Integrating MODIS with AIRS to improve AIRS radiance and retrieval products

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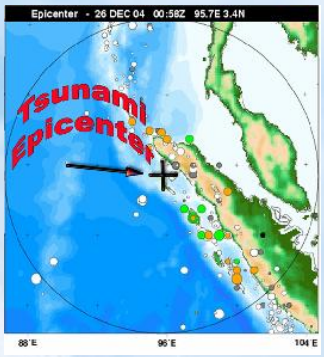
NESDIS Office of Research and Applications

March 23, 2005 – MODIS Science Team Meeting

Integrated Products

- Goal of integrating products is to provide better information and understanding, which in turn empowers the public, private sector and government with informed decision making.
- GEOSS - Global Earth Observation System of Systems
- GEOSS recognizes that we have a growing global system of systems which needs coordination to 1) establish standards/protocols for quality, data formats, data exchange , 2) avoid redundancy, and 3) determine future requirements

GEOSS will focus on Nine Societal Benefit Areas



Natural & Human Induced Disasters

Water Resources

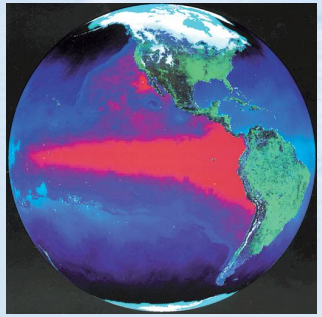
Terrestrial, Coastal & Marine Ecosystems

Human Health & Well-Being

Energy Resources

Sustainable Agriculture & Desertification

Weather Information, Forecasting & Warning



Climate Variability & Change

Biodiversity

NOAA Objectives and Goals

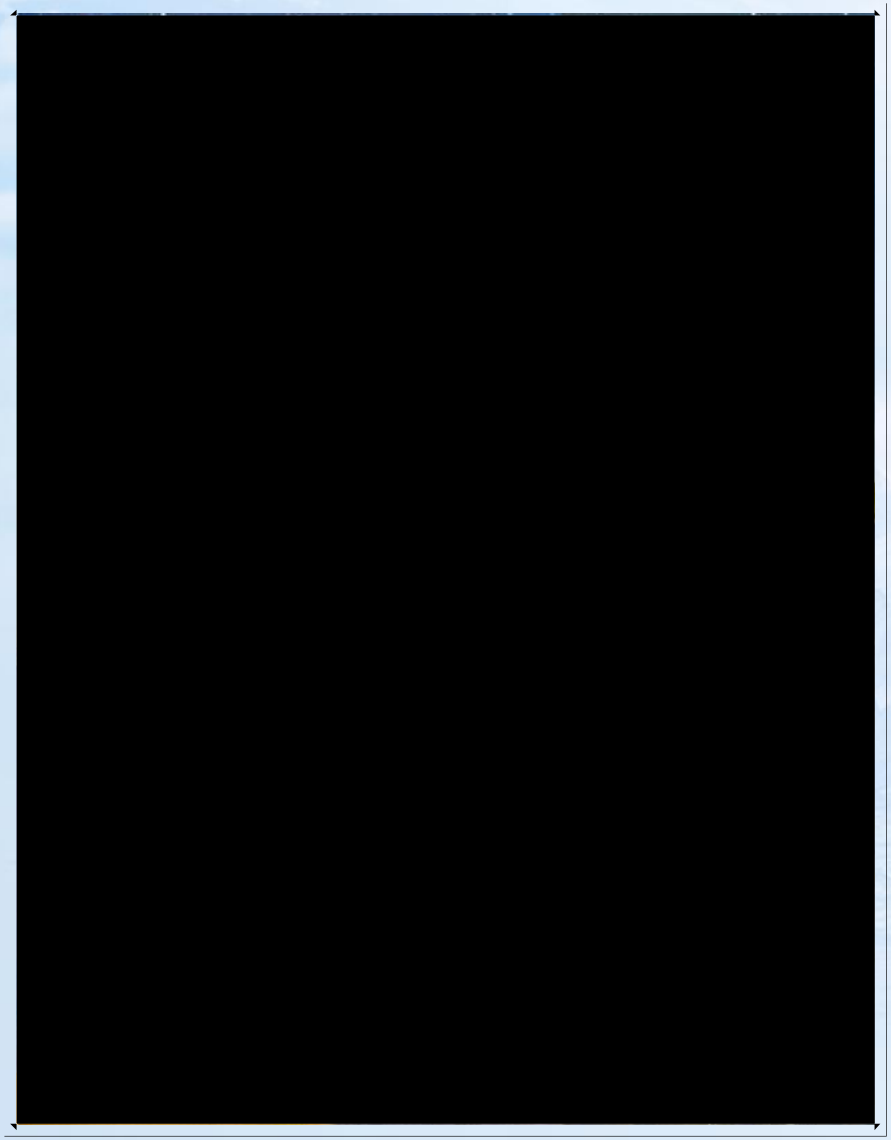
- Cooperation and collaboration in building an integrated global earth observation system
- Expansion of earth observation science, monitoring technology and applications
- Collaborative data exchange
- Integrated Processing Systems

Attributes of an Integrated Global Observing System

- Comprehensive
- Sustained
- Integrated

Comprehensive

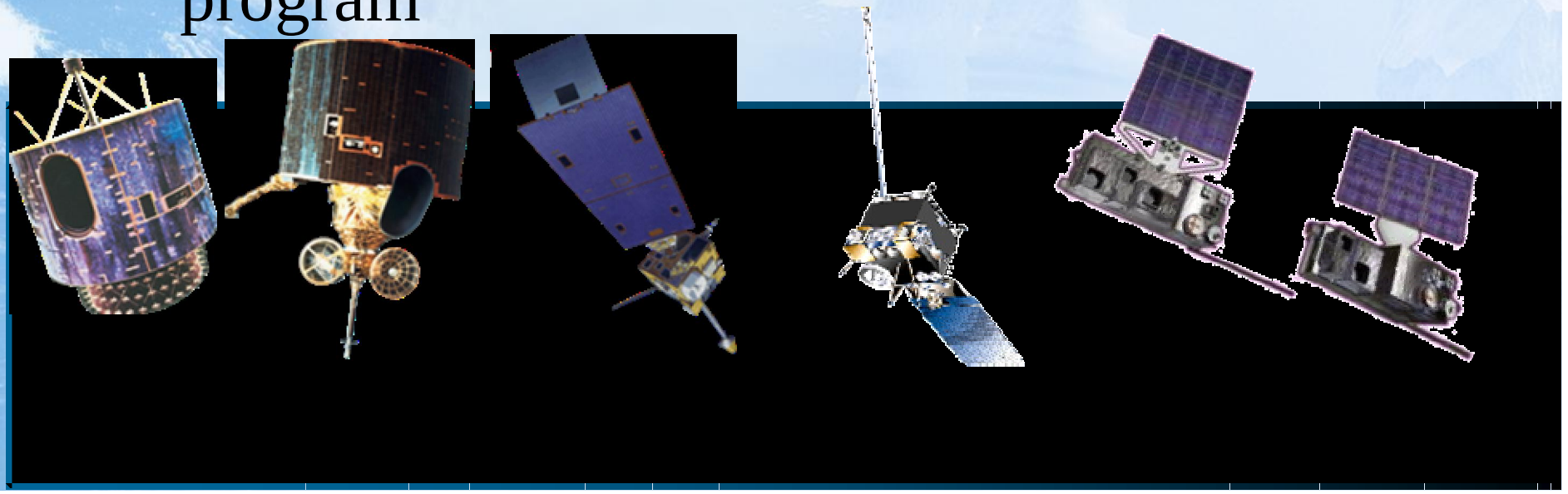
- Consists of physical, chemical, biological systems
- Encompasses *in situ*, mobile, airborne and satellite observations
- Includes broad range of spatial and temporal scales
  - Global to local
  - Years to minutes



Sustained

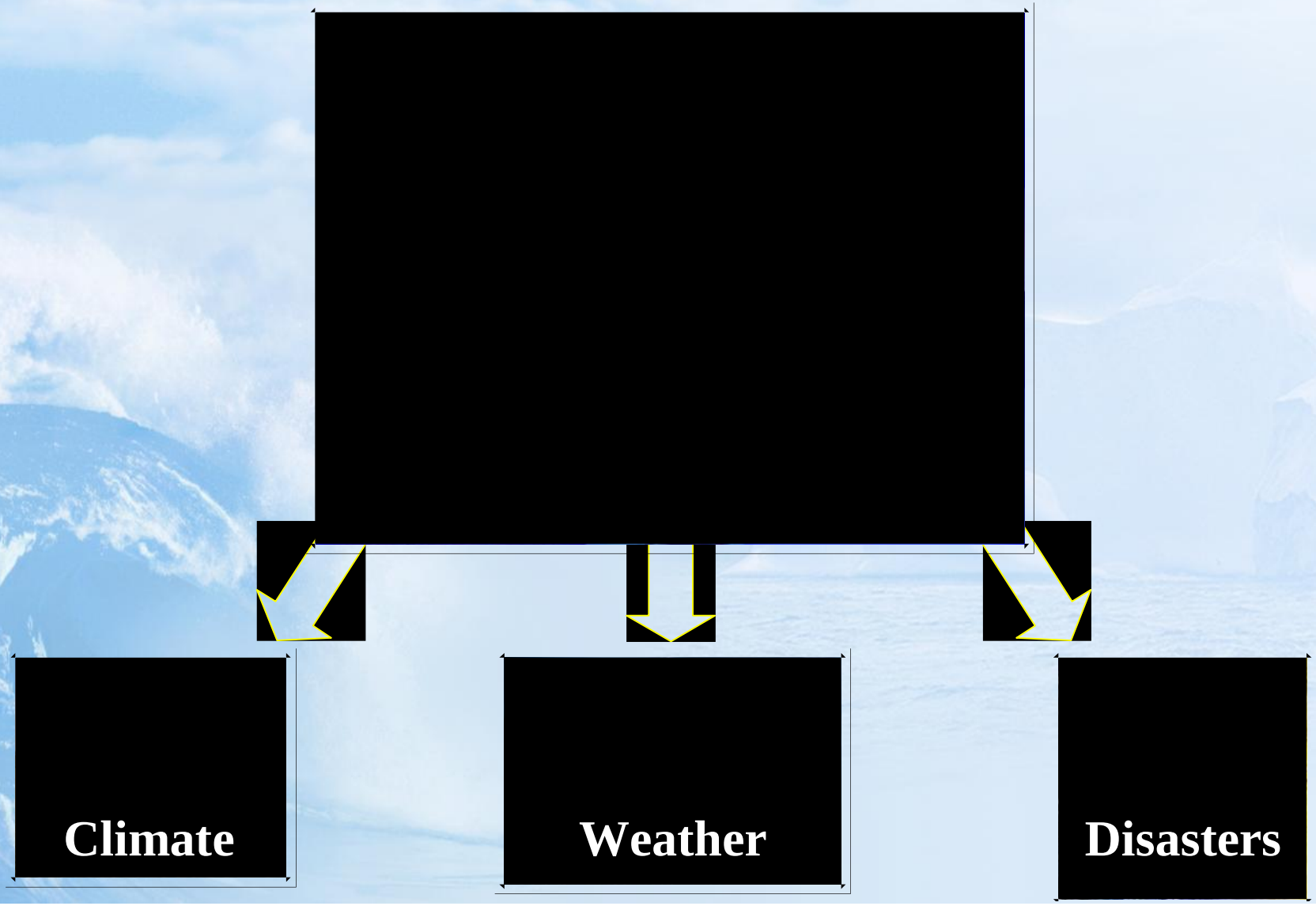
- Consists of future, current, and predecessor systems

- Includes sustained R&D program feeding into evolving long-term operational program



Integrated

Multiple Platforms Orchestrated to Serving One or More Missions



Integrated

e Platform Serving Multiple Missions

Water

Weather

Health

Coastal

Solar Weather

Disasters

Ecosystems

Ocean

Land

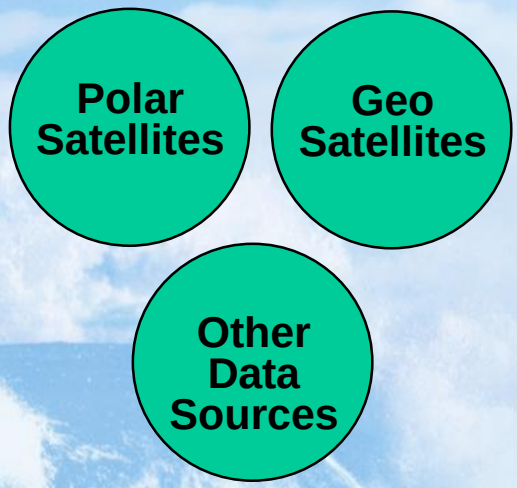
Climate

Benefits of implementing an Integrated, Comprehensive, Sustained Global Observing System in supporting National missions

- More efficient
- More effective
- Ensures sustainability

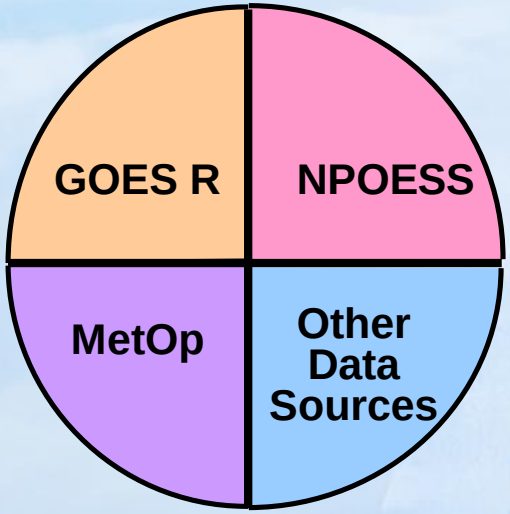
Goal - Transition Products from Individual Satellites to a "System of Systems"

Today



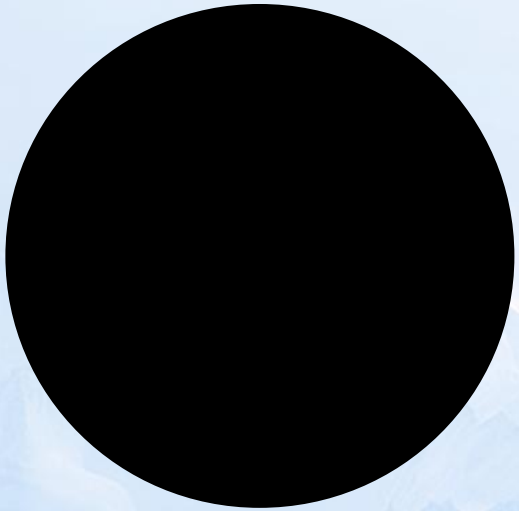
Environmental Products that are mostly generated from observations that are independent of one another

