NCAR UCAR HAO sun earth connections

WACCM-X Recent Development

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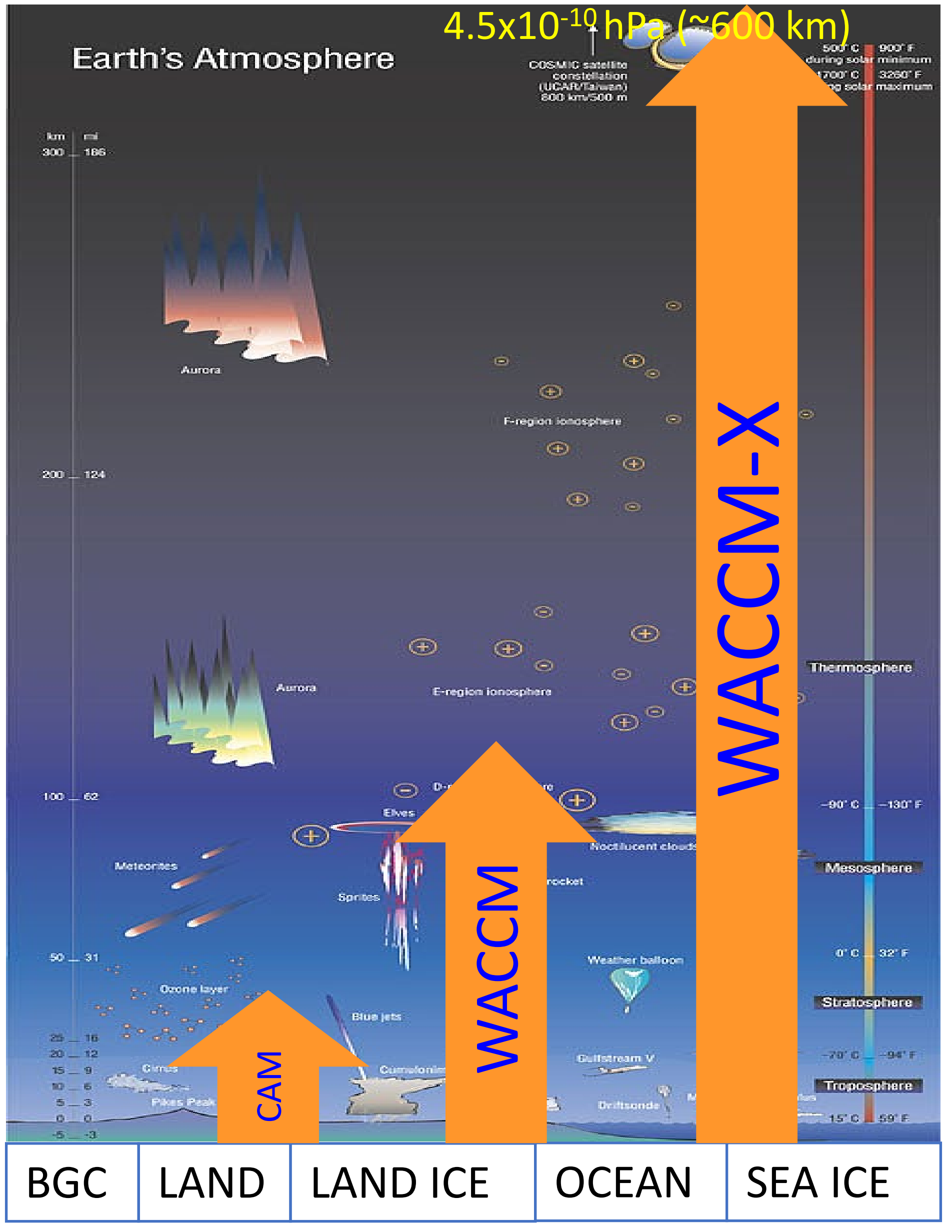
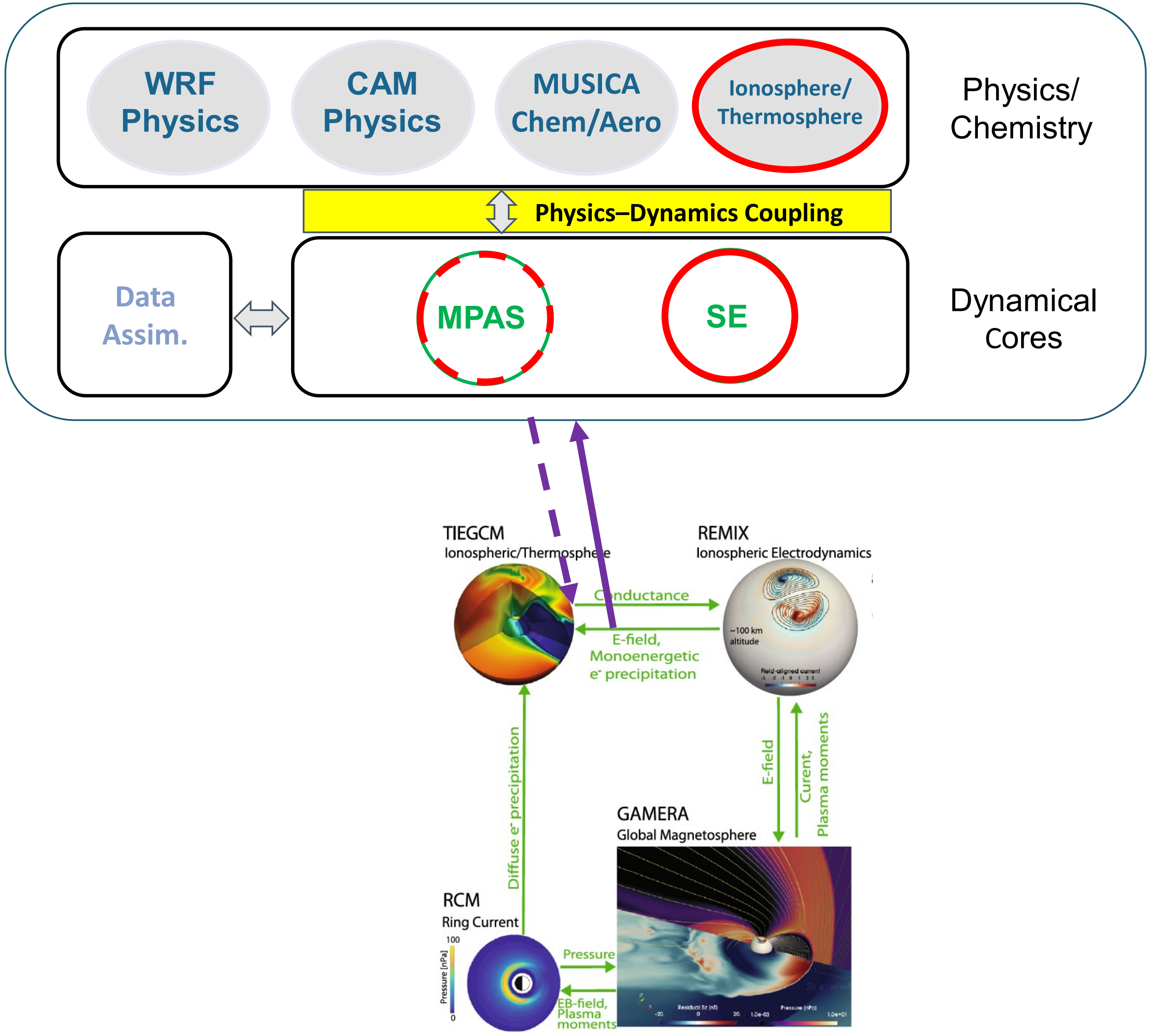
CESM Working Group Meeting, 13 February 2024, Boulder, CO

