Low Earth Orbit (LEO) Infrared Sounding Activities at NOAA

NOAA IR Sounding Workshop

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Greg Mandt
Program Director
LEO/JPSS
NOAA/NESDIS
greg.mandt@noaa.gov

Background

- Microwave (MW) and Infrared (IR) sounders from LEO have been the backbone of NWP
  - Multiple orbits supported by legacy POES, Metop, and JPSS (AMSU, ATMS, MHS, MWS (future), CrIS, IASI, ISASI-NG (future))
  - Other applications include atmospheric chemistry and radiation budget
- The NOAA Satellite Observing Systems Architecture (NSOSA) recommended a partially disaggregated LEO implementation to:
  - Allow for separation of essential missions from those less critical
  - Exploit efficient and quick access to space
    - Launch what we want, when we want, where we want it
  - Use new technology and commercial capability
  - Become agile (adapt to changing needs)
  - Take advantage of new business models

Overview of Sounder studies at NOAA (1)

- NOAA awarded several contracts to industry via a Broad Agency Announcement in 2019 to explore integrated mission and instrument design concepts to form the basis for future acquisitions.
  - Support the design and formulation of an optimal, mission-effective, agile and cost-effective constellation of space-based observing systems.
    - Provide multi-orbit coverage
    - Risk tolerance and observing system risk management
  - Support a future satellite acquisition targeted at providing a constellation supporting high update rate LEO observational capabilities.
    - Sounding instrument designs (microwave, infrared, radio occultation)
    - Commercial launch, operations, and data services
    - Common satellite bus for flexibility in instruments flown
    - Support rapid launch cadence

Overview of Sounder studies at NOAA (2)

- SounderSat BAAs covered a wide trade space, setting Threshold, Target, and Objective requirements for Vertical Temperature and Moisture profiles.
- IR Instruments explored in the BAA span a range of capabilities, but generally fell into three classes based on waveband coverage:
  - HIGH – capabilities similar to CrIS (includes SW, MW and LW bands)
  - MID – reduced channels (SW+MW or MW+LW)
  - LOW – limited channels, SW or MW or LW
- Instrument calibration accuracy, spatial sampling, NEDT, and bandwidth correspond loosely to class

IR Sounder Instrument Classes From BAA Studies

IR Instrument Properties Summary

Class	Possible Channels	NEDN/NEDT (T or q)	Resolution	T and q Precision	Spatial Resolution Single Cell
CrIS	SWIR, MWIR, LWIR (3.92 – 15.38 microns)		0.625 cm-1		14 km
IR-HIGH	SWIR, MWIR, LWIR (3.92 – 15.38 microns), possible hyperspectral	CrIS noise levels or better	CrIS or better	Similar or better than CrIS across all layers	10 km at nadir
IR-MID-SM	SW SmallSat: SWIR/ MWIR (3.7 – 8.6 microns)	CrIS NEDT x1.5	CrIS	Similar to CrIS across reduced layers (depends on band selection to be confirmed)	14 km at nadir
IR-MID-ML	LW SmallSat: MWIR/ LWIR (6.6-15.38 microns)	CrIS NEDT x1.5	CrIS	Similar to CrIS across reduced layers (depends on band selection to be confirmed)	14 km at nadir
IR-LOW	Single band – range specific to science need	CrIS NEDT x2.0	CrIS	Similar to CrIS across targeted layers	14 km at nadir

Overall guidance recommendations for classes of instruments, not to be construed as instrument designs

NOTES:

- BAA Studies showed resolution could be comparable or better than CrIS, although some configurations may have smaller swath and fly at lower altitude
- BAA Studies showed most efficient way to reduce cost is to remove wavebands/adjust detector size, impacting vertical coverage.

CrIS Specs for Baseline Reference

	SWIR	MWIR	LWIR
Reference Range (microns)	3.7-6.6	6.6-8.6	8.6-15.38
Desired Range (gaps/ no gaps)	3.92-4.64	5.71-8.26	9.14-15.38
Desired Spectral Resolution	0.625 cm-1	0.625 cm-1	0.625 cm-1
NEDN/NEDT	CrIS noise levels	CrIS noise levels	CrIS noise levels
Horizontal Resolution/ GSD at Nadir	14 km @ 832 km altitude	14 km @ 832 km altitude	14 km @ 832 km altitude
Swath (km)	2200 km @ 832 km altitude	2200 km @ 832 km altitude	2200 km @ 832 km altitude

