Stratospheric Ozone Temperature Feedback in ECMWF Model

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Summary on Stratospheric Chemistry Modelling and Assimilation in CAMS at ECMWF

Johannes Flemming, Alessio Bozzo, Vincent Huijnen (KNMI), Antje Inness, Beatriz Monge-Sanz and the MACC and BIRA team

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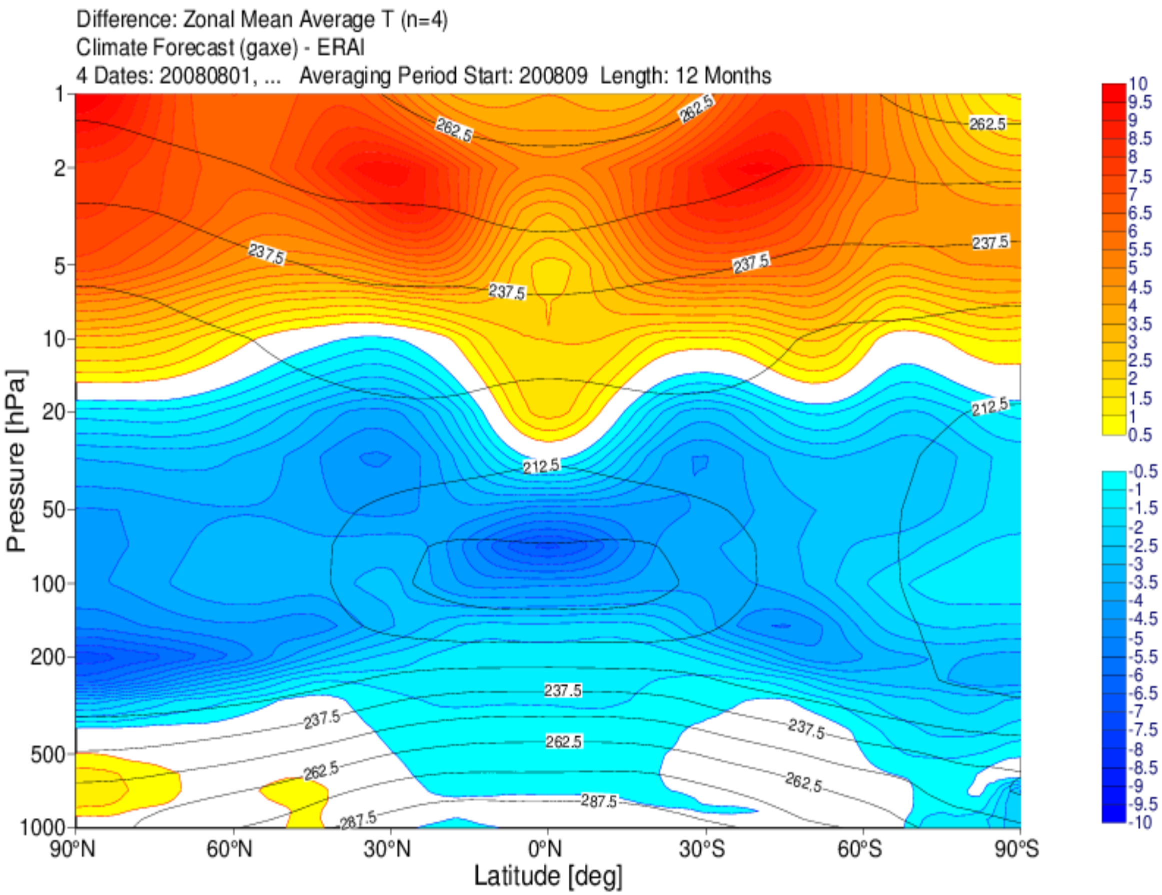
IFS temperature bias in 1yr forecast

IFS Temperature bias (EraInt)



"climate run" with 4 ensemble members

Can it be cured with mitigated with ozone in radiation scheme ?

Heating and cooling due to trace gases

Brasseur G. and Solomon S.,
Aeronomy of the Middle Atmosphere
1984

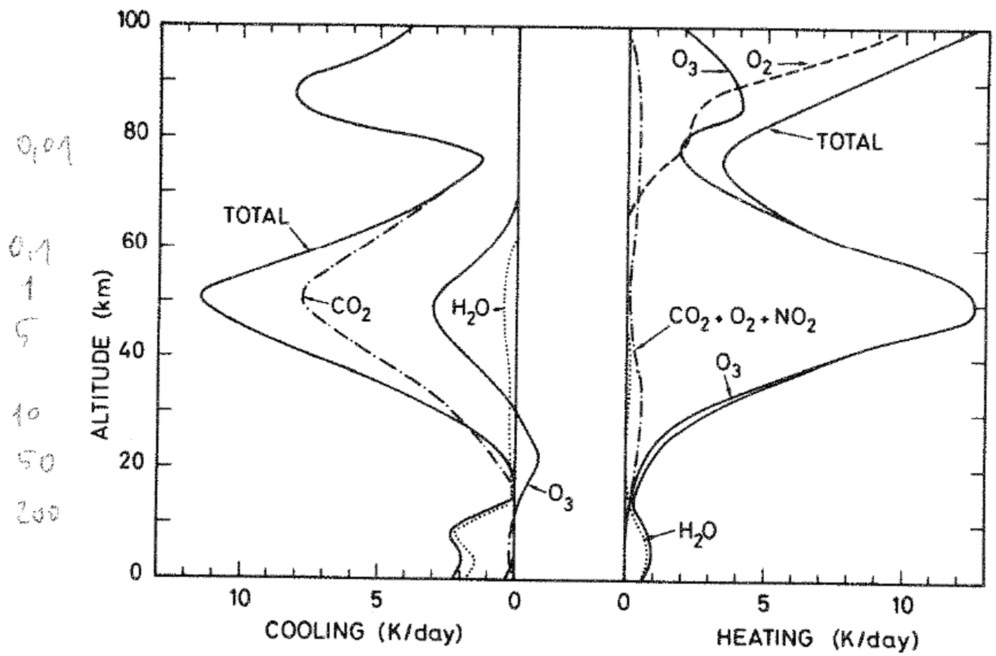


Fig. 4.19b. Vertical distribution of solar short wave heating rates by O_3, O_2, NO_2, H_2O, CO_2, and of terrestrial long wave cooling rates by CO_2, O_3, and H_2O. From London (1980).

Most important:
Stratosphere:
CO_2,(LW), O_3 (SW)
Troposphere: H_2O

Testing ozone representations in radiation scheme of ECMWF model (IFS)

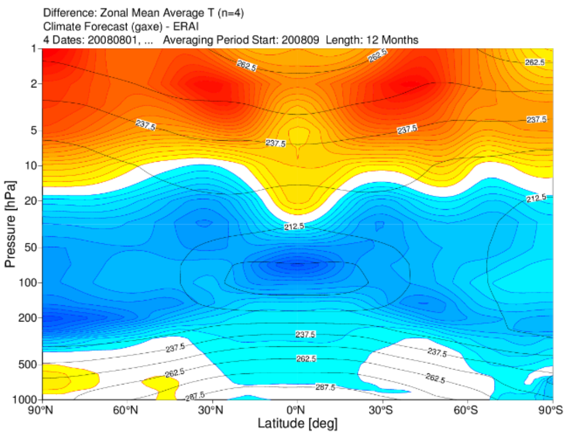
- Monthly Climatology of MACC re-analysis (BASE)
- MACC re-analysis 6 h (MACC6h)
- Cariolle ozone parameterisation CAR
- Monge-Sanz ozone parameterisation (as Cariolle but 3D model base) BMS
- CB05 & BASCOE chemistry scheme C-IFS-B *(old)*
- CB05 & CAR chemistry scheme C-IFS-C
- 1-year "climate" runs (4 ensemble members) with interactive ozone

Some questions …

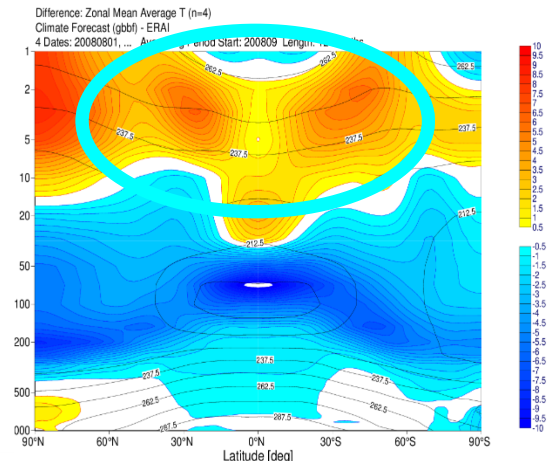
- How different is the T response to different ozone simulations?
- Is improvement in T related to improvement in O_3 ?
- What are reliable observations/analysis for T and O_3 in upper stratosphere and above ?
- Feedbacks on stratospheric chemistry / ozone ?
- Improvements in initialised 10-day forecasts ?

