Evaluation of the separate effects of stratospheric ozone assimilation and total ozone assimilation, and their impacts on the predictability of stratospheric and tropospheric ozone

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Meeting: SPARC-DA (June, 2011)

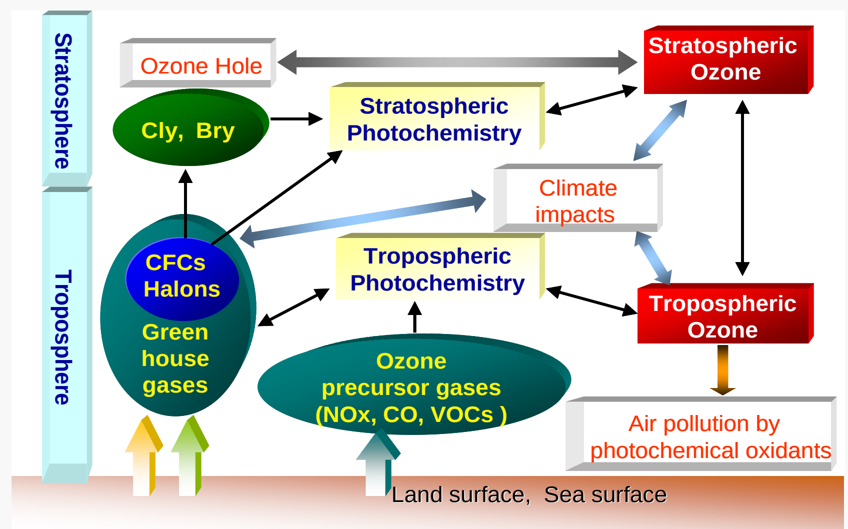
MRI Chemistry-Climate Model, Version 2 (MRI-CCM2)

MRI-CCM2 (Shibata et al., 2005; Deushi and Shibata, 2011) is designed to simulate the distributions and time-evolutions of ozone and related chemical species over the troposphere and the middle atmosphere. This model used for the operational prediction of surface UV-B and photochemical oxidant near the surface at the Japan Meteorological Agency.

The chemistry module of MRI-CCM2 is coupled with a general circulation model (GCM) on-line and treats the following processes: chemical conversions of trace gases, (grid-scale) advective transport, (sub-grid scale) convective transport and boundary-layer diffusion, dry and wet deposition, and emissions. The chemistry module predicts global distributions of 90 chemical species, treating 244 chemical reactions. The employed model horizontal resolution is the triangular truncation at the maximum wave number 42 (T42), corresponding to a grid resolution of 2.8 by 2.8 degrees in longitude-latitude space. In the vertical, the model had 68 layers (L68) extending from the surface to the mesopause (～0.01 hPa).

MRI-CCM2 Model Overview

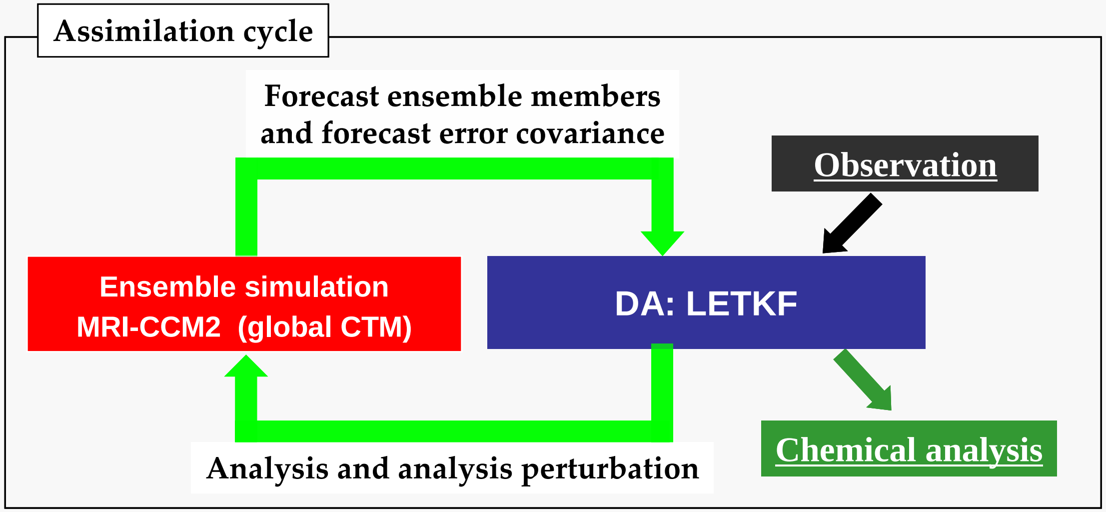
GCM	JMA/MRI GSMUV
Transport	･Grid scale advection … Hybrid Semi-Lagrange ･Sub-grid scale transport and diffusion … Convective transport in the free atmosphere and turbulent mixing in the boundary layer are included.
Chemistry	･Chemical species 90 ･Chemical Reactions 244 (Photolytic 59, Gas phase 169, Heterogeneous 16)
Photo dissociation	･Look-Up table with cloud and surface albedo effect
Emissions	･ Industry, Biomass Burning, Vegetation, Soil, Ocean, Air craft, Lightning, Cosmic Rays ･ NOx, CH_4, CO, NMHC, N_2O, CFCs, Halons
Dry Deposition	･Based on dry deposition velocity calculated from resistance series parameterization of Chang et al. (2002, 2003)
Wet Deposition	･In-cloud and below-cloud scavenging



Data assimilation technique and system: MRICCM2-LETKF

The data assimilation technique used here is the LETKF scheme (e.g. Hunt et al., 2007; Miyoshi and Yamane, 2007). The LETKF scheme is a kind of the ensemble Kalman filter technique, in which covariance localization is applied to remove sampling errors caused by the limited ensemble size.

- Analysis variables : ozone, zonal and meredional winds, and temperature
  Ozone and the other dynamical variables are separately assimilated.
- Ensemble member : 32
- Assimilation cycle : 6-hour
- Adaptive covariance inflation (Maximum inflation is set to 20%)
- Horizontal (vertical) localization length paremeter : 650km (log P=0.4).



Assimilation runs

To evaluate the separate effects of stratospheric ozone assimilation and total ozone assimilation, we performed the following assimilation experiments with MRICCM2-LETKF for the period of July-September in 2006.

Assimilated observational or reanalysis data

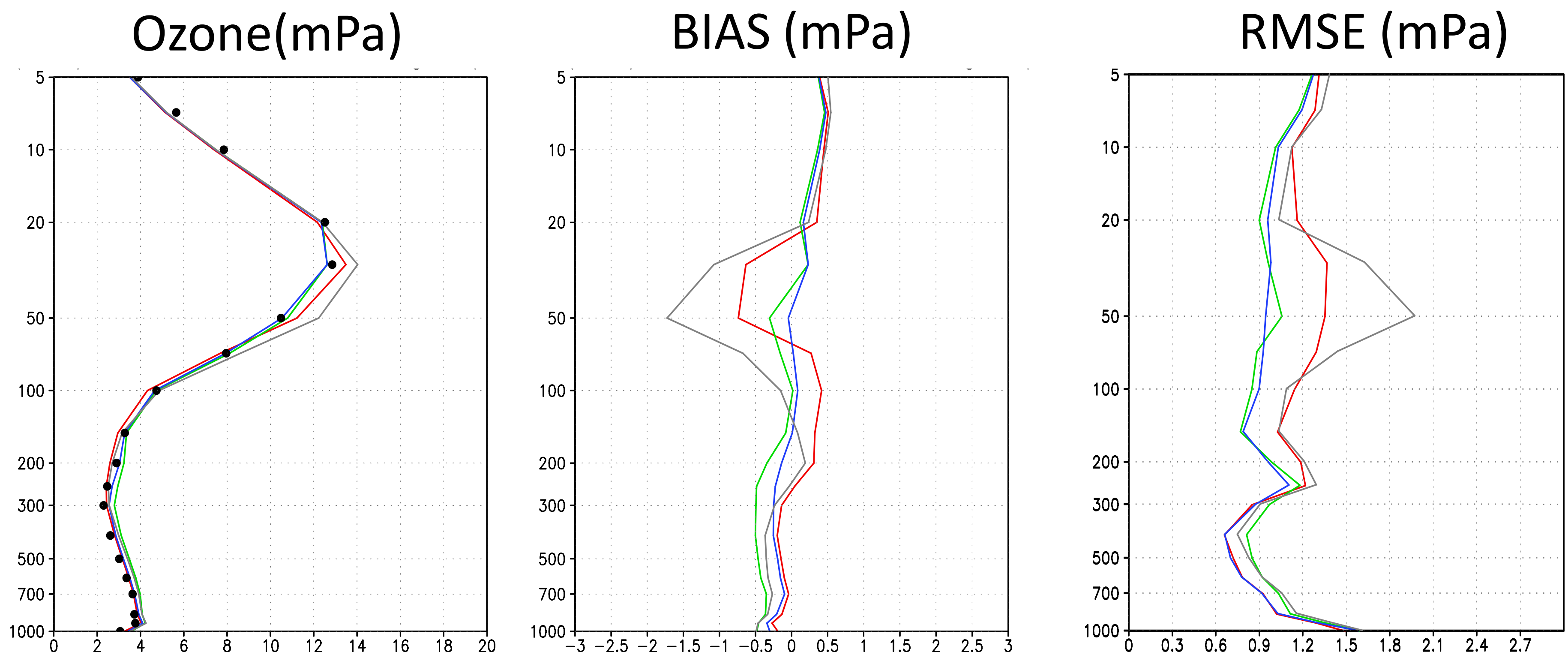
- ☞ MLS ozone data (Level2 Version2.2)
- ☞ OMI-TOMS column ozone data (Level-2G)
- ☞ JMA Climate DA System (JCDAS) reanalysis data (temperature,and zonal and meredional winds)

