On the Development of NCEP 127-L GFS with Its Top Extending to the Mesopause

Fanglin Yang

Environmental Modelling Centre, National Centres for Environmental Prediction, College Park, Maryland, USA

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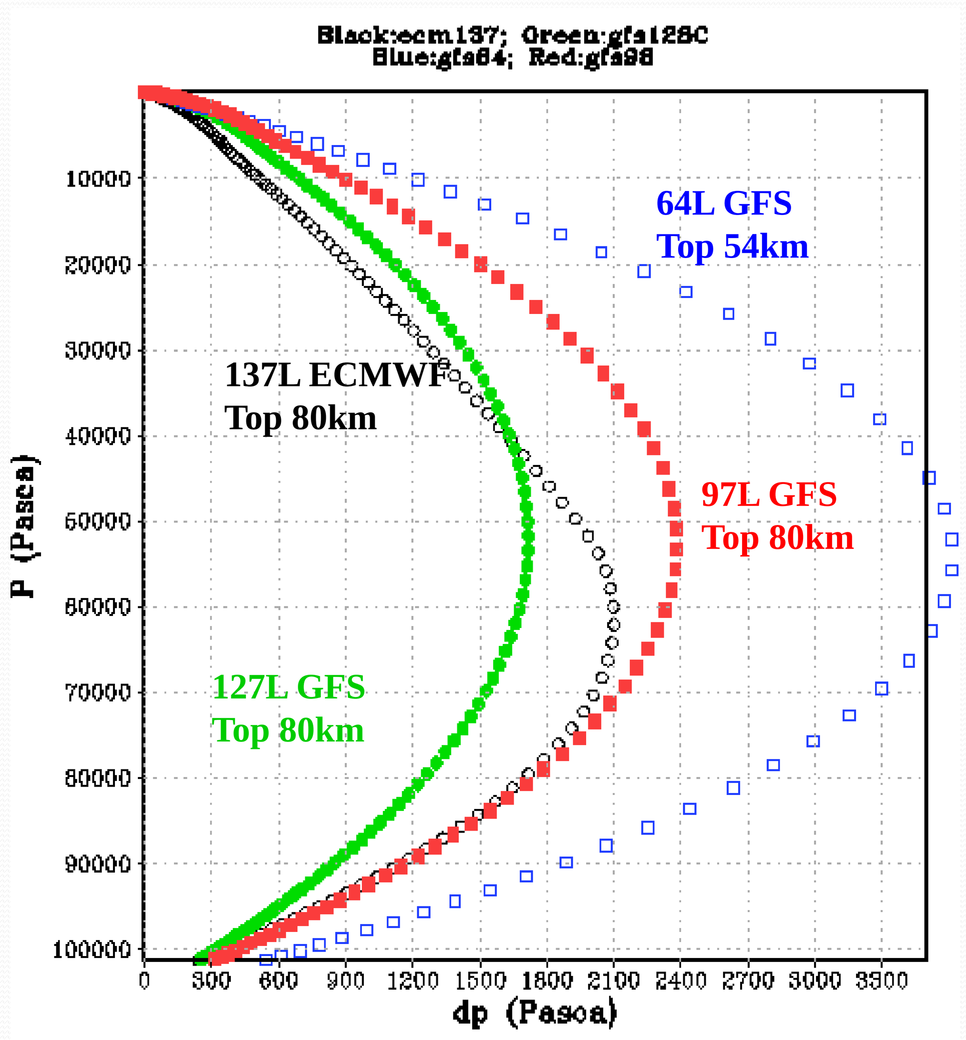
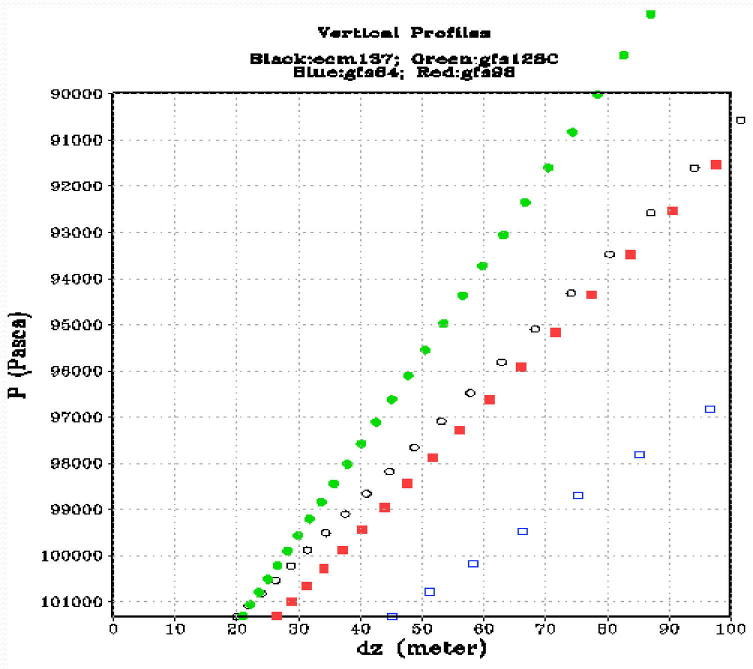
- Version 15 of the NCEP Global Forecast System (GFS) was implemented into operation on June 12, 2019. The spectral dynamic core, which had been in use by NCEP global forecast models in the past few decades was replaced by the GFDL Finite Volume Cubed-Sphere Dynamical Core (FV3). Major changes in model physics include the replacement of Zhao-Carr microphysics with the GFDL microphysics, improved ozone parameterization, and a new parameterization of the middle atmospheric water vapor photochemistry.
- Work is now underway towards building the **GFS version 16** for implementation in 2021. The number of model vertical layers is doubled and the model top is extended from the upper stratosphere to the **mesopause (~80 km)**.
- Upgrades in model physics include 1) employing a new scheme to parameterize both stationary and non-stationary gravity waves that are not explicitly resolved by the model, 2) using a new scale-aware turbulent kinetic energy based moist eddy-diffusivity mass-flux vertical turbulence mixing scheme to better represent the PBL processes and, 3) updating the RRTMG radiation package to improve solar absorption by water cloud and the cloud overlapping algorithm.
- This presentation is focused on the investigation of the **impact of gravity-wave drag physics on the simulation of QBO, SAO and polar night jets** in GFS.v16.
- Changes in other components of the system including system infrastructure, data assimilation, post-processing and product generation. Preliminary results from forecast sensitivity experiments with fixed initial conditions will be presented here.





