Update on GEO Hyperspectral Sounders: GIFTS and GeoMetWatch “Storm”

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Status of High Spectral Resolution IR for Advancing Atmospheric State Characterization (Sounding) and Climate Trend Benchmarking: A Period of Both Opportunity Realized and Squandered

Squan⋅der, verb, skwändər
1. Waste in a reckless and foolish manner
2. Allow (an opportunity) to pass or be lost

International Radiation Symposium 2012, IRS2012-587
Dahlem Cube, Berlin, Germany, 06 – 10 August 2012
Summary from IRS

1. LEO Operational Wx: AIRS, IASI, & CrIS
   Realized, but plan needed for CrIS upgrades

2. GEO Severe Wx: GIFTS/ HES for GOES-R
   Squandered* (in US), but GeoMetWatch offers a Fix

3. Ground-based Wx Networks: AERI
   Not Realized—Have great Promise

4. Climate Benchmark & Intercal: CLARREO
   Squandered** (CLARREO delayed indefinitely), but
   Earth Venture Instrument Proposals (e.g. Zeus) and
   international collaborations could provide a path

*should be in orbit, removed from plans  **delayed indefinitely
Topics

- Hyperspectral Sounding Background

- GIFTS: Cancelled in 2006, followed by cancellation of the GOES-R Sounder but IRS proceeding for MTG in 2019 & Chinese advanced sounder planned for 2015

- GeoMetWatch: A US Company planning to sell advanced sounder data from “STORM”, a GIFTS-like, privately funded sensor
Hyperspectral Sounding Background

High Information Content

Clear: Ocean and Desert

Cloudy: Thin ice, Mid-level, High black

Many Key Weather & Climate Applications
High Spectral Resolution IR

Proven developments in Radiative Transfer & Inter-Calibration form a solid foundation for sounding, GSICS & climate benchmarking

1986: HIS ⇒ LBLRTM/GENLN2

1990: HIS ⇒ AERI (UW/DOE ground-based)

1990s: AERI ⇔ NIST ⇒ LBLRTM

2002+: Scanning HIS ⇔ NIST ⇔ AIRS ⇒ kCARTA/LBLRTM
AIRS ⇒ MODIS, GOES, HIRS

2006: Scanning HIS ⇒ NAST ⇒ IASI ⇒ LBLRTM/kCARTA
IASI ⇒ MODIS, AIRS, ...

2012: Scanning HIS ⇒ NAST ⇒ CrIS ⇒ LBLRTM/kCARTA
CrIS ⇒ VIIRS, GOES...
⇔ AIRS
⇔ IASI

GSICS
Global Space-based Inter-Calibration System
CrIS launched on Suomi NPP
Initiating JPSS with EUMETSAT

Verner E. Suomi 1915-1995

28 October 2011
CrIS: 1990/91
Historical Roots

- **EUMETSAT (John Morgan)** sponsorship
- **Originated by Bill Smith,** in residence at EUMETSAT
- **UW-Madison/SSEC prime,** Hank Revercomb, PI
- **Detailed design by SBRC,** Bomem DA interferometer
  Still Chase, Henry Buijs
AIRS
Atmospheric InfraRed Sounder
Grating spectrometer
166 kg, 256 W
13.5 km FOV at nadir, contiguous
Launched on NASA Aqua in 2002

IASI
Infrared Atmospheric Sounding Interferometer
Michelson interferometer
236 kg, 210 W
2x2 12 km FOVs at nadir, non-contiguous
Launched on Metop-A in 2006

CrIS
Cross-track Infrared Sounder
Michelson interferometer
146* kg, 110 W
3x3 14 km FOVs at nadir, contiguous
Launched on Suomi NPP, 28 Oct 2011

* with vibration isolation that was not deployed
Sample “1st Light” spectra (20 January)
Overlays for a uniform 3x3 FOR

Carbon Dioxide
Sample “1\textsuperscript{st} Light” spectra (20 January)
Overlays for a uniform 3x3 FOR

Water Vapor
Sample “1st Light” spectra (20 January)
Overlays for a uniform 3x3 FOR

\[ SW \, N_2O \, \& \, CO_2 \]
Full Resolution SW band from CrIS

Early 2013 Downlink planned

Calibrated with UW/UMBC CCAST—thanks to Larrabee Strow

Note beautiful CO lines

Many CO₂ lines for spectral Cal
LEO Operational Wx: AIRS, IASI, & CrIS

AIRS: 2002-

IASI: 2006-

CrIS: 2011-

CrIS: 2011-
Full Resolution starting 2013

L1B: > 1200 Resolving Power 9 FOV/50km square

L1C: ±2 cm OPD Gaussian apodized 4 FOV/50km square

±0.8, 0.4, 0.2 cm OPD unapodized 9 FOV/50km square

±0.8 cm OPD unapodized 9 FOV/50km square
Shown versus scene temperature for all FOVs for ~mid-band spectral channels

FOV to FOV spread in LW and especially MW is due to non-linearity

**Final inflight uncertainty far better than spec!**

(< 0.2K 3-sigma, after inflight non-linearity refinement)
CrIS on Suomi NPP

- CrIS instrument performance is exceptional
  - Very low noise
  - Very stable and accurate
  - Provides excellent baseline for future upgrades providing
    - Contiguous spectral coverage
    - Higher spatial resolution

Water Vapor
24 February, 1580 cm\(^{-1}\)

