# Modeling Polar Cap Structure Formation

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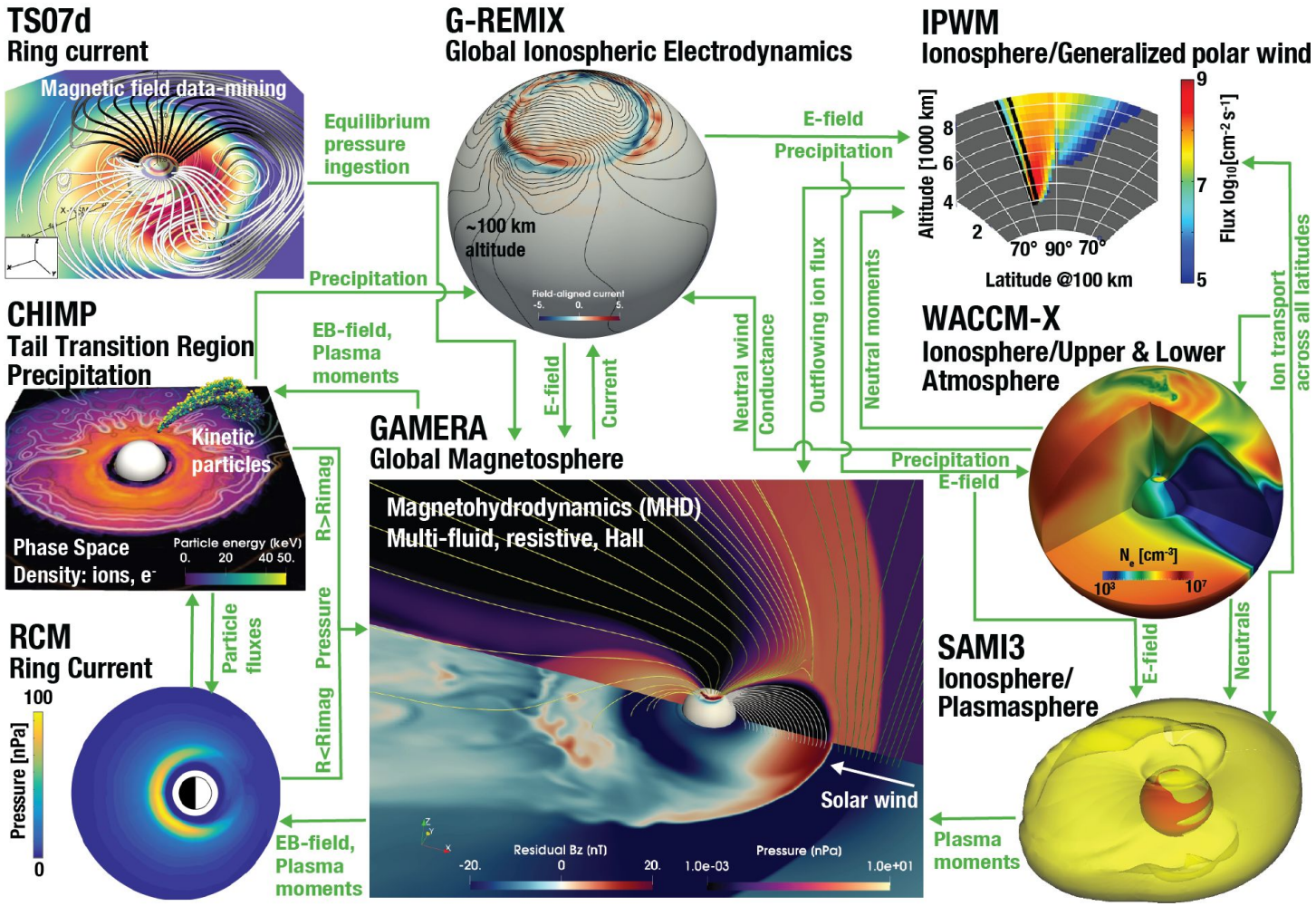
# Ion Outflow Modeling and CGS Goals

MAGE
Multiscale Atmosphere-Geospace Environment




## CGS Science Theme #2:

Stormtime mesoscale ionospheric structure and global geospace mass circulation

- Formation of polar cap patches and tongues of ionization
- Feedback of ionospheric structure to the magnetosphere through ion outflows

Ionosphere/Polar Wind Model (IPWM) is the primary component of the MAGE model for high-latitude ionosphere structure and ion outflow.

