WACCM-X Tutorial Session

- Last CEDAR tutorial in 2018: CESM2.0/WACCM-X with CAM4/5 physics.
- New dynamical cores, physics packages (CAM6 and CAM7), and updated chemistry.
- On the verge of CESM3 release.
- Now available at NASA CCMC.

Agenda:

- What is the NSF NCAR Community Earth System Model and WACCM-X? What are the major model capabilities? (*Nick Pedatella*)
- How to download, set up, build and run the model? (*Francis Vitt & Joe McInerney*)
- What can NASA CCMC do for you? (*Jack Wang*)
- How to request runs at NASA CCMC? (*Jack Wang*).

Google meet link: meet.google.com/atz-qqmp-gwh

Office Hour: 4-5pm today in the multi-function room.

Overview of the Community Earth System Model (CESM) & Whole Atmosphere Community Climate Model with thermosphere-ionosphere eXtension (WACCM-X)

Nick Pedatella, Hanli Liu, Joe McInerney, and Francis Vitt
High Altitude Observatory, NSF NCAR

25 June 2025
CEDAR Workshop

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

Outline

- Overview of CESM
- WACCM-X overview and capabilities
- Recent/upcoming developments

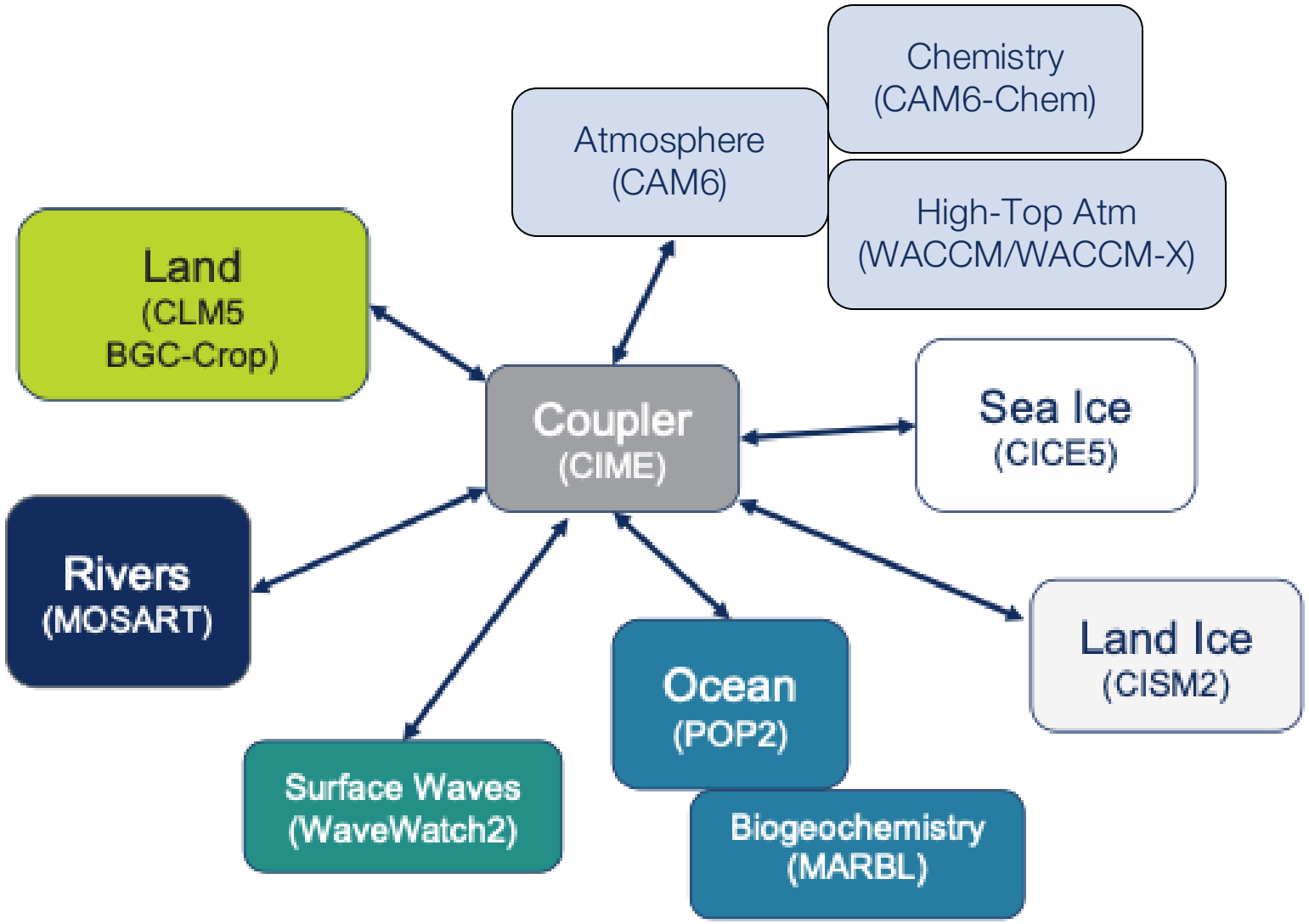
WACCM-X Overview & Science Goals

- WACCM-X is one of the atmospheric components of the NSF NCAR Community Earth System Model (CESM)
- Models the chemistry, dynamics, and physics of the atmosphere-ionosphere from the surface to the upper thermosphere
- Science goals:
  - Impacts of the Sun on the Earth system
  - Understand and quantify couplings between atmospheric layers through chemical, physical, and dynamical processes
  - Implications of the coupling to climate (downward coupling) and to the space environment (upward coupling)

WACCM-X is one of the atmosphere components of the NSF NCAR Community Earth System Model (CESM)

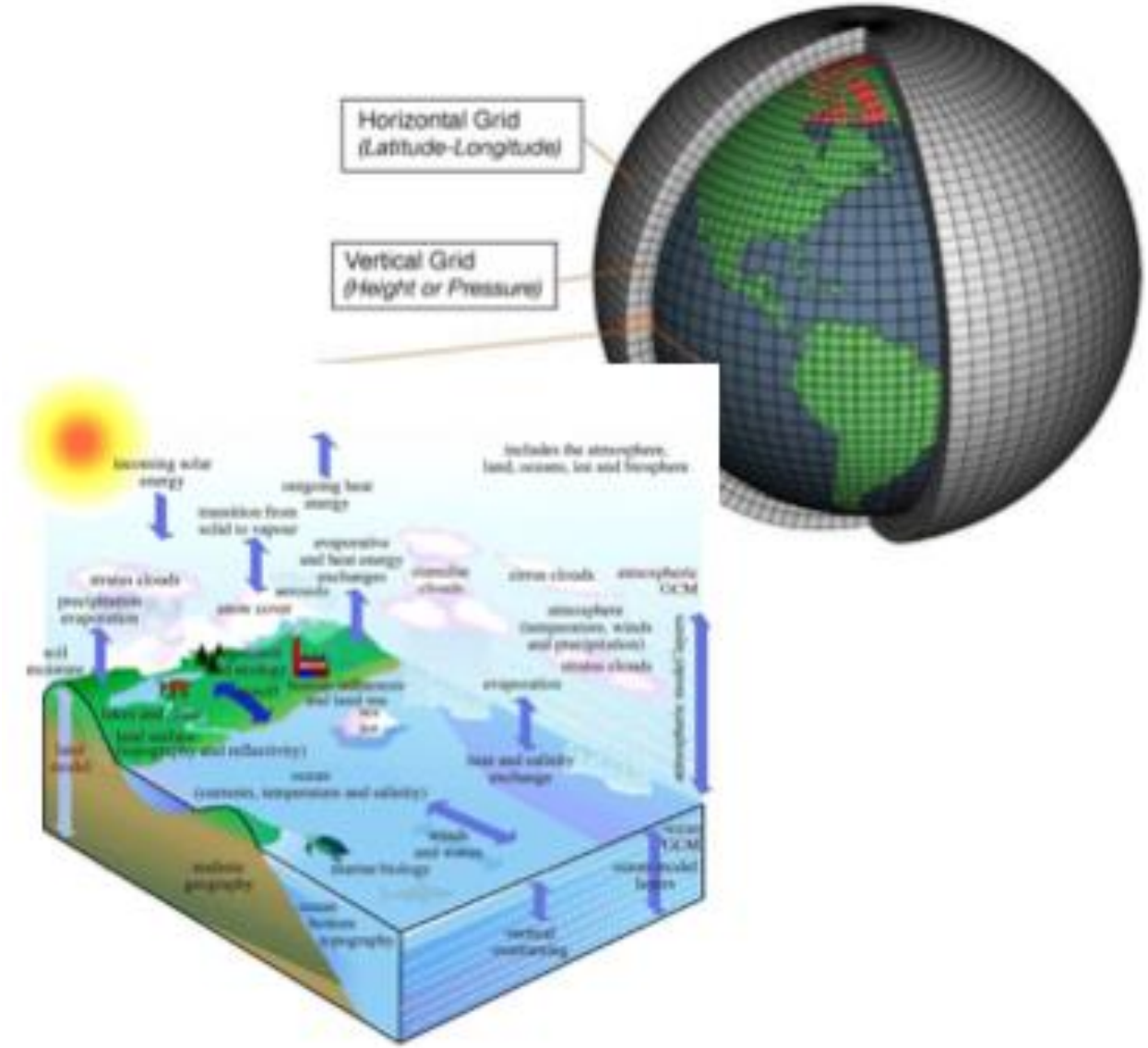
External Forcings:
- Greenhouse gases
- Anthropogenic aerosols
- Volcanic eruptions
- Solar variability

…



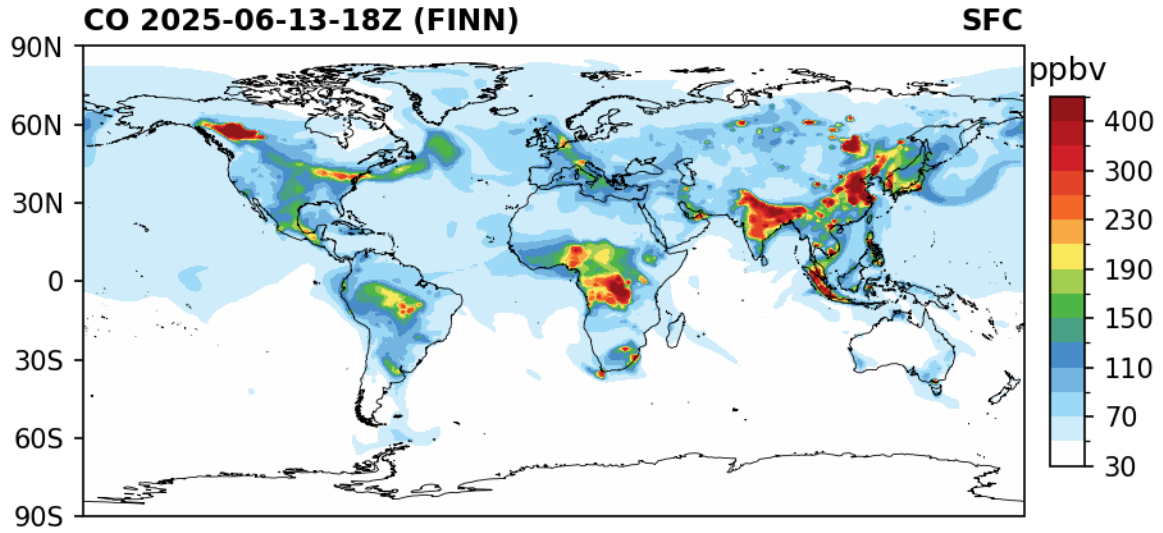
What is an Earth System model?

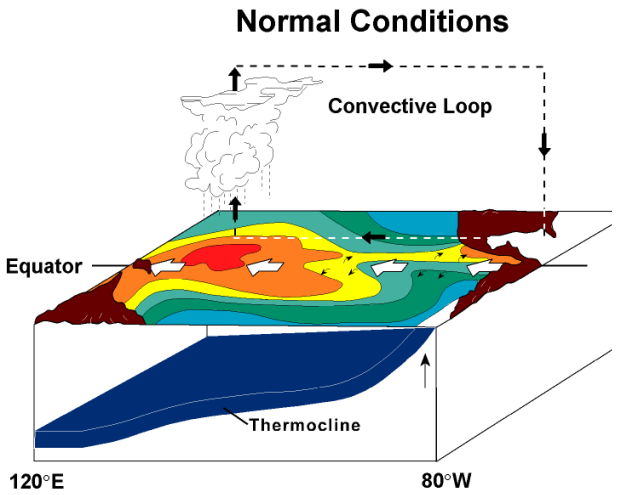
- Use physical equations to simulate key fields and processes in the atmosphere, ocean, land, sea-ice, land-ice, etc. and their couplings
- Processes that are below the grid resolution need to be parameterized
- Build on our understanding of processes from observations and highly-detailed models

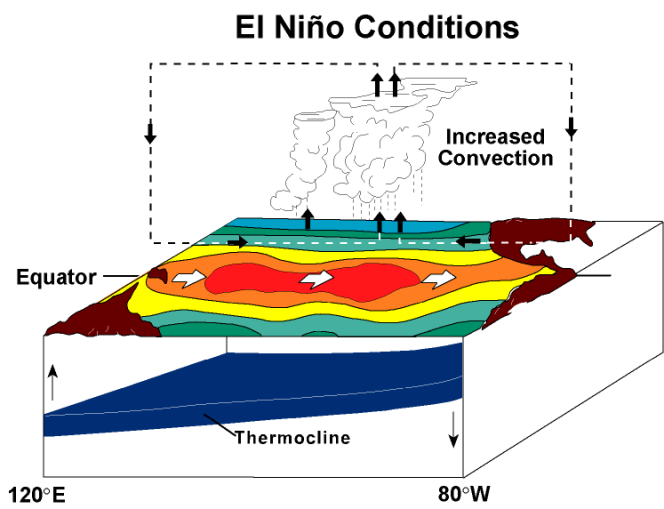


Applications of Earth System Models

- Earth system variability and change
- Air quality
- Biogeochemical cycles
- Sun-climate connections and space weather
- Process understanding
- Land-atmosphere and ocean-atmosphere interactions
- Ice sheet – climate interactions
- Hydrology and ecology
- Earth system predictability
- Weather from local to global scales
- …







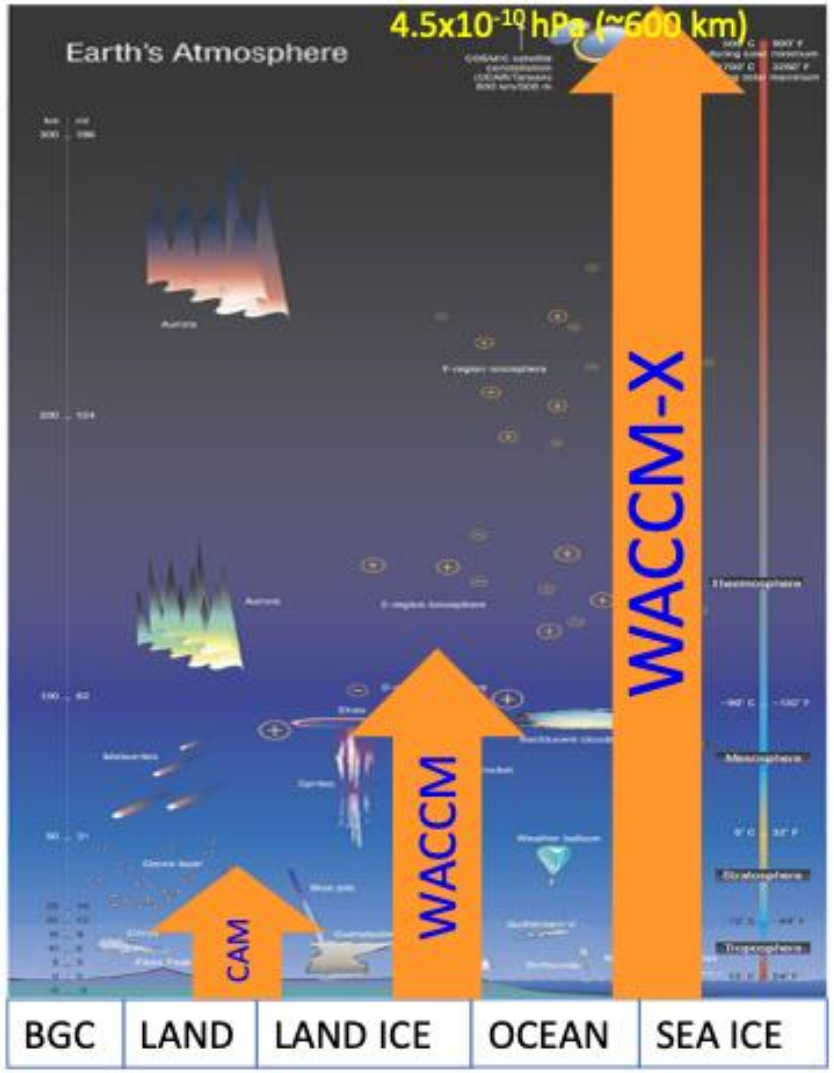
(NOAA, NSF NCAR)

CESM has a large community of developers and users, including large simulation datasets and support for community users

- CESM is based on over 30 years of model development
- A true community model with external developers and support for users
- Community participation through working groups (2000+ researchers)
- Widely used, e.g., 400+ talks using CESM at AGU 2024
- 2.8 million lines of Fortran code, > 1000 geophysical variables
- Available on github: https://github.com/NCAR/cesm

WACCM-X is built upon the underlying CESM infrastructure and the CESM atmospheric models

- WACCM-X leverages the capabilities and developments in the lower-middle atmosphere that are part of the Community Atmosphere Model (CAM) and Whole Atmosphere Community Climate Model (WACCM)
- Detailed treatment of troposphere, stratosphere, and mesosphere processes, including detailed chemistry, are included in WACCM-X
- Dynamical core and physics developments and improvements can be adopted by WACCM-X
- Designed for climate, not necessarily weather timescales



Outline

- Overview of CESM
- **WACCM-X overview and capabilities**
- Recent/upcoming developments

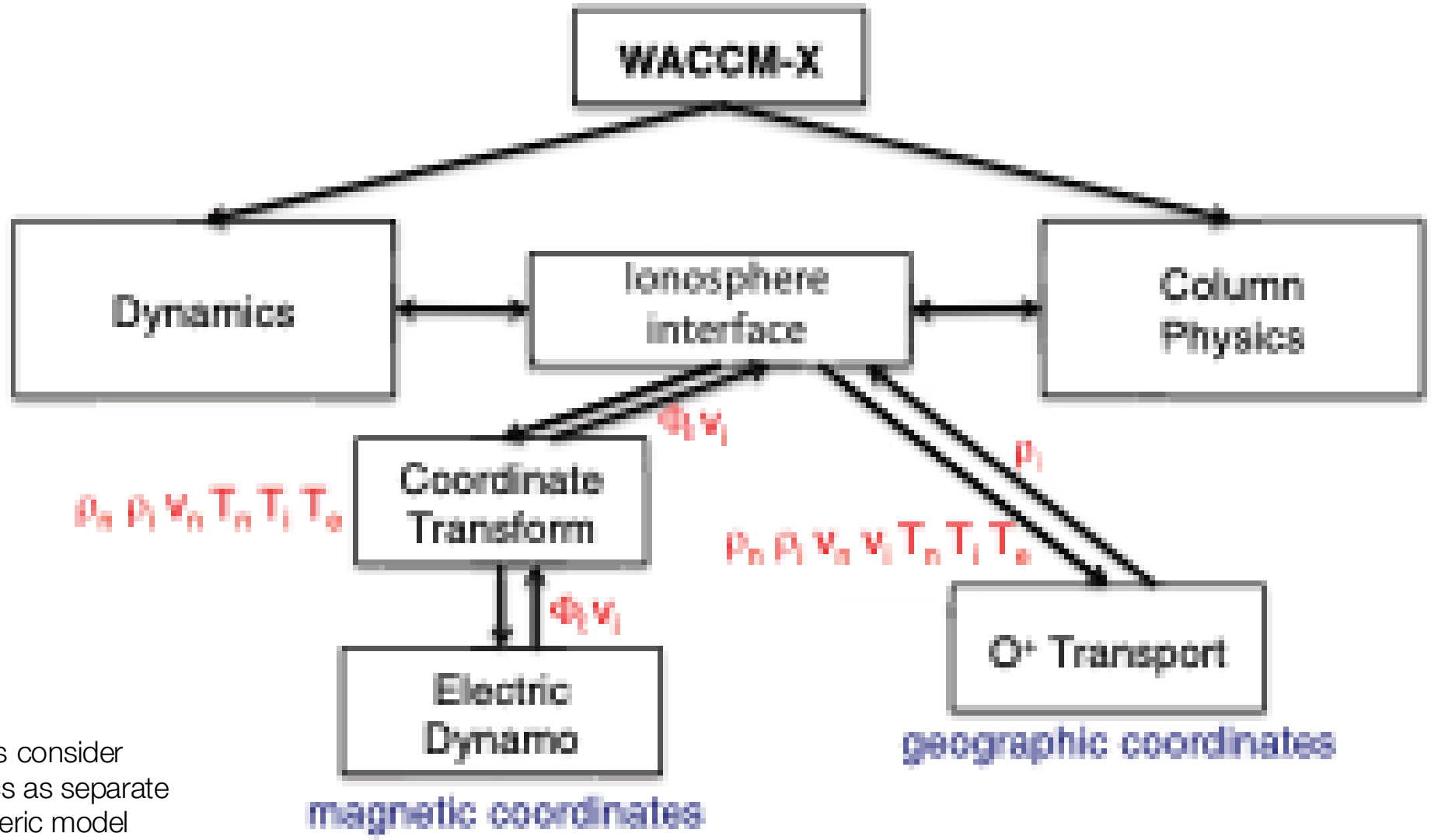
Major CESM WACCM/WACCM-X Components

Model Framework	Chemistry	Neutral Atm. Physics	Ionosphere Physics	Resolution
Atmosphere component of NCAR CESM Extension of the NCAR Community Atmosphere Model (CAM) Finite Volume Dynamical Core (modified to consider species dependent Cp, R, m)	MA/Ion Chemistry (~100 species) Fully-interactive with dynamics	Long wave/short wave/EUV RRTMG IR cooling (LTE/non-LTE) Modal Aerosol Model (MAM) CARMA Convection, precip., and cloud parameterization (CLUBB) Parameterized GW Major/minor species diffusion (+UBC) Horizontal/Vertical molecular viscosity and thermal conductivity (+UBC) Species dependent Cp, R, and m	Parameterized electric field at high latitudes. IGRF geomagnetic field Auroral processes, ion drag and Joule heating Ion/electron energy equations Ambipolar diffusion Ionospheric dynamo Coupling with plasmasphere/magnetosphere	Horizontal (lat x lon): 1.9 x 2.5 0.9 x 1.25 0.47 x 0.625 Vertical: 130, 145 levels (0 - ~600 km)

