WACCM-X Coupling with GAMERA

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WACCM-X With Spectral Element Core and New Regridding

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- The new spectral element (SE) dynamical core for NCAR Community Atmosphere Model (CAM) uses cubed-sphere: it is quasi-uniform and there is no grid singularity.
- It needs to be modified to account for species dependent in the thermosphere.
- There is a need for an efficient regridding scheme between the cubed-sphere grid and geomagnetic/IGRF grid for ionosphere electrodynamics.
- Molecular viscosity and thermal conduction in the horizontal direction now included.

Driving WACCM -X with GAMERA

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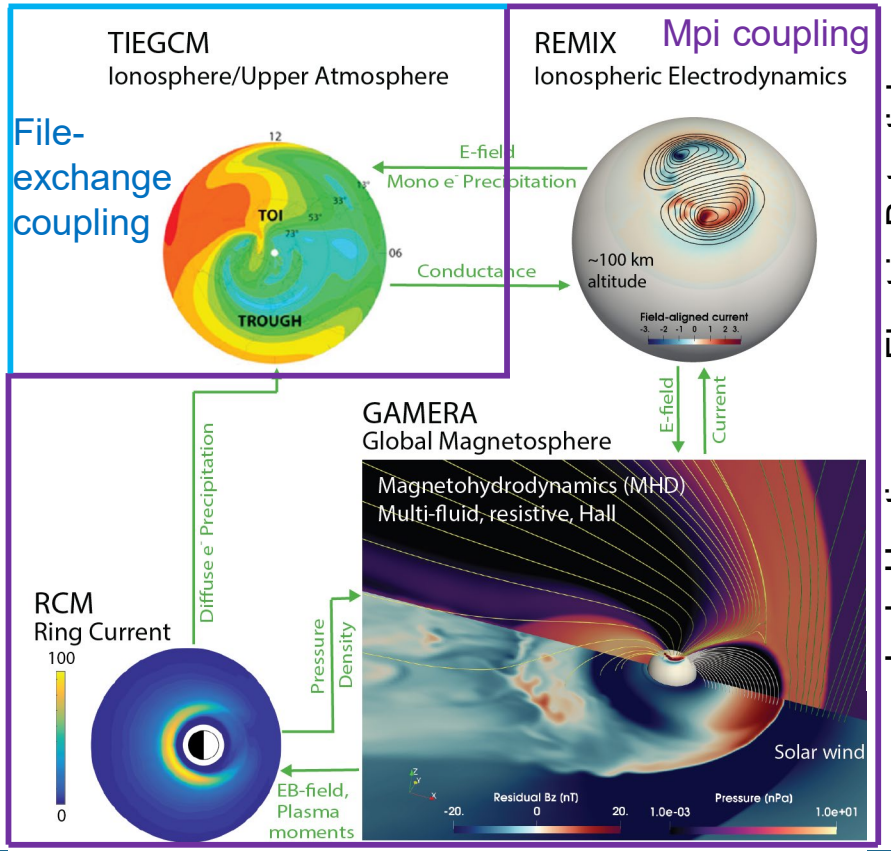
