



# Evaluation of the Stratosphere in Recent Reanalyses

**Craig S. Long**

**Amy Butler, Shuntai Zhou**

*Climate Prediction Center*

*NOAA/NWS/NCEP*

# What is the Purpose of a Reanalysis

- Using a “frozen” data assimilation system eliminates the perceived climate jumps associated with changes in the data assimilation system.
- Makes use of observations that was not available during the original analysis.
- To allow researchers to reliably compare recent anomalies with those in earlier decades.
  - i.e. to produce a better climatology

# Caveats

- **Using a “frozen” data assimilation system**
  - Works for past reanalyses
  - Continuation of reanalysis uses latest DA system
    - Making a “frozen” DA system nearly impossible
- **Makes use of observations that was not available during the original analysis.**
  - Modern DA systems are designed to assimilate millions of observations
  - Earlier years have many fewer observations
    - Need to adjust so few obs still influence analysis
- **To allow researchers to reliably compare recent anomalies with those in earlier decades.**
  - Need to determine how “improvements” to DA system affect climatology

# Parameters

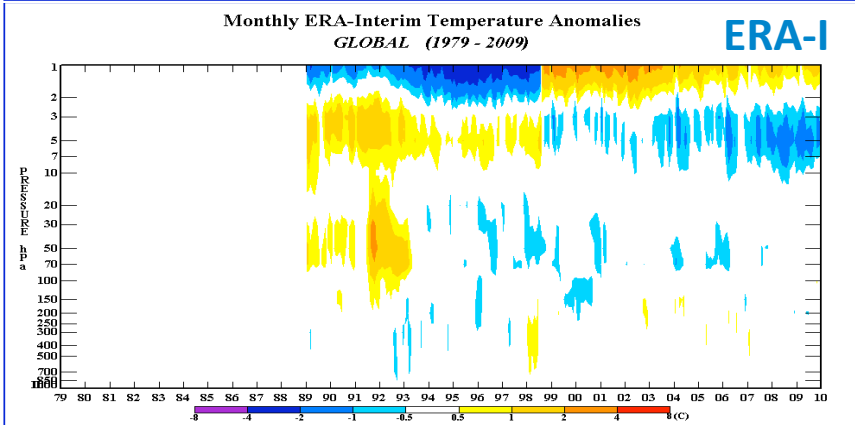
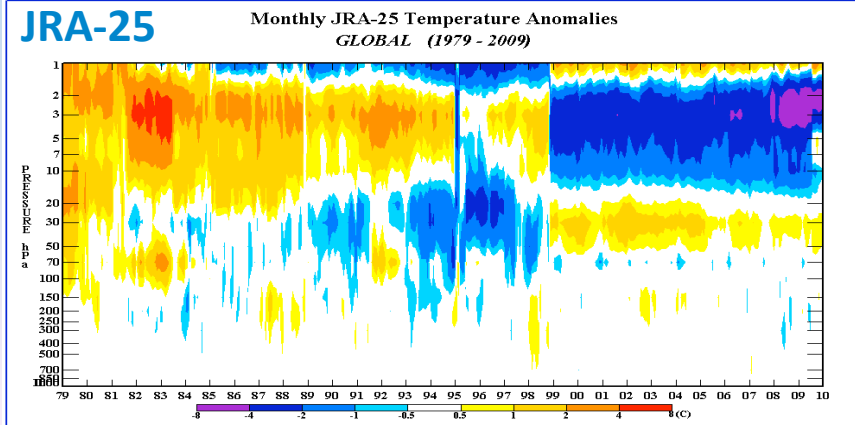
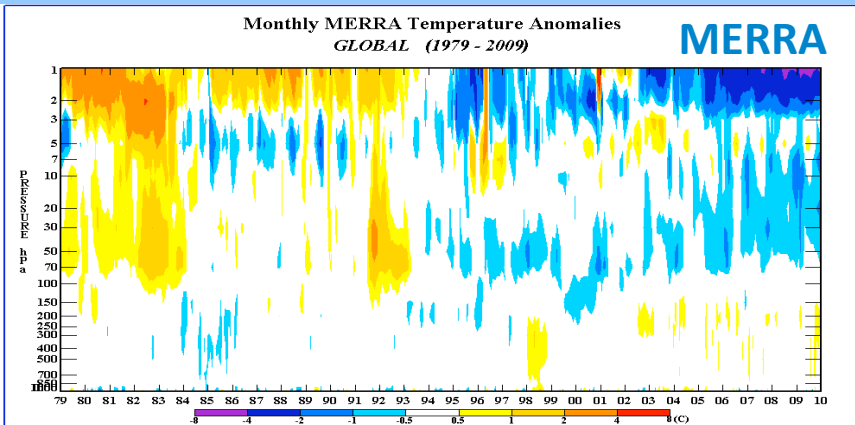
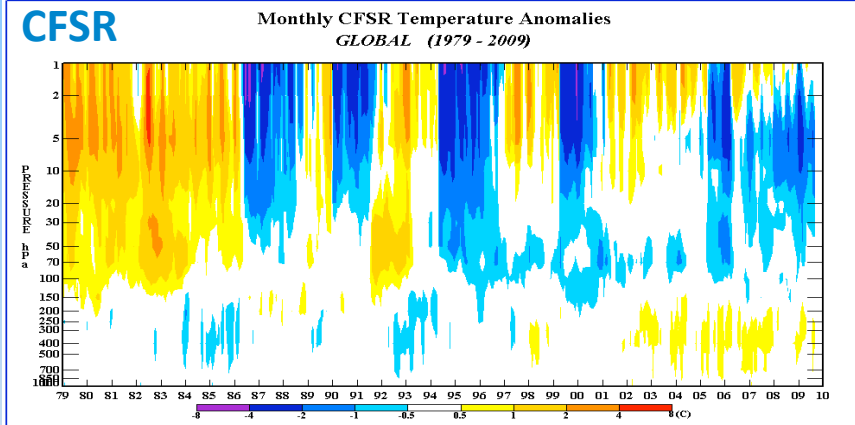
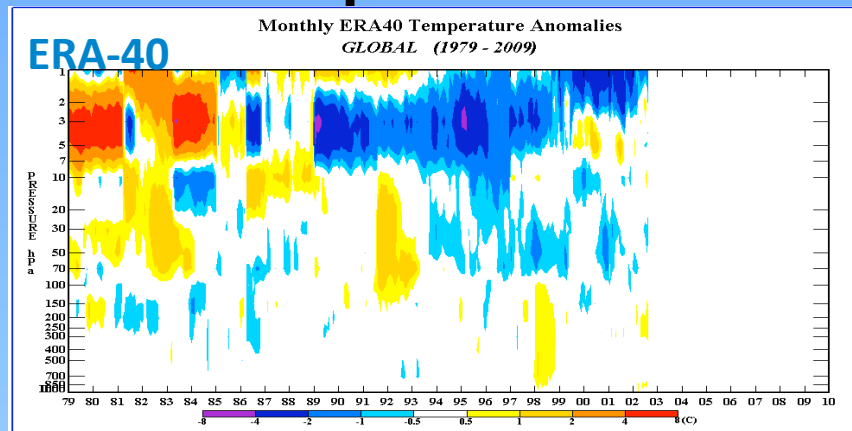
- Temperature
  - Global anomalies
  - Zonal means and anomalies
  - Heat Flux
- Zonal Wind
  - Polar
  - QBO
  - SAO
- Ozone mixing ratio
  - Global anomalies
- Specific Humidity
  - Tropical signature

# Reanalyses Used

- NOAA/NCEP CFSR
  - Coupled Forecast System Reanalysis
    - T382/L64
    - Coupled Ocean, Land, Cryosphere, Atmosphere
    - 1979-Present
- NASA/GMAO MERRA
  - Modern Era Retrospective Analysis for Research and Applications
    - GEOS-5 (72 layers)
    - Atmosphere, Land
    - 1979-Present
- ECMWF ERA-Interim
  - 1989-Present
- JMA-25
  - 1979-Present

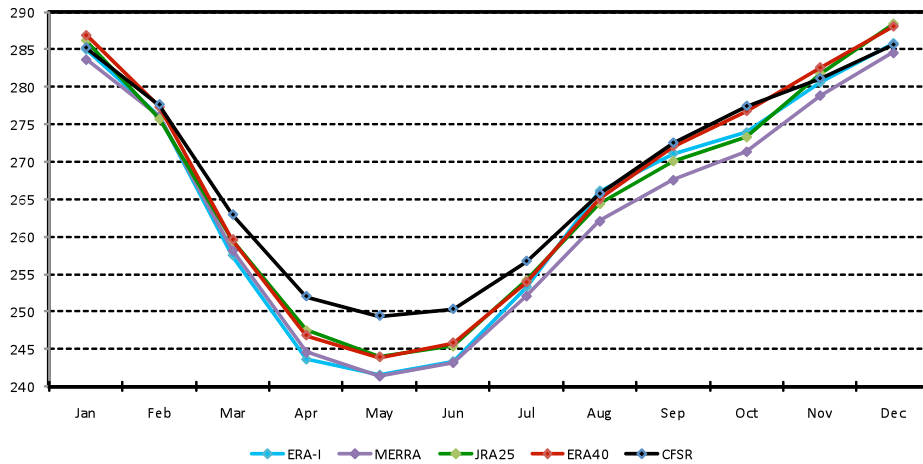
# *Temperatures*

# Global Temperature Anomalies

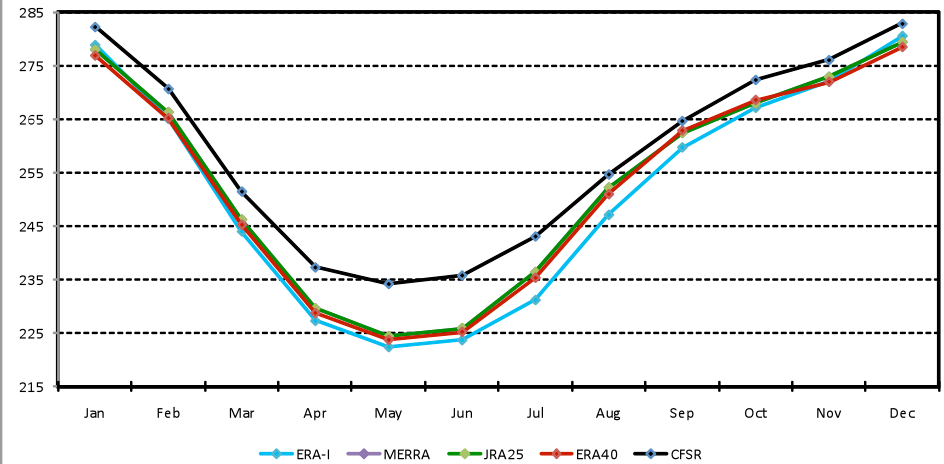


# Reanalysis SH Polar Temps

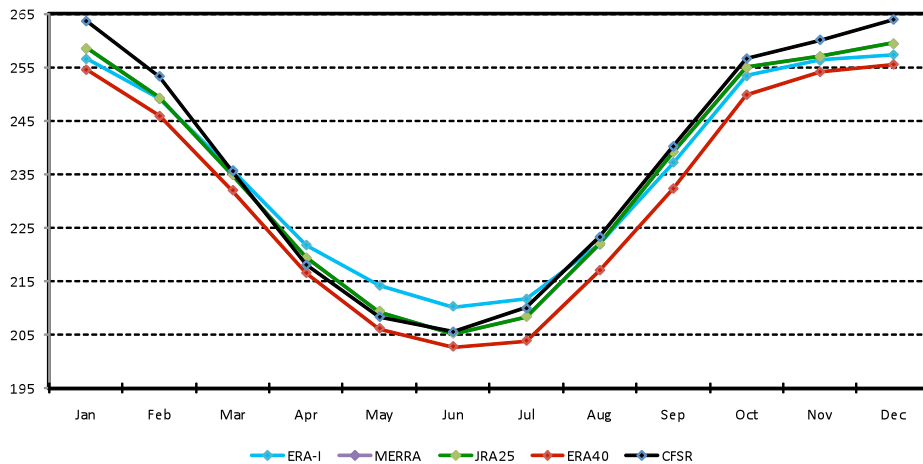
### Reanalysis Temperature Means : 1 hPa : 65-90S



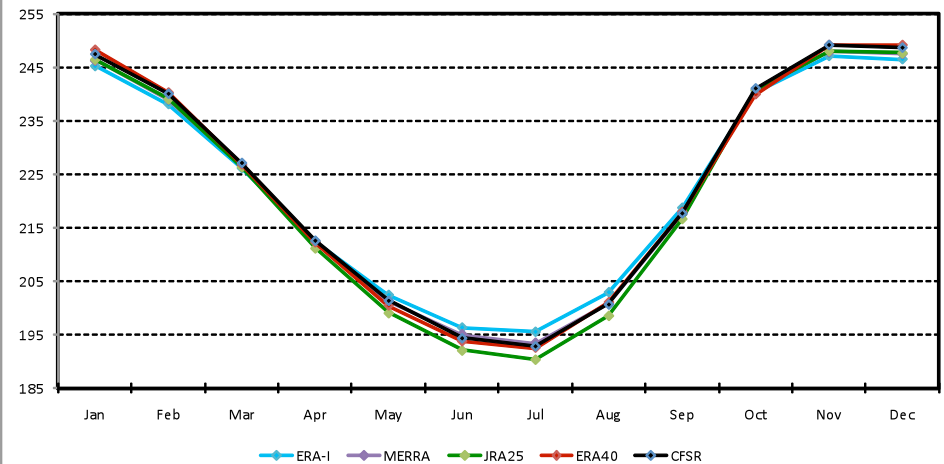
### Reanalysis Temperature Means : 2 hPa : 65-90S



### Reanalysis Temperature Means : 5 hPa : 65-90S



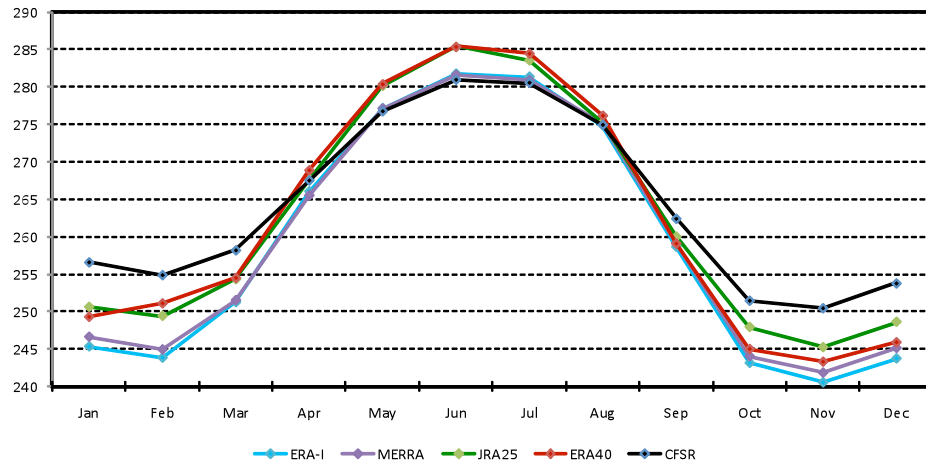
### Reanalysis Temperature Means : 10 hPa : 65-90S



