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On the prognostic treatment of stratospheric ozone in the Environment Canada global NWP system

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Outline

- Ozone assimilation system
- DAS Experiments
- Ozone analyses and forecast
  - Evaluation
  - Transport
  - Radiation
- Conclusions and development

Chemical data assimilation system

- NWP Model : GEM Global
- Operational Configuration:
  - Resolution: 800x600, L80 levels
  - Lid = .1hPa ; timestep: 15 min
- Semi-Lagrangian transport
- On-line chemical interface
- Chemistry modules: [AQ (regional,global), strat O_3, Hg]
- Meteorological and chemical assimilation : 3D-var

Stratospheric chemistry modules:

Comprehensive: BASCOE chemistry (Errera et al., 2008)

Simplified : LINOZ (McLinden et al., 2000)

$$\frac{dq}{dt} = (P-L)\Big|^{o} + \frac{\partial(P-L)}{\partial q}\Big|_{o}(q-q^{o}) + \frac{\partial(P-L)}{\partial T}\Big|_{o}(T-T^{o}) + \frac{\partial(P-L)}{\partial c_{o_3}}\Big|_{o}(c_{o_3}-c_{o_3}^{o}) + R_{trop}$$

q : Ozone mixing ratio

c_{O_3} : Column ozone c_{o_3}

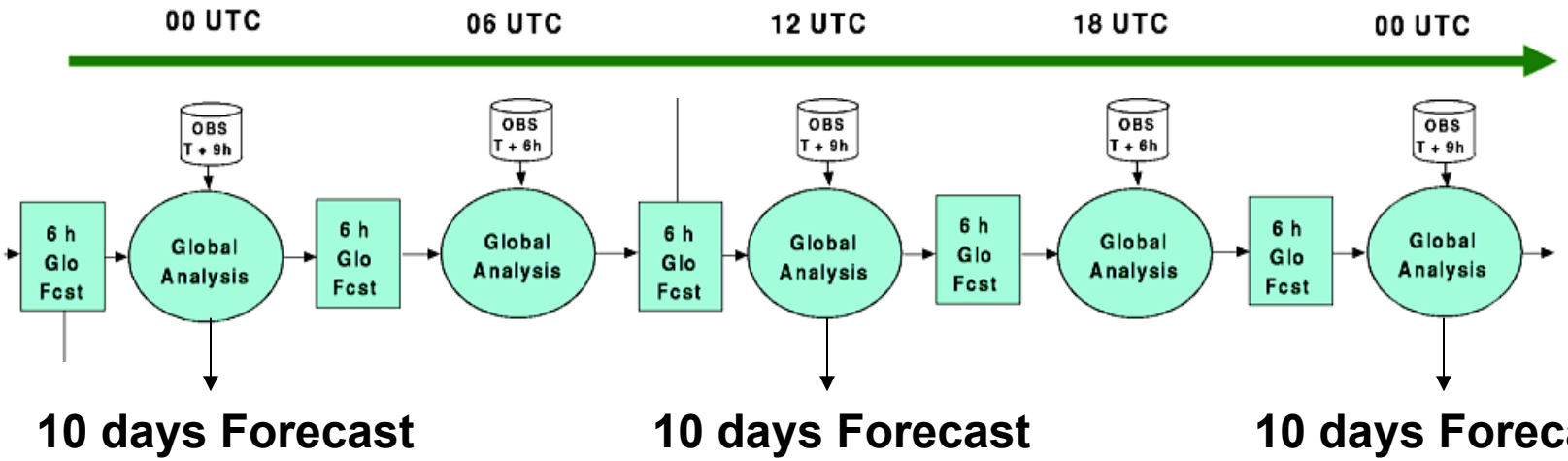
T : Temperature

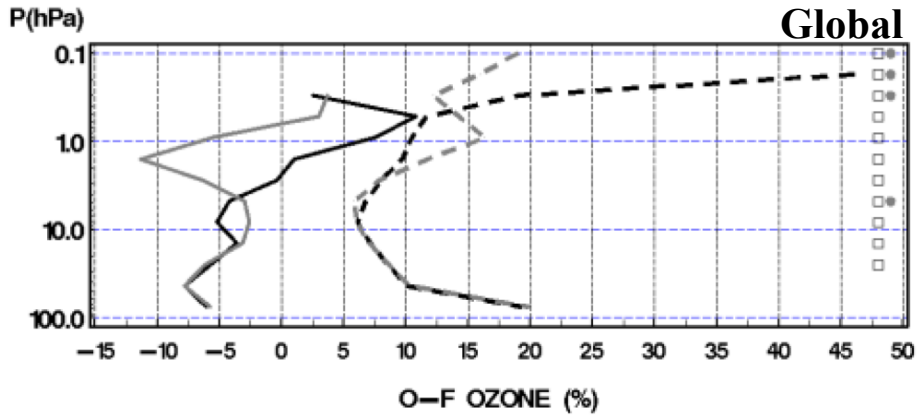
P-L : Photochemical tendency

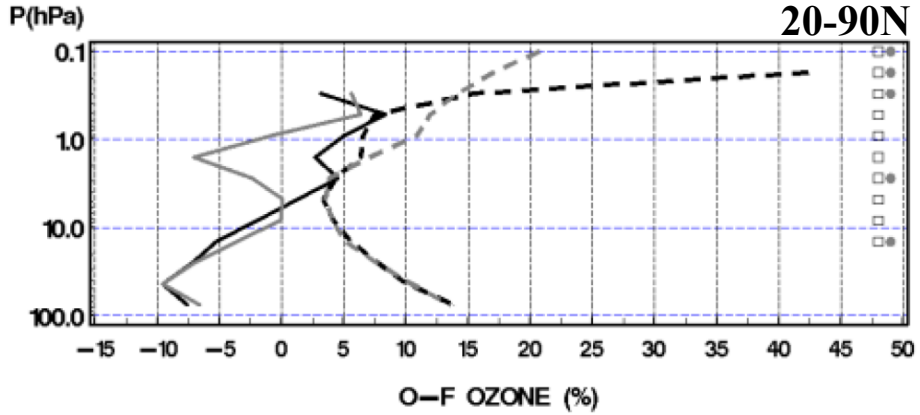
(^{O}) : Climatological values

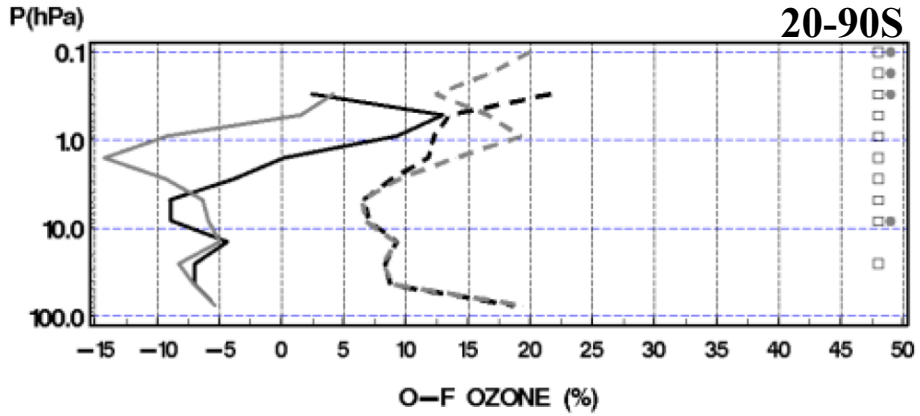
R_{trop} : Tropospheric relaxation term

Global deterministic meteorological and chemical analysis and forecasting system









Ozone forecast against HALOE

No chemical assimilation

Ozone (%) : Observation – Forecast

Period: August 2003

Black : BASCOE chemistry

Grey : LINOZ

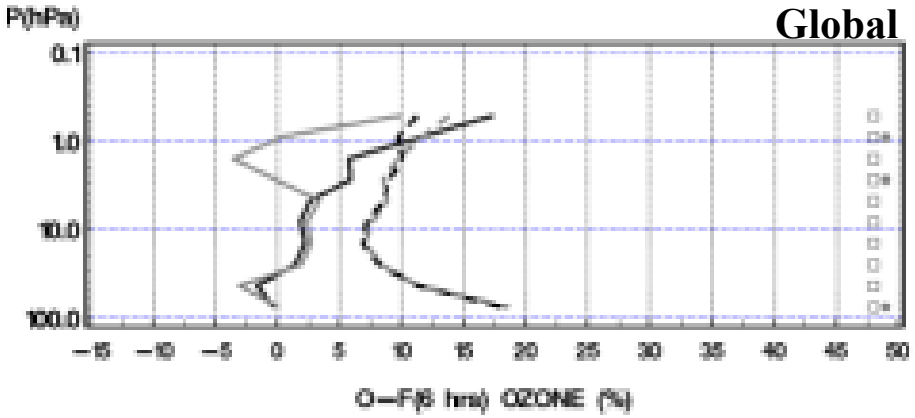
Solid lines : Mean biases

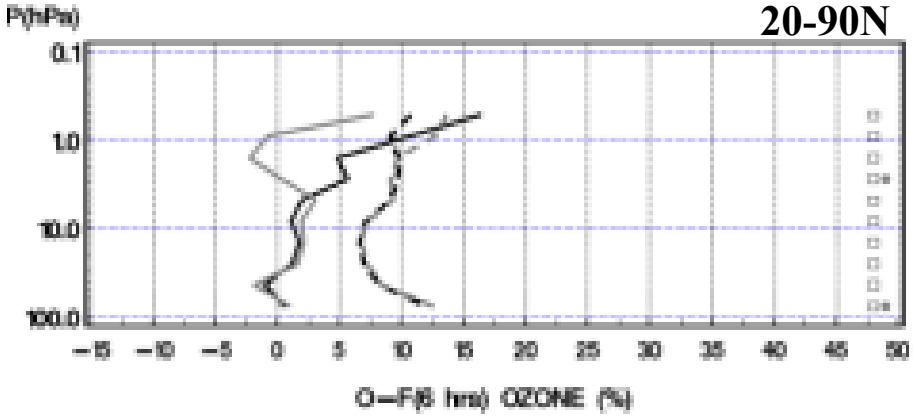
Dashed lines : Standard deviation

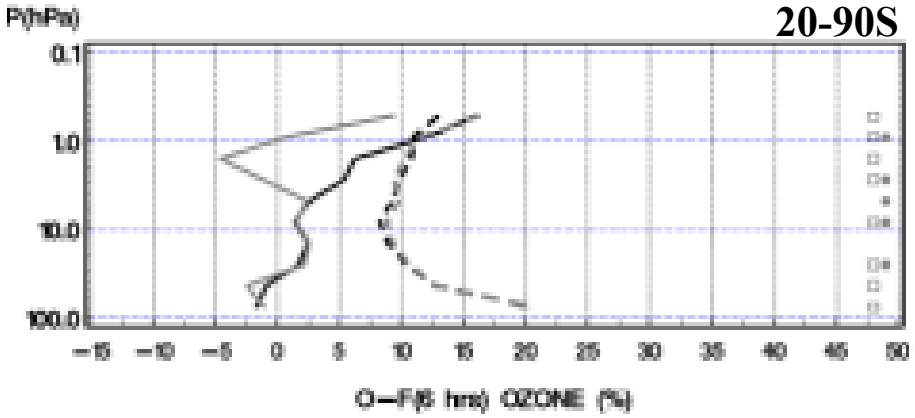
Confidence level : 95%

Squares: Mean

Dots : standard deviation







Ozone analyses against MIPAS

