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

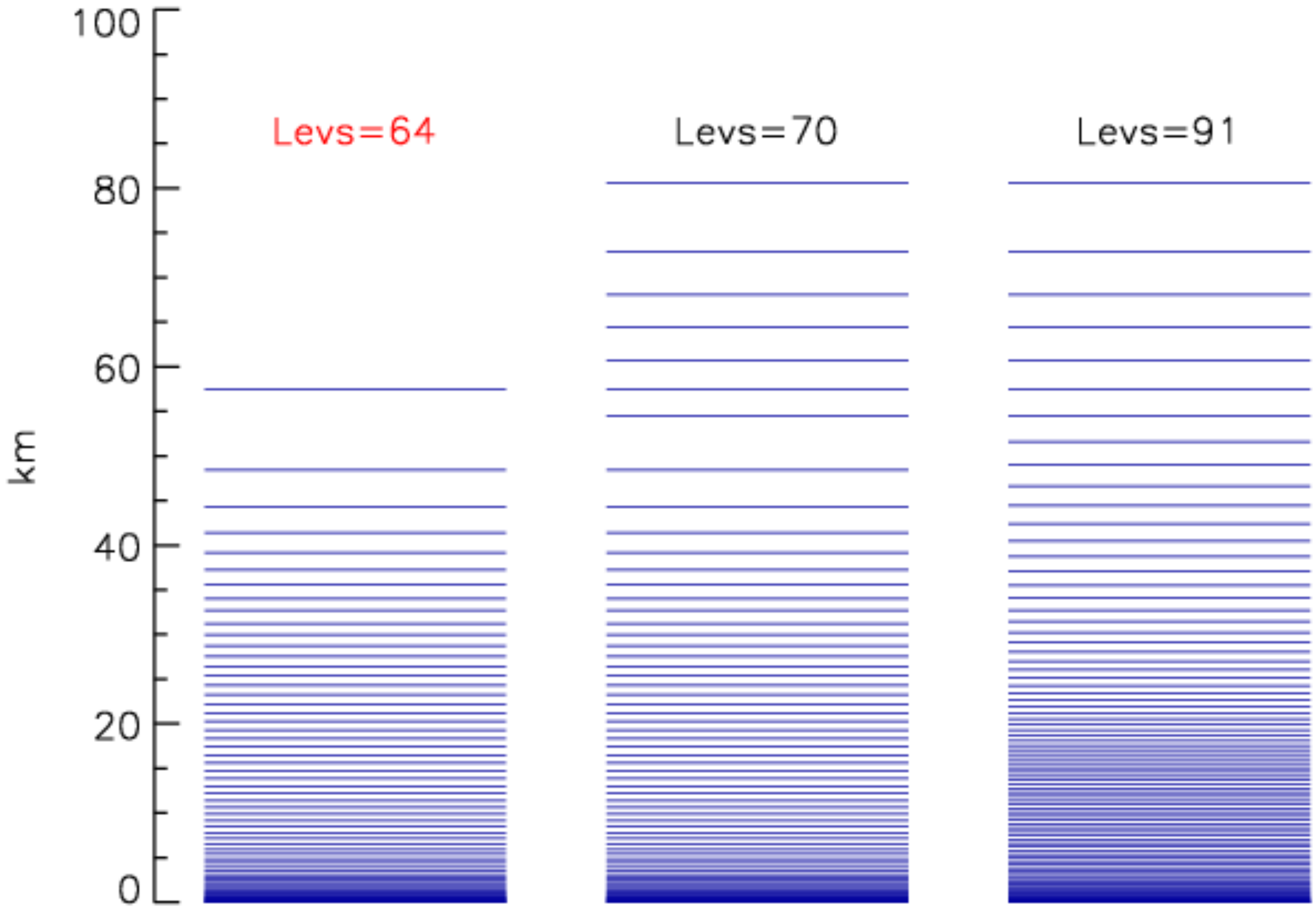
Tasks carried out in Years 1 and 2:

- 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_{CFSv2} 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