# HIDRA: IPWM Code Modernization

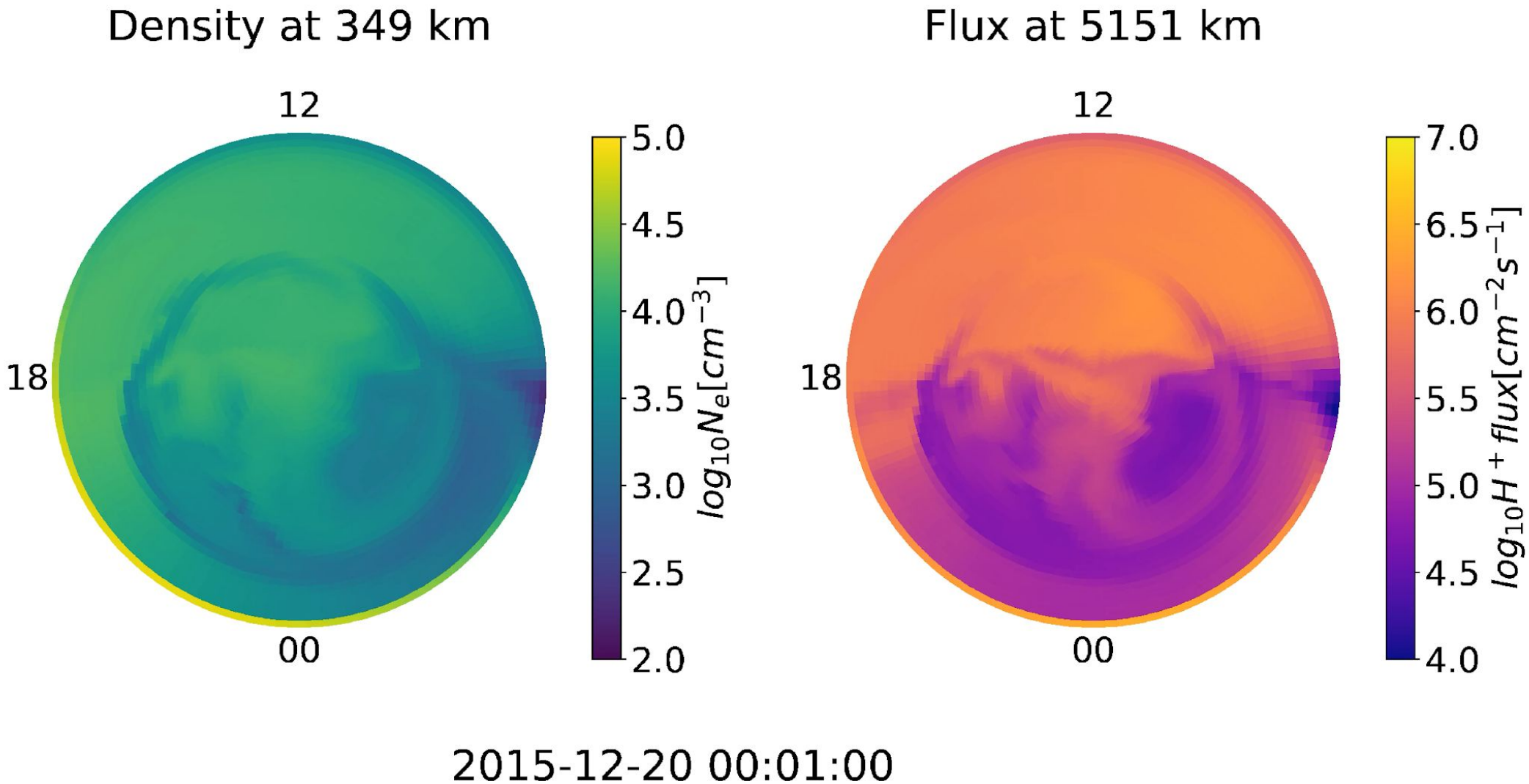
## High-Latitude Ionosphere Dynamics for Research Applications (HIDRA):

