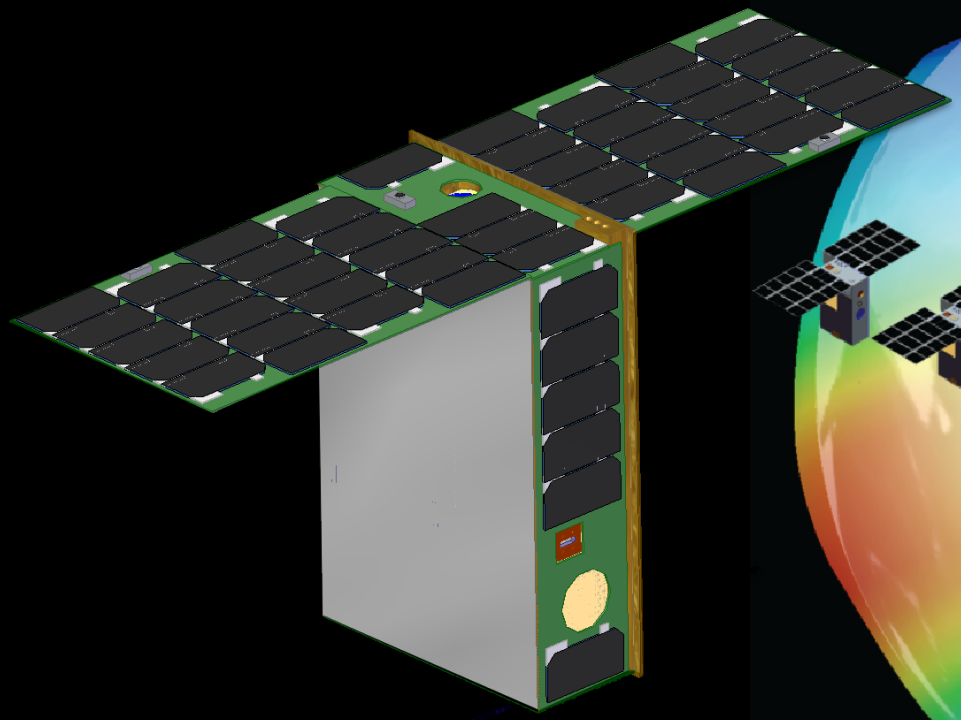
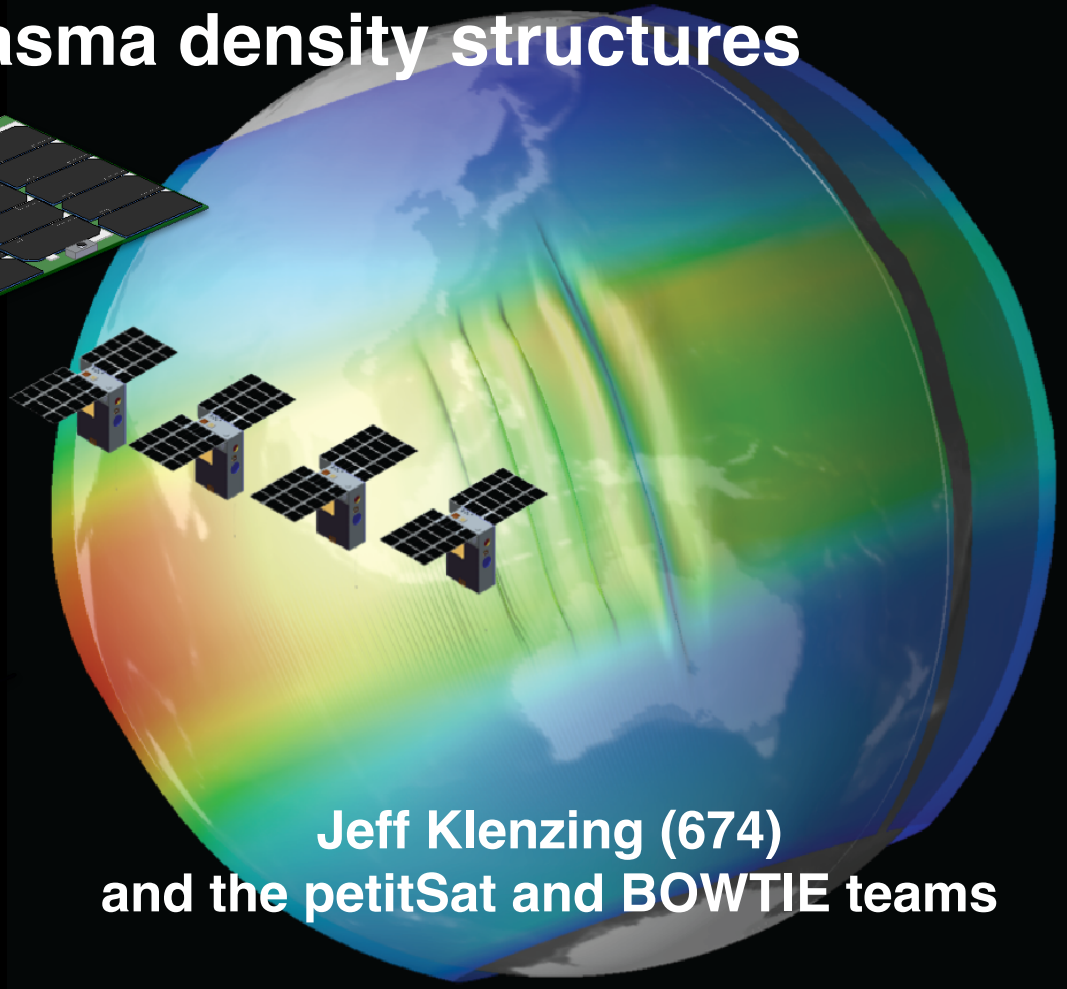
From Space Climate to Space Weather