- 127L GFS has higher resolution than 137L IFS in the middle to lower troposphere, but coarser resolution above 400 hPa.
- 127L GFS 1st layer is 20m thick; 64L GFS 1st layer is 40m thick.

Major Upgrades to Forecast Model and I/O

Model resolution:

Increased vertical resolution from 64 to 127 layers and raise model top from 54 km to 80 km

Physics updates

PBL/turbulence: K-EDMF
=> Scale/Aware-TKE-EDMF

Orographic Gravity Wave Drag:
=> OGWD + CGWD

Radiation: update cloud-overlap assumptions

Microphysics: Improvements to GFDL MP

Coupling to Wave

One-way coupling of atmospheric model with WWIII

I/O

- Write model forecast output in NetCDF format with compression instead of binary nemsio format (reduced file size by a factor of 5)
- Inline POST Processing and product generation

Major Upgrades to Data Assimilation

Local Ensemble Kalman Filter (LETKF)

replace Ensemble Square Root Filter

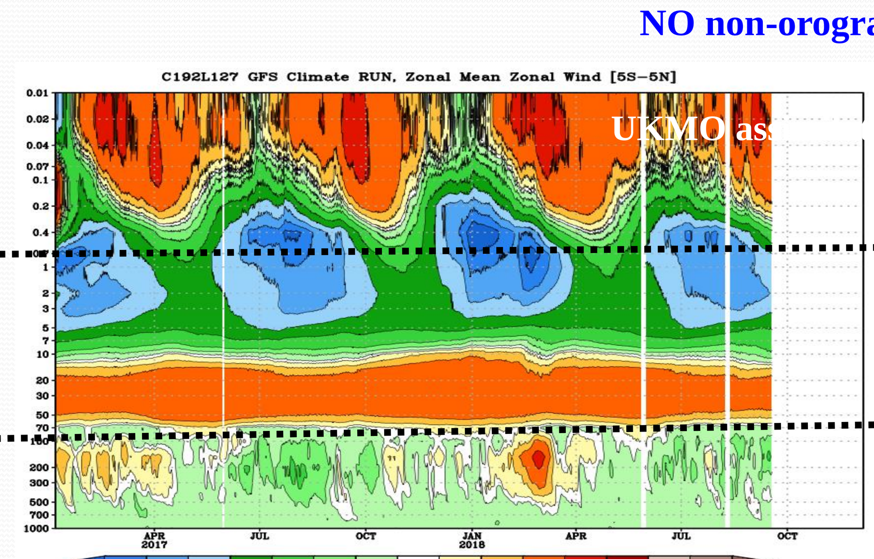
4-Dimensional Incremental Analysis Update (4D-IAU)

Turn on SKEB in EnKF forecasts

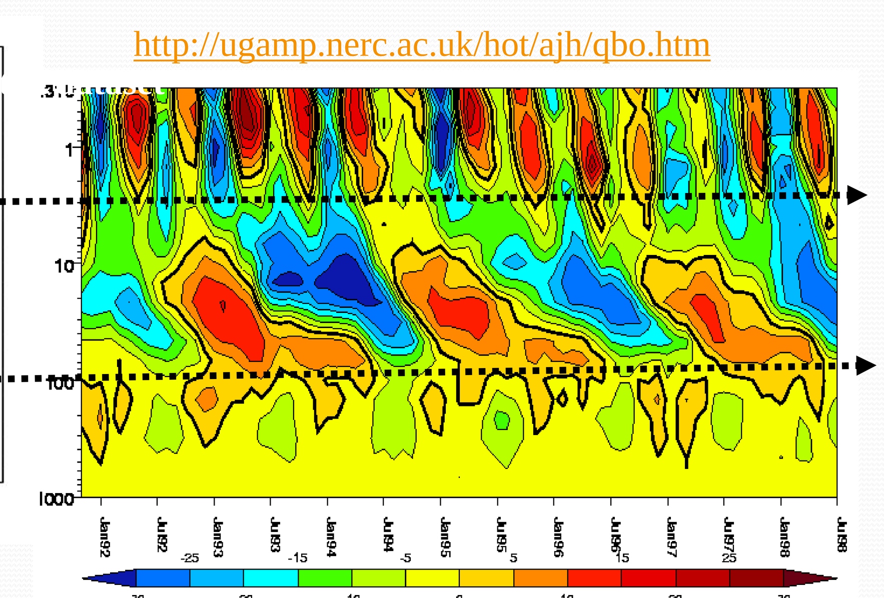
- Update variational QC
- Apply Hilbert curve to aircraft data
- Correlated error for CrIS over sea surfaces and IASI over sea and land surfaces
- Update aircraft bias correction with safeguard
- Disable correlated error in enkf steps
- Assimilate AMSUA channel 14 and ATMS channel 15 w/o bias correction
- Assimilate CSR data from ABI_G16, AHI_Himawari8, and SEVIRI_M08
- Use CRTM v2.3.0

Biases in the Upper Atmosphere, C192 (~50km) L127 AMIP Run

With orographic GWD, Rayleigh friction above 7.5 mb to the model top NO non-orographic GWD

