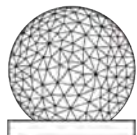# GEMINI at Haystack

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UT DALLAS

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Aeronautical
University

GEMINI (*G*eospace *E*nvironment *M*odel of *I*on-*N*eutral *I*nteractions)

- Three-dimensional ionospheric fluid-electrodynamic model.
    - Fluid system comprised of a set of three conservation equations (mass, momentum, and energy) for each ionospheric species.
    - Coupled to electrostatic description of auroral and neutral dynamo currents.
    - Generalized orthogonal coordinate system

- Applications:
    - Ionospheric responses to infrasonic-acoustic waves
        - Earthquakes, volcanic eruptions, weather events. etc.
    - Modeling auroral current systems
    - Used to drive sensor models
    - This project: Used to predict eclipse event

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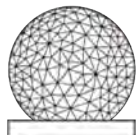
GEMINI Fluid Dynamics Demonstration

Test run: GEMINI response to neutral gas input (MAGIC)
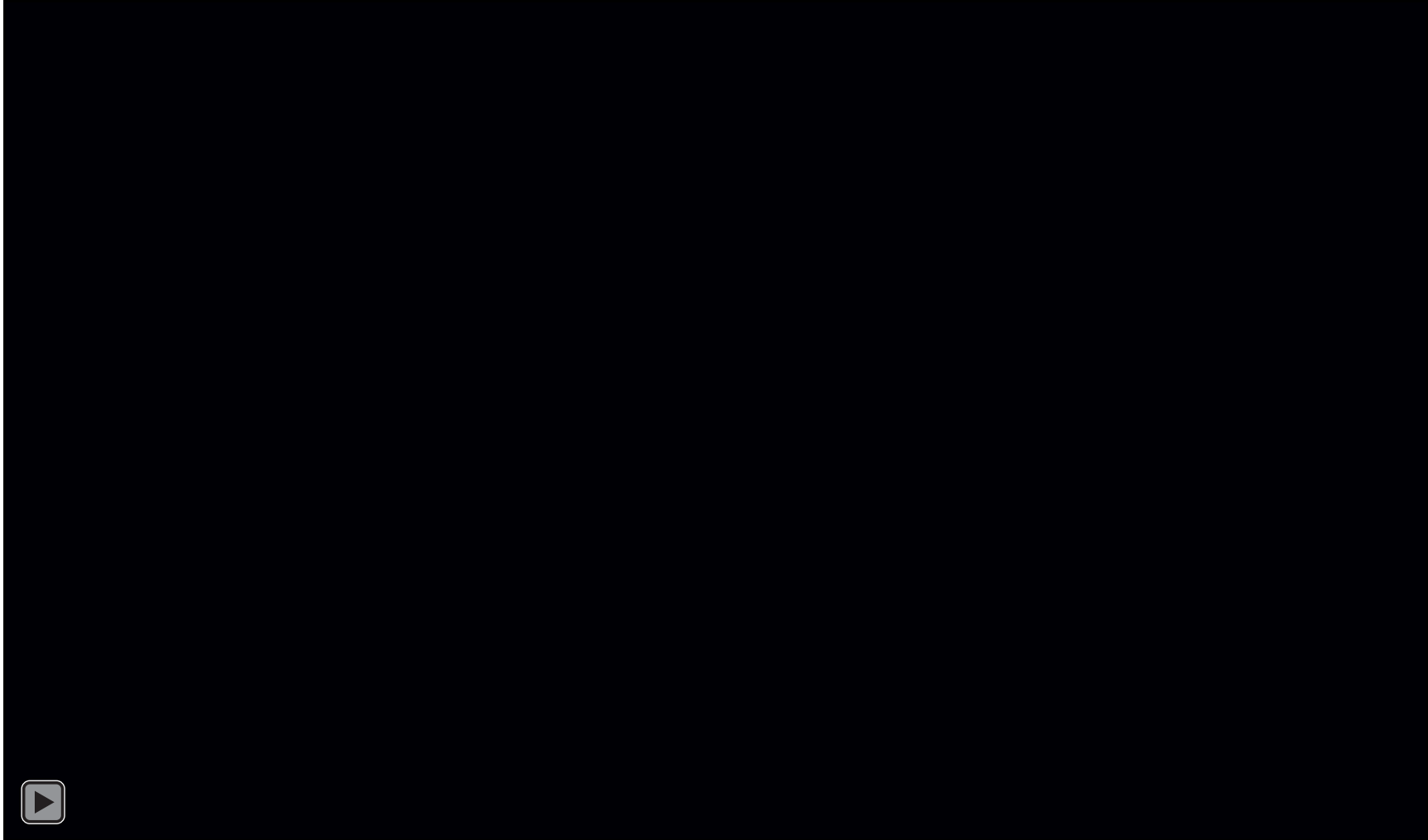
Project Goals

- Setup capabilities for Haystack scientists to use and run GEMINI

- Explore model's capacity in producing physical features (equatorial ionization anomaly, day-night variation in ionospheric parameters, etc.)

