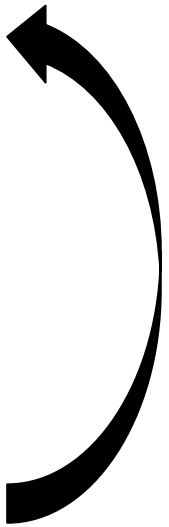
FV3GFS initialization and stochastic physics

Philip Pegion and Jeff Whitaker

Review of DA cycling methodology

- FV3 GFS produces a 9-hour background forecast
- History files are interpolated to Gaussian grid are used as input to GSI/EnKF
- Analysis increments are interpolated back to cubed-sphere grid (inside the model) and added to 6-hour forecast restart file



Steps to create a different resolution initial condition file

- FV3 GFS produces a 9-hour background forecast
- History files are interpolated to Gaussian grid are used as input to GSI
- GSI produces gaussian grid nemsio file.
- Gaussian grid analysis is interpolated to new resolution using global_chgres

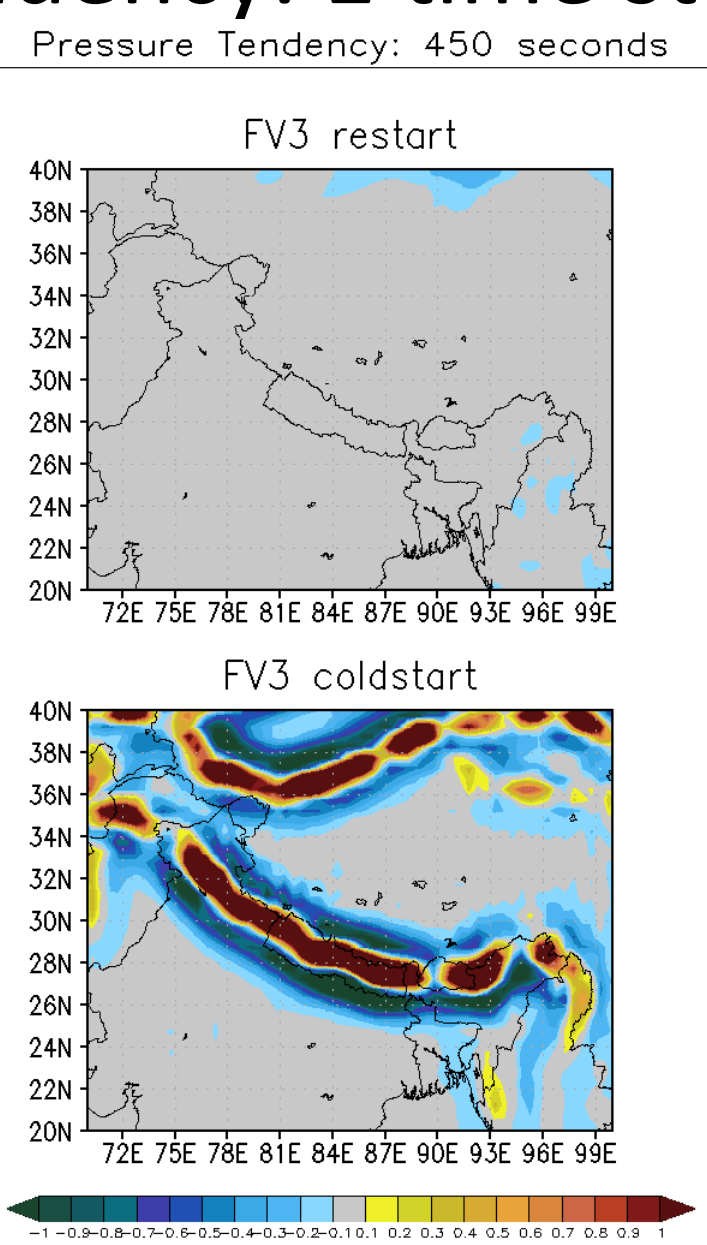
Sanity check of initialization

- Compare a forecast initialized with a restart file to a cold start initialized run created from the history file (by passing the data assimilation step)
- This is a check of two horizontal interpolations
  - Cube Sphere to Gaussian grid: ESMF bilinear interpolations
  - Gaussian grid to Cube Sphere: global_chgres

