Improving the Stratosphere in Reanalysis

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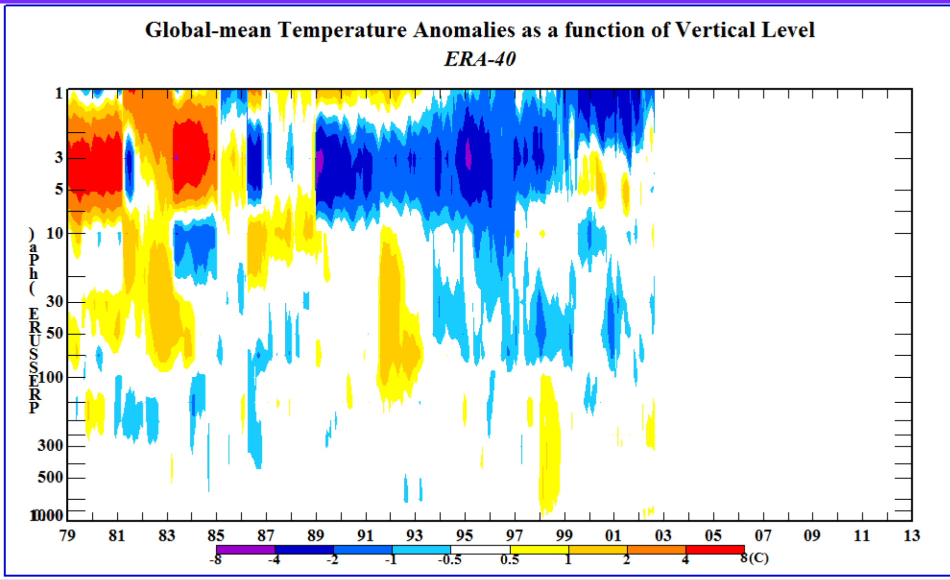
Outline

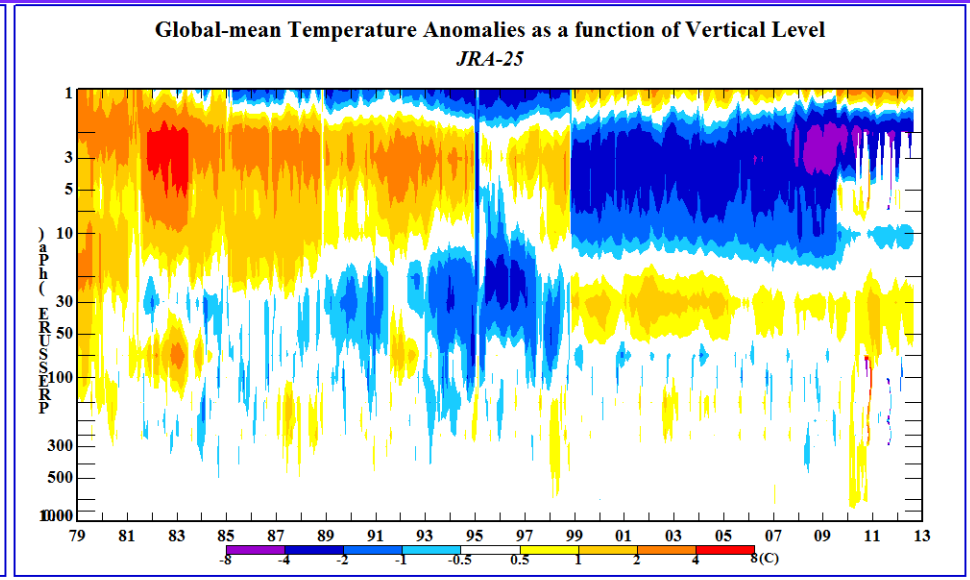
- Problems in Stratosphere in CFSR and other reanalyses
- CFSRL Progress
- Proposed activities
- Status of current work

Problems

- Problems in Stratosphere in CFSR and other reanalyses
  - Stream Jumps
  - QBO issues during wind transitions
  - Bias Correction of temperatures at top of the model
  - SSU to AMSU transition
  - AMSU ch 14 Zeeman correction
  - Ozone variability
  - Water Vapor realism

Global Temperature Anomalies

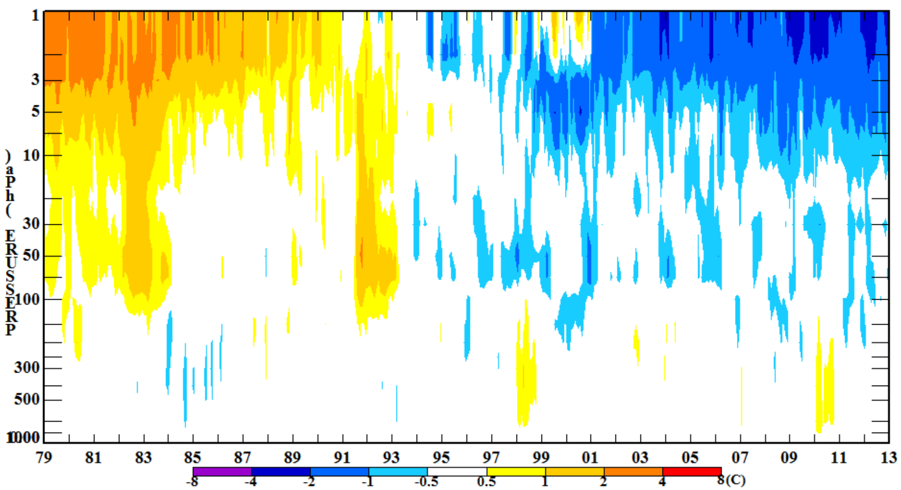




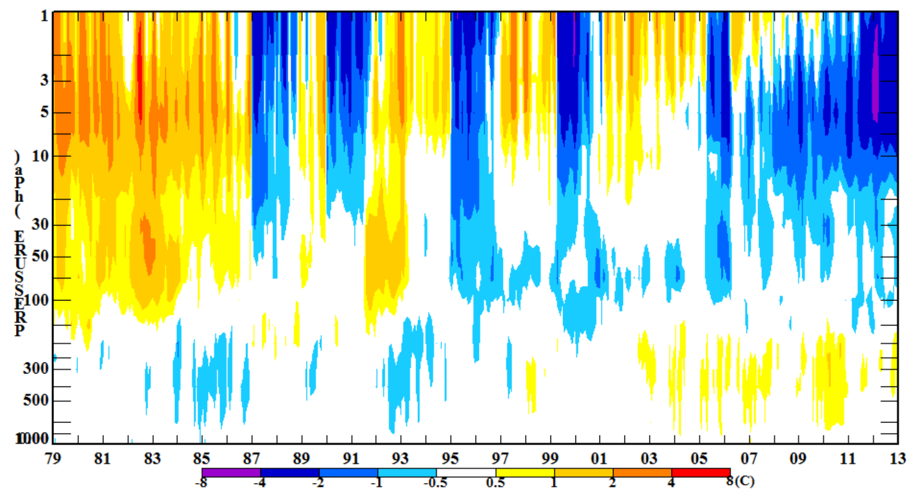
Global Temperature Anomaly time series illustrate temporal discontinuities in temperatures due to changes of instruments and stream transitions.

Global Temperature Anomalies

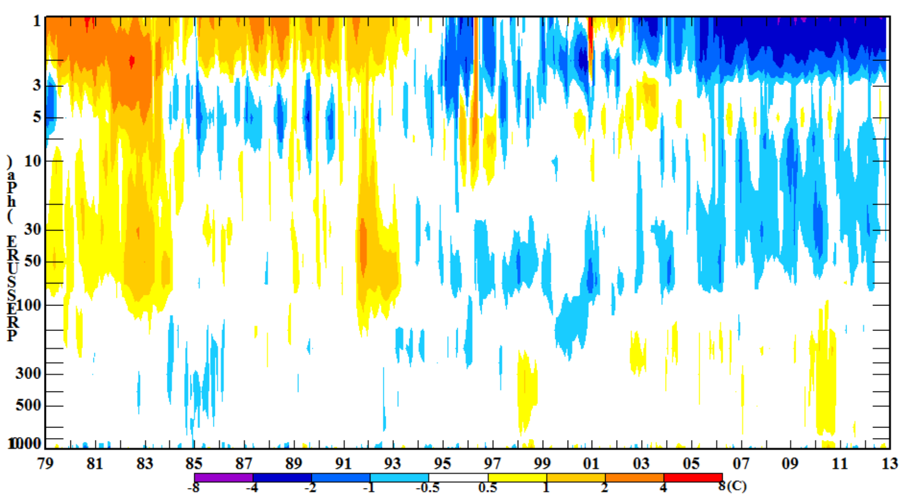
Global-mean Temperature Anomalies as a function of Vertical Level
JRA-55



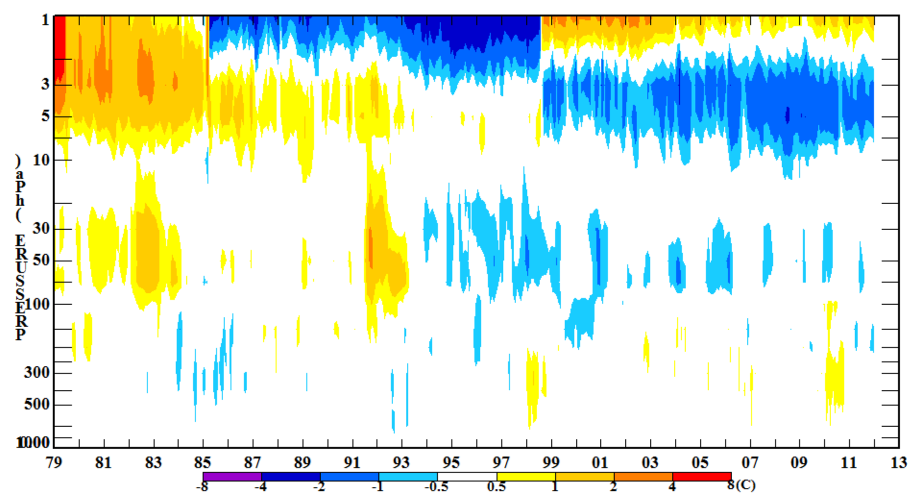
Global-mean Temperature Anomalies as a function of Vertical Level
CFSR

