Coordinated Studies of the Middle and Upper Atmosphere Structure: Results and Lessons-learned from the NASA TIMED Mission

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AGU General Assembly, May 28, 2009 Union Invited Talk Toronto
TIMED: One of The NASA’s ITM Missions

Mission Status

* Launch: Dec. 7, 2001
* Spacecraft: Operational
  -- one wheel failed early 2007
  * currently in 3-wheel operations
  * 2-wheel operations mode tested and loaded
  -- gyro lifetime limited
  * current in star camera mode
* Instruments: Operational
  -- GUVI scan mirror stopped scanning in late 2007
  * currently in downward-looking stare mode
  * continues collecting science data
  -- SEE x-ray photometer filter wheel failure
  * 3 channels still collect data
  * SORCE data were used
* Data: > 99% Data Collection
  -- GUVI: version 3 (L1) and version 8 (L2)
  -- SABER: version 1.07
  -- SEE: version 9
  -- TIDI: version 10
* Operations: Approved to 2012

TIMED began its mission in Jan. 2002
For the first time, over 7 years of ITM data covering the entire decreasing phase of a solar cycle (while ground CO$_2$ increased by ~4%) have been collected.

Combined with observational data taken previously as well as currently by other space and ground assets, we have an extensive data record which can greatly enhance our understanding of solar/geomagnetic as well as human-induced variabilities in the ITM system.
Outline

• **What have we learned?**
  – Significantly Improved Characterization

• **How well do we know?**
  – Quantitative Understanding still Lacking (for some)

• **What questions remain?**
  – Importance and Relevance Needed

• **What do we need to improve and how?**

Some important examples are presented here:
- comments?
- discussion?
Characterizing Thermospheric/Ionospheric Response to Solar and Geomagnetic Disturbances

Quantitative understanding of the overall system response is lacking!
Confirming Thermospheric Thermostat Effect: High Cadence Global Energy Inputs Needed
Improving Characterization of MLT Mean and Variabilities
Characterizing MLT Structure and Variation: Quantitative Understanding is Needed
GCM Model & Observation Studies: Gravity Wave Climatology Needed

Gravity wave parameterization schemes also need to be validated!
Characterizing Minor Species Morphology: Global Distribution of Eddies Needed
Improving Solar Irradiance Measurements: Studies of Minor Species Distribution Needed

Ionization & Dissociation Frequencies

Lyman α parameterization

\[ \text{O}_2 + h\nu \rightarrow \text{O}(^3\text{P} \text{ or } ^1\text{D}) + \text{O}(^3\text{P}) \]

SEE + EUVAC + Finnelly & Torr
Hinteregger+Kirby et al.

SEE + Solomon

TIMED/SEE v9
Nicolet parameterization
New parameterization

UARS/SOLSTICE

2.45 \times 10^6 + 5.43 \times 10^{8b}F10.7 - 8.33 \times 10^{12a}F10.7^4F10.7

Ionization Frequency (sec⁻¹)

Irradiance (photons cm⁻² sec⁻¹)

F10.7 Index

F10.7 (SFU)
Charactering Mesospheric Nightglow Morphology: Importance to Validation and Long-Term Studies

**OH 2.0 micron emission rate at 20LST and at Equator**

![Graph showing OH 2.0 micron emission rate at 20LST and at Equator](image)

**OH 2.0 Micron Peak Emission Rate**

![Graph showing OH 2.0 Micron Peak Emission Rate](image)

**OH 2.0 micron emission rate at 20LST and at 45N**

![Graph showing OH 2.0 micron emission rate at 20LST and at 45N](image)

**OH 2.0 Micron Peak Emission Altitude**

![Graph showing OH 2.0 Micron Peak Emission Altitude](image)
One shuttle plume can contribute significantly (20-30%) to all PMCs observed in one season.

Are NLCs a “Miner’s Canary” for Global Change?

Stevens et al. 2005
Establishing ITM Vertical Coupling Processes: E-fields and E-region Neutral Winds Needed

E-fields, Neutral Winds and Electrodynamics

SABER Temp

COSMIC

Non-Migrating Diurnal Tide (s=3, Eastward) at 0 Degree

SABER Temp versus ROCSAT-1 Vertical Drift

TIMED/SABER QBO -
Establishing Potential Climate Change Signature: Delineation of Solar Variability Needed

Observed Trend (2002-2008)

Modeled Solar Induced Trend
Quantifying ITM Climate Variability
Extensive Measurement Validation Required

Black: HALOE
Red: SABER
Blue: CHAMP
Orange: COSMIC
What do we need to improve and how?

– System Studies to gain quantitative understanding
  • Better characterization of external energy inputs
    – High temporal cadence
    – Global coverage with high spatial resolution
  • Better characterization of small-scale eddy effects
    – Global gravity wave morphology (spatial and temporal)
    – Gravity wave parameterization schemes used in GCM modeling
  • Better characterization of global E-fields, currents, and neutral winds
    – Ion-neutral coupling and vertical coupling
    – Joule-heating parameterization (high cadence, temporal/spatial resolutions)
  • Better characterization of climate forcings of the ITM system
    – Global lower boundary climate forcings (i.e. Greenhouse gases, aerosols, oceans, etc.)
  • Improvement of physics-based theoretical models
    – Sun-Earth System Models – i.e. processes, boundary conditions, resolutions, etc.
    – Whole Atmosphere Climate models

– Collection of long-term ITM observations to delineate natural and human-induced variabilities
  • Continue collection of all relevant ITM data
  • Multi-discipline studies to understand measurement biases and improve measurement accuracies
Sun-Earth Climate System Studies Requires Cross-Discipline Studies

- Instrument Characterization
- Laboratory Measurements
- Computer Modeling
- Data Analysis
- Retrieval Algorithms
- Field Measurements

Cross-Discipline Studies
Studies of Noctilucent Clouds (NLCs) 
Both Models and Observations Needed

AIM/CIPS daily mean NLC map

Red circle is northward SABER limit

SABER $T - T_{\text{frost}}$ point

Red thick dash is zero line

Colder temperature and increasing H$_2$O enhance NLC formation.
Mesospheric Nightglow Emissions:
Atomic Oxygen, Advection and Eddy Transport

Zonal Mean Temperature at 0 Degree Latitude

OH 1.6 micron emission rate (95 km at 0 Latitude)

Atomic Oxygen Density at 95 km (LT: 0 Hour, Lat: 0 Degree)

OH 1.6 micron emission rate (85 km at 0 Latitude)
Establishing MLT Temperature/Density Trends:
Delineation of Natural Variability Needed

Akmaev, 2006
1980-2000

SABER Temperature Trend (1/2002-12/2006)

SABER Density Trend (1/2002-12/2006)