Analysis and Medium range forecasting of MA constituents using a coupled chemistry-dynamics DAS

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Jean de Grandpré, Chris McLinden, Richard Ménard, Simon Chabrillat, Yves Rochon, Cécilien Charette, Alain Robichaud and Yan Yang

§ Atmospheric Science & Technology Directorate,
Environment Canada, Canada

§ Belgisch Instituut voor Ruimte-Aëronomie,
Institut d'Aéronomie de Belgique (BIRA-IASB), Belgium

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Issue : What is the impact of assimilating ozone measurements on temperature predictability?

Outline

- **Ozone predictability**
- **MSC Data Assimilation System**
- **Ozone and temperature (analyses & forecasts)**
- **Conclusions**

Prognostic ozone

$$\frac{O_3(t+\Delta t)-O_3(t)}{\Delta t}=-\vec{V}\bullet\vec{\nabla}O_3+P(Q)-L(Q)O_3$$

$Q\ [q_1, q_2, \ldots, q_n]$: vector of n species mixing ratios

O_3 : Ozone mixing ratio

V : wind vector

$P(Q)$: photochemical production

$L(Q)$: photochemical sink

Prognostic ozone

$$\frac{O_3(t+\Delta t)-O_3(t)}{\Delta t} = -\vec{V}\bullet\vec{\nabla}O_3 + P(Q) - L(Q)O_3$$

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→ ***Maximum ozone predictability occus in the lower stratosphere***

- *Long radiative timescale (τ_{rad} ~ months)*
- $\tau_{rad} < \tau_{chem}$

GEM-Strato

Based on the Canadian operational Global Environmental Multiscale model extended to the stratosphere (Côté et al., 1998).

- Semi-Lagrangian dynamical core
- Lid at 0.1 hPa (80 levels) & (1.5ºx1.5º)
- Correlated-K radiation scheme (Li and Barker, 2005)
  - Ozone climatology
    - Fortuin & Kelder (1998) merged with UARS above 0.5 hPa
  - Prognostic ozone
    - BASCOE CTM (57 species) (Daerden et al., 2007)
    - LINOZ (McLinden et al. , 2000)

$$\frac{dq}{dt} = (P-L)\big|^{o} + \left.\frac{\partial(P-L)}{\partial q}\right|_{o}(q-q^{o}) + \left.\frac{\partial(P-L)}{\partial T}\right|_{o}(T-T^{o}) + \left.\frac{\partial(P-L)}{\partial c_{o_3}}\right|_{o}(c-c^{o}_{o_3})$$

CMC Assimilation System

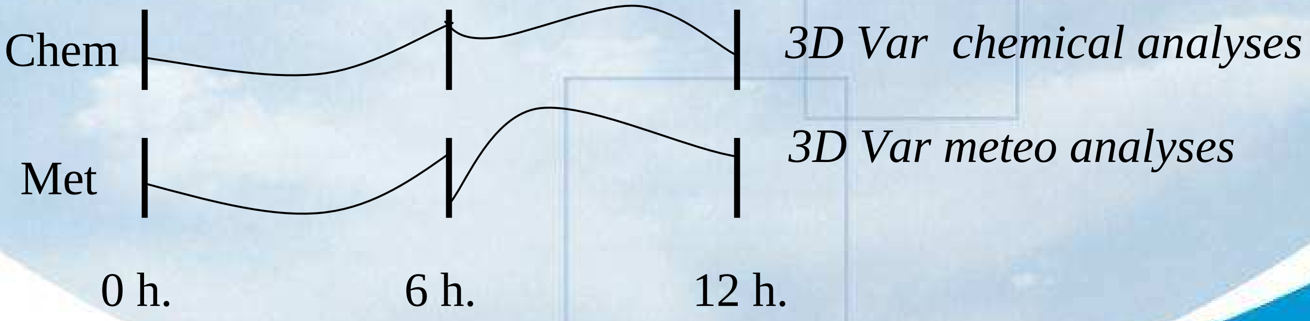
- 3D-Var FGAT (Gauthier et al., 1999)
- Use conventional meteorological observations (radiosondes, surface observations, aircraft winds, AMSU radiances)
- Chemical observations from MIPAS (T, O_3 , CH_4, N_2O, HNO_3, NO_2)
  - Observation and background error statistics:
    - Univariate background error covariances
    - Characterization of the chemistry component done with the Hollingsworth-Lönnberg method
- MIPAS temperatures used as reference for the bias correction of AMSU-a stratospheric channels

Assimilation cycles

- 3D-var FGAT experiments (Aug 11th – Nov 13th 2003) & 15 days forecast (interactive & non-interactive):

  1) GEM-BASCOE
  2) GEM-LINOZ

- On-line approach:



Chem

Met

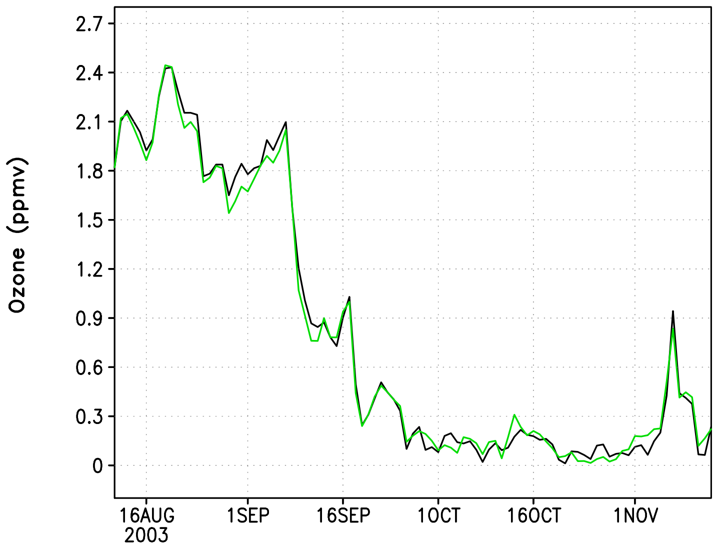
3D Var chemical analyses

3D Var meteo analyses

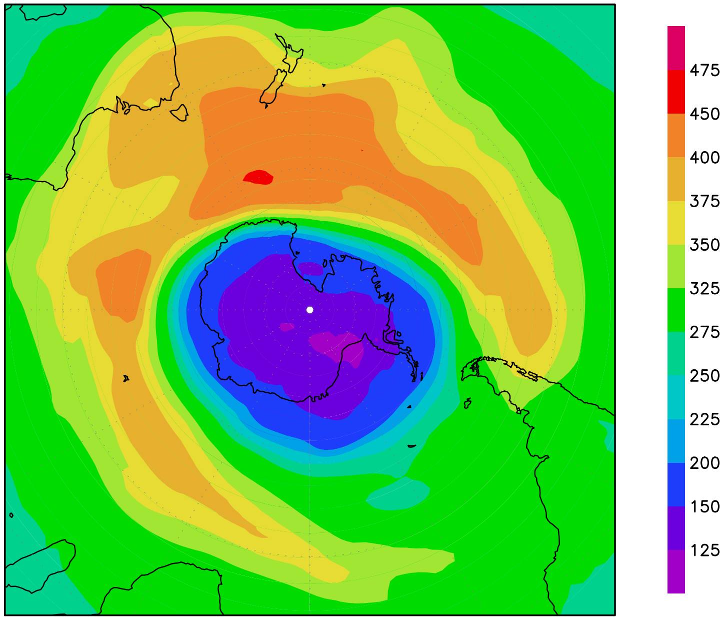
0 h.

6 h.

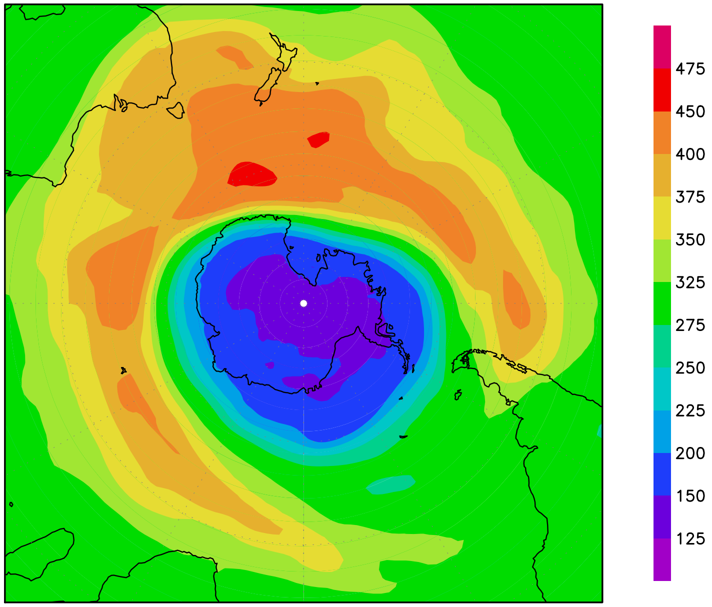
12 h.



