The Ionospheric Connection Explorer

Elsayed Talaat, ICON Program Scientist

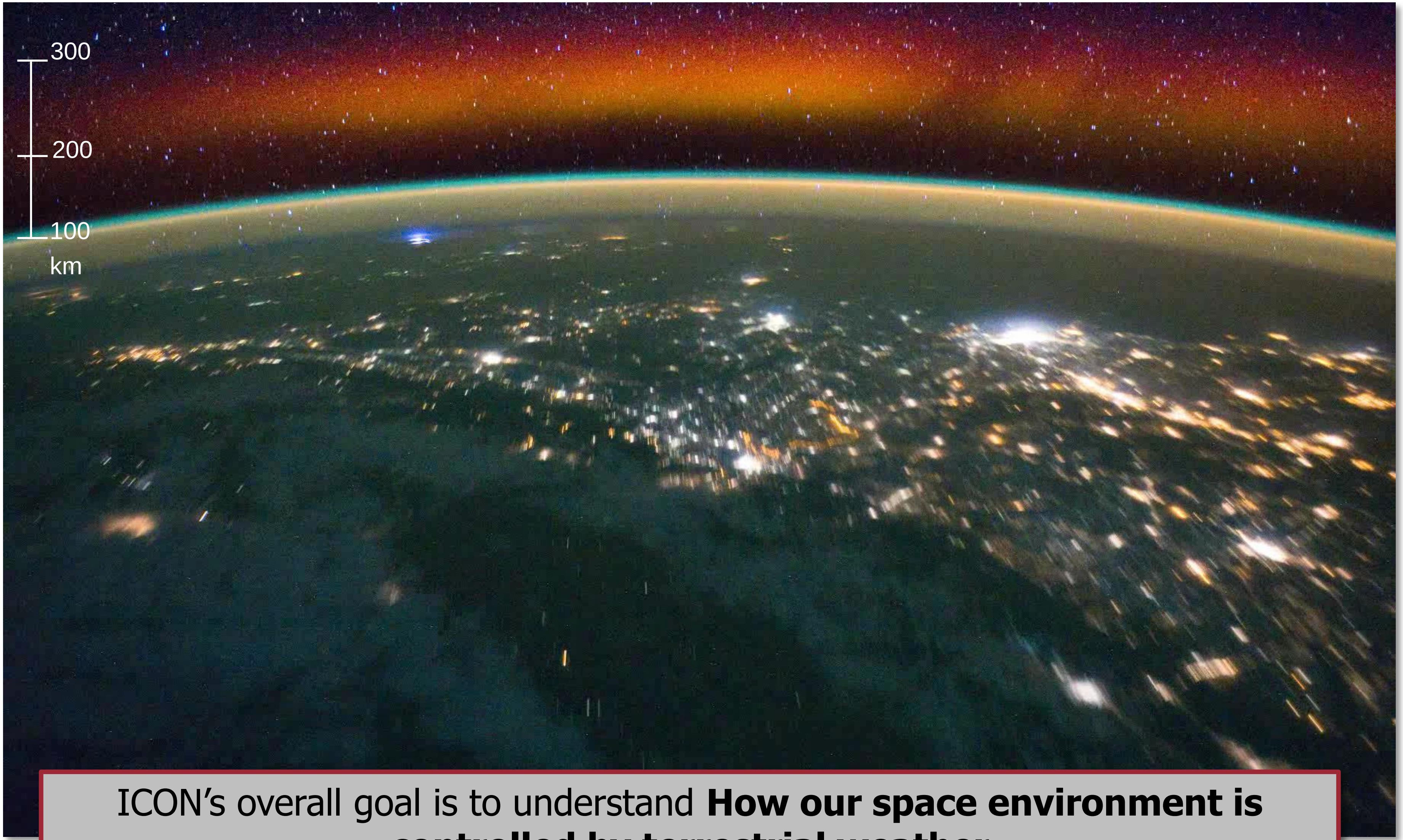
NASA HQ

Thomas Immel, Principal Investigator

University of California, Berkeley

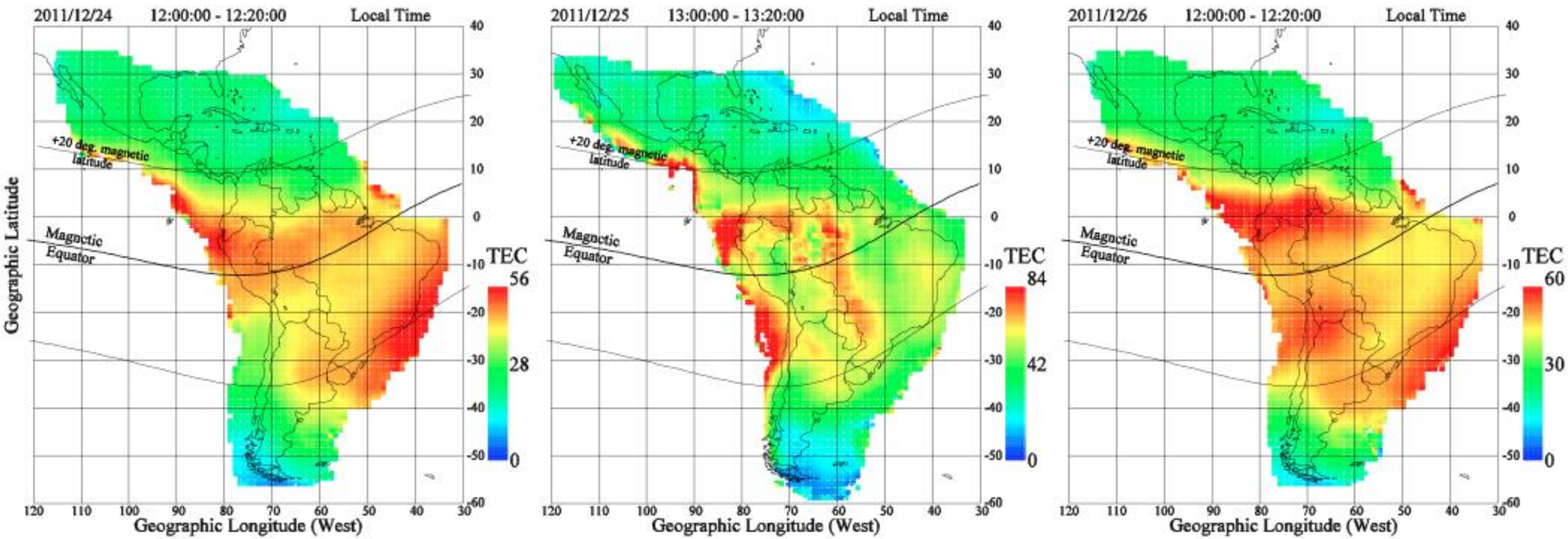
Stephen B. Mende; Roderick A. Heelis; Christoph R. Englert; Jerry Edelstein; Jeffrey M. Forbes; Scott England; Astrid I. Maute; Jonathan J. Makela; Farzad Kamalabadi; Geoffrey Crowley; Andrew W. Stephan; Joseph D. Huba; John Harlander; Gary R. Swenson; Harald U. Frey; Gary S. Bust; Jean-Claude M. Gerard; Benoit A. Hubert; Douglas E. Rowland; David L. Hysell; Akinori Saito; Sabine Frey; Manfred Bester; Cesar E. Valladares

The Ionospheric Connection Explorer – Understanding the link between our Atmosphere and Space



ICON's overall goal is to understand **How our space environment is controlled by terrestrial weather**

