NEMS FV3 write grid component

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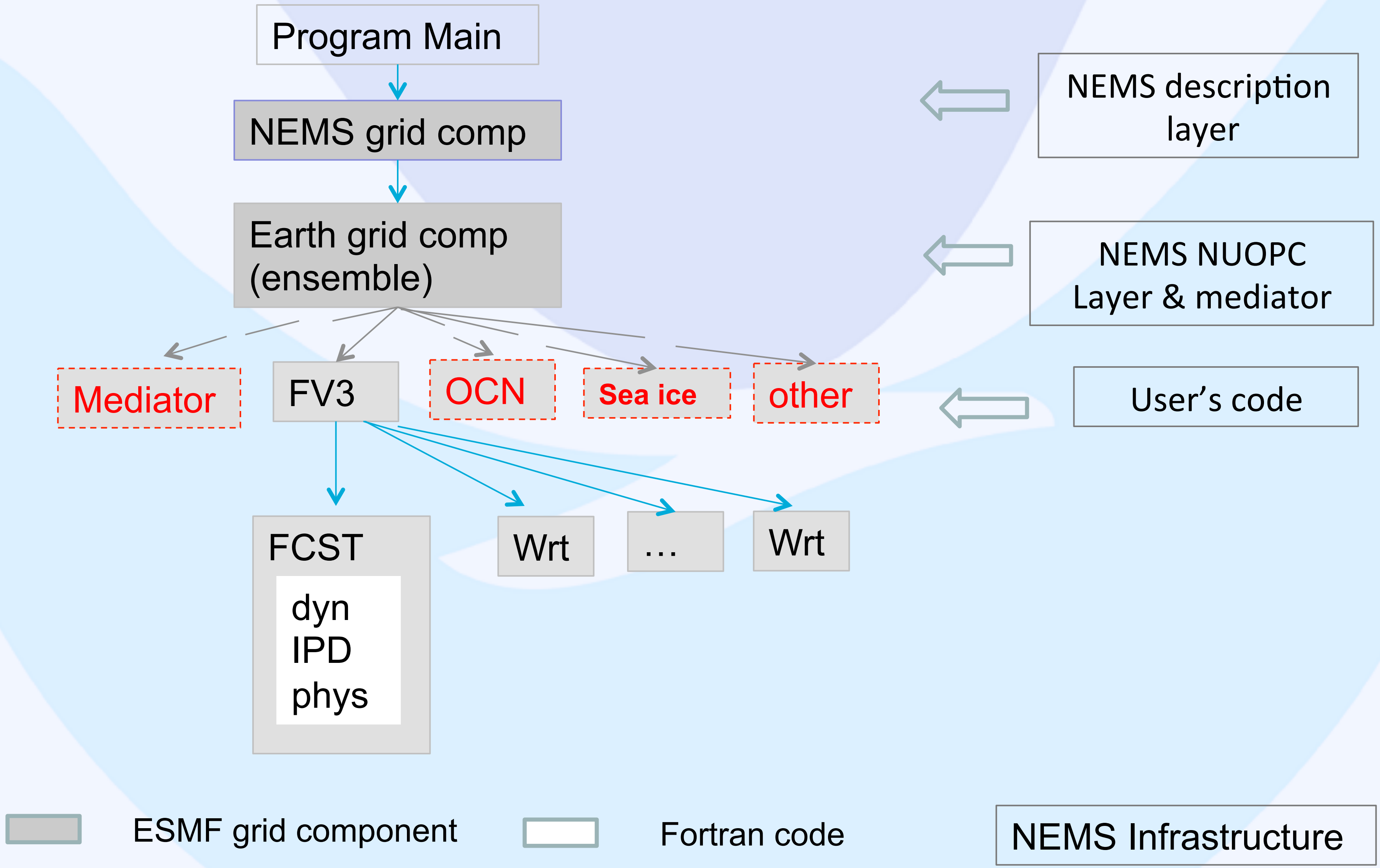
NEMSfv3gfs

- NEMSFV3gfs is built as an application of the unified earth science system with FV3 as atmosphere component.
  - FV3 CAP is the atmosphere grid component interface to the NUOPC model framework.
  - FV3 model (including dynamics and physics) is implemented as atmospheric **forecast grid component** with FV3 dynamics, IPD and GFS physics.
  - The model outputs related downstream processes are implemented using **write grid component**.
  - Downstream jobs such as **POST processing** can be conducted on write grid component where all the output data are available.
  - NEMSfv3gfs is a standalone atmospheric model, but the infrastructure can facilitate FV3 atmosphere grid component in both standalone mode and coupled mode.