Notional IR-HIGH Instrument Specs

	SWIR	MWIR	LWIR
Reference Range (microns)	3.7-6.6	6.6-8.6	8.6-15.38
Desired Range (gaps/ no gaps)	3.92-4.64	4.64-8.26	8.26-15.38
Desired Spectral Resolution	0.625 cm-1 or better	0.625 cm-1	0.625 cm-1
NEDN/NEDT	CrIS noise levels	CrIS noise levels	CrIS noise levels
Horizontal Resolution/ GSD at Nadir	7 km @ 832 km altitude	7 km @ 832 km altitude	7 km @ 832 km altitude
Swath (km)	2200 km @ 832 km altitude	2200 km @ 832 km altitude	2200 km @ 832 km altitude

Notional IR-MID-A (MWIR/LWIR) Instrument Specs

	SWIR	MWIR	LWIR
Reference Range (microns)	3.7-6.6	6.6-8.6	8.6-15.38
Desired Range (gaps/ no gaps)		4.64-8.26	8.26-15.38
Desired Spectral Resolution		0.625 cm-1	0.625 cm-1
NEDN/NEDT		CrIS noise levels x2	CrIS noise levels x2
Horizontal Resolution/ GSD at Nadir		14 km @ 832 km altitude	14 km @ 832 km altitude
Swath (km)		2200 km @ 832 km altitude	2200 km @ 832 km altitude

Notional IR-MID-B (SWIR/MWIR) Instrument Specs

	SWIR	MWIR	LWIR
Reference Range (microns)	3.7-6.6	6.6-8.6	
Desired Range (gaps/ no gaps)	3.92-4.64	5.71-8.26	
Desired Spectral Resolution	0.625 cm-1 or better	0.625 cm-1	
NEDN/NEDT	CrIS noise levels x2	CrIS noise levels x2	
Horizontal Resolution/ GSD at Nadir	14 km @ 832 km altitude	14 km @ 832 km altitude	
Swath (km)	2200 km @ 832 km altitude	2200 km @ 832 km altitude	

- NOTES
  - CrIS without LWIR

Notional IR-LOW Instrument Specs

	SWIR	MWIR	LWIR
Reference Range (microns)	3.7-6.6		
Desired Range (gaps/ no gaps)	4.08-5.13		
Desired Spectral Resolution	1.0-2.0 cm-1		
NEDN/NEDT	< 0.2 K		
Horizontal Resolution/ GSD at Nadir	14 km @ 600 km altitude		
Swath (km)	1520 km @ 600 km altitude		

- NOTES
  - Spectral range may vary according to science need.

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Questions to the Community

Constellation Configuration – Based on your experience…

- What is the ideal configuration for an IR sounder backbone?
  - What measurements are needed (wavelengths, orbits, spatial resolution, NEDT etc)?
- What additional IR measurements would be ideal to augment the backbone?
  - What measurements are needed at increased temporal, spectral, spatial coverage/resolution to provide additional benefit to NWP models and related products? (LEO vs GEO; Are frequent LEO observations a replacement for GEO IR sounder? With more GEO IR sounders planned, how many LEO IR sounders do we need?)
  - What do you like to see more of (temporally and spatially) and how do you capture the impact that justifies these measurements
  - Additional measurements (to augment the backbone) are likely not going to be at the same level of accuracy/precision. What is the level of acceptable degradation in terms of noise, number of channels, resolution, etc?

Wavelength Selection – Based on your experience…

- Which IR wavelengths are most critical/impactful for NWP models?
  - At which wavelengths will improving temporal coverage be most impactful? (i.e., which layers of the atmosphere change the fastest)
  - What would be the impact of having SW and MW channels only (IR-MID- level instruments) in supplemental orbits?
  - What would be the impact of having limited channels only (IR-LOW- level instruments) in supplemental orbits?

- Which wavelengths are used/required in other applications?
  - Atmospheric composition
  - Radiation budget
  - 3D winds

Other Factors

- What is the impact of IR soundings in regional and global models?
- What is the optimum latency for regional and global models?
- Do IR and microwave sounders need to be co-located on the same platform like JPSS, Metop etc or can they be on free flying satellites?
- Impact of IR sounders on reanalysis for climate studies
- Do you use IR soundings for both retrievals as well as direct assimilation in operations? How are retrievals used?
- Are IR soundings used at the Field of Regard resolution or at the Field of View resolution?
- Are there other factors that we should consider?

Thank You!