The Joint Capabilities and Opportunities of the Advanced Sounders on MetOp and NPOESS for NWP and Climate Monitoring in the GEOSS Era

ITSC-16, Session 12: Future Instruments
16th International TOVS Study Conference

Hotel do Frode and Conference Center, Angra dos Reis, Brazil
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We are living in an emerging GEOSS Era …

We are looking forward to contributors to & beneficiaries from the Societal Benefits Areas
Nine Societal Benefits Areas for GEO/GEOSS
“Potential U.S. Contributions to the GEOSS”

NPOESS Will Support All GEOSS Societal Benefit Areas

US GEO focusing on Six Near-Term Opportunities
1.) Disasters
2.) Drought / National Integrated Drought Information System
3.) Land Observation
4.) Air Quality
5.) Sea Level
6.) Data Management
Polar-orbiting Systems: An Opportunity for Integration of Contributions

NPOESS / MetOp Span a Generation!
NPOESS & MetOp
Represent an Emerging “Mini-GEOSS” System for a Generation

NPOESS / MetOp Span a Generation!
Several Climate & Weather [NWP] Time Scales Covered
“Integrated” Polar Satellite Constellations
MetOp / NPP / NPOESS “First Generation” ~ 2010-2026 +

CALENDAR YEAR

05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28

AM
F13 DMSP F17 DMSP F19 DMSP F20 NPOESS C4
M
DMSP F16 DMSP F18
Mid
AM
PM
POES N POES N’ NPOESS C1
AQUA NPP NPOESS C3

Seasonal Inter-Annual
Solar
Inter-Decadal
NPOESS/MetOp
Sounders/Imagers/Ozone

NPOESS 1330 Satellite

MetOp 0930 (2130) Satellite

NPOESS Single Satellite Design with Common Sensor Locations and “Ring” Data Bus Allows Rapid Reconfiguration and Easy Integration
### National Polar-Orbiting Operational Environmental Satellite System

**“IASI/CrIS Features - Enabling a Meaningful Global Atmospheric Sounding System for NWP & Climate”**

<table>
<thead>
<tr>
<th></th>
<th>IASI</th>
<th>CrIS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong># of Channels</strong></td>
<td>8461</td>
<td>1305</td>
</tr>
<tr>
<td></td>
<td>650 to 770</td>
<td>650 - 1095</td>
</tr>
<tr>
<td></td>
<td>770 to 980</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1000 to 1070</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1080 to 1150</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1210 to 1650</td>
<td>1210 - 1750</td>
</tr>
<tr>
<td>Spectral Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(cm⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2100 to 2150</td>
<td>2155 - 2550</td>
</tr>
<tr>
<td></td>
<td>2150 to 2250</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2350 to 2420</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2420 to 2700</td>
<td></td>
</tr>
<tr>
<td>Spectral Resolution</td>
<td>645 0.35</td>
<td>650-1095 &lt;0.625</td>
</tr>
<tr>
<td>(cm⁻¹)</td>
<td>1210 0.35</td>
<td>1210-1750 &lt;1.25</td>
</tr>
<tr>
<td></td>
<td>2000 0.39</td>
<td>2155-2550 &lt;2.50</td>
</tr>
<tr>
<td></td>
<td>2450 0.45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2760 0.5</td>
<td></td>
</tr>
<tr>
<td>Scan type</td>
<td>Step and dwell</td>
<td>Step and dwell</td>
</tr>
<tr>
<td>Scan rate</td>
<td>8 sec. (30 steps earth &amp; 3 calibration)</td>
<td>8 sec. (30 earth &amp; 2 calibration)</td>
</tr>
<tr>
<td>IFOV</td>
<td>3°.3 x 3°.33</td>
<td>3°.3 x 3°.3</td>
</tr>
<tr>
<td>IFOC size at Nadir</td>
<td>12 km</td>
<td>14 km</td>
</tr>
<tr>
<td>Sampling at Nadir</td>
<td>25 km</td>
<td>16 km</td>
</tr>
<tr>
<td>Swath</td>
<td>± 48.3°</td>
<td>± 48 1/3° each side of Nadir</td>
</tr>
<tr>
<td></td>
<td>± 1026 km</td>
<td>± 1100 km each side of Nadir</td>
</tr>
<tr>
<td>Swath</td>
<td>48 km</td>
<td>48 km</td>
</tr>
<tr>
<td>Field of Regard (FOR)</td>
<td>48 km</td>
<td>48 km</td>
</tr>
<tr>
<td># IFOV’s Per FOR</td>
<td>4 (2-by-2)</td>
<td>9 (3-by-3)</td>
</tr>
<tr>
<td>Pixel/scan (FOVs x steps)</td>
<td>120 (4X30)</td>
<td>270 (9X30)</td>
</tr>
</tbody>
</table>

**Field of Regard / Field of View**

- **IASI**:
  - Field of Regard (FOR): 48 km
  - Sampling at Nadir: 12 km
  - Swath: ± 1026 km

- **CrIS**:
  - Field of Regard (FOR): 48 km
  - Sampling at Nadir: 14 km
  - Swath: ± 1100 km each side of Nadir
Future Opportunities: Over-flyers

“Rich” Opportunity e.g.: NPP & A-Train

Satellites in the same orbital plane, but at different altitudes would leverage the extensive cross-comparisons & cal/val efforts of the other satellite(s) (maybe in other trains).