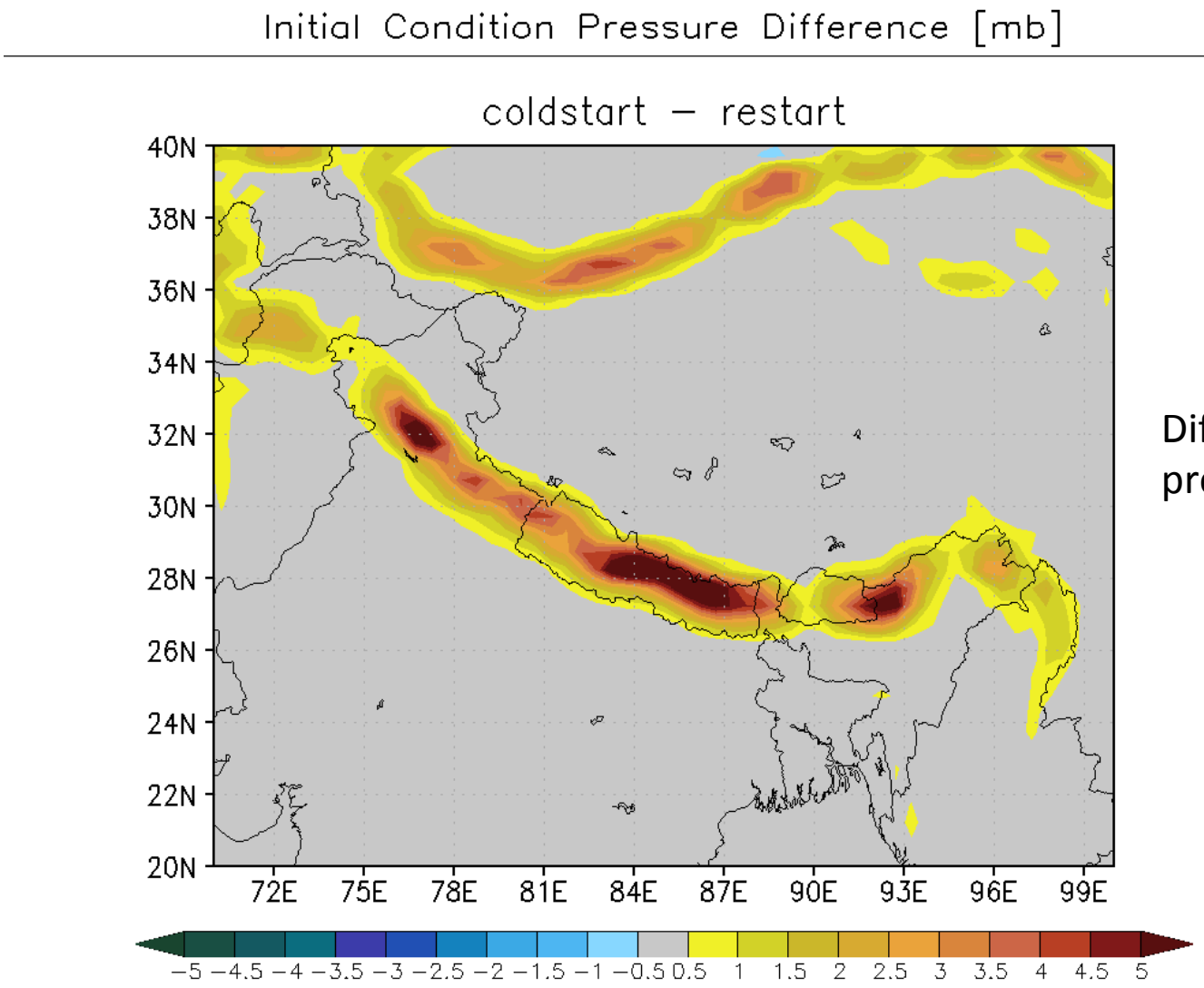
Pressure Tendency: 1 time step

Pressure tendency in one-time step of a forecast when initialized with a restart file

Initial conditions that were processed through 2 interpolations generate significant gravity waves emanating from steep orography