South Pole – 70 hPa

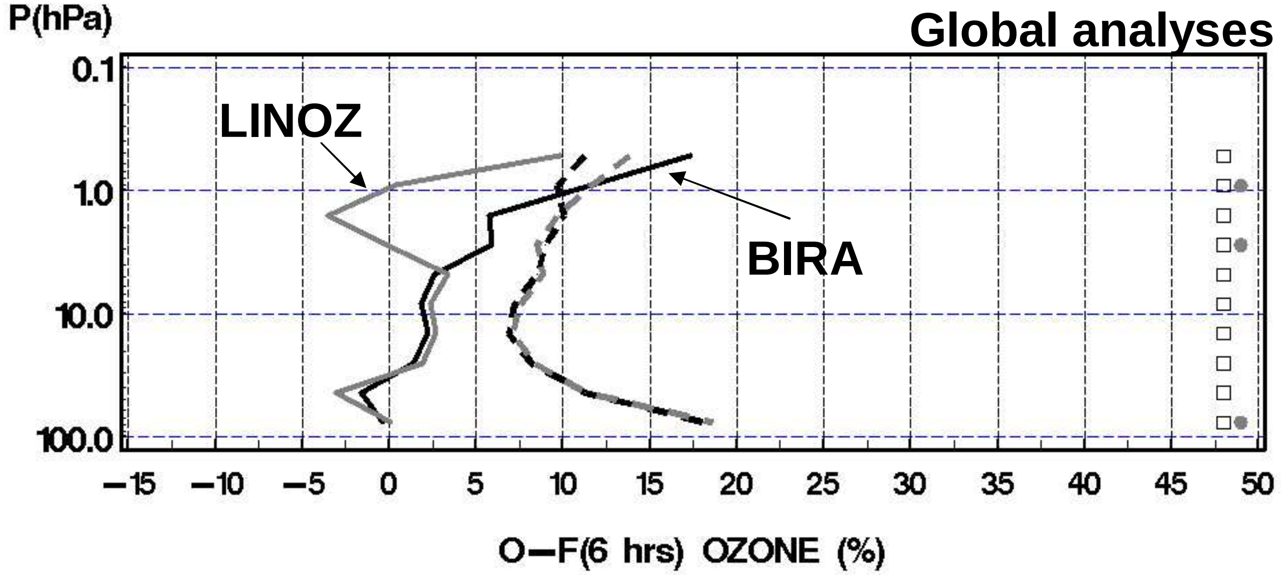


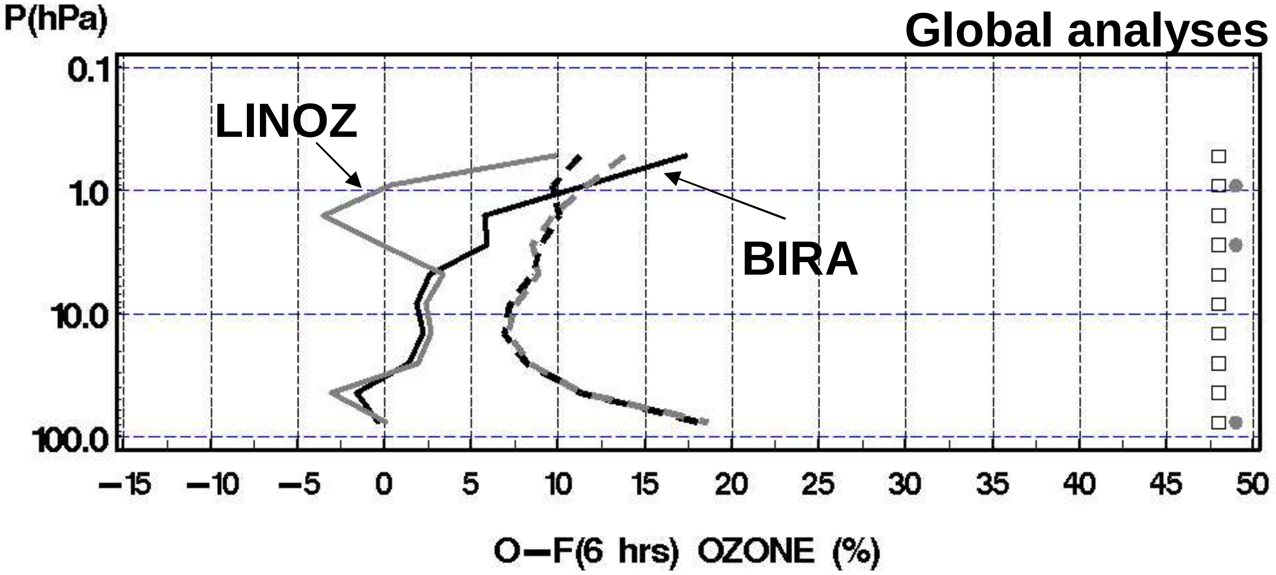
Column ozone (DU)
October 3, 2003 [GEM–BIRA]

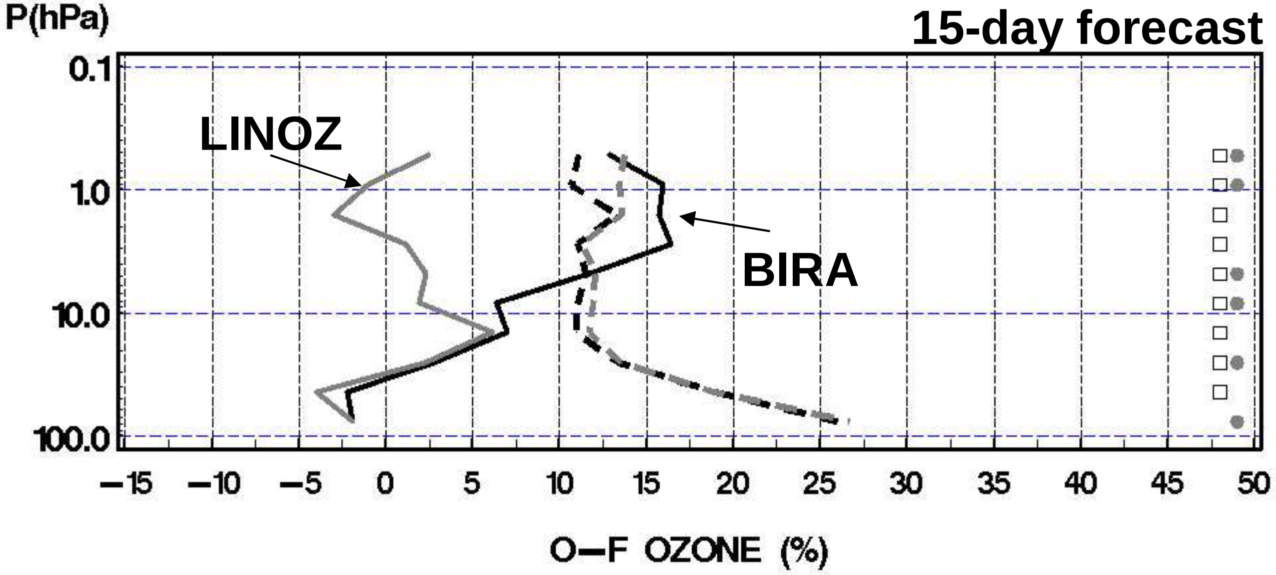


Column ozone (DU)
October 3, 2003 [GEM–LINOZ]

