National Environmental Satellite, Data, and Information Service

NOAA Agency Report to CEOS WGCV

Mitchell D. Goldberg, Chief
NOAA/NESDIS/Office of Research and Applications/Satellite Meteorology and Climate Division

Contrbutions from Changyong Cao, Fuzhong Weng, Alexander Ignatov and Felix Kogan

November 9, 2005

Topics

- N18 on-orbit cal/val
- Applications of Simultaneous Nadir Overpass
- AVHRR Reprocessing
- Issues and Recommendations

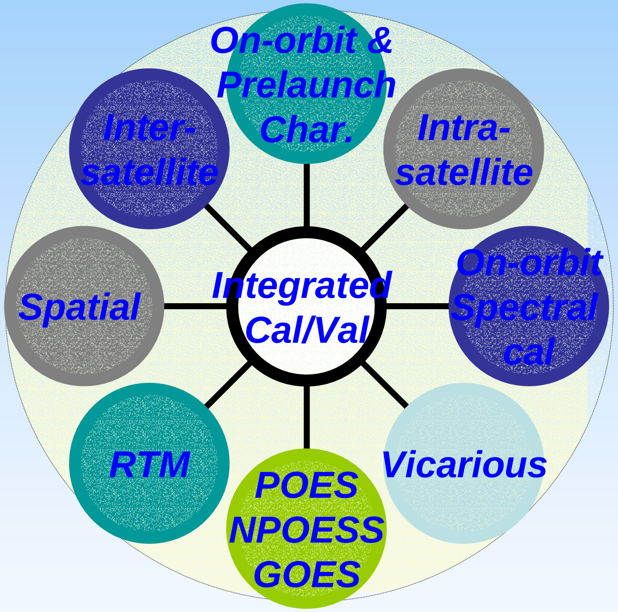
NOAA-18 Cal/Val

Our Team

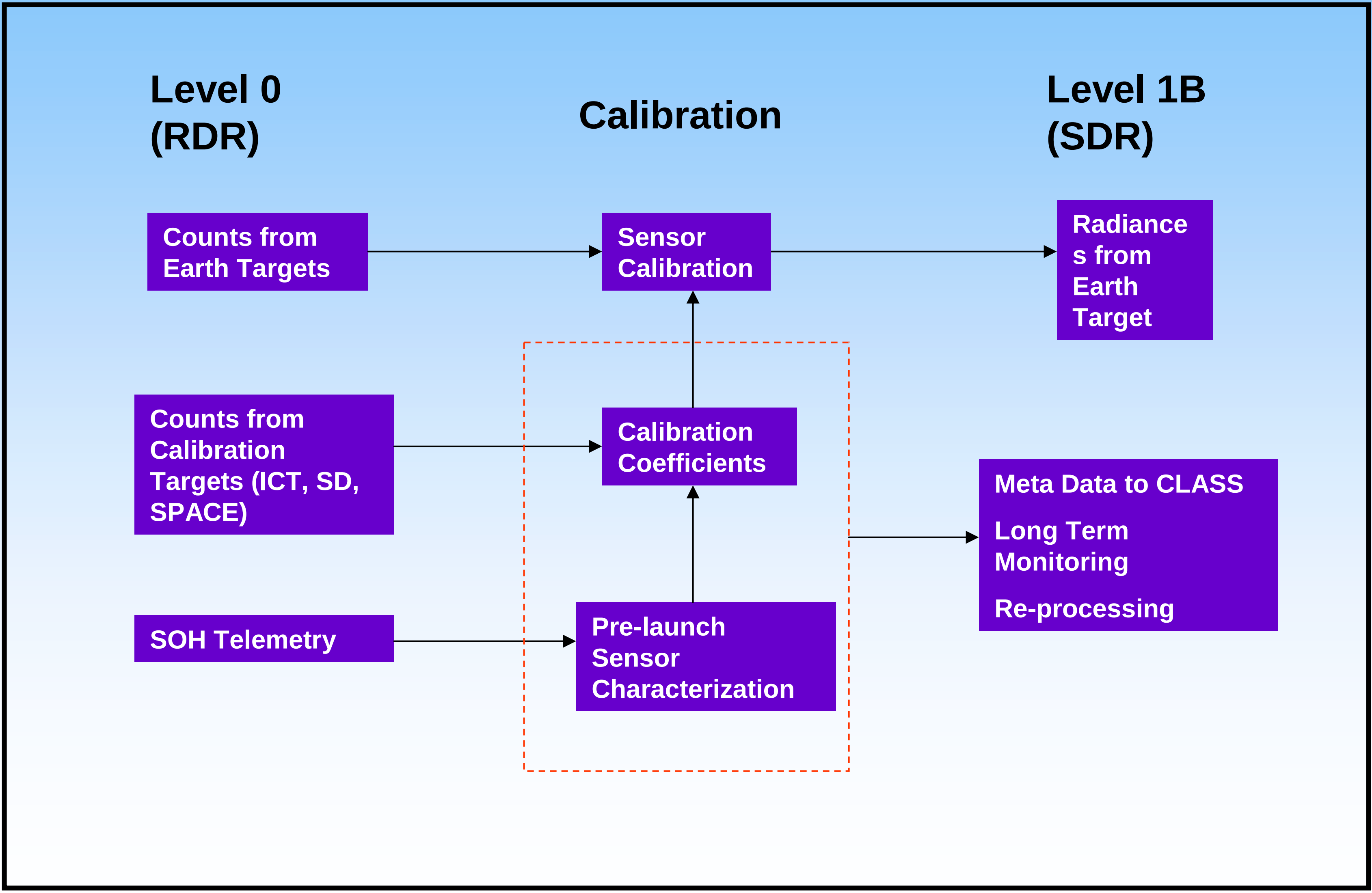
- Mitch Goldberg: ORA/SMCD Division Chief, - Management and Technical Oversight
- Fuzhong Weng: ORA/SMCD/Sensor Physics Branch Chief and NOAA-18 cal/val team leader, instrument asymmetry and microwave products and algorithms, radiance bias assessments for NWP model applications
- Changyong Cao: HIRS instrument calibration
- Fred Wu: AVHRR VIS/IR instrument calibration
- Tsan Mo: AMSU/MHS instrument calibration
- Jerry Sullivan: AVHRR thermal channel calibration/ NDVI validation
- Tony Reale: HIRS/AMSU/MHS sounding channel/products validation
- Mike Chalfant: HIRS/AMSU/MHS sounding channel/products validation /geolocation
- Ralph Ferraro: AMSU/MHS window channels/MSPPS products validation
- Larry Flynn: SBUV product validation
- Tom Kleespies: AMSU on-orbit verification
- Hank Drahos: Sounding product validation
- Dan Tarpley: AVHRR product NDVI monitoring
- Alexsander Ignotov: AVHRR SST and Calibration
- John LeMarshall: Impacts assessments of NOAA-18 data for NWP applications

Integrated Calibration and Validation System - components

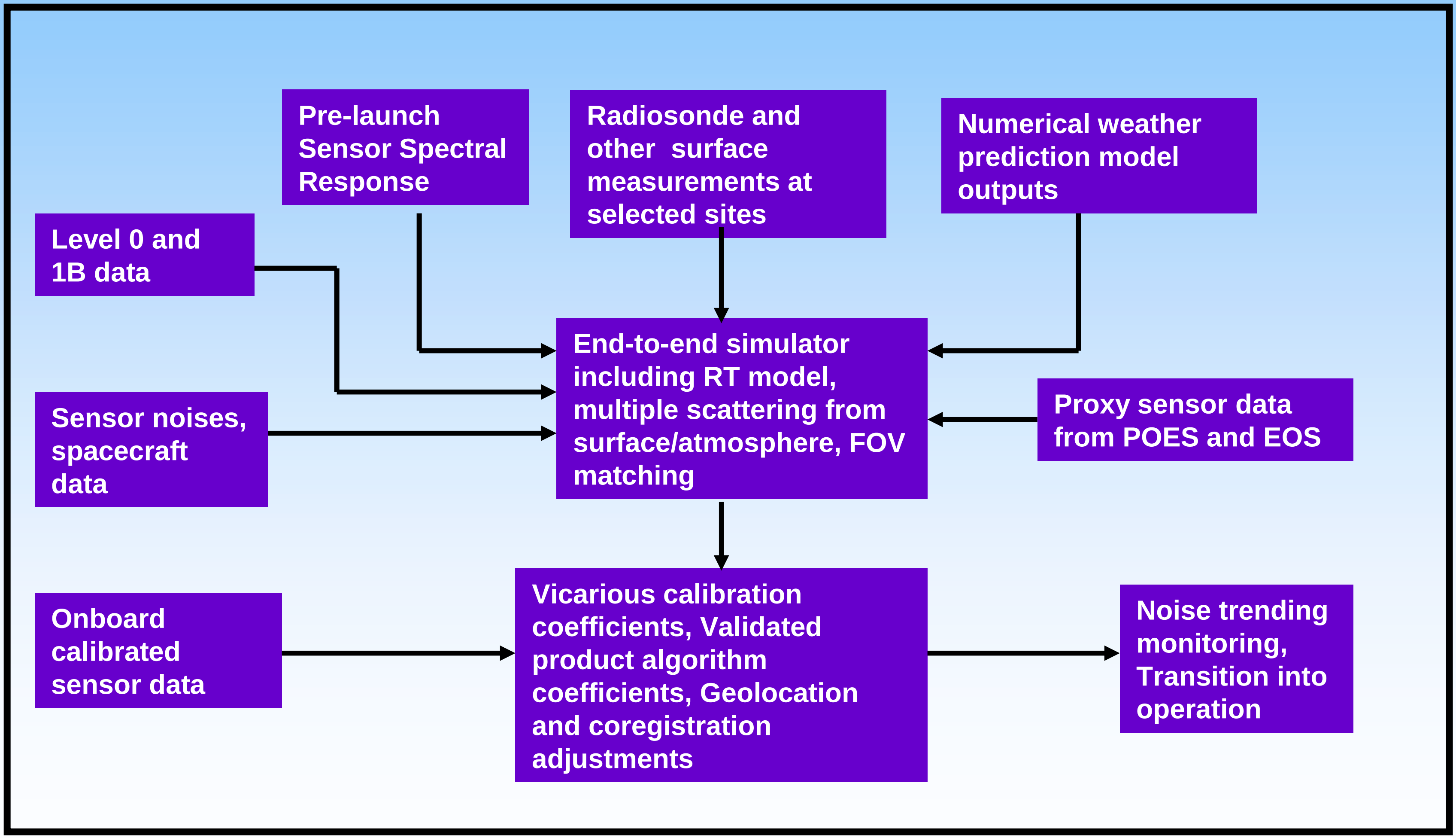
- Monitor and quantify instrument noise by analyzing calibration target and space view measurements (on-orbit & prelaunch)
- Assess instrument geolocation and co-registration errors through real-time pitch and roll, pointing angle adjustments (spatial)
- Characterize other systematic radiance biases through rigorous forward modeling (RTM)
- Characterize the biases between satellites through inter-satellite (inter- satellite)
- Calibration consistency between instruments (intra-satellite)
- Quantify post-launch instrument spectral response function (on-orbit spectral)
- Validate against ground and aircraft observations



ORA Pre-launch Calibration Support



ORA Post-Launch Integrated Cal/Val System Framework



Activities of the ORA NOAA-18 on-orbit Cal/Val Team

- Monitor and quantify instrument noises though analyzing calibration target counts and channel space view measurements
- Assess instrument geolocation biases and co-registration and provide recommended solutions for satellite raw, roll and pitch adjustments
- Characterize other systematic biases in radiance through rigorous forward modeling and inter-satellite calibrations
- Provide initial demonstration and assessments of NOAA-18 data for improving numerical weather prediction
- Validate product algorithms (e.g. ATOVS and MSPPS, TOAST, UV index, NDVI, SST, AOD) for transition into operation
- Communicate with NOAA-18 OV team, instrument vendors and users with timeliness diagnostics of instrument performances and provide root cause analyses

NOAA-N Calibration and Validation - Mozilla Firefox

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http://www.orbit.nesdis.noaa.gov/smcd/spb/n18calval/index.html Go

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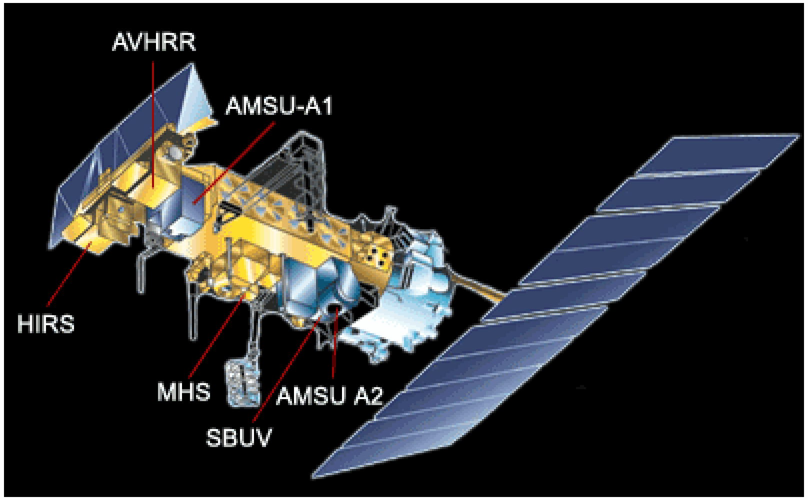
Office of Research and Applications

Sensor Physics Branch

NOAA-18 Instrument Calibration & Validation



What's New in NOAA-18 Instrument Cal/Val

- **HIRS longwave channel noise update:** Channel 1 remains uncalibrated due to space view saturation. Channel 3,8, 11 and 12 meet the noise spec as of Sept 2, 2005. The rest of LW channel noise remain fluctuating near the specification
- **ORA Briefing on NOAA-18 cal/val status at polar satellite monthly**
- **ORA NOAA-18 Cal/Val Group Meetinng (August 9, 2005, Agenda)**
- NOAA-18 was declared operational on August 30, 2005