T bias (ERAInt) – Prog. O_3 in Radiation

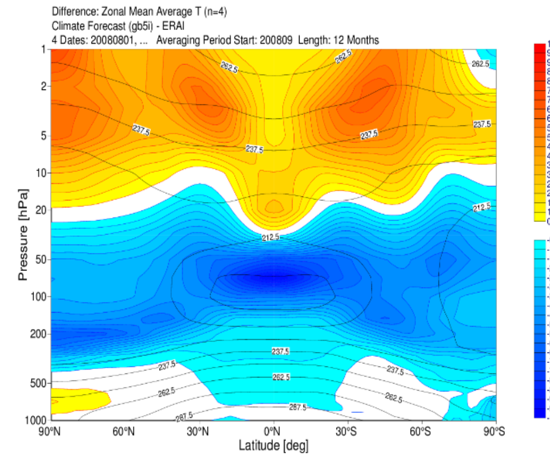
base

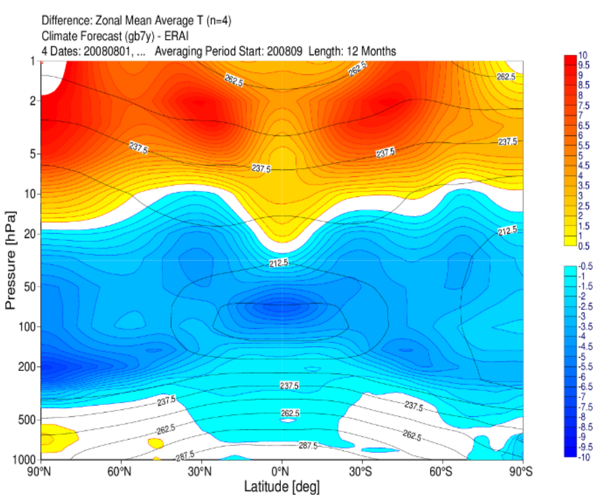


BMS

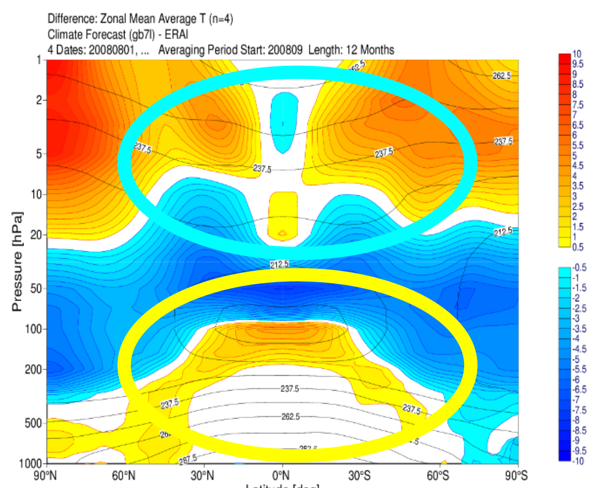


CAR

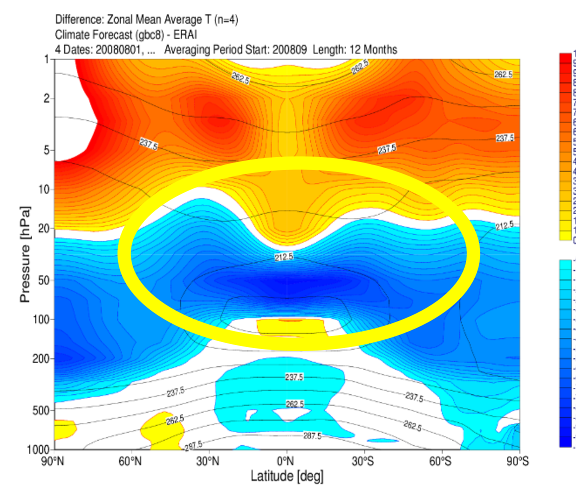




MACC-6h



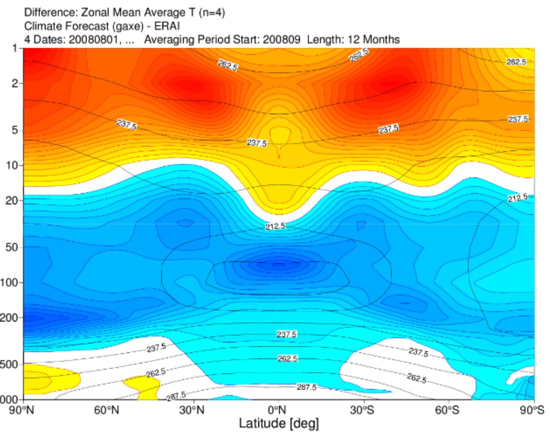
C-IFS-C



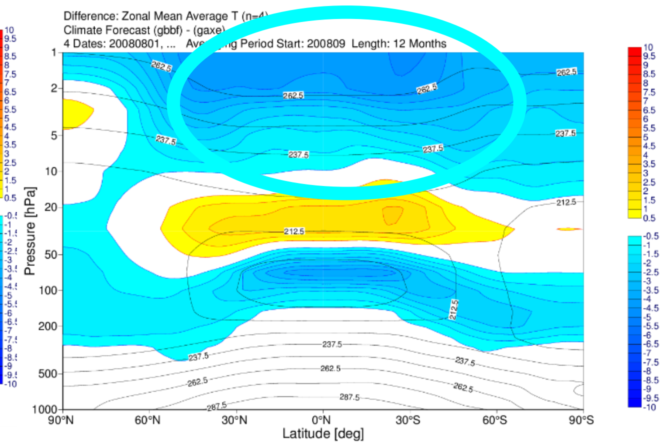
C-IFS-B

T vs T (BASE)

