Toward Improved Climate Data Records with Stable SNPP/JPSS Observations

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Requirements on Climate Data Records (CDRs)

- **CDR Definition: Time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change (US national Research Council)**

- **Essential Climate Variables (ECVs) as identified by the Global Climate Observing System (GCOS) (Red colors are currently available at NESDIS/NCEI: https://www.ncdc.noaa.gov/cdr)**

  - **Atmosphere**: Temperature, Wind speed and direction, Water vapor, precipitation, Cloud properties, Earth radiation budget, Carbon dioxide, Methane, and other long-lived greenhouse gases, Ozone and Aerosol;

  - **Ocean**: Sea-surface temperature, Ocean heat content, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton, Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers;

  - **Terrestrial**: River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture, vegetation index;

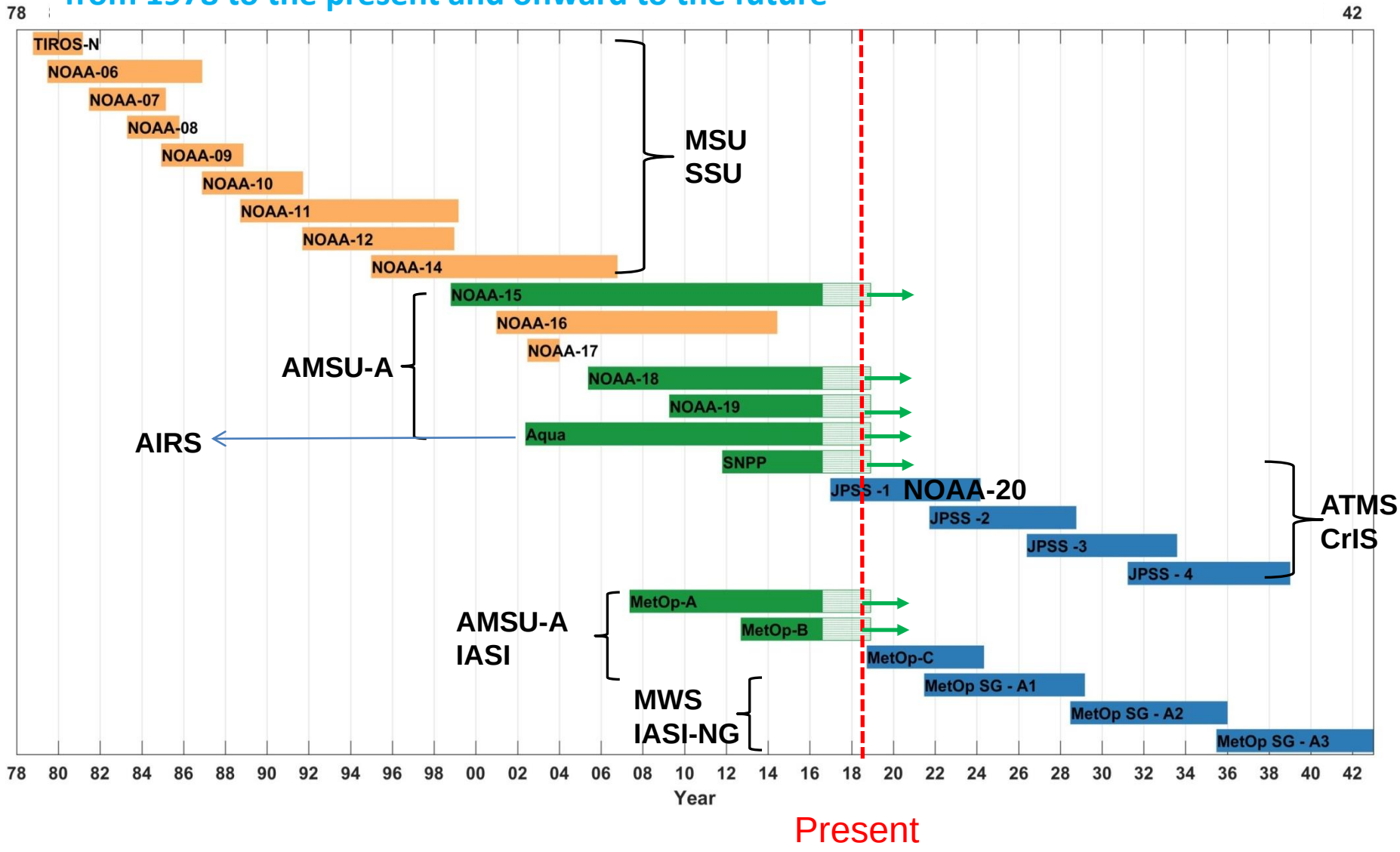
  - **Fundamental:** sensor data; calibrated radiances and brightness temperatures that have been improved and quality controlled over time: MSU/AMSU-A deep layer temperatures, MSU/AMSU-A brightness temperatures, AVHRR radiances and reflectance, AVHRR polar pathfinder, AMSU-B/MHS brightness temperatures, HIRS ch12 brightness temperatures, SSMI(S) brightness temperatures.

