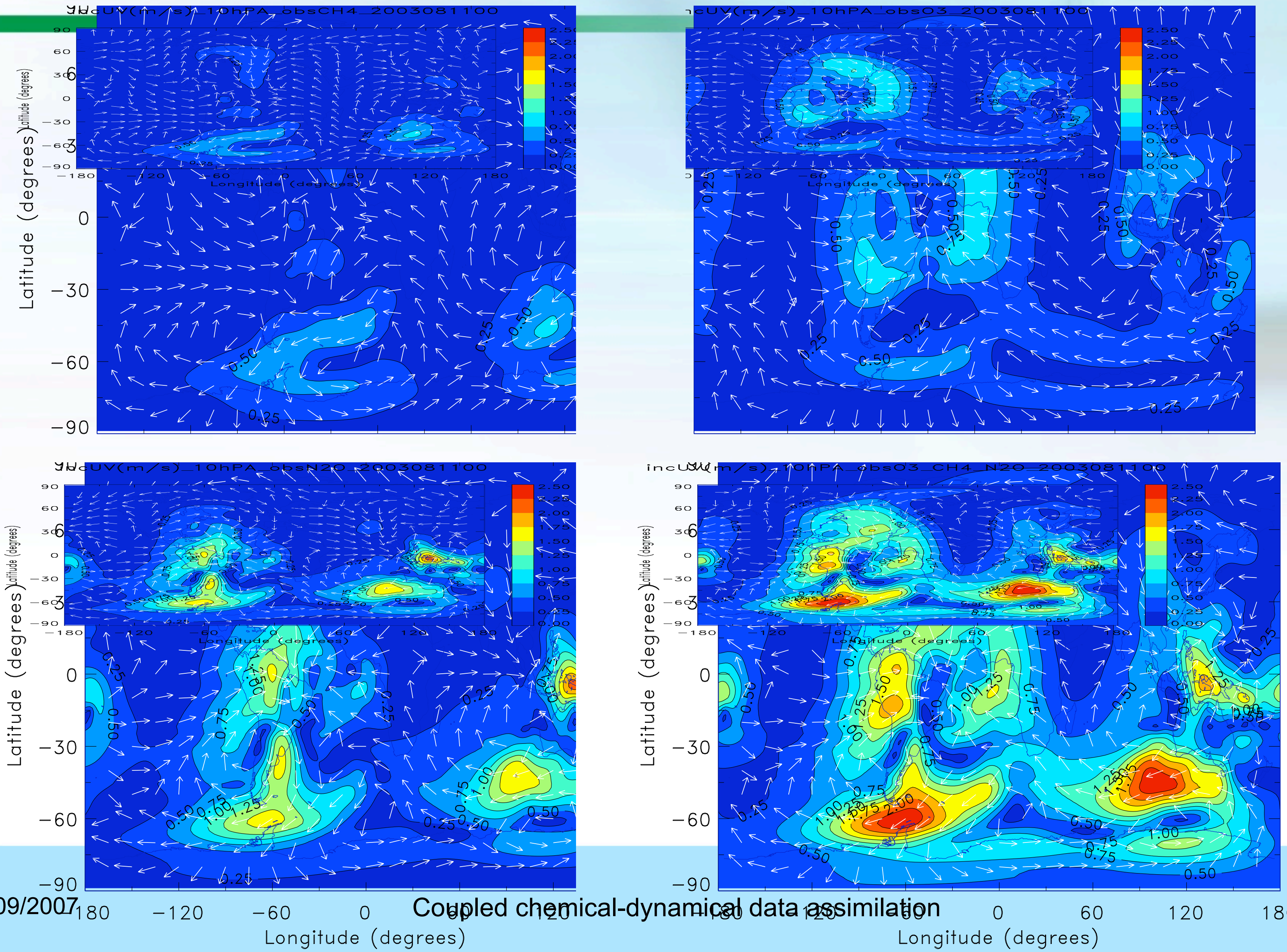
$\Delta \mathbf{X}(+6)$



Increment TLM $\delta \mathbf{x}_a(+6)$

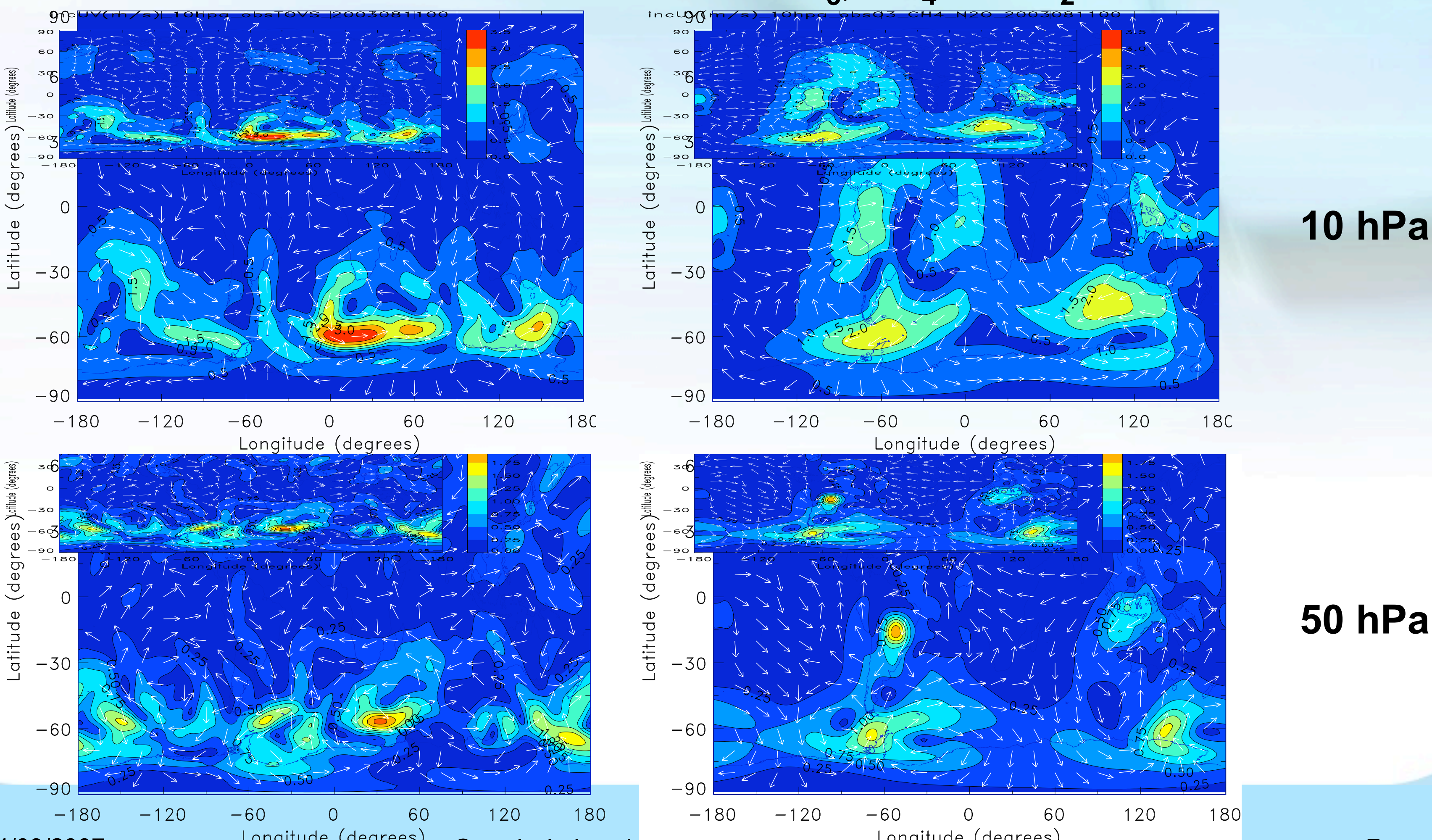


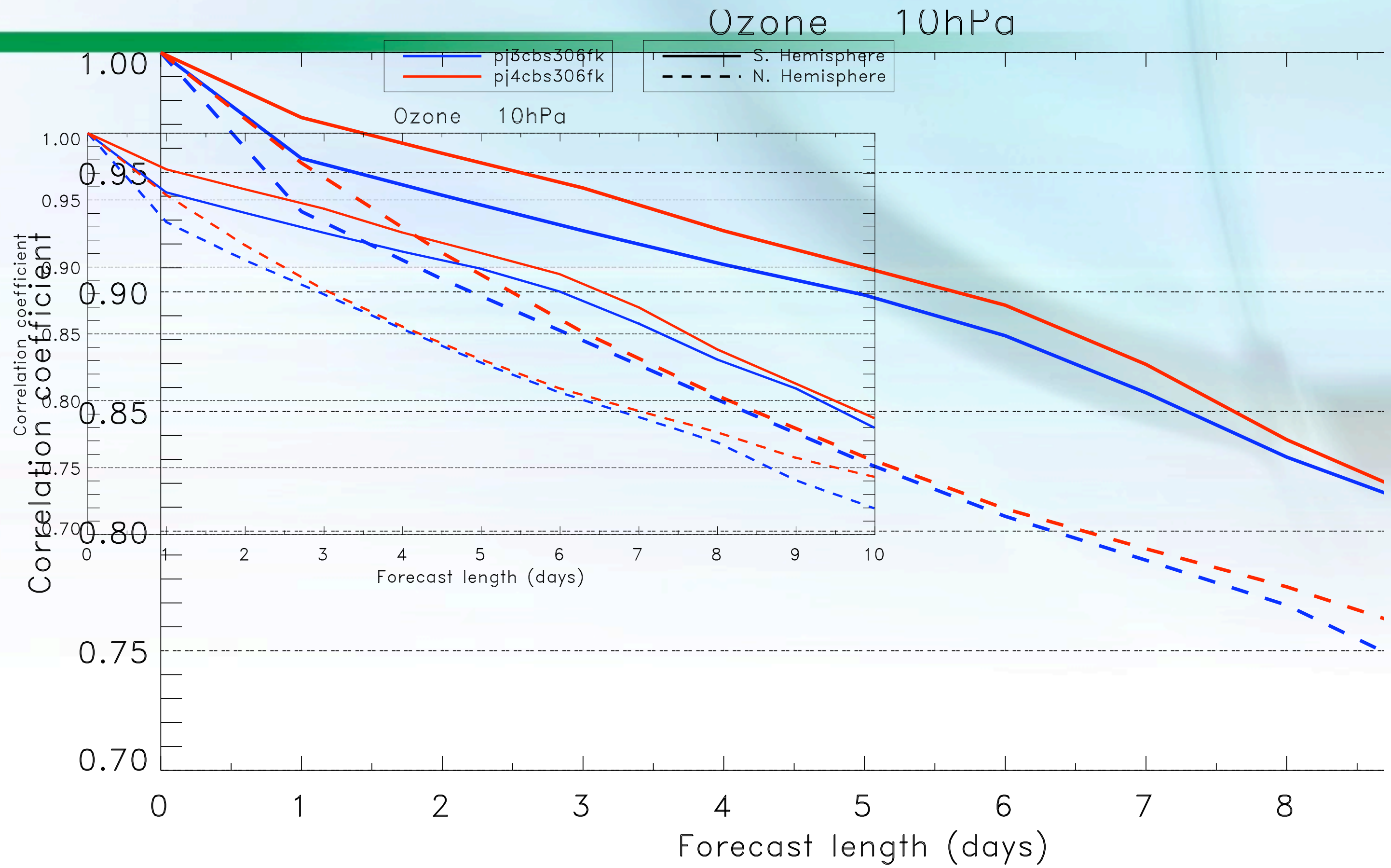
Impact in 4D-Var on winds from individual tracers and all three combined: 10 hPa