Difference in Surface pressure of initial conditions



Differences in surface pressure are > 5 mb

Different ways to interpolate pressure

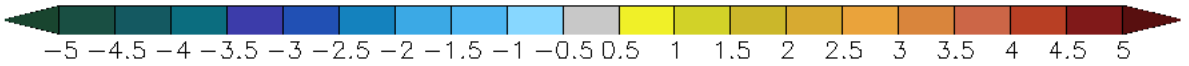
- Linear in pressure – currently used by global_chgres
- Log pressure: assumes atmosphere is isothermal – what GFS uses
- Assume a constant lapse rate
  - $Px=(P/P0)^{(Rd*\gamma/g)}$ If lapse rate is dry adiabatic, then this becomes the exner function

surface pressure interpolation

Cube-sphere-> Gaussian

Gaussian -> Cub-sphere

	Linear-P	γ=10.0	γ=6.5	Log(p)
Linear-P	ps,ps	exner(10),ps	exner(6.5),ps	log(ps),ps
γ=10.0	ps,exner(10)	exner(10),exner(10)	exner(6.5),exner(10)	log(ps),exner(10)
γ=6.5	ps,exner(6.5)	exner(10),exner(6.5)	exner(6.5),exner(6.5)	log(ps),exner(6.5)
Log(p)	ps,log(ps)	exner(10),log(ps)	exner(6.5),log(ps)	log(ps),log(ps)

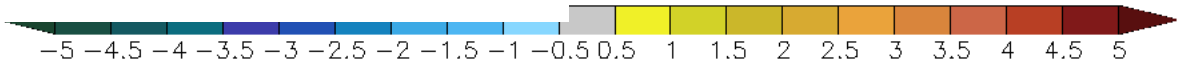


surface pressure tendency

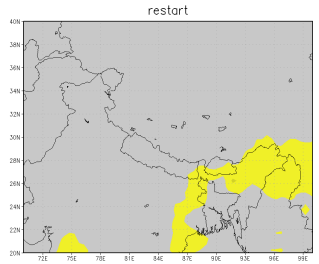
Cube-sphere-> Gaussian

Gaussian -> Cub-sphere

	Linear-P	γ=10.0	γ=6.5	Log(p)
Linear-	ps,ps	exner(10),ps	exner(6.5),ps	log(ps),ps
γ=10.	ps,exner(10)	exner(10),exner(10)	exner(6.5),exner(10)	log(ps),exner(10)
γ=6.5	ps,exner(6.5)	exner(10),exner(6.5)	exner(6.5),exner(6.5)	log(ps),exner(6.5)
Log(p	ps,log(ps)	exner(10),log(ps)	exner(6.5),log(ps)	log(ps)log(ps)



surface pressure tendency



Cube-sphere-> Gaussian

Linear-P γ=10.0 γ=6.5

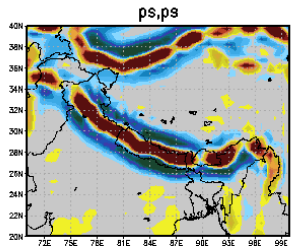
Gaussian -> Cub-sphere

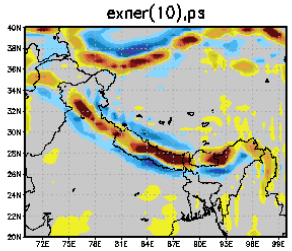
Linear-

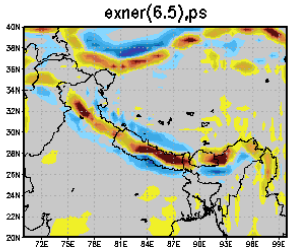
γ=10.

