

# Report on CTB Project

## CFS Stratosphere Improvement

Joint project between NOAA/ESRL/PSD (Judith Perlwitz, Tao Zhang), NOAA/NCEP/EMC (Jordan Alpert) and NOAA/NCEP/CPC (Craig Long, Shuntai Zhou, with additional help from Amy Butler and Emily Riddle)

Thanks to Ed Schneider (COLA & GMU) for sharing CFSv2 coupled model output, and COLA's NSF/NOAA/NASA funding, and NCEP for providing the model to COLA

# Main Goals of the Project

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  - Evaluate the dynamical troposphere-stratosphere coupling in CFSv2
  - Improve stratospheric representation in CVSv2 and troposphere-stratosphere coupling

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**NAS Assessment of intraseasonal to interannual (ISI) climate prediction and predictability:**

***Operational ISI prediction models should be improved to represent stratosphere-troposphere interactions.***

# Our Proposed Approach

- CFSv2 Evaluation of Troposphere-Stratosphere coupling
  - Analysis of CFSRR and AMIP-style simulations
  - AMIP simulations allows to save high frequency output
- Model development
  - Tuning of orographic GWD parameterization
  - Investigate impact of vertical resolution, height of model lid and stratospheric gravity parameterization on seasonal forecast

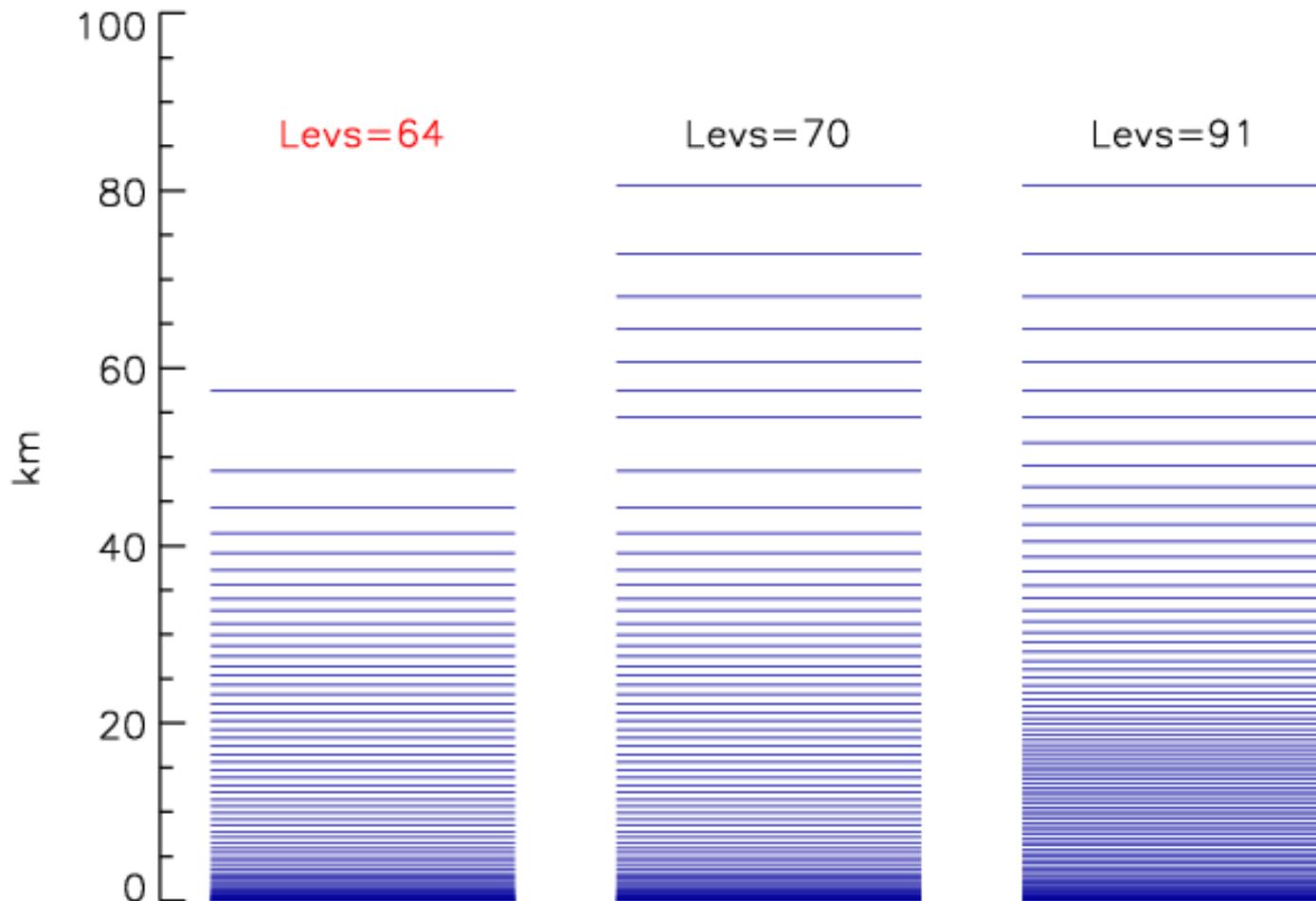
# Tasks carried out in Years 1 and 2:

- Project start: August 2009
- CFSv2: model code released June 2010
- CFSRR output availability: Spring 2011 (still not complete)
- Year 1: worked with interims model versions
  - Compiled and run a set of AMIP style simulations
  - Run baseline and GWD tuning experiments for 2 winters (La Nina and El Nino case)
  - Analysis of strat.-trop. coupling
- Year 2:
  - Compiled GFS<sub>CFSv2</sub> and run 3 AMIP style simulations
  - Analysis of strat.-trop coupling based on daily output of AMIP style simulations
  - Run baseline experiments for 2 winters (La Nina and El Nino case)
  - Analysis of monthly CFSRR output
  - Generated 70 layer version with model top at 0.01hPa and carried out first test run

# Main Results

- Climatology of stratospheric polar night jet significantly different between CFSv1 and CFSv2
- In CFSv2 polar vortex is too weak in early winter and too strong in late winter
- Variability of stratospheric polar vortex is similar between CFSv2 and Reanalysis
- Dynamic coupling between the stratosphere and troposphere is not well represented in the CFSv2
- CFSv2 has a serious spin up problem that is most pronounced in the stratosphere but can also be seen in the troposphere
- First test run with raised model lid successful-results suggestive of reducing spin-up effect

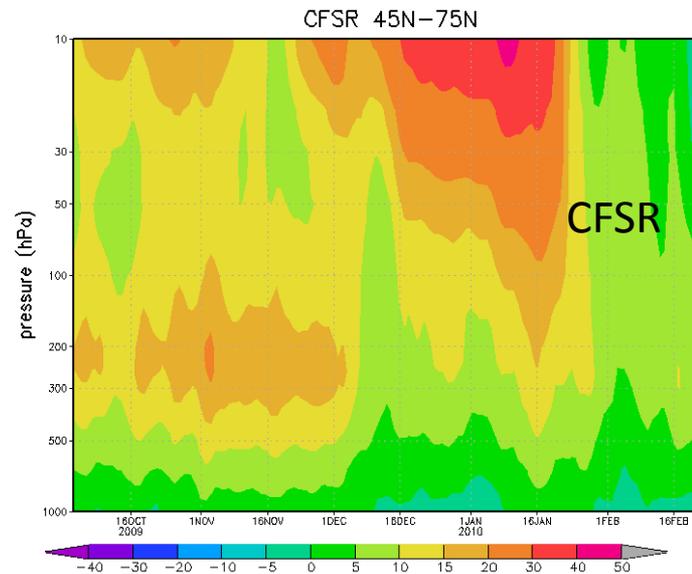
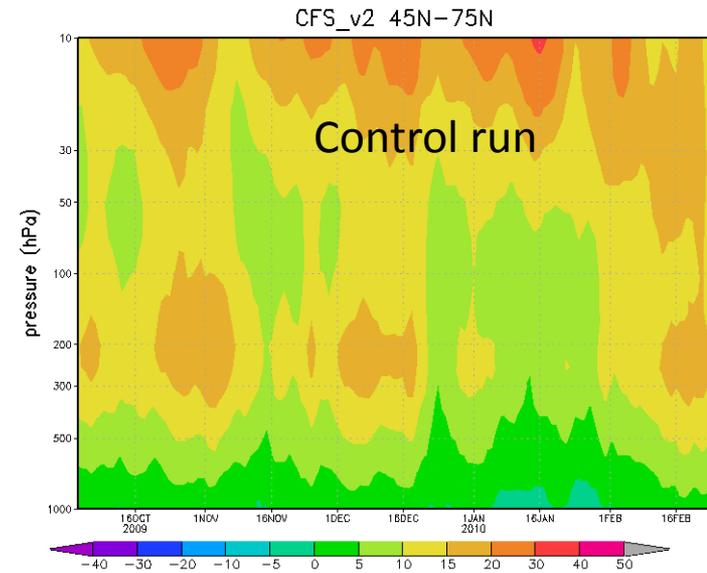
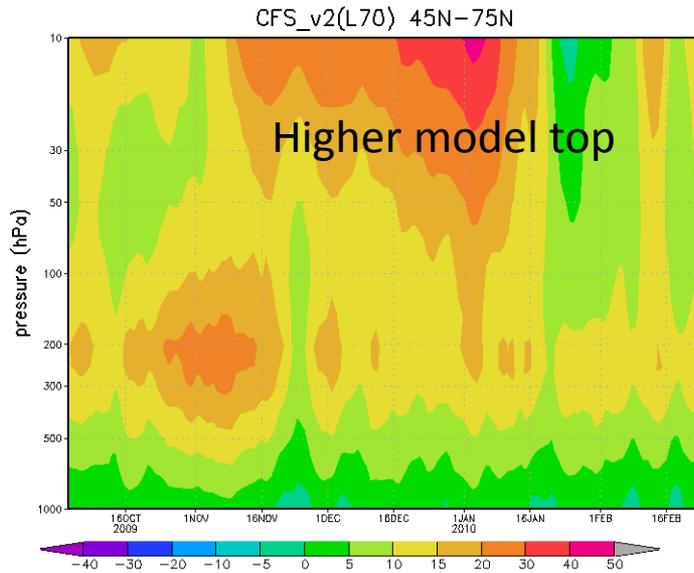
# Results with raised model top



Vertical layers of CFSv2 models. The 70-layer model's bottom 64 layers are the same as the 64-layer model, and the top 6 layers are the same as the 91-layer model.

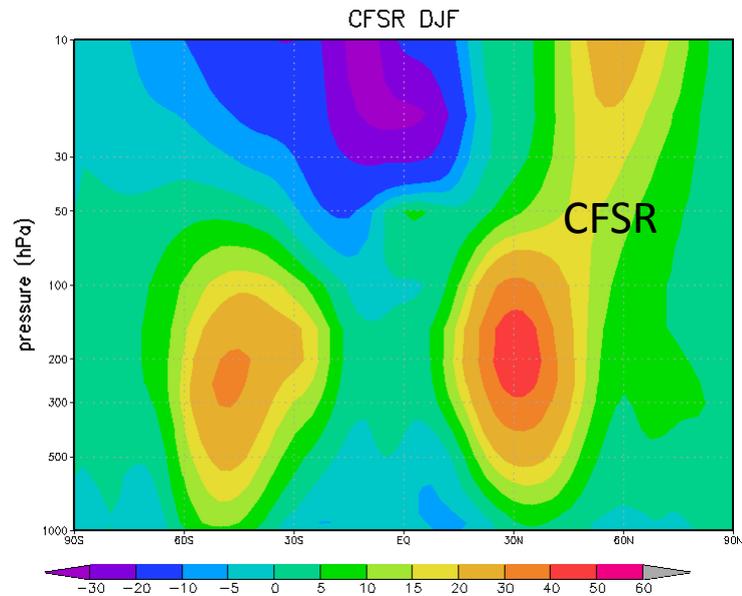
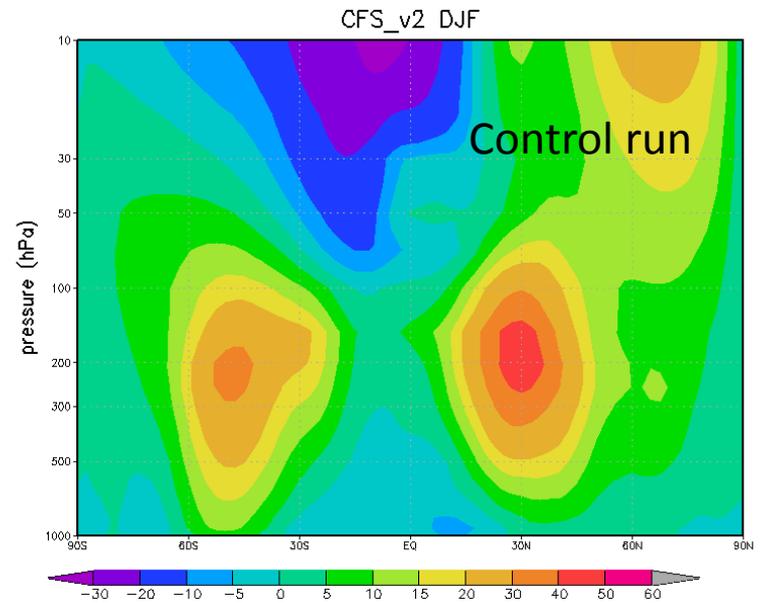
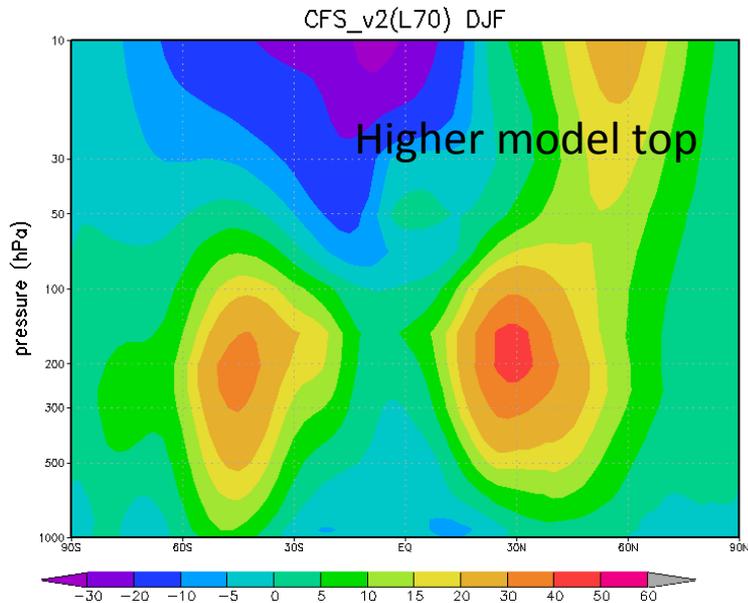
- High top experiment with L70: Starting from 2009100300 (5 month forecast)