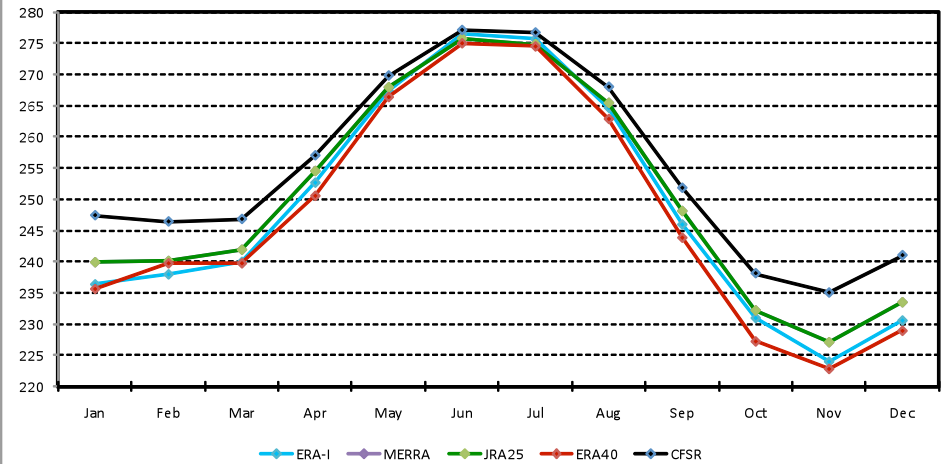


# Reanalysis NH Polar Temps

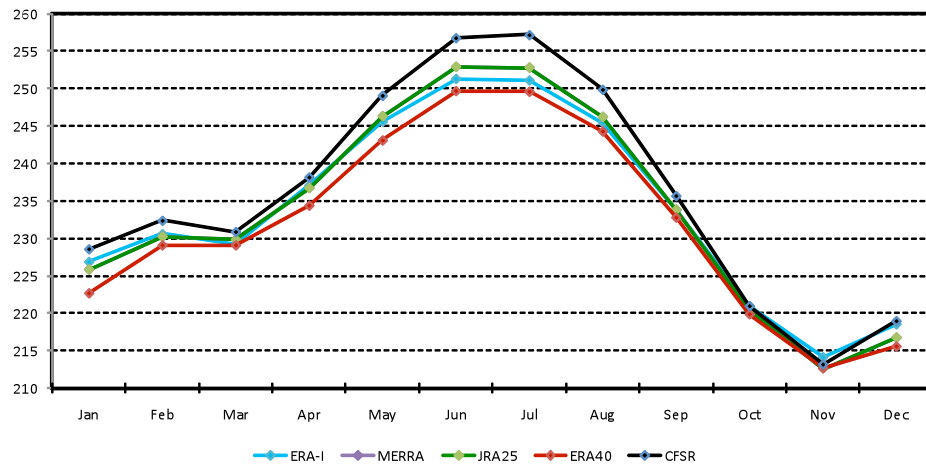
Reanalysis Temperature Means : 1 hPa : 65-90N



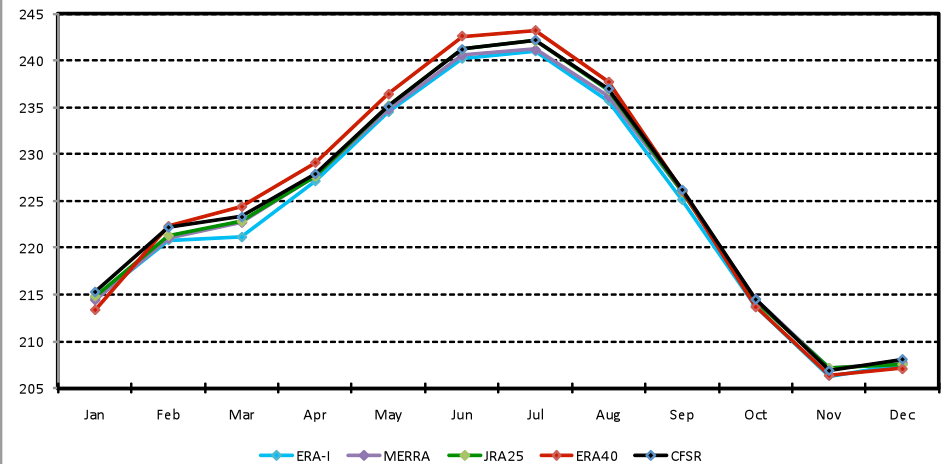
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Reanalysis Temperature Means : 5 hPa : 65-90N

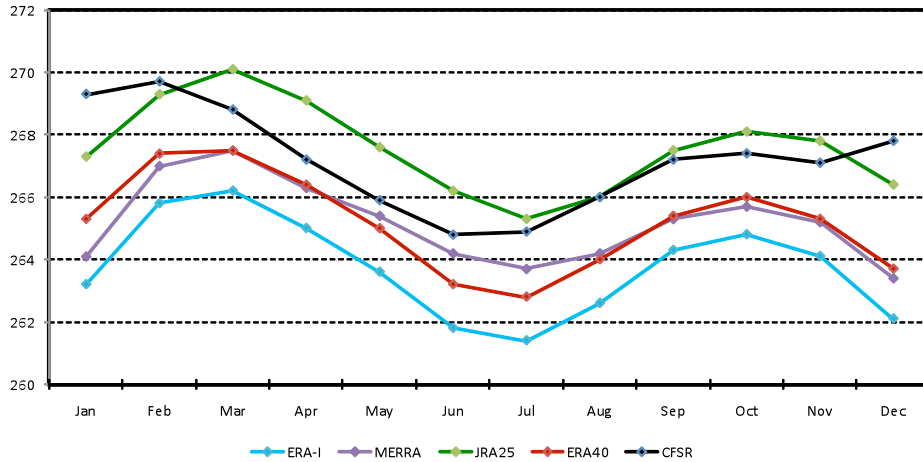


Reanalysis Temperature Means : 10 hPa : 65-90N

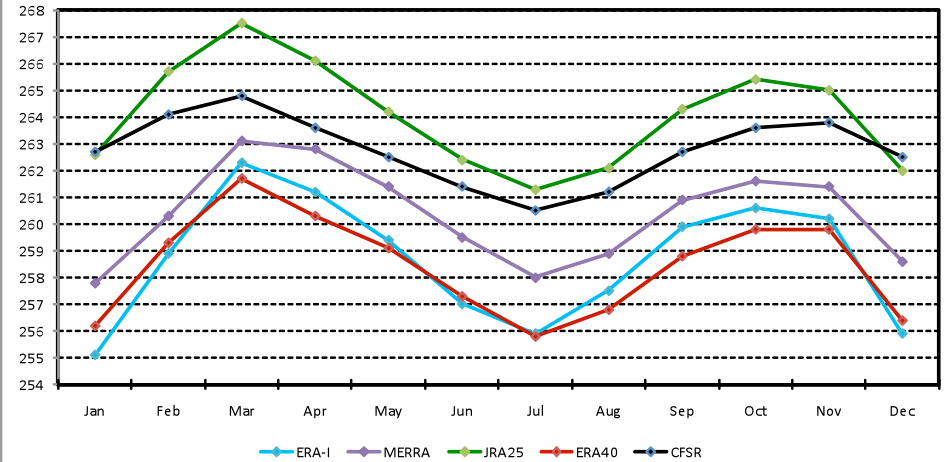


# Reanalysis Tropic Temps

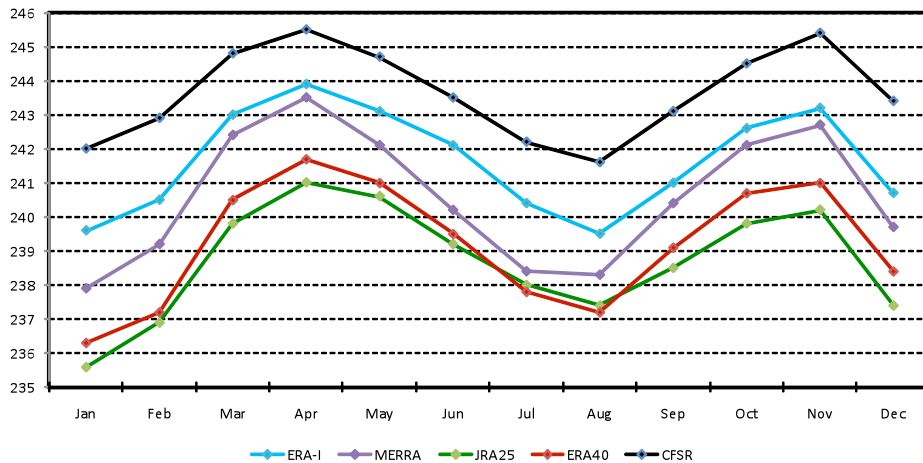
Reanalysis Temperature Means : 1 hPa : 25N-25S



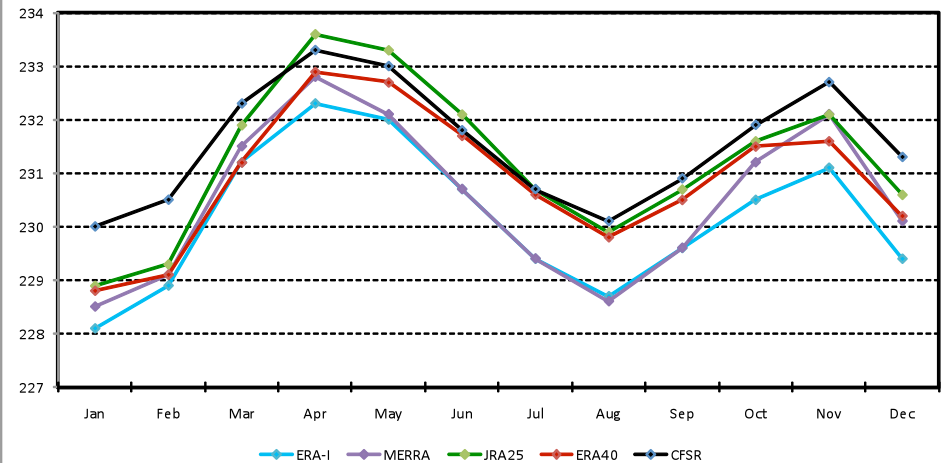
Reanalysis Temperature Means : 2 hPa : 25N-25S



Reanalysis Temperature Means : 5 hPa : 25N-25S

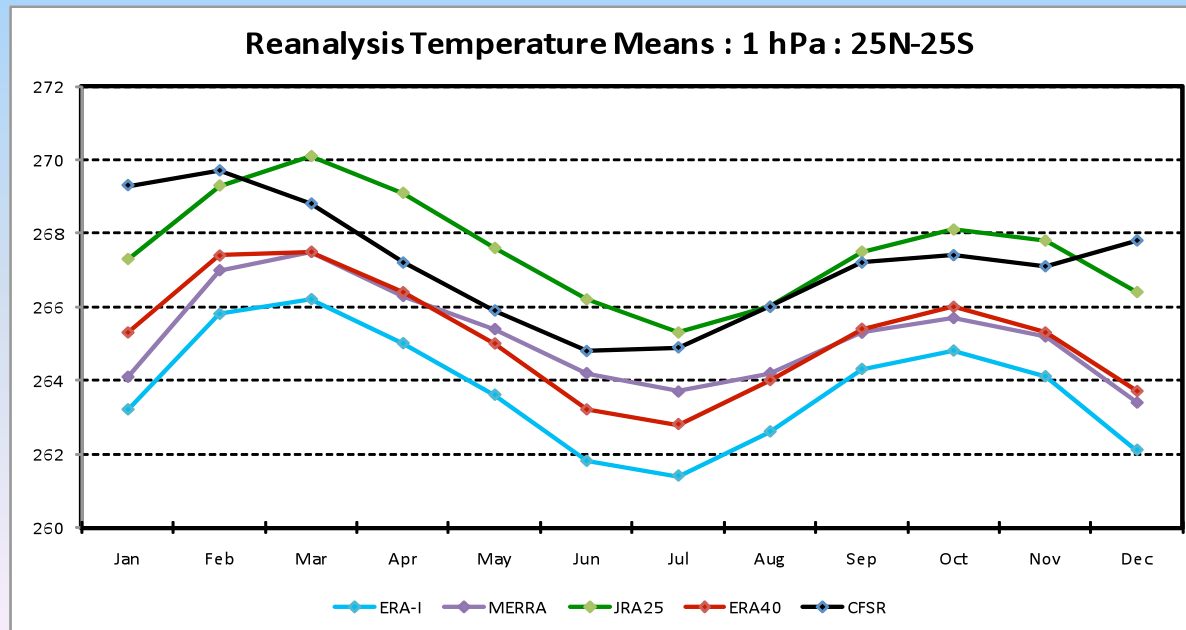
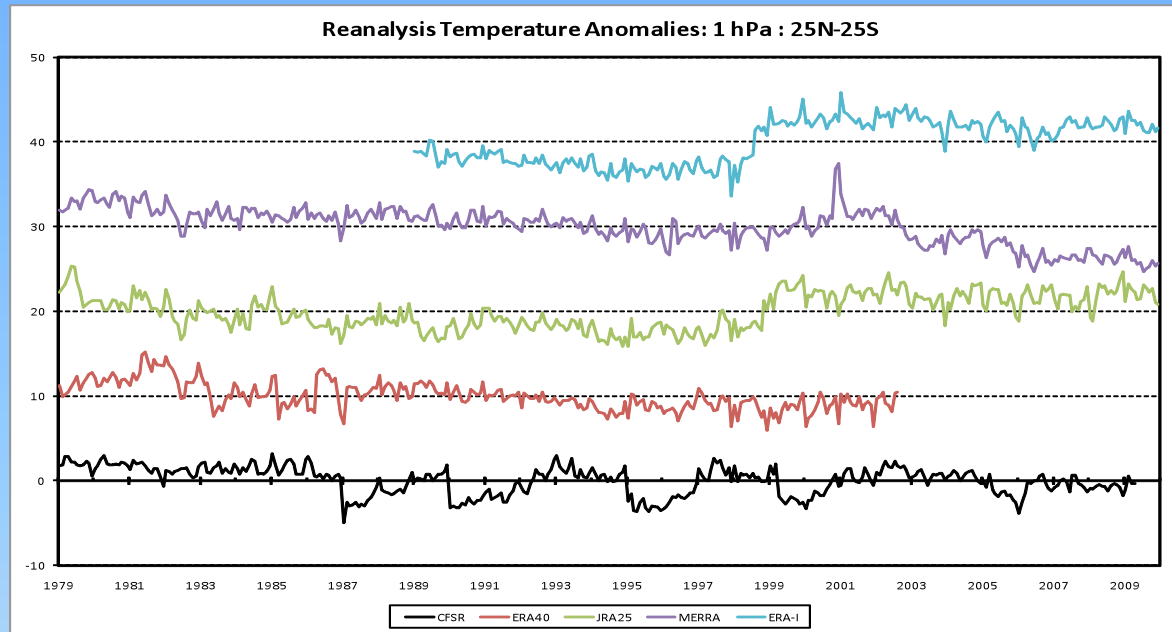