Chemical assimilation : MIPAS ozone

Observation – 6 hr Forecast

Period: August 2003

Black : BASCOE chemistry

Grey : LINOZ

Solid lines : Mean biases

Dashed lines : Standard deviation

Confidence level : 95%

Squares: Mean

Dots : standard deviation

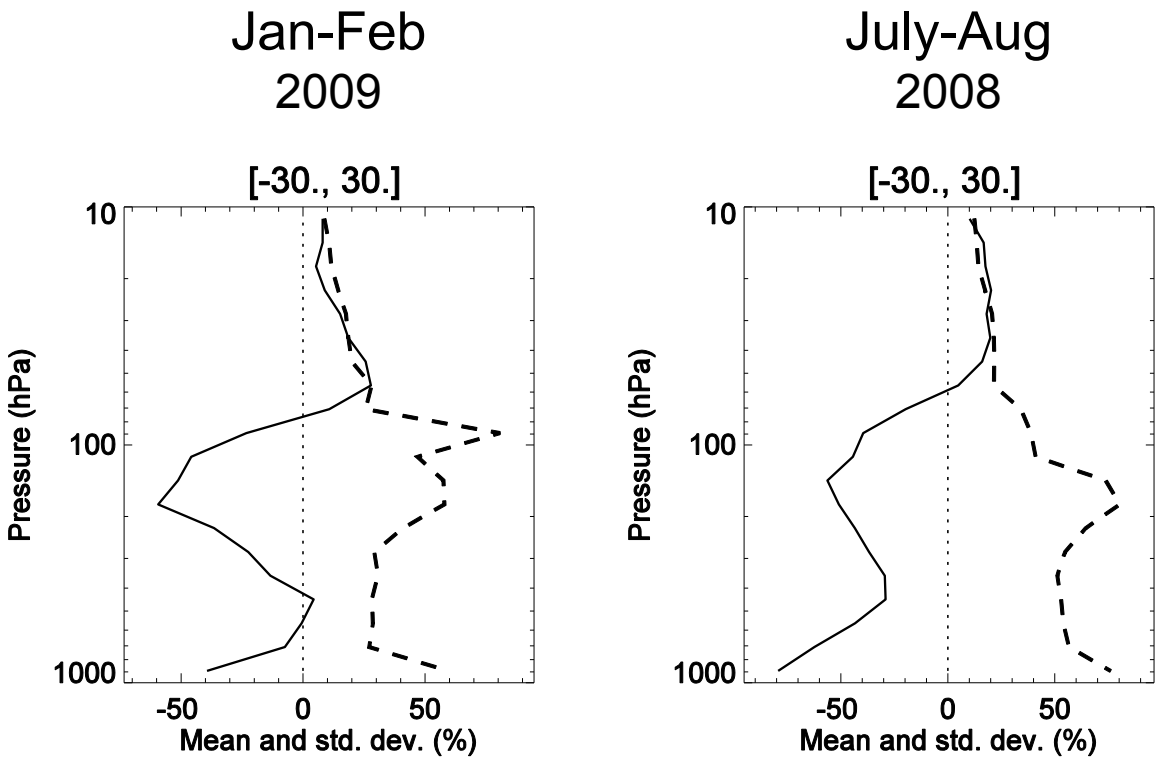
Experiments

- Control cycle: Meteorological assimilation + prognostic ozone (winter and summer cycles)
- Ozone assimilation cycles:

  (Use of 6 hrs met analyses + 3D-Var ozone assimilation)
  - SBUV/2
  - MLS
  - GOME-2
  - SBUV/2 + MLS
  - SBUV/2 + GOME-2
- Ozone interactive cycles : Meteorological and MLS ozone assimilation
- Evaluation of ozone analyses and forecast against independant ozonesonde measurements.

Verification against ozone sondes

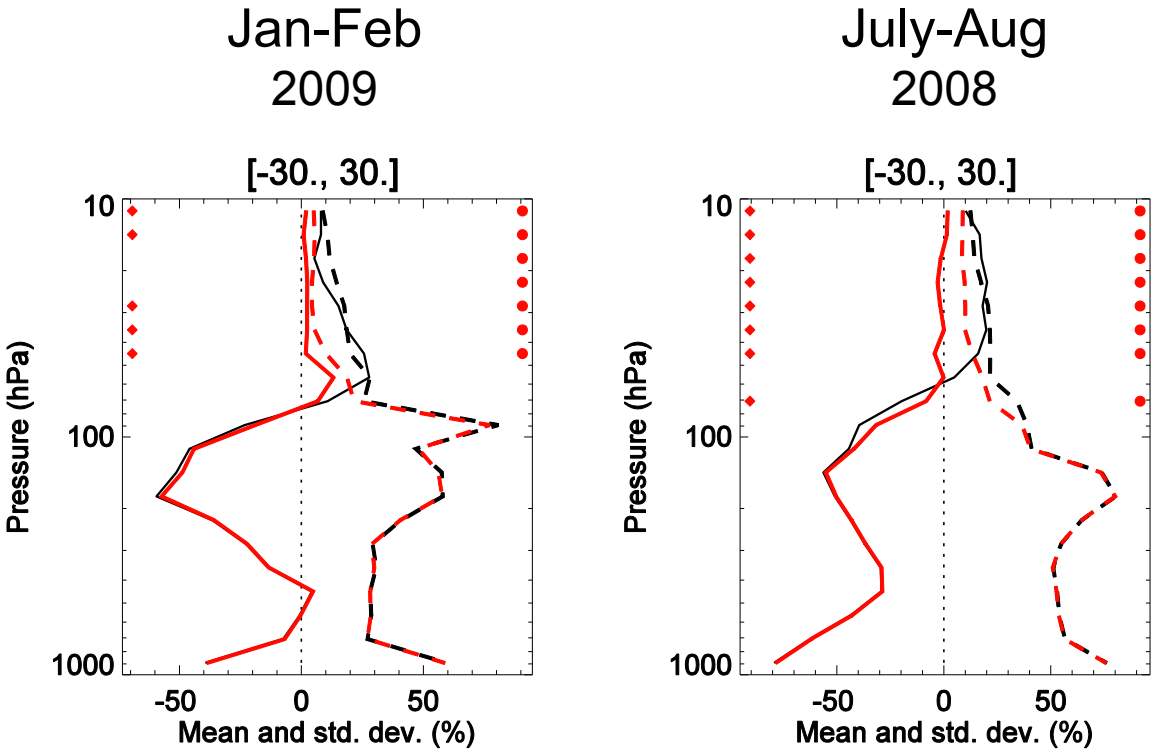
[Ozone differences (%) – Tropics]



No assimilation : Observation – LINOZ

Verification against ozone sondes

[Ozone differences (%) – Tropics]