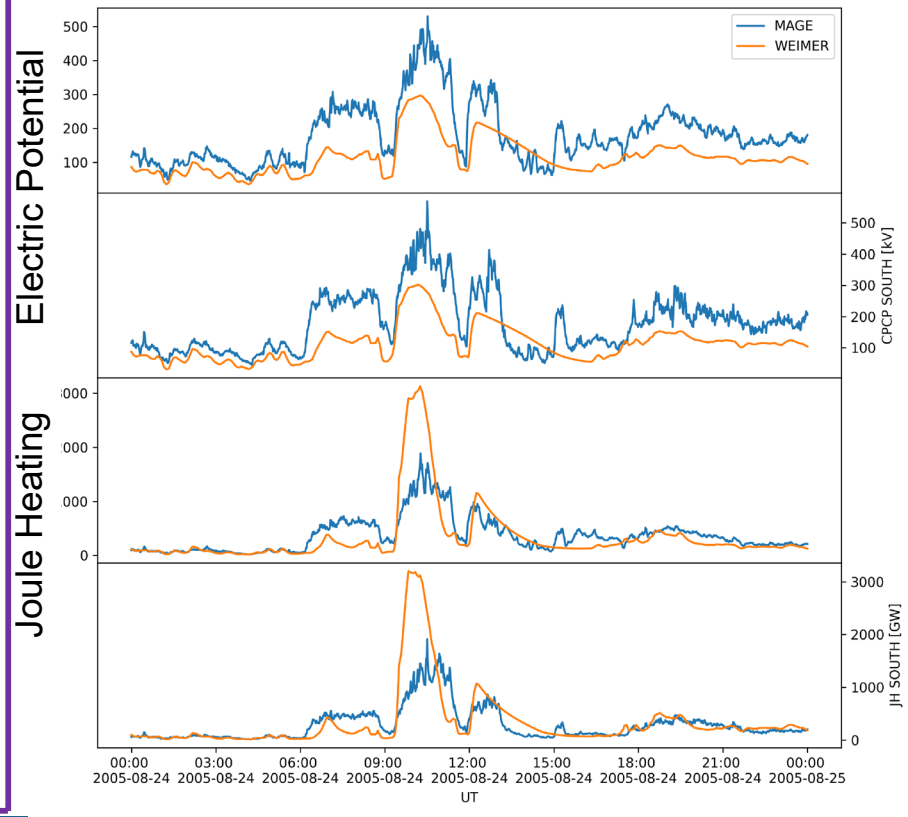
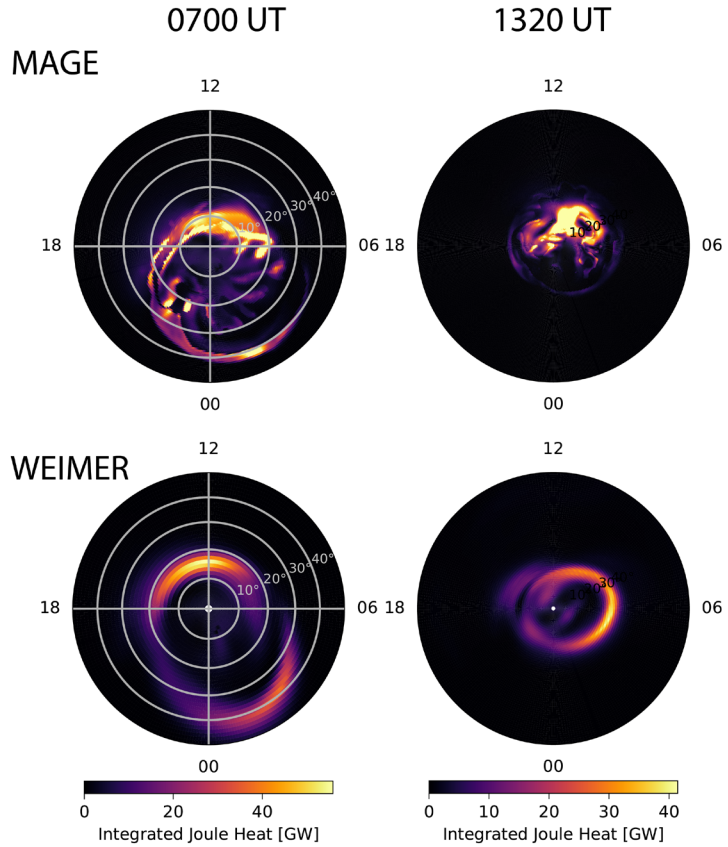
- GAMERA (Grid-Agnostic MHD for Extended Applications, Zhang et al., 2019) is a new magnetosphere MHD code designed with Exascale computing in mind
- WACCM-X and GAMERA coupling is part of the Multiscale Atmosphere -Geospace Environment (MAGE) model system developed by the NASA DRIVE Center: Center for Geospace Storms (CGS, PI: Slava Merkin/JHU/APL)
- Currently one-way coupling from GAMERA to WACCM -X is being tested.
  - Electric potential and energetic particle precipitation at high latitudes in WACCM -X specified by GAMERA at 1-minute cadence.
  - Both WACCM-X FV and WACCM-X SE (with the new regridding scheme) have been tested, and compared with TIEGCM/GAMERA.