CESM/WACCM-X, SIMA-Geospace, and Whole Geospace Model





Multiscale Atmosphere-Geospace Environment (MAGE) Model

Major CESM WACCM/WACCM-X Components

Model Framework	Chemistry	Neutral Atm. Physics	Ionosphere Physics	Resolution
Atmosphere component of NCAR Community Earth System Model (CESM) Extension of the NCAR Community Atmosphere Model (CAM) Finite Volume Dynamical Core (modified to consider species dependent Cp, R, m) Species Dependent Spectral Element (SE) Dynamical Core MPAS-A Regridding scheme	MA/Ion Chemistry (~100 species) Fully-interactive with dynamics.	Long wave/short wave/EUV RRTMG IR cooling (LTE/non-LTE) Modal Aerosol (CARMA) Convection, precip., and cloud param. (CLUBB) Parameterized GW Major/minor species diffusion (+UBC) Horizontal/Vertical molecular viscosity and thermal conductivity (+UBC) Species dependent Cp, R, m.	Parameterized electric field at high latitude. IGRF geomagnetic field. Auroral processes, ion drag and Joule heating Ion/electron energy equations Ambipolar diffusion Ion/electron transport Ionospheric dynamo Coupling with plasmasphere, magnetosphere	Horizontal: 1.9° x 2.5° 0.9° x 1.25° 0.47° x 0.625° (lat x lon configurable as needed) NE16, 30, 60, 120 120 km Vertical: 70 levels (0-140km) 130, 185, 273 levels (0-~600km)