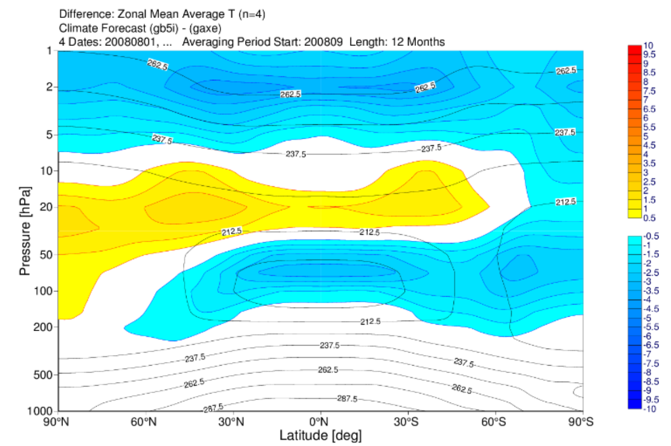
Base - era

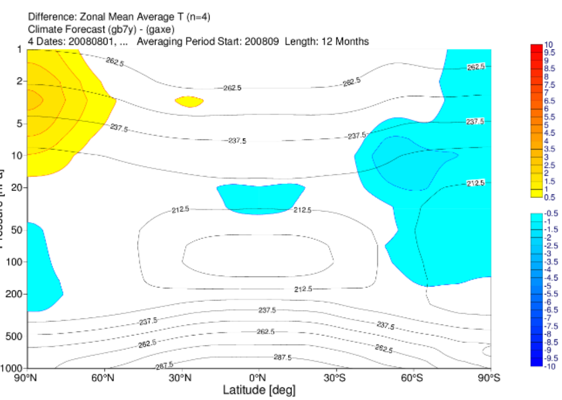


BMS

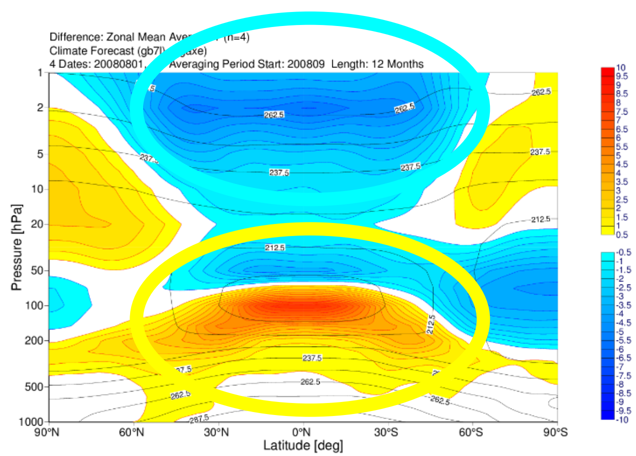


CAR

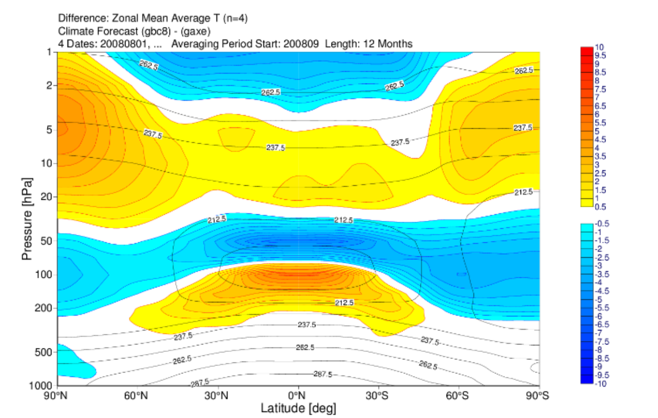




MACC-6h



C-IFS-C



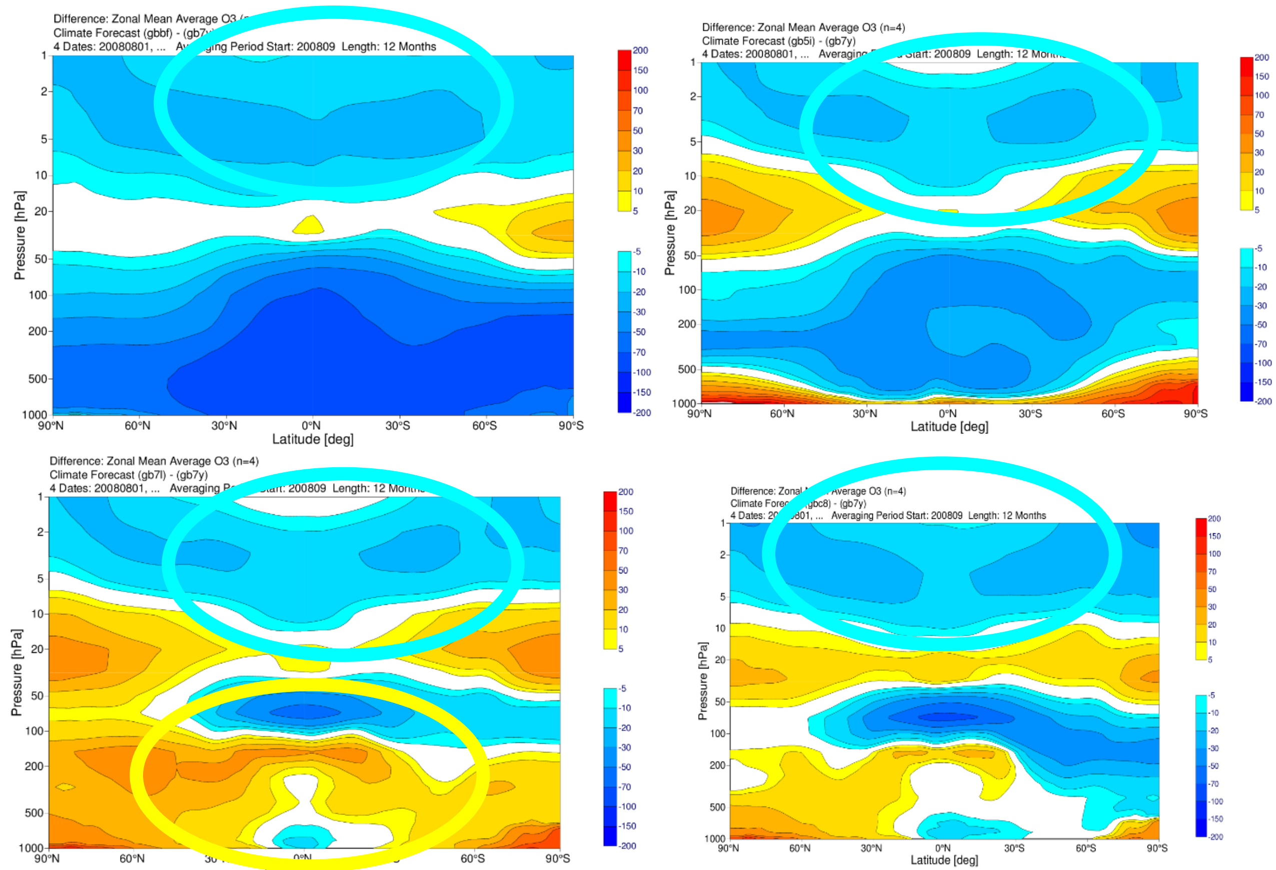
C-IFS-B

O_3 - O_3 MACC RA in %

Base

BMS

CAR



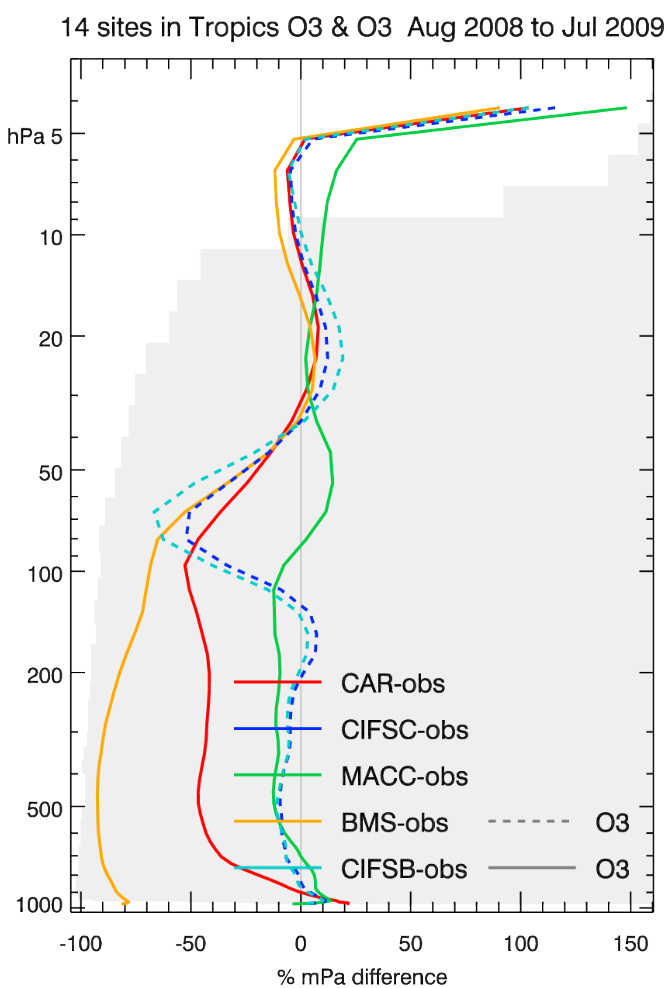
MACC-6h

C-IFS-C

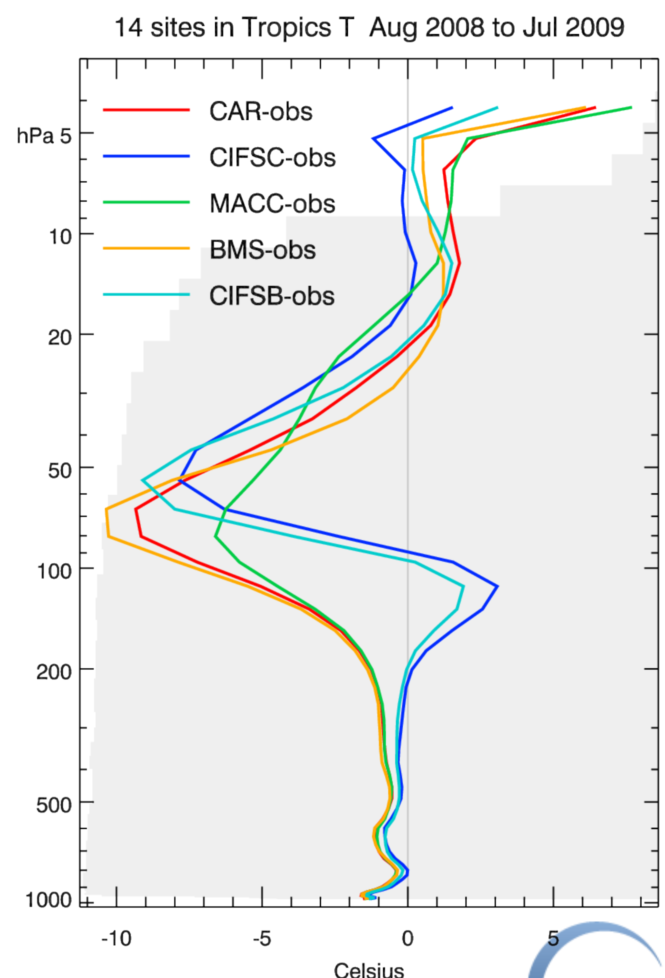
C-IFS-B

O_3 & T biases w.r.t v ozone sondes (Tropics)

O3 bias %



T bias K



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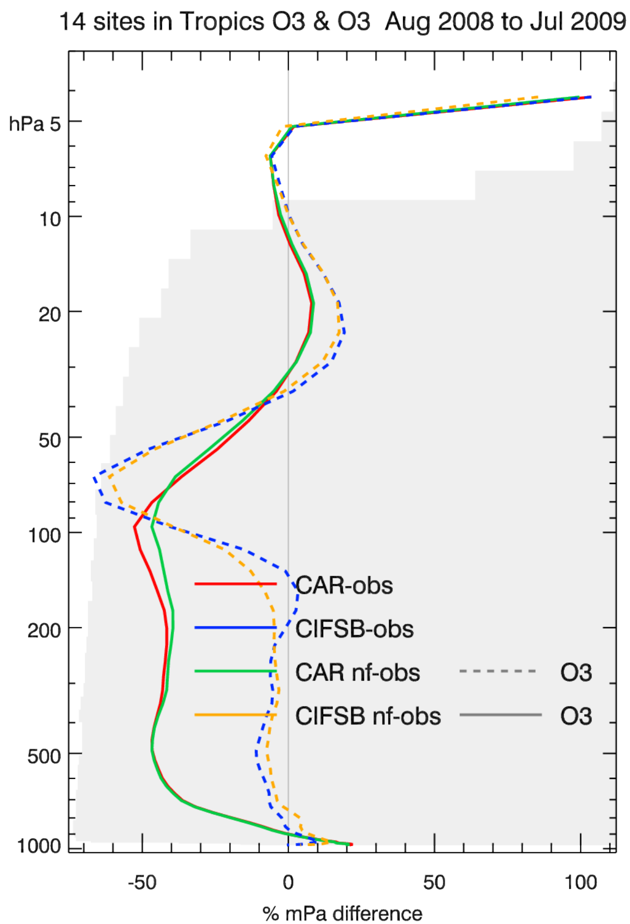
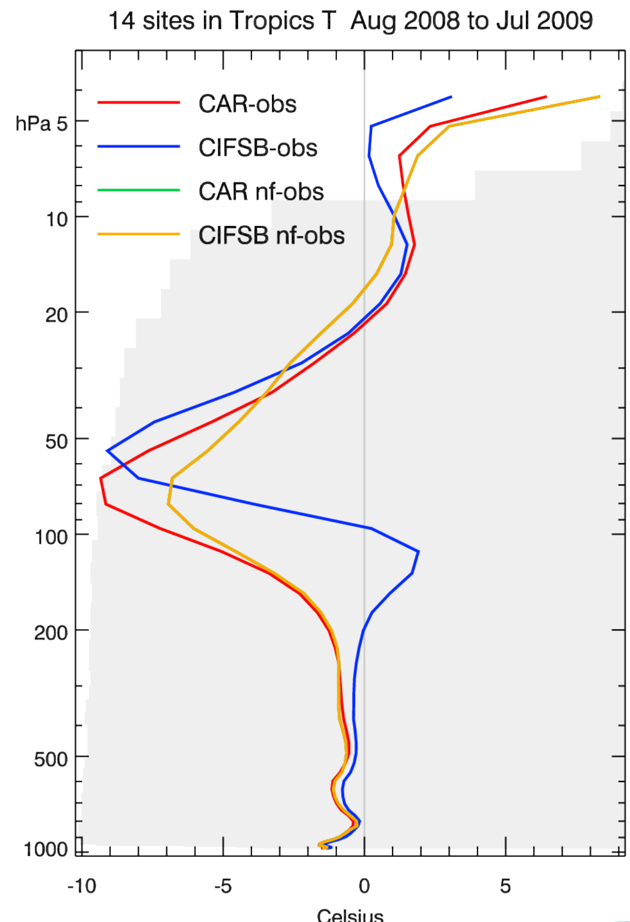
Impact of T changes on O_3 (sondes) (Tropics)

O3 bias %



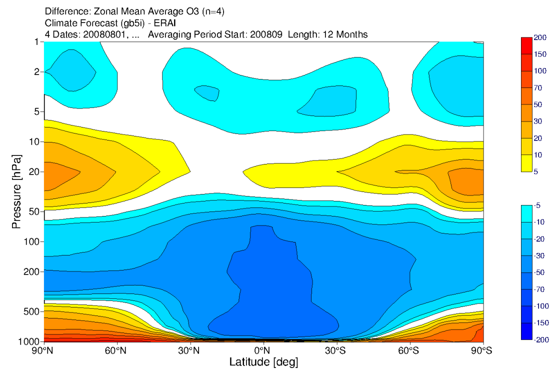
T bias K

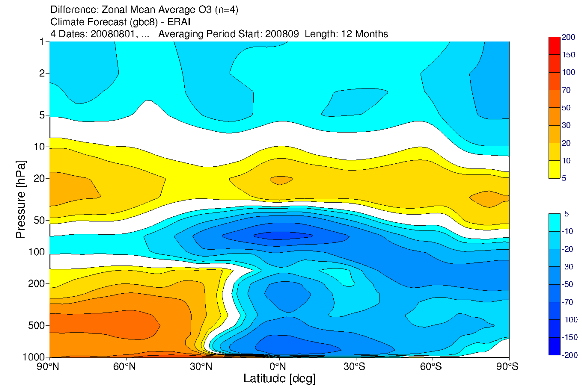


nf
no prognostic ozone in Rad.

