Underestimation of ozone in the BASCOE system

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SPARC-DA
October 16, 2015 Paris, France

Outline

Ozone deficit

- Long standing problem (Prater 1981 - Siskind 2013)
- Chemistry Transport Models (CTMs) usually underestimate ozone by 20-35%
- Upper Stratosphere Lower Mesosphere (USLM)

Methods used to solve ozone deficit problem so far:

To modify chemical schemes, mainly reaction rate constants

General Motivation

- Photochemistry plays an important role in USLM O_3 state
- Chemistry is straightforward
- O_3 is sensible to temperature changes
- O_3 is an indicator of atmospheric response to solar UV-radiation
- Diurnal cycle

Outline

BASCOE

Belgian Assimilation System for Chemical ObsErvations

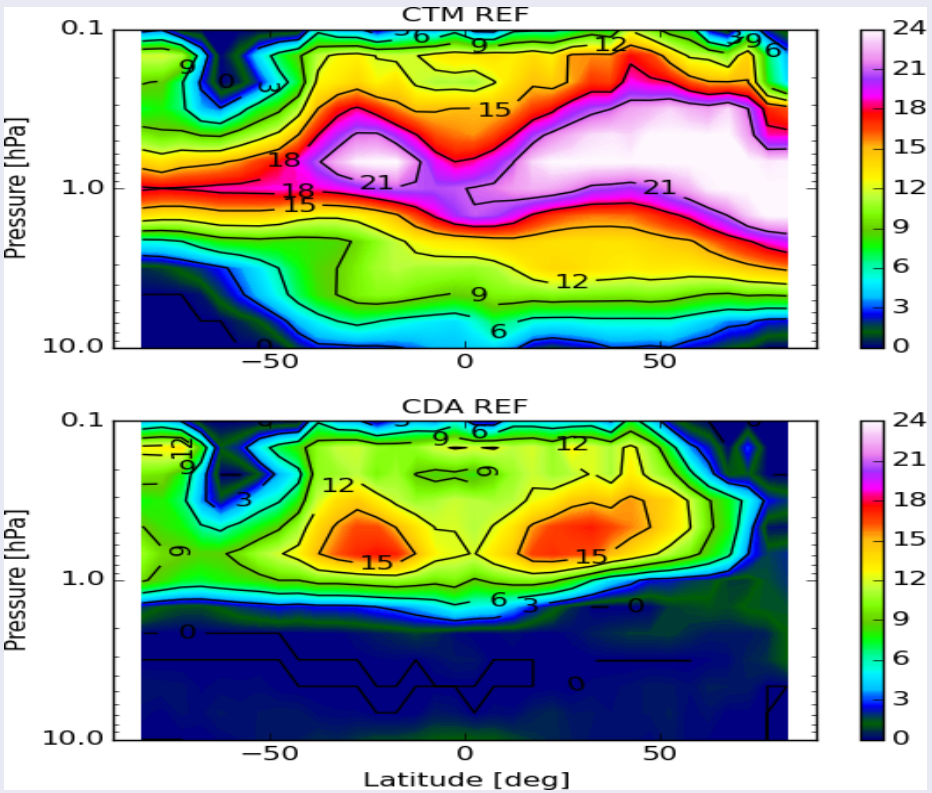
- Near real-time analyses for MACC
- 3D chemical transport model (advection + chemistry):
  - full set of stratospheric chemistry, 58 species
  - 207 gas-phase, photodissociation, and heterogeneous reactions
  - stratospheric sulfate aerosols and Polar Stratospheric Clouds (PSCs)
  - meteorological forcing using global atmospheric reanalyses
- Chemical observations like Aura MLS / MIPAS vertical satellite profiles
- Data Assimilation methods: 4D-Var and EnKF

Ozone underestimation in BASCOE

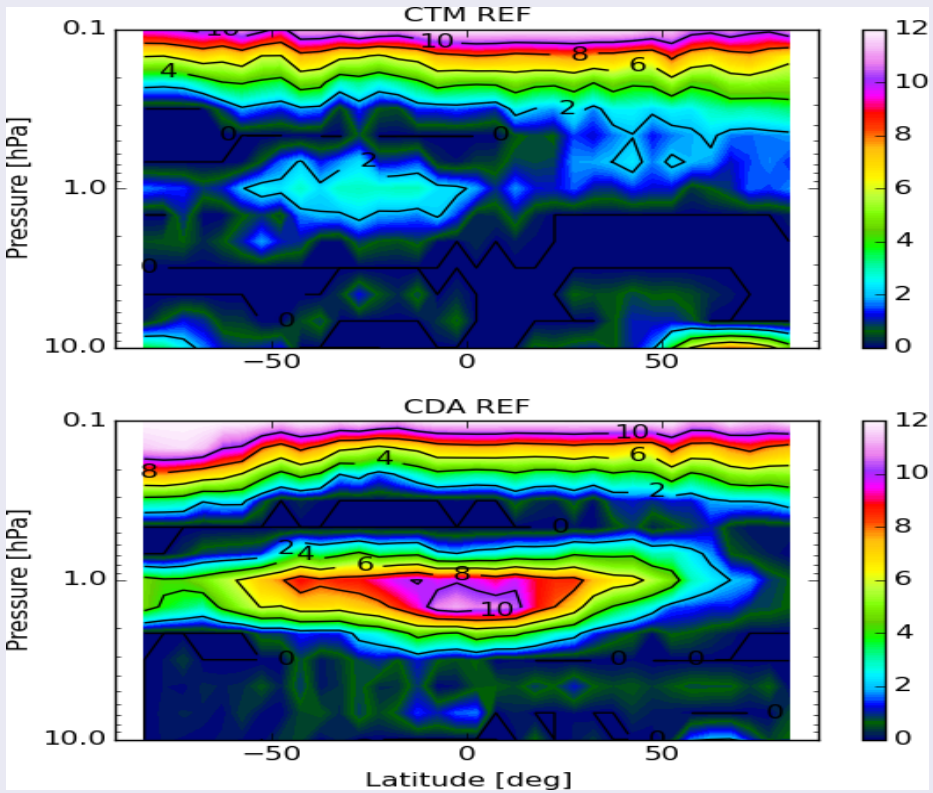
Model (CTM) vs Data Assimilation (CDA)