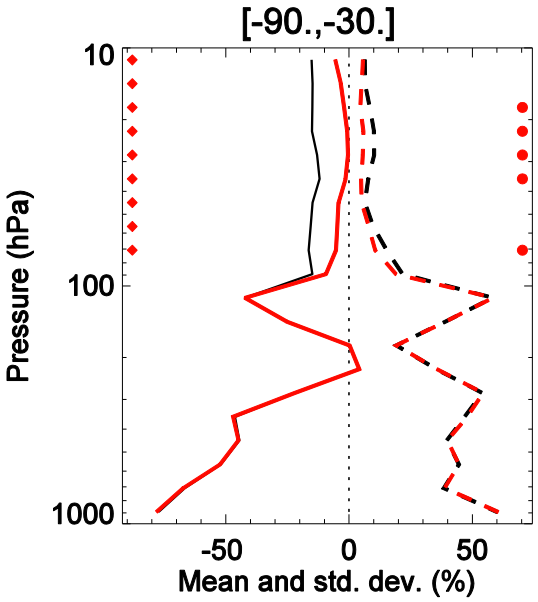
No assimilation : Observation – LINOZ

MLS assimilation : Observation – Analysis

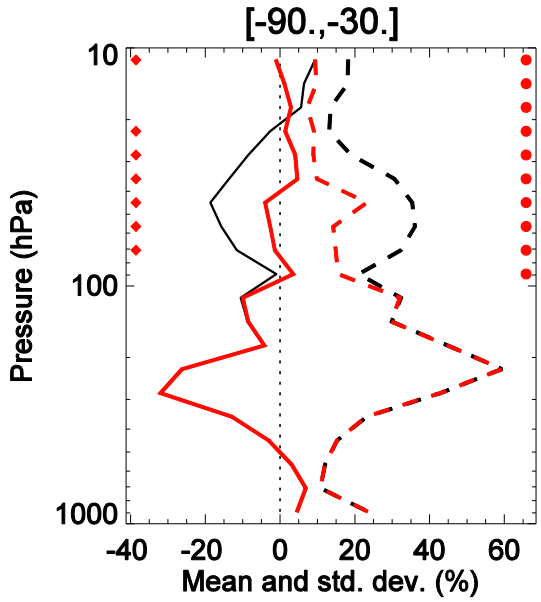
Verification against ozone sondes

[Ozone differences (%) – South Hemisphere]

Jan-Feb
2009



July-Aug
2008



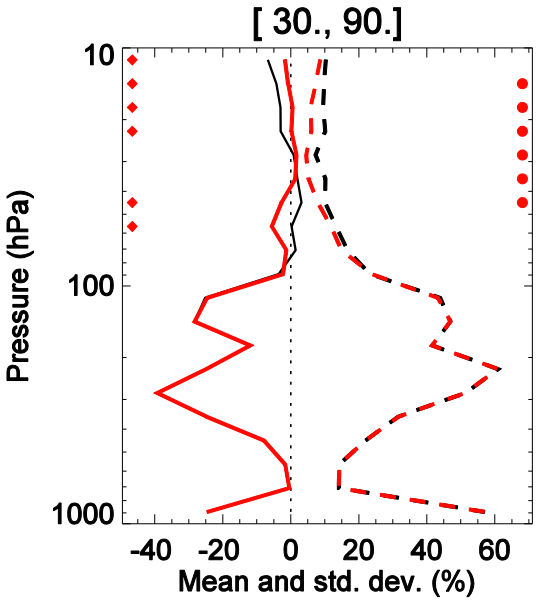
No assimilation : Observation – LINOZ

MLS assimilation : Observation – Analysis

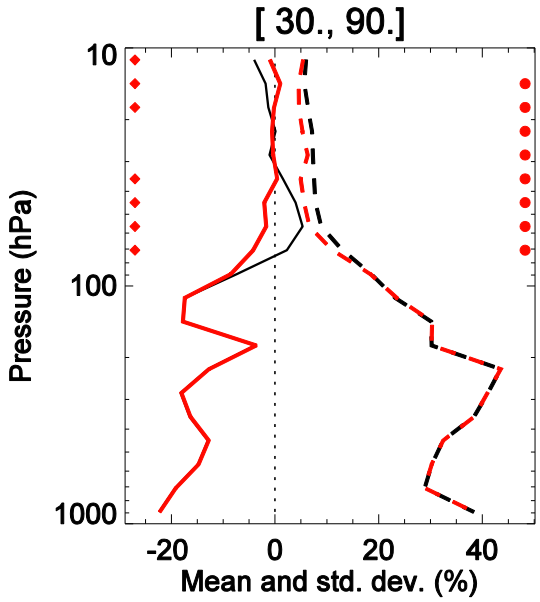
Verification against ozone sondes

[Ozone differences (%) – North Hemisphere]

Jan-Feb
2009



July-Aug
2008



No assimilation : Observation – LINOZ

MLS assimilation : Observation – Analysis

Tropospheric ozone

$$P > P^{ref} \Rightarrow \frac{\mathrm{d}\chi}{\mathrm{dt}} = \frac{(\chi - \chi^{FK})}{\tau} + \mathrm{Transport}$$

P^{ref} = 100 hPa, τ = 7 days

Tropospheric ozone

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P^{ref} = 400 hPa, τ = 2 days

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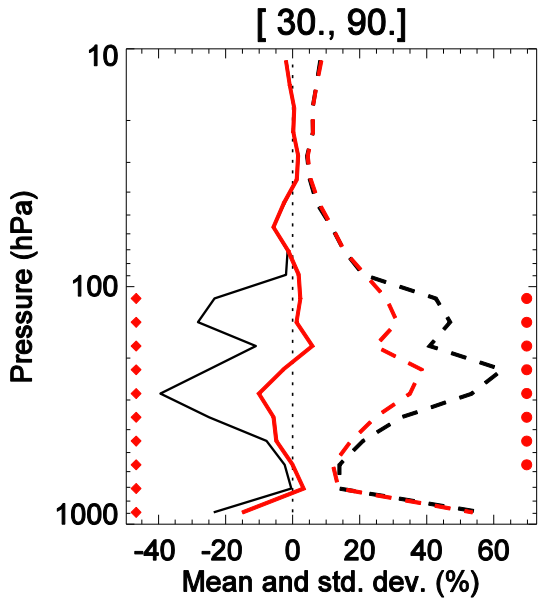