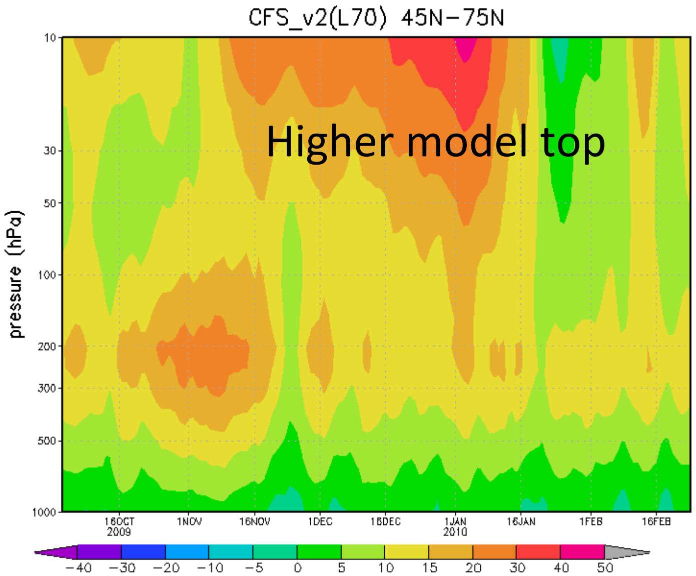
Results with raised model top

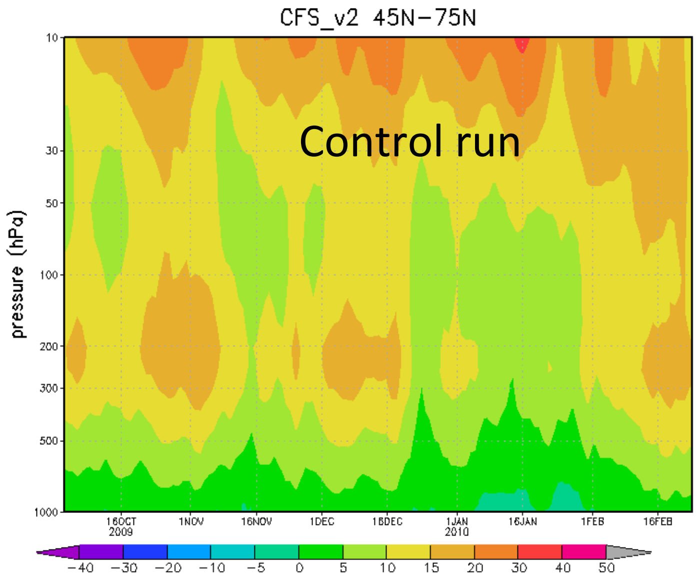


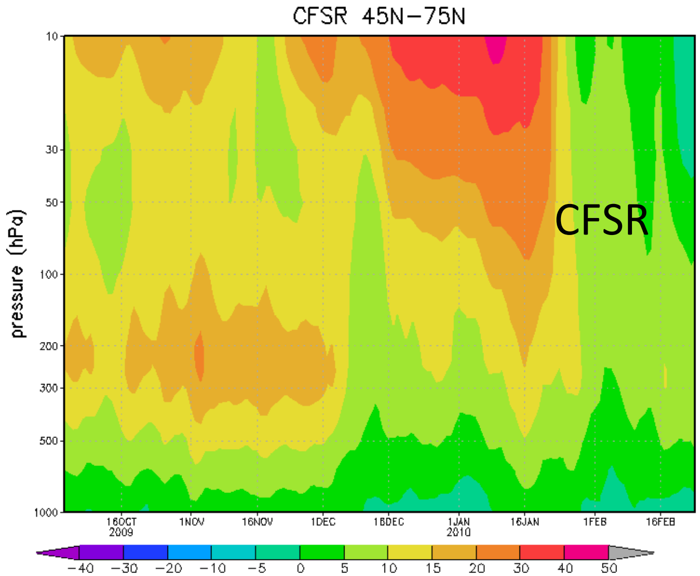
Vertical layers of CFSv2 models. The 70-layer model's bottom 64 layers are the same as the 64-layer model, and the top 6 layers are the same as the 91-layer model.

- 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)