BASCOE REF: the presence of O_3 bias prevents us from assimilating O_3 above 2hPa because it destroys chlorine

O_3 NMB in [%]



HCl NMB in [%]



Normalized Mean Bias (NMB) in [%] w.r.t MLS for Jan. - Feb. 2008

Outline

Solar radiation

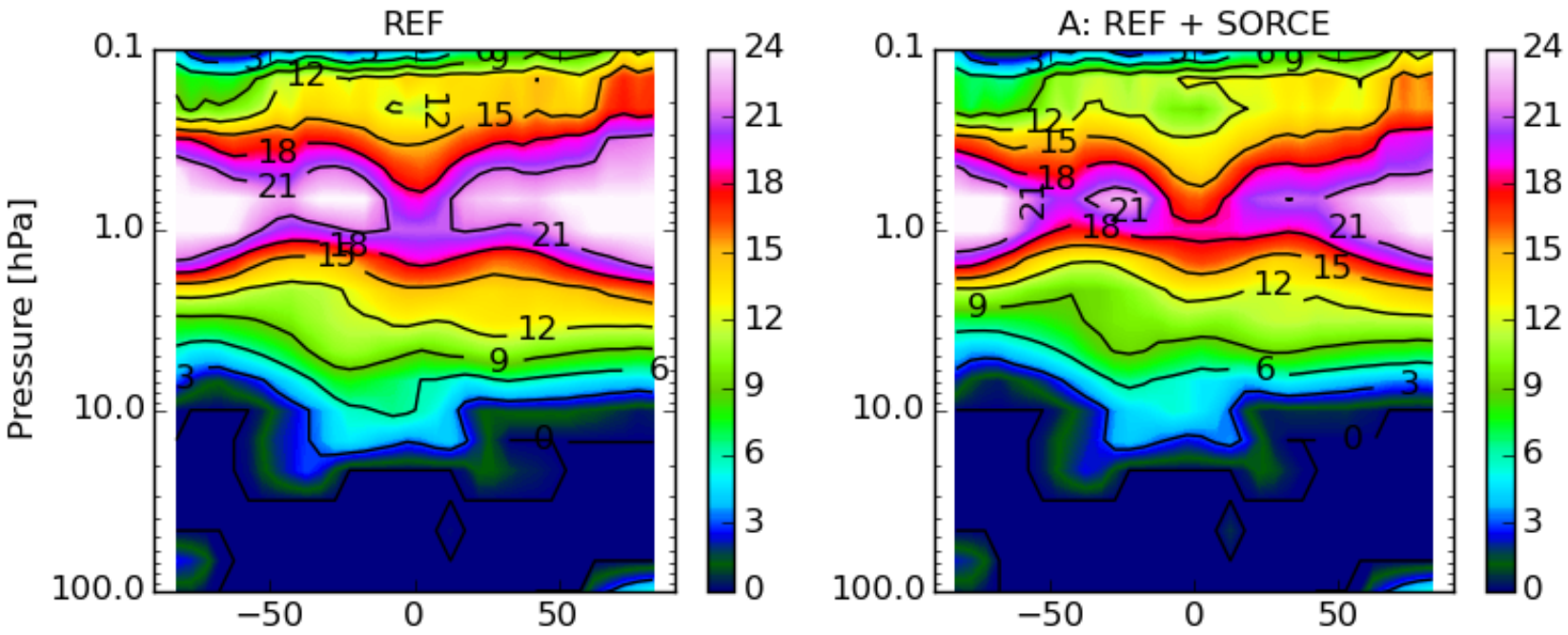
- REF model: BASCOE near-real time model uses an obsolete spectrum from Lean et al. 1997
  - constant in time
  - corresponds to the minimum of solar activity
- Solar Radiation and Climate Experiment (SORCE) daily data
  - NASA-sponsored satellite mission
  - Incoming x-ray, ultraviolet, visible, near-infrared, and total solar radiation

Modification of the BASCOE model

Apply the SORCE forcing on a daily basis

SORCE impact on ozone

Normalized mean bias (NMB) in [%] w.r.t MLS



Using SORCE instead of obsolete solar radiation spectrum leads to 3% gain.