# Comparison of NH polar jet (45N-75N mean zonal wind) evolution (Oct.2009-Feb.2010)



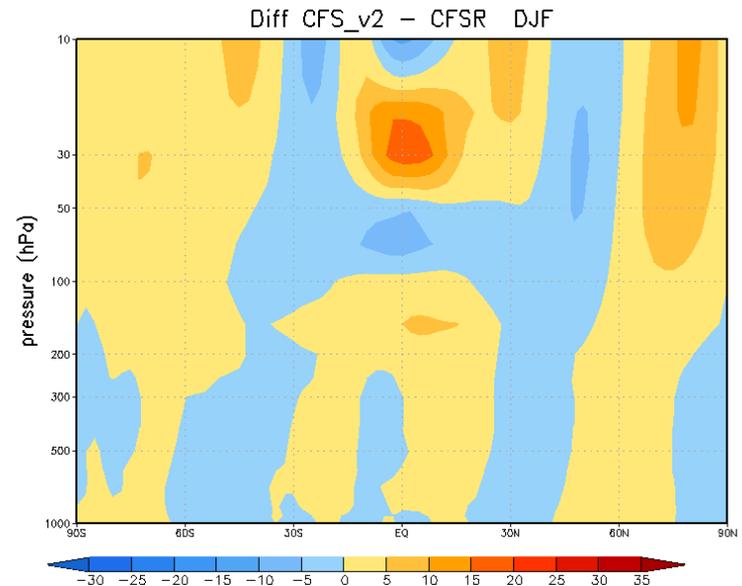
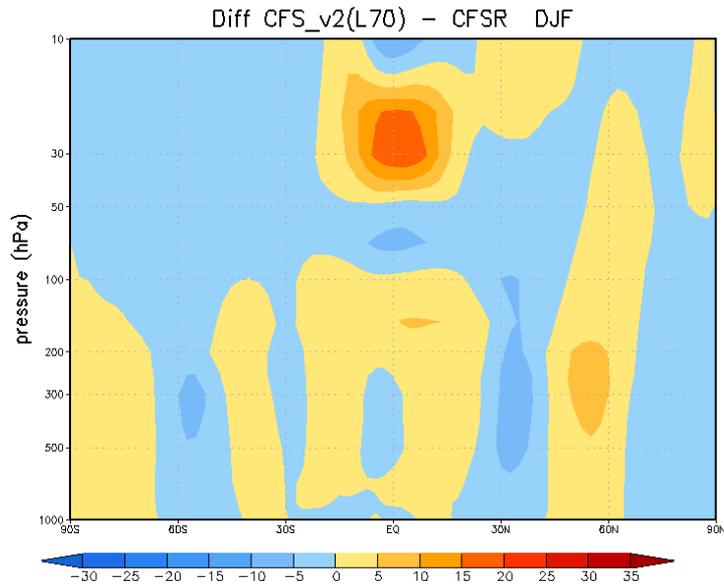
The L70 model seems to perform better than the L64 model (control run).

## Comparison of forecast DJF mean zonal wind



The jet position in the L70 model is more similar to the reanalysis than the L64 model.

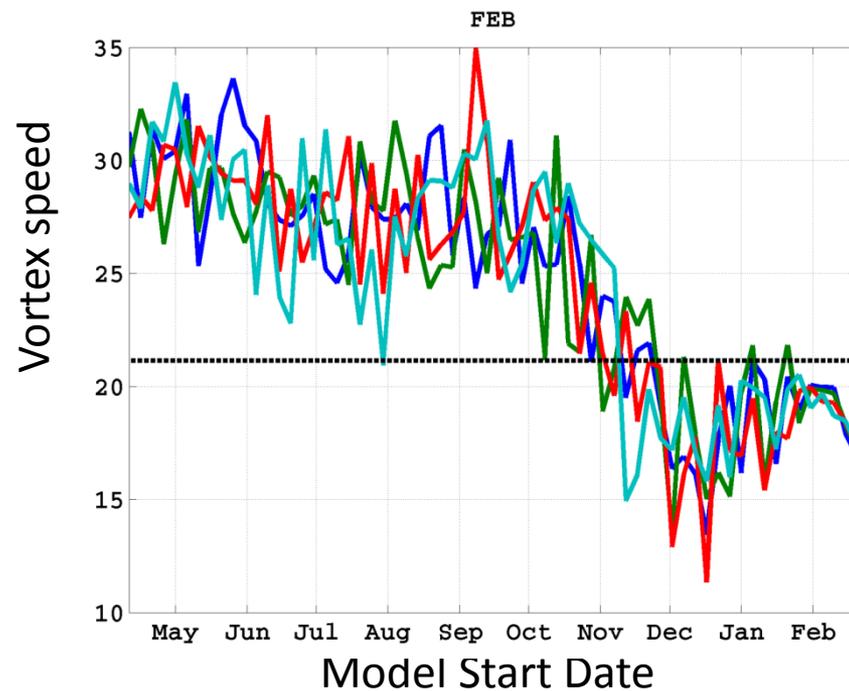
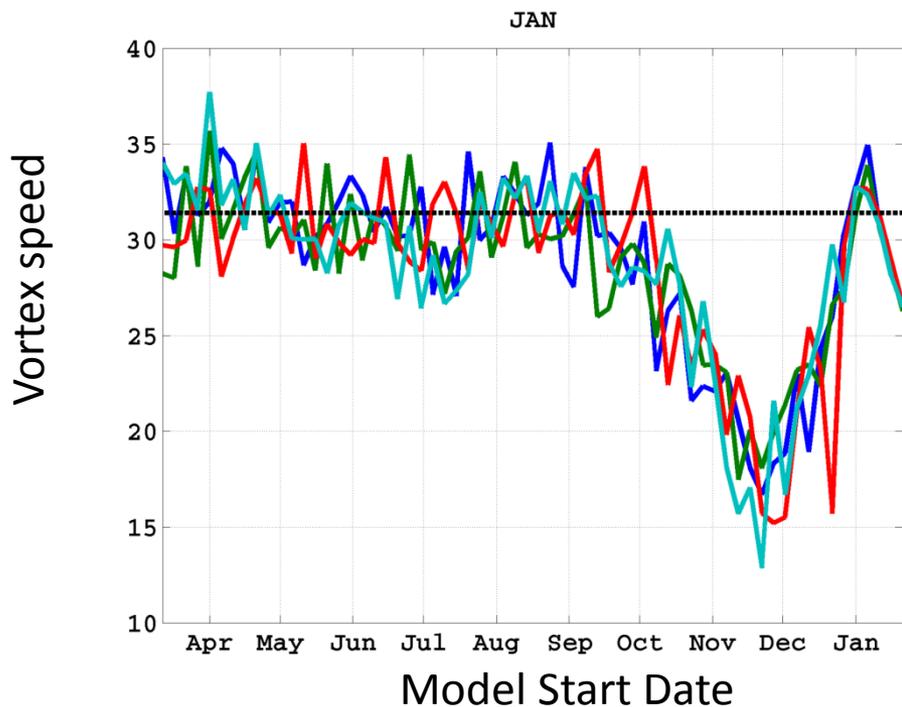
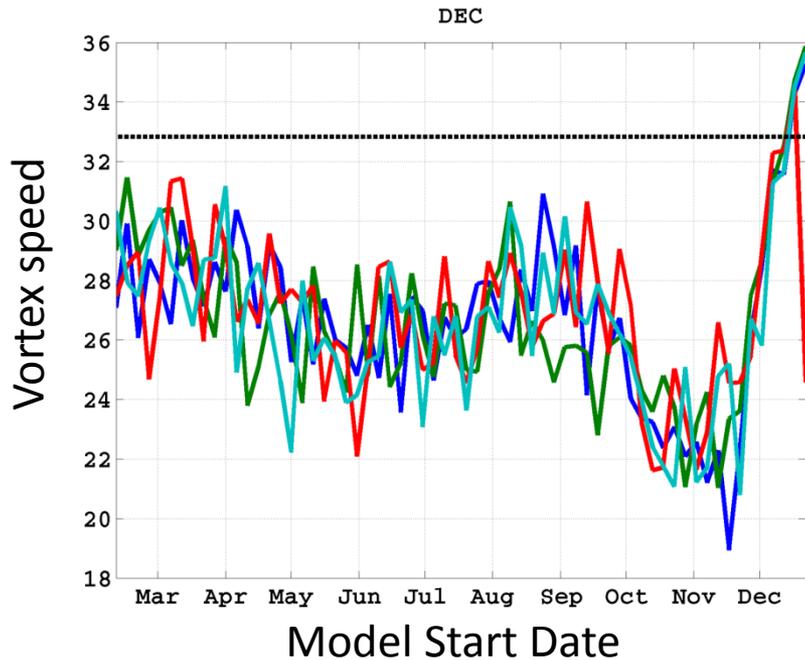
## Forecast DJF mean zonal wind differences.



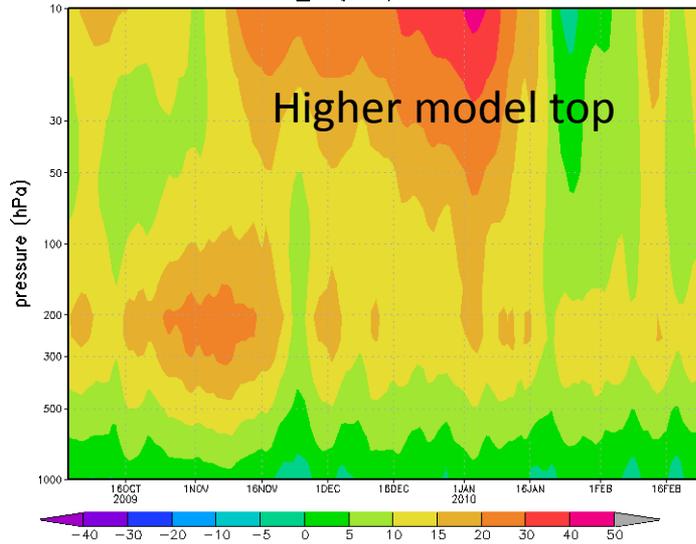
Tropical bias results from lack of simulating the QBO.

