National Environmental Satellite, Data, and Information Service

WMO Concept Study of a Global Space-based Inter-Calibration System (GSICS).

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GEOSS

- GEOSS – international coordinated effort to share Earth observations to provide a level of information about the Earth not previously achieved.
- Goal is to provide better information and understanding of the Earth's environment (past, present and future), which in turn empowers the public, private sector and government with informed decision making

Objectives and Goals

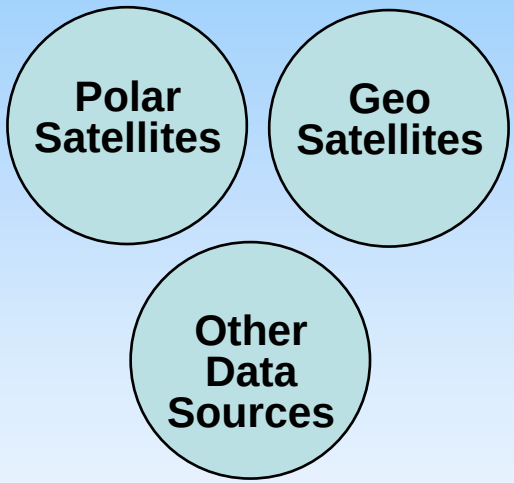
- Cooperation and collaboration in building an integrated global earth observation system
- Expansion of earth observation science, monitoring technology and applications
- Collaborative data exchange
- Integrated Processing Systems

Elements of Integrated Earth Observing System

- Research and operational observation instruments and platforms
- In situ and remote sensing observation networks
- Event-driven and model-driven target observations using in situ obs. and very high spatial resolution sounder/imagers
- Communication links and computing capacity
- Very strong R&D program to develop scientific algorithms for:
  - Intercalibration of the measurements
  - Advanced Products (Information) using multiple observations
  - Earth-System Models

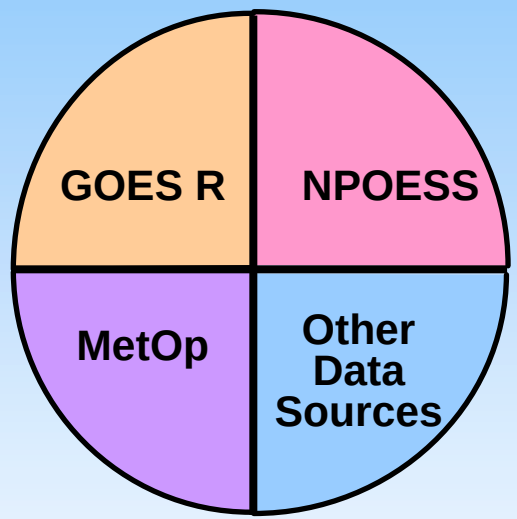
Goal - Transition Products from Individual Satellites to a "System of Systems"

Today



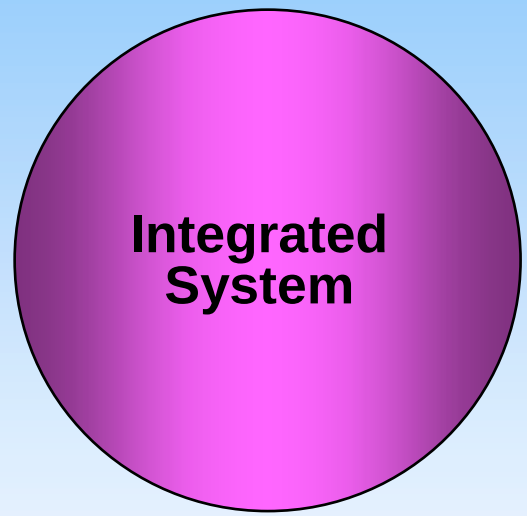
Environmental Products that are mostly generated from observations that are independent of one another

2008-2016



Formulate and Integrate Environmental products using GOES-R series, NPOESS series, and MetOp satellites along with Other Structured Data Sources