Outline

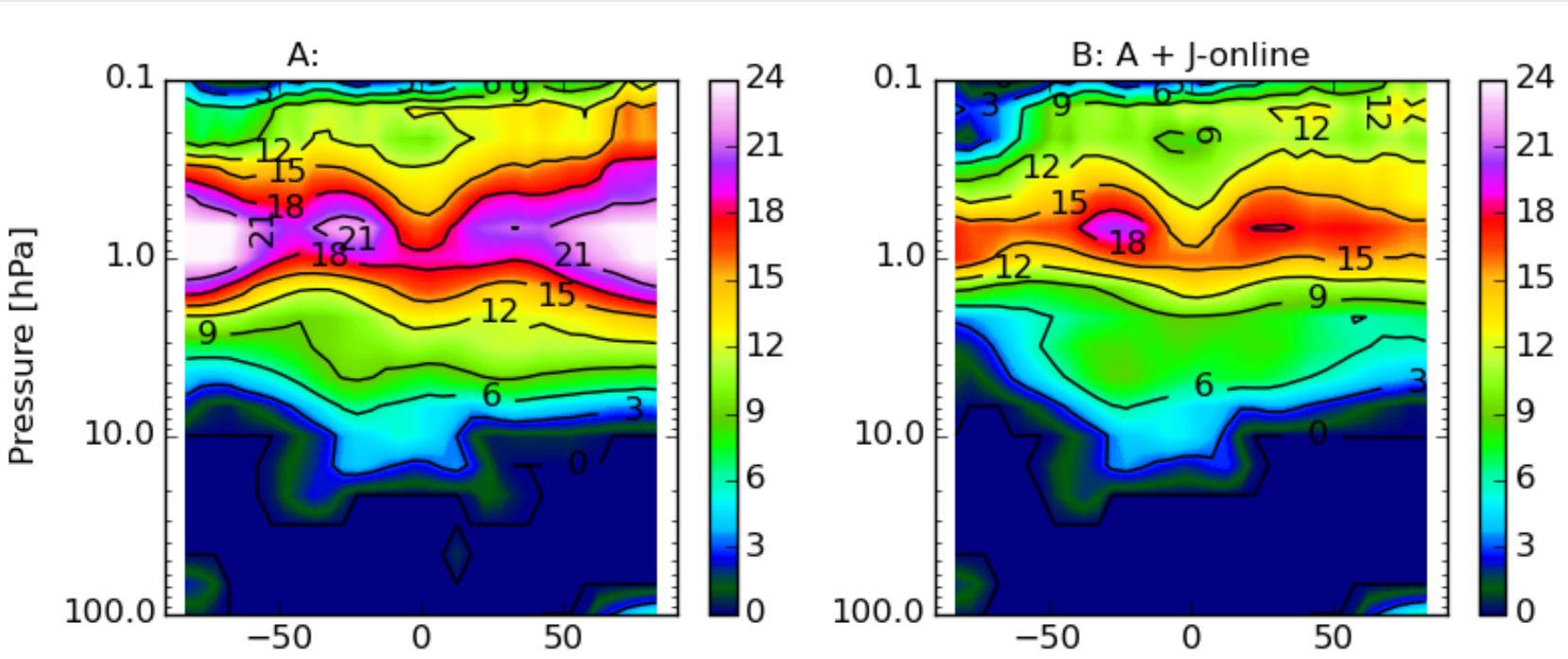
Photolysis rates

- Usually precomputed in J-tables for several atmospheric conditions (solar elevation, pressure, overhead ozone layer)
- Tables of photolysis rates depend on photodissociation cross-sections
- Cross-sections are compiled in the JPL reports
- Cross-sections depend on temperature

Method to compute photolysis rates

- J-offline: precomputed J-tables
- J-online: J-tables computed at every model time step

NMB in [%] with respect to MLS: J-offline vs J-online



J-online gain: up to 10% of ozone deficit

Outline

ECMWF atmospheric reanalysis

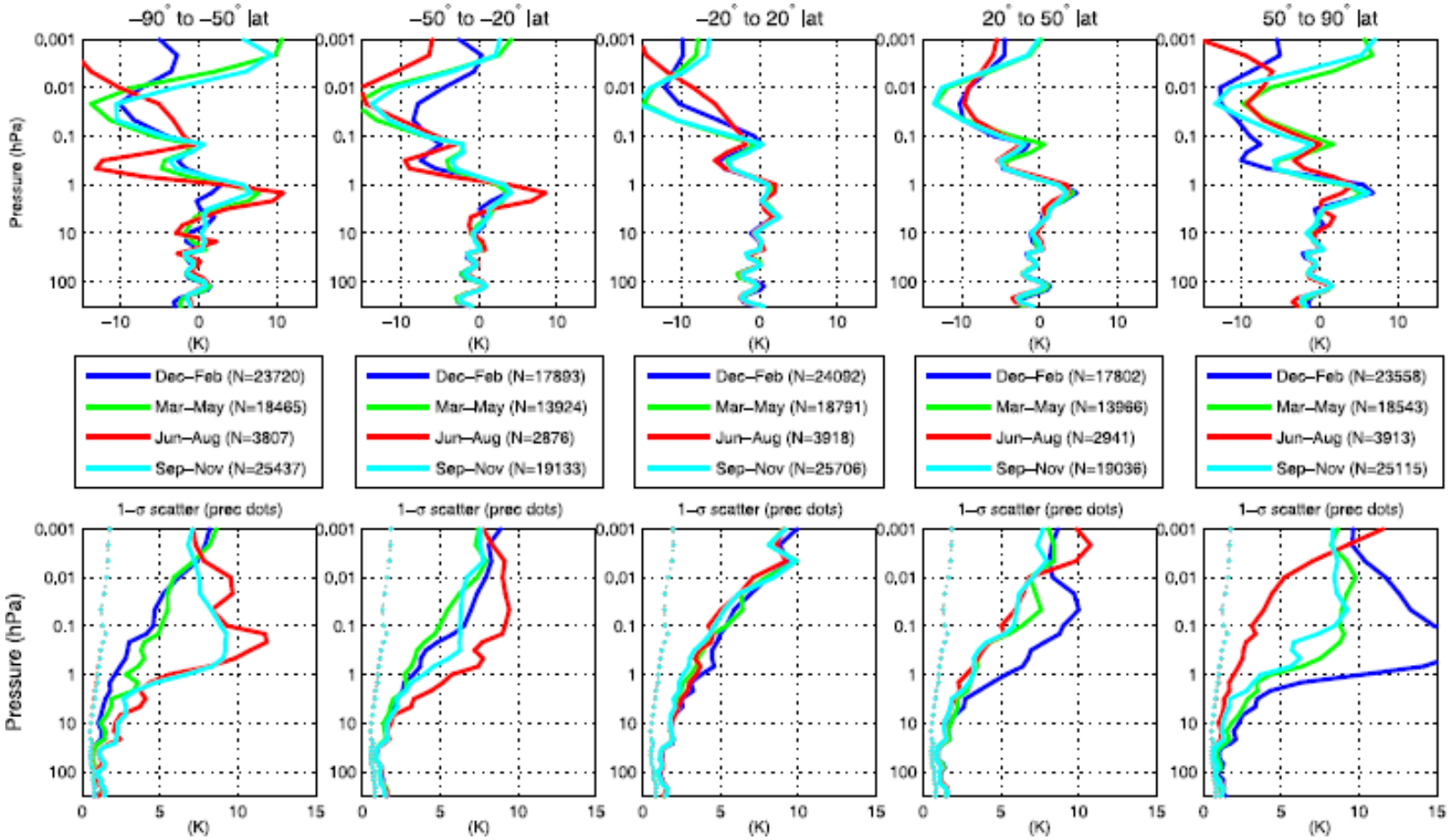
- BASCOE thermodynamic forcing: ECMWF operational analyses (OD) and ERA-Interim
  - BASCOE model lid: 0.01 hPa and 0.1 hPa for OD and ERA-Interim, respectively
  - BASCOE model hybrid pressure levels: 60 (91) with OD, subset of 37 from 60 with ERA-Interim
- ECMWF: Not enough data in USLM to constrain the model
- ECMWF OD and ERA-Interim: warm bias above 2 hPa
- The use of ECMWF OD instead of ERA-Interim doesn't have any valuable impact on O_3 bias