Assimilated OBS

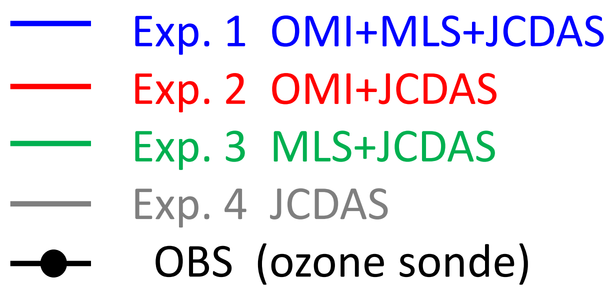
Exp. ① JCADS, OMI and MLS
Exp. ② JCADS and OMI
Exp. ③ JCDAS and MLS
Exp. ④ JCDAS

Accuracy of the assimilated ozone (vs. Sonde, Global mean)

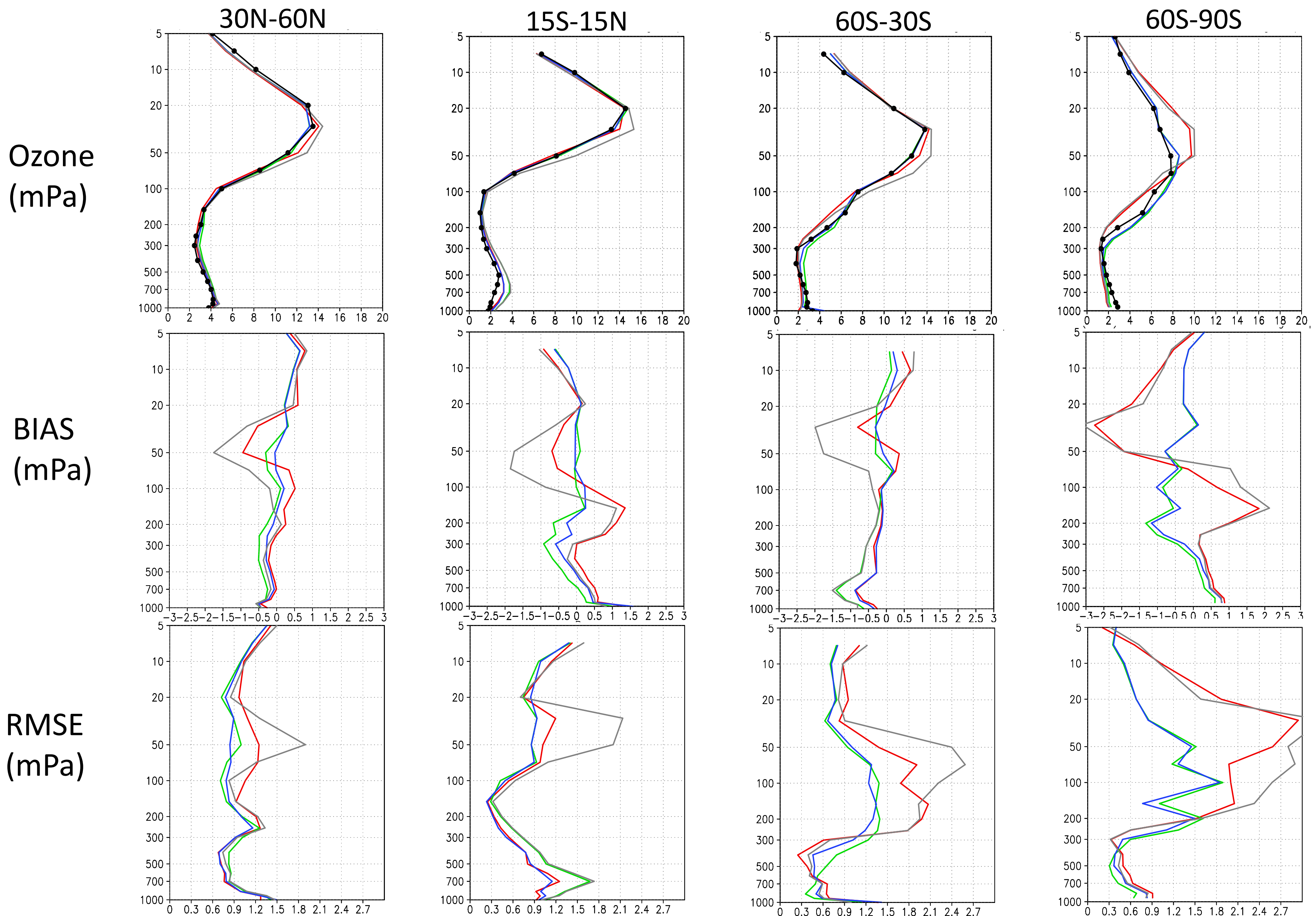
August-September, 2006



(BIAS=OBS-Analysis)

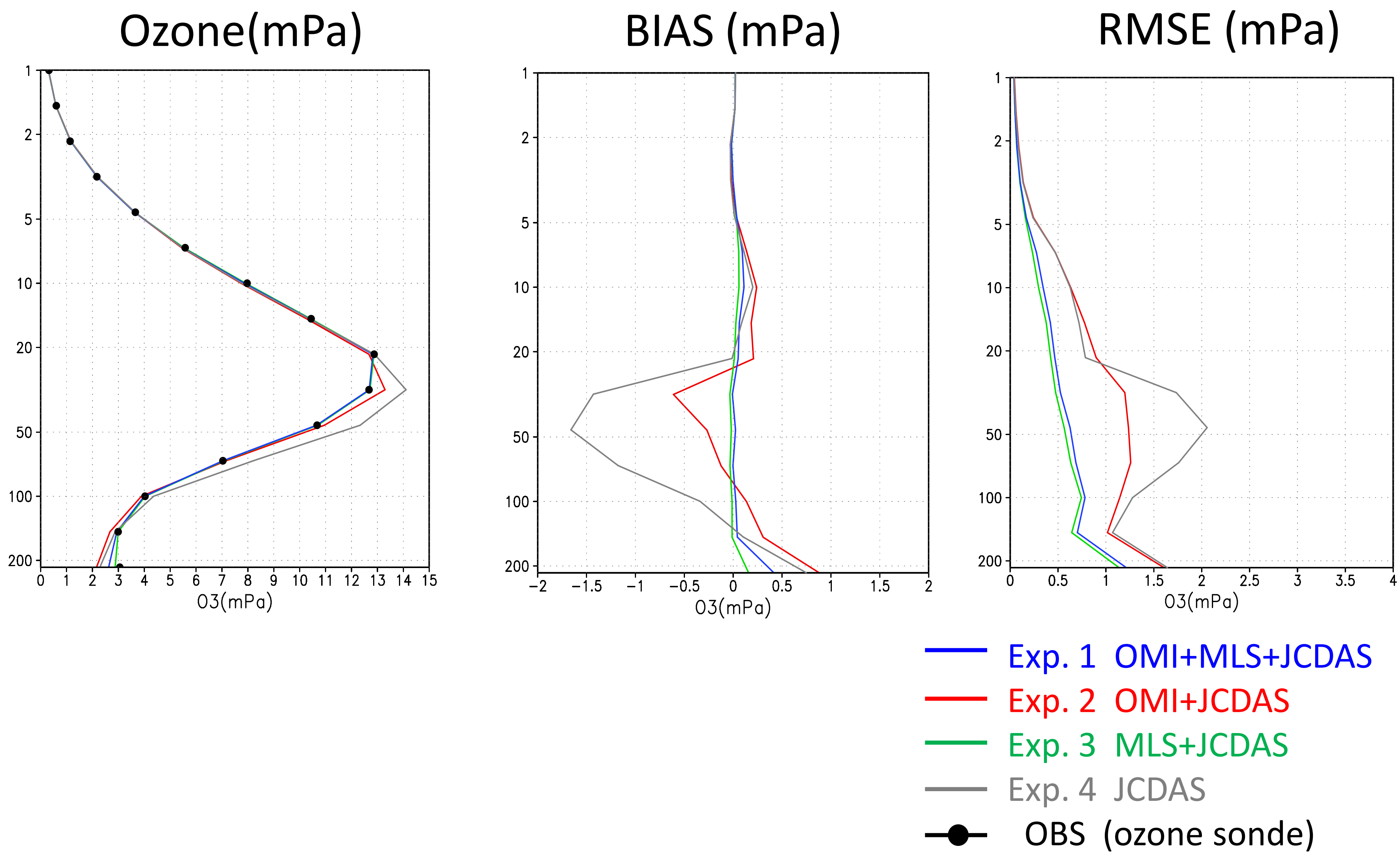


Accuracy of the assimilated ozone (vs. Sonde)