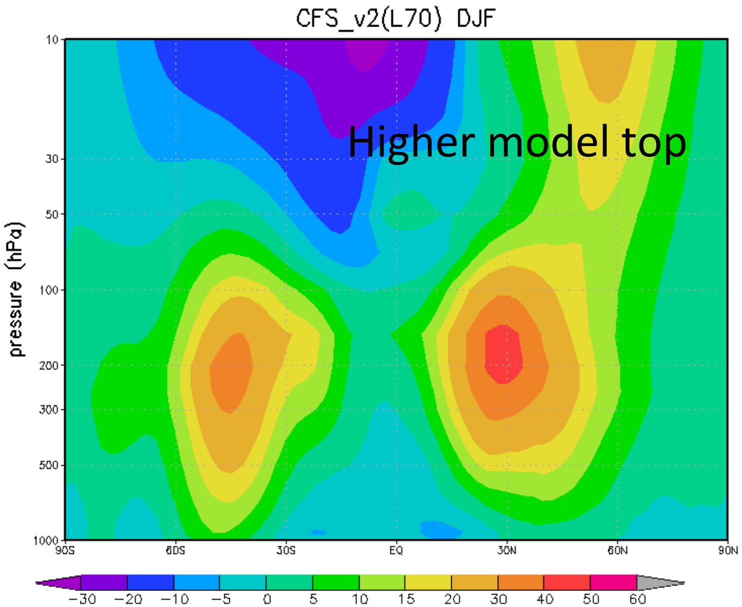


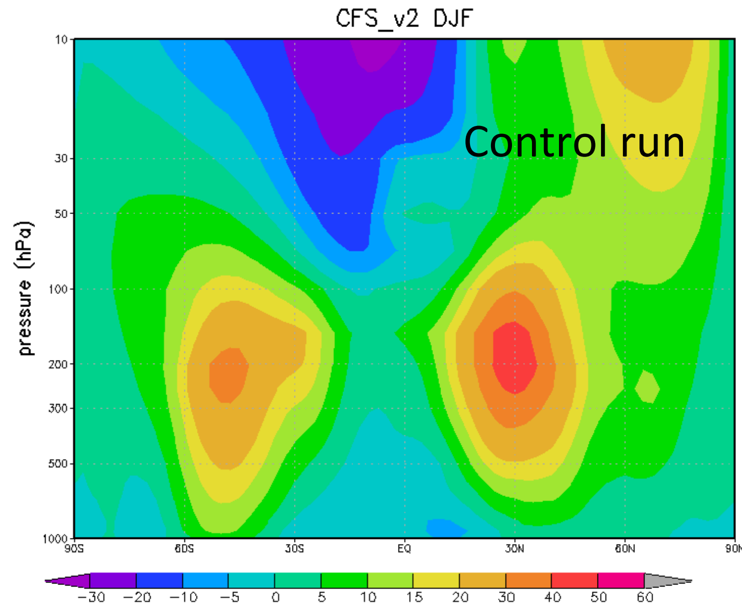


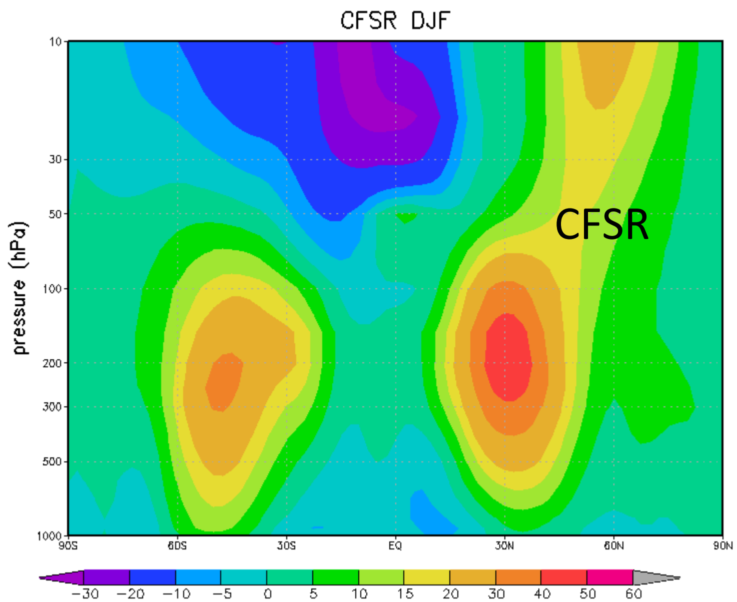


The L70 model seems to performs better than the L64 model (control run).

Comparison of forecast DJF mean zonal wind

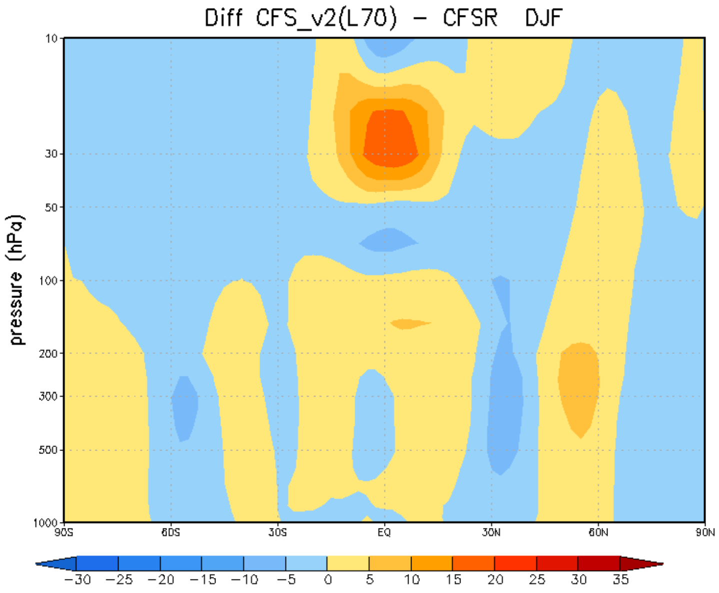


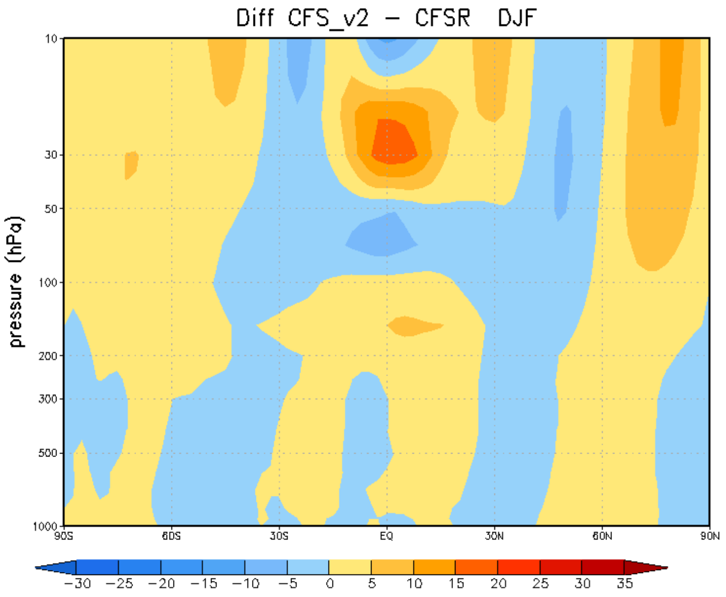




The jet position in the L70 model is more similar to the reanalysis than the L64 model.

Forecast DJF mean zonal wind differences.