2008-2016



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

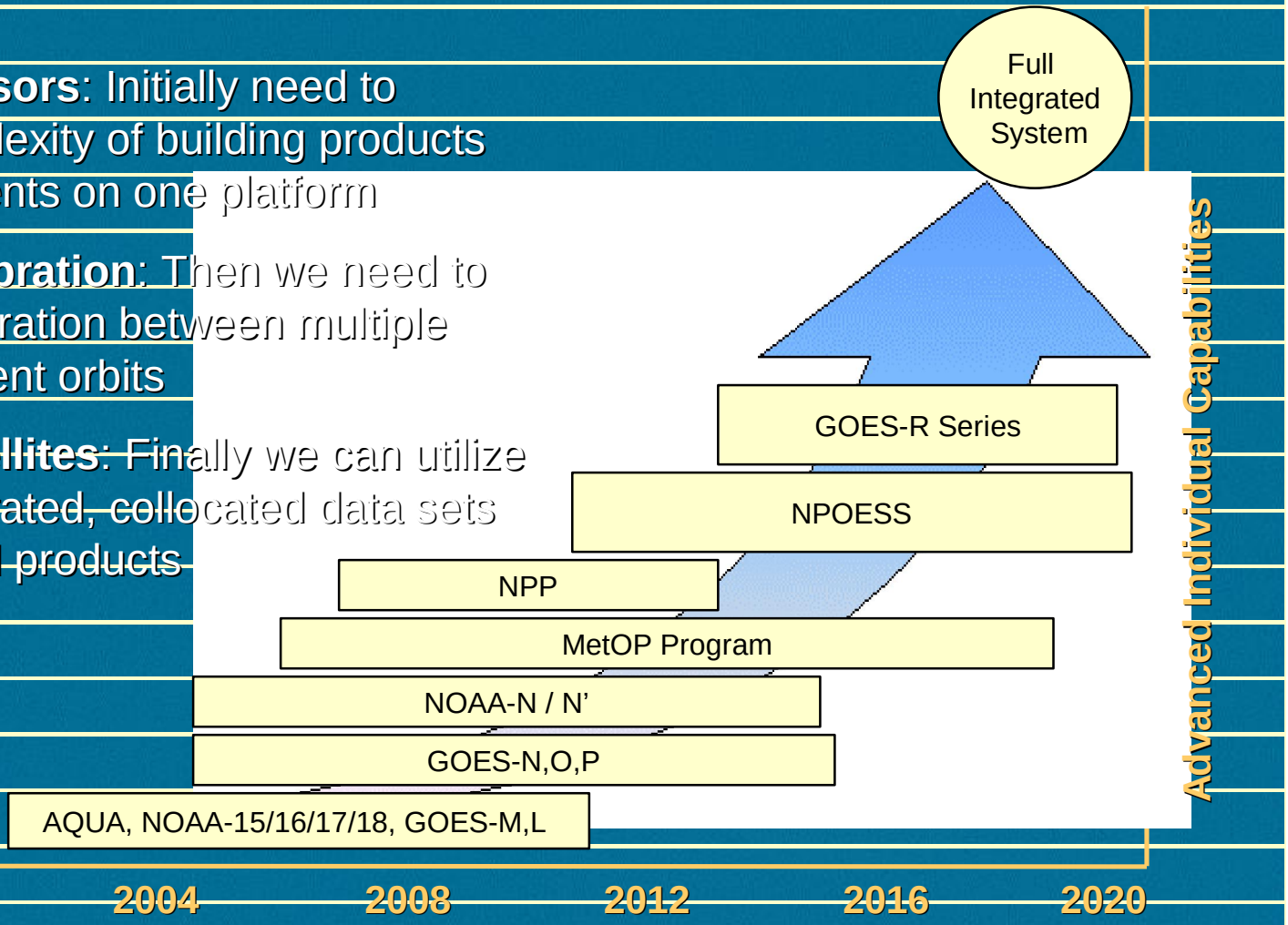
2020+



Products are formulated and produced as one integrated system

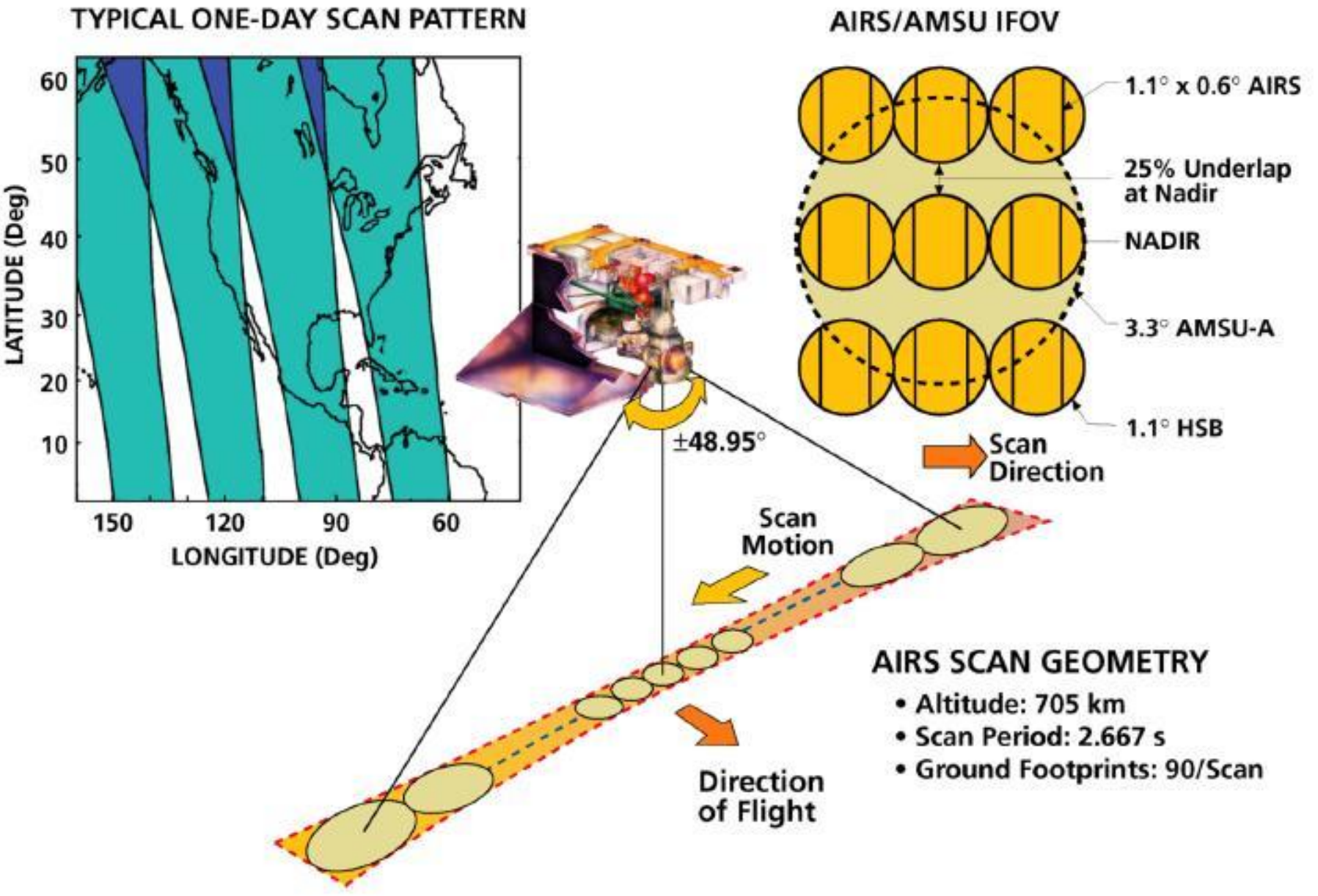
Steps to Integrated Products and Systems

- **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



Integrating MODIS with AIRS and AMSU

AMSU is a critical component of AIRS



AIRS acquires 2,916,000 spectra = 35 GByte/day

AIRS/AMSU Products for a ~150 km footprint (varies w/ view angle), 324,000 footprints/day

- Cloud Cleared Radiance
- Temperature
- Moisture
- Ozone
- Land/Sea Surface Temperature
- Surface Spectral Emissivity
- Surface Reflectivity
- Cloud Top Pressure
- Cloud Liquid Water (AMSU product)
- Cloud Fraction (per 15 km footprint).
- Carbon Monoxide
- Carbon Dioxide
- Methane
- Cirrus Cloud Optical Depth and Particle Size

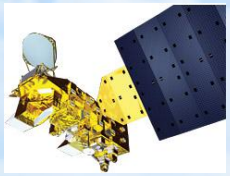
AIRS Update

- NESDIS has implemented the AIRS/AMSU processing system – quasi-operational
- Processing system is based on the retrieval methodologies developed by the AIRS Science Team
- Science Algorithms developed by NASA, NOAA, UW, MIT, UMBC - truly a collaborative effort
- Science improvements are continuing

Science Improvements

- Adding MODIS to improve cloud clearing and soundings
- Adding trace gas retrieval algorithms to derive CO2, CO, and CH4
- Improving surface emissivity/bidirectional reflectance (non-ocean)

AIRS & MODIS PRODUCTS ARE DISTRIBUTED THROUGH THREE MAIN CHANNELS



NOAA NESDIS

NWP Centers
- NCEP
- Navy
- ECMWF
- UK Met Office
- more

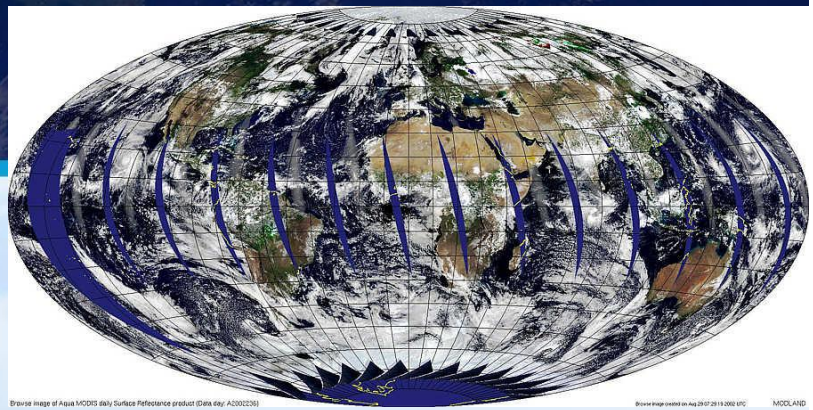
GSFC DAAC

- Science Community
- Public

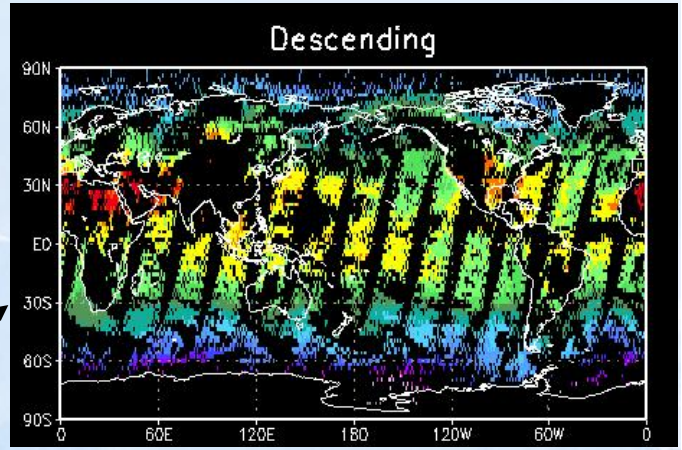
DIRECT BROADCAST

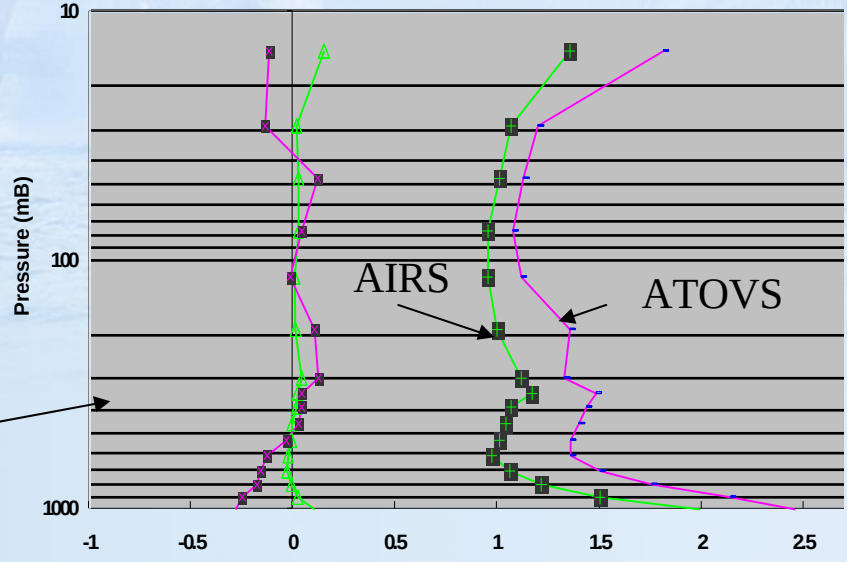
- Universities
- Local Weather Stations
- Brazil (INPE)
- China
- DoD
- Other International

What have we learned?



- AIRS instrument is extremely stable and accurate
- Only 5% of the globe is clear at a 14 km fov
- AIRS has resulted in positive impacts in NWP, however only clear channels are assimilated and larger impacts are still expected.
- Cloud-clearing increases yield to 50 - 70%
- Retrievals from cloud-cleared radiances are significantly more accurate than AMSU-only.
- Demonstrated 1 K/Km precision





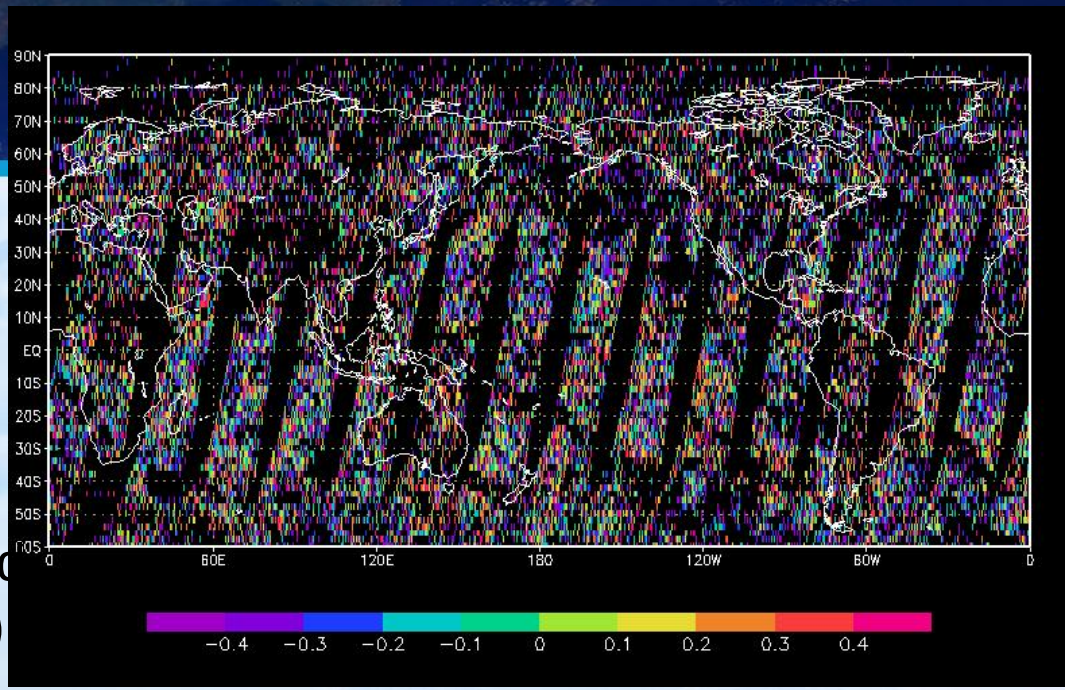
AIRS NWP Challenge

- Assimilate cloud-cleared radiances to improve the yield of observations in lower troposphere.
- Challenges
  - NWP forecast accuracy is highly sensitive to accuracy of input data
  - Need to provide very accurate cloud-cleared radiances
- Strategy
  - Use MODIS to improve accuracy of cloud-cleared radiances