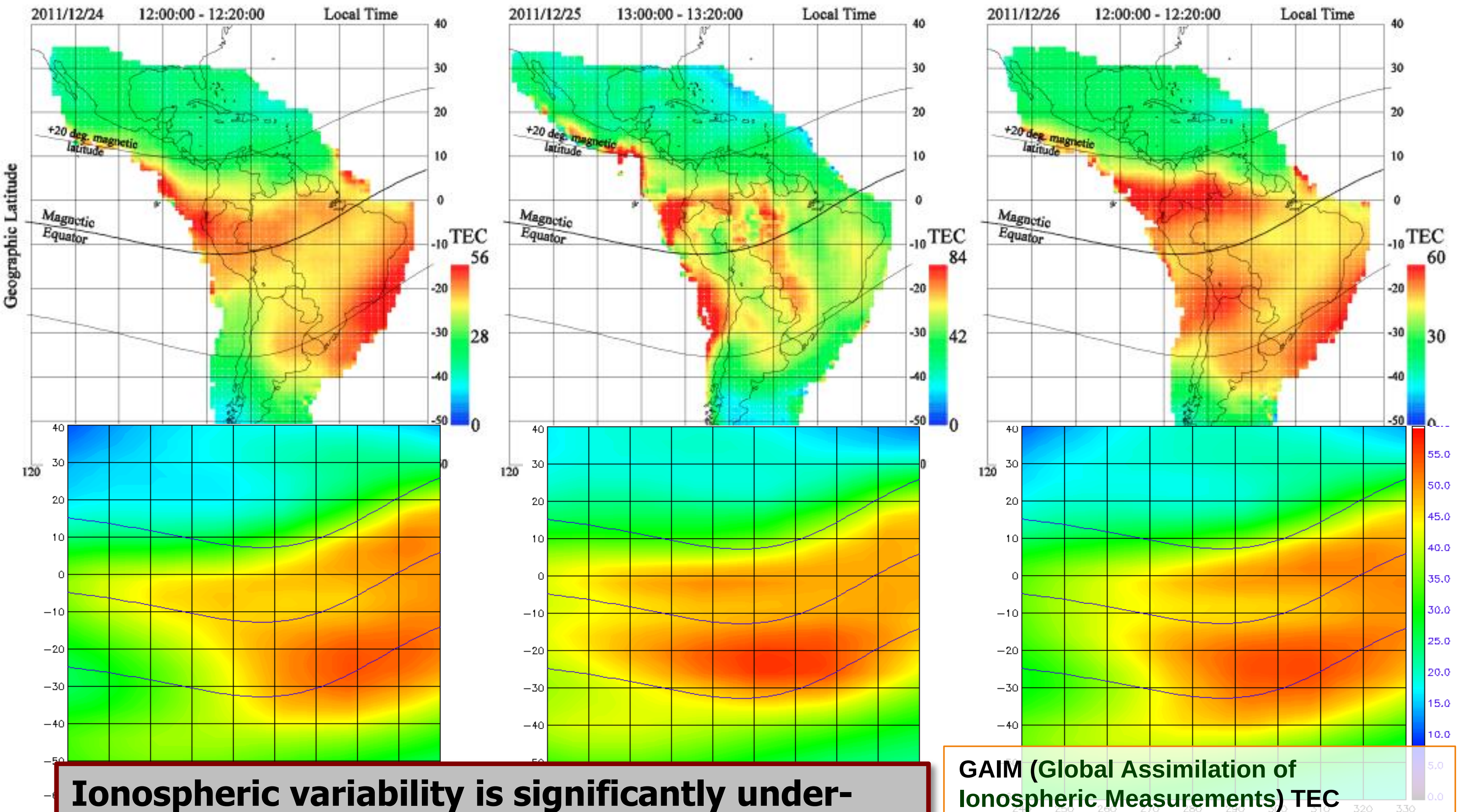
Current knowledge cannot account for what is observed in Near-Earth space



- LISN Network TEC – PI Cesar Valladares, Boston College
- Outstanding day-to-day variability in equatorial ionosphere while Dst = 0 nT
- Cause unknown!

We continue to see behavior of the ionosphere that is completely unexpected.

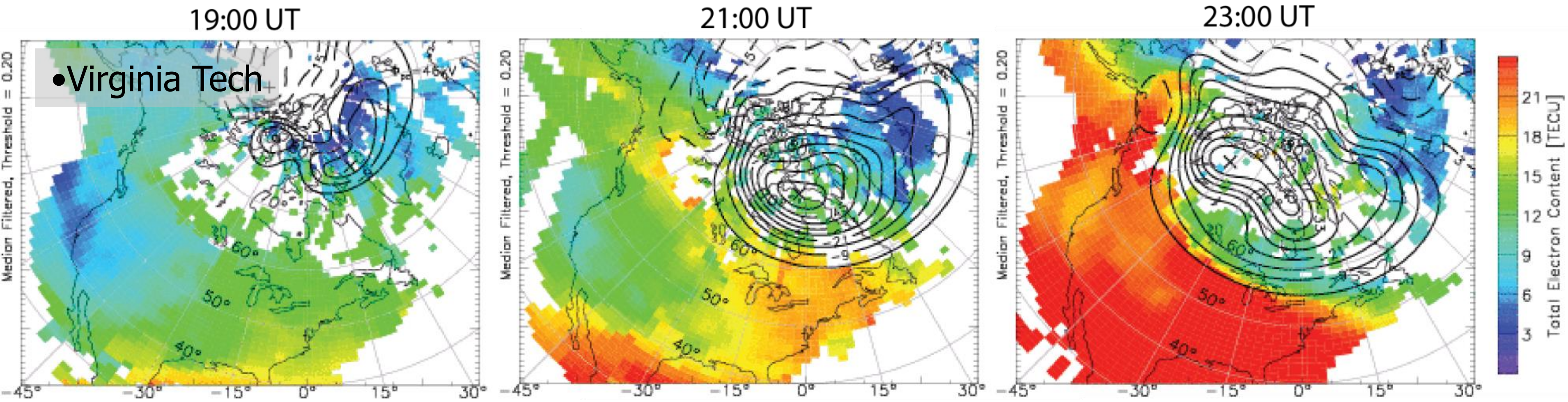
Observations defy predictions



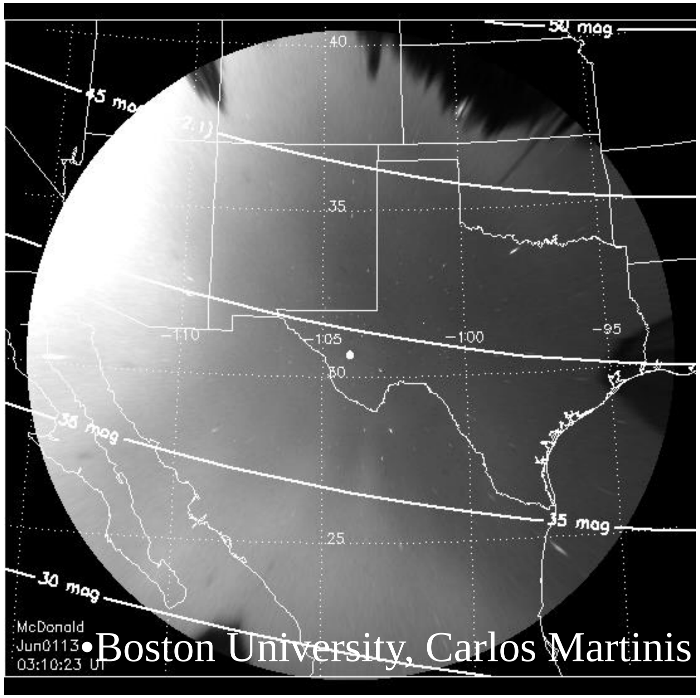
Ionospheric variability is significantly under-estimated by widely used operational models.