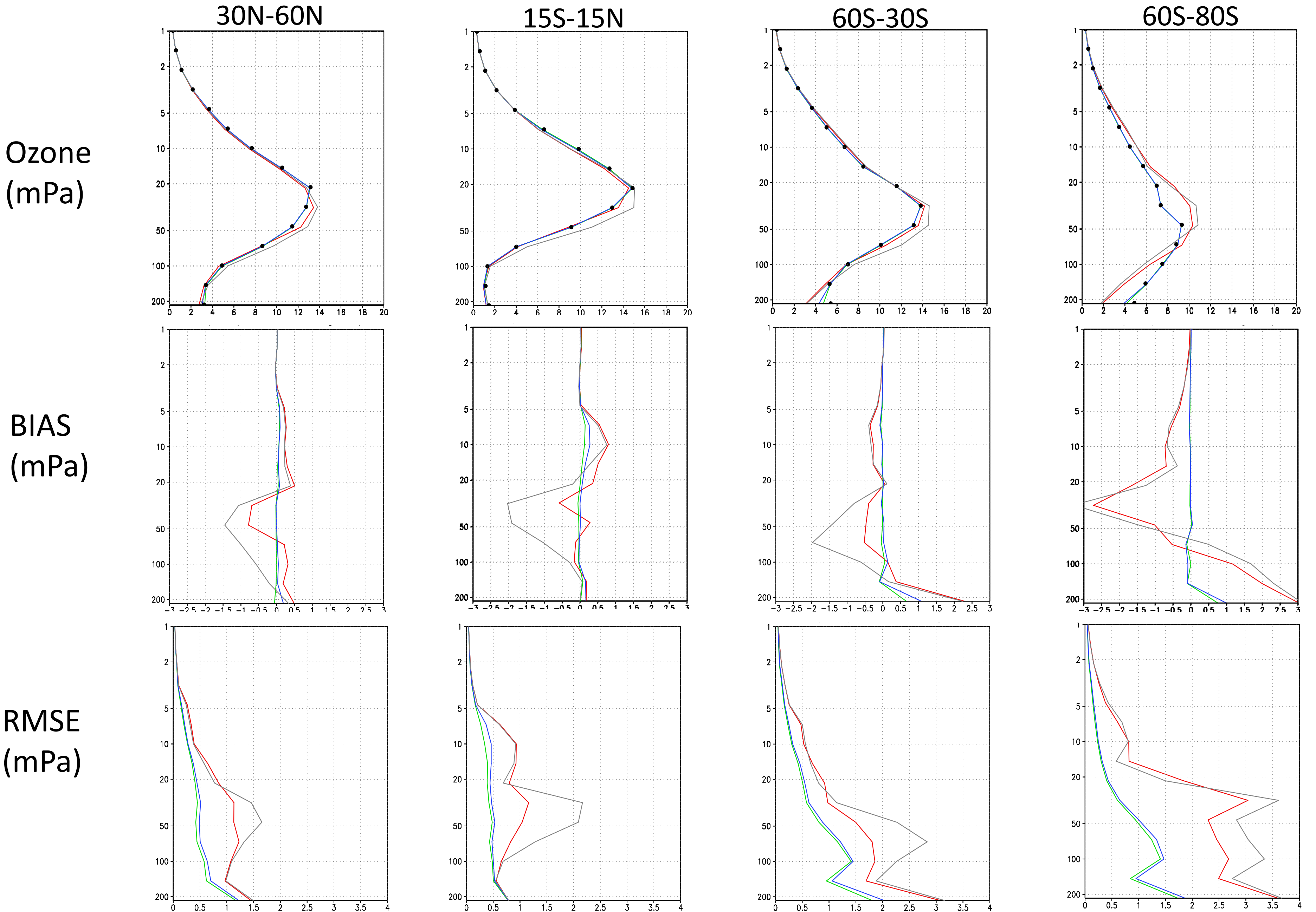


Accuracy of the assimilated ozone (vs. MLS, 80S-80N)

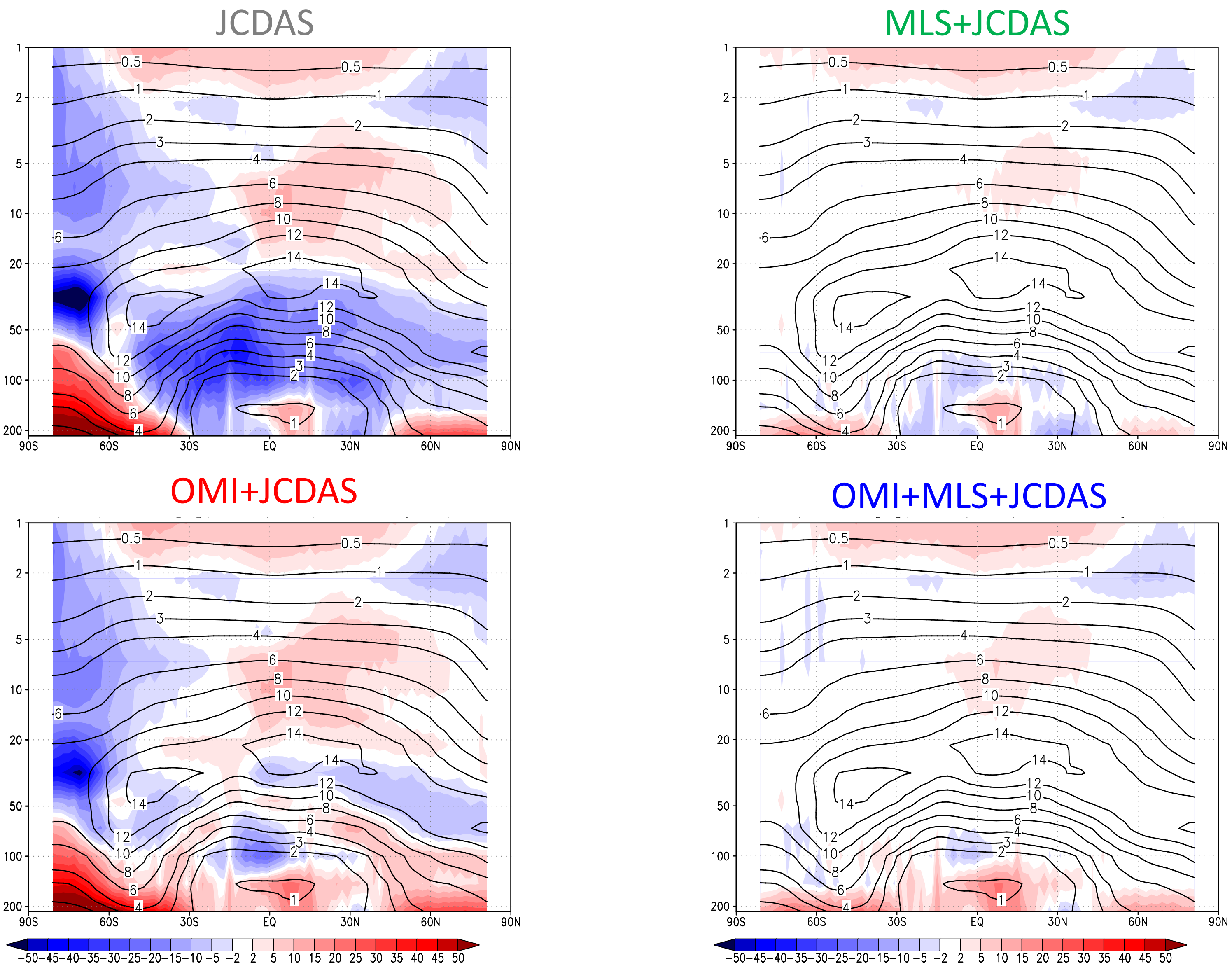
August-September, 2006



Accuracy of the assimilated ozone (vs. MLS)

