A Recalibration of the AVHRR data record to provide an accurate and well parameterized FCDR

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Outline

- Brief Project Overview
- Approach
- Results/Accomplishments
- Validation Strategy/Results
- Algorithm/Product Maturity
- Issues/Risks & Work-Off Plans
- Schedule
- Transition Plan
- Societal Benefits
- Resources

Overview

- Goals
  - To provide recalibrated AVHRR Level 1B radiances for the thermal IR channels (3.7, 11 and 12 μm channels) where the uncertainty on the radiances are better understood and are as accurate and bias free as possible.
- Source Data
  - AVHRR Level 1B
  - (A)ATSR Level 1 (Radiances)
  - IASI
  - (NWP and/or HIRS for pre-1991 - still to be determined)
- Deliverables (TBD)
  - Code to calculate new radiances from AVHRR Level 1B files?
  - Source matchup data (AVHRR/(A)ATSR etc.) in netCDF?
- ECVs addressed (as applicable)
  - N/A
- Review Product Description matrix
  - Product description is still valid

Approach (1)

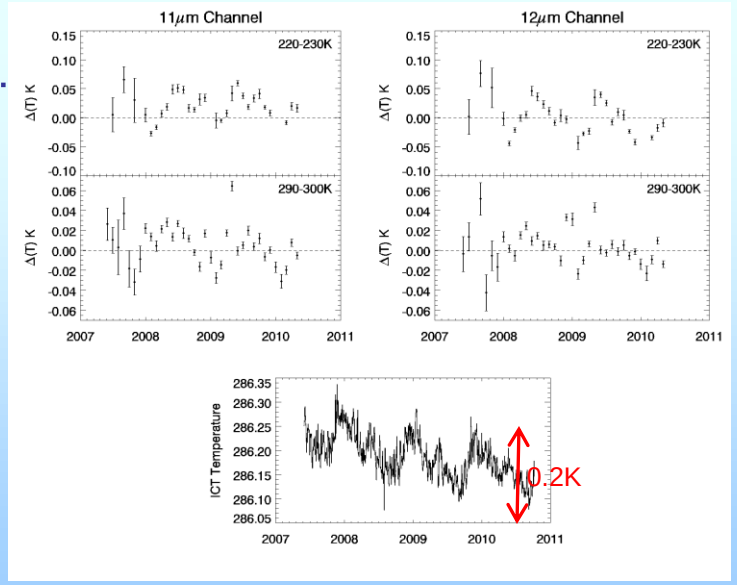
- Use a physically meaningful calibration algorithm (current operational calibration (Walton et al. 1998) is not)
- Apply a uniform calibration methodology to the complete AVHRR data record
  - Current AVHRR Level1B data have a changing calibration methodology over time. Walton et al. calibration is available for NOAA-7,9,10,11,12,14 and all AVHRR/3s but is significantly biased.
- Reanalyze AVHRR pre-launch data to obtain instrument non-linearity
  - Pre-launch data has multiple issues including contamination from scattered light and instrument temperature drifts which need to be accounted for to get a correct non-linearity
- Match AVHRR data with Top-Of-Atmosphere (TOA) sources ((A)ATSR, IASI etc.)
  - Pre-launch calibration values contaminated and must be determined in orbit

Approach (2)

- Use TOA radiance matches to
  - Determine new calibration parameters
  - Determine time variable component of calibration (likely important pre NOAA-17 see later)
- Use TOA proxies pre-1991
  - Yet to be determined – RTM and/or HIRS being considered
- Re-derive times of solar contamination and predict calibration when calibration compromised
  - Physical calibration can predict gains when calibration system contaminated by solar radiation

Results/Accomplishments (1)