**Spin up signal in CFSRR**

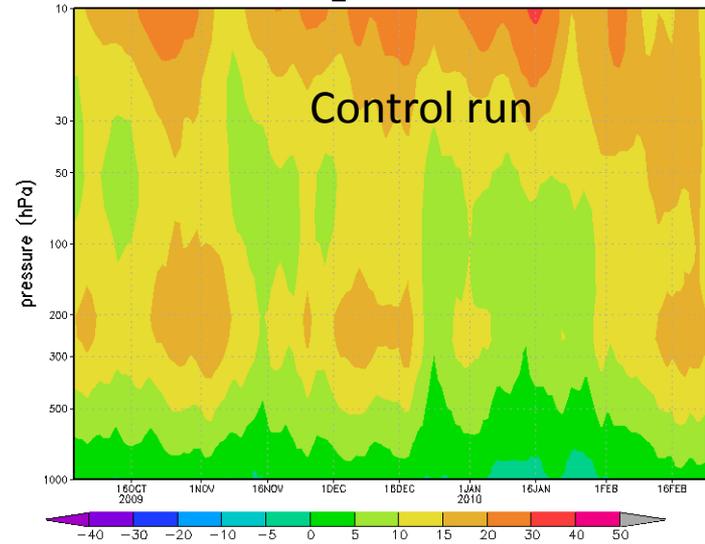
**10hPa 60N  
Zonal Wind at  
different model  
start dates  
(Courtesy of  
Emily Riddle)**



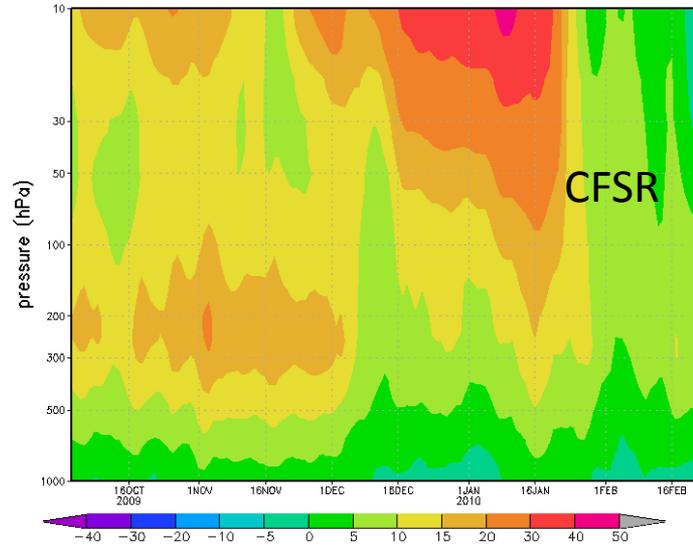
CFS\_v2(L70) 45N-75N



CFS\_v2 45N-75N



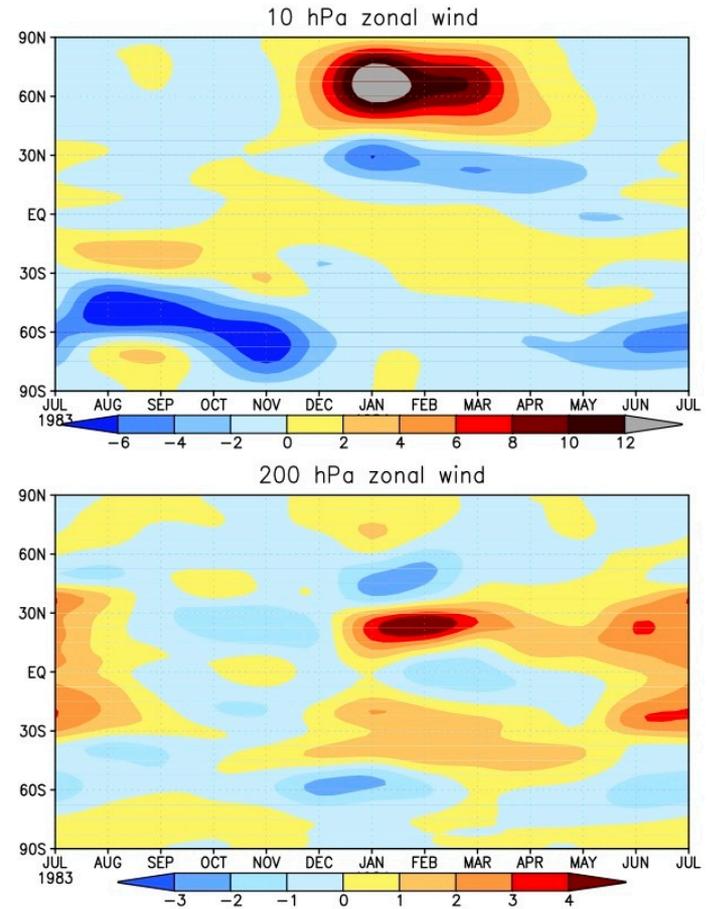
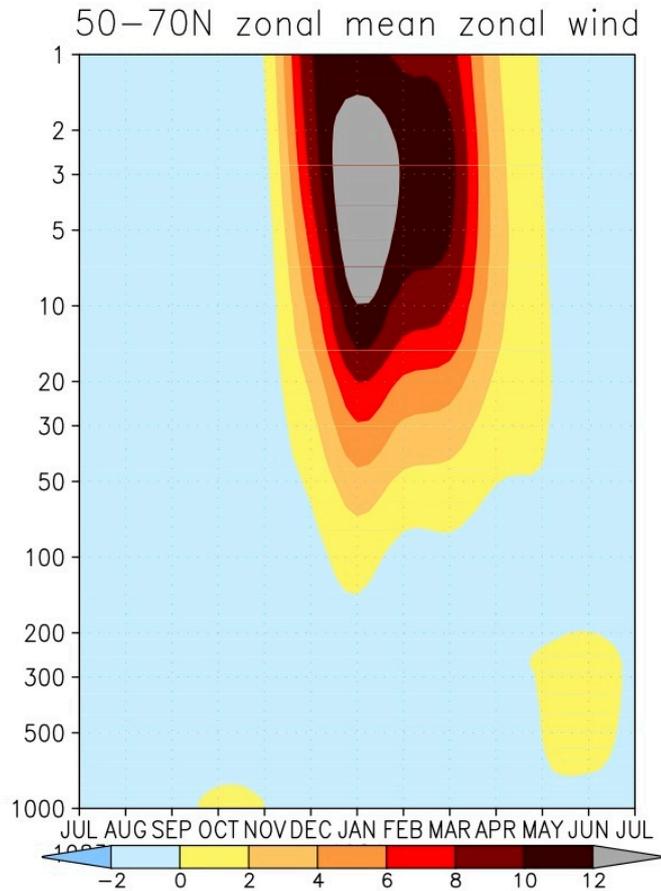
CFSR 45N-75N



Hypothesis: Raising of model top may reduce spin up impact on mid-to lower stratosphere. However to prove this, many more runs with different start dates and for different years have to be carried out.

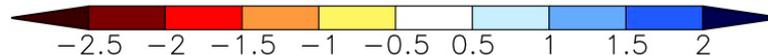
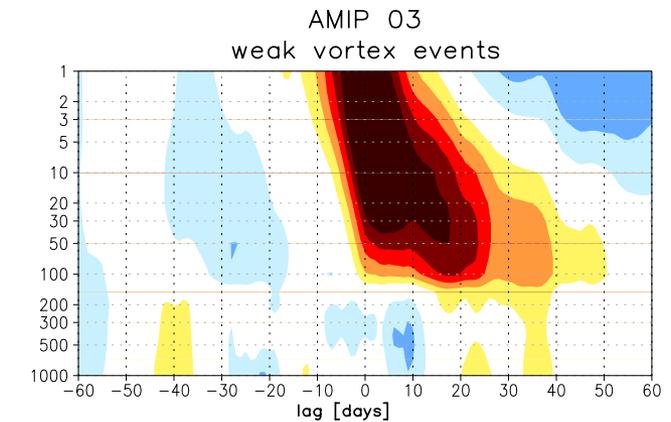
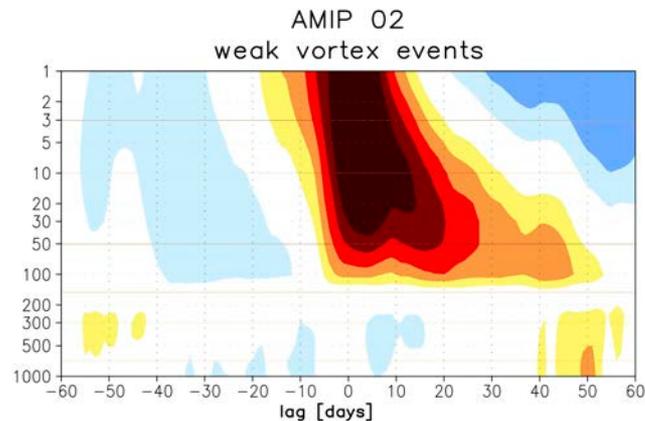
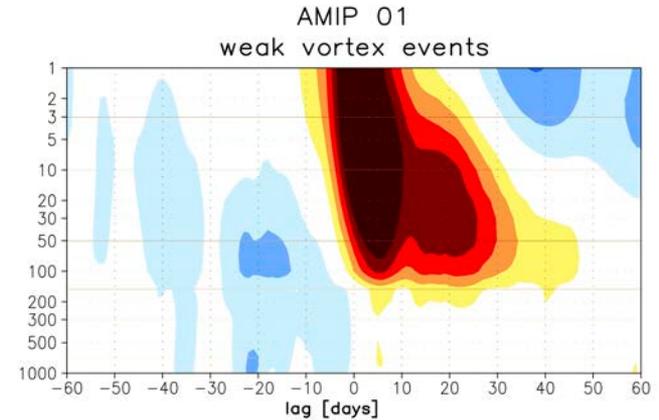
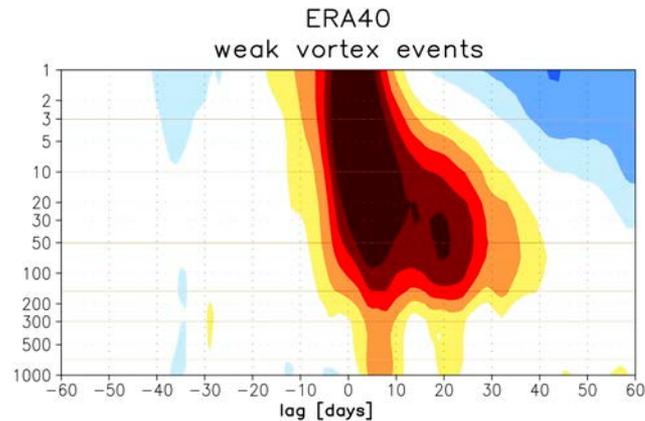
# Spin up effect

## 4mo minus 2mo lead times



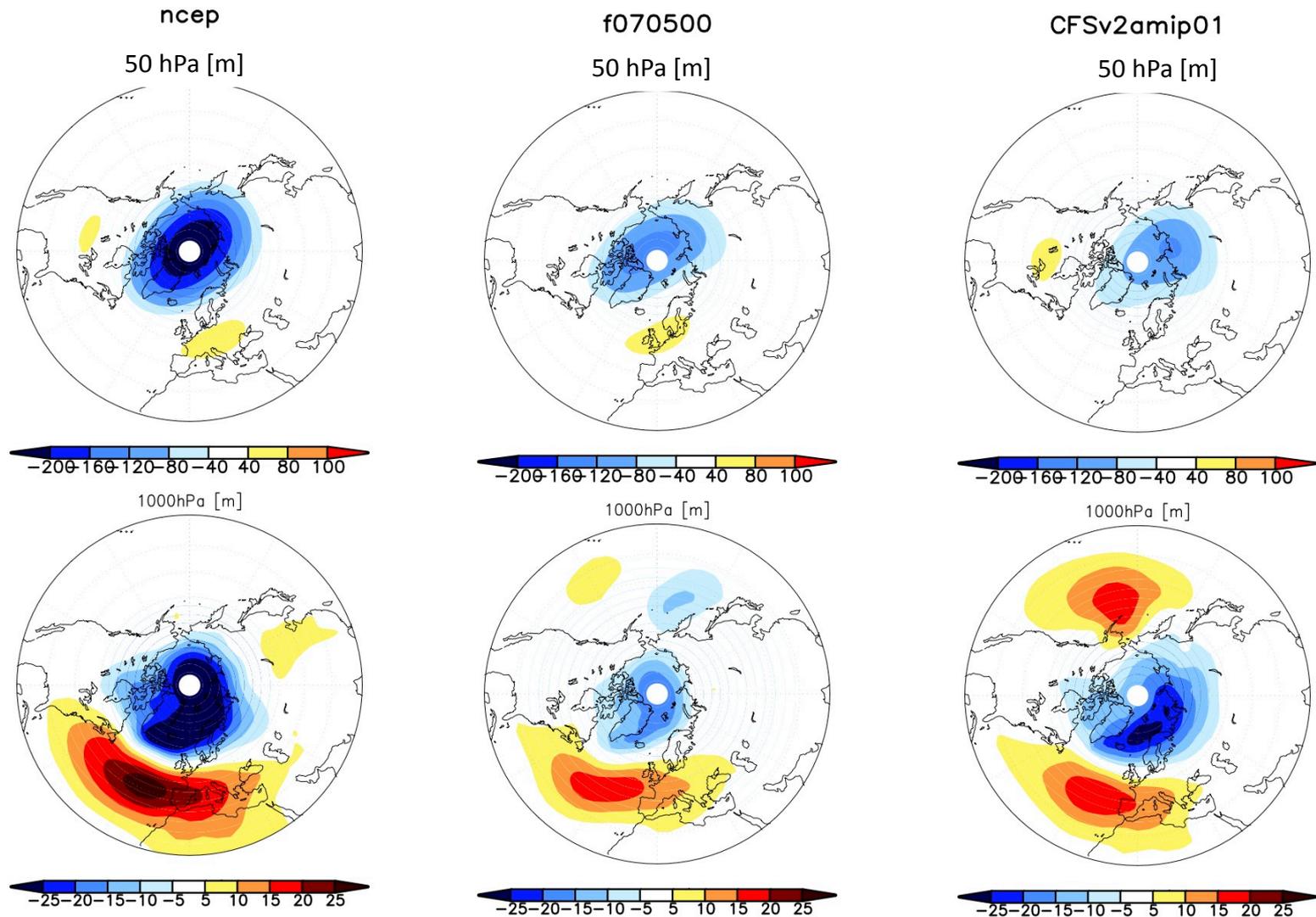
# Stratosphere-troposphere coupling

# Downward Progression of Weak Polar Vortex anomalies (Zonal Mean Component of Annular Mode)



In AMIP simulations, SSW signature does not propagate into the troposphere.  
Such analysis should be repeated based on daily CFSRR output