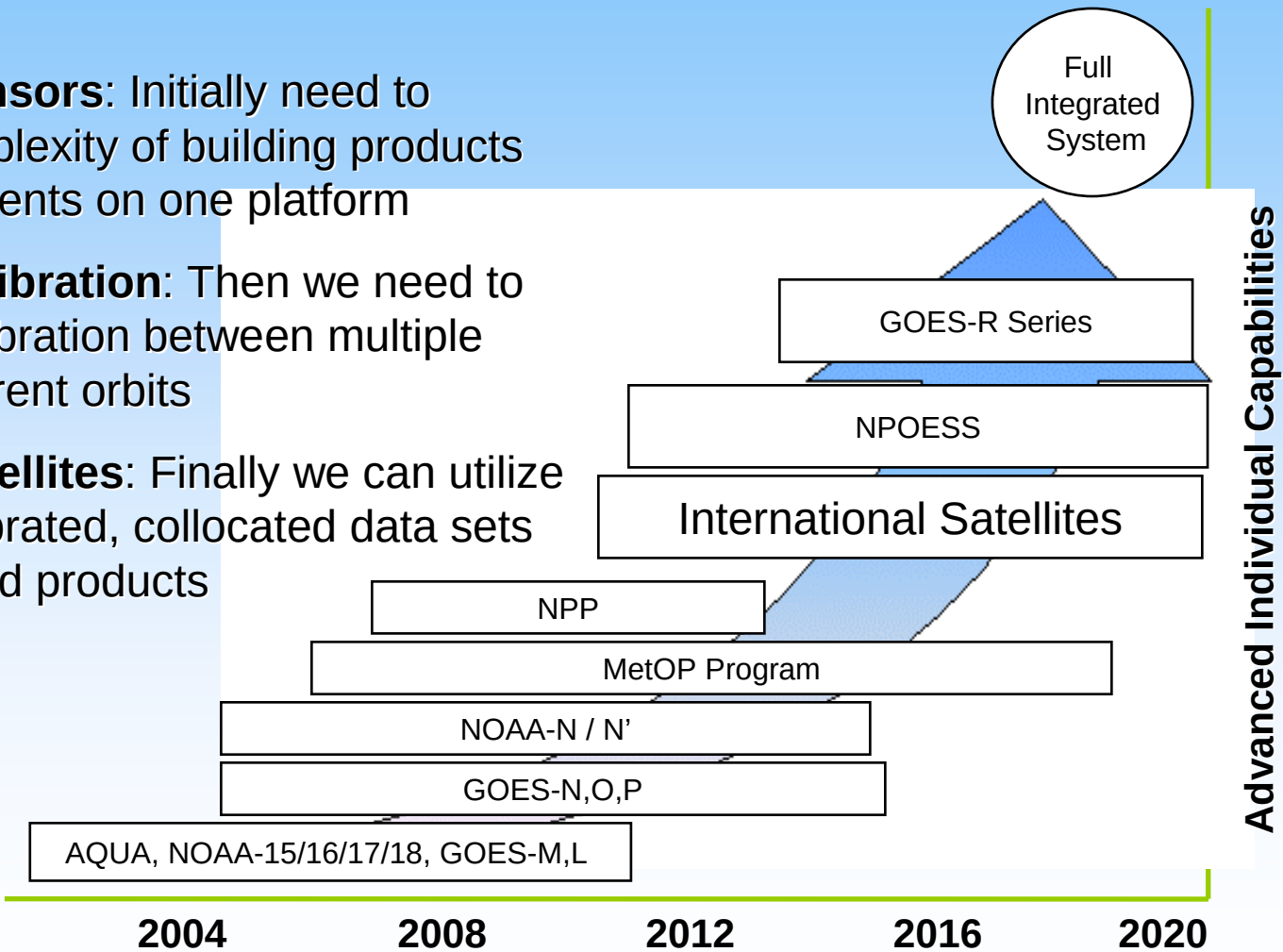
2016+



Products are formulated and produced as one integrated system

Steps to Integrated Products and Systems

- **Integrated Sensors**: Initially need to simplify the complexity of building products between instruments on one platform
- **Integrated Calibration**: Then we need to evaluate the calibration between multiple satellites at different orbits
- **Integrated Satellites**: Finally we can utilize these cross-calibrated, collocated data sets to build enhanced products



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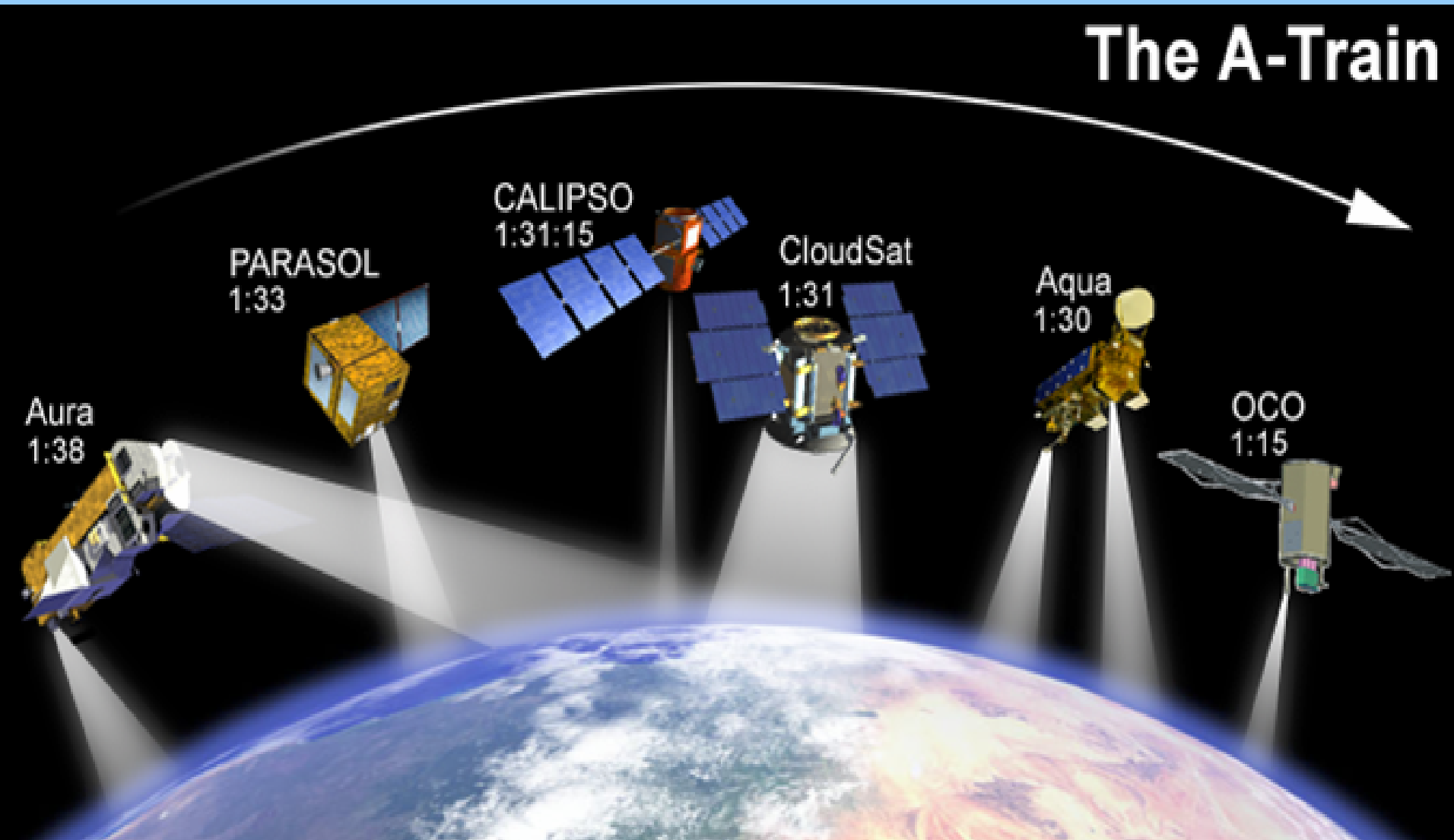
Future opportunities for Data Fusion Pilot Studies



Background

Satellite intercalibration requirements are now part of the GCOS Climate Monitoring Principles

In response to the request by WMO and CEOS to address satellite intercalibration, the CGMS (Sochi, May 2004), the EUMETSAT SAF on Climate Monitoring (Hamburg, July 2004) and WMO's CBS (St. Petersburg, Feb. 2005) had detailed discussions and tasked the WMO Space Programme to help building an international consensus and consortium for a global space-based inter-calibration system for the World Weather Watch (WWW)/Global Observing System (GOS).

The Space Programme of WMO initiated a discussion and held two meetings (June and July 2005) to develop the concept of a Global Space-based Inter-Calibration System (GSICS). The following experts participated:

- Mitch Goldberg – NOAA/NESDIS (Chair)
- Gerald Frazer – NIST
- Donald Hinsman – WMO (Space Program Director)
- John LeMarshall - JC Sat. Data Assimilation
- Paul Menzel –NOAA/NESDIS
- Tillmann Mohr – WMO
- Hank Revercomb – Univ. of Wisconsin
- Johannes Schmetz – Eumetsat
- Jörg Schulz – DWD, CM SAF
- William Smith – Hampton University
- Steve Ungar – CEOS, Chairman WG Cal/Val

Position Statements

To integrate observations and products from different satellite systems, the measurements must be inter-calibrated. Without inter-calibration of the space-based component of the WWW's GOS and of GEOSS, the full benefit of the observations will not be realized.