- Case study to illustrate GEMINI capabilities
  - Modeling June 2021 annular eclipse
    - Photoionization masking
    - Larger scale simulation

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Running GEMINI

- Generally, running GEMINI requires:
  - Generating input files
    - Creating configuration file. Specify inputs such as time, F107, AP, etc.
    - Spatial grid
  - Running a background state equilibrium
    - Run until non-physicalities "ring out"
    - Results interpolated as input conditions for actual simulation.
  - Redefining config, run actual simulation at higher resolution.
    - Outputs files specify pecies temperature, density, and drifts for each relevant ionospheric species ($O+$,$NO+$,$N2+$,$O2+$,$N+$, $H+$,$e-$) and electromagnetic parameters.

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Running GEMINI on MIT Supercloud

- Supercloud
  - Shared high performance computing cluster environment available to MIT staff/students
  - GEMINI benefits from parallelization, well supported by Supercloud
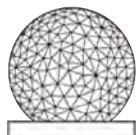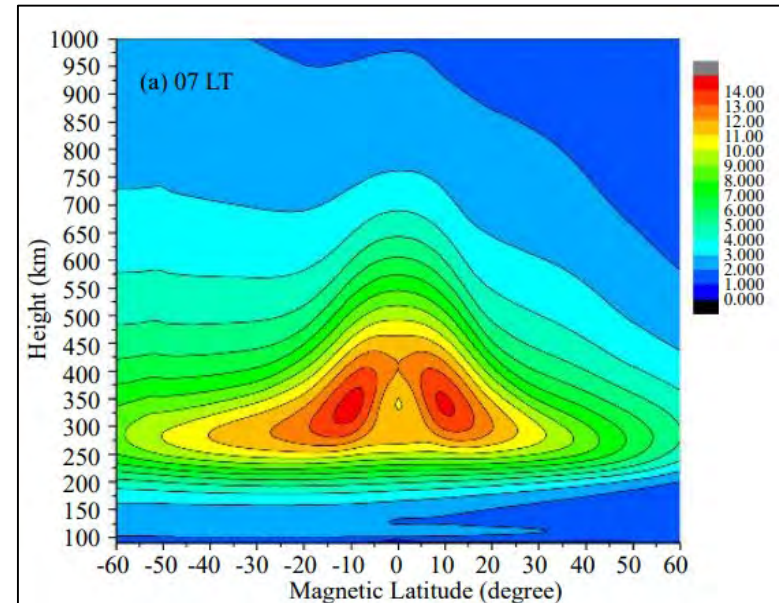 - Unlimited access up to 8 nodes w/ ~48 CPUs per node. More on request

Equatorial Ionization Anomaly (EIA)