Issues Involved in CDR Development

- **CDRs are used to**
  - Investigate long-term climate trends and variability
  - Monitor climate change
  - Validate and verify climate model simulations of climate change

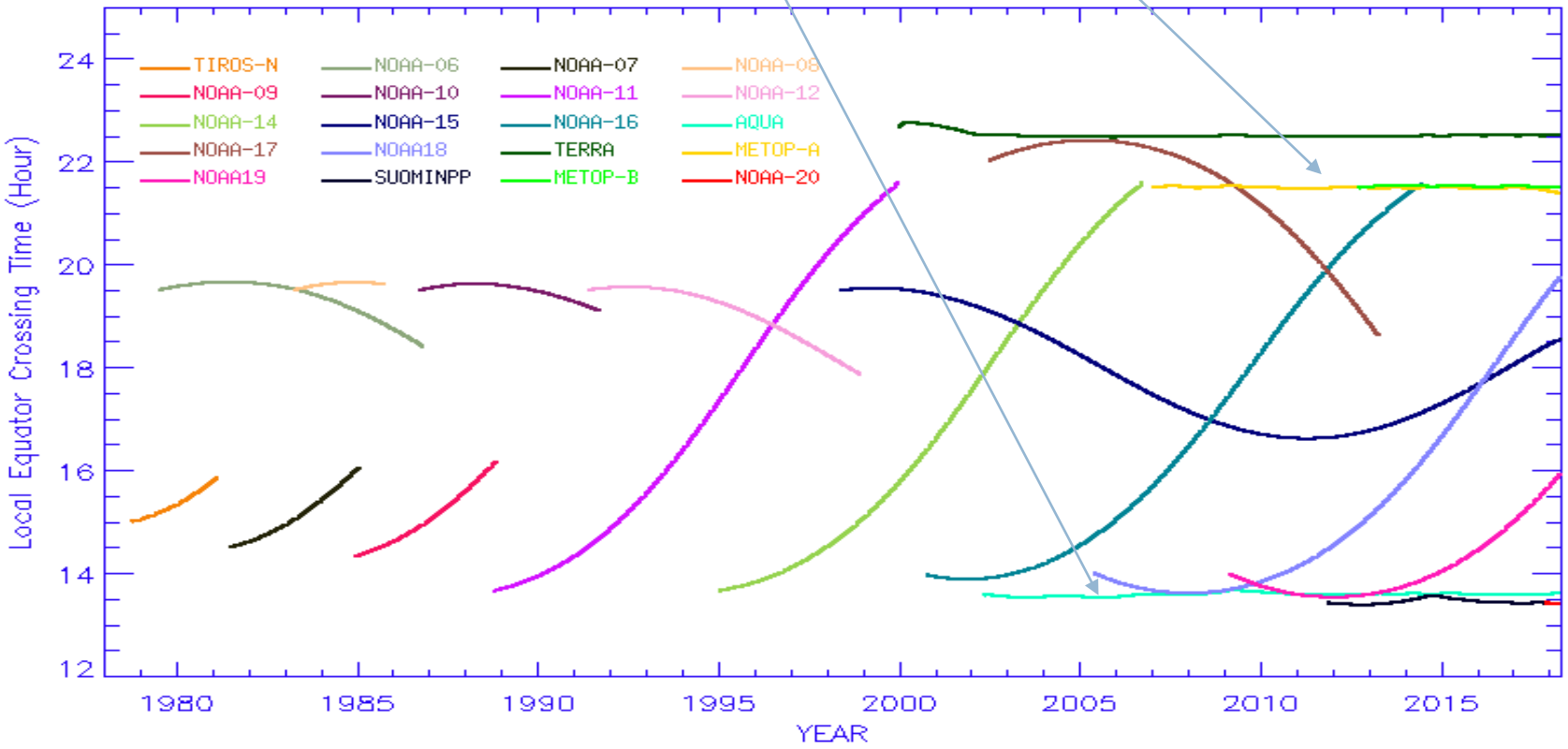
- **CDR development addresses**
  - time series consistency
  - stability of time series
  - inter-sensor calibration/recalibration
  - inter-satellite bias removal
  - continuity in instrument design and channel frequency
  - gap filling between satellites
  - ….