Key WACCM-X Capabilities

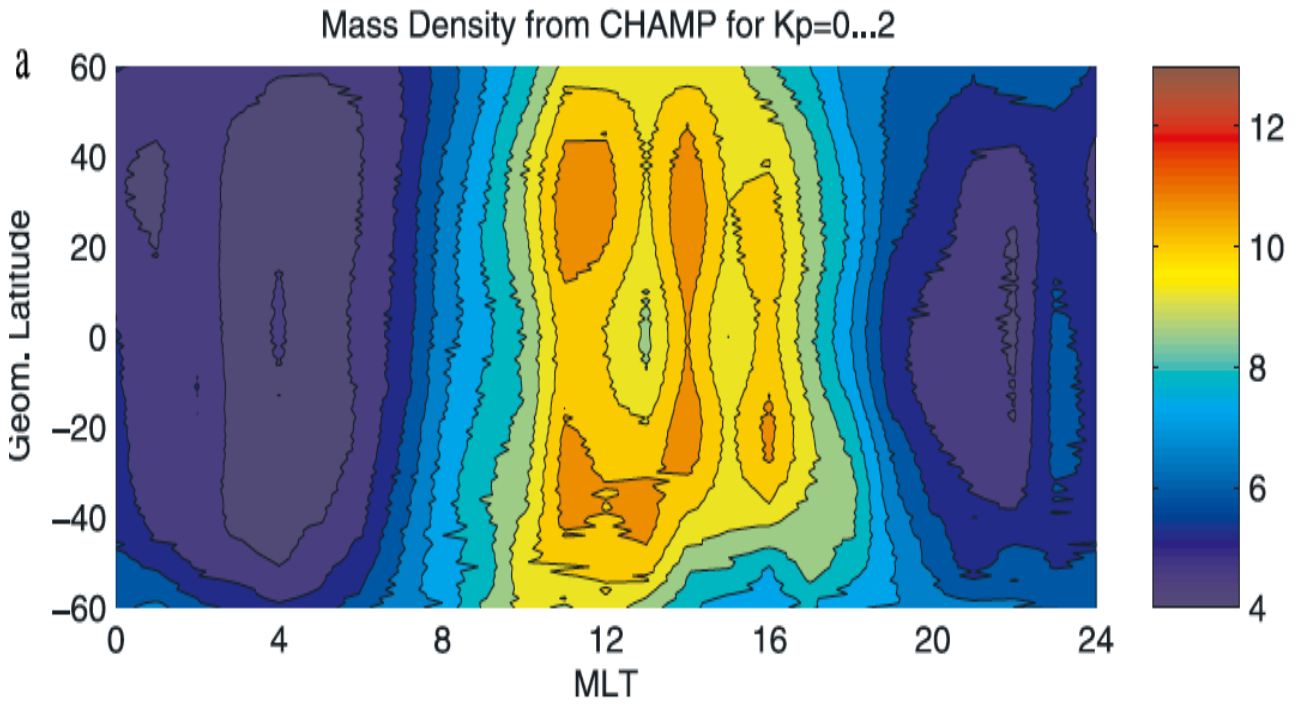
- Fully interactive chemistry, including ion chemistry
- Ionospheric electrodynamics using fully interactive dynamo
- Ion transport in the F-region
- Solar inputs from F107/EUVAC or FISM for solar flares
- Magnetospheric inputs using empirical (Heelis/Weimer) or specifications (AMIE, GAMERA)
- Coupling with SAMI3 plasmasphere model (NRL/Syntek Tech.)
- Specified dynamics to constrain meteorology up to ~50 km
- Whole atmosphere data assimilation for specification and forecast using DART (Data Assimilation Research Testbed)

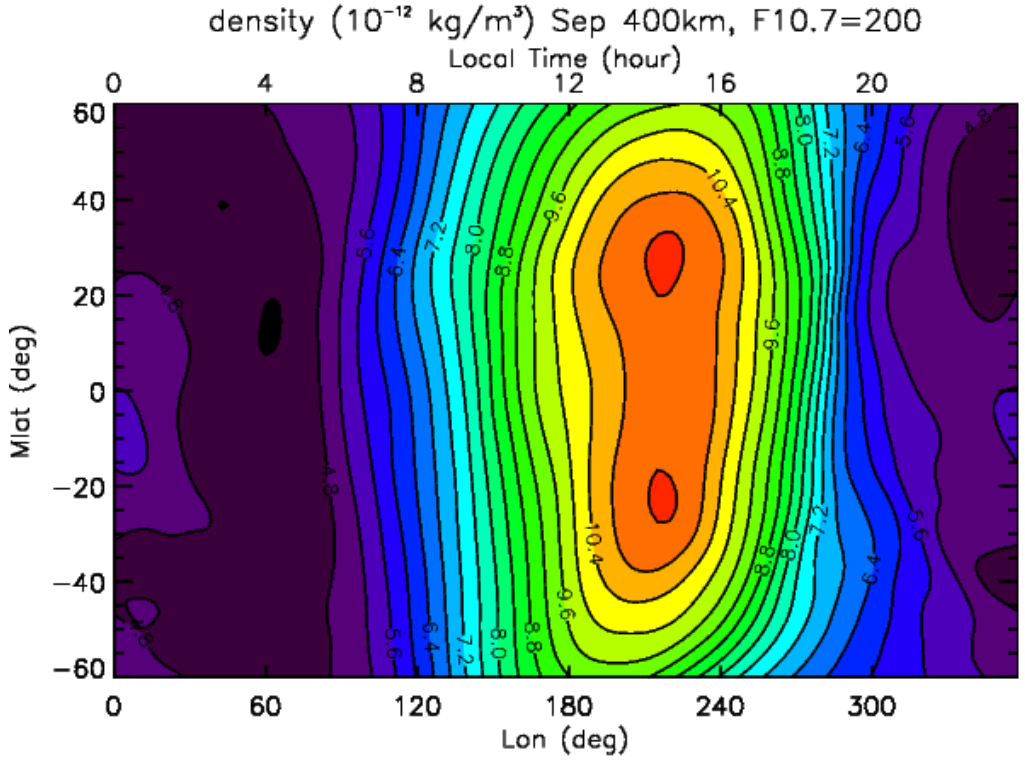
WACCM-X integrates the model dynamics and physics through an ionospheric module that enables electrodynamics and O^+ transport



Note: Climate models consider dynamics and physics as separate parts of the atmospheric model

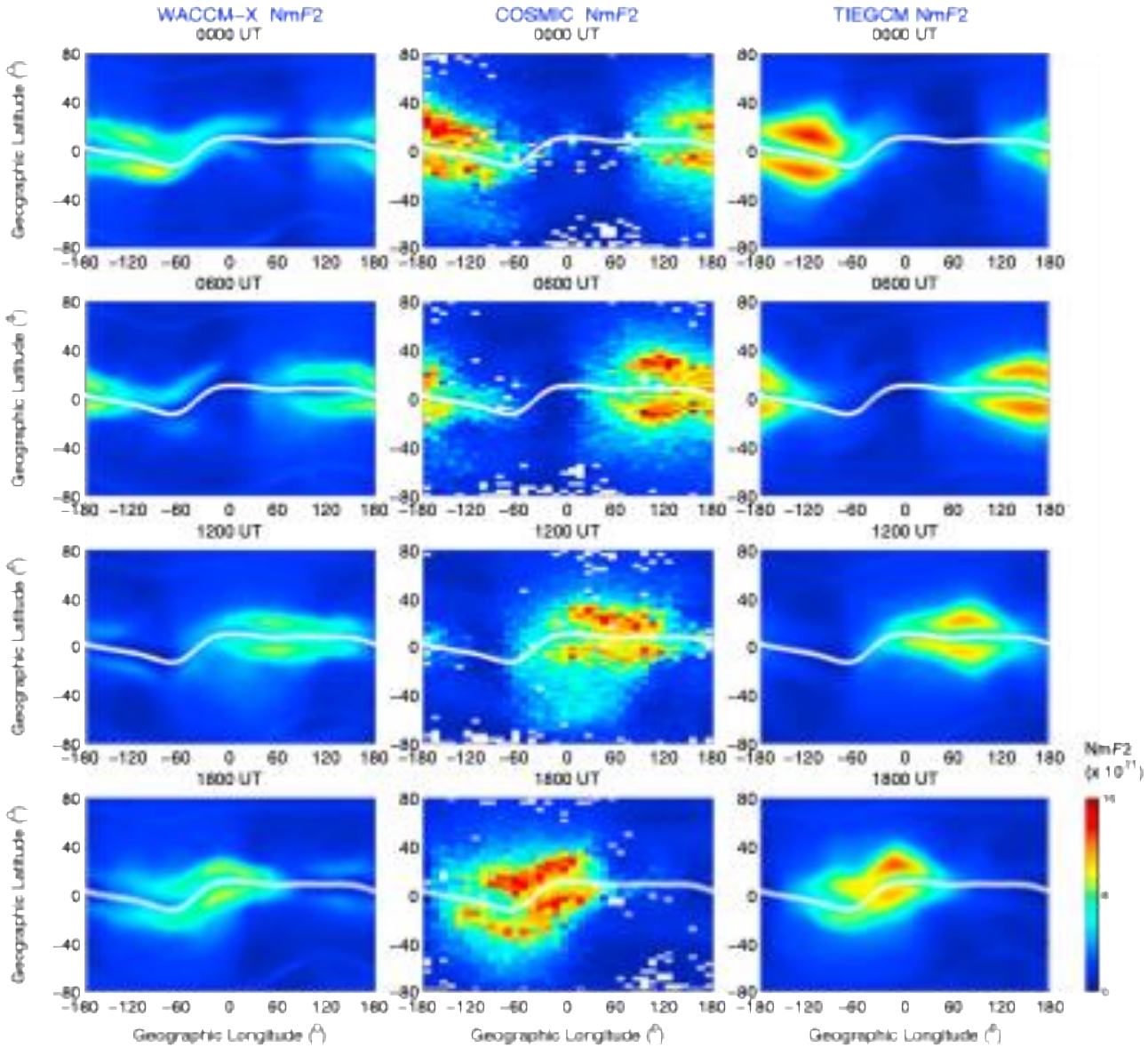
WACCM-X simulated thermosphere mass density is in general agreement with CHAMP satellite observations





(H. Liu et al., 2005; H.-L. Liu et al., 2018)

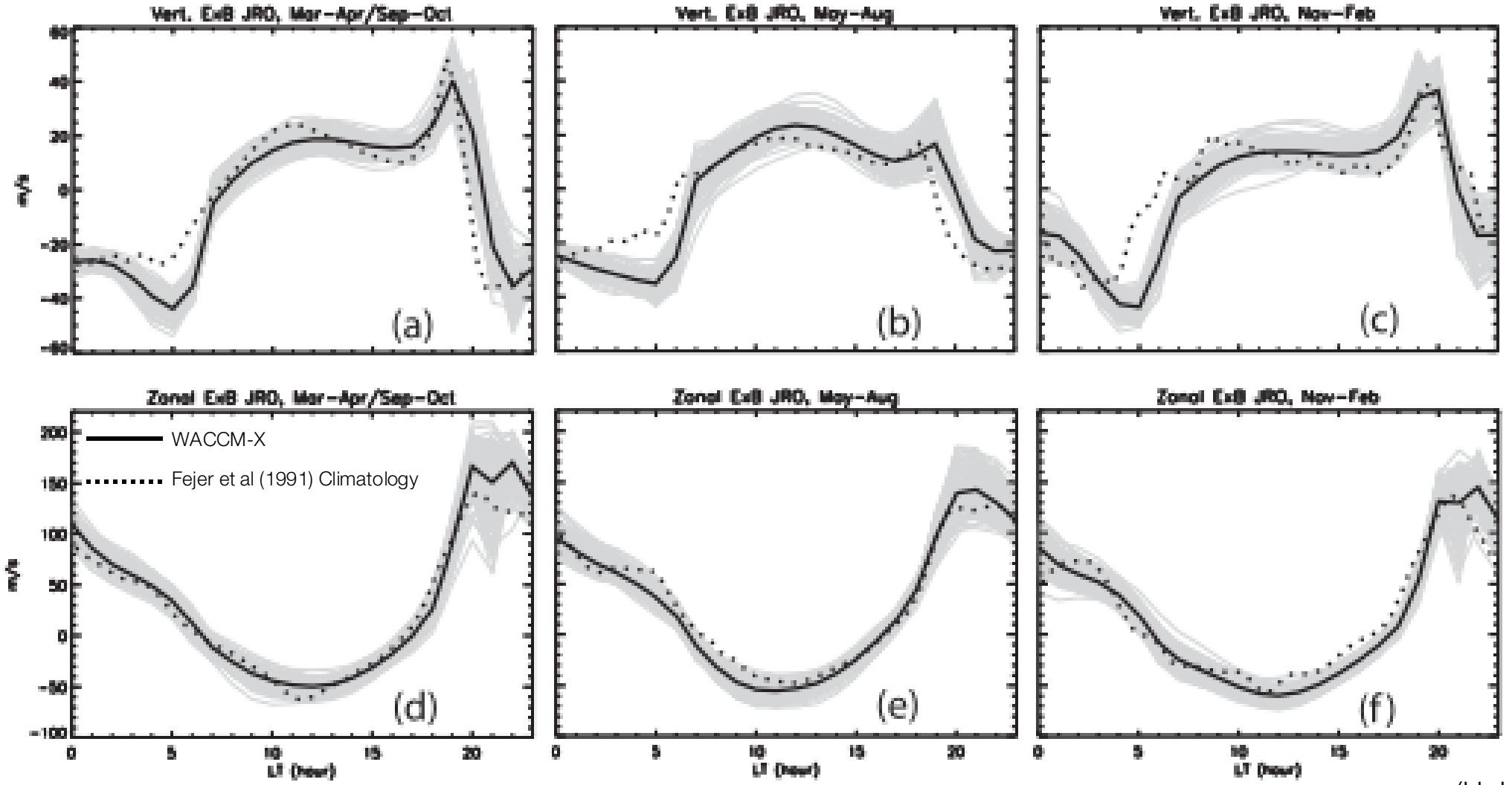
Morphology of electron density climatology is consistent with observations and TIEGCM



*Underestimation of NmF2 due to excessive GW diffusion WACCM-X v2.0 is largely fixed in v2.1

(J. Liu et al., 2018)

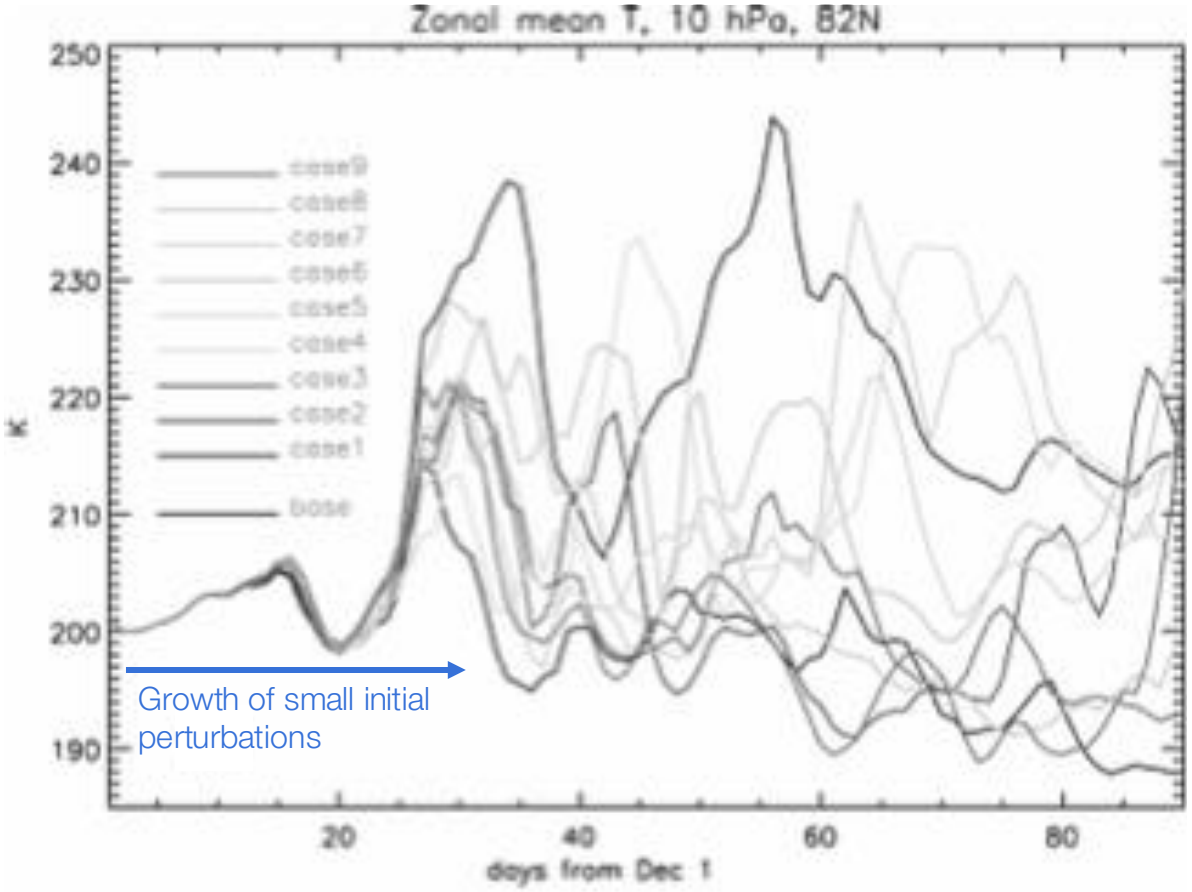
Simulated equatorial vertical drifts in WACCM-X generally agree with climatology and exhibit day-to-day variability due to lower atmosphere variability



(H.-L. Liu et al., 2018)

Lower atmosphere: Free-run versus Specified Dynamics

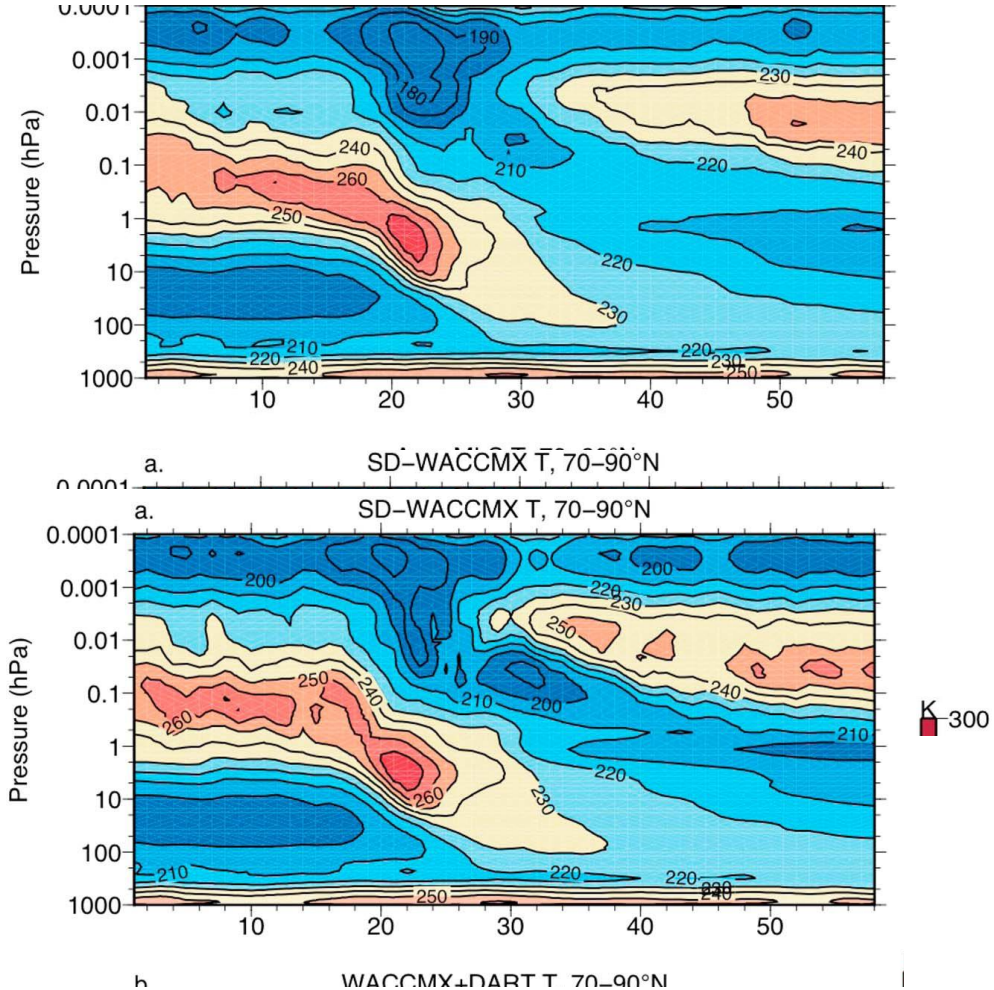
- WACCM-X can be configured as either a free-run or with specified dynamics
- Free-run simulations are unconstrained, and the model generates its own “weather” that is representative of climatological behavior
- Free-running simulations are useful for studying general behavior of the system, long-term simulations and/or time periods when reanalyses are unavailable
- Because of internal model variability, ensemble simulations are often required



(Liu et al., 2009)

Lower atmosphere: Free-run versus Specified Dynamics

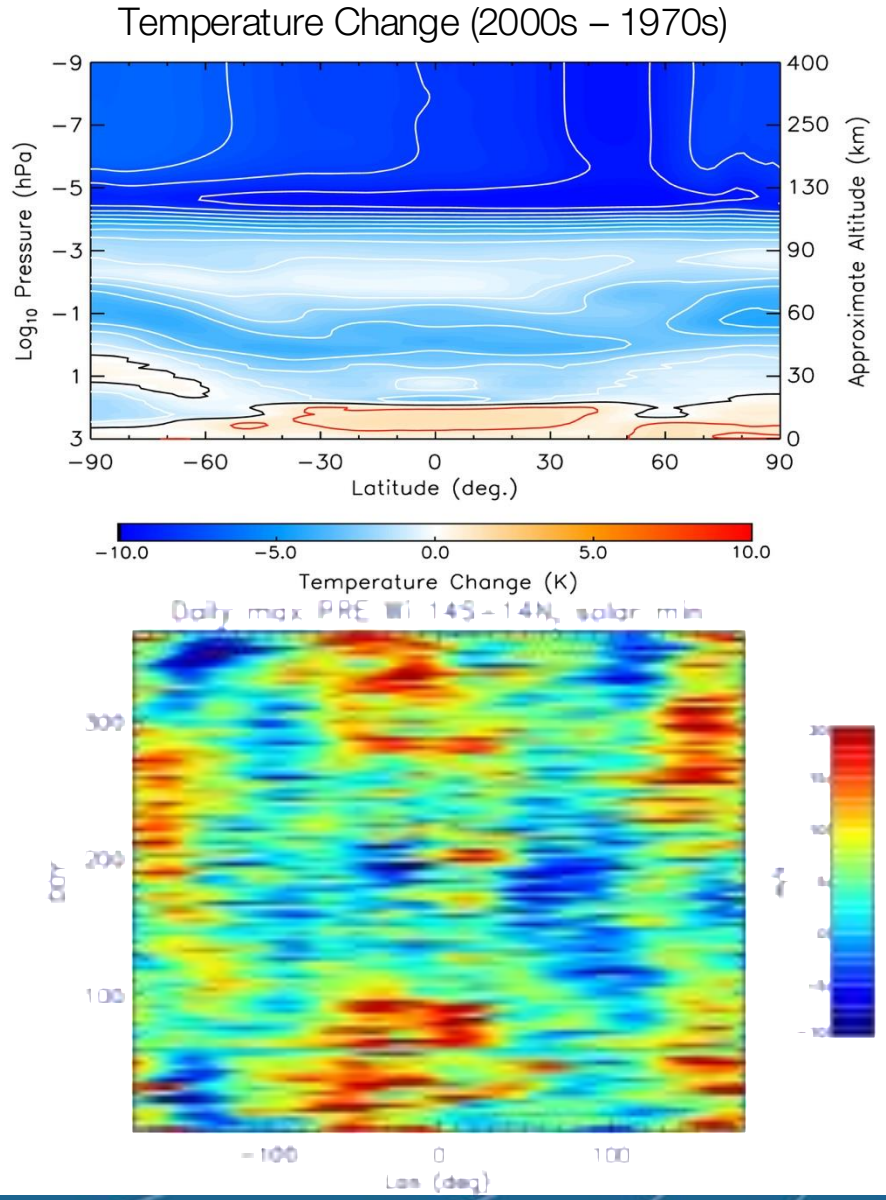
- WACCM-X can be configured as either a free-run or with specified dynamics
- Specified Dynamics (SD) simulations constrain the model meteorology to external fields. $X_{model} = \alpha(X_{met} - X_{model})$
- Default SD configuration is to nudge the model fields to MERRA-2 reanalysis up to ~50 km
- Assumption is that middle-upper atmosphere variability is controlled by dynamics in the troposphere-stratosphere
- Useful for simulating specific time periods and/or comparing to observations