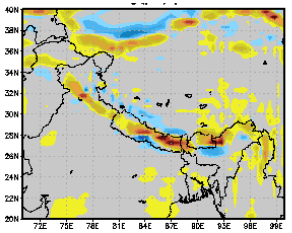
γ=6.5

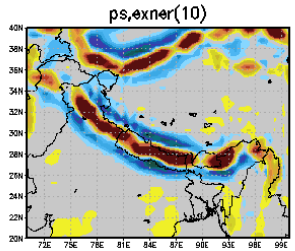
Log(p

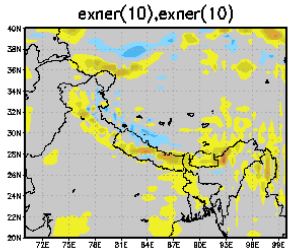


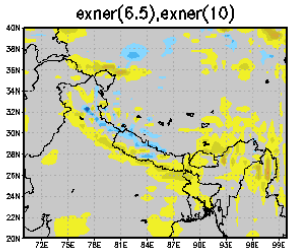


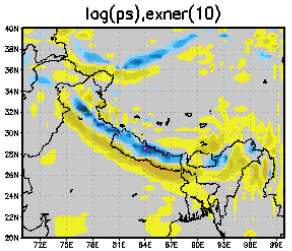


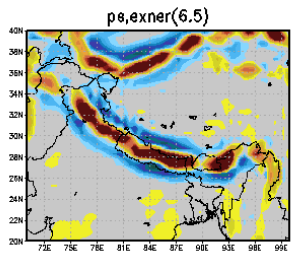


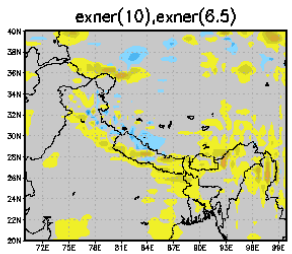


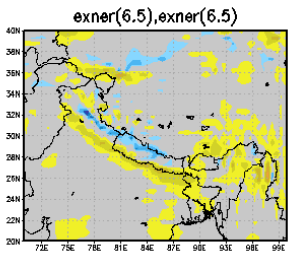


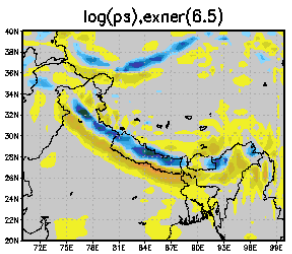