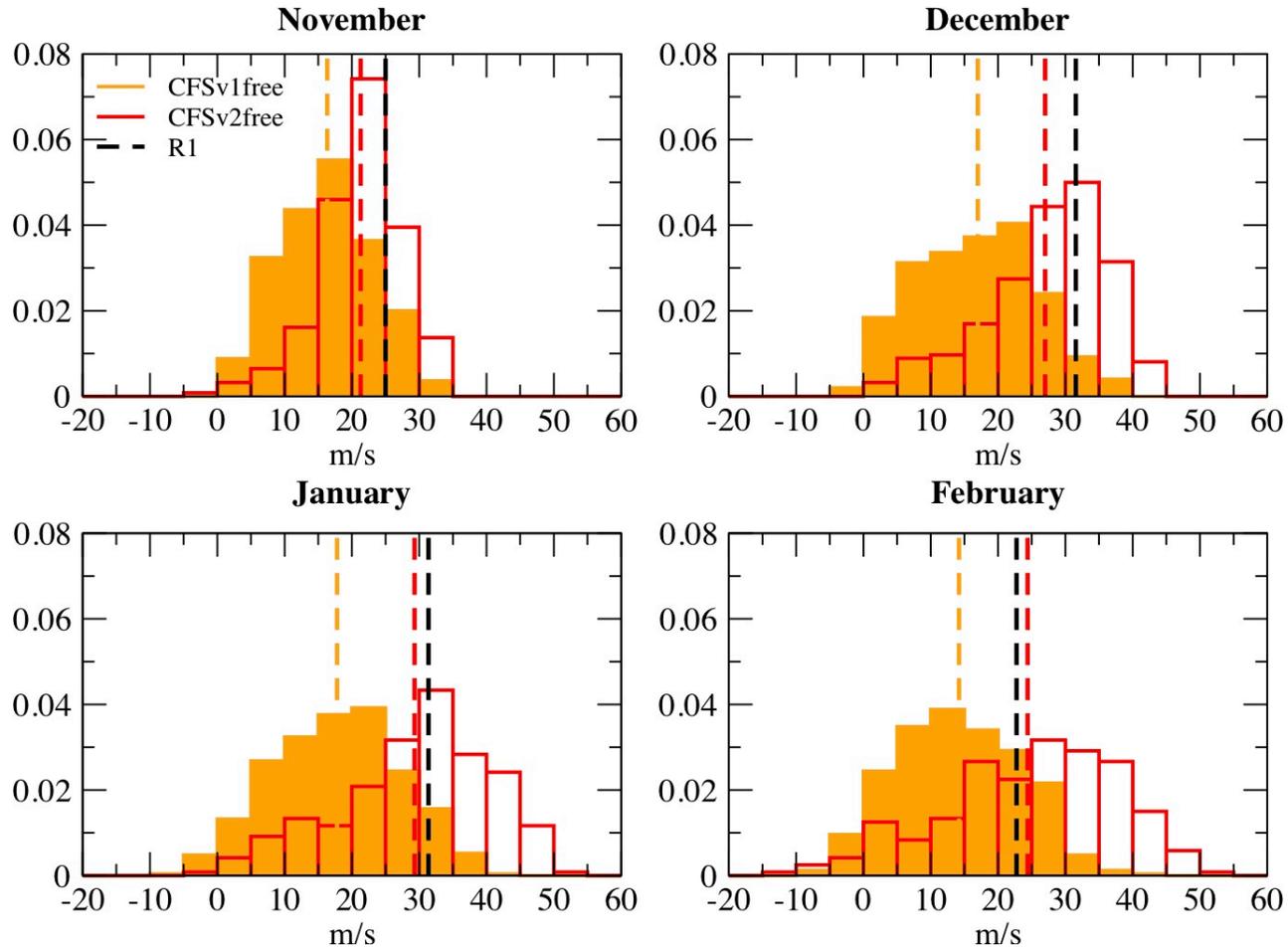
# Coupled Modes of Variability of Geopotential Height Fields



# Polar Night Jet Climatology

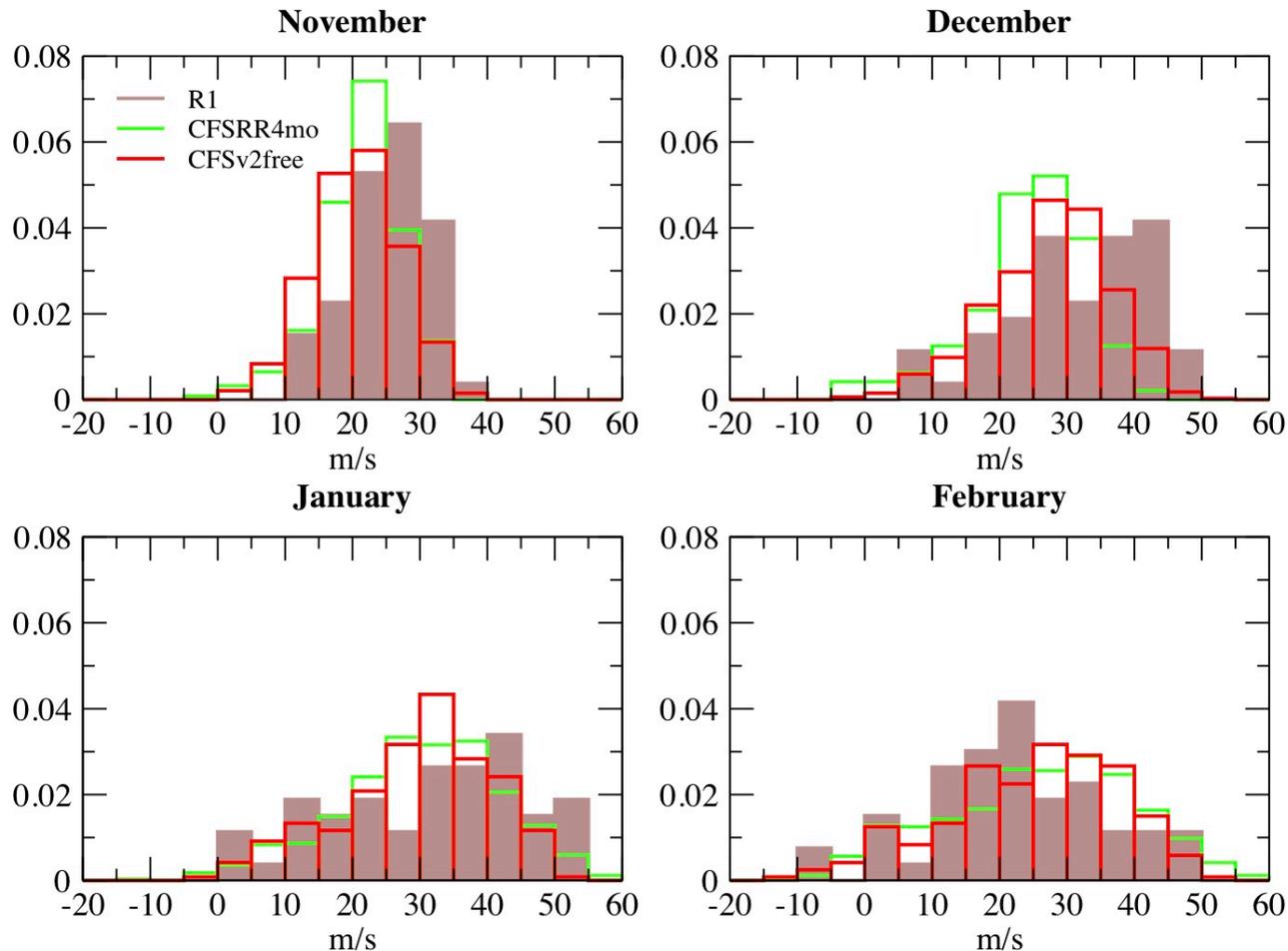
- histogram of 10hPa 60N zonal mean zonal wind

# Comparison between CFSv1 and v2



CFSv1 and CFSv2 have very different polar night jet climatologies

# Comparison between R1, CFSRR and CFSv2



Variability range during D, J, F is similar between CFSv2 and reanalysis

# Next Steps

- Continue model development
  - More test runs with 70 layer model
  - Develop 91 layer version
  - Include stratospheric gravity wave drag parameterization
- Test the impact of model development on tropospheric seasonal forecast

# Next Steps cont.

## Challenges:

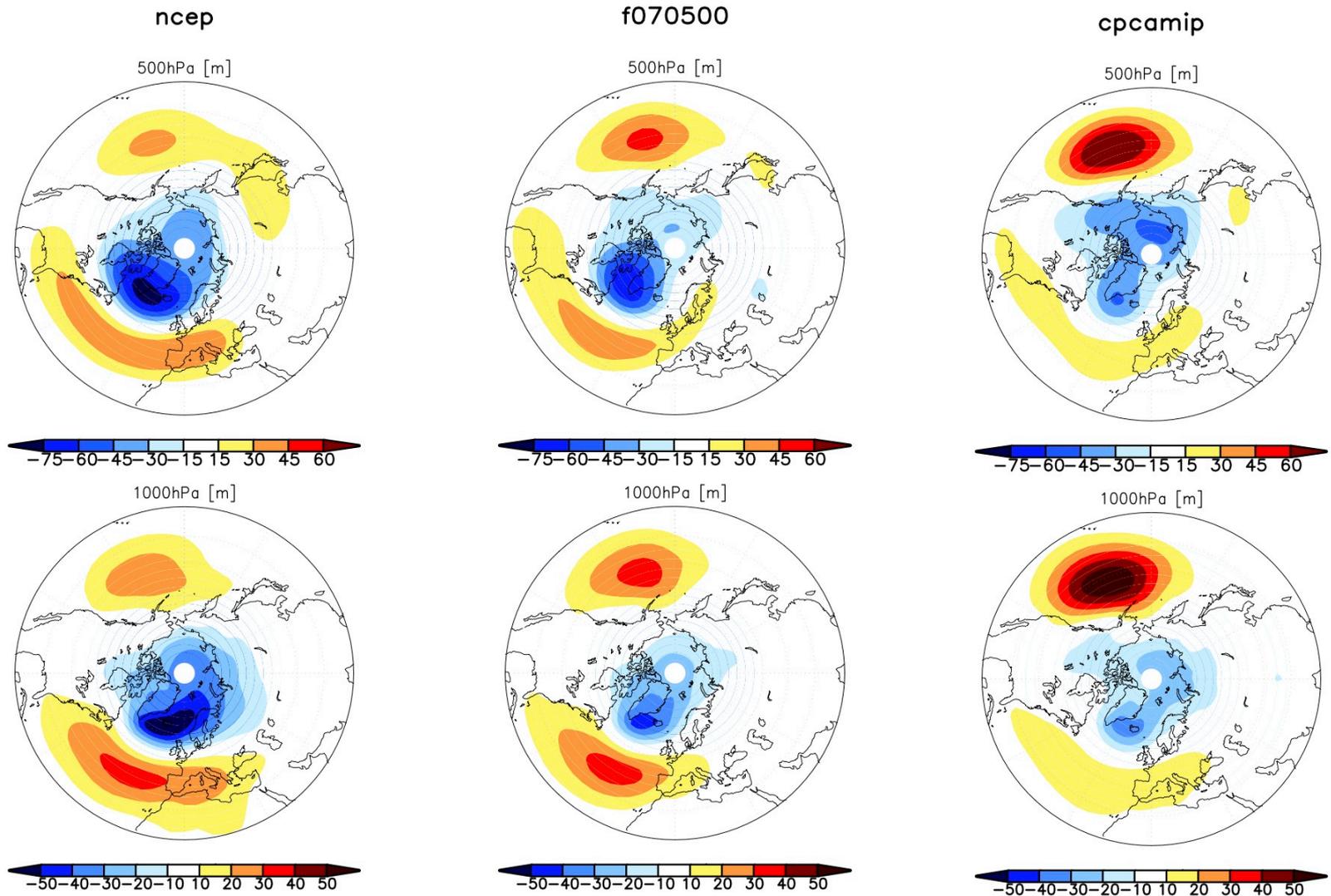
- Model development is difficult because of very limited computing resources. Short runs are quasi impossible because of spin-up problem.
- Analysis of strat-trop. coupling in CFSRR not possible because daily output is not available.