Example of Atmospheric Temperature CDR Development: Involving Microwave/Infrared Sounders on NOAA/NASA/MetOp Satellite Series from 1978 to the present and onward to the future



Challenges in Developing Climate Data Records —Satellite Orbital Drifts

- MetOp-A, -B, and future –C have close to the same 9:30am stable morning orbits
- Aqua, SNPP, NOAA-20, and future JPSS have close to the same 13:30pm stable afternoon orbits
- Terra has a stable 10:30am morning orbit
- All other satellite's orbits drifted with time



Satellite local equator crossing time (LECT) for ascending orbits

(Plot is provided by STAR calibration team)

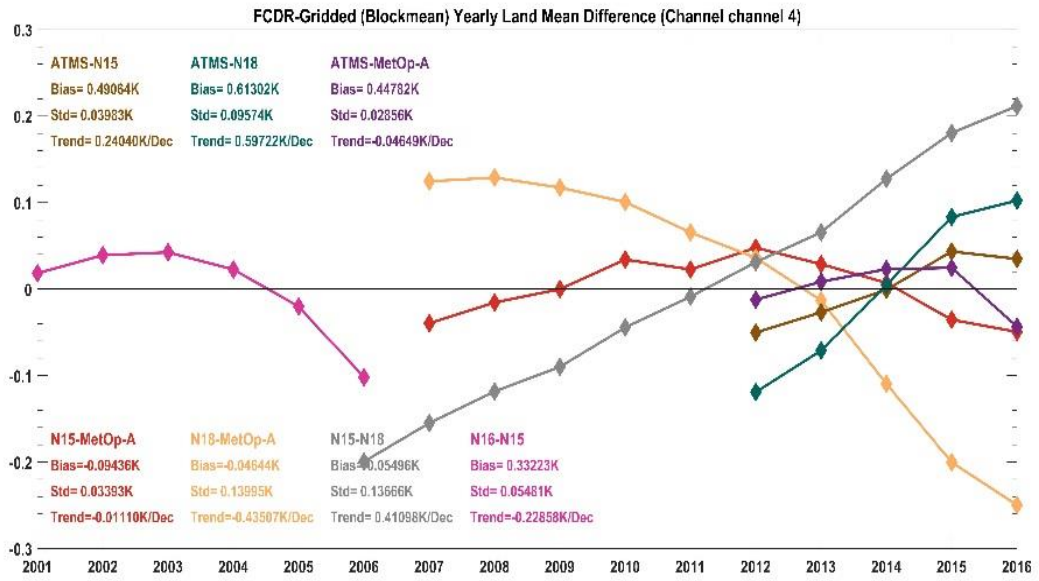
Challenges in Developing Climate Data Records —Satellite Orbital Drifts Induce Bias Drifts

- **Satellite Orbital Drifts Cause**

➢ Changes with time in diurnal Sampling

➢Changes in biases with time

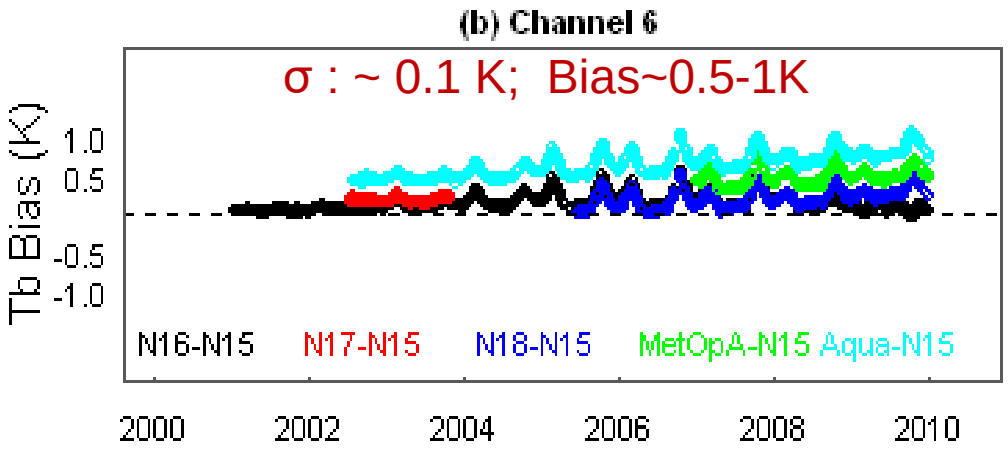
➢Need complicated bias correction algorithms to remove these time-varying biases



Inter-satellite difference time series for AMSU-A satellite pairs.