Global analyses



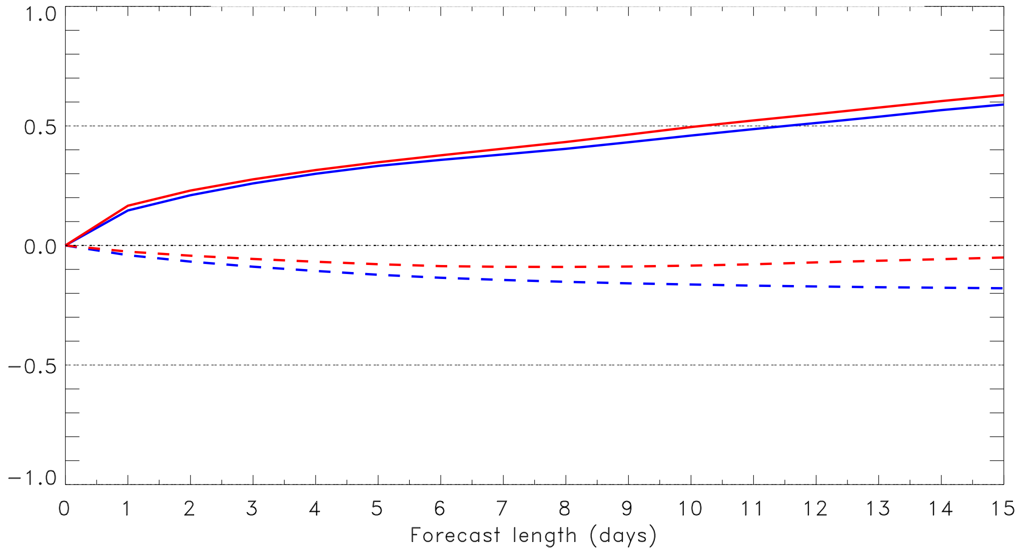

P(hPa)
Global analyses
0.1
1.0
10.0
100.0
LINOZ
BIRA
−15
−10
−5
0
5
10
15
20
25
30
35
40
45
50
O−F(6 hrs) OZONE (%)


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

—— **RMSE**

----- **BIAS**

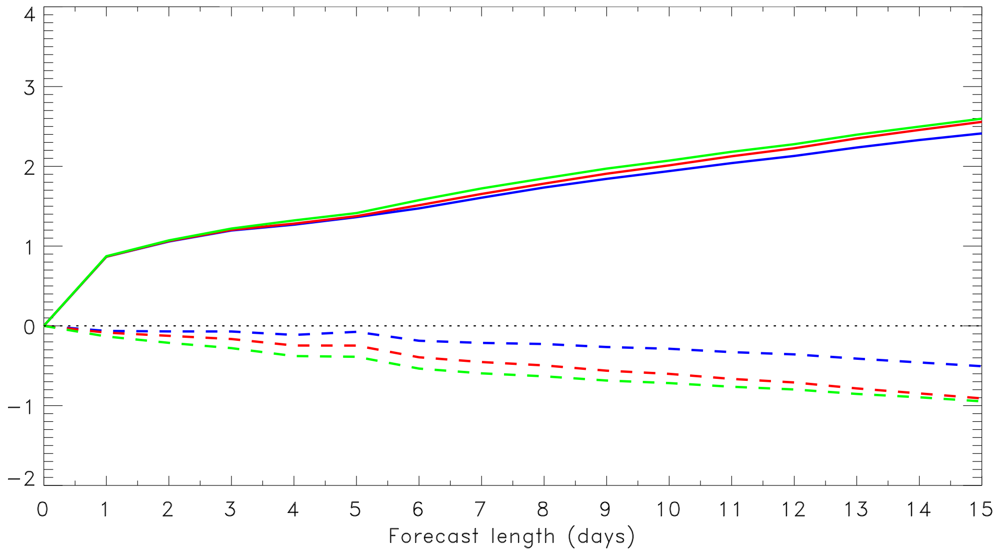
--- **BIRA** --- **LINOZ** ---- **FK**



Ozone (ppmv)

10 hPa

(NH)



Temperature (K)