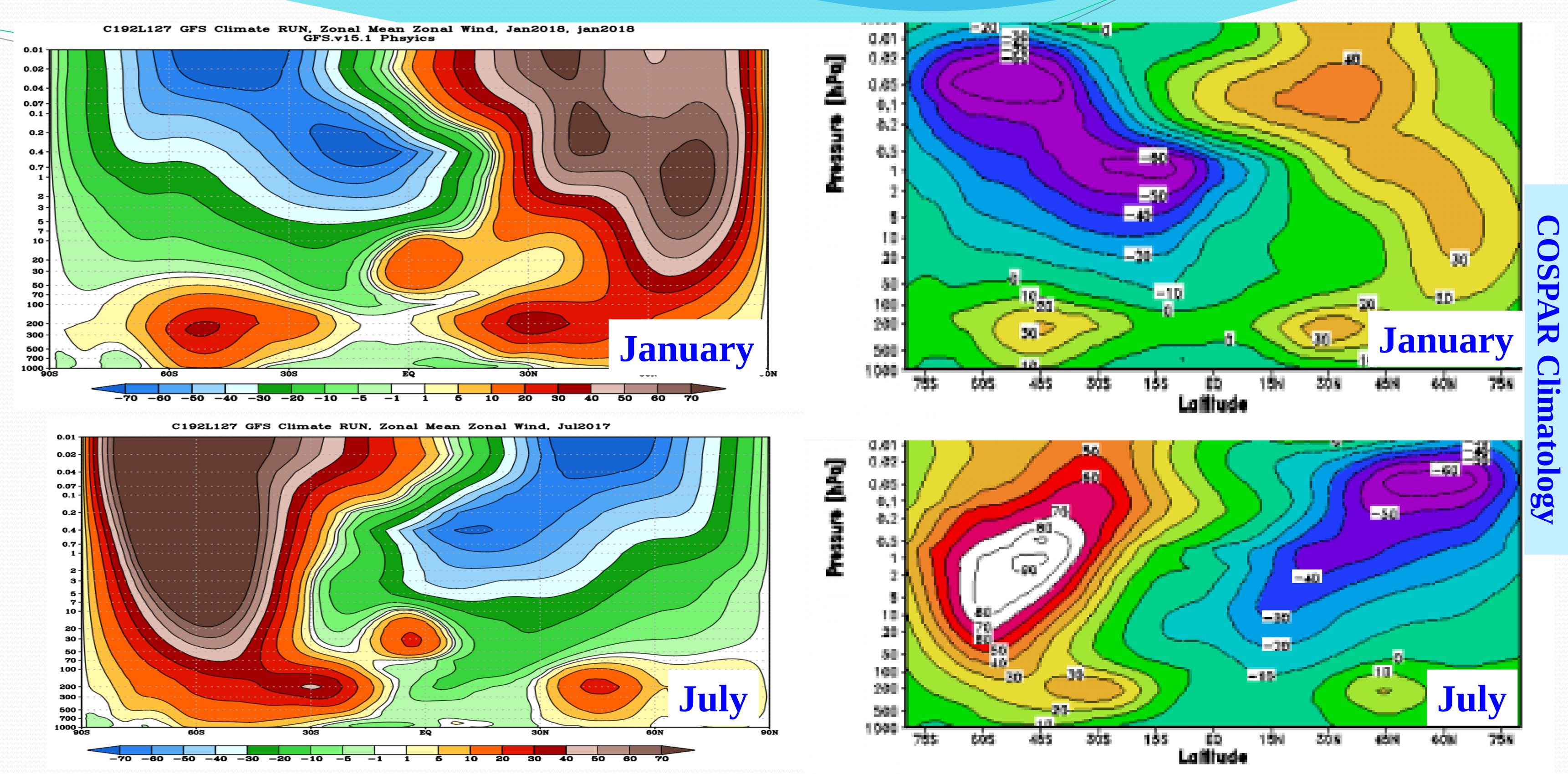


http://ugamp.nerc.ac.uk/hot/ajh/qbo.htm

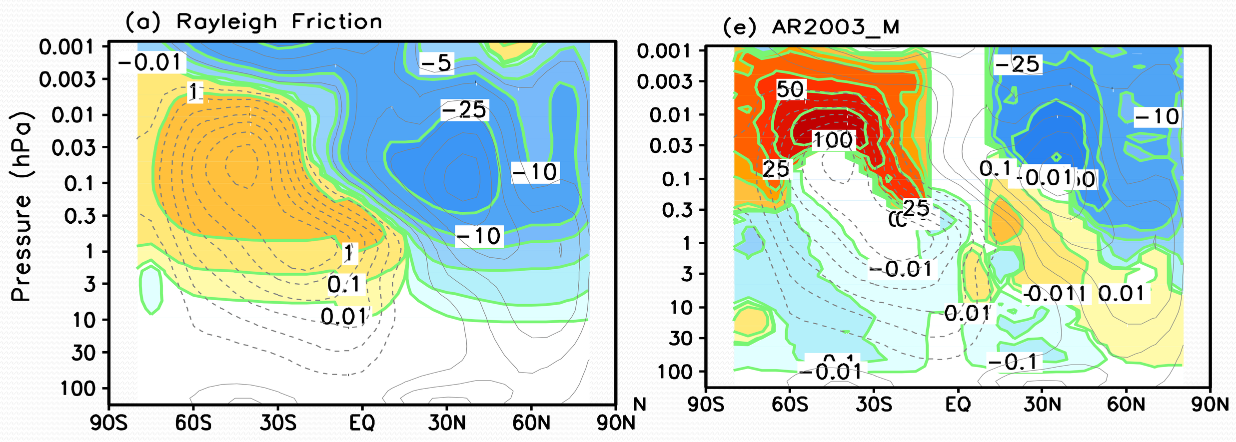


The Model failed to capture the QBO; SAO westerly phase is too weak.

Zonal Mean Zonal Wind



- Polar night jets are too strong, do not tilt towards the equator from the stratosphere to the mesosphere.
- Easterly wind near the mesopause region is too strong, no transition to westerly



Using Holton and Wehrbein (1980) Rayleigh Friction

Using Alexander and Dunkerton (1999) GWD parameterization

Mean-flow forcing (color shadings) of zonal-mean zonal winds (m/s/day) due to Rayleigh friction and breaking gravity waves, January, UIUC 40-L GCM. Yang et al. (2006)

Biases reduced in the Upper Atmosphere after adding a non-orographic GWD parameterization provided by Valery Yudin (*University of Colorado – Boulder)*