GAIM (Global Assimilation of Ionospheric Measurements) TEC nowcast (courtesy of Clayton Coker, NRL)

Geomagnetic Storms also induce strong variability at middle latitudes



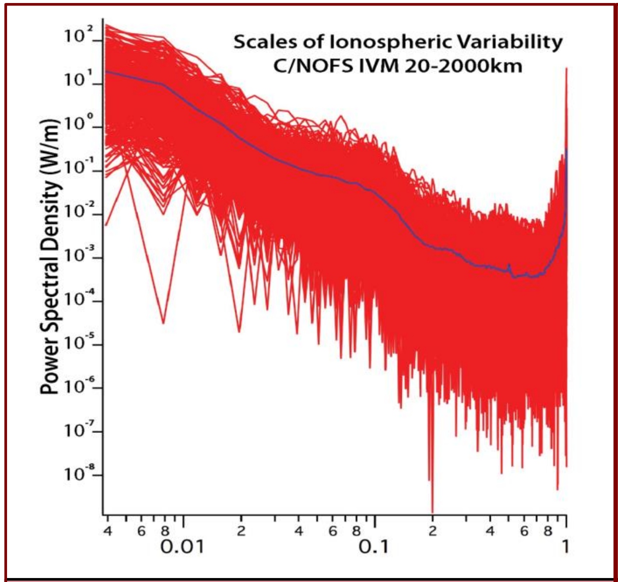
- ❑ Geomagnetic storms draw equatorial plasma to middle latitudes.
- ❑ Nighttime plasma instabilities usually only observed in equatorial region can reach north through CONUS.

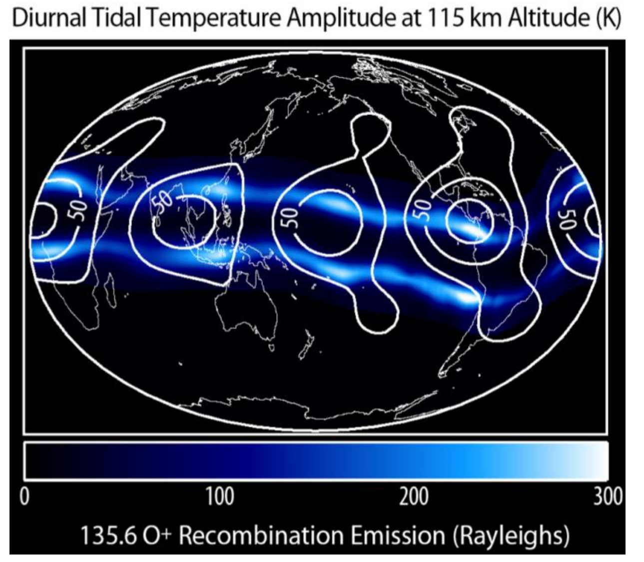


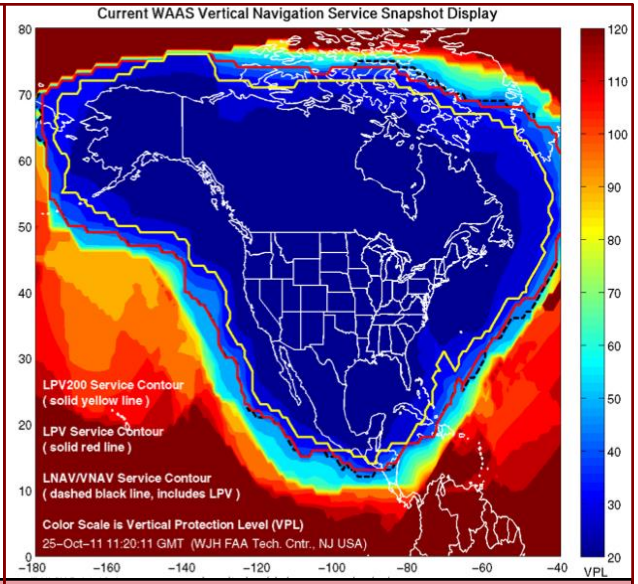
There is new evidence of a link between weather and the equatorial ionosphere that feeds these events.

ICON's Science Objectives drive Temporal and Spatial Measurement Requirements

- ICON addresses the coupling of the atmosphere and ionosphere by examining variability on three key temporal/spatial scales.
- These map directly to ICON's 3 Science Objectives.







Obj. #1: Dynamo Drivers	Obj. #2: Tidal Drivers	Obj. #3: Magnetic Events
Temporal Scale : 1-2 hrs	Temporal Scale : Month-Season	Temporal Scale : 3-48 hrs
Spatial Scale : 500-1500 km	Spatial Scale : 1500-5000 km	Spatial Scale: continent-global

ICON's Science Objectives require measurements of both drivers and responses

The Ionospheric Dynamo, driven by the neutral atmosphere, governs the motion of the plasma:

- We need to measure the **drivers**:

Neutral winds that carry the energy and momentum that drives the dynamo.

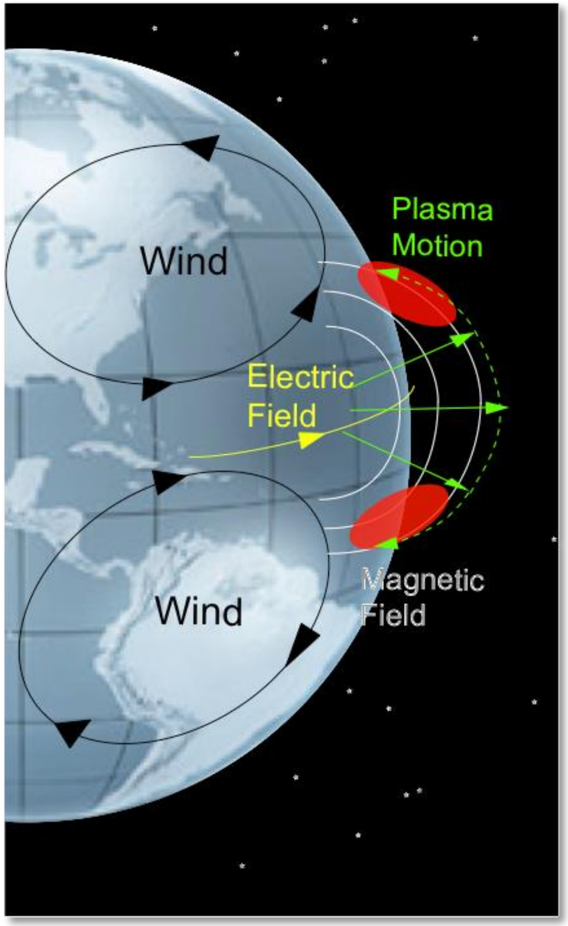
Composition of the atmosphere that controls the chemical production and loss rates of plasma.

Temperature of the atmosphere that reveals the atmospheric waves entering space from below.