- Troughlike structure observed at magnetic equator due, in part, to plasma diffusion and E×B drift (fountain effect)
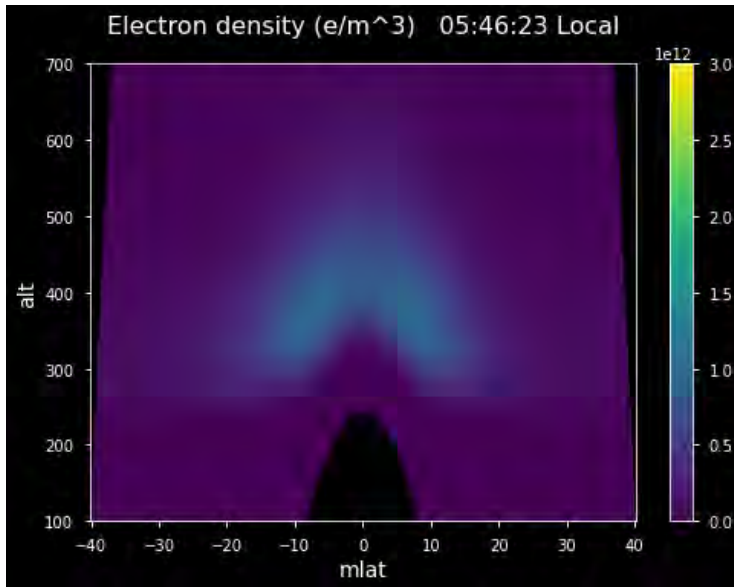- Model results generally consistent with EIA, observed and modeled
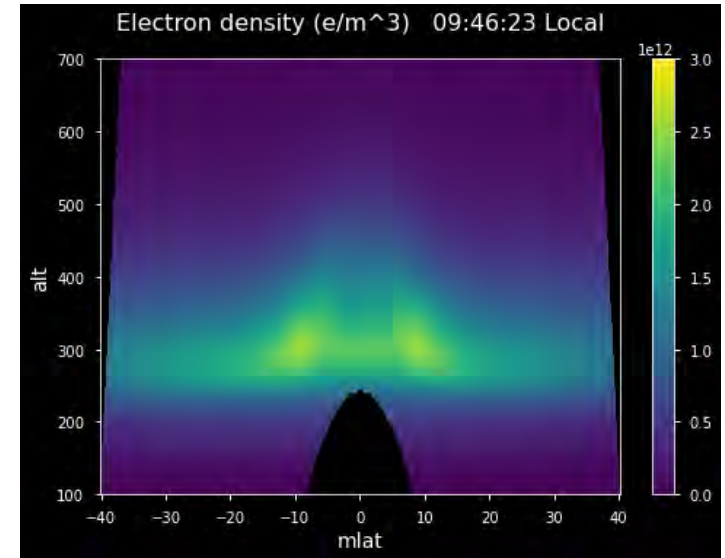
GEMINI
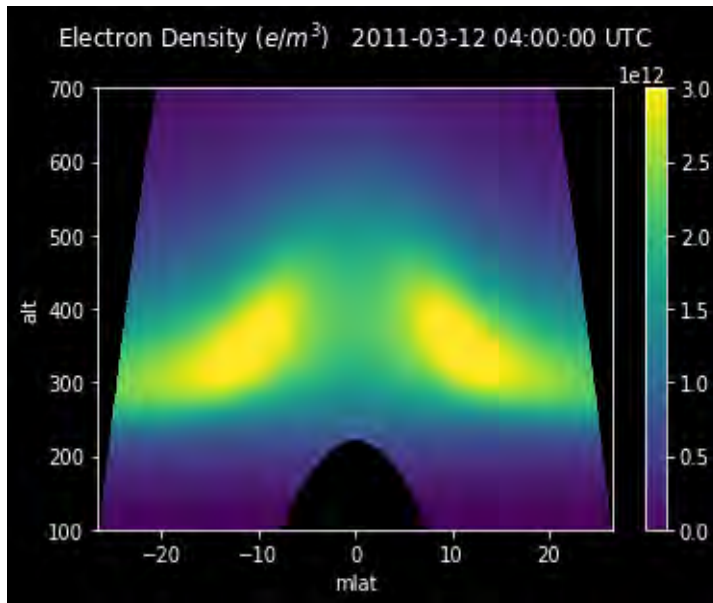
SPUIM

Case: Global Photoionization Mask
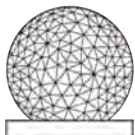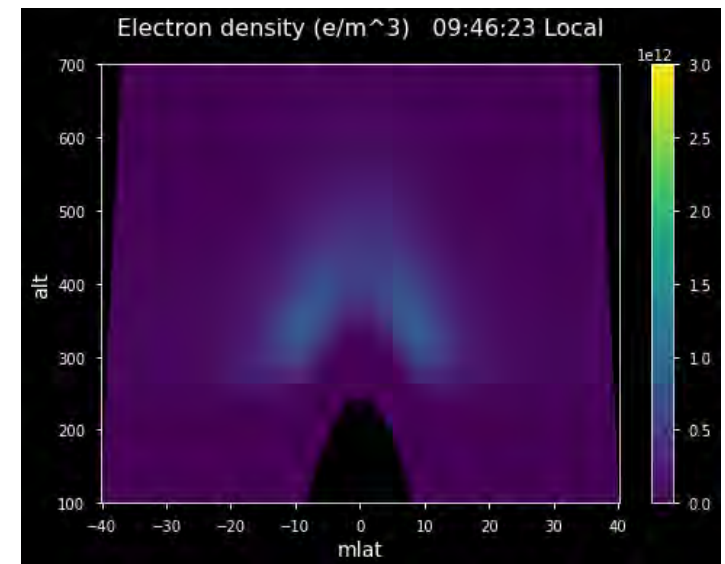
- Can photoionization in GEMINI be modulated and produce reasonable responses?
- Sunrise enabled vs. sunrise disabled