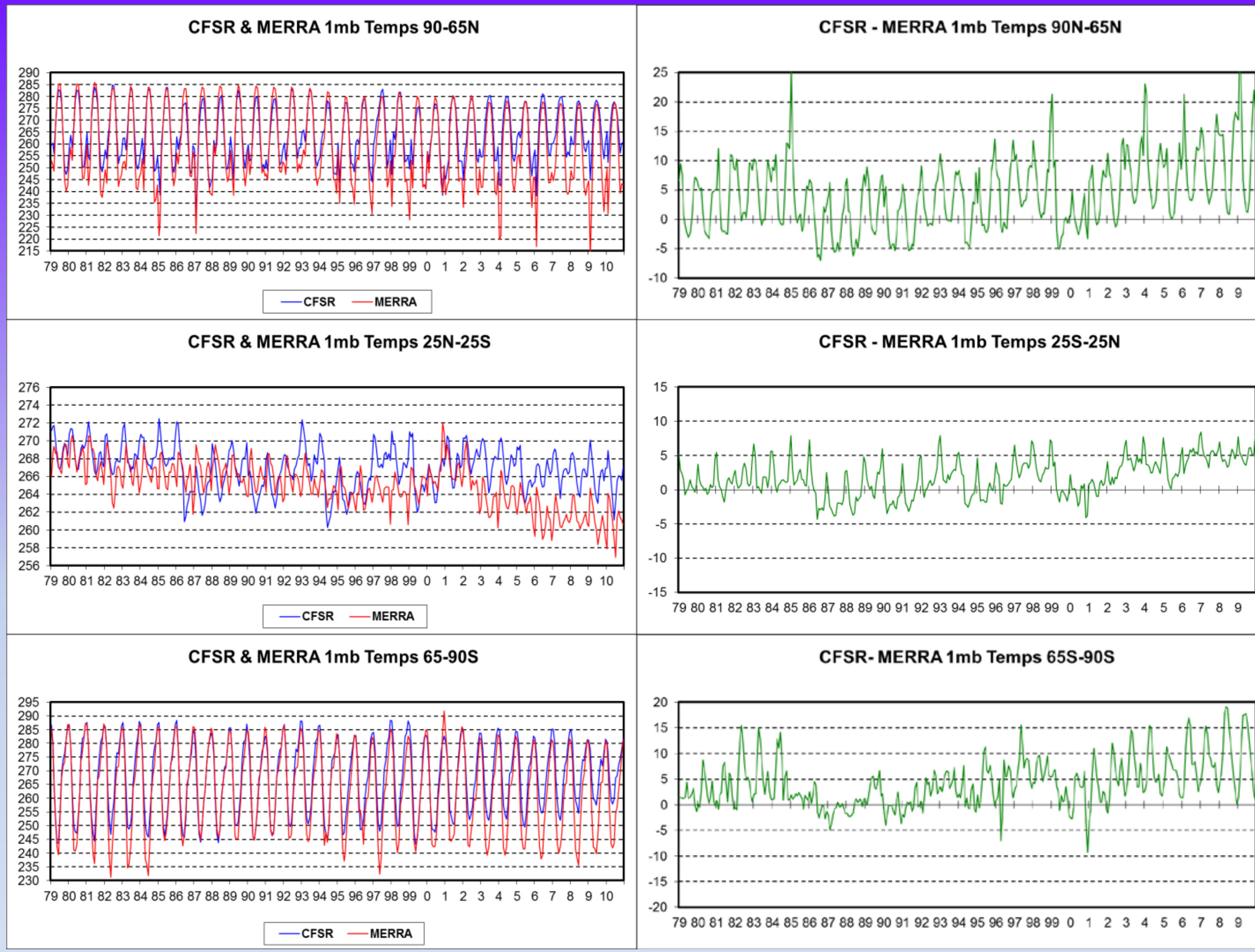


Global-mean Temperature Anomalies as a function of Vertical Level
MERRA



Global-mean Temperature Anomalies as a function of Vertical Level
ERA-Interim



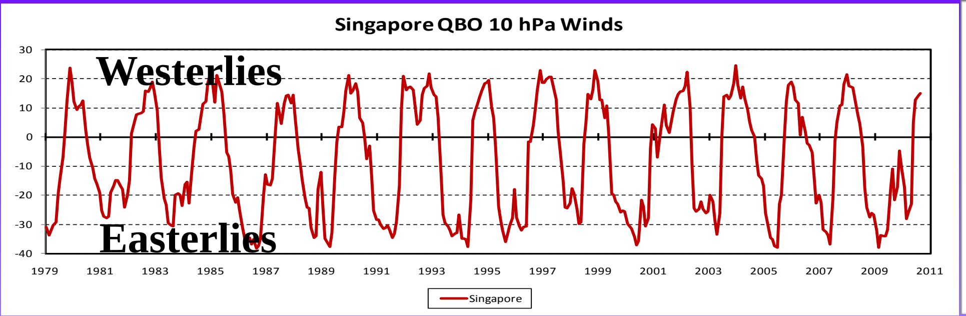


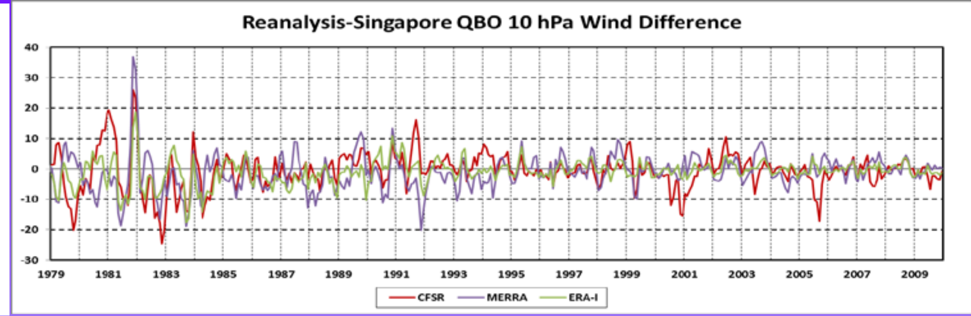
Time series of 1 hPa temperatures (left) and differences (right) between the CFSR and MERRA reanalyses at 90-65N (top), 25N-25S (middle), and 65-90S (bottom). Note the large temperature jumps associated with the CFSR stream boundaries. Note also that the CFSR annual amplitude diminishes during the AMSU-A time period (years > 1998). Note the downward trend in the MERRA tropical temperatures after 2001.

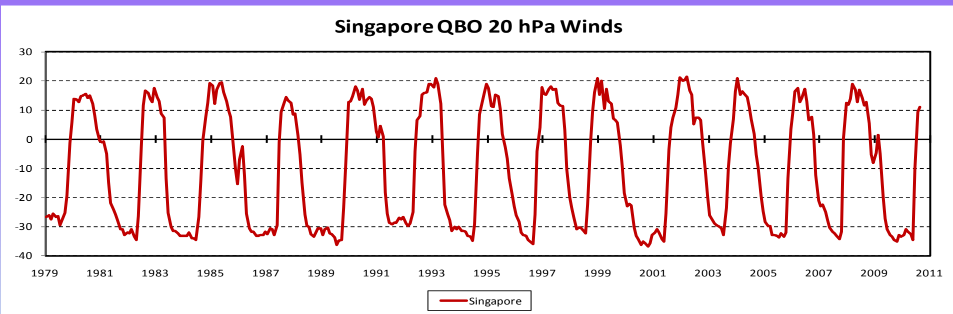
QBO Issues

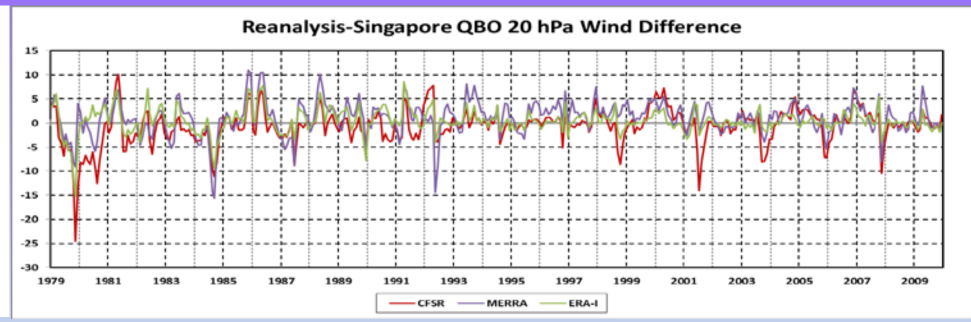
- Just a few radiosonde sites near Equator
- Frequency of radiosonde reaching 10 hPa or higher is low.
- All reanalyses persist winds
  - Results in a delay before analysis follows obs following a shift in wind direction.
- CFSR resorted to using ERA40 tropical winds through 1998.
- Impact of SAO on QBO
  - Needs research
- Impact of SSU on SAO and top QBO winds
  - SSU in 1980's changed frequently
  - Some channels had fast pressure cell changes
  - Some channels were noisy