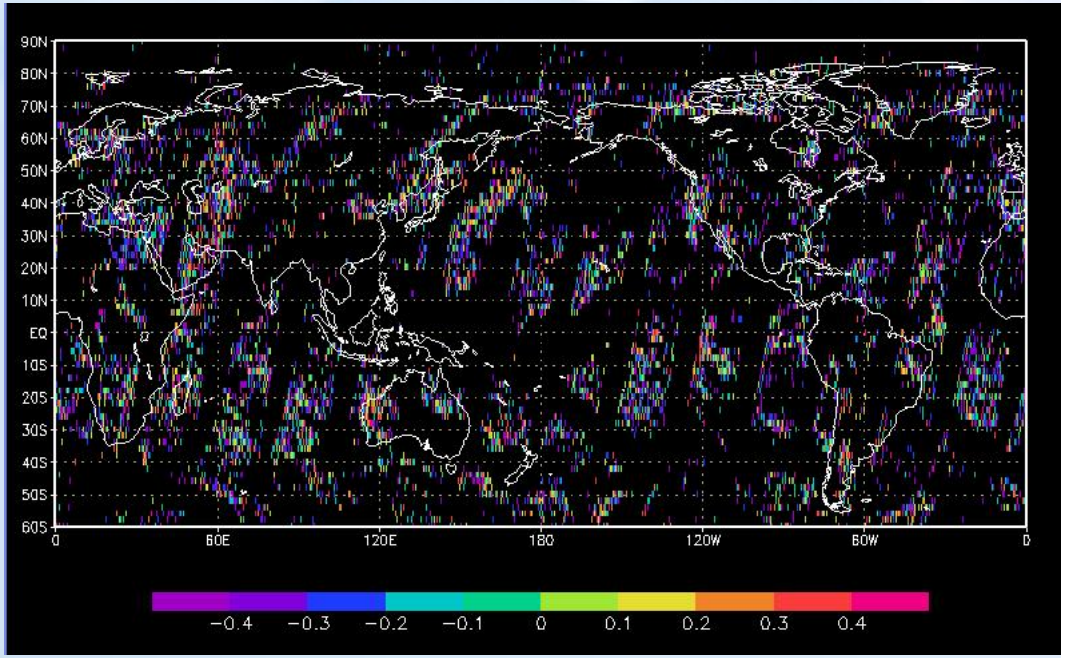
735.69 cm-1 (peak ~ 700 mb)

ALL diff < +- 0.5 K

Cloud-cleared minus clear simulated brightness temperatures (ECMWF)



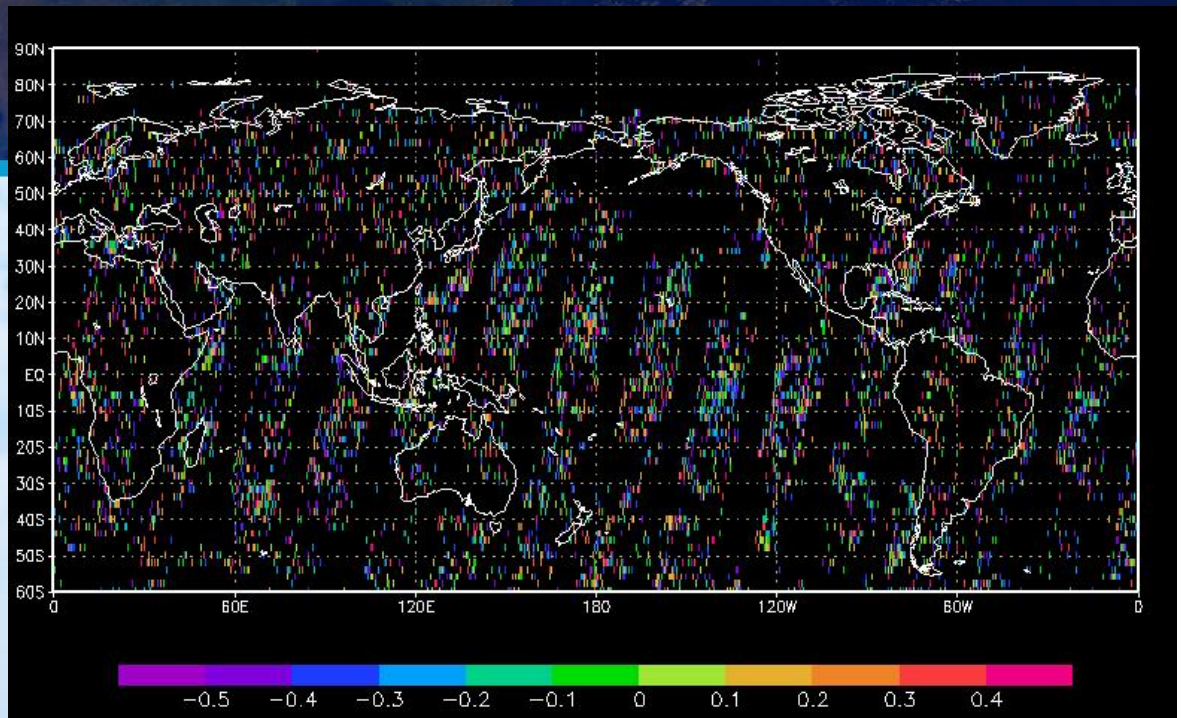
Observed minus clear simulated brightness temperatures (ECMWF)



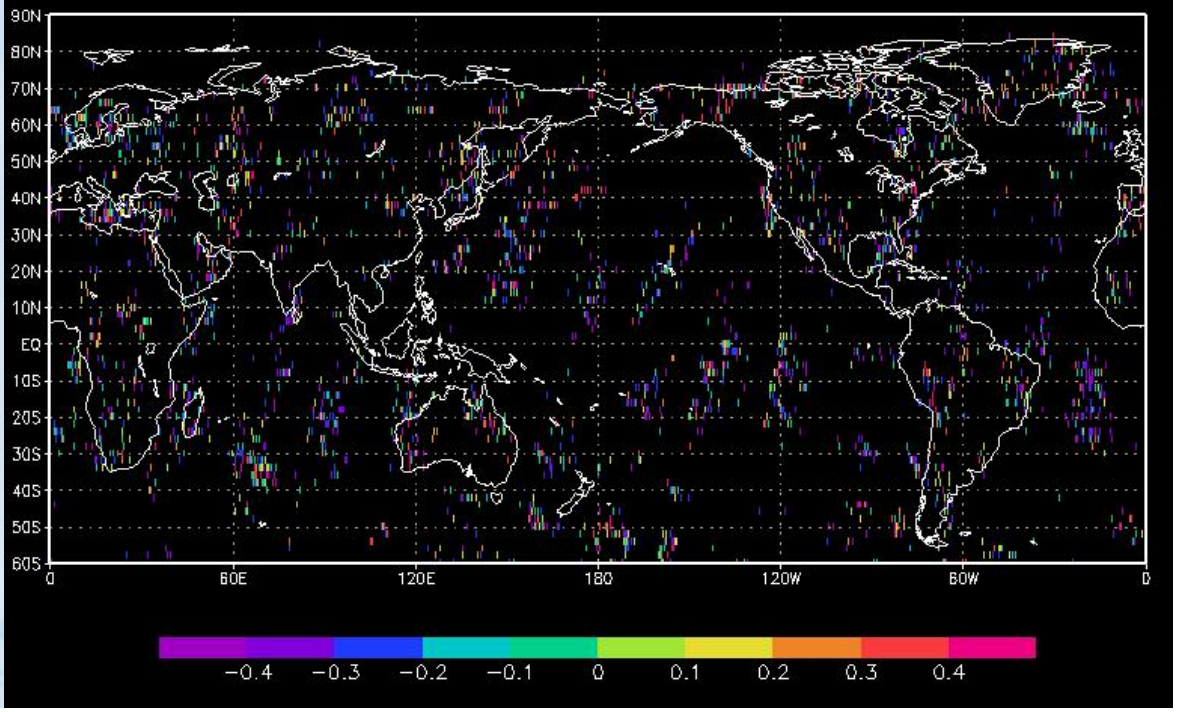
965 cm-1 (window)

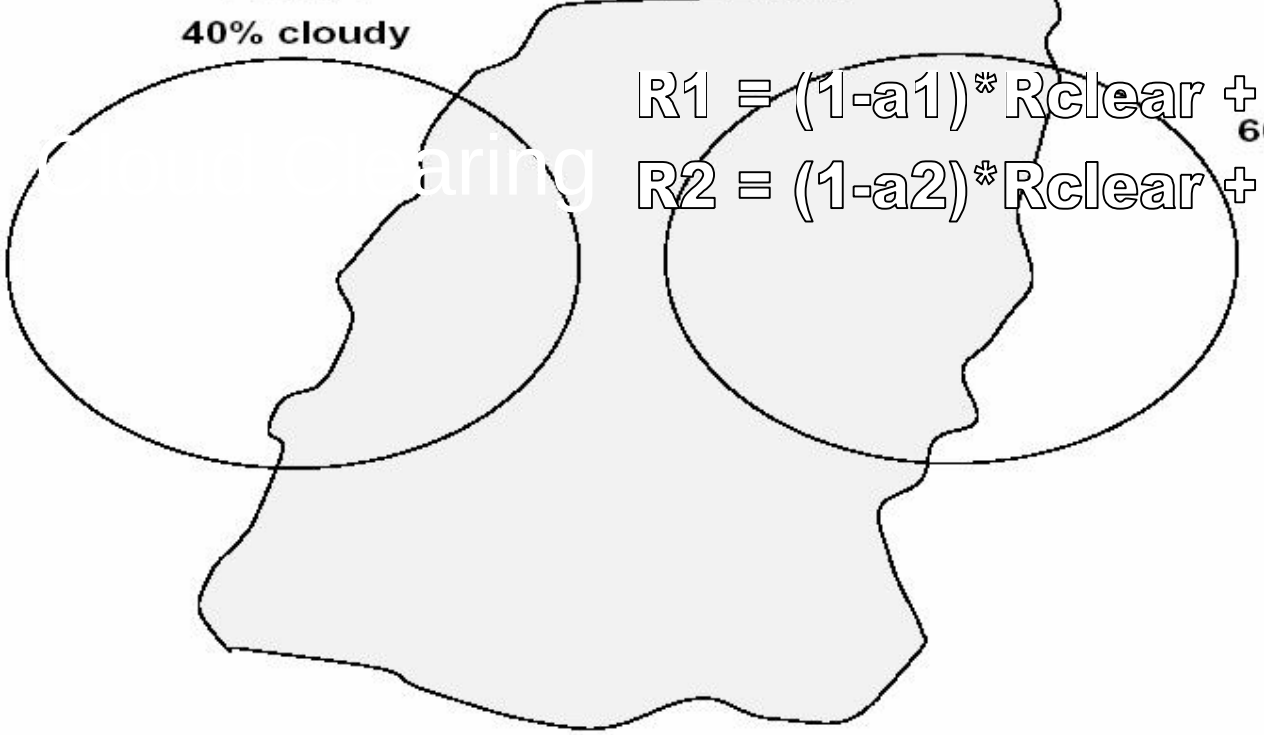
ALL diff < +- 0.5 K

Cloud-cleared minus ECMWF



Raw minus ECMWF



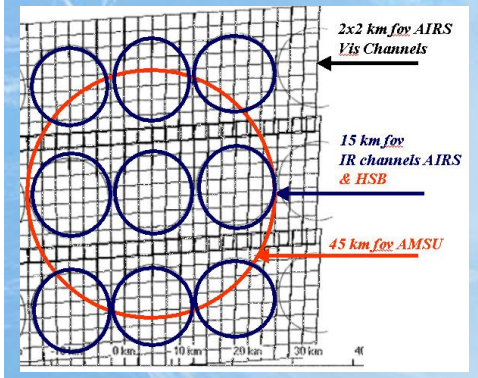


Cloud Clearing

$R1 = (1-a1)*Rclear + a1*Rcloud$

$R2 = (1-a2)*Rclear + a2*Rcloud$

Two AIRS field of views (FOV's) are illustrated showing that each FOV has some fraction of clear radiance and some fraction of cloudy radiance. We define the ensemble of FOV's as the retrieval field of regard (FOR).