Impact in 4D-Var on winds from all tracers with respect to the wind increment obtained from TOVS in 3D-Var

TOVS | **O_3, CH_4 and N_2O**





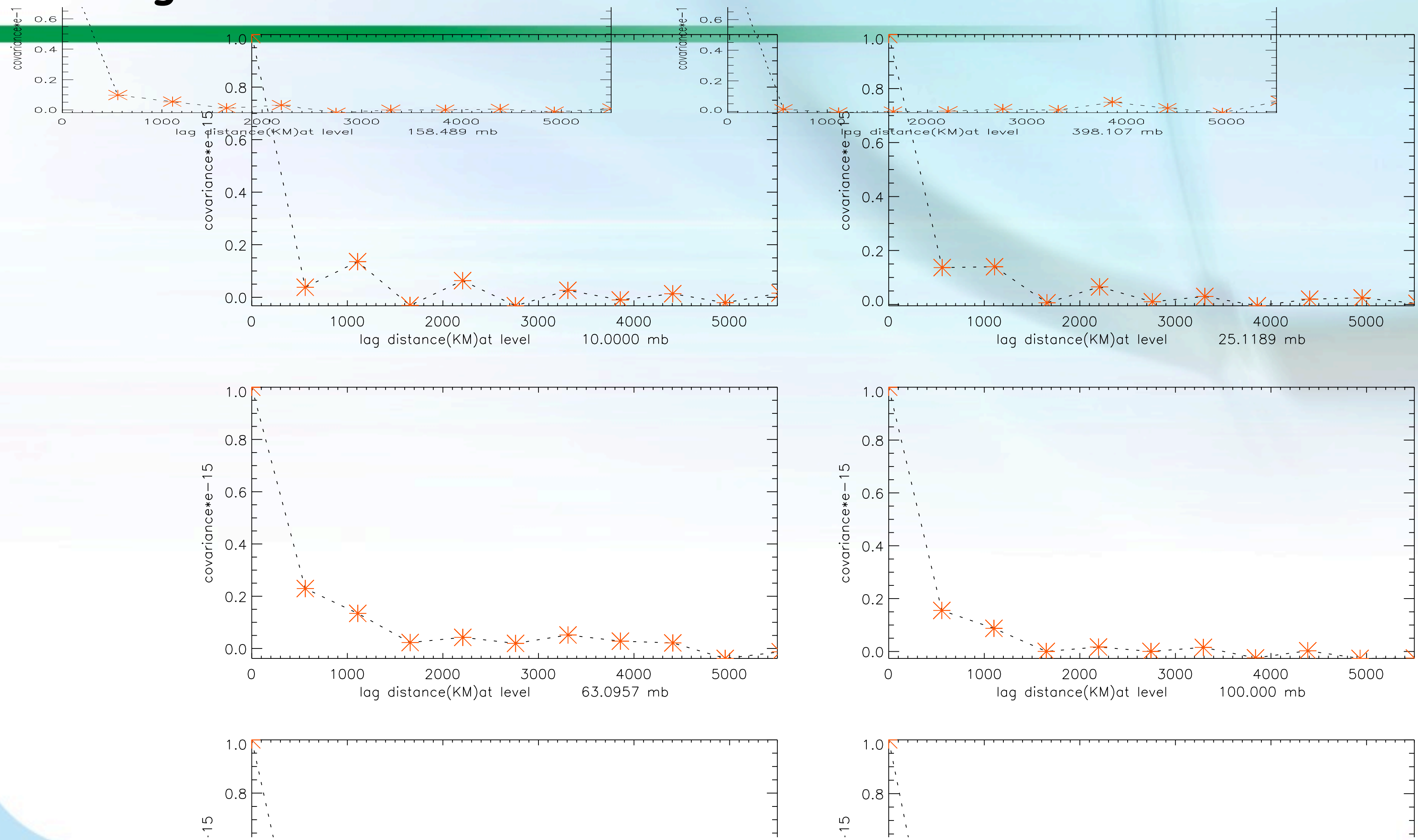
Ozone 10hPa
pj3cbs306fk
pj4cbs306fk
S. Hemisphere
N. Hemisphere
Correlation coefficient
Forecast length (days)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0 1 2 3 4 5 6 7 8
Ozone 10hPa
Correlation coefficient
Forecast length (days)
0 1 2 3 4 5 6 7 8 9 10