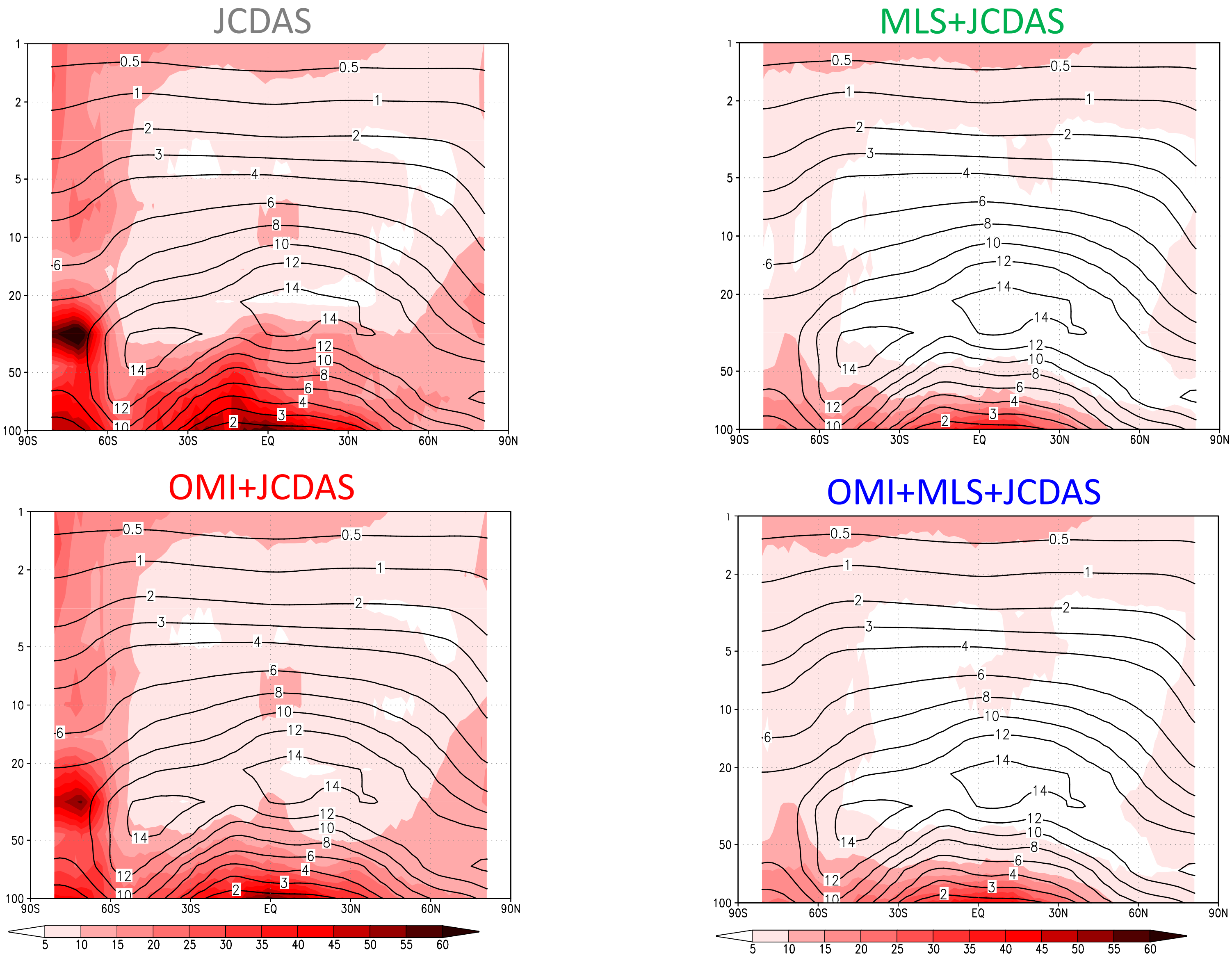


Ozone BIAS (%) (vs. MLS) Aug-Sep, 2006



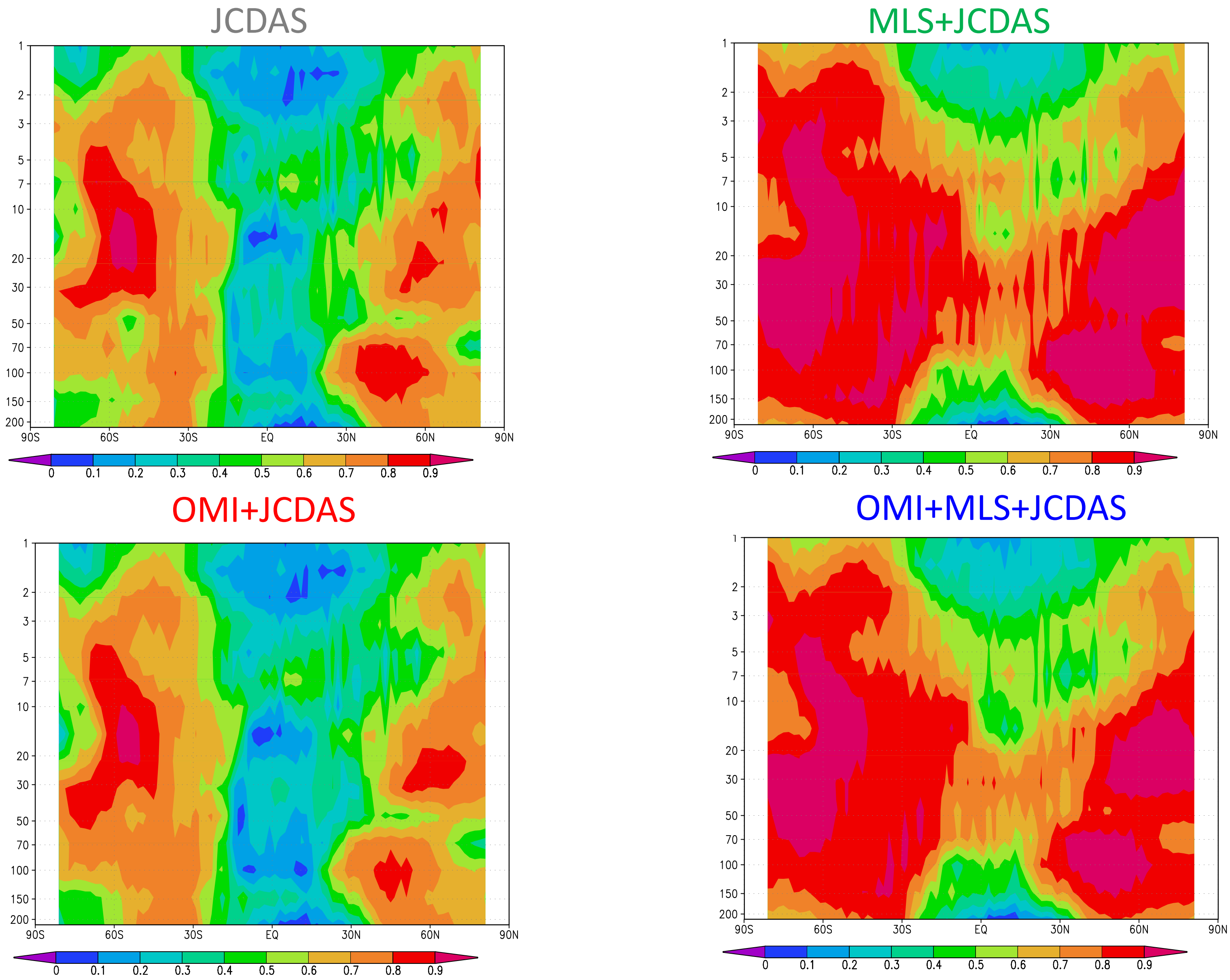
BIAS=OBS-Analysis. Contours : the analyzed zonal-mean ozone (mPa).

Ozone RMSE (%) (vs. MLS) Aug-Sep, 2006

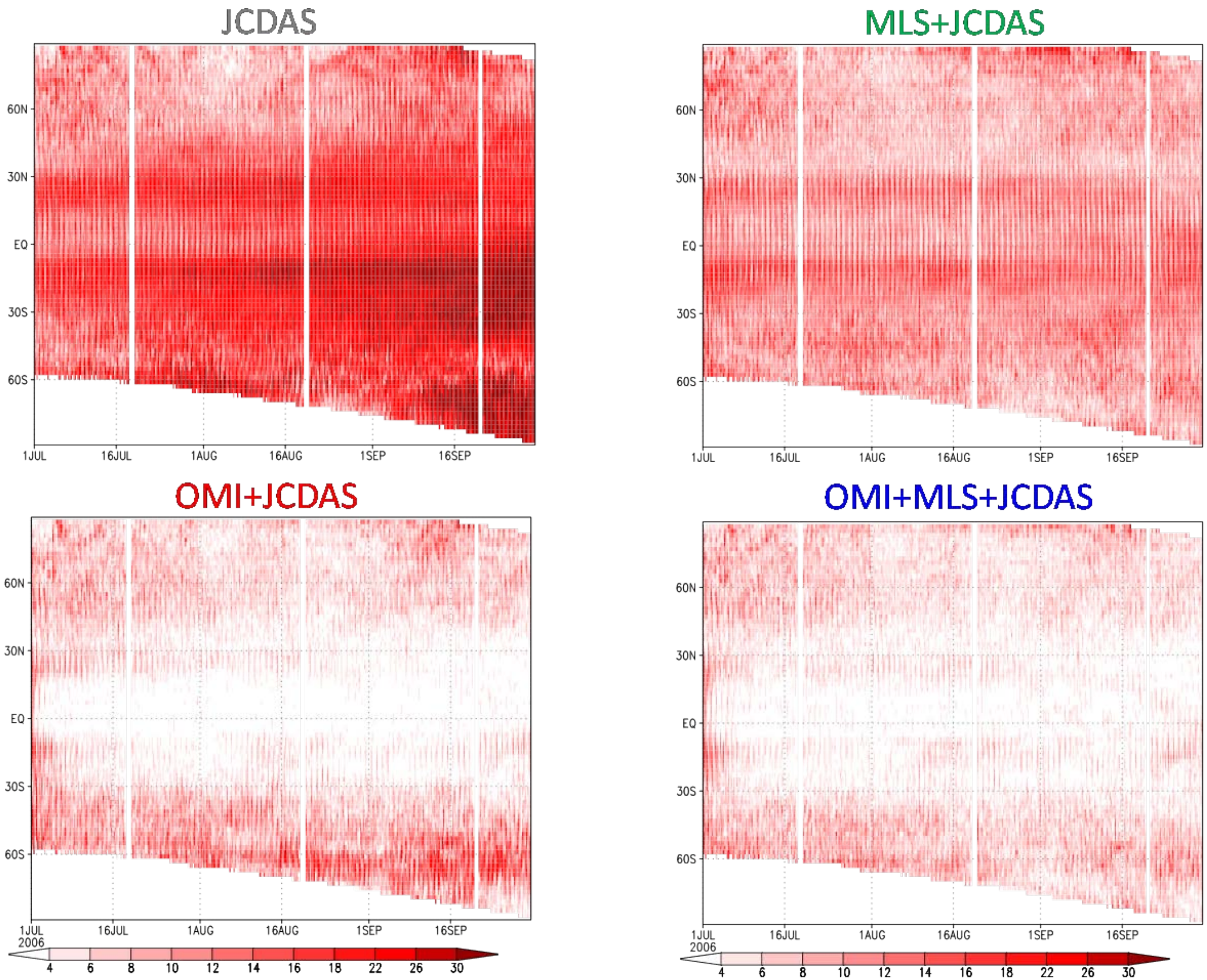


Contours : the analyzed zonal-mean ozone (mPa).