- Adopt advanced numerical methods from GAMERA
  - High-order finite volume reconstruction schemes
  - Careful treatment of grid-singularity at the pole
  - Staggered grids for densities and electric fields
- Code modernization to interface to MAGE framework

## High-resolution simulations in this presentation:

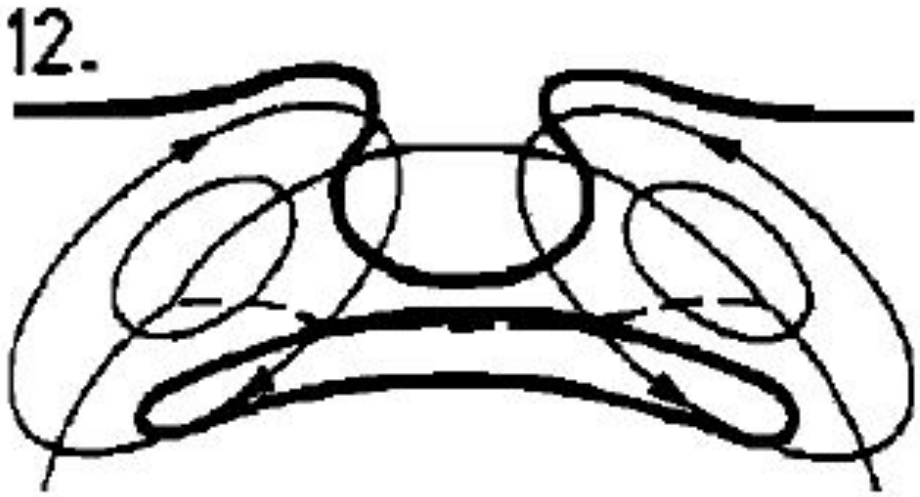
- Oct-res GAMERA-REMIX: 0.5 x 0.5 degrees in ionosphere
  - Provides convection potential and particle precipitation to HIDRA
- Oct-res HIDRA: (64 lat x 256 lon x 76 alts). ~65 km horizontal resolution
  - Equatorward boundary at L=2.8 (53.3 ILAT)
  - 7th-order spatial reconstruction
  - 3rd-order time stepping

# Polar Cap Structures in HIDRA Outputs



# Possible Mechanisms of Structure Formation

- Structured Convection
  - Lockwood & Carlson (1992) mechanism
- Variable Particle Precipitation
- Temperature Dependent Chemistry
  - $O^+ + N_2 \rightarrow NO^+ + N$ speeds up at high temperature, accelerating recombination

