CEDAR Student Day 2023

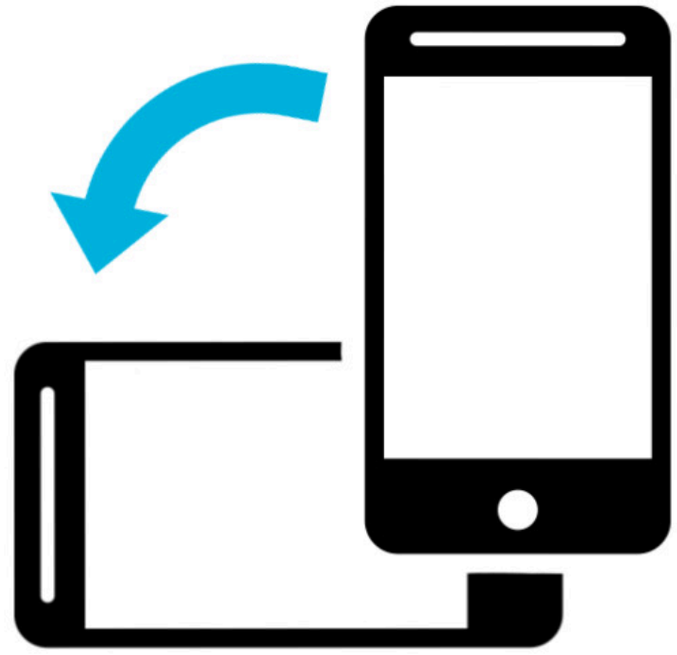
NASA Community Coordinated Modeling Center Tutorial

Jack Wang and all CCMC members
Community Coordinated Modeling Center, NASA GSFC
June 25th, 2023

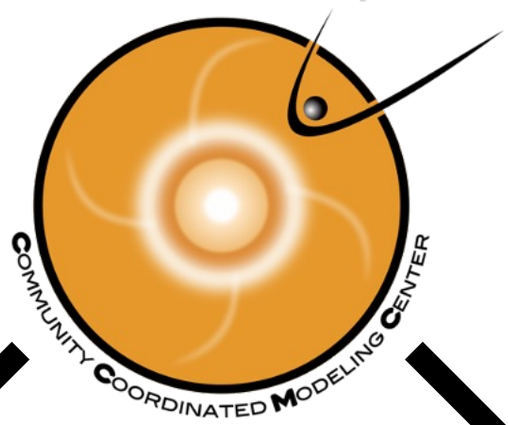
Outlines

- Who we are
- What we do
- How we can support your research
  - Simulation Services
  - Visualization & Analysis


10:10
21
CELL PHONE USE
PERMITTED IN THIS AREA



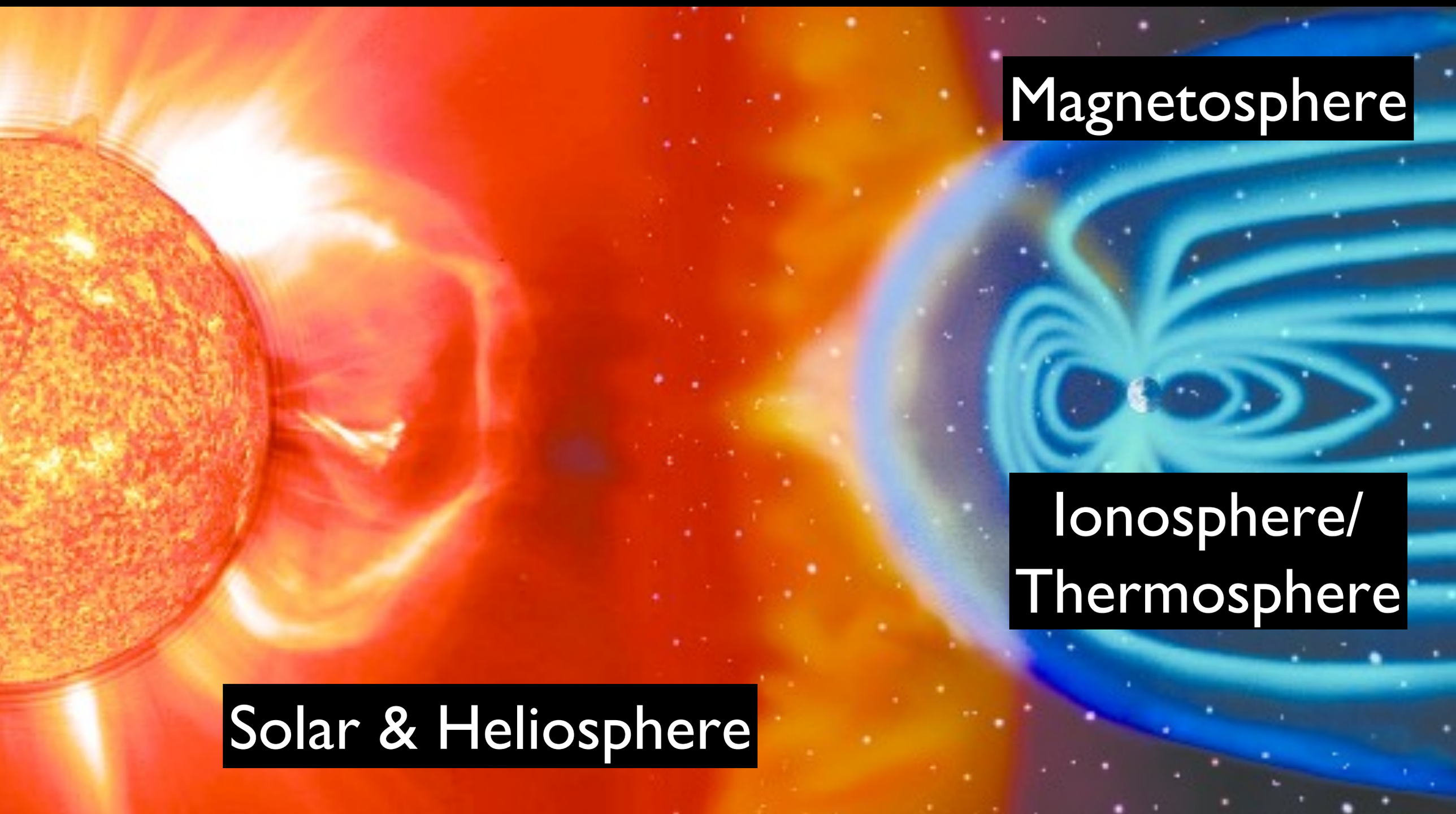
Multi-agency Strategic Investment in US Space Weather Program



support transition of advances in research to **space weather operations**

facilitate space science & space weather **research & model development**

Our mission: building an inclusive, community-accessible computational asset to space weather community



There is always NOT easy to install a model without the help of model developers

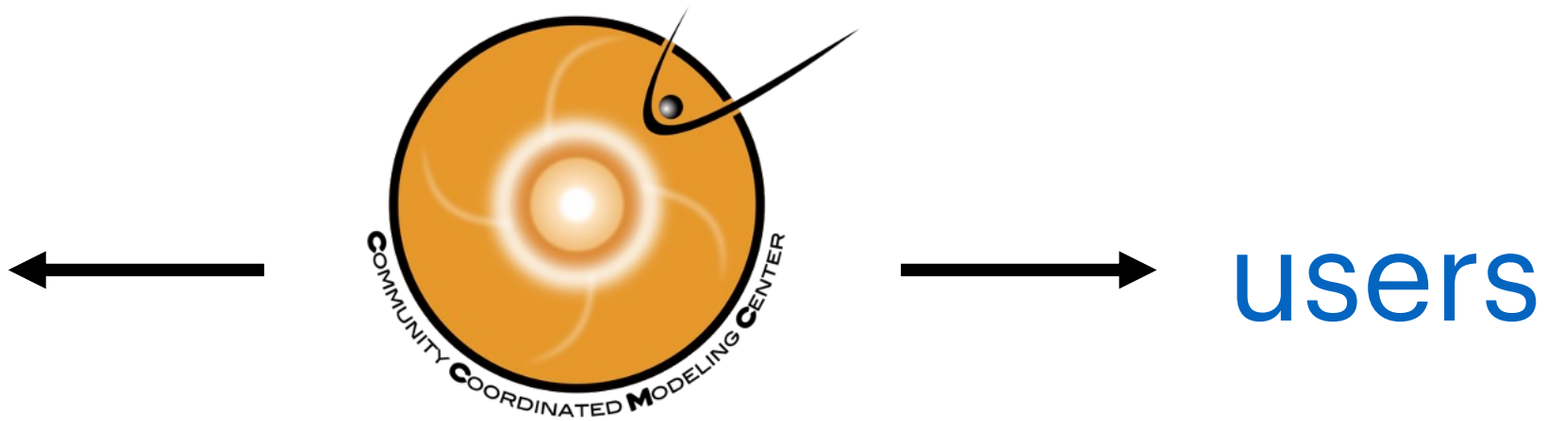
model developers

users

CCMC acts as a bridge between developers and end-users

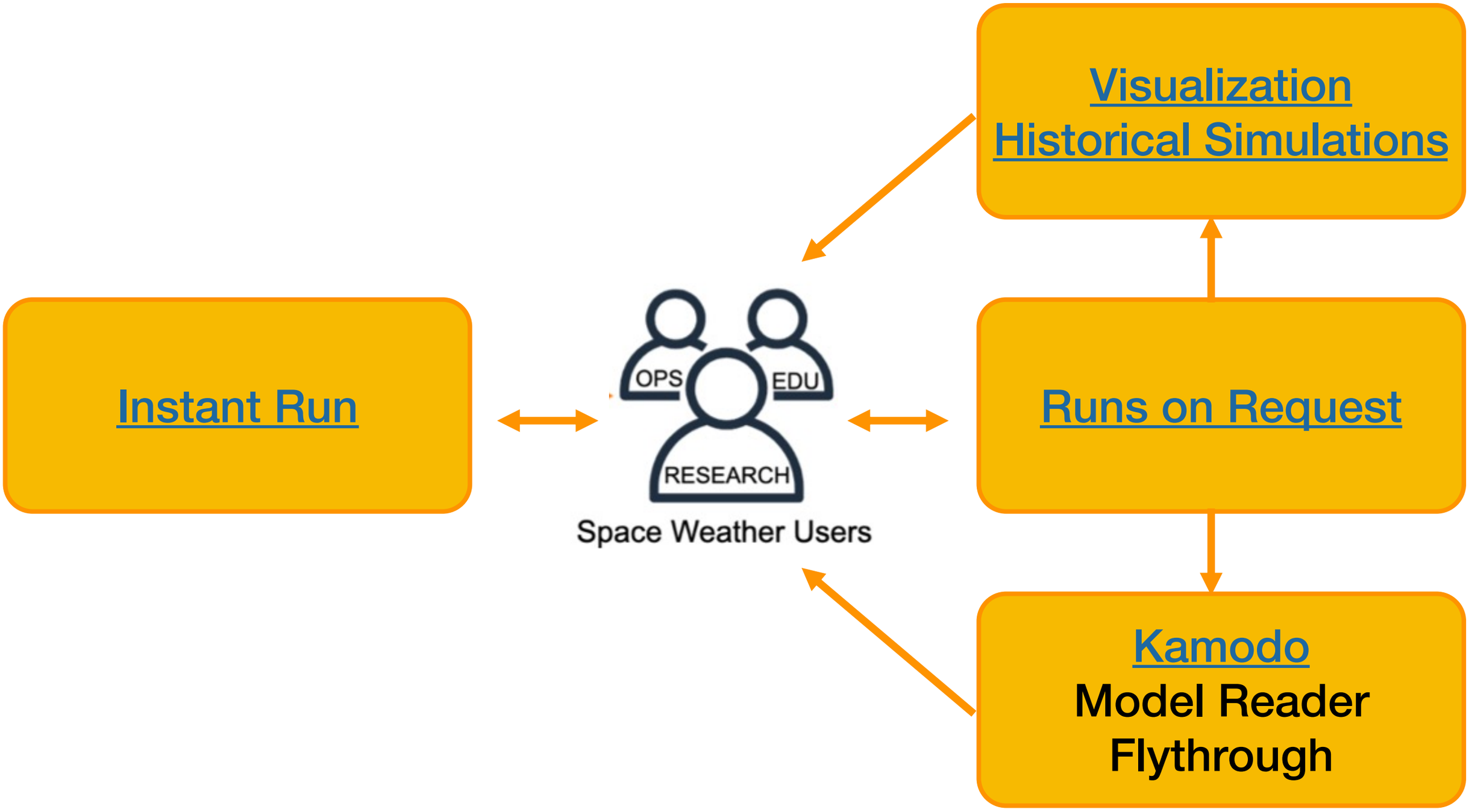
model developers

users

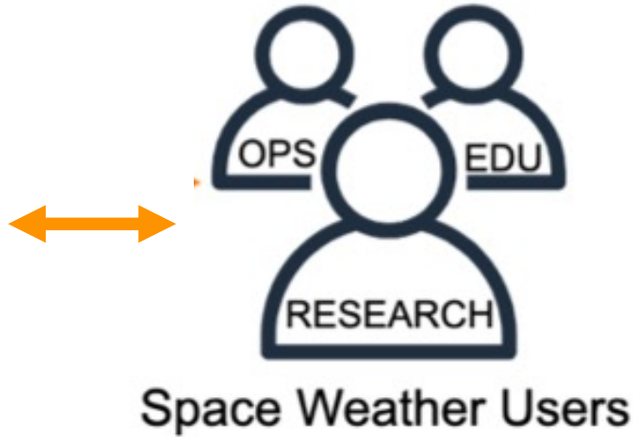


CCMC acknowledges all the model developers for the permission to use the models and software tools at CCMC

Facilitate Research and Model Development



Instant Run



Space Weather Users

CCMC Instant Run: SuperDARN convection model

CCMC Instant Run System

SuperDARN Convection Models

Convection Model

- (•) TS18 (Thomas & Shepherd, 2018)
- ( ) TS18 KP (Thomas & Shepherd, 2018)
- ( ) CS10 (Cousins & Shepherd, 2010)
- ( ) PSR10 (Pettigrew, Shepherd, & Ruohoniemi, 2010)
- ( ) RG96 (Ruohoniemi & Greenwald, 1996)

Input Mode

** Manually setting the tilt of the Earth's dipole only applies to the output files. No plots will be generated.*

Input Type*

Use Date/Time

Date Time

01/01/2000, 12:00 AM

Solar Wind

Input

Specify |B| and Angle

IMF B Magnitude (0 to 50 nT)

5

IMF B Angle (-180° to 180°, 0 = north)

180

Velocity (0 to 500 km/s)