... More

Background	Calibration & Validation Information					Archiving
Long-Term Goals	AMSU-A	MHS	HIRS/4	AVHRR/3	SBUV/2	Briefings
Cal/Val Activities	Instrument Noise Charactorization	Instrument Noise Charactorization	Instrument Noise Charactorization	Instrument Noise Charactorization	Instrument Noise Charactorization	Meetings
Sensor Summary	Geolocation & Co-registration	Geolocation & Co-registration	Geolocation & Co-registration	Geolocation & Co-registration	Geolocation & Co-registration	
	Products Demo &	Products Demo &	Products Demo &	Products Demo &		

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http://www.orbit.nesdis.noaa.gov/smcd/spb/calibration/icvs/index.html Go

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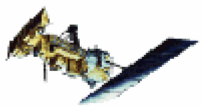
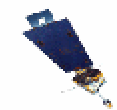
NOAA Satellites and Information

National Environmental Satellite, Data, and Information Service

Sensor Physics Branch



Integrated Satellite Instrument Calibration/Validation System



- Introduction
- Microwave Sounders >>
- Microwave Imagers >>
- IR Sounders >>
  - Inter-satellite Cal. (SNO) >>
  - NOAA-18/HIRS
  - NOAA-17/HIRS
  - NOAA-16/HIRS
  - GOES
  - HIRS Spec. Resp. Functions
  - Planck Calculator
  - Forward Calculation
- IR Imagers >>
- VIS/NIR Imagers >>
- Intra-satellite Calibration >>
- Current Projects >>

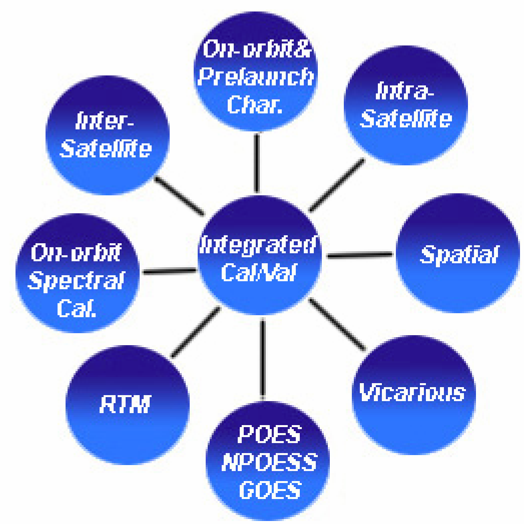
This integrated system is developed to independently verify the radiances produced by satellite instruments to better serve the user community in direct radiance assimilation for numerical weather prediction, physical retrievals, and climate monitoring and reanalysis. The core components of the system include:

...unch instrument characterization and long-term monitoring ...ance.

...ration of radiances using the simultaneous nadir overpass ...ous conical overpass (SCO) methods.

...n of radiances using state-of-the-science radiative transfer ...mospheric profiles for validation and resolving spectral ...es.

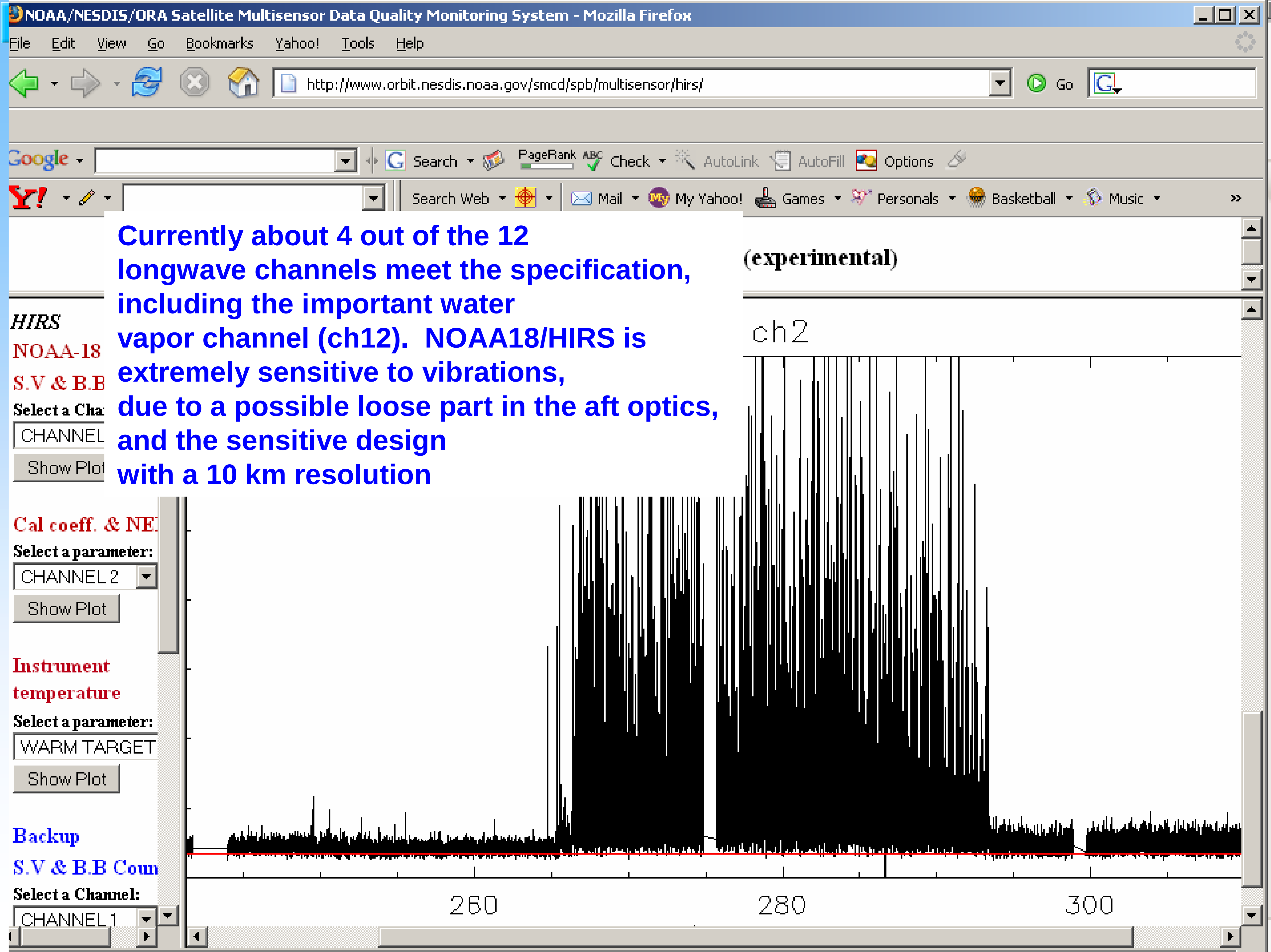
...alibration using hyperspectral data and atmospheric ...



- Intra-satellite calibration, or calibration between instruments on the same satellite, and inter-channel calibration.

http://www.orbit.nesdis.noaa.gov/smcd/spb/multisensor/hirs/

Currently about 4 out of the 12 longwave channels meet the specification, including the important water vapor channel (ch12). NOAA18/HIRS is extremely sensitive to vibrations, due to a possible loose part in the aft optics, and the sensitive design with a 10 km resolution



ORA NOAA-18 HIRS/3 Cal/Val Findings

Support to NOAA's Critical Satellite Program

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Noises, Bias and Anomaly

- HIRS/3 LW noises are fluctuating and most of channel noises are 2-3 times higher than the spec.
- Noises among all channels are highly correlated
- Occasionally a few channels meet the noise specification
- Space view counts at ch1 remain saturated
- Noise trending website is developed for real-time monitoring

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Navigation and Co-registration

- HIRS geolocation is nearly perfect
- HIRS and AVHRR are well aligned with a mean constant shift of 3-4 AVHRR pixel. (due to AVHRR has roll biases)

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NWP Readiness and Product Demo

- Coefficients in radiative transfer model and data assimilation system are updated
- Brightness temperatures at some good channels are assessed and show good sounding capability

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Recommended Solutions and Mitigation Strategy

- ORA has several telecons with OV team to present the noise assessment results
- ORA diagnosed filterwheel clamp system outputs and related circuit and proposed several possible coherent noise generators, 1)clamp system itself, 2) interference of the clamp system or 3) through the clamp system (many possible freqs)
- These root cause analyses are likely confirmed by MIT/Lincoln Lab.

National Environmental Satellite, Data, and Information Service

ORA NOAA-18 AMSU-A Cal/Val Findings

Support to NOAA's Critical Satellite Program

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Noises, Bias and Anomaly

- AMSU-A on-orbit noises are evaluated and NEDTs from all channels meet the specification.
- AMSU-A2 module display the smallest cross-track asymmetry among all previous module and results in a high quality of cloud liquid water and TPW products
- However, AMSU-A1 module display a larger asymmetry

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Navigation and Co-registration

- AMSU-A1 is correctly navigated
- AMSU-A2 is off by 0.7 MHS scanline along track and 0.36 MHS FOVs across track.

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NWP Readiness and Product Demo

- Coefficients in radiative transfer model and data assimilation system are updated
- Impacts of AMSU on weather prediction are being assessed
- AMSU microwave surface and precipitation products are demonstrated

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Recommended Solutions and Mitigation Strategy

- Recommend to OV team for possible roll and pitch adjustments to A2 navigation errors
- Recommend to OV team for investigating AMSU-A1 cross-track asymmetry
- Study the antenna pattern correction algorithm

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ORA NOAA-18 AMSU-A Cal/Val Findings

Support to NOAA's Critical Satellite Program

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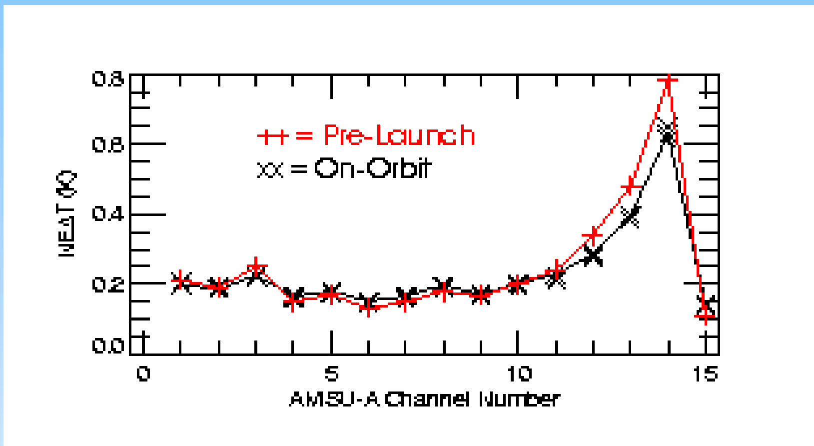
Noises, Bias and Anomaly



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Navigation and Co-registration

Instrument	Orbit	Des/Asc	Cross-Track [Instrument FOVS]		Along-Track [Scan lines]	
AMSU-A2 23 GHz	D05172 S0244	D	+0.30	+0.50	+0.50	+0.70
	D05172 S0952	A	-0.10	-0.10	+0.70	+0.80
	D05172 S0434	A	+0.50	+0.30	+0.80	+0.80
	D05172 S1747	D	+0.40	+0.30	+0.60	+0.70
A2-Average			+0.26 (=+4.7 km@nadir)		+0.70 (=+12.5 km@nadir)	
AMSU-A1 50 GHz	D05172 S0244	D	+0.20	+0.20	-0.30	-0.35
	D05172 S0952	A	-0.20	-0.10	+0.00	+0.00
	D05172 S0434	A	+0.20	+0.30	0.00	0.00
	D05172 S1747	D	+0.20	+0.20	+0.20	+0.00
A1-Average			+0.13 (=+2.2 km@nadir)		+0.06 (=+1.0 km@nadir)	
MHS 89 GHz	D05172 S0244	D	+0.35	+0.35	-1.00	-1.00
	D05172 S0952	A	+0.10	+0.00	-0.90	-0.90
	D05172 S0434	A	+0.10	+0.10	-0.70	-0.80
	D05172 S1747	D	+0.20	-0.20	-0.80	-1.20
MHS-Average			+0.18 (=+3.2 km@nadir)		-0.92 (=-16.4 km@nadir)	

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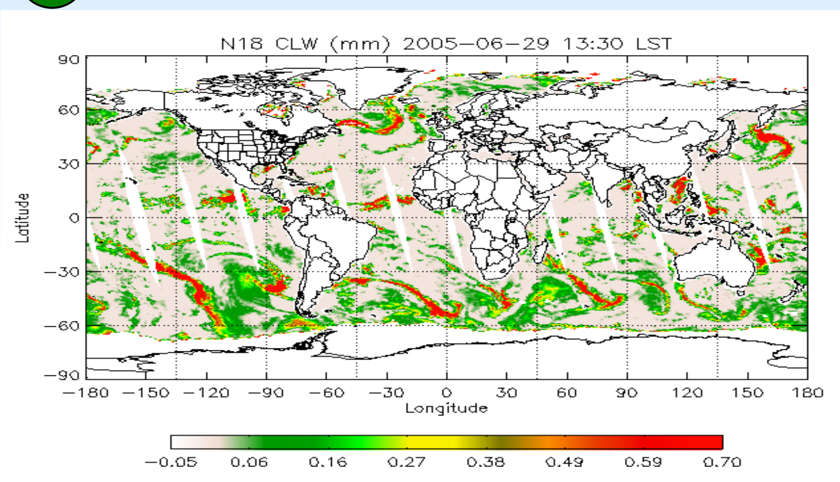
NWP Readiness and Product Demo