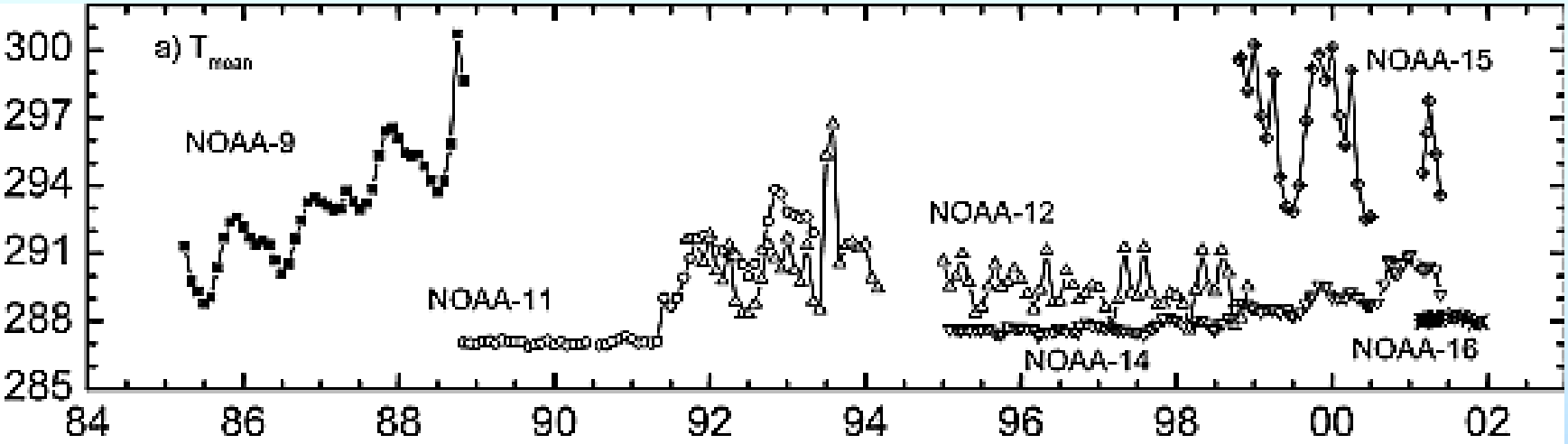
- Analysis team now in place
  - Research Assistant (Manik Bali) employed from May 2011 (much later than planned)
  - Version of TOA sources against AVHRR matchup code is being tested (Bali)
- Pre-launch data for all AVHRRs obtained
  - Still have ITAR issues but A.Harris now permanent resident so can be scanned/analyzed (J.Mittaz submitted green card application) . Need to get ITAR access for Bali. Copies will be given to NCDC.
- Detailed analysis of MetOp-A against IASI completed and in press
  - Final proof sent back to journal
  - Shows importance of using TOA recalibration - good AVHRR calibration must to use TOA sources.
  - Shows possible warm AVHRR bias (up to 1.2K) at high zenith angle for cold scenes
  - Comparison over >3 years between IASI and AVHRR – trends at estimated < 0.07K/decade but also shows seasonal variability related to instrument temperature



AVHRR can be very stable as long as the thermal environment is stable

Results/Accomplishments (2)

- Code for solar contamination removal added to Level1B reader
  - Necessary to accurately find and remove solar contamination events
- Level 1B code ported to University of Edinburgh for use in ESA Climate Change Initiative program for SST
  - Code written and tested on all AVHRR sensors to 1991
- Assessment of possible instrument temperature bias