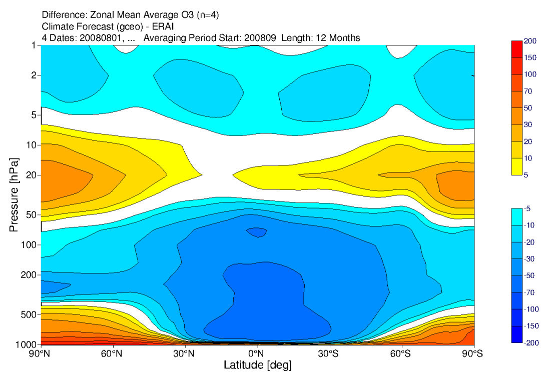
Impact of T changes on O_3

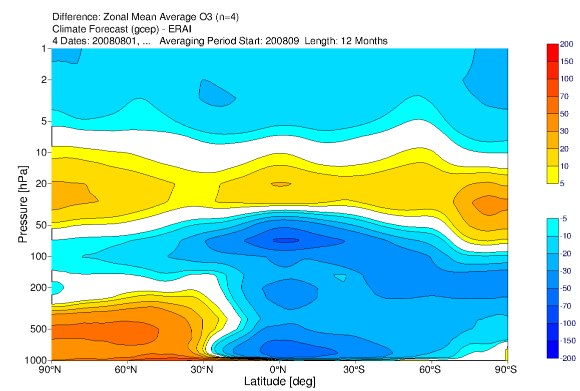
Difference to ERAint Ozone





interactive



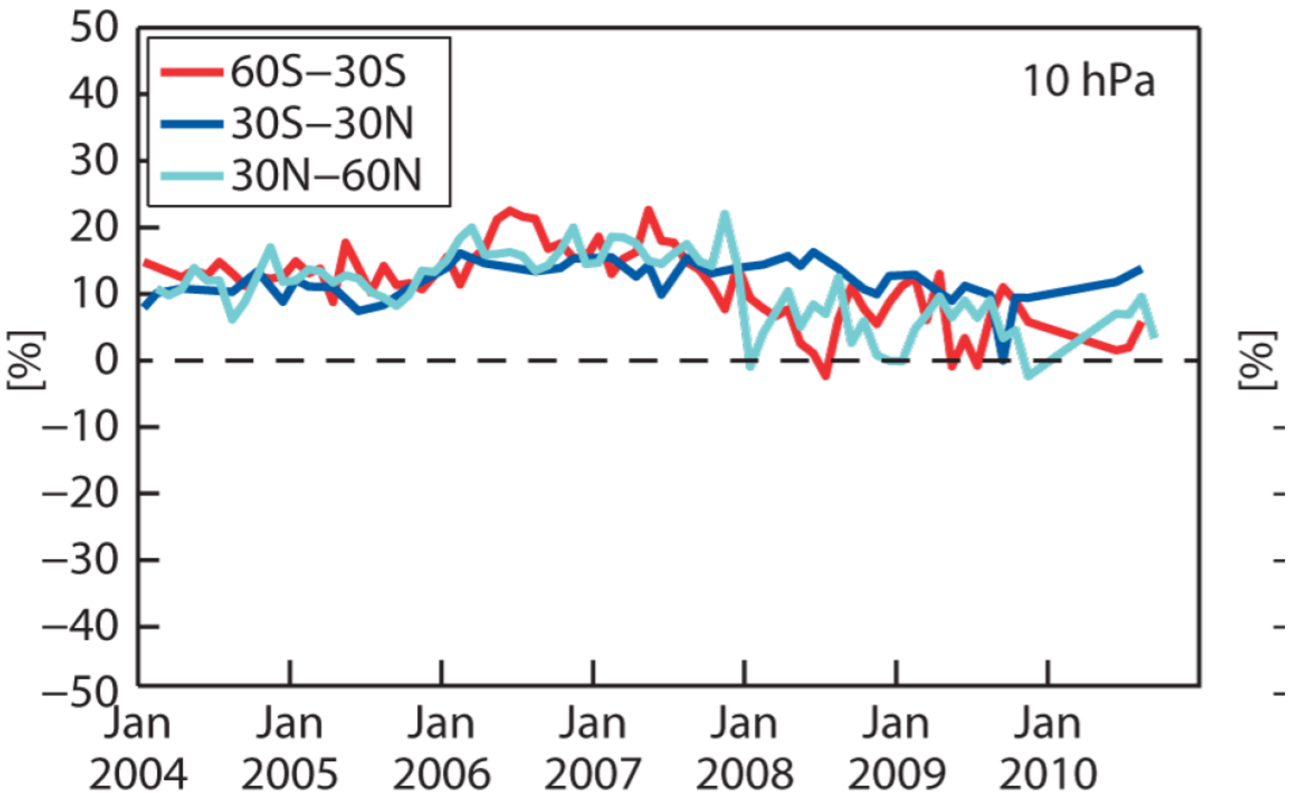


BASE
(MACC RA)

Cariolle

CIFS -BASCOE CB05

Bias of MACC RA w.r.t ACE-FTS



Inness et al. 2013

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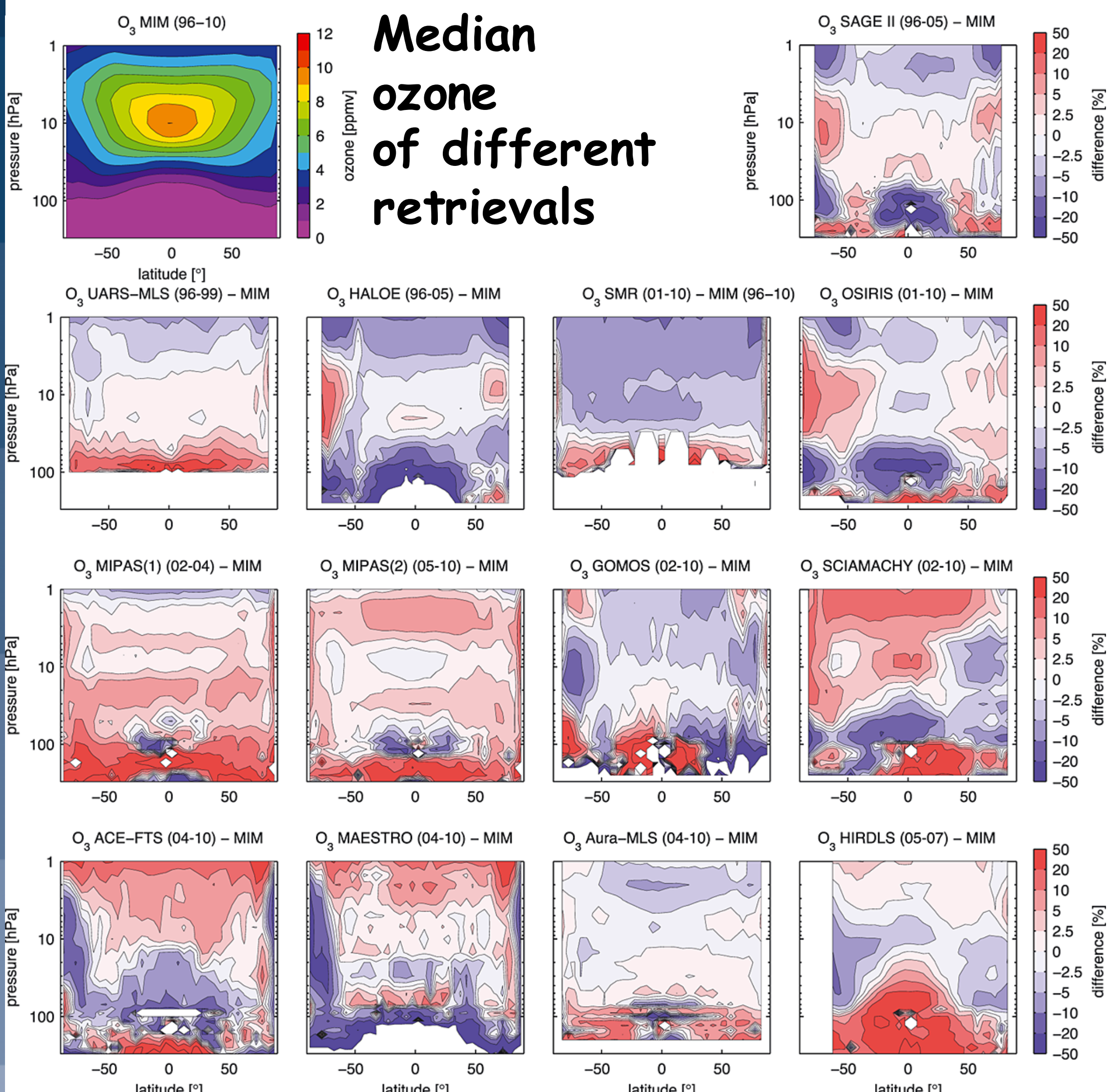
Multi instrument Ozone Retrievals

Median ozone of different retrievals



Differences of Instruments retrievals against multi-instrument median

SPARC data initiative Tegtmeier et al. 2013, JGR

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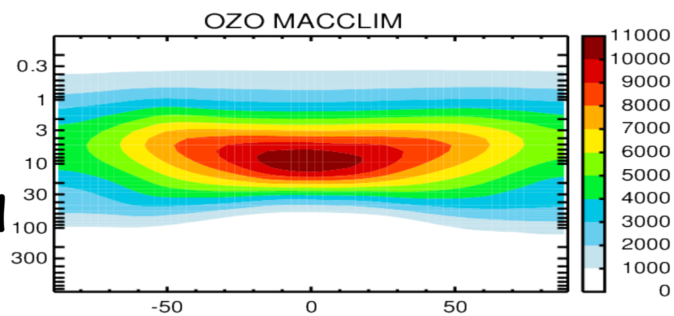
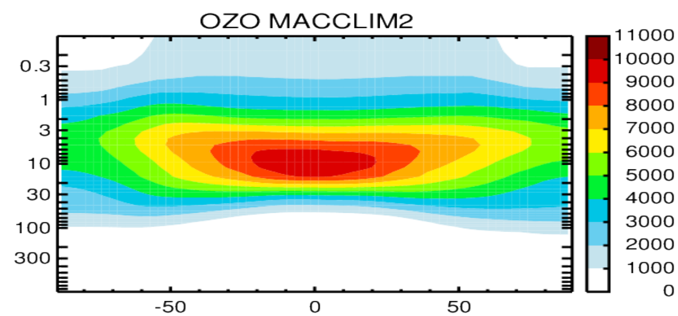
Bias correction of MACC RA ozone climatology above 15 hPa with NASA GOZCART product