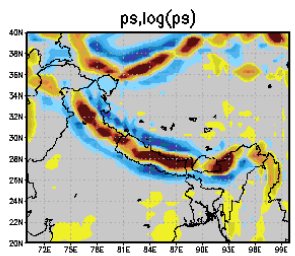


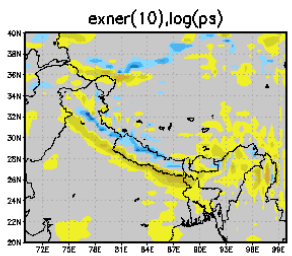


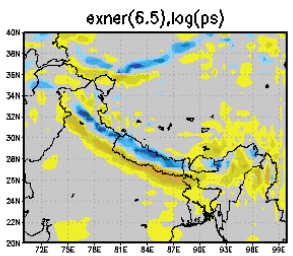


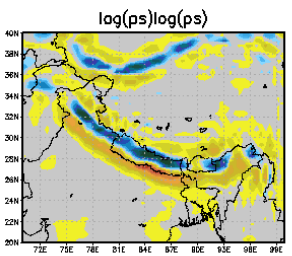


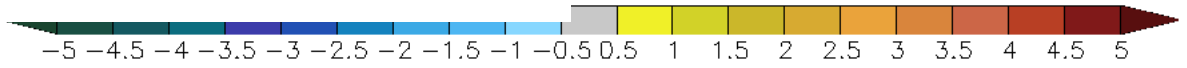




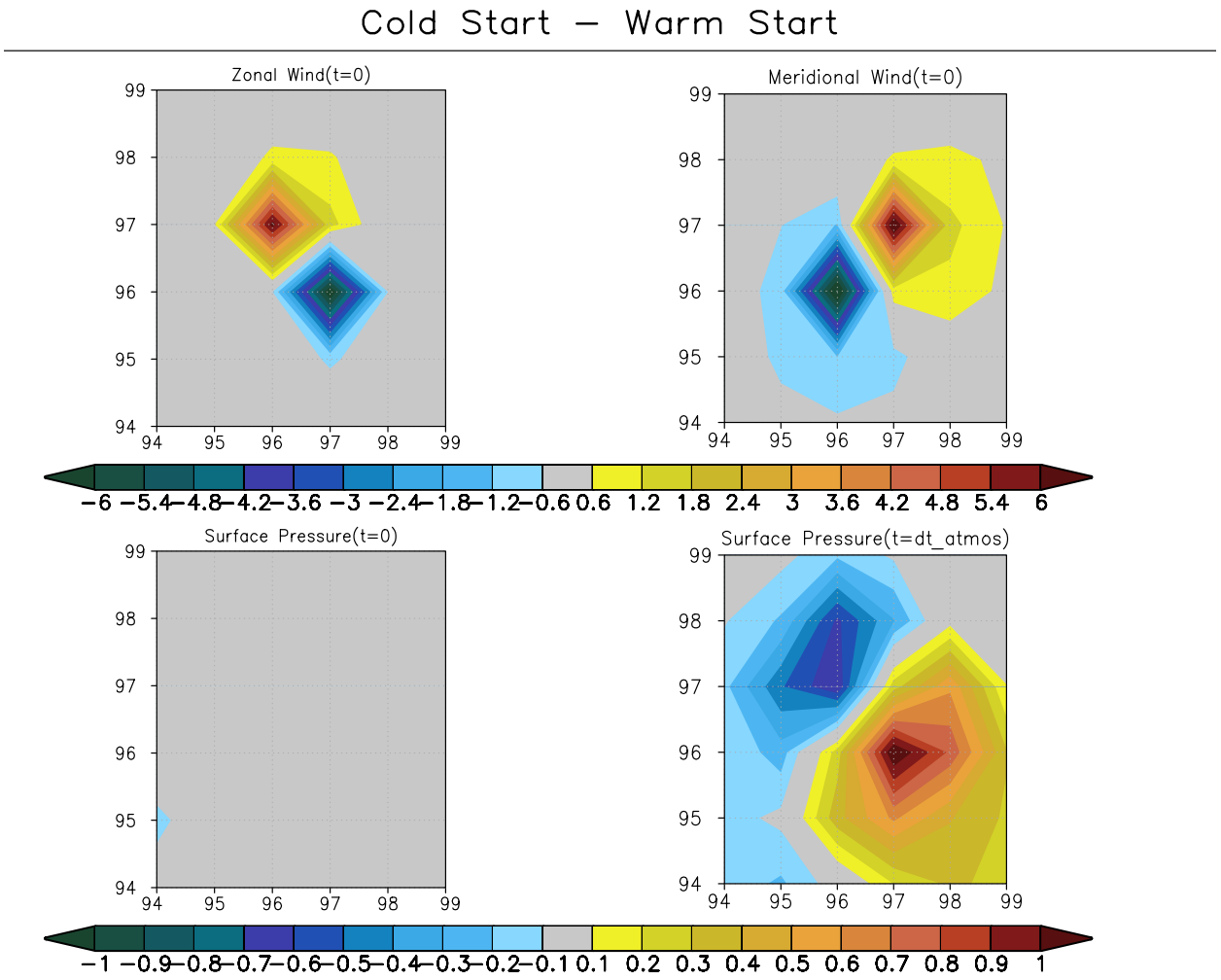






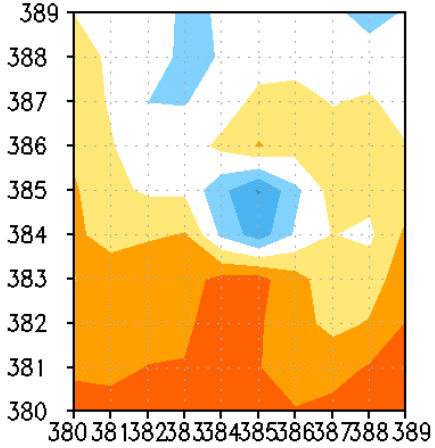


Issue near the poles

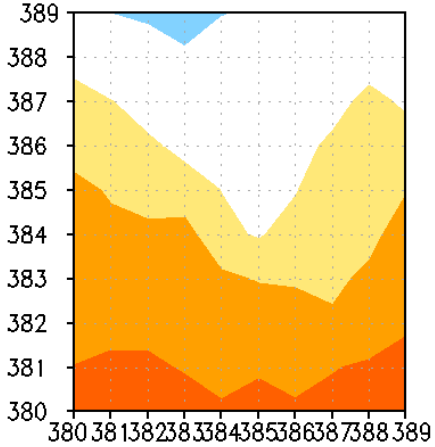


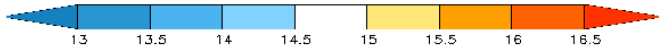
Wind Speed [m/s]