(Pedatella et al., 2018)

Example science use cases of WACCM-X

- Day-to-day variability in the ionosphere and thermosphere
- Long-term trends (historical and projection)
- Sudden stratospheric warmings: dynamics, chemistry, and ionospheric effects
- Effects of gravity waves, tides, and planetary waves on the circulation and chemistry of the MLT
- Geomagnetic storms
- …



(Liu et al., 2018; Solomon et al., 2018)

Outline

- Overview of CESM
- WACCM-X overview and capabilities
- **Recent/upcoming developments**

From CESM2 to CESM3

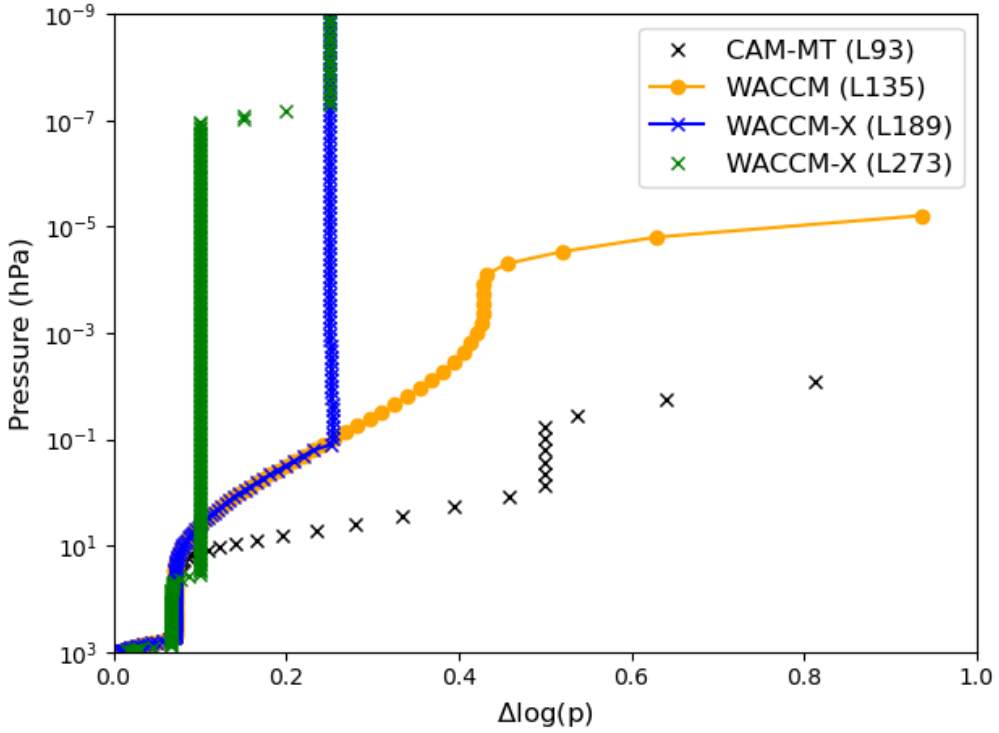
- CESM2 was released in 2018 and included the initial release of WACCM-X
- Subsequent CESM2.x model releases include developmental (i.e., not scientifically supported) updates and bug fixes
- NSF NCAR intends to release CESM3 in the near future
- CESM3 will include many new features, including a new dynamical core and significant updates to the atmospheric physics and chemistry (CAM7/WACCM7/WACCM7-X)

Major CESM WACCM/WACCM-X Components

Model Framework	Chemistry	Neutral Atm. Physics	Ionosphere Physics	Resolution
Atmosphere component of NCAR 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 Regridding scheme MPAS-A CESM2 WACCM-X CESM3 WACCM-X WACCM Development	MA/Ion Chemistry (~100 species) Fully-interactive with dynamics	Long wave/short wave/EUV RRTMG IR cooling (LTE/non-LTE) Modal Aerosol Model (MAM) CARMA Convection, precip., and cloud parameterization (CLUBB) Parameterized GW (+ MM parameterization) Major/minor species diffusion (+UBC) Horizontal/Vertical molecular viscosity and thermoal conductivity (+UBC) Species dependent Cp, R, and m	Parameterized electric field at high latitudes. IGRF geomagnetic field Auroral processes, ion drag and Joule heating Ion/electron energy equations Ambipolar diffusion Ionospheric dynamo Coupling with plasmasphere/magnetosphere	Horizontal (lat x lon): 1.9 x 2.5 0.9 x 1.25 0.47 x 0.625 NE16, 30, 60, 120 120 km Vertical: 70, 135 levels (0 – 140 km) 130, 145 levels (0 - ~600 km) 130, 189, 273 (0 - ~600 km)

WACCM & WACCM-X for CESM3

	Dyn. Core	Resolution	# levels	Chemistry	Physics
WACCM6	FV	1°, 2°	70 (110)	TSMLT, MA	CAM6
WACCM7	SE	ne30, ne16	135	t1ma, t4ma	CAM7
WACCM-X 2.1	FV	1°, 2°	130	TSMLT, MA, IT chemistry	CAM6
WACCM-X v?	SE	ne30, ne16 (ne120)	189 (273)	t1ma, t4ma IT chemistry	CAM7

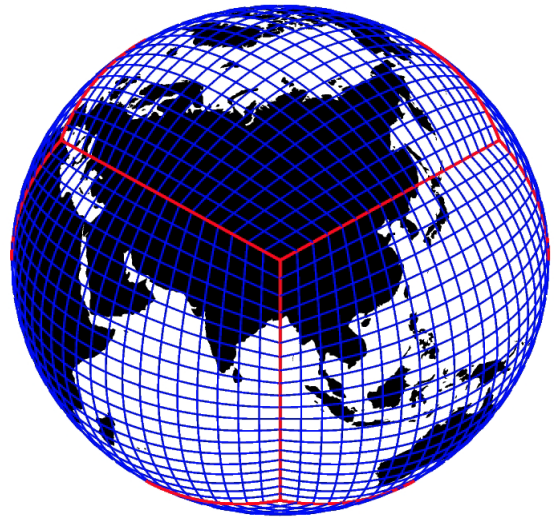


Priority development objectives:

- Good QBO at both 1° and 2° resolutions
- Seasonal cycle of winds/temperatures in the stratosphere-mesosphere and the impact on chemistry
- Thermosphere extension of SE dycore, ionosphere-thermosphere climatology

Extension of Spectral Element (SE) dynamical core into the thermosphere

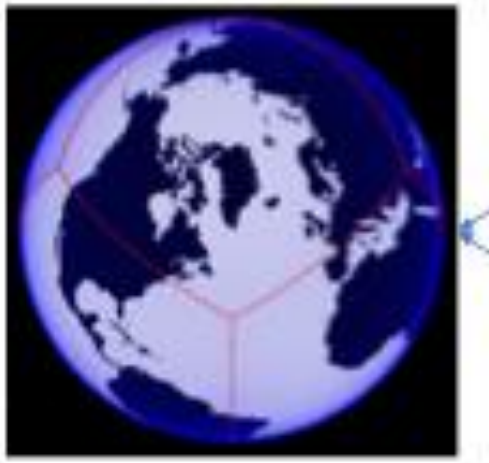
- Spectral Element (SE) dynamical core will be used by future versions of CESM atmosphere models (CAM, WACCM, WACCM-X)
- Cubed sphere grid that eliminates polar singularity
- Capability for high-resolution and nested grids
- SE dynamical core has been extended into the thermosphere: species dependence; horizontal molecular viscosity/diffusion

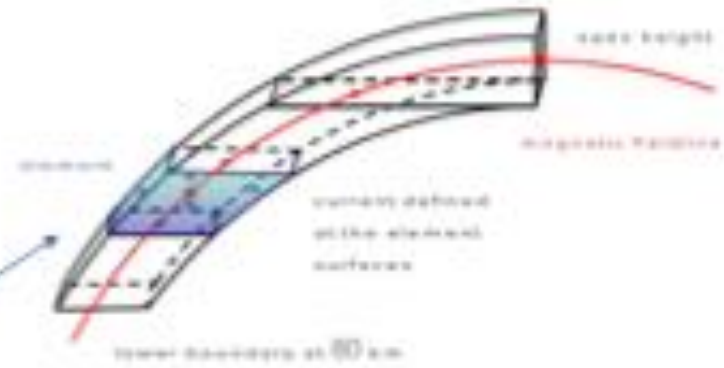


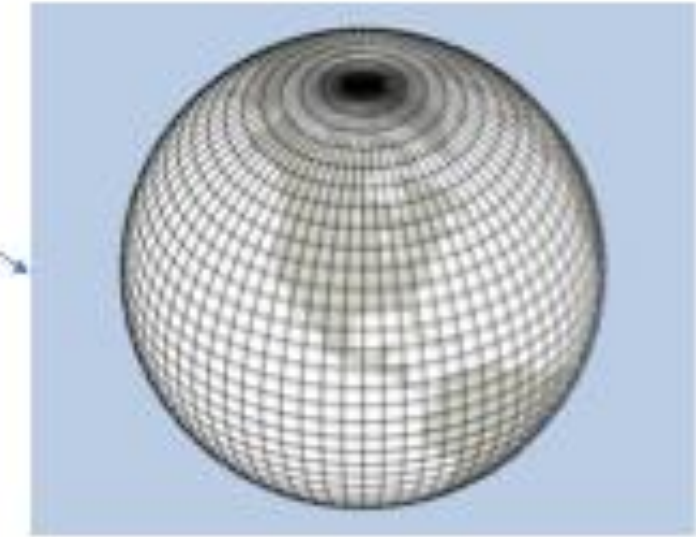
New regridding scheme for mapping between regular/irregular grids

- Earth System Modeling Framework (ESMF) based regridding scheme maps fields between physics mesh and regular/irregular grids

- Independent of dynamical core grid





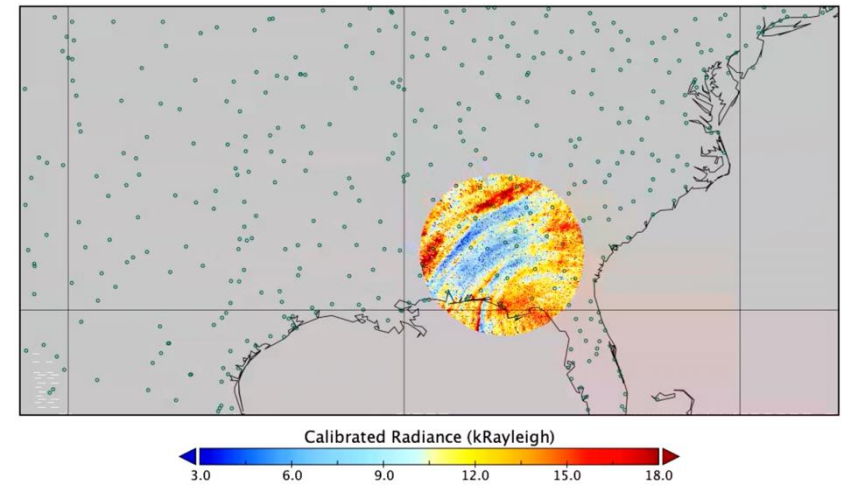


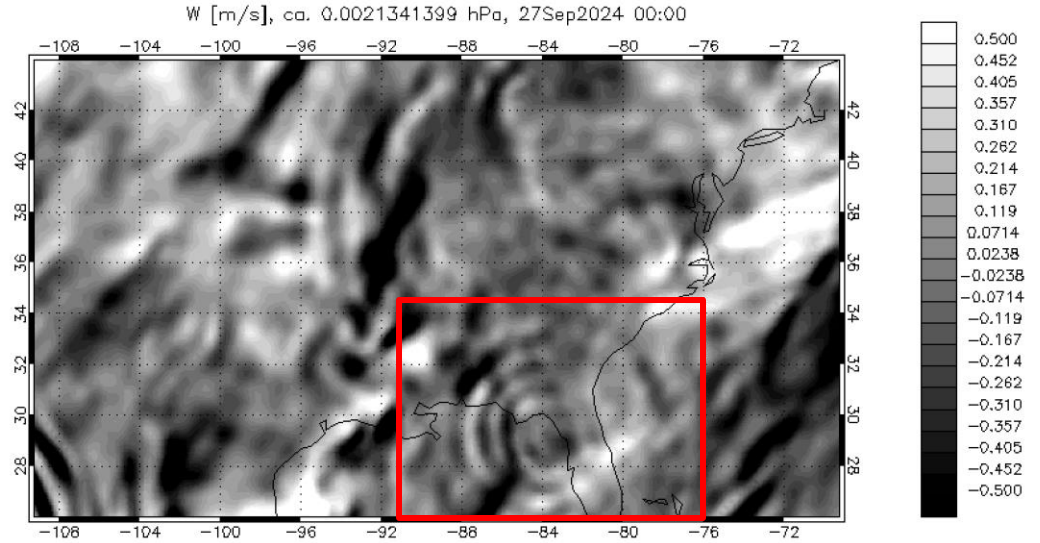
Implementation of meteorological constraint for high-resolution (ne120, ~0.25°) WACCM-X

- Recently implemented physics-side nudging for high-resolution WACCM-X simulations
- Enables simulations of the day-to-day variability of small-scale waves, and their impacts, on the middle and upper atmosphere
- Capability enables new scientific studies and is used to support current and future satellite missions

Gravity Waves from Hurricane Helene

NASA AWE Observation 02:49 UT, Sept 27, 2024 (~87 km)





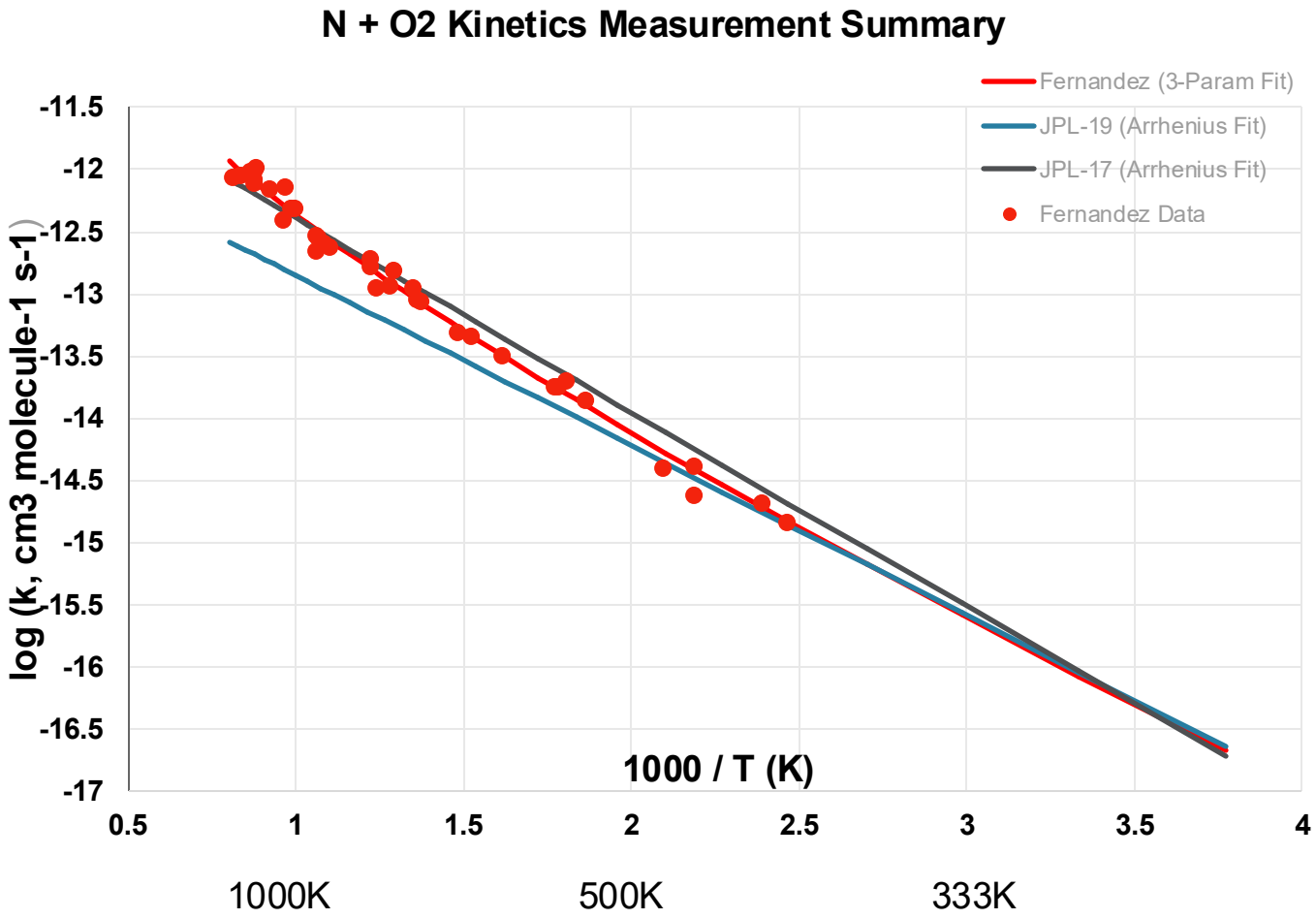
Credit: Hanli Liu (HAO), Jiarong Zhang (USU)

Chemistry Updates for the Mesosphere and Thermosphere

	Reaction	Original Rate Constant (A, Ea/R)	Updated	Comment
Updated rates	$N(^4S) + O_2$ -> $NO + O$	JPL-19 3.3e-12, 3150	3-parameter fit, Next slide	Fernandez et al., 1998
	$N(^2D) + O_2$ -> $NO + O(^1D)$	5e-12	K=6.2e-12 (T/300.)	Duff et al., 2003
New reactions	$N(^2D) + NO$ -> $N_2 + O(^1D)$	NA	K = 7.3e-11	Roble, 1995
	$N(^2D)$ -> $N(^4S)$ + hv	NA	K = 1.06e-5	Roble, 1995
	$N(^2D)$ + e -> $N(^4S)$ + e + 2.38 eV	NA	K = 3.6e-10_r8 * $(Te/300.0\_r8)^{1/2}$	Roble, 1995

Credit: Doug Kinnison, Jun Zhang (ACOM)

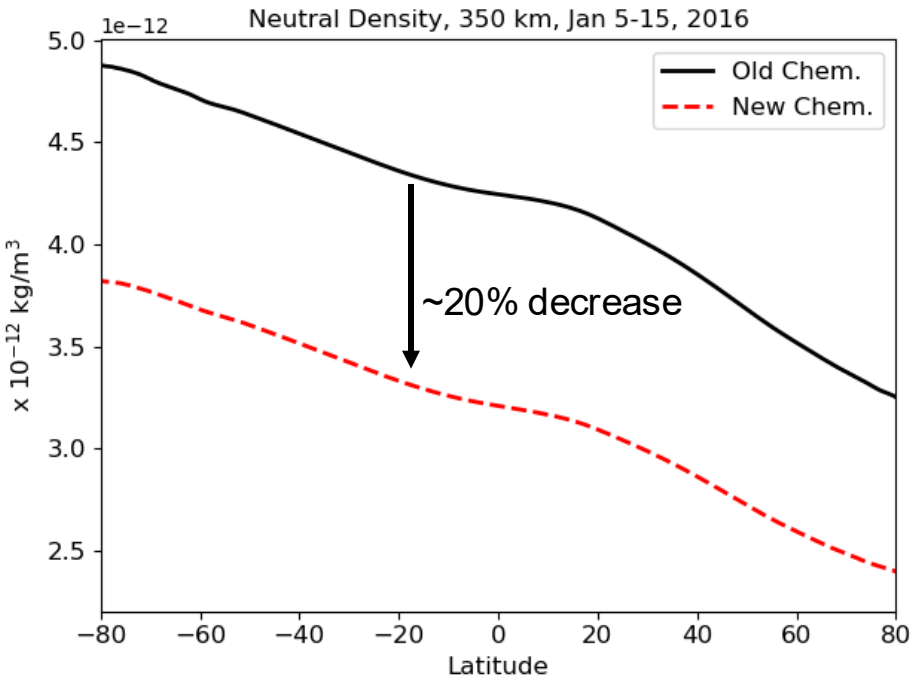
Updated N + O_2 Reaction Rate

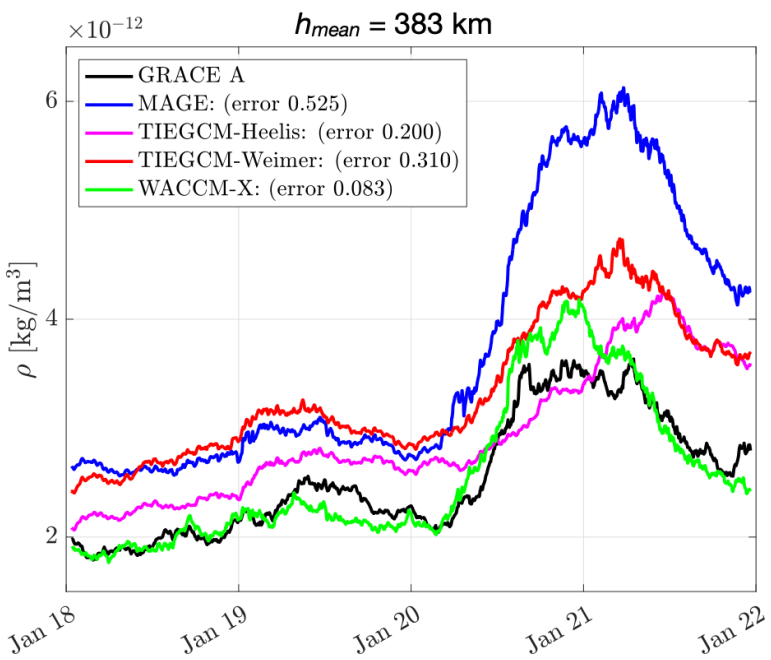


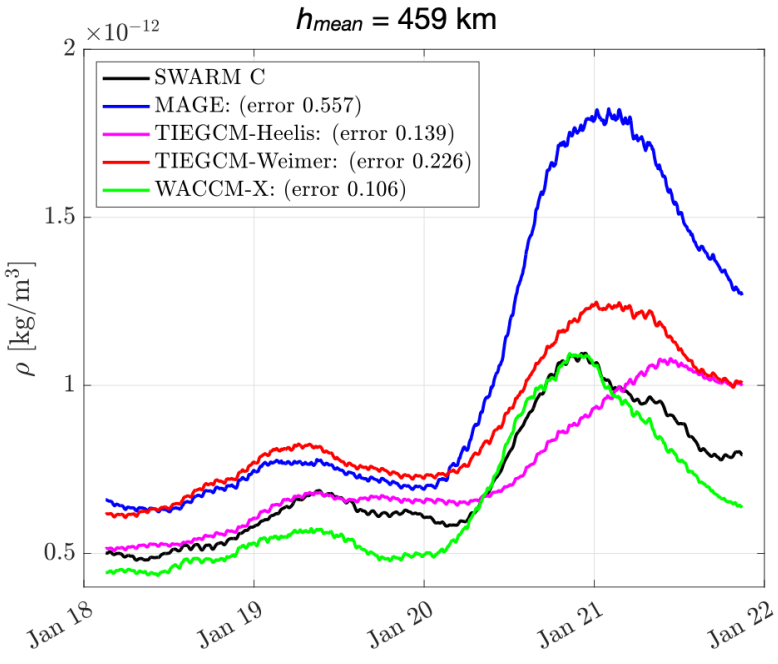
- Decrease in reaction rate from JPL-17 (CESM2) to JPL-19 leads to less NO production at high temperatures
- NO cools the thermosphere, so less NO leads to larger temperatures and neutral densities

Credit: Doug Kinnison, Jun Zhang (ACOM)

WACCM-X simulated neutral densities with updated reaction rates show good agreement with observations