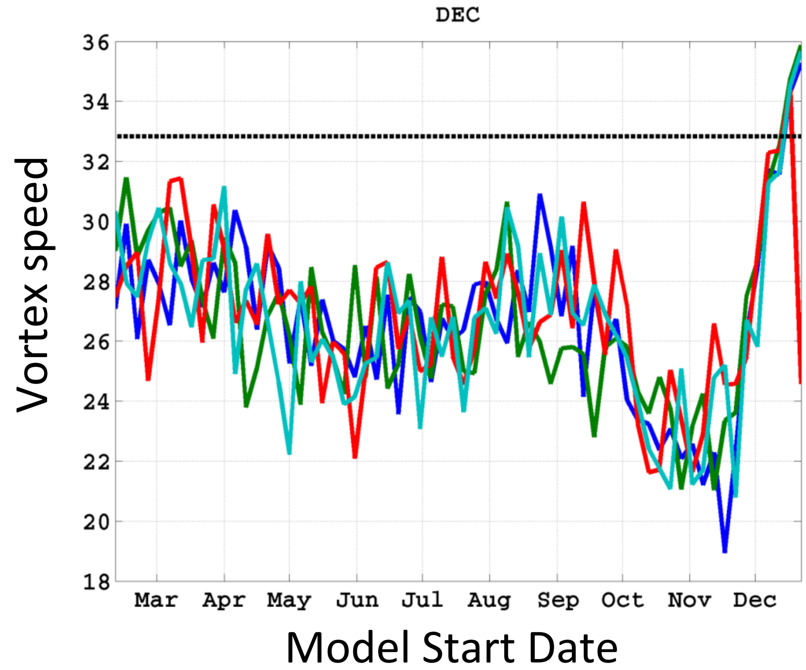


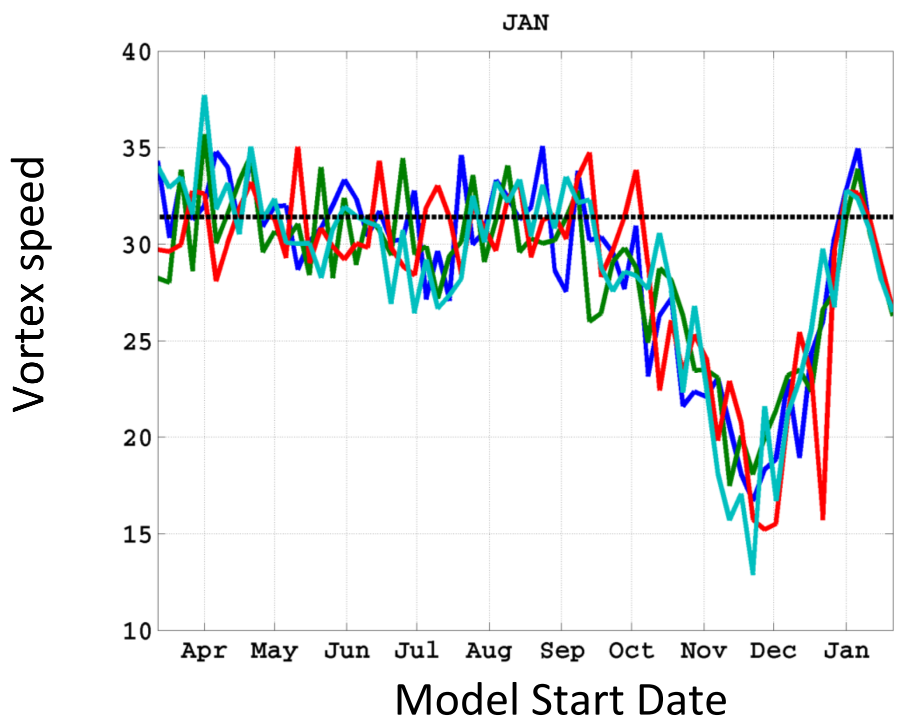
Tropical bias results from lack of simulating the QBO.

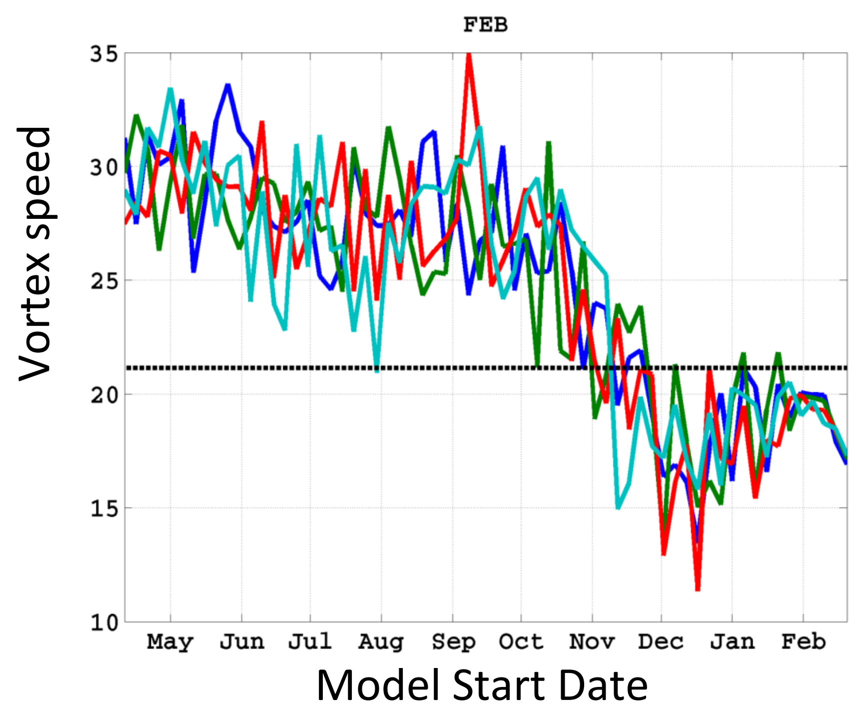
Spin up signal in CFSRR

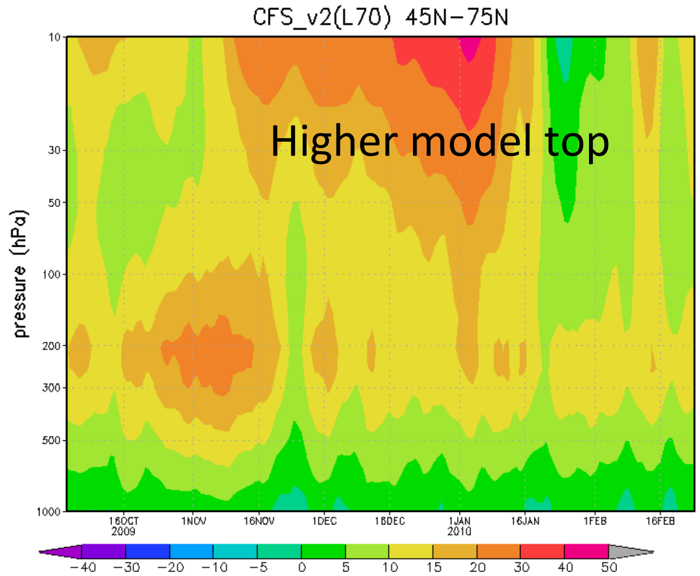
10hPa 60N Zonal Wind at different model start dates