Species Dependent Spectral Element Dynamical Core

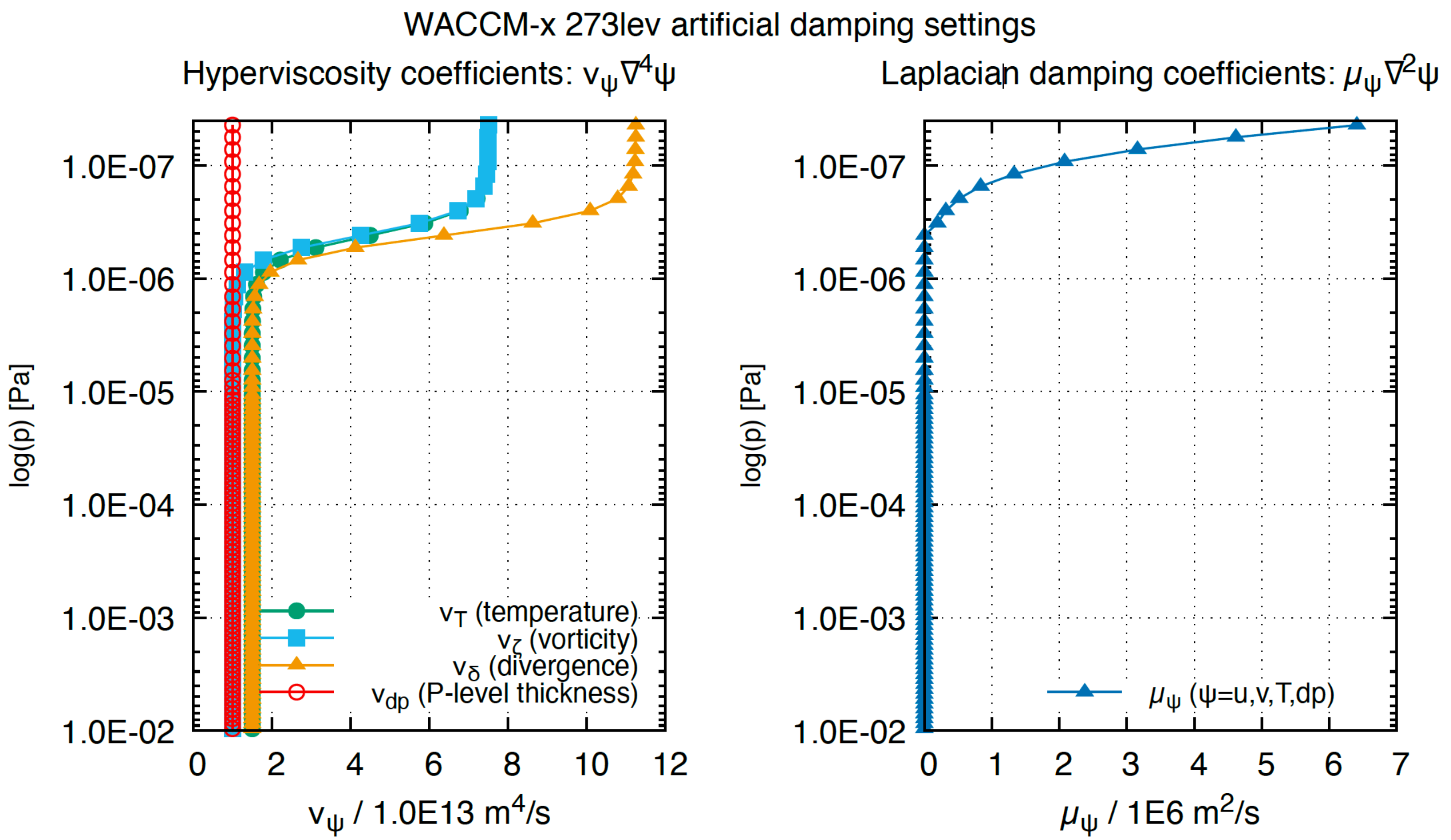
- Based on the standard SE dynamical core in CAM/WACCM
- In the thermosphere dependence of Cp, R and mean molecular weight on major species (O, O2, H and N2) needs to be taken into consideration.
- Generalized formulation and dycore independent implementation.
- Major species transport by CSLAM.
- Pressure gradient formulation (non-Exner) used for momentum equation.
- Temperature used as state variable in energy equation.

Horizontal Molecular Viscosity/Diffusion

- In the ionosphere F-region height (~200 km) the molecular damping time becomes comparable or shorter than the buoyancy frequency for waves with horizontal wavelength ~< 200 km (~4000 km at model top).
- When these waves are resolved it is important to consider horizontal molecular viscosity/diffusion.
- Now taken into consideration in SE dynamical core.
- Explicit scheme and sub-cycling used for the horizontal viscosity/diffusion.