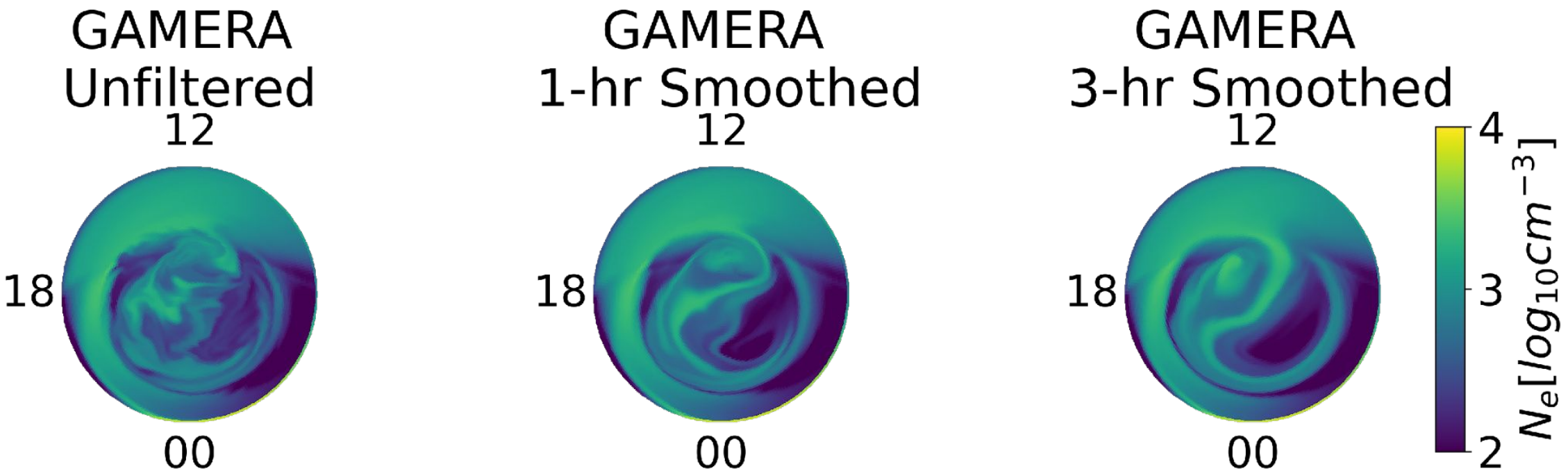



How can we distinguish different mechanisms?

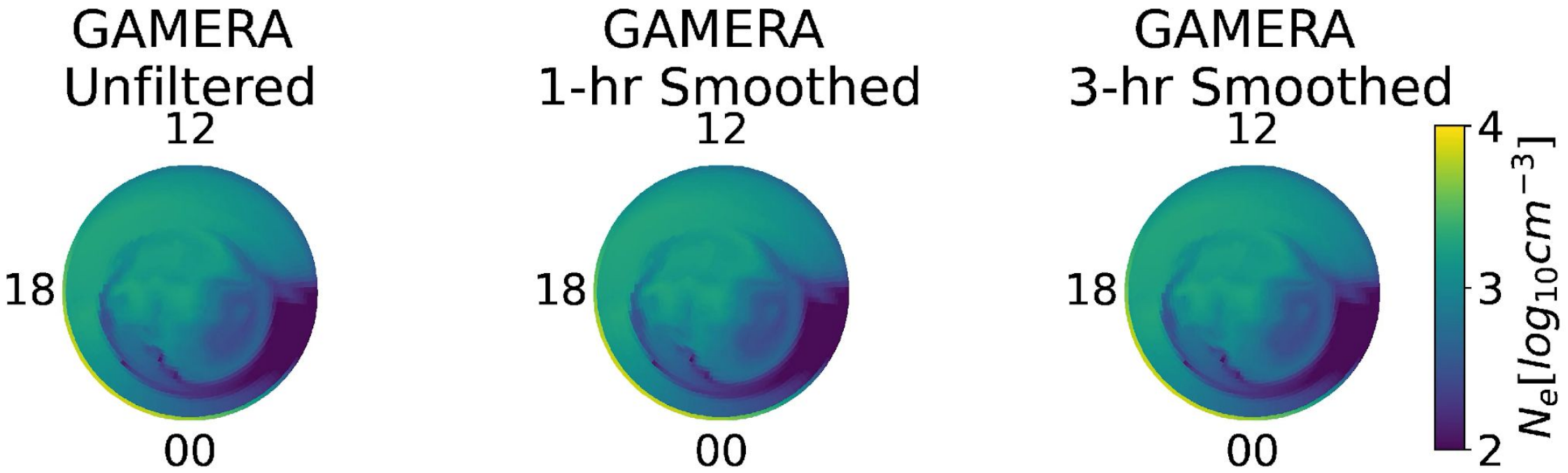
- Perform mechanism denial numerical experiments

# Testing Smoothed Convection

Numerical Experiments: Apply moving average (boxcar filter) to convection potential to smooth out convection variations.