400

[ ] No Interpolation

Plot

Parameters

[x] Potential
[x] Convection Velocity

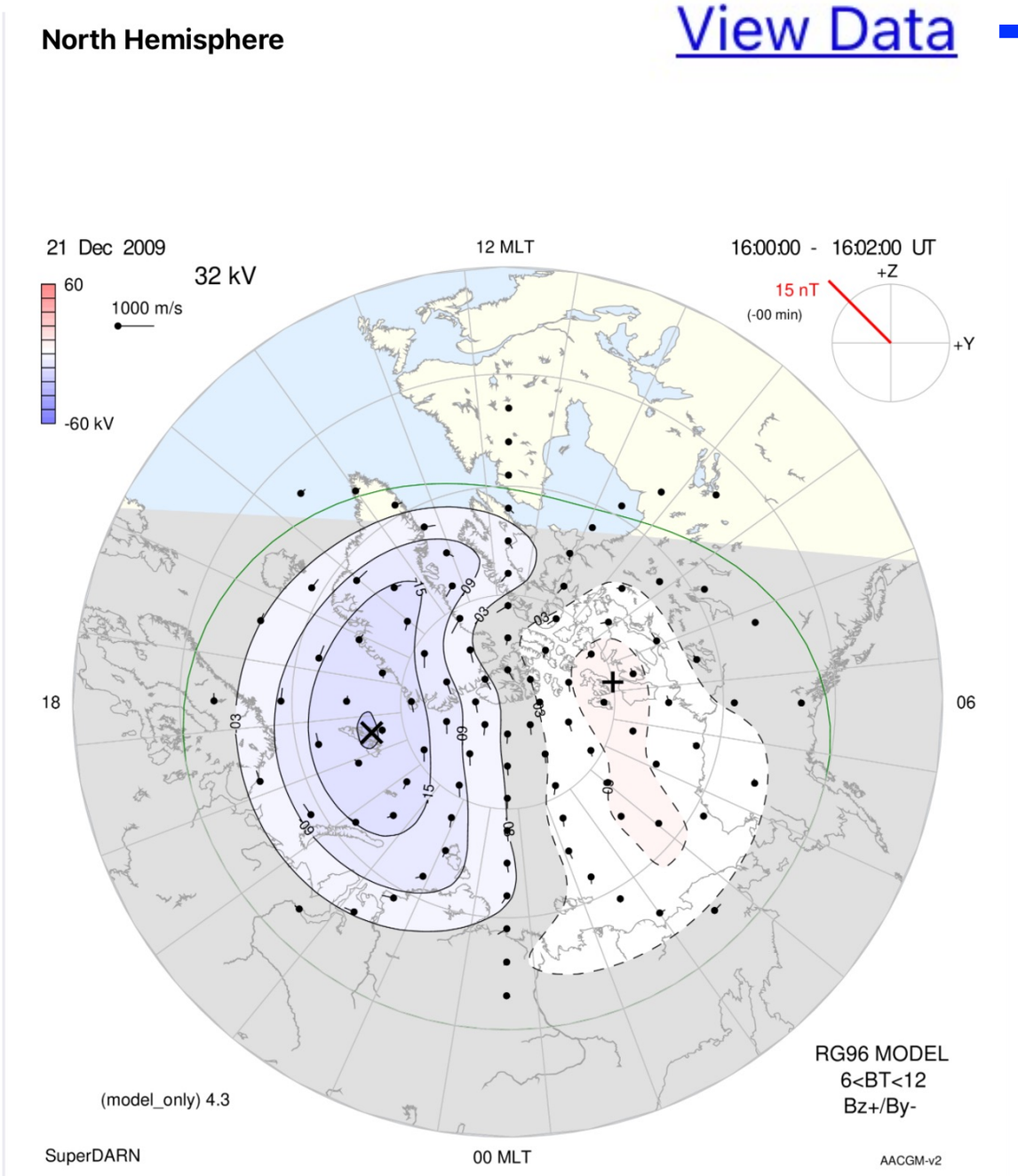
Grid Options

Grid options are only for output files and do not

North Hemisphere

South Hemisphere

CCMC Instant Run: SuperDARN convection model



View Data

Date: 2009-12-21 16:00
Model: RG96
Bin: 6<BT<12, Bz+/By-
Grid: Uniform (lat_step: 1.00, lon_step: 2.00 [deg])

MLAT [deg]	MLT [hr]	Pot [kV]	Vazm [deg]	Vmag [m/s]
60.5000	0.00000	0.577197	91.6187	105.769
60.5000	0.133333	0.593757	91.4927	112.146
60.5000	0.266667	0.609896	91.3796	118.395
60.5000	0.400000	0.625591	91.2774	124.506
60.5000	0.533333	0.640820	91.1844	130.469
60.5000	0.666667	0.655562	91.0991	136.276
60.5000	0.800000	0.669795	91.0204	141.915
60.5000	0.933333	0.683502	90.9473	147.379
60.5000	1.06667	0.696662	90.8792	152.658
60.5000	1.20000	0.709259	90.8154	157.743
60.5000	1.33333	0.721276	90.7553	162.624
60.5000	1.46667	0.732698	90.6985	167.295
60.5000	1.60000	0.743508	90.6445	171.745
60.5000	1.73333	0.753696	90.5930	175.966
60.5000	1.86667	0.763247	90.5438	179.952
60.5000	2.00000	0.772150	90.4965	183.694
60.5000	2.13333	0.780396	90.4510	187.184
60.5000	2.26667	0.787976	90.4070	190.417
60.5000	2.40000	0.794881	90.3643	193.384
60.5000	2.53333	0.801105	90.3228	196.081
60.5000	2.66667	0.806642	90.2823	198.500
60.5000	2.80000	0.811487	90.2427	200.637
60.5000	2.93333	0.815638	90.2038	202.486
60.5000	3.06667	0.819092	90.1656	204.044
60.5000	3.20000	0.821847	90.1279	205.306
60.5000	3.33333	0.823904	90.0906	206.269
60.5000	3.46667	0.825263	90.0536	206.929
60.5000	3.60000	0.825927	90.0168	207.286
60.5000	3.73333	0.825897	89.9801	207.336
60.5000	3.86667	0.825179	89.9435	207.081
60.5000	4.00000	0.823777	89.9068	206.519
60.5000	4.13333	0.821696	89.8699	205.651
60.5000	4.26667	0.818944	89.8328	204.479

Instant Run - play it on your mobile device!

Ionosphere/Thermosphere

HWM | IRI | NRLMSIS | Weimer

Heliosphere

DBM

Geoelectric Field Calculation Tool

SuperDARN

CCMC Instant Run Website

Magnetosphere

IGRF | WINDMI | CM5

AE-8/AP-8 RADBELT

Tsyganenko Magnetic Field

Space Weather Users

Runs on Request

TIE-GCM RoR Step-by-Step

Request a TIE-GCM Run

1. Generate your request
2. Select model version
3. Set the simulation time interval
4. Choose the run type and boundary condition
5. Choose spatial resolution
6. Submit ****All submissions take resource!!**

All submissions take resource!!

Runs-on-Request

whole atmosphere

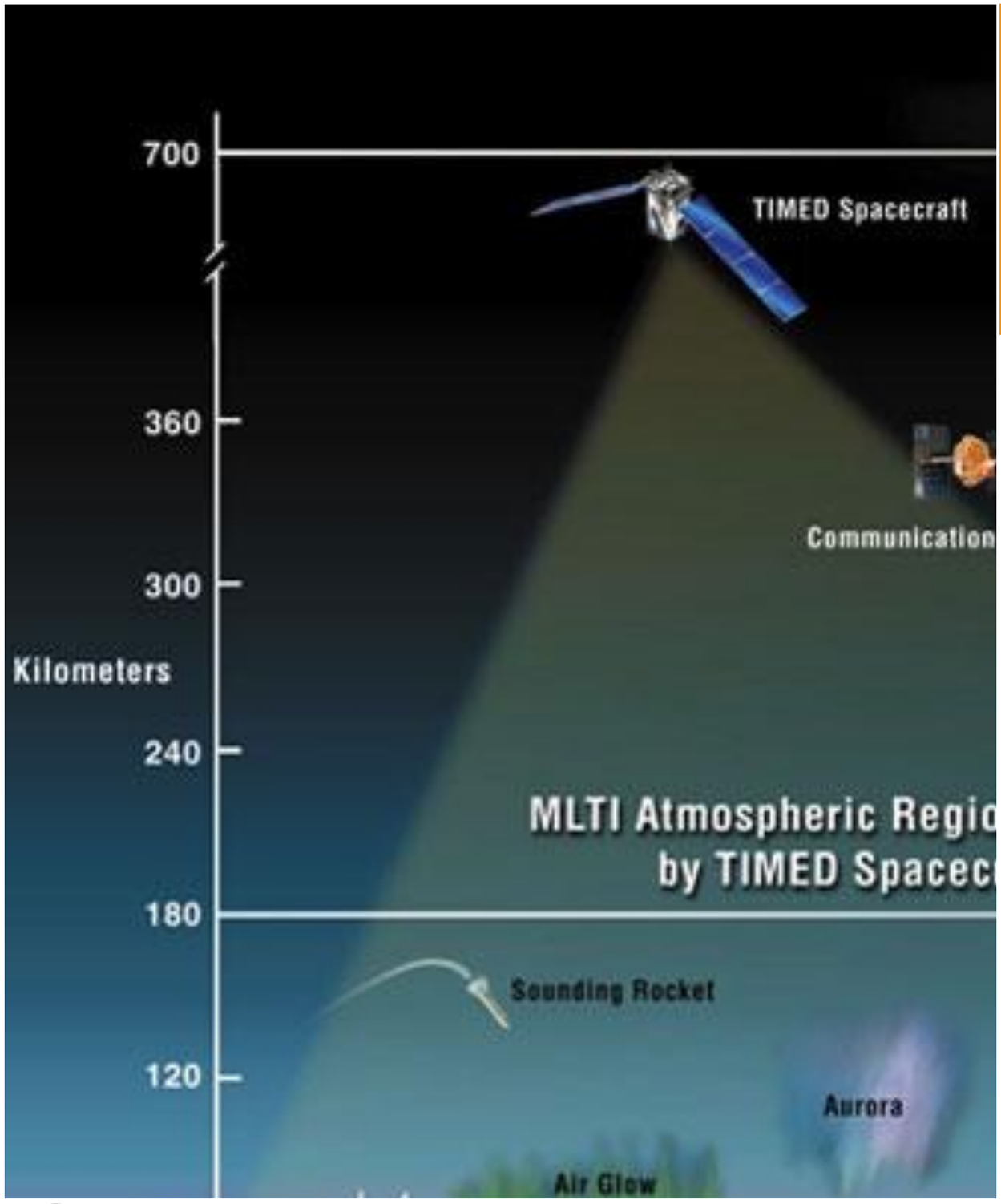
ionosphere/thermosphere

global magnetosphere

CCMC Model Catalog

DTM	JB2008	IRI	← Empirical
GITM	TIE-GCM	CTIPe	
SAMI3	USU-GAIM	PBMOD	
WACCM-X	MAGE/GAMERA	HYPERS-Global	Physics-based
GUMICS			
OpenGGCM	LFM	SWMF	

TIE-GCM can now be utilized for A-Train and TIMED orbit propagation



1000 km

TIE-GCM V2.5 upper boundary

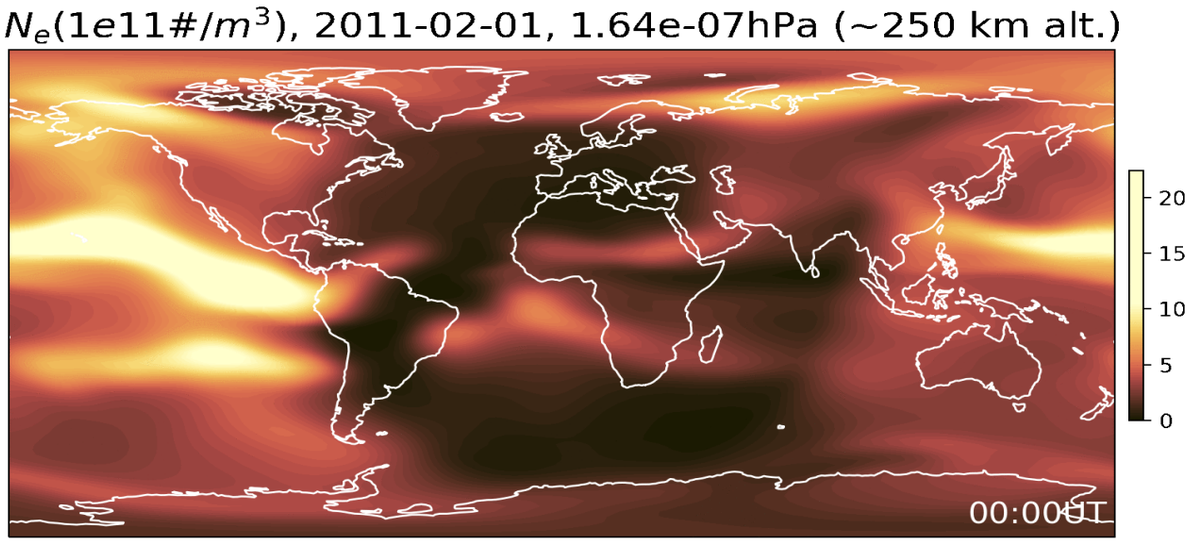
Most NASA LEO satellite orbits can now be simulated during solar max.