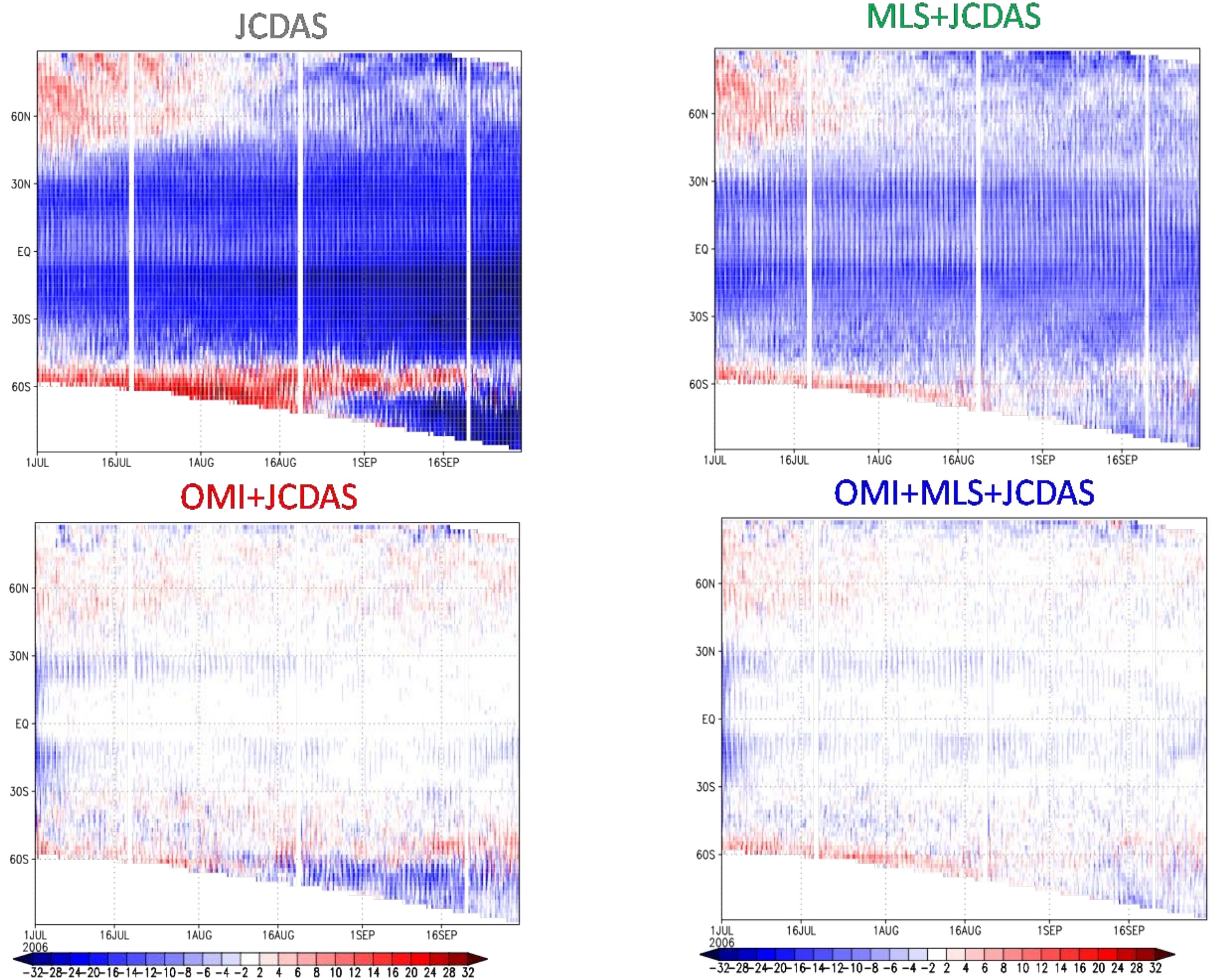
Ozone Pattern Correlation (vs. MLS) Aug-Sep, 2006



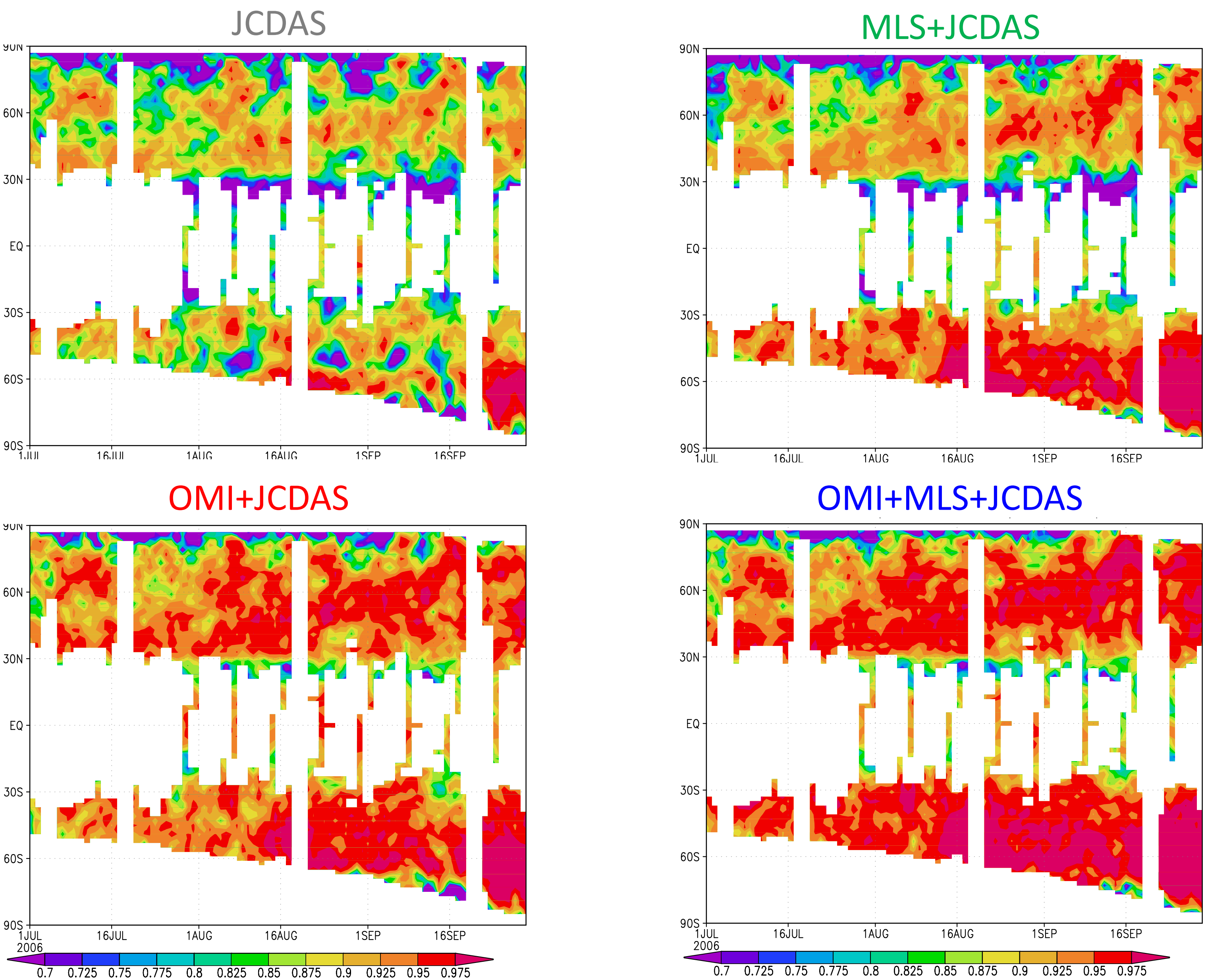
Column ozone RMSE (DU) (vs. OMI) July-Sep, 2006



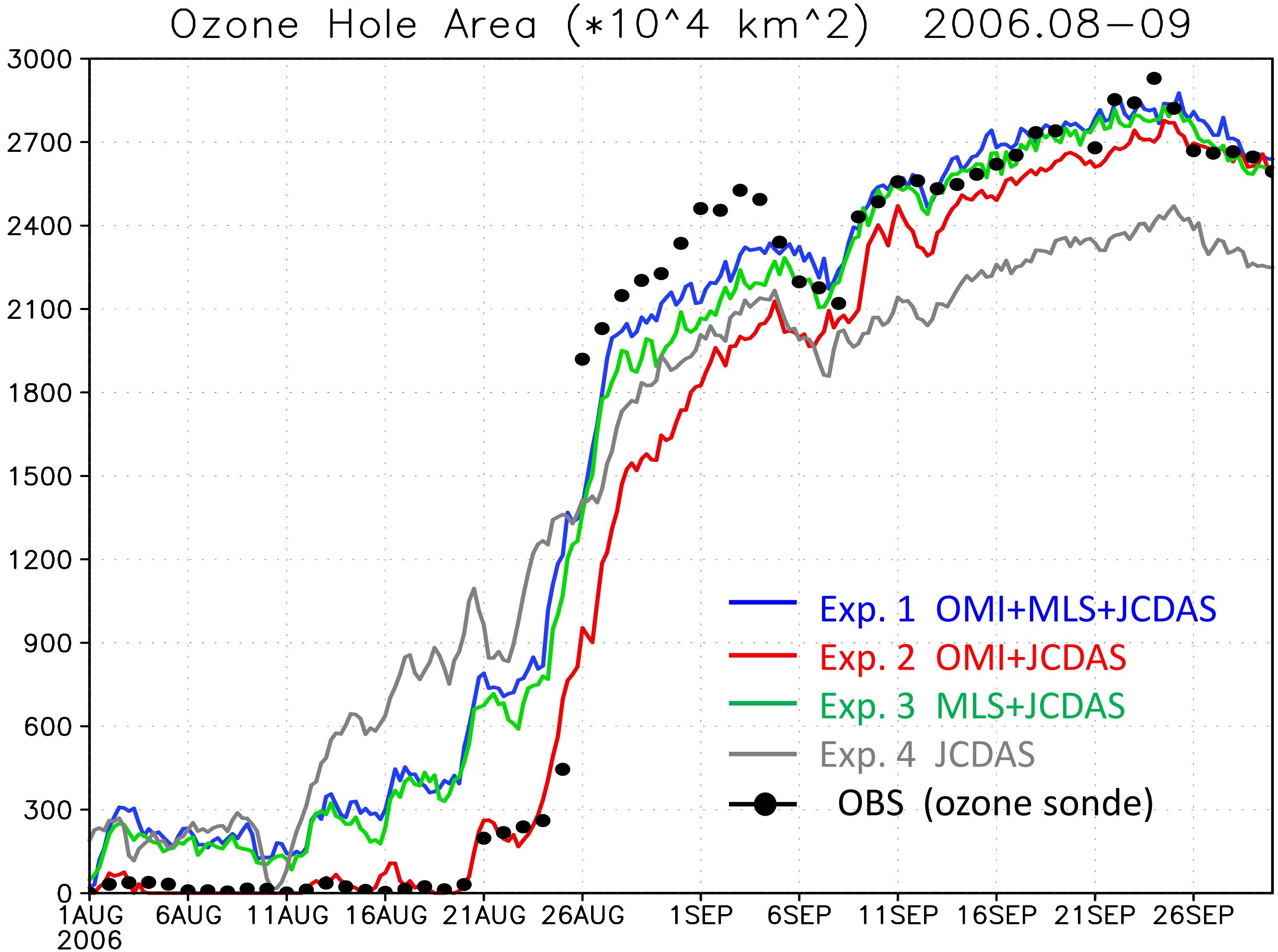
Column ozone BIAS (DU) (vs. OMI) July-Sep, 2006



Pattern Correlation (vs. OMI) July-Sep, 2006



Ozone hole area (vs. OMI) Aug-Sep, 2006



The observational ozone hole area is calculated using the OMI-TOMS column ozone data.