Merci

Thank you

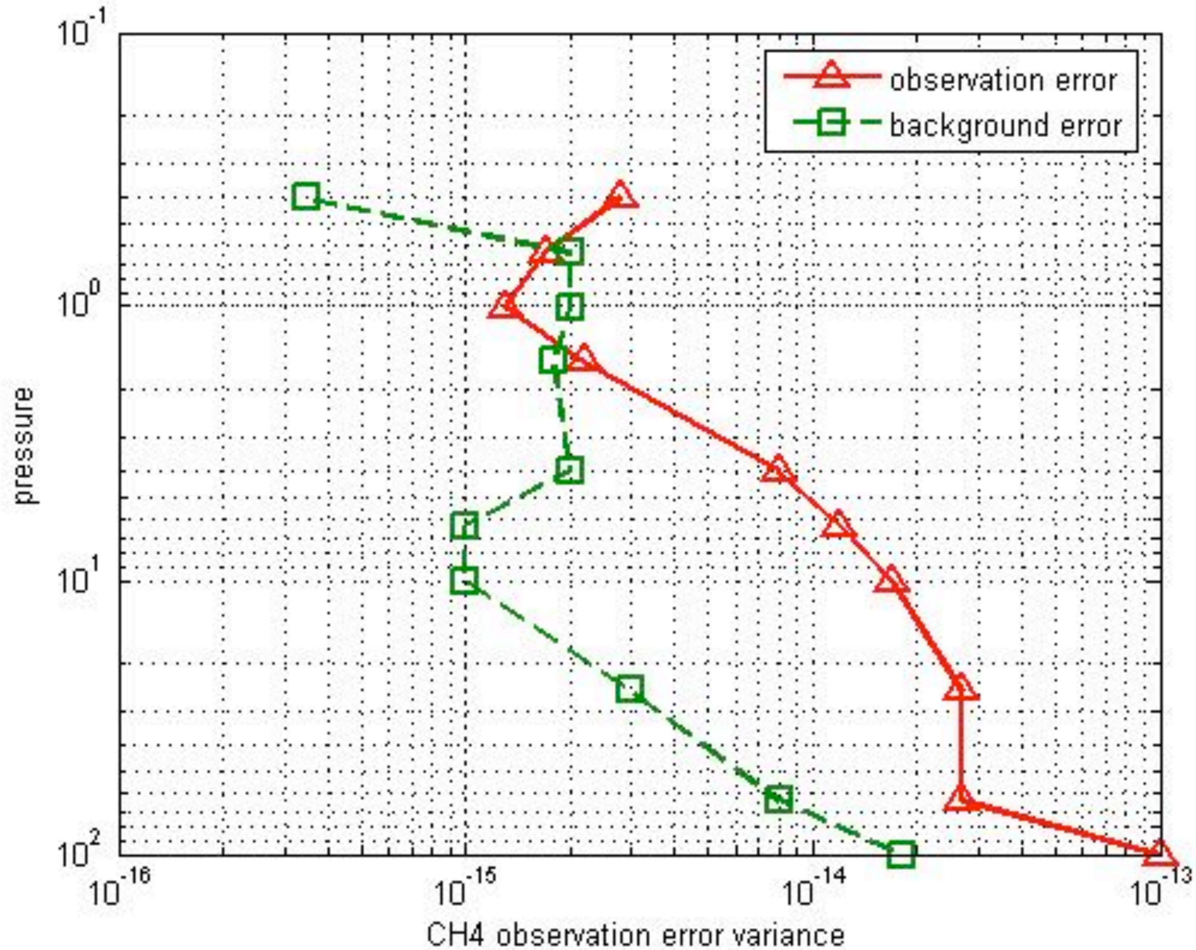
Error statistcis

Along track innovation covariance – ozone assimilation