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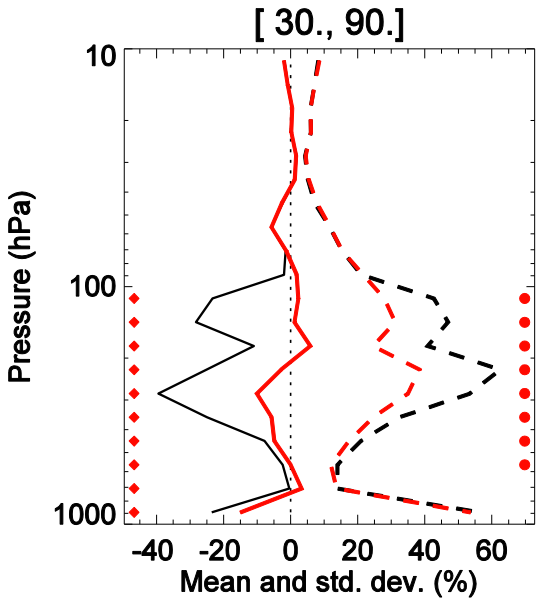
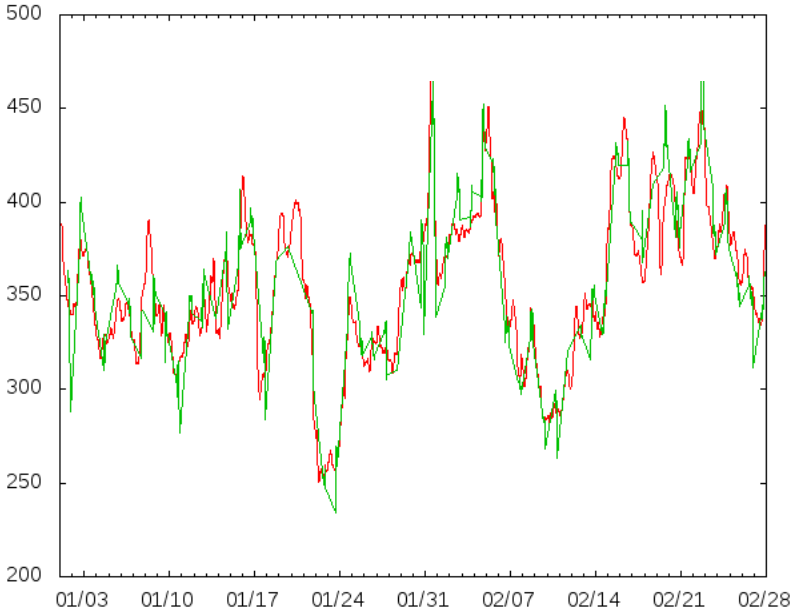
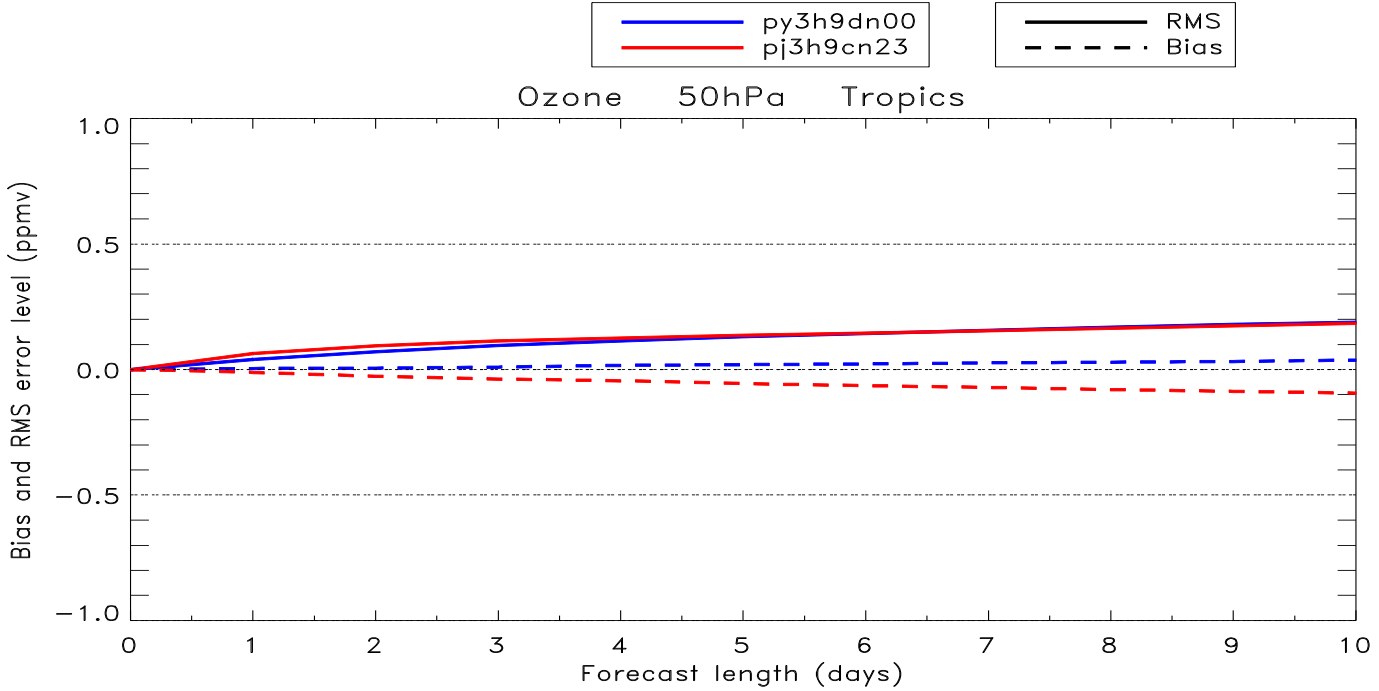
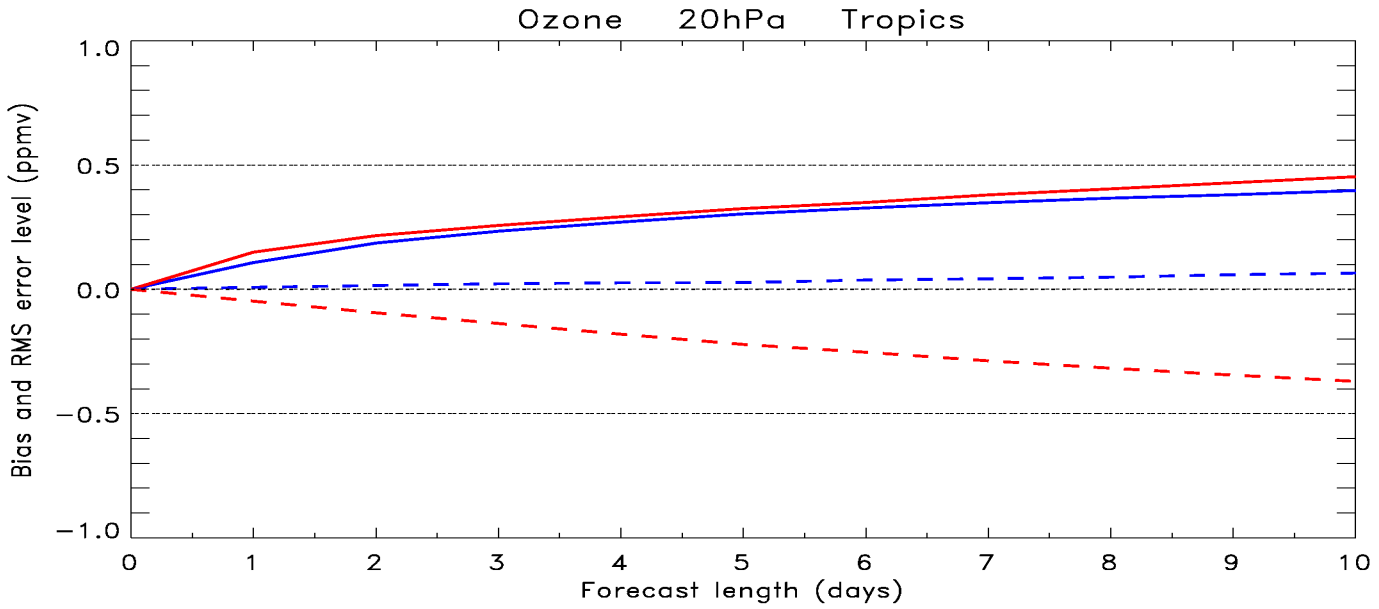