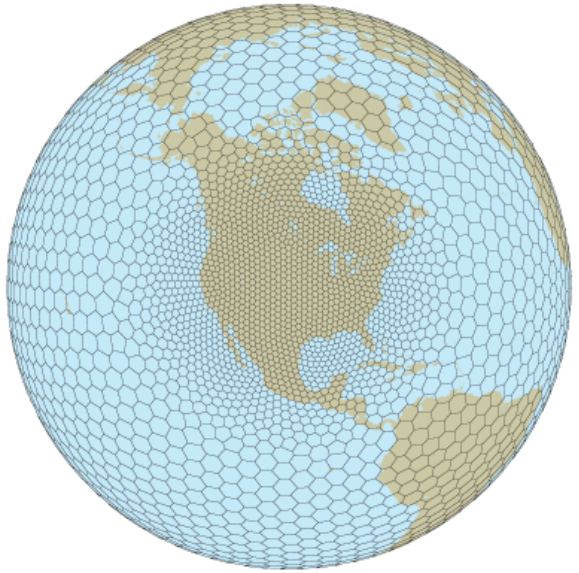


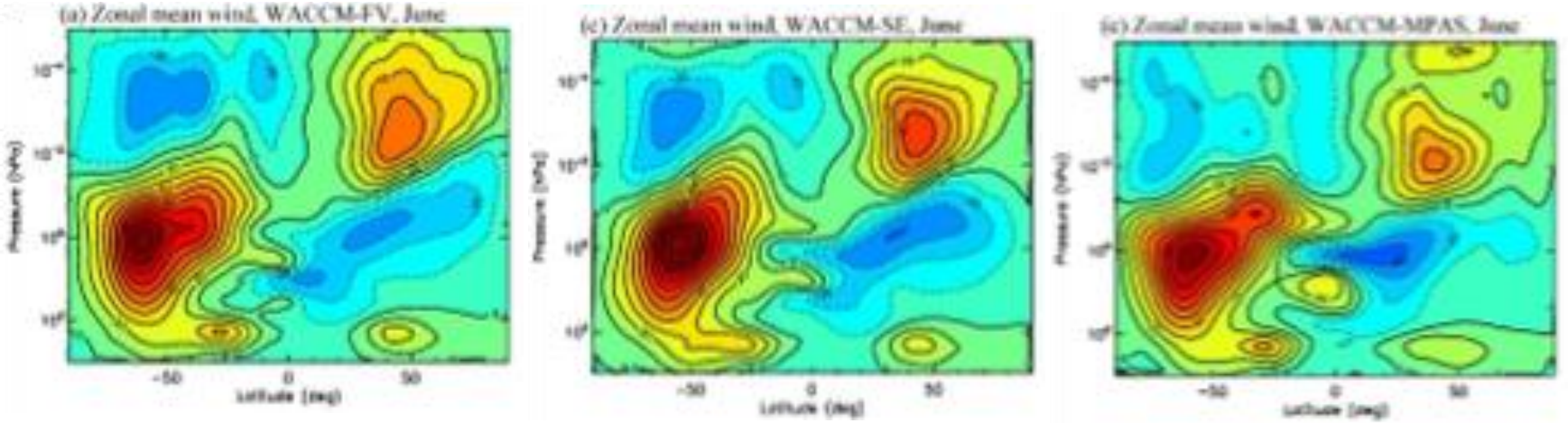


Credit: Jordi Vila Perez (HAO)

Model for Prediction Across Scales (MPAS) dynamical core

- MPAS-A is a non-hydrostatic dynamical core solved on centroidal Voronoi mesh
- MPAS has been extended into the lower thermosphere (Kamali et al., 2024)
- Further developing the MPAS dynamical core for future use as the dynamical core in WACCM-X

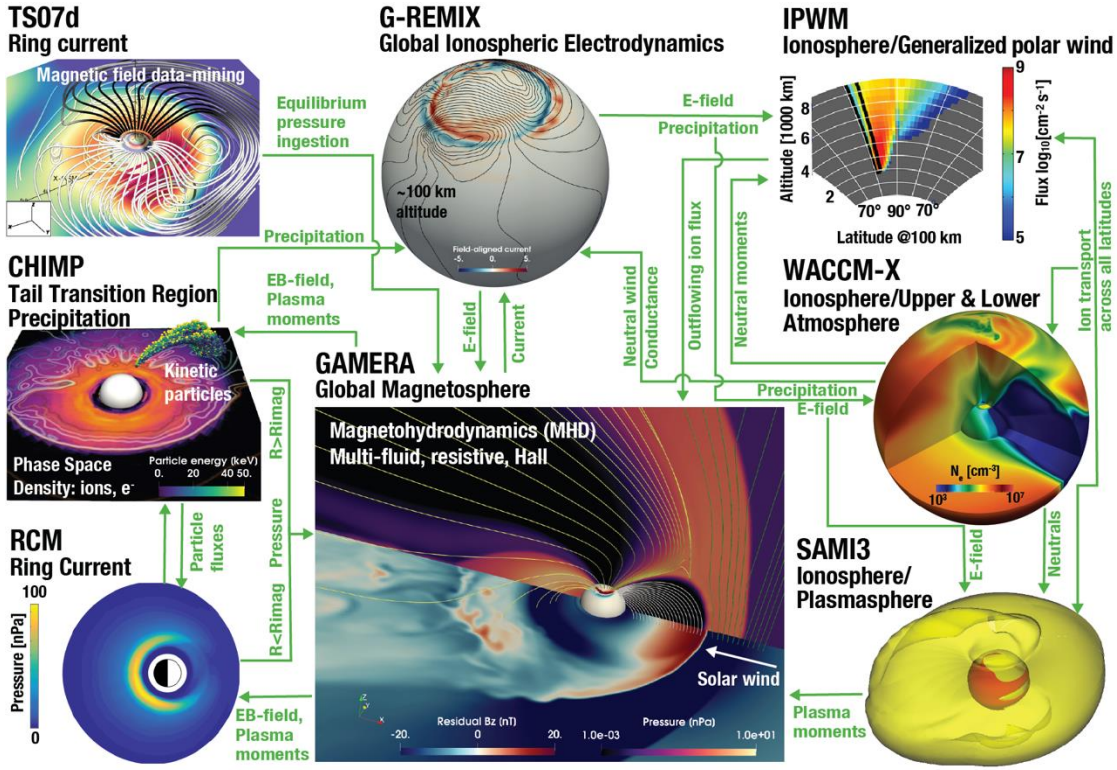




WACCM-X/GAMERA: Towards a whole geospace model

NASA Center for Geospace Storms (CGS) and HAO have recently completed ***two-way coupling*** between WACCM-X and the GAMERA magnetosphere model, paving the way for a whole geospace model

Model Framework for CGS MAGE



MAGE: Multiscale Atmosphere-Geospace Environment Model

CENTER FOR GEOSPACE STORMS

JOHNS HOPKINS APPLIED PHYSICS LABORATORY

Summary

- CESM/WACCM-X is an open source, community, model of the whole atmosphere-ionosphere coupled system
- CESM2 (WACCM-X v2.x) has significantly advanced scientific understanding of day-to-day variability, SSWs, wave-driven variability, long-term trends, …
- Release of CESM3 (WACCM7-X) will provide new modeling capabilities, including SE dynamical core that enables high-resolution simulations
- CESM is a community model and we welcome scientific and development collaborations

References

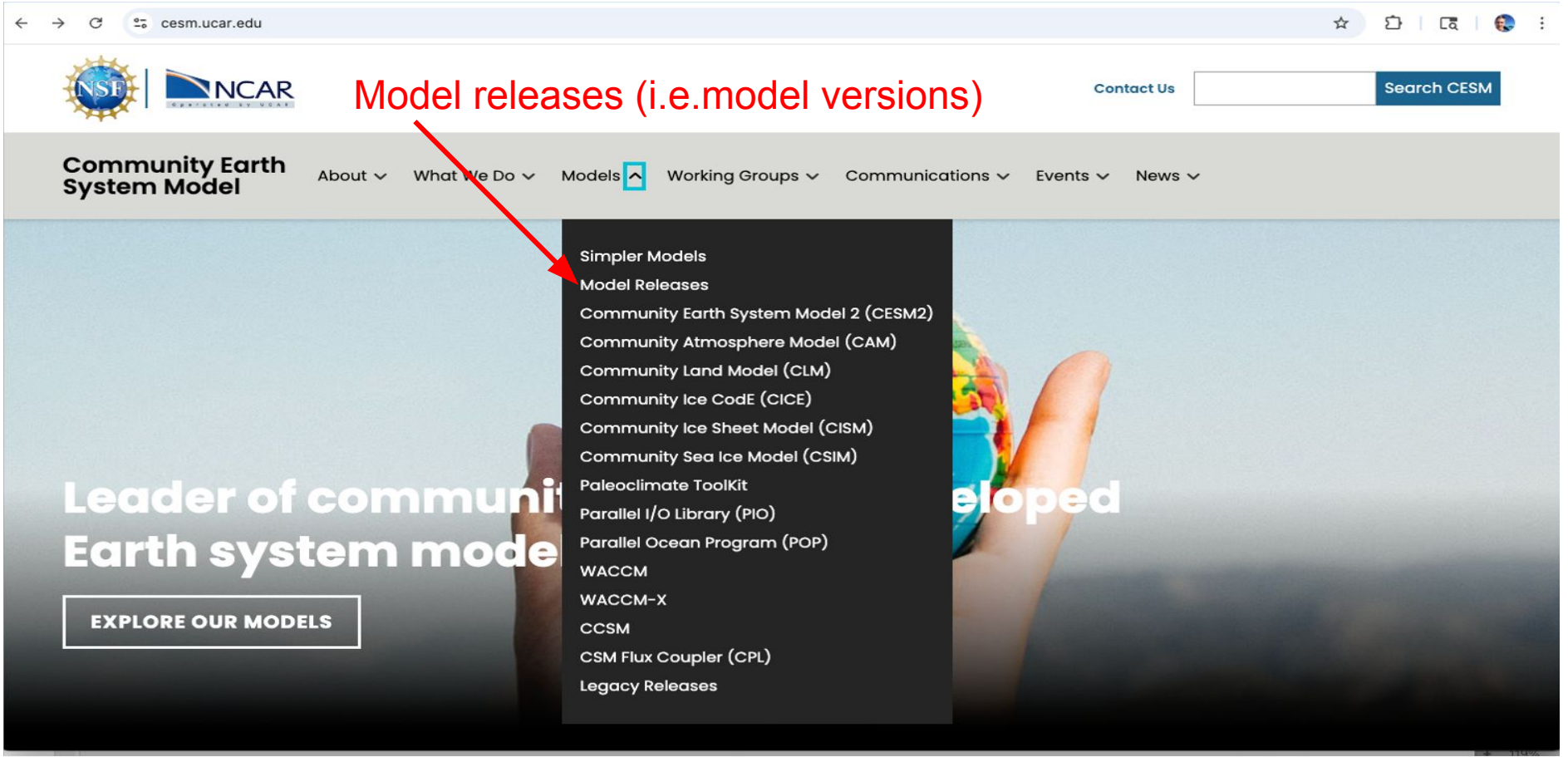
WACCM-X Tutorial

CEDAR 2025

Overview

- Downloading model source code
- Creating a case directory
- Case setup, build, and run
- Contents of directories
- Modifying case settings
- Description, access, and viewing model output
- Documentation and help

CESM Web Page: http://www.cesm.ucar.edu



Latest supported release – CESM2.1.5

cesm.ucar.edu/models/releases

CAM Workflow - R... | MUSICA-v0 / SE ta... | CSEG | Developme... | Issues 139 | CESM Aerosol Wor... | Requirements | dtc... | 8. Testing — CIME... | MUSICA Software... | Professional HVAC... | Login | Planview L... | All Bookmar

Parallel Ocean Program (POP)

WACCM

WACCM-X

CCSM

CSM Flux Coupler (CPL)

Legacy Releases

Current Release

CESM 2.2.2

CESM 2.2.z Quickstart Guide

DOWNLOAD

CESM 2.1.5

CESM 2.1.z Quickstart Guide

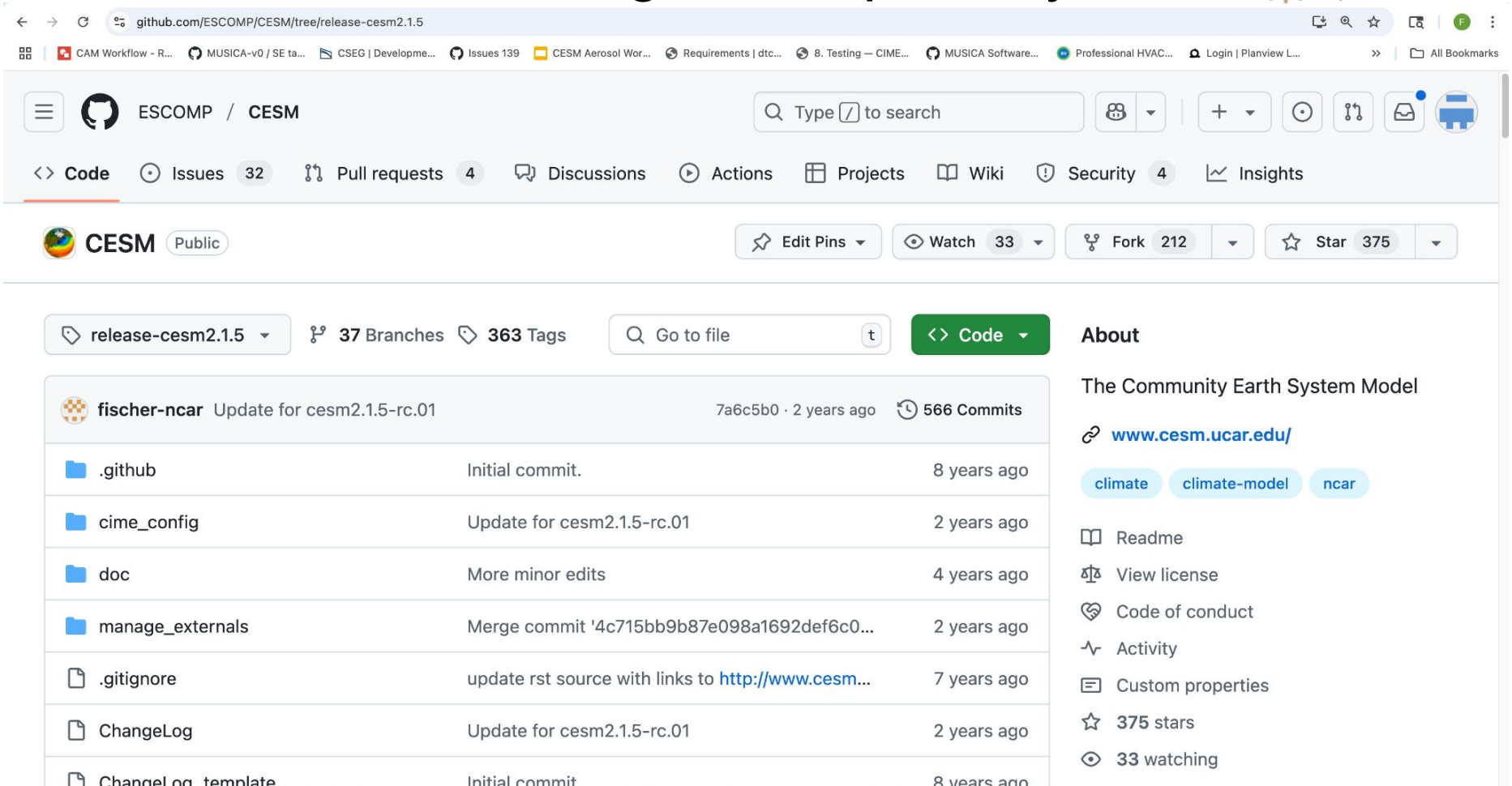
DOWNLOAD

Past Versions

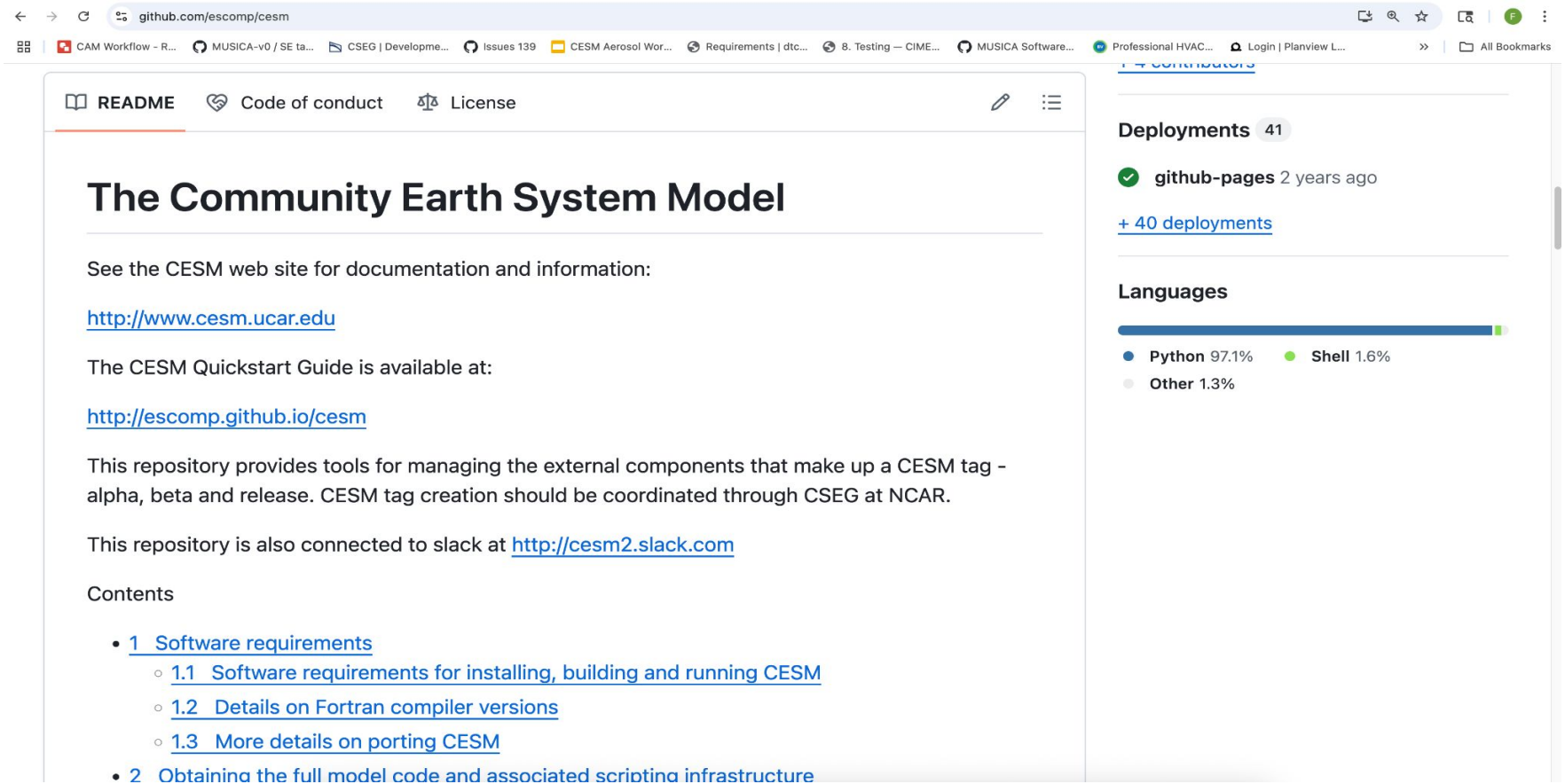
CESM 1.2.z

- Release notes

CESM github repository



See the README



Download and Basics

Download from github

```
> git clone https://github.com/ESCOMP/CESM.git -b cesm2.1.5 cesm2.1.5
> cd cesm2.1.5
> manage_externals/checkout_externals
```

Not covered here for unsupported machines (.e.g. derecho)

- Porting
- Create input data root directory

Basic steps for running

- Create case
- Invoke case.setup, case.build
- Submit the run …

Download listing of CESM

```
> cd cesm2.1.5
> ls -1
ChangeLog
ChangeLog_template
cime
cime_config
components
describe_version
doc
Externals.cfg
LICENSE.txt
manage_externals
README.rst
```

Scripts for creating case, etc. under cime

Model source code under components

Components listing

```
> cd components
> ls -1
cam
cice
cism
clm
mosart
pop
rtm
ww3
```

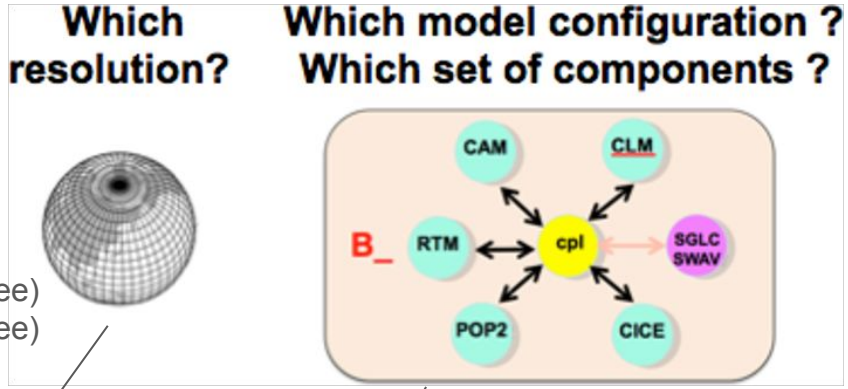
- **Community Atmosphere Model**
- Community Sea Ice Model
- Community Ice Sheet model
- Community Land Model
- Model for Scale Adaptive River Transport
- Parallel Ocean Program
- River Transport Model
- WaveWatch3

```
> cd cam/src
> ls -1
advection
chemistry
control
cpl
dynamics
ionosphere
physics
unit_drivers
utils
```

Create a new case

In the **cime/scripts** directory, **create_newcase** is the tool that generates a new model case.

create_newcase requires **3 arguments**:



Supported WACCM-X resolutions:

- f19_f19_mg17 (2-degree)
- f09_f09_mg17 (1-degree)

```
> ./create_newcase --res f19_f19_mg17 --compset FXHIST --case /glade/work/fvitt/cesm/cases/fe21.FXHIST.f19.t001
> ./create_newcase --help
```

What is a compset?

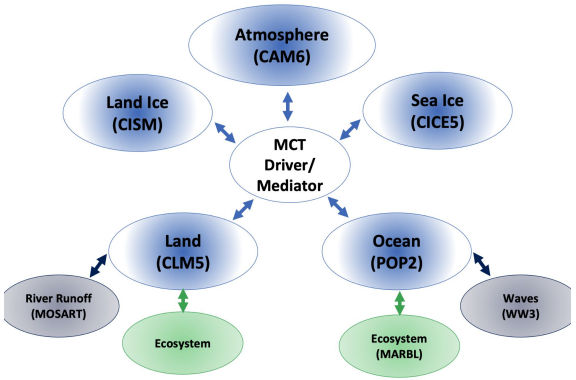
“FXHIST” is an example of a component set, or “compset”, which defines the configuration of the CESM component models: atmosphere, land, ocean, sea ice, and land ice.

All WACCM-X components use non-interactive data models for ocean and sea ice, and do not include interactive land ice. Such compsets all begin with the letter “F”.