T-forcing correction

- to assess the impact on ozone
- using available observations
- simple method

Aura MLS v3.0 temperature observations

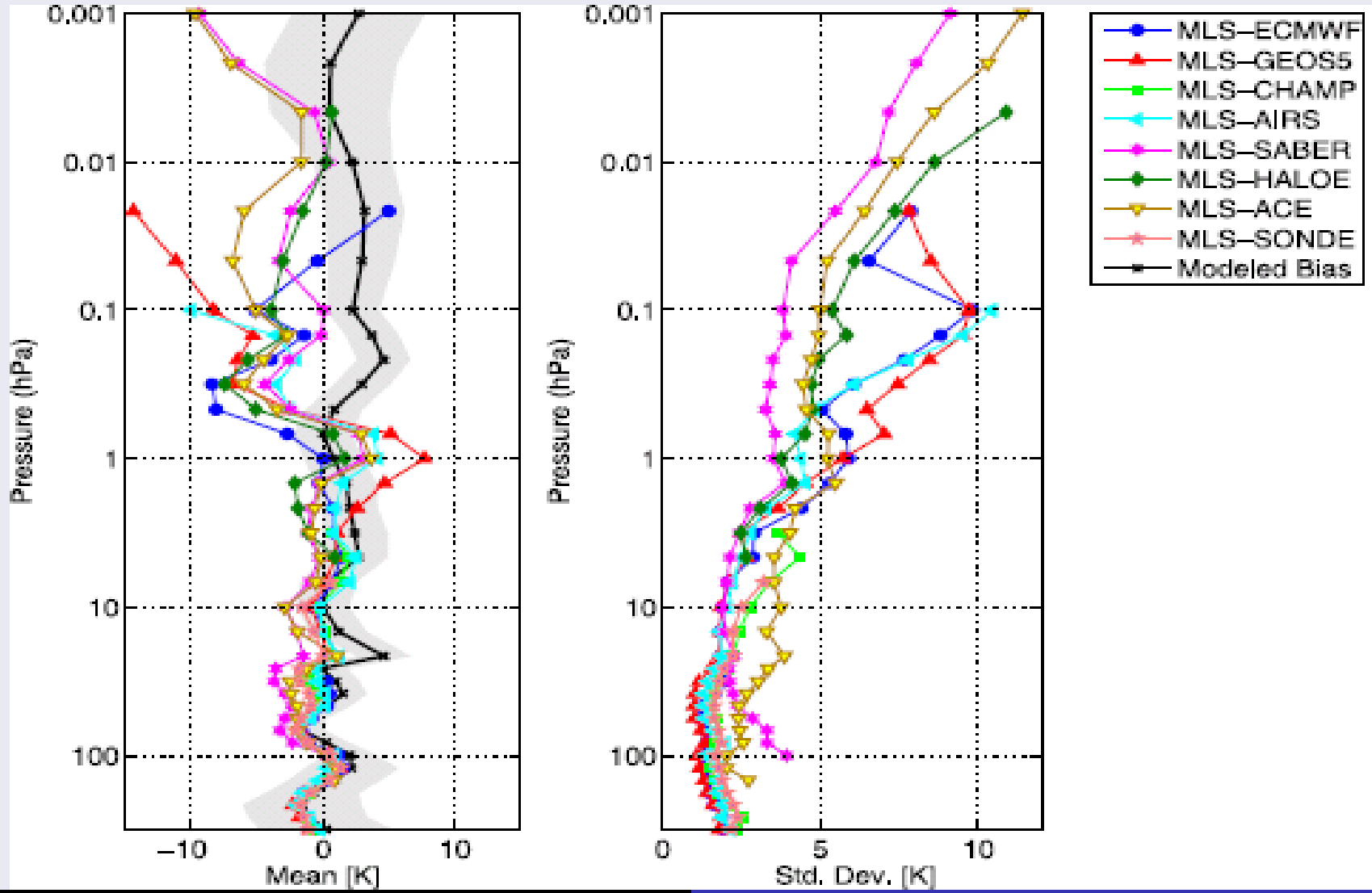
- up to 1 hPa: GEOS5 (Rienecker et al. 2007) a priori T
- above 1 hPa: CIRA86 climatology (Flemming et al. 1990)