Prescribed non-orog GWD

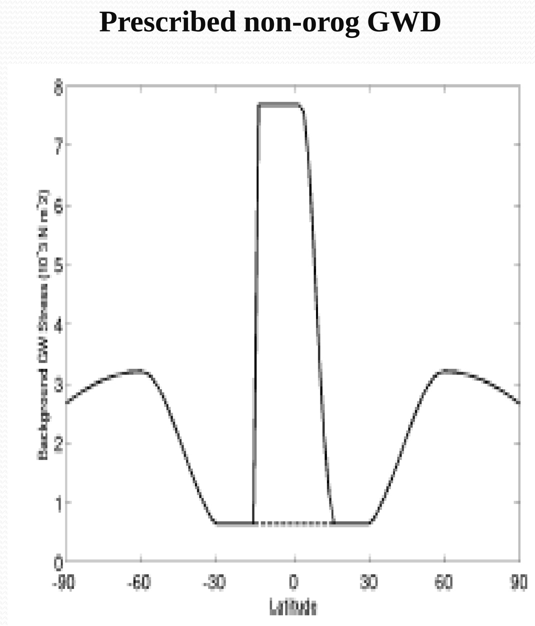
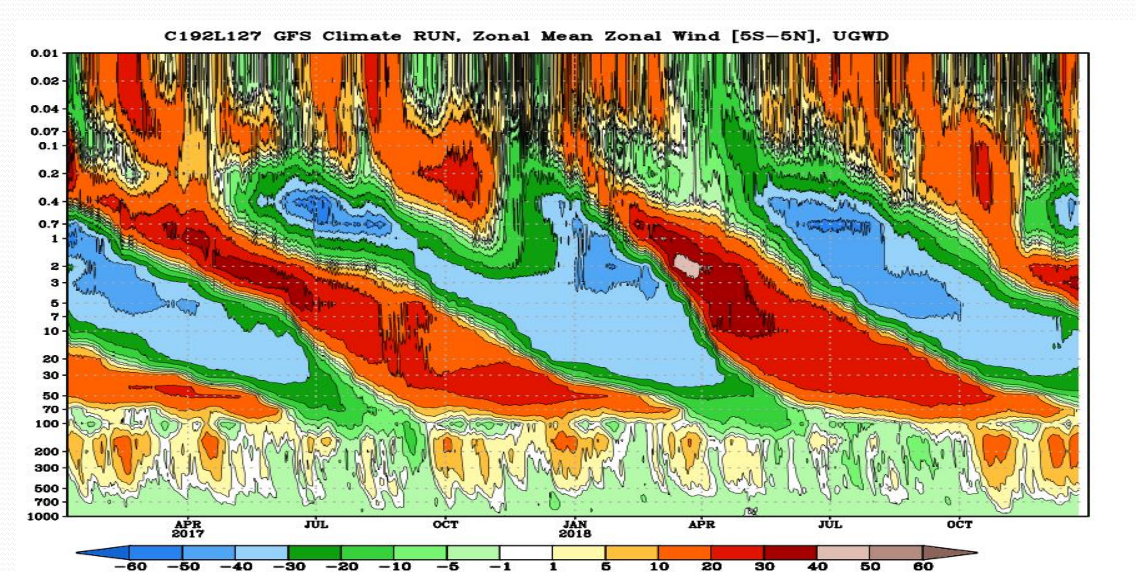
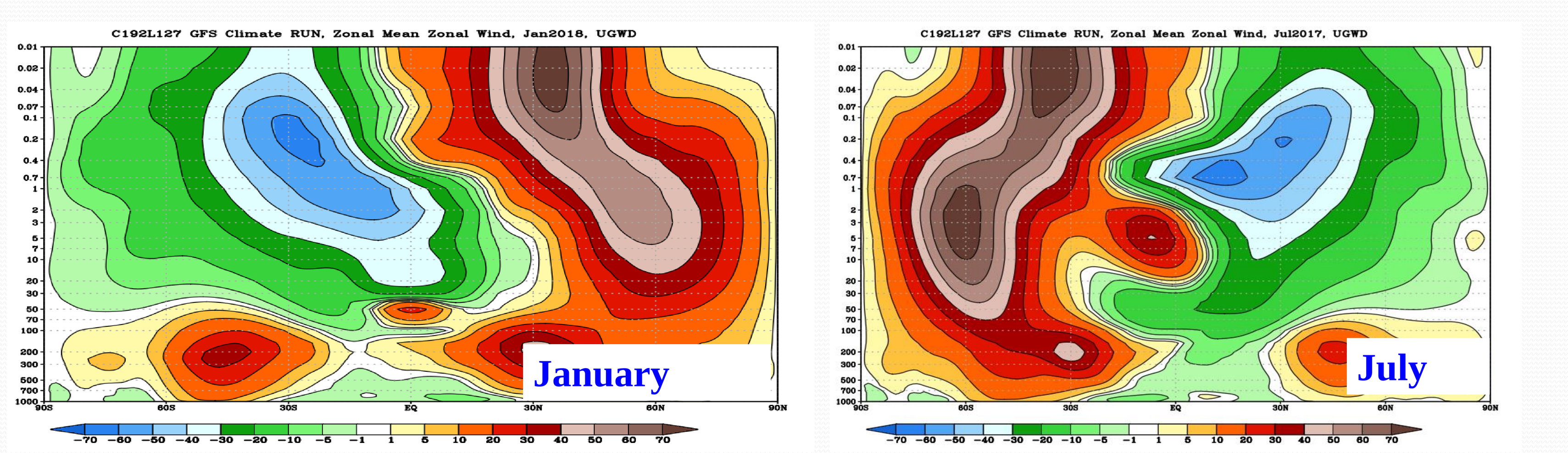


Figure 3. Background non-orographic drag from the MERRA (dashed line) and MERRA2 AGCM (solid line) simulations. The dashed line underlies the solid line outside of the tropics.