Control
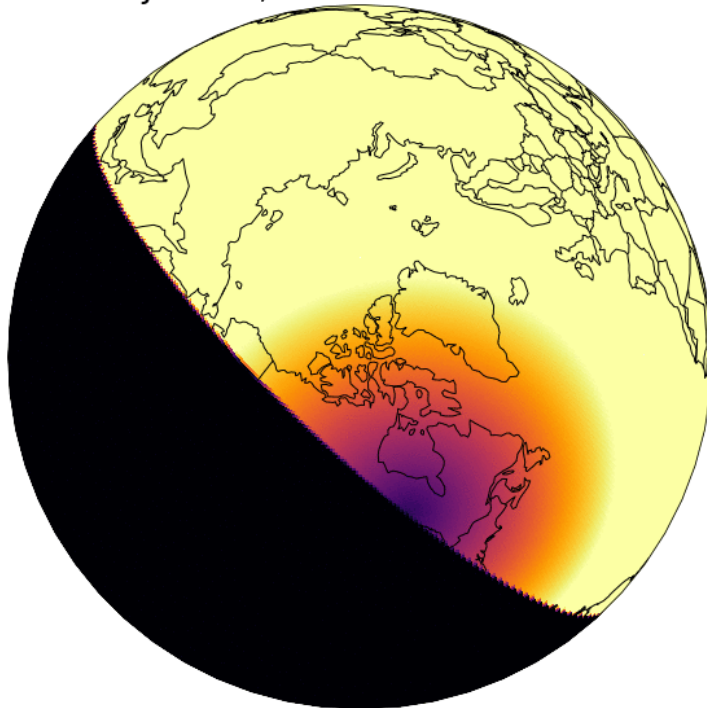
Masked

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Case Study: 2021 Annular Eclipse

- June 10, 2021 Annular Eclipse:
    - Coincided with sunrise
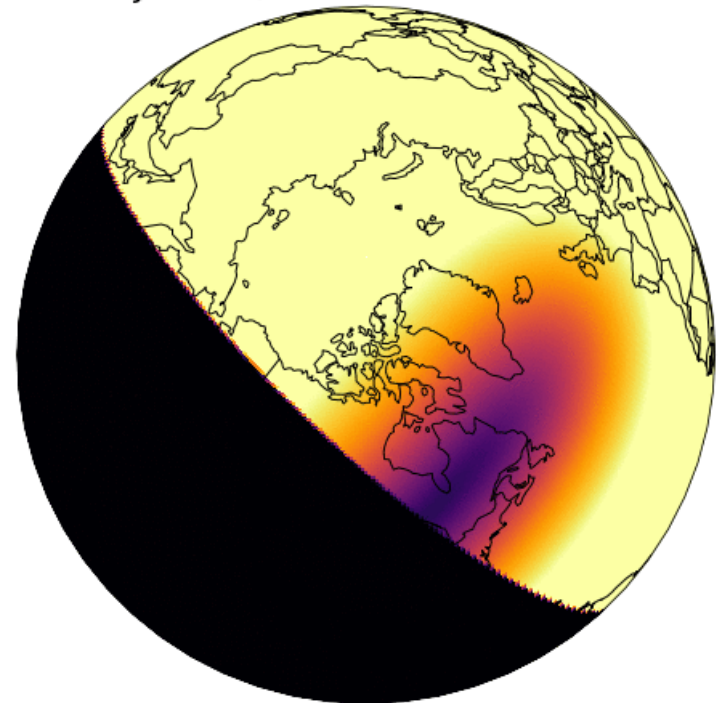   - Eclipse mask approximated from SAMI3 modeling of 2017 total solar eclipse

Mask implemented in study


**Real world obfuscation
Credit: Juha Vierinen**

June 2021 Annular Eclipse: Preliminary Results

- Grid: 128 x 388 x 312 dimension=~15M grid cells spanning 900km, altitude 268-300 longitude, 35-75 latitude,

- Up to 18% decrease in electron density at 300 km after 60 minutes compared to no eclipse control simulation
  - SAMI3 found ~25% decrease in density