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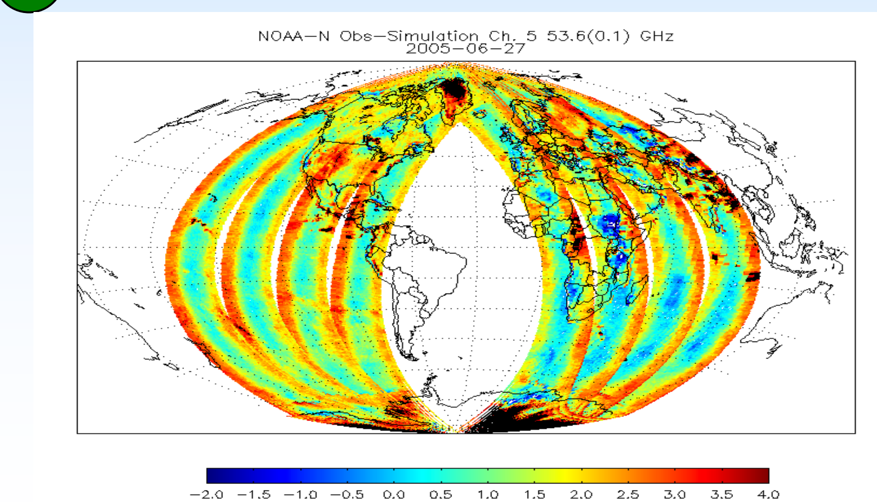
Recommended Solutions and Mitigation Strategy



ORA NOAA-18 MHS Cal/Val Findings

Support to NOAA's Critical Satellite Program

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Noises, Bias and Anomaly

- MHS noises meet the specification and are better than AMSU-B

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Navigation and Co-registration

- Display 0.9 MHS scanline error along track

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NWP Readiness and Product Demo

- Coefficients in radiative transfer model and data assimilation system are updated
- Impacts of MHS on weather prediction are being assessed
- MHS microwave surface and precipitation products are demonstrated

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Recommended Solutions and Mitigation Strategy

- Recommend to OV team for possible roll adjustment to correct MHS navigation errors

ORA NOAA-18 MHS Cal/Val Findings

Support to NOAA's Critical Satellite Program

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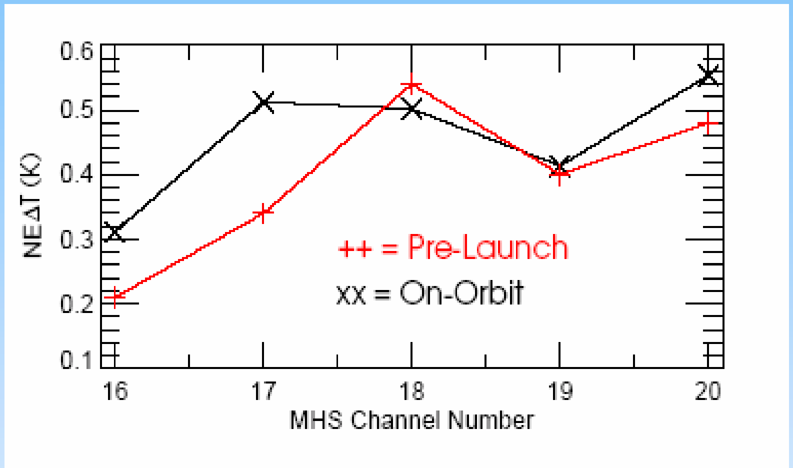
Noises, Bias and Anomaly



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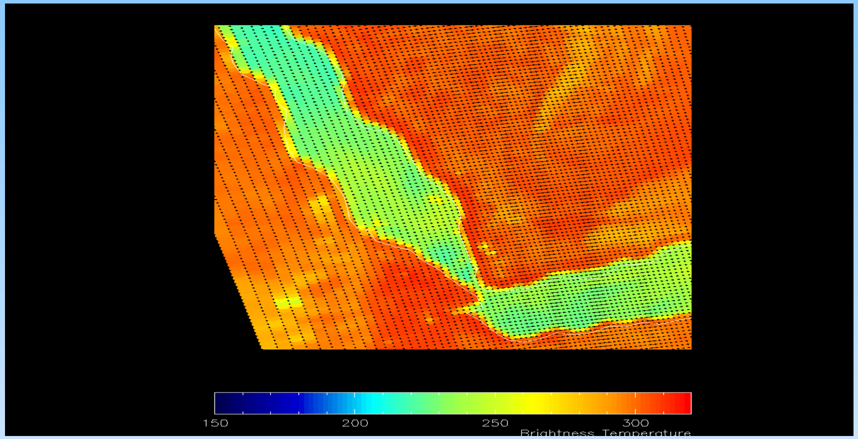
Navigation and Co-registration



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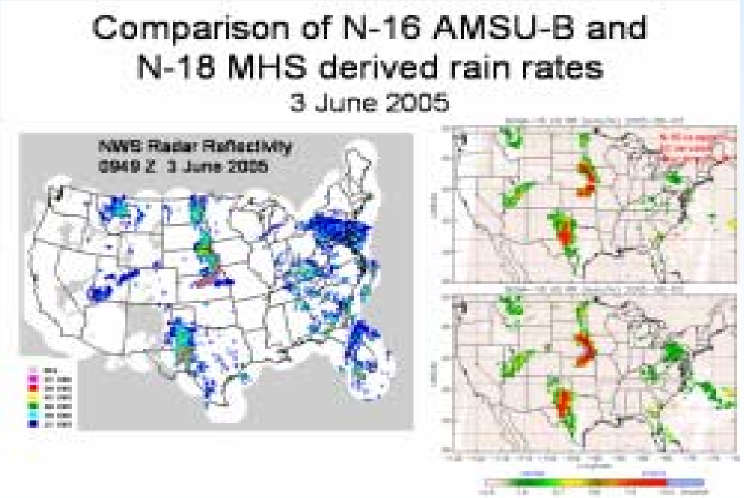
NWP Readiness and Product Demo



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Recommended Solutions and Mitigation Strategy

- Recommend to OV team for possible roll adjustment to correct MHS navigation errors

ORA NOAA-18 AVHRR/4 Cal/Val Findings

Support to NOAA's Critical Satellite Program

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Noises, Bias and Anomaly

- The blackbody temperature changes are monitored and shows in a small range of variability (only 2K)
- Thermal channel (3-5) calibration is healthy
- Wu's Vis/IR calibration algorithms are working well

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Navigation and Co-registration

- AVHRR/4 has possible 2-3 pixels navigation errors

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NWP Readiness and Product Demo

- AVHRR/4 produces a good quality of NDVI
- AVHRR/4 produces SST and aerosol optical depth with smaller biases

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Recommended Solutions and Mitigation Strategy

- Recommend to OV team to have possible roll adjustments

ORA NOAA-18 AVHRR/4 Cal/Val Findings

Support to NOAA's Critical Satellite Program

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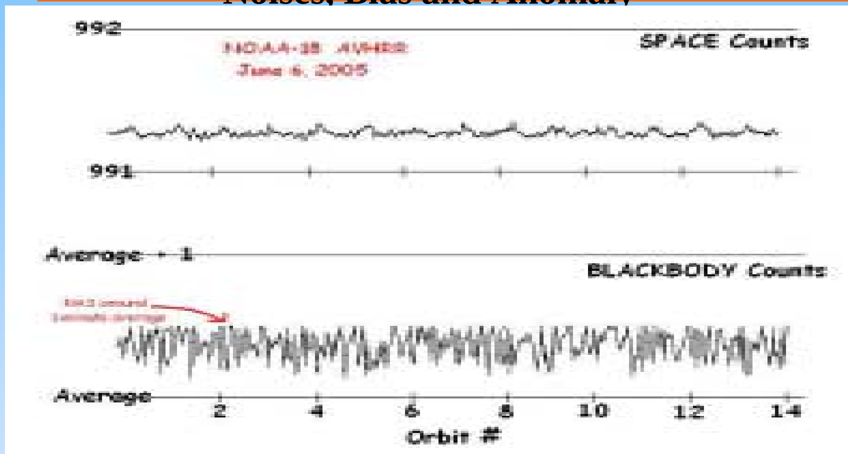
Noises, Bias and Anomaly



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Navigation and Co-registration

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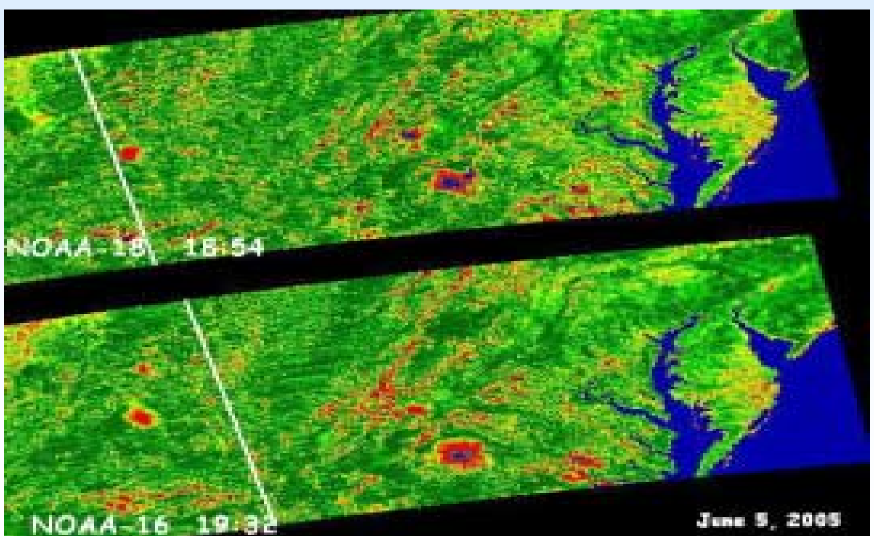
NWP Readiness and Product Demo



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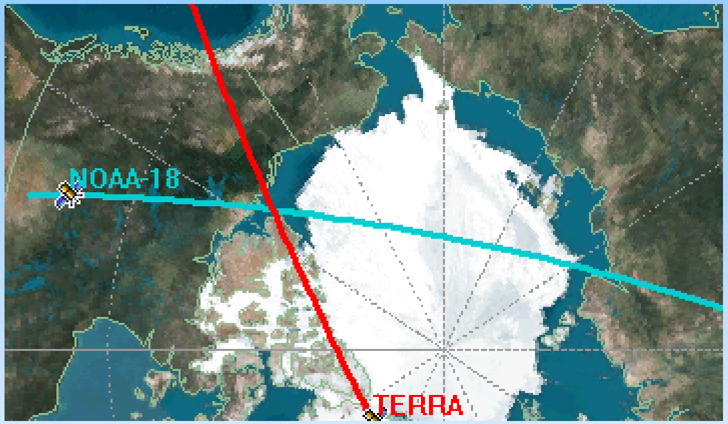
Recommended Solutions and Mitigation Strategy

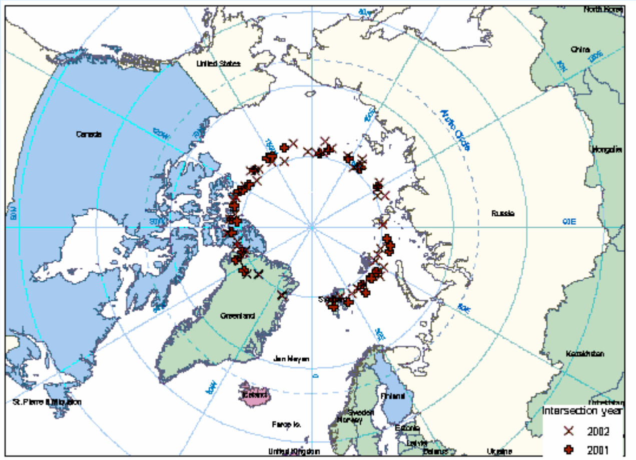
- Recommend to OV team to have possible roll adjustments

Simultaneous Nadir Overpass Applications

Intersatellite Calibration using the Simultaneous Nadir Overpass (SNO) method

- SNO – every pair of POES satellites with different altitudes pass their orbital intersections within a few seconds regularly in the polar regions (predictable w/ SGP4)
- Precise coincidental pixel-by-pixel match-up data from radiometers provides reliable long-term monitoring of instrument performance
- The SNO method has been used for operational on-orbit longterm monitoring of AVHRR, HIRS, AMSU and for retrospective intersatellite calibration from 1980 to 2003 to support climate studies
- The method is expanded for SSMI with the Simultaneous Conical Overpass (SCO) method