Why Couple WACCM -X to GAMERA (MAGE)

- Normally, the high latitude driving is specified by an empirical model (Heelis or Weimer)
- Comparison to MAGE using 1.25° TIEGCM
- Future plan is to replace TIEGCM with WACCM-X in this coupling

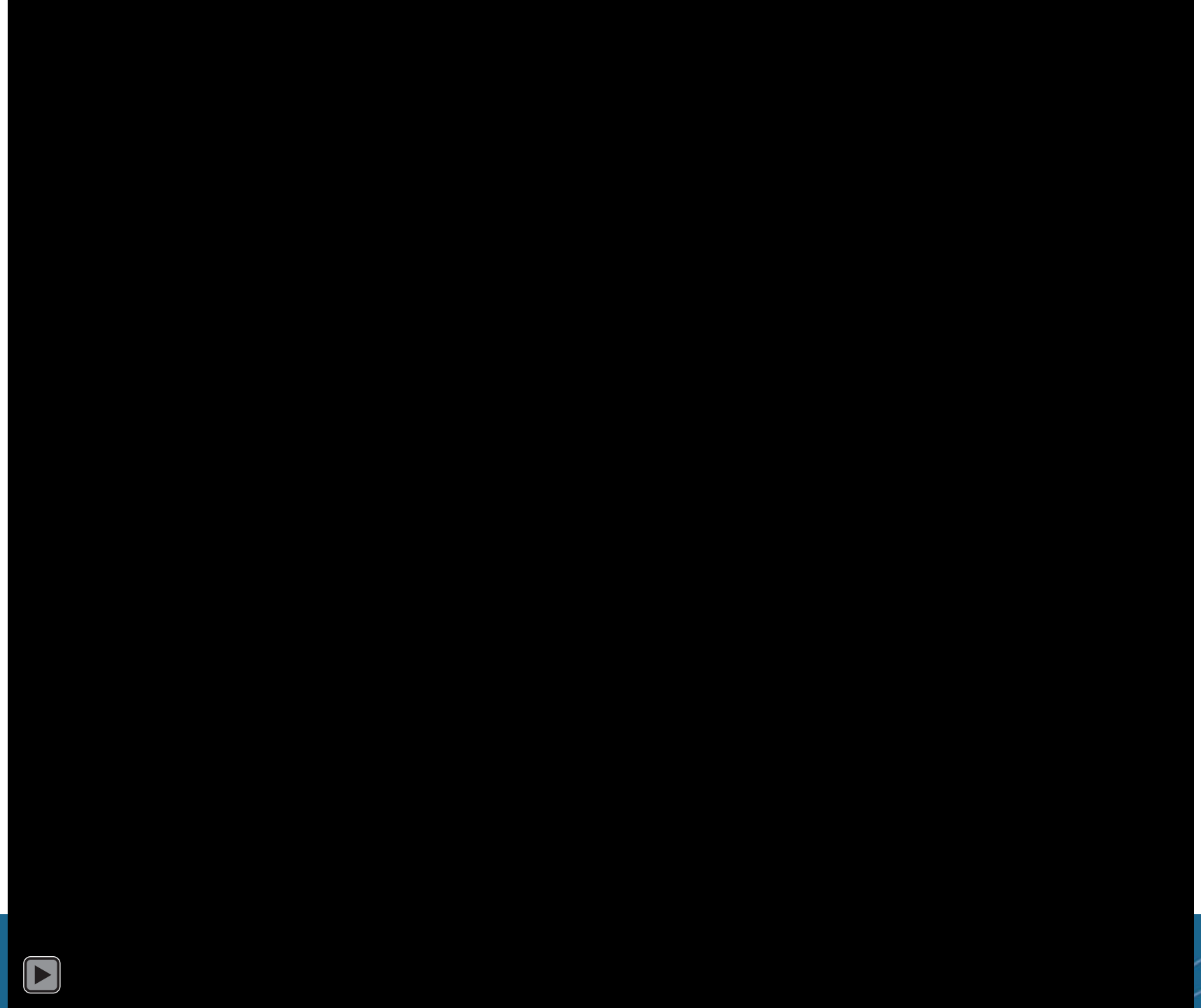




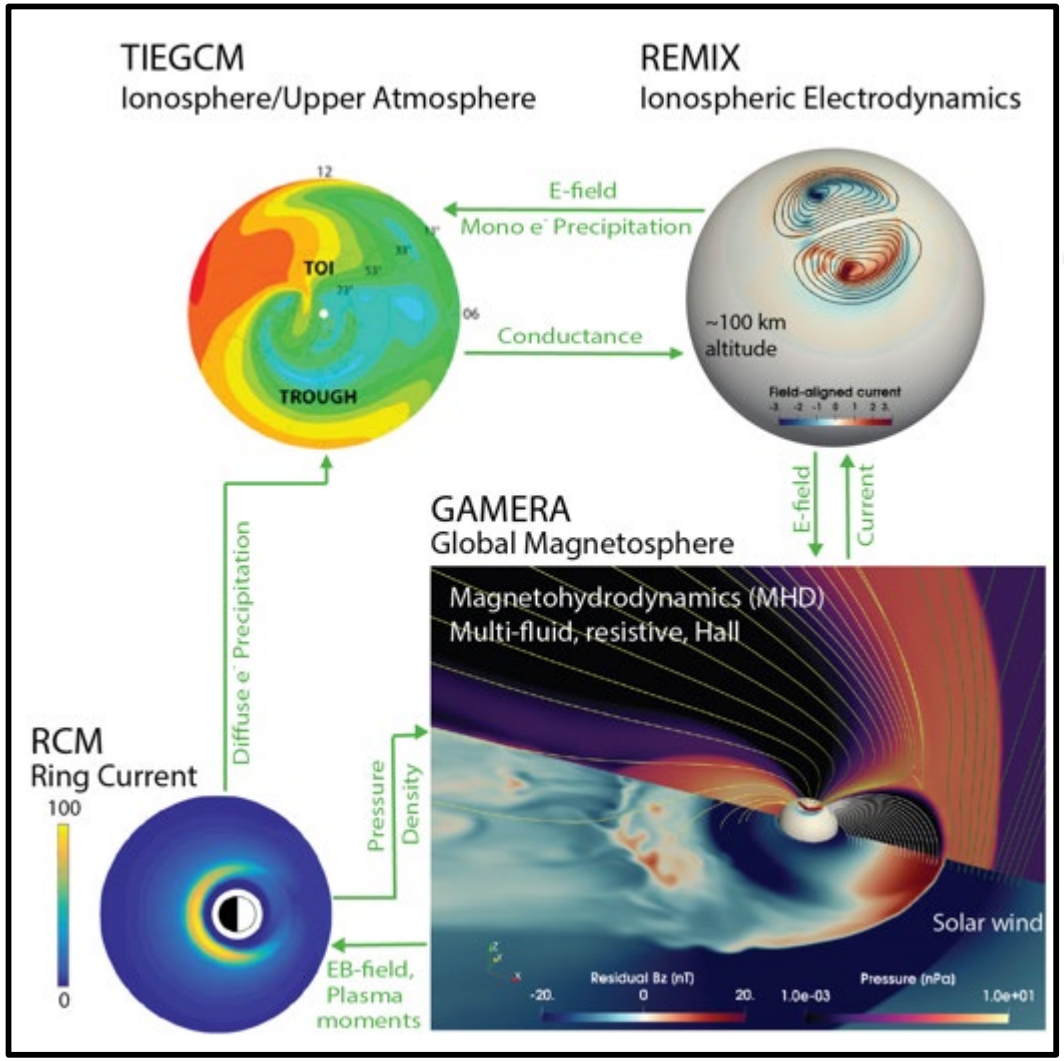


Current Performance

- CHAMP and GRACE at LEO satellites
- Neutral density measurements mapped to 400km
- Comparison to existing coupled model