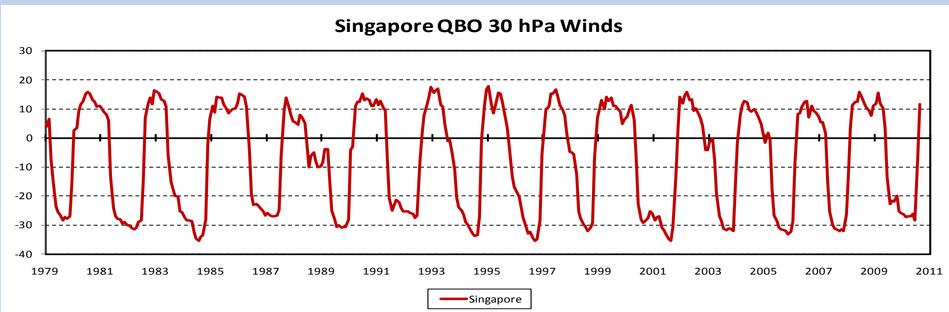
QBO Winds at Singapore

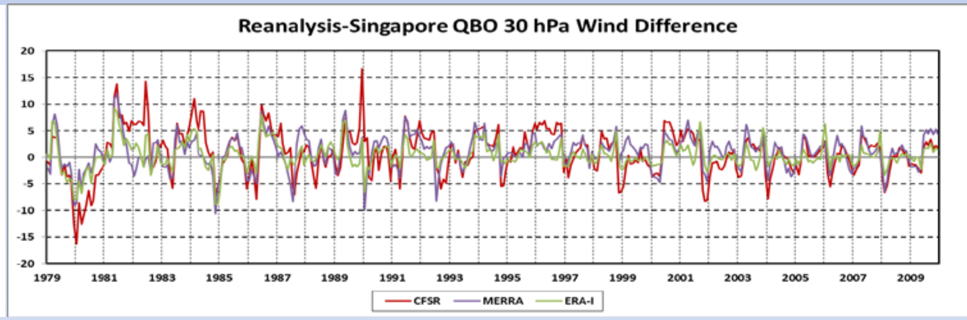


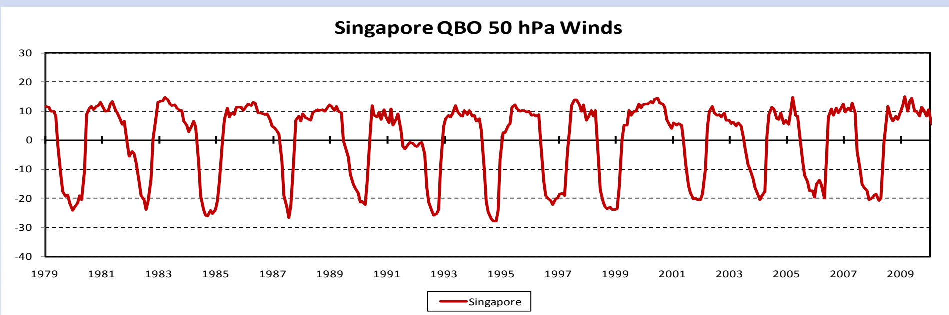


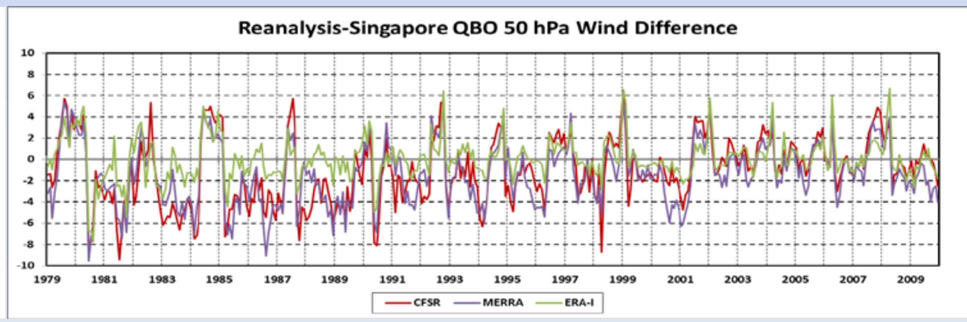




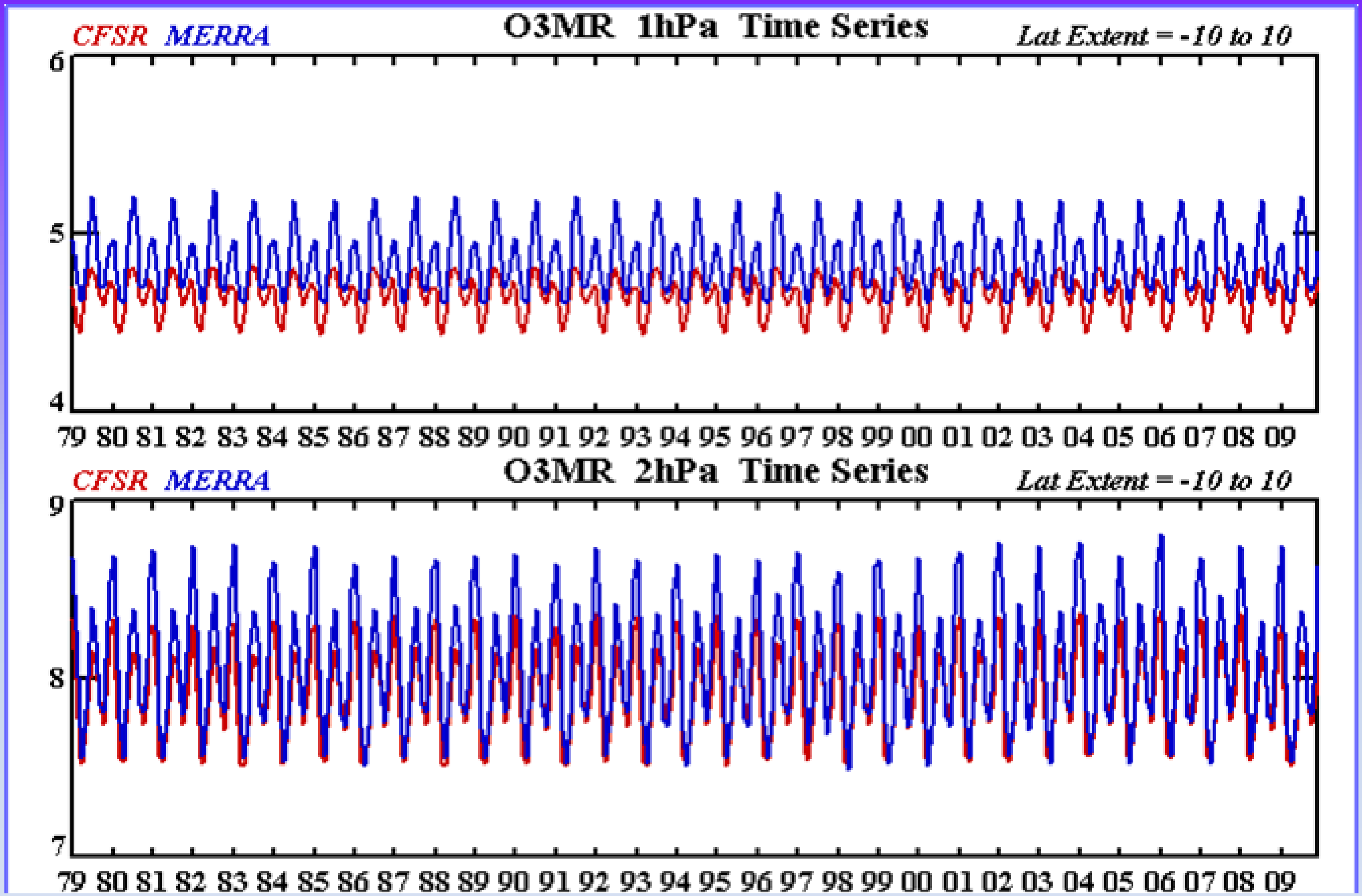






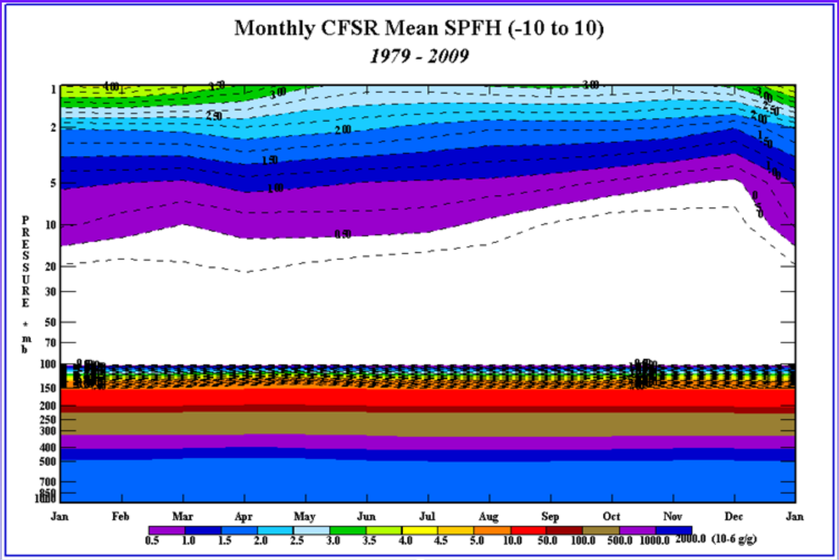


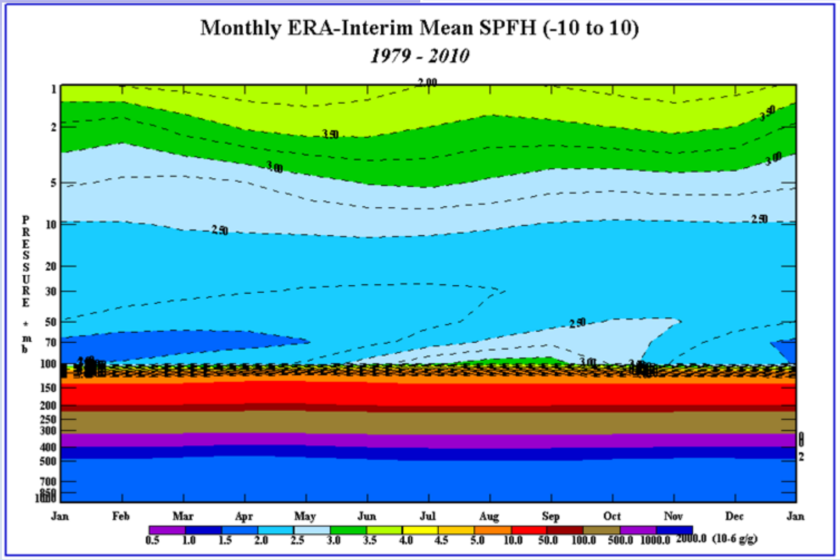
Ozone Observation Error Issue

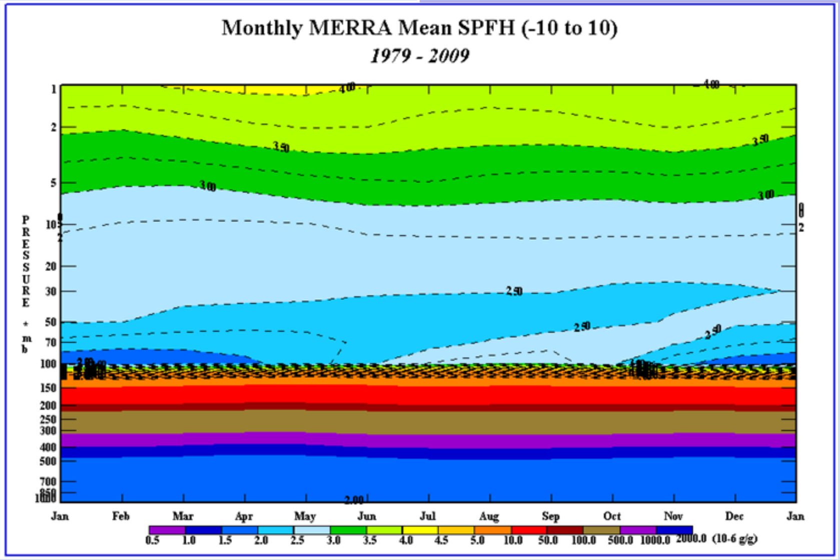


Time series of ozone mixing ratios (ppm) at 1 and 2 hPa between 10N and 10S from the CFSR and MERRA reanalyses. The observation errors were 60x too large in both GSI assimilation systems preventing any SBUV(/2) ozone observations from being assimilated. The repeating cycles are the models climatology.