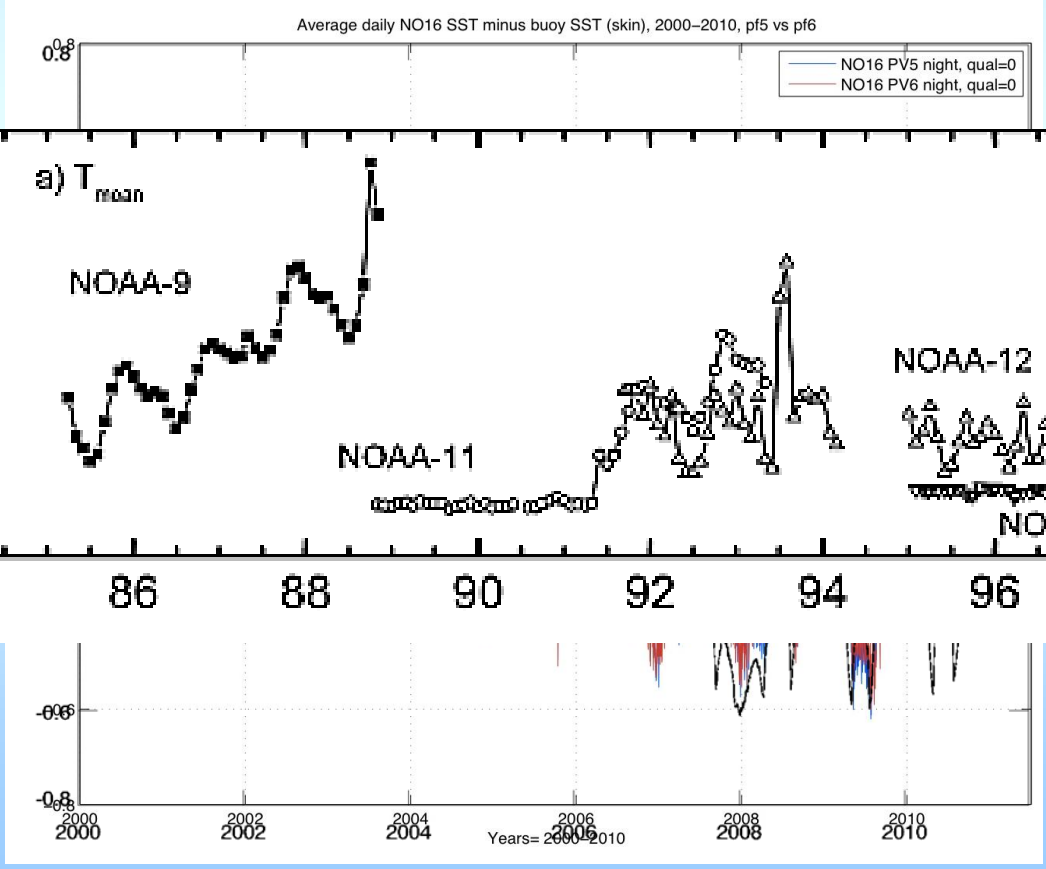
Plot taken from Trischenko, A. P., G. Fedosejevs, Z. Li, and J. Cihlar, Trends and uncertainties in thermal calibration of AVHRR radiometers onboard NOAA-9 to NOAA-16, J. Geophys. Res., 107(D24), 4778, doi:10.1029/2002JD002353, 2002.

0.2K and is almost in the noise.

Large instrument temperature variations are not uncommon in the earlier AVHRR sensors and have to be dealt with

Results/Accomplishments (3)

- Analysis of NOAA-16 against AATSR
  - NOAA-16 known to be problematic so good test case to determine final recalibration methodology
  - Shows strong SST biases in Pathfinder 6 methodology – indicate large time variable BT biases



Use AATSR to find linear relationship between channel bias and average orbital

$C)^2$

is

n

dependent bias

Importance of effect not included in original proposal and will need to be determined for all AVHRRs

Validation Strategy/Results

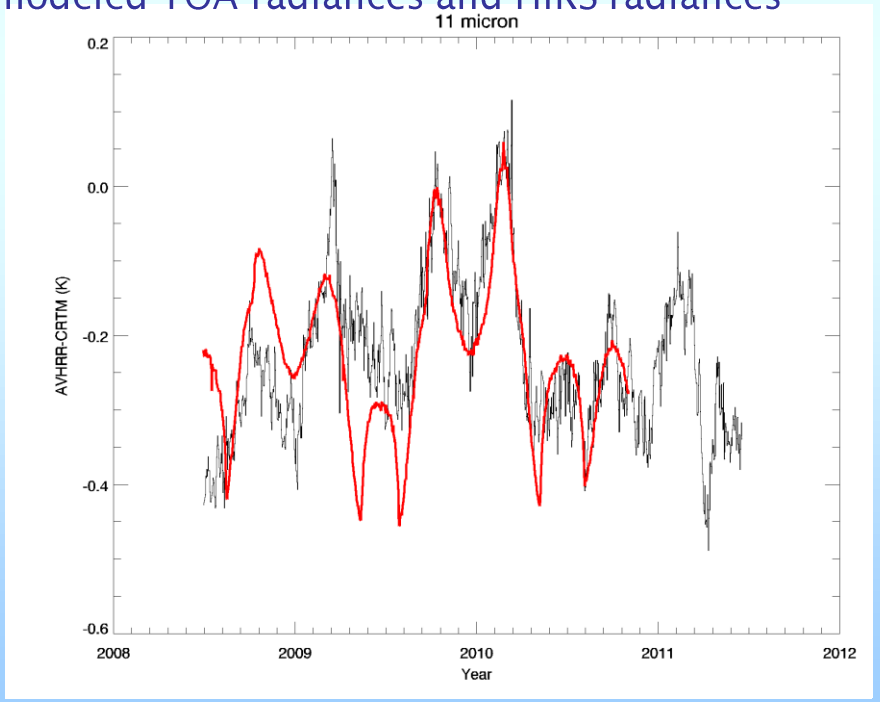
- When available we will use hyperspectral sounders to check calibration (AIRS and IASI)
  - (A)ATSR series is used to determine calibration which allows a consistent calibration from 1991-present
- If possible use HIRS as a reference
  - Use HIRS recalibrated data if possible
  - Pre-1991 may need HIRS as part of AVHRR recalibration
- Sea Surface Temperature
  - As shown by the NOAA-16/Pathfinder example, SST can be very sensitive to errors in the longwave IR channels and so can be used for validation.