$$Rclear(i) = R1(i) + \eta[R1(i)-R2(i)]$$

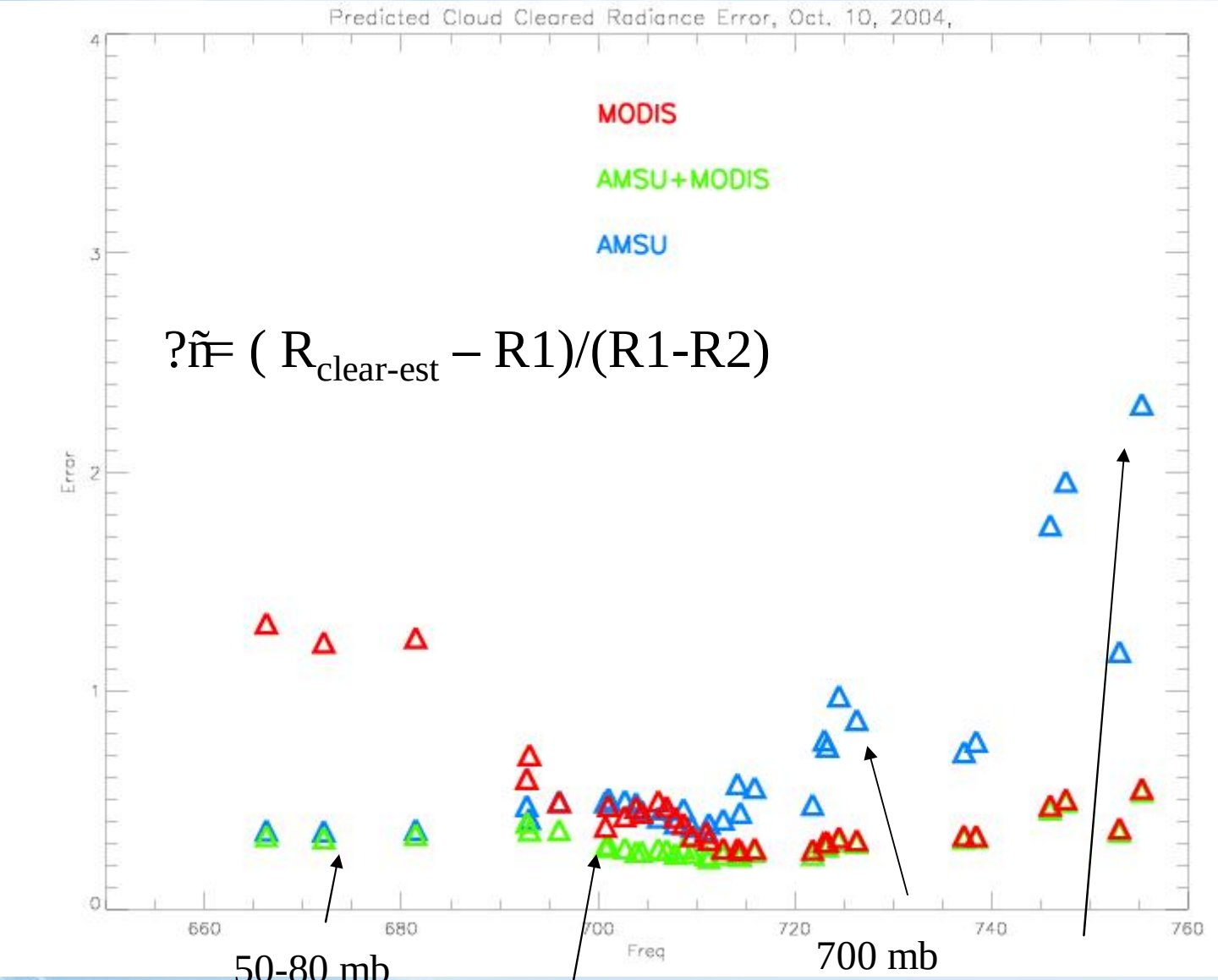
$$\eta = a1/(a2-a1)$$

$$\eta = (R_{clear\text{-}est} - R1)/(R1-R2)$$

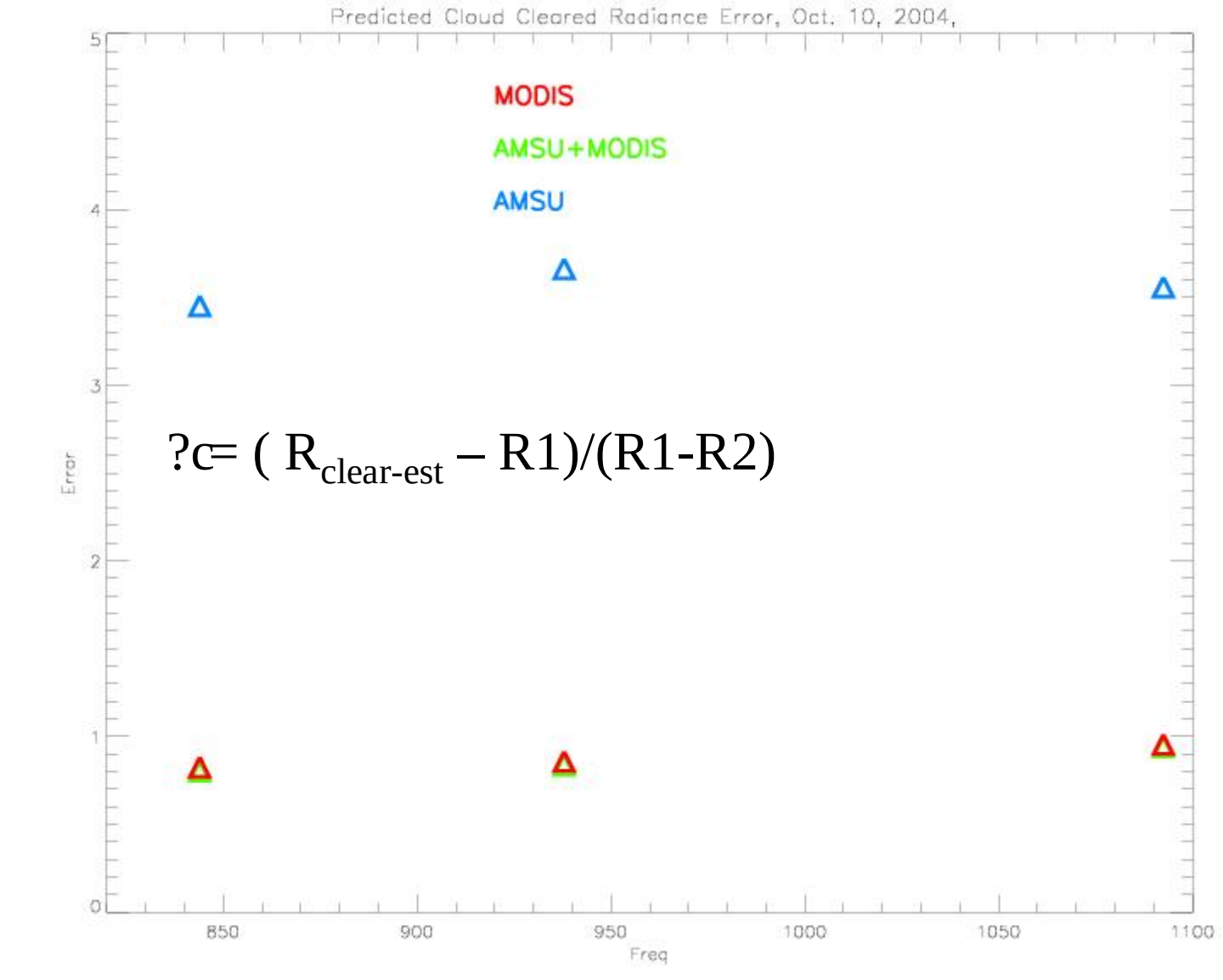
MODIS in addition to AMSU will improve cloud clearing

- AMSU has limitations in predicting lower tropospheric AIRS channels.
- Therefore, AIRS cloud clearing will not be as accurate for lower tropospheric clouds
- AMSU is still important especially when there are no clear MODIS fovs in the AIRS fov
- Our approach is to use both AMSU and MODIS for cloud clearing

Predicting AIRS from MODIS, AMSU



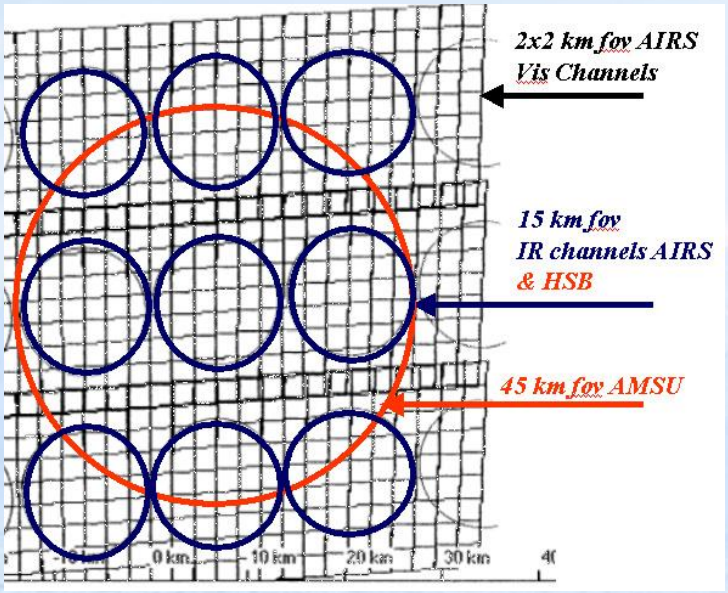
Predicting AIRS from MODIS, AMSU



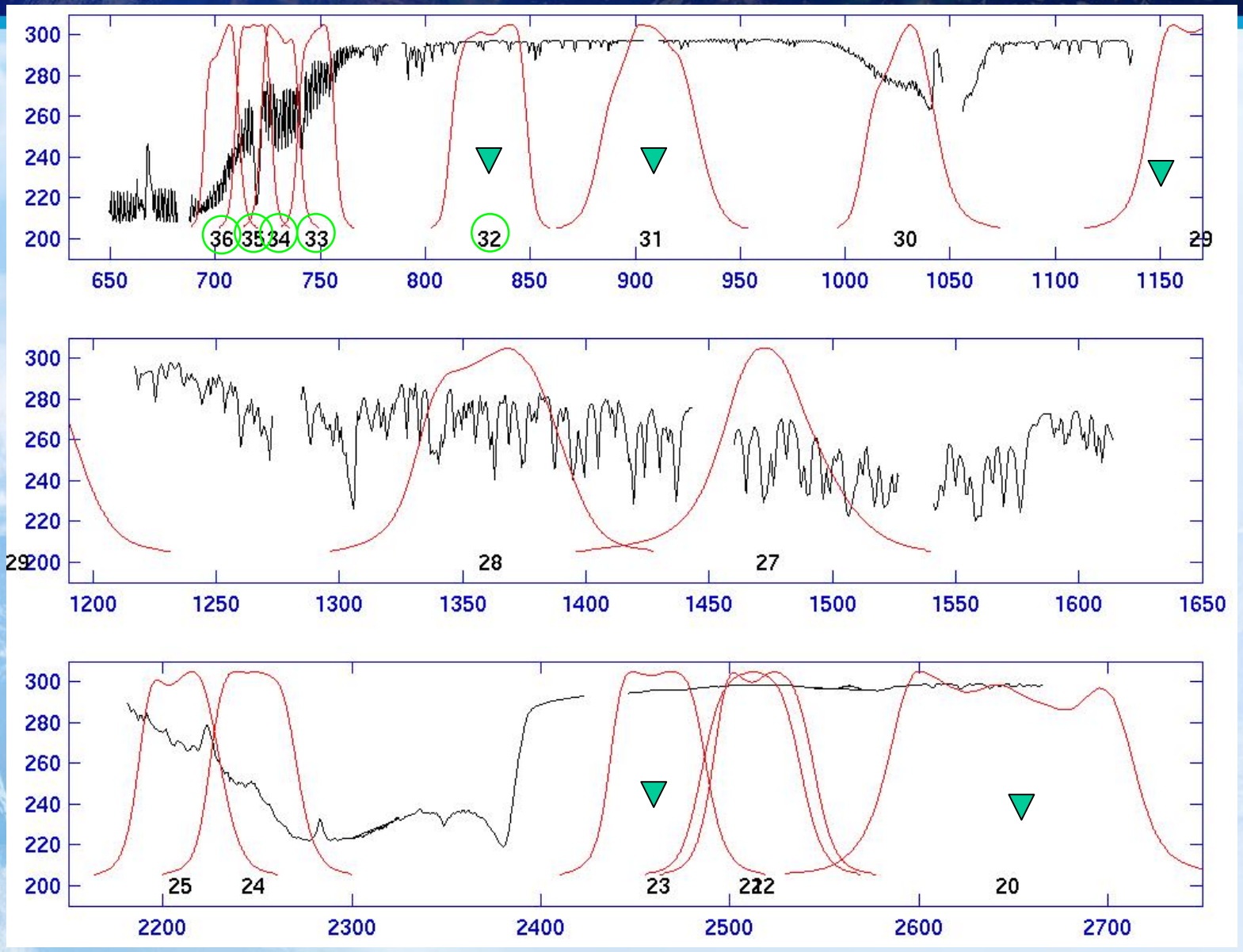
?c= ($R_{clear\text{-}est}$ – R1)/(R1-R2)

MODIS Cloud-Clearing Strategies

- MODIS 1 km resolution can be used to find clear holes
- Clear MODIS channels can be compared with cloud-cleared AIRS convolved to MODIS spectral resolution for QC
- Clear MODIS can be used to provide the clear estimate for cloud clearing



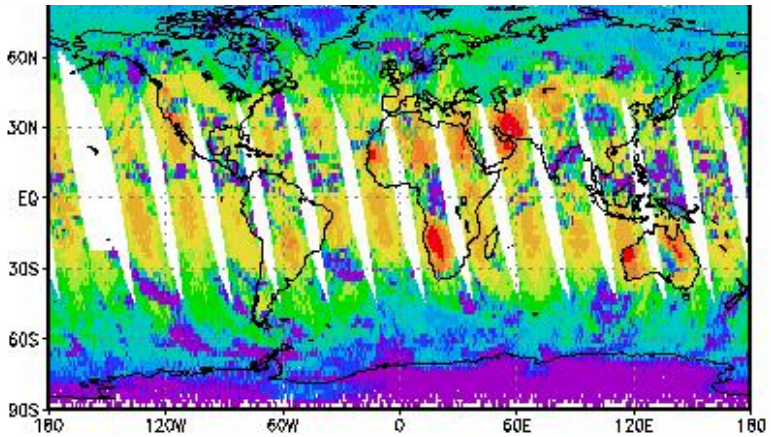
Aqua MODIS SRF Overlay on AIRS Spectrum

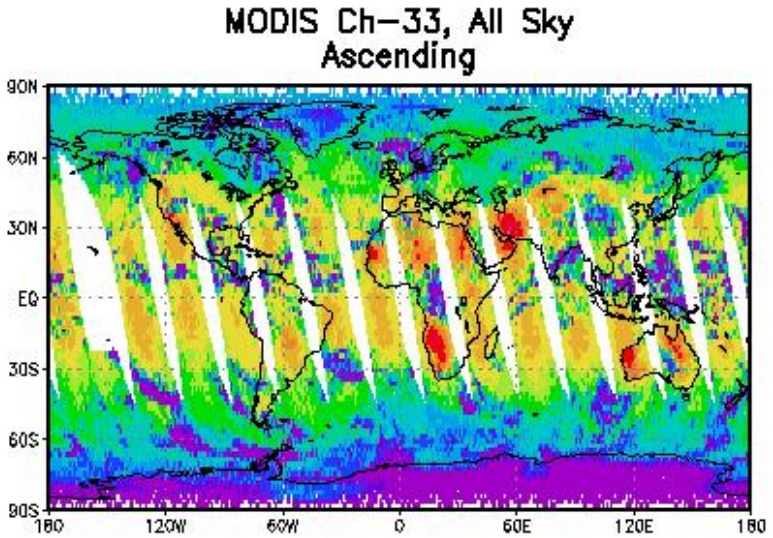


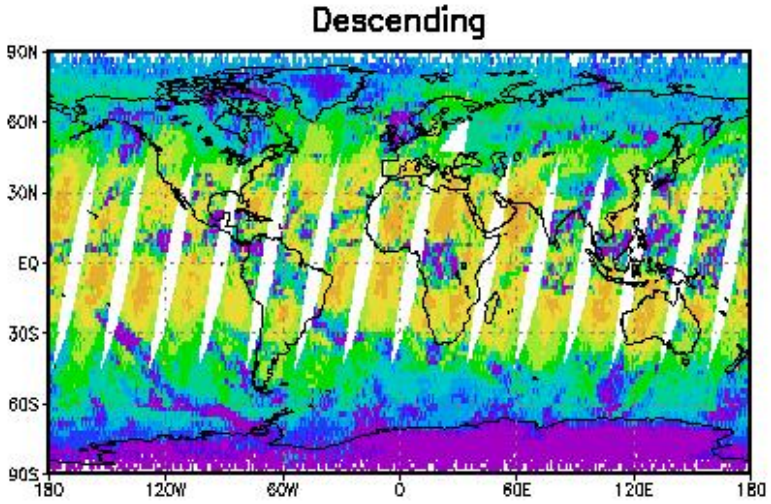
▽ ~ VIIRS channel

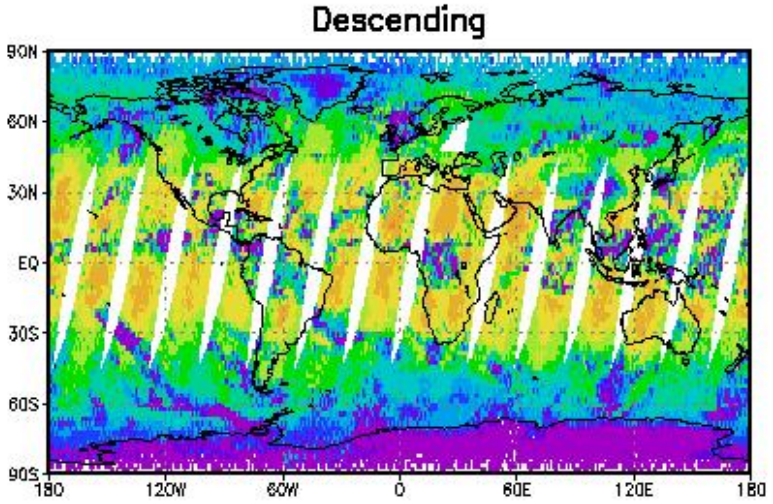
Using MODIS to QC AIRS Cloud-Cleared Radiances