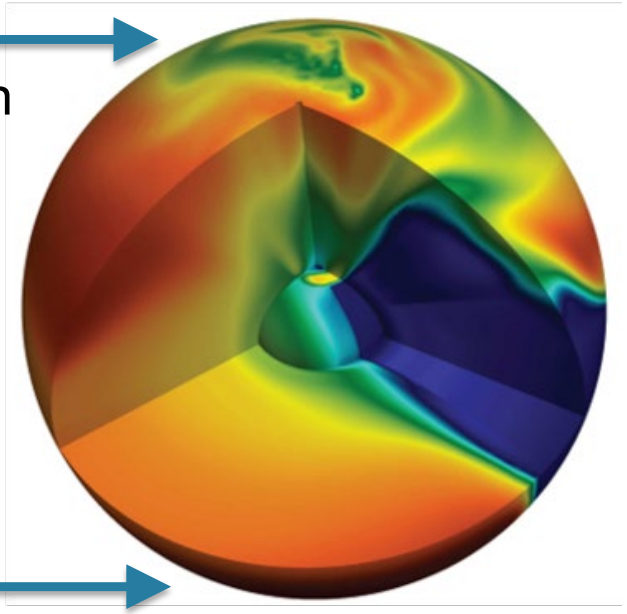


One-way Coupling to WACCM -X



WACCM-X

High Latitude Convection
Electron Precipitation



High Latitude Convection
Electron Precipitation

Aug 24 2005 UT8

High Altitude

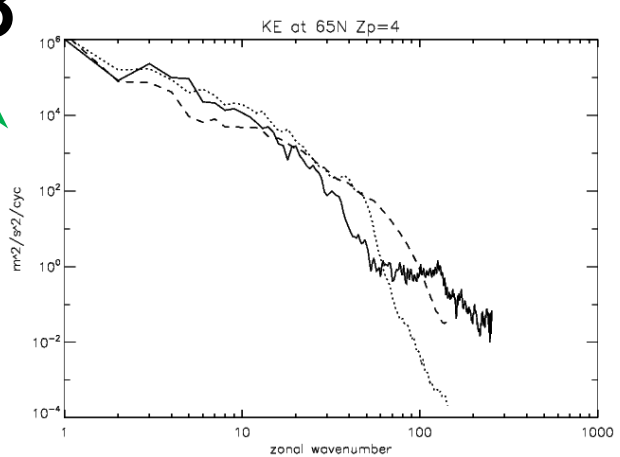
Dotted Line:
····· TIEGCM

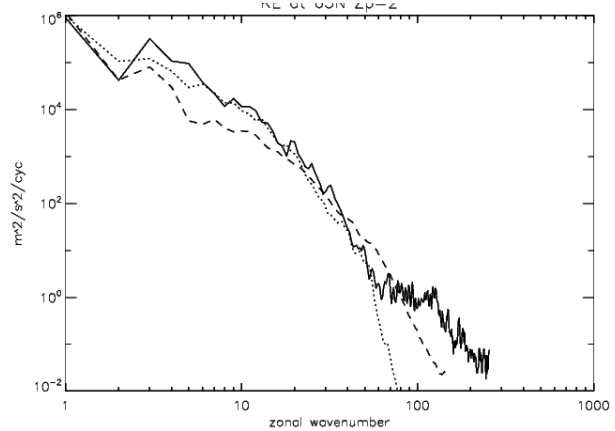