NEMSfv3gfs code structure



NEMS FV3 write grid component

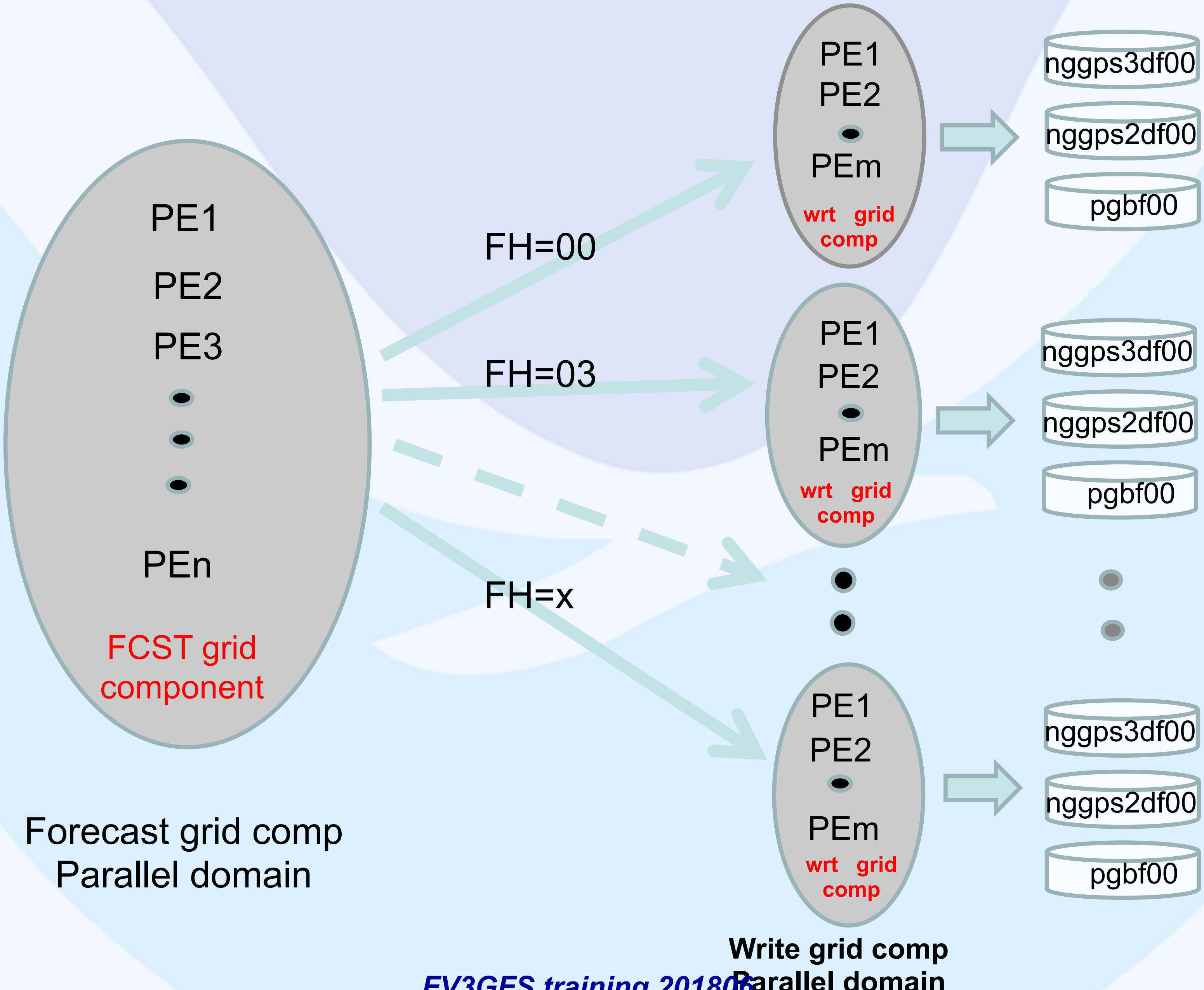
- Asynchronized IO is implemented through the write grid component: to release forecast from IO related work, to process forecast data and to write out forecast results.

- The data transferred to write grid component is in ESMF field, a self-describing data representation. It allows write grid component to perform independent data process without inquiring information from forecast component.

- The data transferred to write grid component can be on different grids from forecast grid component. The regridding is conducted through ESMF regridding function call. The weights for regridding is computed once in the initialization step.

- Inline POST processing and other down stream processes can be called on write grid component besides outputting history files.

Parallelization of NEMS FV3 write grid component



Current output capabilities in NEMSfv3gfs

- Without write grid component, FV3 outputs history files in native cubed sphere grid in tiles, one file for each tile in NetCDF format with all the output time.

- With write grid component:
  - ❑ global:
    - History files in global cubed sphere grid in six tiles, one file per tile in netcdf format at specific output time
    - History files in global Gaussian grid, one file for global at specific output time
      - Output in NetCDF format
      - Output in nemsio format
  - ❑ Regional:
    - History files on standalone regional domain on rotated lat-lon grid in NetCDF format

Output history files in cubed sphere grid using write grid comp

- Set up write grid comp
  - Forecast grid component is created. Cubed sphere grid is created in forecast grid component, ESMF field bundles are created and filled up with ESMF fields in fv3 dynamics and gfsphysics. These field bundles are attached to the export state of the forecast grid component
  - Cubed sphere grid is defined at write grid comp, the fields bundles from forecast grid comp are mirrored on write grid at write grid component and added in the import state of the write grid component.
  - The field bundle route handles that contain data redistribution information and weight for regridding are stored once in the fv3_cap initialization step.
  - Data are transferred to write grid component using ESMF regridding (data distribution only in this case)
- Write out 6 tiles history files in NetCDF format using ESMF FieldBundle write, results are verified against GFDL write

GFDL write

[0]	--				
[0]	Block	User time	System Time	Total Time	GID
[0]	--				
[0]	ATMOS_INIT	11.8409	0.0000	11.8409	0
[0]	**TOTAL**	**1232.7345**	**0.0000**	**1232.7345**	**0**
[0]	NGGPS_IC	9.3757	0.0000	9.3757	0
[0]	COMM_TOTAL	360.5388	0.0000	360.5388	0
…					
[0]	**FV_DIAG**	**220.8266**	**0.0000**	**220.8266**	**0**

Write grid comp native cubed sphere 6 tile output

[0]	--				
[0]	Block	User time	System Time	Total Time	GID
[0]	--				
[0]	ATMOS_INIT	14.6361	0.0000	14.6361	0
[0]	**TOTAL**	**1044.4040**	**0.0000**	**1044.4040**	**0**
[0]	NGGPS_IC	10.4291	0.0000	10.4291	0
[0]	COMM_TOTAL	321.4978	0.0000	321.4978	0
…					
[0]	**FV_DIAG**	**20.6646**	**0.0000**	**20.6646**	**0**

C768, 1 day hourly output, 64+6nodes, 2*96 for write grid comp, on theia

Output history files on other grids

- Gaussian grid/(rotated) lat lon is set up on write grid component, the fields bundles from forecast grid are now mirrored on Gaussian grid on write grid component and added in the import state of the write grid component.

- Data are interpolated and transferred to write grid component on global domain using ESMF regridding function.

- The data are written out in nemsio format sequentially.

- The data can be written out in NetCDF files using ESMF fieldbundle parallel write or using regular sequential write

Configuration for write grid component

- The setting for write grid component is in model configuration file: model_configure

quilting:	.true.	! turn on write grid component
write_groups:	1	! the number of write groups
write_tasks_per_group:	6	! write tasks in each write group
num_files:	2	! number of output files
filename_base:	'dyn' 'phy‘	! Output file names
output_grid:	'gaussian_grid‘	! Output grid
write_nemsiofile:	.true.	! Output nemsio file, .false.-> NetCDF
write_nemsioflip:	.true.	! Flip to N->S and B->T
imo:	384	! Number of points in Gaussian/latlon ! grid I direction
jmo:	190	! Number of points in j direction for !Gaussian/latlon grid

Interpolation methods for regridding

- Regridding interpolation method is critical to the quality of output data.