Mission concepts to unravel the enigma of ionospheric plasma density structures

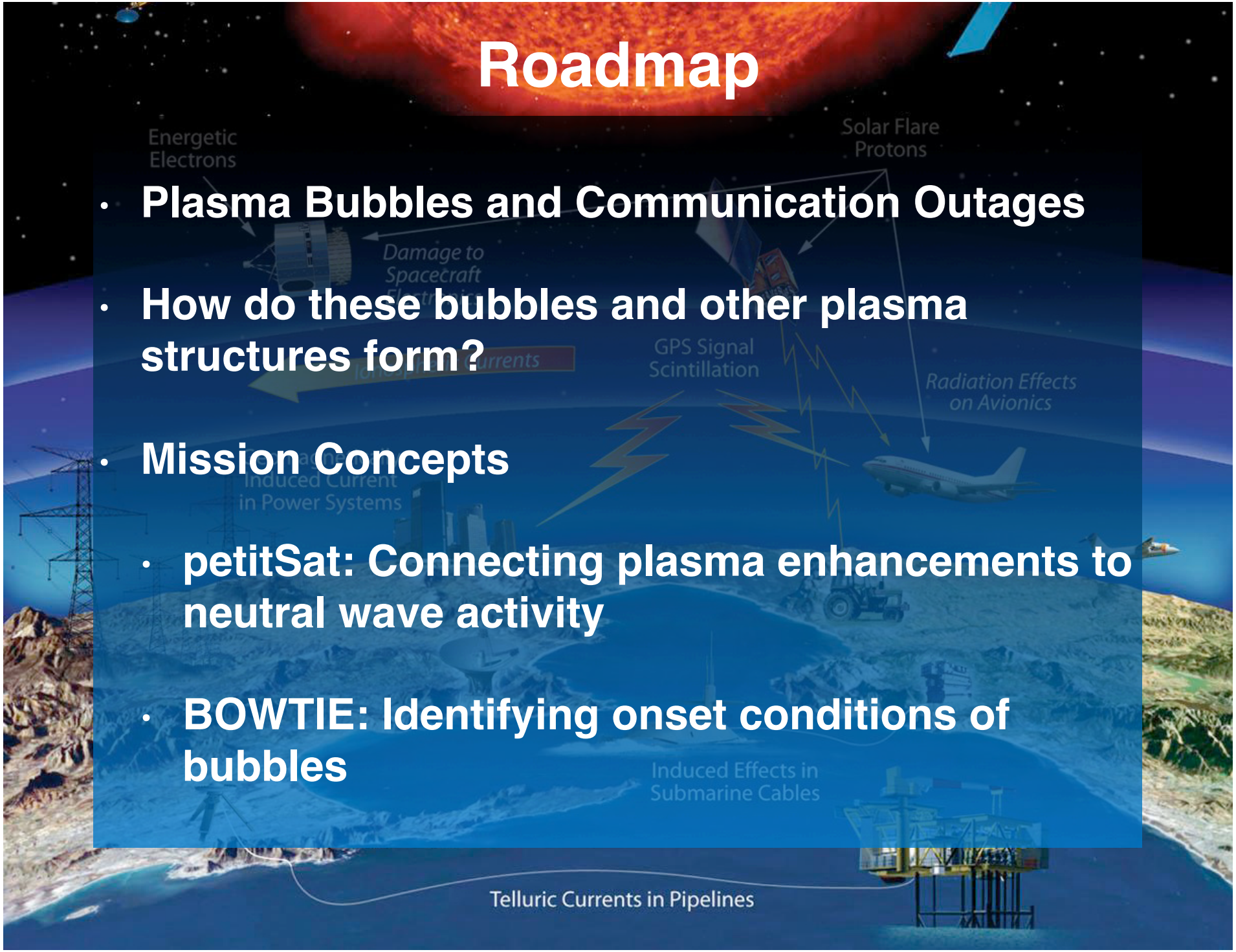


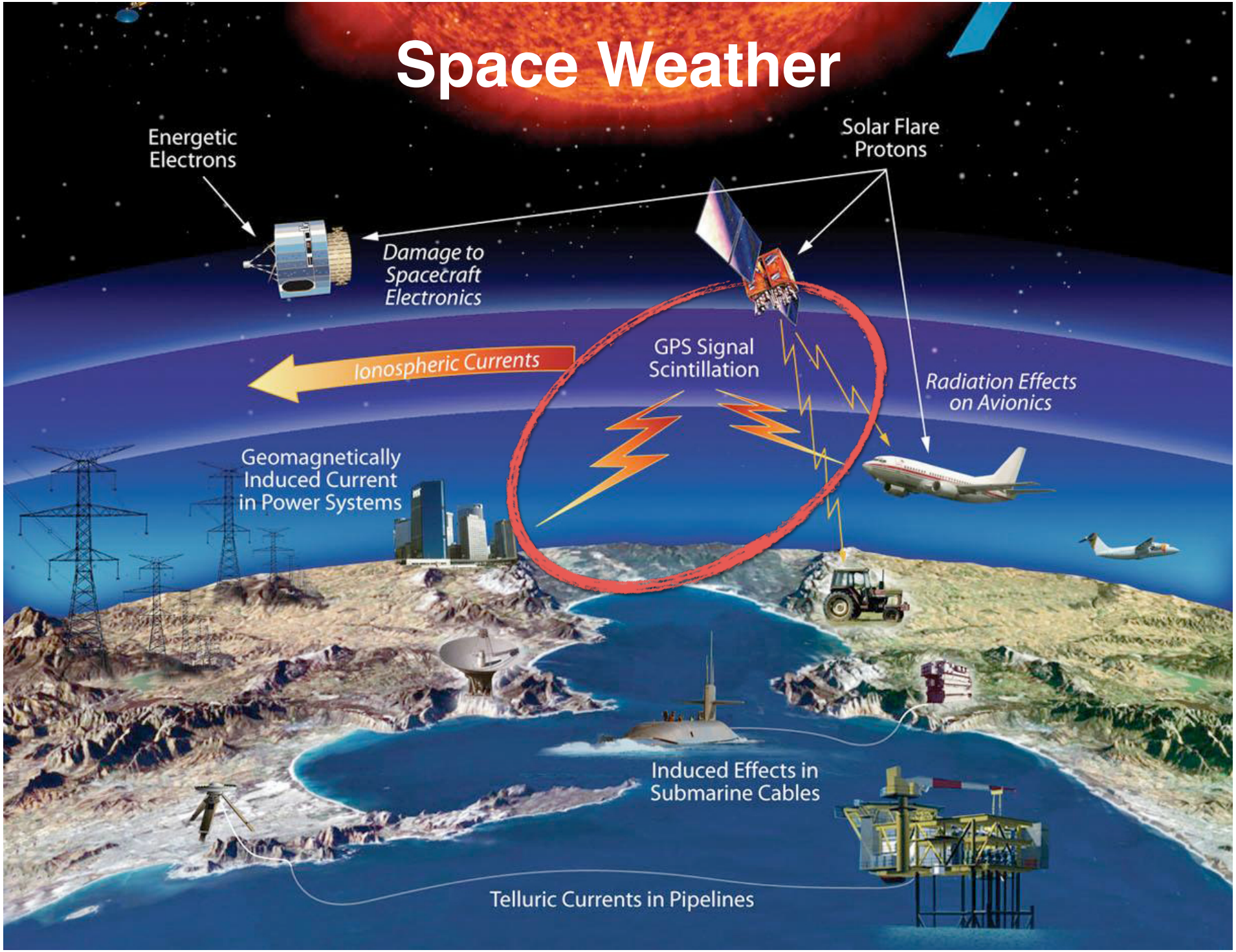


Jeff Klenzing (674)
and the petitSat and BOWTIE teams

Roadmap

- Plasma Bubbles and Communication Outages
- How do these bubbles and other plasma structures form?
- Mission Concepts
  - petitSat: Connecting plasma enhancements to neutral wave activity
  - BOWTIE: Identifying onset conditions of bubbles




Space Weather
Energetic Electrons
Solar Flare Protons
Damage to Spacecraft Electronics
Ionospheric Currents
GPS Signal Scintillation
Radiation Effects on Avionics
Geomagnetically Induced Current in Power Systems
Induced Effects in Submarine Cables
Telluric Currents in Pipelines