Reanalysis Temperature Means : 10 hPa : 25N-25S



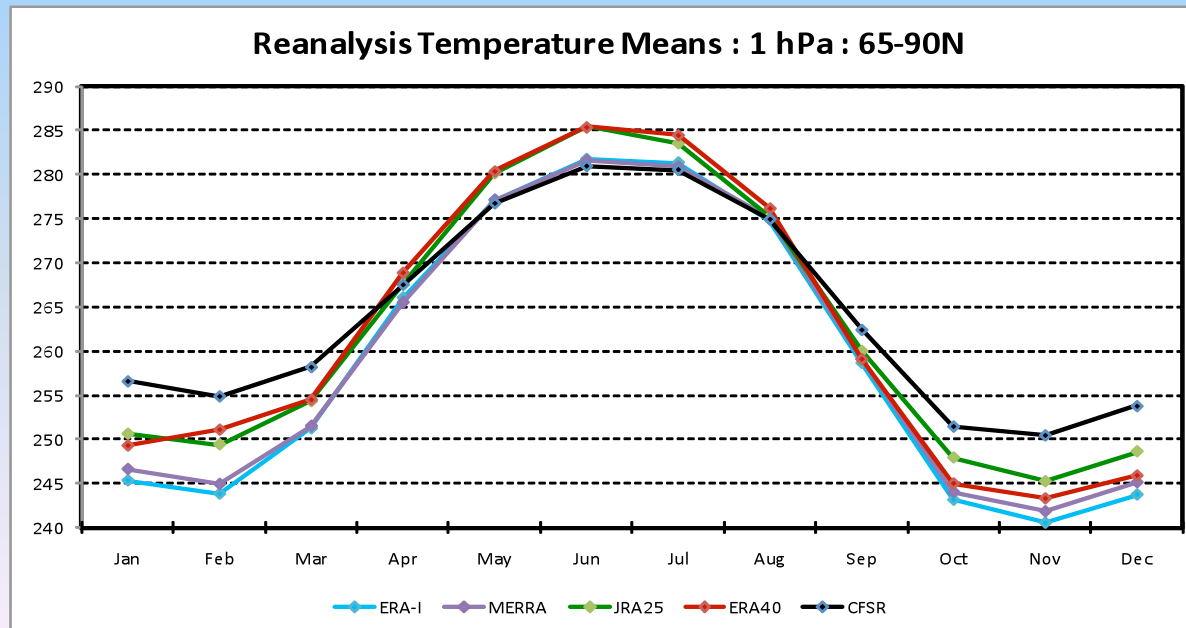
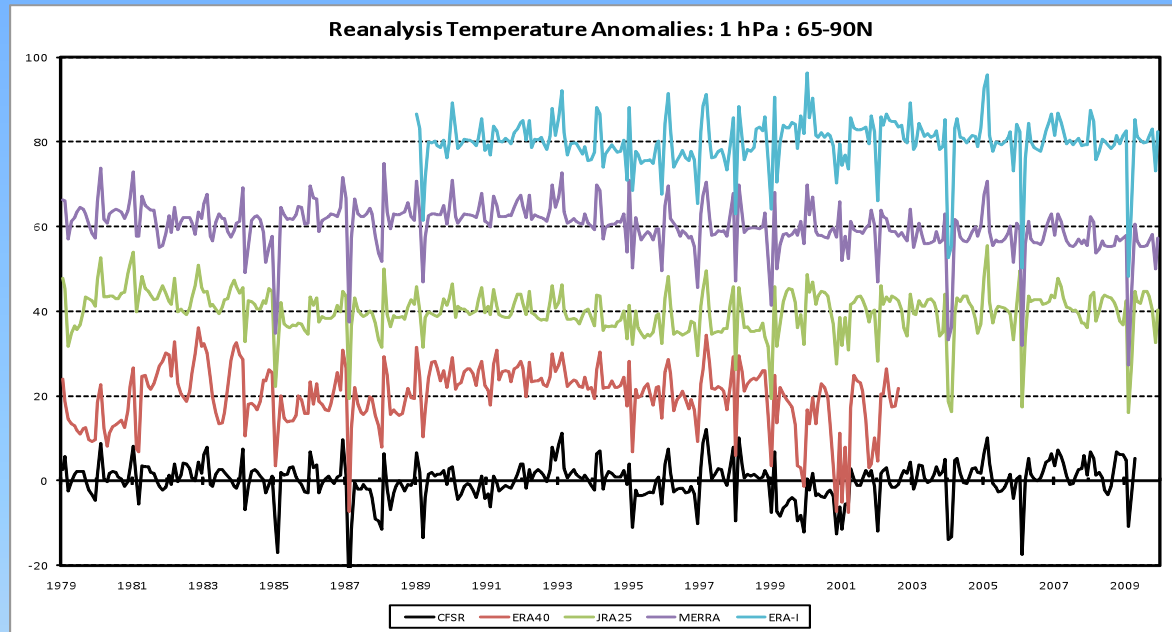
# Reanalysis Temp Anomalies

1 hPa  
25N-25S



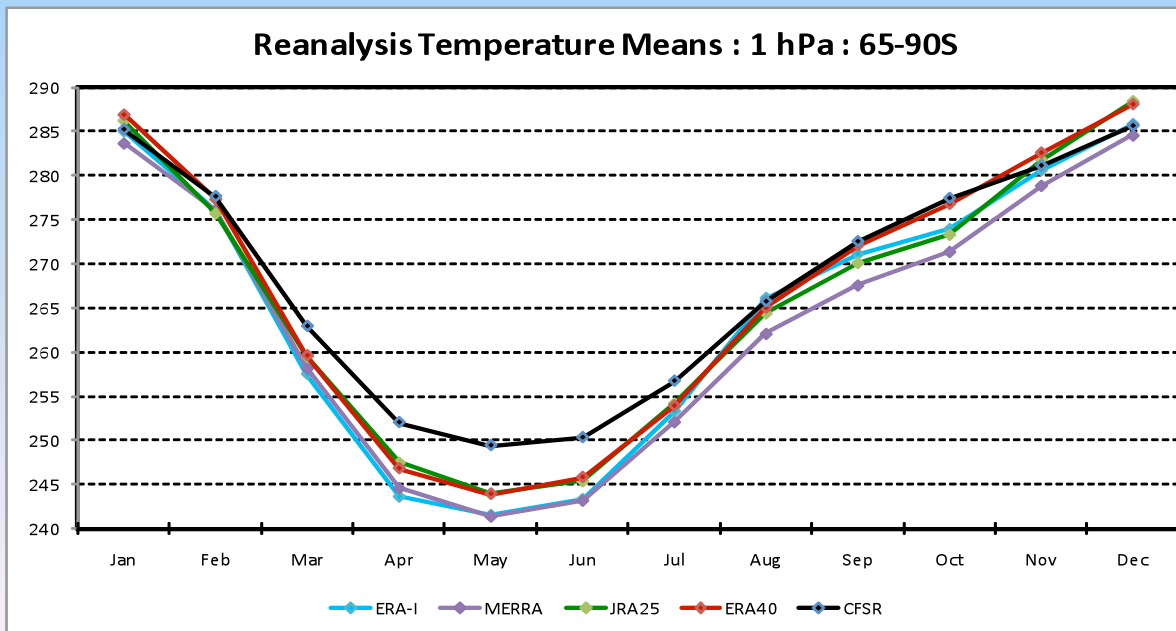
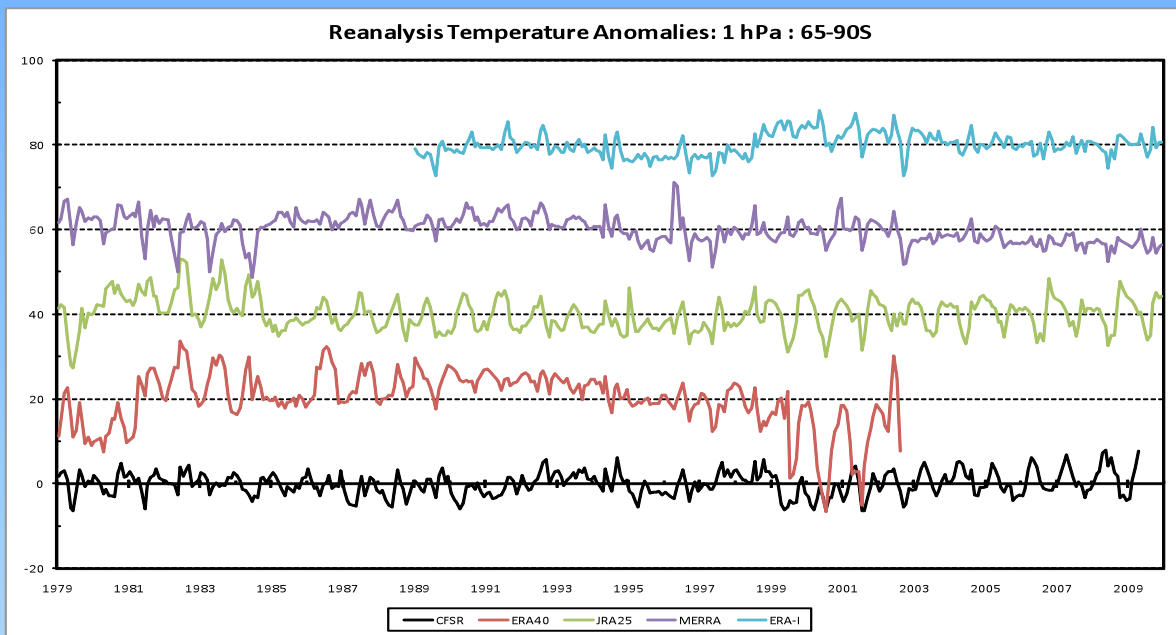
# Reanalysis Temp Anomalies

1 hPa  
90N-65N



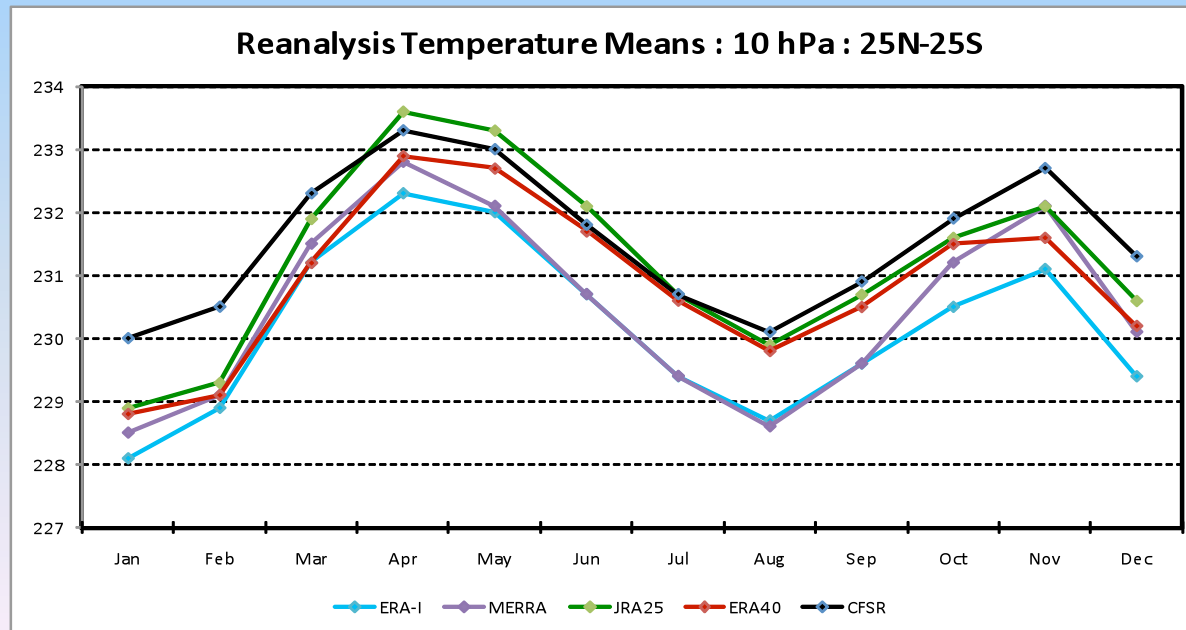
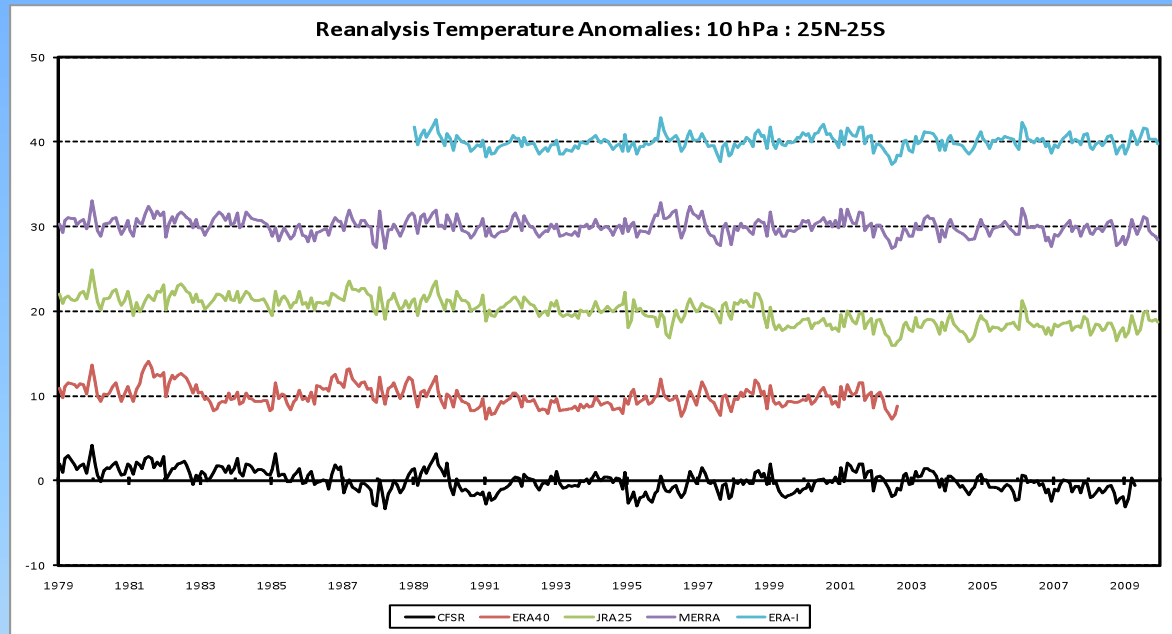
# Reanalysis Temp Anomalies