# Comparison With Different Convection

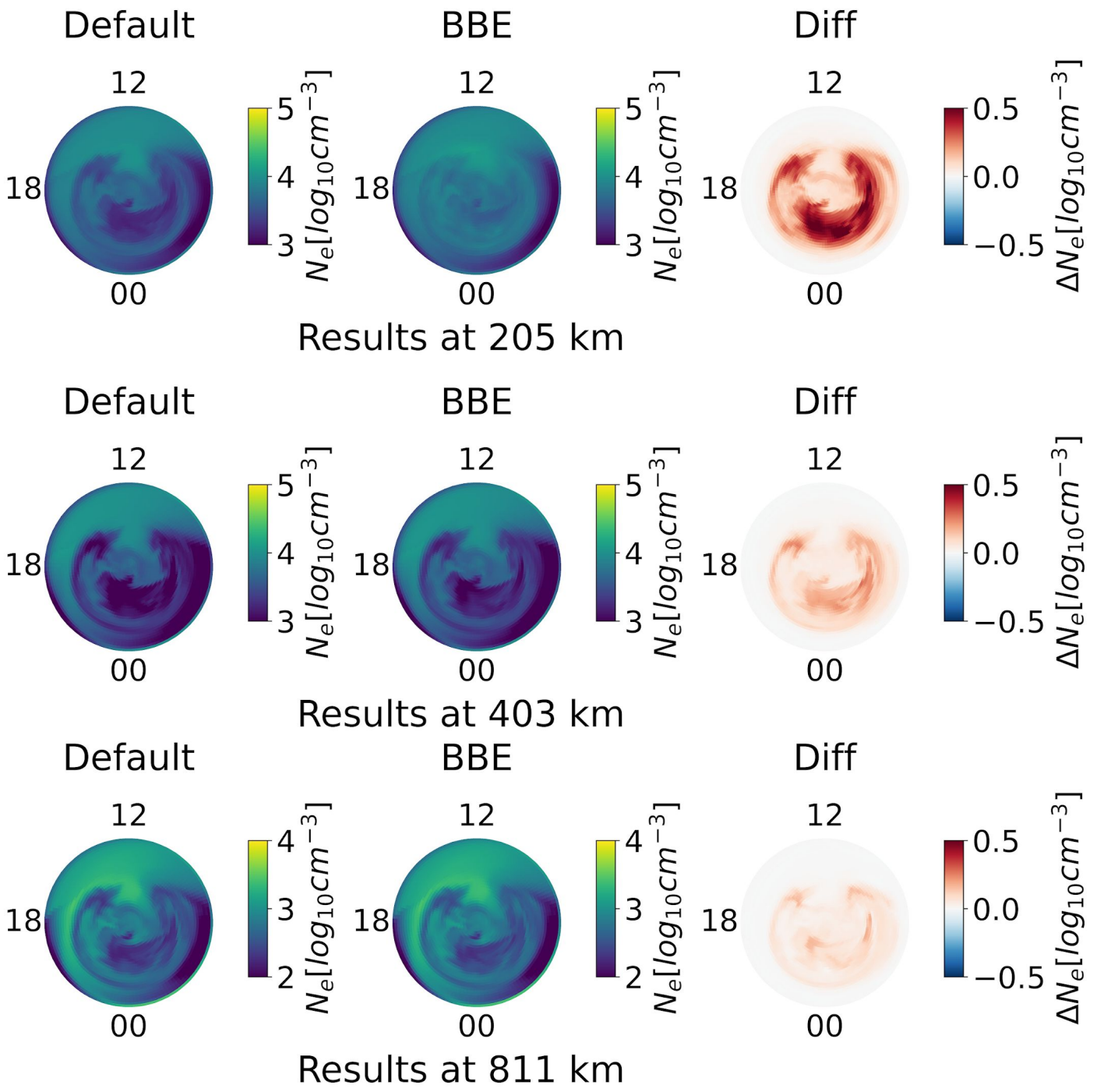



2015-12-20 00:01:00 at 811 km

These runs are identical except for convection potential

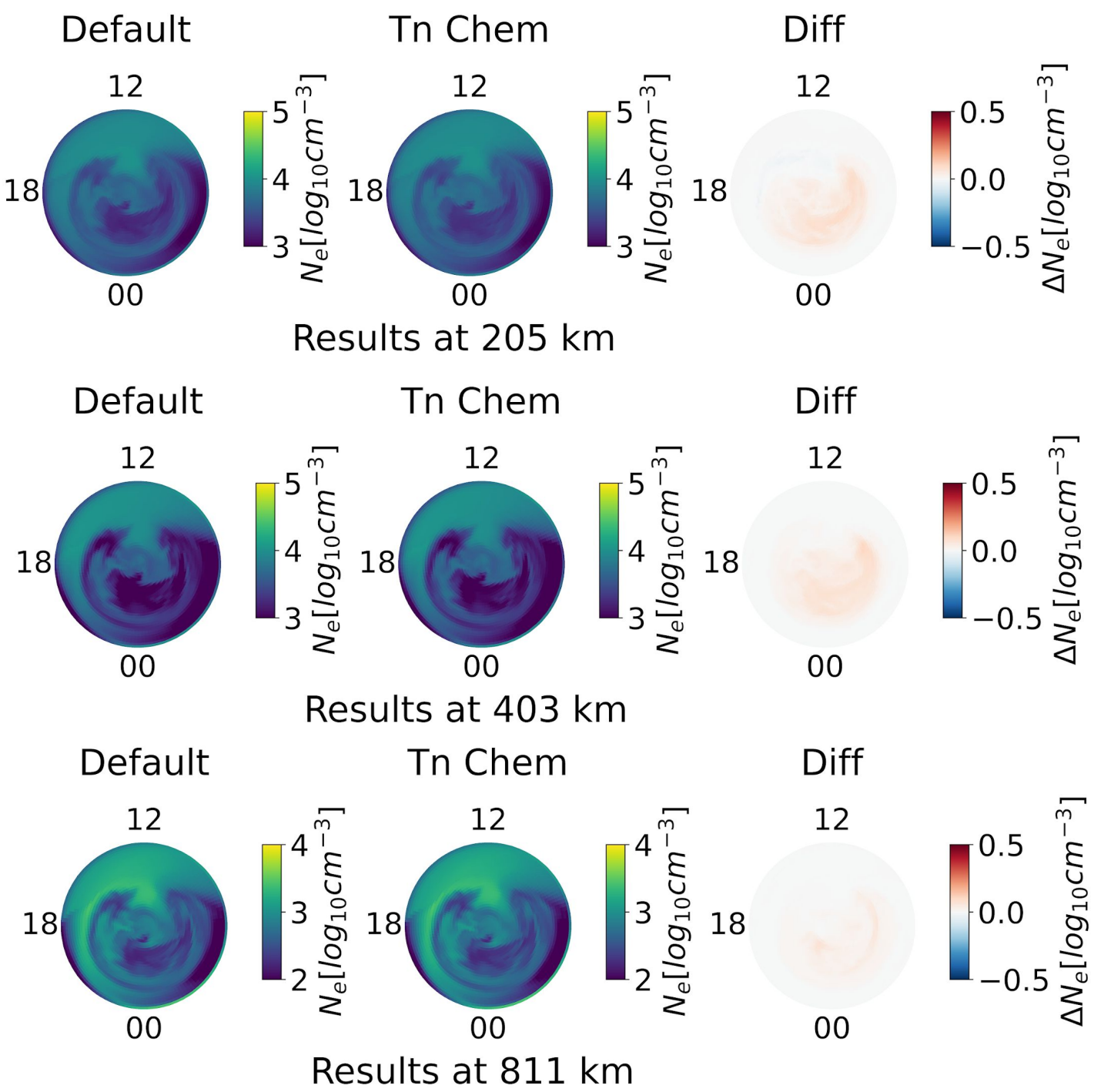
# Experiments with Soft Precipitation

- Experiments with enabling Broad-band Electron (BBE) precipitation.
- Soft BBE precipitation primarily affects densities at ~200 km.

