Infrared sounding of the boundary layer: potential benefits of high ~~spatial~~ resolution

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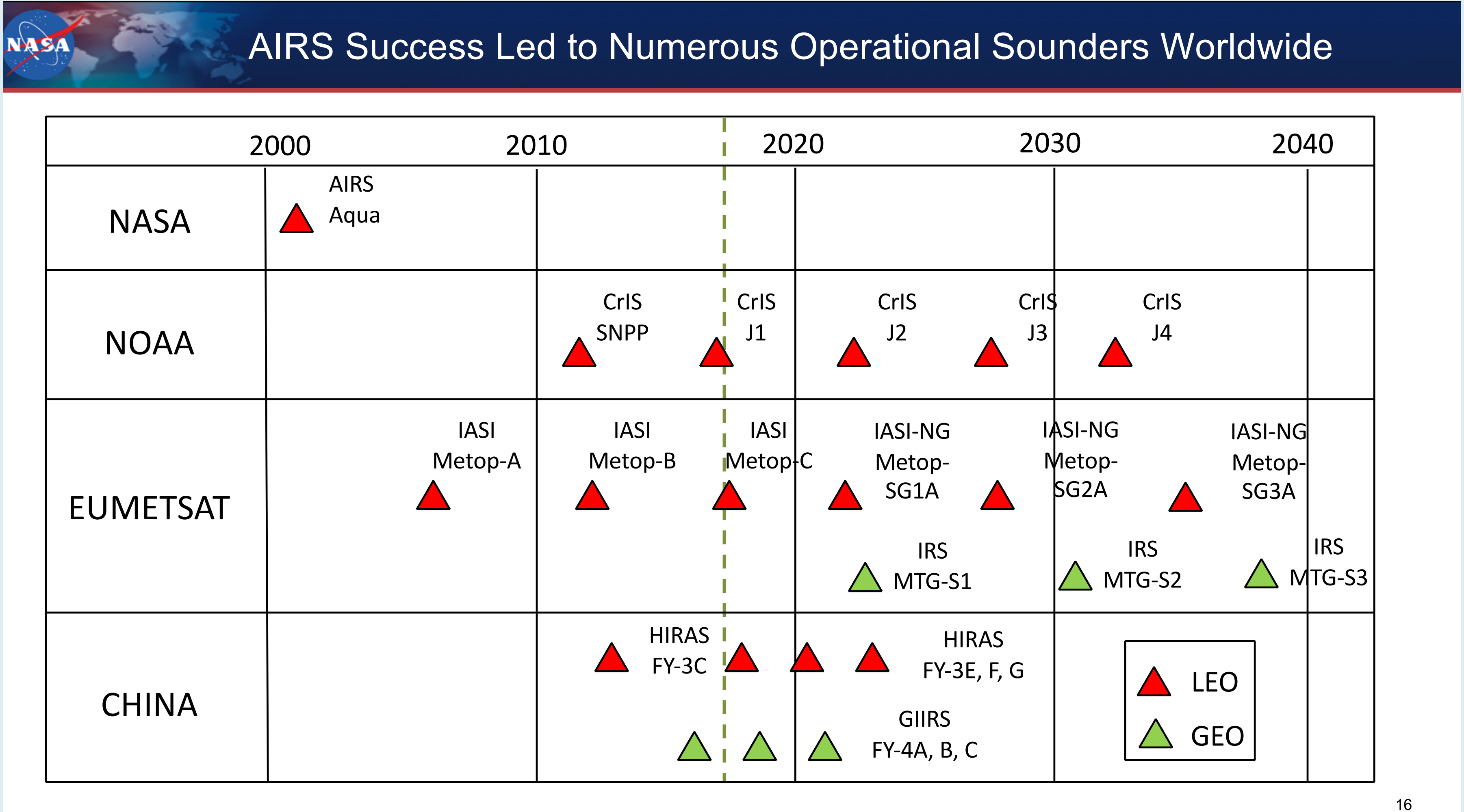
Today's Talk

- Motivate science where high resolution might be needed.
- Tie science in the 2017 Earth Sciences Decadal Survey to sounding.
- Show some enabling technology

Currently Five Hyperspectral Infrared Instruments in LEO

International commitment to similar instruments through ~2035.

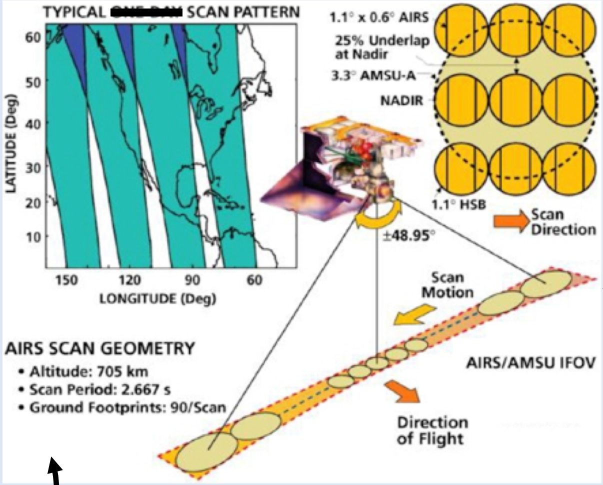
Infrared Instrument	AIRS	IASI	CrIS	IASI	CrIS
Start Date	31 Aug 2002	19 Oct 2006	28 Oct 2011	17 Sep 2012	18 Nov 2014
Agency	NASA	EUMETSAT	NOAA	EUMETSAT	NOAA
Satellite	Aqua	MetOp-A	S-NPP	MetOp-B	JPSS-1
Equator crossing time	1:30 PM	9:30 PM	1:30 PM	9:30 PM	1:30 PM
Orbit Period	98 minutes	101 minutes	101 min	101 minutes	101 min
Orbit altitude	700 km	817 km	817 km	817 km	817 km



From Tom's introductory remarks.