- Interpolation methods used in dynamics fields :
  - Bilinear interpolation:
    - 3D fields: temperature, tracers, delp, delz, dzdt
    - 2D field: hgtsfc
  - Vector bilinear interpolation:
    - 3D fields: ugrd, vgrd
  - Bilinear interpolation variation:
    - 2D fields: pressfc, interpolated through (P/P0)**(rd/g*LapseRate)

Interpolation methods for regridding (cont.)

- Interpolation methods used in physics fields :
  - Nearest neighbor interpolation:
    - All the surface related fields such as land sea mask, soil type, veg type etc
  - Bilinear interpolation:
    - radiation fields:
    - precip field
    - 2m temperature/specific humidity
  - Vector interpolation:
    - wind fields: u10/v10, ugrd/vgrd at lowest model layer

Implementation of interpolation methods in write grid component

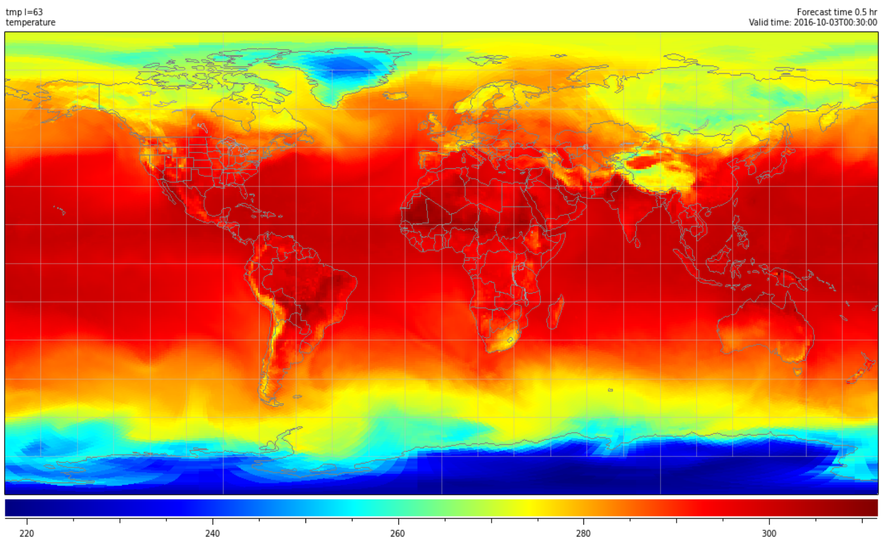
- **Vector interpolation**
  - wind components are used to form the wind vector in 3D Cartesian, the 3D Cartesian wind vector are regridded to Gaussian grid, and then the wind vector is projected back to the local directions on the new grid.

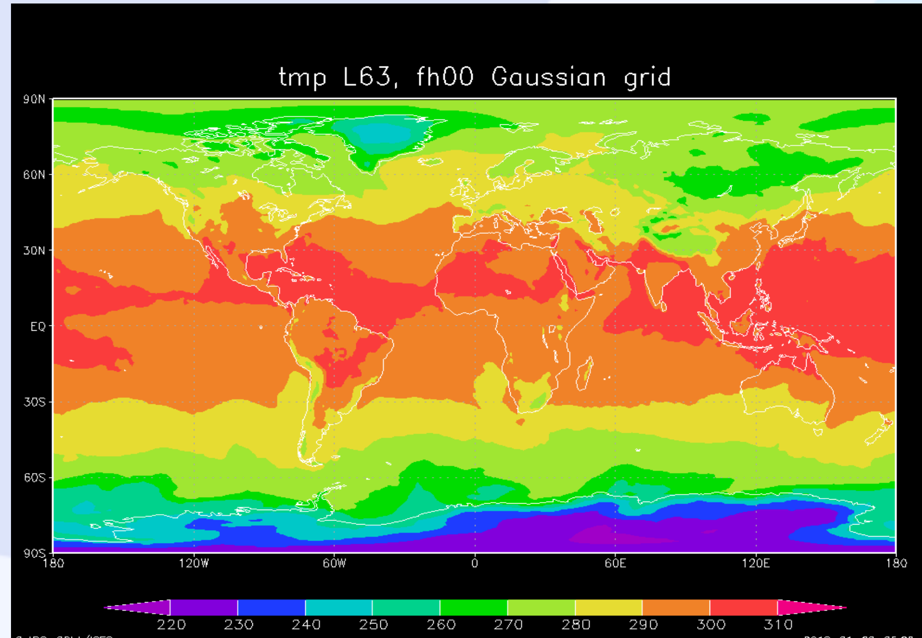
- **Bilinear interpolation variation**

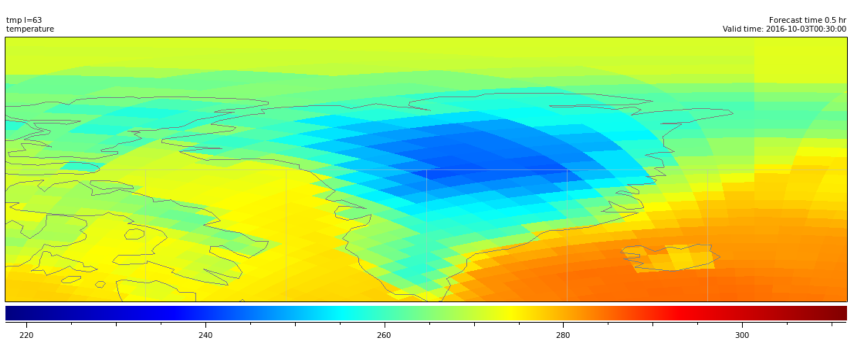
  - Surface pressure is implemented as pseudo surface pressure field using constant lapse rate in the forecast grid comp, and then recovered as surface pressure on write grid comp