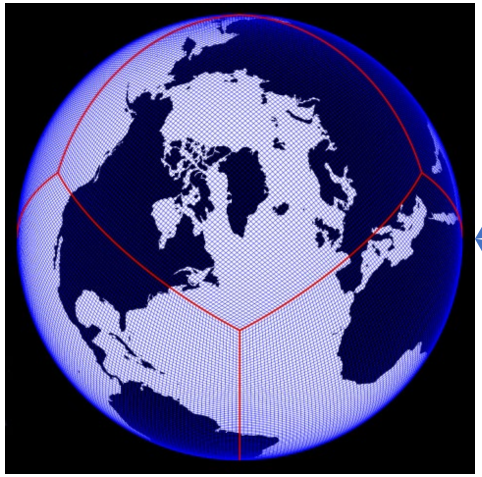
Numerical Damping

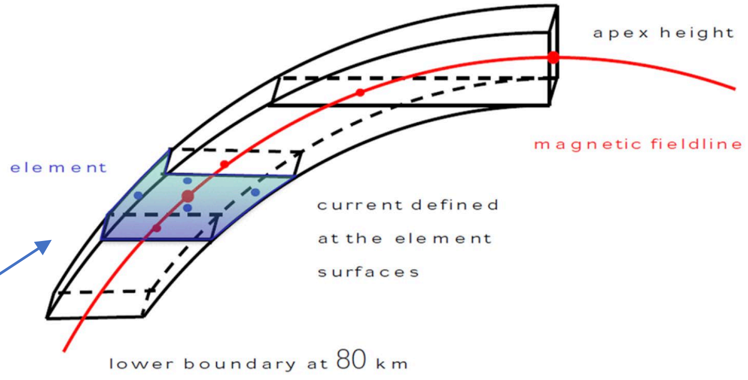
- Second order diffusion (Laplacian) applied to T, v and pressure level thickness and 4th order hyper-diffusion applied to T, divergence, vorticity, and pressure level thickness.

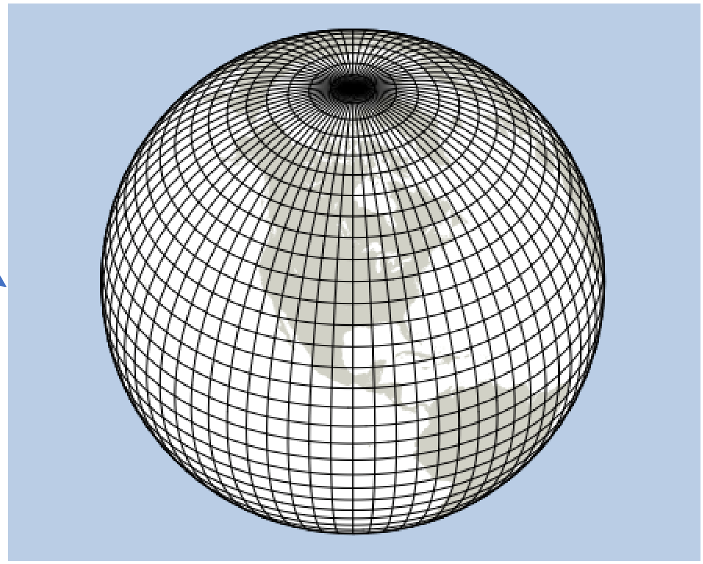


Regridding Scheme

- ESMF-based regridding scheme maps fields between physics mesh and regular/irregular grid.
- Independent of dycore grid.