Water Vapor in the Tropical Stratosphere





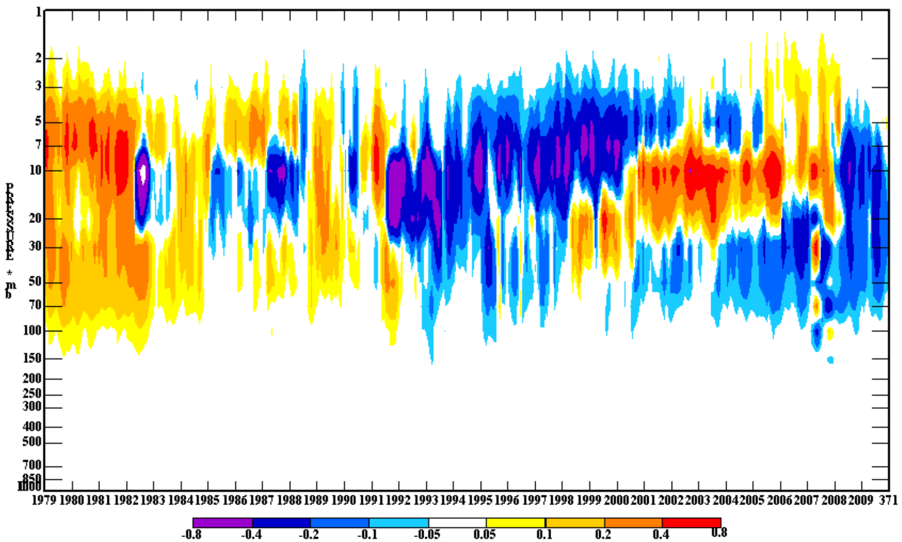


Monthly mean vertical profiles of the specific humidity (g/g10^6) for the CFSR (top),ERA-Interim (lower left), and MERRA (lower right) reanalyses. The ERA-I and MERRA exhibit a dry and wet seasonal pattern in the water vapor immediately above the tropopause. The CFSR does SPFH values are too small immediately above the tropopause and there is no evidence of a seasonal pattern.*

Global Ozone Anomalies

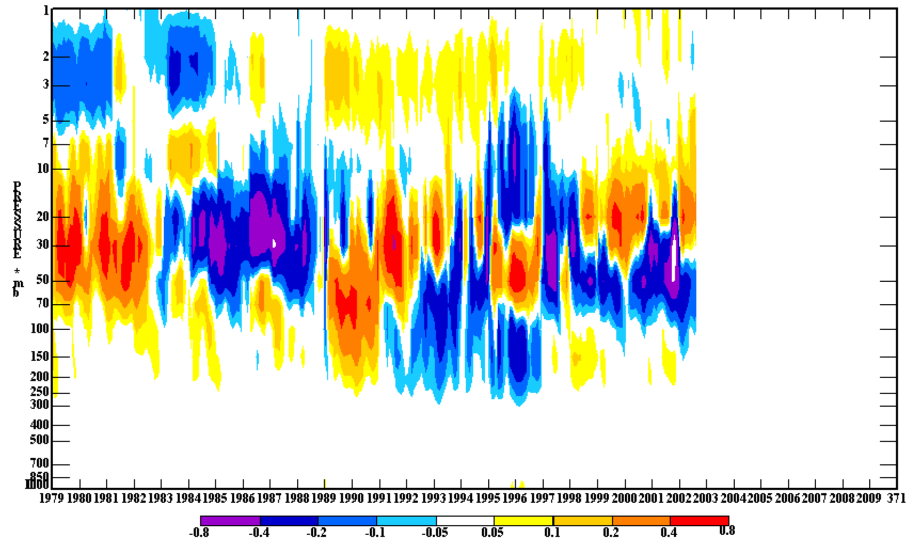
Monthly CFSR O3MR Anomalies (PPM)

GLOBAL (1979 - 2009)



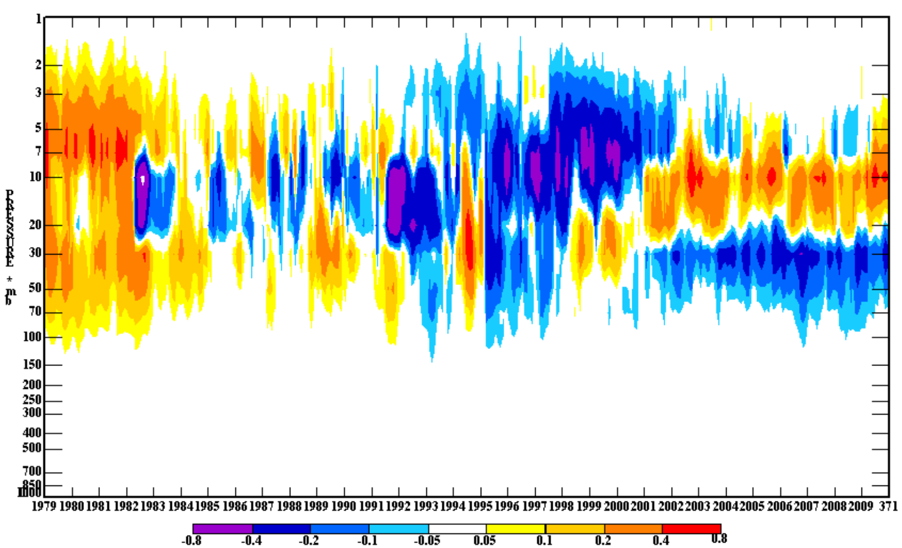
Monthly ERA40 O3MR Anomalies (PPM)

GLOBAL (1979 - 2009)



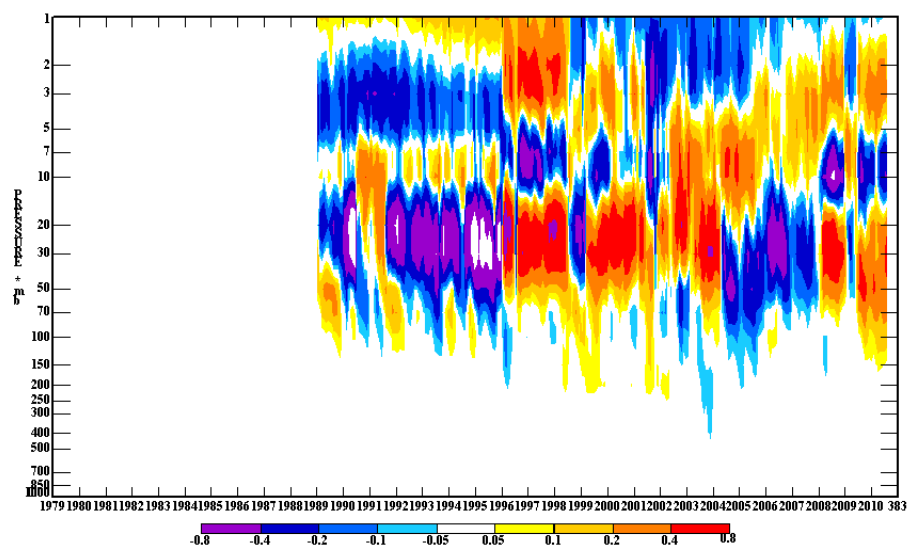
Monthly MERRA O3MR Anomalies (PPM)

GLOBAL (1979 - 2009)



Monthly ERA-Interim O3MR Anomalies (PPM)

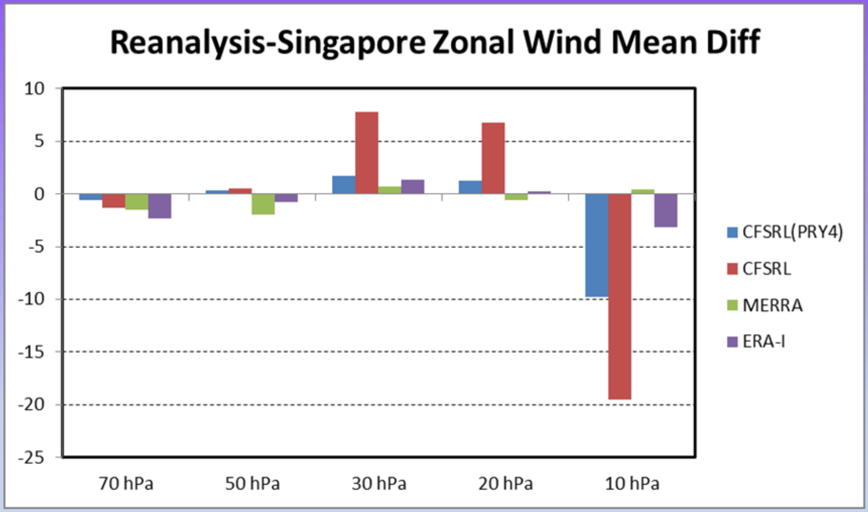
GLOBAL (1979 - 2010)

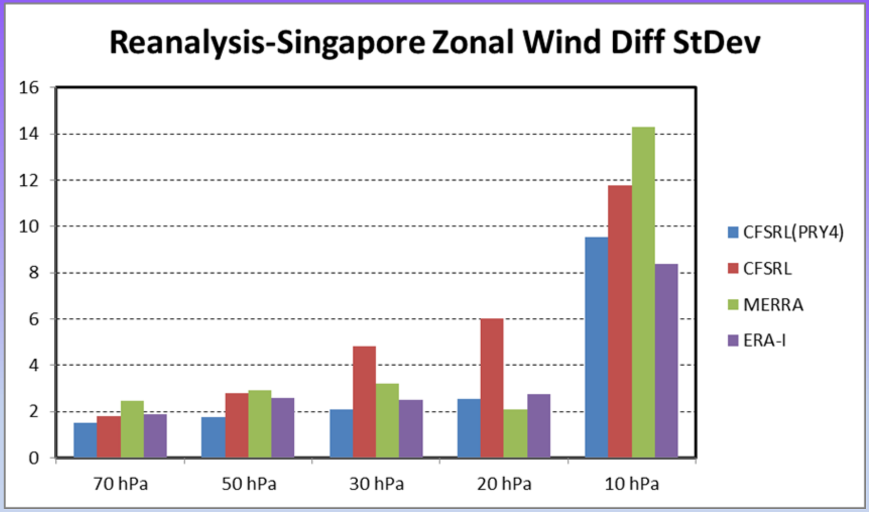


CFSR-Lite

- CFSRL Progress
  - Ozone corrections
  - No bias correction for SSU ch 3
  - Improvement in QBO in early 1980's