The purpose of inter-calibration is to quantitatively relate the radiances from different sensors viewing the same target to allow consistent measurements to be taken over the globe by all elements of the space-based observing system

Objectives

- The objectives for the operational Global Space-based Inter-calibration Systems (GSICS) are:
  - Primary goal: To improve the use of space-based global observations for weather, climate and environmental applications through operational inter-calibration of satellite sensors.
  - Secondary goal: To provide for the ability to retrospectively re-calibrate archive satellite data using the operational inter-calibration system in order to make satellite data archives worthy for climate studies

Enabler

- An operational global space-based inter-calibration system to better characterize space-based observations by measuring, documenting, understanding and accounting for differences between different sensors viewing the same target - **analyses of the differences will provide for recommended actions to meet the following benefits.**

Benefits

- High-level
  - Enhanced usefulness of satellite products to observe climate variability
  - Improved utility (ease of use) of satellite radiances in NWP
  - Improved cost-benefit ratio from an optimized global system of satellites.
- Technical
  - Consistent calibration of space-based radiometers
  - Allows adjustments to sensors with less stringent stability
  - Significantly improved characterization of space-based radiometers
  - Move towards absolute calibration; this would also necessitate a reference measurement network
  - Improve understanding of physical processes in atmospheric models (requires absolute calibration)

Prerequisites

- Extensive pre-launch characterization of all instruments traceable to SI standards
- Some instruments in space with appropriate accuracy, spectral coverage and resolution to act as a standard for inter-calibration
- Independent observations (calibration/validation sites – ground based, aircraft)

Building Blocks for Satellite Intercalibration

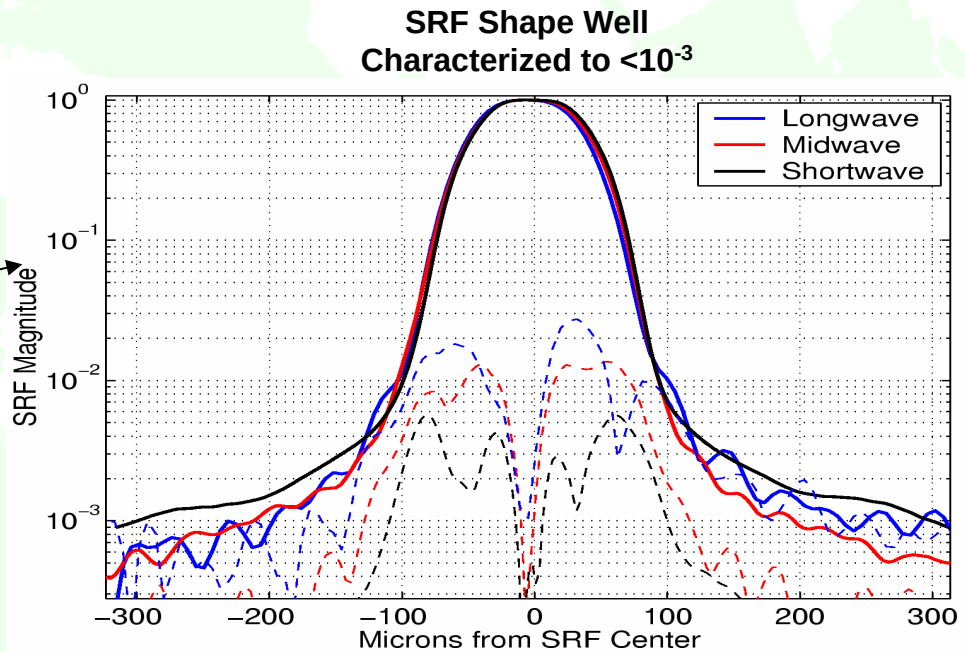
- Collocation
  - Determination and distribution of locations for simultaneous observations by different sensors (space-based and in-situ)
  - Collocation with benchmark measurements
- Data collection
  - Archive, metadata - easily accessible
- Coordinated operational data analyses
  - Processing centers for assembling collocated data
  - Expert teams
- Assessments
  - communication including recommendations
  - Vicarious coefficient updates for “drifting” sensors

Summary

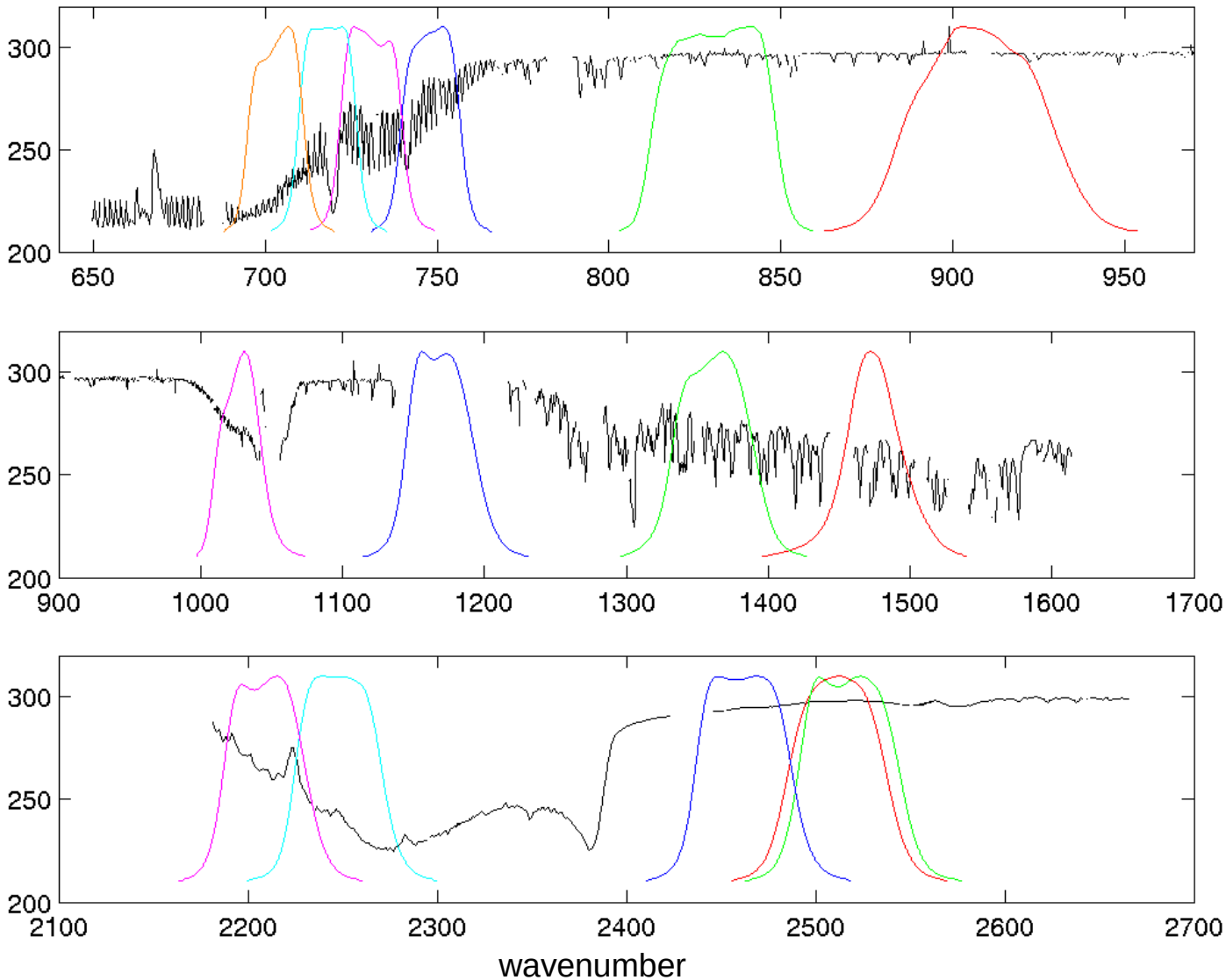
- Phase 1 concept study – completed
- Phase 2 – begin in January – development of a implementation plan