Monthly NASA GOZCARDS Ozone Product (MLS & ACE-FTS) <0.2 hpa

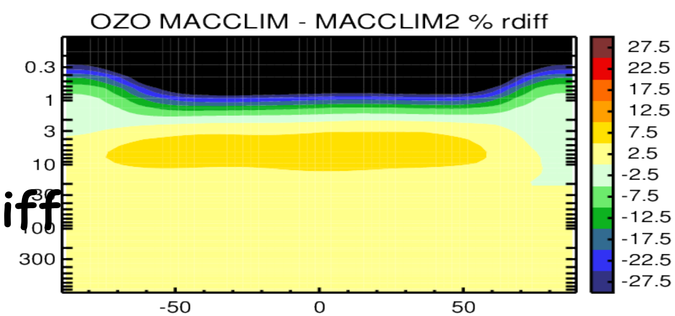
old

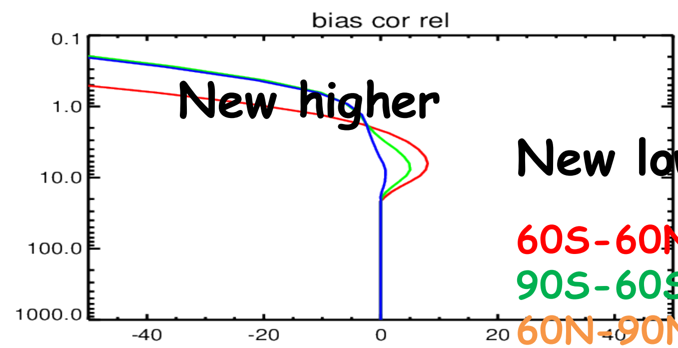




new

Rel diff





New higher

New lower

60S-60N

90S-60S

60N-90N

No data from 0.2 to 0.01 hPa

Rel diff

Uncertain above 1 hPa

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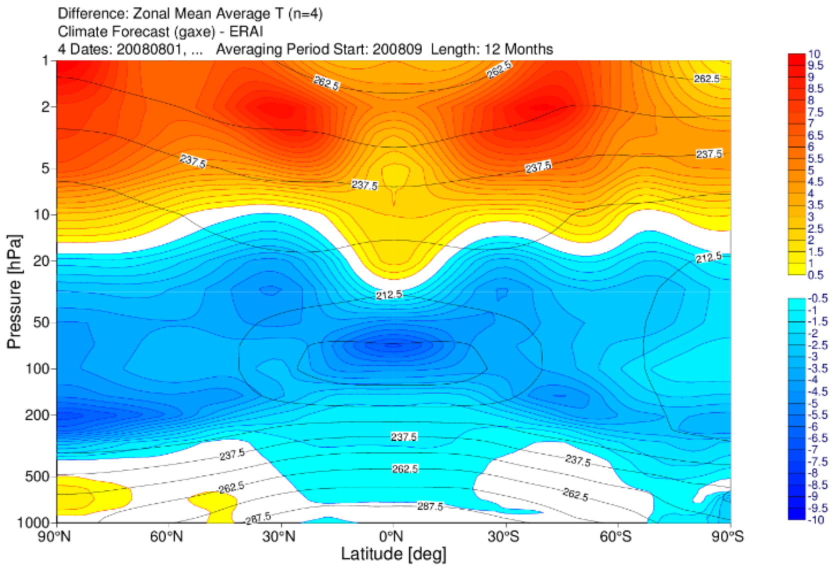
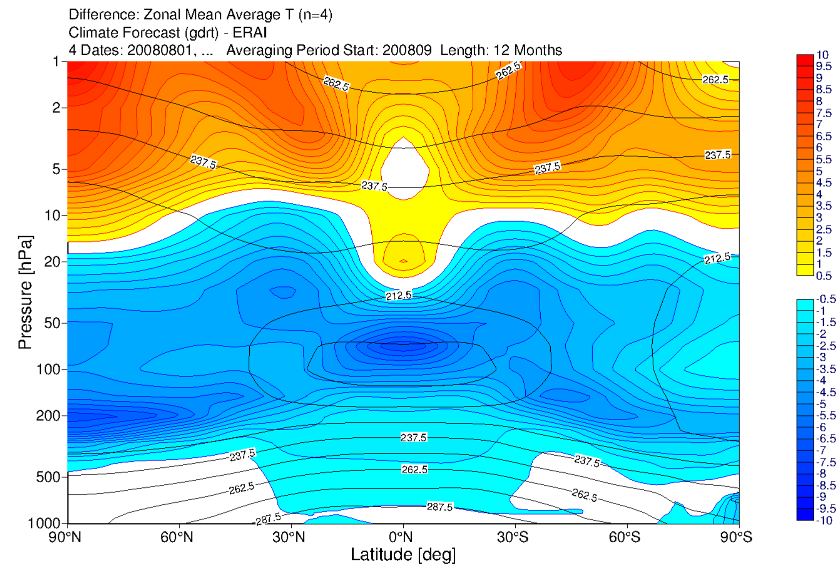
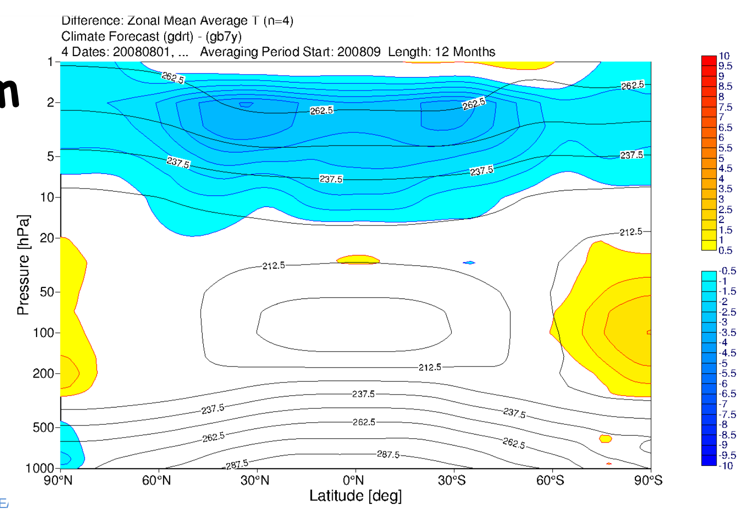
Impact of new ozone climatology in 1 yr. climate runs





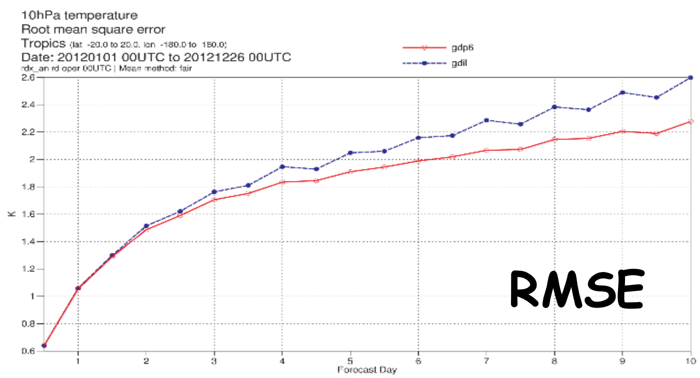
MACC RA Clim

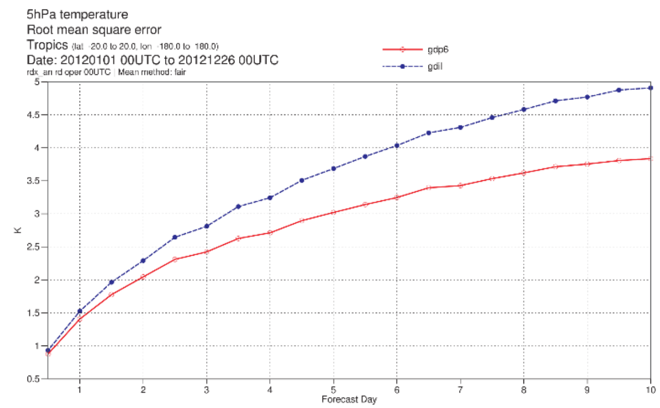
NEW MACC RA Clim



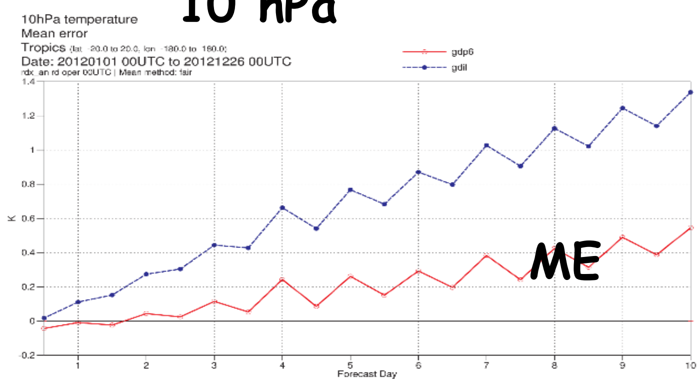
DIFFERENCE

Improved T (and U) scores in 10 day forecasts (initialised)