Synergies, Synergies, Synergies …

Adapted from S. Kidder et al.
Opportunities for Cross-Comparisons

- **Comparison of instruments on the same platform:** CrIS/ATMS/VIIRS; Similar approaches as AIRS/AMSU/MODIS
- **SNO method:** Simultaneous Nadir Overpass eliminates issues with viewing angles, atmospheric paths, observation time and location
- **Cross-Comparisons with instruments on other platforms, e.g. A-Train instruments:** Very useful for aerosols, clouds, temperature and water vapor

*Different Ways To Carry Out Cross-Comparison In Terms of Platform(s)*

Adapted from Frank Sun et al., NGST, 2008
Opportunities
Simultaneous Nadir Overpasses (SNO)

LEO vs. LEO Cross-Comparison

- NOAA-18 [AM] & EOS-Terra [PM] e.g.
- MetOp (1, 2 or 3) [AM] & NPP [PM] = similar
- MetOp (1, 2 or 3) [AM] & NPOESS (C1 or C3) [PM] = similar
- NPOESS (C2 or C4) [early AM] & NPOESS (C1 or C3) [mid AM]

LEO vs. LEO Inter-Calibration

- EOS/Hyperion & GOES-R e.g.
- Any LEO & Any GEO = similar

GEO vs. LEO Cross-Comparison

- MetOp (1, 2 or 3) [AM] & EOS/Hyperion e.g.
- MetOp (1, 2 or 3) [AM] & NPP [PM] = similar
- MetOp (1, 2 or 3) [AM] & NPOESS (C1 or C3) [PM] = similar
- NPOESS (C2 or C4) [early AM] & NPOESS (C1 or C3) [mid AM]

Orbit Trajectories courtesy of Changyong Cao and Mitch Goldberg, NOAA/NESDIS
What Cross-Comparisons Can Do

- To provide early on orbit quick look of NPP/MetOp/NPOESS instruments & algorithms performance by comparing with other well understood/calibrated instruments & validated products.
- Independently and periodically calibrate, validate, & monitor NPP/Metop/NPOESS instruments, algorithm performance throughout the mission/instrument lifetimes.
- Independent evaluation for the transfer of trends from EOS, MetOp, through NPP, to NPOESS
- MetOp/NPP/NPOESS to be an important part of WMO Global Space-based Inter-Calibration System (GSICS)

Adapted from Frank Sun et al., NGST, 2008
Overview of Cross-Comparisons

SDR Cross-Comparison (L1B, SDR data)
[Major emphasis by IPO]
Issues: location, time, scan angle, fp differences, & band & band characterization differences

EDR Cross-Comparison (L2, EDR products)
[Emphasis by IPO for selected EDRs]
Issues: resolution, algorithm differences (CTP, for example); instrument signatures

CDR Cross-Comparison (L3 gridded data, higher level products)
[To be performed by other groups/agencies, e.g. NCEP/NASA/ECMWF]

Three Levels of Cross-Comparison in Terms of Data Products

3 Levels of Cross-Comparison for Sounding & Imaging Products

Adapted from Frank Sun et al., NGST, 2008
JAIVEx (Joint Airborne IASI Validation Experiment)
International collaboration to validate radiance and geophysical products obtained by the Infrared Atmospheric Sounding Interferometer (IASI) aboard the MetOp satellite

- **Location/dates**
  - Ellington Field (EFD), Houston, TX, 14 Apr – 4 May, 2007
- **Aircraft**
  - NASA WB-57 (NAST-I, NAST-M, S-HIS)
  - UK FAAM BAe146-301 (ARIES, MARSS, SWS; dropsondes; in-situ cloud phys. & trace species; etc.)
- **Ground-sites**
  - DOE ARM CART ground site (radiosondes, Raman Lidar, etc.)
- **Satellites**
  - Metop (IASI, AMSU, MHS, AVHRR, HIRS, ASCAT)
  - A-train (Aqua AIRS, AMSU, HSB, Modis; Aura TES; CloudSat; and Calipso)
- **Participants**
  - US: IPO, NASA, UW, MIT, MIT-LL, NOAA,
  - Europe: UKMO, EUMETSAT, ECMWF, …
"Enabling a Meaningful Global Atmospheric & Ozone Sounding System for NWP & Climate"

[CrIS/IASI & ATMS/AMSU-MHS & OMPS/GOME-2 & MIS* & GRAS]