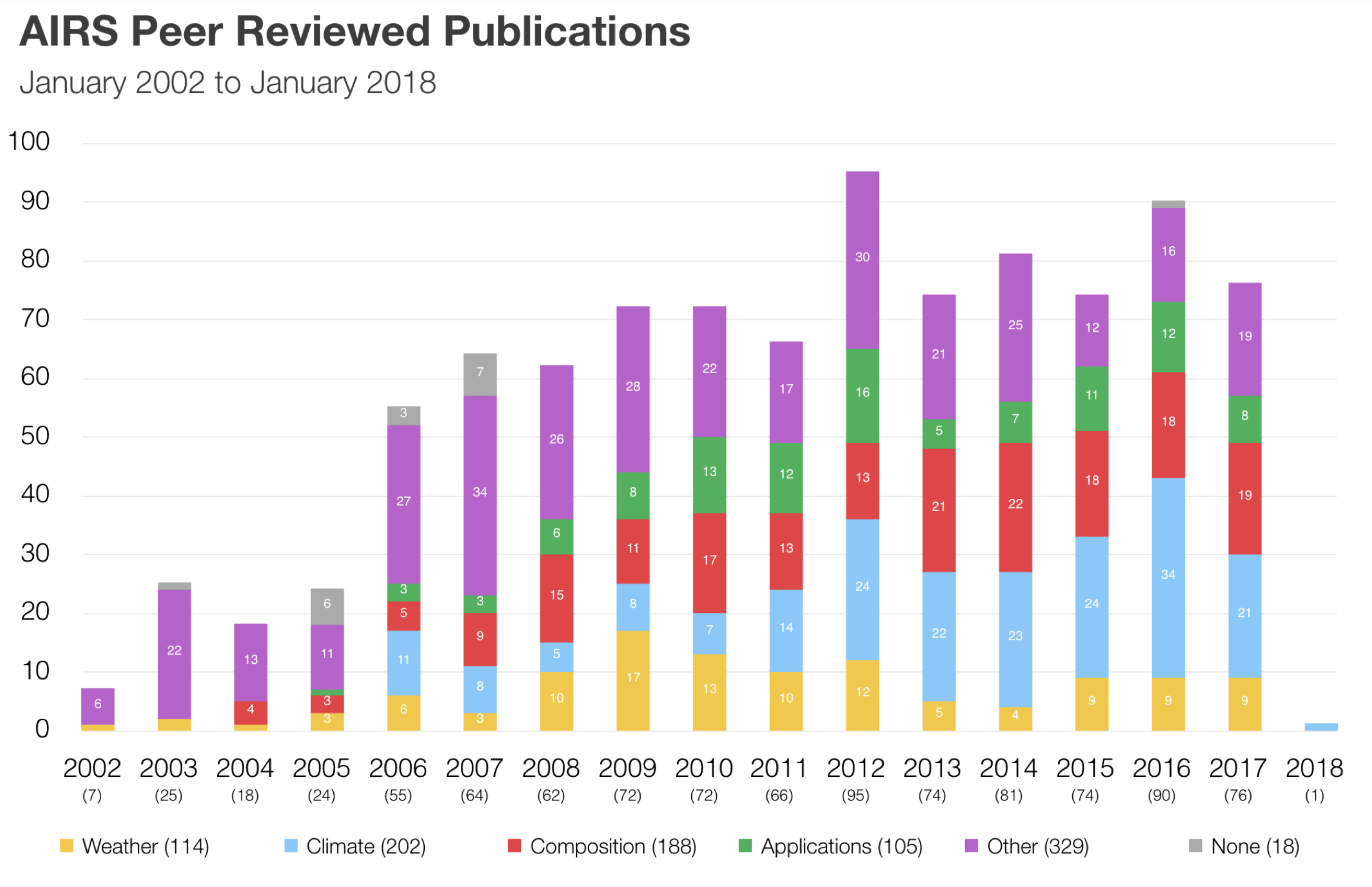
AIRS Geometry and Sampling

Broadly similar to the four other operating sounders

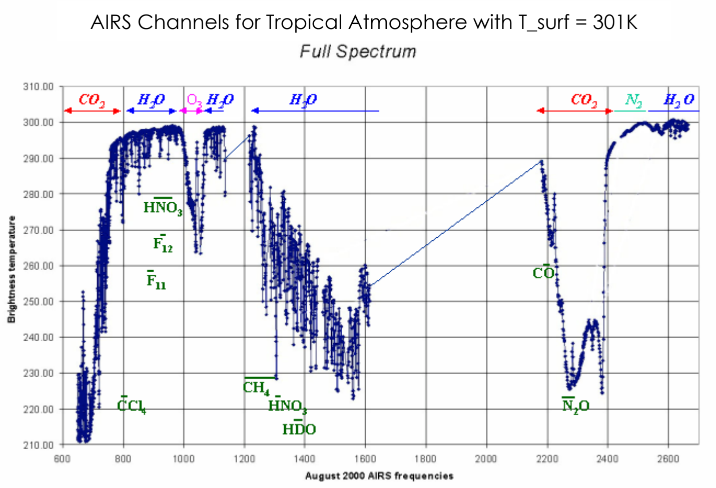


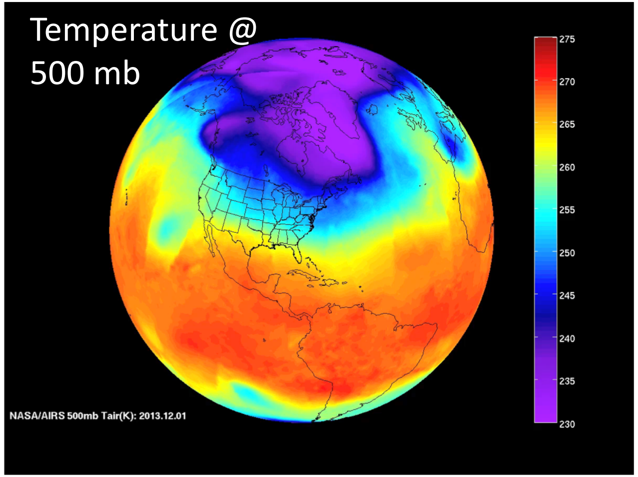
1. AMSU footprint, 45 km across at nadir, contains 9 AIRS spectra
   – THIS IS THE RETRIEVAL GRANULARITY.
2. Viewing swath 30 AMSU footprints or ~1650 km wide.
3. The result: 2,916,000 IR spectra and 324,000 retrievals per day