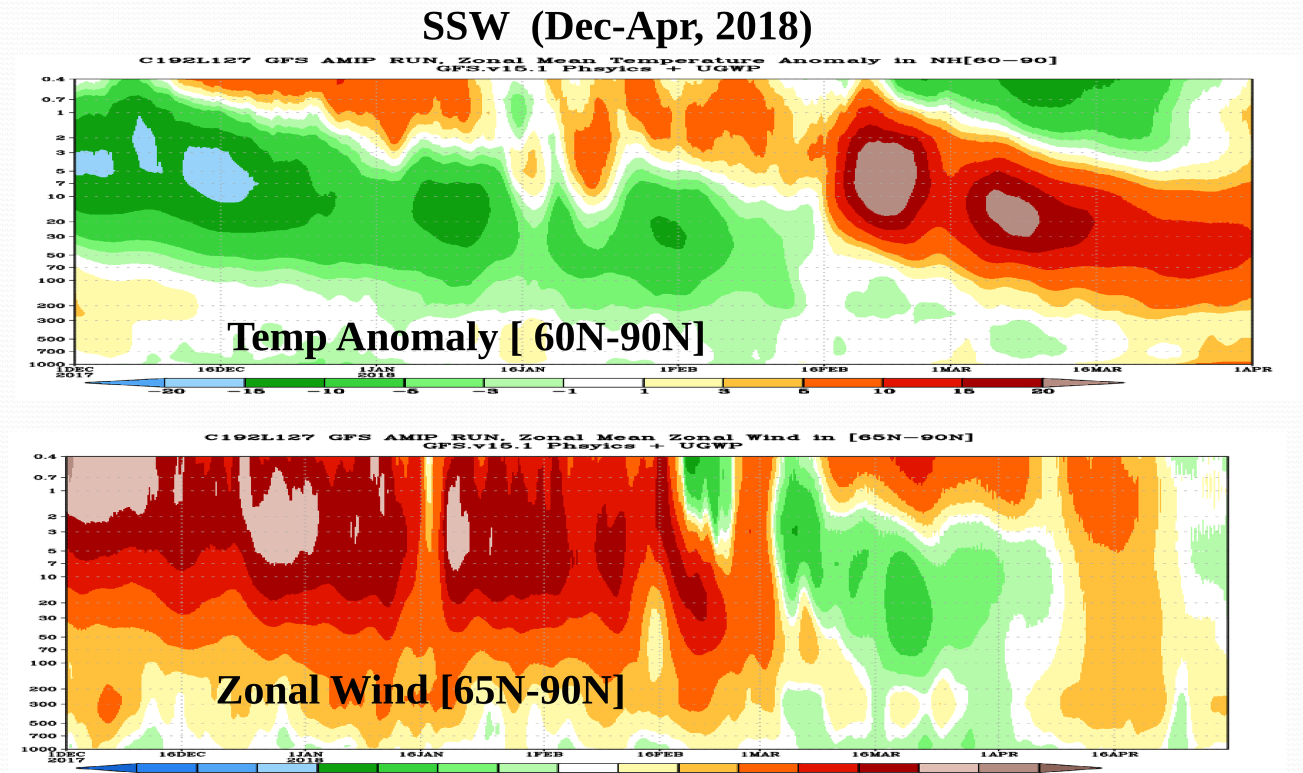


QBO-like feature captured, but the period is too short, appears to be an downward propagating SAO. Needs further improvement.



- Polar nights jet are improved, have the correct orientation, although they are still too strong near the mesopause.
- Easterly winds near the mesopause are also greatly improved.

SSW (Dec-Apr, 2018)



SSW is captured with UGWP included

Further Development

- **Physics-based specification of non-stationary GW triggers, e .g. , link to convection**
- **Improve QBO periodicity**
- **Scale-aware GW parameterization schemes**
- **Connection between eddy mixing/diffusion with gravity-wave physics and PBL**