Radio waves in the Ionosphere

Transmission

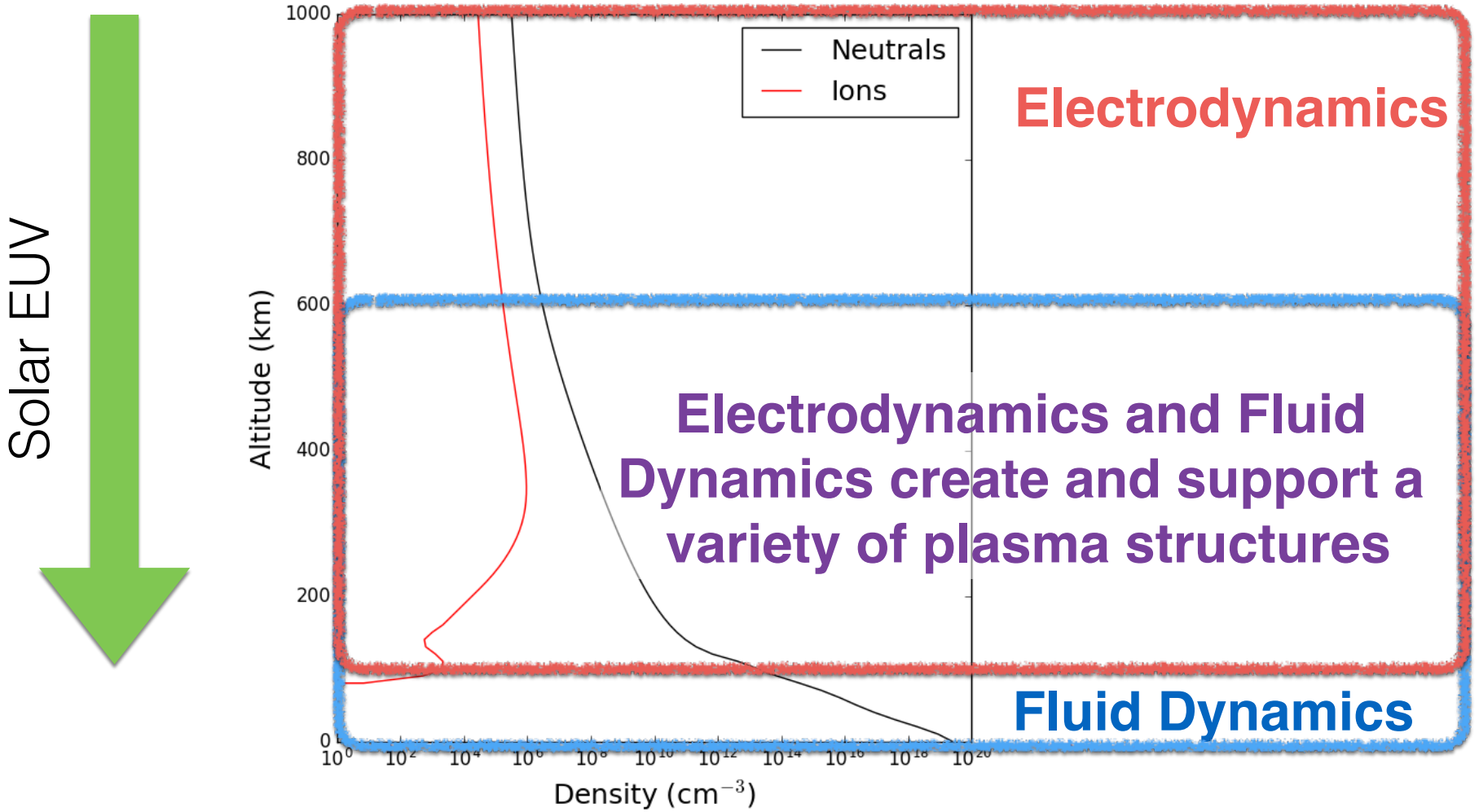
Refraction

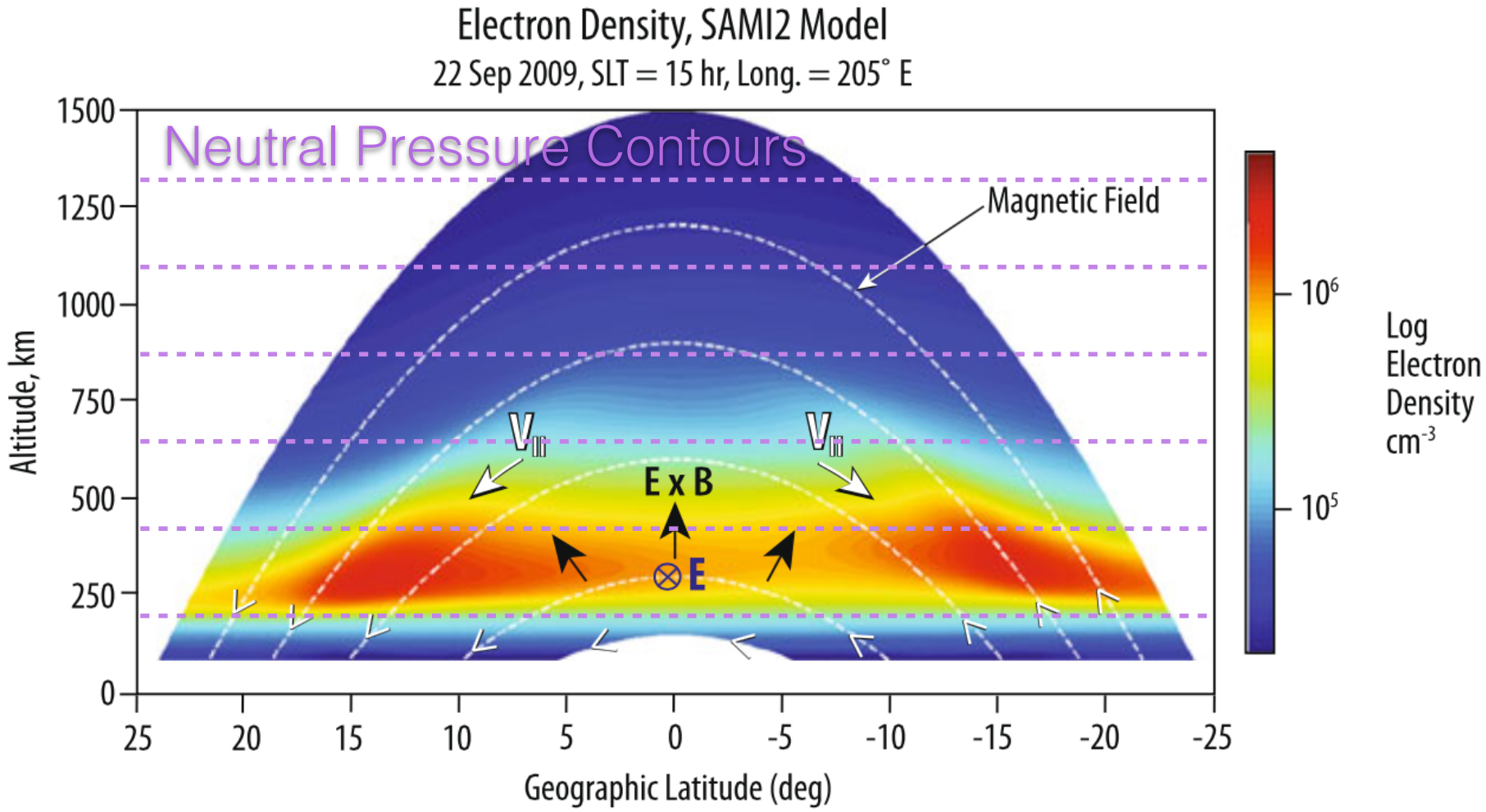
Reflection

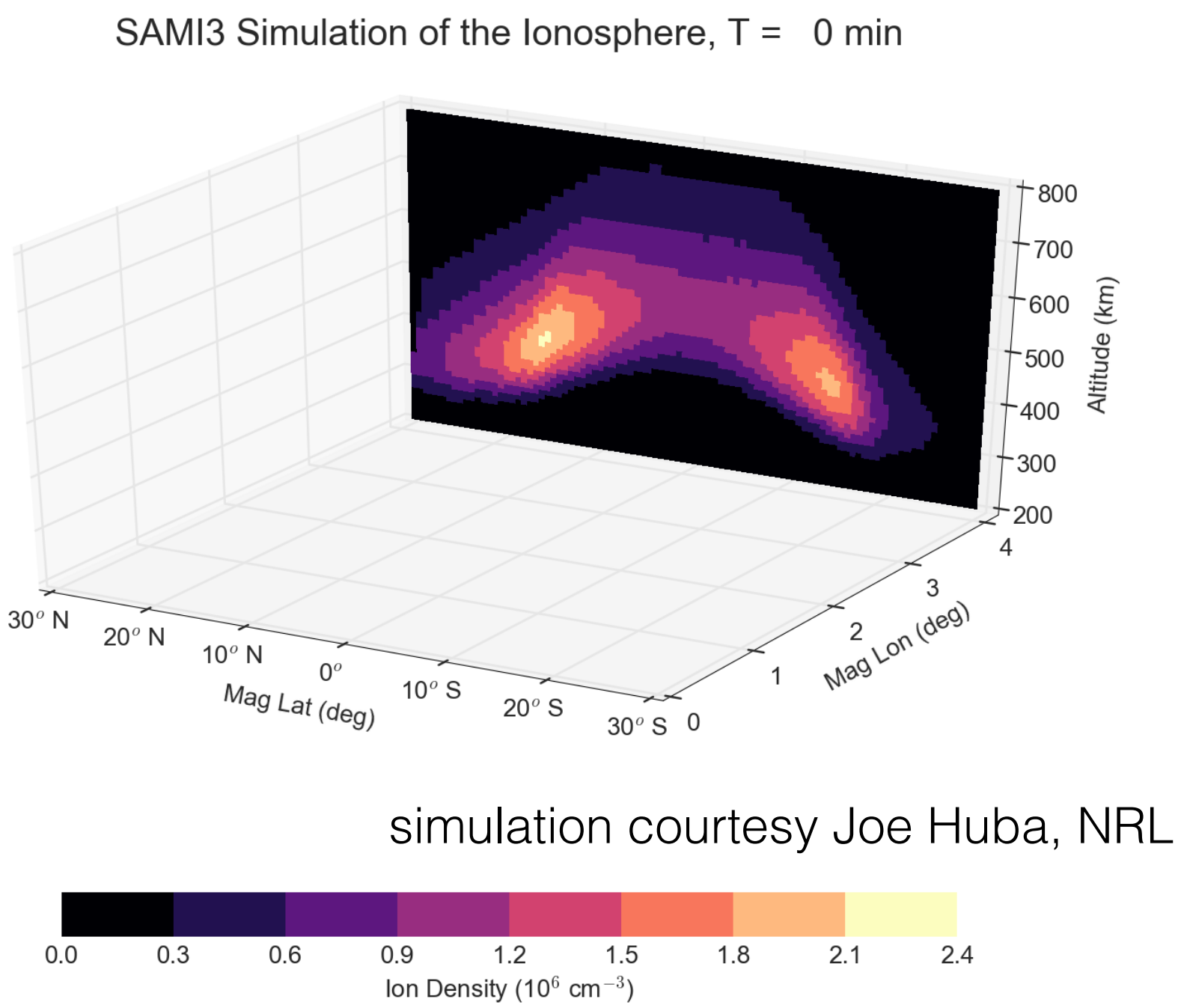
Plasma bubbles disperse electromagnetic waves, affecting radar, GPS, and communications signals.

image from http://www.astrosurf.com/luxorion

What drives the Ionosphere?




Electron Density, SAMI2 Model
22 Sep 2009, SLT = 15 hr, Long. = 205° E
Neutral Pressure Contours
Magnetic Field
V_{ii}
V_{ii}
E x B
⊗E
Altitude, km
1500
1250
1000
750
500
250
0
25
20
15
10
5
0
-5
-10
-15
-20
-25
Geographic Latitude (deg)
10^6
10^5
Log Electron Density cm^{-3}



simulation courtesy Joe Huba, NRL

SAMI3 Simulation of the Ionosphere, T = 0 min

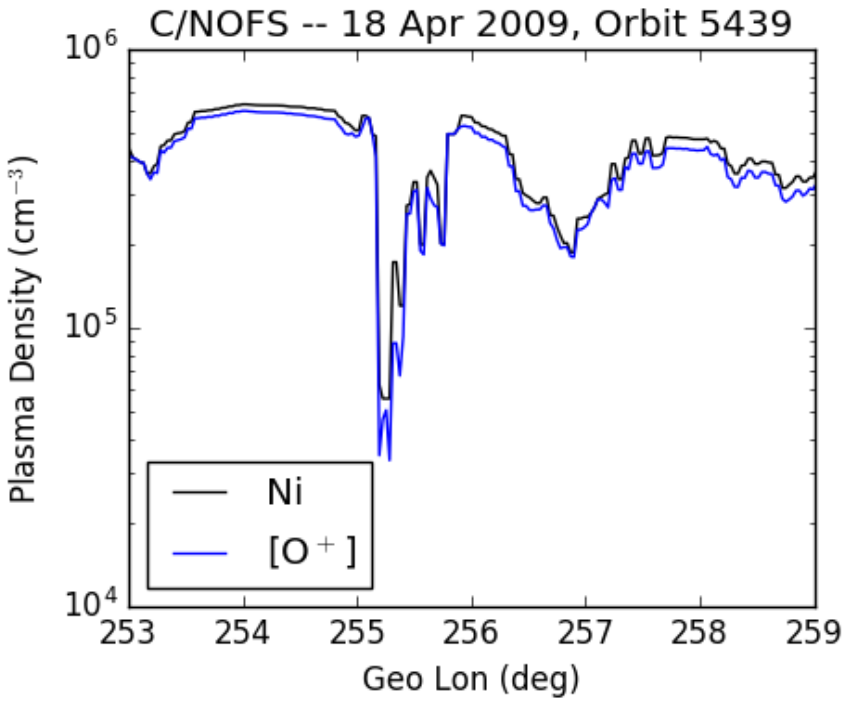
800
700
600
500
400
300
200
Altitude (km)
4
3
2
1
Mag Lon (deg)
0
0° S