Lots of Good Science from AIRS and Other Sounders



IR Sounders Support Weather Forecasting and Climate Science





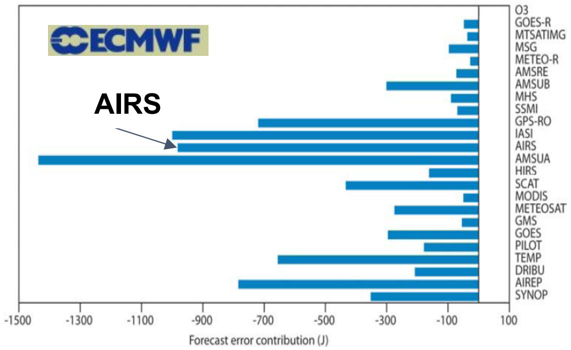
Infrared sounding from space supports weather and climate research and applications related to human health and aviation safety.

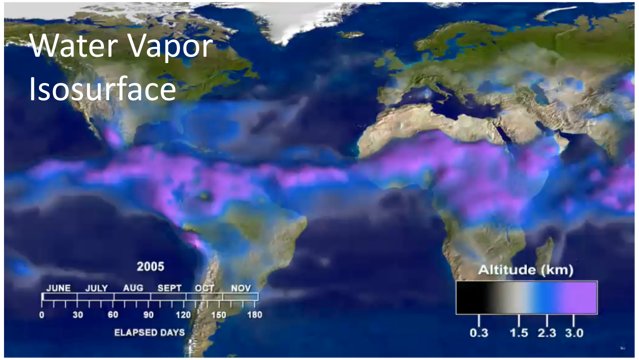
IR Sounder Radiances Assimilated into NWP Models

JPL/GSFC

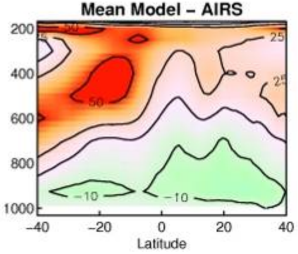
NOAA NESDIS/NCEP

JCSD

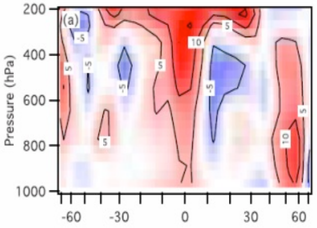




Water Vapor Climatology
(Pierce, Scripps, 2006)



Water Vapor Feedback
(Dessler, Texas A&M, 2008)



The Decadal Survey

Some relevant high-priority research areas:

- **Clouds, Convection and Precipitation**
  - Hyperspectral IR (and also microwave) sounders specifically mentioned.
- **Atmospheric Winds**
  - Another mention: motion vector winds from IR and MW.

- **Boundary Layer Structure**

- **Surface Geology and Biology**
  - Atmospheric information needed for surface interactions.

High spatial resolution near-surface atmospheric temperature and water vapor observations to improve prediction of drought and vector borne disease outbreak and advance weather forecasting models

Community Input White Paper for the

Committee on Earth Science and Applications from Space

ESAS 2017 Request for Information (RFI #2)

May 15, 2016

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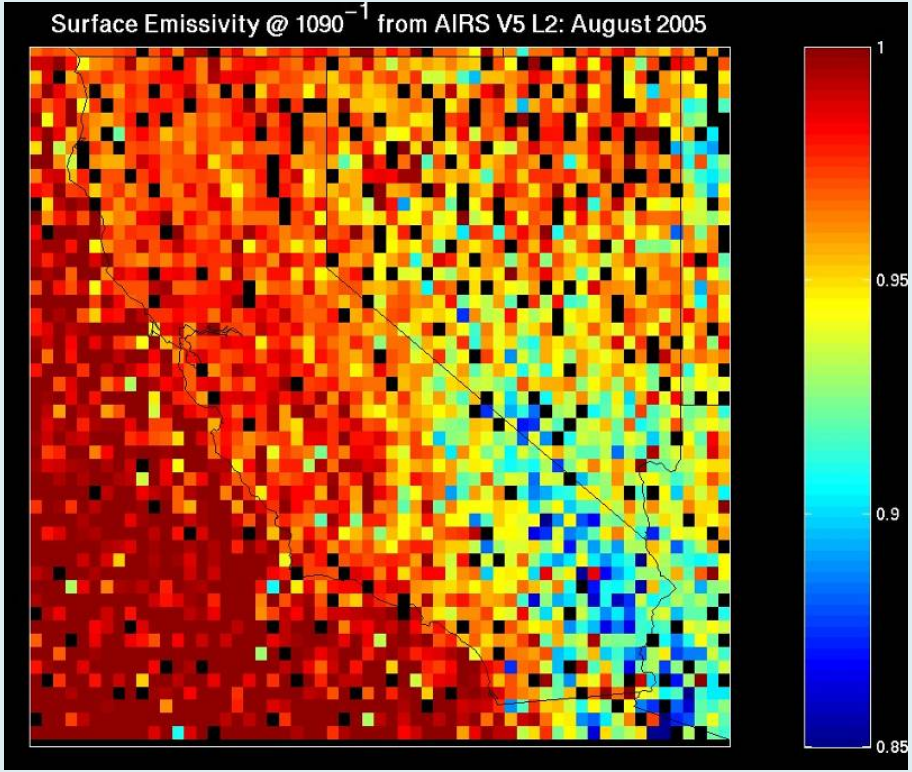
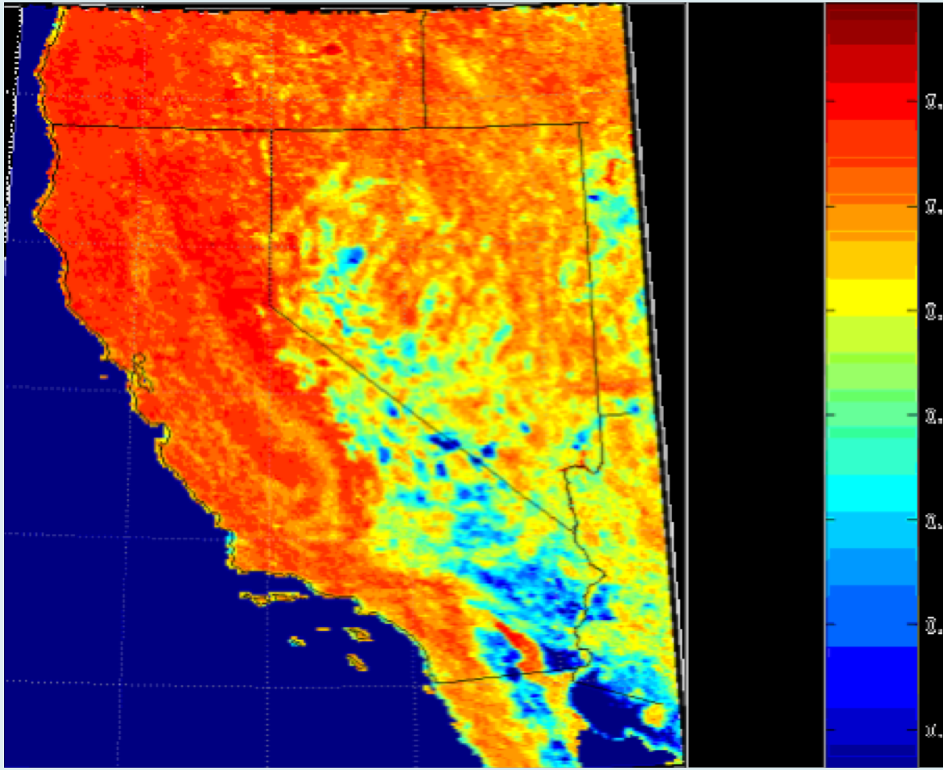
Why High Spatial Resolution Matters