Dashed Line:
– – · WACCM-X FV

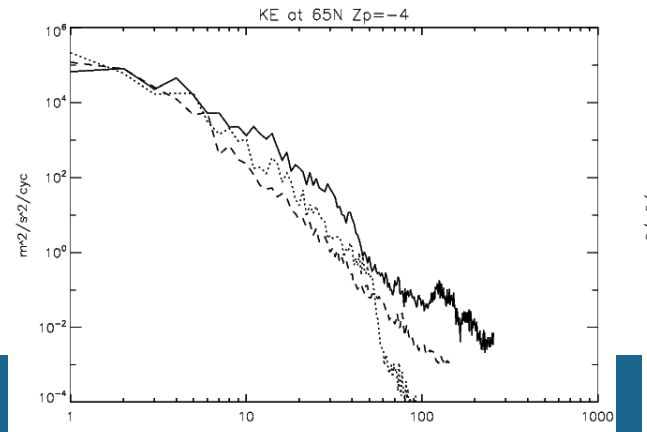
Solid line:
— WACCM-X SE

Lower Altitude

65° North

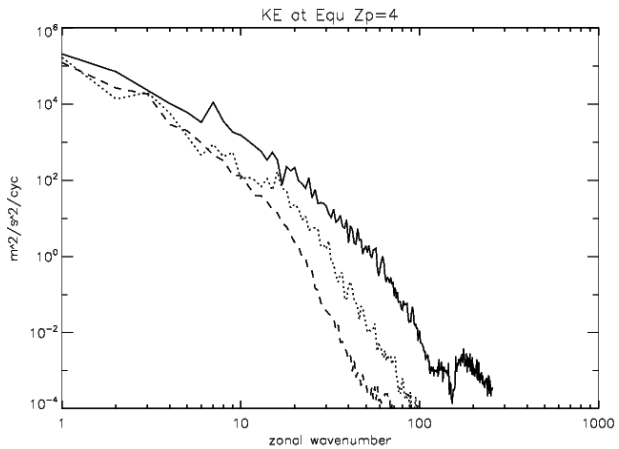


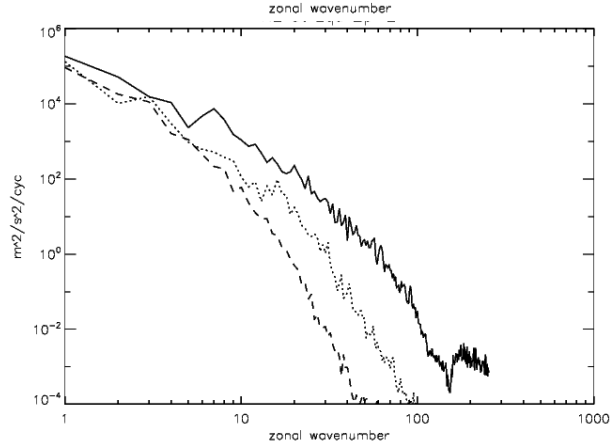


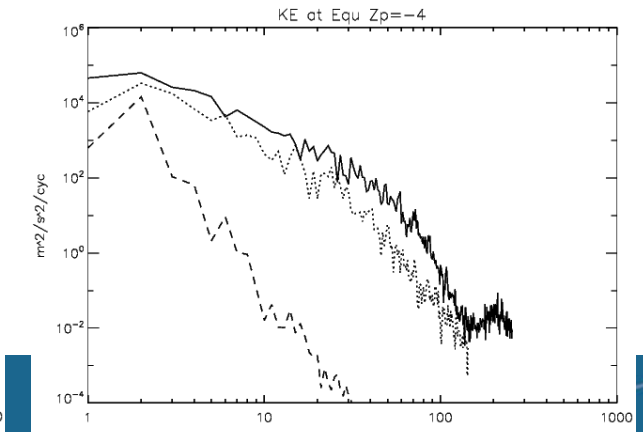


Zonal Wavenumber

Equator