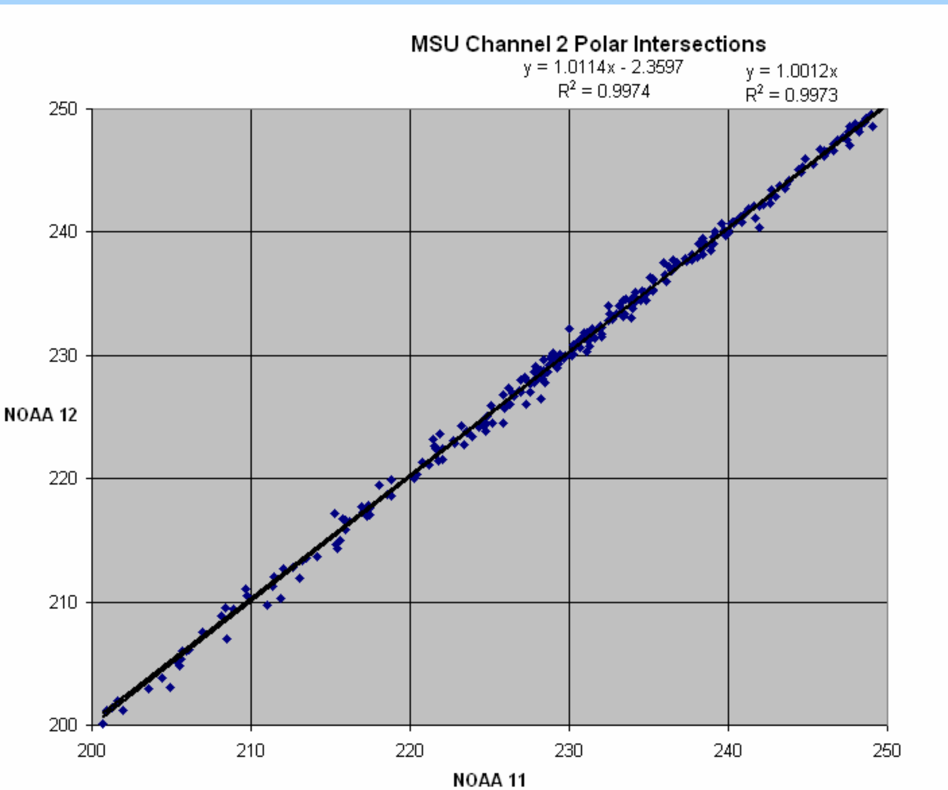




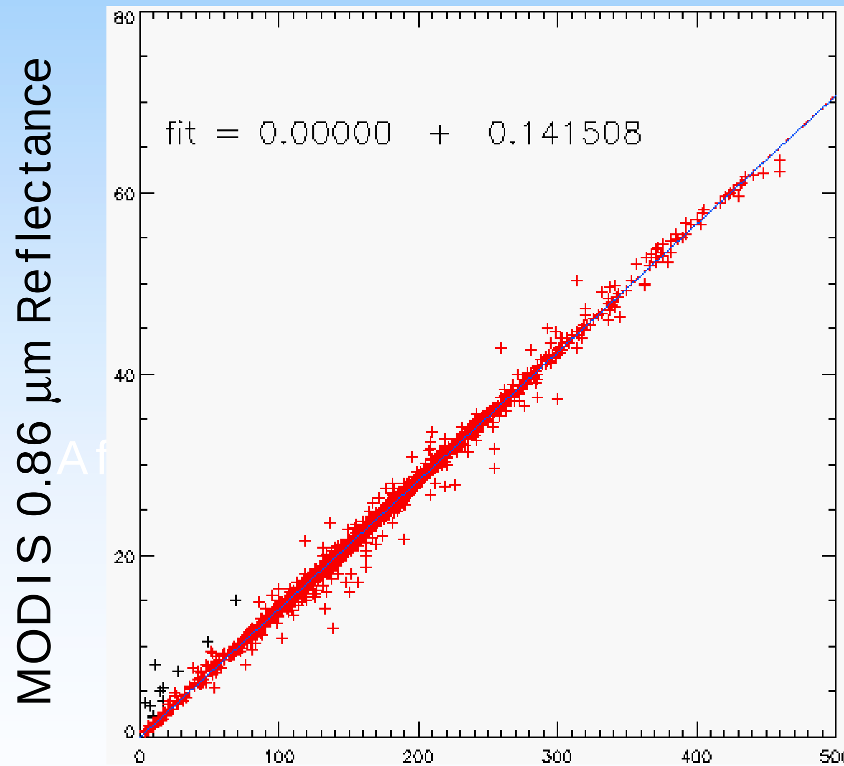
SNOs occur regularly in the +/- 70 to 80 latitude

SNO Applications

NOAA-12 vs NOAA-11 MSU Channel 2



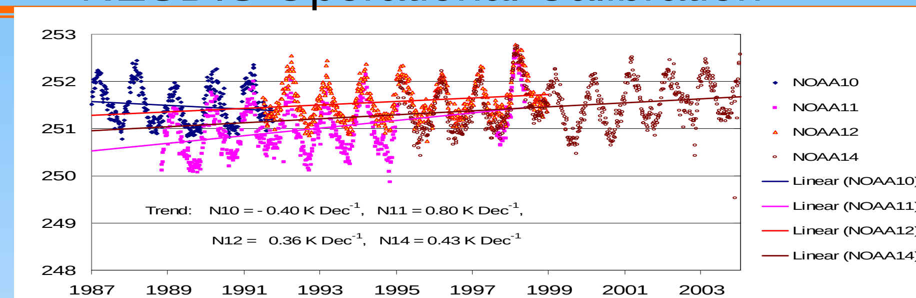
Example of one month of SNO's between TERRA/MODIS and NOAA-17 AVHRR

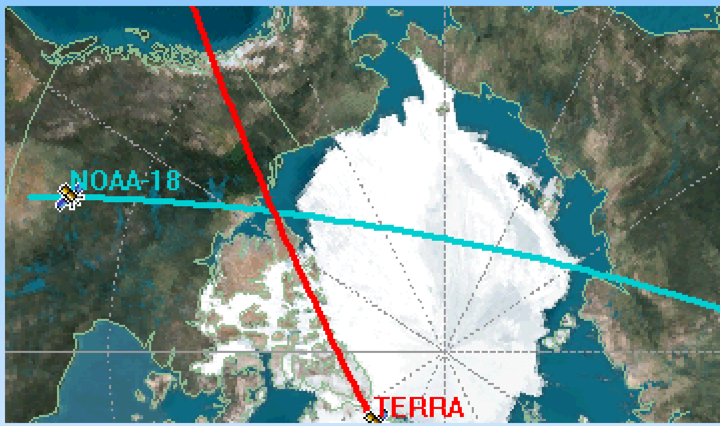


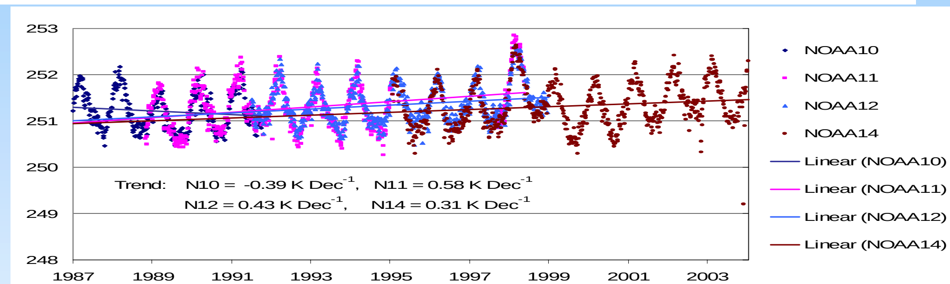
AVHRR Ch2 (0.86 µm) Count

Result: Improved MSU time series

NESDIS Operational Calibration

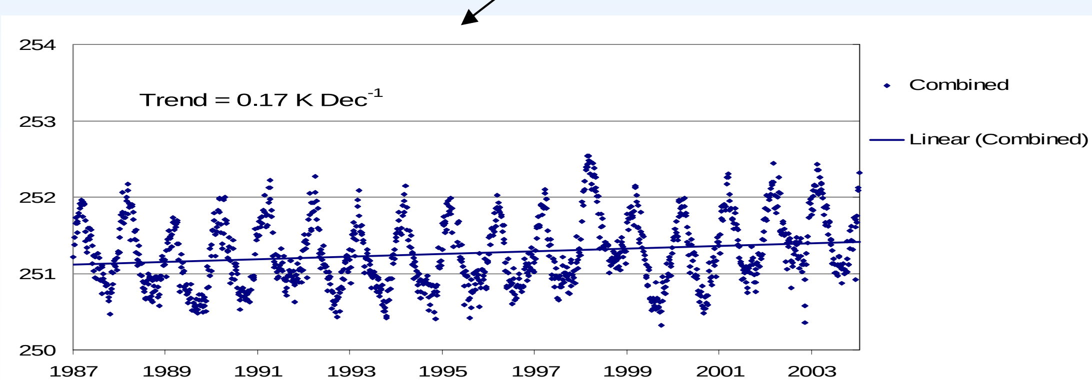






Simultaneous Nadir Overpass (SNO)

Improved calibrated radiances using SNO- improved differences between sensors by order of magnitude.



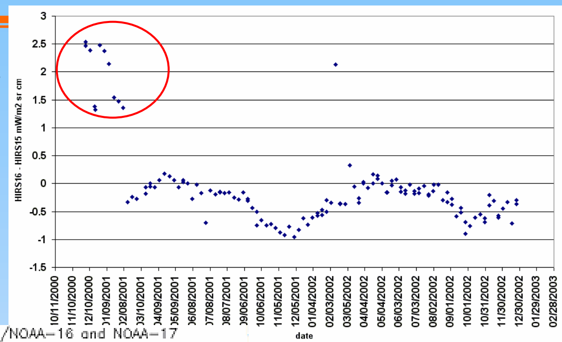
Trends for nonlinear calibration algorithm using SNO cross calibration

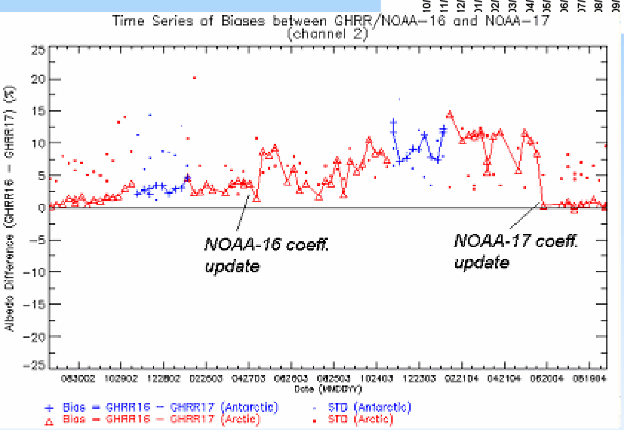
0.17 K Decade^{-1}

(trend without SNO is 0.22K)

SNO Studies at NOAA/NESDIS

•Detected onboard calibration anomalies (HIRS)





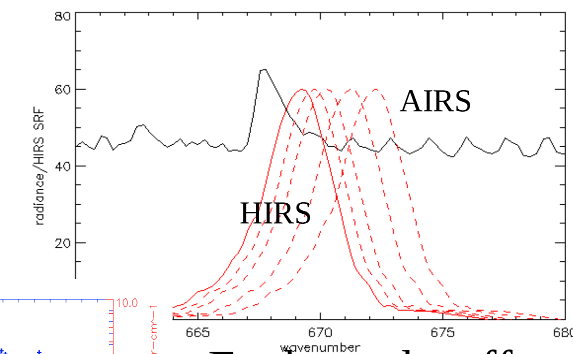
•Monitor cal coeff. updates (AVHRR VIS)

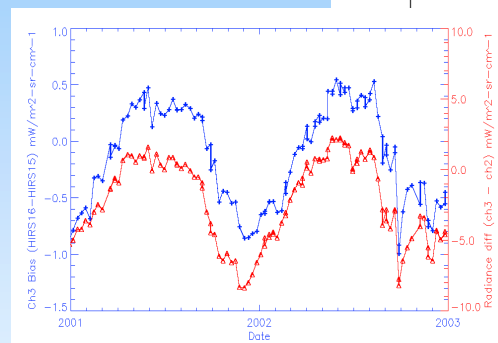
• Quantify biases between MODIS and AVHRR/N-16 (uncertainties < NEDT)

• Study MODIS striping in the SST bands

AVHRR-MODIS

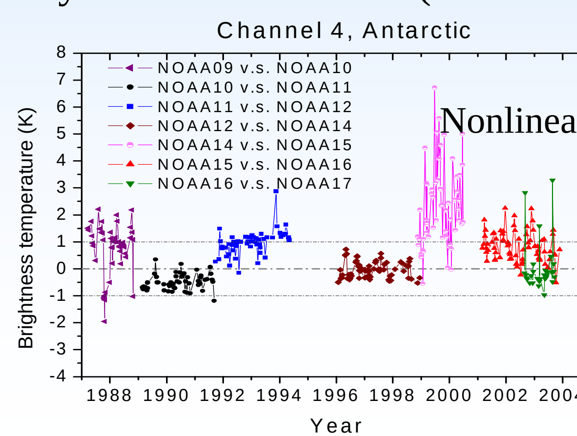
•Spectral cal of HIRS using AIRS





•Evaluate the effect of spectral uncertainties on climate trending

•Intersatellite cal (1980-2003) to improve consistency for climate studies (AVHRR&HIRS)

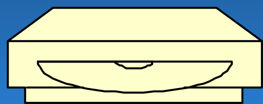


AVHRR Reprocessing

The ORA AVHRR Processing System (as used for PATMOS-x)

INPUT

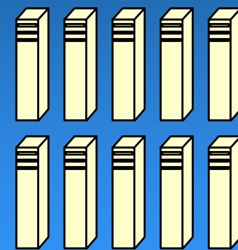
12 TB of online storage



- •AVHRR GAC Level 1B from CLASS (65 MB/ 32 TB)*
- •Clevernav – new pixel geolocation (10 MB / 2 TB)
- •NCEP Reanalysis (50 GB)
- •Clear-sky Ch1 and NDVI Composites (1 MB / 3 GB)
- •OISST (0.5 MB / 700 MB)

PROCESSING

10 dual CPU
Linux Workstations



CLAVR-x**

OPTRAN

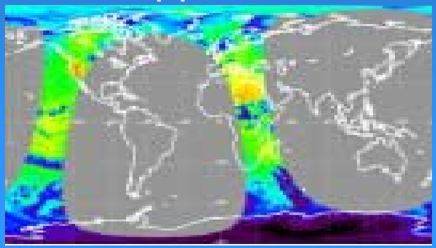
Mapping

Averaging

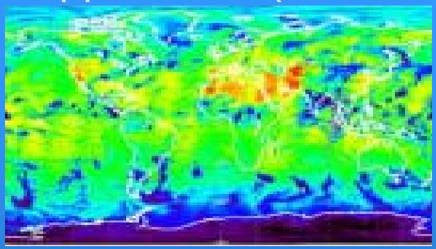
OUTPUT (0.5°)

Orbital pixel-level products
- *Used for GVI-x processing*

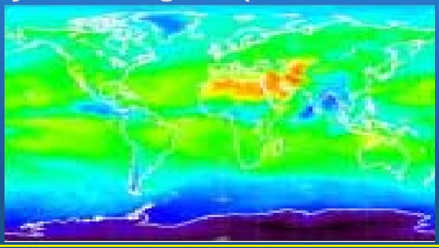
Orbital Mapped Products



Daily Mapped Files (50 MB / 2TB)



Monthly Averages (50 MB / 45 GB)