Intra-Calibration Example: MODIS from AIRS

AIRS



AIRS spectrum and Aqua MODIS Band Spectral Response Functions



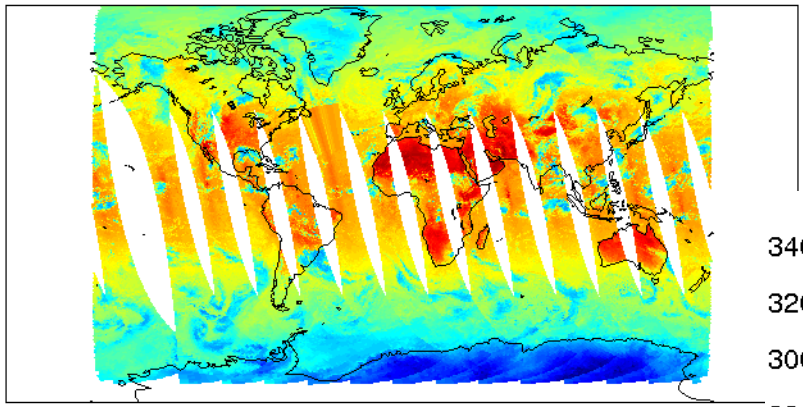
MODIS Band / wavelength(μm)

36 / 14.2
35 / 13.9
34 / 13.7
33 / 13.4
32 / 12.0
31 / 11.0

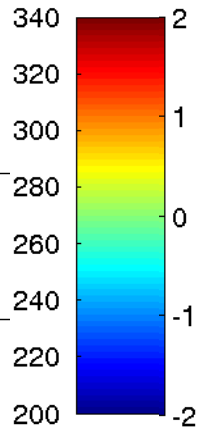
30 / 11.0
29 / 9.7
28 / 7.3
27 / 6.8

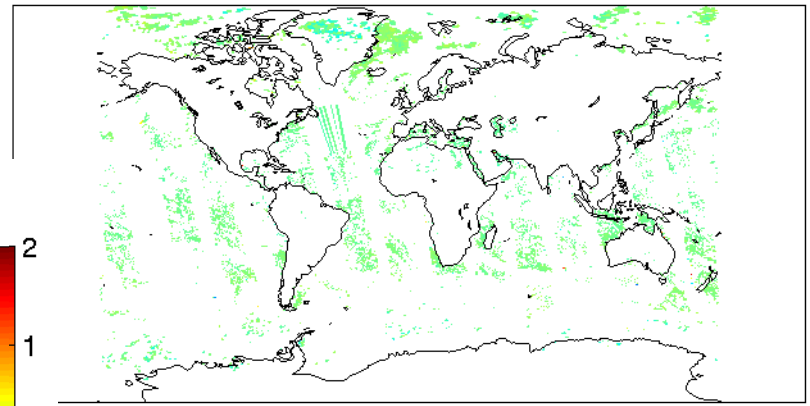
25 / 4.5
24 / 4.4
23 / 4.1
22 / 4.0
21 / 4.0

Fantastic AIRS - MODIS Agreement for Band 22 (4.0μm)!

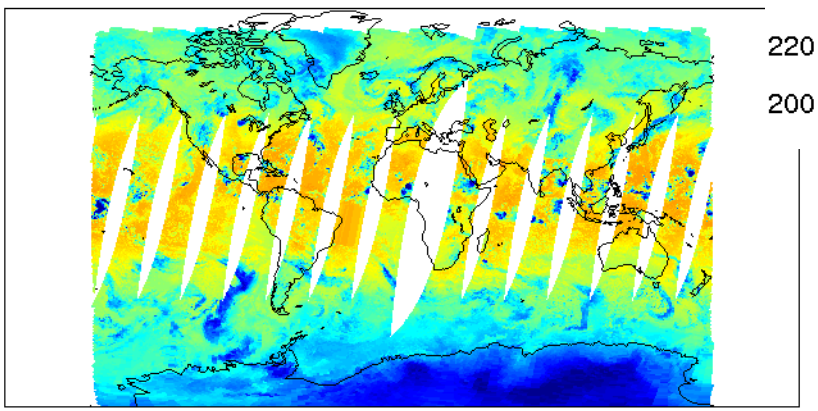


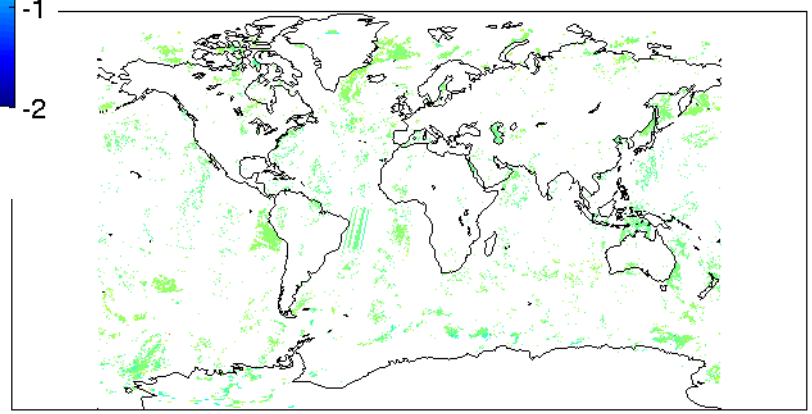
AIRS Tb (K)