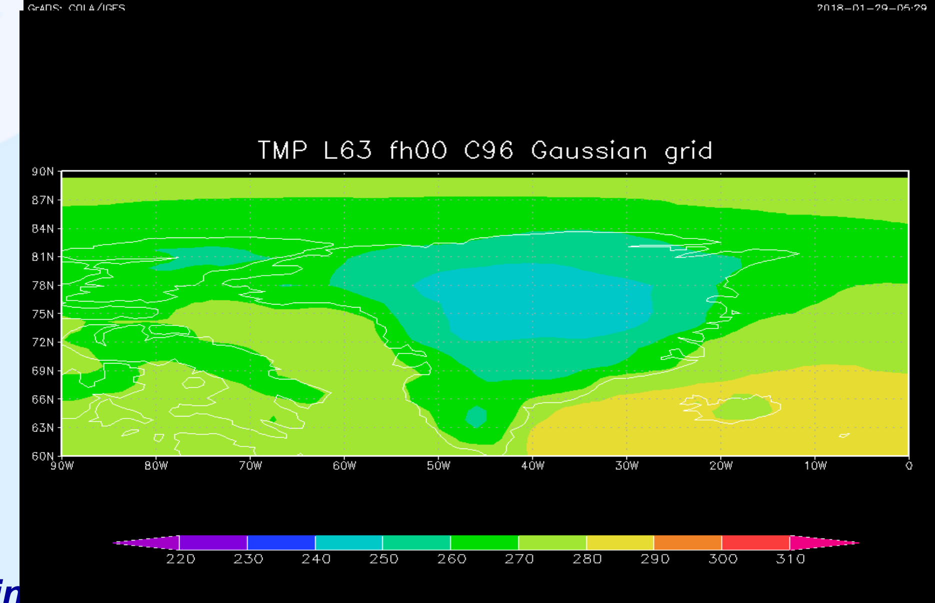
- **Different interpolation methods in physical files**
  - Fields from operational physics files are divided into two categories according to the required interpolation methods. Two field bundles are created, they are be output to a single physics file.

Bilinear interpolation: temperature









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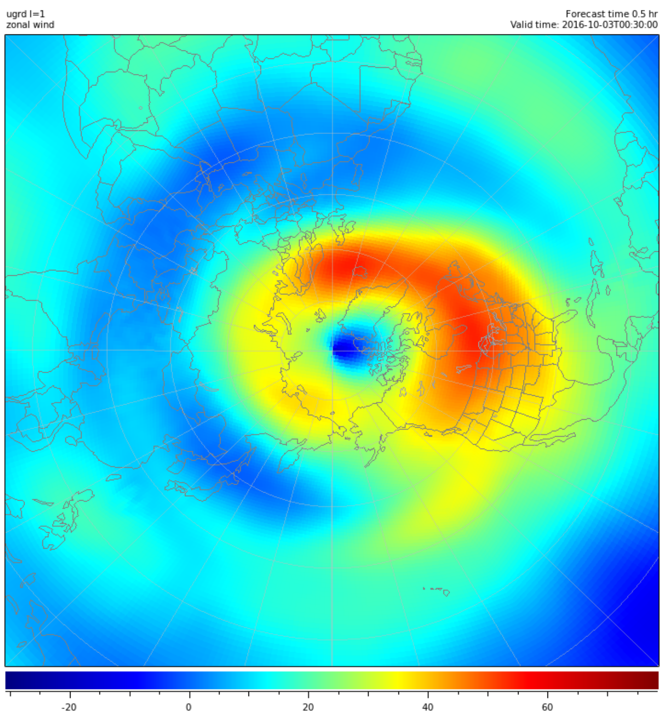
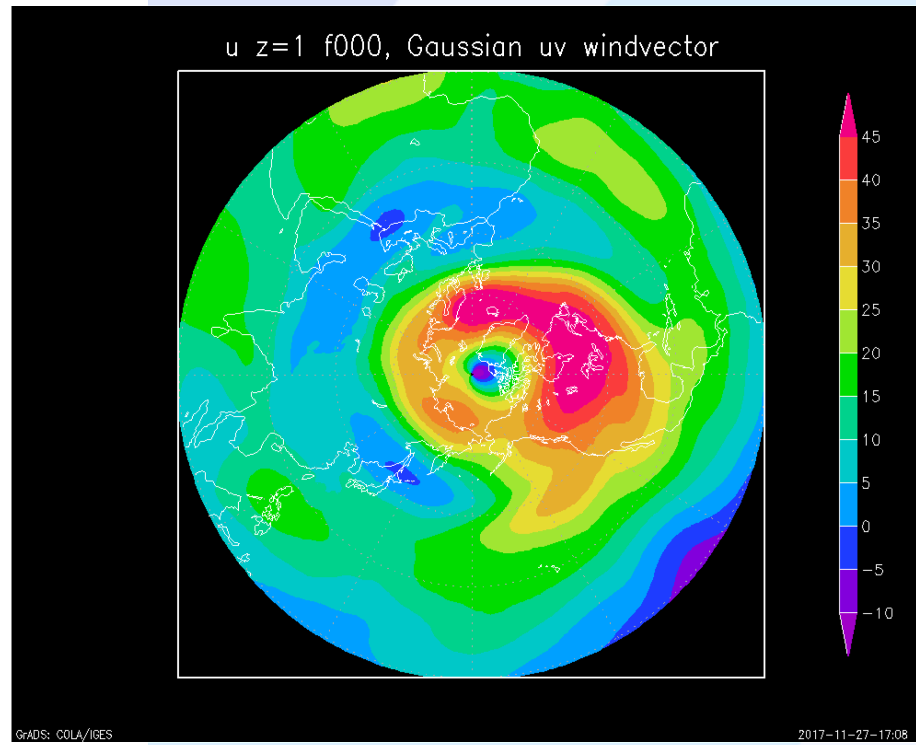
Full wind vector interpolation

U on native cubed-sphere grid
-Cubed sphere to cubed sphere,
No interpolation, no wind vector