1 hPa  
65S-90S



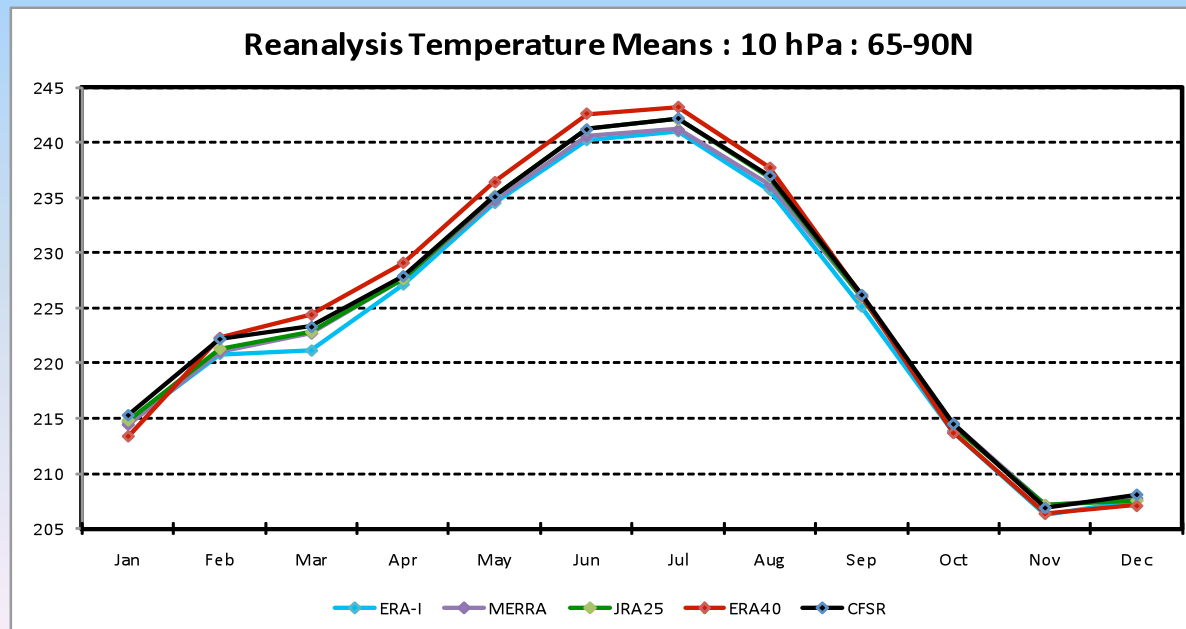
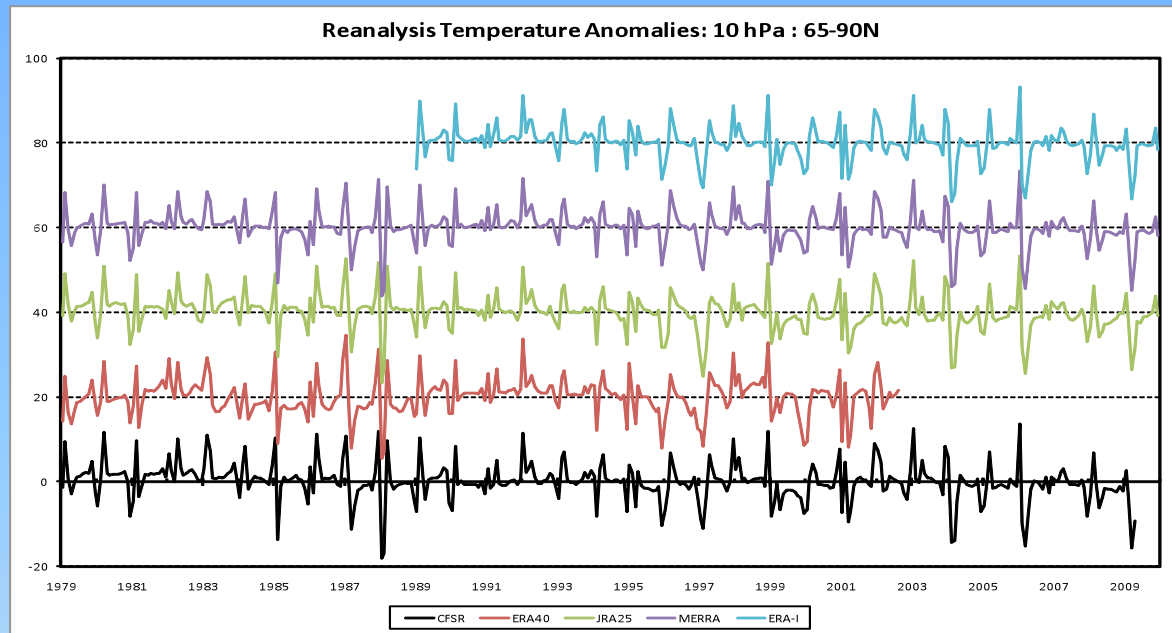
# Reanalysis Temp Anomalies

10 hPa  
25N-25S



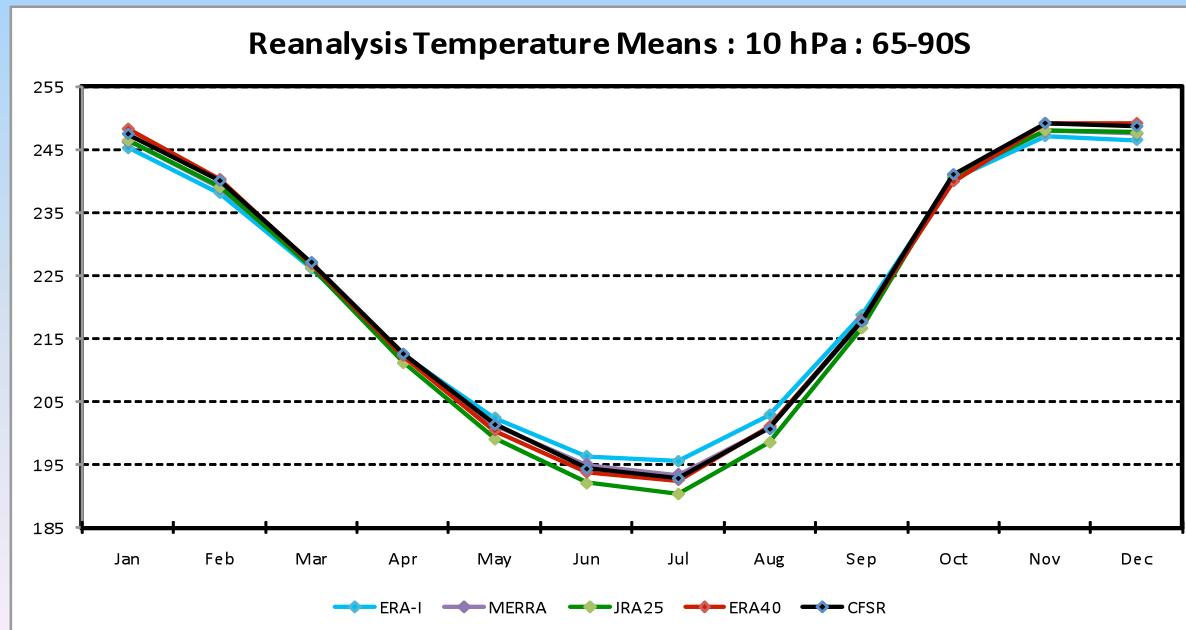
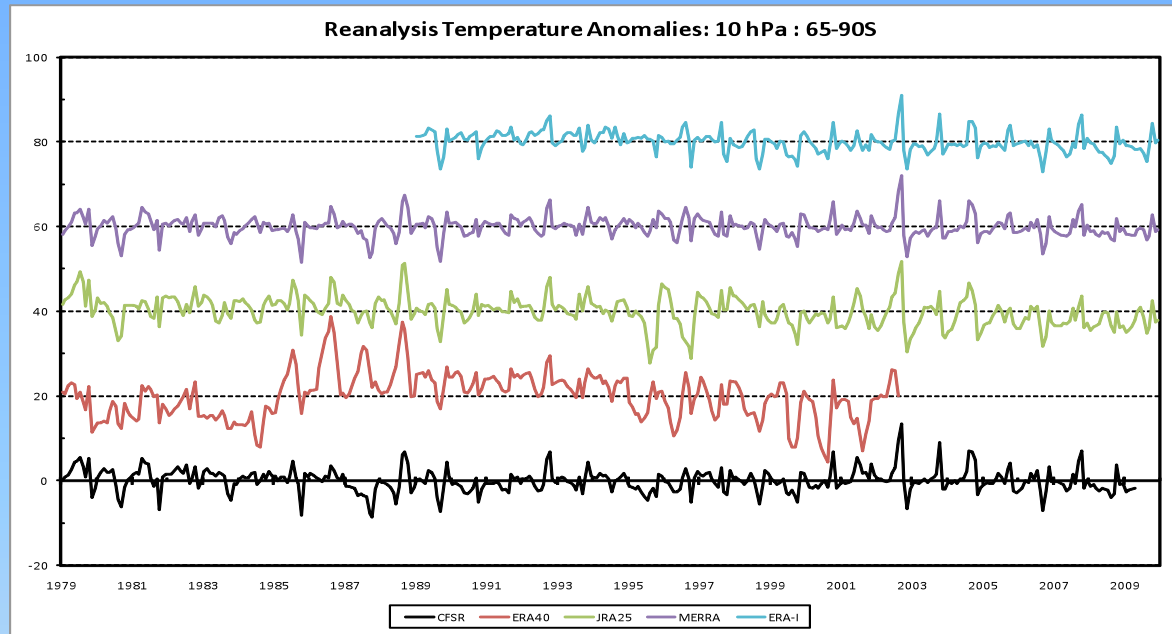
# Reanalysis Temp Anomalies

10 hPa  
90N-65N



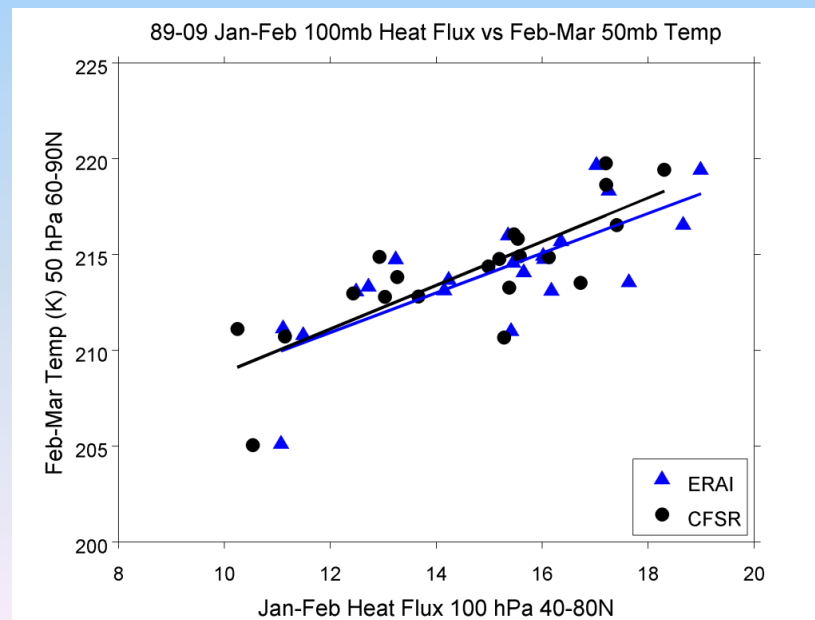
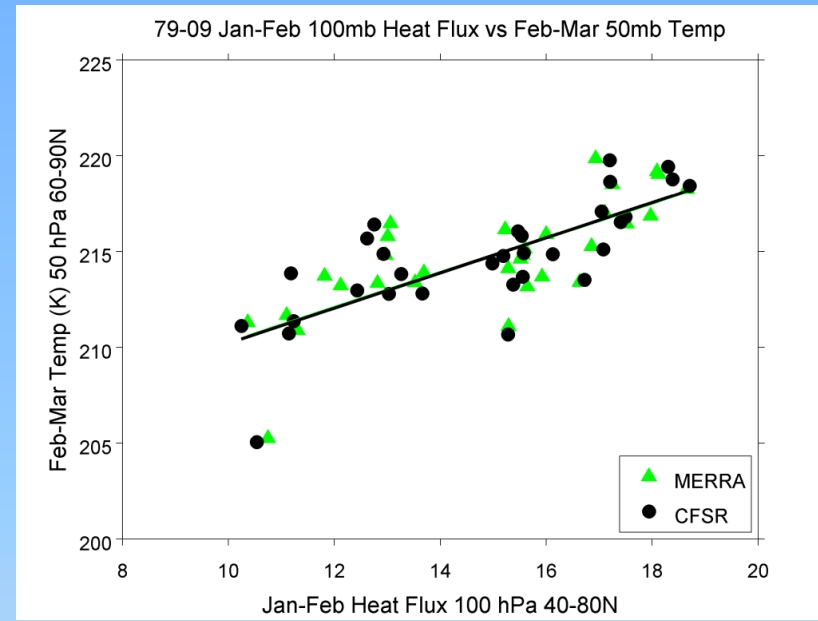
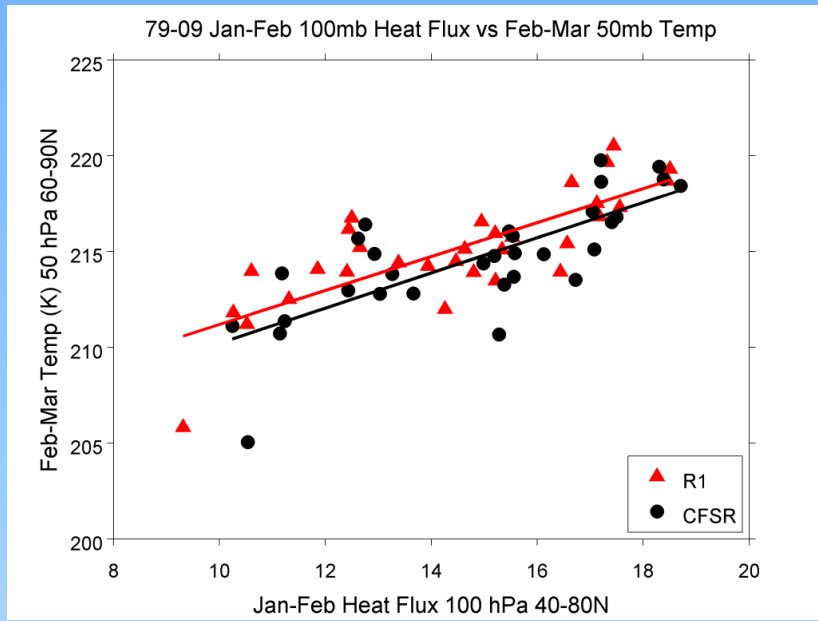
# Reanalysis Temp Anomalies