SAMI3 2017 total eclipse simulation
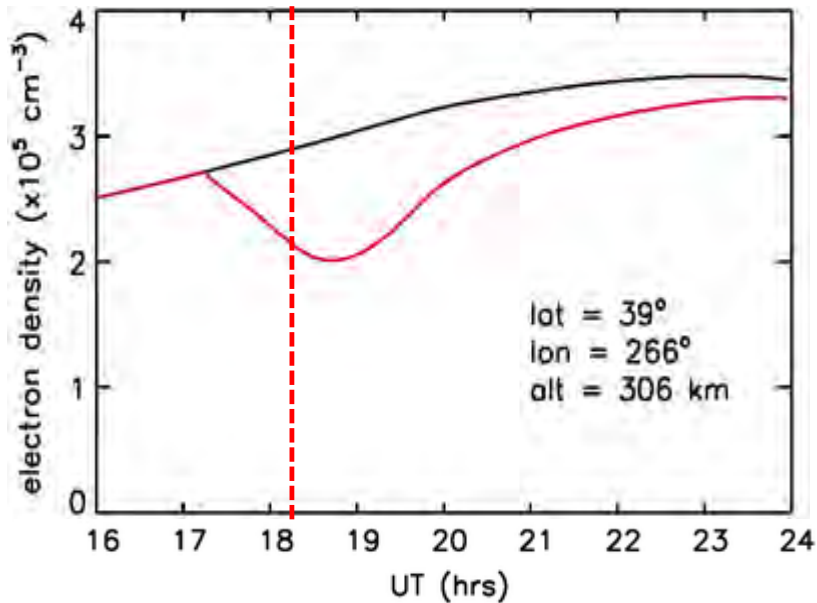
% difference electron density GEMINI

Lat=46.3° N
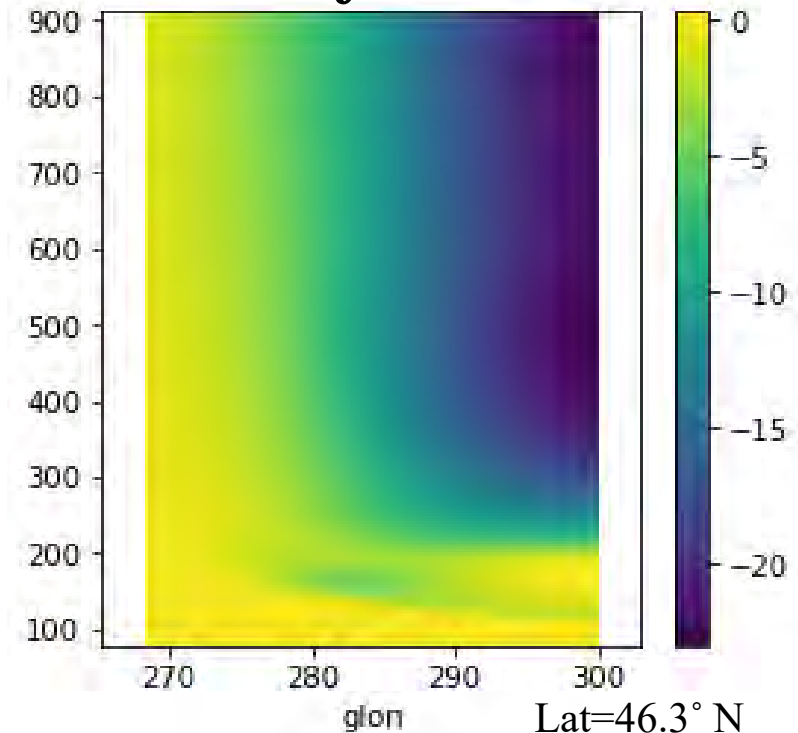
Summary & Future Work

- Contributions
  - Helped pave the way for setting up and running GEMINI simulations on MIT Supercloud
  - Explored GEMINI features and capabilities
  - Worked to simulate June 2021 annular eclipse as a case study
  - Contributed to model development (code, bug testing)

- Future work
  - More in depth eclipse analysis
    - Larger grid
    - More accurate model & ionospheric parameters
  - Drive sensor models
  - MIT Supercloud involvement with other REU projects

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Acknowledgments

- Very special thanks to:
    - Dr. John Swoboda, for managing me as lead project mentor and introducing me to several software resources including Supercloud
    - Prof. Matthew Zettergren, developer of GEMINI, for instructing me on how to use GEMINI and implementation
    - Dr. Larisa Goncharenko and Dr. Shunron Zhang, for assisting in ensuring that GEMINI outputs generally corresponded to physical structures and observations
    - Dr. Phil Erikson for assisting in obtaining an MIT Supercloud account

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