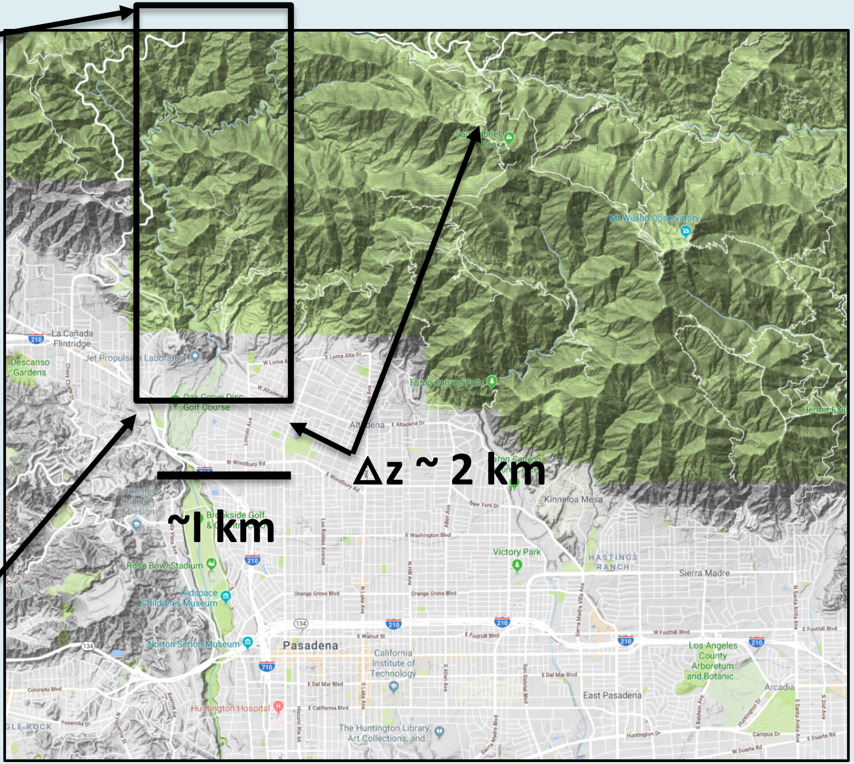




Left: surface emissivity as observed by AIRS/AMSU at 45 km resolution. Right: emissivity as observed by MODIS at 5 km resolution. Hulley et al., from Decadal Survey White Paper.