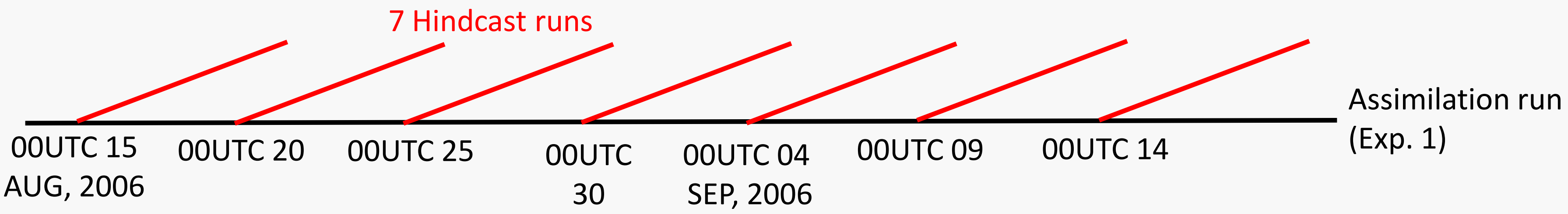
Hindcast runs

We performed the hindcast runs to examine the predictability of the MRI-CCM2 model on the column ozone.

In the hindcast runs, the assimilated ozone and dynamical fields in Exp. 1 are used as the initial data, and the nudging of zonal and meridional winds to JCDAS reanalysis data are applied with 24 hour e-holding time.

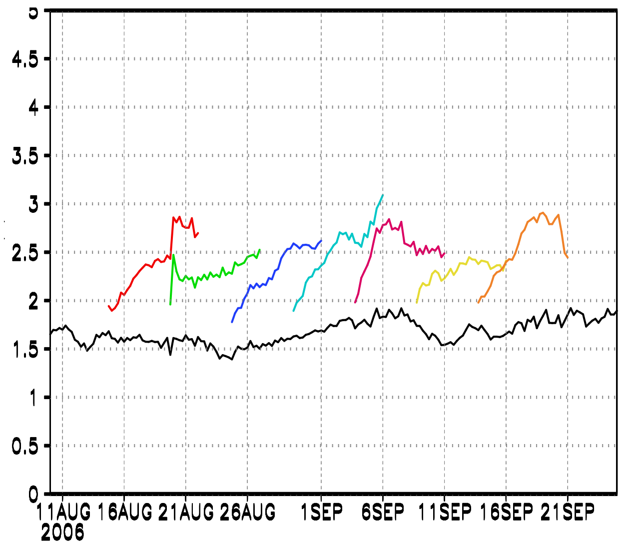
Hindcast Runs

- ☞ Model: MRI-CCM2 with nudging to JCDAS
- ☞ Hindcast Period: 7days
- ☞ 7 hindcast runs every 5days

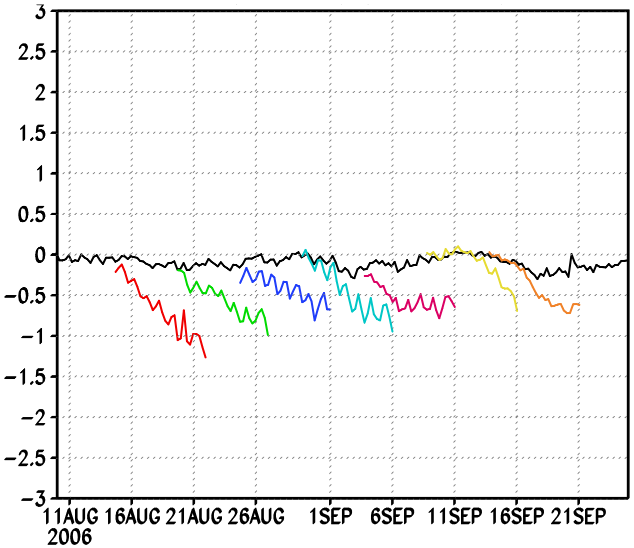


Accuracy of the hindcast runs (vs. OMI, 30N-60N)

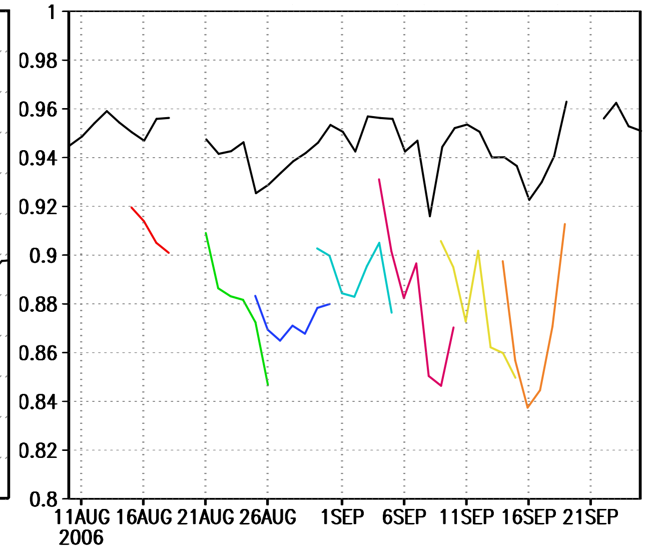
RMSE(%)



BIAS (%)

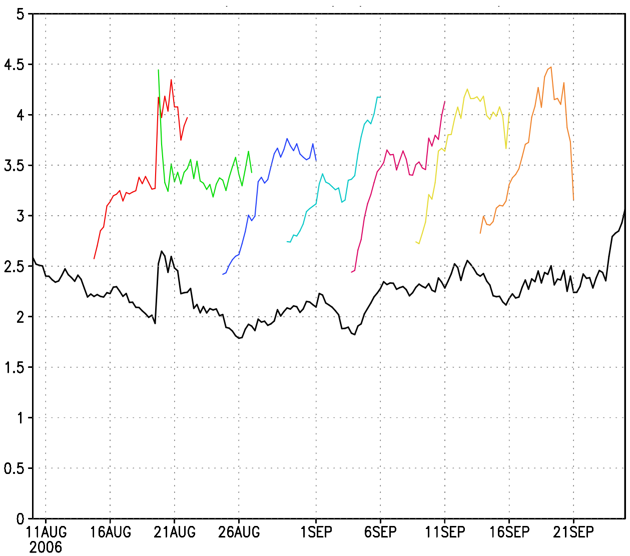


Pattern Corr.

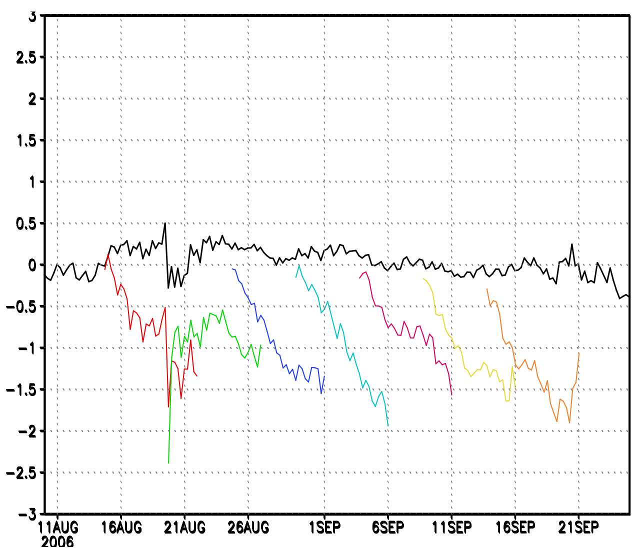


Accuracy of the hindcast runs (vs. OMI, 60S-30S)

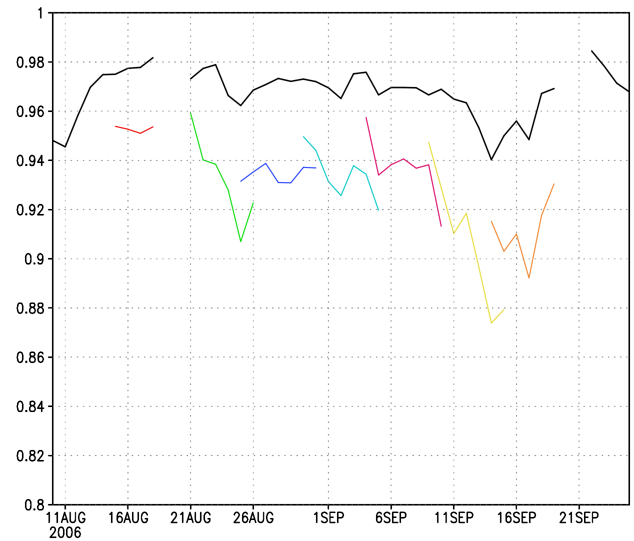
RMSE(%)