10 hPa  
65S-90S

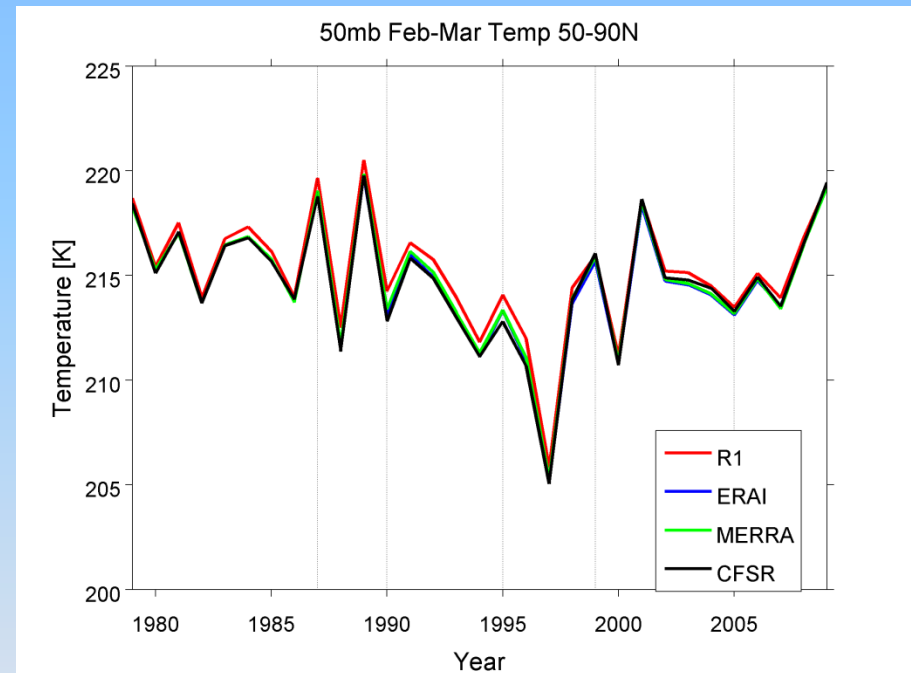
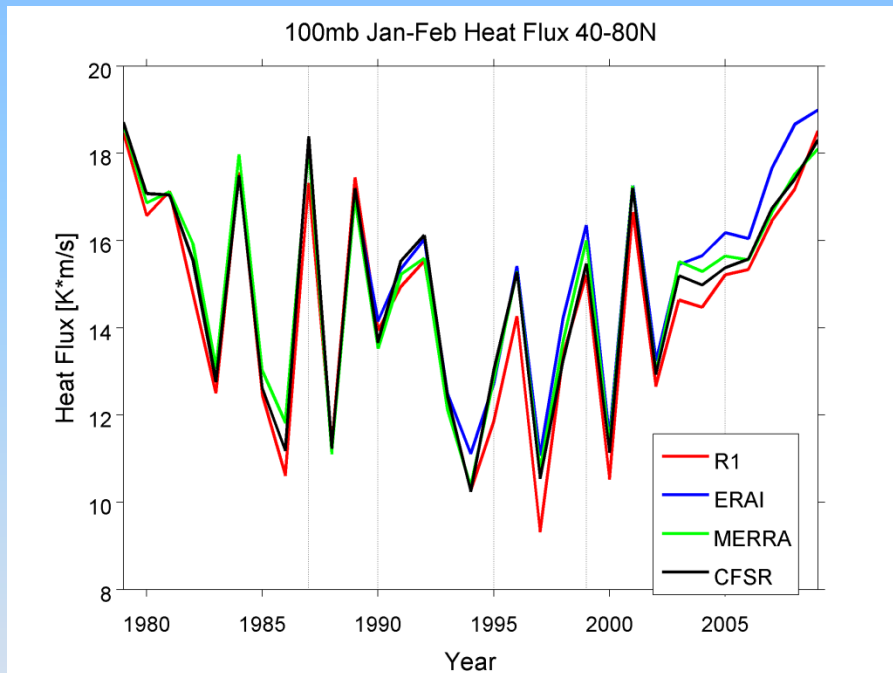