AIRS convolved to MODIS

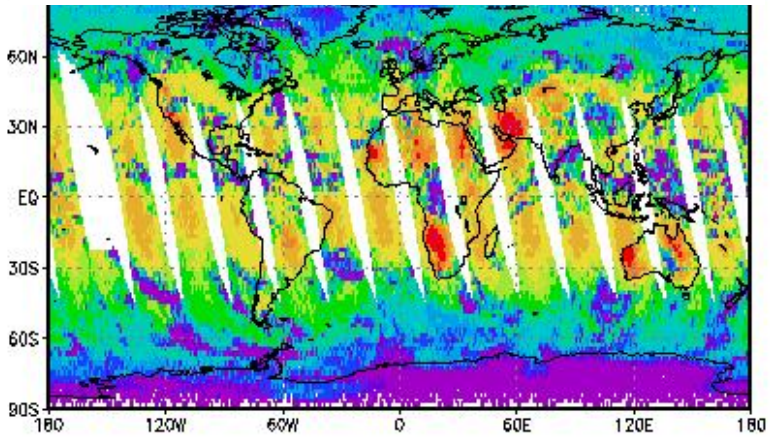


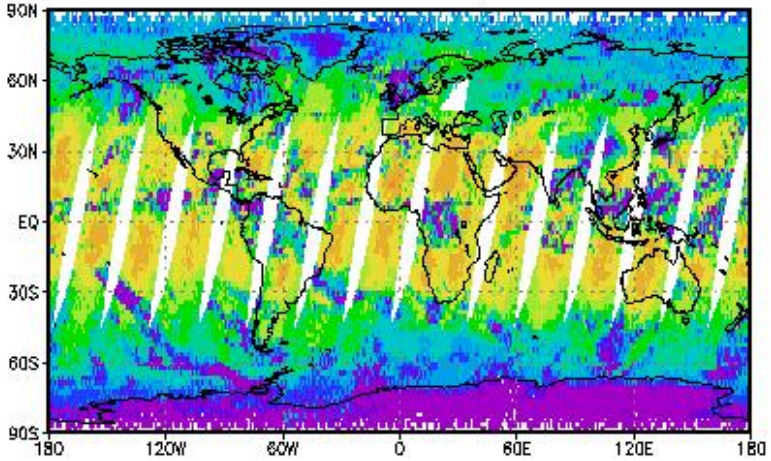


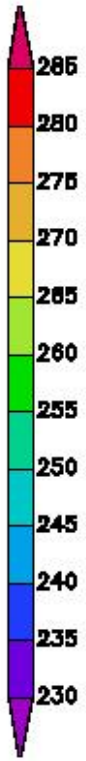


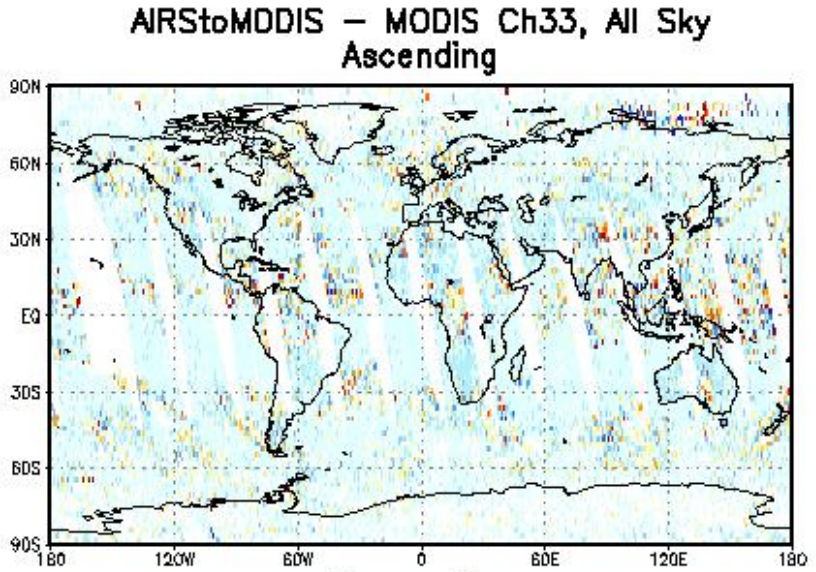


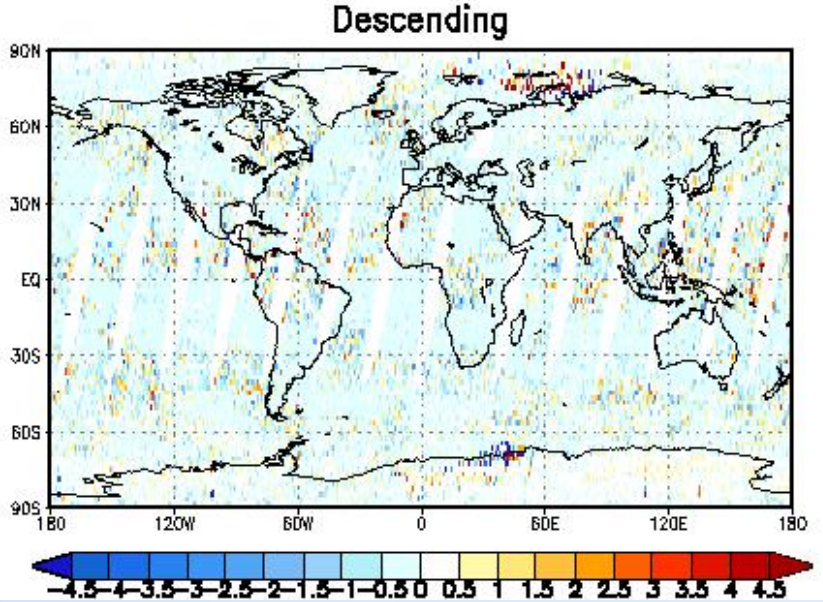
AIRS convolved to MODIS

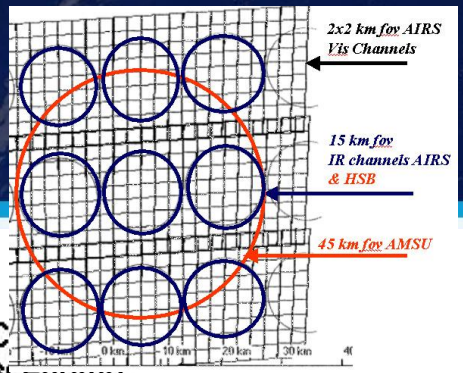




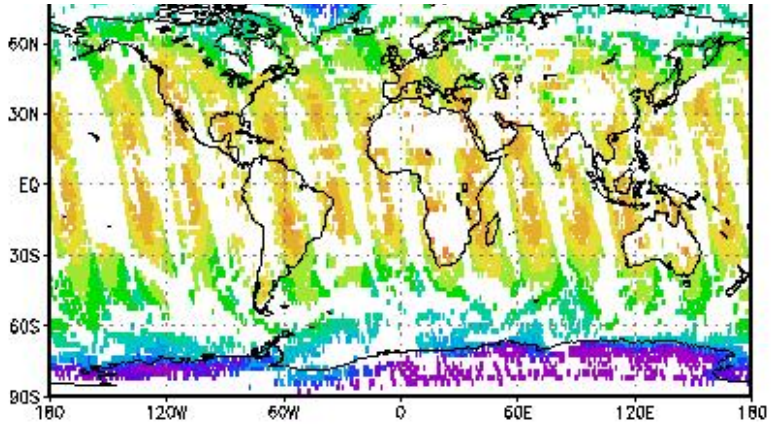


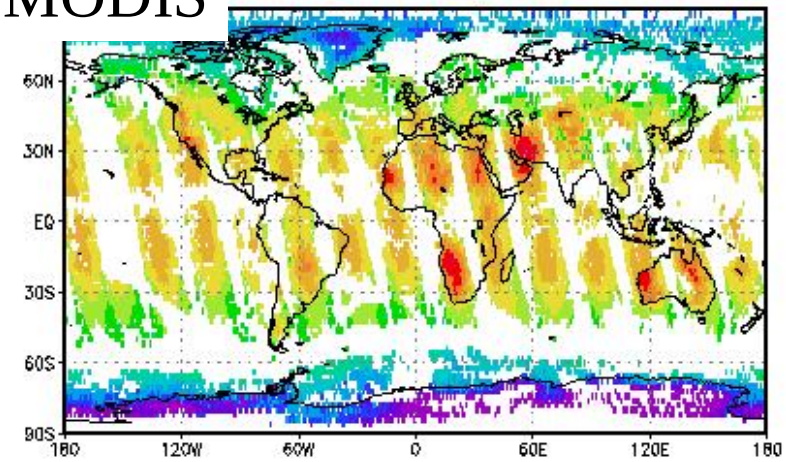


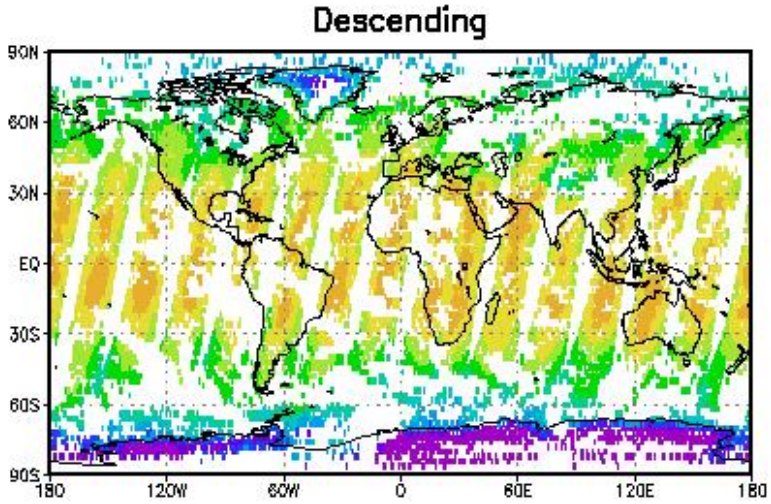


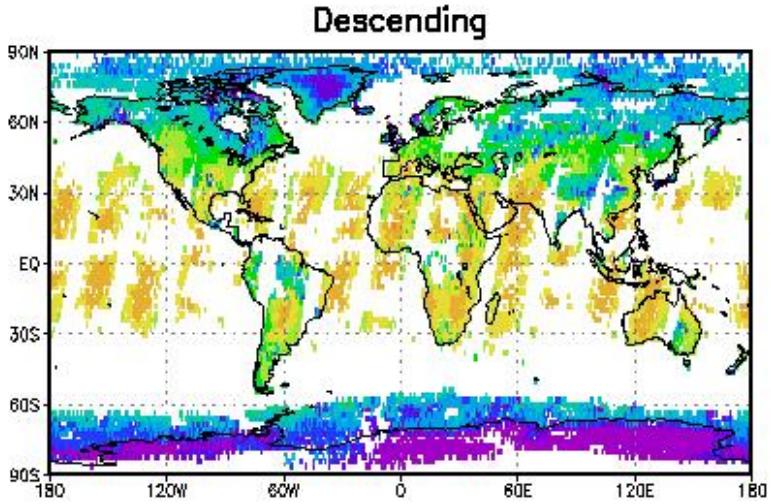


Cloud-Cleared AIRS convolved to MODIS





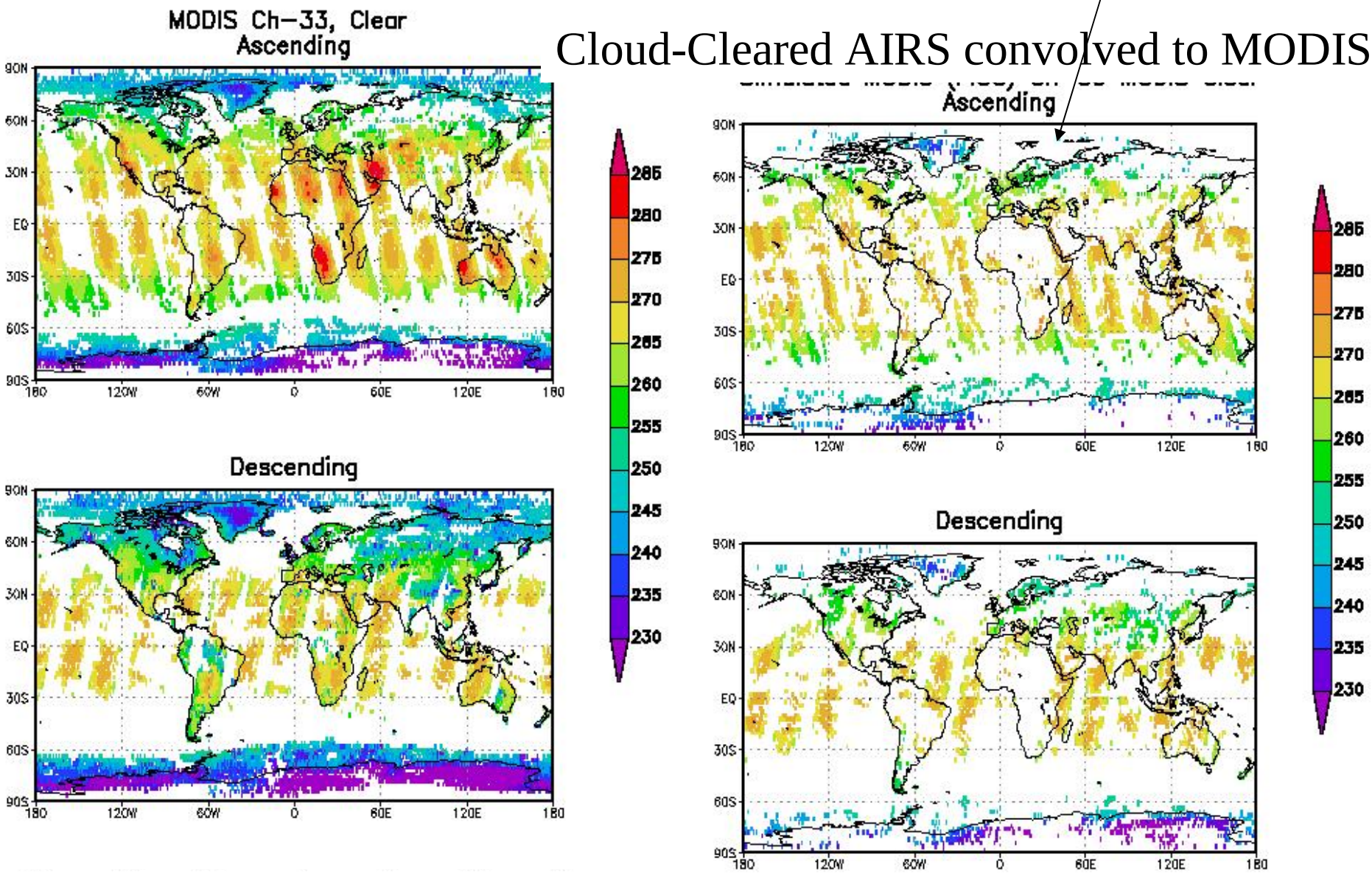




Use of MODIS to QC AIRS (Abs(AIRS-MODIS)< 0.5 K)