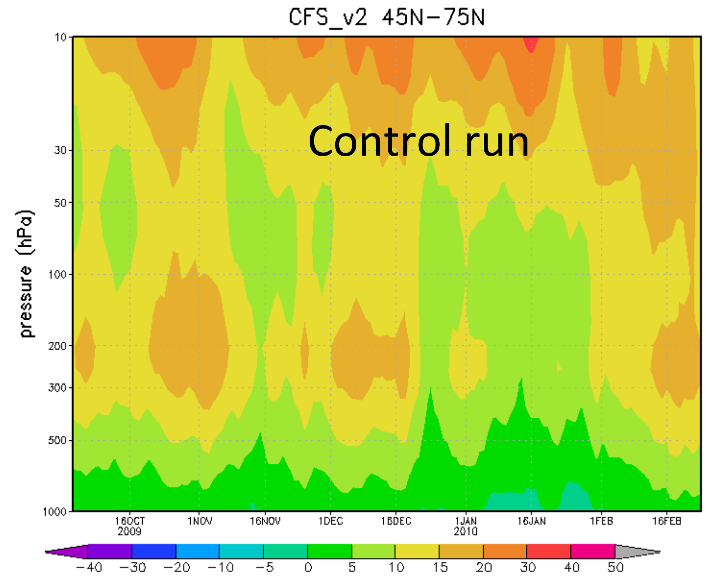
(Courtesy of Emily Riddle)