courtesy Joe Huba, NRL

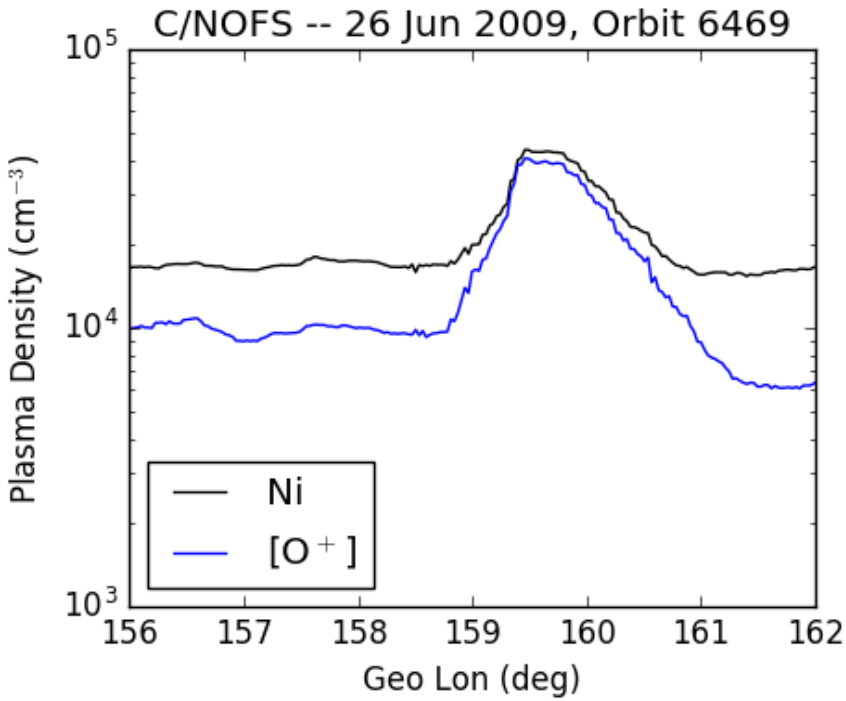
.5 1.8 2.1 2.4

Plasma Structure as viewed by Satellite

Plasma Depletion
"Bubble"

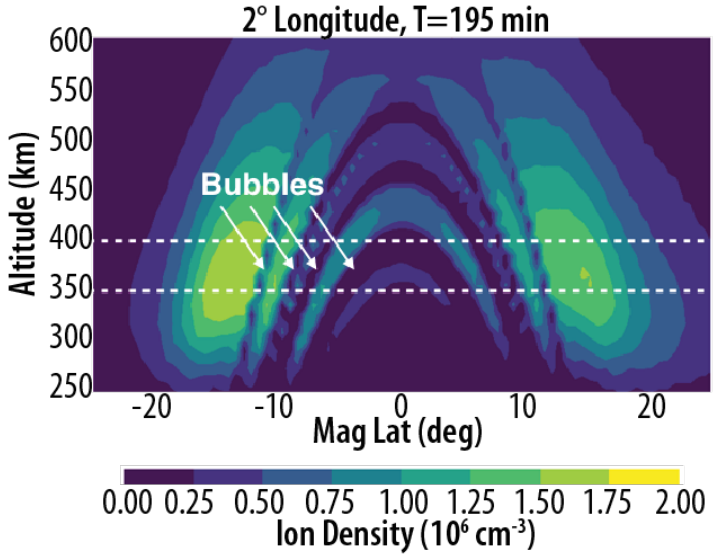


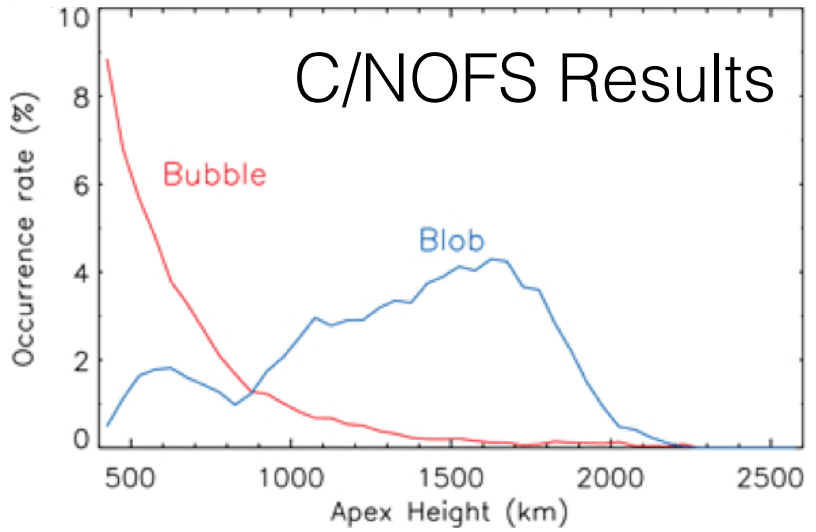
Plasma Enhancement
"Blob"



Are Plasma Enhancements related to Bubbles?

- Previously, many statistical surveys combined all irregularities. Local enhancements in plasma can form on the edge of a bubble due to the electric fields generated by the bubble.