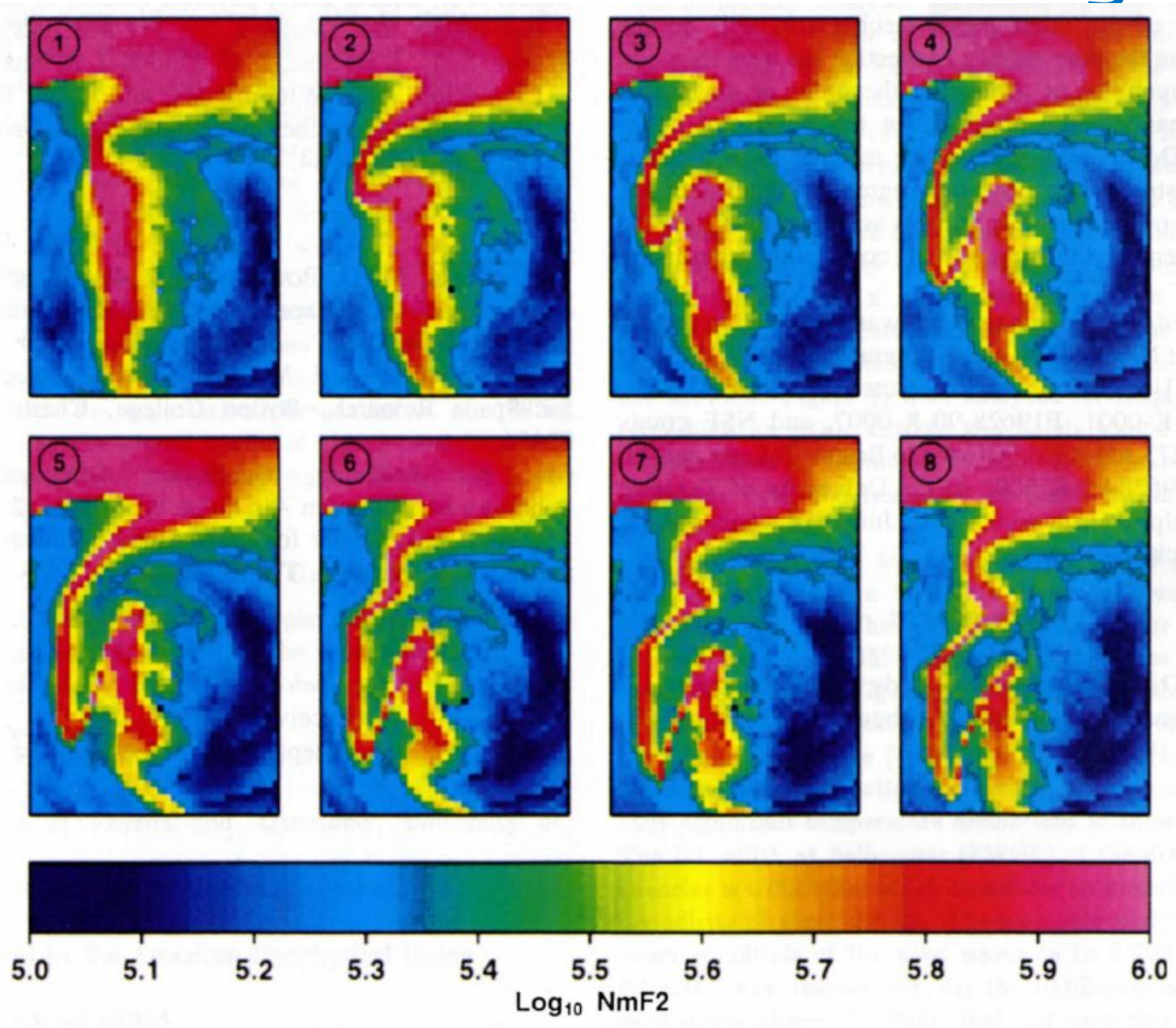


# Experiments with Ion Chemistry

- Replaced Ti with Tn in the following chemical reactions:
  - $O^+ + N_2 \rightarrow NO^+ + N$
  - $O^+ + O_2 \rightarrow O_2^+ + O$
- These reactions normally speed up in response to high Ti (Joule heating)