- along with the **responses**:

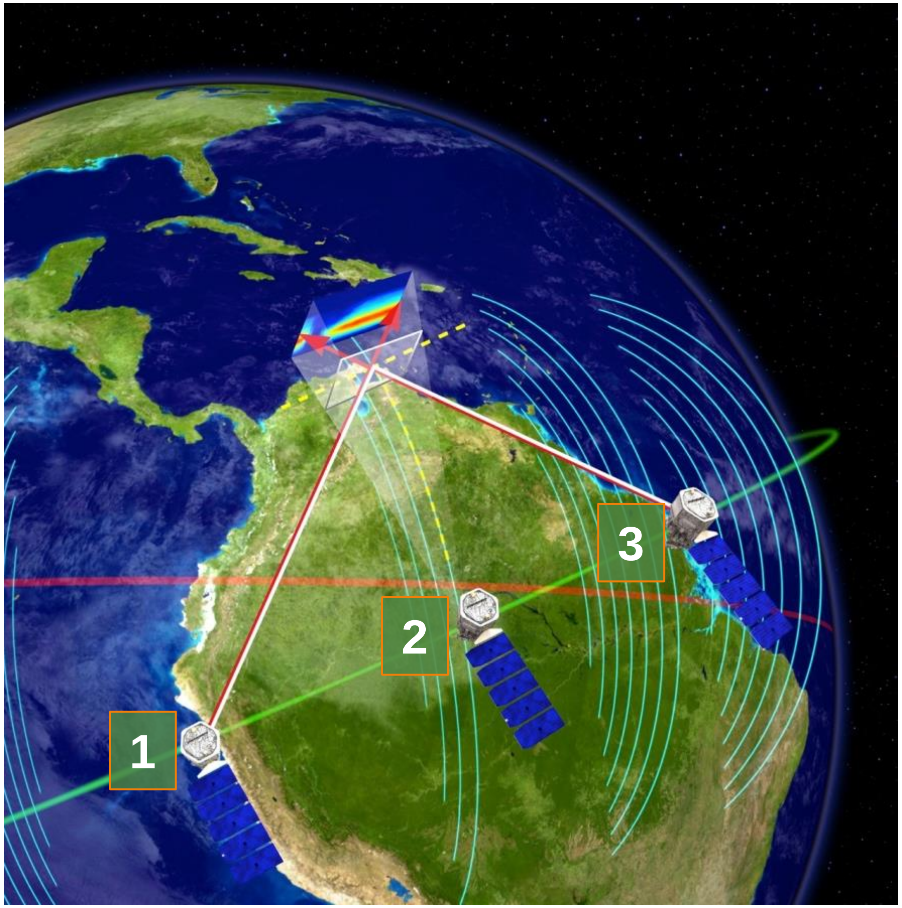
Electric fields and **plasma motion**, both the result of the wind dynamo forcing.

Plasma density of the ionosphere, the combined result of solar production and plasma motion.



To understand the ionospheric dynamo, the drivers and response must be measured **at all relevant altitudes and at the same time.**

ICON coordinates these key science measurements in a new way



Pos. 1 and 3 MIGHTI wind, temperature

Pos. 2 EUV/FUV ion,neutral density and composition. IVM – ion drift on field line

- ICON measures the **drivers**:

  Neutral winds, temperatures and **composition** in the thermosphere

- ICON measures the **responses**:

  Electric field, plasma motion and **plasma density**

ICON makes measurements remotely in the critical boundary region between the atmosphere and ionosphere (90-160 km)

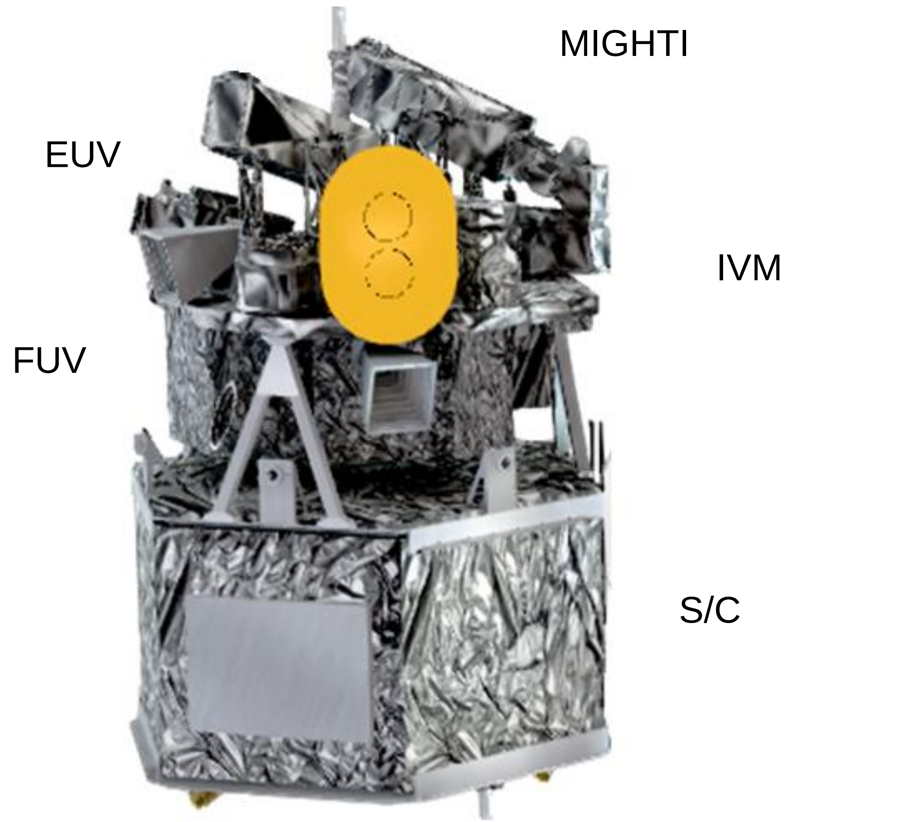
– un-reachable by in-situ spacecraft,

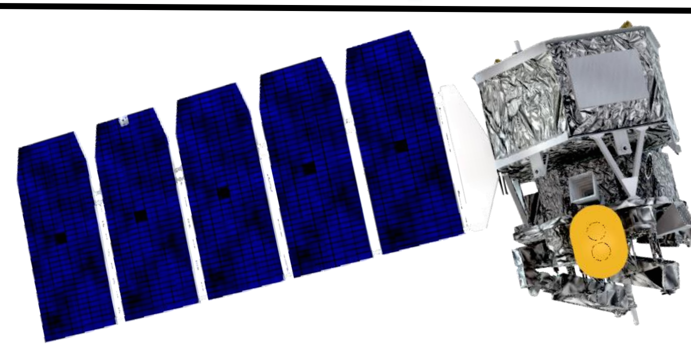
– measuring all of the key quantities,

– at the same place and the same time.

Mission implementation

Mission Summary	
Program	Explorer Office (GSFC)
Launch vehicle	Pegasus XL RTS - Kwajalein
Spacecraft	LEOStar-2, 3-axis stabilized, no consumables
PDR/CDR	July 2014/April 2015
Launch	June 2017
Orbit	575 km circular, 27° inclination
Ground segment	Berkeley Ground Station, WGS, Santiago
Mission & Science Ops	24 months Phase E Operated from UCB

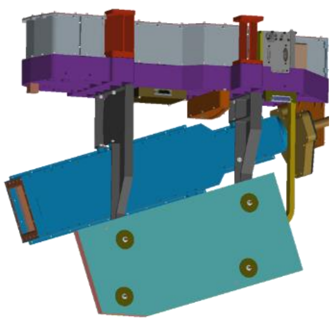


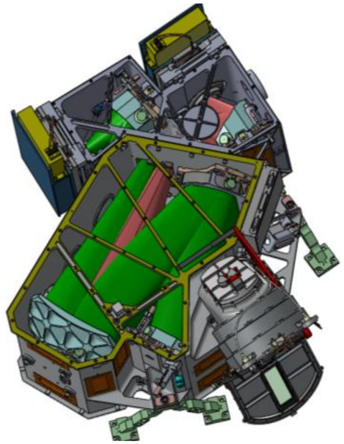


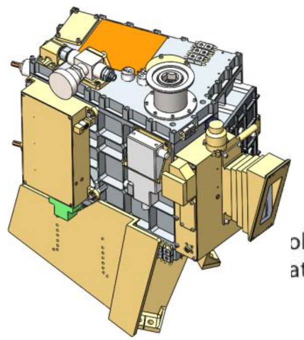
ICON optical remote sensing measurements need inversions