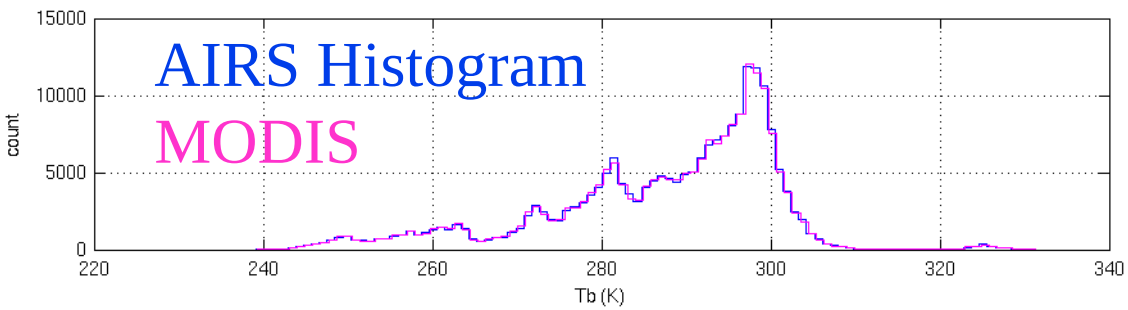




AIRS minus MODIS (K)

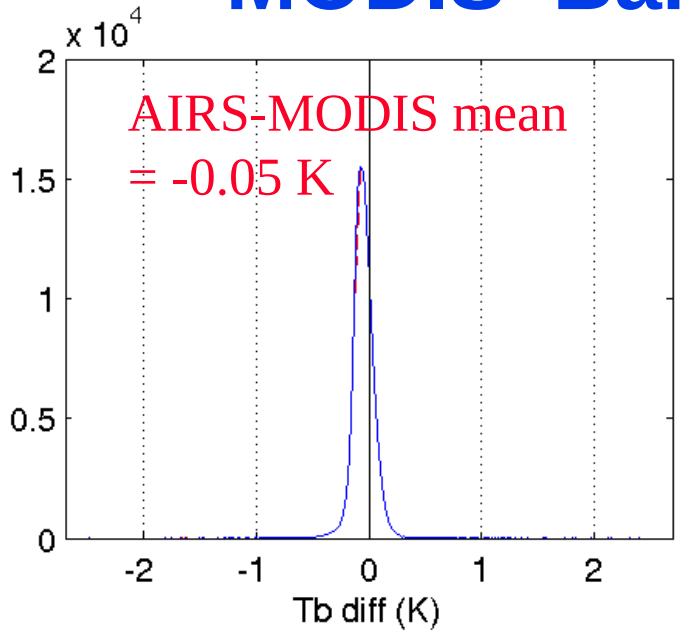


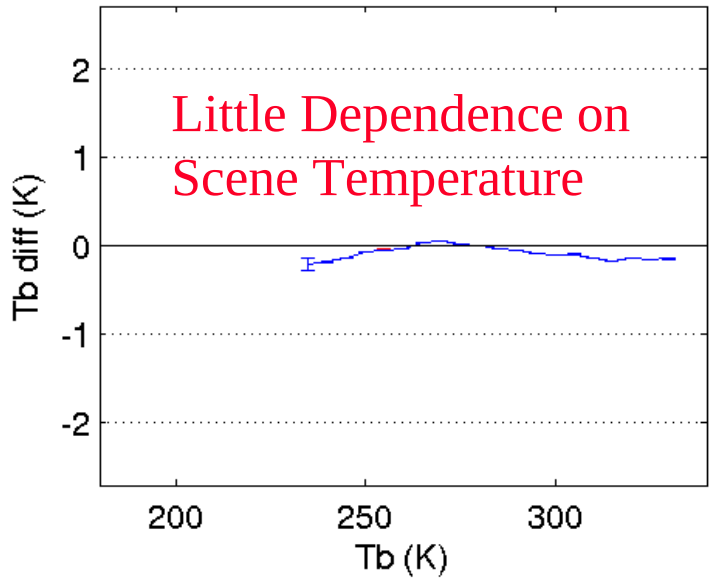


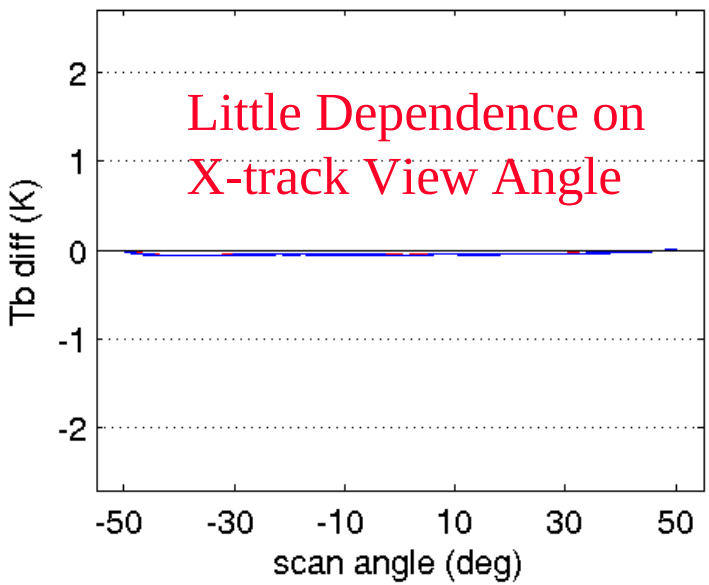


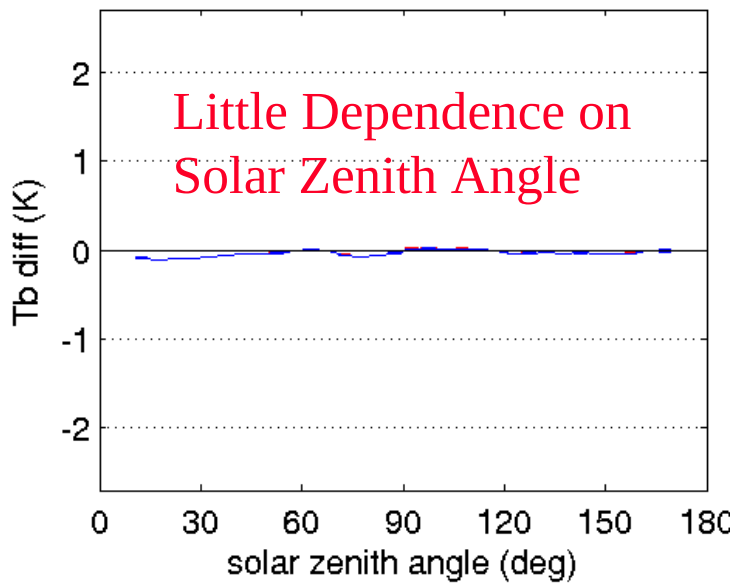
Uniform Scenes Selected

MODIS Band 22 (4.0μm)