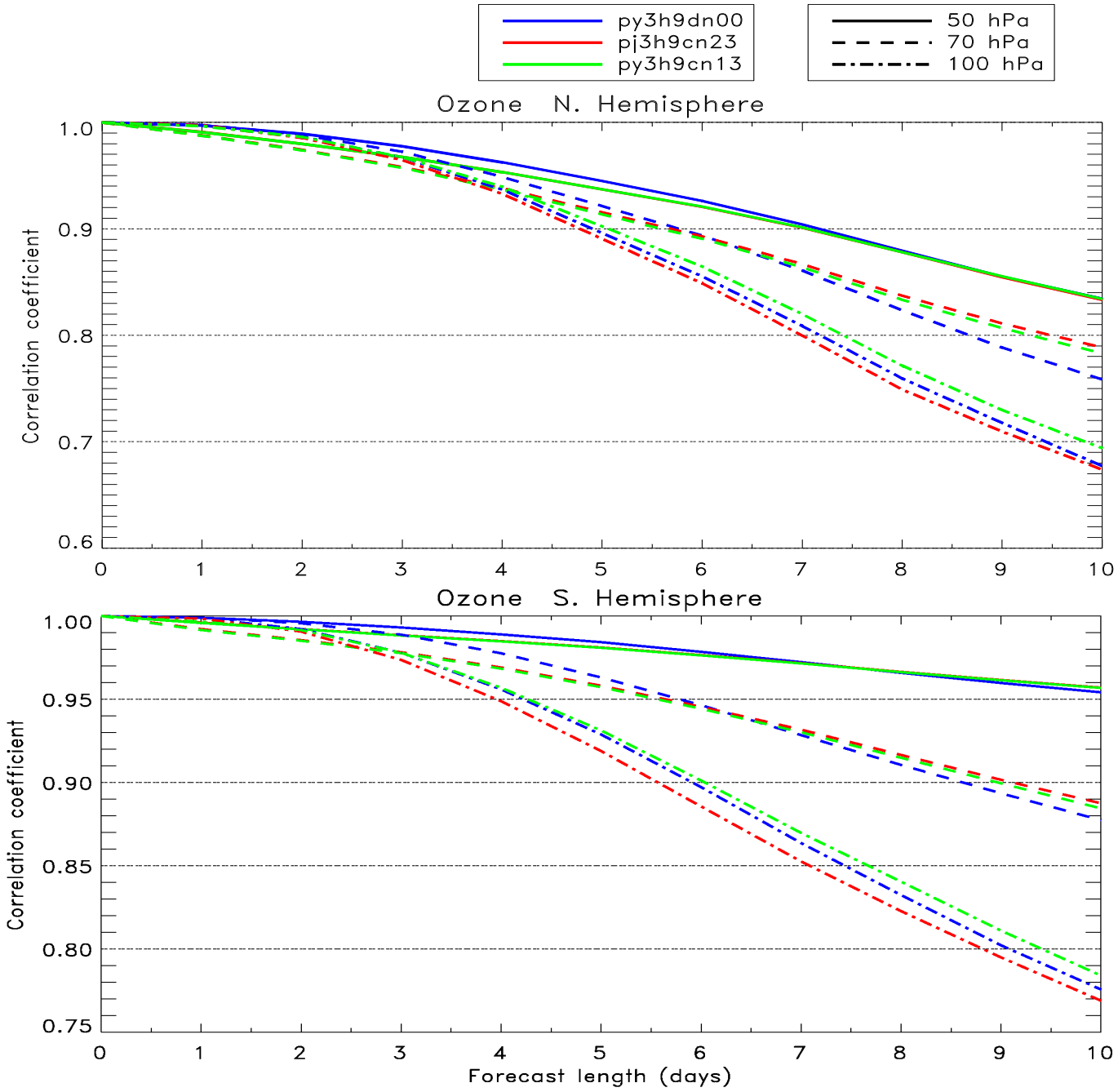
Column Ozone (DU) – Toronto

Brewer (green) vs analyses (red)