Issues/Risks & Work-Off Plans

- Pre-launch data ITAR compliance
  - A. Harris can now view the data
  - J. Mittaz and M. Bali cannot
- Access to (A)ATSR archive slow
  - Trying to get complete archive on tape
- AATSR 12□m channel suspect
  - Known 0.2K bias but not well understood and likely to be more complex
- Pre-1991 algorithms still not finalized
  - 2 options being looked at – RTM modeled TOA radiances and HIRS radiances

As an example of RTM modeling NOAA MICROS provides TOA simulated radiances which could be used for recalibration

Comparison with AVHRR estimated bias due to instrument temperature dependence – some similarities but not exact. Need better RTM radiances



Schedule

Full time/dedicated work really started when Post-Doc started in May 2011

This year

Post-Doc

Create and test/document final AVHRR TOA matchup code for (A)ATSR/IASI/HIRS etc. (4 months)

Create (A)ATSR/AVHRR matchup databases for re-calibration/validation and investigate remaining algorithm issues (8 months)

A. Harris

Obtain and start analysis of AVHRR/1 and AVHRR/2 pre-launch data (3 months)

J. Mittaz

Analyze (A)ATSR matchups to continue investigating instrument temperature dependent bias and effect of solar contamination on 11/12μm channels and derive new calibration parameters for AVHRRs from 1991 ((A)ATSR overlap period. Continue studying RTM/HIRS/Overlap methods for pre-1991 data. Supervise Post-Doc (6 months)

Next year

Post-Doc

Determine and apply new calibration parameters to AVHRR data record (post-1991) to look for possible calibration trends in the long term record (6 months)

Support J. Mittaz investigation and analyze/validate pre-1991 data (6 months)

A. Harris

Determine best SST product/algorithm for validation of recalibrated AVHRR (3 months) and check against data.

J. Mittaz

Concentrate of pre-1991 data to finalize required algorithm and do final validation against SST as a check. Continue paper write ups together with ATBD (6 months)

Final year

Post Doc to complete writing code for final re-calibration and write associated documentation to derive calibration for all AVHRRs and provide all validation results under supervision of J.Mittaz.

Transition Plan

- DOCUMENTATION
  - Algorithm still to be finalized – strong instrument temperature dependent bias needs to be added and algorithms determined
  - Climate Algorithm Theoretical Basis Document (C-ATBD)
    Should be ready by Aug 2012
  - Data Flow Chart and Maturity Matrix
    Data flow chart should be ready by Aug 2012
    Maturity Matrix will be updated as needed (currently unchanged)

- DATA SET(S)
  - Possible use GHRSST Level 1P NetCDF format which will be defined as part of the GHRSST Rescue & Reprocessing of Historical AVHRR Archives (R2HA2-WG) Working Group (Chair: Peter Cornillon, University of Rhode Island)
  - Will be to GHRSST standards
  - Size as yet unknown (and see concerns)

- SOURCE CODE
  - User guide will be provided
  - Code will be in Fortran 90
  - README will be provided

- CONCERNS (Risks)
  - Unlikely will have time/manpower/disk space to provide complete AVHRR data record in standard format
  - Single AVHRR recalibrated dataset should be provided - need to merge IR recalibrated data with other AVHRR recalibration datasets e.g. visible channel work
  - Improved navigation needs to be added