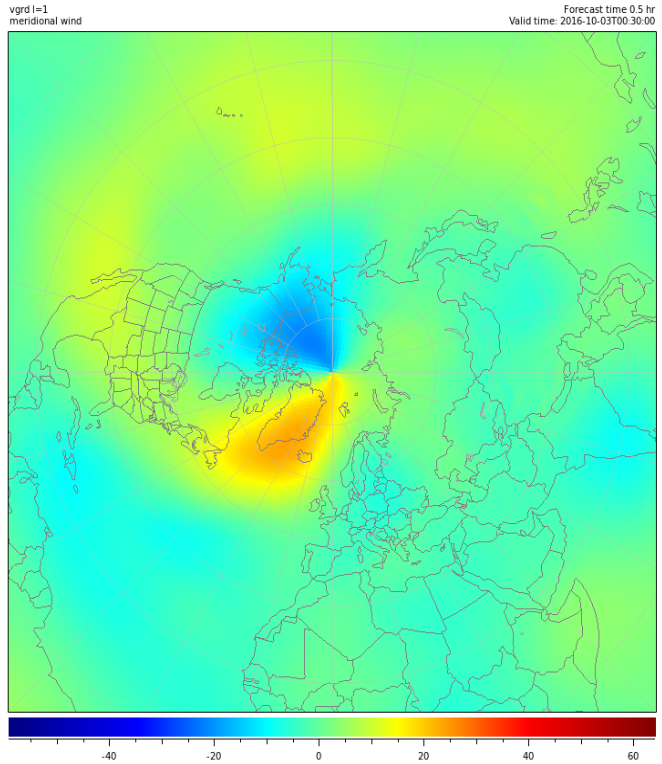
U on Gaussian grid
-Cubed sphere to Gaussian grid
Wind vector bilinear interpolation



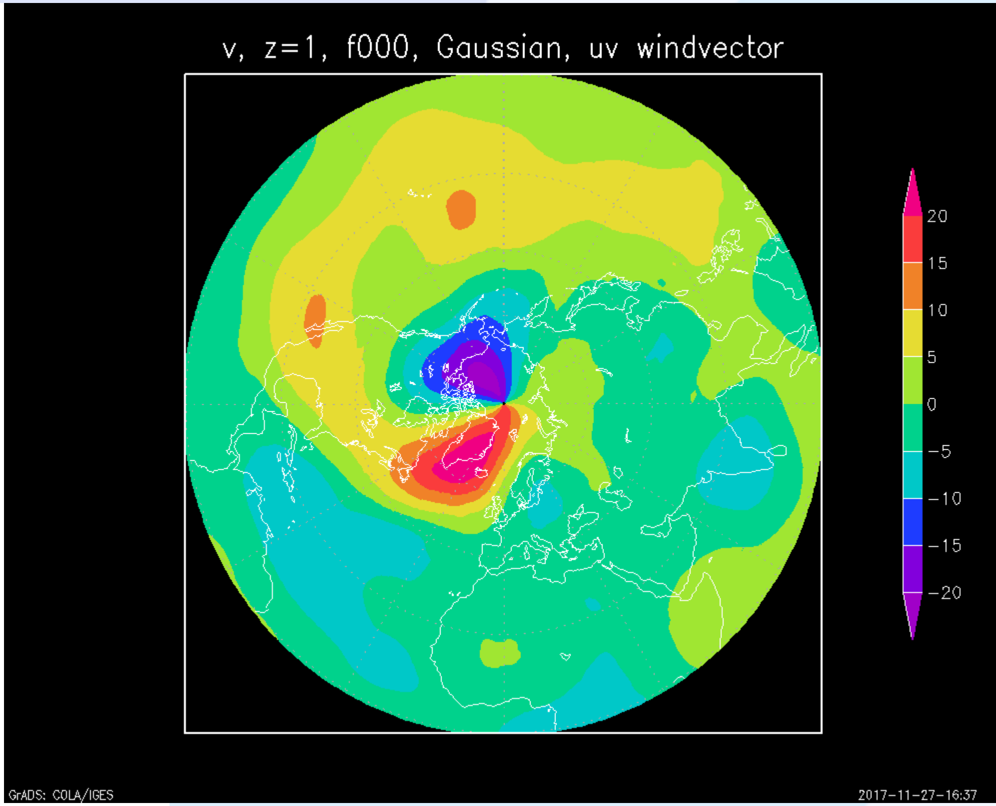


Full wind vector interpolation

V on native cubed-sphere grid
-Cubed sphere to cubed sphere,
-No interpolation, no wind vector