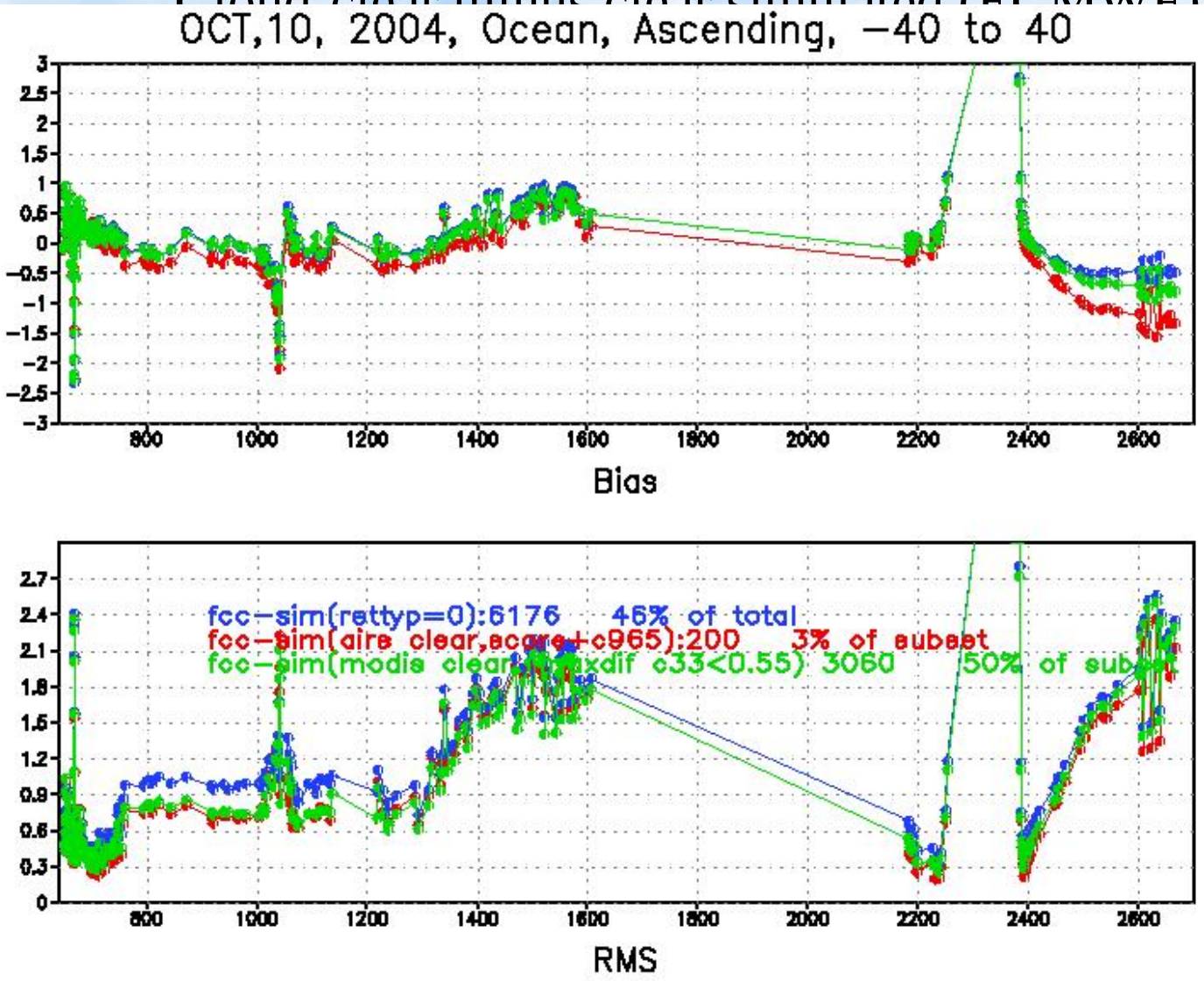
50% of 46%

Cloud-Cleared AIRS convolved to MODIS



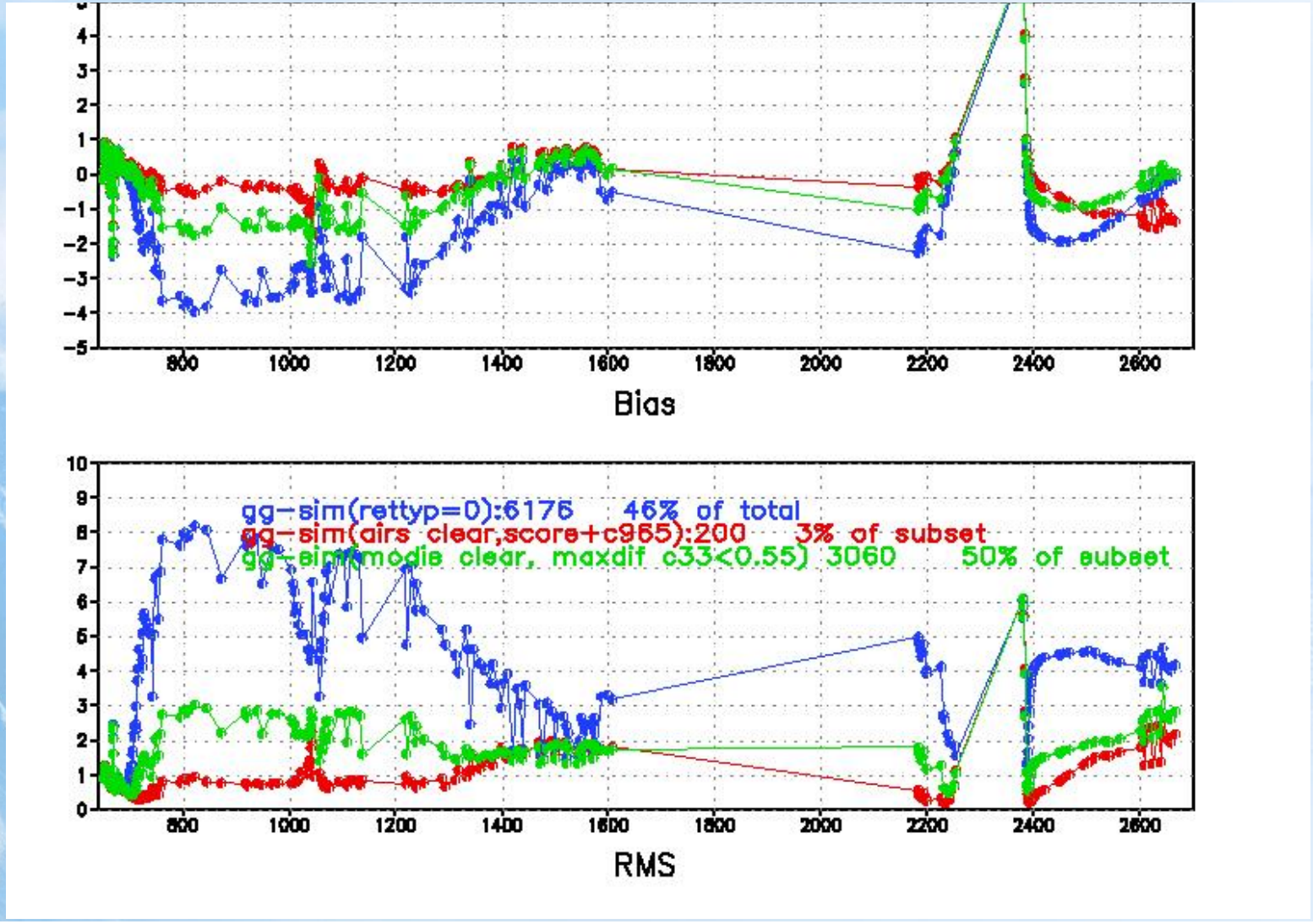
Currently using MODIS to quality control AIRS Cloud-Cleared Radiances

Cloud clear minus clear simulated (ECMWF)

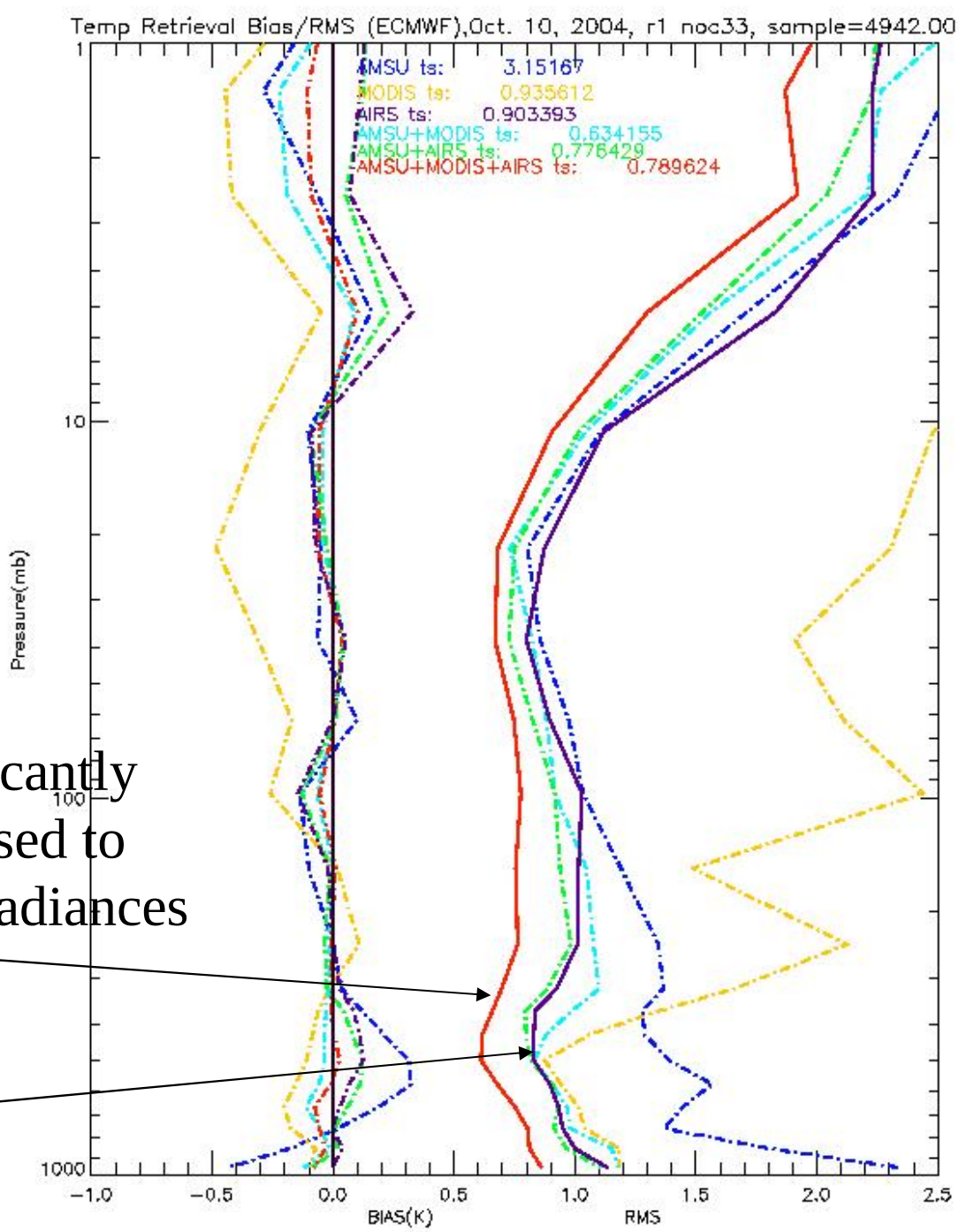


Consequence of not cloud-clearing

All-sky minus clear simulated (ECMWF)

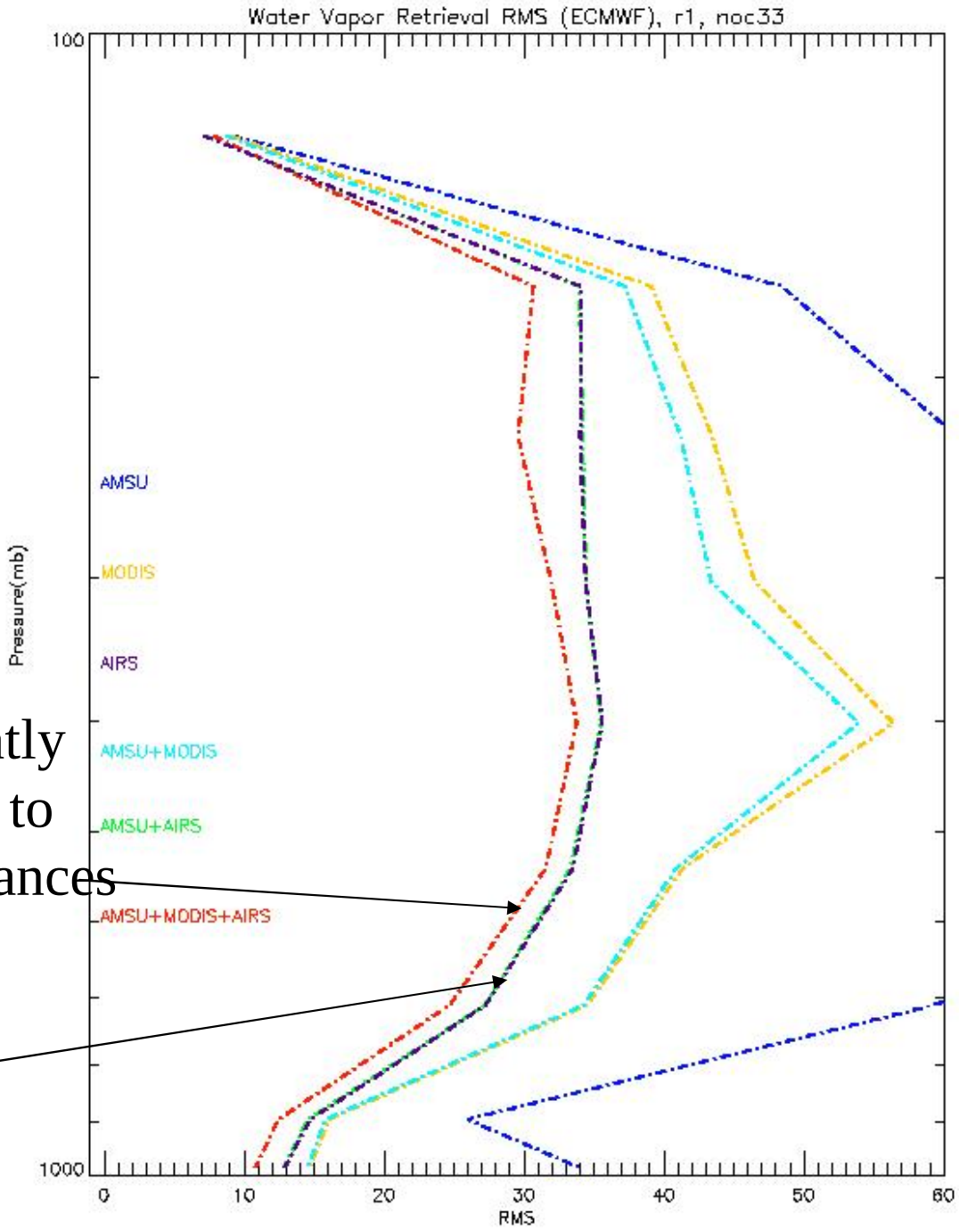


Improved QC of Cloud Cleared Radiances Improves Retrieval Accuracy



Retrieval errors are significantly reduced after MODIS is used to QC AIRS cloud-cleared radiances