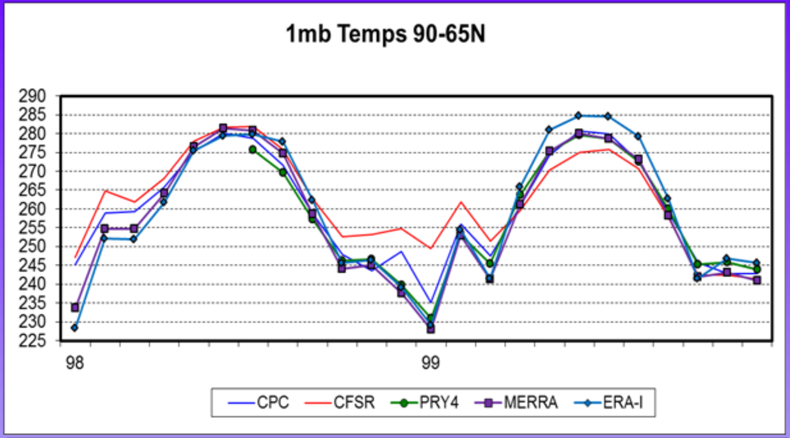
CFSRL QBO Winds Improvements

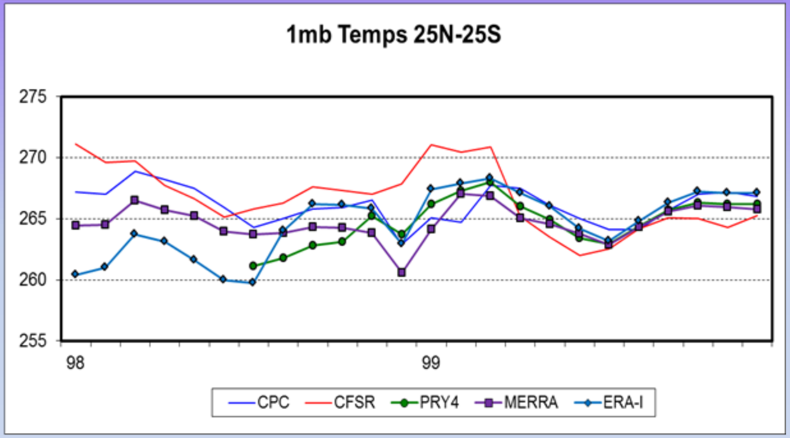


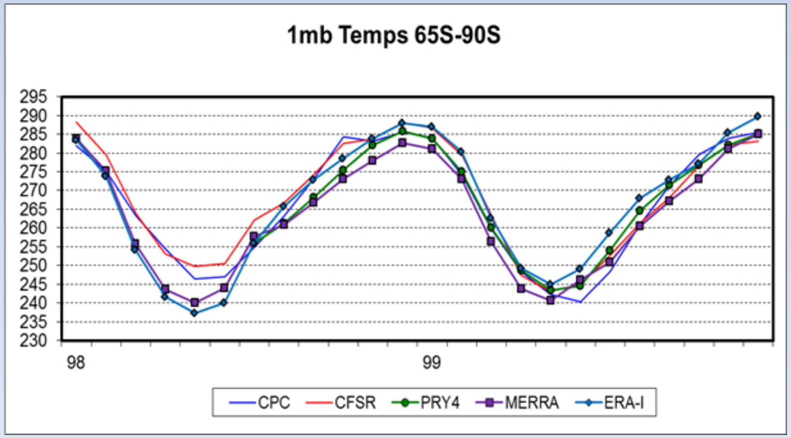


Comparison of reanalyses' QBO zonal wind differences from Singapore zonal radiosonde zonal winds for the 1981-1983 period in which the CFSR-Lite was run with an enlarged structure function and repeating the tropical radiosonde observations at 6 and 18 UTC. Mean differences from the Singapore zonal winds are in the left diagram and the standard deviation of the differences are in the right diagram. The CFSR-Lite differences and St Dev (blue) are smaller than the CFSR (red) and are comparable with the MERRA (green) and ERA-Interim (purple) differences. Note that all three reanalyses have largest differences and variability at 10 hPa.

CFSRL SSU to AMSU Improvements

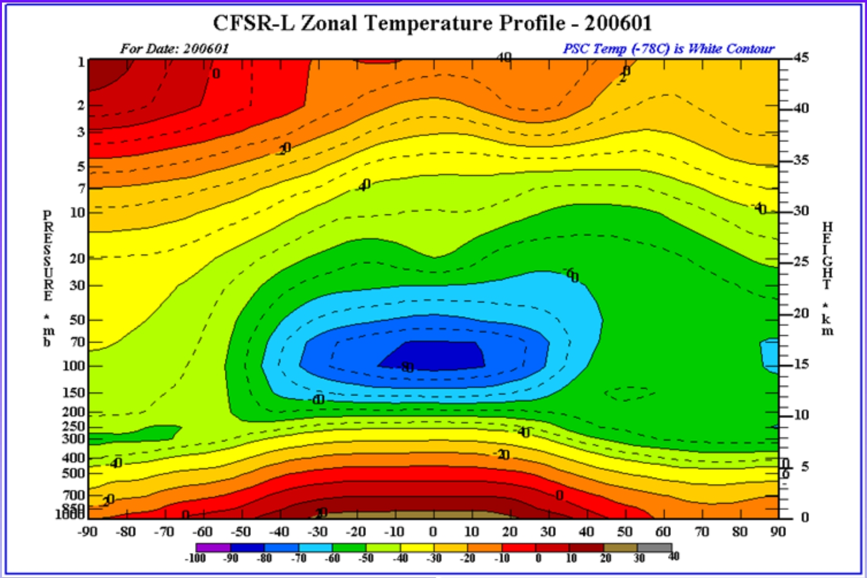


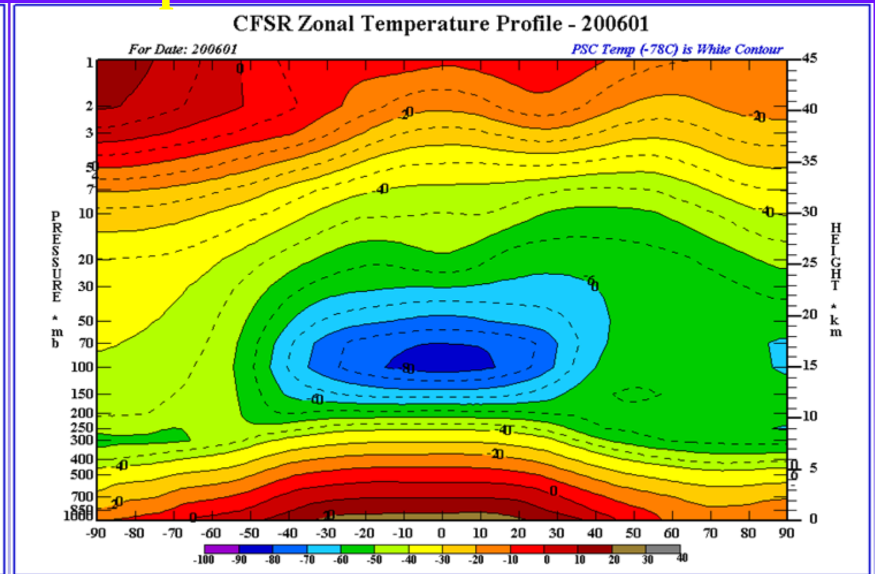


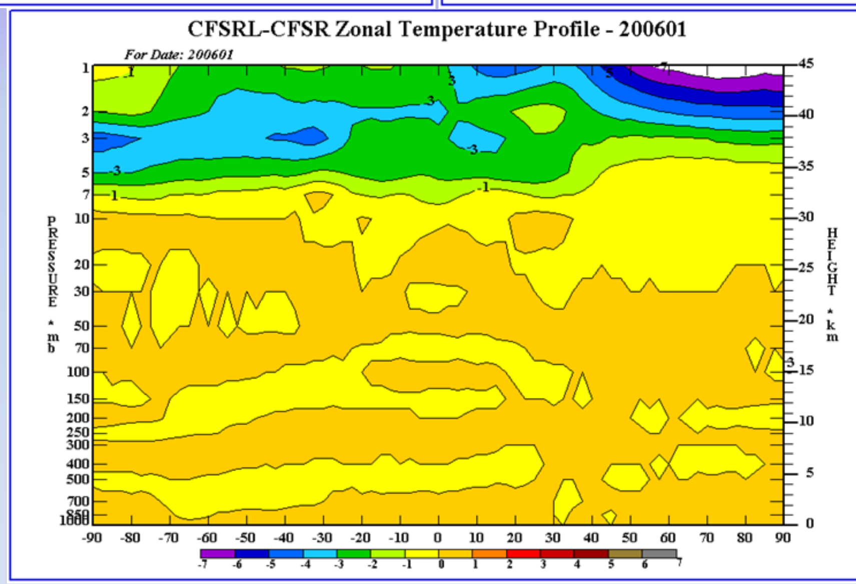


Transition from SSU radiance assimilation (pre November1998) to AMSU-A radiance assimilation (post November 1998) in a CFSR-Lite test. 1 hPa temperature time series for 1998 and 1999 at 90-65N(top), 25N-25S (middle), and 65-90S (bottom) are presented. Note how the CFSR-Lite (green w/closed circles; "PRY4") is in greater agreement with MERRA (purple w/squares) and ERA-Interim (Blue w/diamonds) than the CFSR (red).