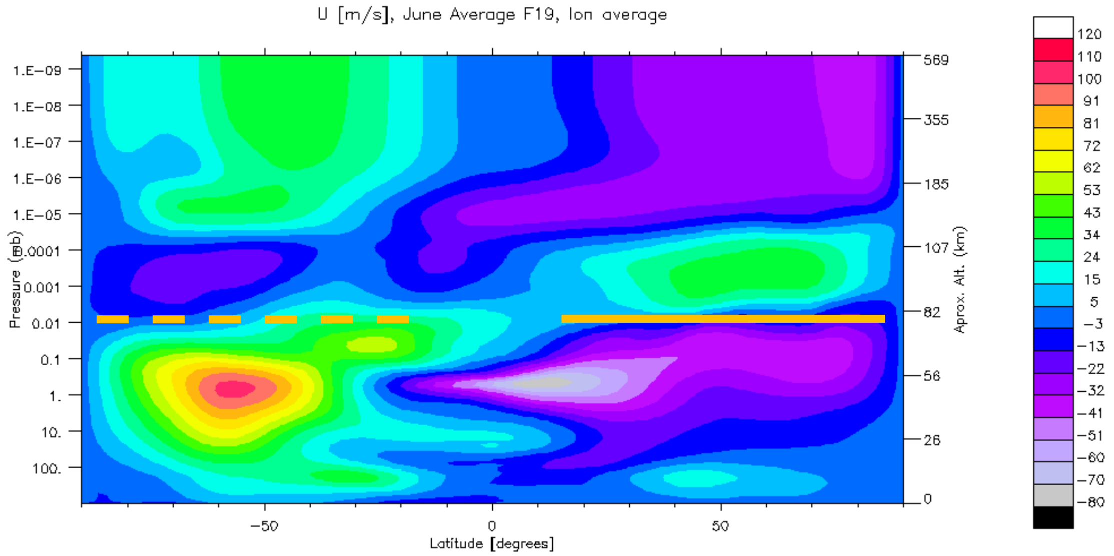


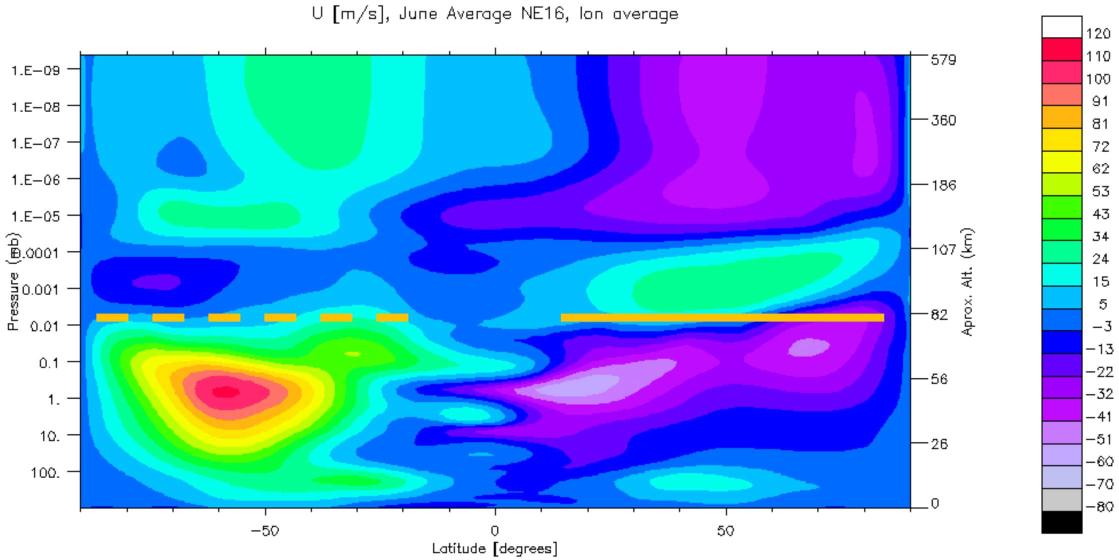


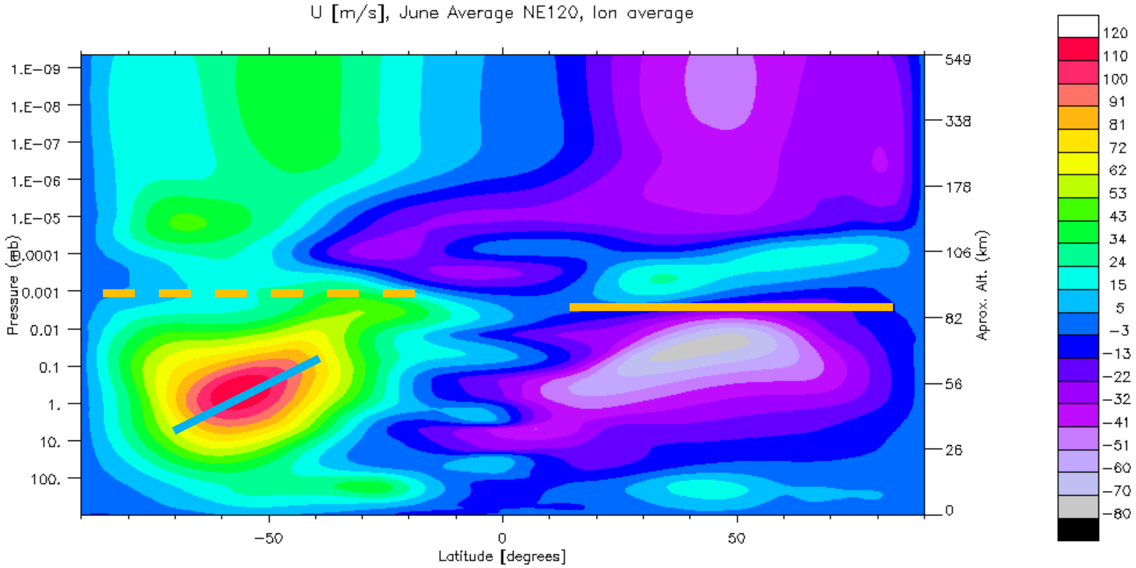
WACCM-X SE Model Resolutions

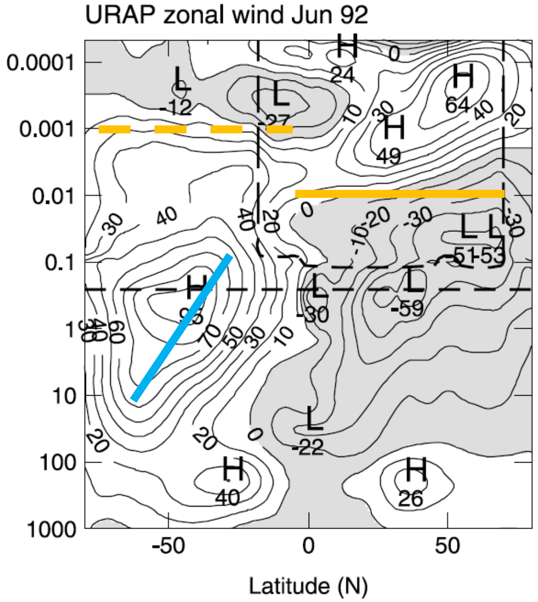
NE16/L130	NE16/L189*	NE30/L130	NE60/L130	NE120/L273
1 model year (FX2000, F10.7=120, Kp=0.33)	Test runs * *Additional troposphere/stratosphere levels.*	Short test runs; WACCM-X/GAMERA storm time for comparison	Short test runs; Specified-dynamics (SD) runs	1 model year Nature run (FX2000, F10.7=120, Kp=0.33); WACCM-X/GAMERA storm time; Hunga-Tonga simulation