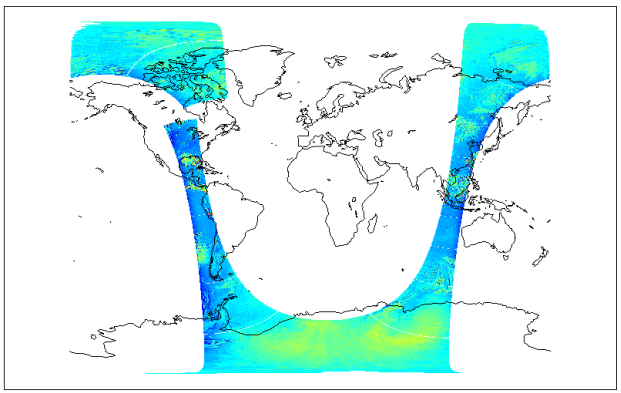


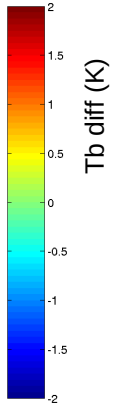


Shifting MODIS Band 35 (13.9 μm) by 0.8 cm^{-1} Works

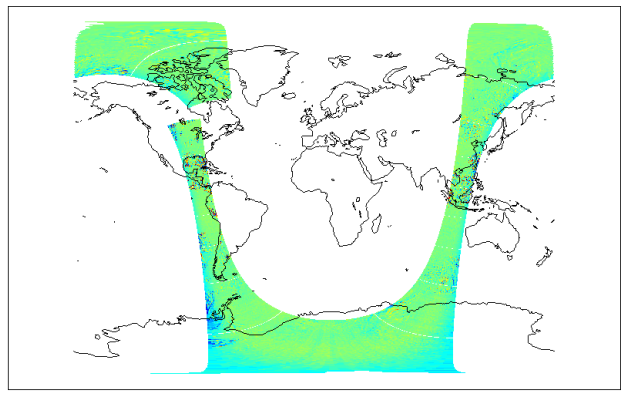
to Remove Mean bias and Scene Tb Dependence

No Shift

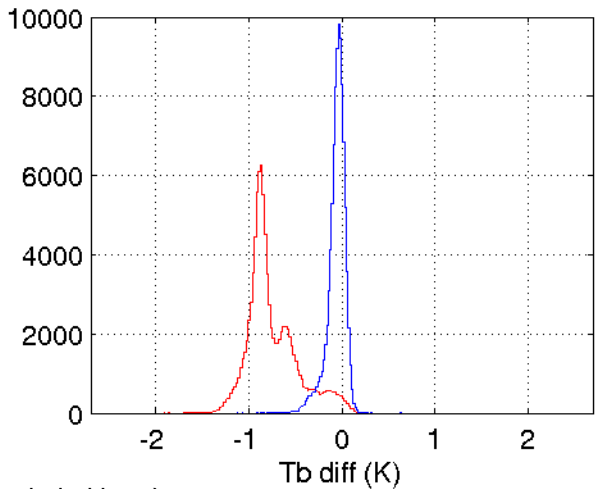


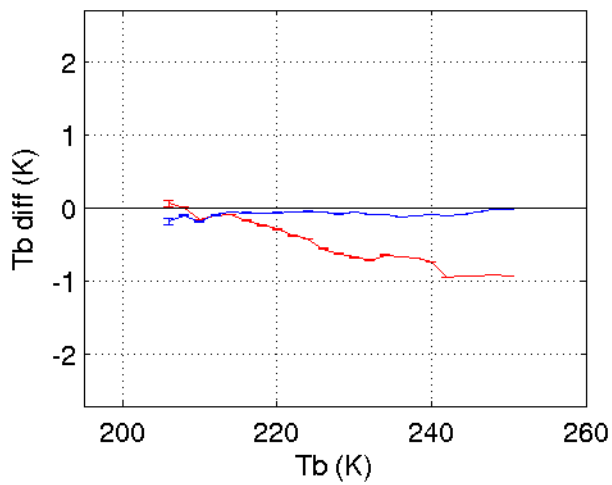


MODIS shifted



AIRS-MODIS: un-shifted, shifted





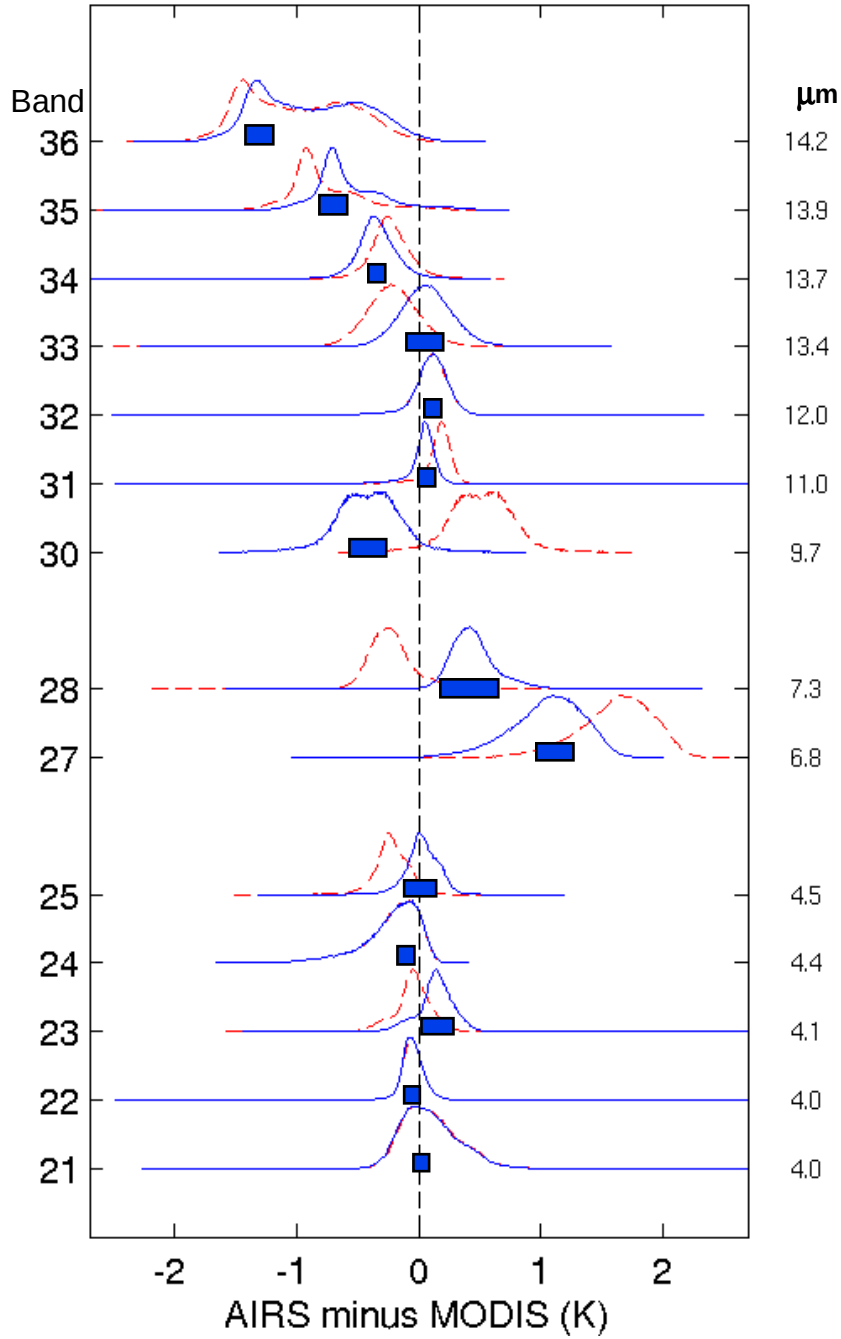
(ce (0.21K) not included here)