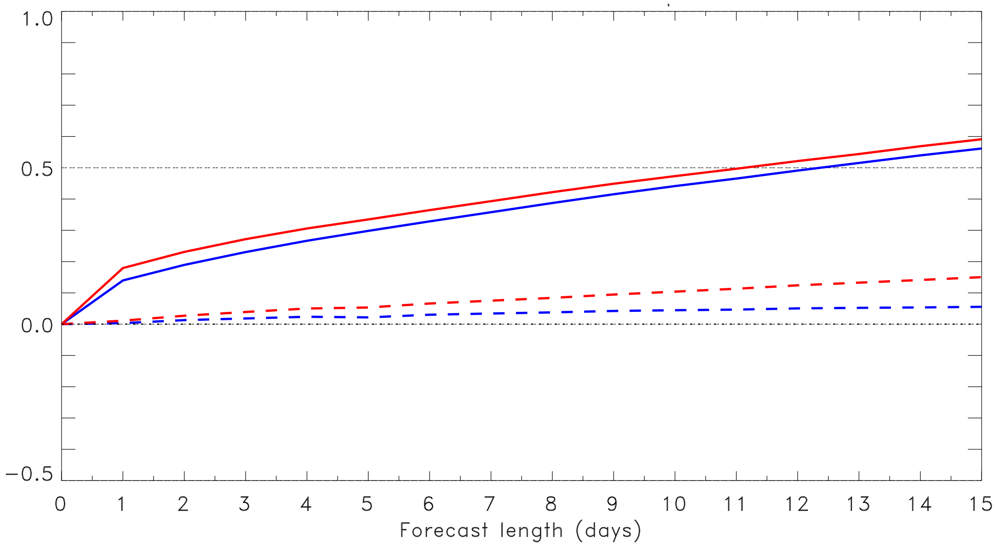
10 hPa

(NH)

—— **RMSE**

----- **BIAS**

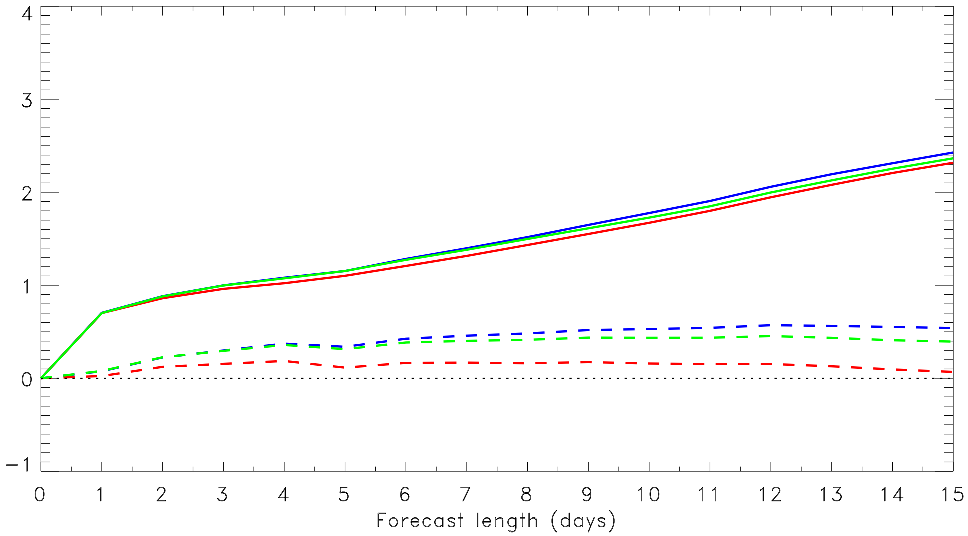
--- **BIRA** --- **LINOZ** ---- **FK**



Ozone (ppmv)

20 hPa

(NH)



Temperature (K)

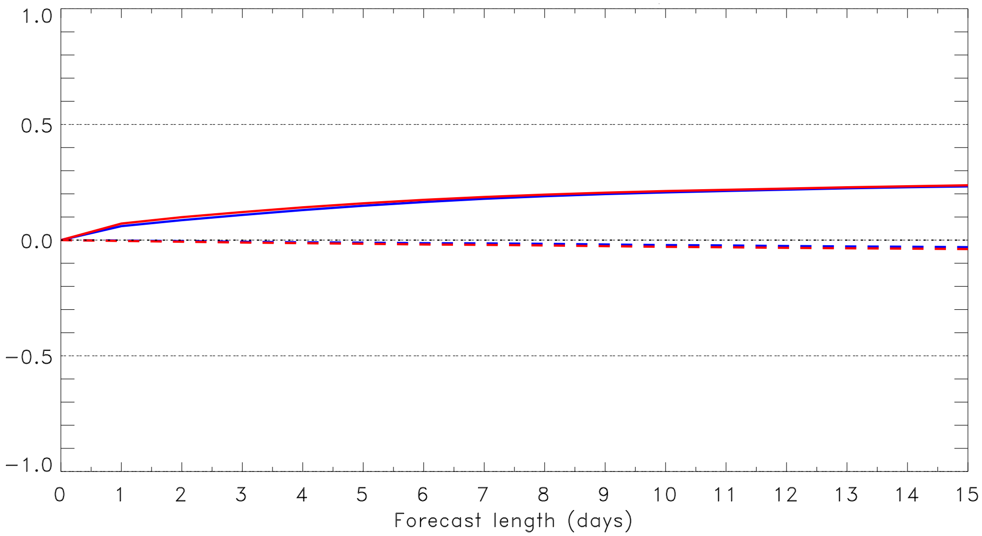
20 hPa

(NH)