CrIS on Suomi NPP a fitting tribute to Verner Suomi
GIFTS
(Geostationary Imaging Fourier Transform Spectrometer)
Operational Weather Satellites

**ROLE**
- Global NWP
- Meso-scale
- Severe Wx

**APPROACH**
- POES
- GOES
- GPS

GOES Sounder
- $= \frac{1}{4}$ Wx Sat. role
- $= \frac{1}{2}$ Severe Wx Sat. role

Not just one in a long list!
GEO IR Imaging Sounder capability is unique

- **Polar Sounders**: Inadequate temporal coverage
- **GPS**: Inadequate spatial resolution and temporal coverage
- **Current GEO Sounder**: Vertical resolution 2-3 times lower
- **ABI Imager**: Inadequate vertical resolution
- **GEO Microwave**: Vertical resolution 2-3 times lower
GIFTS offered 2 orders of magnitude temporal/spatial resolution improvement

*OSSE shows 4-5 hours extra warning of severe wx*

**Improvement Factors compared to current GOES**
- Horizontal resolution = \((10\text{ km}/4\text{ km})^2 = 6.3\)
- Vertical resolution = 3 x higher
- Temporal coverage = 5.5 x faster
OSSE of GEO advanced IR sounder for storm Nearcasting

True
06-12-2002, 1200 UTC
Lifted index [°C]

GIFTS/HES/IRS
06-12-2002, 1200 UTC
Lifted index [°C]

Red = extreme instability

Simulated Radar

ABI/GOES Sounder like

Jun Li, Jinlong Li, Jason Otkin, and Tim Schmit
OSSE of GEO advanced IR sounder for storm Nearcasting

Extreme instability indicated

1300 UTC
OSSE of GEO advanced IR sounder for storm Nearcasting

True
06-12-2002, 1400 UTC
Lifted index [°C]

GIFTS/HES/IRS
06-12-2002, 1400 UTC
Lifted index [°C]

Simulated Radar

ABI/GOES Sounder like

1400 UTC
OSSE of GEO advanced IR sounder for storm Nearcasting

Simulated Radar

ABI/GOES Sounder like

1500 UTC
OSSE of GEO advanced IR sounder for storm Nearcasting

**True**
06-12-2002, 1600 UTC
Lifted index [°C]

**GIFTS/HES/IRS**
06-12-2002, 1600 UTC
Lifted index [°C]

**Simulated Radar**
06-12-2002, 1600 UTC
Radar reflectivity [DBZ]

**ABI/GOES Sounder like**
06-12-2002, 1600 UTC
Lifted index [°C]

1600 UTC
OSSE of GEO advanced IR sounder for storm Nearcasting

Start to see extreme instability 1700 UTC in GOES 4 hours later
OSSE of GEO advanced IR sounder for storm Nearcasting

**True**
06–12–2002, 1800 UTC
Lifted index [°C]

**GIFTS/HES/IRS**
06–12–2002, 1800 UTC
Lifted index [°C]

**Simulated Radar**
06–12–2002, 1800 UTC
Radar reflectivity [dBZ]

**ABI/GOES Sounder like**
06–12–2002, 1800 UTC
Lifted index [°C]

GOES shows extreme instability 1800 UTC 5 hours later, but note false alarms.
OSSE of GEO advanced IR sounder for storm Nearcasting

1900 UTC
OSSE of GEO advanced IR sounder for storm Nearcasting

True

06-12-2002, 2000 UTC
Lifted index [°C]

GIFTS/HES/IRS

06-12-2002, 2000 UTC
Lifted index [°C]

Simulated Radar

06-12-2002, 2000 UTC
Radar reflectivity [dBZ]

ABI/GOES Sounder like

06-12-2002, 2000 UTC
Lifted index [°C]

2000 UTC
OSSE of GEO advanced IR sounder for storm Nearcasting

True
06–12–2002, 2100 UTC
Lifted index [°C]

GIFTS/HES/IRS
06–12–2002, 2100 UTC
Lifted index [°C]

Rain line shows in simulated radar 8 hours later 2100 UTC
OSSE of GEO advanced IR sounder for storm Nearcasting

Red = extreme instability

GIFTS/HES/IRS provides needed instability and warning information hours earlier than current GOES Sounder (+4-5 hrs) and Radar (+8 hrs)
2006! GIFTS Engineering Model Viewed Atmosphere from T/V chamber at Space Dynamics Lab
Lunar Views Demonstrated GIFTS Imaging Capability

Results from a single interferometer scan of the moon, viewed in the visible, mid-wave IR, and long-wave IR. Also the spectral intensities of two selected pixels from the IR images, one viewing the moon, the other the clear sky background.
Privately owned commercial data provider offers “STORM” leveraging GIFTS technology development


Promises to restore critical data for severe weather forecasting cancelled from GOES-R and much more at a fraction of the cost, in record time!

Potential Customers: US, top sovereign governments world-wide, and & commercial enterprises
GeoMetWatch Partnership

Space Dynamics Laboratory
Utah State University

Space Science & Engineering Center
University of Wisconsin

“STORM” SENSOR

DATA CENTER

Users

Unprecedented
Severe Weather Disaster
Mitigation Capability

See GeoMetWatch.com
Summary

- GeoMetWatch is moving ahead with the concept of a privately funded advanced sounder named “Storm”
- Flight during 2016 is still possible
- Populating 6 orbital locations is ultimately envisioned