Zonal Mean Zonal Wind: June









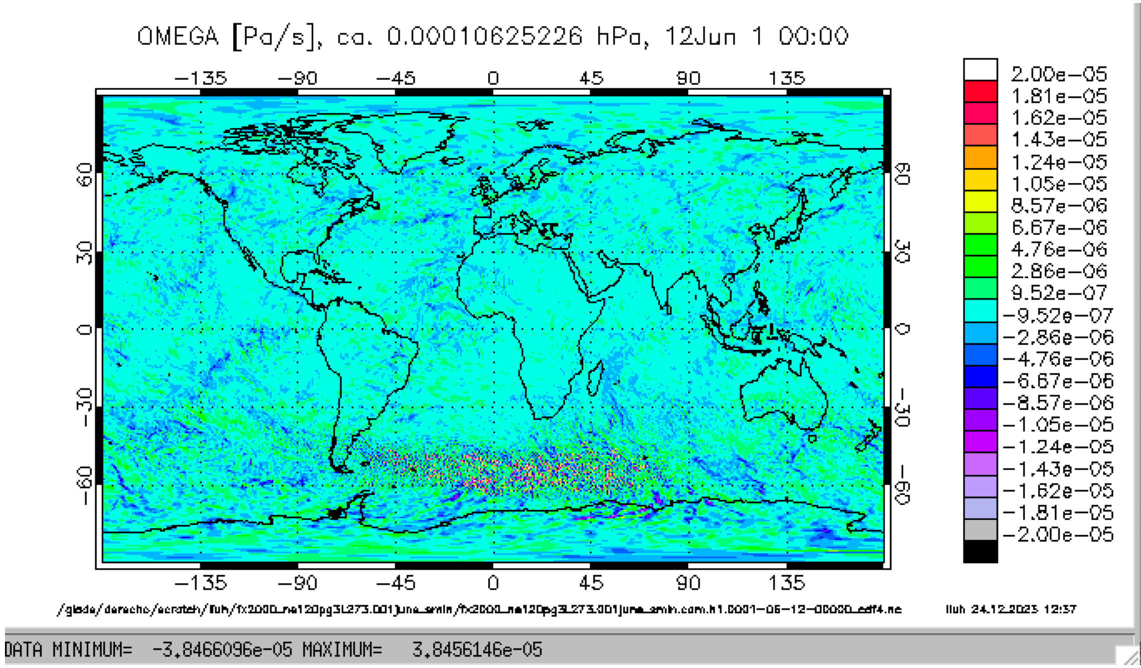
Swinbank & Ortland, 2003

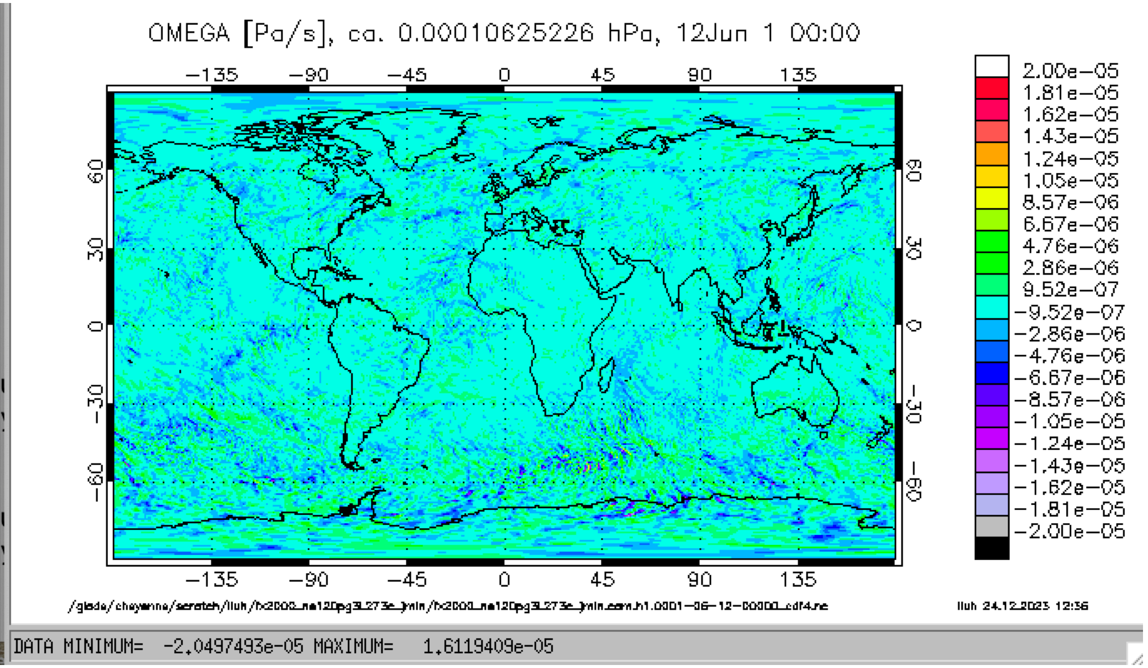
A Few Nice Surprises from Nature Run (Tomorrow)

- Gravity wave distribution from the tropopause to the upper thermosphere in general agreement with observations.
- Stronger tides and tidal wave breaking.
- Better SAO.
- Improved thermosphere composition (O/N2)
- Improved MLT NO, especially in polar night.
- Resolved TIDs with characteristics comparable with observations.
- Mesoscale thermosphere and ionospheric structures.

Special Needs/Issues with High-Resolution WACCM-X

- Large memory footprint
  - Cheyenne: large-memory nodes or under-subscription for regular nodes.
  - Derecho: node under-subscription no longer needed after code optimization.
- More recent tag on derecho has stability issue when run at high-resolution
- Older tag is now running stably on derecho.
- Data serving and issue with Globus