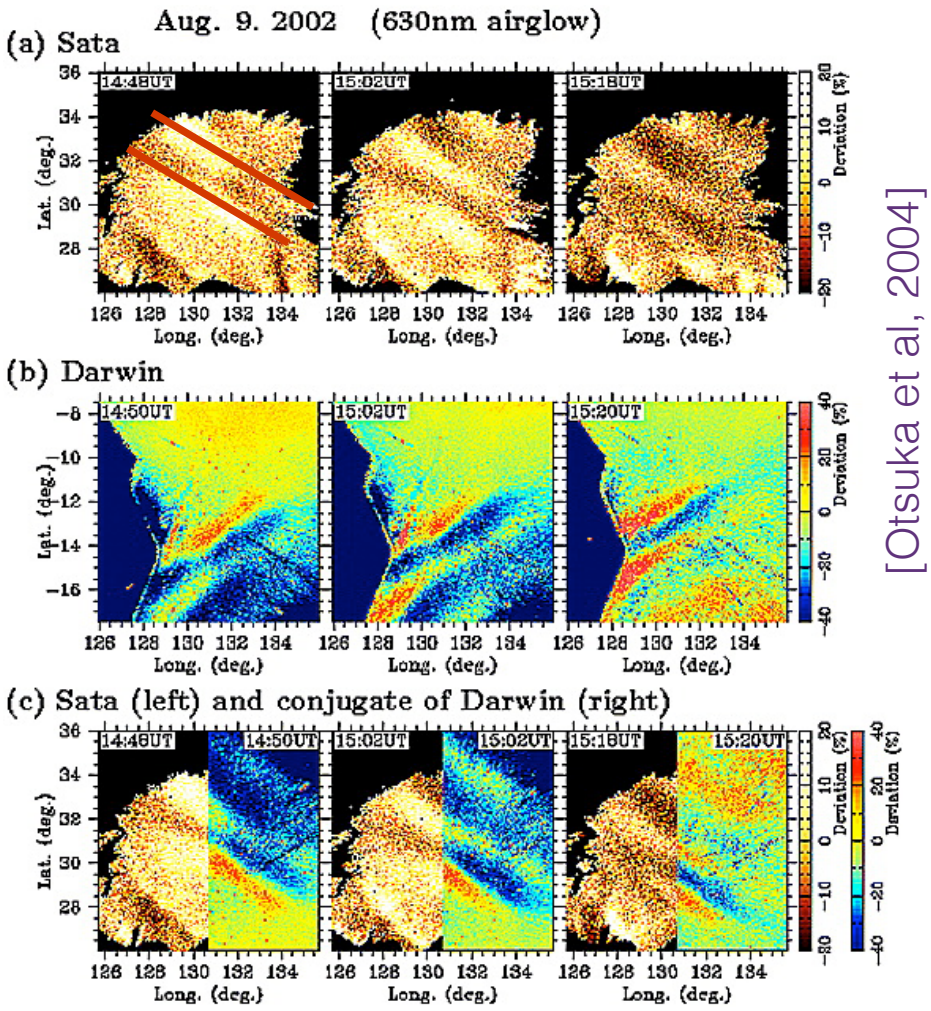




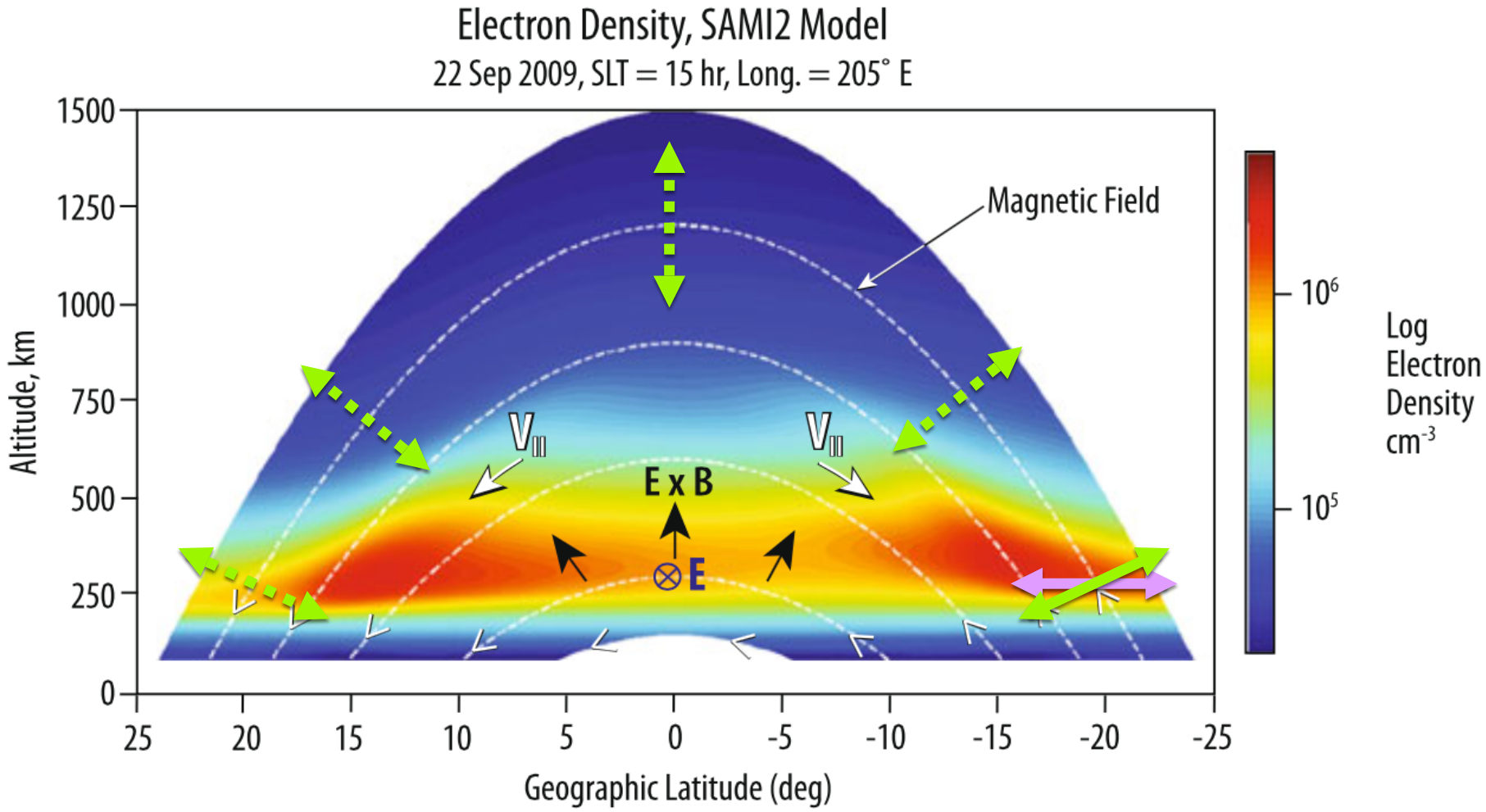
[Choi et al, 2011]

Are Plasma Enhancements formed by MSTIDs?

- Medium-Scale Traveling Ionosphere Disturbances
- Wave-like structures propagating westward and equatorward
- Waves in one hemisphere can map to the other



[Otsuka et al, 2004]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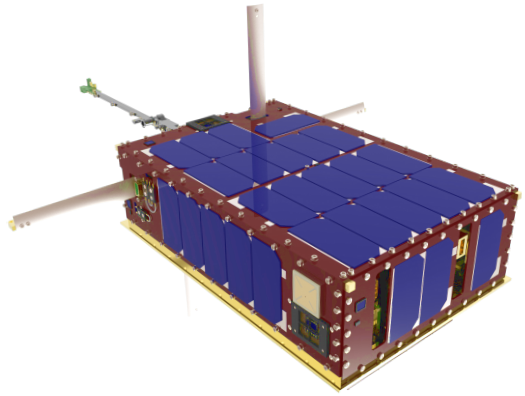
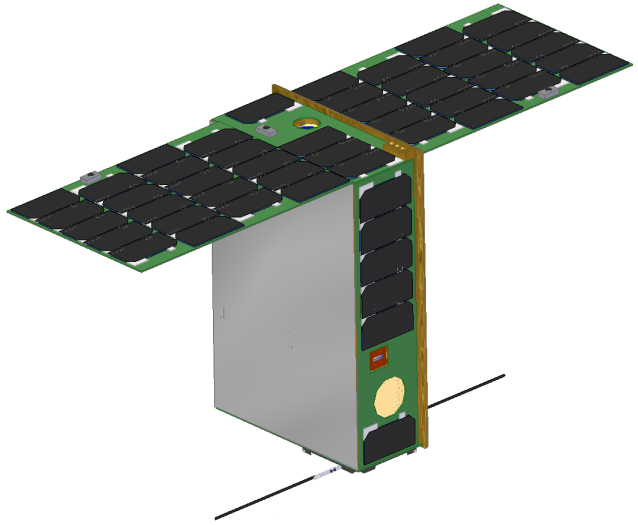
-25
Geographic Latitude (deg)
Magnetic Field
V||
V||
E x B
⊗E
10^6
10^5
Log Electron Density cm^-3

What do we need?

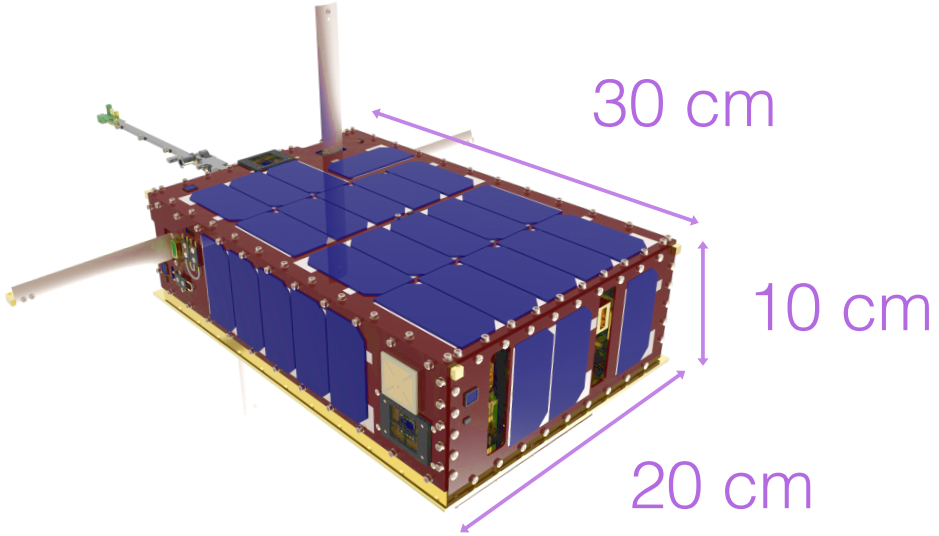


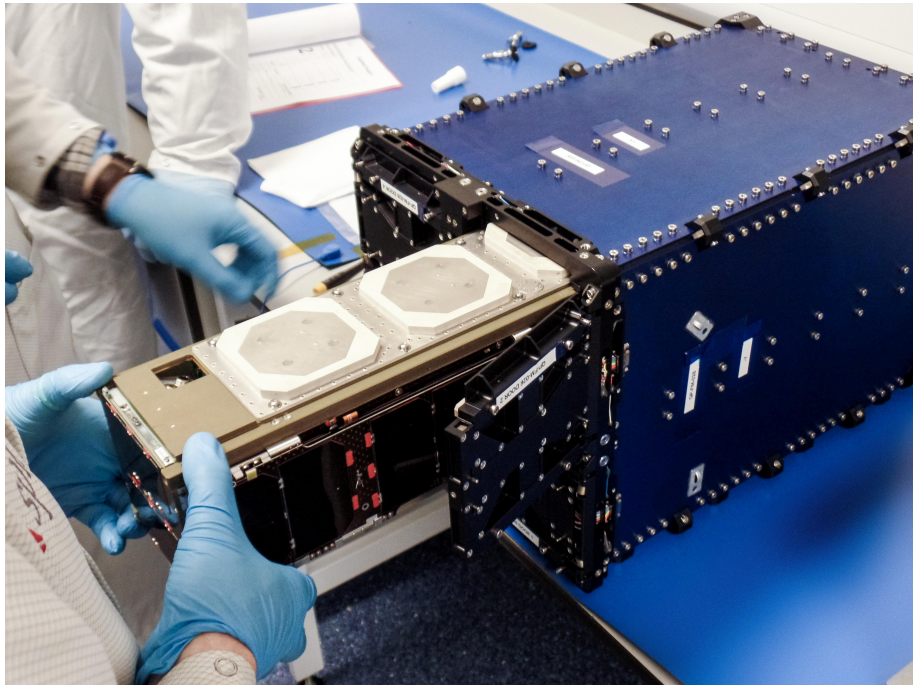


- A satellite in a mid-inclination orbit low enough to observe the F-region ionosphere.
- Ion densities and 3D drifts to identify plasma blobs and the flow structure within.
- Neutral composition to identify local waves in the neutral atmosphere.
- Ground-based imagers to confirm MSTID behavior.