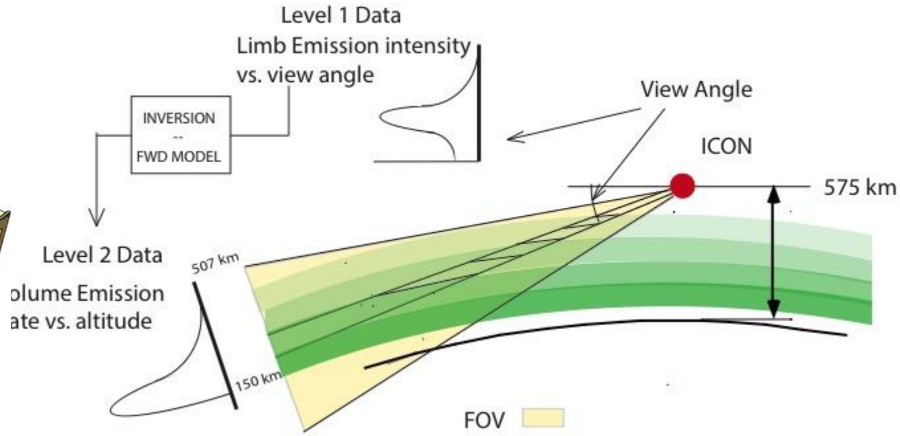
Remote sensing requires inversion (forward model) or re-mapping the remotely sensed data.

MIGHTI, FUV and EUV use optical remote sensing:



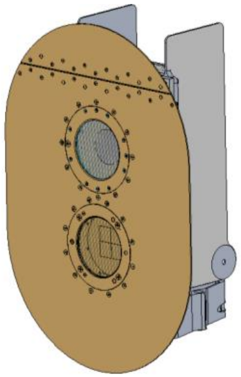


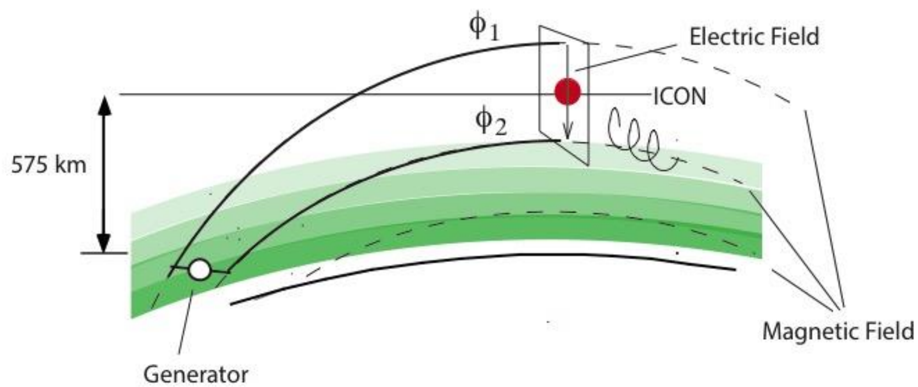




Largest contribution - from limb tangent, removal of upper regions is needed.

E-field is mapped down to the key region from IVM data by using the equipotential property of magnetic field lines >150km.

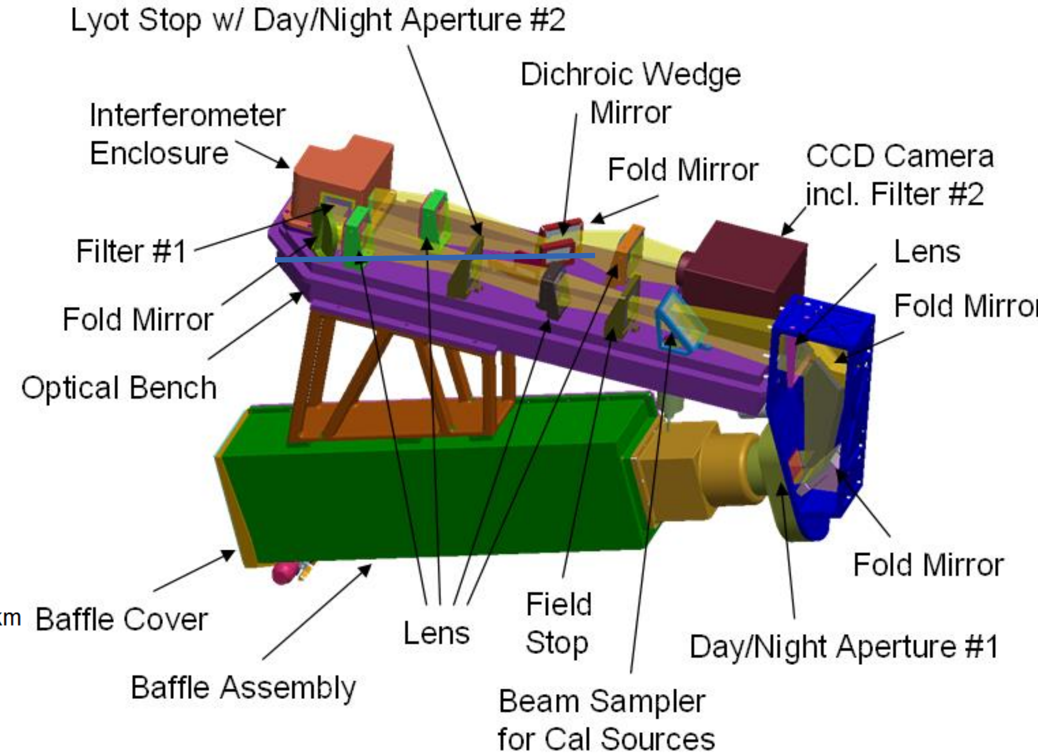


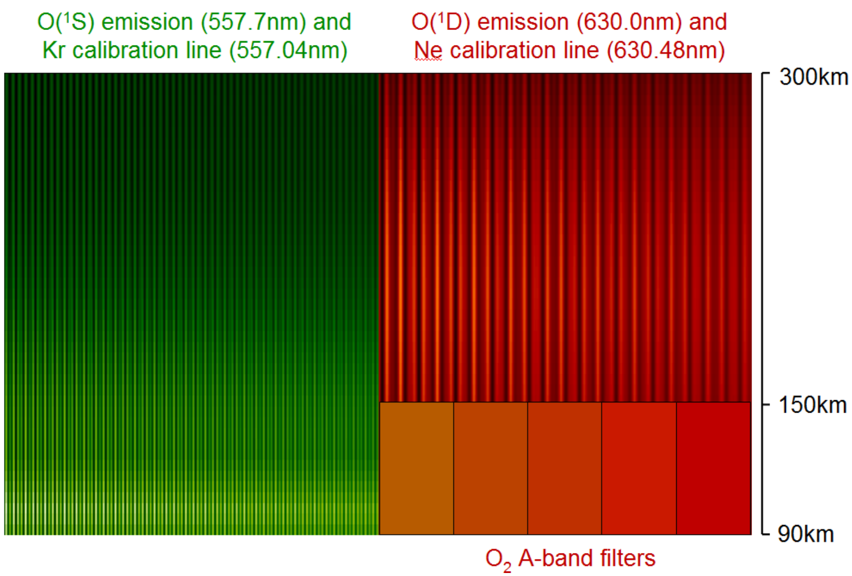


Instrument #1: Michelson Interferometer for Global Heterodyne Thermospheric Imaging – MIGHTI

PI : Chris Englert – Naval Research Lab

- **Provides Neutral Winds in the 100-300 km range, and Neutral temperatures in the 100-120 km range.**
- **Measures Doppler shift of atomic 557.7 and 630.0 nm lines, and rotational temp of O_2 at 762.0 nm.**