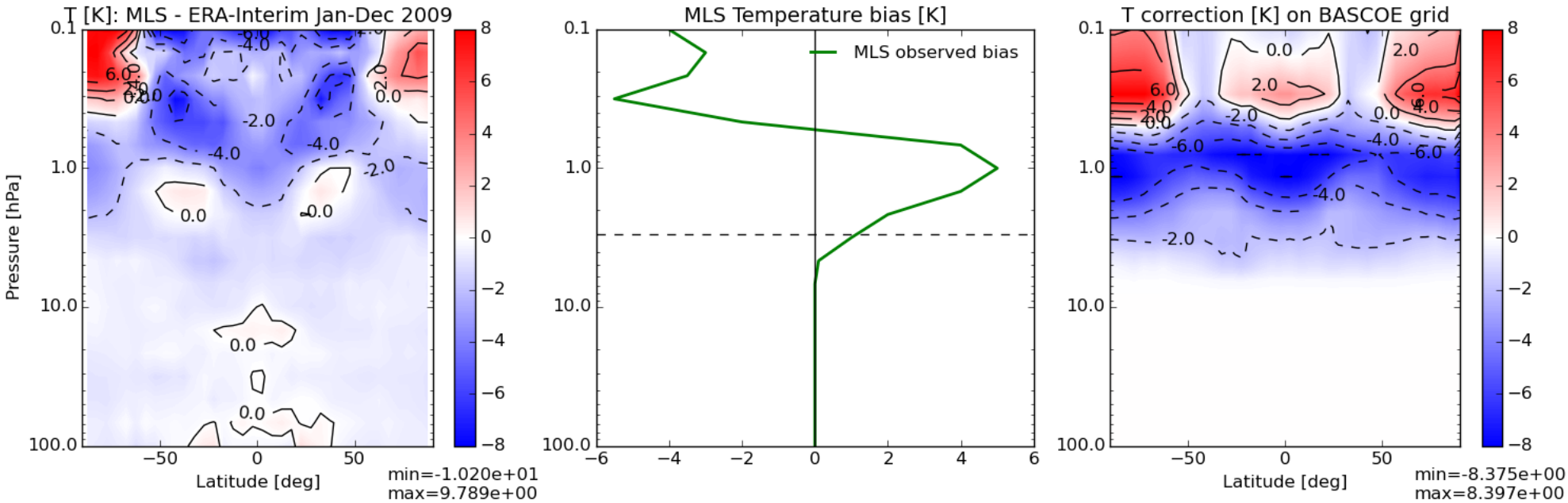
MLS v2.2 minus its a priori (Schwartz et al. 2008)

MLS Temperature observed bias

Bias and scatter w.r.t correlative sets (Schwartz et al. 2008)