500 km

TIE-GCM V2.0 upper boundary

97 km

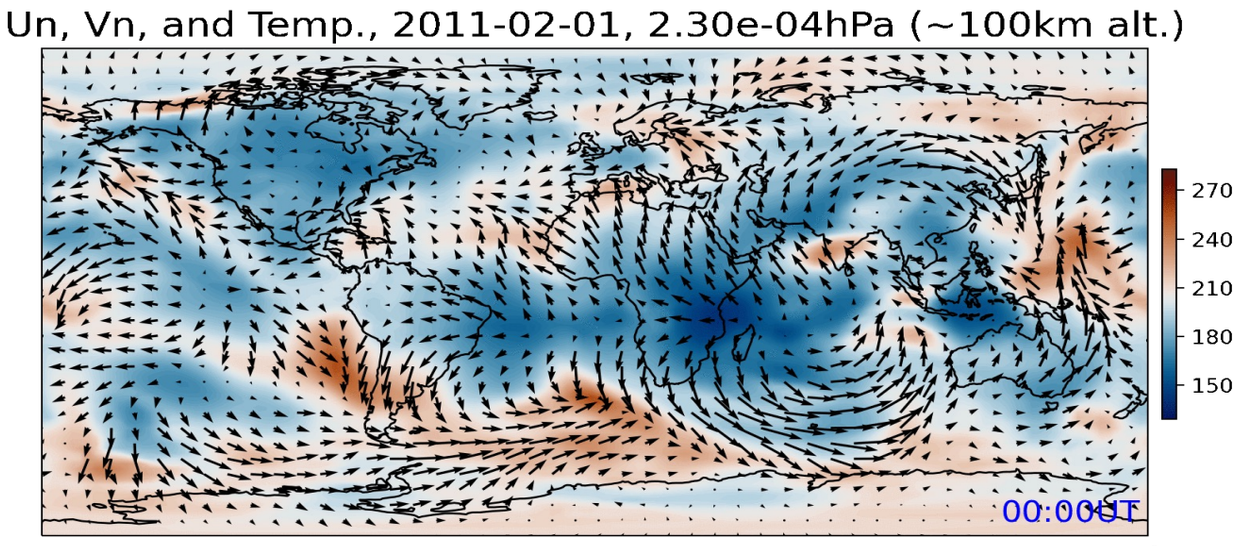
Whole Atmosphere Community Climate Model – eXtended (WACCM-X) is available now, first whole atmosphere model at CCMC

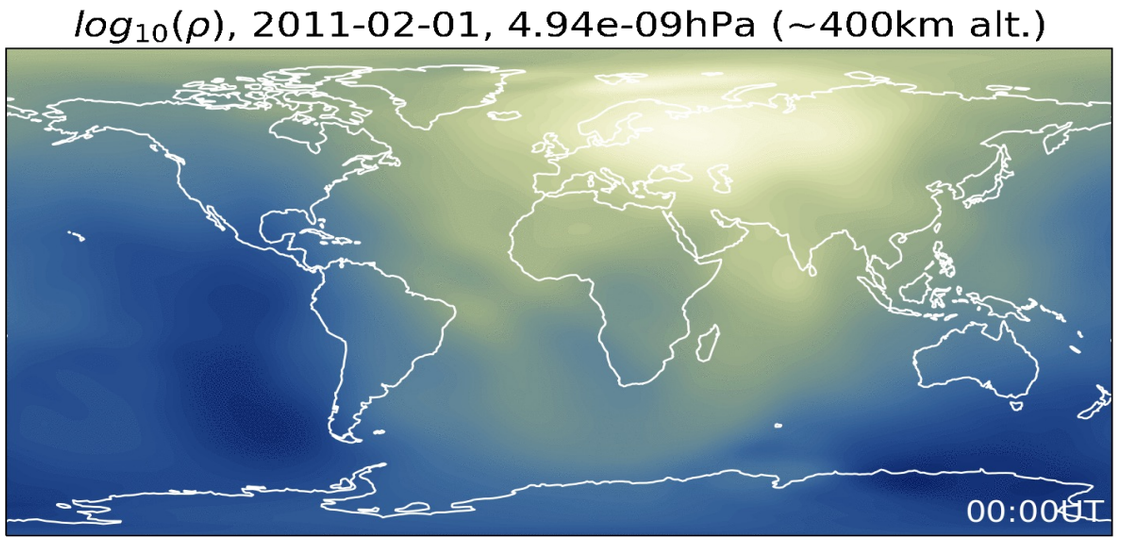


- Model domain from surface to 500 and 700 km
- Couples to ocean, sea ice, and land, enabling studies of thermospheric/ionospheric coupling with the lower atmosphere

dynamics-chemistry coupling

ion-neutral coupling



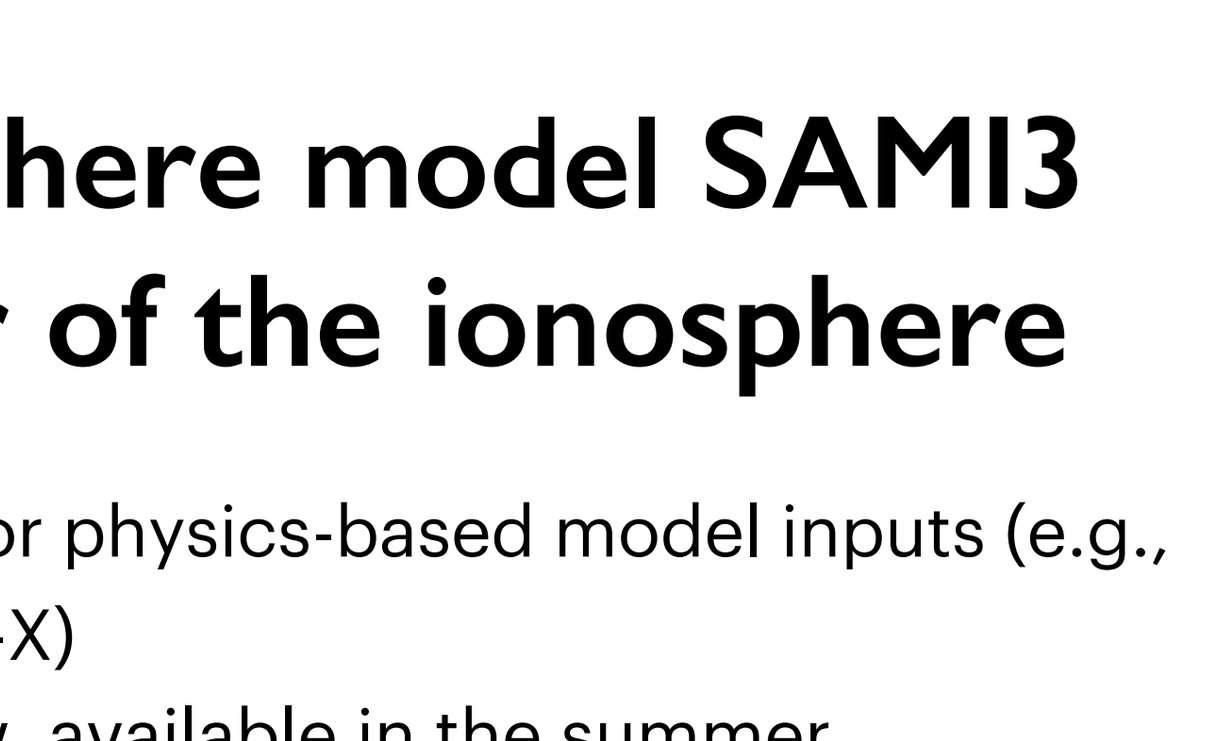


lower-upper atm. coupling

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)
- Onboarding SAMI3/WACCM-X now, available in the summer.
  - Will enable to study **day-to-day variability** of plasma bubbles and TIDs

solar min. in Aug.

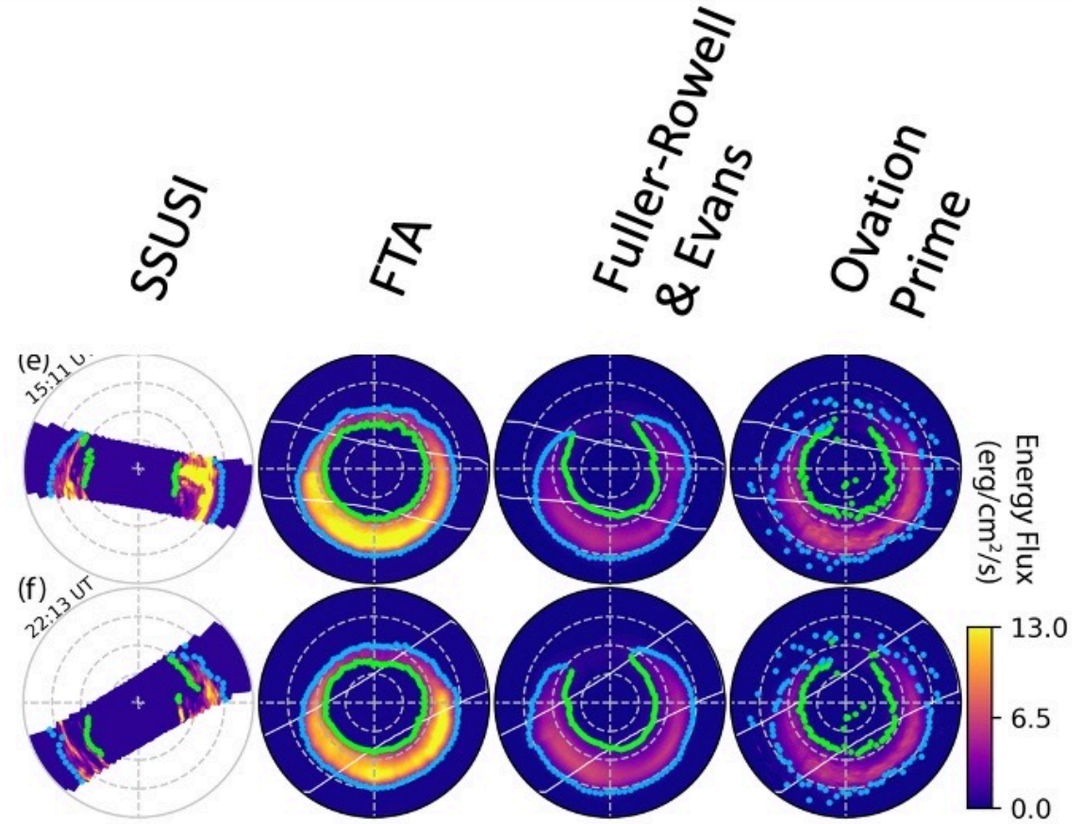


solar medium in Mar.

GITM Updates

- v22.03 –> v23.01 next month
- High lat. precipitation driver default is now **FTA** model for event simulations
- Fuller-Rowell and Evans still used for idealized runs with Hemispheric Power (HP) input
- Available as a special request and coming soon on an updated webform:
  - Ovation Prime precipitation
  - FTA idealized run
  - SWMF simulation as a convection/precipitation driver
- Coming soon: AMGeO assimilative model as a convection/precipitation driver!

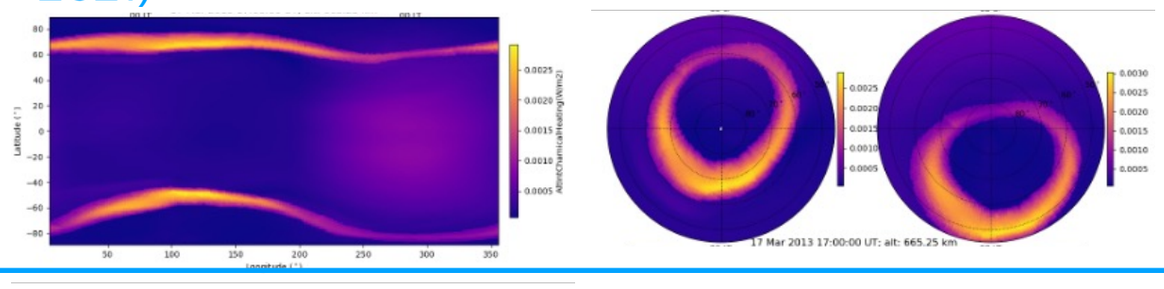
https://github.com/GITMCode/GITM



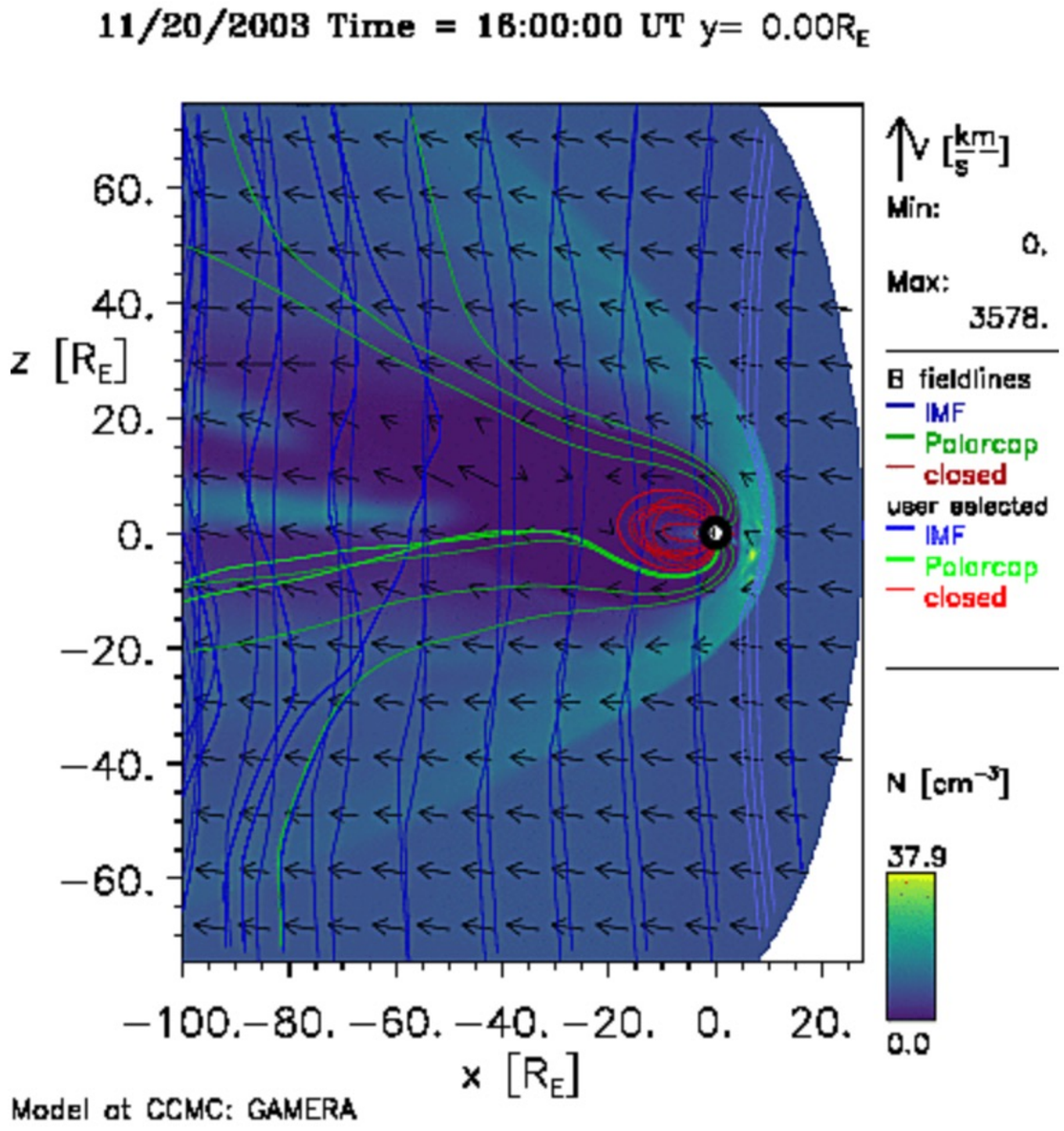
Energy deposition is done with Fang+ (2010) monoenergetic beams:

- Get average energy and energy flux from auroral model
- Point-by-point convert to Maxwellian distribution (except OVATION…) with 100 monoenergetic beams
- Use Fang to get 100 ionization profiles
- Heating through ionization + exothermic reaction (no direct heating)