To list available WACCM-X compsets, under **`cime/scripts`** enter:

```
> ./query_config --compsets | grep %WXIE
```

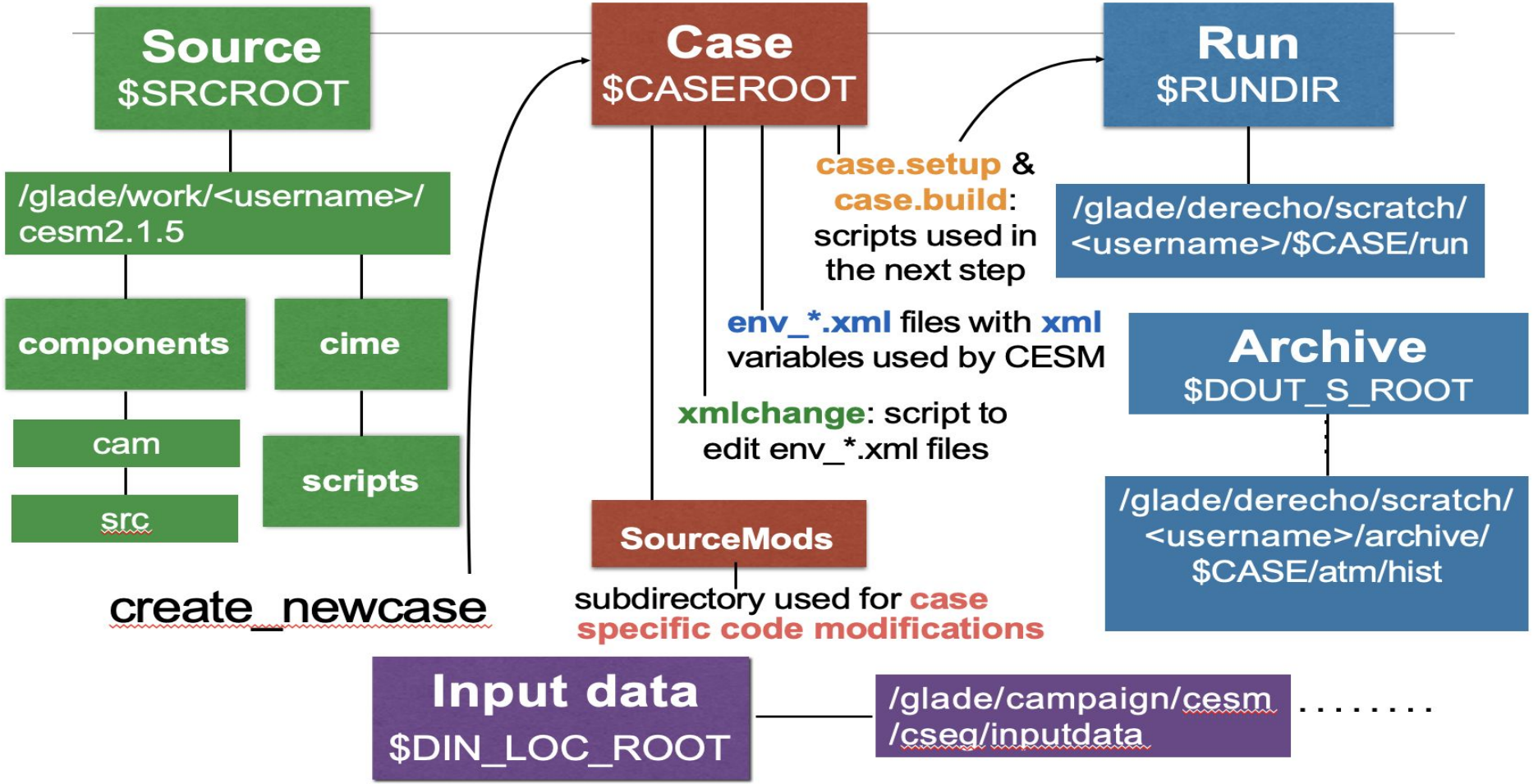
Short name	Long name
FX2000	: 2000_CAM40%WXIE_CLM40%SP_CICE%PRES_DOCN%DOM_RTM_SGLC_SWAV
FXHIST	: HIST_CAM40%WXIE_CLM40%SP_CICE%PRES_DOCN%DOM_RTM_SGLC_SWAV
FXmadHIST	: HIST_CAM40%WXIED_CLM40%SP_CICE%PRES_DOCN%DOM_RTM_SGLC_SWAV
FXSD	: HIST_CAM40%WXIE%SDYN_CLM40%SP_CICE%PRES_DOCN%DOM_RTM_SGLC_SWAV
FXmadSD	: HIST_CAM40%WXIED%SDYN_CLM40%SP_CICE%PRES_DOCN%DOM_RTM_SGLC_SWAV



WACCM-X Compsets

FX2000	Perpetual year 2000 emissions forcings	Middle atmosphere WACCM chemistry
FXHIST	Transient emissions forcings	Middle atmosphere WACCM chemistry
FXmadHIST	Transient emissions forcings	Middle atmosphere chemistry plus D-region ion chemistry
FXSD	Transient emissions forcings Nudged to MERRA meteorology	Middle atmosphere WACCM chemistry
FXmadSD	Transient emissions forcings Nudged to MERRA meteorology	Middle atmosphere chemistry plus D-region ion chemistry

Directory Structure of Model Source and Created Case, Run, Archive, and Input Data



Compiling: Setup and Build (Derecho)

After creating your case, go to the case directory:

```
> cd /glade/work/fvitt/cesm/cases/fe21.FXHIST.f19.t001
```

Setup the case:

```
> ./case.setup
```

Build the case:

```
>./case.build
```

Problems? Try:

```
>./case.setup --reset
>./case.build --clean-all
>./case.build
```

Running: Submit and Checking Output (Derecho)

After compiling and building the case, submit the job:

```
> ./case.submit
```

Check the run in the queue:

```
> qstat -u fvitt
```

Check run directory while running::

```
> ls /glade/derecho/scratch/fvitt/fe21.FXHIST.f19.t001/run
```

Check archive directory after run completes::

```
> ls /glade/derecho/scratch/fvitt/archive/fe21.FXHIST.f19.t001/atm/hist
```

Problems? Log files in run directory can help : cesm*log*, atm*log*, cpl*log*

After running out-of-the-box, can make changes to run configuration

XML Files (build and run control variables)

There are multiple `env_*.xml` files in the `$CASEROOT` directory:

- `env_archive.xml`: specifies rules for short term archive script `case.st_archive`
- `env_batch.xml`: specifies batch specific settings used in `case.submit` script
- `env_build.xml`: specifies build information used in the `case.build` script
- `env_case.xml`: set by create_newcase and cannot be modified
- `env_mach_pes.xml`: specifies PE layout on NCAR HPC for components and used by `case.run` script
- `env_mach_specific.xml`: specifies machine specific information used in `case.build` script
- `env_run.xml`: sets run time information (such as length of run, number of submissions, …)

Use xmlquery tool to see settings

```
>./xmlquery --partial STOP --full
```

Use xmlchange to change settings:

```
>./xmlchange $CONTINUE_RUN="TRUE"
```

Component processor usage (or layout)

```
> ./pelayout
Comp  NTASKS  NTHRDS  ROOTPE PSTRIDE
CPL :   1536/     1;      0      1
ATM :   1536/     1;      0      1
LND :   1536/     1;      0      1
ICE :   1536/     1;      0      1
OCN :   1536/     1;      0      1
ROF :   1536/     1;      0      1
GLC :   1536/     1;      0      1
WAV :   1536/     1;      0      1
ESP :   1536/     1;      0      1
ESMF_AWARE_THREADING is False
ROOTPE is with respect to 128.0 tasks per node
```

To change number of MPI tasks:

```
> ./xmlchange NTASKS=-10
```

Negative value indicates number of compute nodes

Modifying Model Settings In user_nl_cam File

CaseDocs/atm_in file has current settings which can be modified in user_nl_cam

```
> less $CASEROOT/CaseDocs/atm_in
```

Output fields:

Search for “MASTER FIELD LIST” in atm log file output in archive directory

```
> less /glade/derecho/scratch/fvitt/archive/fe21.FXHIST.f19.t001/logs/atm*log*
```

Modified by setting “fincl” namelist variables

```
fincl2= 'Z3', 'T', 'TIon', 'TElec', 'e', 'U', 'V', 'OMEGA', 'UI', 'VI',
'WI','EDens', 'ElecColDens', 'PHIM2D', 'PS', 'EDYN_ZIGM11_PED',
'EDYN_ZIGM2_HAL', 'ED1', 'ED2', 'O', 'O2', 'H', 'NO',
'TTGW','UTGW_TOTAL','DTCOND', 'QRS','QRL','QNO'
```

Output frequency, times per file, averaged or instantaneous

```
nhtfrq = 0, -3 ,  -24,  -24, -120, -24
mfilt =  1,  8,     7,    7,   10, 365
avgflag_pertape= 'A',  'I',  'I',  'A',  'A', 'A'
```

Characteristics of WACCM-X Output netCDF History Files

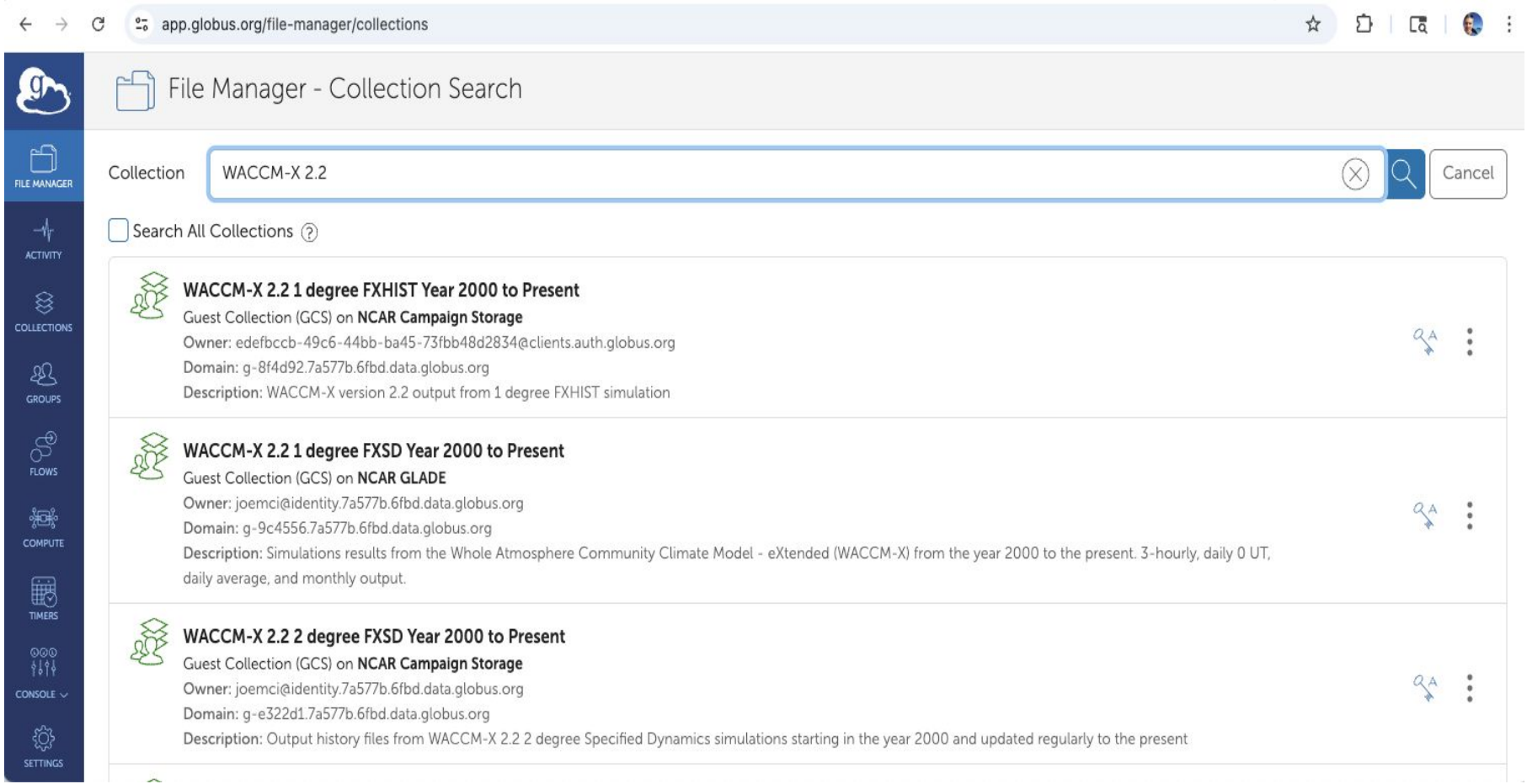
- **netCDF:** self-describing binary data format used for primary CESM output
- **History files:** WACCM-X output is written to several output streams, each with a particular frequency and averaging characteristic which can be modified in the user_nl_cam file

  - **h0:** monthly averages
    - f.e22.FXSD.f09_f09_mg17.001.cam.h0.2000-01.nc (January 2000)
    - f.e22.FXSD.f09_f09_mg17.001.cam.h0.2000-02.nc (February 2000)
  - **h1:** 3-hourly instantaneous
    - f.e22.FXSD.f09_f09_mg17.001.cam.h1.2000-01-01-00000.nc (January 1, 2000)
    - f.e22.FXSD.f09_f09_mg17.001.cam.h1.2000-01-02-00000.nc (January 2, 2000)
  - **h2:** daily instantaneous
  - **h3:** daily averages
  - **h4:** 10-day average tidal coefficients
  - **h6:** daily averages, zonal mean circulation diagnostics

WACCM-X Output on Globus (1)

- WACCM-X output is available Globus website globus.org
- Three collections of WACCM-X output from 2000 through 2024
- 1 degree horizontal resolution historical (FXHIST) simulation output
- 1 (f09) and 2 (f19) degree horizontal resolution specified dynamics (FXSD) simulation output
- Updated regularly
- If new to Globus, go to https://www.globusid.org/create to sign up
- Log in, choose “File Manager” tab on left then in “Collection”, search for “WACCM-X 2.2” (next slide)

WACCM-X Output on Globus (2)



University Allocations

https://arc.ucar.edu/docs - Left side bar “Getting Started” > “Allocations” > University Allocations”

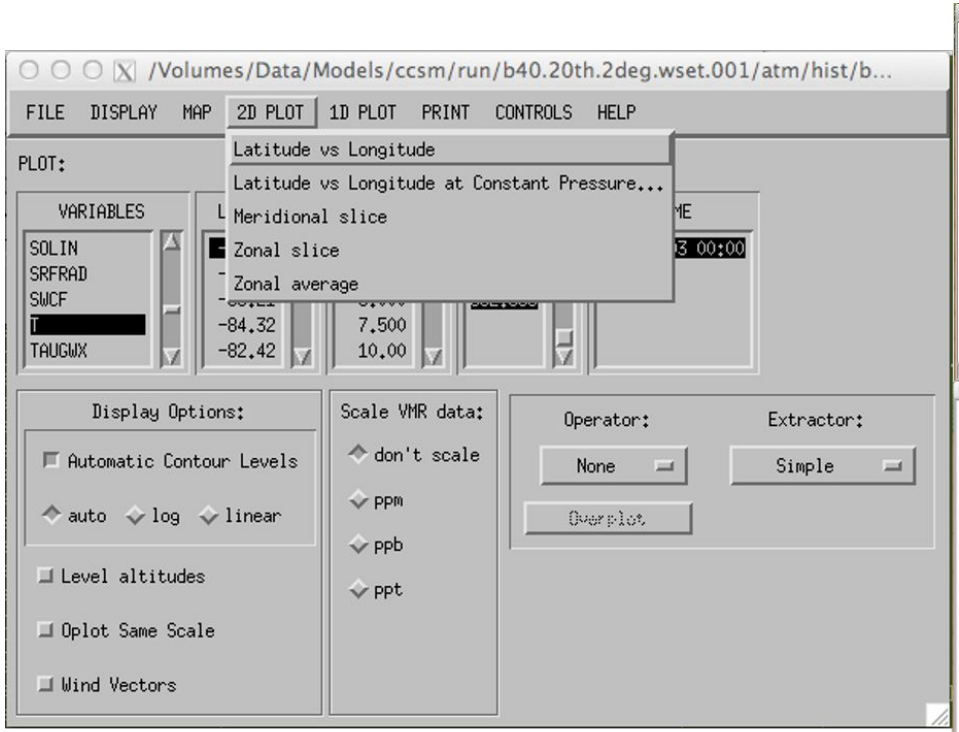
The table below summarizes the HPC resource limits for each type of allocation. For Small, Exploratory, and Classroom projects, the amounts shown assume use of only Derecho or Derecho GPU. For requests to use both parts of Derecho, proportionally smaller limits apply—e.g., up to half the Derecho limit and half the Derecho GPU limit can be requested together.

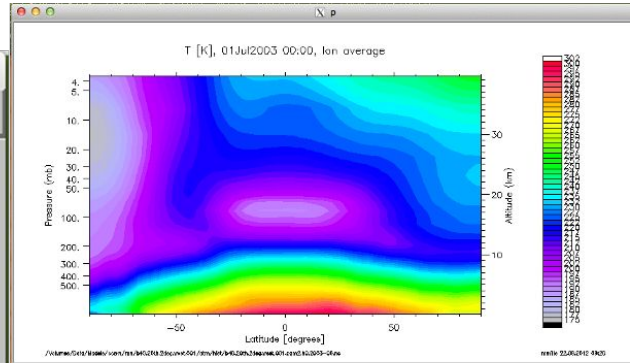
Allocation request	Initial HPC limit*	Supplement HPC limit	Frequency	Funding eligibility
Large	No upper limit (subject to availability)	No upper limit (subject to availability)	Semi-annual panel review	NSF award required
Small	Derecho: 1 million core-hours Derecho GPU: 2,500 GPU-hours	Derecho: 1 million core-hours Derecho GPU: 2,500 GPU-hours	Continuous	NSF award required
Exploratory & Classroom	Derecho: 500,000 core-hours Derecho GPU: 1,500 GPU-hours	Derecho: 500,000 core-hours Derecho GPU: 1,500 GPU-hours	Continuous	No external funding award
Data Analysis	n/a (Casper only)	n/a (Casper only)	Continuous	Any funding source

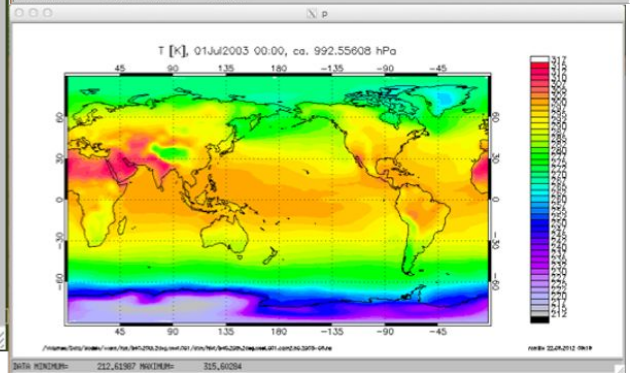
Submitting Your Request. For all types of university allocations, including any subsequent extension or supplement requests, requests should be submitted via the **ARC portal’s Allocations section**. If you have questions about these options, please contact us via the **Research Computing help** desk.

Quick view of WACCM-X output

GEOV is an IDL-based viewer for geophysical history files







Quick view of WACCM-X output: GEOV

GEOV can be downloaded from github:

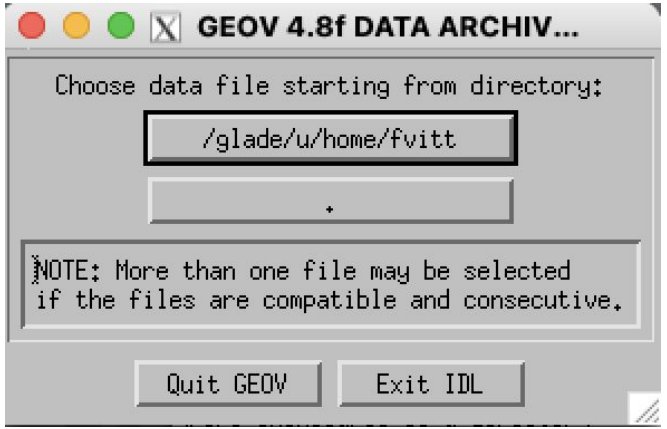
```
> git clone https://github.com/NCAR/GEOV.git
```

Can append GEOV path to `idl_path`:

```
idl_path = expand_path('+/location/GEOV')
```

On NCAR machines (.e.g., casper or derecho)

```
> module load idl
> export IDL_STARTUP=~fvitt/idl_startup
> idl geov
```



Resources

Quick Start

https://escomp.github.io/CESM/versions/master/html/index.html

Online Tutorial

https://ncar.github.io/CESM-Tutorial/README.html

CESM Discuss Forums (get help)

https://bb.cgd.ucar.edu/cesm/

NASA Community Coordinated Modeling Center (CCMC)

WACCM-X/RoR Overview

Jack Wang and all CCMC members
Community Coordinated Modeling Center, NASA GSFC
June 25nd, 2025

CCMC provides on-demand model simulations to support research studies, missions, and event analyses

Instant Run

Run-on-Request

Continuous Run

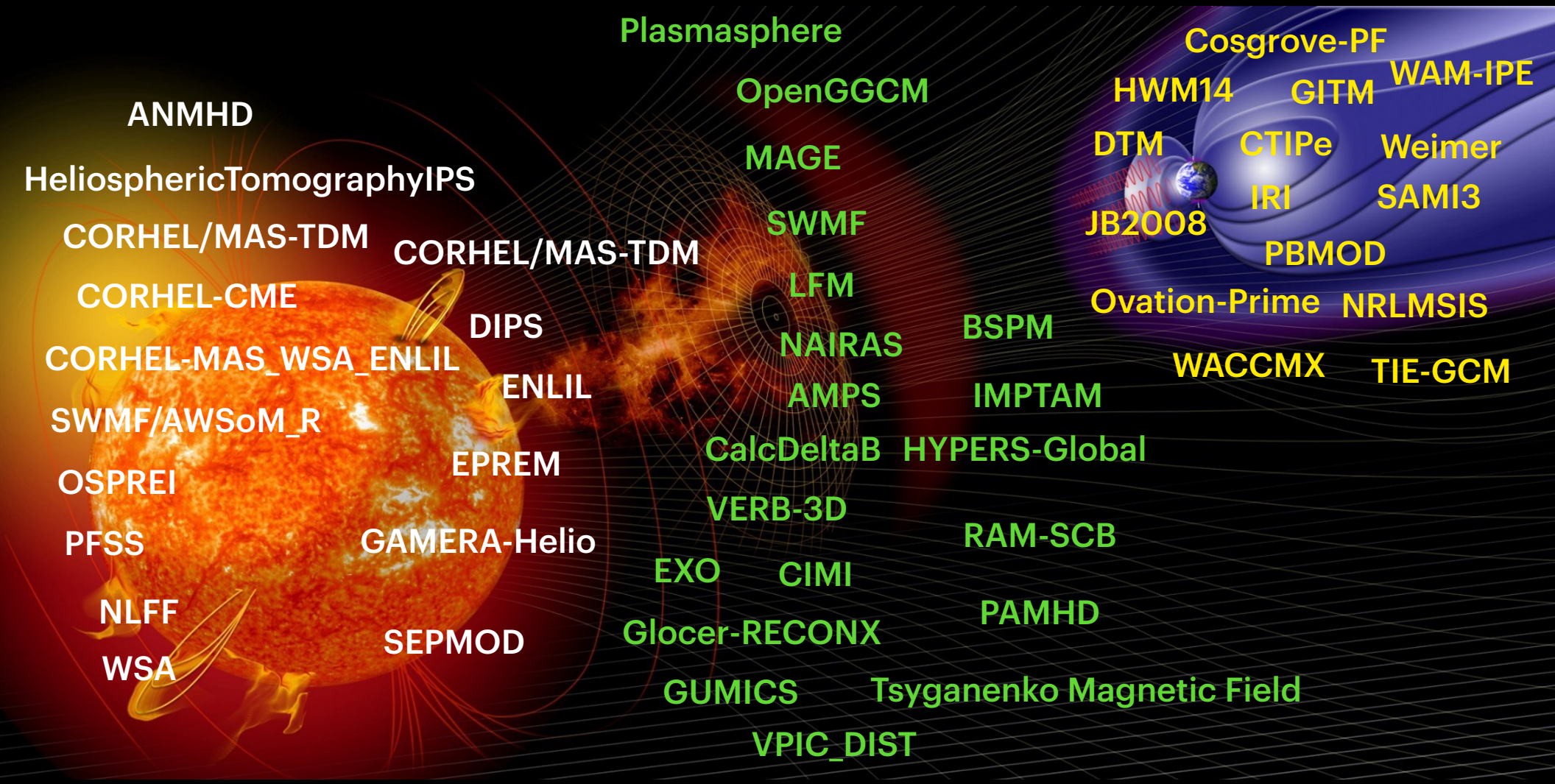
CCMC Model Catalog

CCMC builds bridges between model developers and end users

V.S.