Benefit to the Science Community

- All users who require a stable long time series of satellite measurements of surface temperature will benefit
  - Previously, the AVHRR data record could not be used for monitoring temperature trends without reference/tuning to *in situ* data. This robbed the data of its independence
  - In particular, satellite data have the greatest impact where *in situ* data are sparse/absent. The dependence on *in situ* tuning meant that the AVHRR record was least reliable where it had the greatest impact
  - Our new physically-based calibration will allow the AVHRR data (the longest continuous satellite imager record in existence) to be used as an independent monitoring instrument for the first time
- Practical examples
  - Pathfinder SST (Kilpatrick, K. A., G. P. Podestá, and R. Evans (2001), Overview of the NOAA/NASA advanced very high resolution radiometer Pathfinder algorithm for sea surface temperature and associated matchup database, *J. Geophys. Res.*, 106, 9179–9197
  - Coral Reef Watch (Strong, A.E., F. Arzayus, W. Skirving and S.F. Heron (2006). Identifying Coral Bleaching Remotely via Coral Reef Watch - Improved Integration and Implications for Changing Climate. In J.T. Phinney, et al. [Eds.], *Coral Reefs and Climate Change: Science and Management*. Coastal and Estuarine Studies, Vol. 61, American Geophysical Union, Washington, DC. 163-180 pp
  - Operational sea surface temperature retrieval (Merchant C J, P Le Borgne, A Marsouin and H Roquet (2008), Optimal estimation of sea surface temperature from split-window observations, Rem. Sens. Env., 112 (5), 2469-2484)
  - Land surface temperature retrieval (Yu, Y., J. L. Privette, and A. C. Pinheoro (2008), Evaluation of split window land surface temperature algorithms for generating climate data records, *IEEE Trans. Geosci. Remote Sens.*, 46, 179–192
  - Radiation budget (Wang, Xuanji, Jeffrey R. Key, 2005: Arctic Surface, Cloud, and Radiation Properties Based on the AVHRR Polar Pathfinder Dataset. Part I: Spatial and Temporal Characteristics. *J. Climate*, **18**, 2558–2574

Benefit to Society

- One example - Improved Sea Surface Temperature measurements
  - The stability and accuracy requirement for using SST for climate change studies are very stringent and require very stable SST algorithms. Current AVHRR calibration not capable of giving the required level of stability (see NOAA-16/Pathfinder example).
  - Latest SST algorithms are now requiring well understood and stable input radiances for their algorithms to work. Two examples are the latest Pathfinder v6 algorithm and the ESA CCI SST project which will likely use Optimal Estimation techniques which require bias free radiances. Without the well defined and trend free radiances this FCDR will provide, the most accurate and consistent SSTs will not be available.
  - More accurate SSTs will then support work into, for example, Hurricane Formation, Coral Reefs bleaching and, of course, Climate.
- Examples and resources
  - Because this product is an FCDR there is no direct link to resources, but any derived product that uses the AVHRR would benefit from the new AVHRR radiances by providing reduced uncertainties and trend free data.
  - This would then link to such resources as water resources and even to agriculture and health. For example AVHRR data (visible and IR) has been used to model the distribution of the cattle tick in South America (Estrada-Peña, "Geostatistics and remote sensing using NOAA-AVHRR satellite imagery as predictive tools in tick distribution and habitat suitability estimations for Boophilus microsplus (Acari: Ixadidae) in South America", Veterinary Parasitology 81 (1999) 73.

Resources

- Number of personnel
  - one post-doc (full time) – started May 4th 2011 (significantly delayed)
  - Andy Harris 3 months/year
  - PI (J. Mittaz) 6 months/year
- Key equipment or observatories used
  - Level 1B data archive at NOAA/STAR
  - Level 1P TOA data from ESA (A)ATSR archive
- Key collaborating projects or personnel
  - NOAAs ARC (AVHRR Reanalysis for Climate) P.I. Chris Merchant (Univ. Edinburgh) – SST retrieval using new radiances
- NOAA point-of-contact
  - Eileen Maturi NOAA/NESDIS
- Target NOAA Data Center (if known)
- How can CDR program office help you?
  - ITAR complience
  - Processing/merging of all AVHRR data