What is a CubeSat?

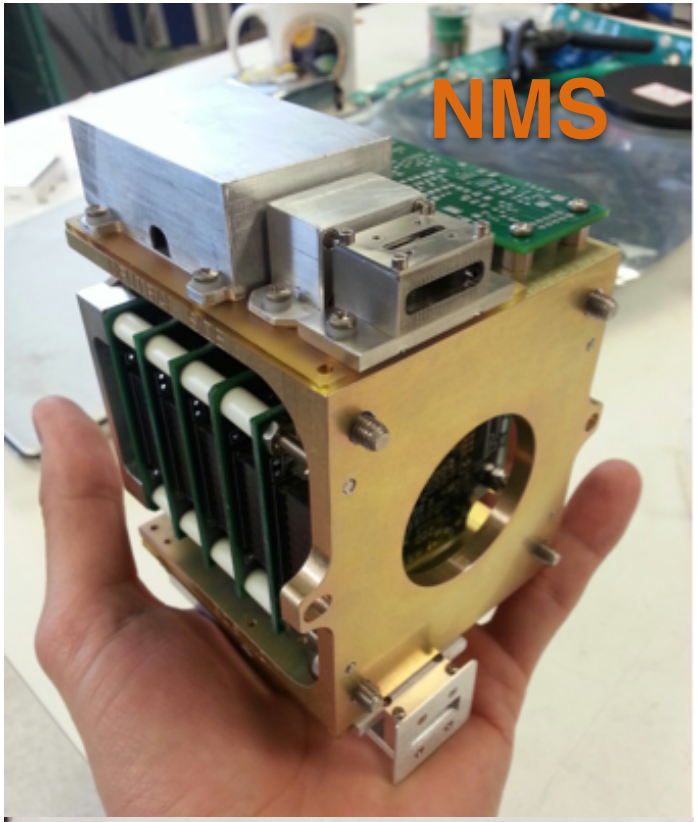
- Small Spacecraft designed to be launched from a canisterized dispenser.
- 1U = 10 cm Cube
- Launch as a secondary payload from International Space Station or commercial satellites.

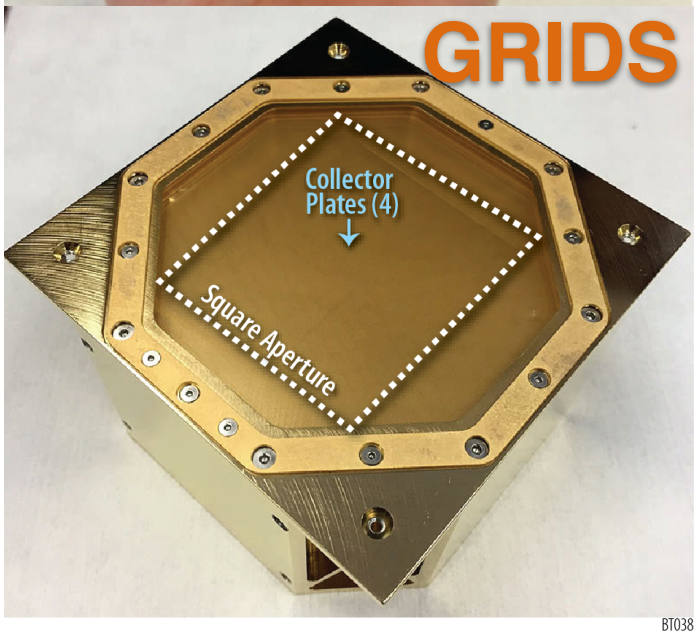




petitSat

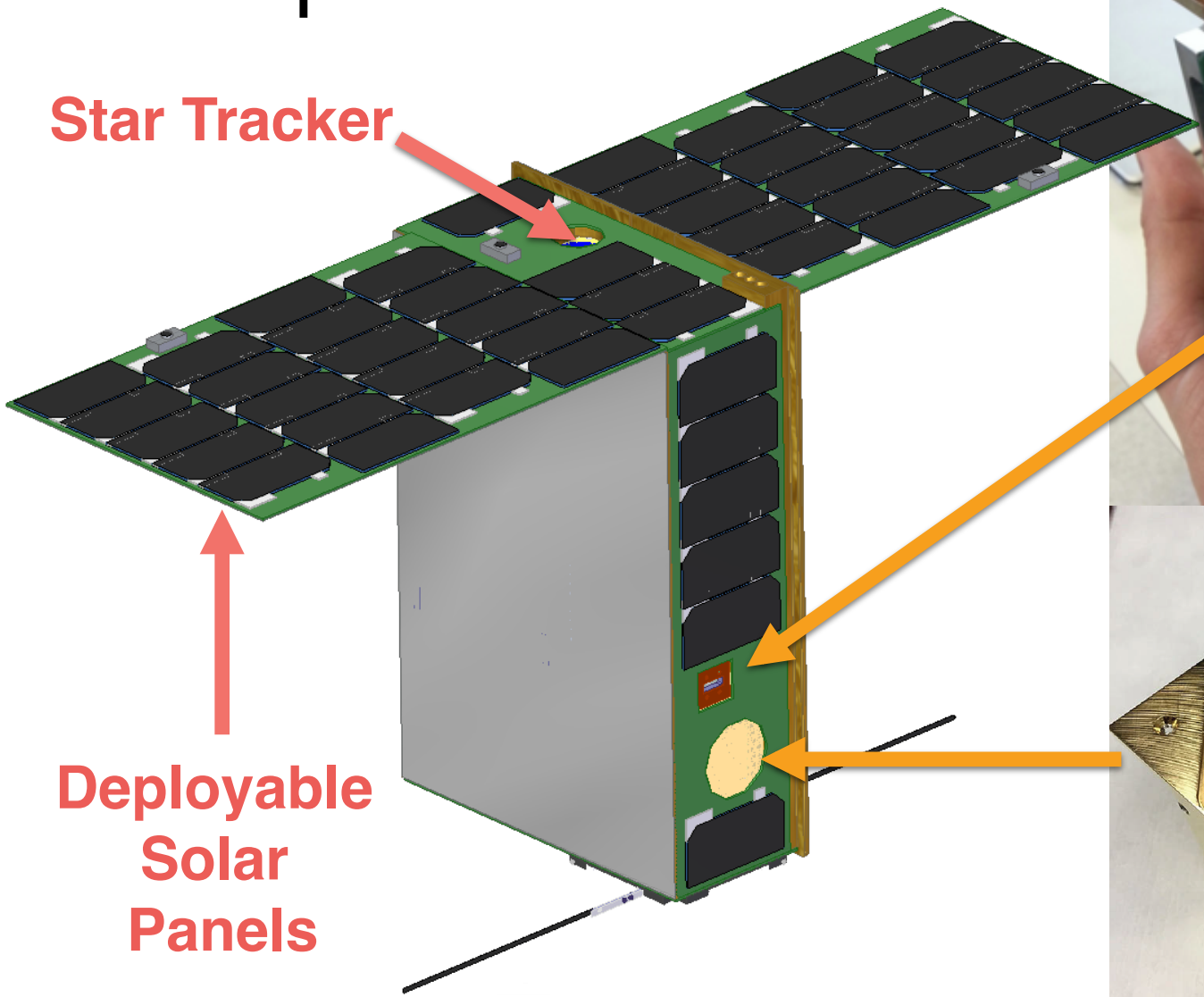
- Plasma Enhancements in The Ionosphere-Thermosphere
- 6U H-TIDeS CubeSat based on Dellingr
- Scheduled for a 2020 launch from the ISS
- Neutral Mass Spectrometer (NMS, GSFC) - identify local neutral waves
- Gridded Retarding Ion Distribution Sensor (GRIDS, USU/VT) - identify plasma enhancements and drift structures