## Vision for follow up project:

- QBO -> improve stratospheric representation so that the CFS can generate QBO

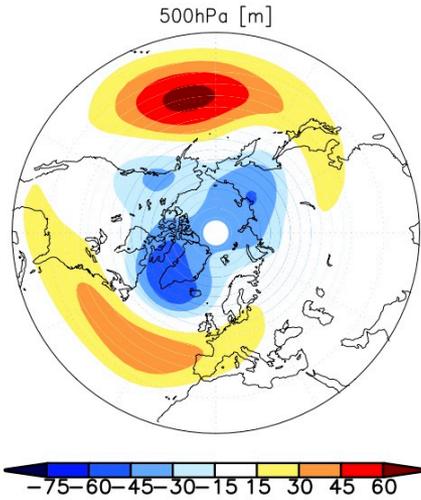
# Backup slides

# Coupled modes of 500 and 1000hPa heights for Dec to MAR months

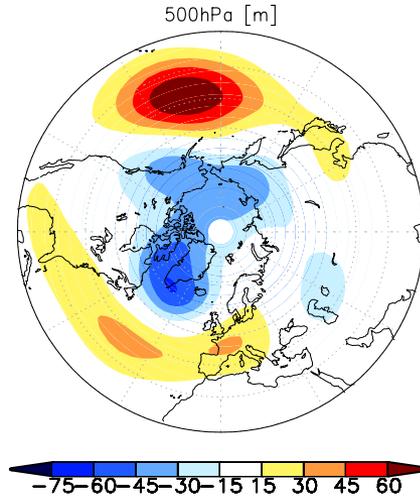


# Coupled modes of 500 and 1000hPa heights for Dec to Mar months

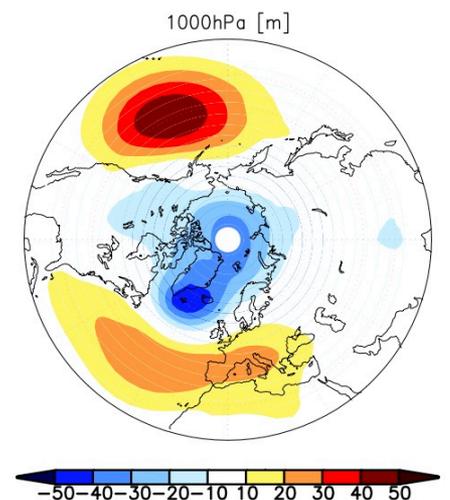
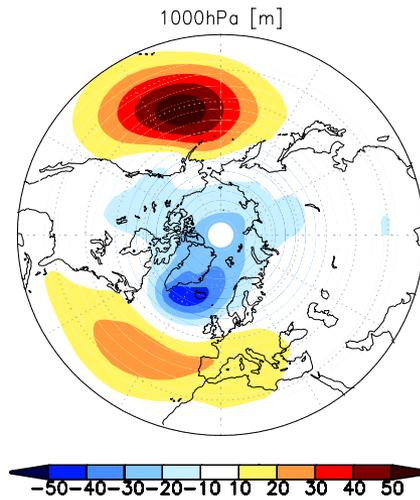
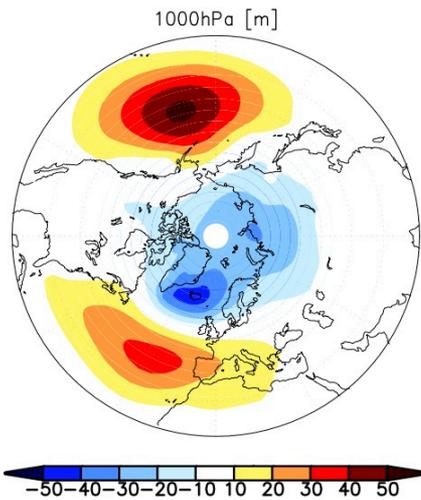
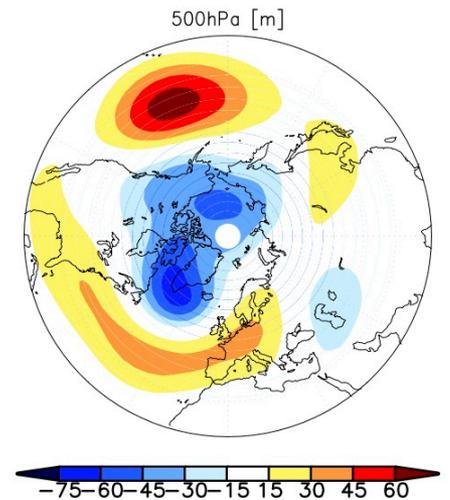
CFSv2amip01



CFSv2amip02

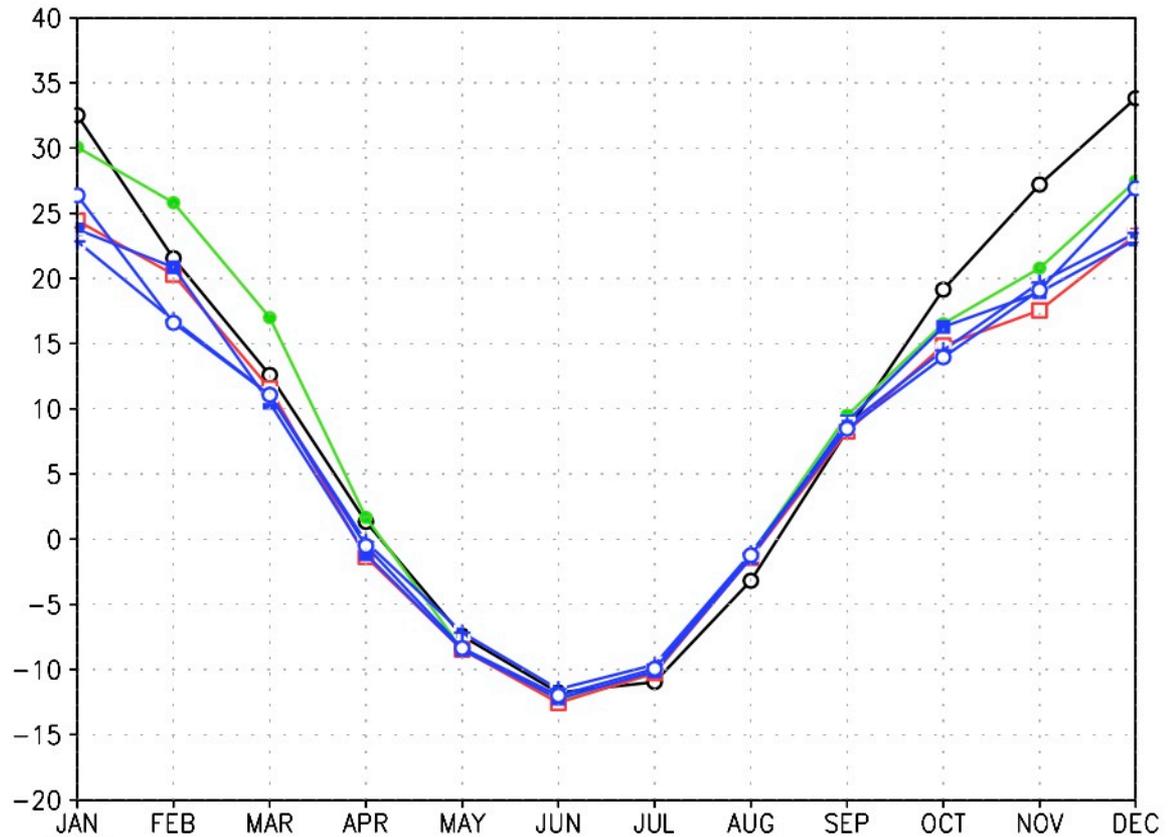


CFSv2amip03

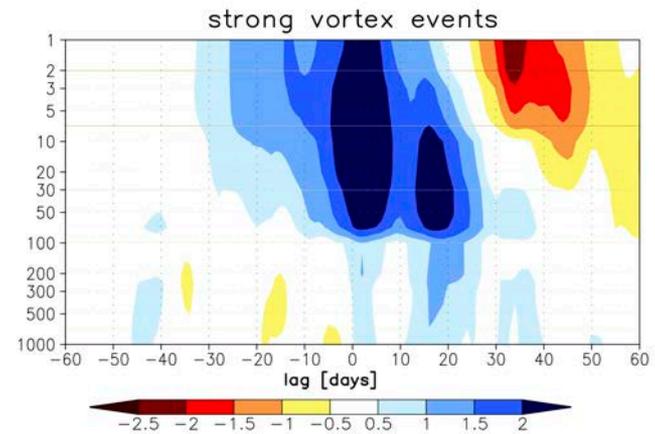
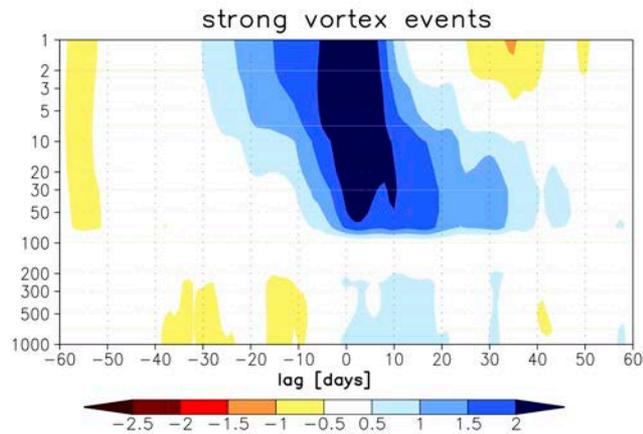
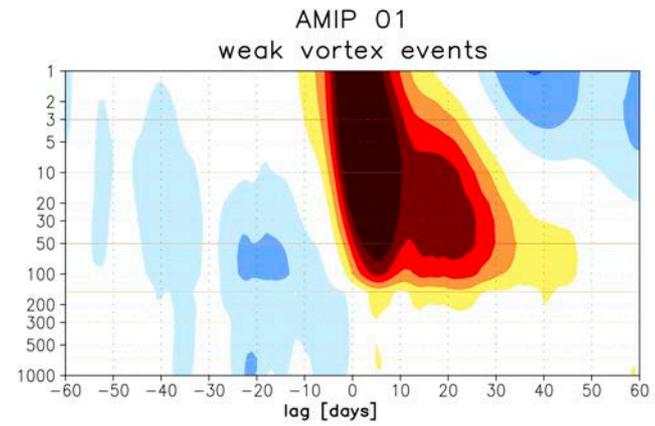
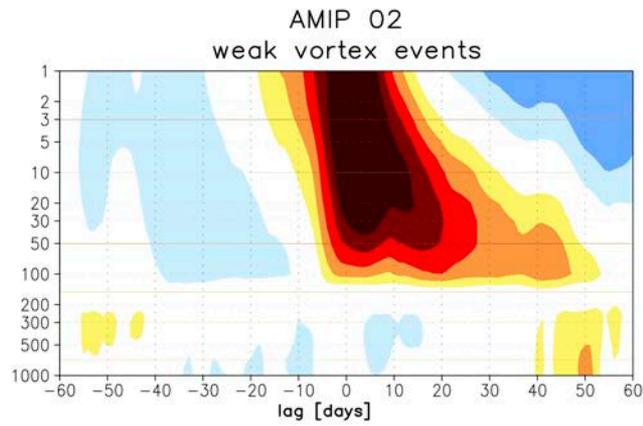


# Seasonal Cycle of 10 hPa 60N zonal wind

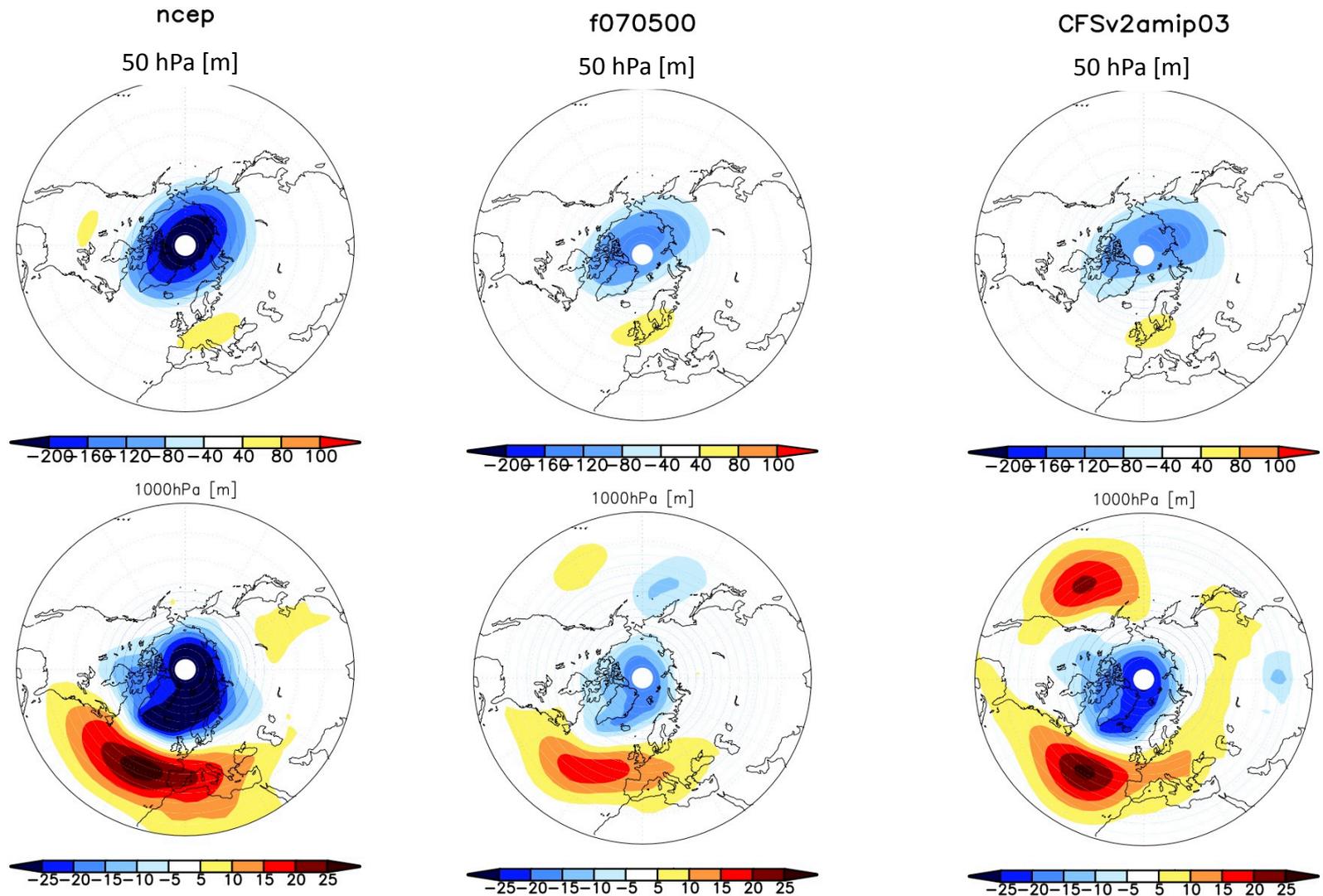
CFSR  
CFSRR4molead  
CPCamip01  
PSDamip01  
PSDamip02  
PSDamip03