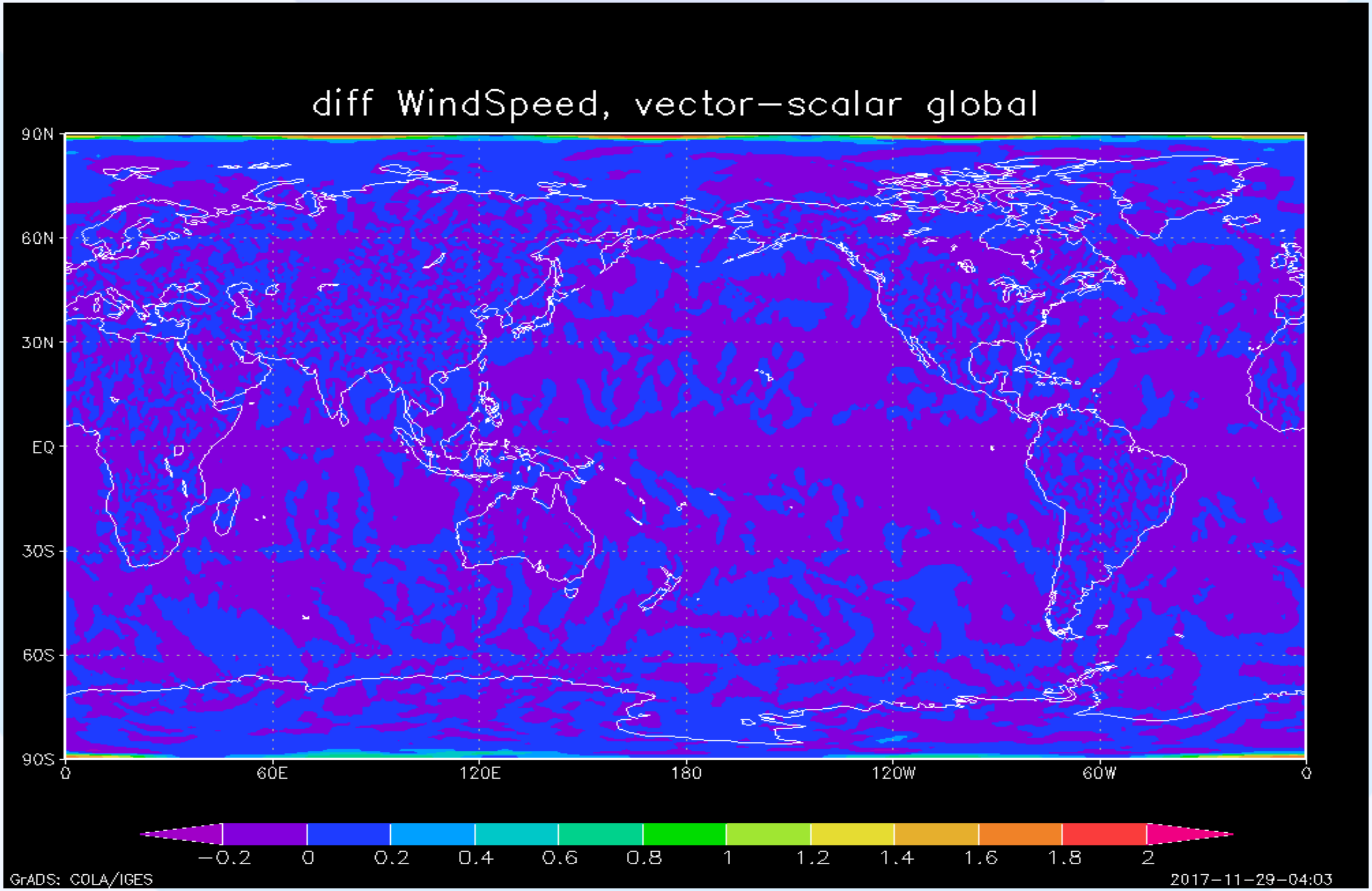


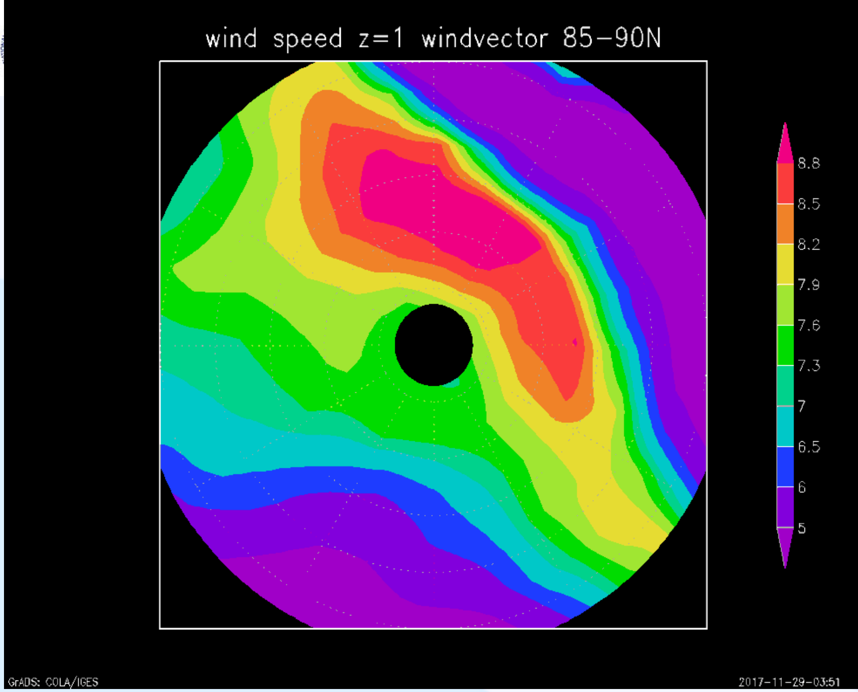
V on Gaussian grid
-Cubed sphere to Gaussian grid
-Wind vector interpolation