Challenges in Developing Climate Data Records —Calibration Drifts

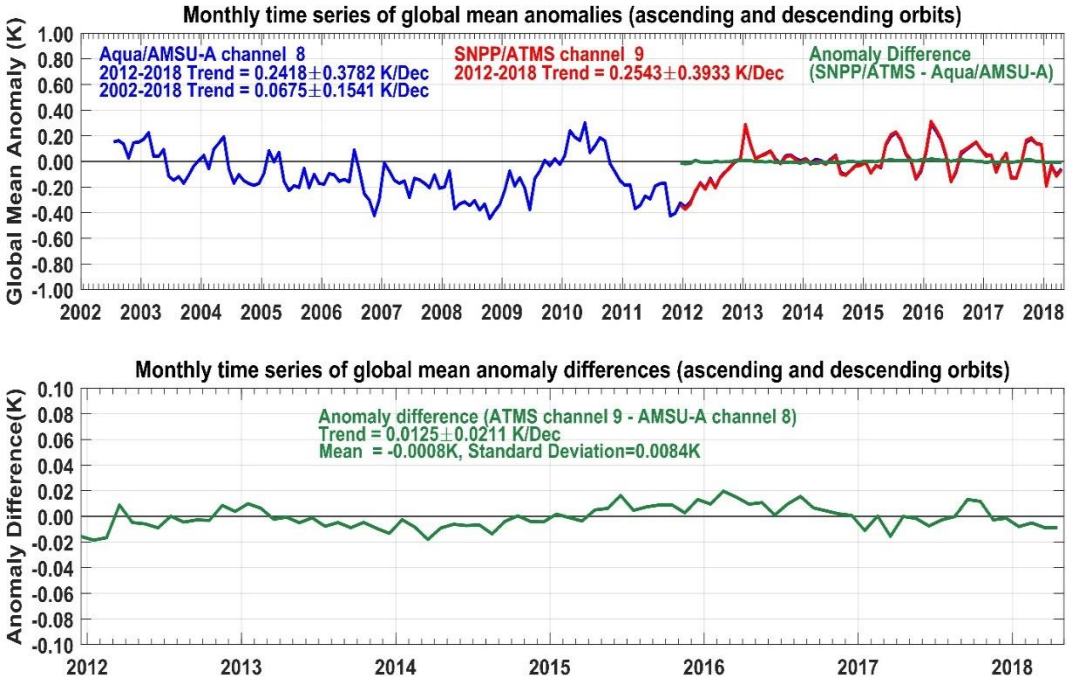
- Inaccurate instrument calibration could result in time-varying biases between satellite pairs
- Need complicated inter-calibration/recalibration algorithms to remove these time-varying biases



Inter-satellite difference time series for AMSU-A satellite pairs showing calibration drifting errors (plot from Zou and Wang 2011)

Stable SNPP and JPSS Orbits Make A Difference

- Diurnal sampling difference is absent – diurnal sampling biases are naturally removed by satellites with stable orbits of the same overpass time
- Time series from different satellites match with each other nearly perfectly without applying any diurnal drift corrections
- Calibration drifts could be estimated quite accurately
- Small trend differences suggest absolute stability on either instruments
- Radiometric stability within 0.04K/Decade for SNPP/ATMS and Aqua/AMSU-A for all analyzed channels



Monthly global mean anomaly time series of brightness temperatures for AMSU-A channel 8 onboard Aqua (blue, top panel) versus ATMS channel 9 onboard SNPP (red, top panel) and their difference time series (green, top and lower panels). The AMSU-A and ATMS data are respectively from June 2002 and December 2011 to April 2018. The AMSU-A anomaly time series are overlaid by ATMS during their overlapping period with their differences shown as nearly a constant zero line in the same temperature scale. Amplified scale of temperature is used in the bottom panel to show detailed features in the anomaly difference time series. Both ATMS and AMSU-A data are from limb-adjusted views and averaged over ascending and descending orbits (plot from Zou et al. 2018).