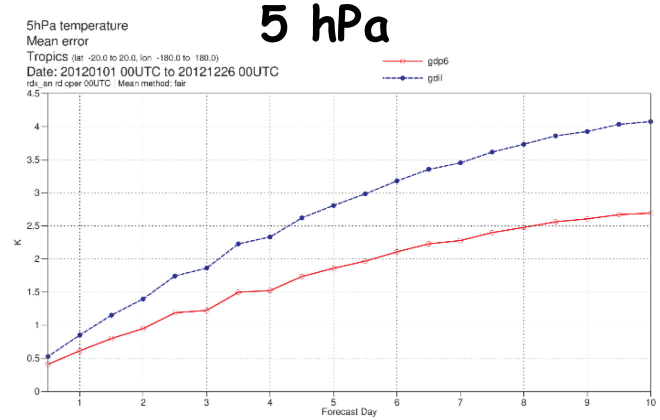




10 hPa



5 hPa



Corrected MACC ozone climatology to be implemented in next cycle

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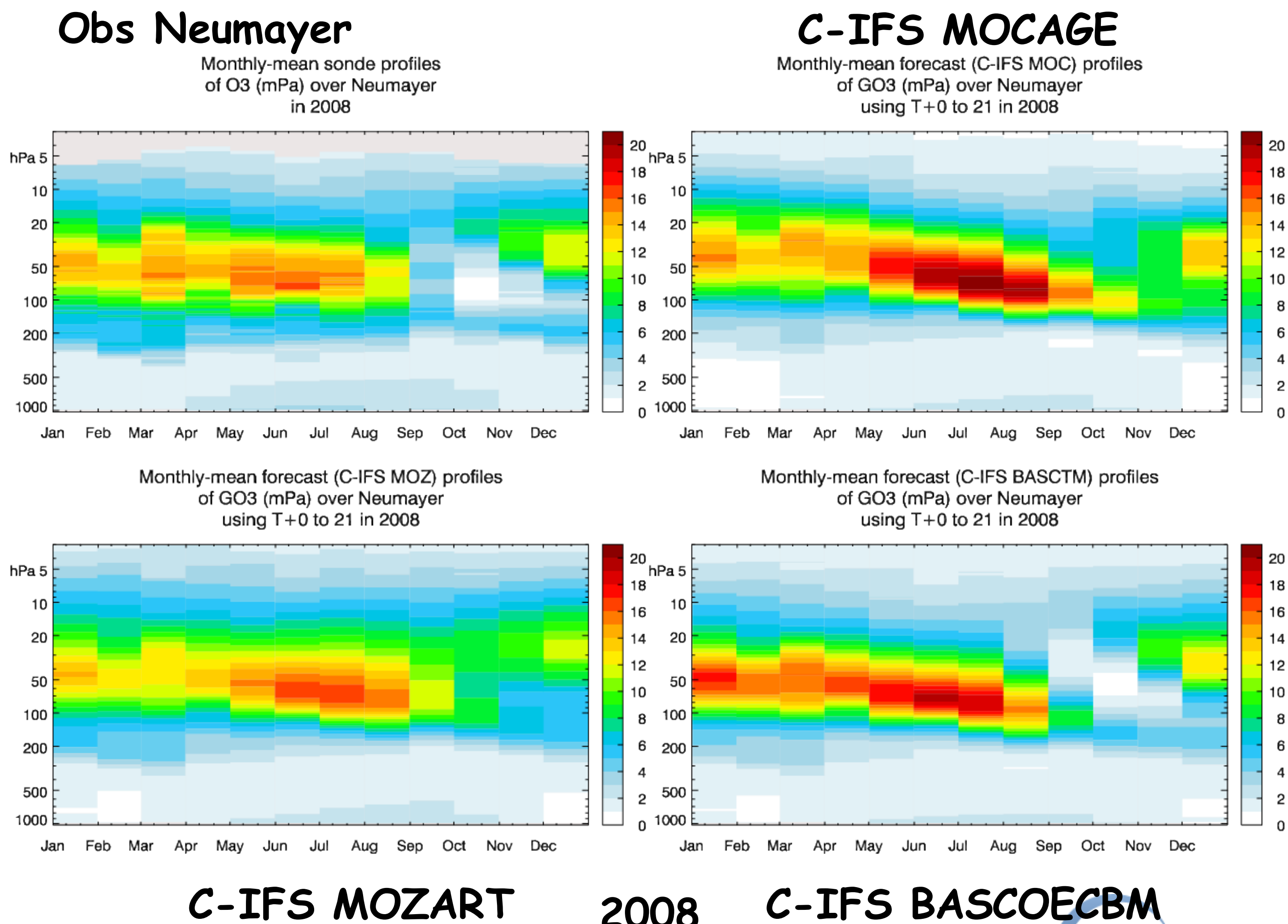
Summary O3 – T feedback

- Different ozone representations in radiation scheme lead to considerable temperature differences
- IFS temperature biases not curable with ozone alone
- Prognostic aspect (vs. climatology) O_3 seems less important
- Clearer correlation between ozone and T high bias above 15 hPa
- Bias corrected (above 15 hPa using GOZCART) MACC RA climatology improves T (and u v) in climate runs and 10 day forecasts (without deterioration of scores elsewhere)
- Next Steps
  - Investigate upper troposphere impact in more detail
  - Refine ozone climatology further with satellite observations
  - Explore sensitivity to T biases for different chemistry schemes

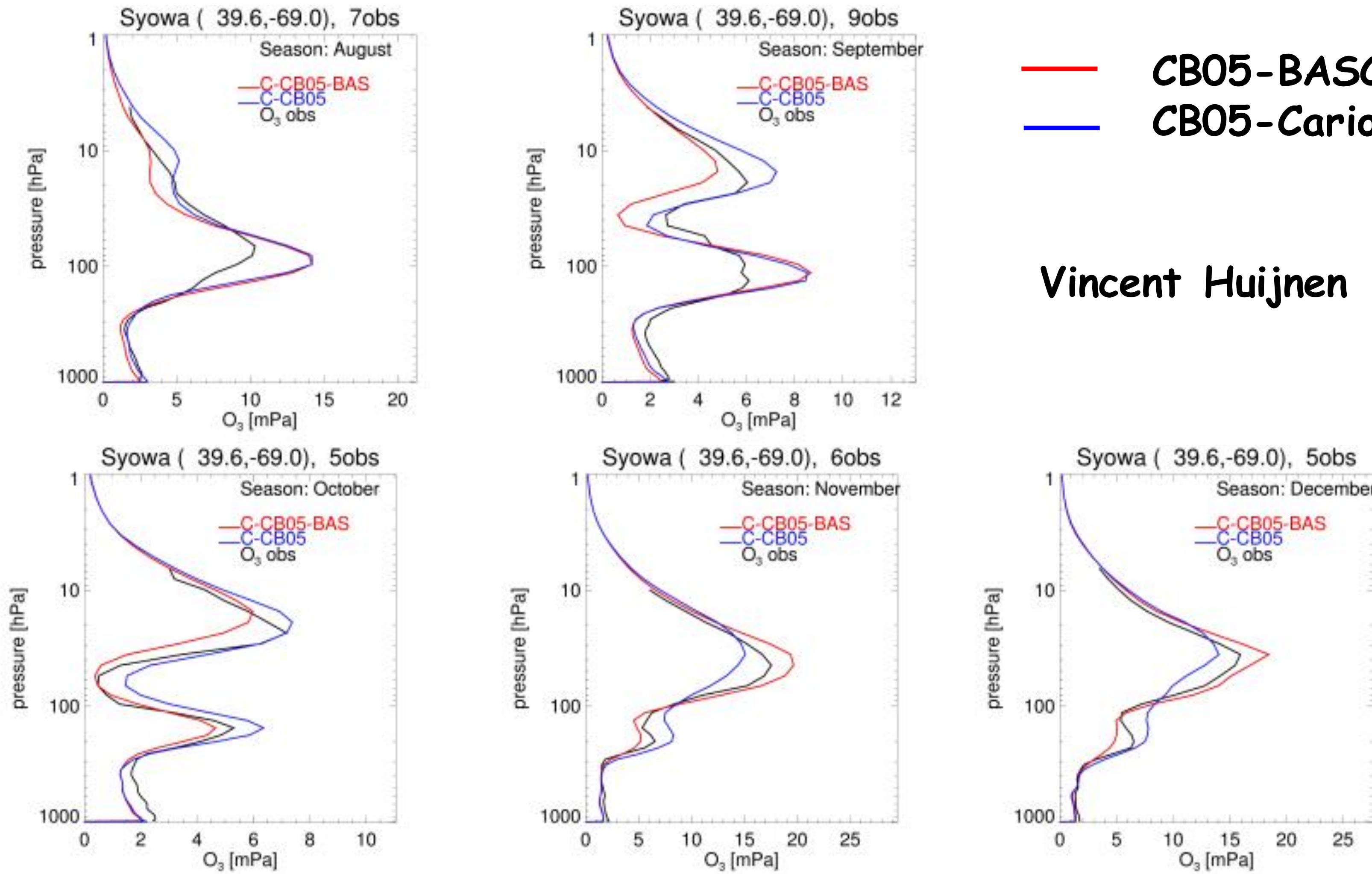
Stratospheric Chemistry in CAMS

- Copernicus Atmosphere Monitoring Service provides global NRT forecast and re-analysis of stratospheric composition (gas) as well as other regional and global tropospheric data: http://atmosphere.copernicus.eu/
- MACC heritage - stratosphere:
  - Partners CTM BASCOE(BIRA), SACADA (DLR), TM3DAM(KNMI)
  - ECMWF: C-IFS with troposphere & stratosphere chemistry schemes:
    - C-IFS BASCOE/CB05
    - CIFS MOCAGE (RACMOBUS)
    - C-IFS MOZART
    - C-IFS Cariolle/CB05 (CAMS operational)