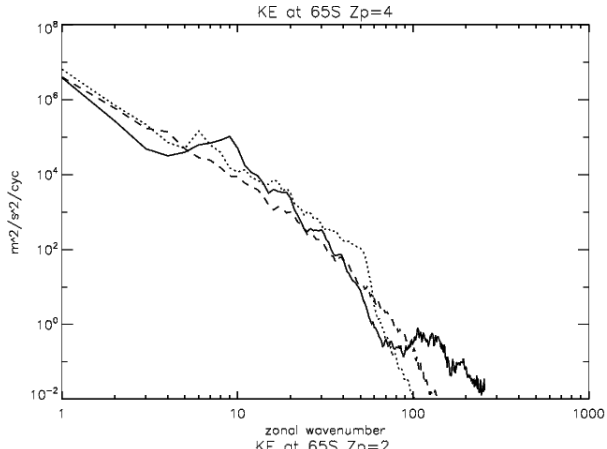


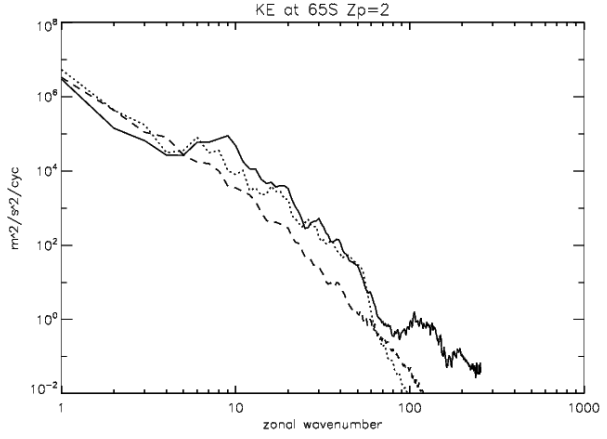


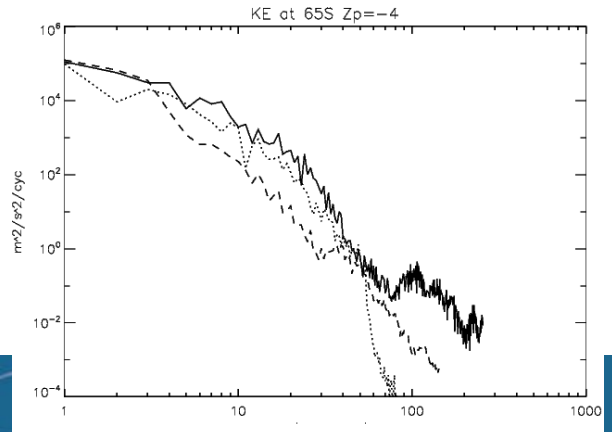


Zonal Wavenumber

65° South







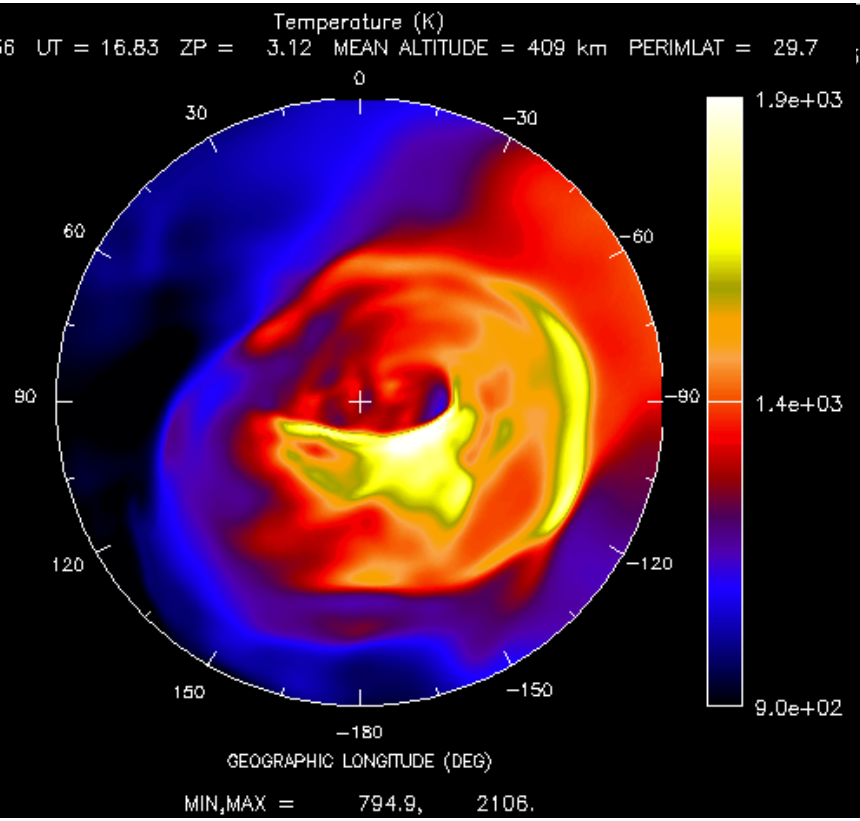
Zonal Wavenumber

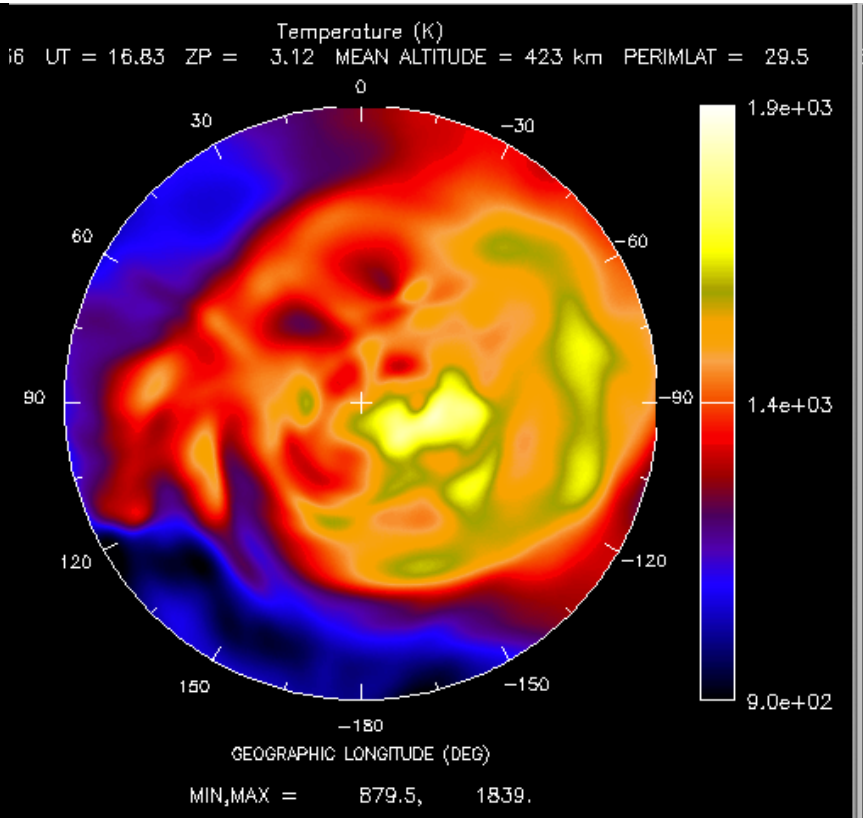
Temperature Variation at ~400km during a Storm