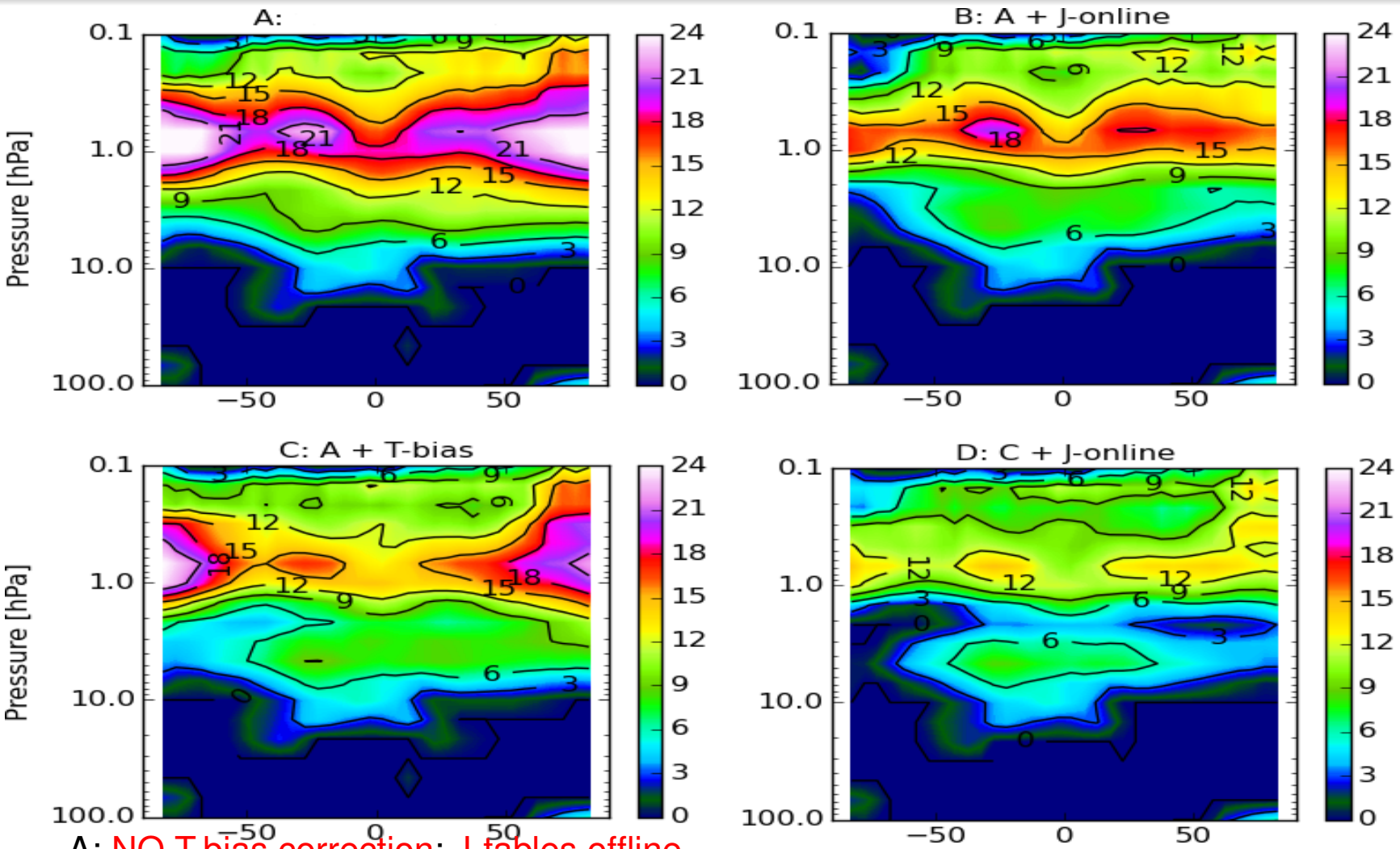


Temperature forcing correction



(left) Annual zonal mean between Aura MLS v3.0 and ERA-Interim.
(centre) Observed MLS bias from Schwartz et al. 2008.
(right) Resulting T-correction computed as a differene between (left) and (centre).

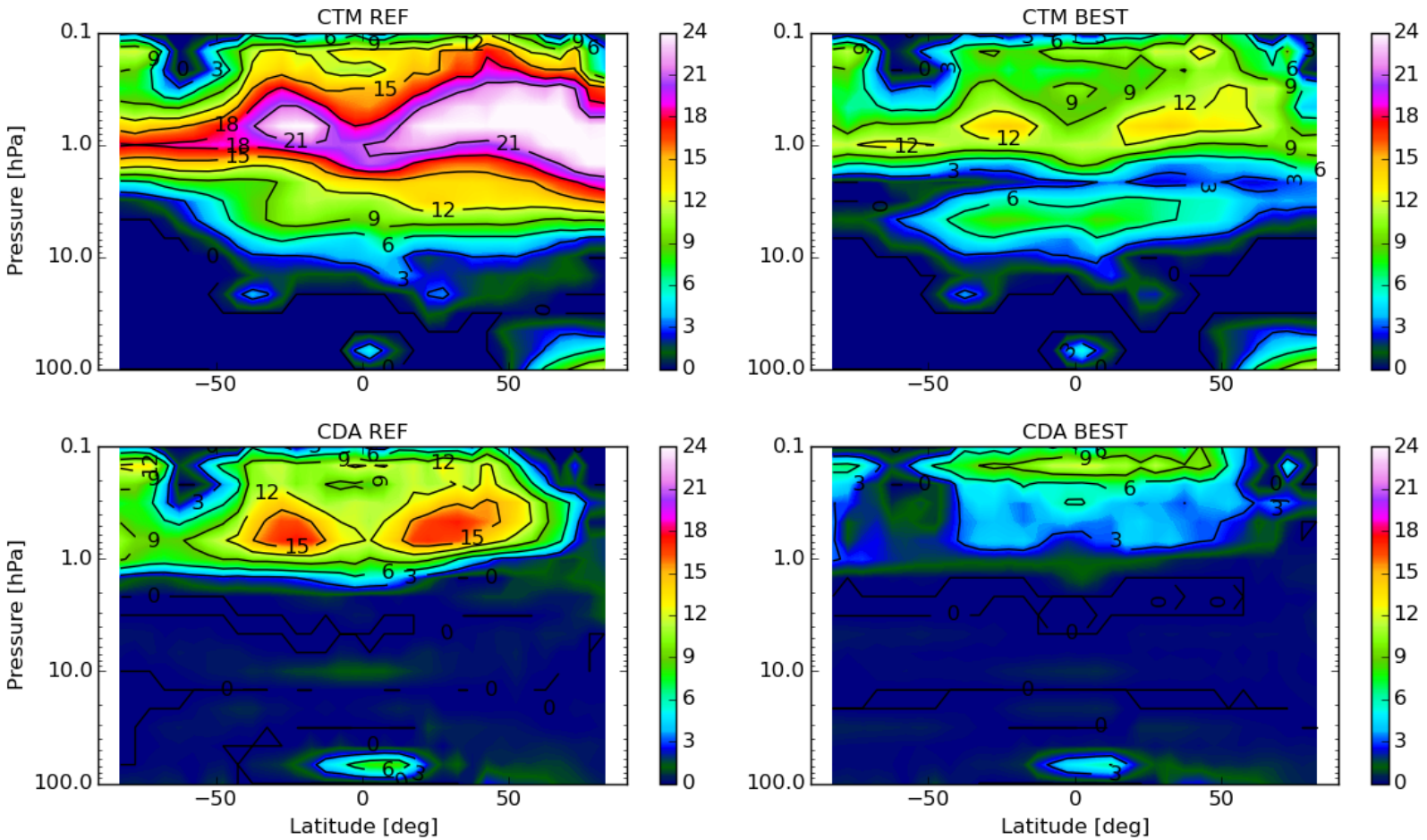
Impact of T correction on O_3. NMB in [%] w.r.t. MLS



A: NO T-bias correction; J-tables offline
B: NO T-bias correction; J-tables online
C: T-bias correction; J-tables offline
D: T-bias correction; J-tables online