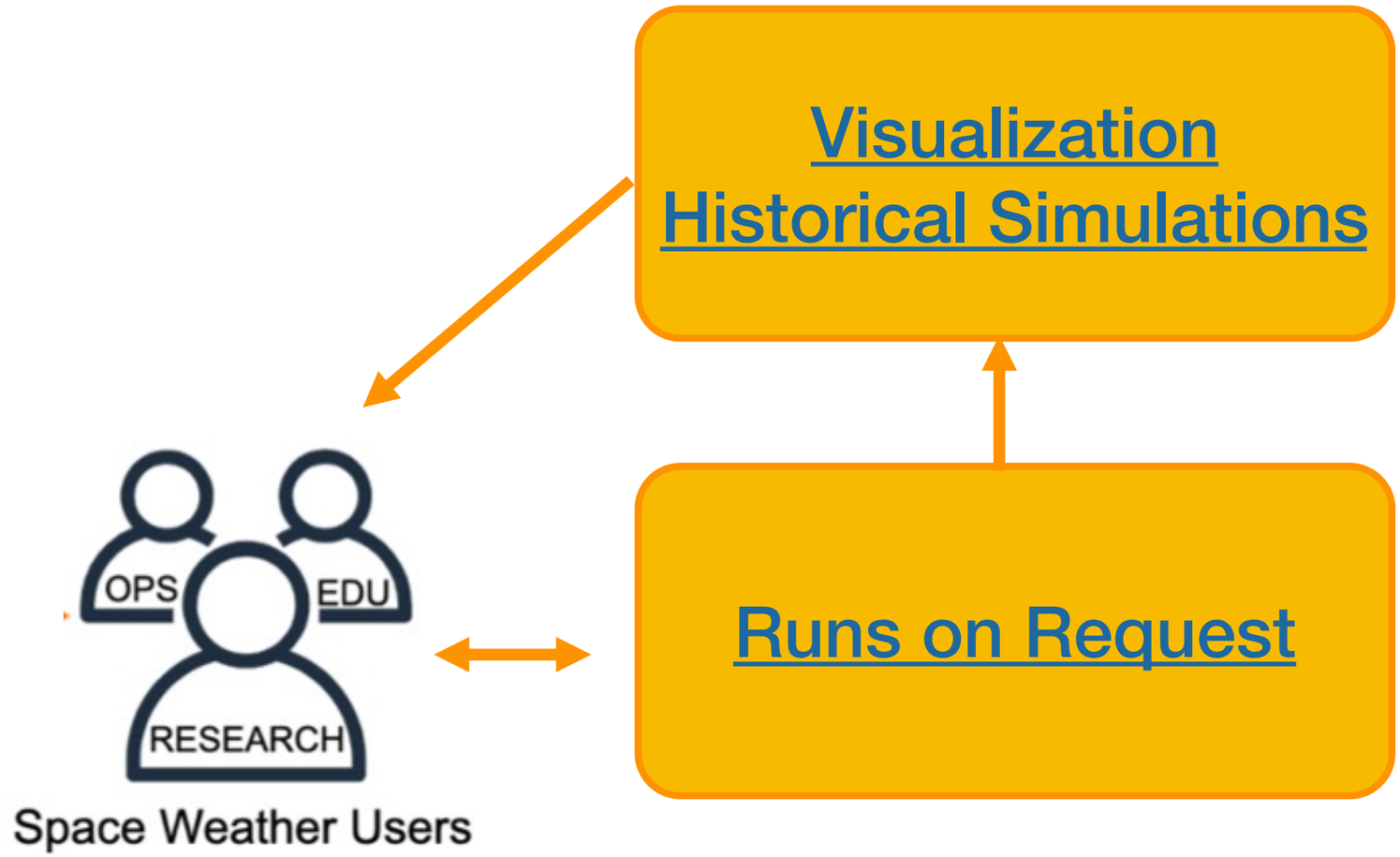
FTA: A Feature Tracking Empirical Model of Auroral Precipitation (Wu+, Space Weather, 2021)



MAGE/GAMERA is now available at CCMC RoR

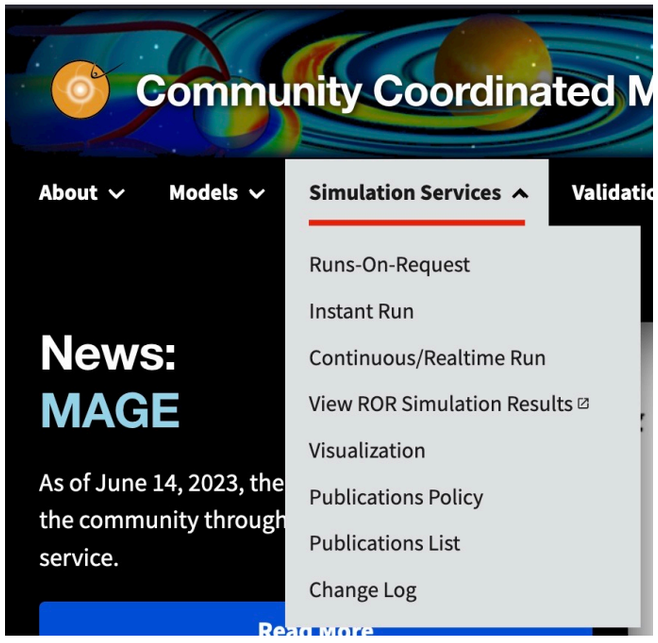


MAGE/GAMERA is developed by the NASA DRIVE Science Center for Geospace Storms (CGS), which is a new MHD simulation tool building and improving upon the high-heritage LFM code


Visualization
Historical Simulations
OPS
EDU
RESEARCH
Space Weather Users
Runs on Request

Access simulation archive

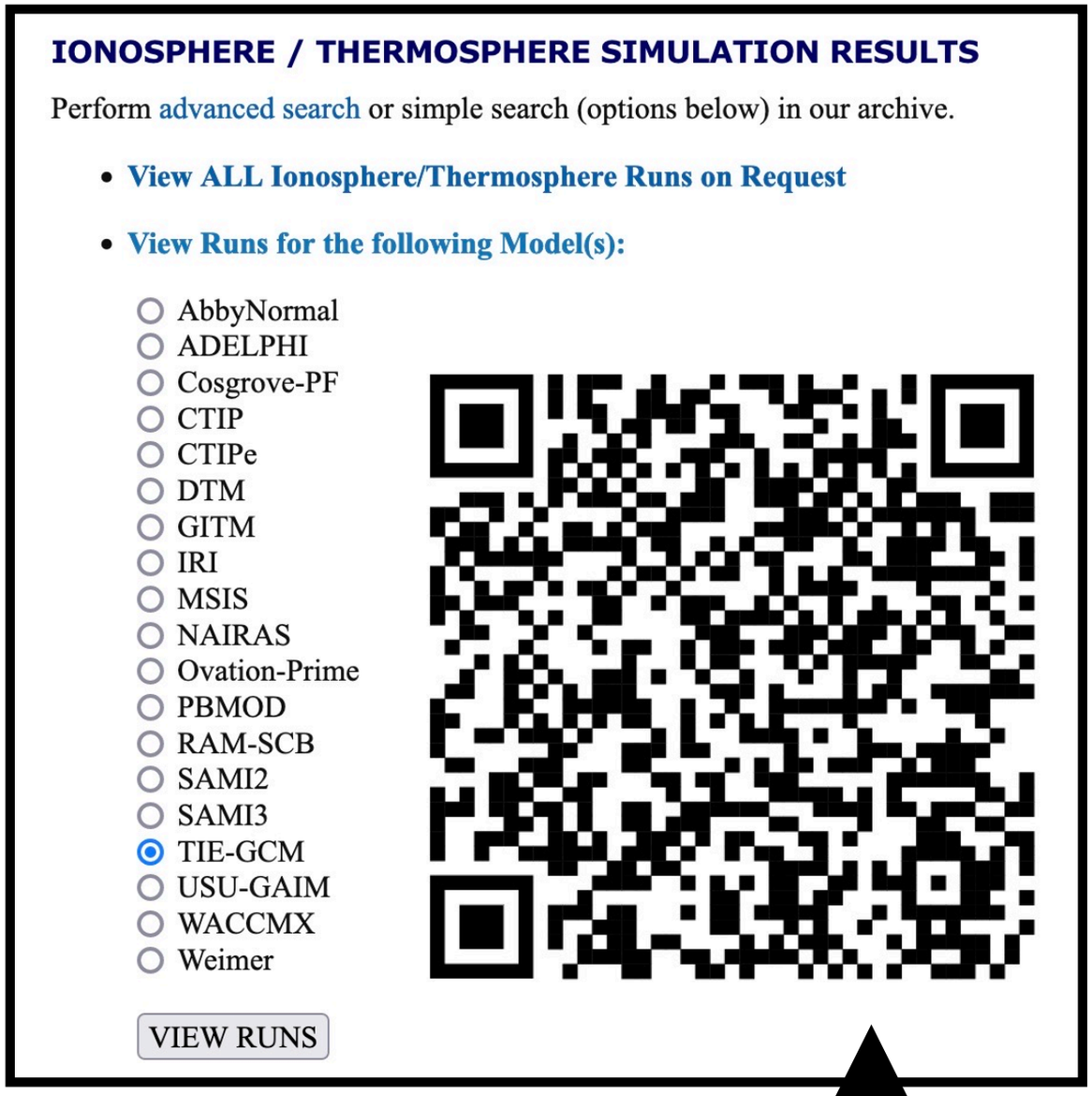
https://ccmc.gsfc.nasa.gov/

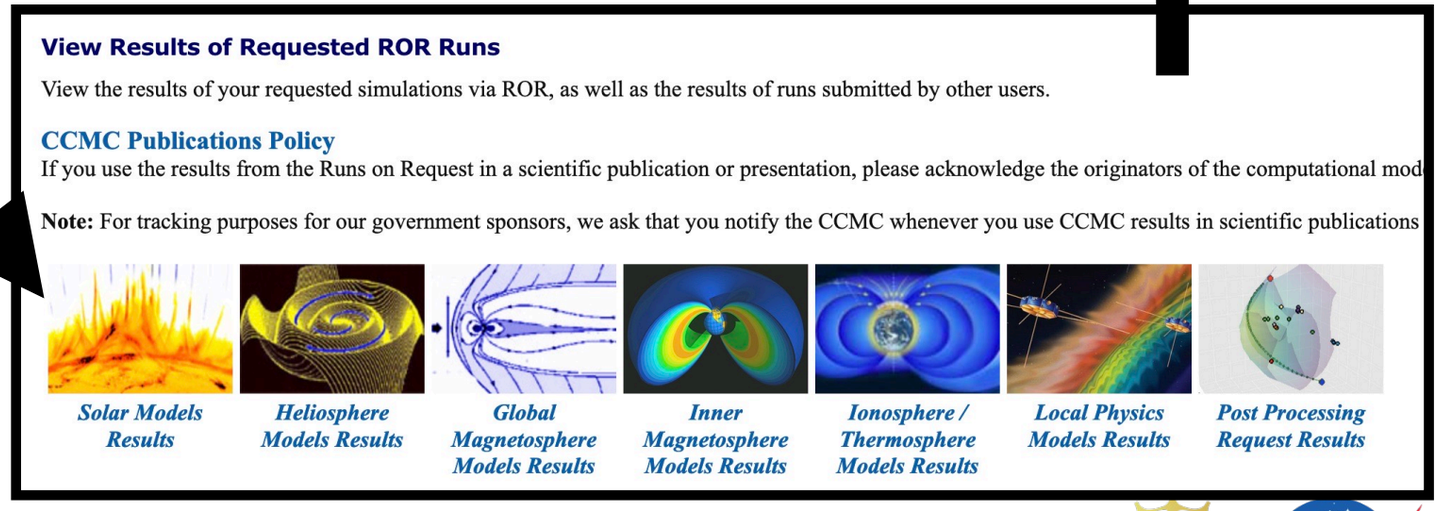


Simulation Services

↓

View RoR Simulation Results





Choose a published one

Status	Run Number
running	Anistah_Udhin_062323_IT_2
running	Vanshika_Rambukus_062323_IT_2
running	Wang_Li_062023_IT_1
running	Wang_Li_062023_IT_2
running	Tikemani_Bag_061923_IT_4
Published	Tiku_Bag_061923_IT_3
running	wei_wang_061623_IT_1
running	wei_wang_061623_IT_2
running	wei_wang_061623_IT_3
running	wei_wang_061623_IT_4
Published	Ian_Collett_061323_IT_1
running	Pengyu_Zhang_061123_IT_1
running	Pengyu_Zhang_061123_IT_2

Ian_Collett_061323_IT_1

Run Status: Run Complete

Status updated: 2023-06-14T15:45:55+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:	TIE-GCM
Model Version:	2.0
Key Word:	13mar2022_storm
CS output:	GEO
Run type:	event
Boundary condition type:	var
Year run:	2022
DOY:	71
Start time:	2022/03/12 00:00:00
End time:	2022/03/19 00:00:00
E-field model:	WEIMER

Output Data

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

Choose “View 3D Ionosphere”

Visualization

Choose **Plot Mode**:
ColorContour (2D)

Show advanced options

Choose quantity to be displayed:
Q 1: DEN

Customized variables are possible!
Email the formula that you would like to see and that uses existin

Plot Options for selected Plot Modes:

Color Contour:
Color table: plasma
New:new tables added: cividis, viridis, magma, plasma, inferno.
Reverse Colortable
Number of levels: 256

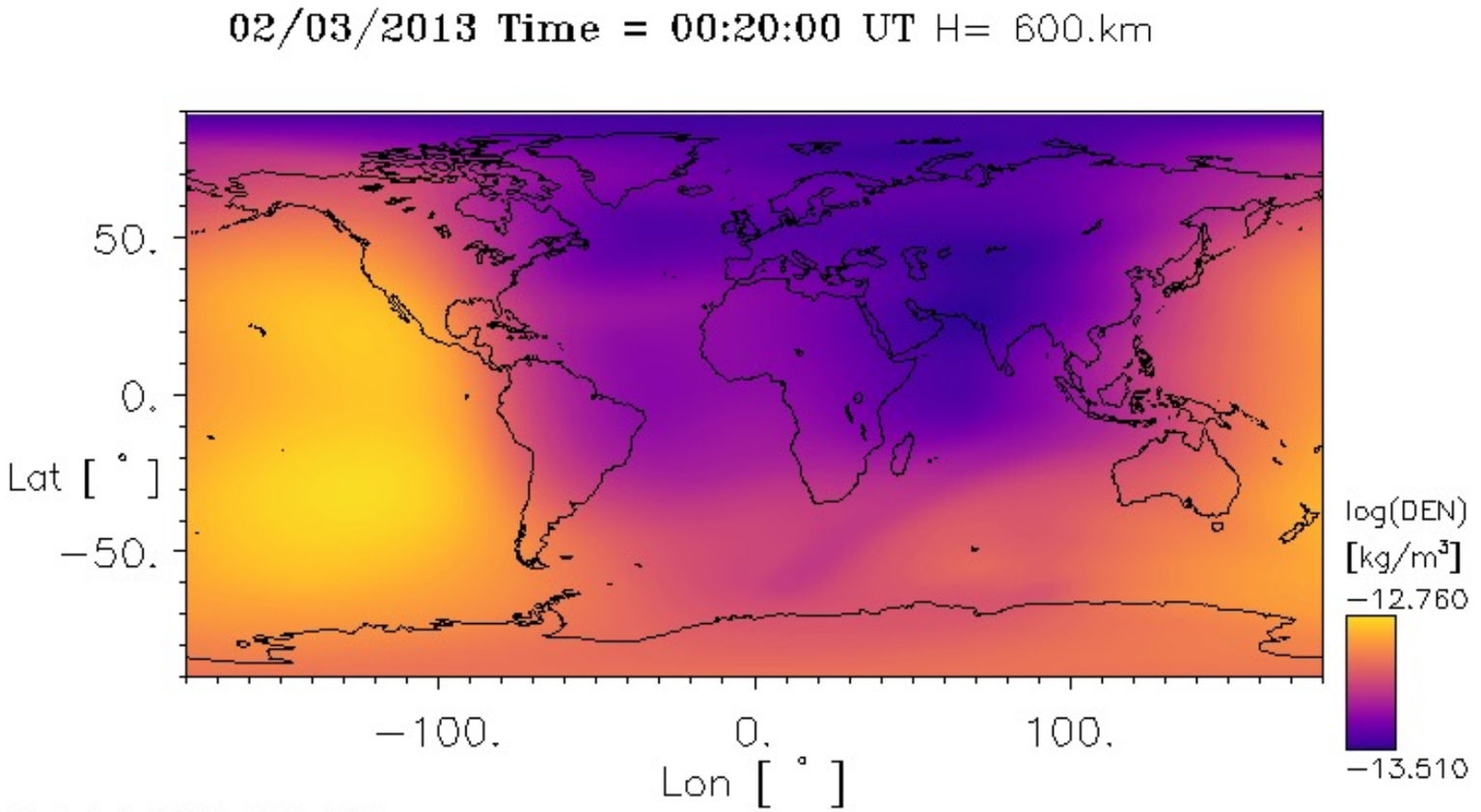
Lock color range:
Min.: -1 Max.: 1
Log scale (use all data>0 in non-negative fields)