Topography and emissivity can be as variable as clouds at scales of kilometers

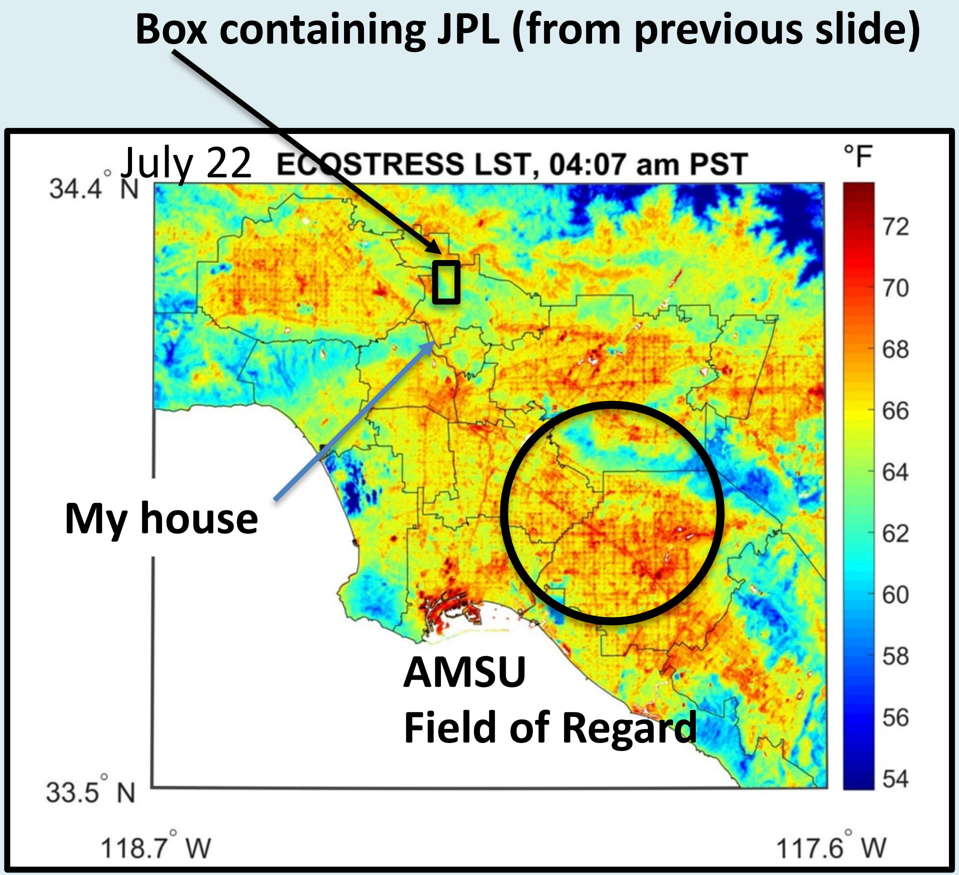
JPL



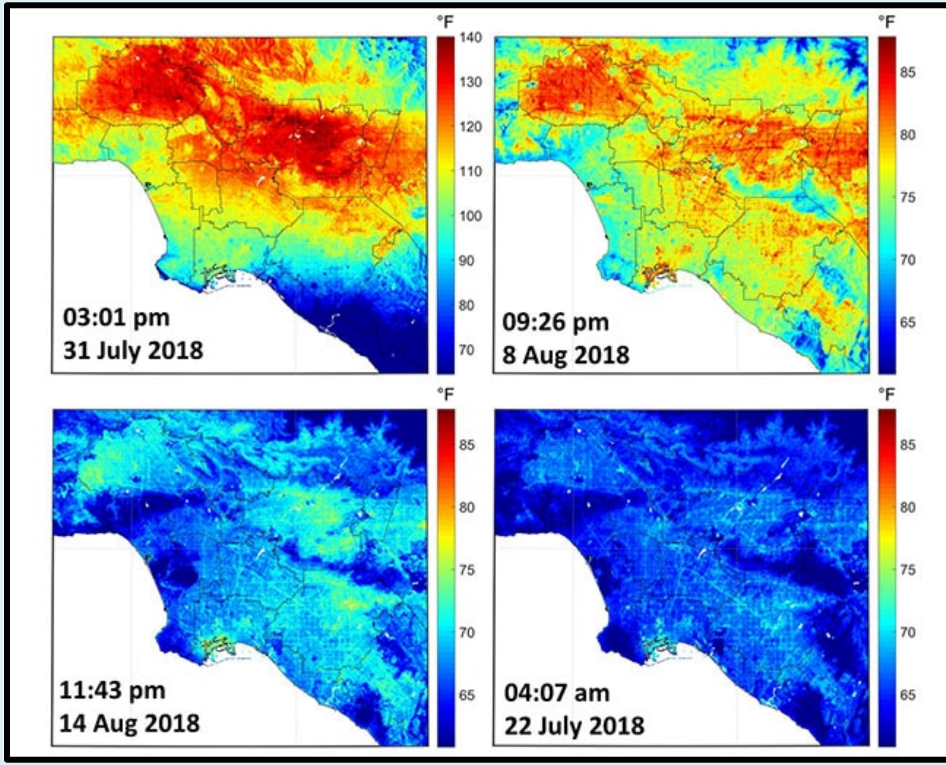
JPL and vicinity

ECOSTRESS 70 m Land Surface Temperatures

What is the near-surface atmosphere doing at ~1 km resolution?



Can't ignore the diurnal cycle

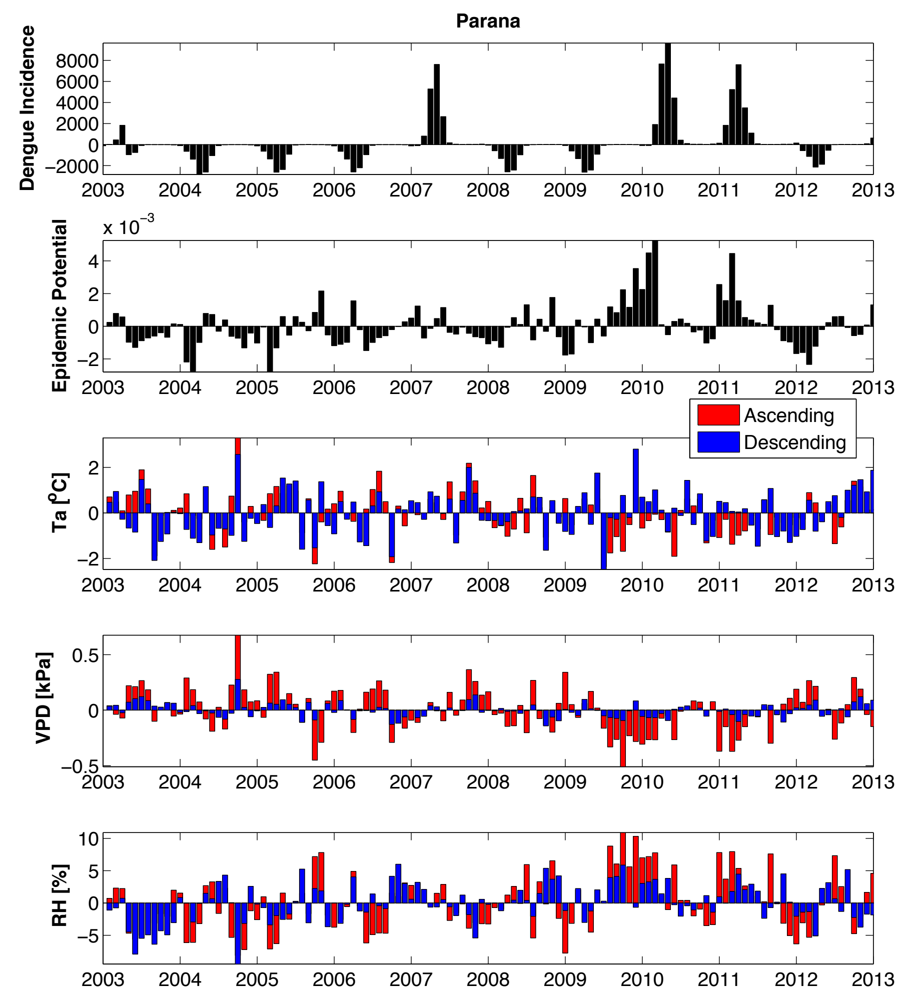


Some Effects are Very Local:

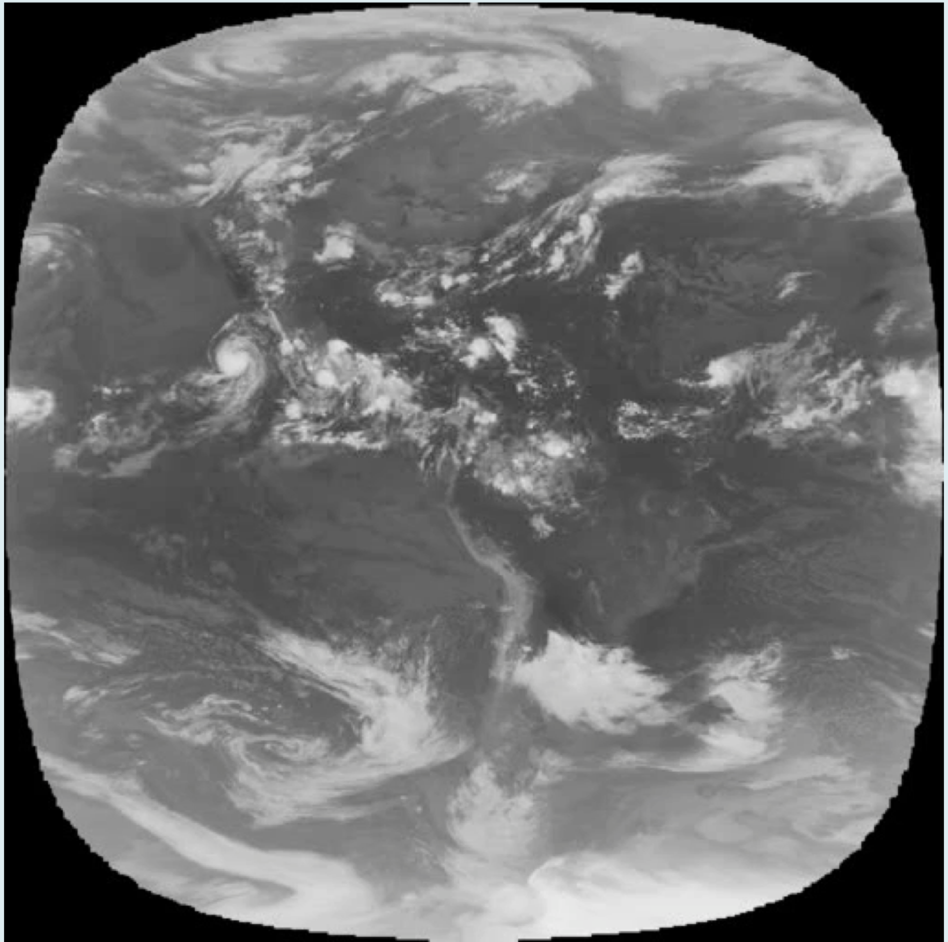
Mosquitoes and Dengue Fever

Dengue fever incidence in the Brazilian state of Parana (top curve) was preceded by high epidemic potential (second curve), and warm, humid conditions as indicated by the bottom three curves of AIRS-derived surface air temperature, vapor pressure deficit and relative humidity, respectively. Here ascending / descending indicates daytime/nighttime conditions. Note in particular that the dengue fever outbreaks in 2010 and 2011 are preceded by low nighttime vapor pressure deficit and high relative humidity.

Darren Drewry, from Decadal Survey white paper.

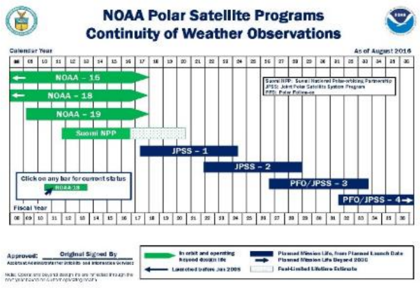


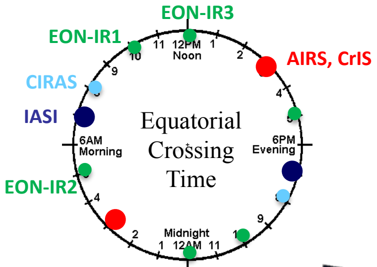
Can’t ignore the diurnal cycle: GOES IR

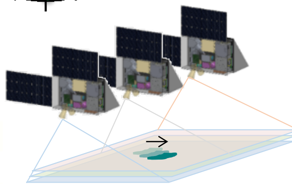


IR Sounder CubeSats Support a Wide Range of Uses

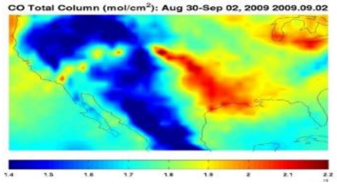
- Gap Mitigation
  - Support the NOAA Joint Polar Satellite System (JPSS) project as a gap mitigation of infrared sounding in the event of a loss of the Cross-track Infrared Sounder (CrIS) instrument
- Improved Timeliness
  - Low cost of IR Sounder CubeSats lends itself to placement in orbits to complement existing sounders and improve revisit time
- 3D AMV Winds
  - 2 or 3 instruments flown in formation and separated in time by 15 min – 1 hr would measure 3D Atmospheric Motion Vector (AMV) winds
- Atmospheric Turbulence
  - Trading a larger telescope for the scan capability enables hyperspectral imaging at high spatial resolutions enabling measurements of atmospheric turbulence
- Atmospheric Chemistry
  - The CubeSat IR Sounders can be tailored to see a variety of gases in addition to CO including N2O and HDO with moderate to high spatial resolution.