# Downward Progression of Annular Mode Signature

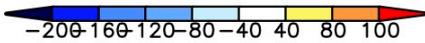
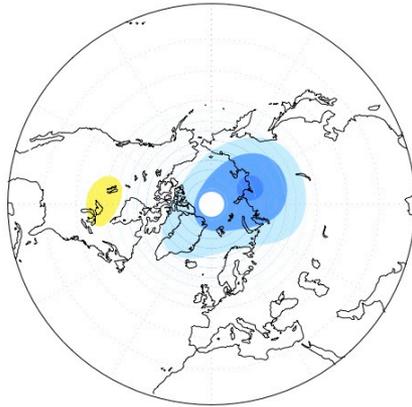


# Coupled modes of 50 and 1000hPa heights for Dec to Mar months

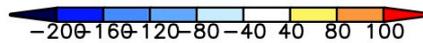
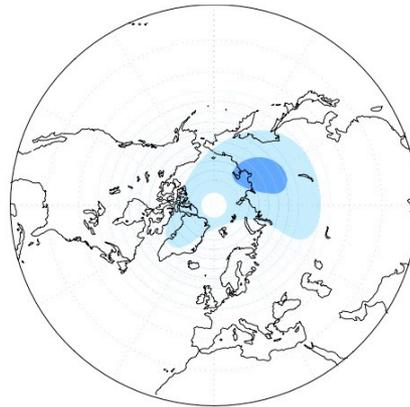


# Coupled modes of 50 and 1000hPa heights for Dec to Mar months

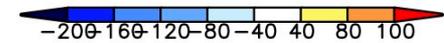
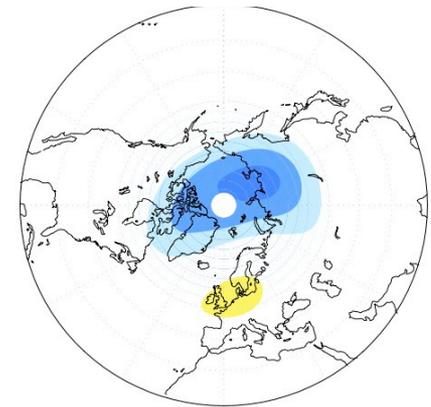
CFSv2amip01  
50 hPa [m]



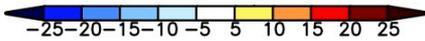
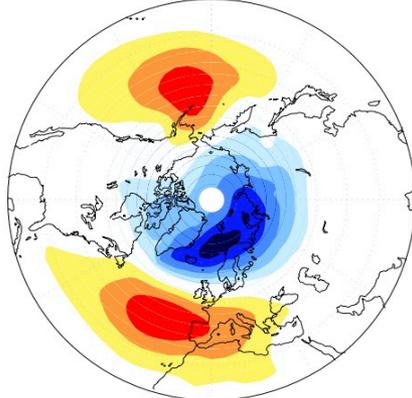
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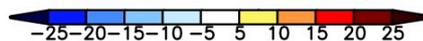
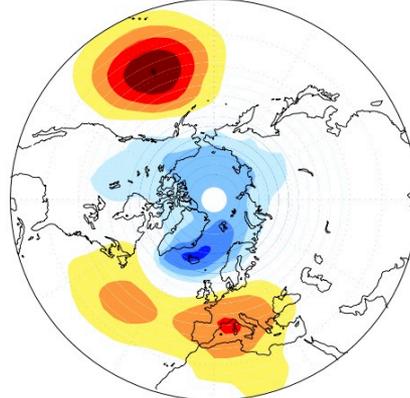
CFSv2amip03  
50 hPa [m]



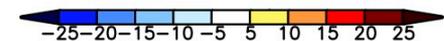
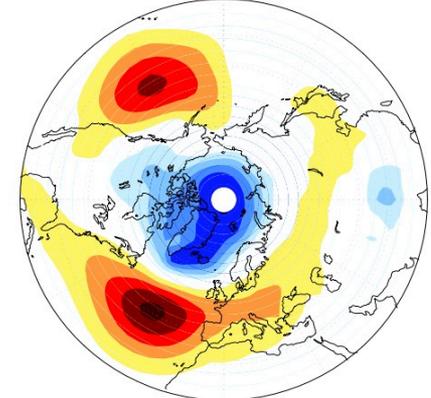
1000hPa [m]

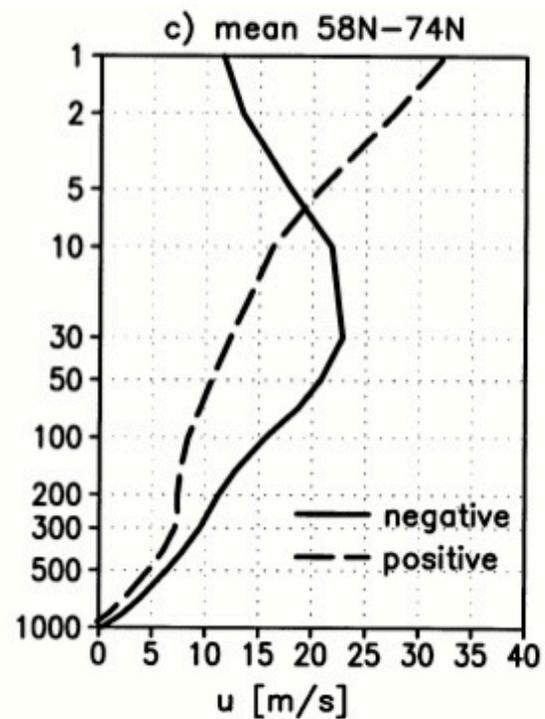
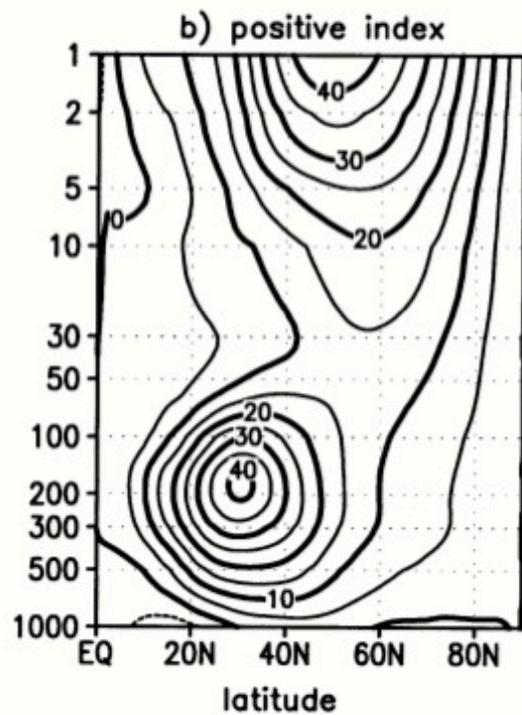
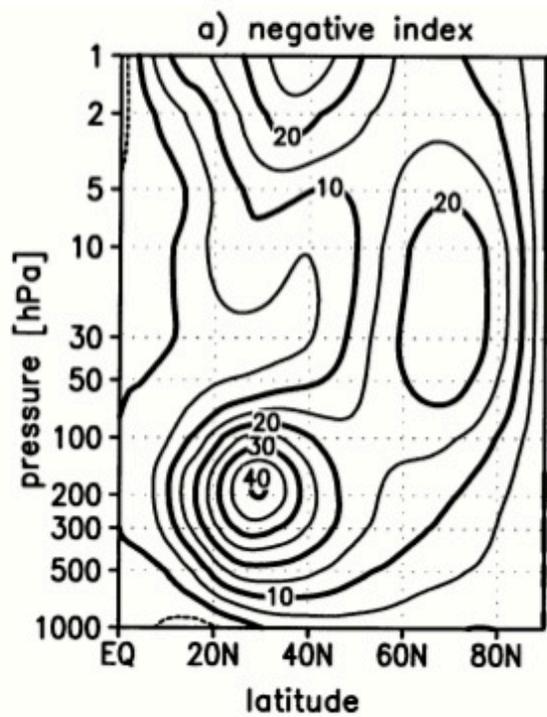


1000hPa [m]



1000hPa [m]

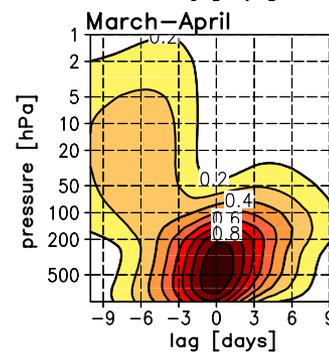
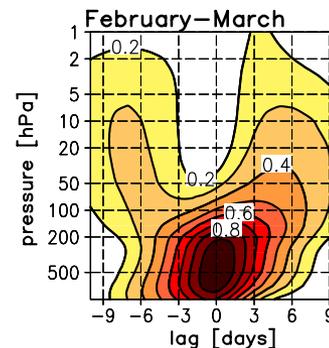
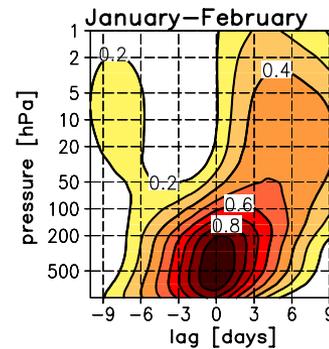
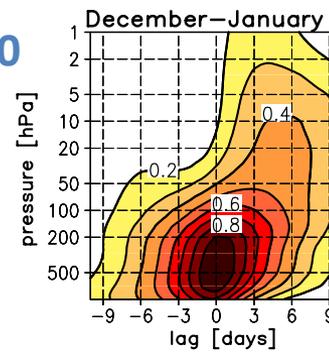




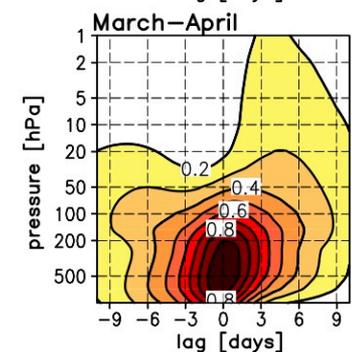
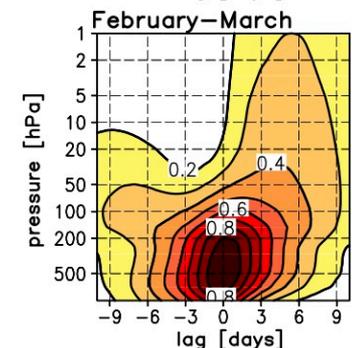
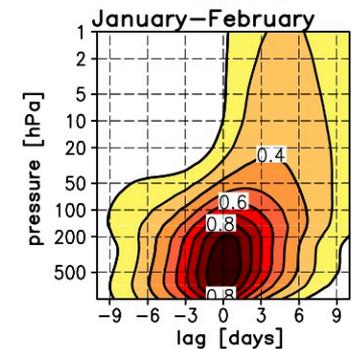
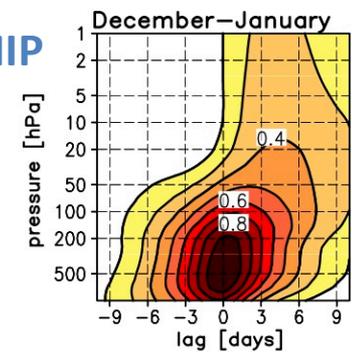
# Wave One Propagation in Northern Hemisphere