Choose Plot Area:
All **Plot Modes** except **Line Plot** and **Vertical Plot**: Select lov
area on the left, and the upper right corner on the right.

lon_1 -180 lon_2 180 Range

lat_1 -90 lat_2 90 Range

TIE-GCM data: the vertical coordinate can either be IP or H for
Note that the full range in H will not be reached at all times. Lim
plot



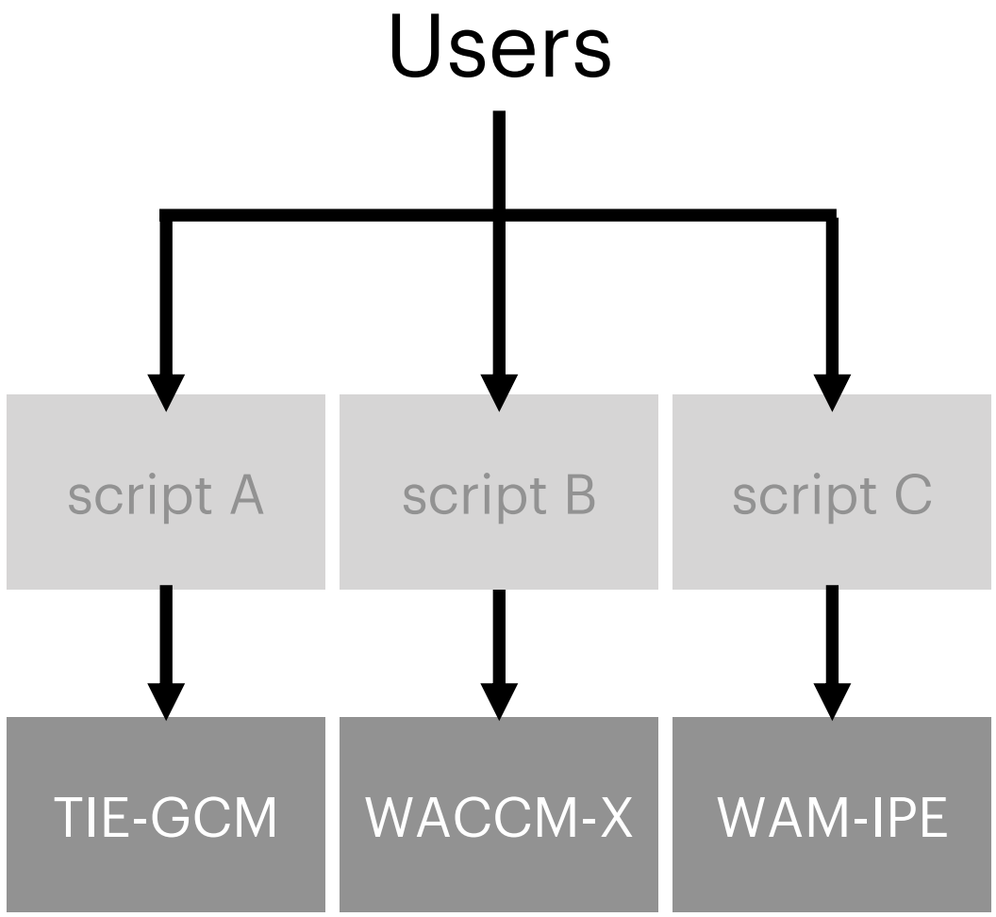
Model at CCMC: TIE-GCM

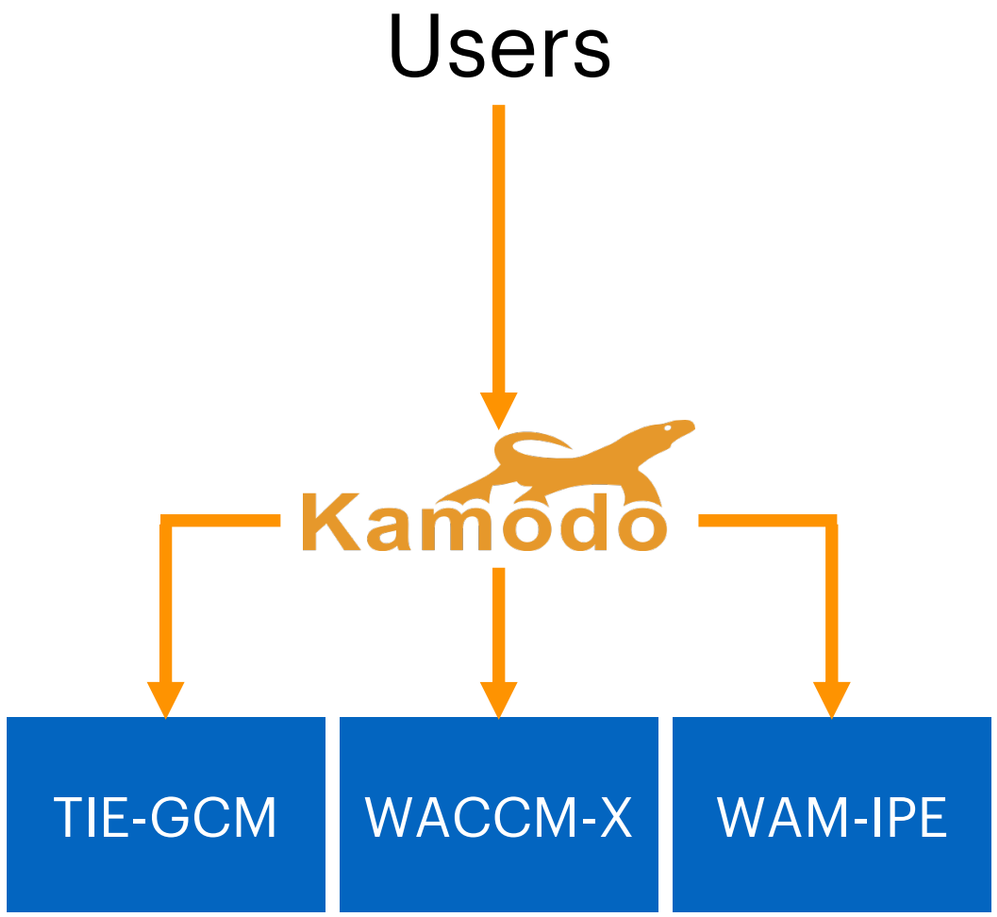
Space Weather Users

Runs on Request

Kamodo
Model Reader
Flythrough

Simplifying Model Data Access at CCMC



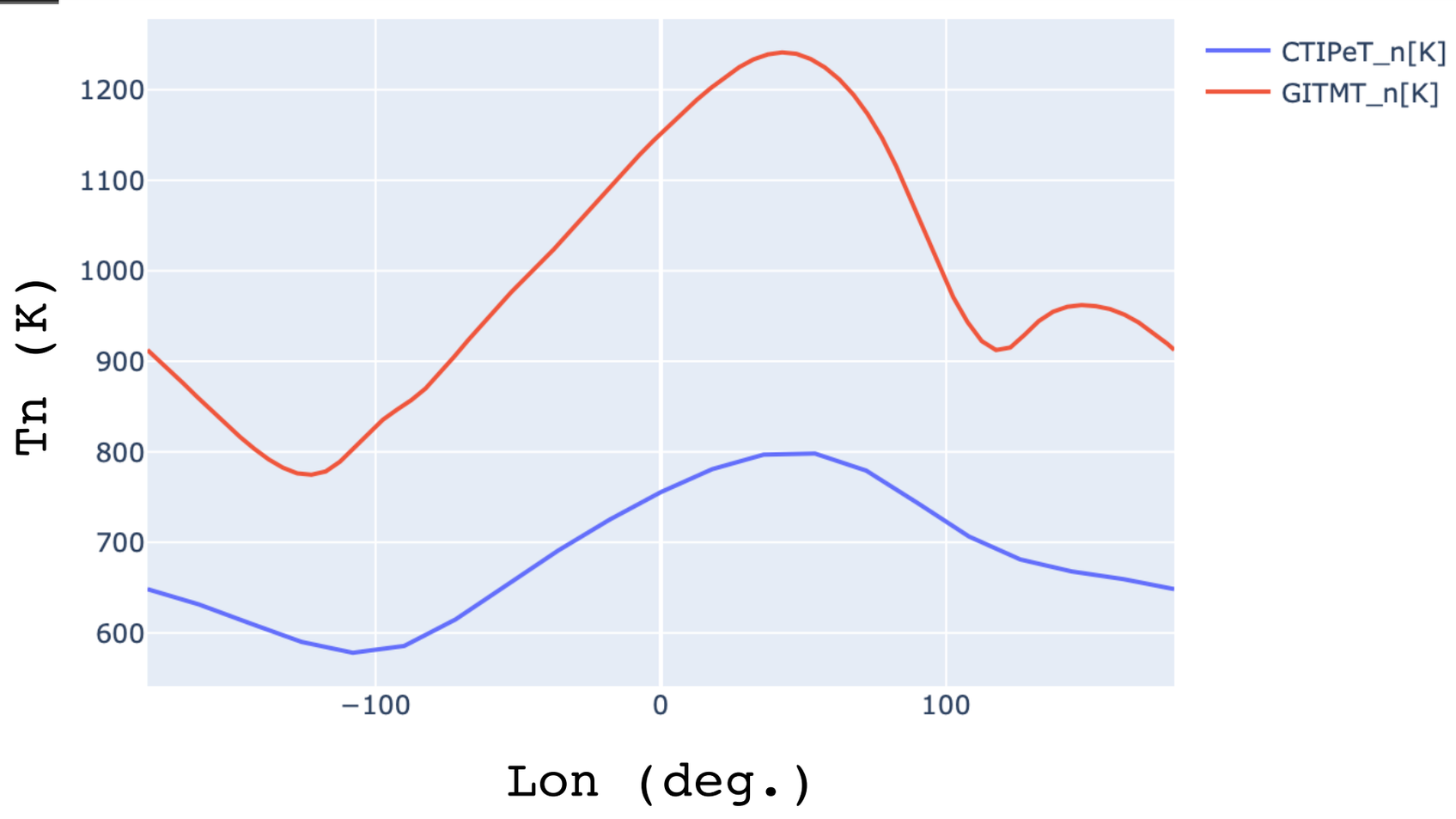


List of Models Currently Available in Kamodo

CTIPe	DTM	GITM	TIE-GCM
IRI	SuperDARN	WACCM-X	WAMIPE
AMGeO	ADELPHI	OpenGGCM	Weimer
	SWMF	GAMERA	

Cross-Model Comparison - Example

```
# Directly compare corresponding slices.
# Note the time resolutions are different, but Kamodo automatically interpolates
# to the finer resolution. Also note that the function composition analysis does NOT compensate for
# differences in the data start days. The user must ensure these are the same by retrieving
# any missing data or removing extra data. The datasets can end on different days/times and start
# at different times BUT must start on the same day.
kamodo_object.plot('CTIPeT_n', 'GITMT_n',
                   plot_partial={'CTIPeT_n': {'time': 12., 'lat': 25., 'height': 300.},
                                 'GITMT_n': {'time': 12., 'lat': 25., 'height': 300.}})
```



Collaborating with HAPI

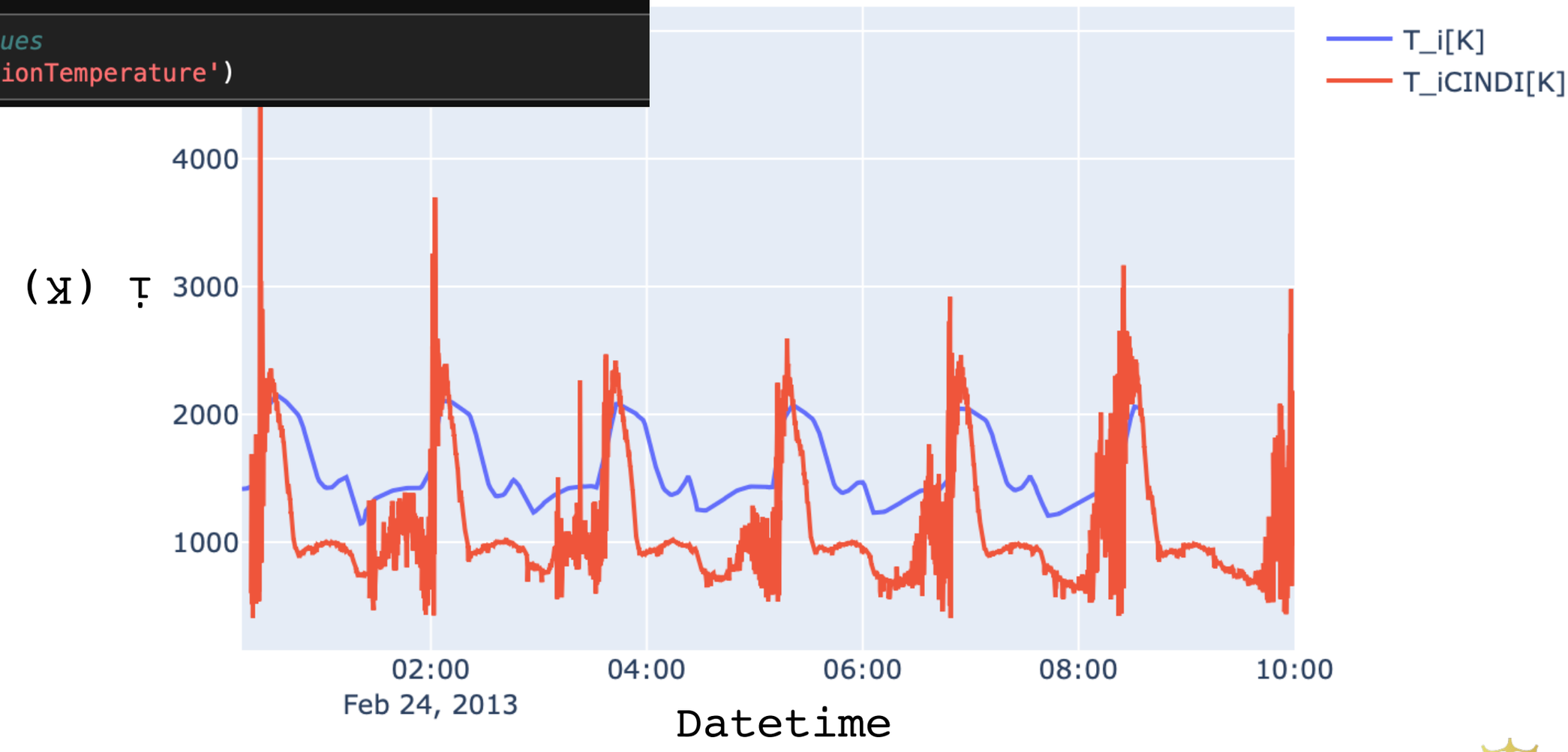
- Get CINDI data via HAPI server from CDAWeb

```
# Set details of data and grab it
server = 'https://cdaweb.gsfc.nasa.gov/hapi'
dataset = 'CNOFS_CINDI_IVM_500MS'
parameters = 'ionTemperature'
start      = '2013-02-24T00:20:00'
stop       = '2013-02-24T10:00:00'

hapiCDA = HAPI(server, dataset, parameters, start, stop)
```

```
# Plot The values
hapiCDA.plot('ionTemperature')
```