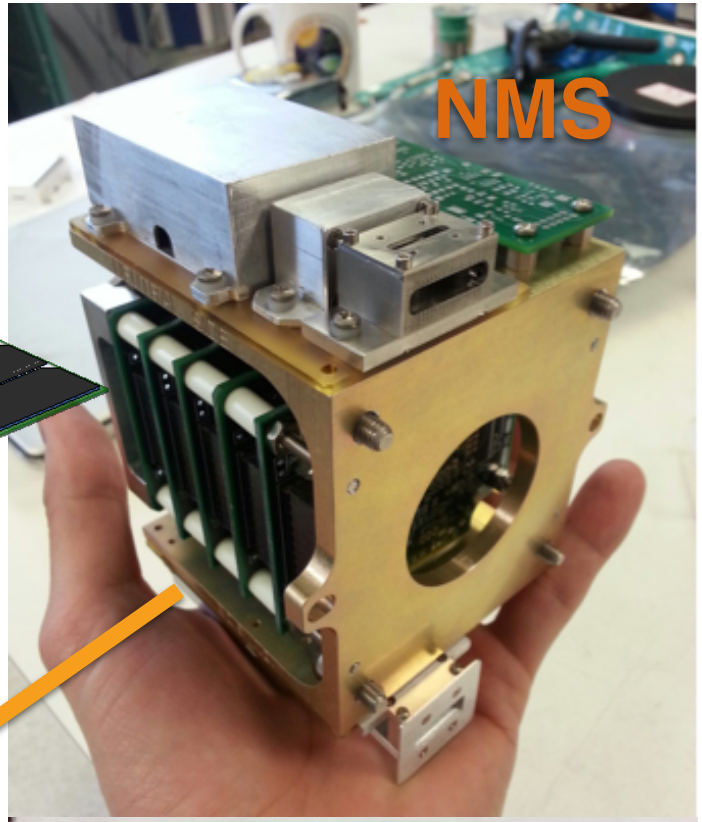


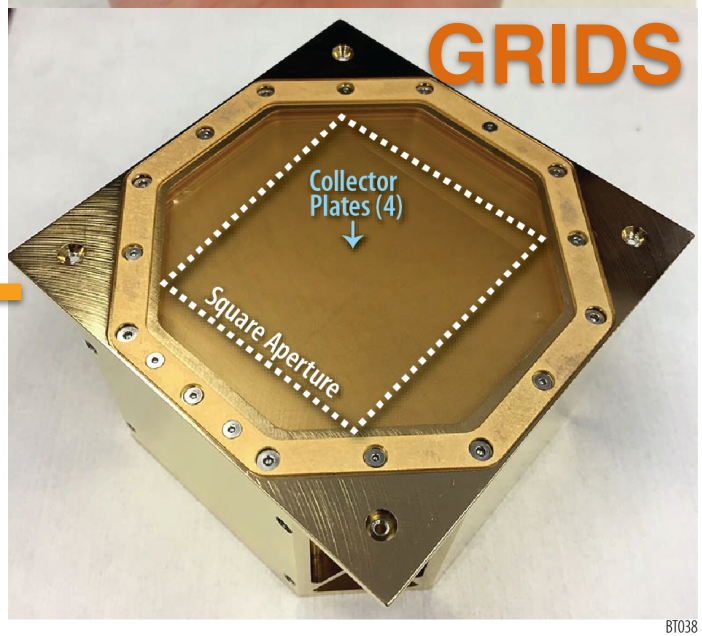


BT038

petitSat



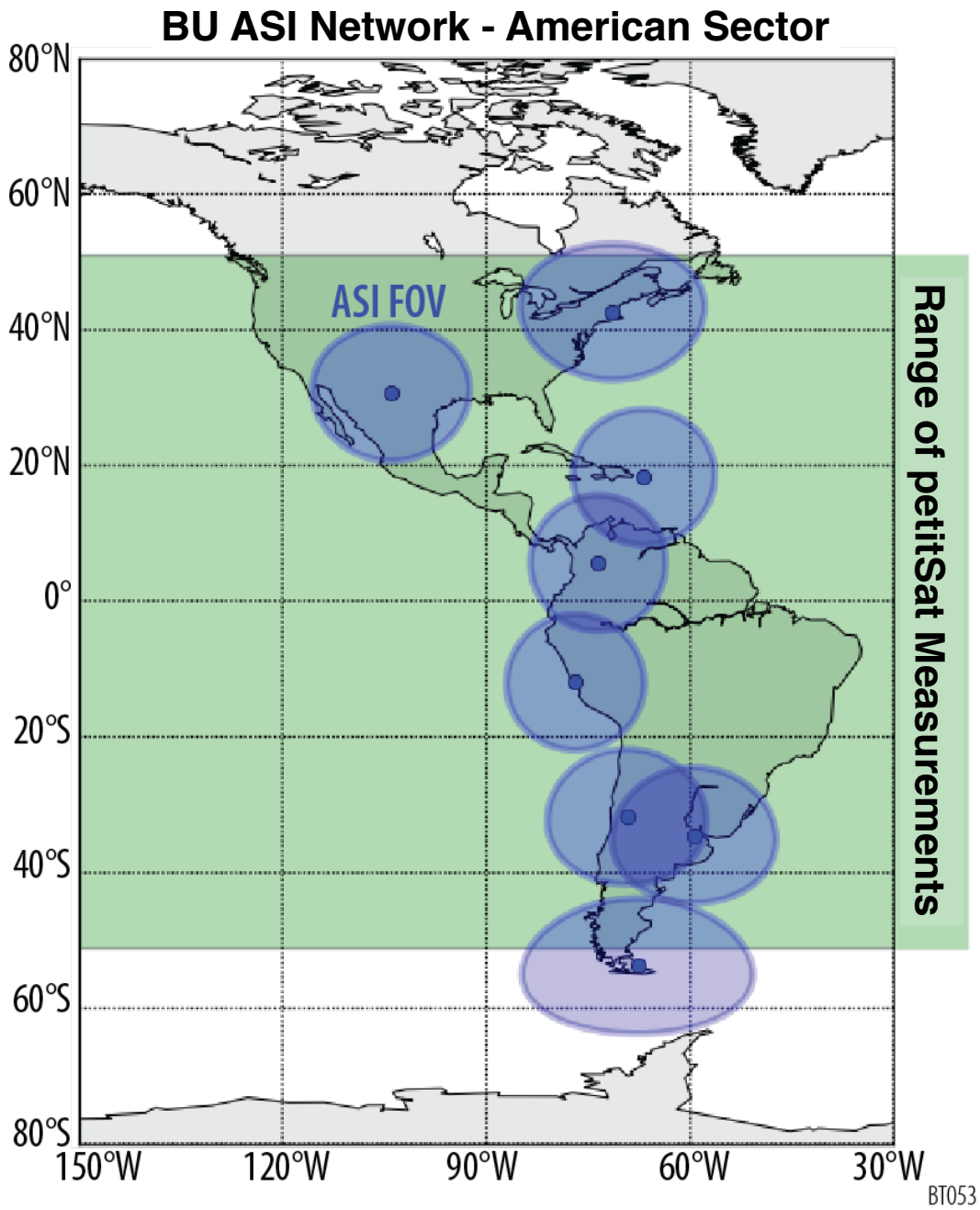




BT038

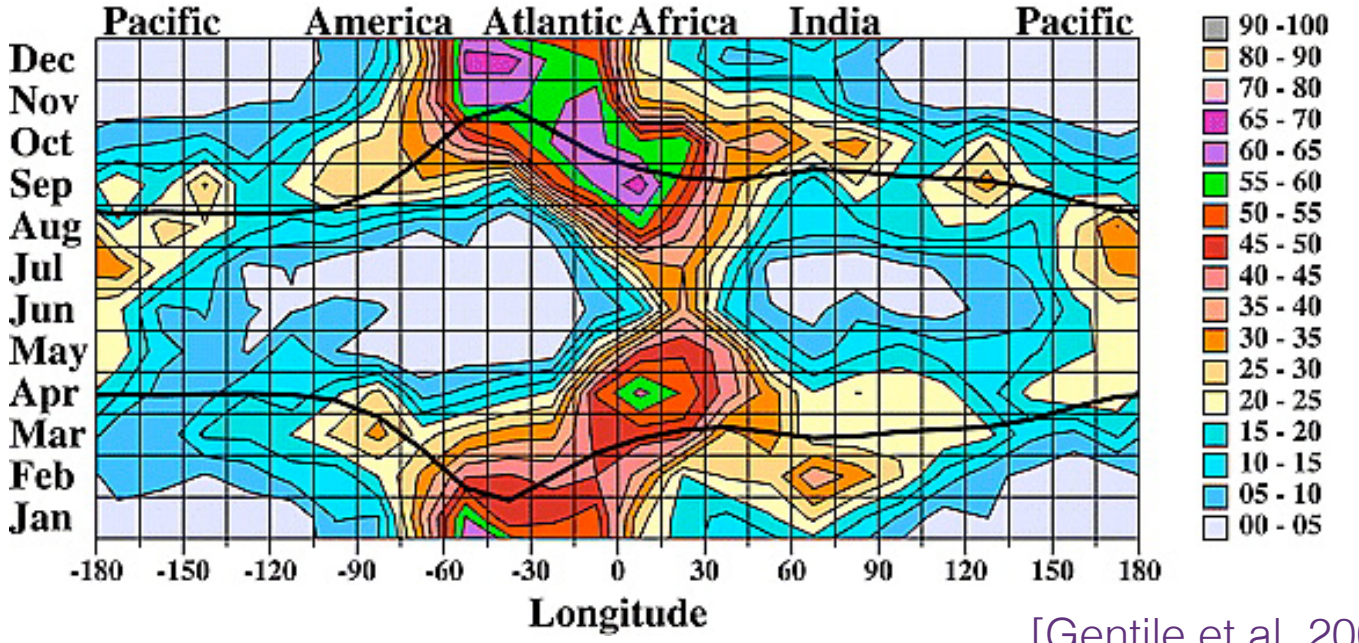
petitSat will provide the first comprehensive study of plasma density enhancements and their causes