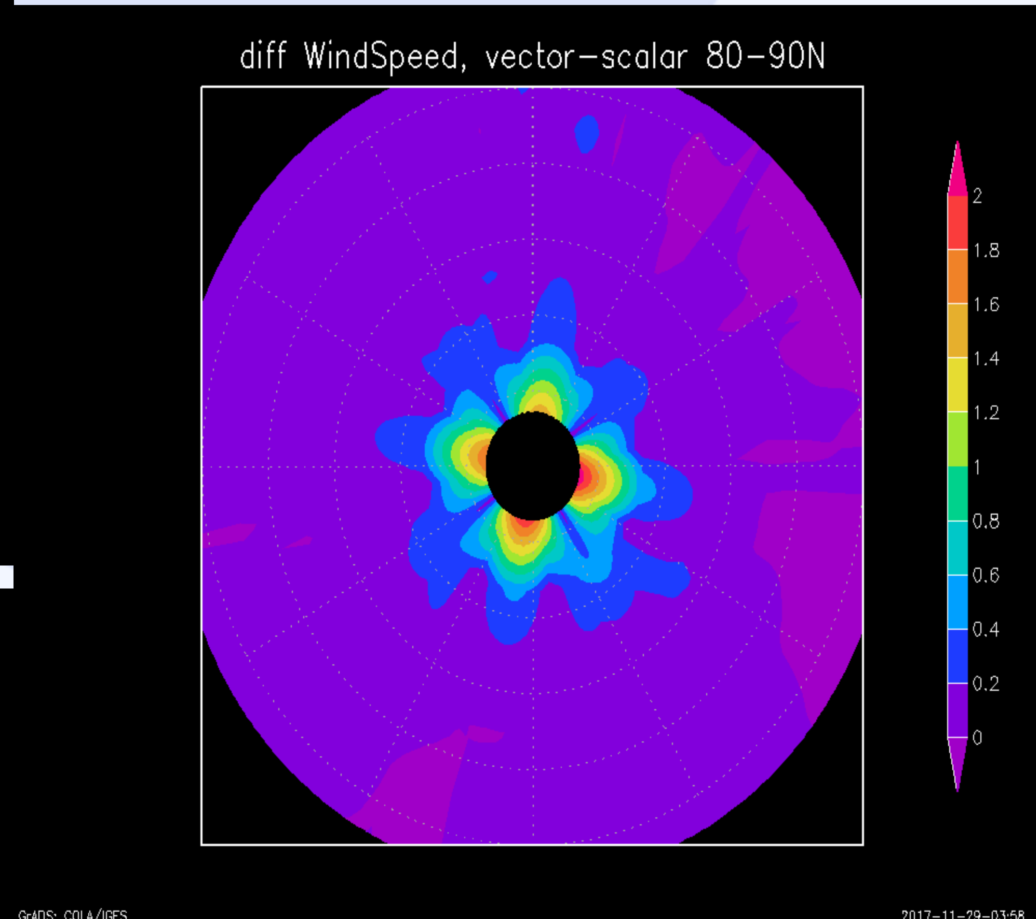


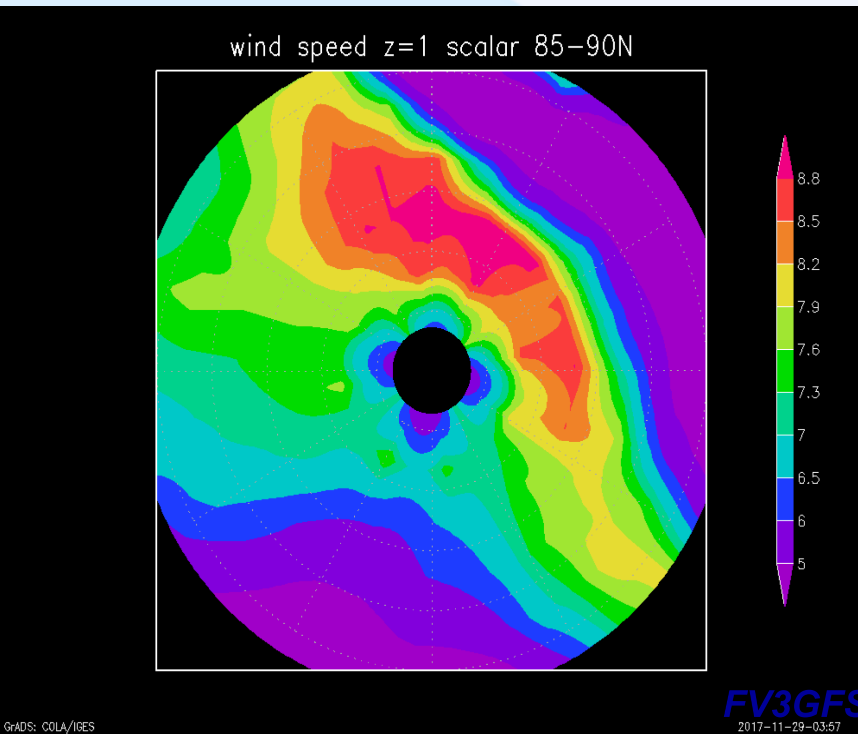
Wind speed difference on Gaussian grid vector interpolation – scalar interpolation