# Jan&Feb Polar Heat Flux vs Feb&Mar Temperatures



# Jan&Feb Polar Heat Flux and Feb&Mar Temperatures *Lower Stratosphere*

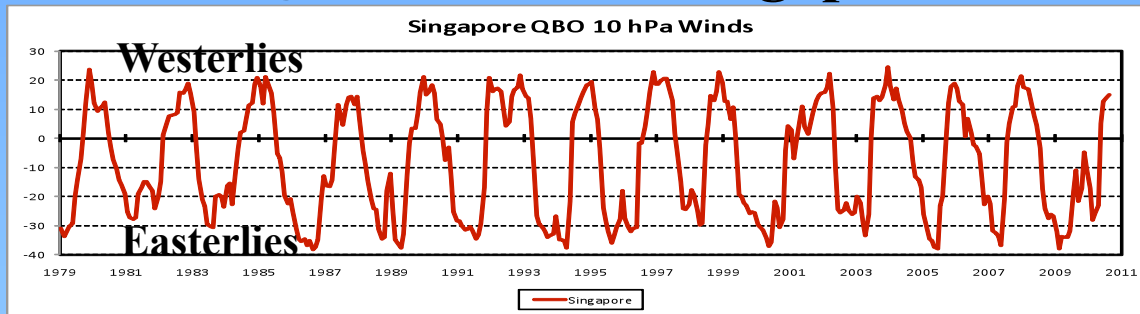


**All looking at the same earth!**

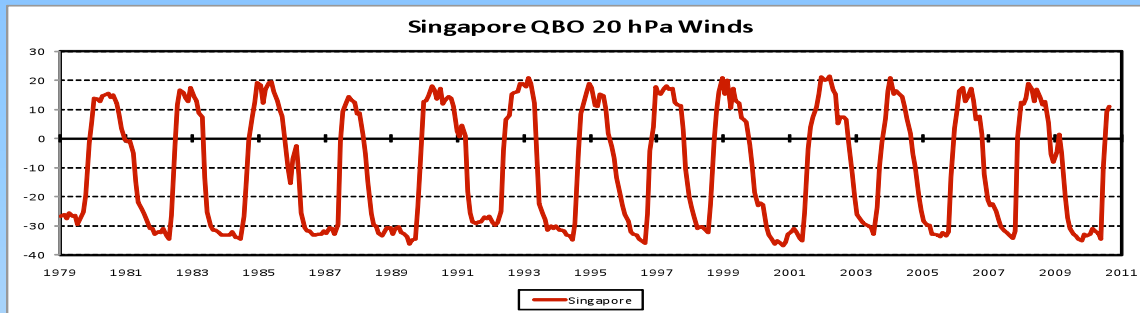
# *Zonal Winds*

# QBO Winds at Singapore

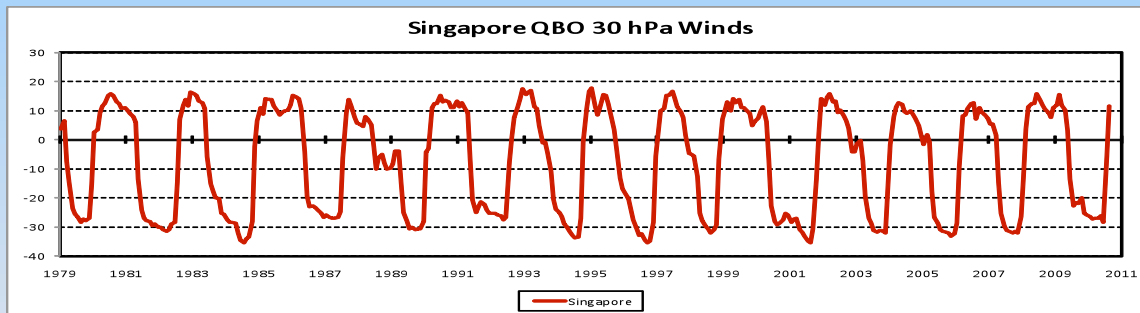
10 hPa



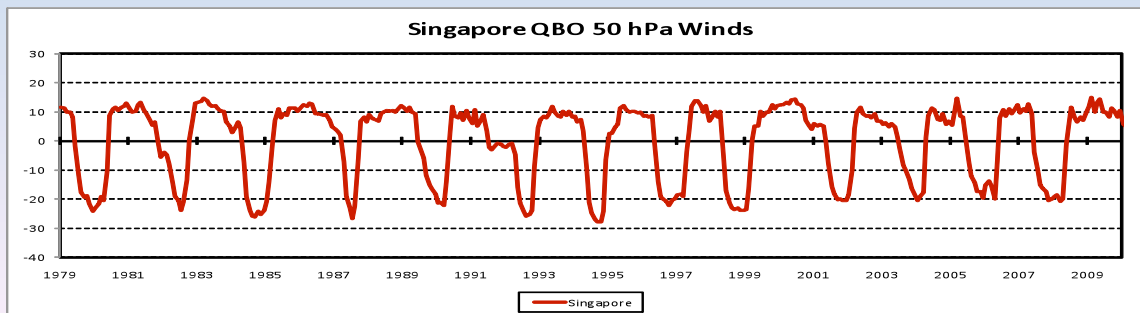
20 hPa



30 hPa

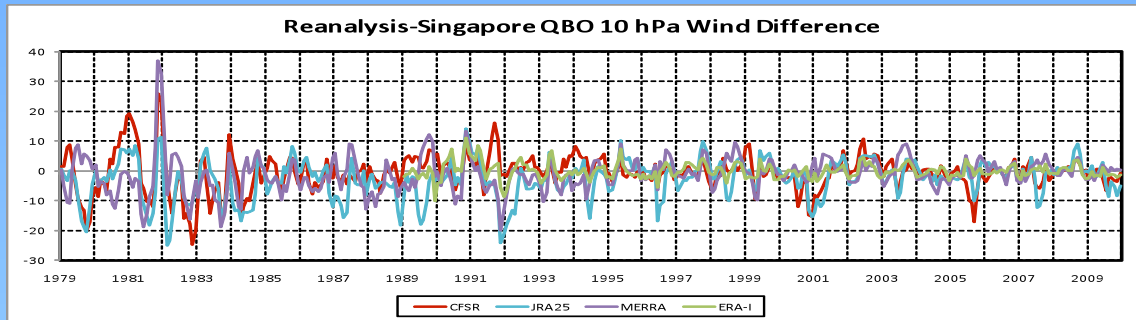


50 hPa

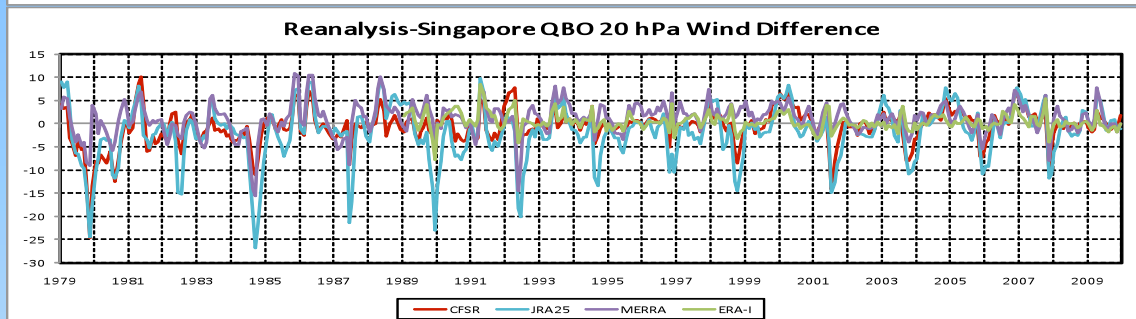


# Reanalysis QBO Wind Differences from Singapore

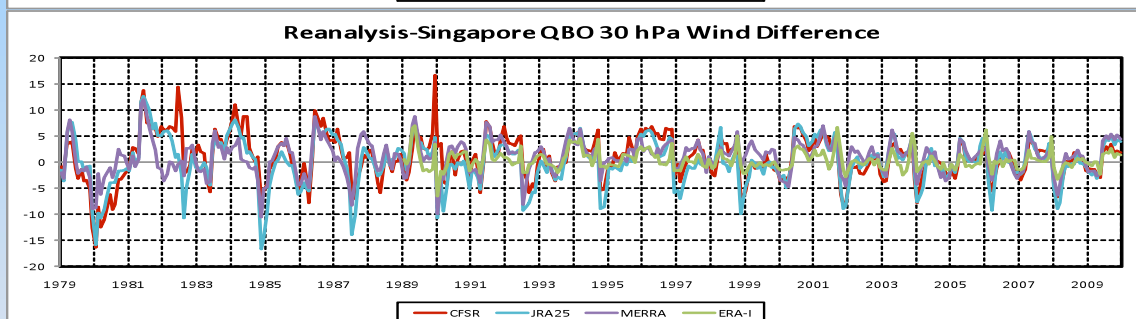
10 hPa



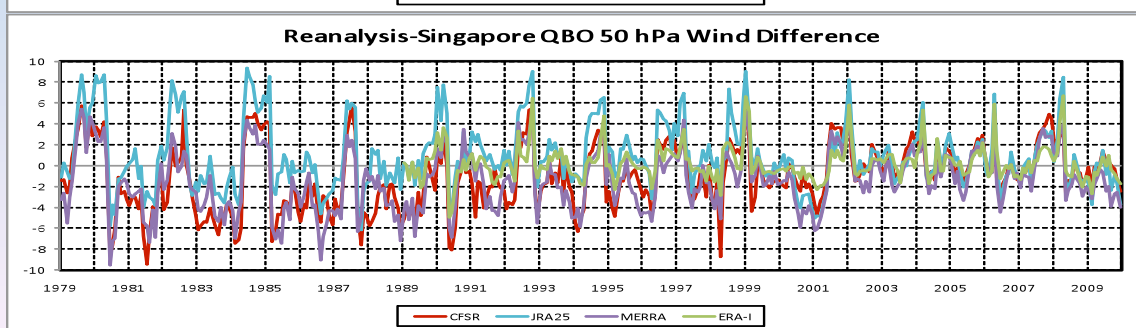
20 hPa



30 hPa



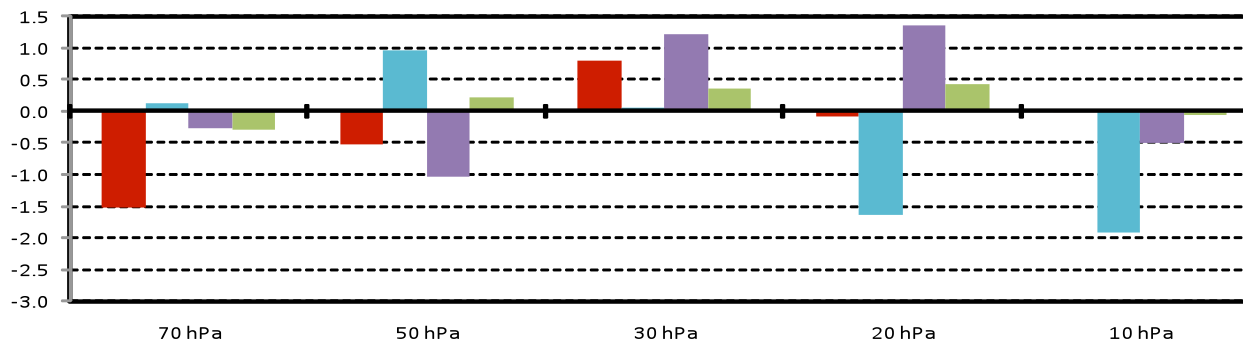
50 hPa



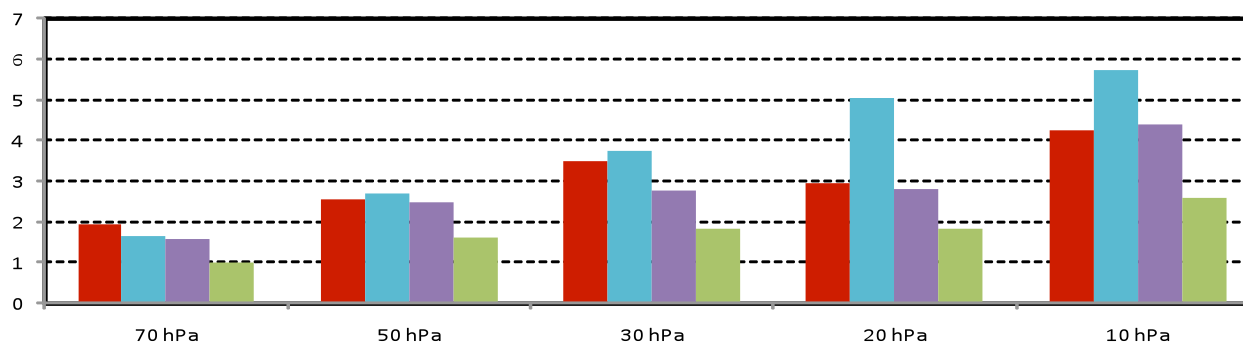
Largest differences occur at transition from Easterlies to Westerlies

# Reanalysis QBO Wind Difference Statistics

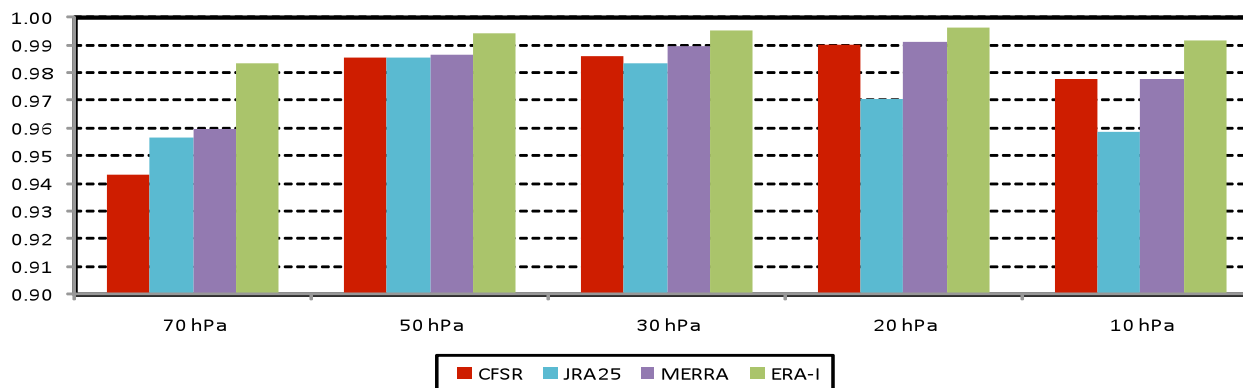
Reanalysis Mean Difference from Singapore u Winds (89-09)



Reanalysis Difference St Dev from Singapore u Winds (89-09)

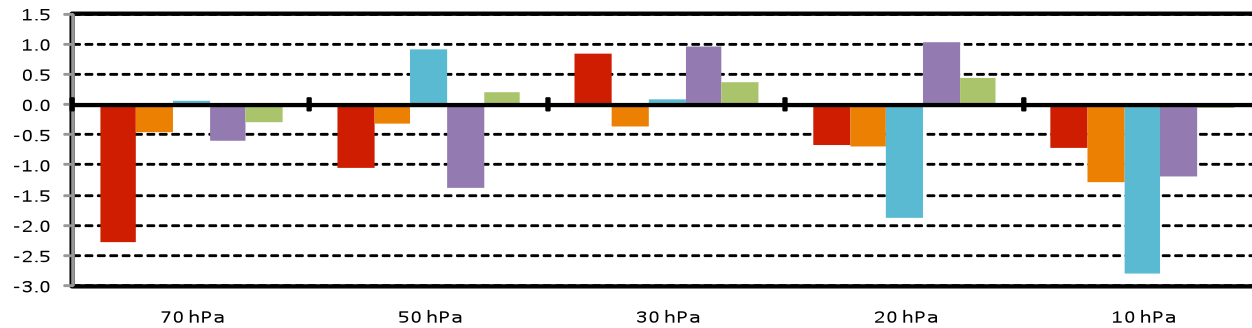


Reanalysis Correlation with Singapore u Winds (89-09)

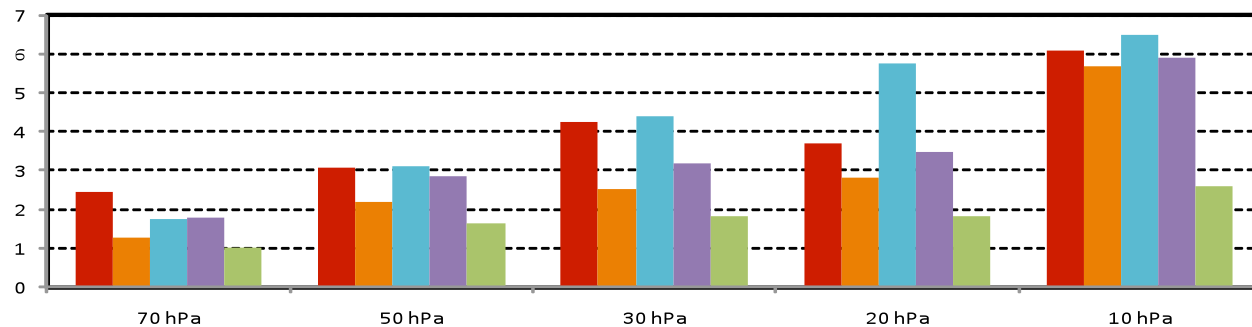


# Reanalysis QBO Wind Difference Statistics

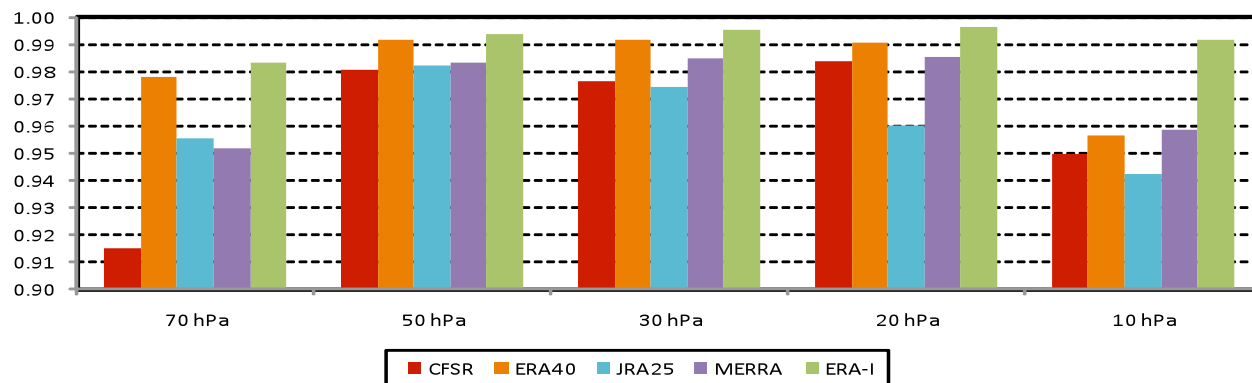
Reanalysis Mean Difference from Singapore u Winds 1979-2009



Reanalysis Difference St Dev from Singapore u Winds

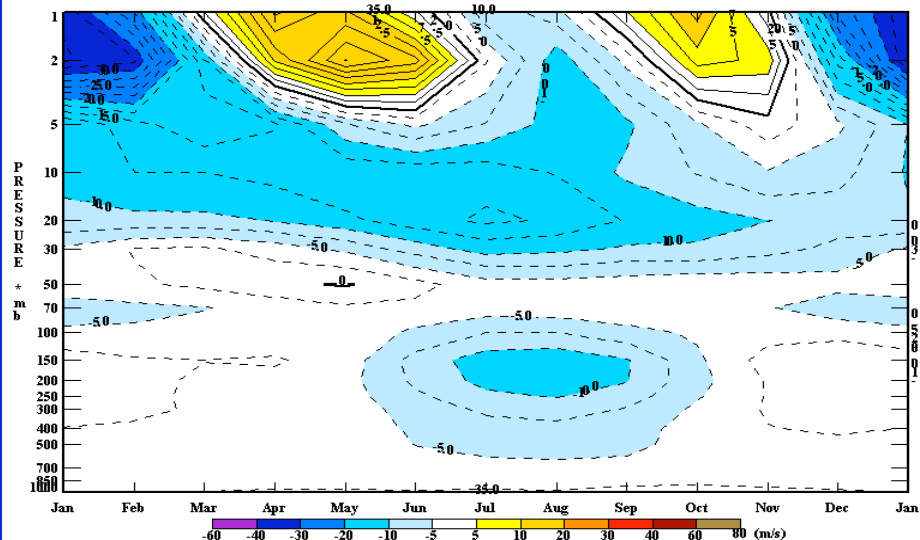


Reanalysis Correlation with Singapore u Winds

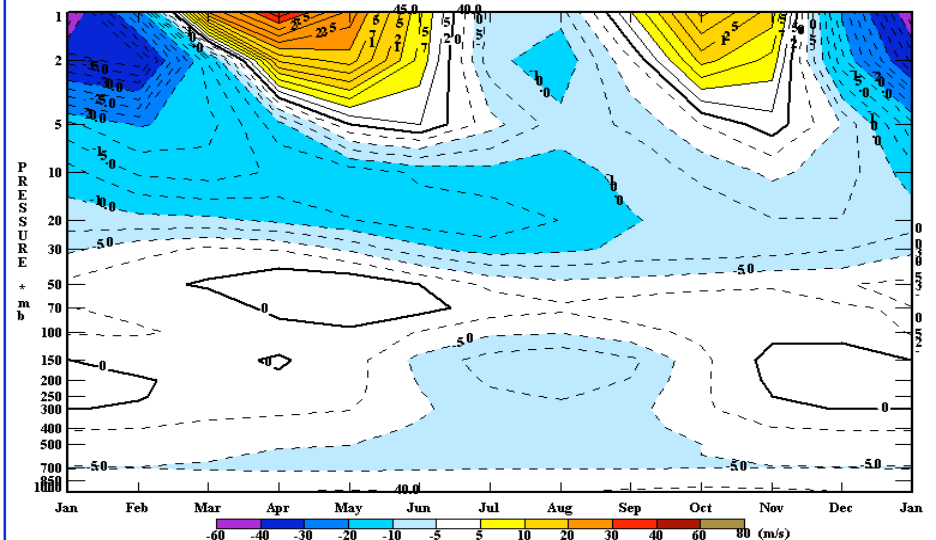


# Reanalysis Tropic Zonal Winds

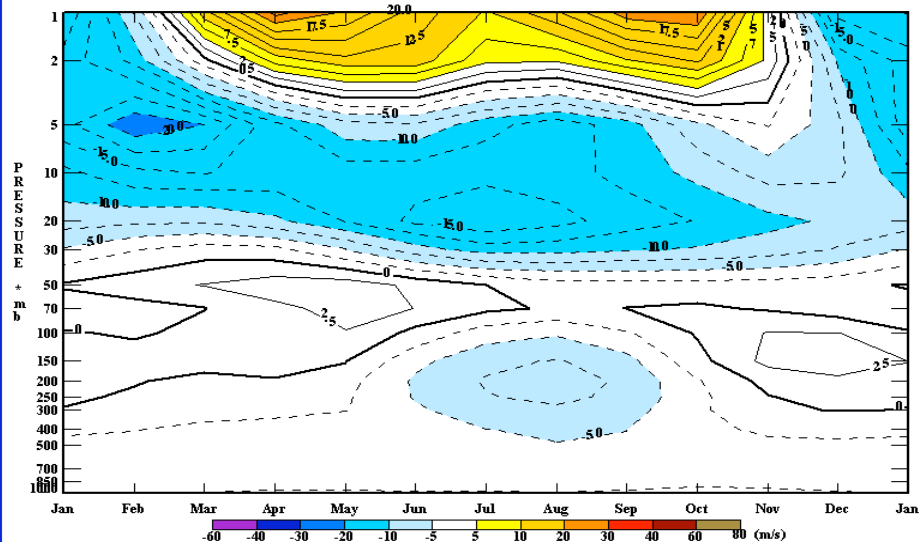
Monthly CFSR Mean Zonal Wind (-5 to 5)  
1979 - 2009



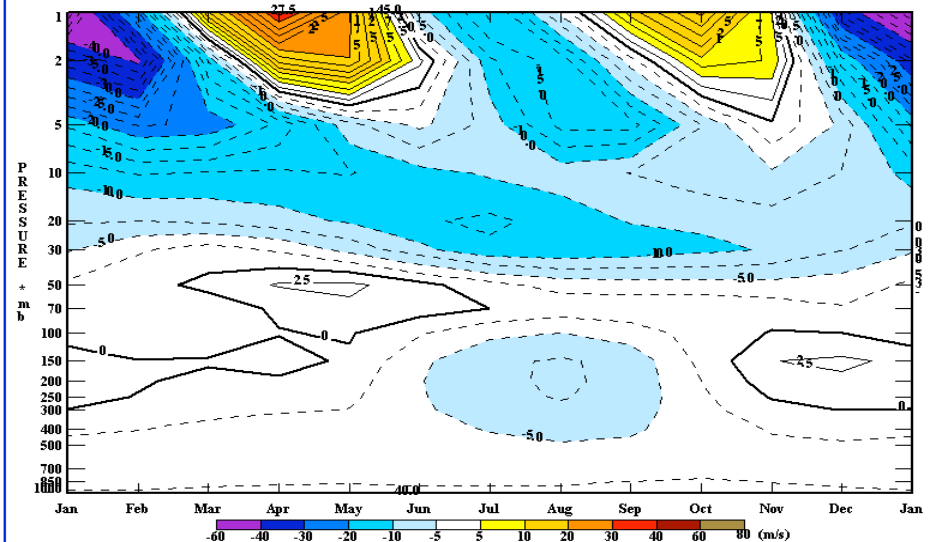
Monthly MERRA Mean Zonal Wind (-5 to 5)  
1979 - 2009