** Size given per orbit (or day) processing and for processing all orbits or days.*

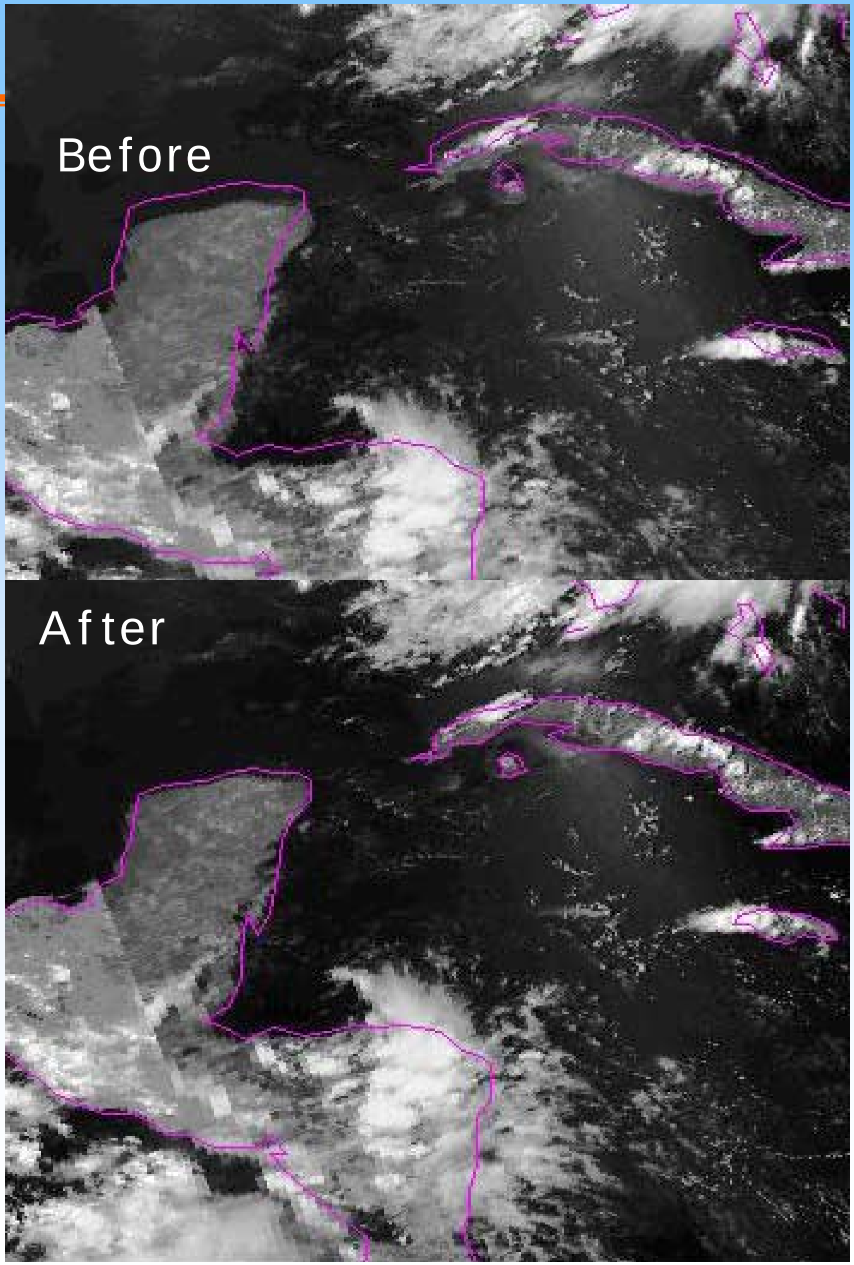
***Note, CLAVR-x is same system used by OSDPD but run in different configuration for PATMOS-x*

AVHRR Scientific Stewardship Pilot Study

•University of Miami provided a database of the AVHRR clock errors. These clock errors are the dominant source of along-track geolocation errors.

•We have used these clock error estimates along with an orbital prediction model to compute the geolocation for each pixel. This removes the need for spatial interpolation which could lead to large errors at high latitudes.

•The new geolocation results also correct for lines with missing geolocation.



Example of an AVHRR Data Improvement Activity: Reflectance Calibration

- The AVHRR has no onboard calibration source for its solar reflectance channels (0.63 and 0.86 µm).

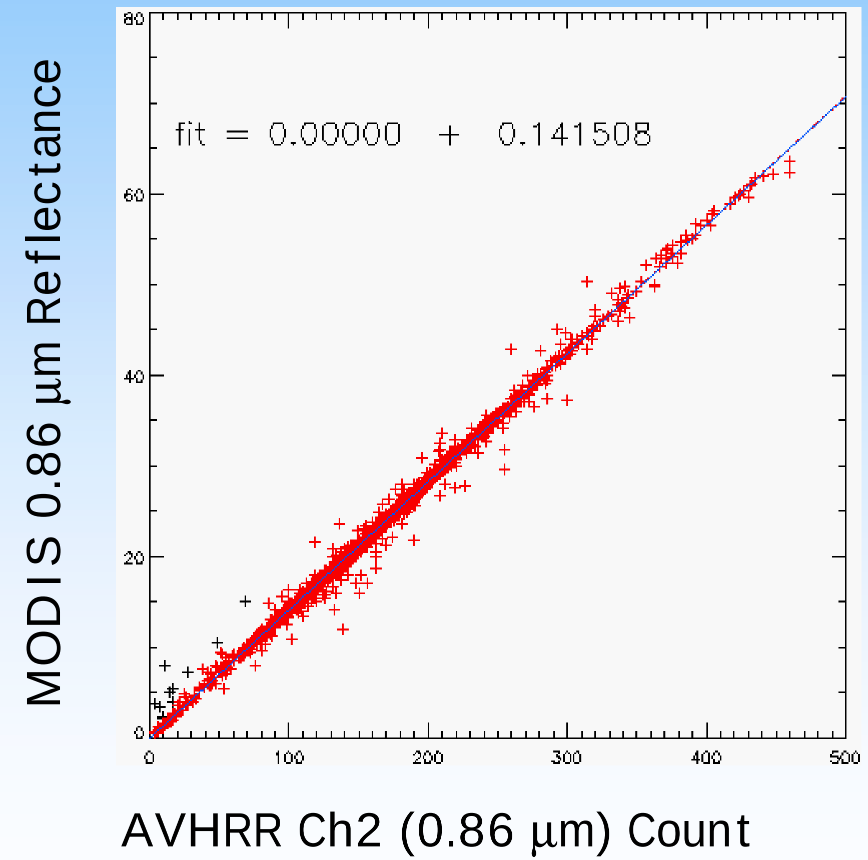
- Use of the AVHRR for climate applications requires continuous post-launch adjustment of the reflectance calibration.

- With the launch of MODIS and other sensors with on-board calibration for reflectance channels, we can transfer their calibration to the AVHRR

- We have used simultaneous nadir observations (SNO) with MODIS and AVHRR (see right).

- We have used MODIS to characterize other stable desert targets to transfer MODIS's calibration to AVHRR data before 2000.

Example of one month of SNO's between TERRA/MODIS and NOAA-17 AVHRR



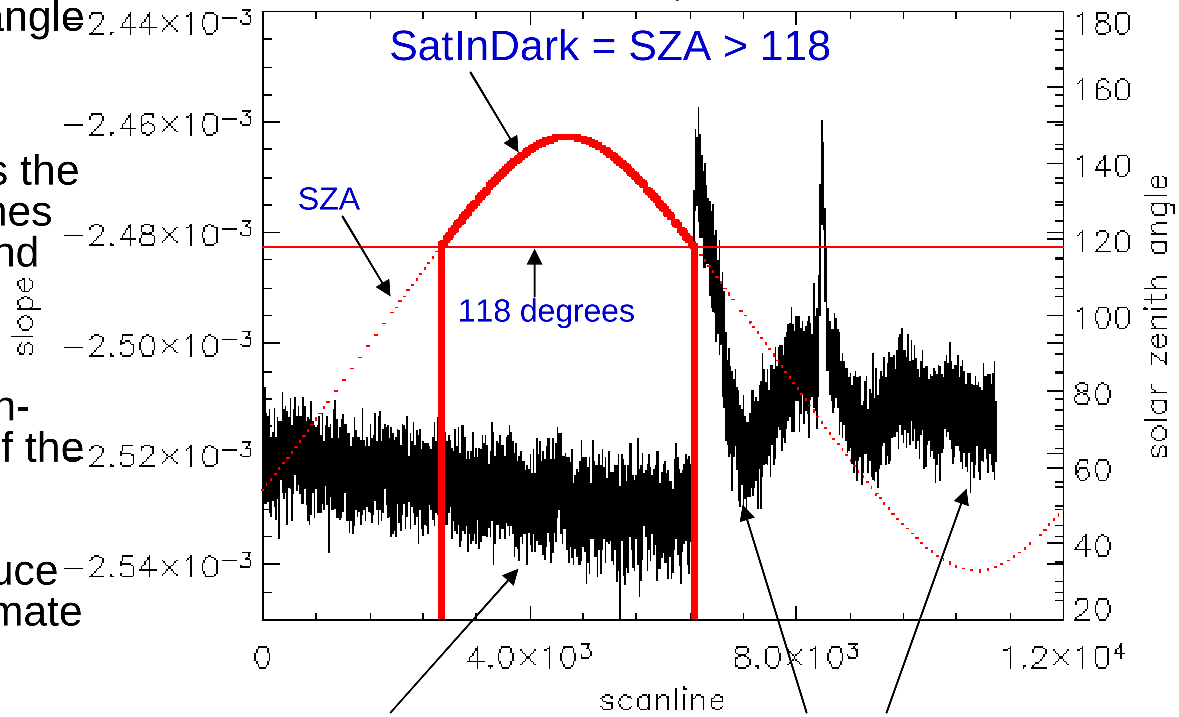
AVHRR Re-calibration for Climate

- AVHRR onboard calibration is contaminated by the Sun, causing biases in all IR channels when SatInLight (nadir solar zenith angle SZA < 118 degrees).
- The bias varies ~0.2 – 1 K. As the orbit drifts, %SatInLight becomes longer, causing a cold bias trend over time in observations.
- This problem can be fixed by in-depth analysis and modeling of the blackbody orbital thermal dynamics; generating better calibration coefficients to produce more accurate radiance for climate trending studies.
- Slope is the key for calibration accuracy and climate trending

Radiance = delta count * slope

(Delta count is reliable most of the time)

Slope over an orbit for NOAA-16/AVHRR Channel 3b, 2003



Slope shows excellent stability when SatInDark

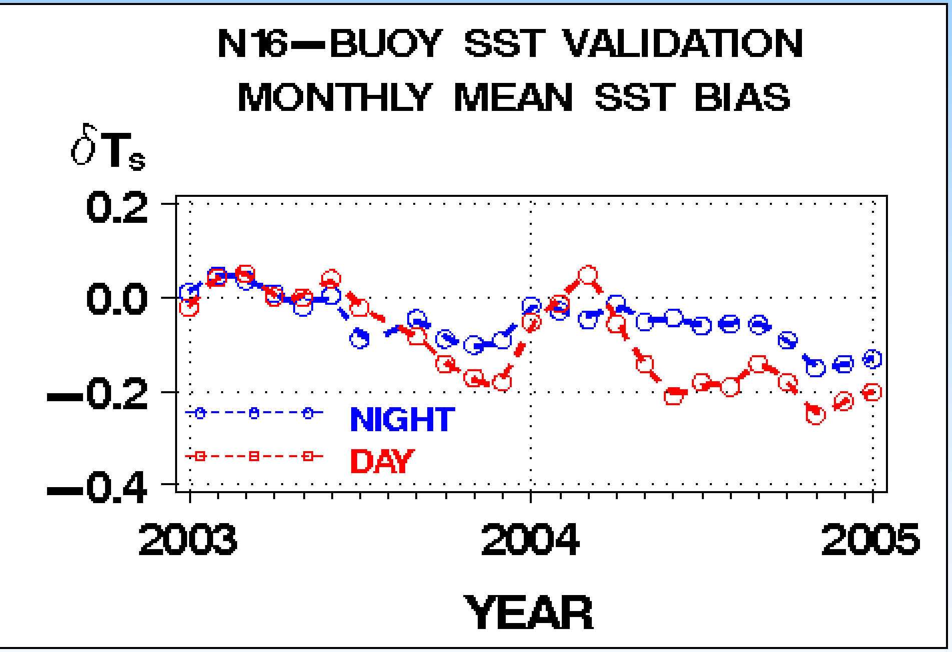
SatInLight slope fluctuation due to blackbody contamination

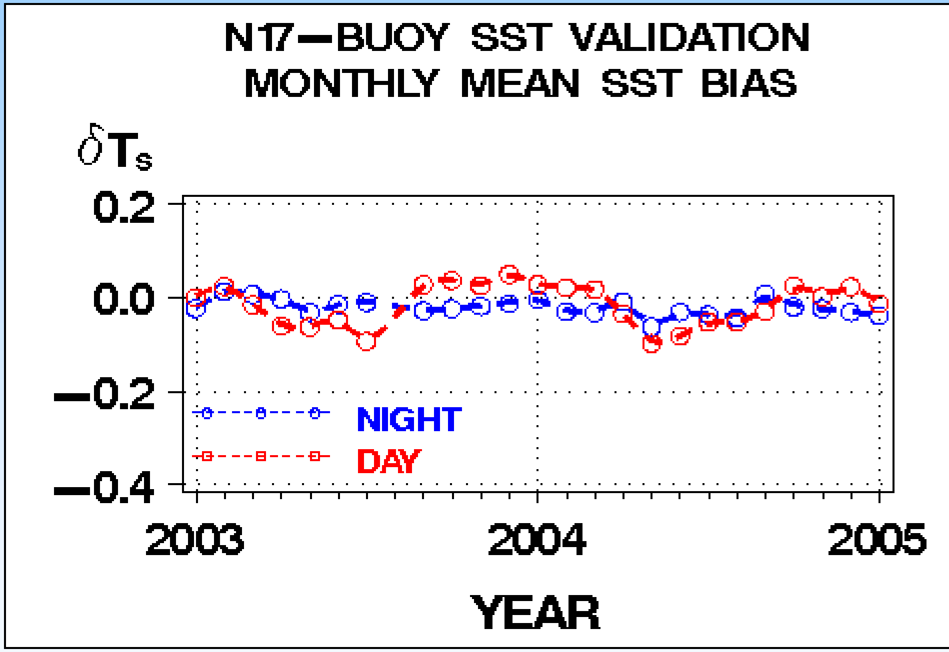
Results-2:
SST vs. Drifting Buoys

N16 SST trends are artifacts (not real climate change)