AIRS Carbon Monoxide



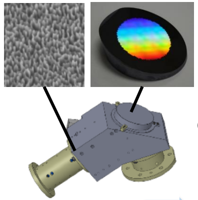
Grating Spectrometer Atmospheric Infrared Sounder Technology Development at NASA JPL and Industry

AIRS | MIRIS | CIRAS

Spectrometers

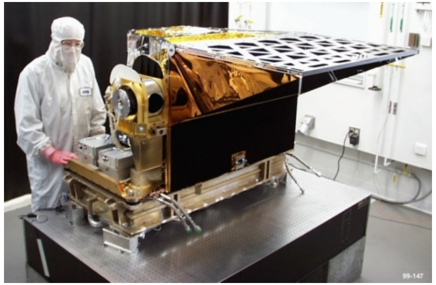
AIRS
BAE Systems
Pupil-Imaging
Grating Spectrometer
FOV = 1.1°
D = 2 mm

SIRAS, SIRAS-G
Ball Aerospace
Imaging MWIR
Grating Spectrometer
FOV = 16°
D = 25 mm

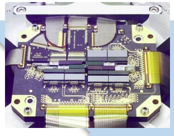


CIRAS
Ball Aerospace /
JPL Imaging
MWIR Immersion
Grating Spectrometer
FOV = 16°
D = 15 mm

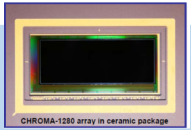
AIRS
2002



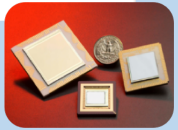
Detectors



AIRS
BAE Systems
PV/PC HgCdTe
17 modules
2 x ~180
100 x 50 um

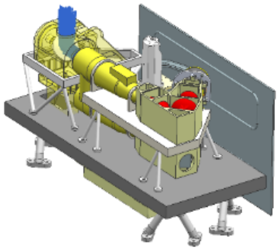


CHROMA
Teledyne
PV HgCdTe
13.5 um Cutoff
480 x 1280
30 x 30 um

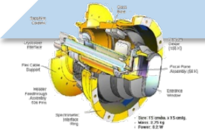


HOTBIRD
JPL
5.5 um Cutoff
640x512
24 x 24um

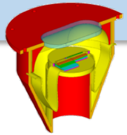
MIRIS
2010
(Concept)



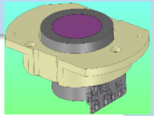
Dewars



AIRS
BAE Systems
Cryo Dewar

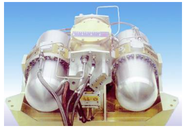


SIRAS
Ball Aerospace
Reflecting
Warmshields



CIRAS
IR Cameras
IDCA

Cryocoolers

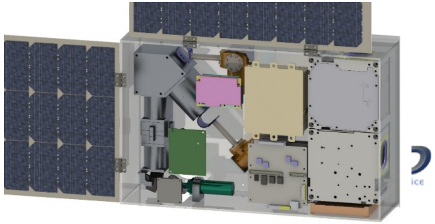


AIRS
Northrop
Grumman
Pulse Tube
Cryocoolers

ABI / OCO-2
Northrop
Grumman
Smaller
Pulse Tube
Cryocoolers

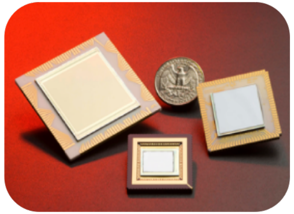
Ricor
K508
Integral Sterling
Cryocooler

CIRAS
(Concept)

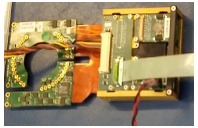


CubeSat Infrared Atmospheric Sounder (CIRAS) Hardware Subsystems

FPA HOTBIRD (JPL)

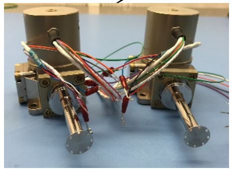


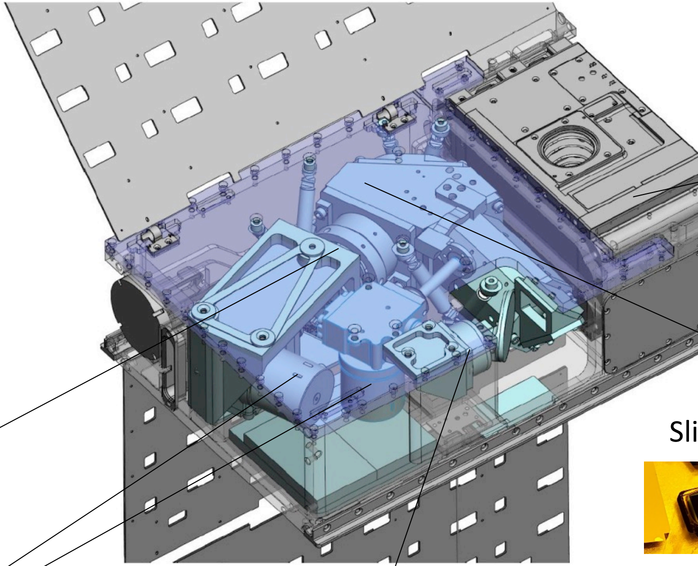
Camera Electronics (IR Cameras)



Dewar (IDCA) (IR Cameras)

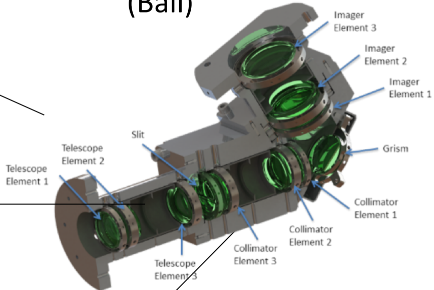
Cryocoolers + Electronics (Ricor K508N)





Spacecraft (BCT)

Optics Assembly (Ball)

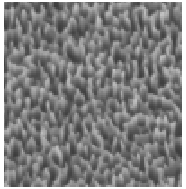


Slit (JPL)