Antarctic ozone C-IFS



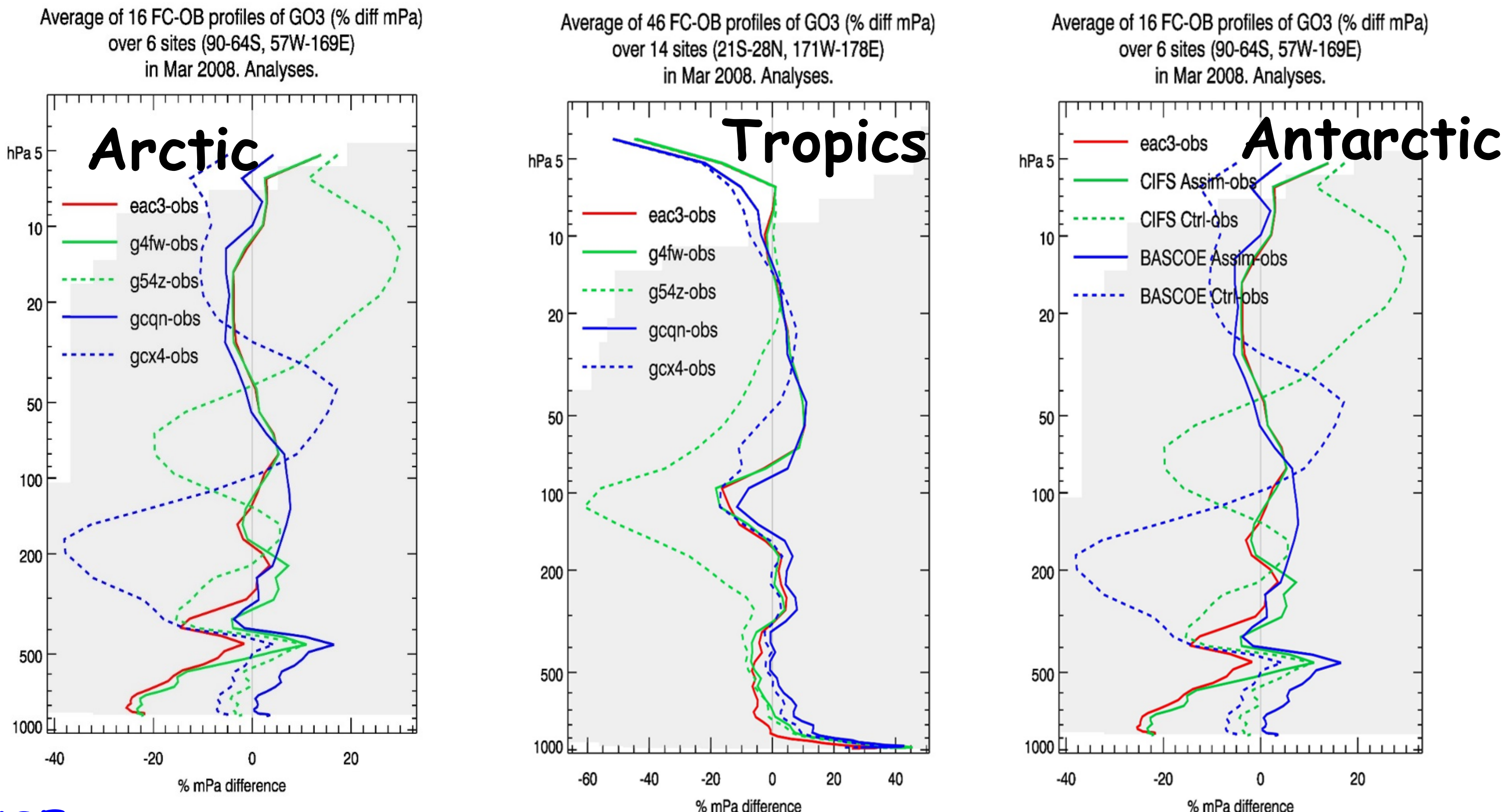
C-IFS BASCOE/CB05 against O_3 sondes



CB05-BASCOE
CB05-Cariolle

Vincent Huijnen

C-IFS BASCOE/CB05 data assimilation



BASCOE
CIFS TM5
Interim rean

Assim: ———

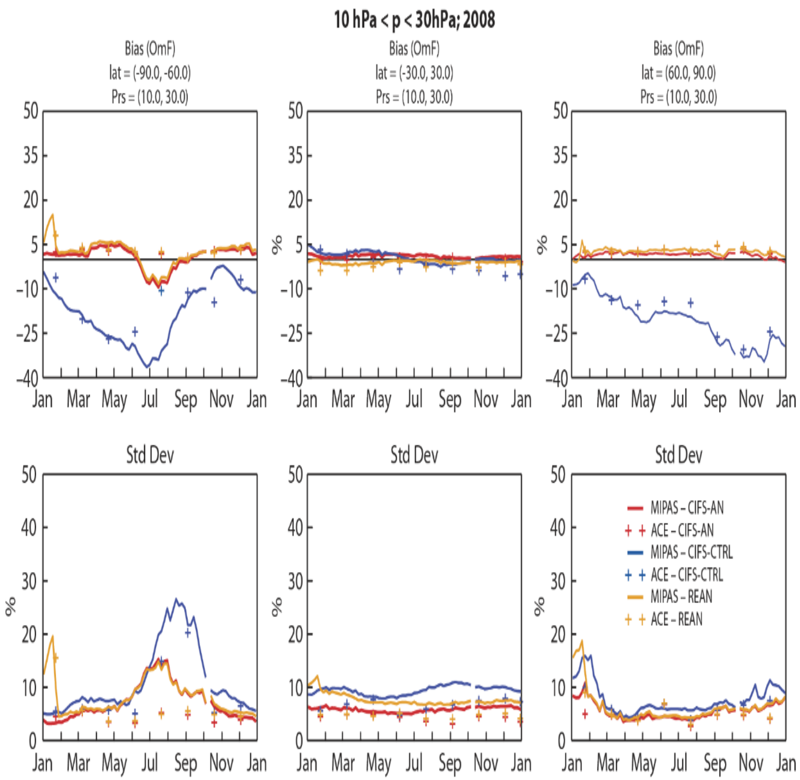
Ctrl: - - - - - -

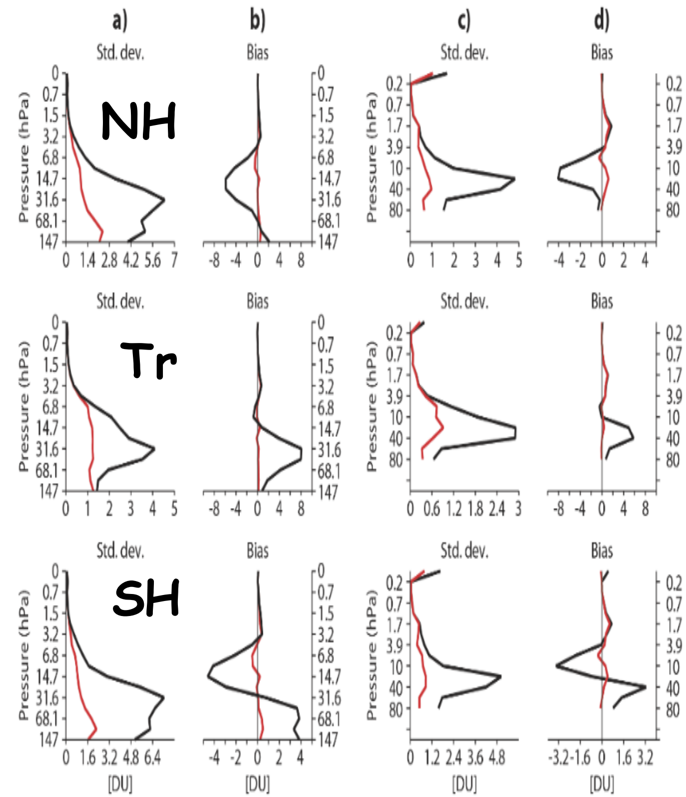
41R1 40R1 40R2

- Assim shows small differences in stratosphere even though controls are different
- Larger differences in troposphere

C-IFS CAR/CB05 assimilation performance

Comparison against ACE





Inness et al. 2015

MIPAS

MLS

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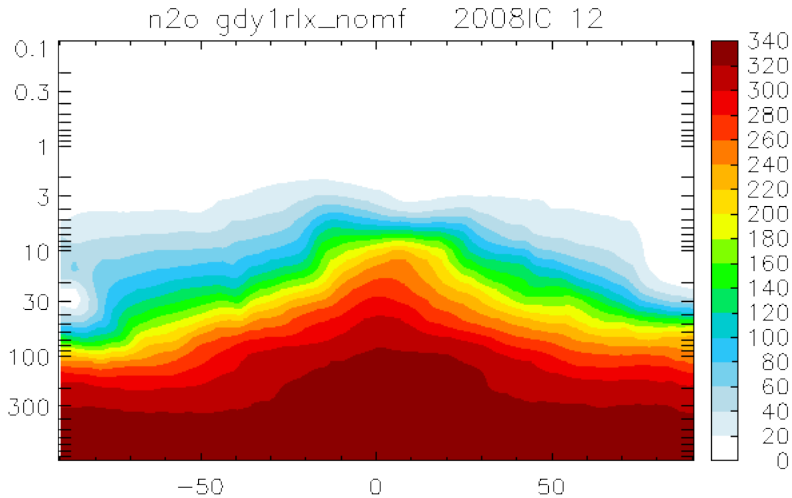
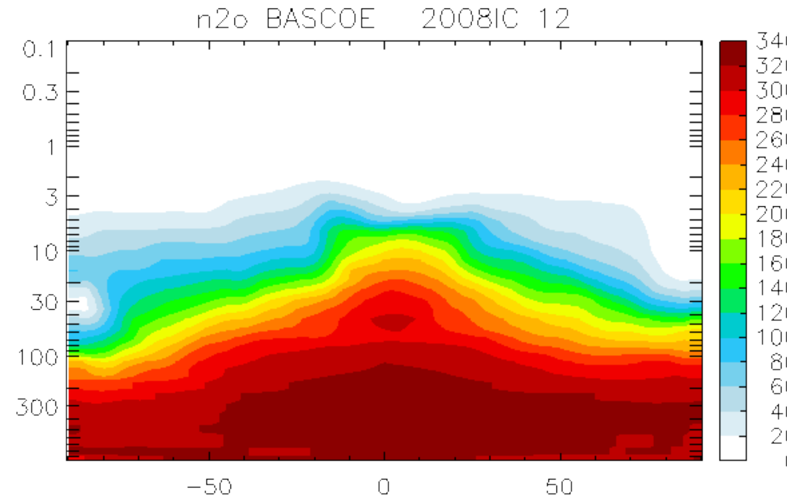
N_2O & O_3 stratospheric transport test suite

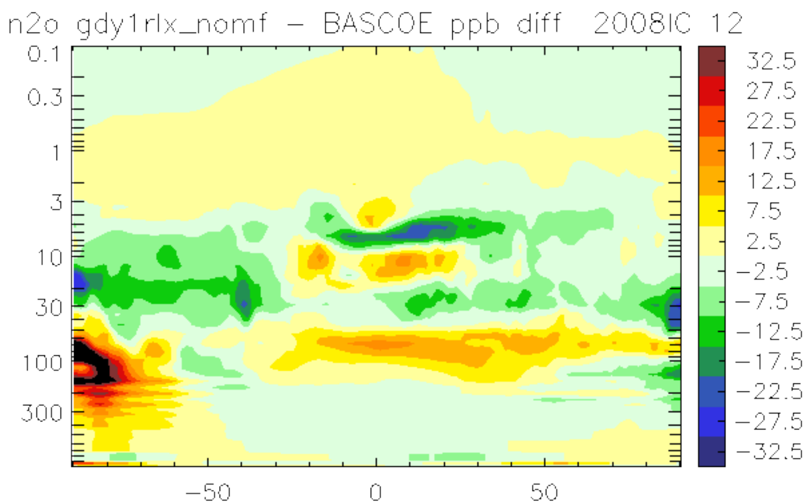
- Simplified N_2O scheme (BASCOE lookup-table for the N2O photolysis rate, O1D lookup-table based on JO3->O1D photolysis rate pressure, based on O1D-output) & O_3 Cariolle
- Initialise with N_2O Analysis (BASCOE, GOZCART) and O_3
- Compare against analysis after 1-12 month / or base case
- Test different advection scheme options
  - Mass Fixers
  - Quasi-monotone limiters
  - SL interpolation approach