N16: negative trends in both DAY= $f(T_{11},T_{12})$ and NIGHT=$f(T_{3.7},T_{11},T_{12})$ SSTs

N17:
No trends in both DAY and NIGHT SSTs





DAY:
split-window NLSST

$$T_S = a_o + a_1 T_{11} + a_2 T_{SFC}(T_{11} - T_{12}) + a_3 (T_{11} - T_{12})(\sec\theta - 1)$$

NIGHT:
triple-window MCSST

$$T_S = a_o + a_1 T_{3.7} + a_2 T_{11} + a_3 T_{12} + a_4 (T_{3.7} - T_{12})(\sec\theta - 1) + a_5 (\sec\theta - 1)$$

...nmental Satellite, Information Service

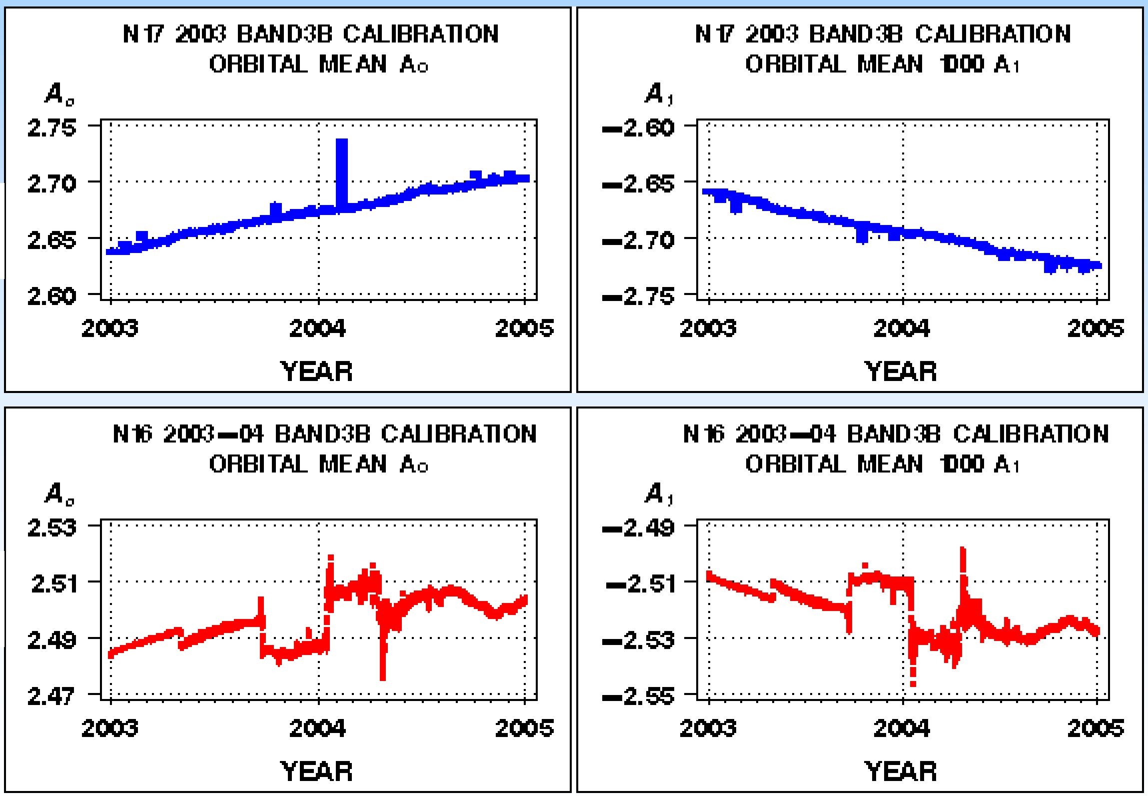
Results-3:
IR Cal trending from Cal HDF

- AVHRR Thermal bands: Calibrated onboard
- Two reference points: 1) Onboard black body; 2) deep space

Ch3B (3.7 μm): detector response linear $R_{3B} = A_o + A_1 C_{3B}$

N17

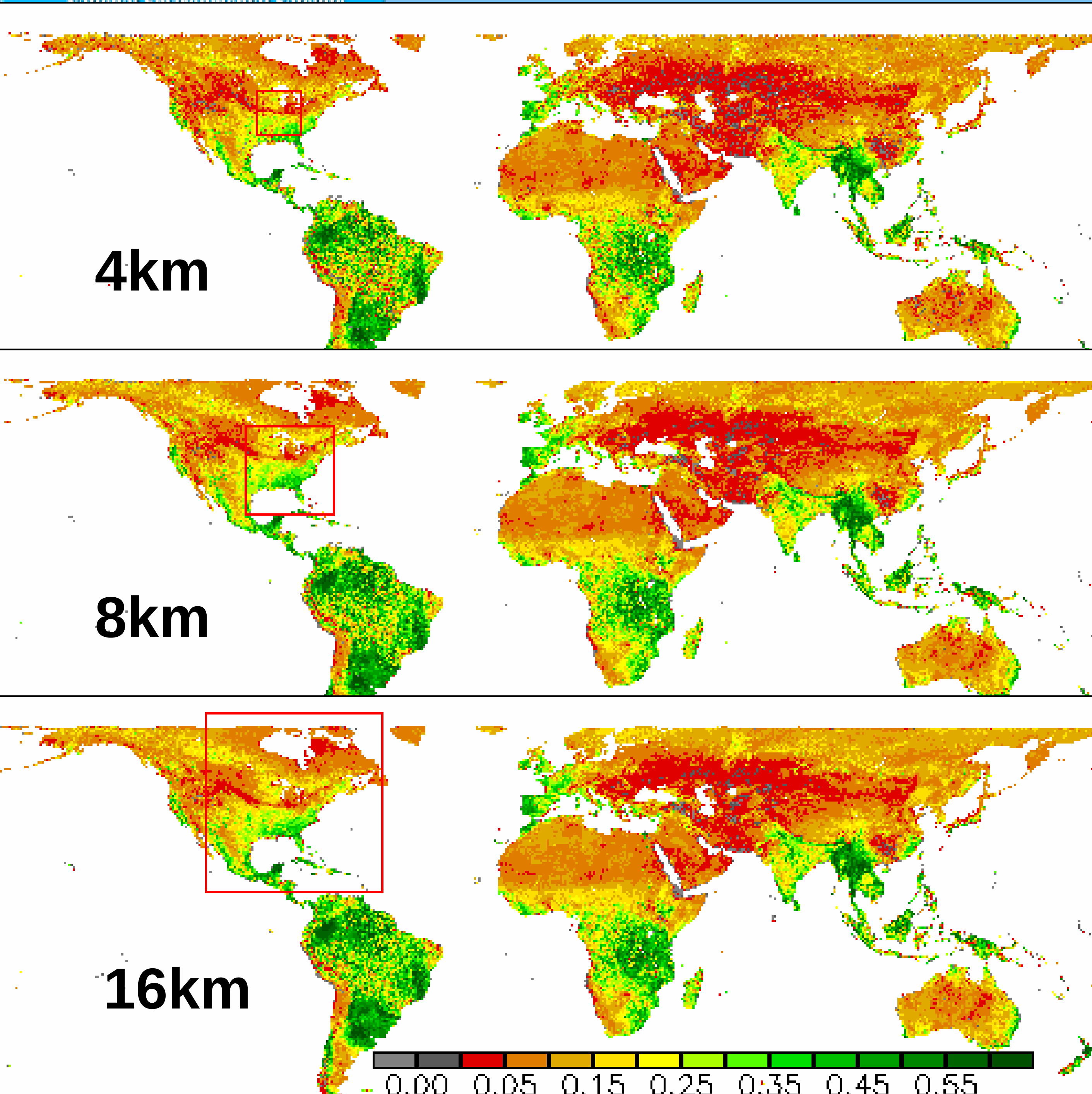
N16



Trends “well-behaved”

Not so well-behaved

Bands 4/5 (11/12 μm): Similar/More complex (detectors non-linear)

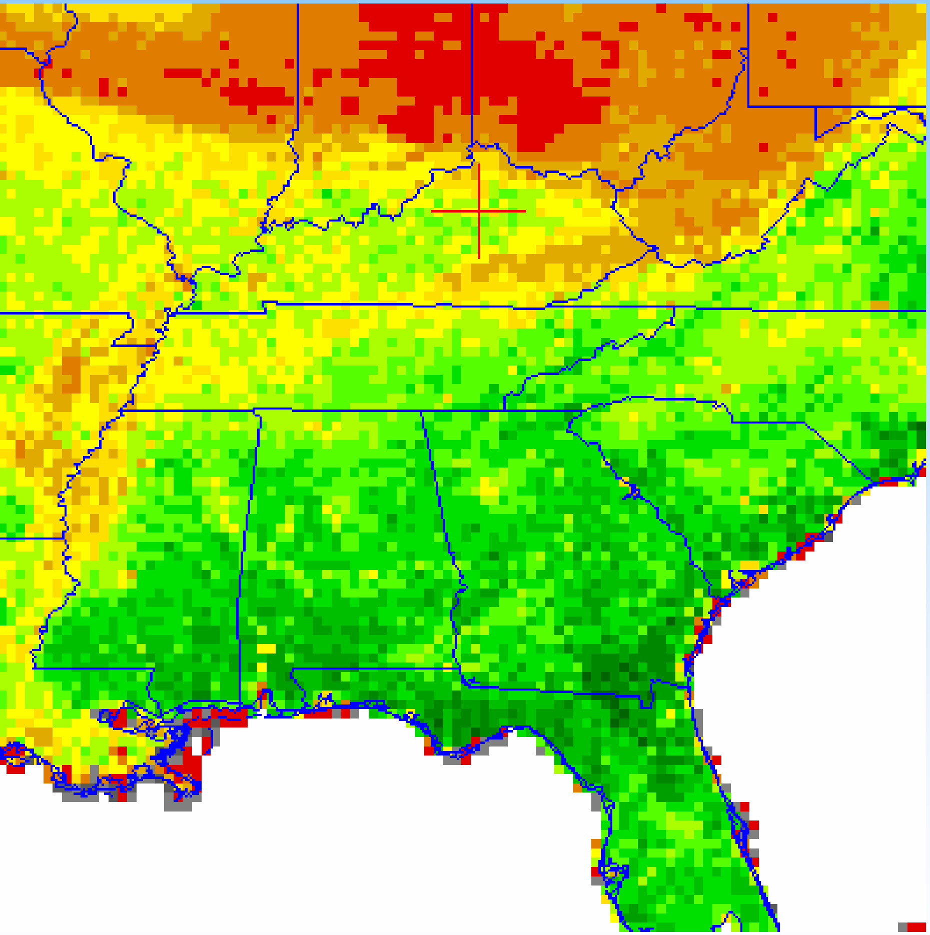


NDVI

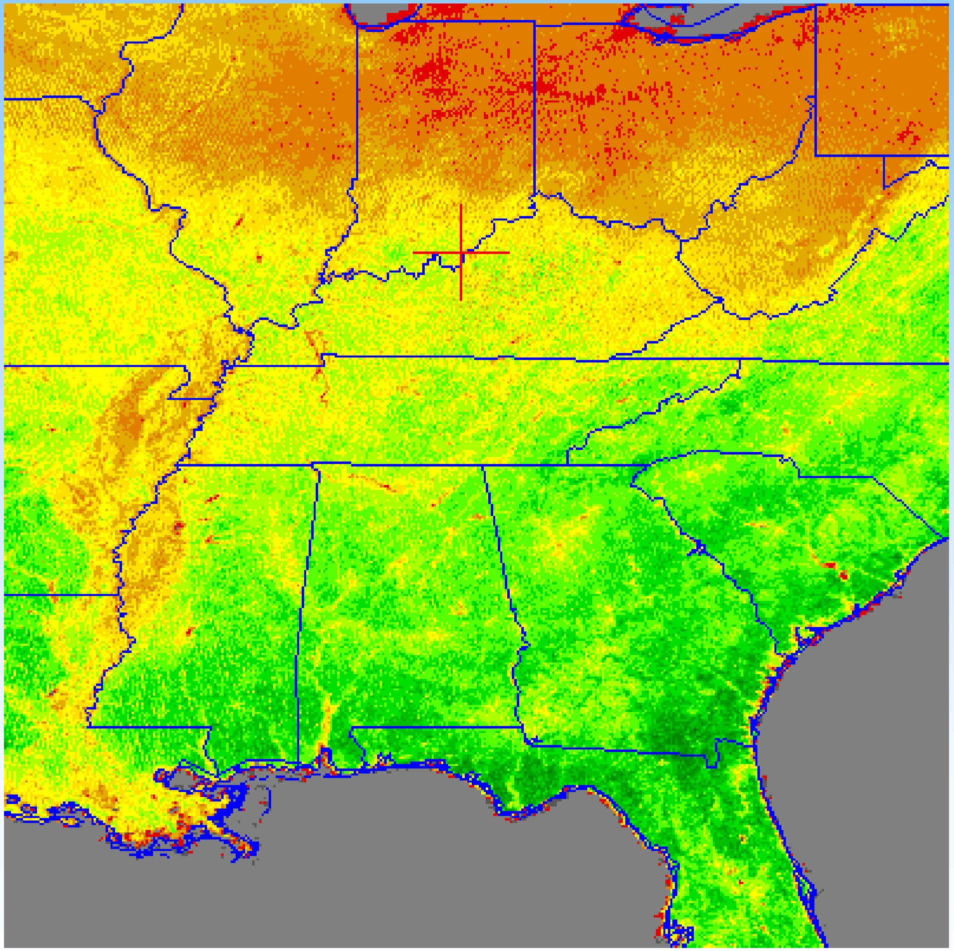
Patterns are identical.