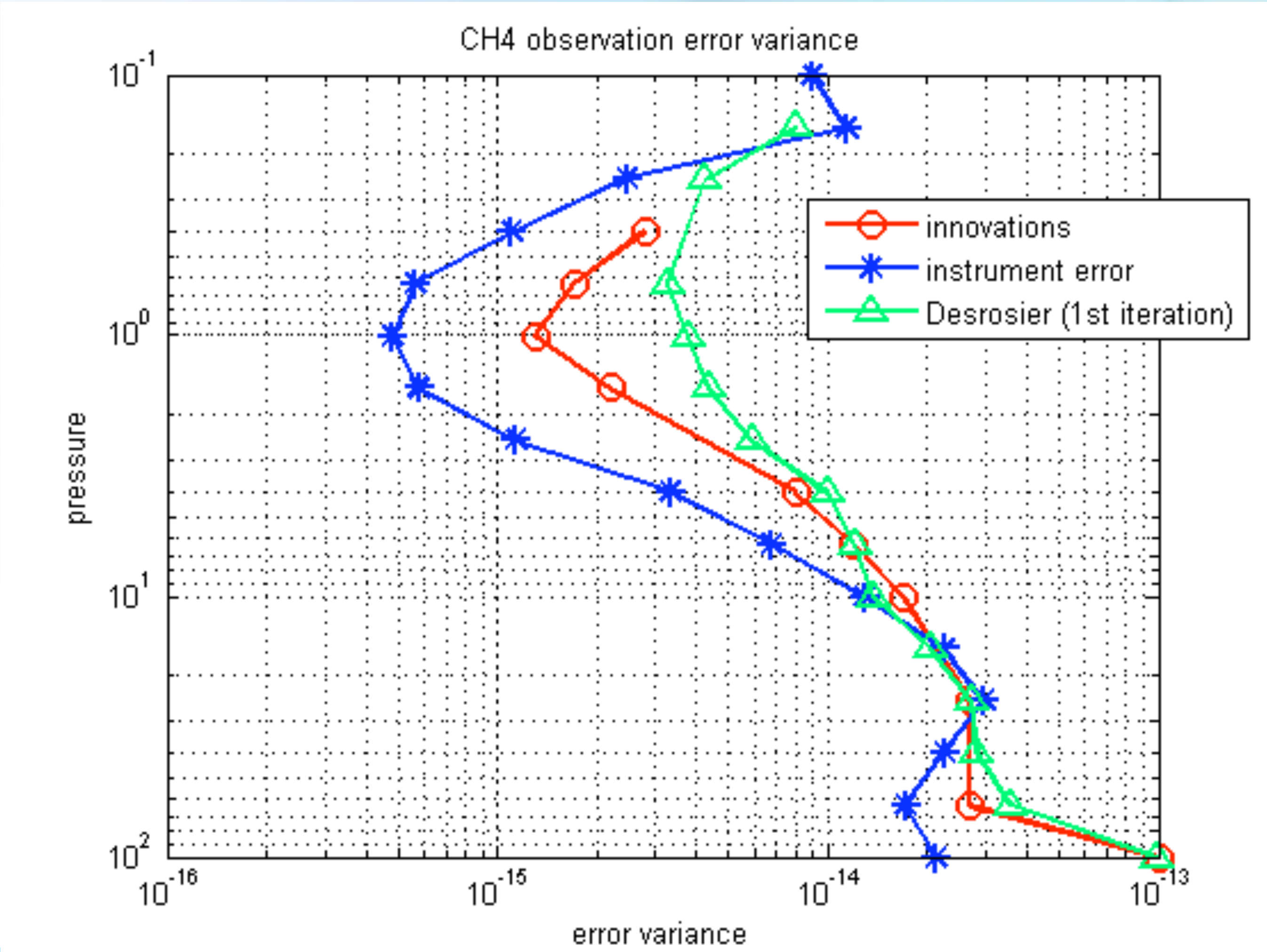


Only CH_4 so far …

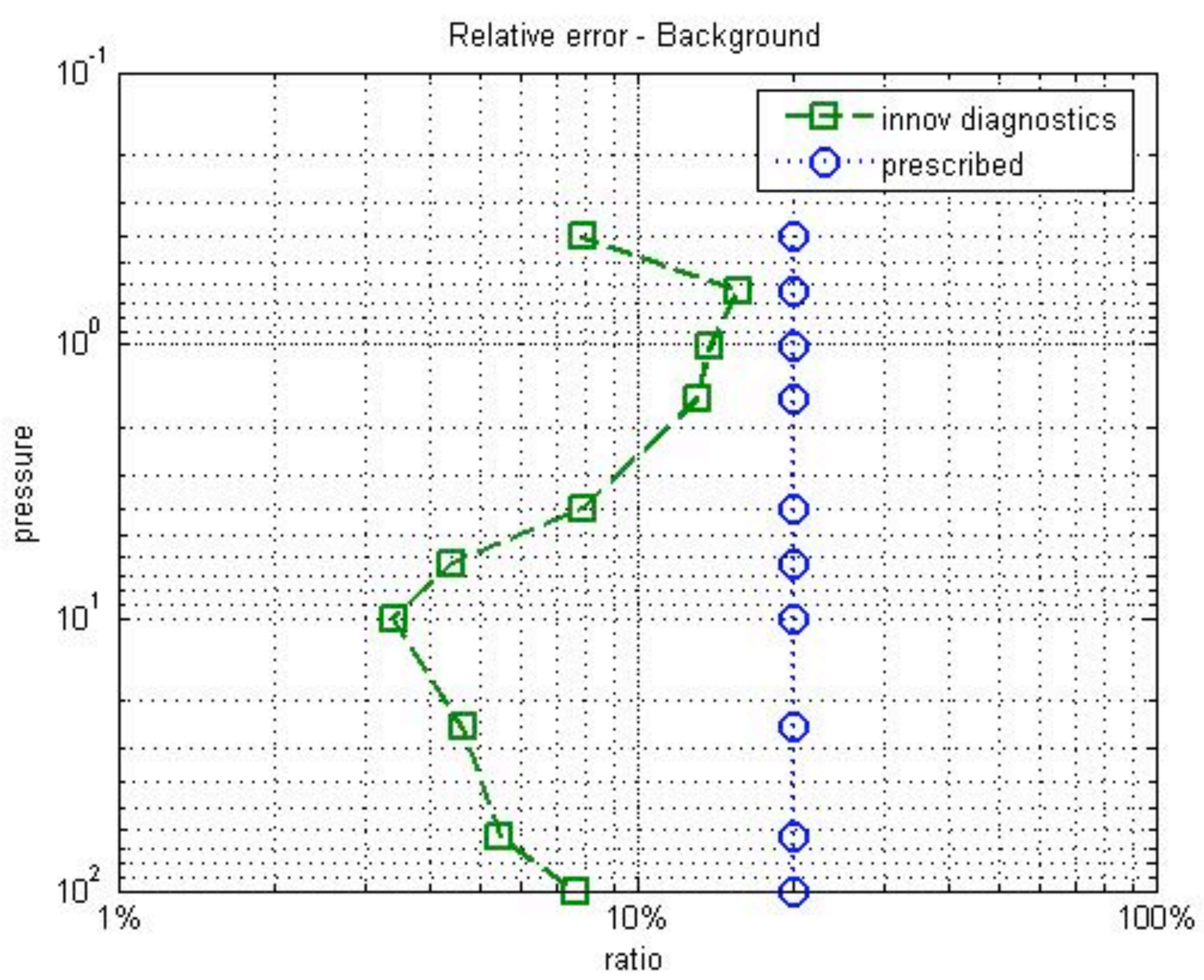
Method of Hollingsworth and Lonnberg



Comparison with other estimates



Relative background error formulation:
Error standard deviation proportional to the state