C-IFS N2O 4 month

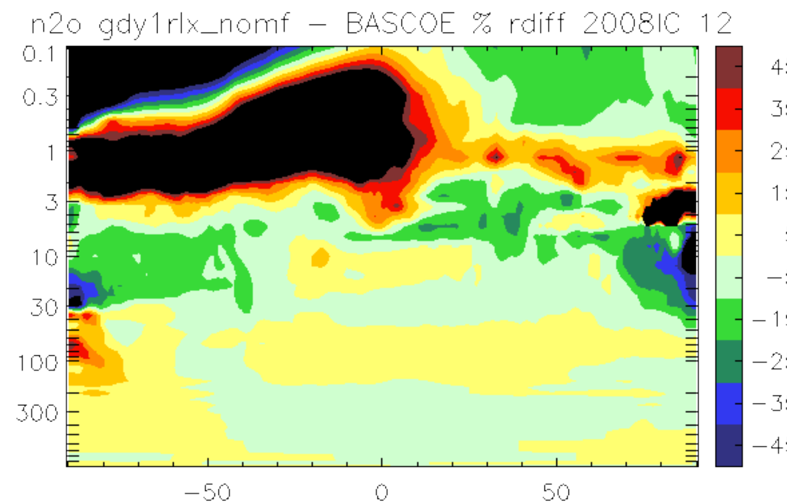
N2O BASCOE RA







Difference



Rel. Difference

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THANK YOU

Ozone in IFS radiation scheme

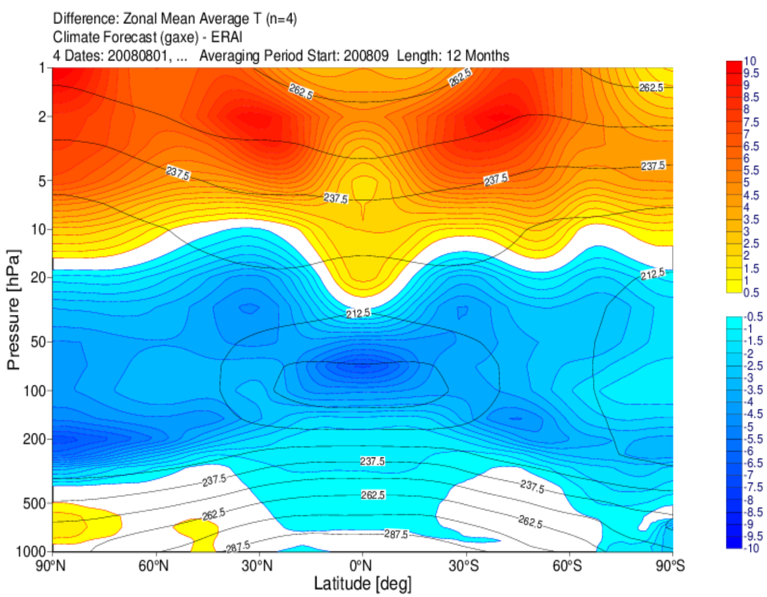
- IFS shows large T biases in stratosphere and lower mesosphere in 1-year forecast run (climate runs)
  - Lower troposphere to mid-stratosphere too cold (300-20hPa)
  - Upper stratosphere to mesosphere (20-0.01hPa) too warm
  - Stratospheric T bias problematic to C-IFS stratospheric chemistry
- Can the biases be related to trace gases concentrations used in IFS radiation scheme ?
- Above 50 hpa ozone related heating & CO2 related cooling dominating terms

Evaluation with independent T and O_3 observations

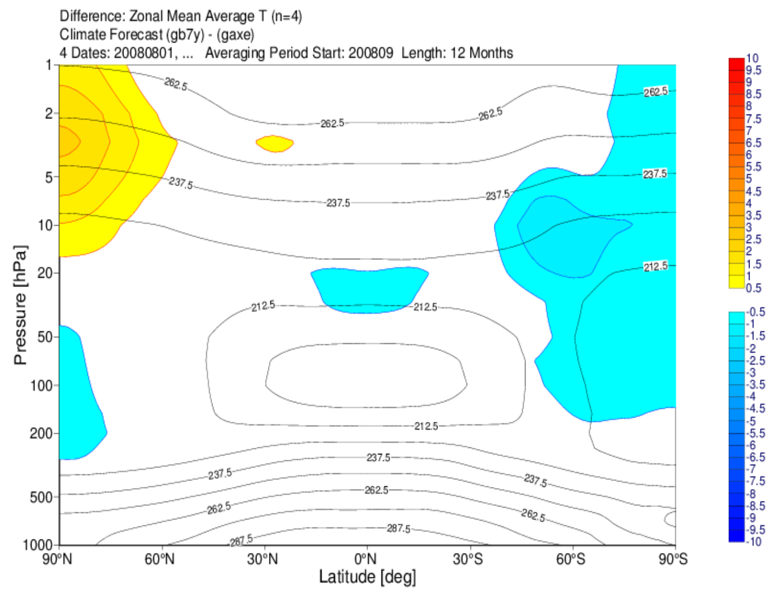
- O_3 and T from ozone sondes averaged for different latitude ranges
- fewer observations above 10 hPa – (5hPa)
- MACC RA overall best ozone apart from above 10 hPa and sometimes lower troposphere
  - T high bias > 10 hpa corresponds to O3 high bias > 10 hPa
- More complex picture below 10 hPa w.r.t to O3 and T biases (dynamics)

Monthly mean vs. 6 hourly MACC RA

T bias (12 month) of 1-year climate run (BASE) vs. ERA interim



T difference Nudged (6h) O3 RA – base (RA O3 MM)



Change in "prognostic vs. climatological ozone is less important. T biases could be perhaps be cured already with better O3 climatology.

NOTE that 6 h MACCRA O3 is not synoptically consistent with 1-year climate run

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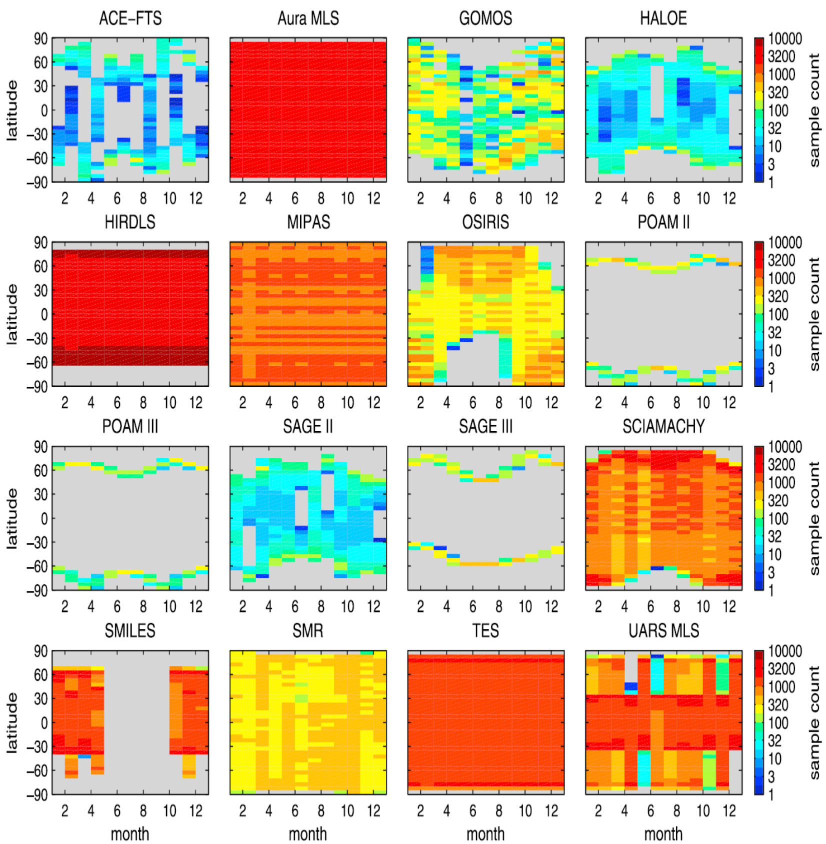
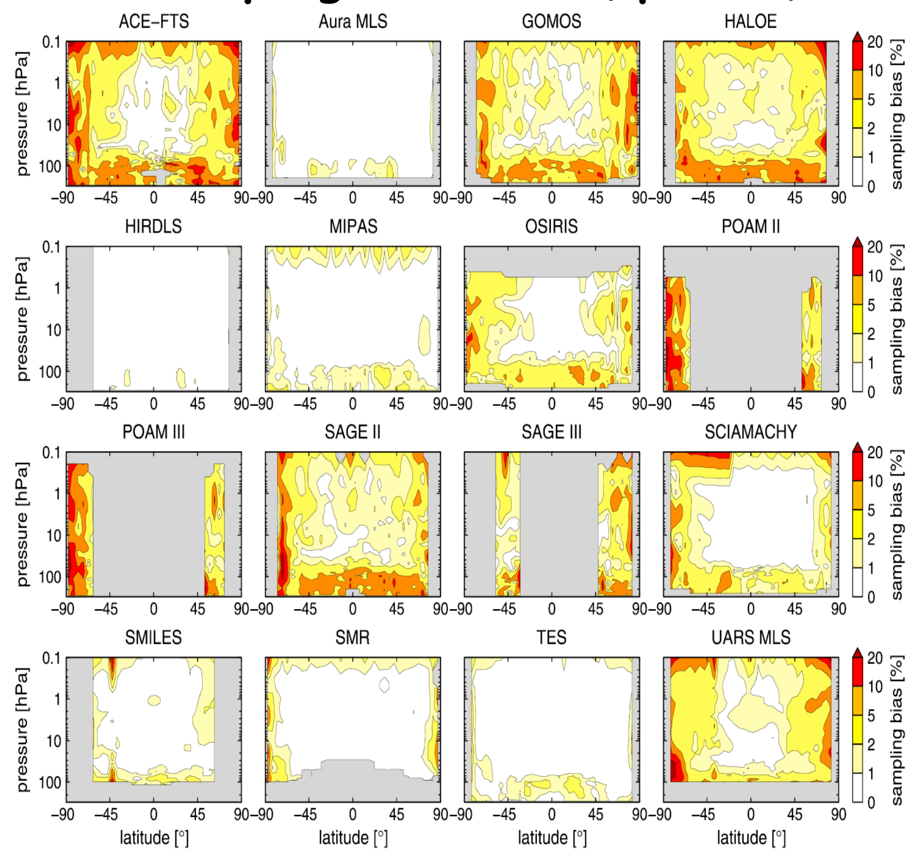
Multi instrument Ozone Retrievals Coverage and Sampling Bias

Coverage (lat-month)



Sampling bias in % (p – lat)



SPARC data initiative Toohey al. 2013, JGR

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