Heliophysics **A**pplication **P**rogrammer's **I**nterface



Easy Flythrough in Models

Model Output

SSCWeb →

user input →

user input →

Real Flight

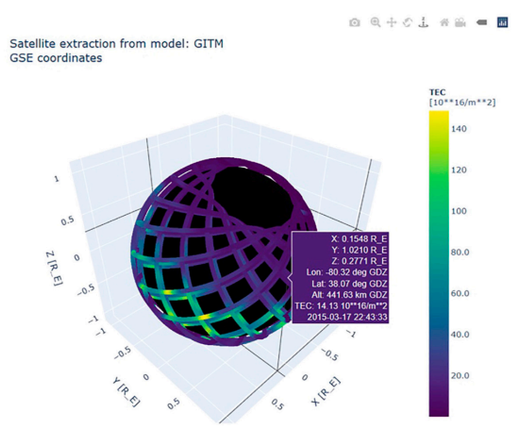
TLE Flight

Synthetic Flight

trajectory

(x,y,z,t)

Model Flythrough

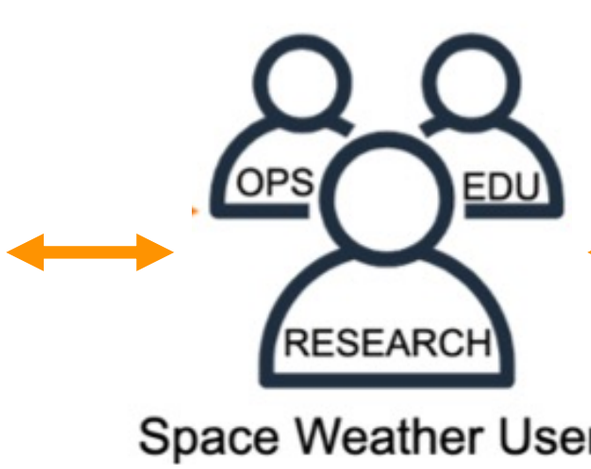


Sample Output at Given Sat. Trajectory

CCMC: One-stop shop to meet research community needs

Visualization

Instant Run



Space Weather Users

Runs on Request

Kamodo
Model Reader
Flythrough

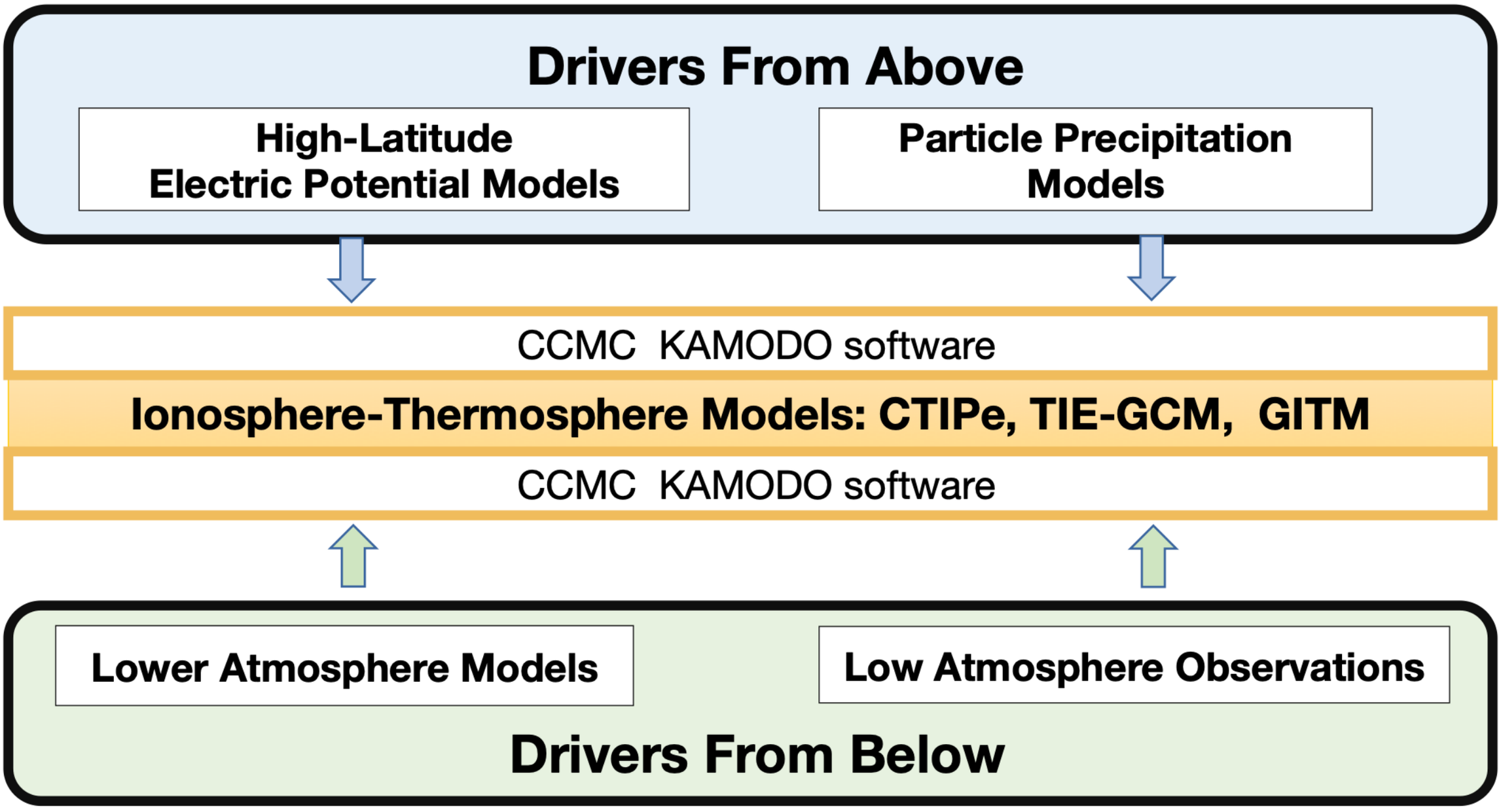
Vision for the Future

- Solidify CCMC role as a fast response unit to evolving community and agencies needs

- Facilitate innovation: move towards high-quality, high-resolution runs, implement ML/AI capabilities, utilize GPUs, enable generic model coupling capabilities

- Facilitate open science: establish CCMC as a hub for collaborative development and evaluations of open-source models/software

Vision of the Future: Model Coupling



CCMC: One-stop shop to meet research community needs

Please contact us if you have any suggestions or questions
jack.c.wang@nasa.gov; jia.yue@nasa.gov; min-yang.chou@nasa.gov

For Model Developers!!!

Please contact us if you want to make your models accessible to the world

Our goal: make it easier and faster to onboard a new model/model upgrade to get it into the hands of the community faster

References

Kamodo: GitLab repository

https://github.com/nasa/Kamodo

CCMC website

https://ccmc.gsfc.nasa.gov

Please contact us if you have any suggestions or questions
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Back-ups

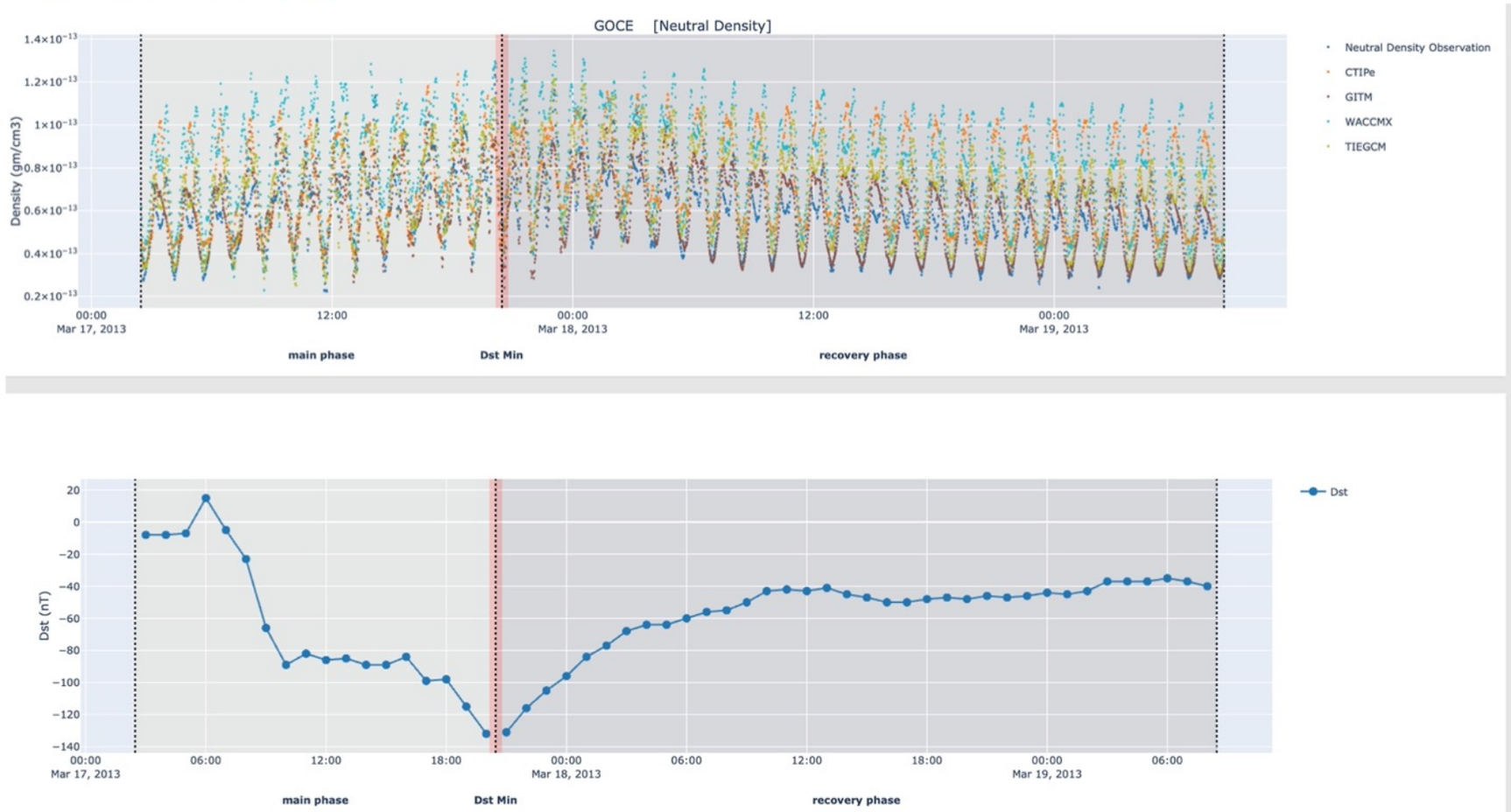
Multi-agency Strategic Investment in US Space Weather Program

support transition of advances in research to **space weather operations**

facilitate space science & space weather **research & model development**

Neutral Density Validation at CCMC

CAMEL: Comprehensive Assessment of Models and Events based on Library tools



https://webserver1.ccmc.gsfc.nasa.gov/camel/NeutralDensity/

Assessment of ionospheric models during the geomagnetic storm times

TEC=*f*(lon.,lat.,UT)