W/O QC



Retrieval errors are significantly reduced after MODIS is used to QC AIRS cloud-cleared radiances

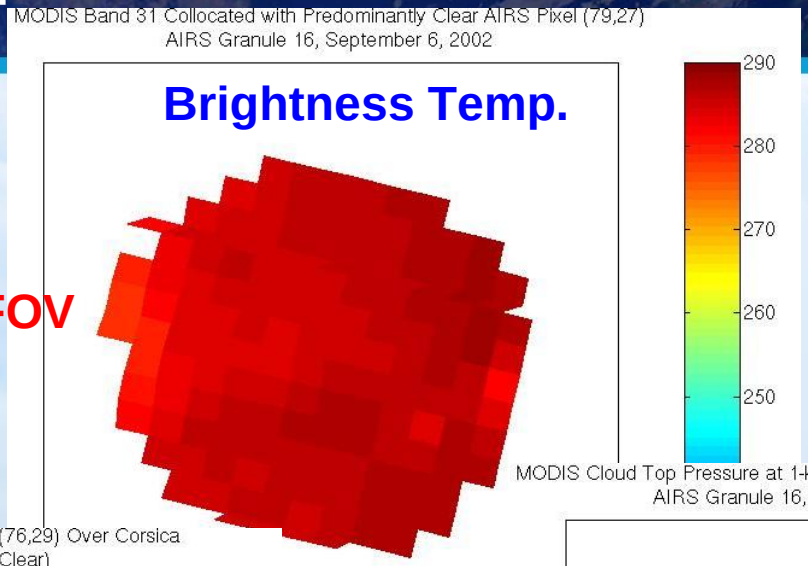
W/O QC

Summary

- We are beginning to build integrated processing systems by focusing on AQUA.
- We plan to experiment with sensors from the A-Train
- We are adapting our AIRS/AMSU/MODIS processing system to generate operational products from IASI/AMSU/AVHRR (2006) and from CrIS/ATMS/VIIRS (2008)
- Same Science (e.g. same transmittance model, same cloud detection/clearing, etc) and Software will process AIRS, IASI and CrIS

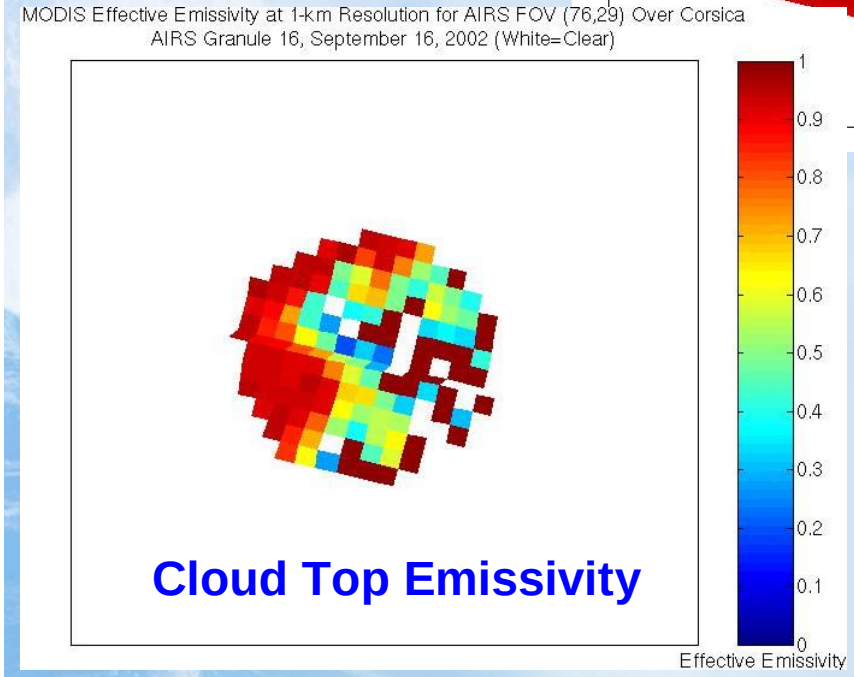
Additional Slides

AIRS Spatial Features Seen from MODIS



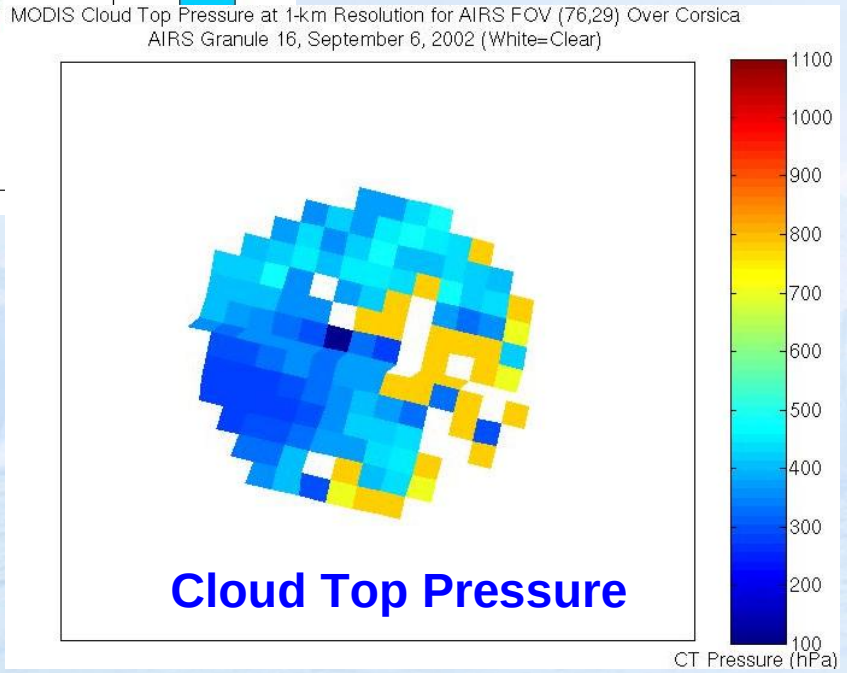
Brightness Temp.

Clear AIRS FOV



Cloud Top Emissivity

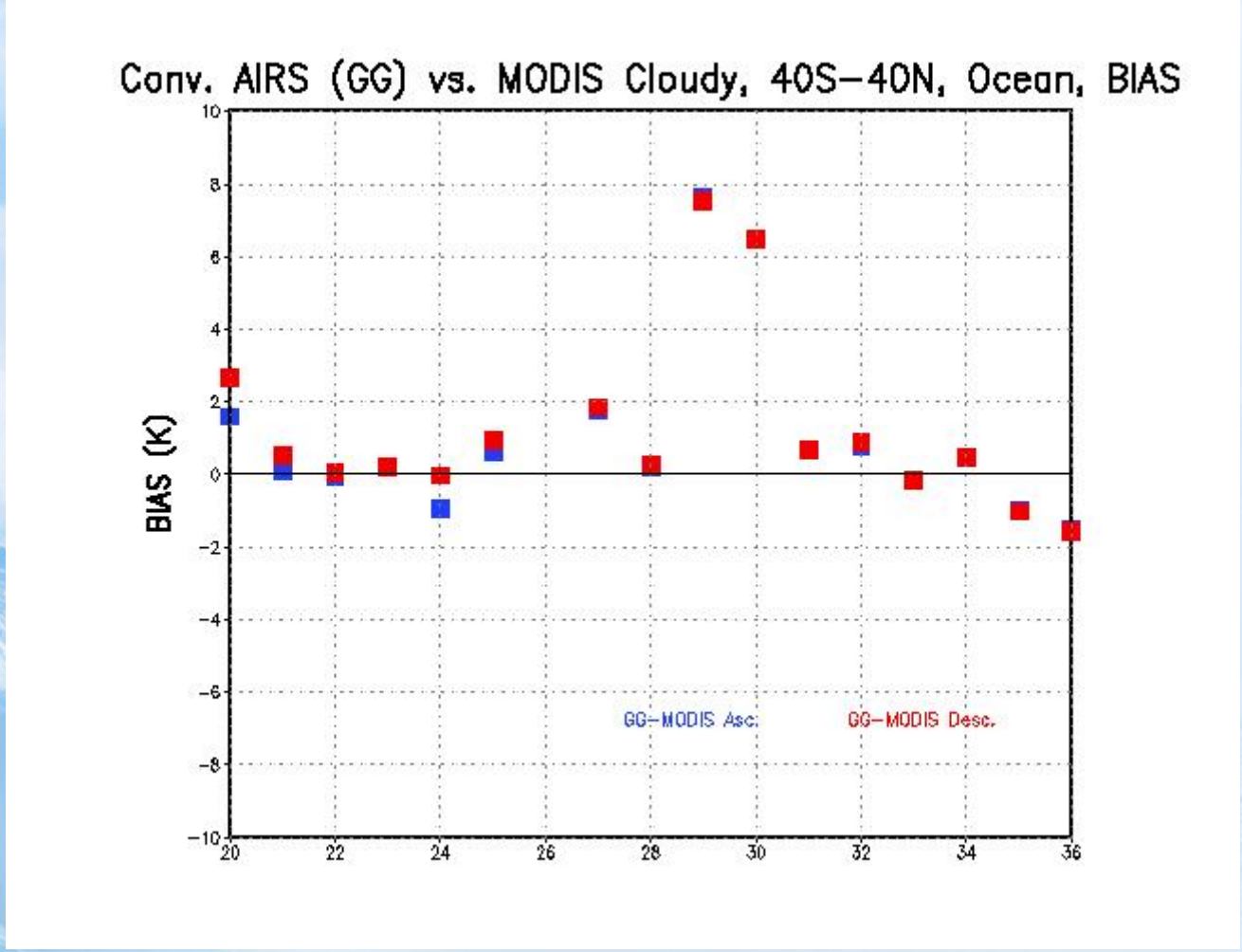
Cloudy AIRS FOV



Cloud Top Pressure

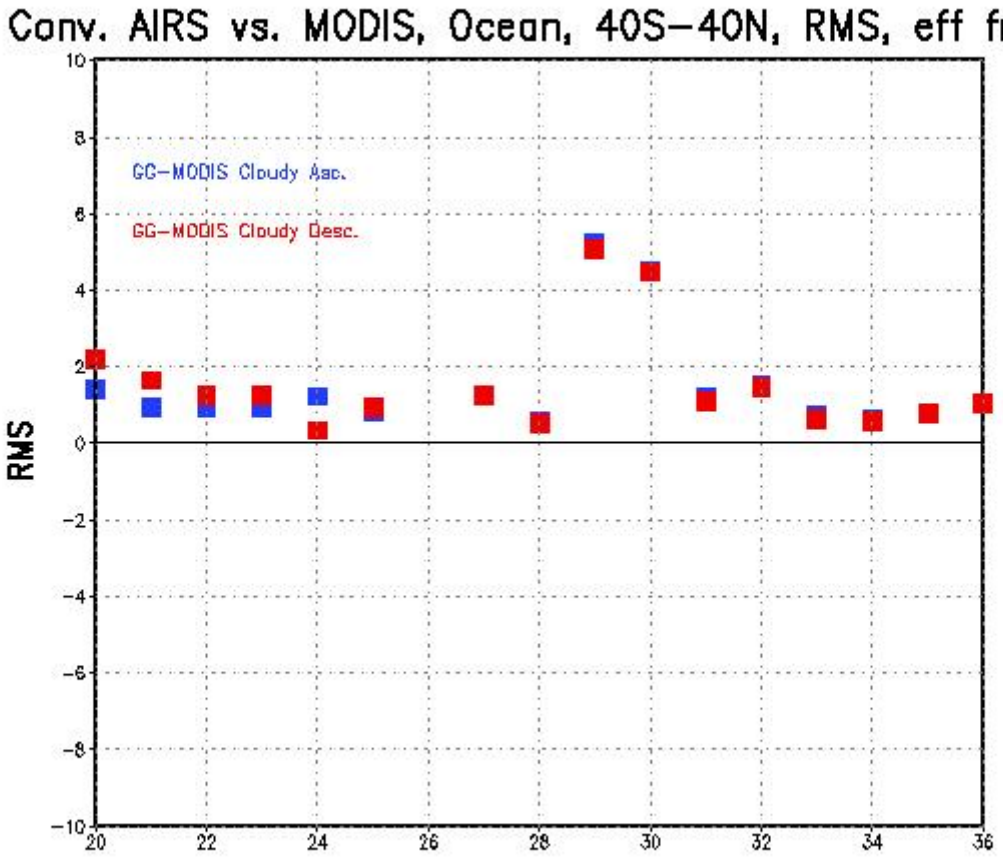
Cloudy AIRS FOV

AIRS convolved to MODIS spectral resolution and MODIS spatially convolved to AIRS spatial resolution