Monthly JRA25 Mean Zonal Wind (-5 to 5)  
1979 - 2009



Monthly ERA-Interim Mean Zonal Wind (-5 to 5)  
1979 - 2009





*Ozone*

# ERA-Interim Sources of Profile and Total Ozone

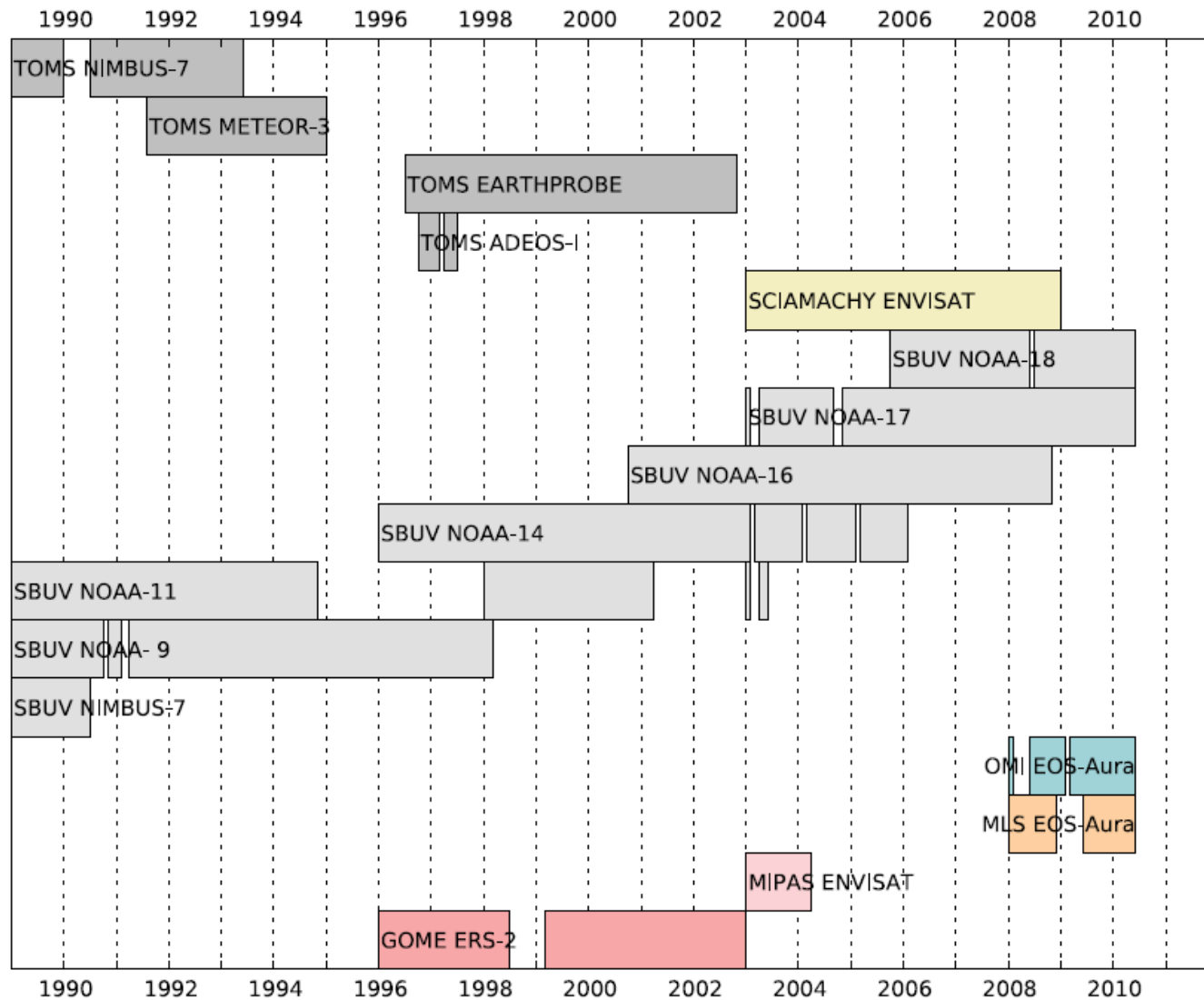
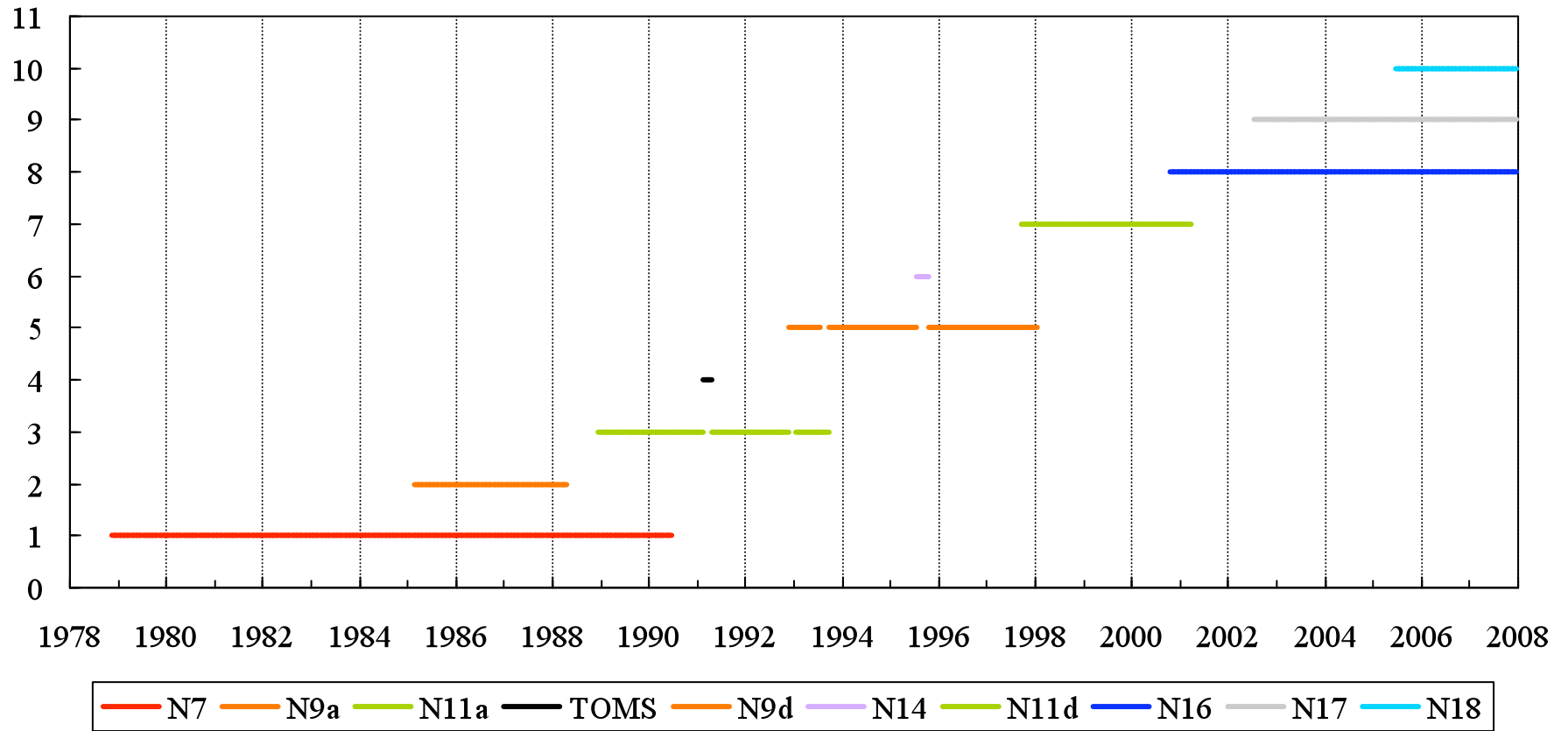


Figure 15. Timeline of ozone data assimilated in ERA-Interim.

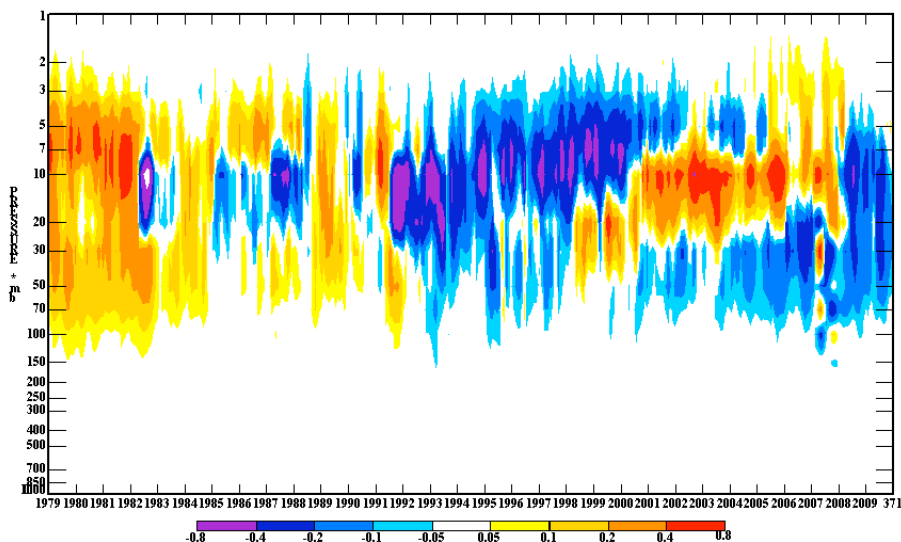
# CFSR Sources of Profile and Total Ozone

## SBUV and SBUV/2 Satellite Time Periods for CFSRR

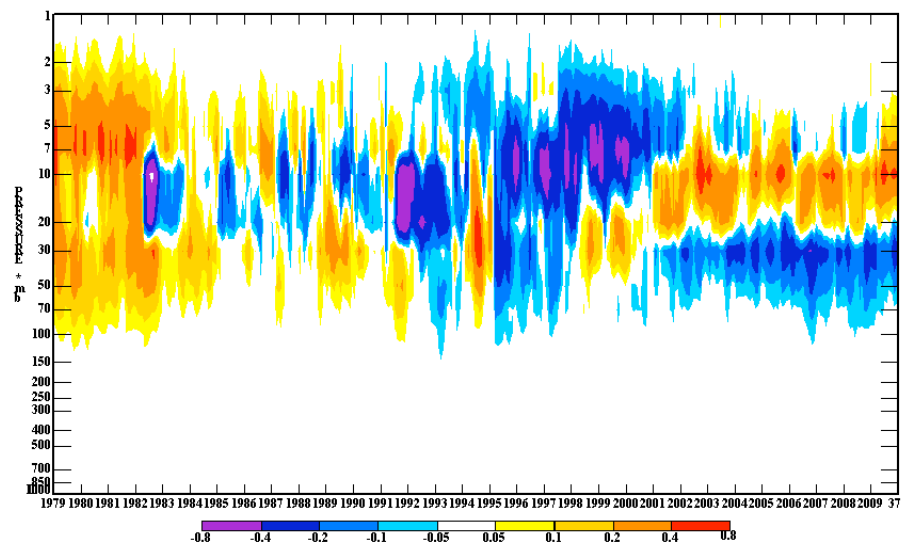


# Global O3MR Anomalies

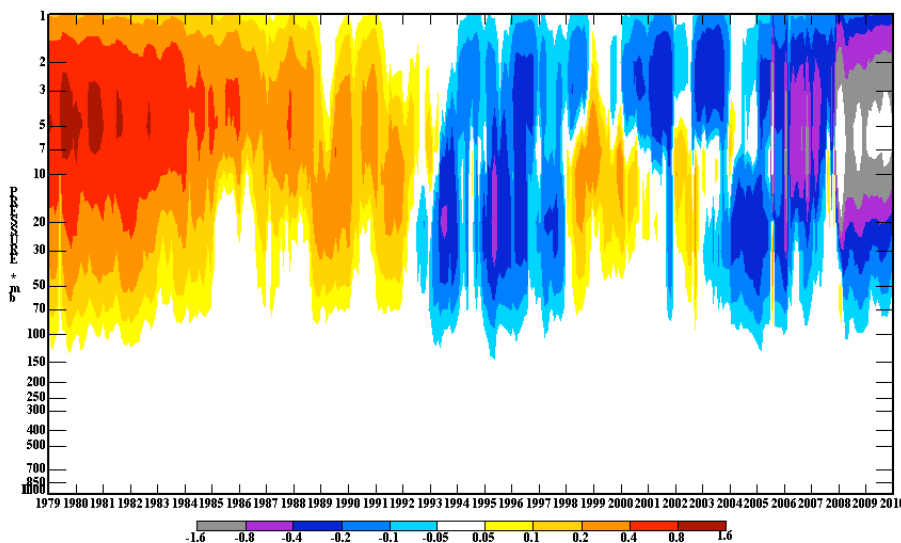
Monthly CFSR O3MR Anomalies (PPM)  
GLOBAL (1979 - 2009)



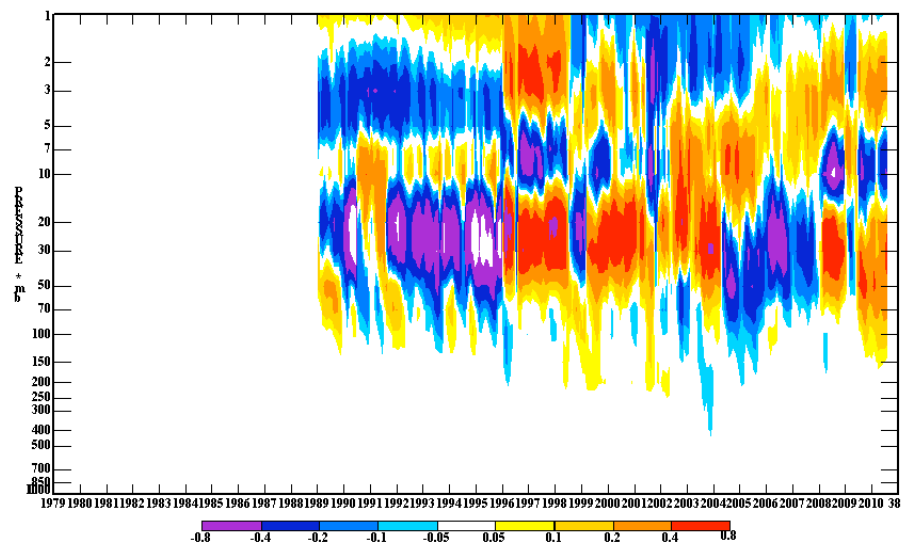
Monthly MERRA O3MR Anomalies (PPM)  
GLOBAL (1979 - 2009)