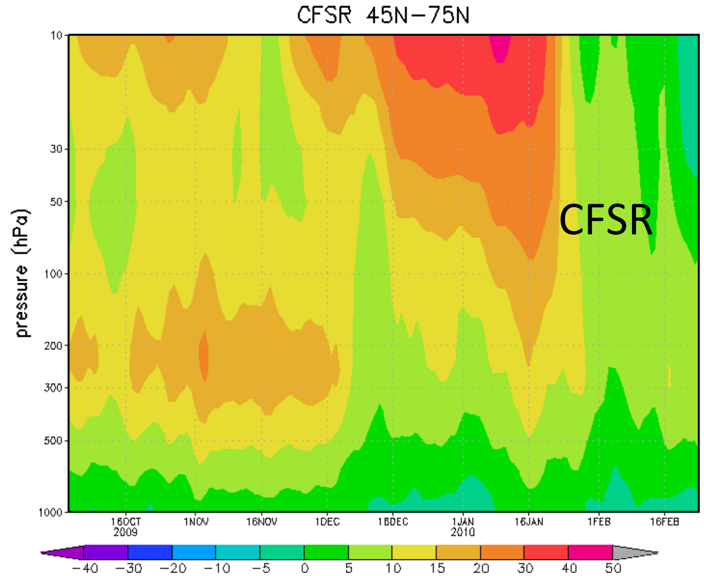






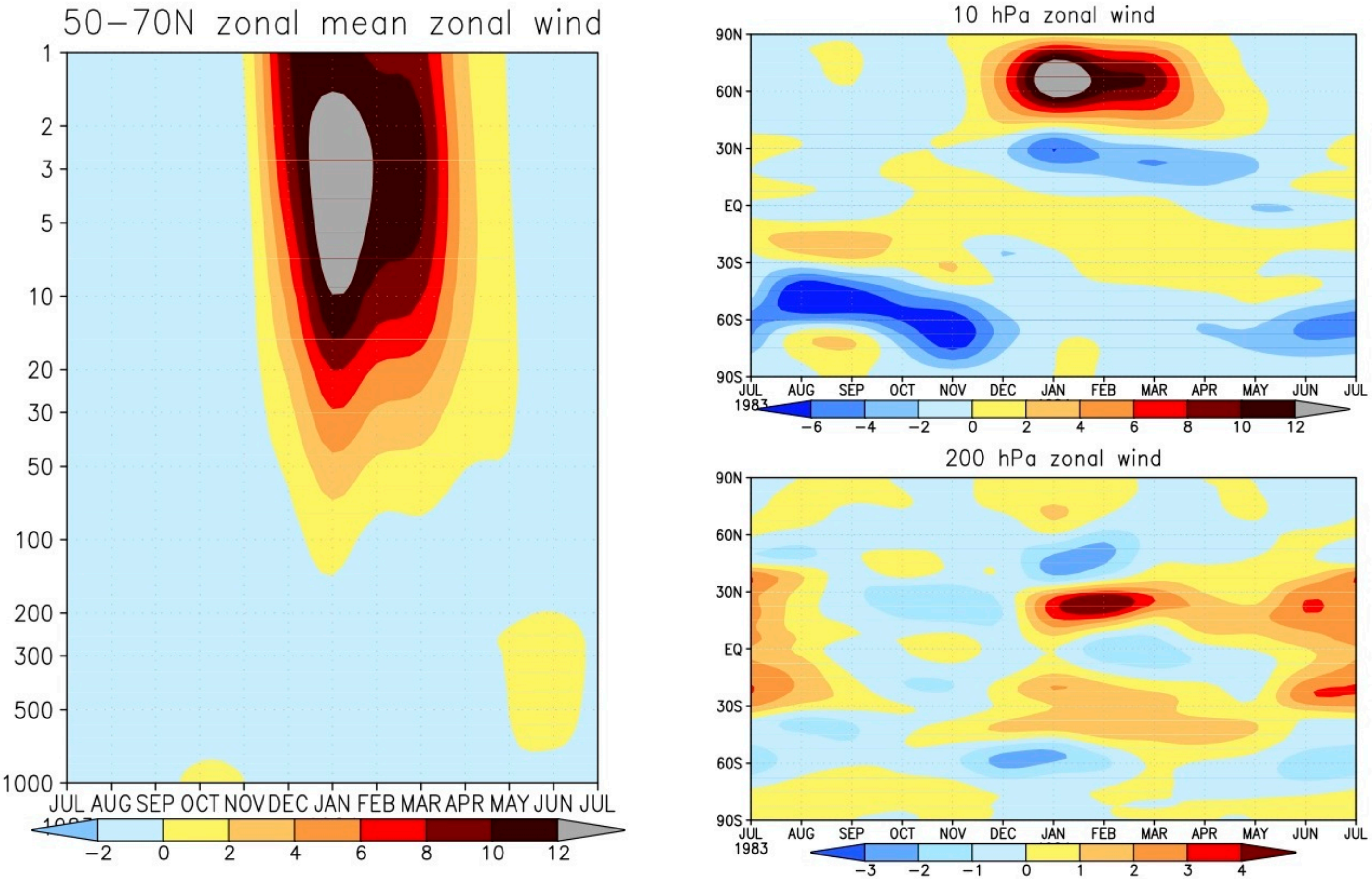






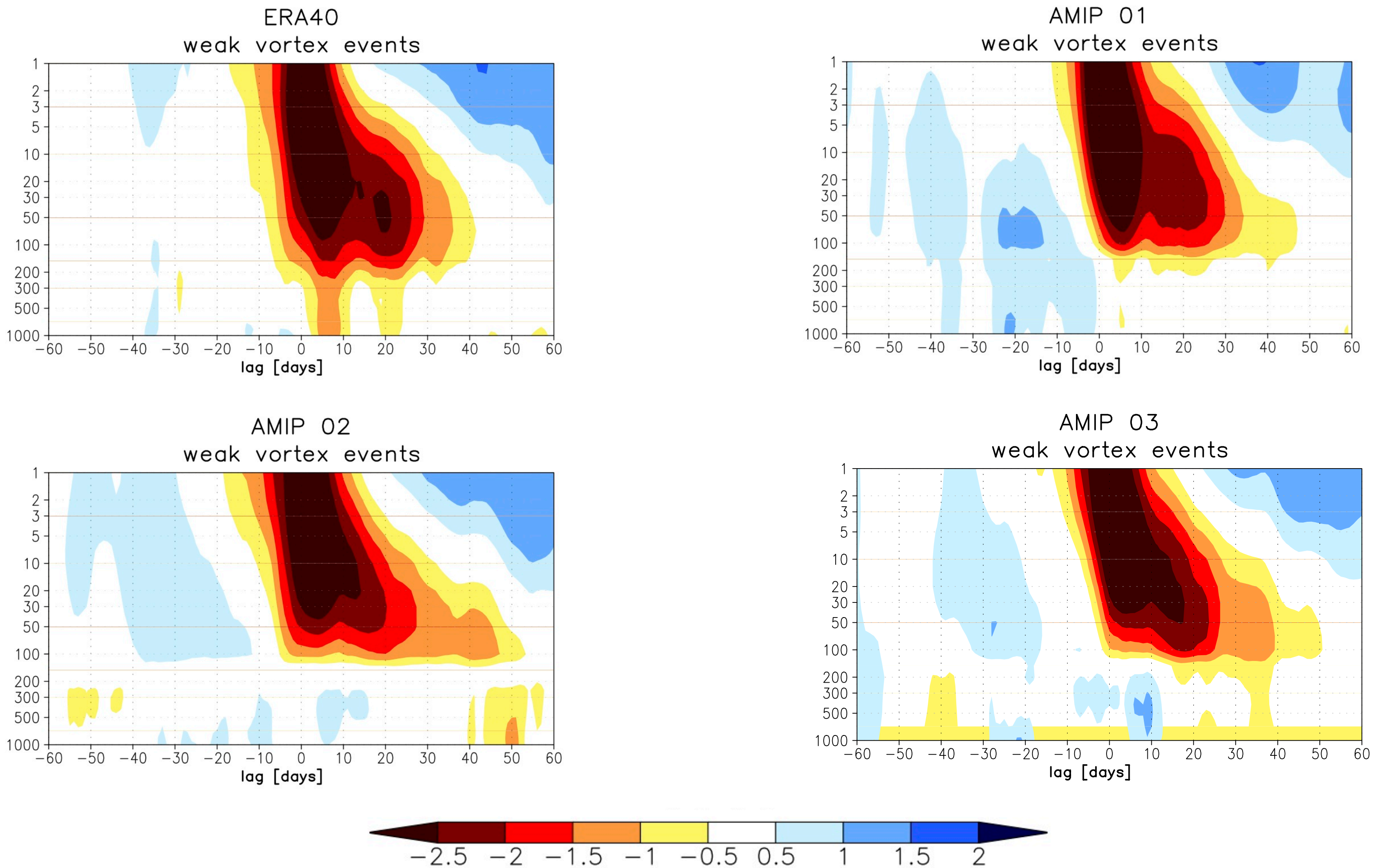
Hypothesis: Raising of model top may reduce spin up impact on mid-to lower stratosphere. However to prove this, many more runs with different start dates and for different years have to be carried out.