—— RMSE

----- BIAS

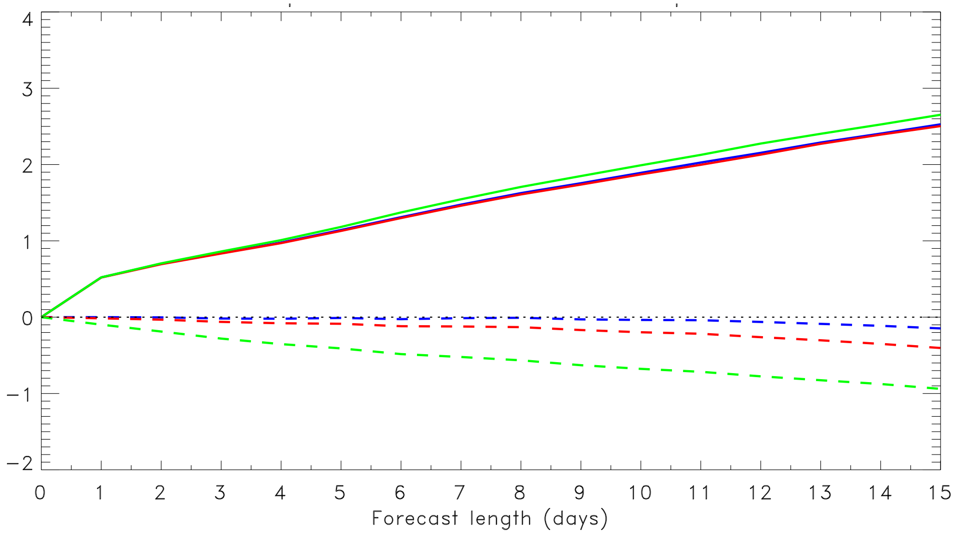
--- BIRA --- LINOZ ---- FK



Ozone (ppmv)

50 hPa

(NH)



Temperature (K)

50 hPa

(NH)

—— RMSE

----- BIAS

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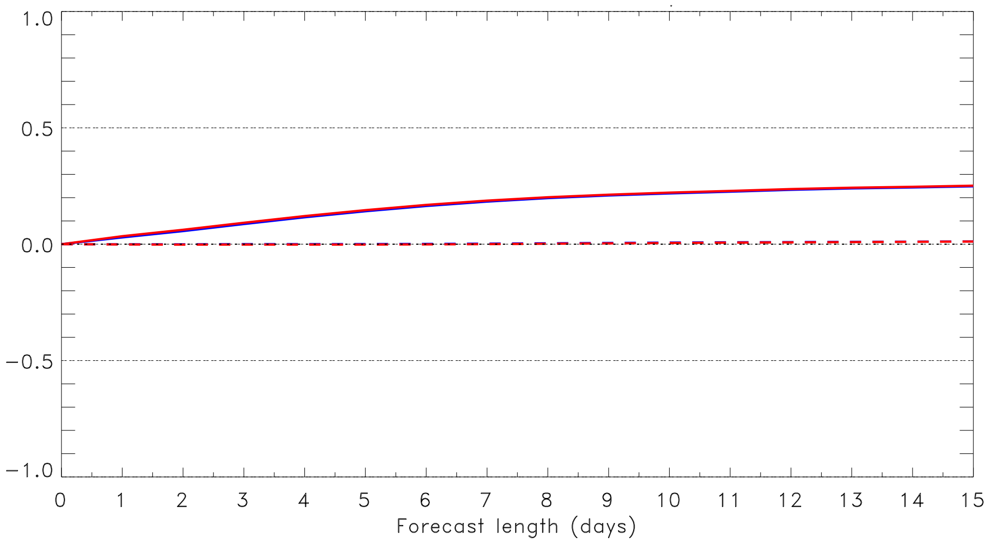
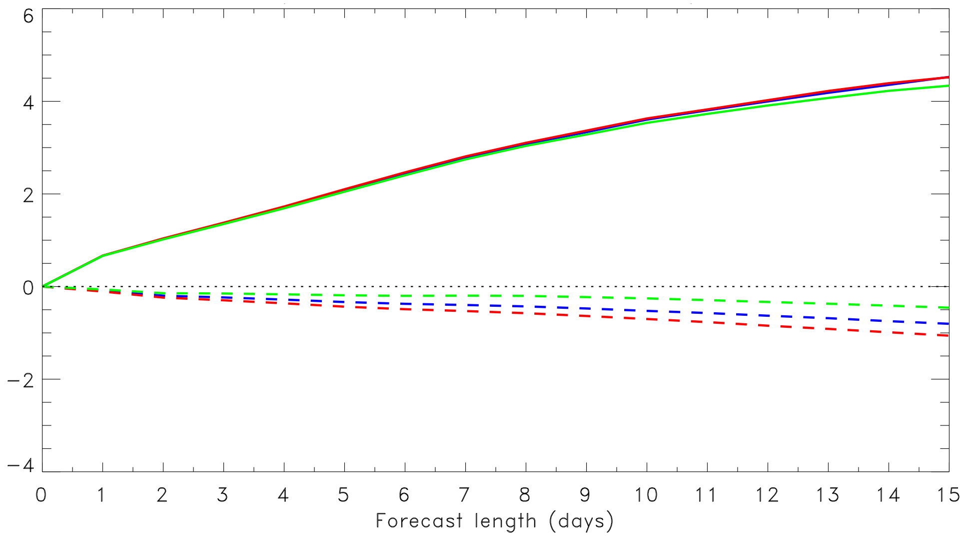