Differences are mainly near poles



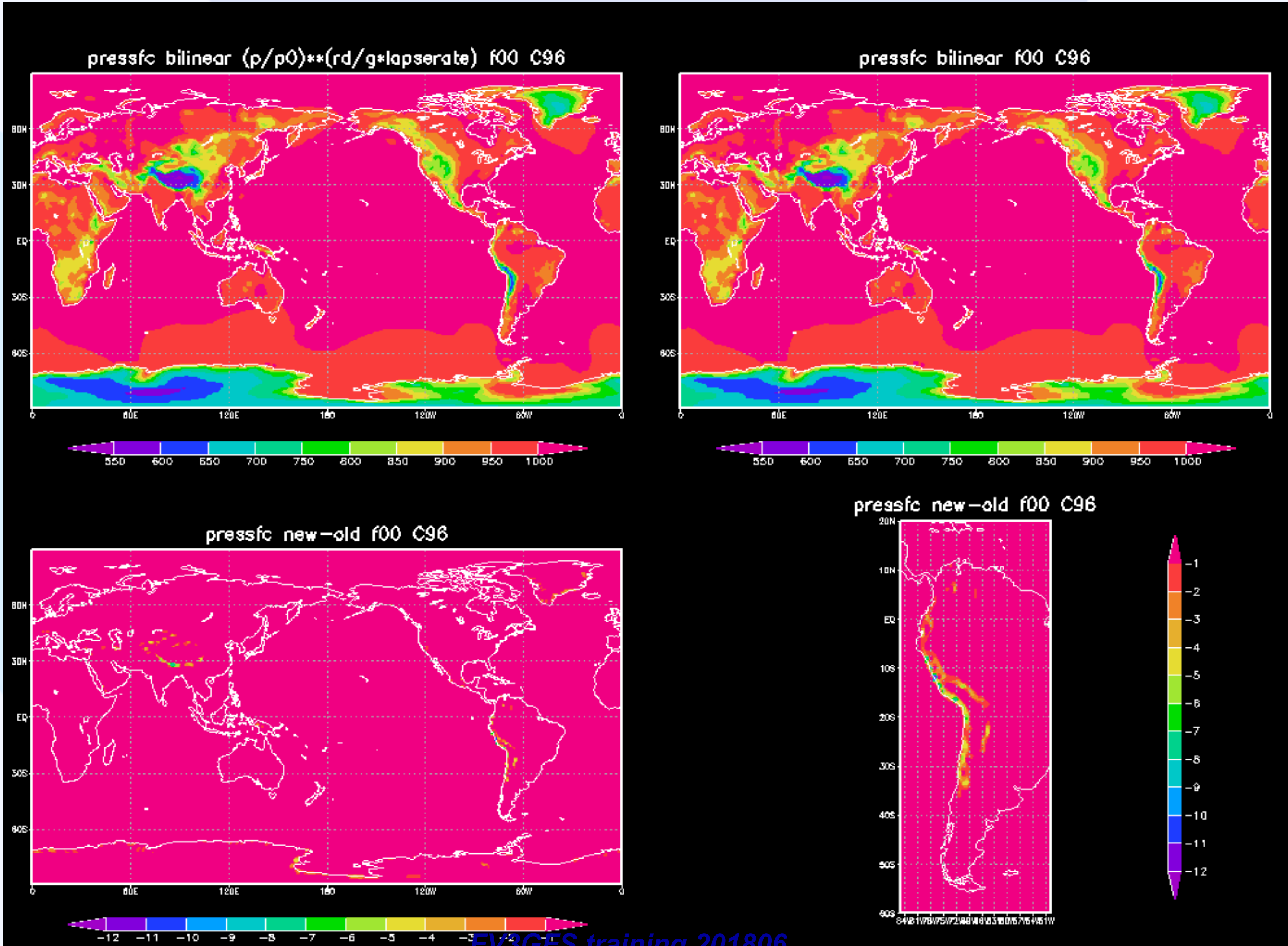




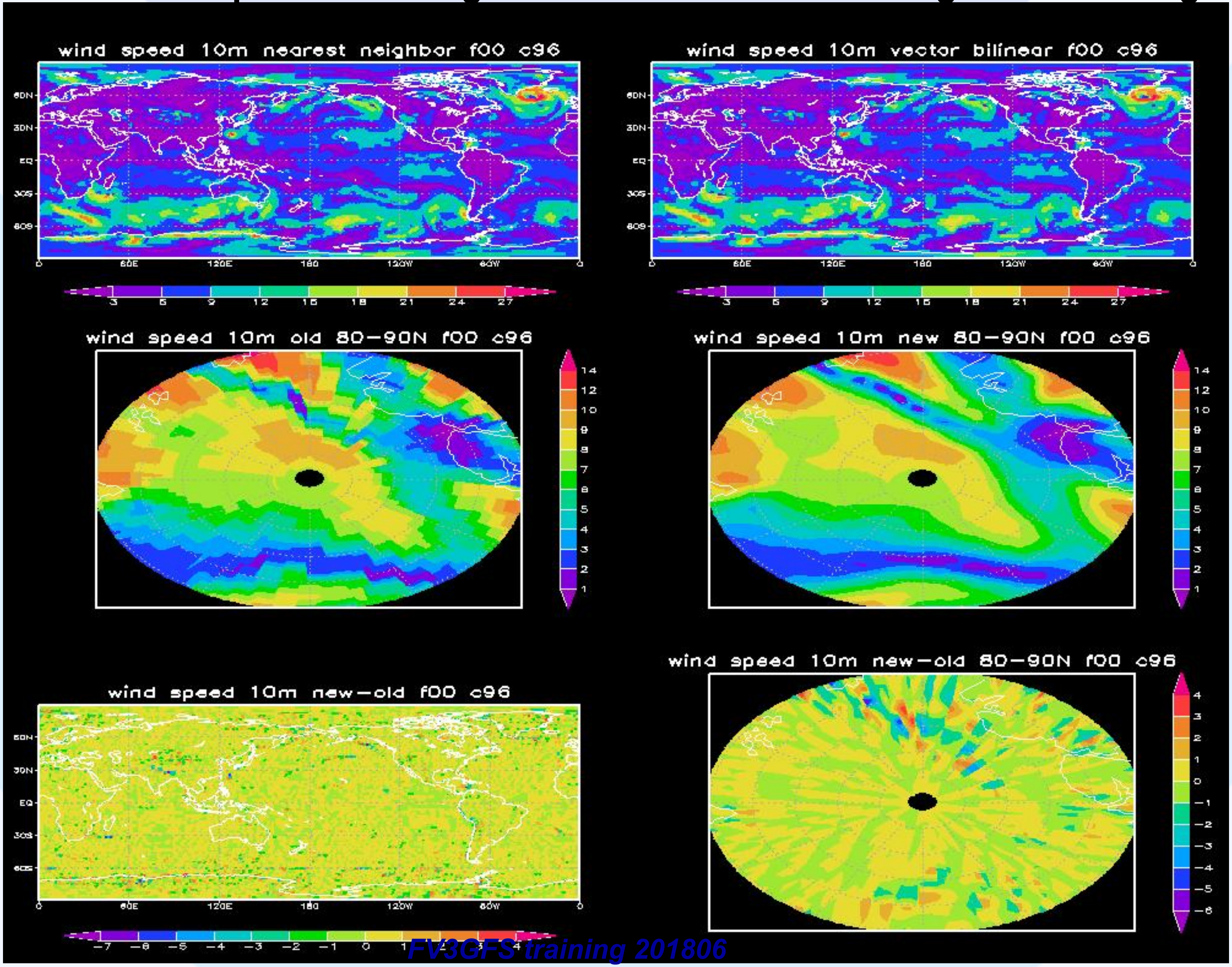


Wind speed from vector interpolation is smoother than the wind speed from scalar, especially near the pole region.

Surface pressure interpolation



10 meter wind interpolated through vector bilinear and through nearest neighbor



Work plan for write grid comp

- For the upcoming FY2019 NEMSfv3gfs implementation, model history files stay on global Gaussian grid in nemsio format.
  - Generating operational like nemsio files allows minimal code changes in the GFS downstream jobs such as GSI, POST-Processing, hurricane relocation, regional models that use GFS as lateral boundary condition
  - It allows down stream applications to evaluate model results from appropriated ESMF regridding methods

- For future global NEMSfv3gfs or regional FV3 implementation, history files on NetCDF format are under consideration
  - Sample NetCDF files will be provided to downstream applications to develop NetCDF interface
  - All the GFS downstream jobs will be able to ingest NetCDF file before the implementation

Ongoing work

- Other Interpolation methods for regridding forecast fields from cubed sphere grid to Gaussian/latlon grid
  - "Conserve" interpolation method may need to be considered for radiation flux fields.
  - Masks need to be applied the masked fields during interpolation
- Setting up write grid component on nested grid
- Implement Fortran streamIO will be implemented to write out nemsio files to improve output efficiency.

Future work on write grid component

- Inline post and potential other down stream job
- Flexibility of writing out different output resolution at frequency during forecast integration
- IO bottleneck in fv3 write grid component
  - Preliminary tests show the scalability issue with the write grid component. With more cores are required to run forecast integration, a scalable IO approach needs to be explored

Thank you!