Space Weather Studies by new NASA Missions collaborating with the Formosat 7 / COSMIC 2 Satellite Program

Stan Solomon
High Altitude Observatory
National Center for Atmospheric Research
Boulder, Colorado, USA
Incomplete Overview of Thermosphere/Ionosphere Missions

- **GOLD**
  - Global-scale Observations of the Limb and Disk
- **ICON**
  - The Ionosphere Connections Explorer
- **Formosat 7 / COSMIC-2**
  - Constellation Observing System for Meteorology, Ionosphere, and Climate
- **AMPERE**
  - Active Magnetosphere and Planetary Electrodynamics Response Experiment
- **TIMED**
  - Still ticking...
- **Swarm**
  - Earth’s Magnetic Field and Environment Explorers
- **International Space Station**
  - LITES and GROUP-C
- **DMSP**
  - Special Sensor Ultraviolet Spectrographic Imager
- **Continued IMF and Solar Wind measurements**
  - ACE and DSCOVR
- **Various CubeSat opportunities**
  - LAICE, SORTIE, MinXSS, DAILI, many others
- **Extensive Ground-based Observations**
  - ISRs, Ionosondes, FPIs, Imagers, GPS, Magnetometers...
Formosat 7 / COSMIC-2

- 6 satellites, near-equatorial orbits
- GNSS Radio Occultation
- Ion Velocity Meter
- RF Beacon

Launch: 2018
ICON focuses on the processes that govern the creation and distribution of ionospheric plasma:

**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.

**Responses:**

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

**Plasma density** of the ionosphere

Launch: 2018
Ongoing operations supported by NSF
Global-scale Observations of the Limb and Disk

Richard Eastes, PI
CU/LASP

Bill McClintock, Dep. PI
CU/LASP

Alan Burns, Project Scientist
HAO/NCAR

Launch: 2018
Scientific Objectives

1. How do geomagnetic storms alter the temperature and composition structure of the thermosphere?

2. What is the global-scale response of the thermosphere to solar extreme-ultraviolet variability?

3. How significant are the effects of atmospheric waves and tides propagating from below on thermospheric temperature structure?

4. How does the nighttime equatorial ionosphere influence the formation and evolution of equatorial plasma density irregularities?
GOLD Observations

Daytime Far-Ultraviolet Spectrum

- Temperature obtained on disk from rotational shape of \( \text{N}_2 \) LBH bands
- \( \text{O}/\text{N}_2 \) composition measured using ratio of O 135.6 doublet to \( \text{N}_2 \) LBH bands
- Temperature on limb determined by slope of emission altitude profile
- \( \text{O}_2 \) profile on limb from stellar occultations
- \( \text{O}^+ \) at night observed using 135.6 recombination emission
GOLD Observing System Simulation Concept

- TIE-GCM
- MSIS-IRI

Airglow model

Vibrational-Rotational Band Model

Line-of-Sight & Radiative Transfer

Instrument Model

GLOW

LBH VRB

LOS-RT

INSTR

Analysis Algorithms

Disk

Limb
Simulation of GOLD Photometric Observations

O(\(^5\)S) Doublet at 135.6 nm

N\(_2\) LBH “short” bands 141-153 nm
Simulation Animation
Simulation Including Instrumental Effects

- Noise
- Slit width
- PSF
- L1 bins (125 km at nadir)
Simulation of GOLD Spectroscopic Observations

Disk Image

Detector Image
Spectroscopic Animation

Disk Image

Detector Image
Collaborations with Ground-Based Observations

- Ionospheric Convection: SuperDARN / SuperMAG
- Ionospheric Parameters: Incoherent scatter radars
- Total Electron Content: Measurements from GPS stations
- Neutral Winds and Temperatures: Fabry-Perot and Michelson Interferometers
- Auroral Airglow Emissions: Imagers
- Mesosphere and Lower Thermosphere Dynamics: Lidars & Radars
GOLD Field-of-Regard

Sub-satellite point:
0° latitude
47.5° W longitude
Some Specific Scientific Investigations

- The response of the ionosphere-thermosphere system to geomagnetic storms:
  - How do electric fields and composition change interact to produce negative and positive ionospheric responses?
  - What are the contributions of penetration electric fields and neutral wind disturbances to the low-latitude ionospheric dynamo?

- The role of the lower atmosphere in driving ionospheric variability:
  - How do tides and planetary waves impact the composition of the thermosphere and ionosphere?
  - How well can we predict the state and variability of the thermosphere driven by tropospheric weather?

- The physics behind low-latitude ionospheric instabilities:
  - Why do plasma bubbles form on some nights, but not on others, under similar solar-geomagnetic conditions?
  - Is seeding by neutral atmosphere fluctuations necessary to generate instabilities, or are strong vertical electric fields sufficient?

- The contributions to observations, modeling, and forecasting of space weather:
  - Can we construct data assimilation weather models that extend through the thermosphere and include the ionosphere?

http://www2.hao.ucar.edu/geogoldicon
Next Steps?

• Continue advocacy for scientific support at national agencies.

• We will soon have a wealth of thermosphere-ionosphere observational data, but should have more resources devoted to analysis.

• Promulgate the notion that this serendipitous juxtaposition of various satellite and ground based observations forms the equivalent of an

  *International Thermosphere-Ionosphere Community Mission.*