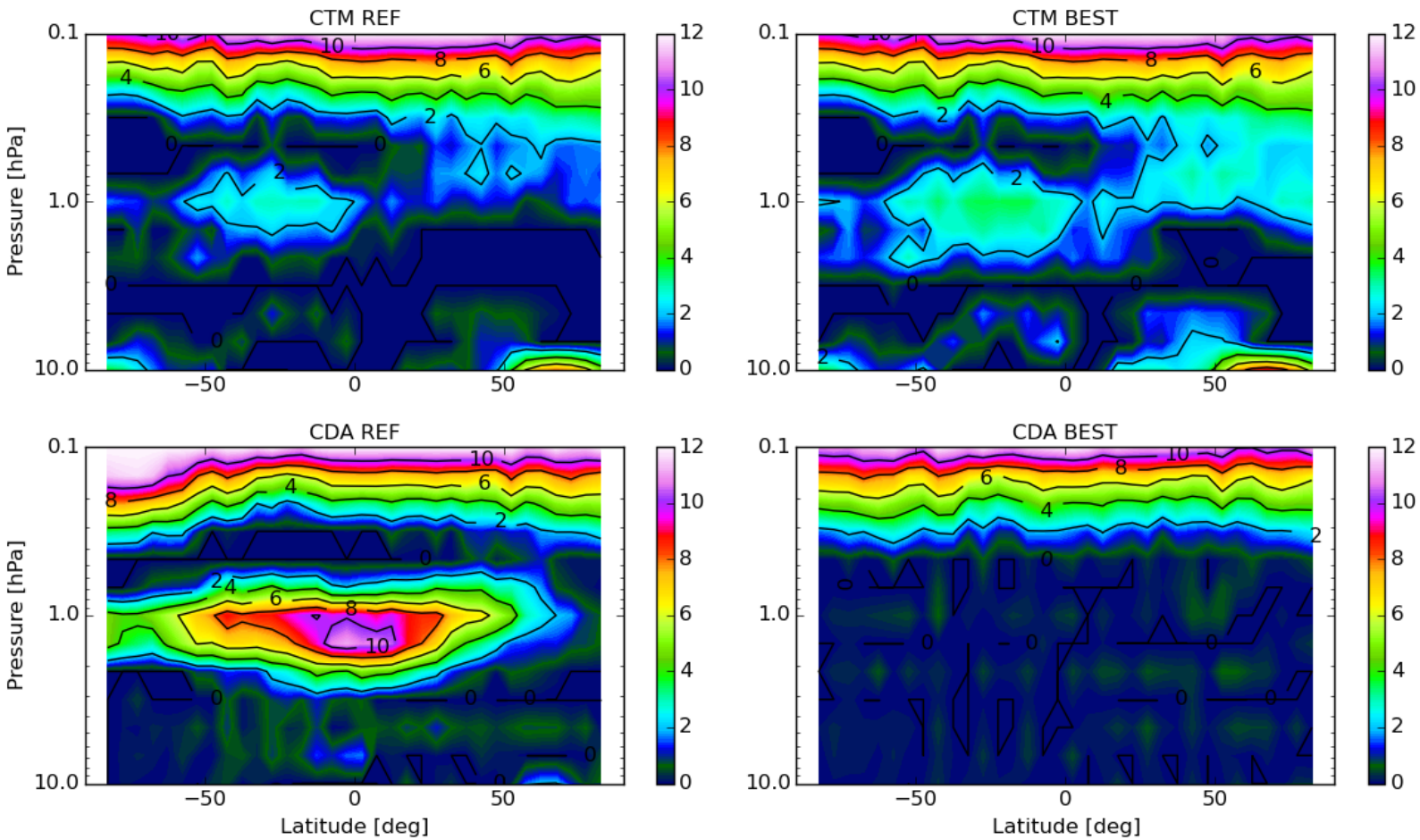
How Data Assimilation responds

NMB in [%] with respect to MLS for ozone

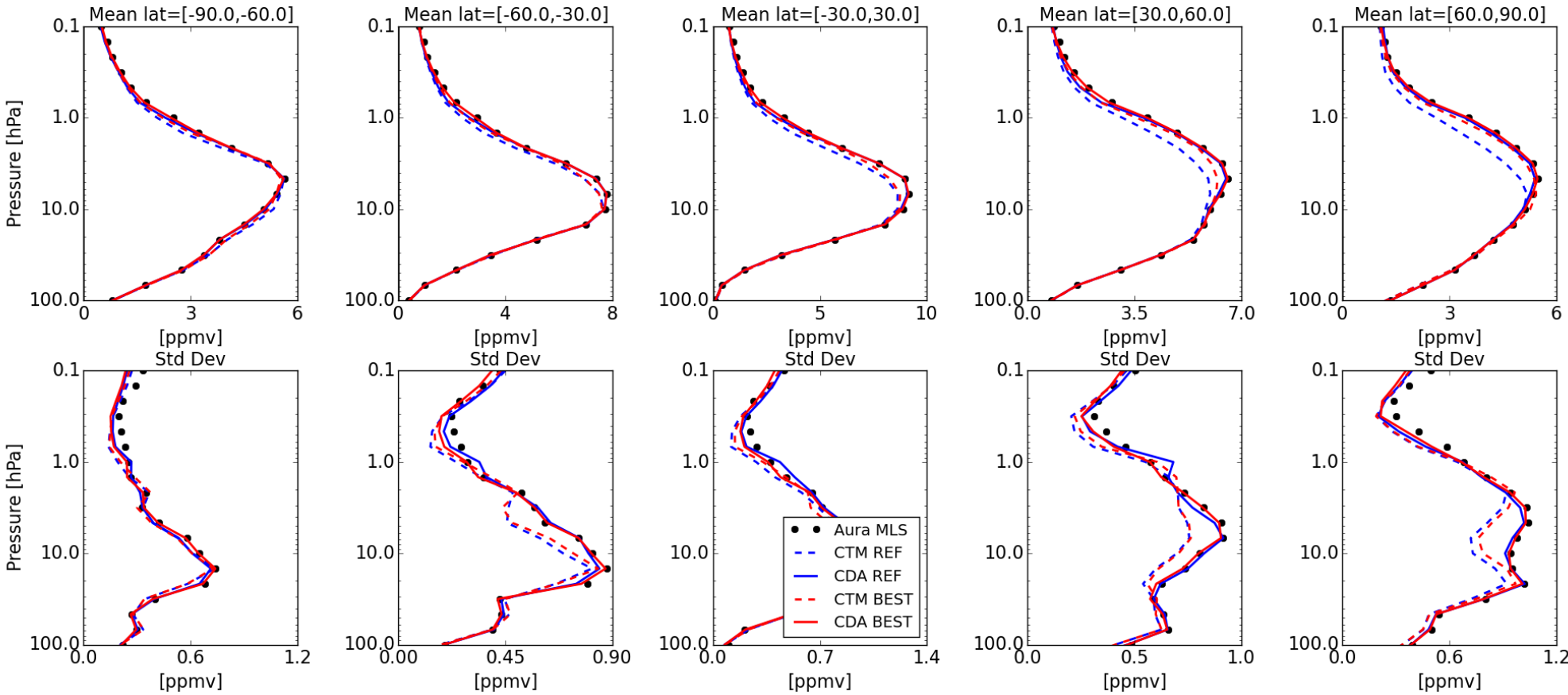


How Data Assimilation responds

NMB in [%] with respect to MLS for HCl

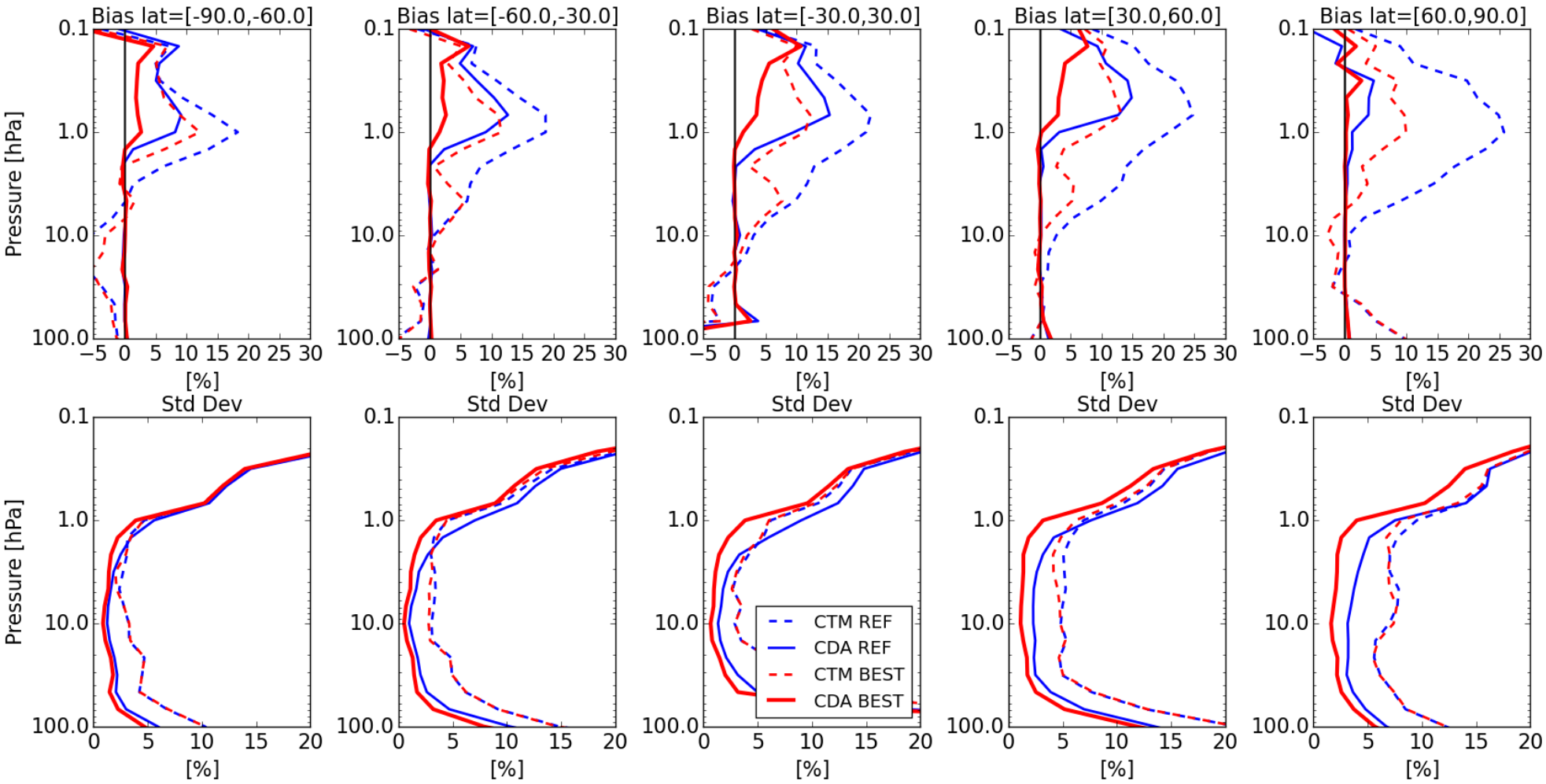


Mean ozone profile: summary of experiences



Mean ozone concentration and its standard deviation profiles

Summarizing OmF statistics



Ozone NMB and standard deviation profiles

Summary

- The ozone bias in BASCOE at 1 hPa was decreased from 20-25% to 8-12% using modelling issues only
  - SORCE Solar radiance: 3% of initial bias
  - Evaluative J-rates: 5-10%
  - The presence of T-bias is responsible for ozone bias: 5-10%
- We can now assimilate ozone above 2hPa without disturbing chlorine state
- CDA reduces the bias to 0-4%

How to deal with temperature forcing field?

- Assess how accurate the MERRA2 temperature is.
- Assimilate SABER or MIPAS IMK temperatures in USLM to get a new atmospheric reanalysis?
- Estimate T as a parameter using assimilation of ozone obs. within a coupled AGCM-CTM system?

Thank you