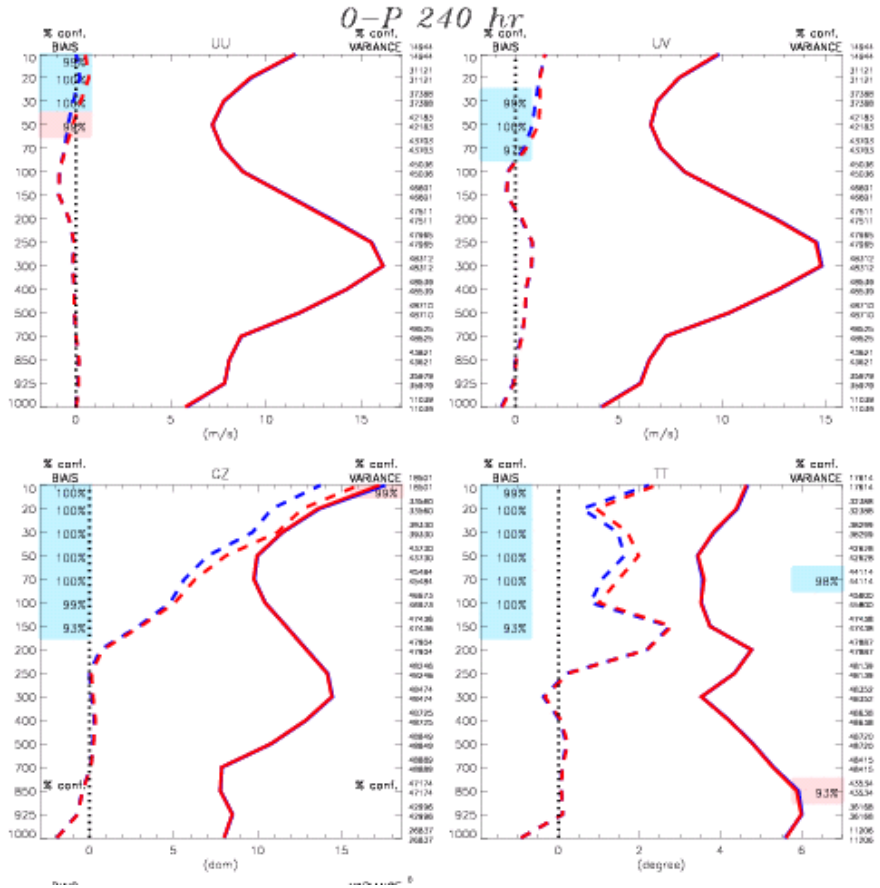

py3h9dn00
pj3h9cn23
RMS
Bias
Ozone 50hPa Tropics
Bias and RMS error level (ppmv)
1.0
0.5
0.0
−0.5
−1.0
0
1
2
3
4
5
6
7
8
9
10
Forecast length (days)


Ozone 20hPa Tropics
Bias and RMS error level (ppmv)
1.0
0.5
0.0
−0.5
−1.0
0
1
2
3
4
5
6
7
8
9
10
Forecast length (days)


py3h9dn00
pj3h9cn23
py3h9cn13
50 hPa
70 hPa
100 hPa
Ozone N. Hemisphere
Correlation coefficient
1.0
0.9
0.8
0.7
0.6
0
1
2
3
4
5
6
7
8
9
10
Ozone S. Hemisphere
Correlation coefficient
1.00
0.95
0.90
0.85
0.80
0.75
Forecast length (days)

O-P 240hr

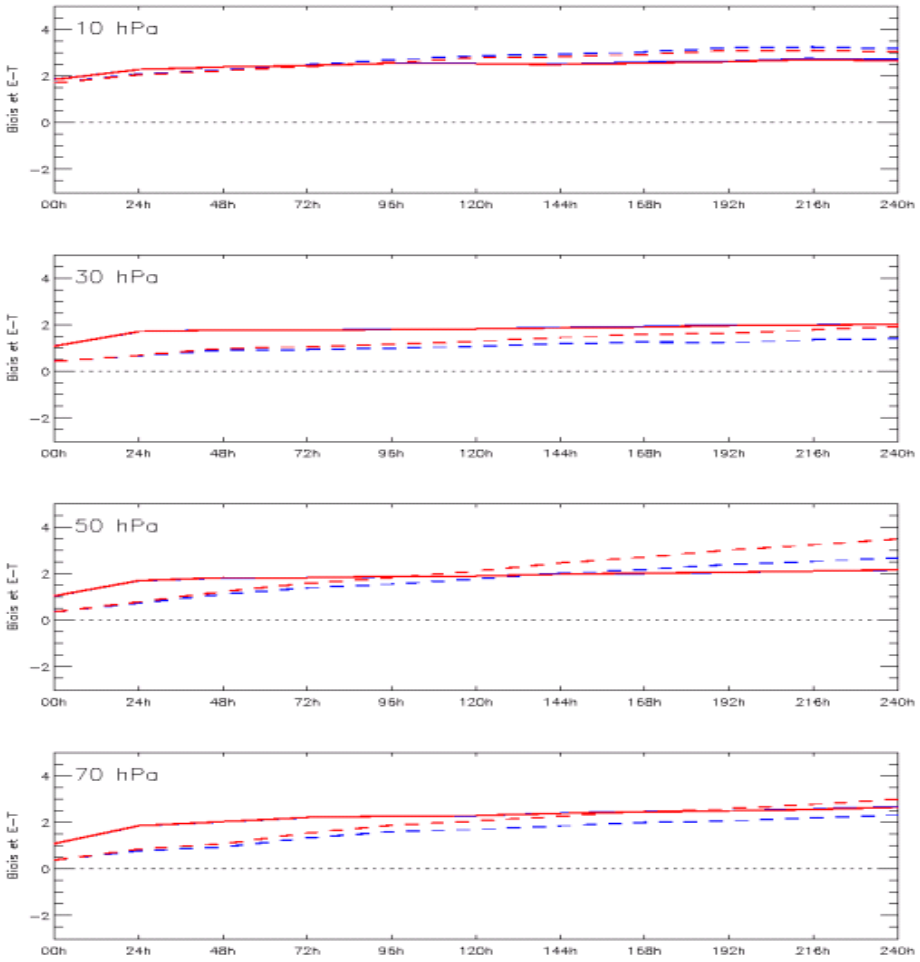
Jan-Feb 2009 – Global mean



Non-interactive cycle

Ozone interactive cycle

O-P – Temperature - Jan-Feb 2009
Lower Stratosphere [30S-30N]