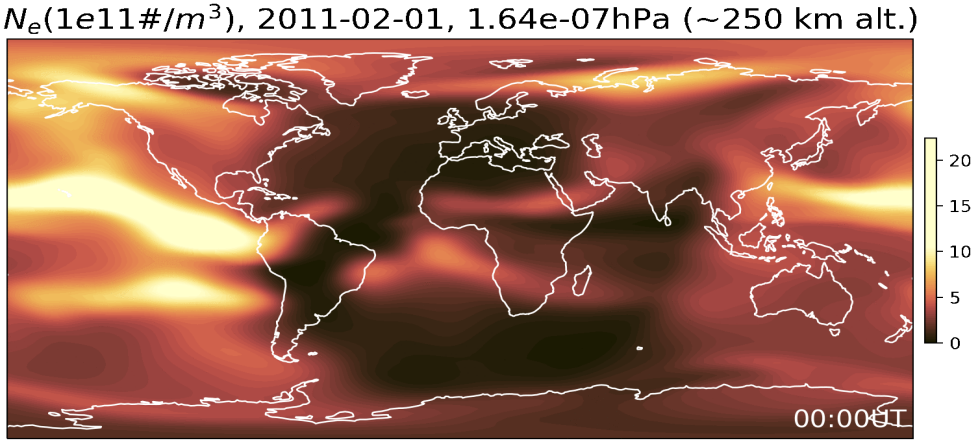
CCMC acknowledges all the model developers for the permission to use the models and software tools at CCMC

Runs-on-Request (RoR) - Execute simulations upon customer request



Corona | Heliosphere | Magnetosphere | Inner Magnetosphere | Ionosphere/ Thermosphere

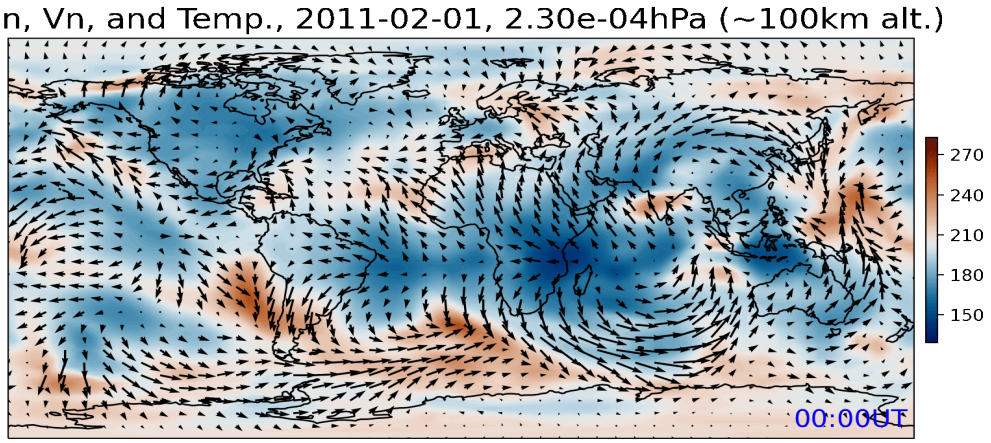
WACCM-X (CESM2.2.0) is available through RoR since 2023, first whole atmosphere model at CCMC



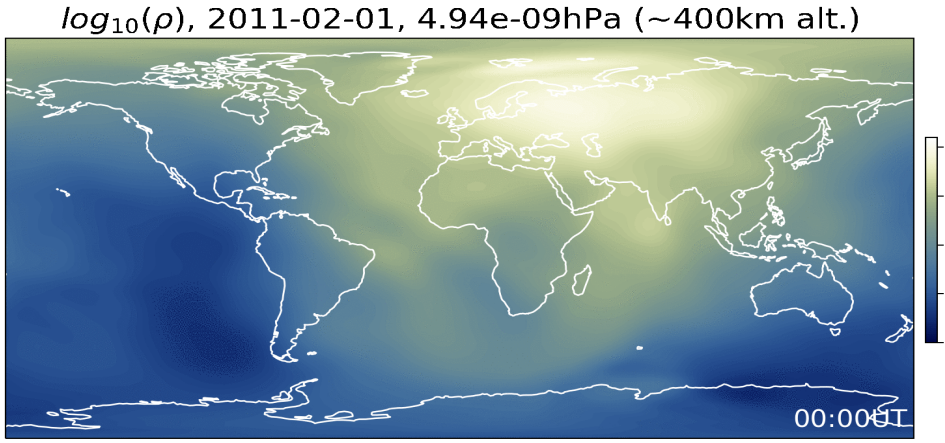
- output cadence: 10 mins.
- resolution: 0.9° Lat. x 1.25° Lon.
- variable: T, U, V, Z, drift, TEC, NE, composition…

dynamics-chemistry coupling

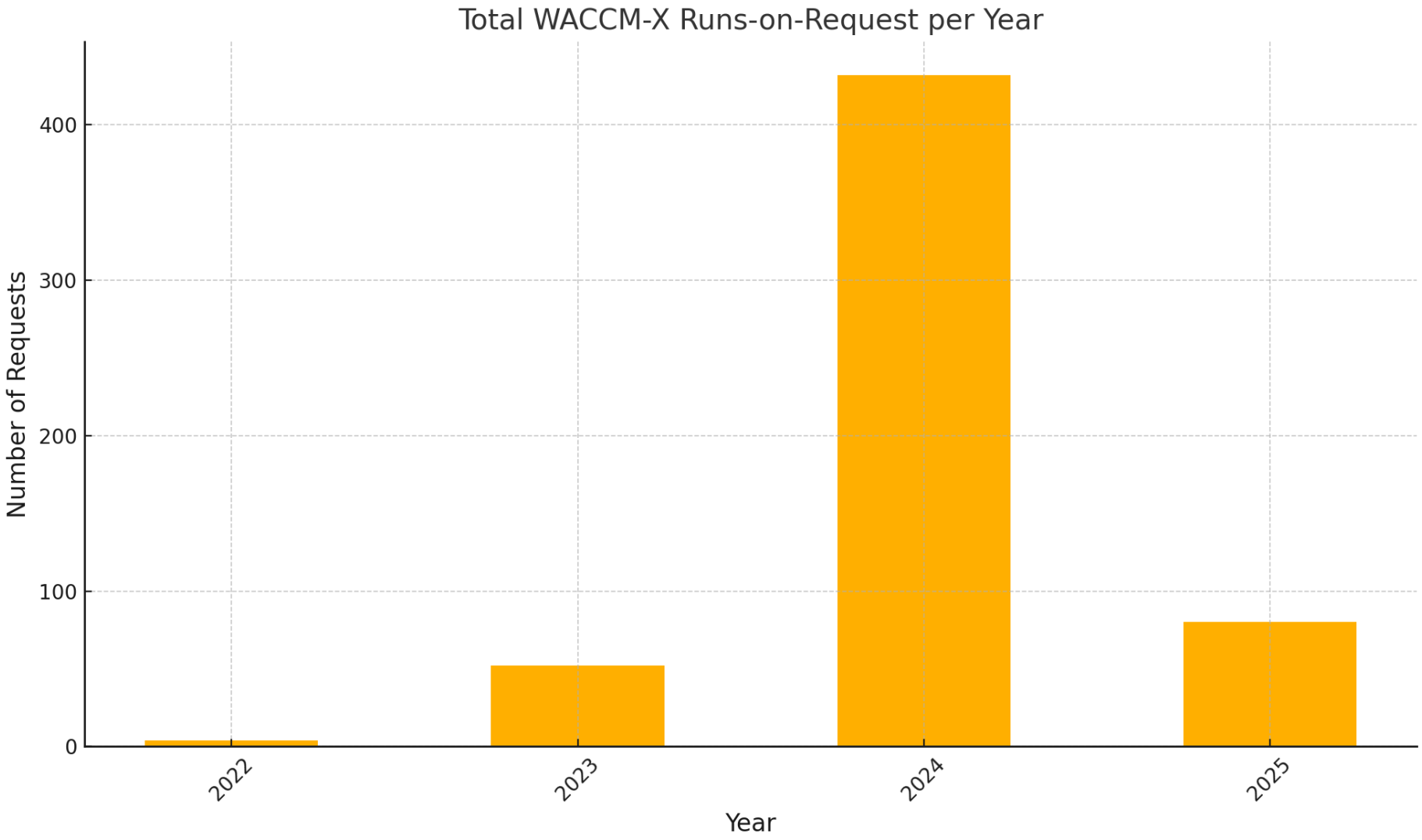
ion-neutral coupling



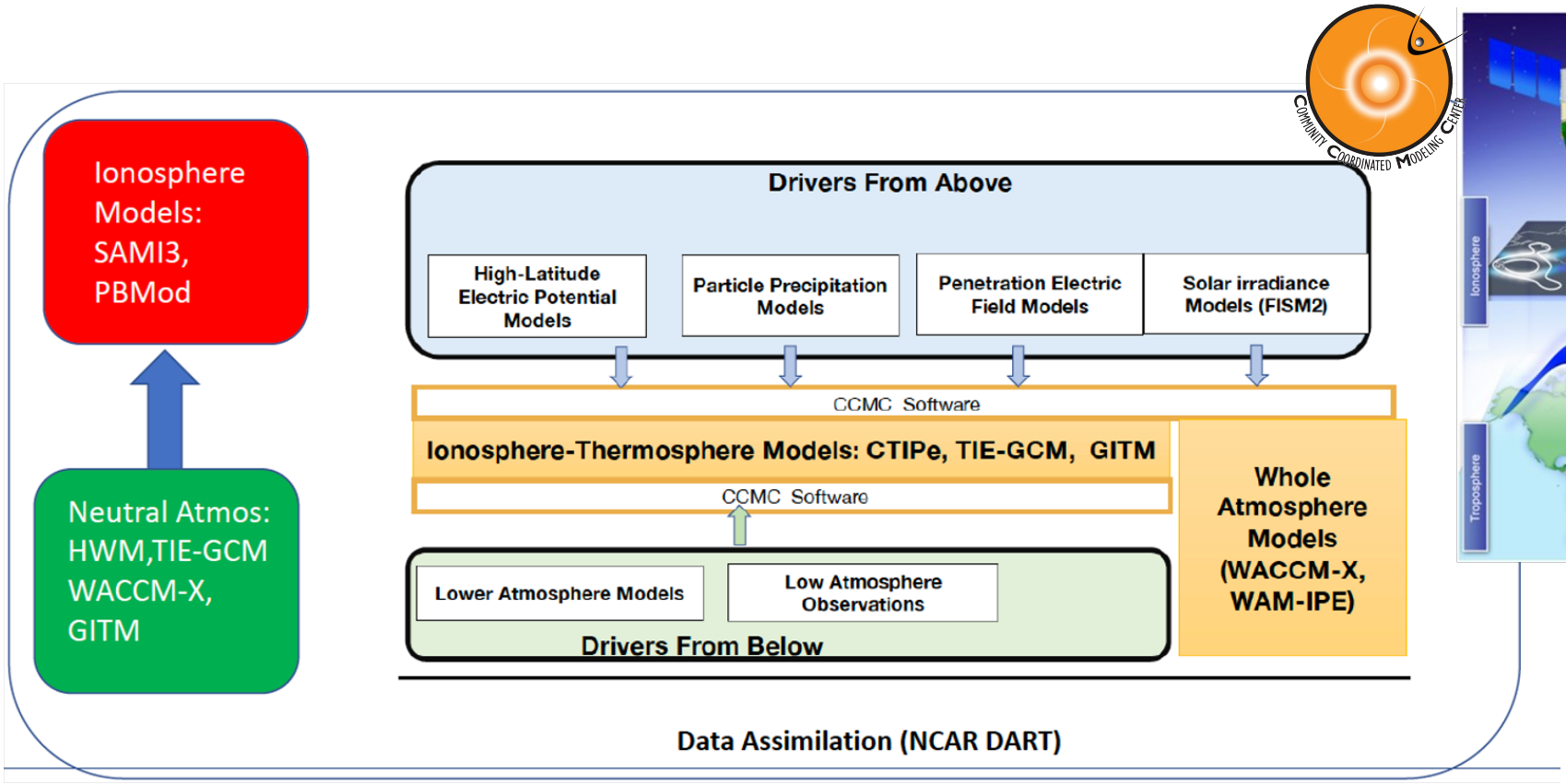
lower-upper atm. coupling

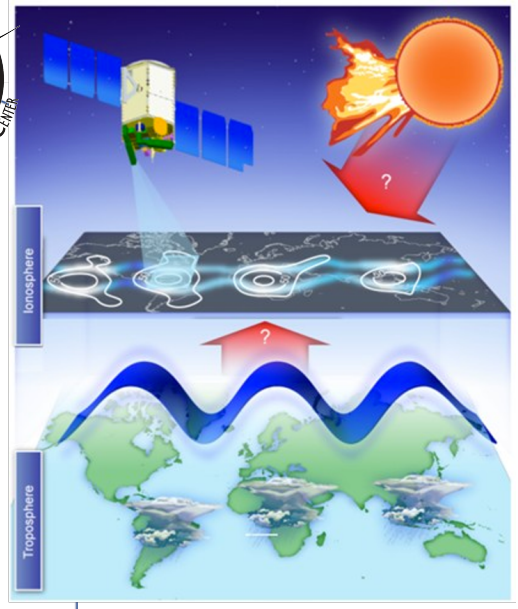


Over 560 WACCM-X requests since 2023 (from ~100 unique users across > 10 countries)



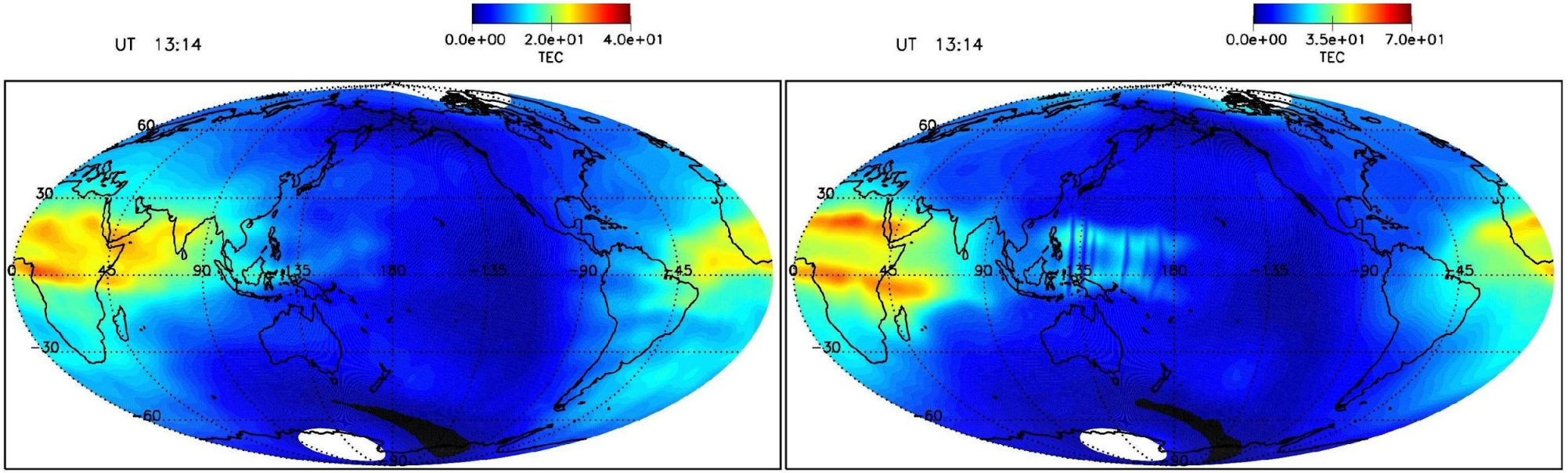
Models and services available at CCMC (thermosphere/ ionosphere models coupling with magnetosphere MHD and lower atmosphere drivers) -- providing system solution





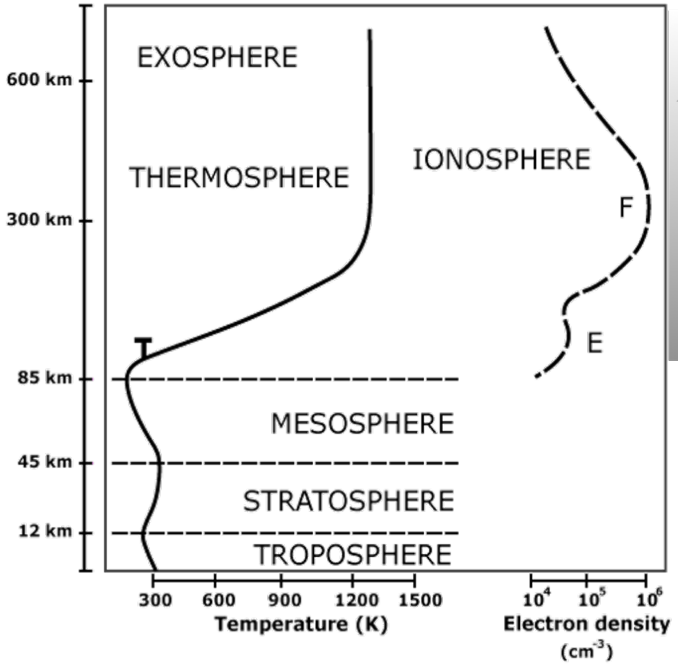
First global ionosphere model SAMI3 simulates weather of the ionosphere

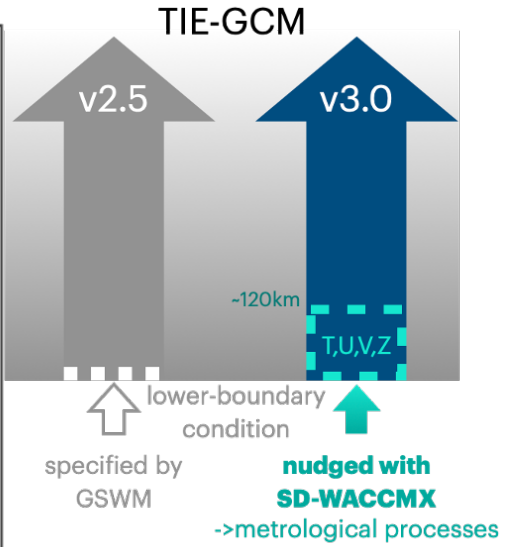
- Options of empirical (HWM/MSIS) or physics-based model inputs (e.g., TIE-GCM, TIE-GCM/ICON, WACCM-X)
- SAMI3/WACCM-X is available through CCMC RoR.
  - enable to study day-to-day variability of plasma bubbles and TIDs

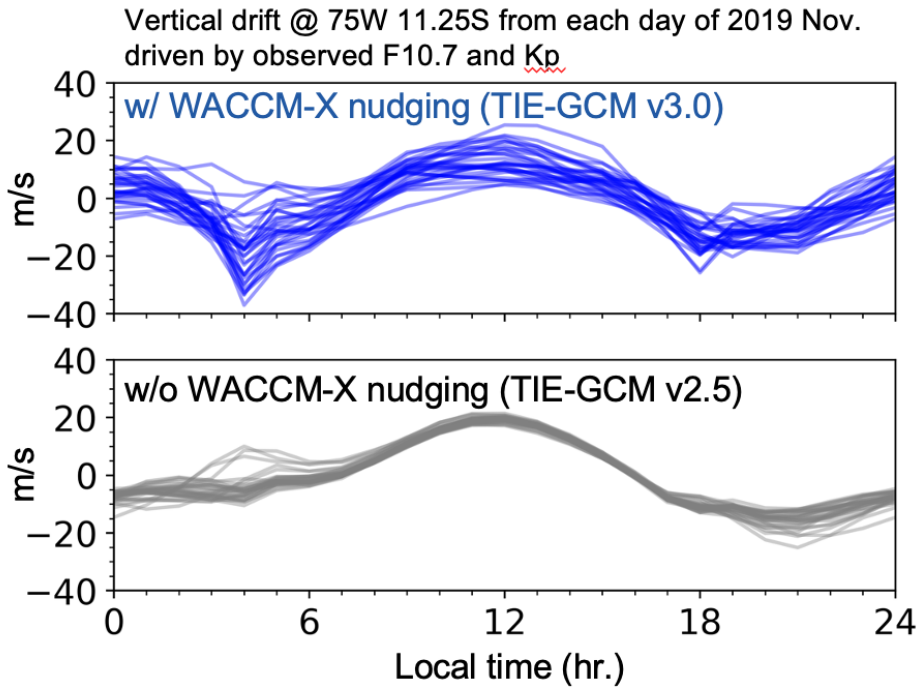


solar min. in Aug. solar medium in Mar.

TIE-GCM v3.0 nudged with SD-WACCMX captures day-to-day variability in the Ionosphere/Thermosphere

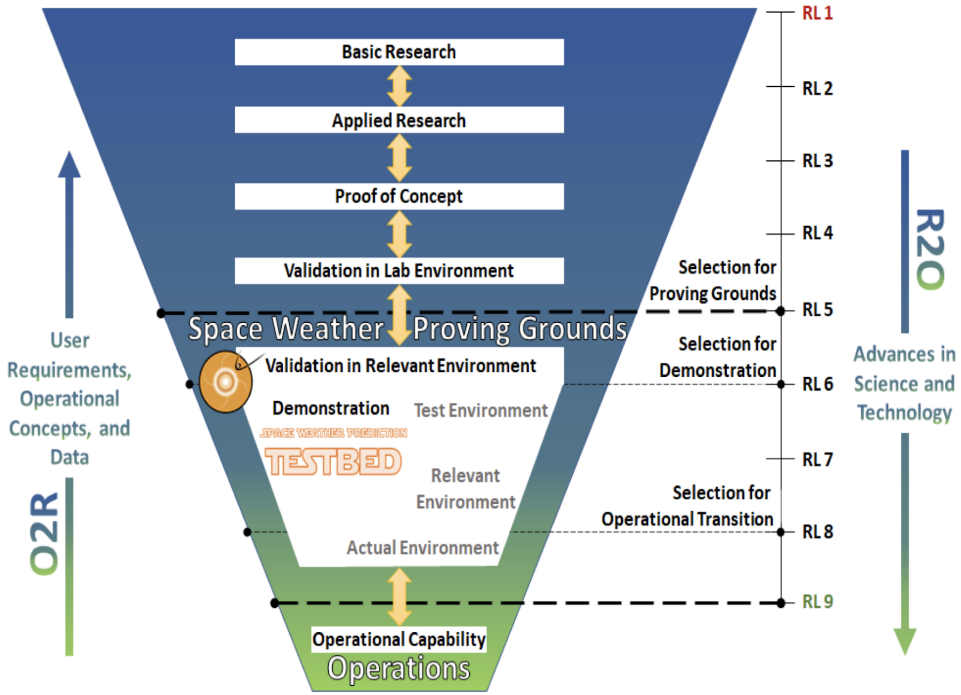


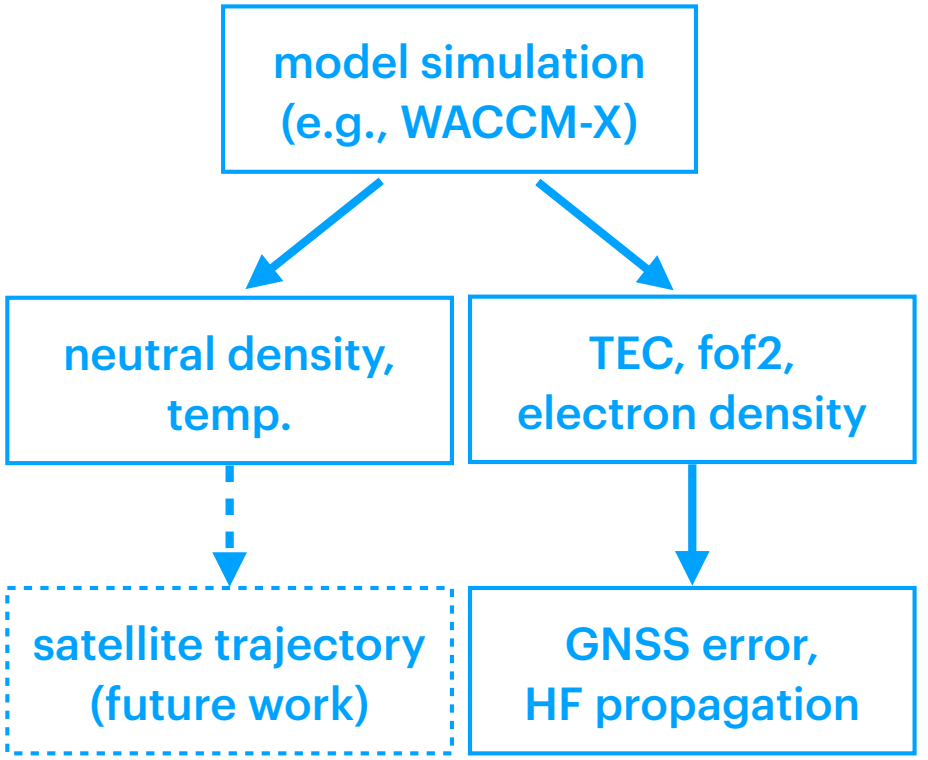




Enhancing the model capability to reproduce variability of the space environment as related to lower atmosphere forcing on day-to-day weather scales.