Perspective

- **Radiometric stability assessment for other SNPP/Aqua instruments:**

- Aqua instruments: AMSR-E, AMSU-A, HSB, AIRS, MODIS, CERES
- SNPP/JPSS instruments: ATMS, CrIS, VIIRS, OMPS, CERES

Similar comparisons could be made for

CrIS—AIRS
ATMS—AMSU-A (Done for 8 out of 15 channels)
ATMS—HSB
VIIRS—MODIS
CERES—CERES

Perspective

- **Radiometric stability assessment for MetOp instruments:**

  - MetOp instruments: AMSU-A, ASCAT, AVHRR, GOME-2, GRAS, HIRS, IASI, MHS,SARP, SARR, SEM
  - Comparisons for the same instruments could be made for MetOp-A (launched on 10/19/2006) and Metop-B (launched on 09/17/2012), which has 6 years of overlap now

Perspective

- **Improving CDRs:**

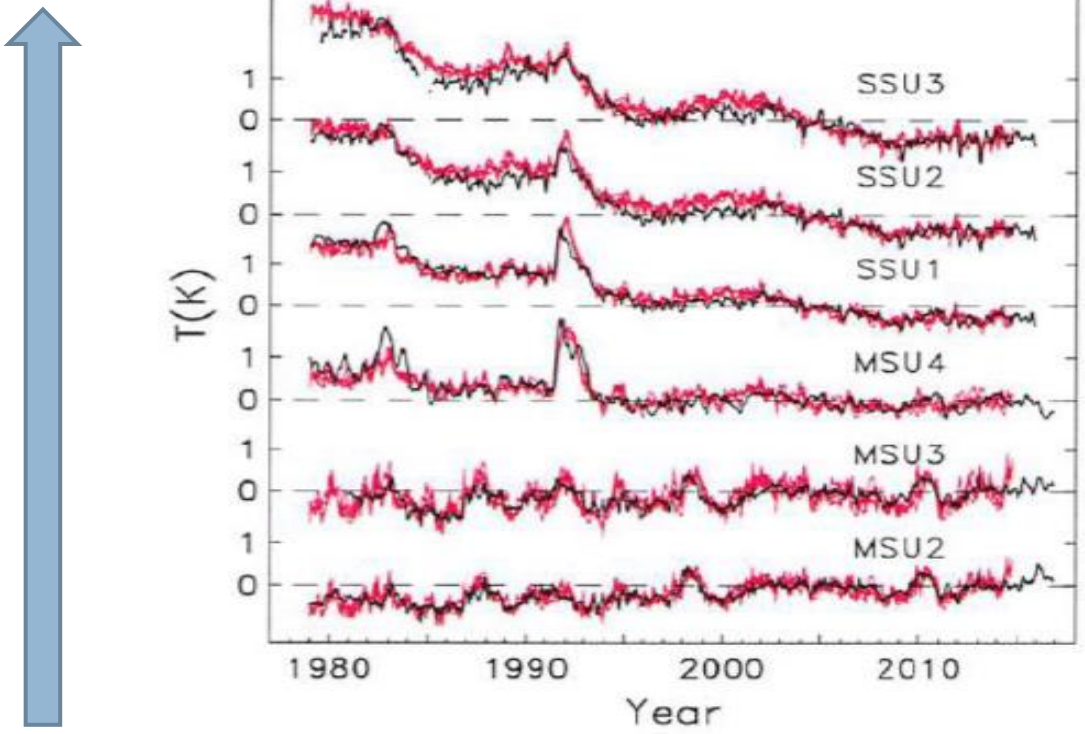
  - Stable observations from SNPP and Aqua and MetOp could be used as references
  - SNPP/JPSS satellites could be merged together without conducting diurnal drift correction
  - Adjusting satellites with orbital drifts to the references using their overlaps. Developing CDRs from the stable satellites backward to the earlier satellites
  - Improved diurnal correction algorithms—need reference for best effect
  - Improved accuracy in trend determination from CDRs are expected

An example for CDRs to verify climate model simulation of the past climate changes

Black Curve: Satellite observations of layer mean temperatures
Red Curve: NCAR WACCM Simulations (SST control runs)

Upper Atmosphere (cooling)

Lower atmosphere (warming)



Plot from Randel et al. (2017)

Conclusion and Path Forward

- The stable SNPP and Aqua orbits with the same overpassing time naturally remove diurnal sampling differences, allowing accurate assessment of instrument calibration drifts
- Preliminary evaluation of SNPP and Aqua microwave sounders suggest they achieve an absolute stability within 0.04K/Decade. Such an accuracy meets requirements for instruments to reliably detect climate trends
- Such evaluations could be extended to many other instruments on SNPP/Aqua/MetOp satellites to determine their radiometric stability
- Stability information is critical for use of these instruments as references in developing climate data records for a variety of essential climate variables
- Improved CDRs are expected in terms of accurate trend determination with the help of stable SNPP/JPSS satellite observations