<table>
<thead>
<tr>
<th>Timeliness</th>
<th>MetOp IASI/HIRS/AMSU/MHS &amp; GOME-2 &amp; GRAS</th>
<th>NPOESS CrIS/ATMS &amp; OMPS &amp; MIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency Requirement (Minutes)</td>
<td>180</td>
<td>156 Threshold 15 Objective</td>
</tr>
<tr>
<td>Latency Performance (Minutes)</td>
<td>104 – 135</td>
<td>28</td>
</tr>
<tr>
<td>Revisit Time (Hours)</td>
<td>12 (Any One Satellite) 6 (Two OZONE Satellites)¹</td>
<td>6 (Two* Sounder Satellites)²</td>
</tr>
<tr>
<td></td>
<td>6 (MetOp with 2 NPOESS) 6 (Two Sounder Satellites) *Incl. 1 NPOESS &amp; 1 MetOp</td>
<td></td>
</tr>
</tbody>
</table>

¹ 6 hour revisit for two phased satellites (OMPS on 1330 NPOESS & GOME-2 on METOP 2130)
² 6 hour revisit for three phased satellites (CrIS/ATMS/CMIS on NPOESS 1330 & IASI/AMSU/MHS/GOME-2/GRAS on 2130 MetOp; also MIS on NPOESS 2130 [C2C3,C4] )
CrIS + ATMS = CrIMSS
Will Allow Several Atmospheric/Surface Products to be Retrieved for NWP & Climate

- The CrIMSS product algorithm, developed by AER (SDR-to-EDR) and BOMEM (RDR-to-SDR), is an iterative physical retrieval algorithm to retrieve atmospheric temperature, moisture and pressure profile EDRs from the Cross-track Infrared and Microwave Sounder Suite (CrIMS) measurements.

- Retrieved Parameters will include:
  - Temperature Profile (reconstructed from 20 temperature EOFs)
  - Moisture Profile (reconstructed from 10 moisture EOFs)
  - Pressure Profile
  - Surface Temperature
  - Surface IR Emissivity (at 12 frequency hinge points)
  - Surface IR Reflectance (at 12 frequency hinge points)
  - Ozone Total Column
  - Surface MW Emissivity (reconstructed from 5 MW emissivity EOFs)
  - MW Cloud Top Pressure and Cloud Liquid Water Path

- Additional possible Products [GHG / Trace Gases] (special cases)
- CO, N\textsubscript{2}O, CH\textsubscript{4}, CO\textsubscript{2}
- [NPOESS Users’ IORD Requirements, Pre-Planned Product Improvements]
### Trace/Greenhouse Gases (CO, CH₄, CO₂)

**NPOESS Users’ P³I* IORD EDR Requirements**

<table>
<thead>
<tr>
<th>CH₄ Column</th>
<th>CO Column</th>
<th>CO₂ Column</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objectives</strong></td>
<td><strong>Objectives</strong></td>
<td><strong>Objectives</strong></td>
</tr>
<tr>
<td><strong>Vert Coverage</strong></td>
<td><strong>Vert Coverage</strong></td>
<td><strong>Vert Coverage</strong></td>
</tr>
<tr>
<td><strong>Total Column</strong></td>
<td><strong>Total Column</strong></td>
<td><strong>Total Column</strong></td>
</tr>
<tr>
<td><strong>Horizontal Resolution</strong></td>
<td><strong>100 km</strong></td>
<td><strong>100 km</strong></td>
</tr>
<tr>
<td><strong>Mapping Uncertainty</strong></td>
<td><strong>25 km</strong></td>
<td><strong>25 km</strong></td>
</tr>
<tr>
<td><strong>Meas Range</strong></td>
<td><strong>40-80 μmoles/cm²</strong></td>
<td><strong>0-7 μmoles/cm²</strong></td>
</tr>
<tr>
<td><strong>Meas Precision</strong></td>
<td><strong>1%</strong></td>
<td><strong>3%</strong></td>
</tr>
<tr>
<td><strong>Meas Accuracy</strong></td>
<td><strong>5%</strong></td>
<td><strong>+/-5%</strong></td>
</tr>
<tr>
<td><strong>Latency</strong></td>
<td><strong>15 min</strong></td>
<td><strong>15 min</strong></td>
</tr>
<tr>
<td><strong>Refresh</strong></td>
<td><strong>24 hrs</strong></td>
<td><strong>24 hrs</strong></td>
</tr>
</tbody>
</table>

**CO₂ Column**

- **Objectives**
  - **Vert Coverage**: Total Column
  - **Horizontal Resolution**: 100 km
  - **Mapping Uncertainty**: 25 km
  - **Meas Range**: 11,000-15,000 μmoles/cm²
  - **Meas Precision**: 15-20 μmoles/cm²
  - **Meas Accuracy**: TBD
  - **Latency**: 15 min
  - **Refresh**: 24 hrs

**All three trace gas EDRs require:**
- Total column measurement
- 100 km horizontal resolution
- No Thresholds, only Objectives in IORD

*P³I = Pre-Planned Product Improvement Requirements in NPOESS Users’ Integrated Operational Requirements Document [IORD II]*
Possible Future CrIS Capability e.g. Carbon Monoxide [CO] Trace Gas Profiling & Column Density

Airborne NAST- I
EAQUATE AIRS Validation Campaign
14 and 18 September 2004

Spaceborne AQUA AIRS
CO Daily Averages - Month of July 2004
At Single Height Level - 500 mb

NAST- I CO Vertical Cross Sections
CO [carbon monoxide] in ppbv
Muito Obrigado para sua atenção!