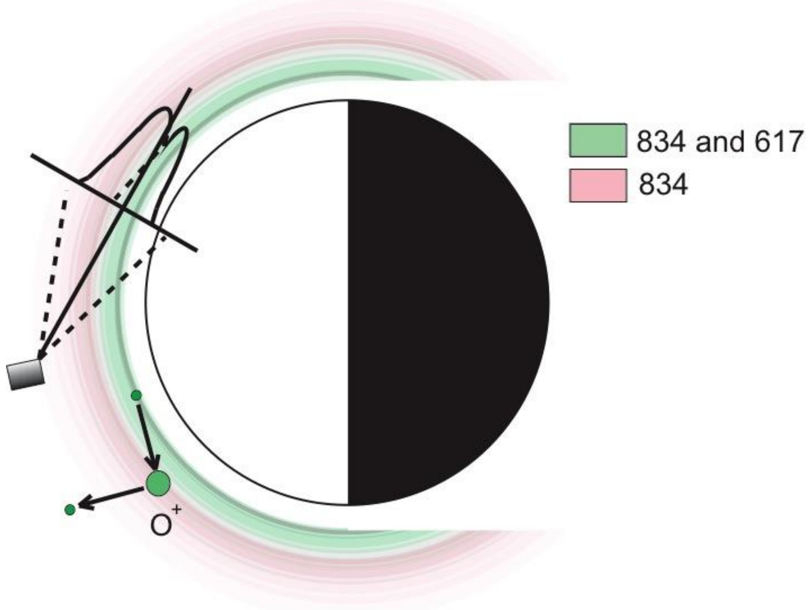


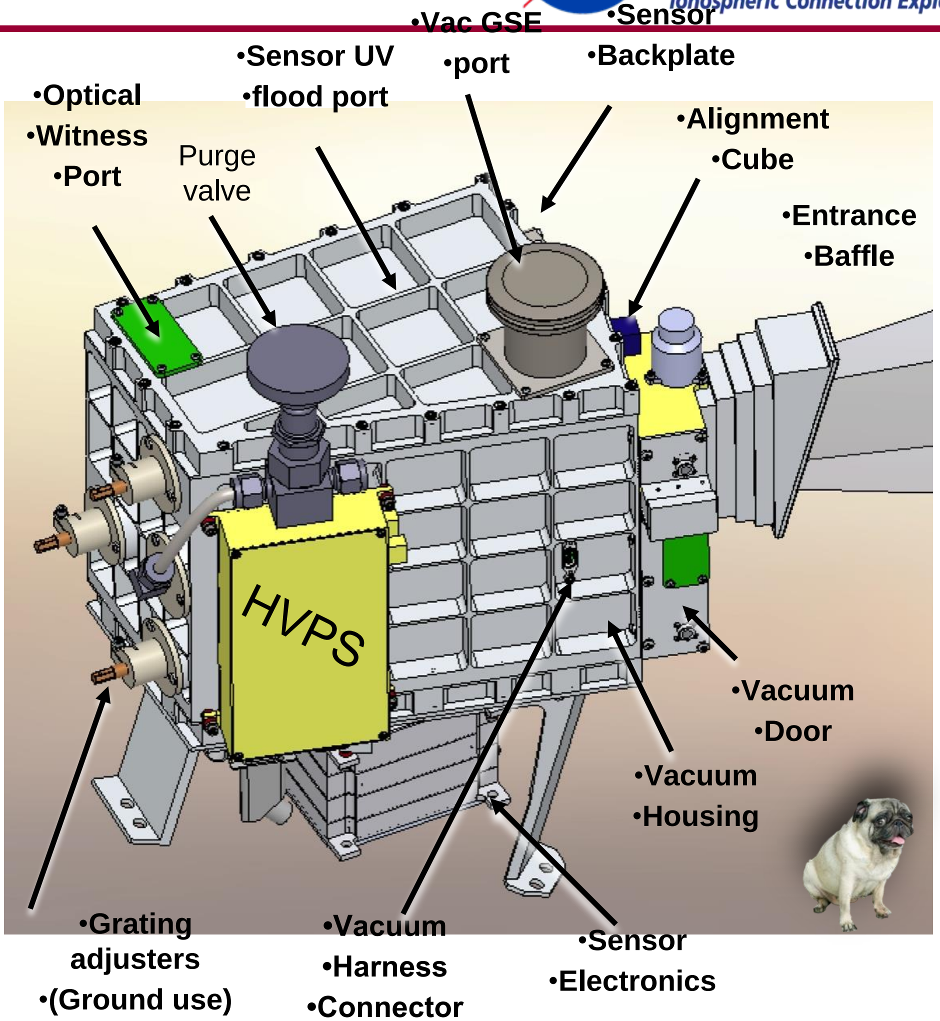
Instrument #2: ICON EUV Spectrographic Imager

PI : Jerry Edelstein - Berkeley

- **Provides NmF2 and HmF2 with each daytime observation (12 seconds)**
- **Measures the altitude intensity profile and spatial distribution of ionospheric <u>O+ emissions @ 83.4 nm</u> and <u>61.7 nm.</u>**

EUV: Daytime hmF2 and NmF2





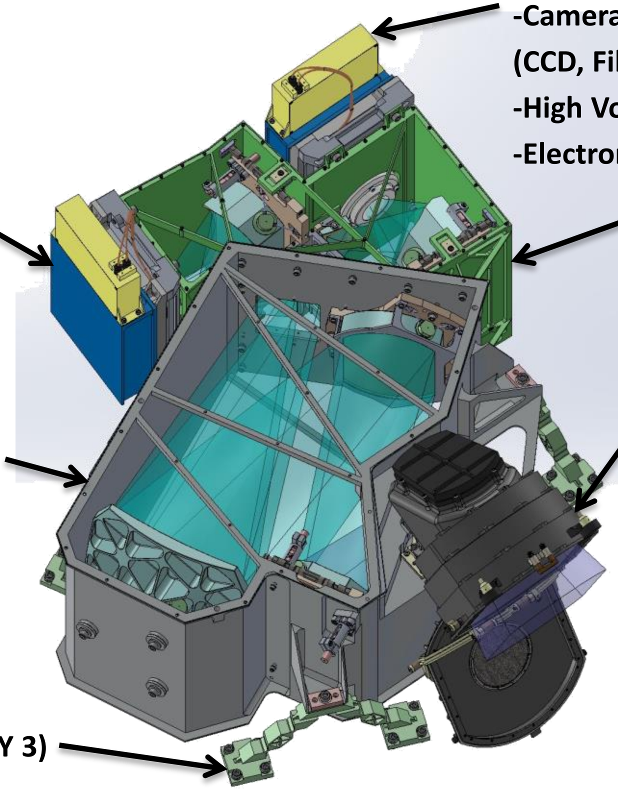
EUV design based on EURD / SPEAR

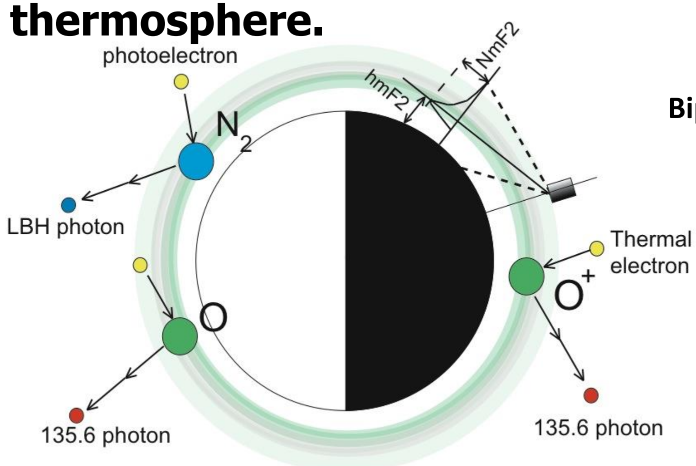
- Single optic grating spectrometer
- Micro-channel plate detector