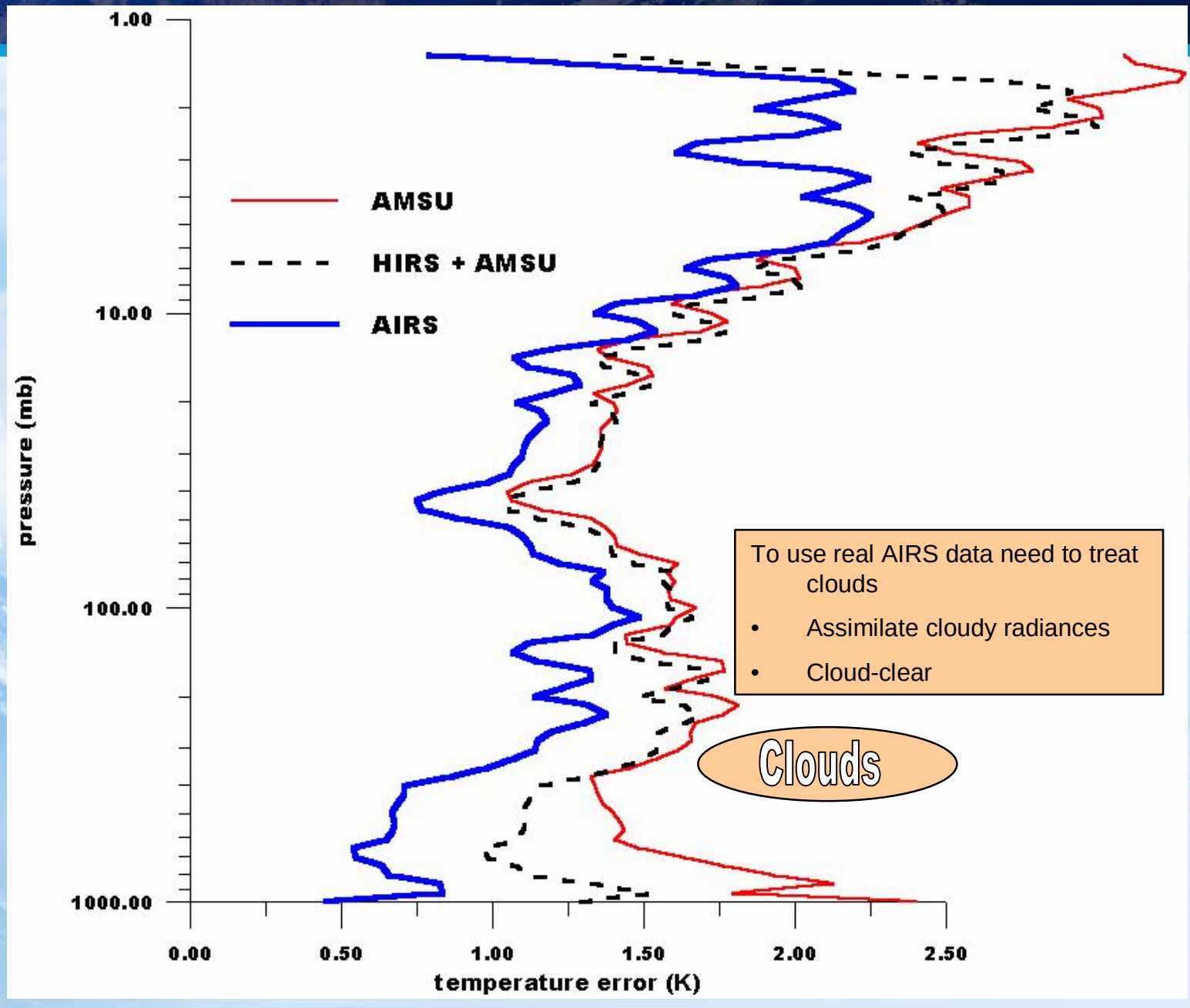
BIAS

AIRS convolved to MODIS spectral resolution and MODIS spatially convolved to AIRS spatial resolution



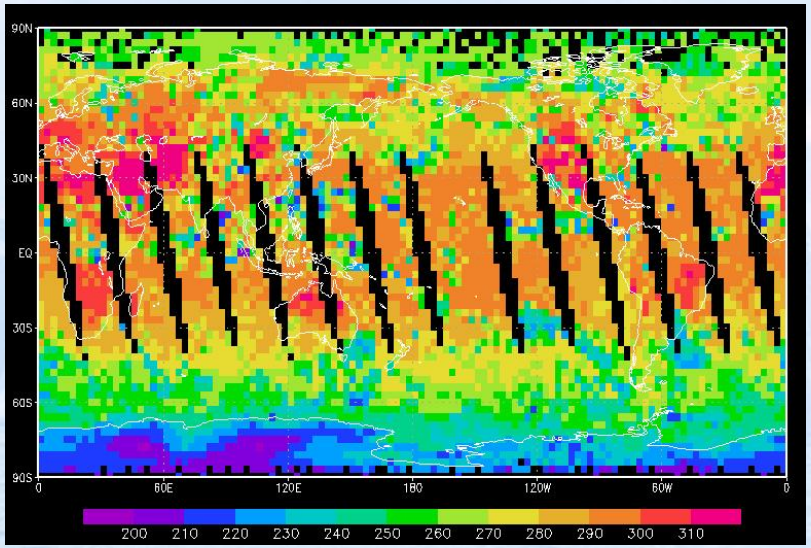
RMS

Temperature errors as a function of sounder instrumentation



NOAA-Unique AIRS Products

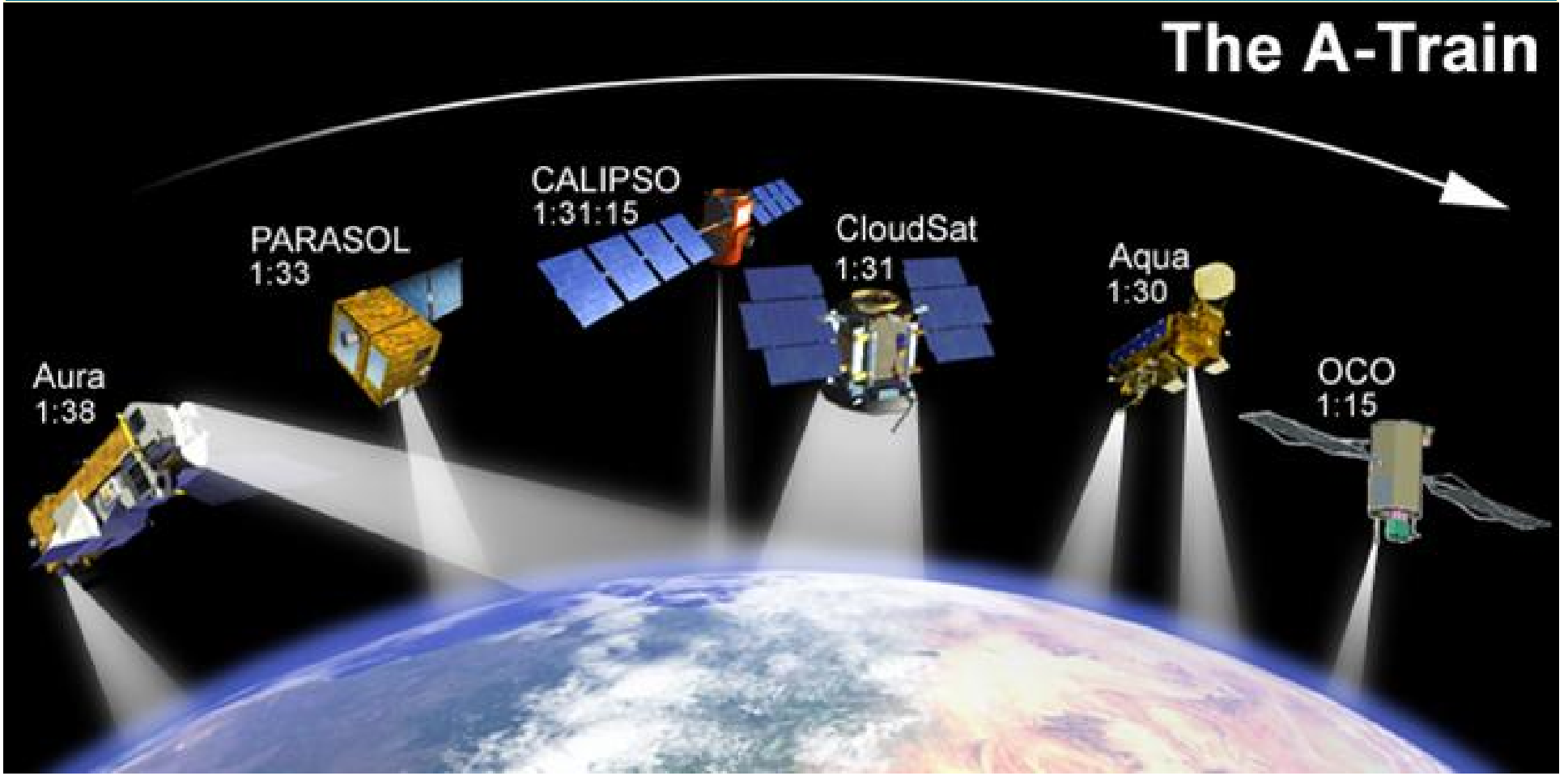
- Thinned radiance datasets for NWP data assimilation, including PC scores
- Products into BUFR format
- Use of MODIS to improve AIRS cloud-cleared radiances.
- Noise-filtered radiances based on eigenvector decomposition
- Thinned datasets for scientific studies, including reprocessing for climate.



How to integrate observations?

- Blend derived products (Optimal Interpolation)
- Assimilation by a numerical weather prediction model (Variational Analysis)
- Algorithm integration of multi-sensor time synchronous observations to improve product accuracy

Algorithm integration of multi-sensor near-time synchronous observations

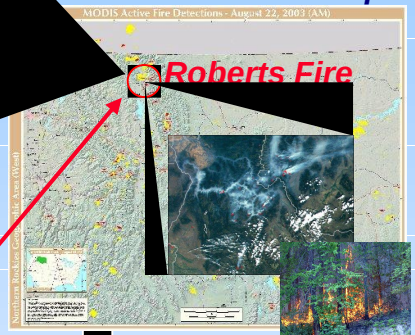


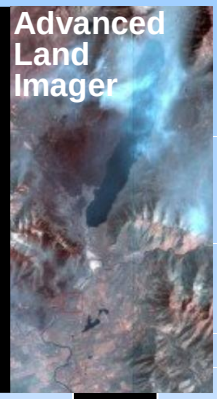
Elements of Integrated Earth Observing System

- Research and operational observation instruments and platforms
- In situ and remote sensing observation networks
- Communication links and computing capacity
- Research and applications development
- Scientific and mathematical algorithms to combine multiple-source data
- Event-driven and model-driven target observations using in situ and very high spatial resolution imagers

EO-1 Targets National Priority Wildfires

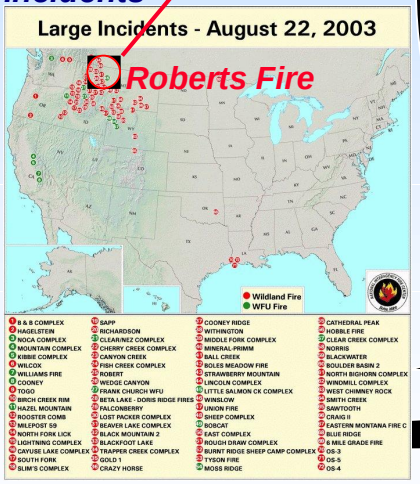
USFS RSAC
MODIS Active Fires Maps



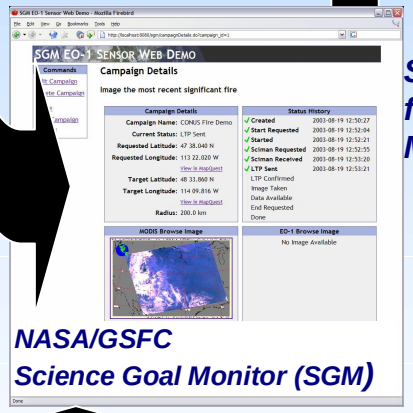


Fire location confirmed
Target info provided to EO-1
planning & scheduling
systems (MOPS, Casper)
EO-1 commands uplinked

NIFC-tracked
Wildfire
Incidents



National Interagency Fire Center
Boise, Idaho

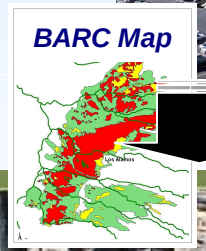


SGM correlates
fire location with
MODIS imagery

NASA/GSFC
Science Goal Monitor (SGM)

LZP
L1a

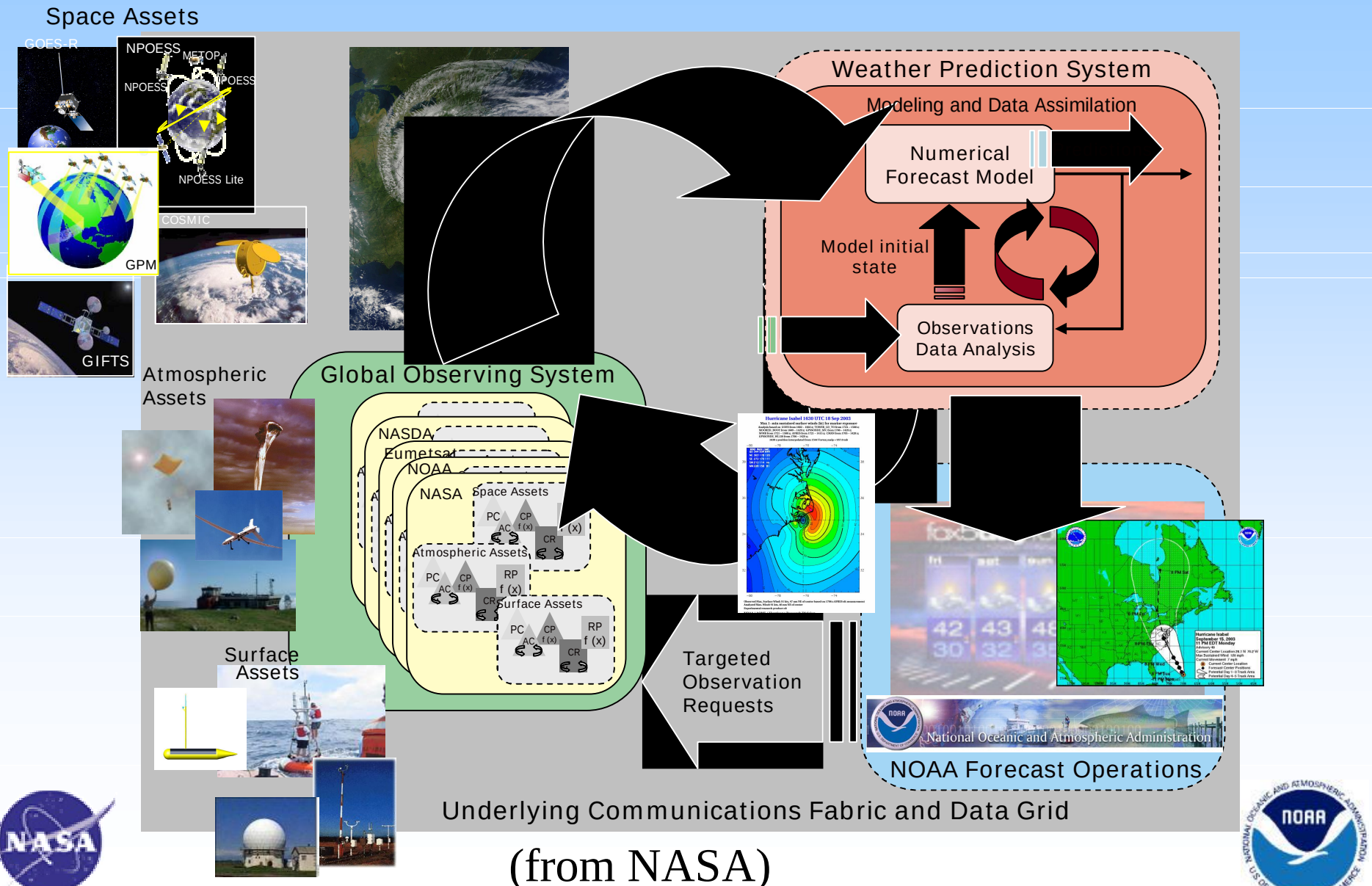
Calibration
Geolocation
Remapped
ERDAS Product



(from NASA)

2025 Weather Forecast System Architecture

Targeted Observations to Reduce Forecast Model Error Growth



(from NASA)