CFSRL AMSU Ch 14 Improvements







Comparison of January 2006 zonal mean temperature profile between the CFSR-Lite (CFSRL) (top left) and the CFSR (top right). The CFSR-Lite test included the assimilation of AMSU-A channel 14 radiances not bias corrected. The CFSR did not assimilate the AMSU-A channel 14 radiances. The differences (CFSR-Lite – CFSR) are presented in the lower plot. The CFSRL temperatures are cooler above 7 hPa.

Work Plan

- **Year 1** of the project:
  - Make the multi-year AMIP run of the operational GFS forecast model to determine its climatology.
  - Run tests for the early 1980's time period to evaluate EnKF GSI ability to capture the QBO.
  - Validate the QBO winds using Singapore radiosonde winds and other radiosondes in the equatorial region.
  - Use the new SBUV(/2) version 8.6 ozone observations in all tests.
  - Determine if ozone in the upper stratosphere varies from year to year and closely matches the satellite observations.
  - Test the adjustments of the gravity wave parameterization which has been shown in other works to improve the capturing of the QBO winds and generated more reasonable temperatures in the upper stratosphere. Impact of the gravity wave parameterization on the (O-F) differences will be evaluated.

Work Plan

- **Year 2** of the project:
  - Evaluate the bias correction of temperatures in the upper stratosphere using the EnKF GSI.
  - Evaluate the transition from SSU to AMSU, between 1998 and 2005.
  - Determine if the both SSU and AMSU radiances can be assimilated at the same time.
  - Compare similar tests using NOGAPS-ALPHA DAS to determine the differences in their impacts upon the upper stratospheric temperatures.

Work Plan

- **Year 3** of the project:
  - Conduct tests to improve the state and seasonality of stratospheric water vapor above the tropopause.
  - Our proposed methodology is to identify to what extent the poor water vapor state impacts the radiation, thermal structure and dynamical behavior in the lower stratosphere.
  - Assimilate MLS ozone profile observations for the period 2004 to present. Make runs to study how adding the MLS ozone observations improves the analysis of the ozone hole. Replicate case studies to determine how using MLS data impacts the detection of stratospheric intrusions. Determine if a diurnal cycle in the ozone profile results from assimilating MLS ozone observations.

Status of Current Activities

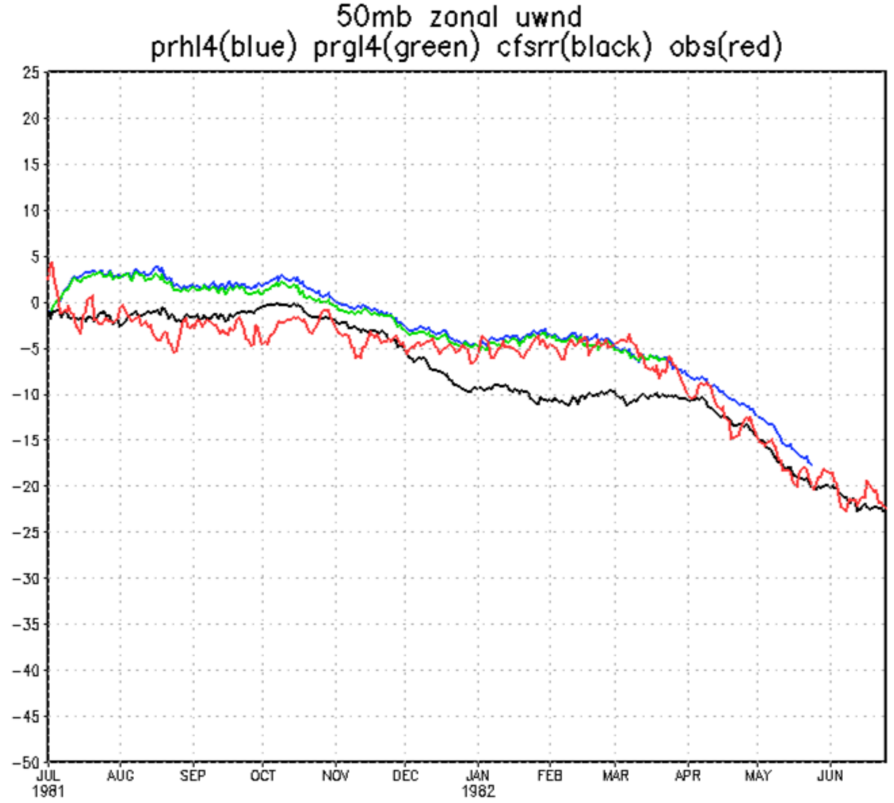
- Status
  - EnKF vs 3D Var
  - QBO progress
  - SSU radiances
  - CRTM

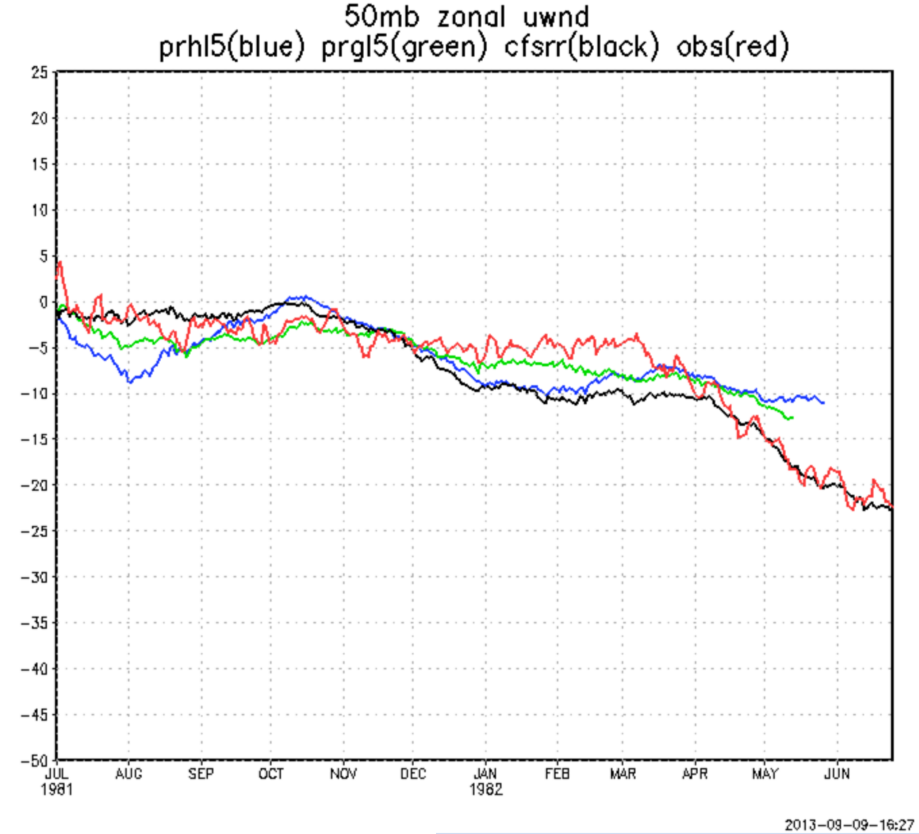
How EnKF Works

- 80 Ensemble members in EnKF
- The variance of the ensemble member dictates how much the obs adjusts the guess
  - Low variance : obs not used to adjust guess
  - High variance: obs used to adjust guess
  - What to do when we know the obs is truth yet model ensemble agree with incorrect guess

EnKF and 3dvar QBO tests

EnKF | 50 hPa | 3dVar





During this time period the CFSR is using ERA40 winds

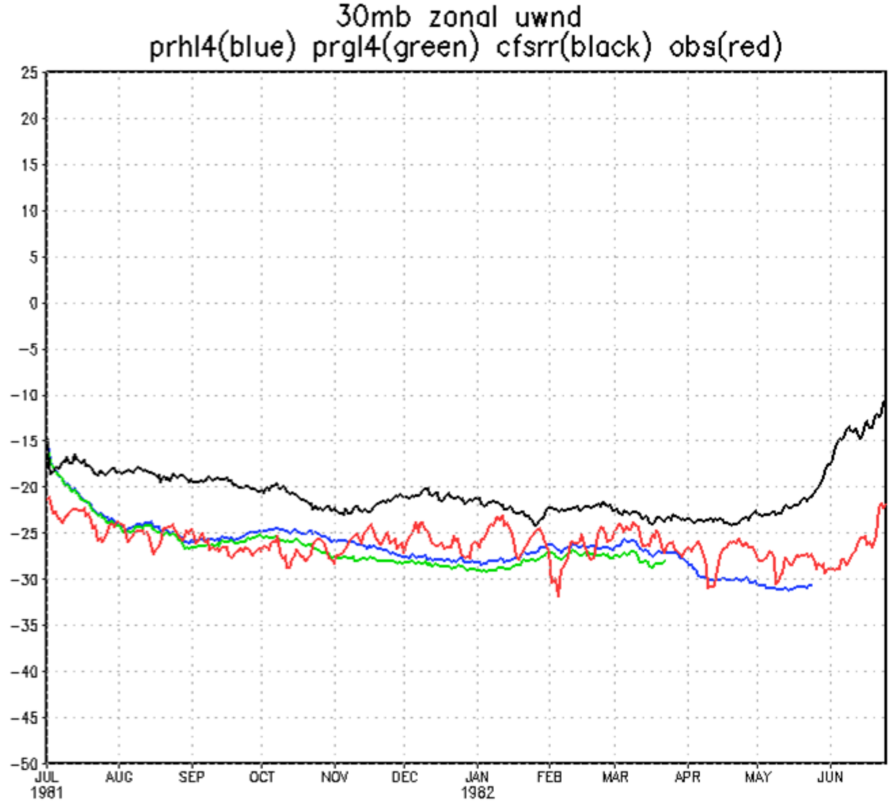
QBO comparisons of zeus and gaea **hybrid** and **3dvar** runs