Instrument	Identifies
GRIDS	Plasma Enhancements
NMS	Local Neutral Waves
ASI	MSTIDs



The next step: Forecasting

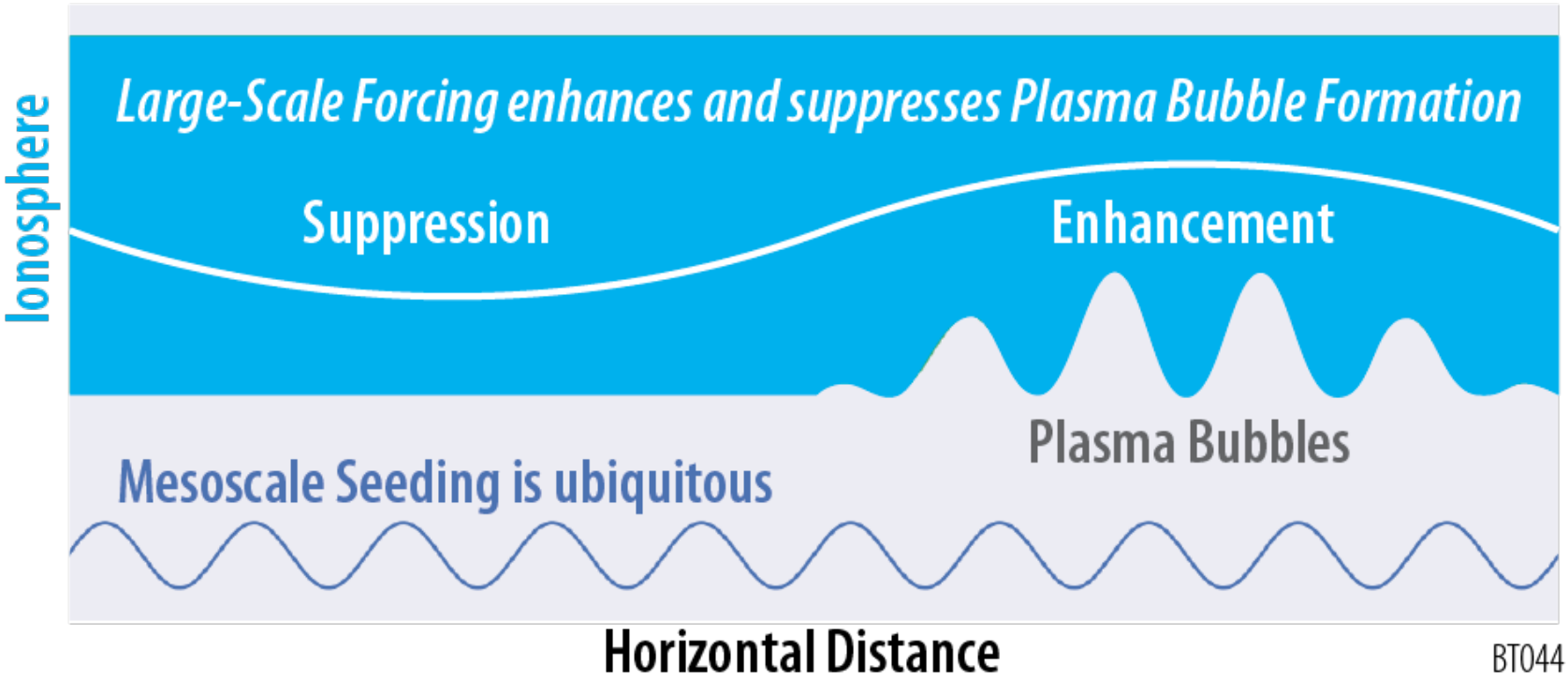
Probability of observing a bubble at 800km



[Gentile et al, 2004]

We can identify the probability of bubbles forming in a season, but not on a given day.

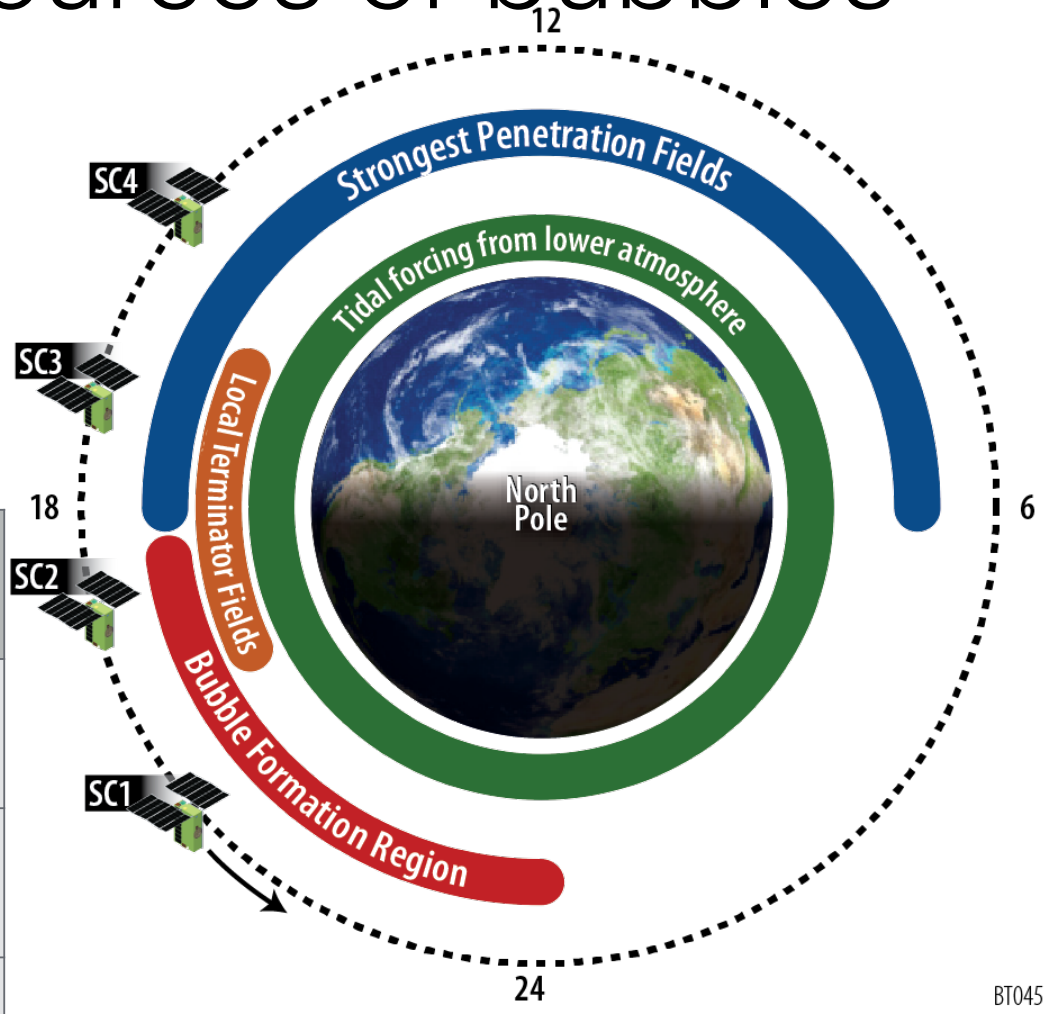
What is the effect of large-scale forcing on bubble formation?

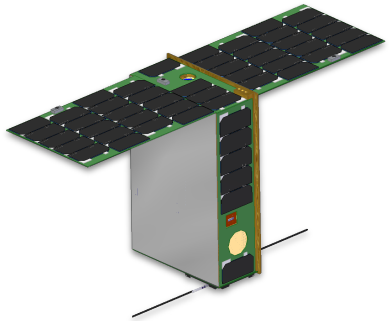


Use a CubeSat Constellation to Identify the sources of bubbles

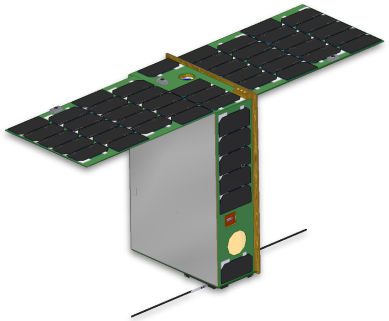
Four spacecraft flown as "pearls on a string" untangle the spatial and temporal variations in the ionosphere.

Organized by	Caused by
Longitude	non-migrating Tides
Local Time	Local Terminator Fields
UT	High-lat forcing





Summary



- Plasma bubbles in the ionosphere disrupt critical radio signals, including radar, GPS and communication signals.
- To aid forecasting, CubeSats can aid by providing new research:
  - petitSat - bubbles need to be isolated from plasma irregularities from other sources.
  - CubeSat constellation - separate spatial and temporal variations to understand how external forcing can enhance and suppress bubble growth.