Ozone (ppmv)

100 hPa

(NH)



Temperature (K)

100 hPa

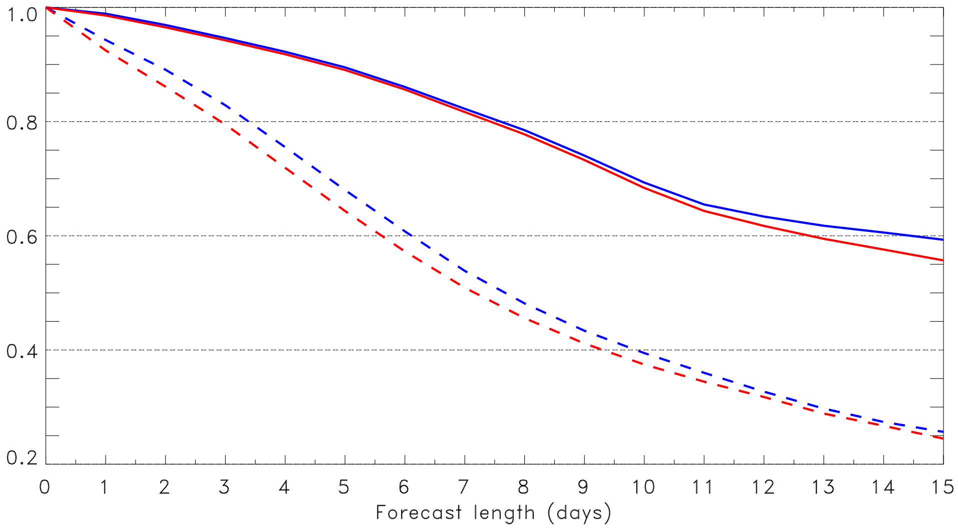
(NH)