Monthly JRA-25 O3MR Anomalies (PPM)  
GLOBAL (1979 - 2009)



Monthly ERA-Interim O3MR Anomalies (PPM)  
GLOBAL (1979 - 2010)



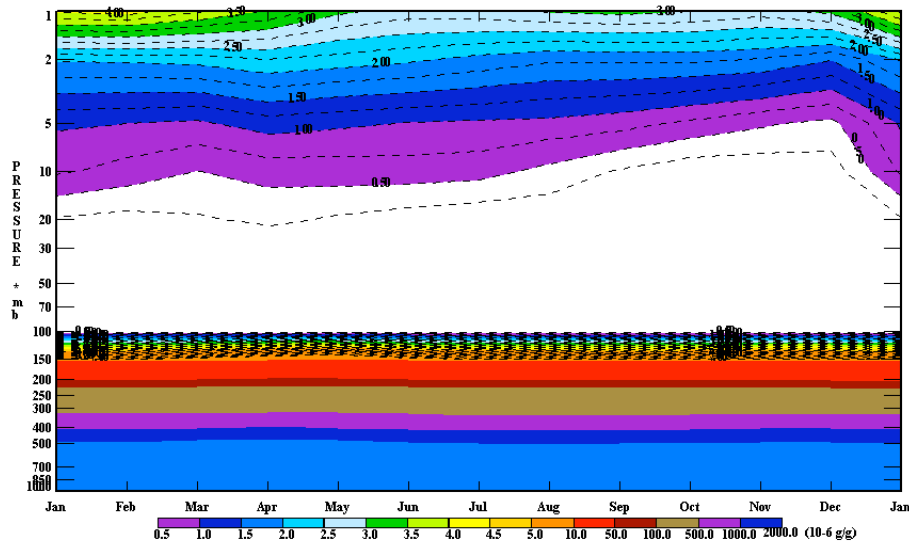
# *Specific Humidity*

# CFSR, MERRA and ERA-I SPFH

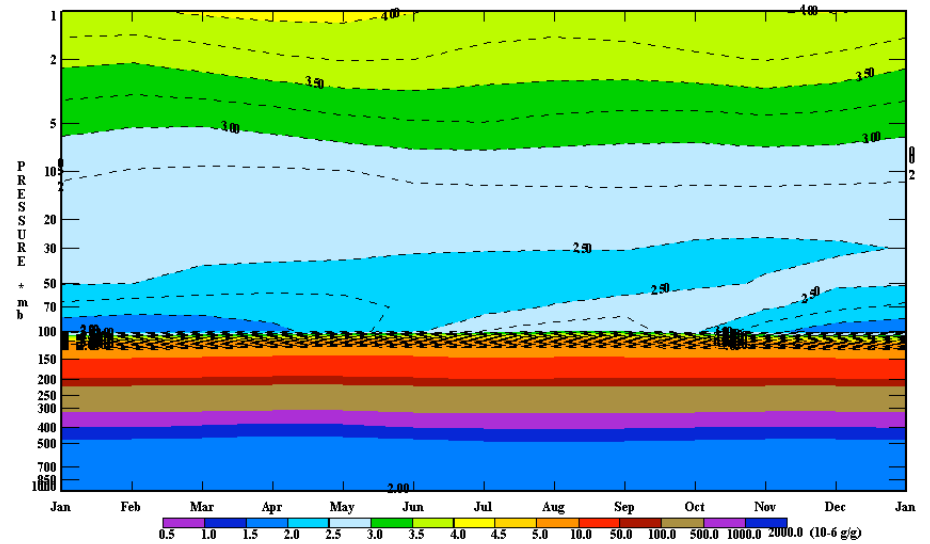
- Comparison of monthly mean Specific Humidity concentrating above the tropopause
- NCEP has had issues with water vapor above the tropopause
- MERRA and ERA-I have realistic structure and annual cycle
  - CFSR does not
  - JRA does not output water vapor above 300 hPa
- CFSR stream jumps also show up vividly and initialization values are incorrect.
- MERRA and ERA-I do show “tape recorder” structure
  - Parameterized or uses satellite obs(?)
- Why is this important:
  - Like ozone, water vapor is radiatively important. It is also another indicator of climate change.

# Reanalysis Tropic Specific Humidity

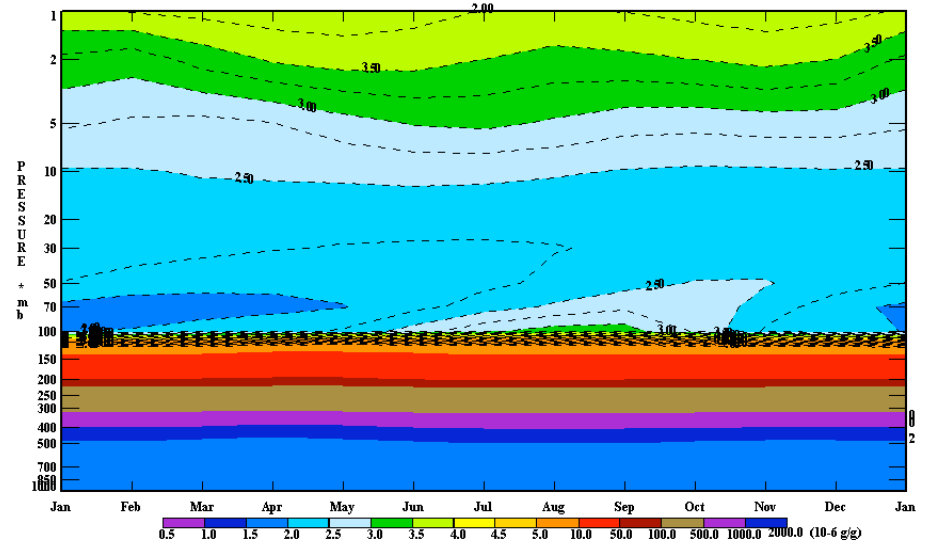
Monthly CFSR Mean SPFH (-10 to 10)  
1979 - 2009



Monthly MERRA Mean SPFH (-10 to 10)  
1979 - 2009

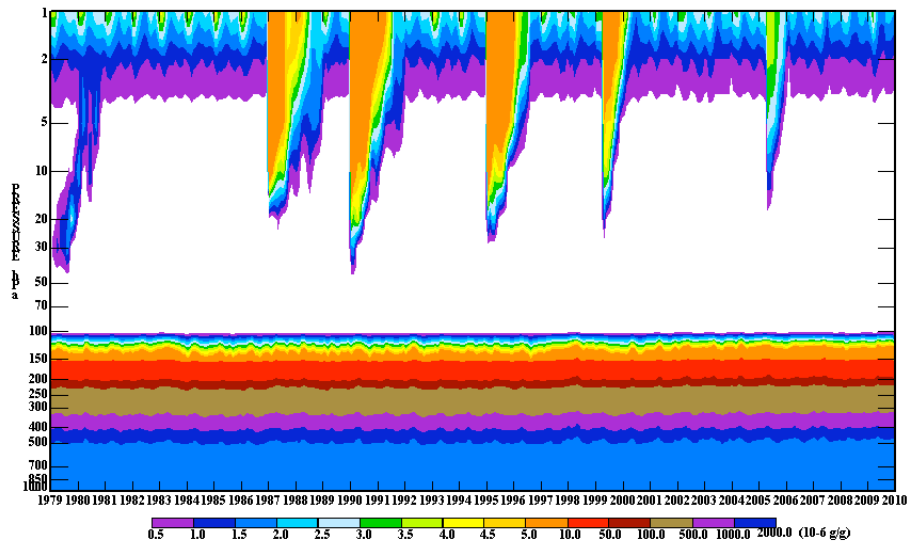


Monthly ERA-Interim Mean SPFH (-10 to 10)  
1979 - 2010

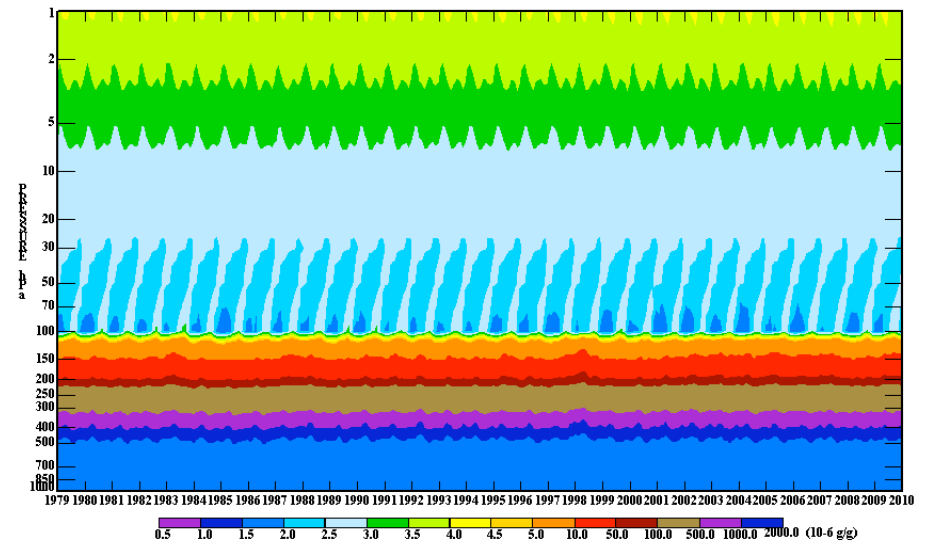


# Monthly Time Series of Tropical SPFH

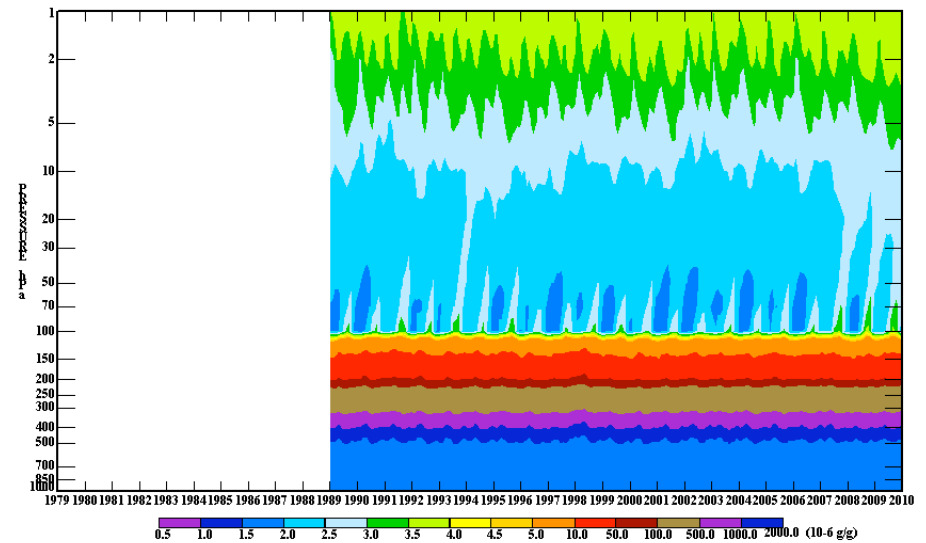
Monthly CFSR SPFH (-10 to 10)  
1979 - 2009



Monthly MERRA SPFH (-10 to 10)  
1979 - 2009



Monthly ERA-Interim SPFH (-10 to 10)  
1979 - 2009





# Reanalyses Conclusions

- All reanalyses have to deal with SSU issues
  - More recent reanalyses have resolved many of these issues
    - CFSR does good job
    - ERA-I avoids this time period
    - ERA40, JRA25 and to lesser extent MERRA have noisier first 10 years.
- CFSR has issues with 6 streams and temperature trends within each stream
  - Due to bias correction of SSU channels
- All reanalyses have to deal with transition from SSU to AMSU.
  - Some do a better job than others
- Reanalyses zonal mean temperatures above 10 hPa disagree with each other by several degrees in summer and winter months in NH and SH Polar and Tropics.
  - CFSR has warm bias wrt other reanalyses
- Reanalyses that begin in 1979 have problems resolving the QBO correctly.
  - Less data available in this time period.
  - Model needs to give more weight to observations
- QBO anomalies from Singapore winds show that all Reanalyses have issues responding to QBO wind reversals.
  - ERA-Interim performs the best, with CFSR and MERRA close behind

# Reanalyses Conclusions - *Cont*

- Multiple ozone sources may add noise to long term data set.
  - Is more = better
  - Obs not radiances assimilated
- Ozone data sets used need to be further refined.
  - SBUV v8.6 comings soon.
  - Usable for ozone trends? (not yet)
- MERRA and ERA-Interim have realistic SPFH annual cycle
  - Parameterized
  - Pre-AMSU obs not very usable for reanalysis

# CFSR -Lite

- CFSR-Lite will address many of the issues revealed in the CFSR.
- CFSR-Lite will be a one stream-low resolution (T126) reanalysis from 1979-2010
- Issues Addressed:
  - SSU bias correction – remove warm bias in mid and upper stratosphere
  - Inclusion of AMSU-A channel 14 (upper stratosphere) - ditto
  - Give more weight to observations in earlier years – better QBO winds
  - Corrected observational error for ozone mixing ratio – more weight to SBUV/2 obs
  - Remove cold bias in troposphere - Improves wind shear in troposphere

# Reanalysis References

- **NCEP/NCAR Reanalysis**
  - Kalnay et al., The NCEP/NCAR 20 year reanalysis project, Bull. Amer. Meteorol. Soc. 77:437-471, 1996.
- **ERA-40**
  - Uppala et al., The ERA-40 re-analysis, QJRMS, 131:2961-3012, 2005.
- **JRA-25**
  - Onogi et al., The JRA-25 Reanalysis, J. Meteor. Soc. Japan, 85:369-432, 2007.
- **NCEP CFSR**
  - Saha et al., The NCEP Climate Forecast System Reanalysis, Bull. Amer. Meteorol. Soc., 91:1015-1057, 2010.
- **NASA/GMAO MERRA**
  - Rienecker et al., MERRA-NASA's Modern-Era Retrospective Analysis for Research and Applications, J. Climate, DOI:10.117/JCLI-D-11-00015.1, 2011.
- **ERA-Interim**
  - Dee et al., The ERA-Interim reanalysis configuration and performance of the data assimilation system, QJRMS 137:553-597, April 2011. DOI:10.1002/qi.828.