GFS initial condition, scalar interp



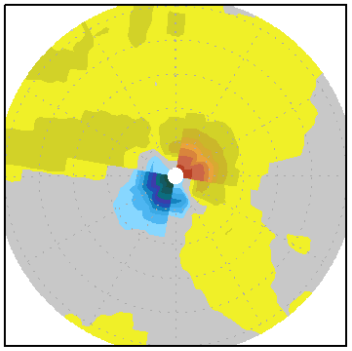
GFS initial condition, scalar interp



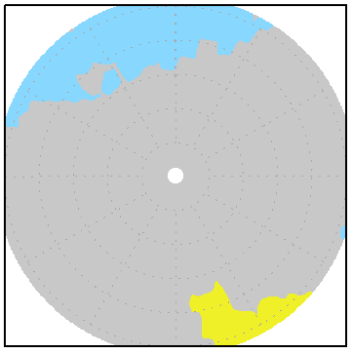


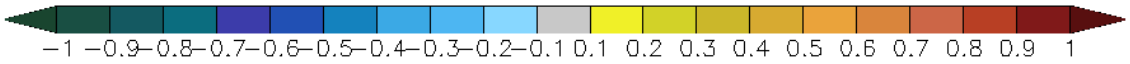
1-hour pressure tendency

scalar wind interpolation



vector wind interpolation





- Errors in the interpolation of the winds cause an imbalance that causes a shockwave in the pressure field
- Correctly handling the wind field as vectors alleviate this problem

Stochastic Physics

- Ported random pattern generator from the GFS to work with the cubed-sphere grid
  - Code converts from spherical harmonics to Gaussian grid
  - Interpolate from Gaussian grid to cubed-sphere
- Currently only SPPT and SHUM are implemented. SKEB requires additional coding for numerical dissipation estimate

Stochastic Physics - needs

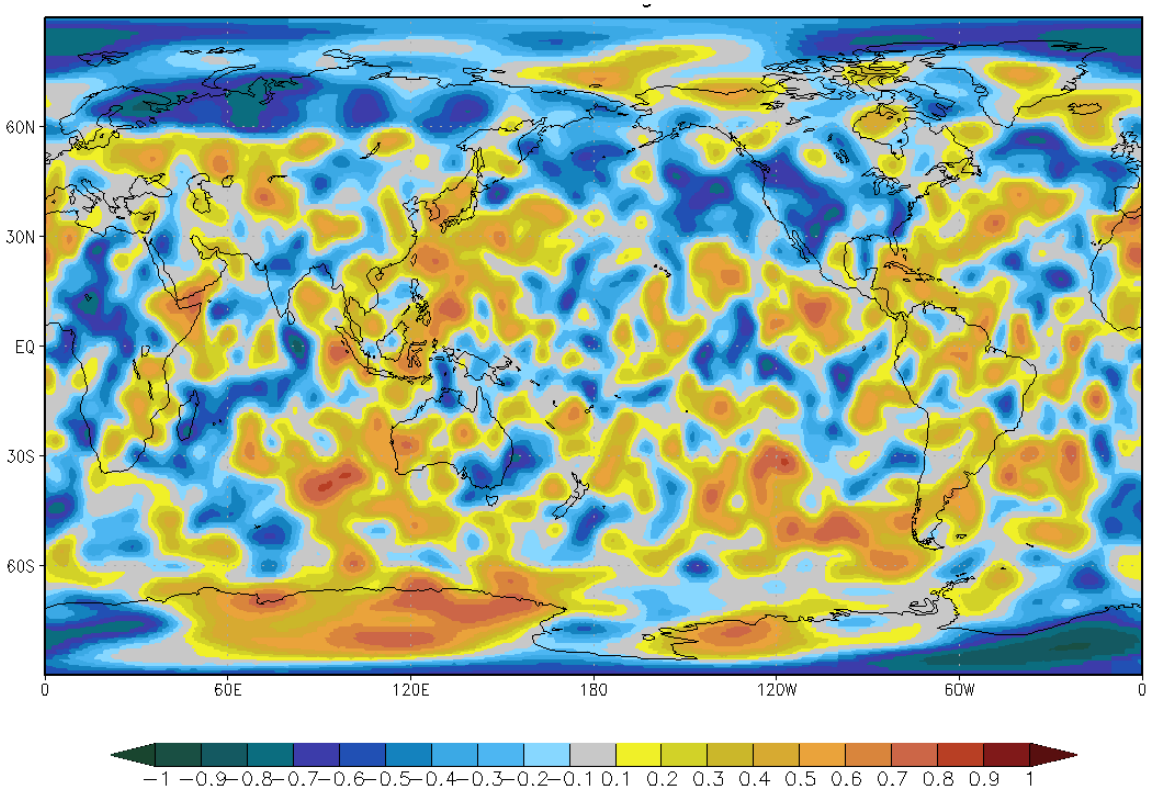
- There are two mpi calls that are currently not supported by fm_mp_mod

- Mpi_all_reduce for a vector
- mpi_alltoallv

And I have created a temporary workarounds, but would like to work with software engineers for a better solution.