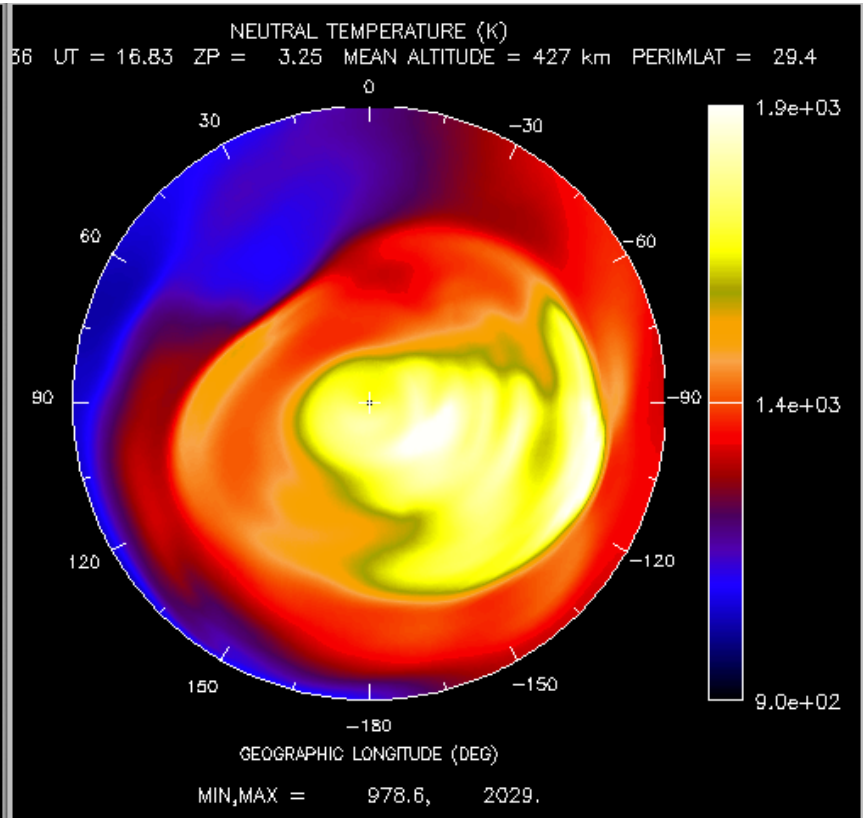
Has smaller scale structures
Large pole artifact

No pole artifacts
Captures both large and small scale structures

Large scale structure







WACCM-X FV/GAMEA

WACCM-X SE/GAMERA

TIEGCM/GAMERA

All at nominal ~1 deg horizontal resolution, same vertical resolution (0.25 scale height)

Model Performance Evaluation

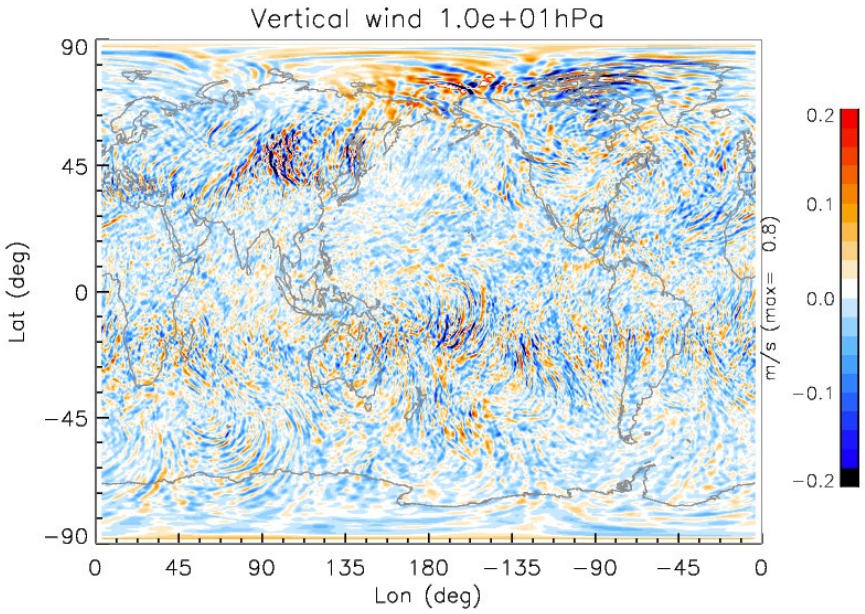
		RMSE (10^{-12}) (Smaller is Better)				R^2 (Close to 1 is better)			
		Quiet	Main	Recovery	All	Quiet	Main	Recovery	All
CHAMP	WEIMER	0.30	1.71	2.30	1.82	0.88	0.30	0.21	0.46
	MAGE	0.31	1.36	1.82	1.45	0.80	0.51	0.41	0.66
	WACCM-X SE	0.31	1.16	1.22	1.05	0.71	0.55	0.42	0.68
GRACE	WEIMER	0.42	1.78	2.17	1.77	0.87	0.49	0.28	0.49
	MAGE	0.41	1.539	1.71	1.44	0.80	0.63	0.59	0.70
	WACCM-X SE	0.33	1.711	1.32	1.30	0.69	0.52	0.56	0.65