NDVI 16km vs 4 km

Week 4 of 2003

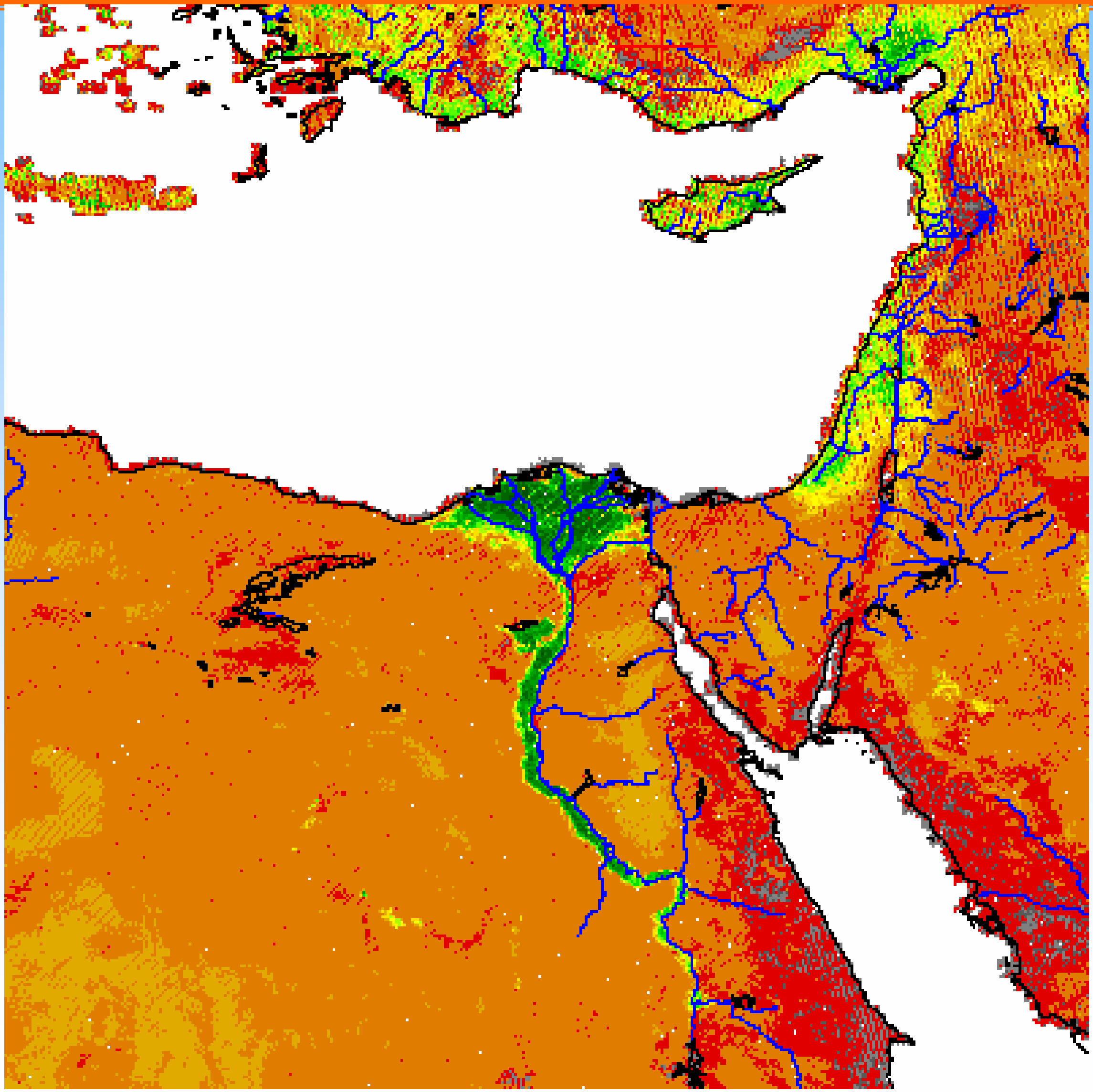


16km NDVI

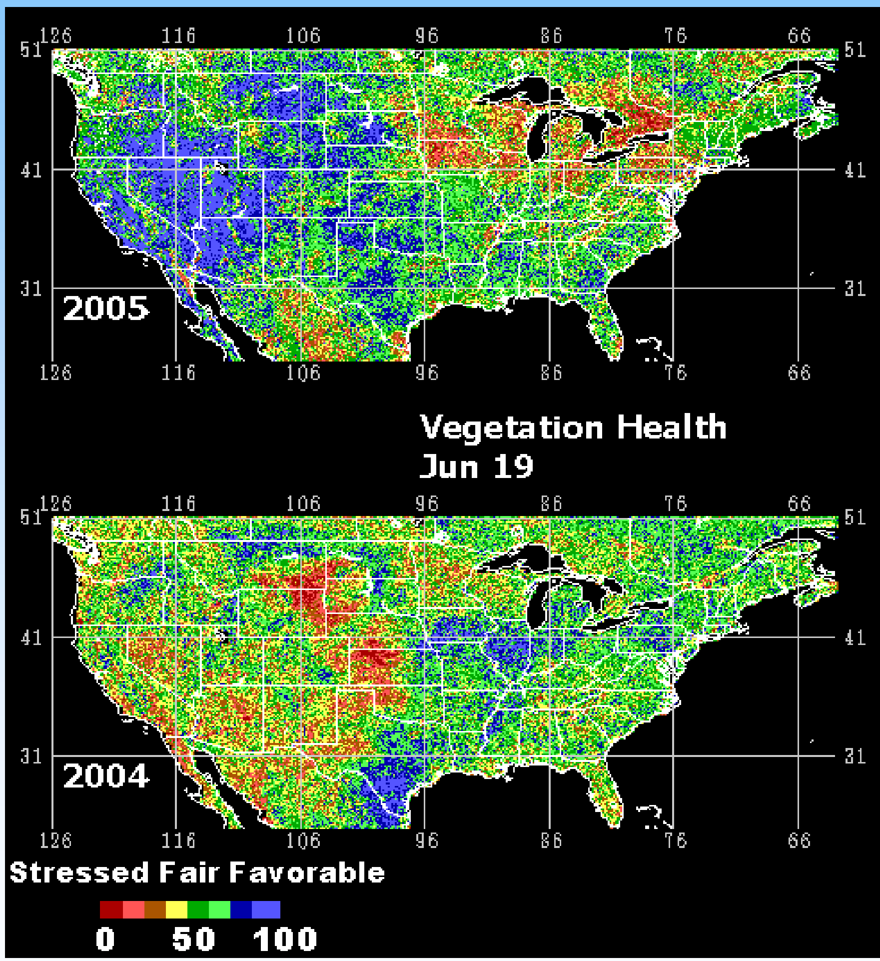


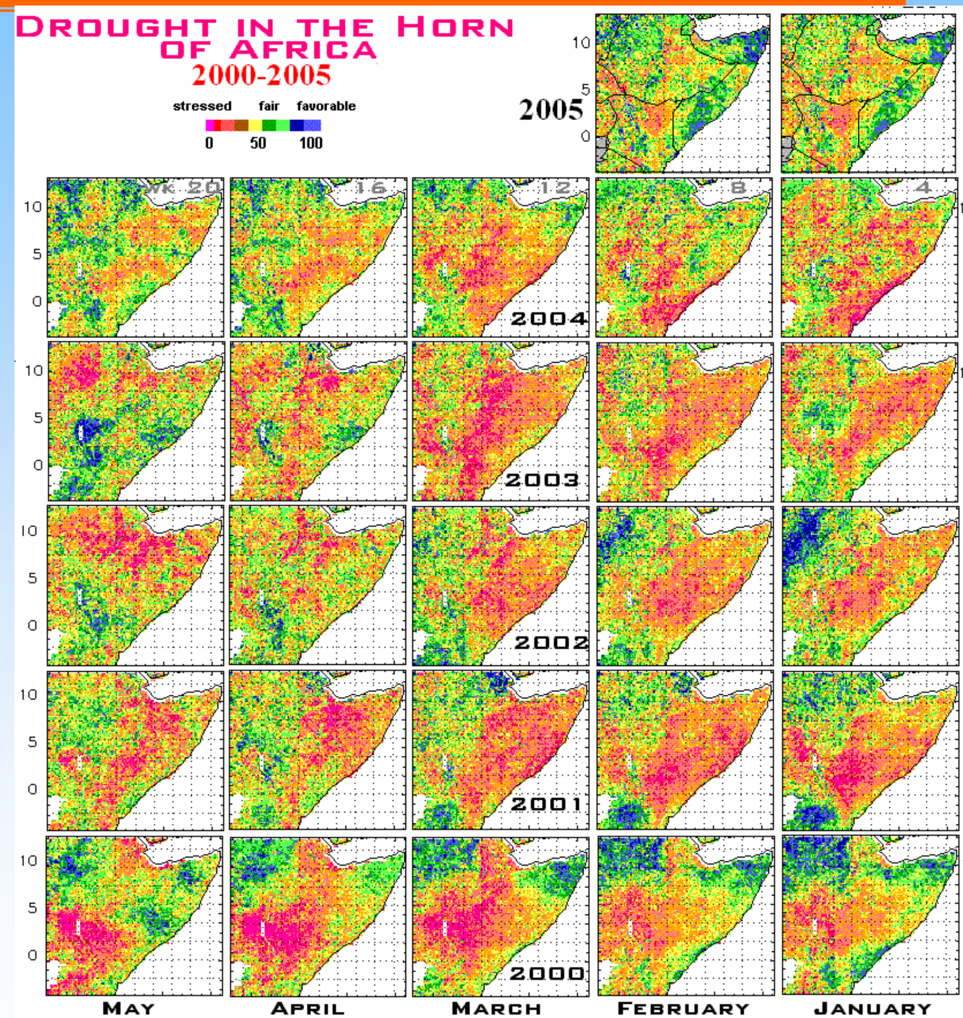
4km NDVI (Smoothed

4km NDVI Map with River and Coast lines (The geo-location is acceptable)



Vegetation Health





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http://www.orbit.nesdis.noaa.gov/smcd/emb/vci/index.html

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Vegetation Health Image Map Resources

[Current Vegetation Health Image Maps]

[Changes in Vegetation Health from Previous Week]

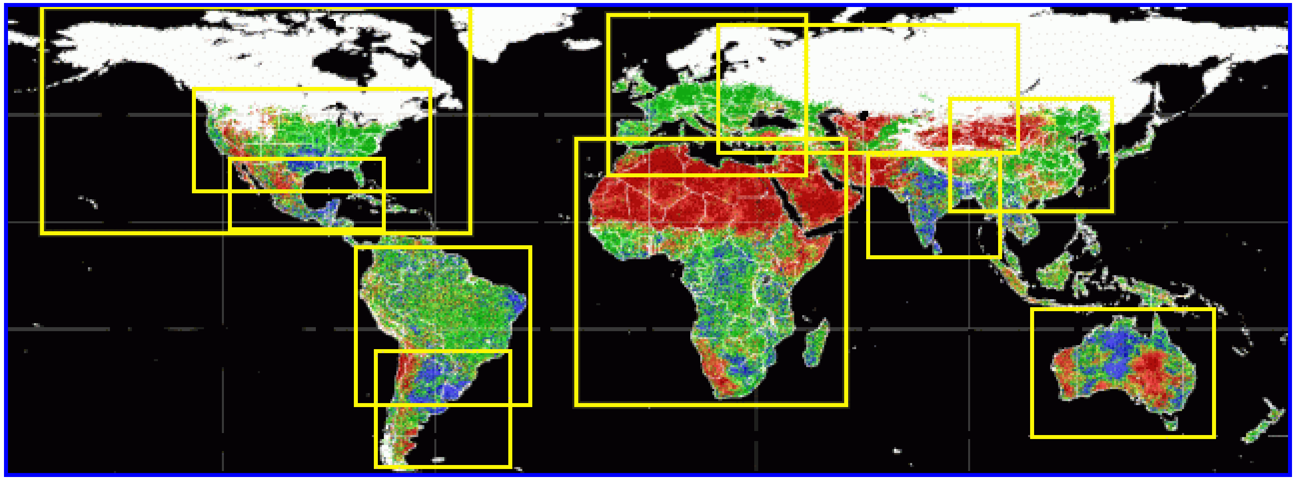
[Changes in Vegetation Health from Previous Year]

[Archived Vegetation Health Image Maps]