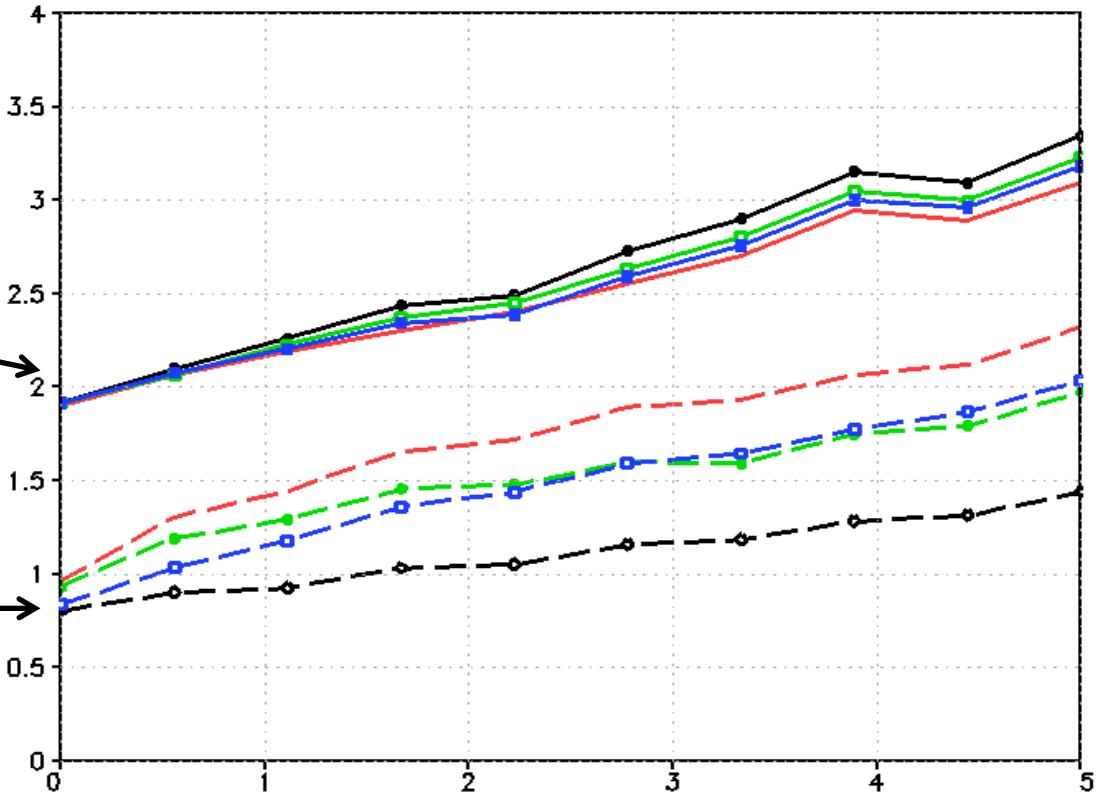
Update of random pattern is called from
atmos_cubed_sphere/driver/coupled/atmosphere.f90
Perturbations are actually applied in gfs_physics_driver.f90

Snapshot of Random pattern



Random pattern for SPPT, decorrelation length scale is 500 km.

850 hPa winds: 20°S-20°N



RMS error

Ensemble Spread

Control
SPPT
SHUM
SPPT+SHUM

Results are what is expected, even get the reduction in error!

Results from a single 20-member ensemble run at C192, initialized with EnKF analysis after only 1 cycle from phase-2 test. Verified against operational EC analysis.

Summary

- Cold Start initialization issues
  - Handling the wind field as vectors fixes initialization shock at poles
  - Assuming a U.S. standard atmosphere lapse rate (6.5^{o}C/Km) improved the surface pressure field around steep orography, and associated initialization shock
- Stochastic Physics
  - A working version of the random pattern generator is implemented, but it needs to be optimized for performance.