Spin up effect
4mo minus 2mo lead times



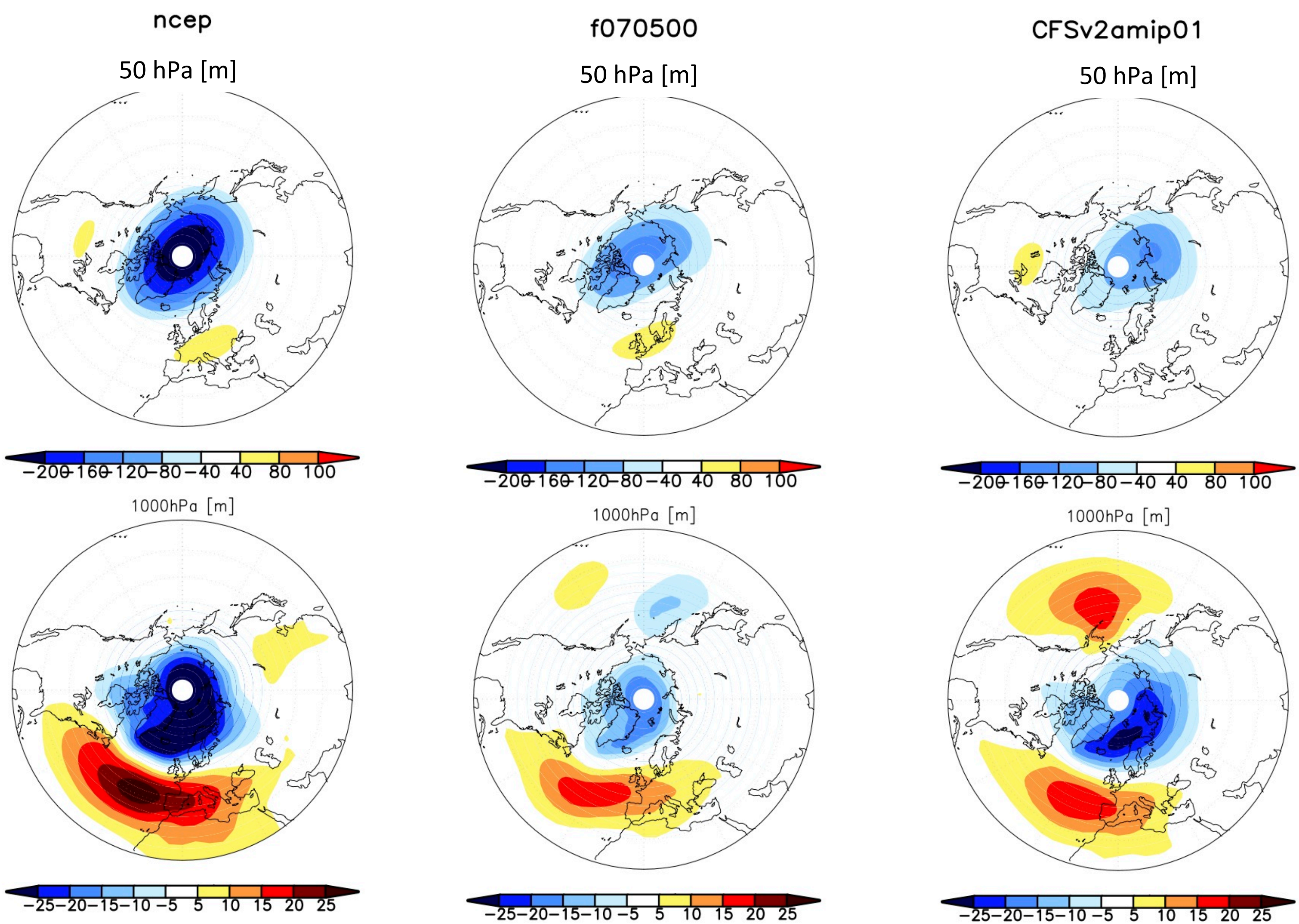
Stratosphere-troposphere coupling

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

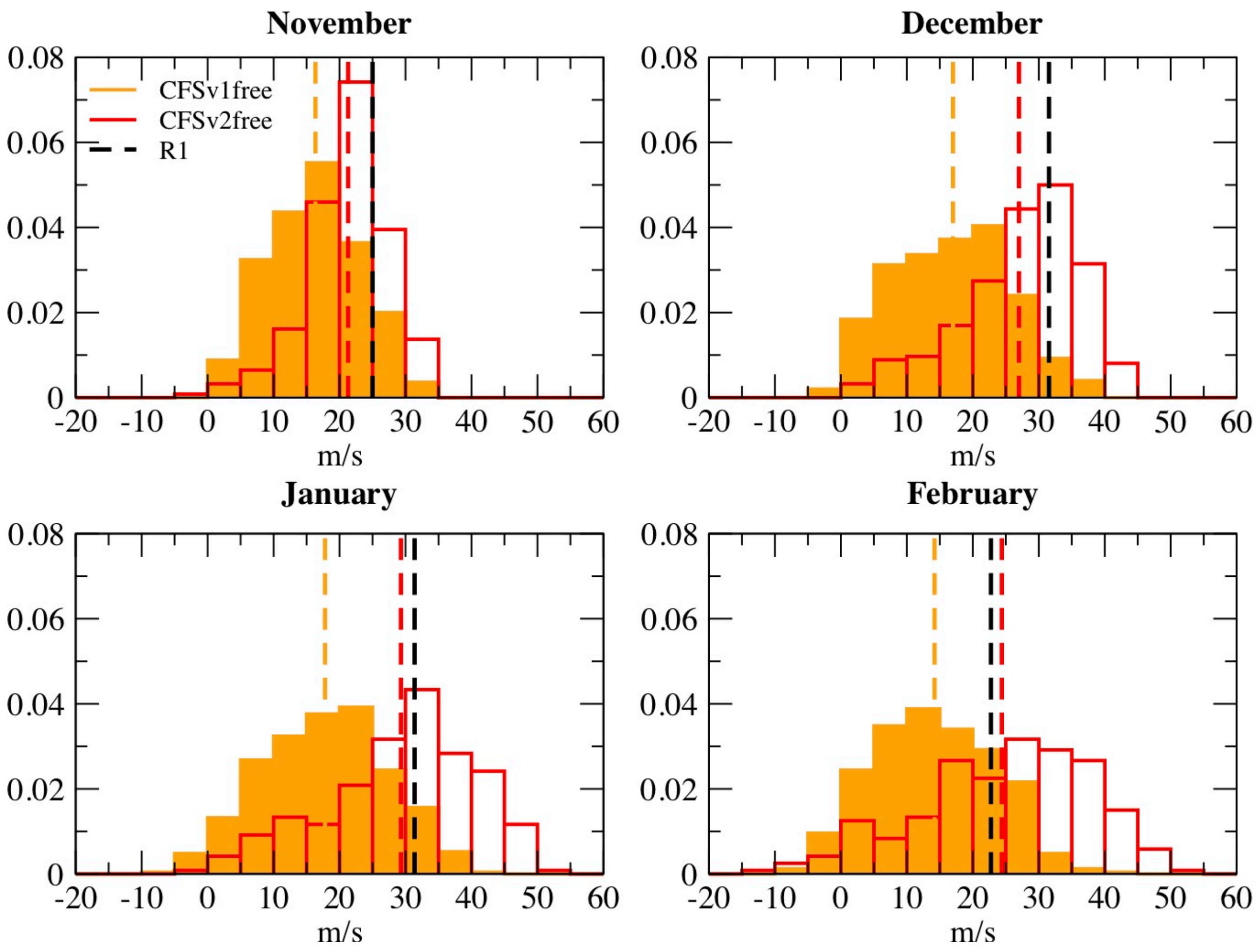
Coupled Modes of Variability of Geopotential Height Fields