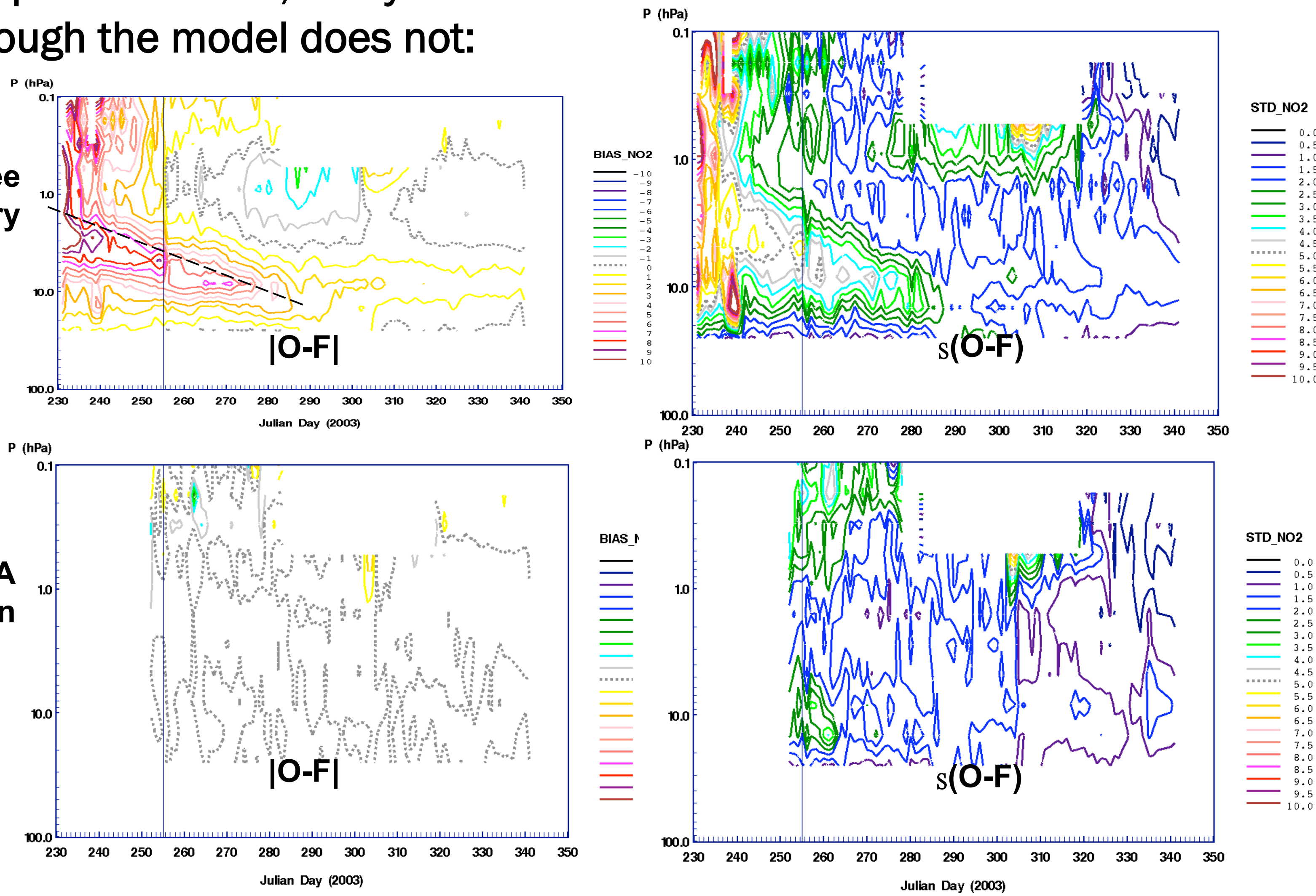


Assim with *too* (?) simple chemistry in model: Absence of mesospheric NOx

With proper error stats, analyses *do* take this NOx into account even though the model does not:

free chemistry

MIPAS-ESA assimilation



Merci

Thank you

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