Summary of AIRS-MODIS mean Tb differences

Red=without accounting for convolution error
Blue=accounting for convolution error with mean correction from standard atmospheres

p-p Convolution Error (CE) Estimate

Band	Diff	CE	Diff	Std	N
21	0.10	-0.01	0.09	0.23	187487
22	-0.05	-0.00	-0.05	0.10	210762
23	-0.05	0.19	0.14	0.16	244064
24	-0.23	0.00	-0.22	0.24	559547
25	-0.22	0.25	0.03	0.13	453068
27	1.62	-0.57	1.05	0.30	1044122
28	-0.19	0.67	0.48	0.25	1149593
30	0.51	-0.93	-0.41	0.26	172064
31	0.16	-0.13	0.03	0.12	322522
32	0.10	0.00	0.10	0.16	330994
33	-0.21	0.28	0.07	0.21	716940
34	-0.23	-0.11	-0.34	0.15	1089663
35	-0.78	0.21	-0.57	0.28	1318406
36	-0.99	0.12	-0.88	0.43	1980369

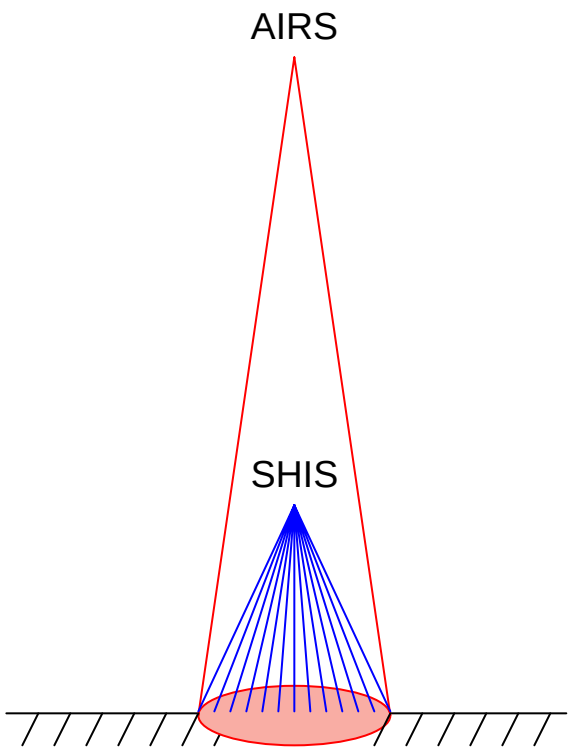


Satellite to Aircraft Intercomparisons

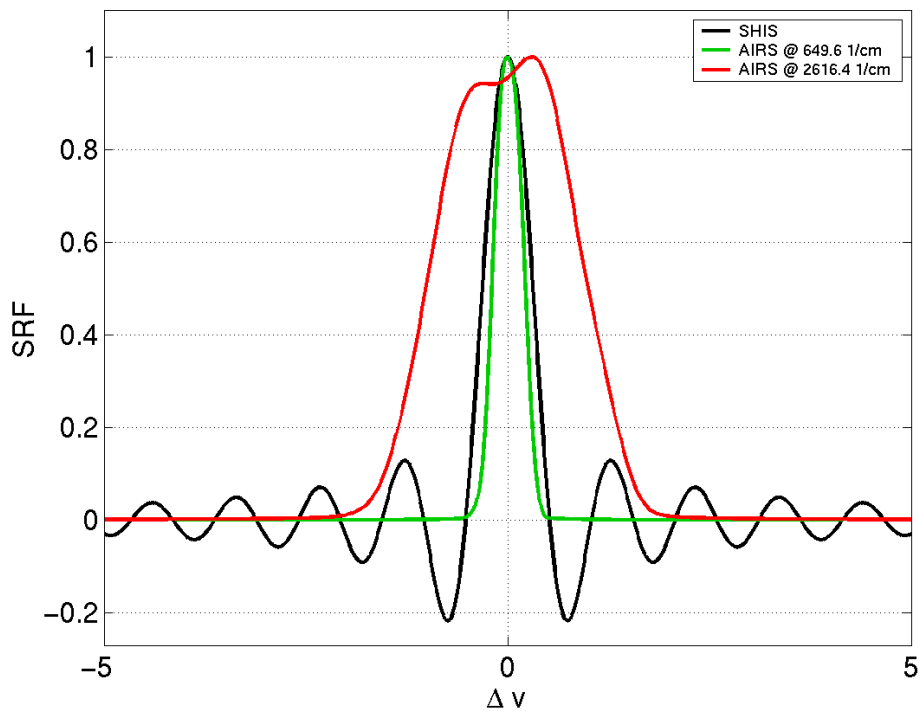
Very accurate observations need to be compared with other very accurate observations to confirm stability

A detailed comparison should account for:

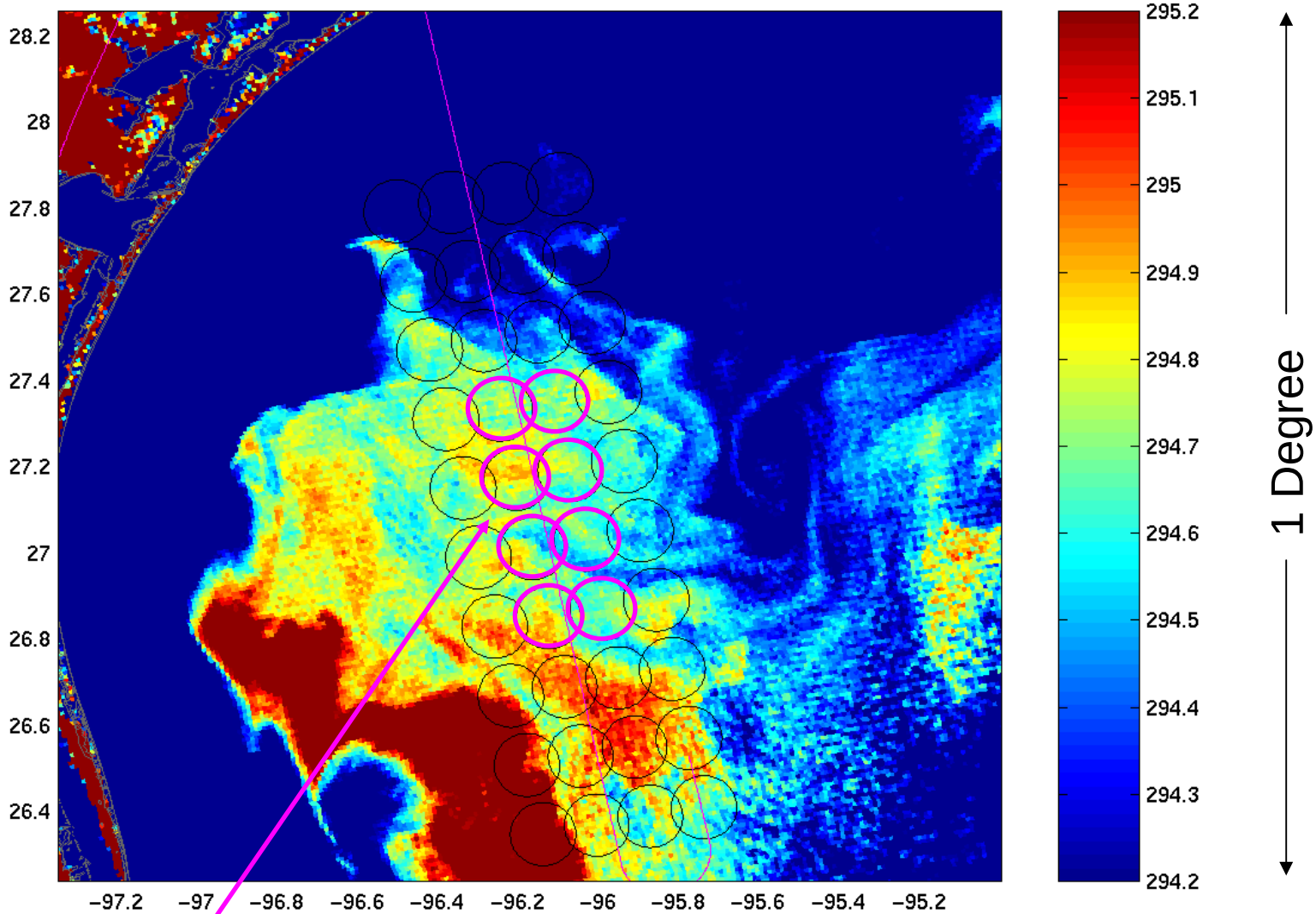
- instrumental noise and scene variations
- Different observation altitudes (AIRS is 705km, SHIS is ~20km)
- Different view angles (AIRS is near nadir, SHIS is ~±30deg from nadir)
- Different spatial footprints (AIRS is ~15km at nadir, SHIS is ~2km at nadir)
- Different spectral response (AIRS $\Delta\nu=\nu/1200$, SHIS $\Delta\nu=$~0.5 cm^{-1}) and sampling



SHIS and AIRS SRFs



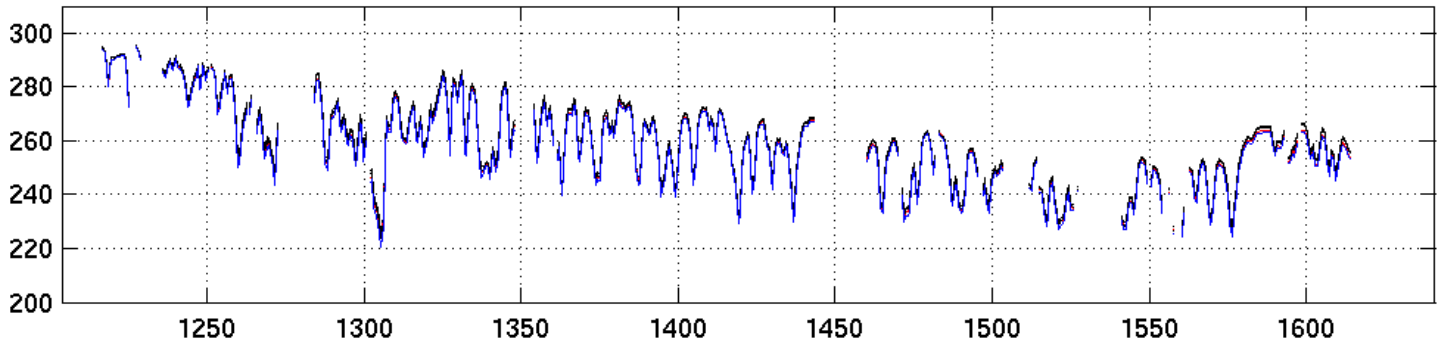
MODIS Band 32 and near-nadir AIRS FOVs



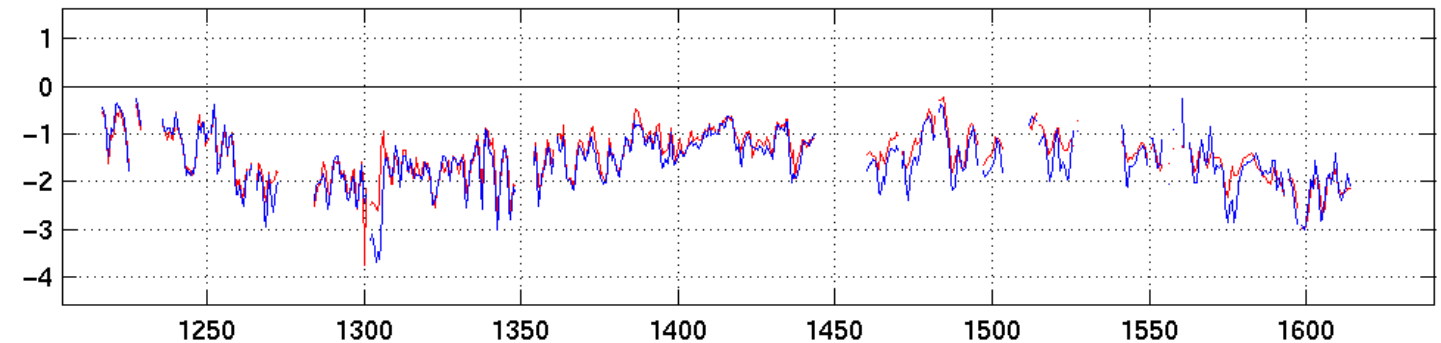
8 AIRS FOVs and SHIS Data w/in them (448 fovs) used in the following comparisons

“comparison 3”

AIRSobs
SHISobs



(AIRSobs-AIRScalc)
(SHISobs-SHIScalc)



(AIRSobs-AIRScalc)-
(SHISobs-SHIScalc)