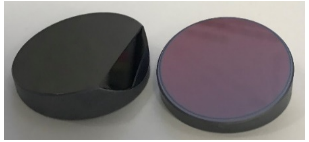
Payload Electronics

Stepper Motor + Mirror (Lin Eng)

Blackbody Assembly Black Silicon



Immersion Grating (JPL)



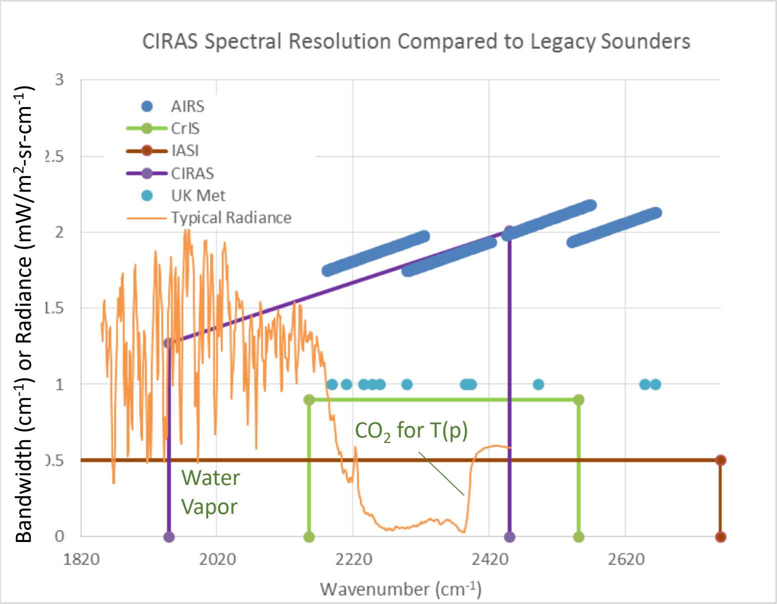
CIRAS spectral performance comparable to AIRS in the MWIR

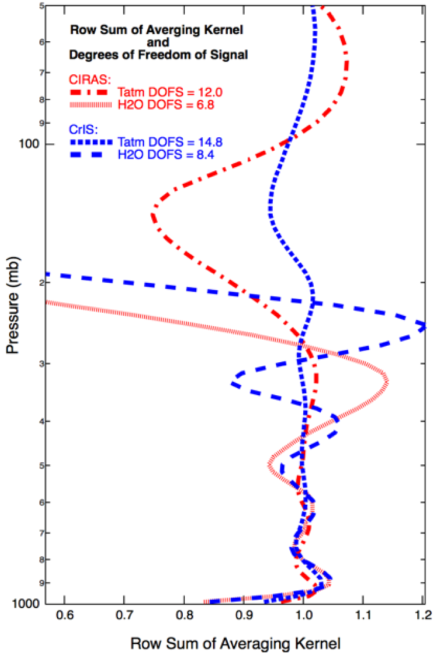
CIRAS Spectral like AIRS but Extends into the Water Band

1950 cm^{-1} – 2450 cm^{-1}

$\Delta\nu$ = 1.2-2.0 cm^{-1} , N_{ch} = 625

CIRAS Information Content Extends from the Surface to 300 mb

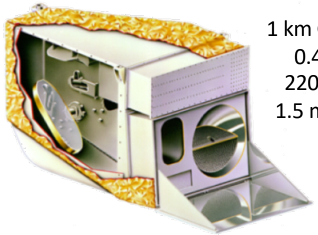




MIRIS + OCI Can be Next Gen Imager Sounder Facility Instruments

NASA (Aqua/Terra) 1999-2022

MODIS



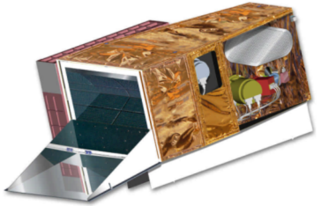
1 km GSD, ±55°
0.4-14.4 μm
220 kg, 160 W
1.5 m^3, 11 Mbps

AIRS

14 km GSD, ±49.5°
2378 Channels
0.4-15.4 μm
177 kg, 256 W
0.9 m^3, 1.3 Mbps

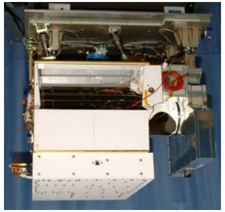
NPP/JPSS 2011-2038?

VIIRS



<1 km GSD, ±55°
0.4-14.4 μm
270 kg, 240W
1.5 m^3, 11 Mbps

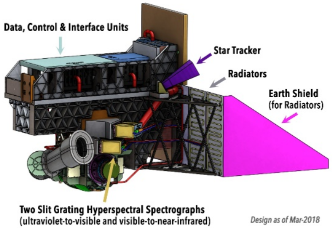
CrIS



14 km GSD, ±48.3°
1305 Channels
165 kg, 135 W,
0.5 m^3, 1.5 Mbps

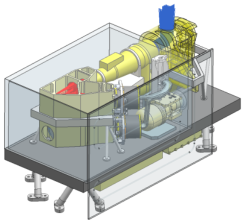
Future = Hyperspectral > 2038?

OCI



1 km GSD. ±58°
>100 Channels
0.35-2.26 μm
241 kg, 275 W
~0.75 m^3, 13 Mbps

MIRIS



0.25 x 0.5 km Imaging
<2 km Sounding
Scans ±55°
4096 Channels
3.3-15.4 μm
100 kg, 150 W
0.5 m^3, 40 Mbps

T.S. Pagano, C.R. McClain, "Evolution of Satellite Imagers and Sounders for Low Earth Orbit and Technology Directions at NASA', Proc. SPIE, 7807-20, San Diego, California, August 2010

From Tom's introductory remarks.

Summary and Questions

Five currently orbiting operational LEO sounders

- **Others planned into the 2030s.**

Planned sounders will not be able to characterize behavior at fine spatial (and temporal) scales.

- **Technology improvements will enable new capabilities.**

What about retrievals at fine scales (especially spatial)?

- **Aircraft data could be a useful testbed.**

What about constraints to models at ~5 km resolution?