CCMC performs unbiased testing and validation of hosted models

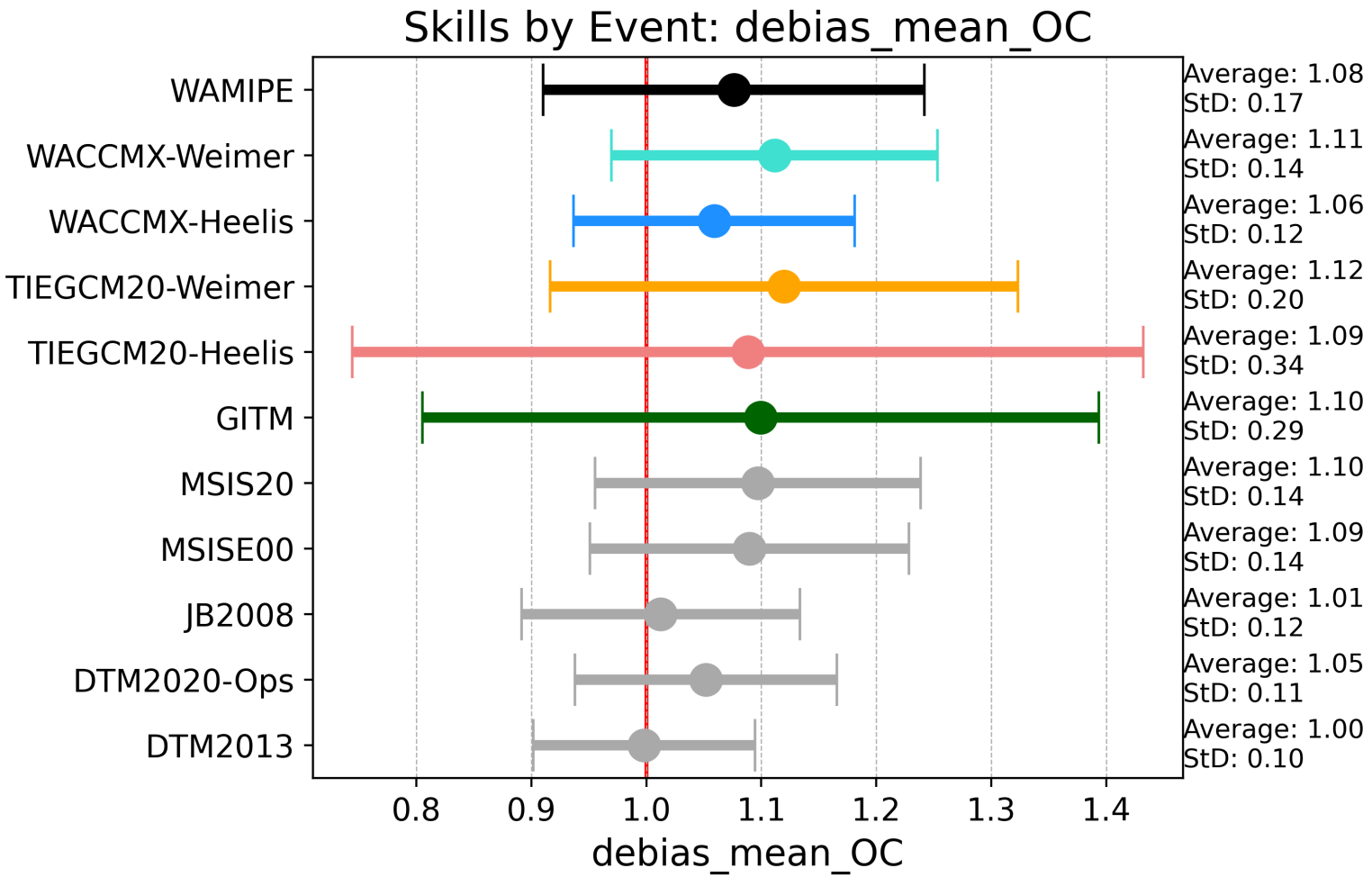




impact-based validation

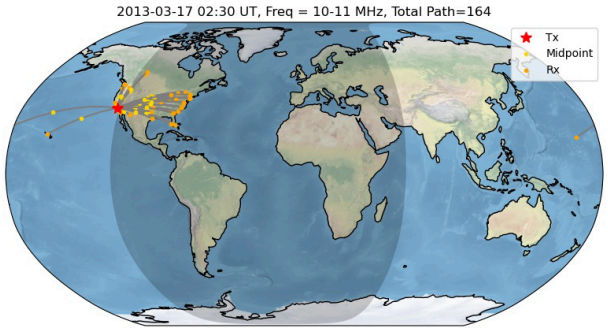
Validation of neutral density during 151 storm events from 2001 to 2023

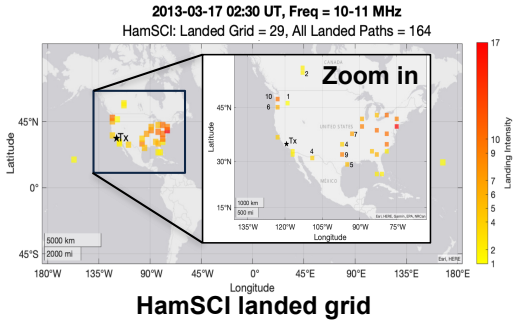
O/C = 1, no model bias on average (best)
> 1, underestimate
< 1, overestimate



Ionosphere Model Validation with Amateur Radio Community (HamSCI), led by Dr. Min-Yang Chou

Goal: To reproduce the **HF propagation** from the **HamSCI data**, we will be able to use HamSCI data for ionospheric research and **model validation**.





HamSCI landed grid

HamSCI

- An official NASA citizen science project
- allows researchers to collaborate with the amateur radio community in scientific investigations

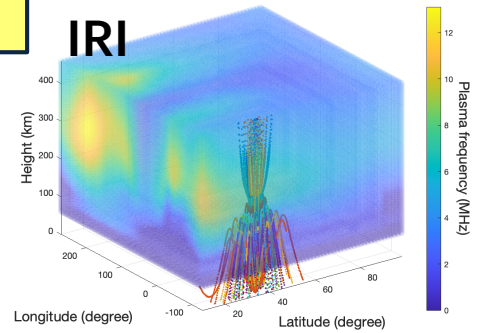
PHaRLAP (Ray tracing tool)

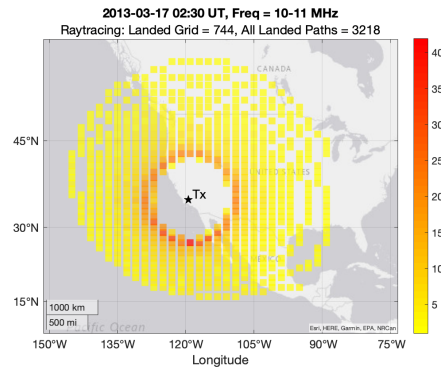
- Developed and controlled by Dr. Manuel Cervera, DoD, Australian Government.
- Matlab toolbox for modeling of the propagation of High Frequency (HF) radio waves
- Semi-open source (some of the key codes are precompiled.)

Raytracing landed grid

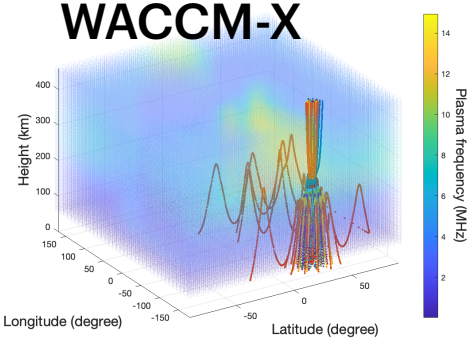
Same landed grid

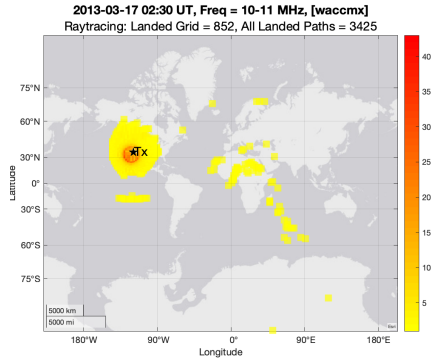
IRI



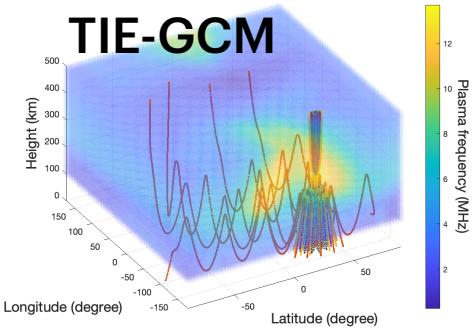


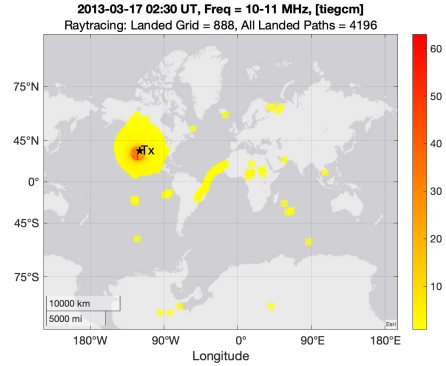
WACCM-X



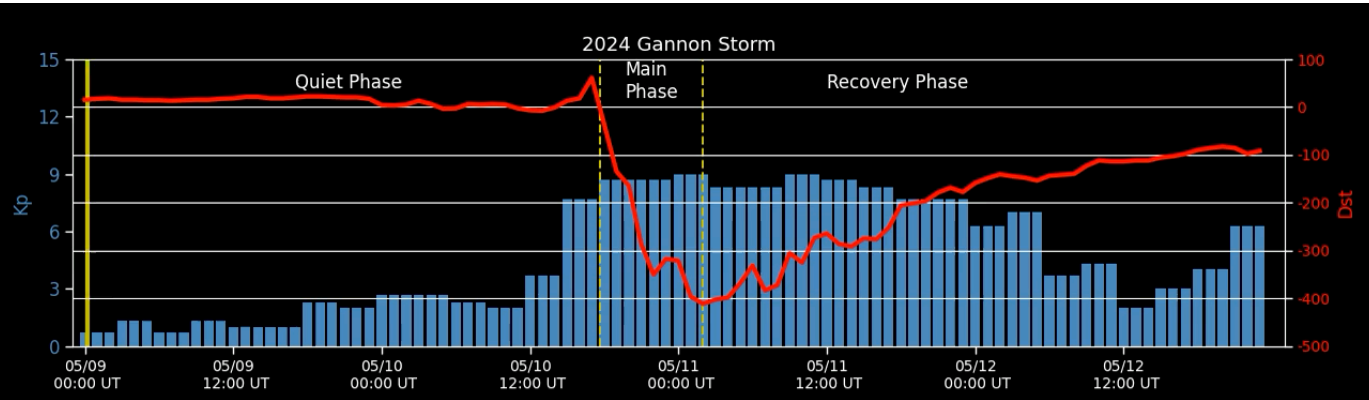


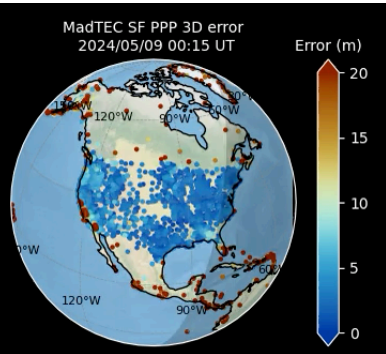
TIE-GCM

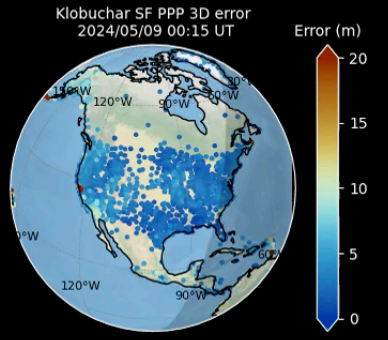




(not all raypaths)


2024 Gannon Storm
Quiet Phase
Main Phase
Recovery Phase
Kp
Dst
05/09 00:00 UT
05/09 12:00 UT
05/10 00:00 UT
05/10 12:00 UT
05/11 00:00 UT
05/11 12:00 UT
05/12 00:00 UT
05/12 12:00 UT


MadTEC SF PPP 3D error
2024/05/09 00:15 UT
Error (m)


Klobuchar SF PPP 3D error
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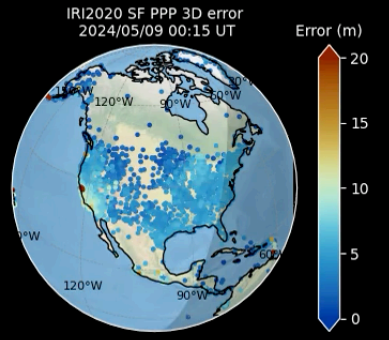
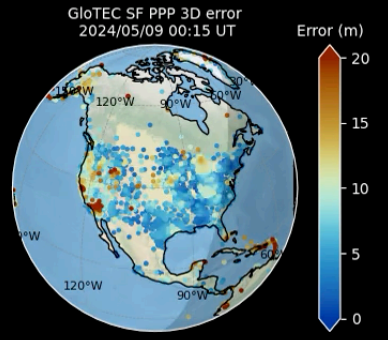
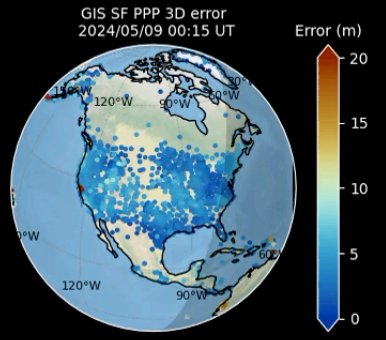
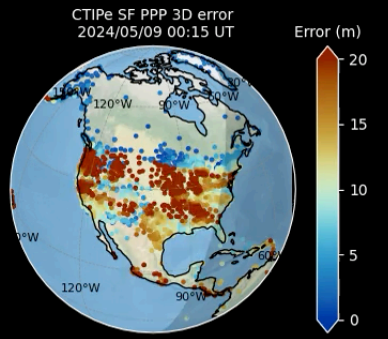
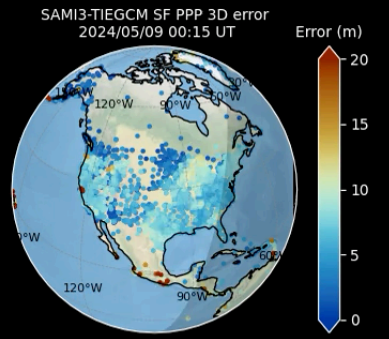
Error (m)

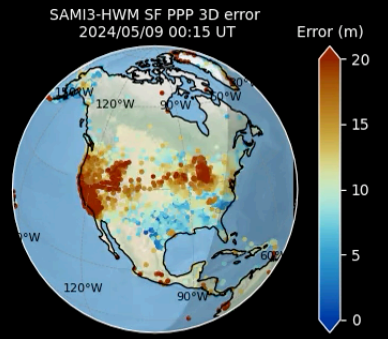

IRI2020 SF PPP 3D error
2024/05/09 00:15 UT
Error (m)


GloTEC SF PPP 3D error
2024/05/09 00:15 UT
Error (m)


GIS SF PPP 3D error
2024/05/09 00:15 UT
Error (m)


CTIPe SF PPP 3D error
2024/05/09 00:15 UT
Error (m)


SAMI3-TIEGCM SF PPP 3D error
2024/05/09 00:15 UT
Error (m)


SAMI3-HWM SF PPP 3D error
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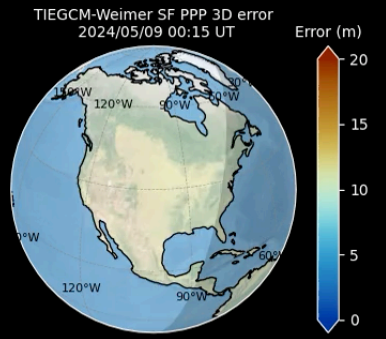
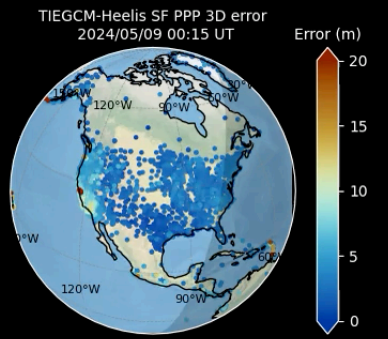
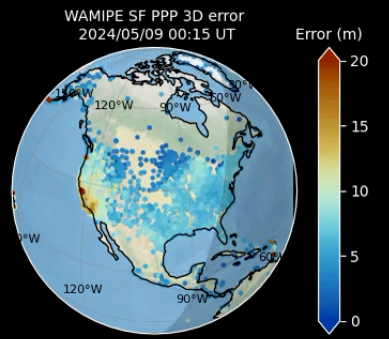
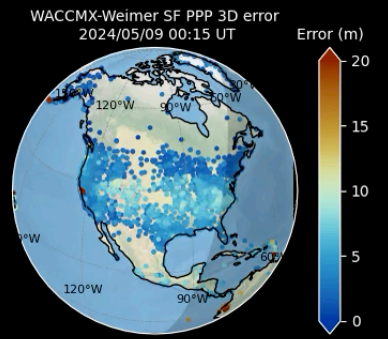
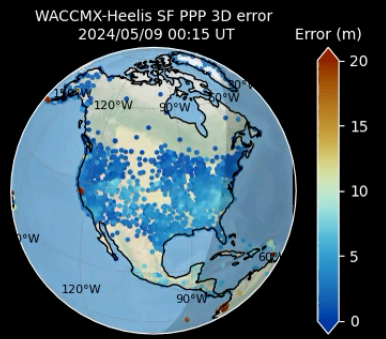
Error (m)


TIEGCM-Weimer SF PPP 3D error
2024/05/09 00:15 UT
Error (m)


TIEGCM-Heelis SF PPP 3D error
2024/05/09 00:15 UT
Error (m)


WAMIPE SF PPP 3D error
2024/05/09 00:15 UT
Error (m)


WACCMX-Weimer SF PPP 3D error
2024/05/09 00:15 UT
Error (m)


WACCMX-Heelis SF PPP 3D error
2024/05/09 00:15 UT
Error (m)

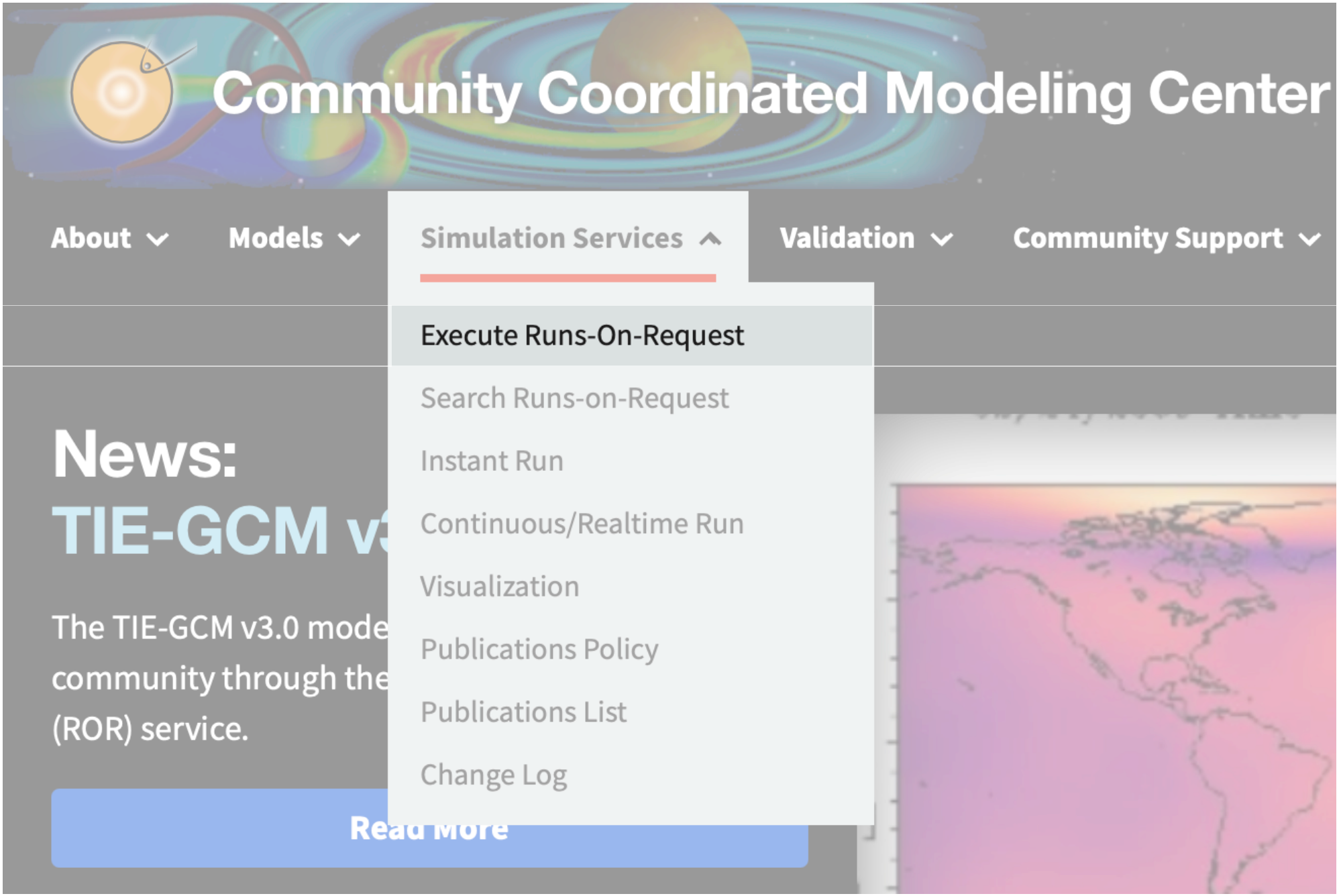
Future outlook

- Onboarding CESM3 as soon as it becomes available
  - 0.5-deg resolution, dynamical core to SE:
    resolving GWs is particularly important for plasma bubble seeding
- New NO scheme should improve neutral density
- SWMF/WACCM-X; WACCM-X/PBMOD
- Expand validation activities (e.g, satellite trajectories, see Jia Yue's science highlight talk on Thursday for an example)

NASA Community Coordinated Modeling Center (CCMC)

WACCM-X/RoR Demo

Jack Wang and all CCMC members
Community Coordinated Modeling Center, NASA GSFC
June 25nd, 2025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Continuous/Realtime Run
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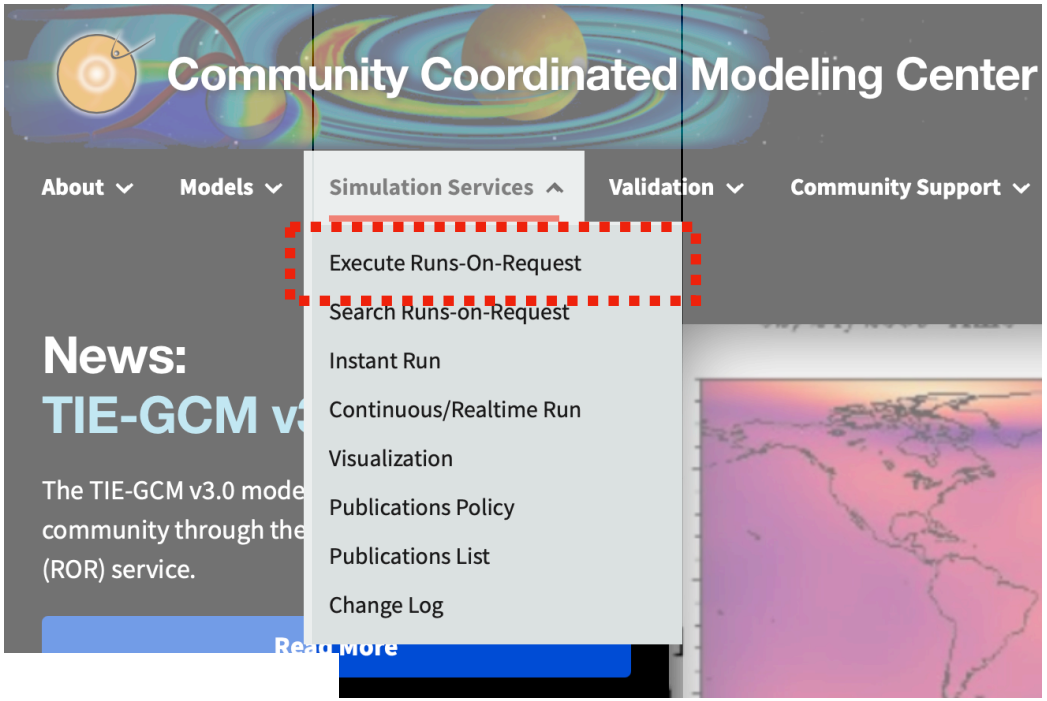
News:
TIE-GCM v
The TIE-GCM v3.0 mode
community through the
(ROR) service.
Read More



Home › CCMC Developed Web Apps/Tools

CCMC Runs on Request System

Runs on Request (ROR) is a simulation service accessible to anyone wishing to execute space science and space weather models hosted by the CCMC.