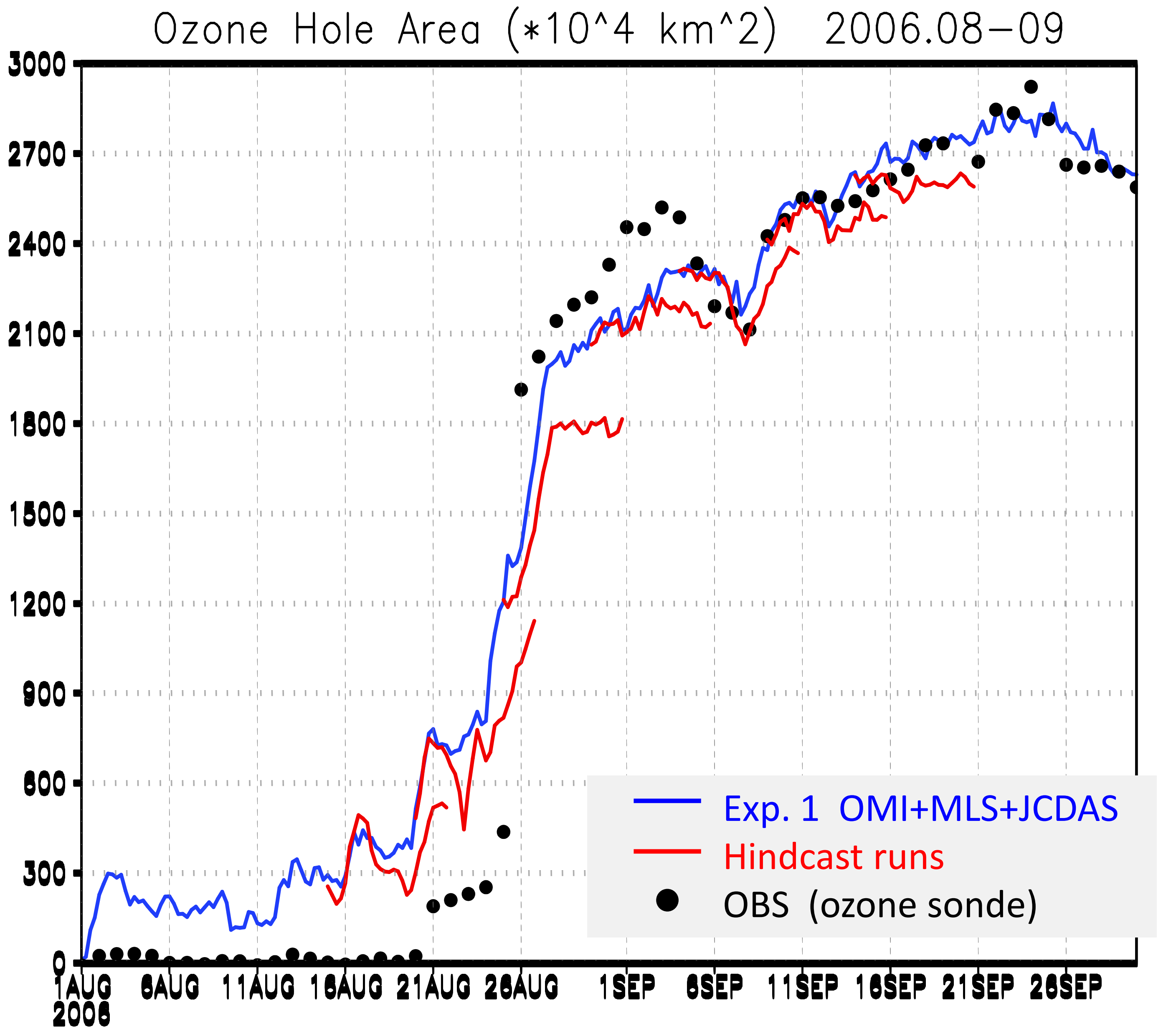
BIAS (%)



Pattern Corr.

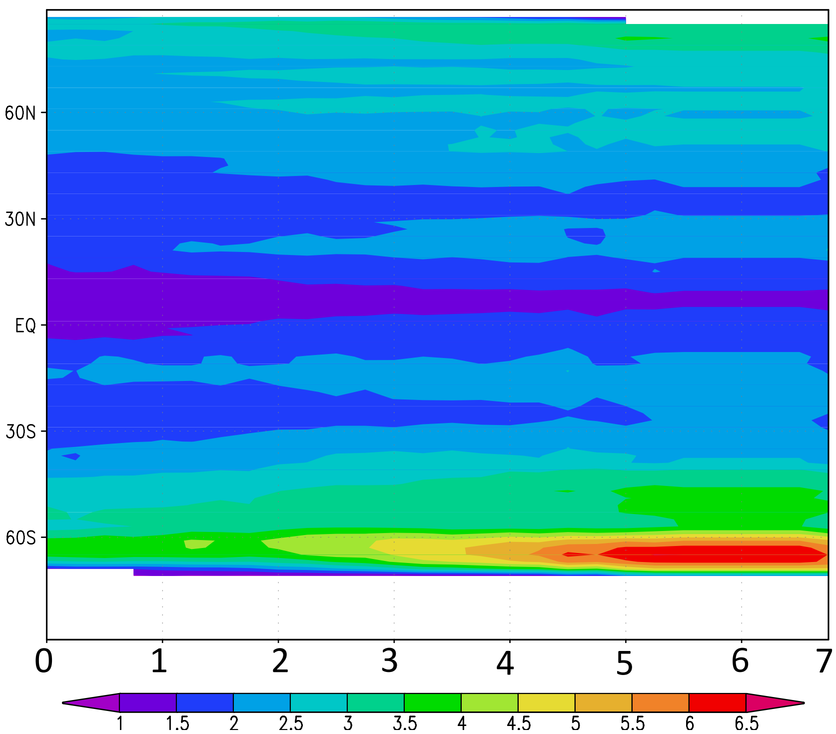


Ozone hole area (vs. OMI) Aug-Sep, 2006

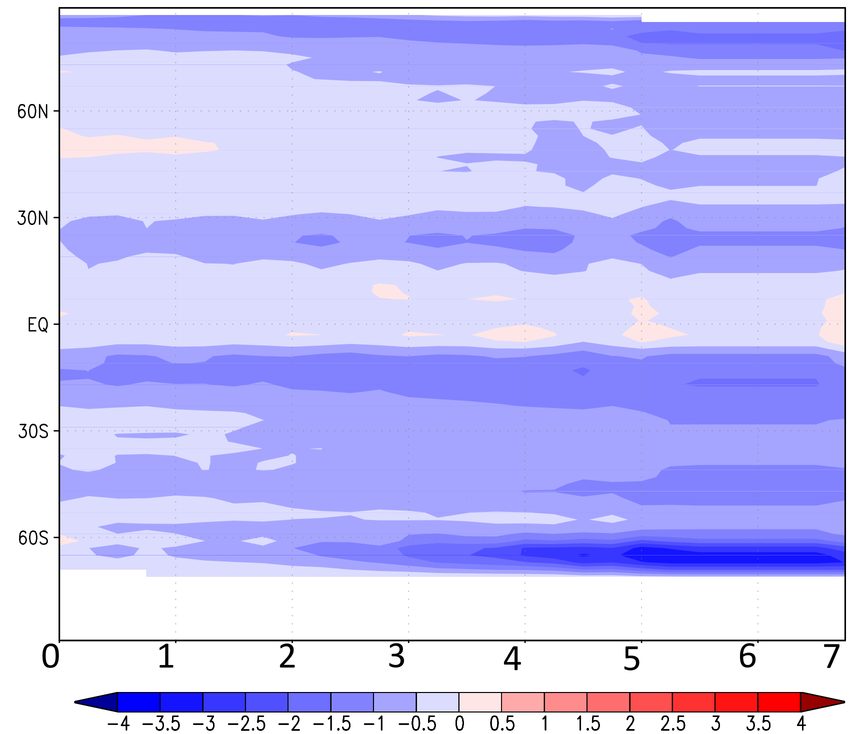


Composite of 7 hindcast runs (vs. OMI, 30N-60N)

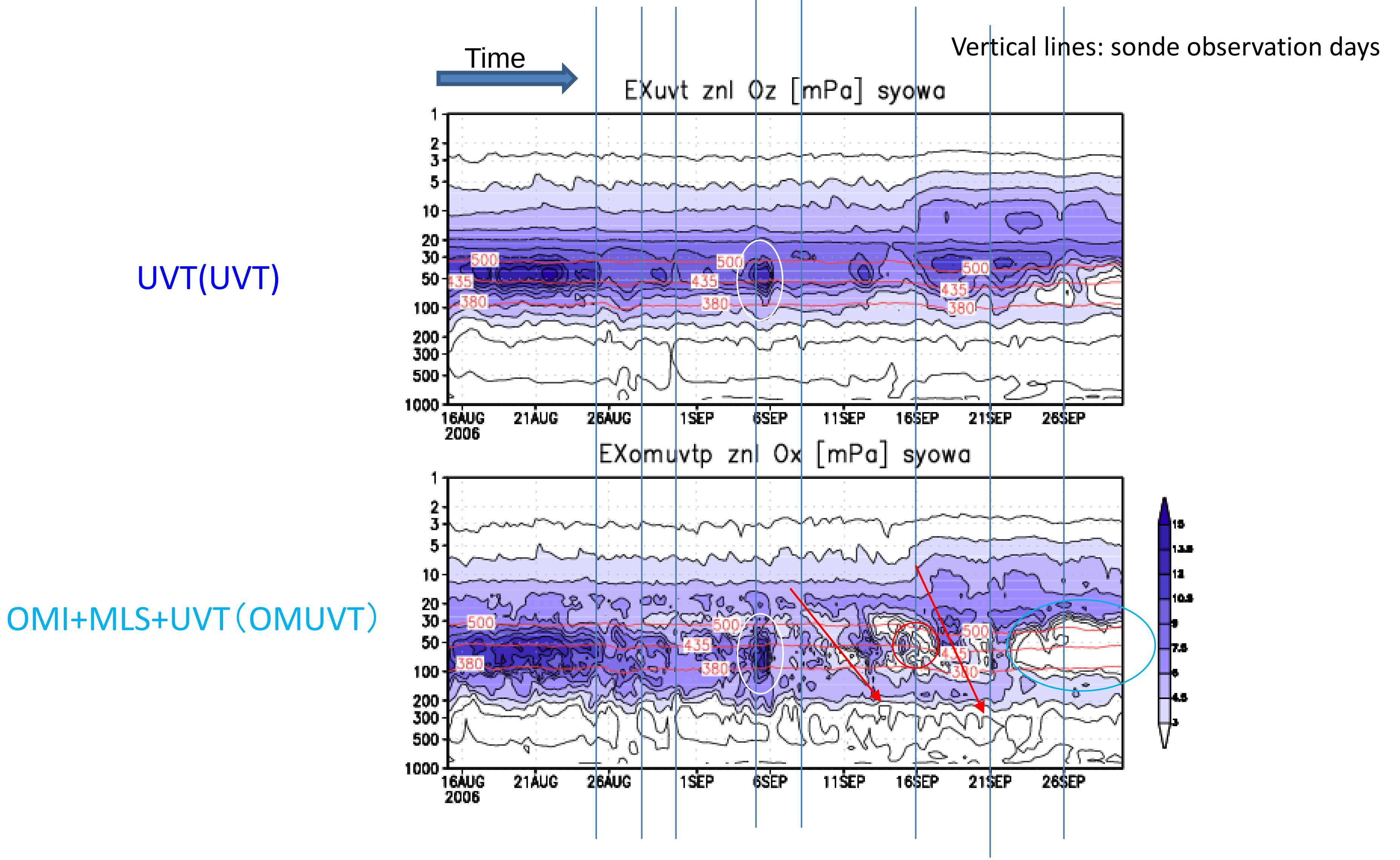
RMSE (%)