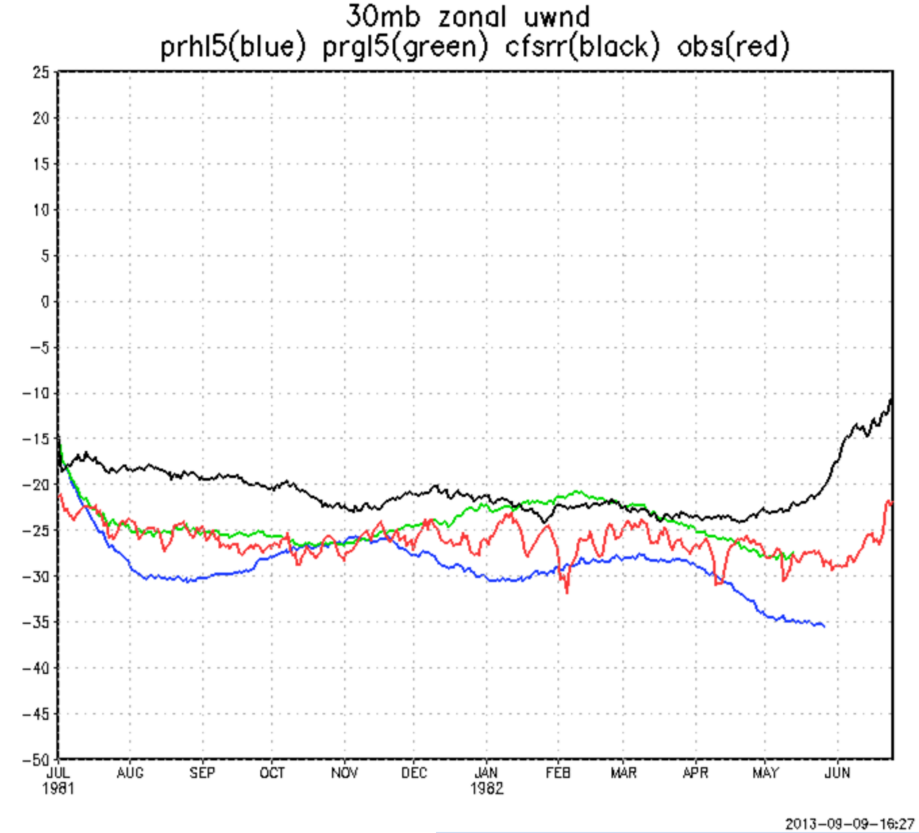
hybrid: prhl4(zeus) prgl4(gaea)

3dvar: prhl5(zeus) prgl5(gaea)

EnKF and 3dvar QBO tests

EnKF **30 hPa** **3dVar**





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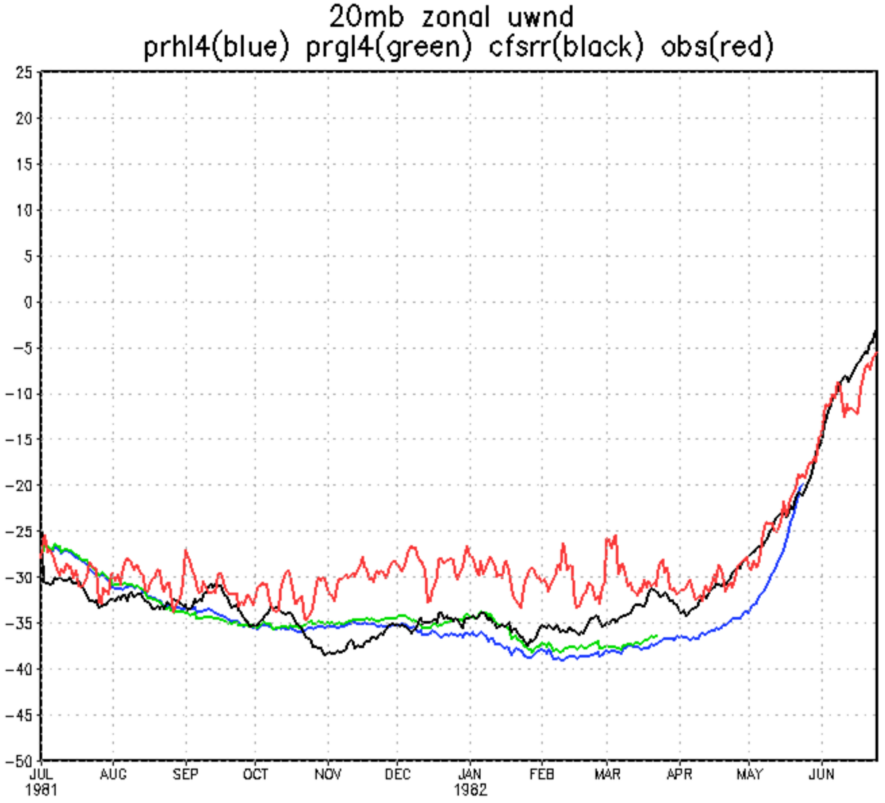
<u>QBO comparisons of zeus and gaea **hybrid** and **3dvar** runs</u>

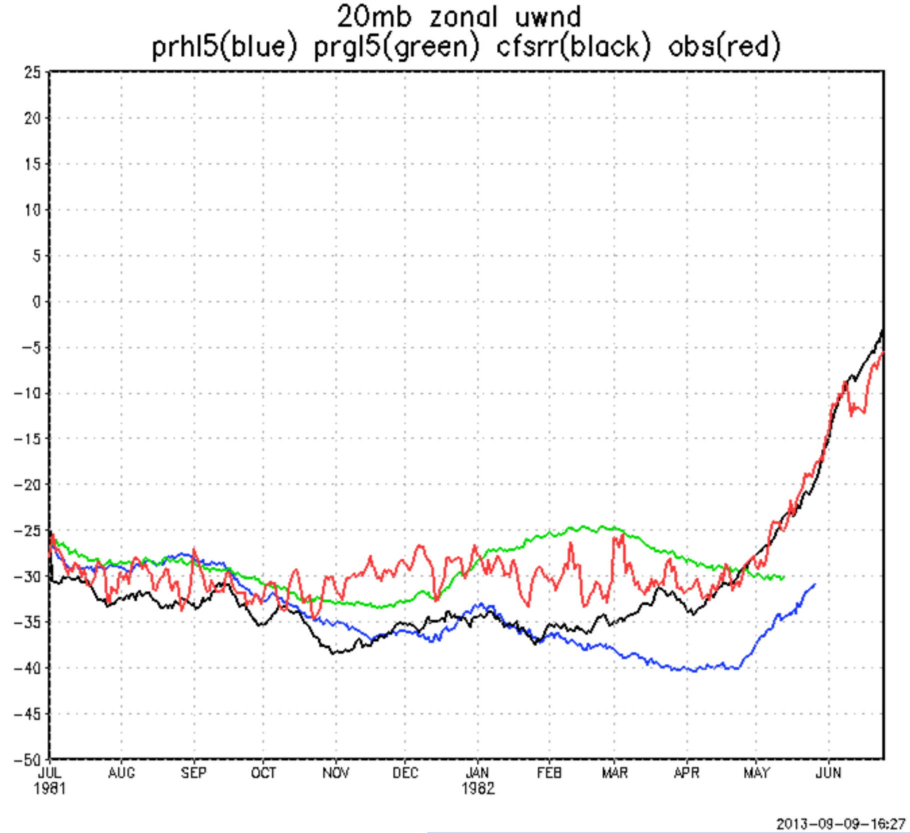
hybrid: prhl4(zeus) prgl4(gaea)

3dvar: prhl5(zeus) prgl5(gaea)

EnKF and 3dvar QBO tests

EnKF **20 hPa** **3dVar**





During this time period the CFSR is using ERA40 winds

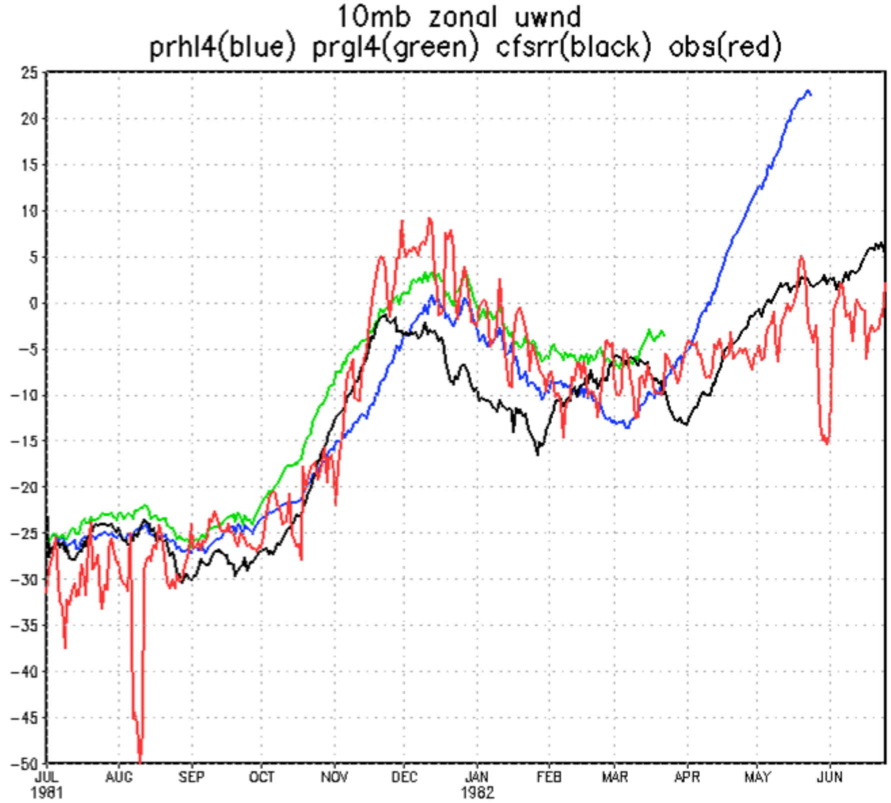
QBO comparisons of zeus and gaea **hybrid** and **3dvar** runs