Non-interactive cycle

Ozone interactive cycle

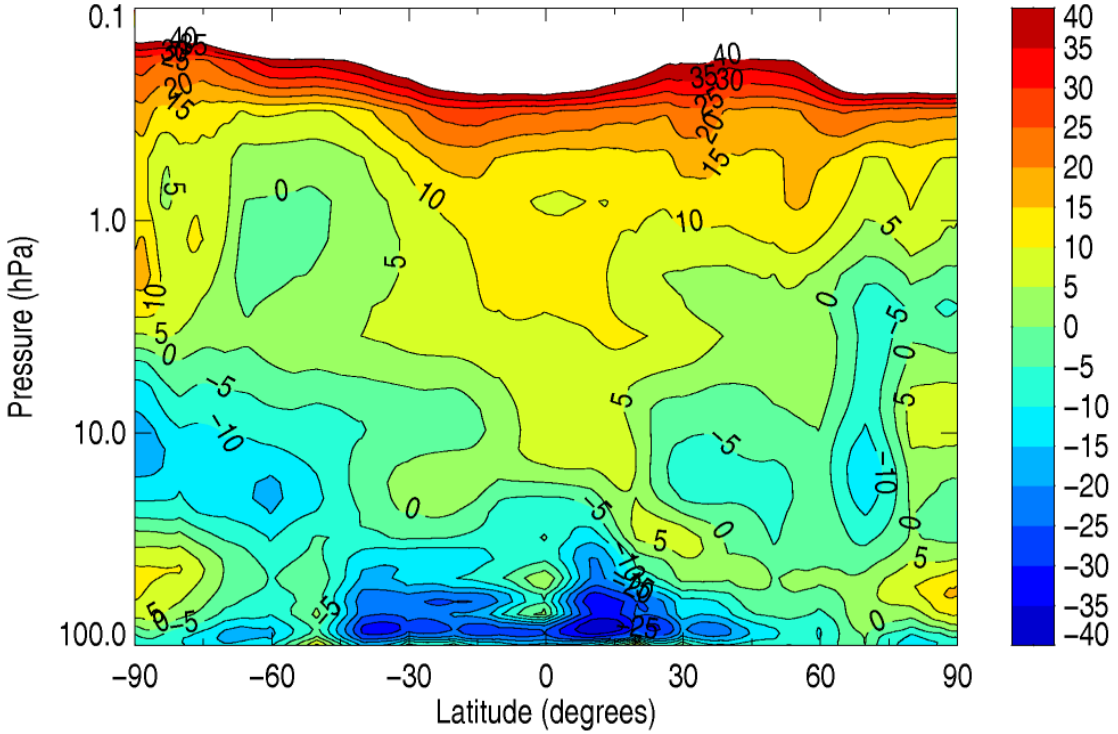
Conclusions and development

- Ozone analyses in good agreement with independant measurements (ozone sondes, Brewer spectrometers, HALOE,MIPAS,MLS).
- Ozone is a useful diagnostic to characterize model errors
- Indication of strong vertical ascent and weak mixing barriers in the UTLS.
- Ozone interactive forecasts amplifies an existing cold bias in the model in the lower stratosphere.
- Both effects need to be re-visited with the next version of the NWP model
- Impact of model resolution on transport and mixing
- Implementation of heterogeneous chemistry in the LINOZ module.

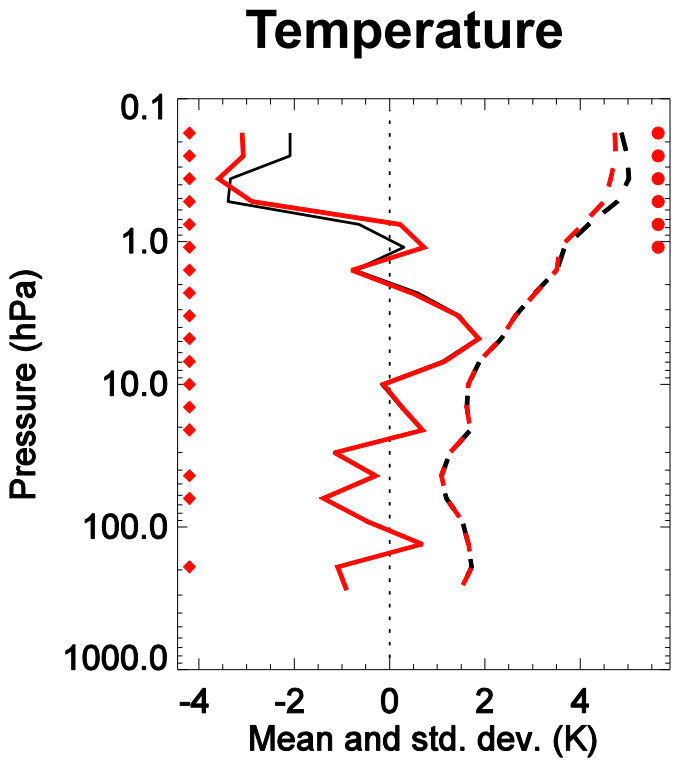
Impact of ozone on temperature (through model radiation)

Ozone difference (%) - January

Analysis(MLS) – GEM Climatology (F-K)



O-P 6hr
Against MLS temperature
Jan-Feb 2009 – Global mean



Non-interactive cycle

(Fortuin & Kelder)

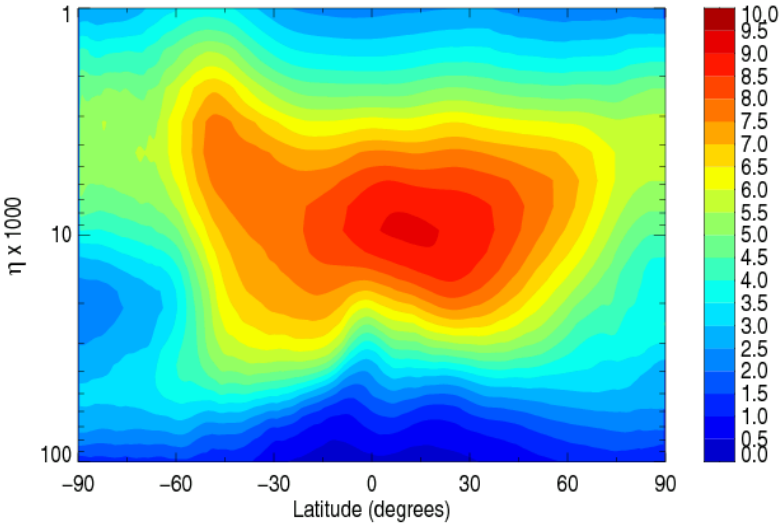
Ozone interactive cycle

LInoz + MLS ozone assimilation

Assessment of ozone analyses/forecasts

- Tropical ozone perturbation (ozone wiggle) on zonal mean (31 August 2008)

Without ozone assimilation



With MLS ozone assim.