BIAS (%)

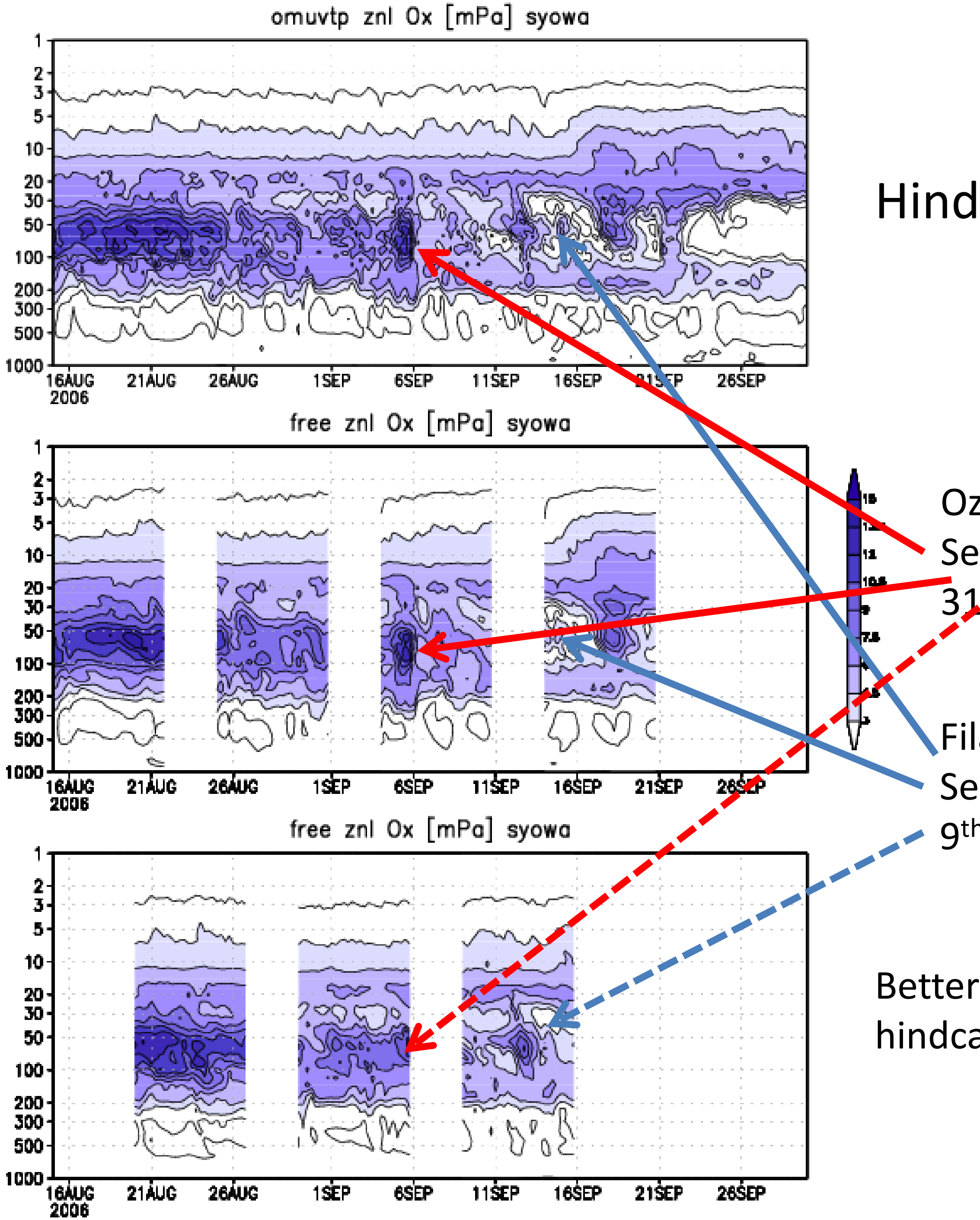


Time evolution of assimilated ozone profile (mPa) over Syowa Station Antarctica



OMI+MLS+UVT assimilation captured fine structure around 30-100 hPa, which the UVT assimilation could not necessarily capture.

Hindcast by free CCM

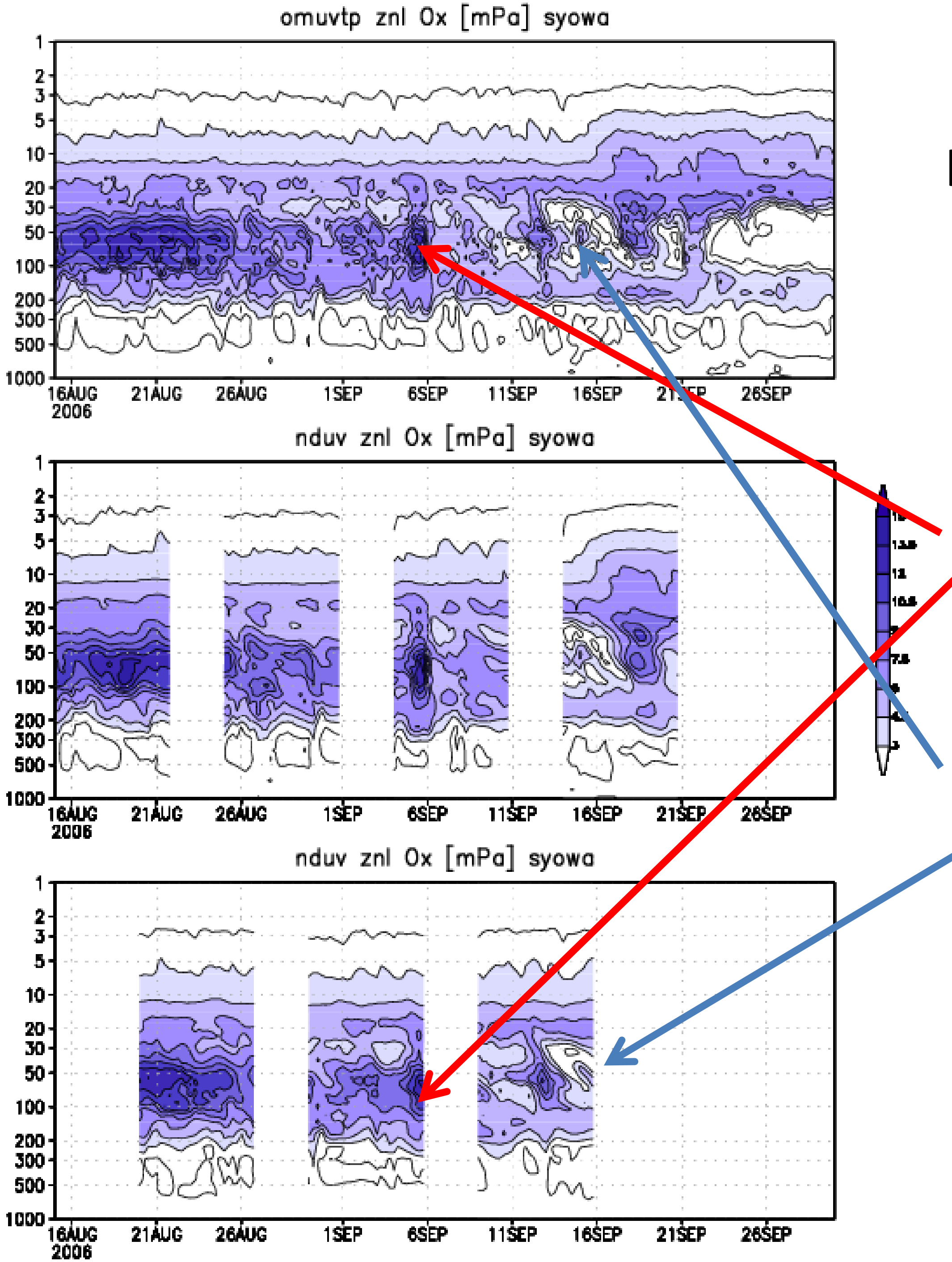


Ozone-rich air around Sep. 5th:
Sep. 4th initial reproduced, while Aug. 31st could not well predict.

Filament structure on Sep 15th:
Sep. 14 initial reproduced, while Sep. 9th initial did not.

Better performance only for 2-3 days hindcast

Hindcast by nudging CCM



Ozone-rich air around Sep. 5th: Aug. 31st reproduced.

Filament structure on Sep 15th: Sep. 9th initial reproduced.

Much better performance even in 7-day hindcast

Summary

- The performance of ozone data-assimilation is evaluated for the period of July-August in 2006 by assimilating the MRI-CCM2 to the objective analyzed atmospheric field (JCDAS), total ozone (OMI), stratospheric ozone profile (MLS).
- The best performance is when all (JCDAS, OMI, and MLS) are used, while the worst is for JCDAS alone.
- Total ozone assimilation alone does not necessarily produce better ozone profile, indicating that the large-correction heights strongly depend on model biases.
- Under non-negligible biases of model atmospheric field, assimilation or nudging to the analyzed atmospheric field is preferable to produce better ozone prediction in the transport-dominant domain below the middle stratosphere such as ozone hole in the Antarctic.