View all models available for Runs on Request (ROR) →

Track current active request progress on the ROR Requests Dashboard →

Search ROR Archive →

Home

Model Catalog

WACCMX

Found 2 models

Reset Filters

WACCMX

Whole Atmosphere Community Climate Model With Thermosphere and Ionosphere Extension

Version: 2.2

Status: Production

Runs-on-Request | Public Repository

WACCM-X RoR submission interface

E-field model
- Weimer
- Heelis

Solar EUV model
- EUVAC
- FISM2 daily band

Request an WACCMX Model Run

Please complete the form below. * Indicates a required field.

****You must agree to the CCMC Data Policy in order to submit a run****

Do you give your consent?
☑ **YES**

Step 1: GENERATE YOUR REQUEST

Your run results will be published online *under your Run Registration Number* (FirstName_LastName_MMDDYY_ModelType_RunNumber)

WORK OR SCHOOL EMAIL how to contact you		Enter a valid work or school email address
FIRST NAME (GIVEN)* your given name		Enter your given name
LAST NAME (FAMILY)* your family name		Enter your family name
RUN NUMBER* max 15 runs per day	choose run number for today	Unless you want to overwrite it
KEYWORD/S* helps to sort and search the results of simulations		Enter a keyword

Step 2: Dates Range

Select start and end dates of your simulation spanning at least 1 and at most 10 days.

Start date YYYY/MM/DD		Select or type a valid date in the suggested format, e.g. 2016/01/15
End date YYYY/MM/DD		Select or type a valid date in the suggested format, e.g. 2016/01/15

Step 3: E-Field Model

Choose E-Field model
Parameters of the solar and E-field inputs are based on the observational dataset

Weimer

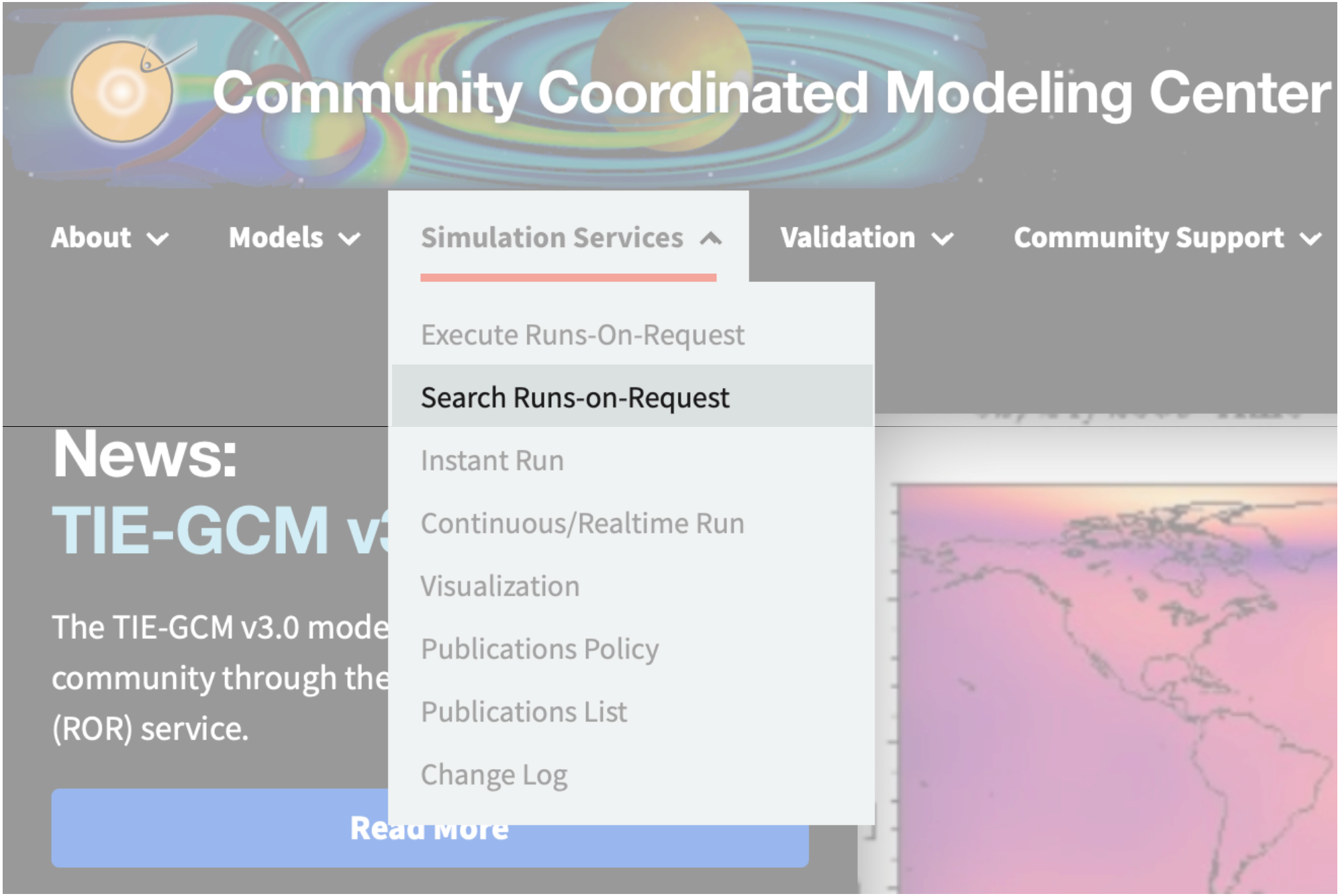
Please, select a valid model for the selected dates range or adjust the dates

Weimer: 1996/01/01 - 2024/06/01
Heelis: 1960/01/01 - 2024/06/01

Step 4: Solar EUV model

Choose EUV model

EUVAC (default)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TIE-GCM v
The TIE-GCM v3.0 mode
community through the
(ROR) service.
Read More

Status	Run Number	Key Words	Model	Model Version	Validation Level	Year	DoY at Start	F10.7 at Start	F10.7 (three year average)	Run Type	Input Type	Event Date
running	Dr_SC_062325_IT_1	test_run	WACCMX	2.2	--	2024	131	0.00000	0.00	event	--	May 10, 2024
Published	Huang_Guo-wei_062025_IT_1	Guo	WACCMX	2.2	--	2024	151	0.00000	0.00	event	var	2024-05-30
Published	Dmytro_Kotov_061425_IT_1	Ionospheric storms	WACCMX	2.2	--	2023	150	0.00000	0.00	event	var	2023-05-30
Published	Dmytro_Kotov_061325_IT_4	Ionospheric storms	WACCMX	2.2	--	2023	150	0.00000	0.00	event	var	2023-05-30
Published	Huang_Guo-wei_061325_IT_1	Guo	WACCMX	2.2	--	2024	142	0.00000	0.00	event	var	2024-05-21
Published	Shrivansh_Panwar_060825_IT_1	Meridional Wind	WACCMX	2.2	--	2004	203	0.00000	0.00	event	var	2004-07-21
Published	Huang_Guo-wei_060525_IT_1	Guo	WACCMX	2.2	--	2024	132	0.00000	0.00	event	var	2024-05-11
running	Huang_Guo-wei_060425_IT_1	Guo	WACCMX	2.2	--	2024	132	0.00000	0.00	event	--	May 11, 2024
Published	Swati_Chowdhury_060225_IT_1	meridional wind	WACCMX	2.2	--	2020	337	0.00000	0.00	event	var	2020-12-02
Published	Huang_Guo-wei_052825_IT_1	Guo	WACCMX	2.2	--	2024	122	0.00000	0.00	event	var	2024-05-01
Published	chaneMoges_Seid_052725_IT_1	temperature	WACCMX	2.2	--	2019	339	0.00000	0.00	event	var	2019-12-05
Published	Meenakshi_S_052625_IT_2	wave4	WACCMX	2.2	--	2020	14	0.00000	0.00	event	var	2020-01-14
running	Huang_Guo-wei_052325_IT_1	Guo	WACCMX	2.2	--	2024	122	0.00000	0.00	event	--	May 01, 2024
Published	Sophia_Laranja_052325_IT_1	WACCMX_10032014_Weimer_EUVAC	WACCMX	2.2	--	2014	276	0.00000	0.00	event	var	2014-10-03
Published	Sophia_Laranja_052325_IT_3	WACCMX_11202013_Weimer_EUVAC	WACCMX	2.2	--	2013	324	0.00000	0.00	event	var	2013-11-20
Published	Sophia_Laranja_052325_IT_4	WACCMX_11202013_Heelis_EUVAC	WACCMX	2.2	--	2013	324	0.00000	0.00	event	var	2013-11-20
Published	Sophia_Laranja_052325_IT_2	WACCMX_10032014_Heelis_EUVAC	WACCMX	2.2	--	2014	276	0.00000	0.00	event	var	2014-10-03
Published	Sophia_Laranja_052225_IT_3	WACCMX_01172012_Heelis_EUVAC	WACCMX	2.2	--	2012	17	0.00000	0.00	event	var	2012-01-17
Published	Min-yang_chou_052225_IT_1	gannon storm for sami3	WACCMX	2.2	--	2024	130	0.00000	0.00	event	var	2024-05-09

Runs on Request | 37,855 View Results | 90 View Active Runs

Fatemeh_Bagheri_042225_IT_1

Run Status: Run Complete
Status updated: 2025-04-24T21:40:58+0000

Run Metadata

Metadata Record:	View Full Run Metadata in the CCMC Metadata Registry (CMR)
Metadata as JSON:	View Full Run Metadata as JSON
Model Domain:	IT
Model Name:	WACCMX
Model Version:	2.2
Key Word:	tides

CS output:	GEO
Run type:	event
Boundary condition type:	var
Year run:	2017
DOY:	272
Start time:	2017/09/29 00:00:00
End time:	2017/09/30 00:00:00
E-field model:	weimer

Output Data

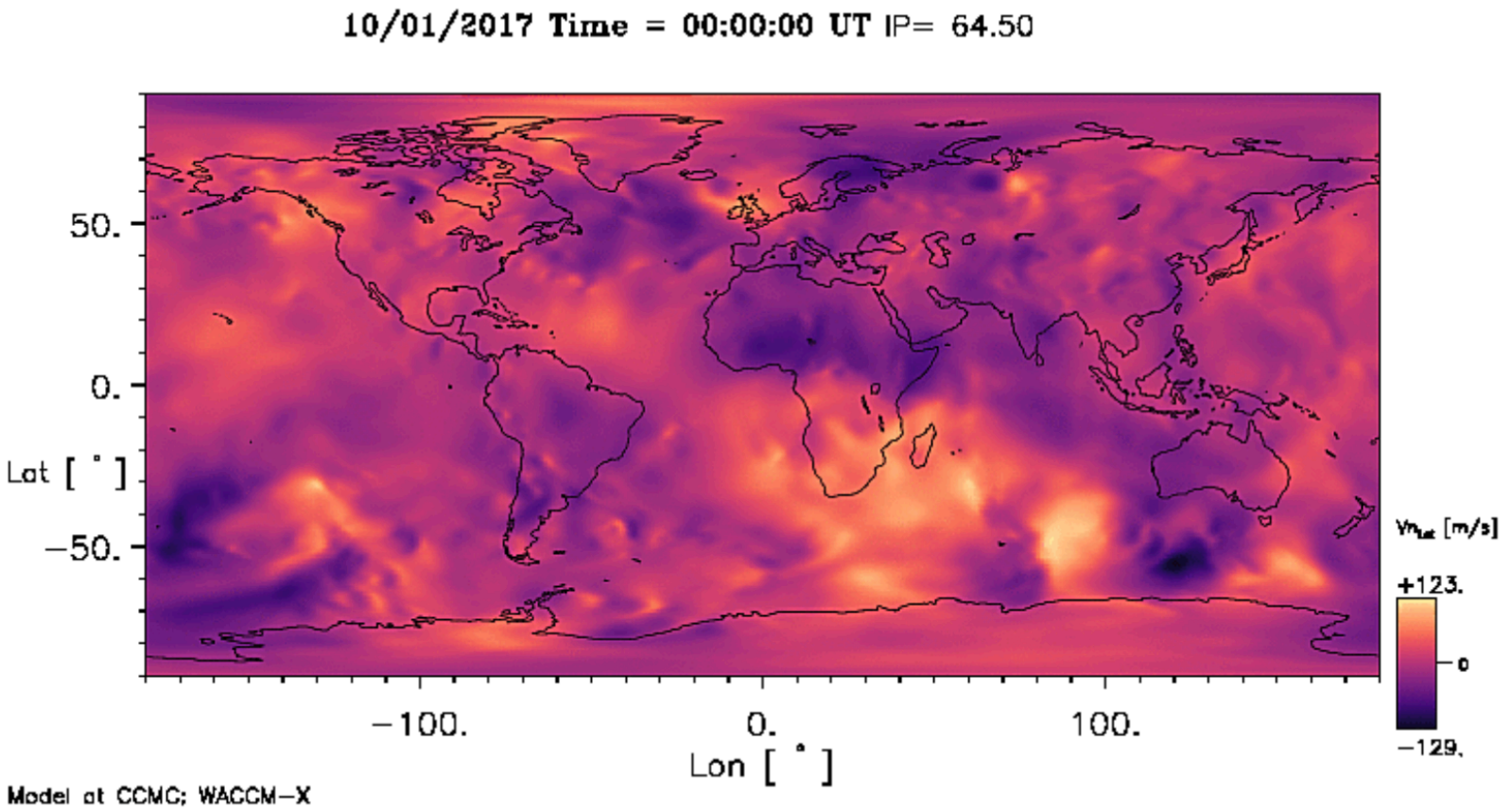
- View 3D Ionosphere/Thermosphere
- Create Timeseries in 3D Ionosphere/Thermosphere

Run Services

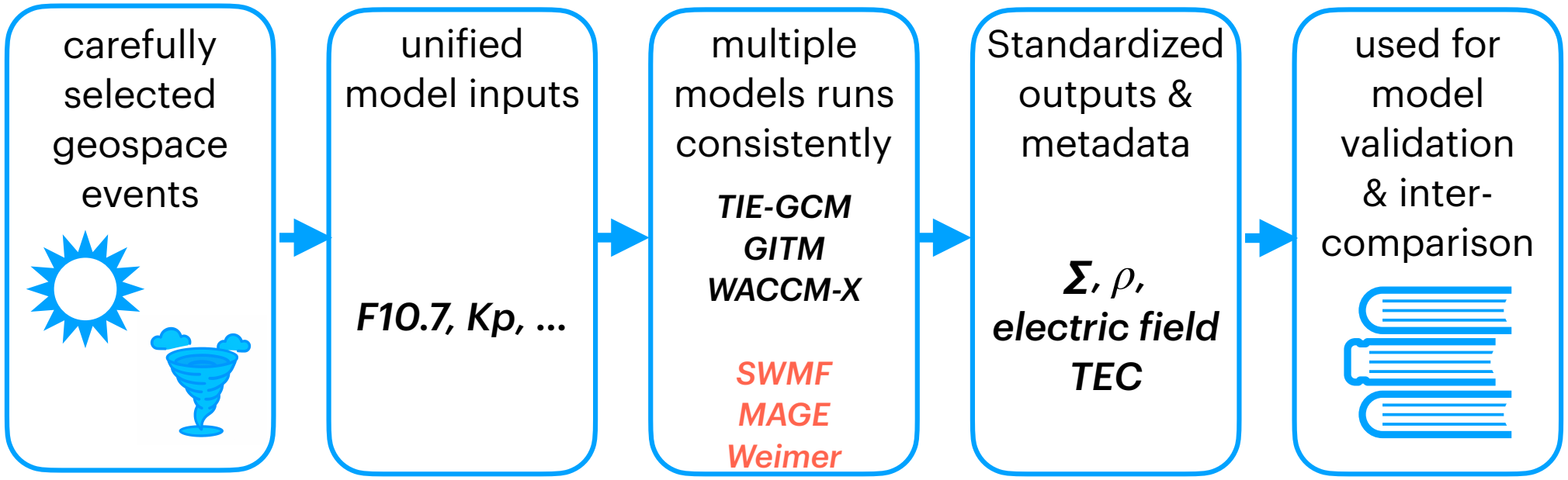
- Request output data in bulk
- Browse individual output files

Supplementary Services

- CCMC DONKI notifications during the run period:



Time Period database: a curated collection for consistent model evaluation



All model simulation output are publicly available on CCMC TP database. (https://kauai.ccmc.gsfc.nasa.gov/CMR/TimeInterval/viewAllTI)

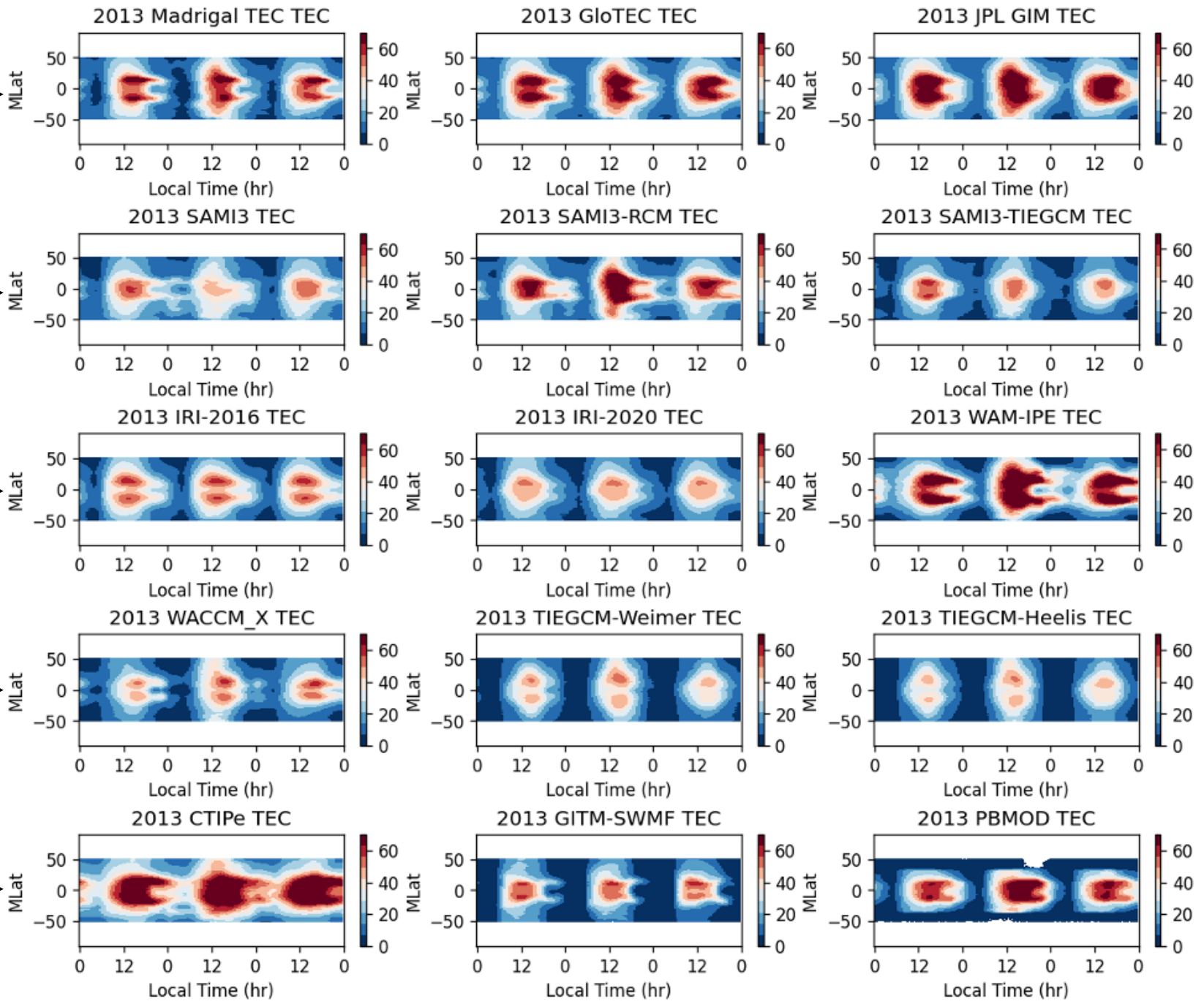
Back-ups

Space weather societal impact

- Ionosphere variability (navigation, communications)
- Atmosphere variability (satellite/debris drag)
- Geomagnetically induced currents - GICs (electric power systems)
- Near-earth radiation and plasma environment (aerospace assets functionality)
- Solar energetic particles - SEPs (human exploration, aviation safety, aerospace assets functionality)
- Galactic cosmic rays - GCRs (human exploration, aviation safety, aerospace assets functionality)

TEC 2013 March Storm, Lat x LT. map

Madrigal
GloTEC
JPL GIM



SAMI3

IRI
WAM-IPE

WACCM-X
TIE-GCM

CTIPe
GITM
PBMOD