- In model, upward propagation of wave activity is more disperse, especially in Feb-Mar
- Model does not capture downward wave coupling, most likely due to lack of formation of reflective configuration of stratospheric basic state
- In Mar-April, model shows very different propagation characteristics for planetary wave 1 than reanalysis

ERA40



AMIP



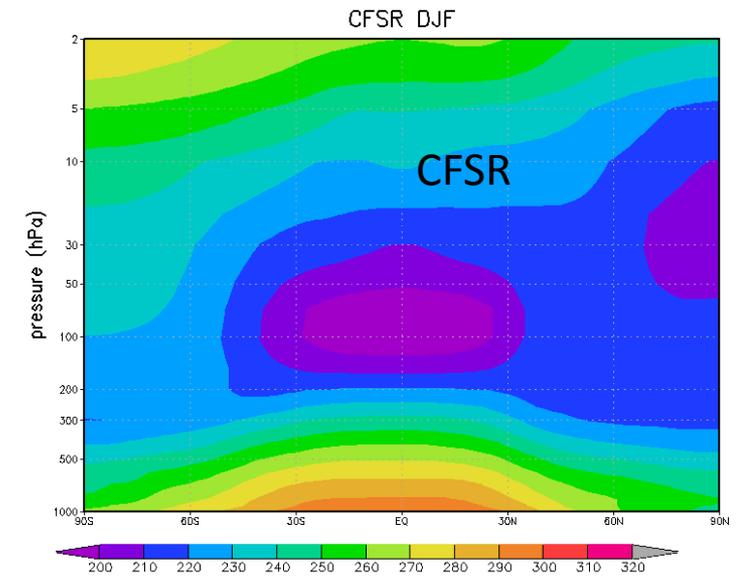
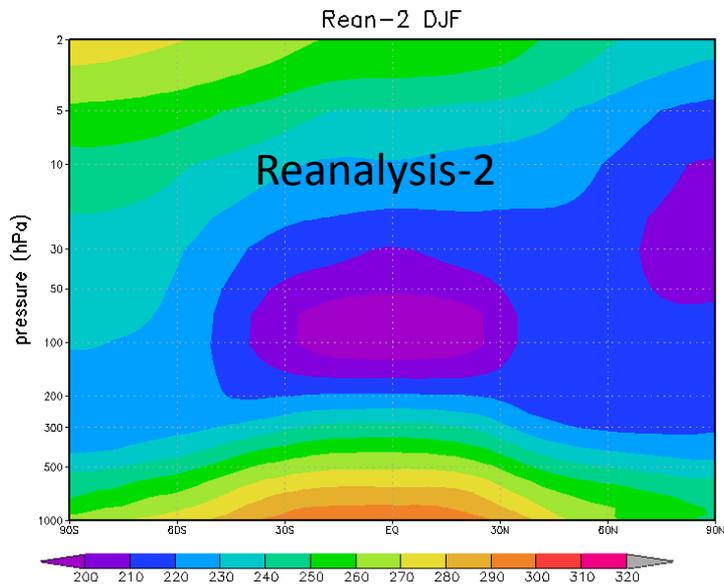
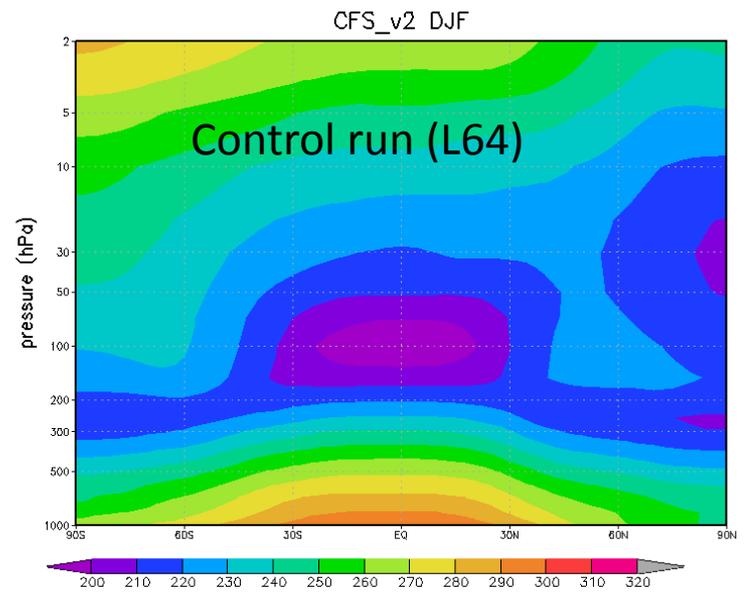
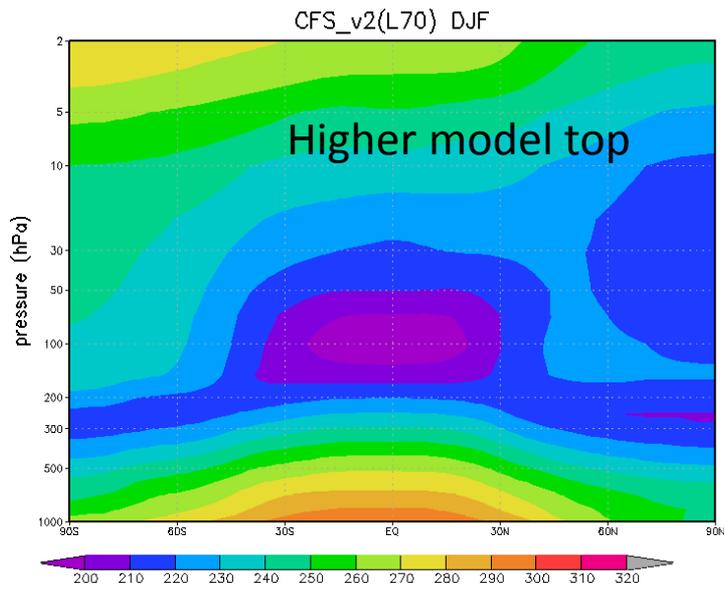


Fig.3 Comparison of forecast DJF mean temperature.

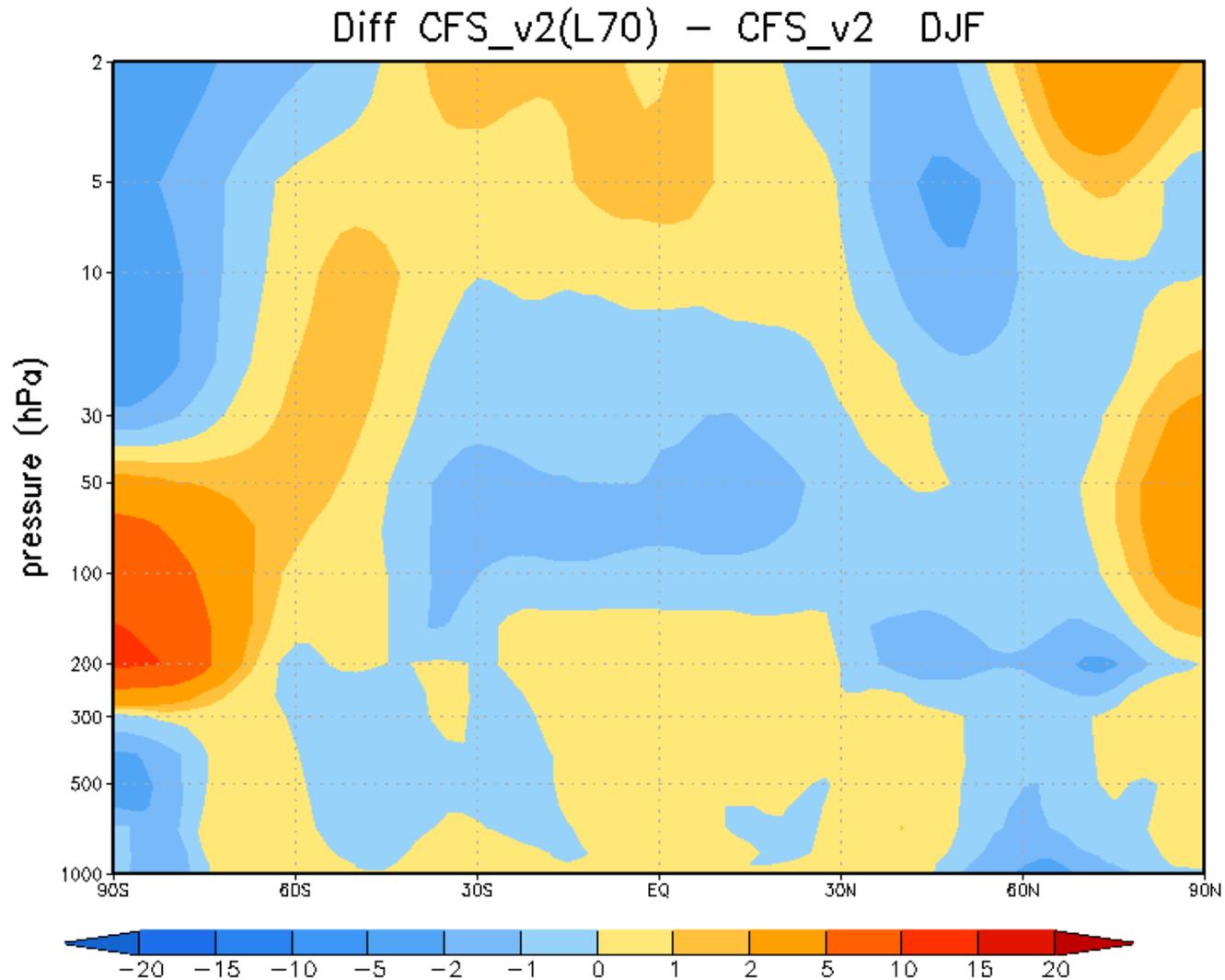
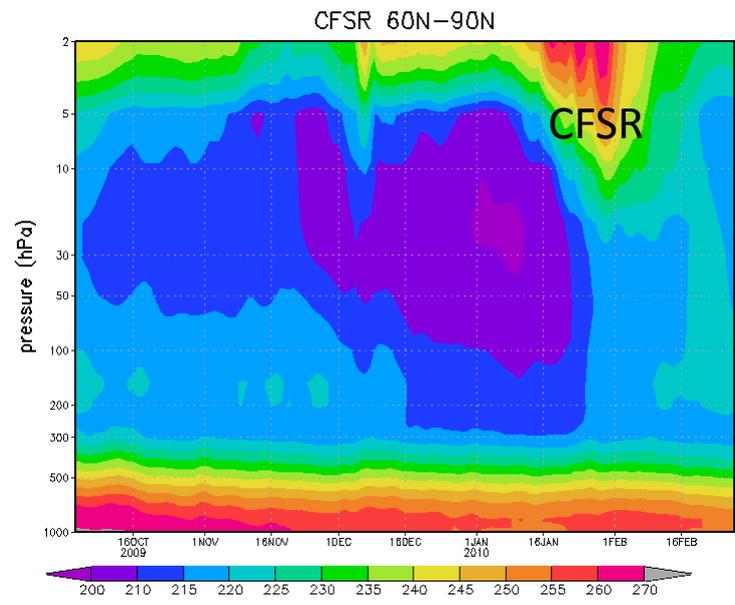
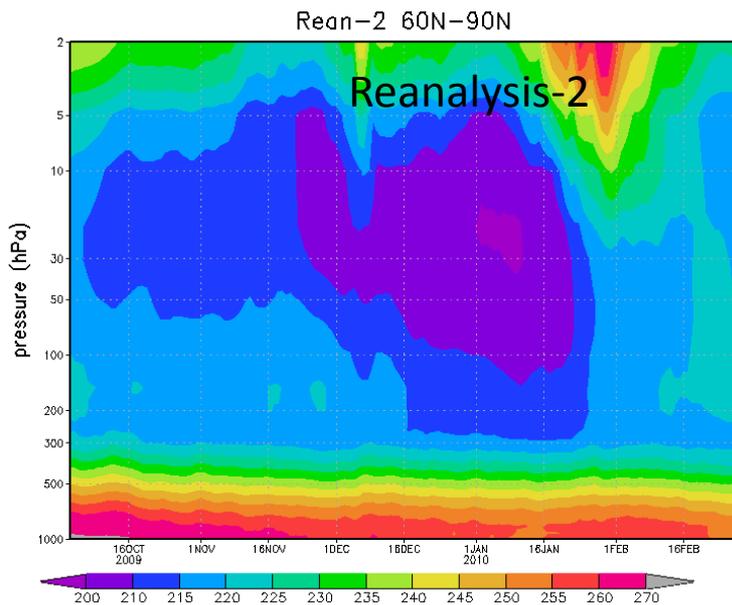
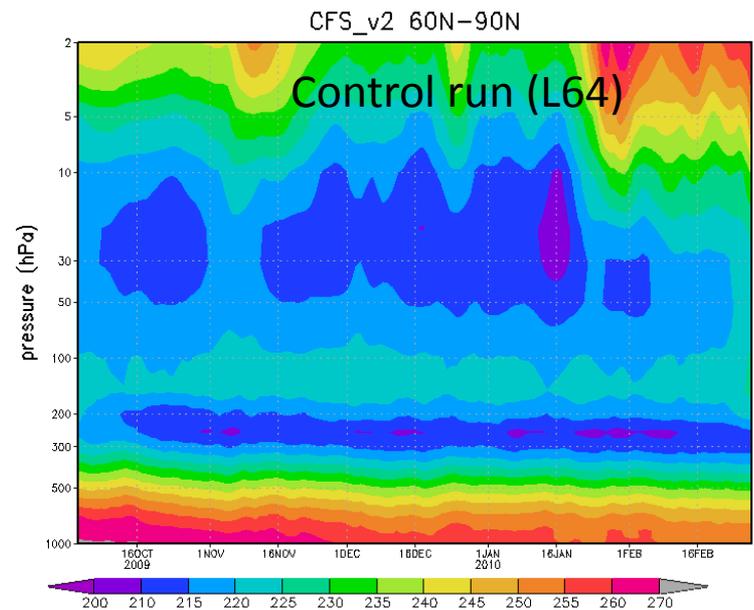
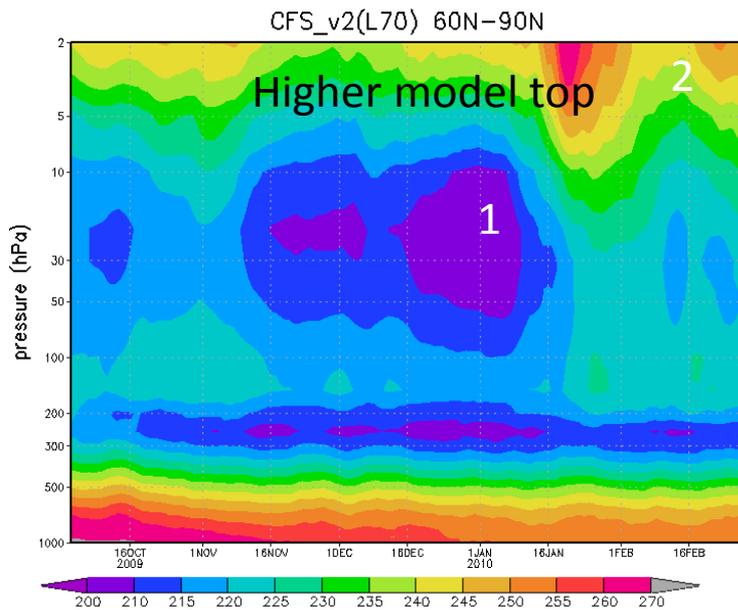
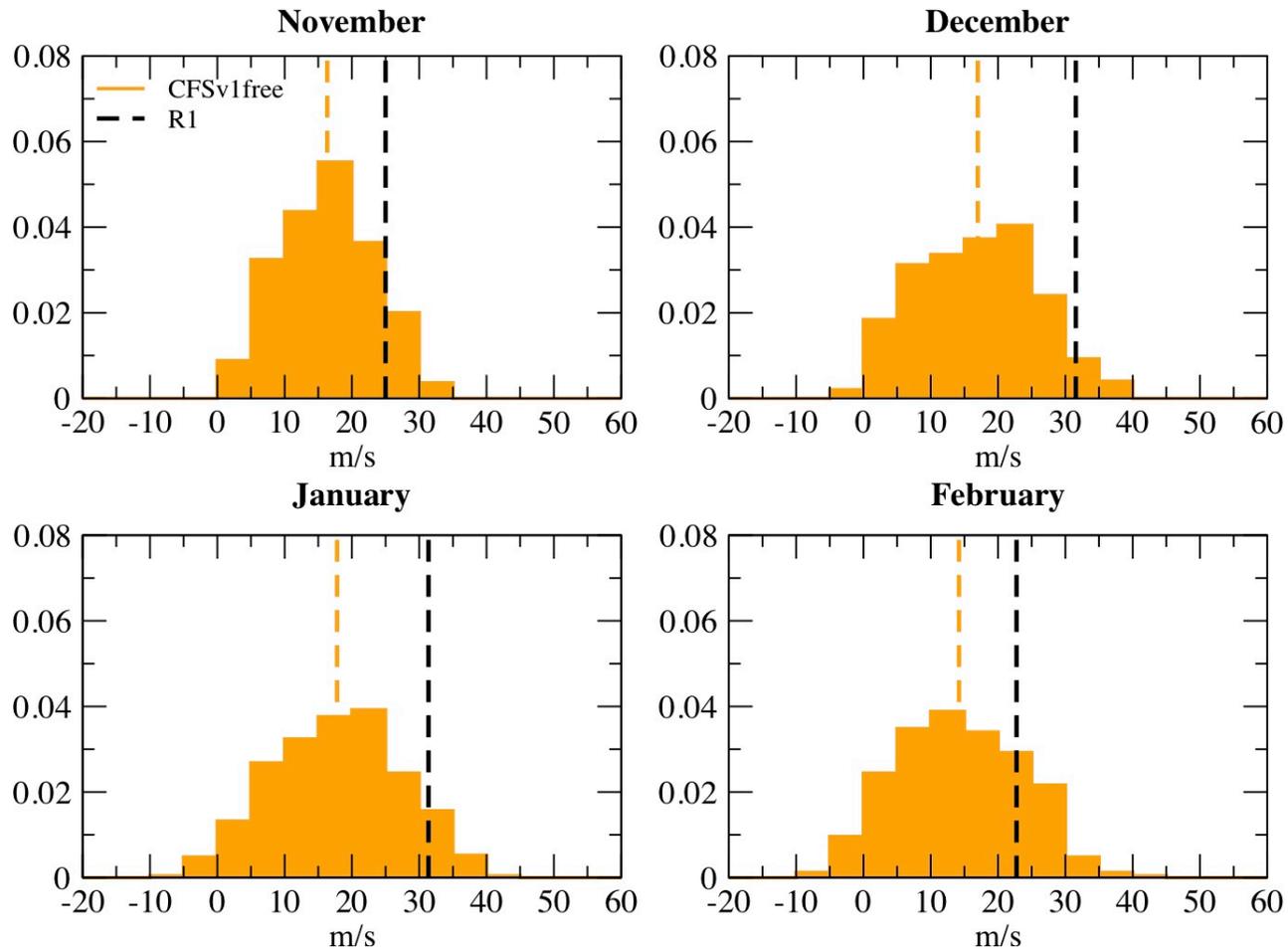