Instrument #3: ICON FUV Spectrographic Imager

PI: Stephen Mende – Berkeley

- **Provides nighttime NmF2 and HmF2 with continuous 12 second readout.**
- **Provides daytime thermospheric composition (O and N2).**
- **Imaging mode at nighttime for resolution of plasma structure.**
- **Measures the altitude intensity profile of atomic oxygen (<u>OI @ 135.6 nm)</u> and molecular nitrogen (<u>N2 LBH ~150 nm</u>) emissions on the limb in the thermosphere.**





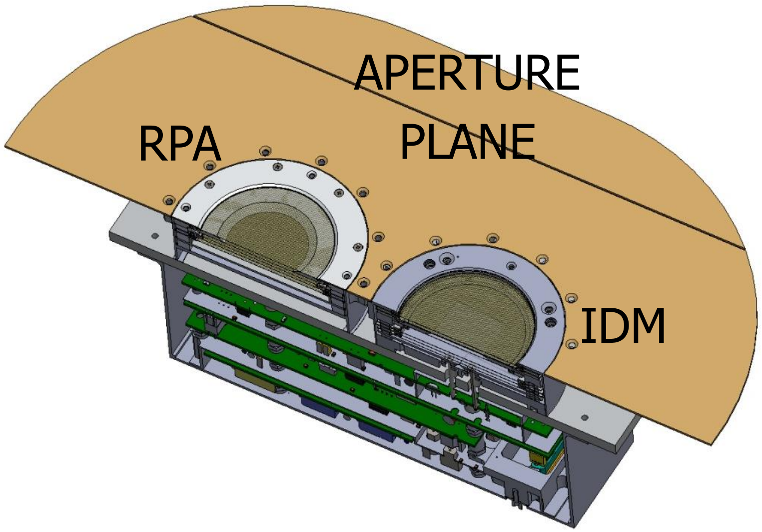
FUV design based upon IMAGE FUV with,

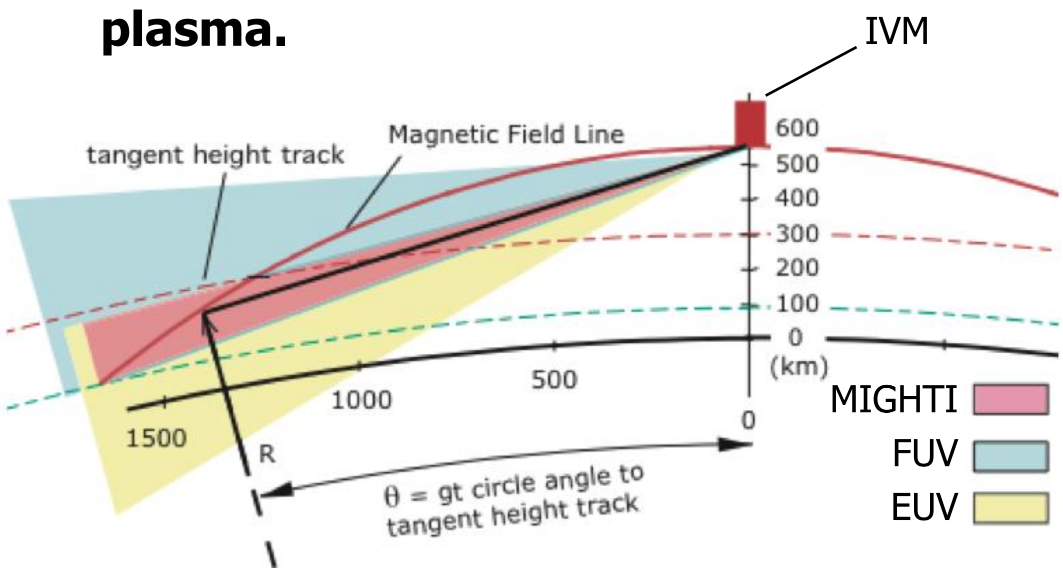
- Czerny-Turner Spectrometer
- Dual MCP-CCD detectors.

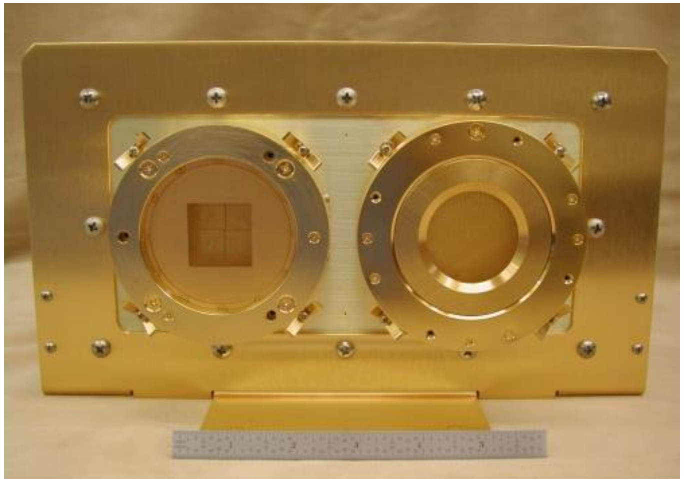
Instrument #4: ICON Ion Velocity Meter

PI : Rod Heelis, U. Texas at Dallas

- **Provides Vi every second.**
- **A combined Retarding Potential Analyzer and Ion Drift Meter (RPA, IDM) measures the <u>in-situ 3D velocity vector</u> of the local plasma.**