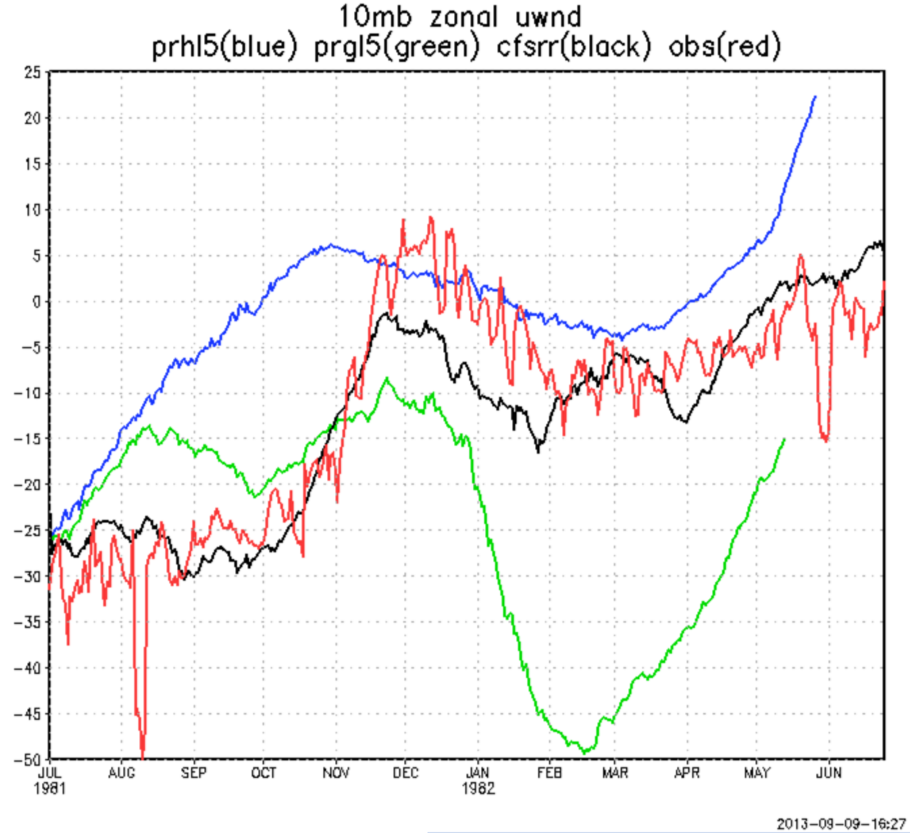
hybrid: prhl4(zeus) prgl4(gaea)

3dvar: prhl5(zeus) prgl5(gaea)

EnKF and 3dvar QBO tests

EnKF **10 hPa** **3dVar**





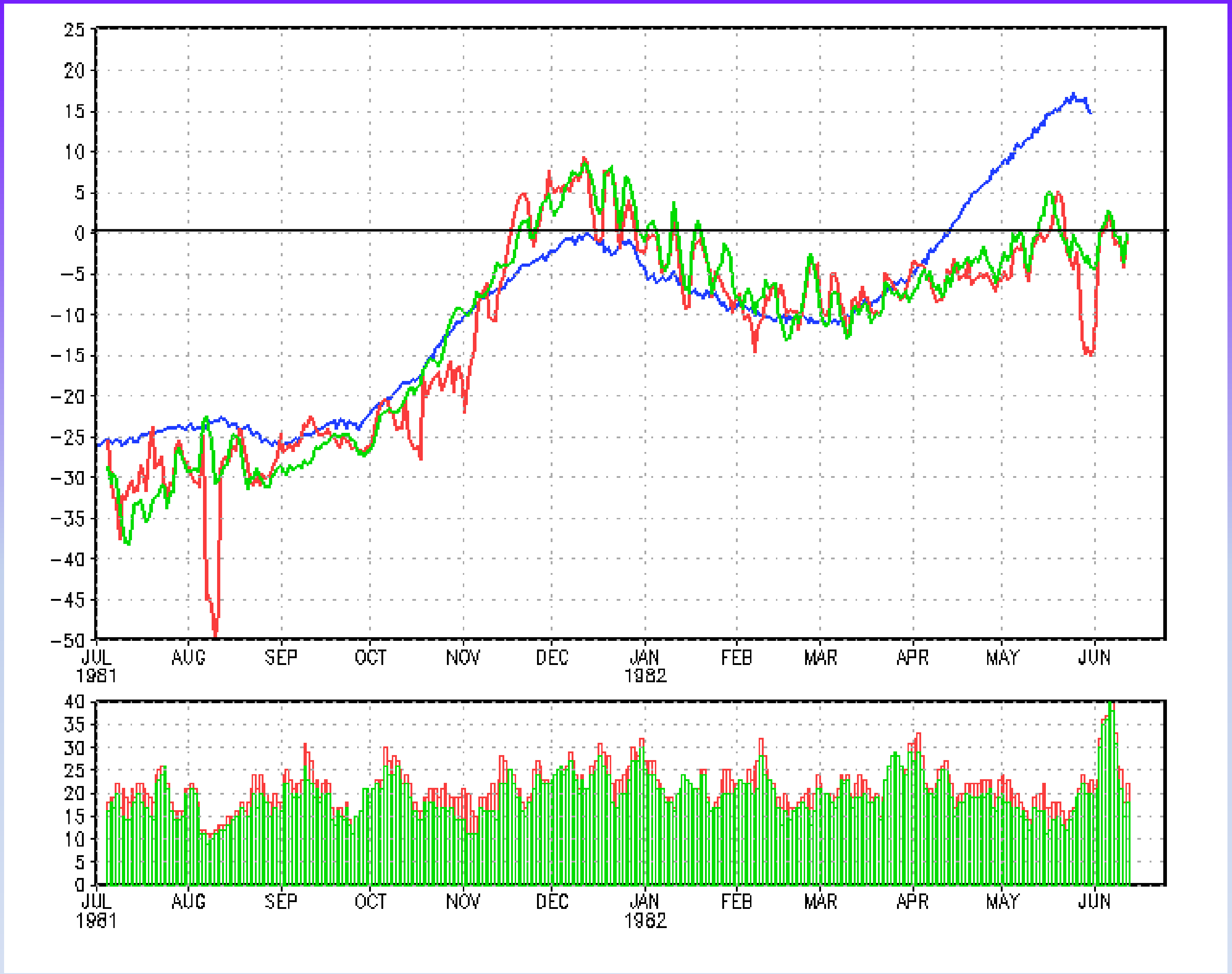
During this time period the CFSR is using ERA40 winds

QBO comparisons of zeus and gaea **hybrid** and **3dvar** runs

hybrid: prhl4(zeus) prgl4(gaea)

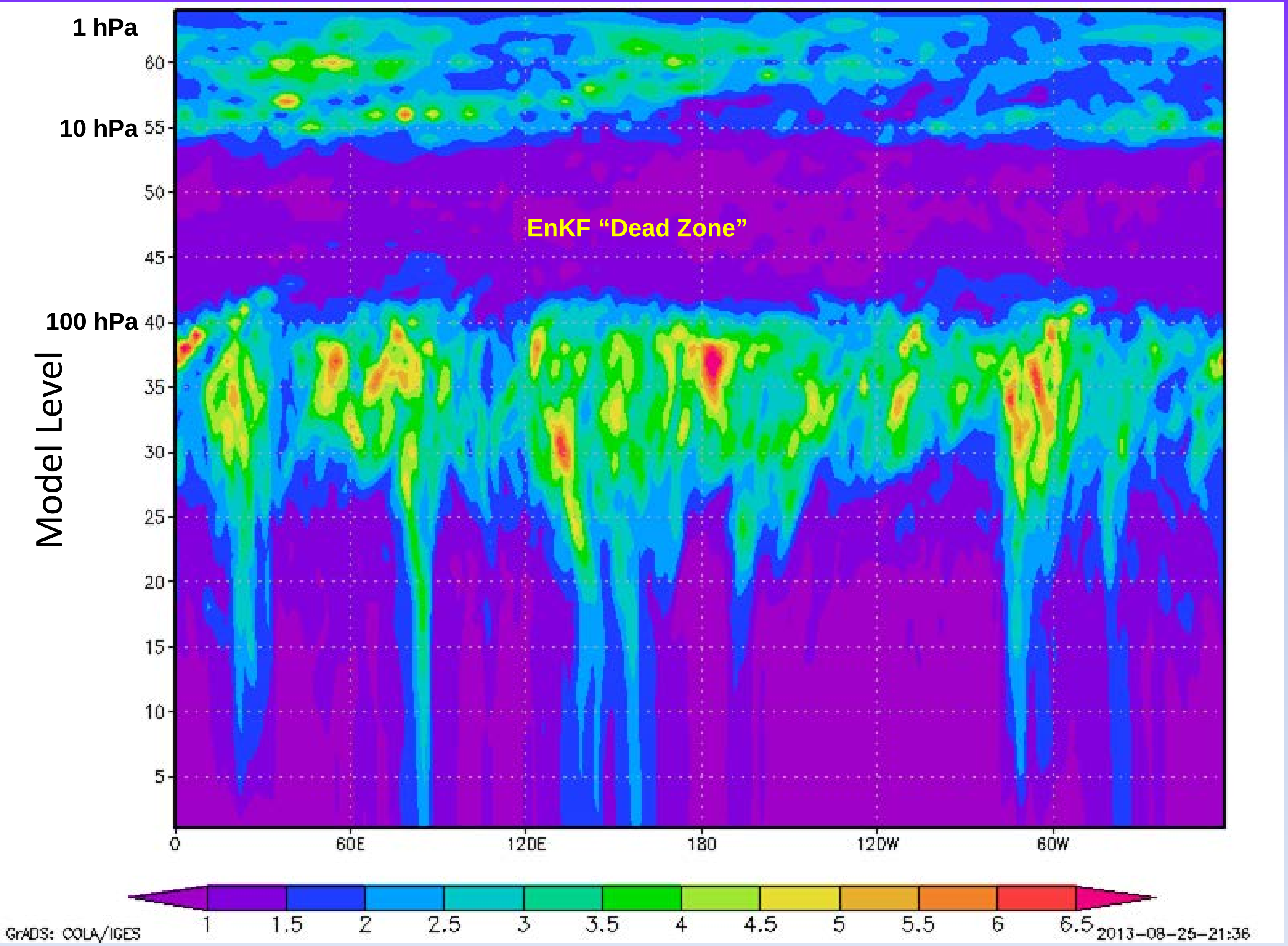
3dvar: prhl5(zeus) prgl5(gaea)

QBO Tests Show Zonal Winds Diff from Radiosonde Locations



> **Blue line** is the **U wind zonal mean analysis** at each 00z averaged 10s-10n
> **Red line** is the **radiosonde U obs** reporting at 10mb averaged +/- 48 hrs around each 00z
> **Green line** is the **U analysis at 10 mb radiosonde locations** averaged +/- 48 hrs around each 00z
> The **bar graph** shows 10mb radiosonde U obs +/-48hrs around each 00z, with green part accepted with varqc.

EnKF Spread of U Winds at Equator on April 20, 1982 00Z



Summary

- Number of issues in the stratosphere that is present in current reanalyses
- CFSR-Lite provided strategies towards addressing issues with CFSR
- Clear set of issues and strategies towards resolving or improving these issues.
- Current tests addressing QBO in early 1980’s
- Analysis near Radiosondes agrees well, however away from radiosondes the zonal wind differs considerably.
- Next step is to discern the role of SSU upon QBO and SAO
- More to come…..