# Past Work on “Stirring” During By Flips

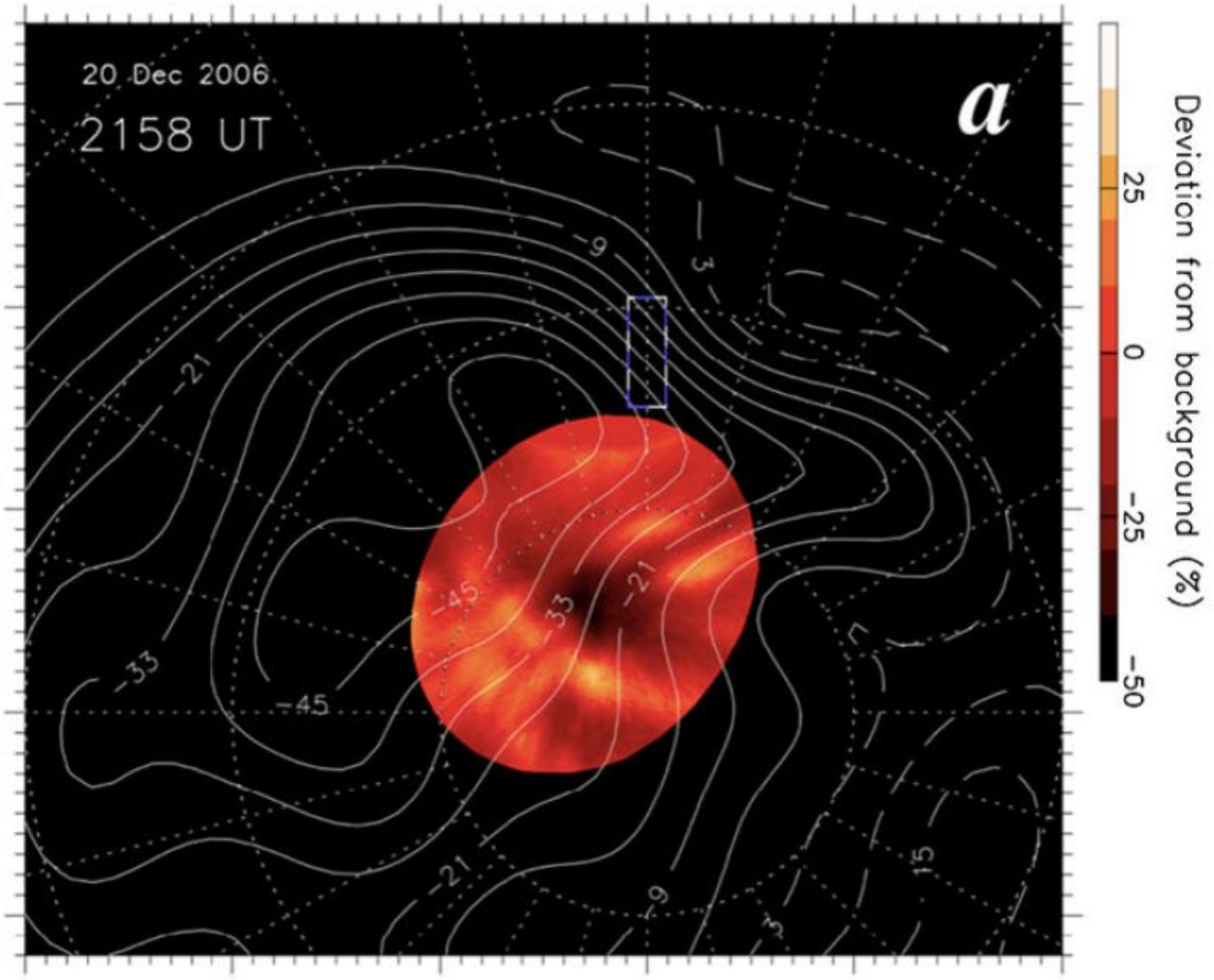



Sojka et al. (1993)

Modeling polar cap F-region patches using time varying convection

https://doi.org/10.1029/93GL01347

# Problems Reproducing Patch Elongations




- Patches are commonly observed elongated in the cross-flow direction (~ east-west)
- Variable convection simulations produce twisted structures elongated in the along-flow direction (~ north-south)
- Are we missing something fundamental about convection?
  - Bursty reconnection?