[Moisture and Thermal

NOAA/NESDIS Office of Research and Applications

Current Vegetation Health Image Maps



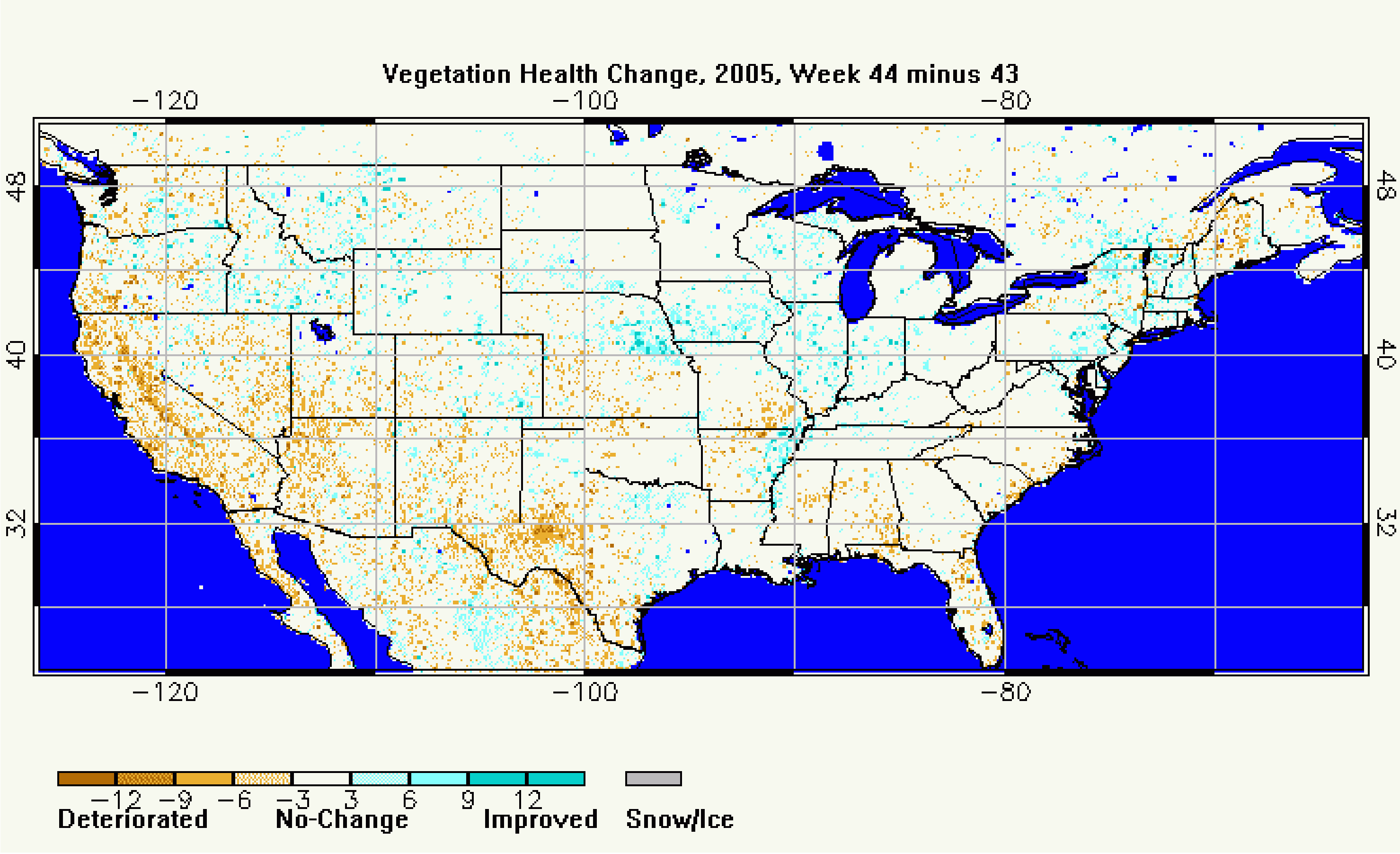
- View the current Vegetation Health image map by clicking on the yellow box for your area of interest.
- View the current Vegetation Health image map for the entire globe by clicking on any area outside of the yellow boxes.
- Or click on any of these links:
    - [The United States]

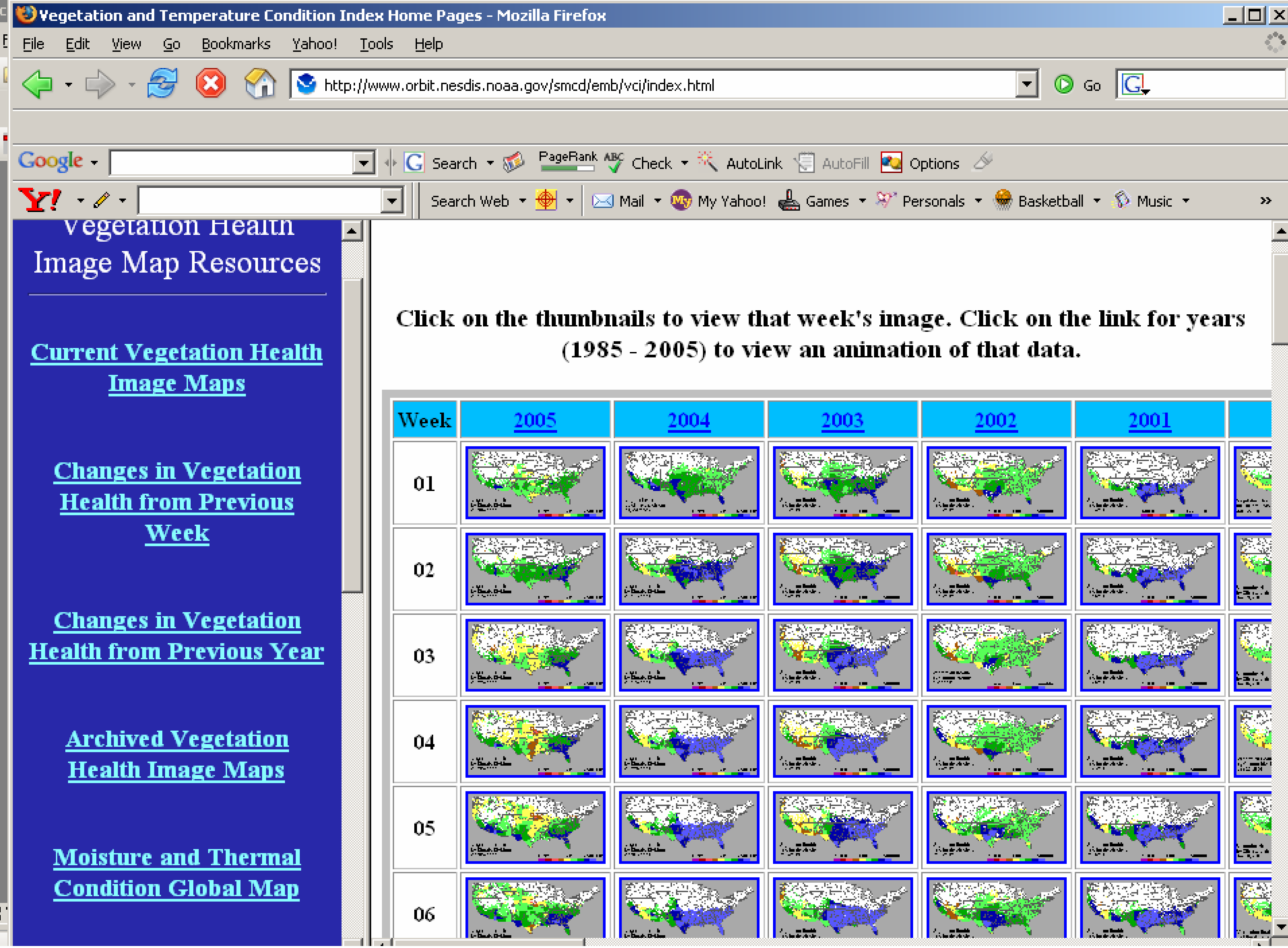
Weekly Change Vegetation Condition Index Group Home Pages: US Vegetation Health - Mozilla Firefox

File Edit View Go Bookmarks Yahoo! Tools Help

http://www.orbit.nesdis.noaa.gov/smcd/emb/vci/wcusa.html

Change in Vegetation Health: Brown - Deteriation; Blue - Improvement




Vegetation and Temperature Condition Index Home Pages - Mozilla Firefox
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http://www.orbit.nesdis.noaa.gov/smcd/emb/vci/index.html
Go
Google
Search
PageRank
Check
AutoLink
AutoFill
Options
Search Web
Mail
My Yahoo!
Games
Personals
Basketball
Music
Vegetation Health
Image Map Resources
Current Vegetation Health Image Maps
Changes in Vegetation Health from Previous Week
Changes in Vegetation Health from Previous Year
Archived Vegetation Health Image Maps
Moisture and Thermal Condition Global Map
Click on the thumbnails to view that week's image. Click on the link for years (1985 - 2005) to view an animation of that data.
Week
2005
2004
2003
2002
2001
01
02
03
04
05
06

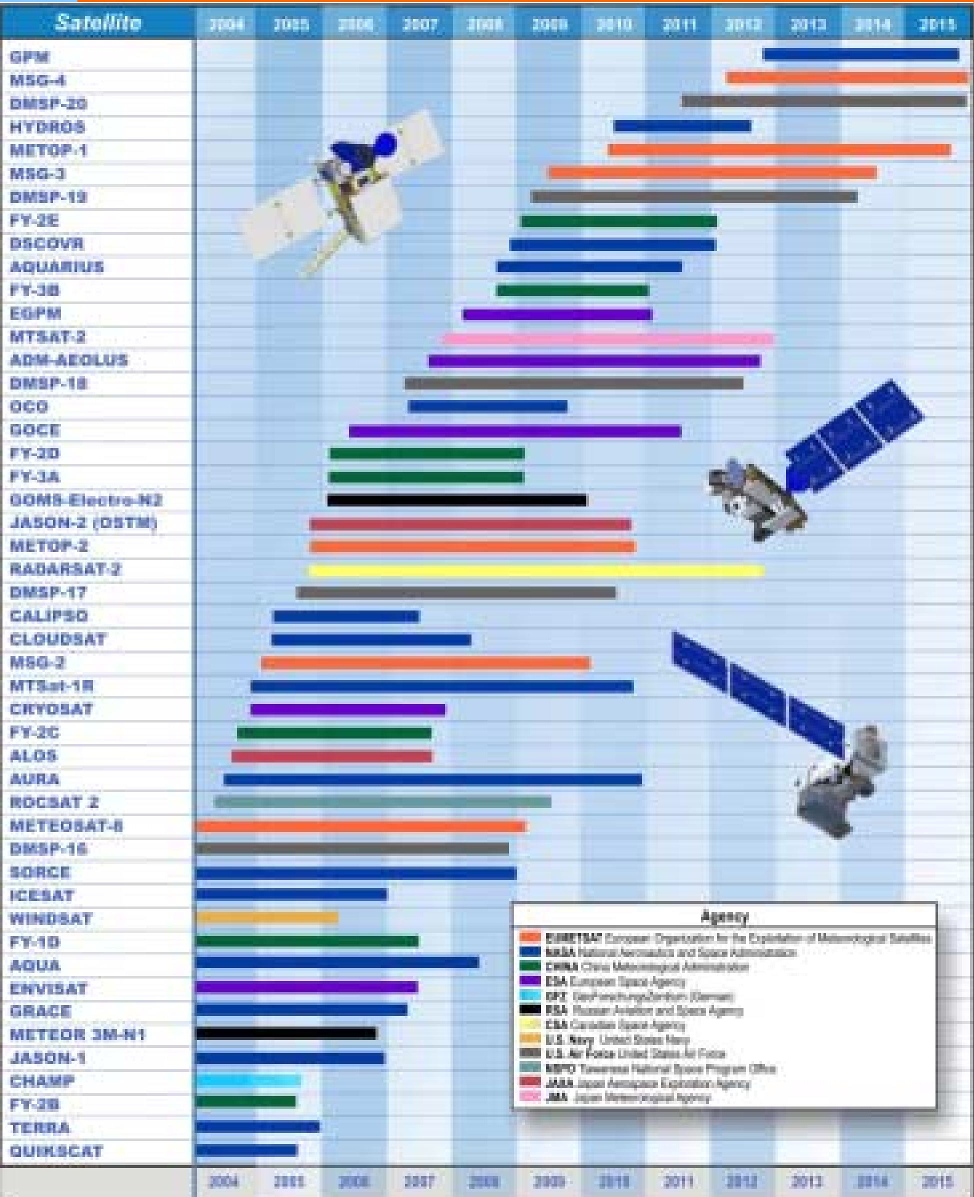
Summary

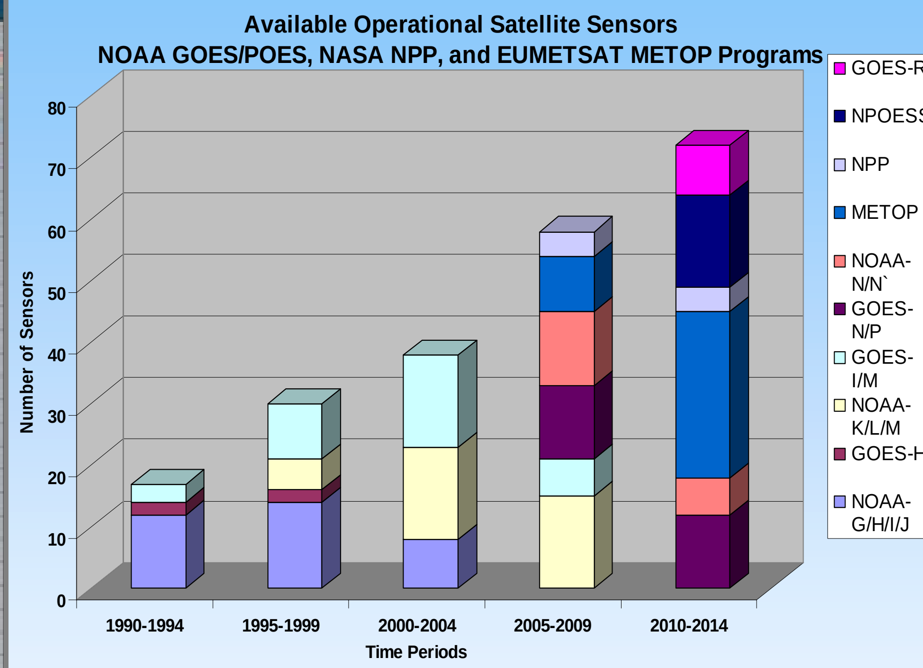
- NESDIS/ORA is developing an integrated cal/val system to support GEOSS objectives
- Adapting our satellite intercalibration techniques to NPOESS and Metop
- Apply current approach to support GOES-N
- Results are posted on websites

Issues

- Sustained cal/val is needed and there is little funding
- Pre-launch characterization is critical
- Number of satellites are increasing rapidly
- Resources needs to commensurate with number of sensors
- Need reference sites for validation

Significant increase in number of satellites and sensors





NON-NOAA

Recommendations

- Emphasize the importance of calibration and validation to meet GEOSS objectives
- Need to share capabilities, develop tool kits
- WGCV agency reps can develop agreed upon deliverables - free and open
- For example, US could contribute – surface emissivity and atmospheric radiative transfer models
- Develop a work plan to build the components of a science data analysis tool kit.
- Need to emphasize importance of reprocessed products using state-of-the-art science for understanding past environmental changes

Recommendations

Encourage CEOS agencies to use the expertise of National standards laboratories such as NIST and NPL to help with the organisation and operation of post-launch comparison/calibration/validation activities. In particular, making use of their independence in the development of comparison protocols, analysis of results and uncertainties and the identification of instrument biases through the use of common SI traceable standards as part of the pre-comparison activities.