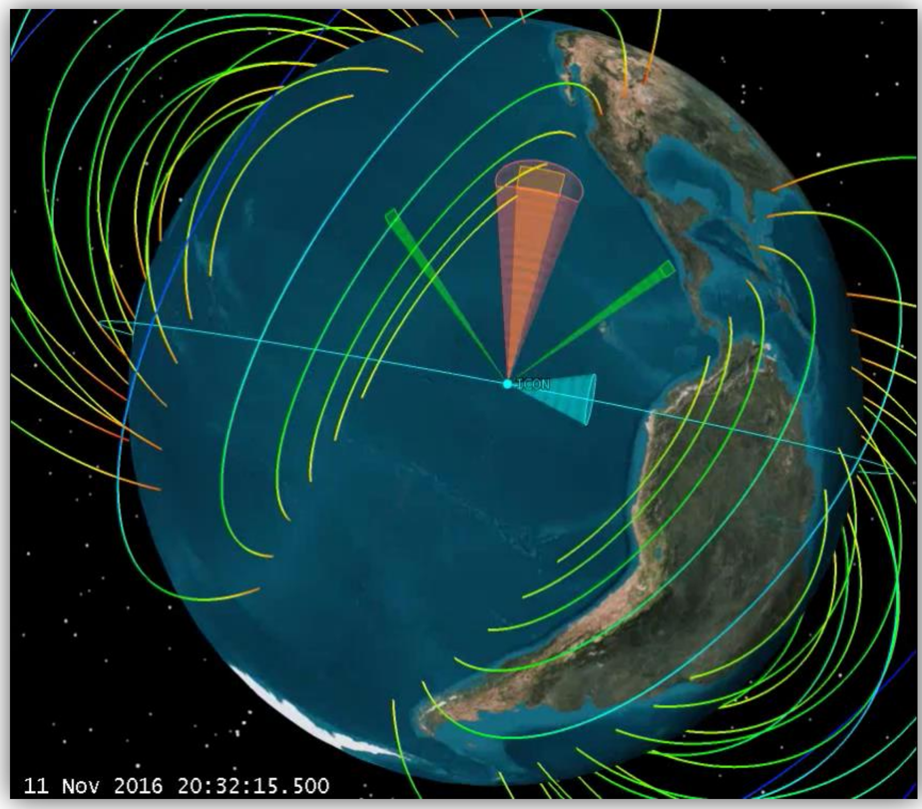


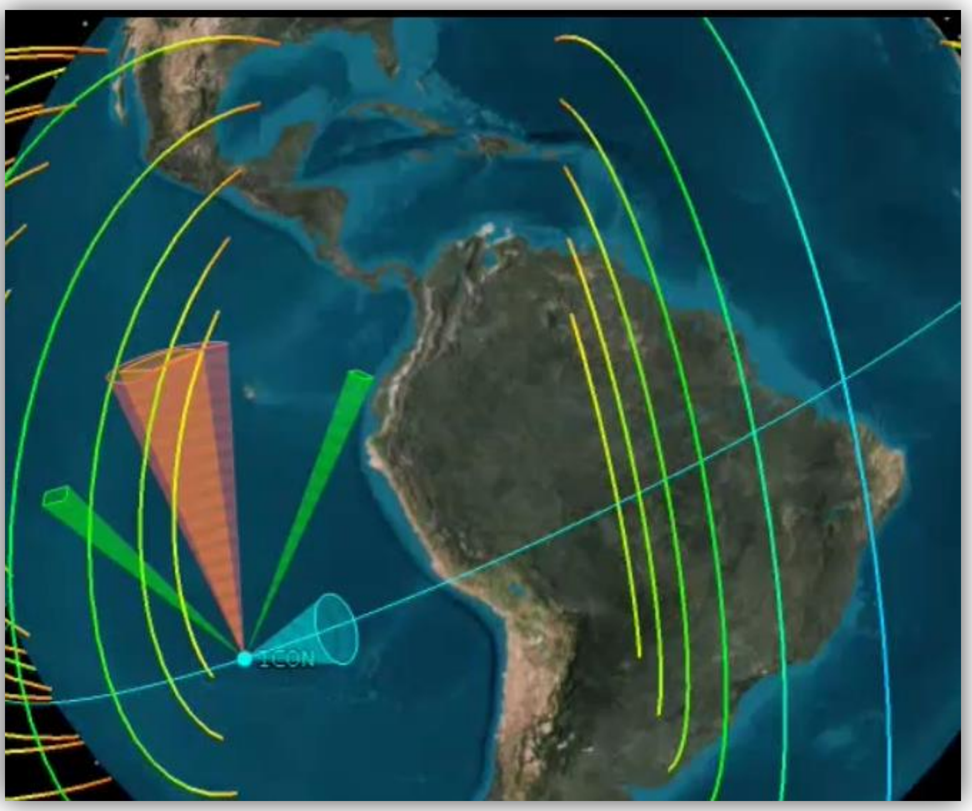




- Design very similar to CINDI on Air Force C/NOFS mission

ICON has two science observation modes





Survey Operations

- Ion Velocity Meter pointed to "ram", imaging instrument views to port.
- Operates in this configuration >90% of mission.

Conjugate Operations

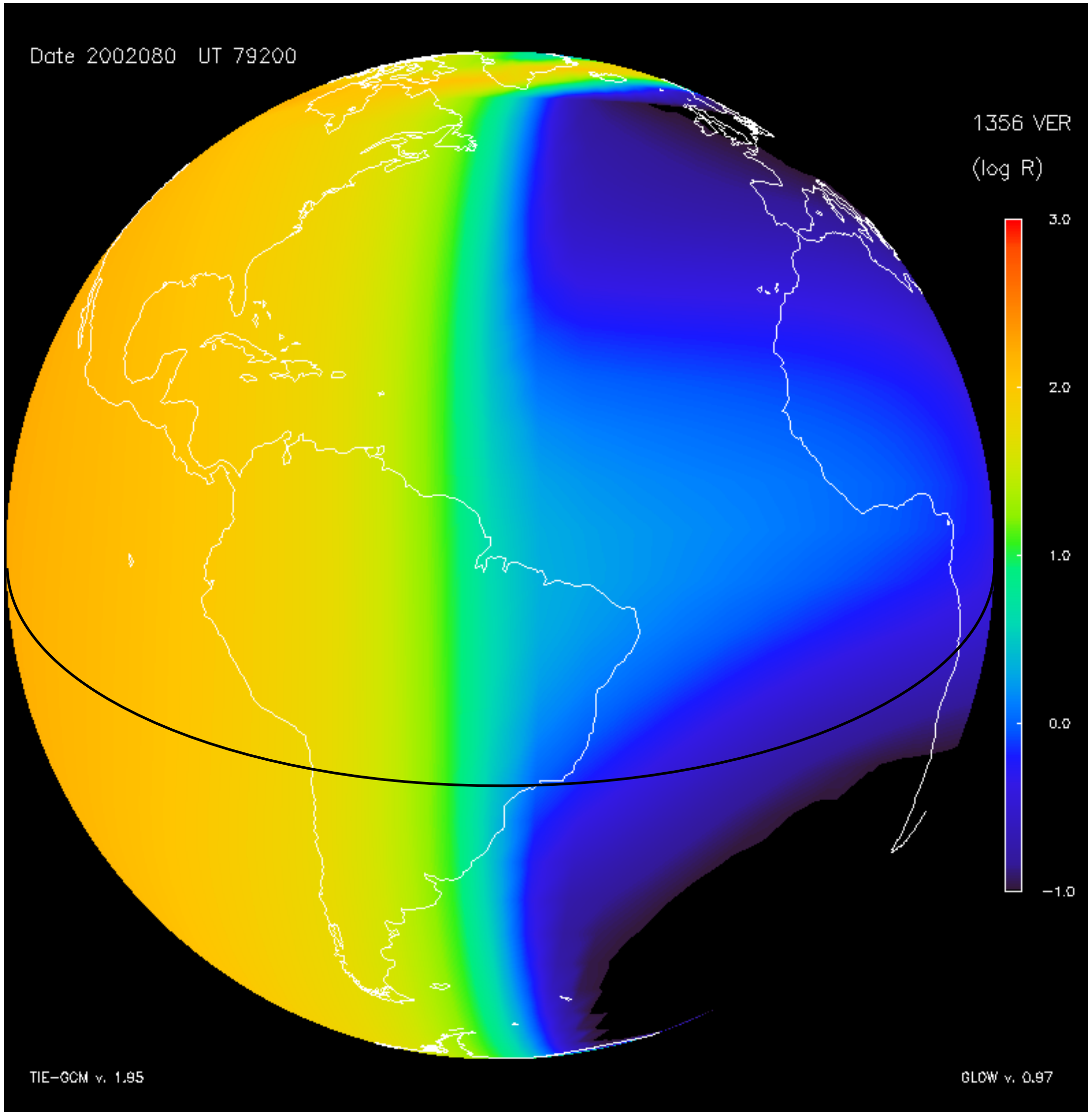
- Set of yaw maneuvers to provide winds at both magnetic footpoints with IVM in ram when transiting magnetic apex.
- Up to twice per day in two weeks per month.

ICON in the Big Picture

- Multi-spectral TDI FUV imaging with steerable baffle.
- Wind and temperature imaging, day and night with 1 minute cadence or better.
- In situ, high-precision plasma measurements, combined with North or South facing views.
- Daytime ionospheric emission profiles with highest possible S/N.

All these measurements in the FOV of the geosynchronous imaging GOLD mission every 90 minutes.

Truly an outstanding combination and an opportunity for discovery.



Summary

- ICON will be the first investigation of the drivers of variability in the dense plasma of the equatorial ionosphere using an innovative combination of remote sensing and in situ measurements
- Scientific performance of ICON has been preserved through detailed design.
- Ready to move forward to final implementation and on to major scientific impact on-orbit!