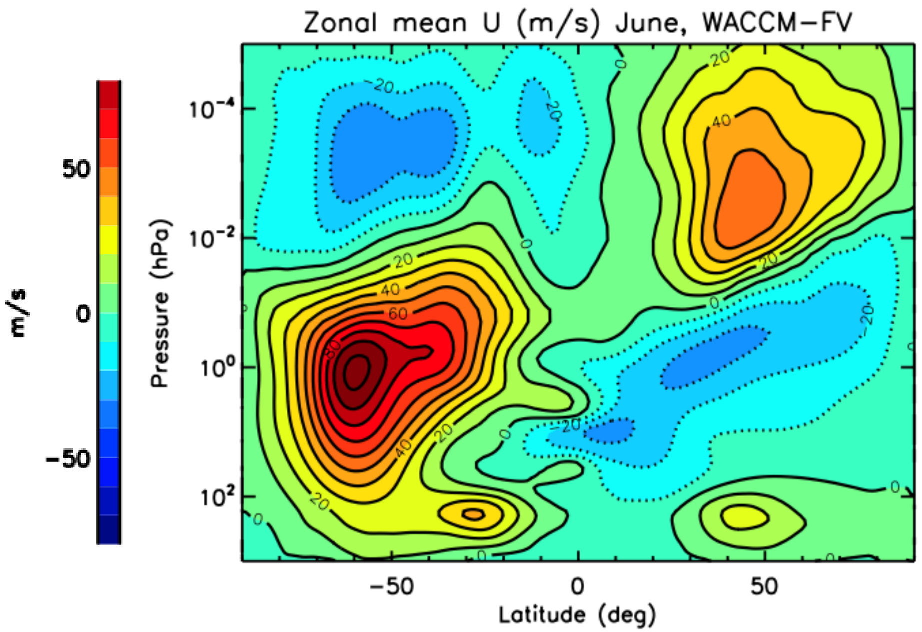




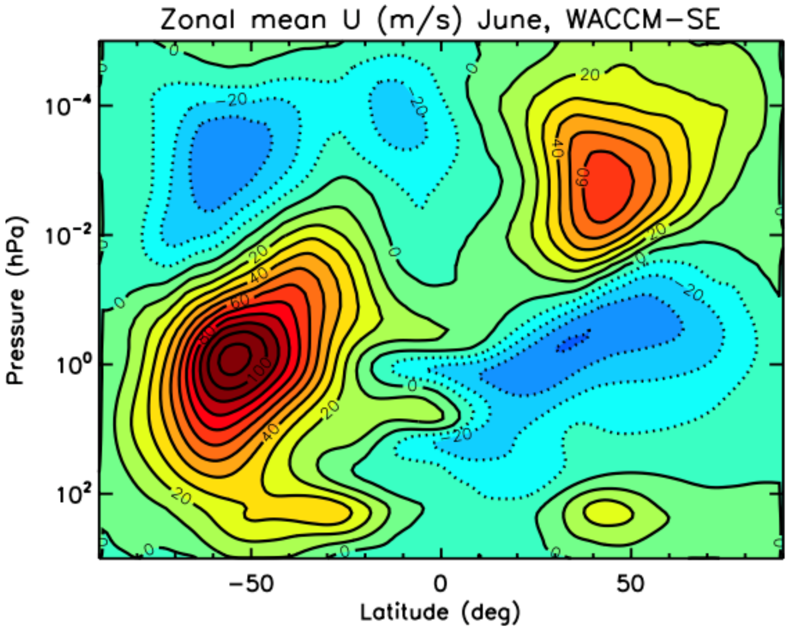
WACCM using MPAS-A

- MPAS-A: Non-hydrostatic dynamical core solved on centroidal Voronoi mesh.
- Finite-volume, C-grid staggering.
- Hybrid terrain-following height vertical coordinate.
- ~120 km horizontal resolution with 70 levels.
- 1 model year simulation with specified chemistry configuration.
- Mean wind and temperature compare well with FV and SE runs with similar resolution.
- Will be further developed for SIMA $S2S^2$ project.

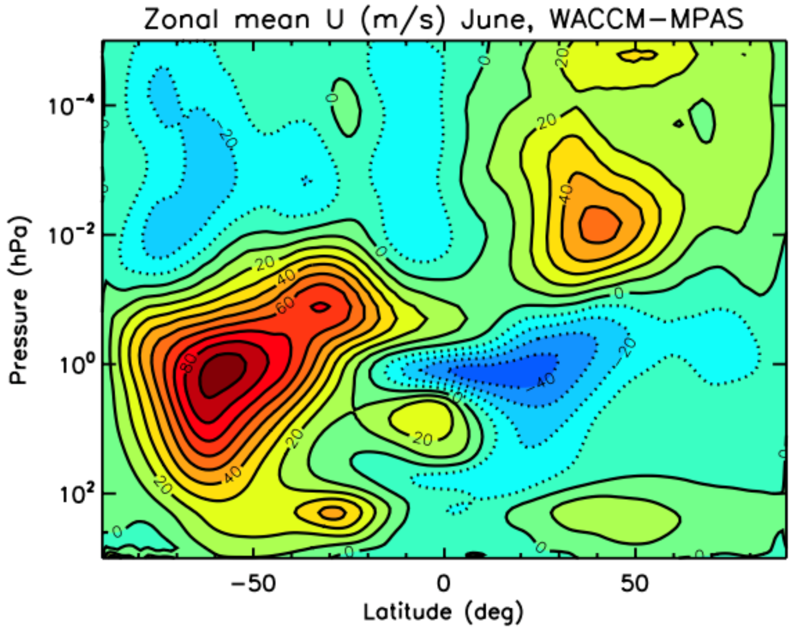
Finite Volume (FV)



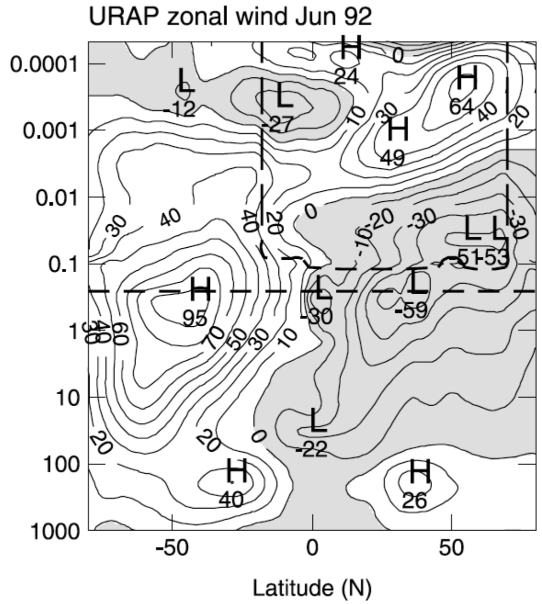
Spectral Element (SE)



MPAS-A



Kamali et al. (submitted)



Swinbank & Ortland, 2003