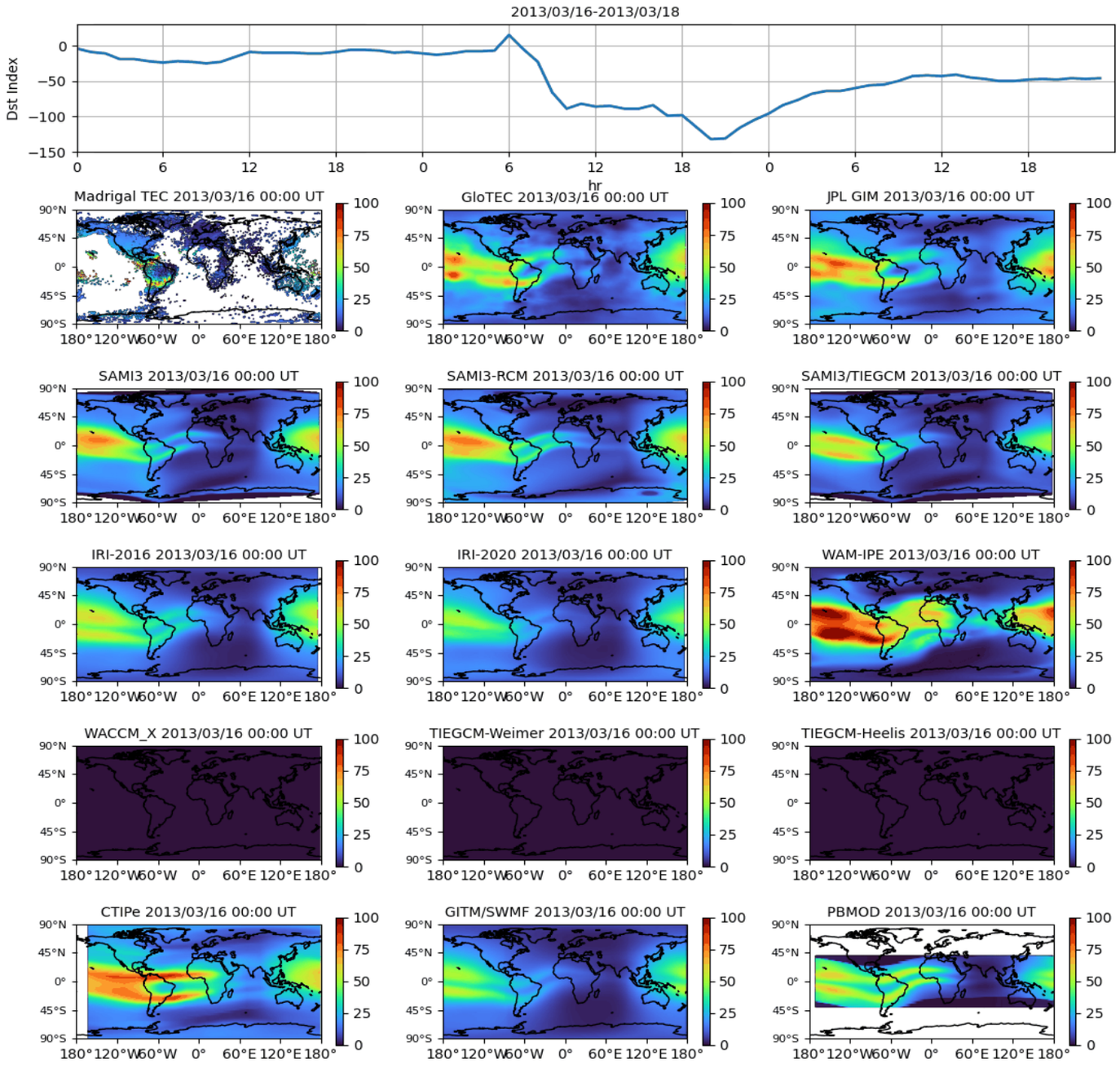
Madrigal
GloTEC
JPL GIM

SAMI3

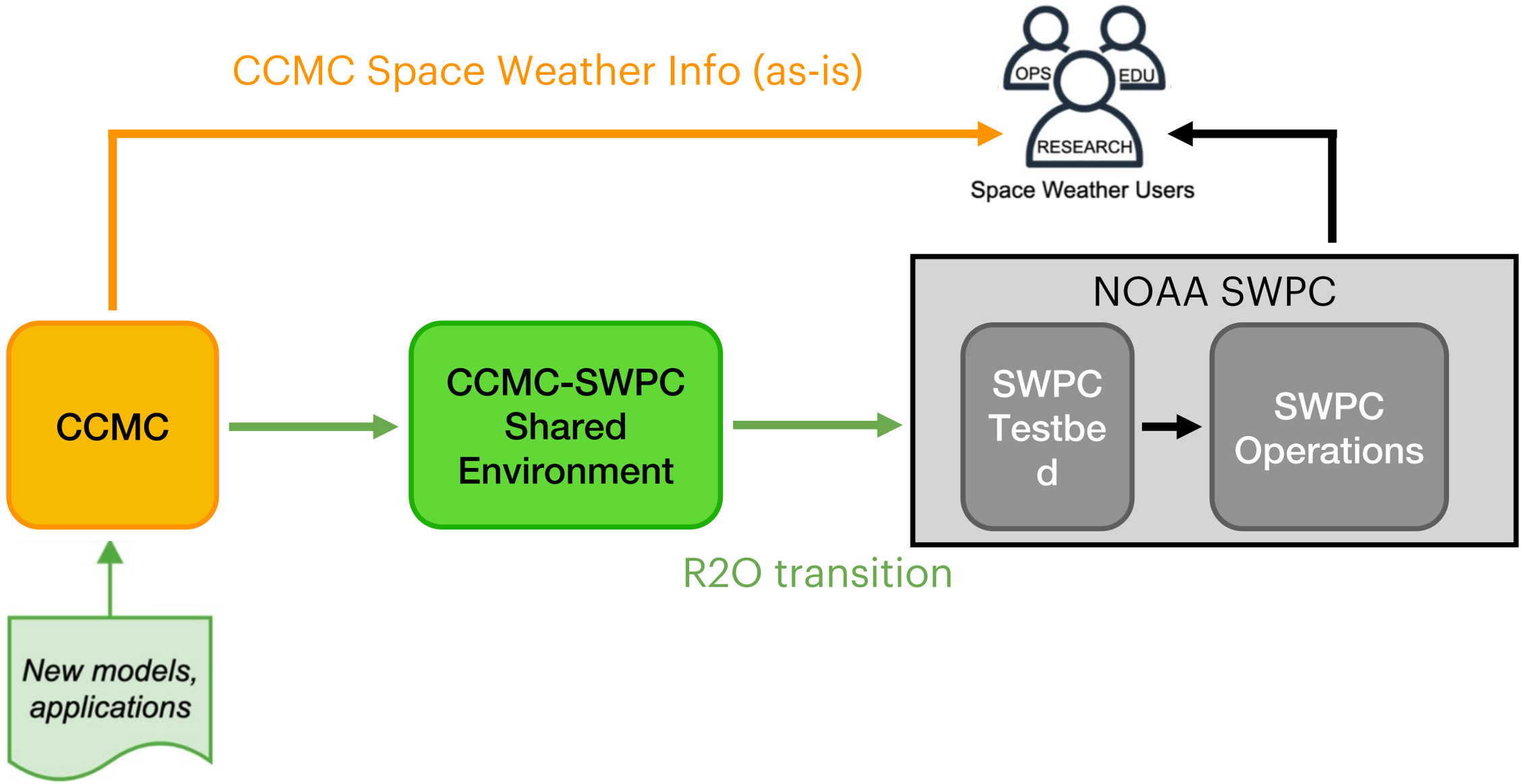
IRI
WAM-IPE

WACCM-X
TIE-GCM

CTIPe
GITM
PBMOD

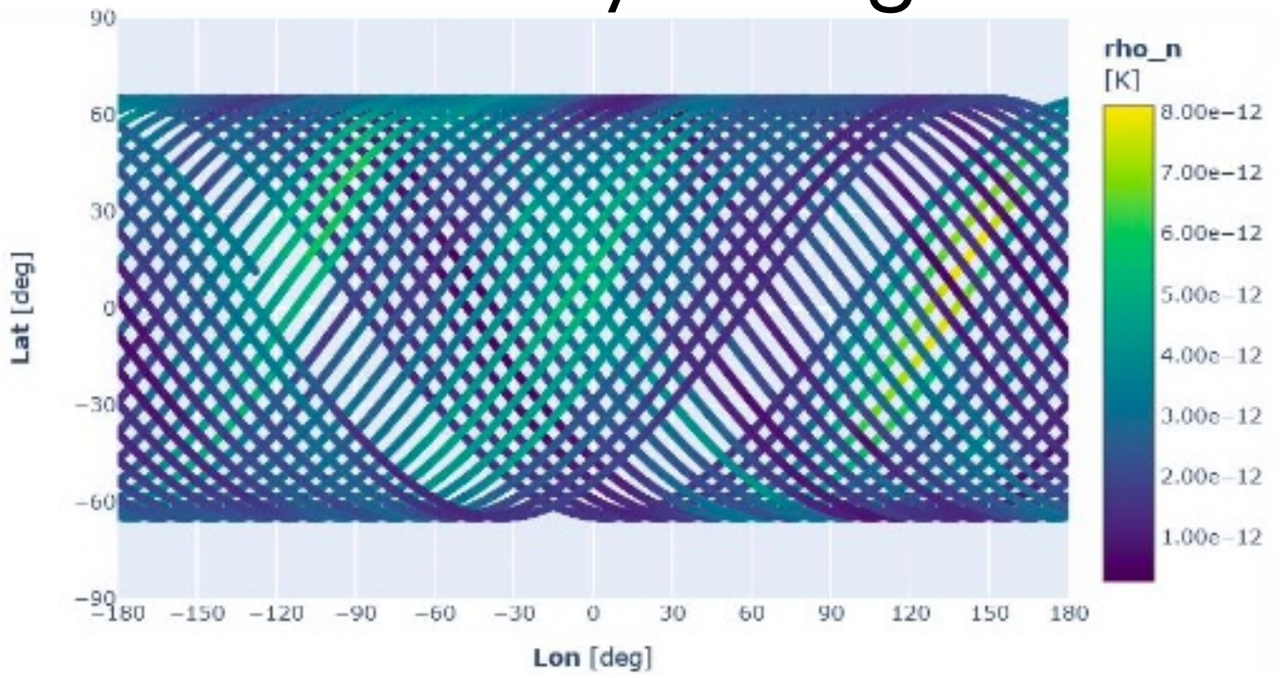


Research->Operations (R2O) Pipeline



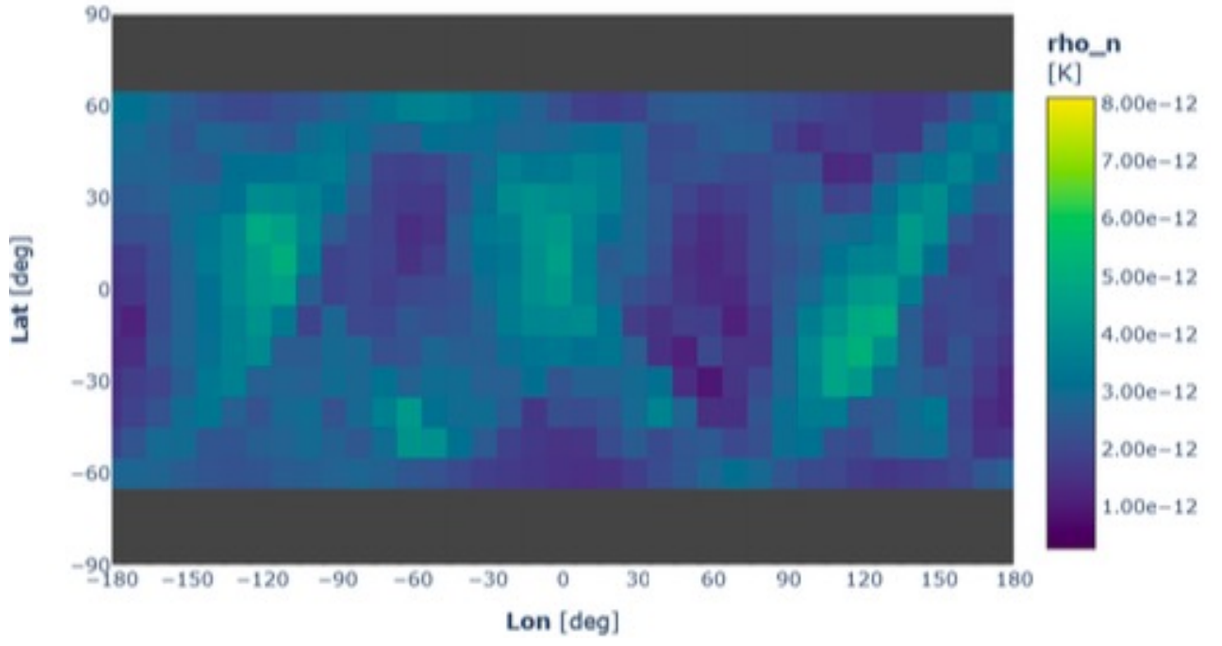
Mission Planning Tool: reconstructed observation from model flythrough

Model Flythrough



Kamodo

reconstructed “observation”



- Reconstruct what a satellite would see using model data as a virtual reality.

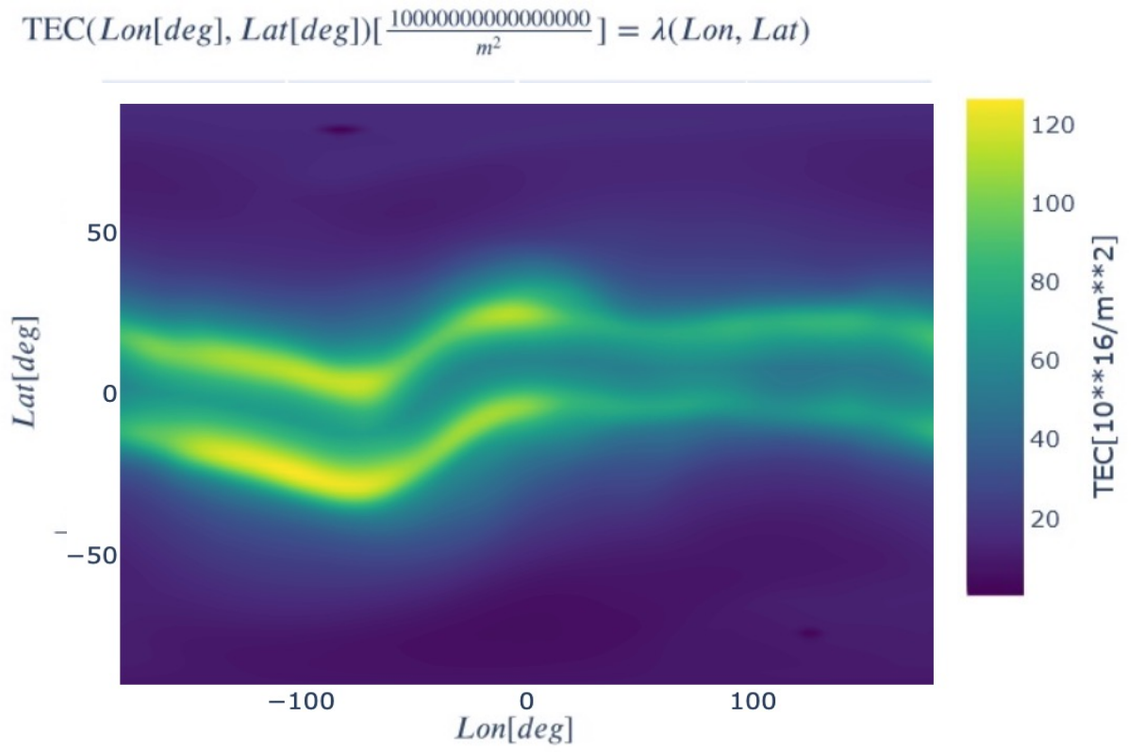
Satellite Constellation Mission Planning Tool:

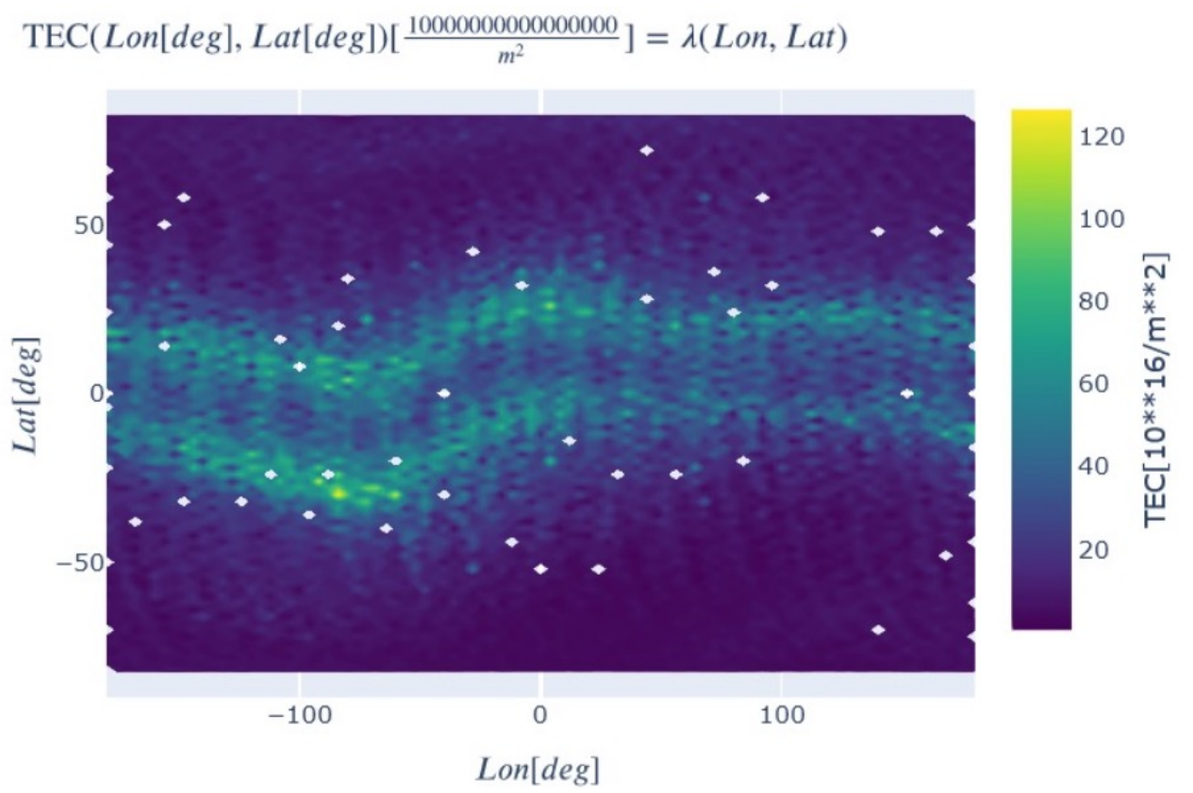
Irregular Constellations

Kamodo

model data

DMSP 15 - 18



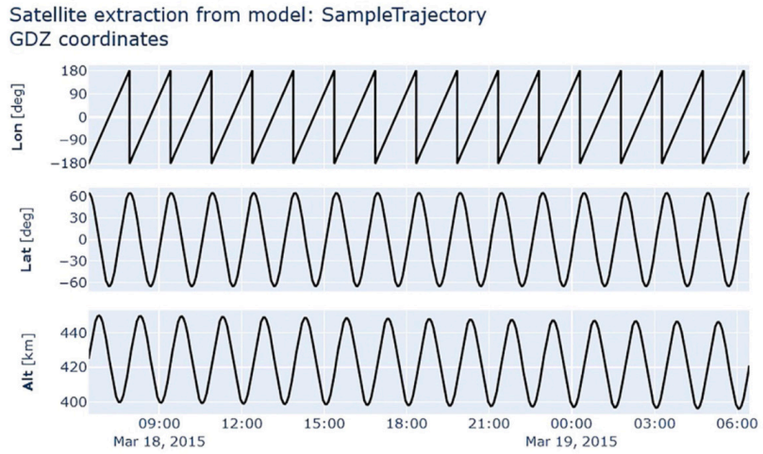


Fake Flight: Tool for CubeSat Mission Planning

Fake Flight

input
UTC

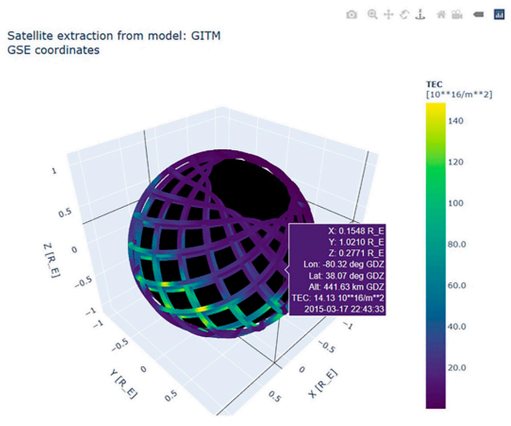
optional input
precession rate
latitude range
decay rate of height
time cadence



trajectory

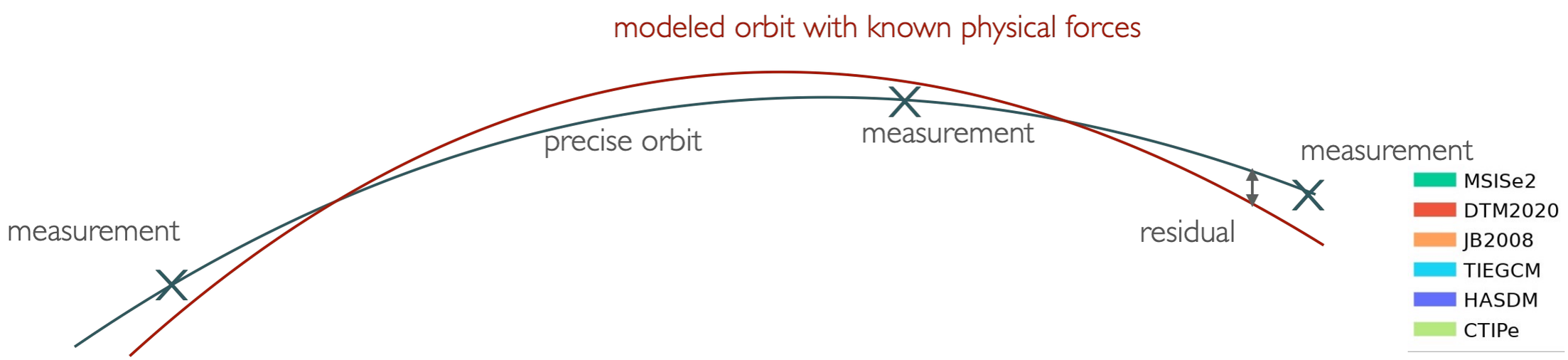
(x,y,z,t)

Model Flythrough

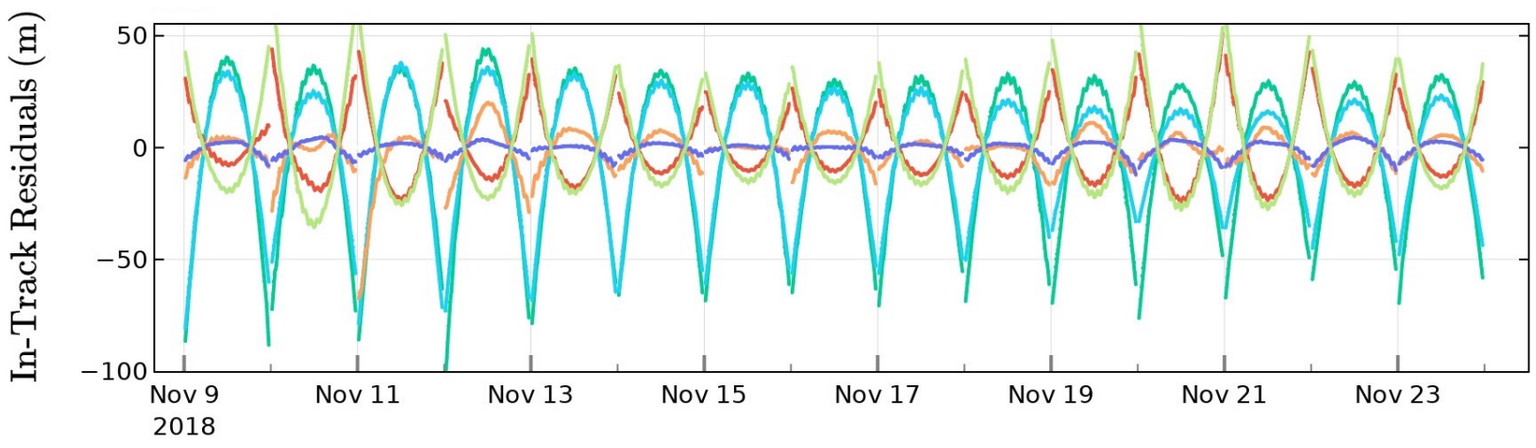


Sample Output at Given Sat. Trajectory

Kamodo Application: Validating Thermospheric Models for Orbital Drag



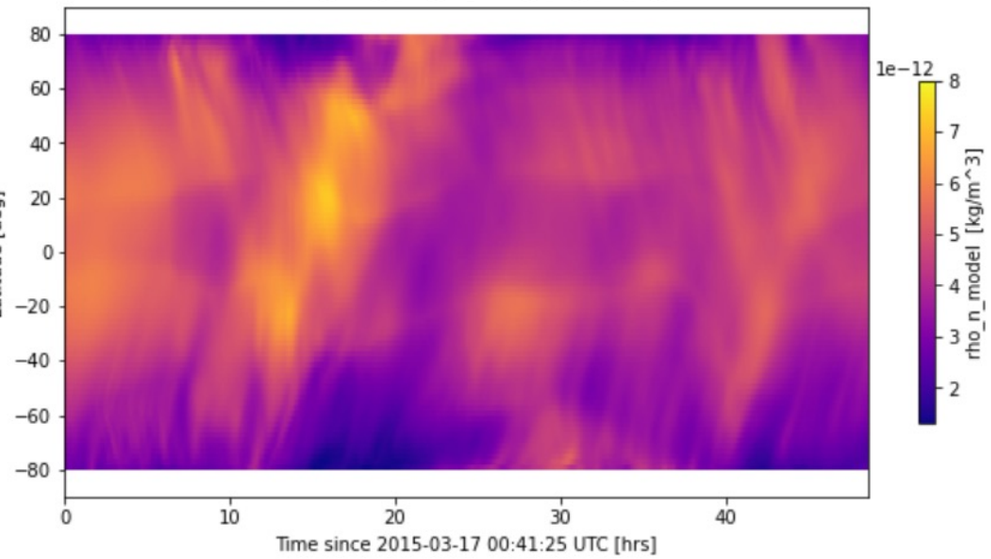
- CCMC-hosted thermosphere models are included in the GEODYN orbit propagator
- Physics-based models are integrated via Kamodo package
- Differences in thermospheric density translate to differences in orbit residuals with respect to ICESat-2 precise orbit determination



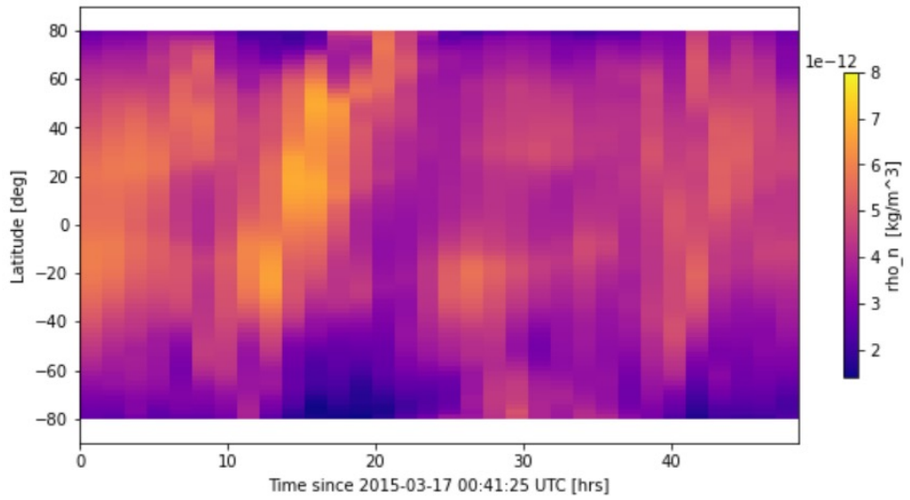
from Zachary Waldron, CU Boulder

Satellite Constellation Mission Planning Tool

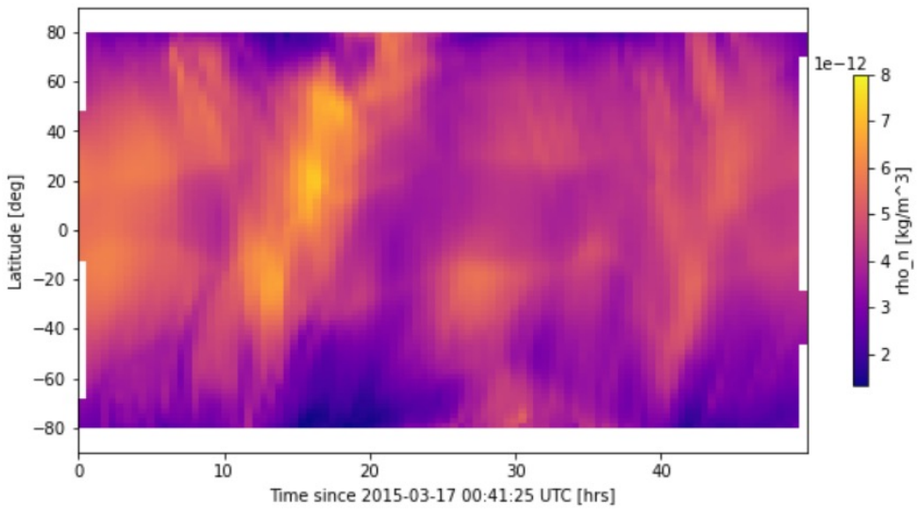
model data



one satellite



3 equidistant satellites



- New satellite constellation tool reconstructs in any pair of dimensions what a given constellation configuration would see.
- Currently available for a range of ITM models with model-agnostic syntax.

“ModelWeb Catalogue and Archive” provides a list of heliophysics models dating back to before 1979

https://git.mysmce.com/ccmc-share/modelwebarchive

- Archived-Models-InfoPages
- Auroral-Oval-Representation
- CIRA
- Chiu-Ionospheric-Model
- Exospheric-H-Model
- GSFC-Model-Coefficients
- Geomagnetic-Cutoff-Rigidity
- Heppner-Maynard-Rich_Electric-Field-Mo...
- ISR-Ion-Drift-Model
- Jacchi-Reference-Atmosphere
- Jensen-Cain-Model-Coefficients
- LWS
- MET-Model
- MGST-Model-Coefficients-All
- PV-Ionosphere-Mode
- PV-Thermosphere-Model
- RADBELT
- Revised-SERF2-Solar-EUV-Flux-Mode
- SHIELDOSE
- SOLPRO
- Xu-Li-Neutral-Sheet-Model

Model Reader - Example

```
from kamodo_ccmc.tools.plotfunctions import figMods
fig = kamodo_object_default.plot('T_n_ijk',
                                 plot_partial={'T_n_ijk': {'time': 22.5, 'height': 300.}})
figMods(fig, ncont=200, colorscale='Viridis', newTitle='Plot of Tn for CTIPe at 300km')
```