—— **SH**

----- **NH**

--- **BIRA** --- **LINOZ** ---- **FK**

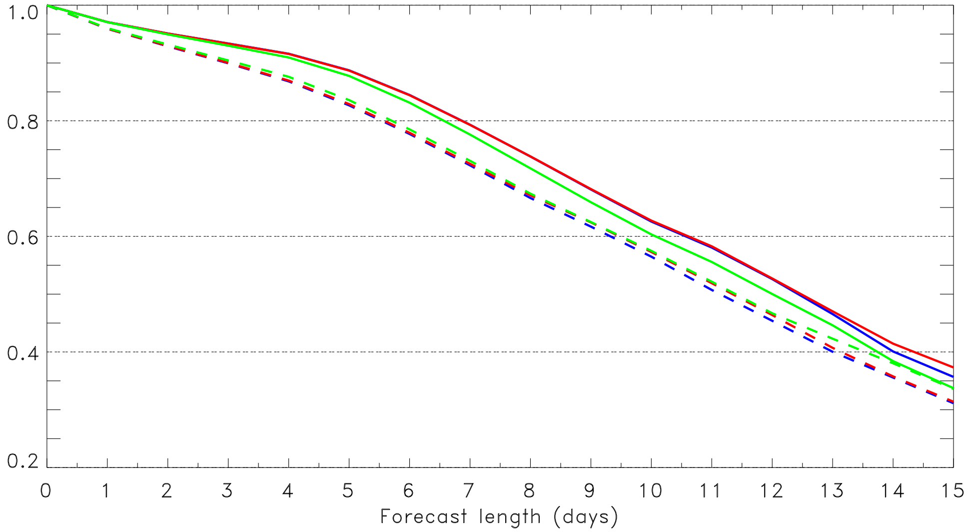
AC



Ozone

50 hPa

AC



Temperature

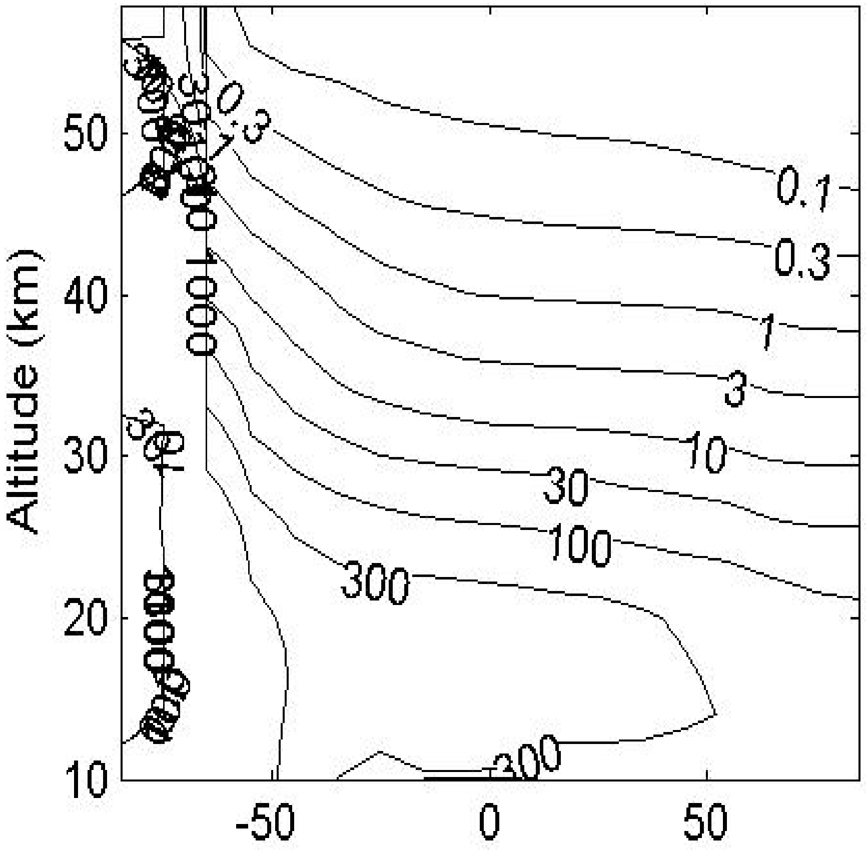
50 hPa

Conclusions

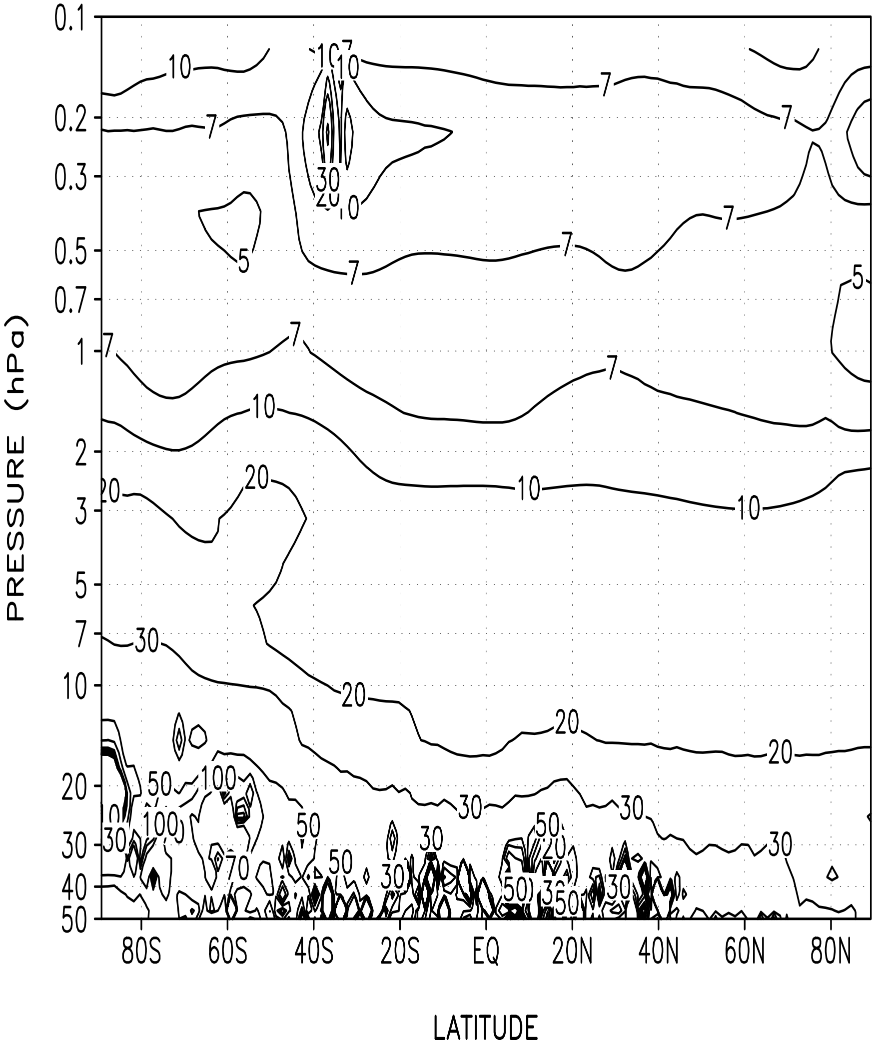
- The temperature predictability in the middle and lower stratosphere has improved with the use of ozone analyses for the computation of heating rates.
- In the middle stratosphere (~ 10 hPa) the impact of using different photochemistry modules is neutral. The comprehensive scheme better resolve ozone-temperature interactions but develop stronger ozone biases. It requires a better constraint of the ozone budget.
- In the lower stratosphere (~50 hPa) both approaches have a positive impact on temperature. The ozone predictability in the region mainly depends on the quality of ozone analyses in terms of vertical resolution.
- In the lowermost stratosphere (below 100 hPa) both approaches have a negative impact on temperature which is associated to the representation of ozone in the upper troposphere region.

Radiative and photochemical timescales

τ_{O_3}(days) - August



τ_{rad} (days) - August



BASCOE CTM

- 57 chemical species, all advected (S-L)
- O_x, HO_x, NO_x, ClO_x, BrO_x and few hydrocarbons
- Source species: N_2O, CH_4, H_2O, CFCs, HCFCs and Halons
- 142 gas-phase reactions; 7 heterogeneous reactions
- 52 photodissociation reactions, *J* interp from tables
- Photochemical rates are taken from JPL-2002
- Solver generated by KPP (Sandu and Sander, ACP, 2006)
- Numerical method: 3rd – order Rosenbrock
- 45-min timesteps divided into sub-timesteps
  (can be as short as 1 μs)

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