Polar Night Jet Climatology

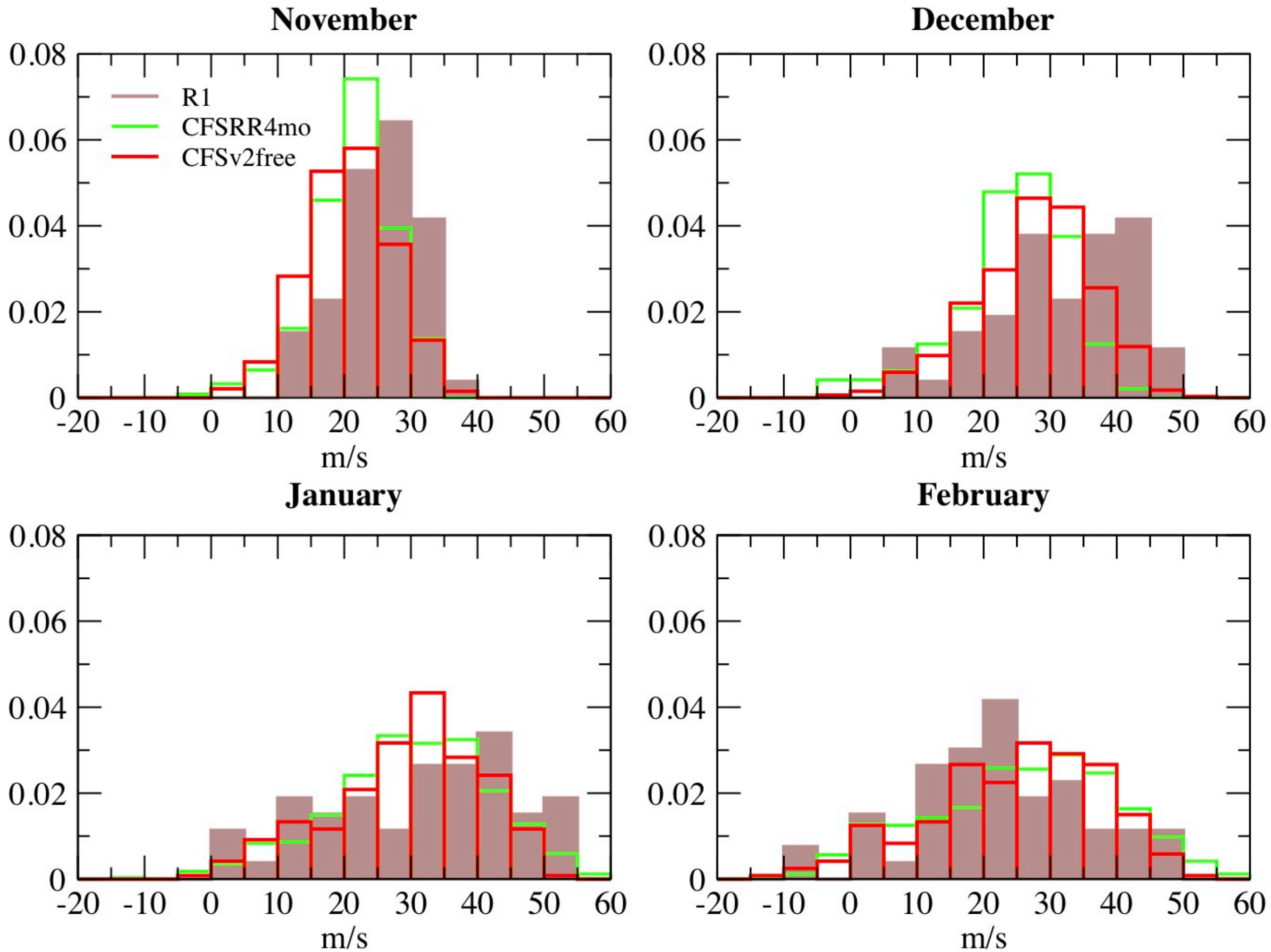
- histogram of 10hPa 60N zonal mean zonal wind

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