Fig. 5 Forecast DJF mean temperature difference between the L70 model and the L64 model.



Comparison of NH polar temperature evolution (Oct.2009-Feb.2010). Note that the L70 model performs better than the L64 model (control run), and R-2 is very similar to CFSR.

# CFSv1

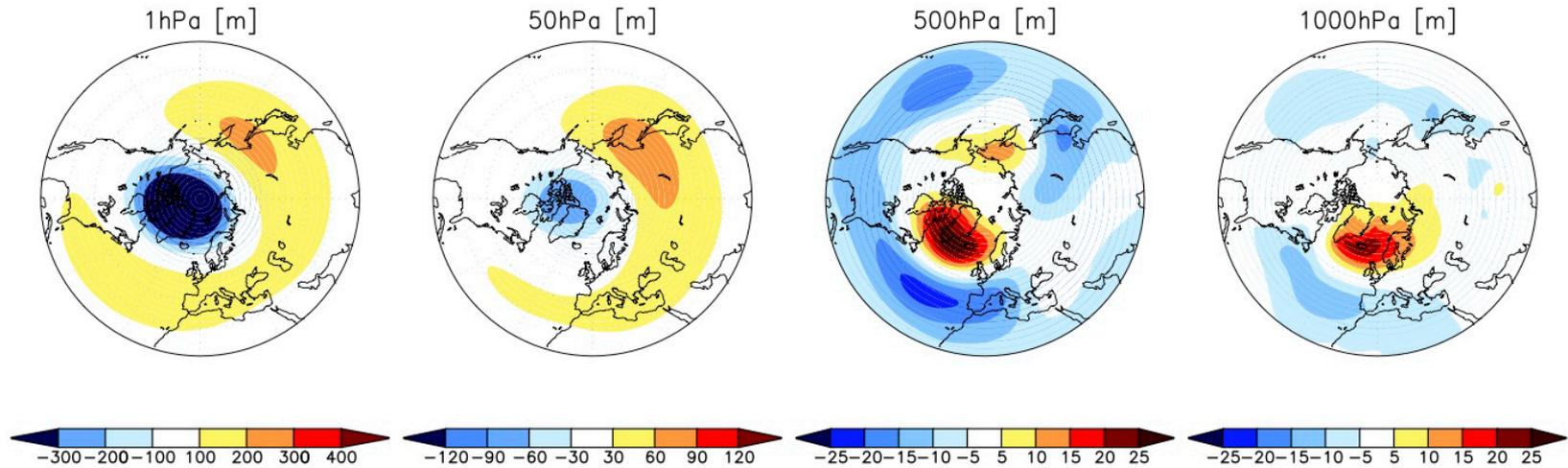


Stratospheric polar night jet in winter is too weak compared to reanalysis

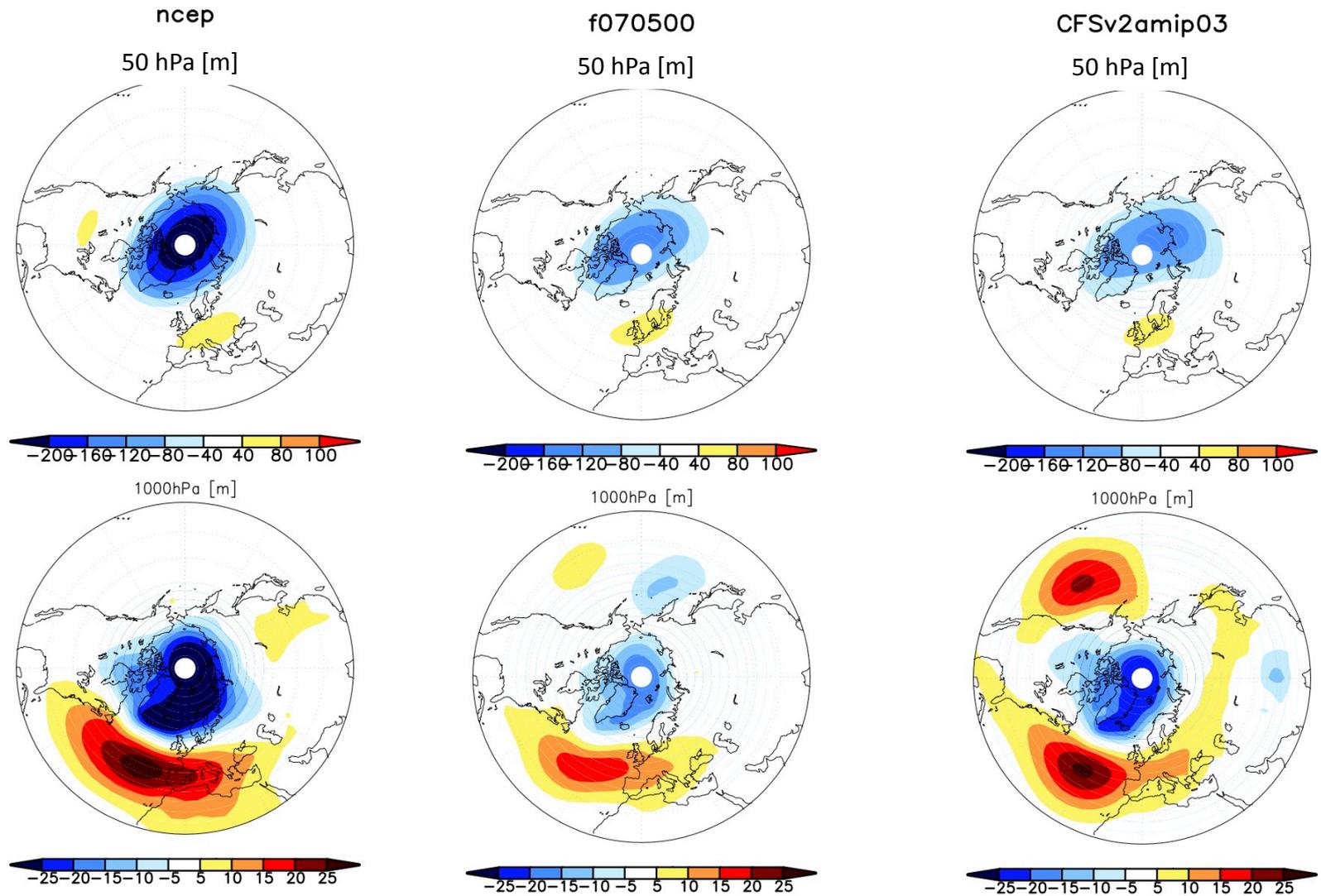
# Spin up effect

## 4mo minus 2mo lead time

### DJF mean



# Coupled Modes of Variability of Geopotential Height Fields



# Results with raised model top

- To test effects of higher model top
- 6 more layers (.34,.21,.19,.07,.04,.02 hPa)  
added to the top of the 64-layer model (.64 hPa)
- Starting from 2009100300
- 5 month forecast