In-Development and Future Works

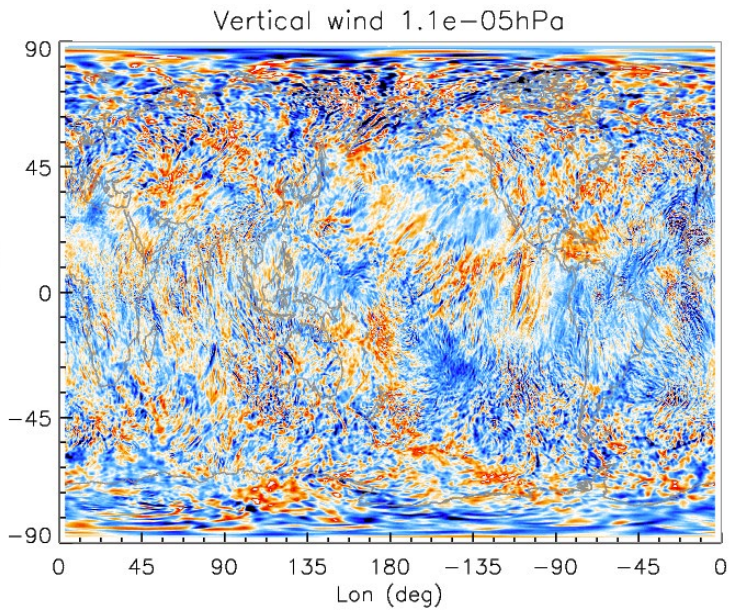
- Higher resolution WACCM-X (both vertical and horizontal)
- One-way couple high resolution WACCM-X with high resolution (0.5° or better) GAMERA
- Two-way couple WACCM-X with GAMERA

Vertical winds: WACCM -X (NE120/L273)

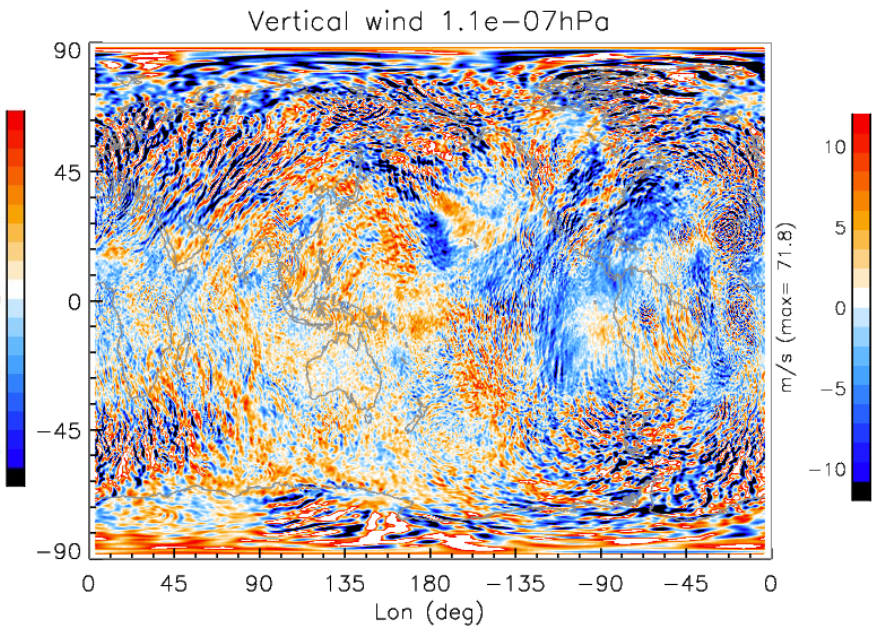
120 elements ~ 25km resolution, 273 vertical levels ~ 1/10 scale height



Stratosphere ~30km



E-region ~130km



F-region ~250km

Summary

- One way driving of WACCM-X SE performs better than two-way coupled TIEGCM

- WACCM-X SE provides significant improvement over TIEGCM, especially when considering small-scale structures

- More self-consistent and high resolution driving of WACCM -X high latitude should further improve model performance
- Work to two-way couple WACCM-X into MAGE is ongoing
- Enables lower-atmosphere to play a role in dynamically influencing all of geospace