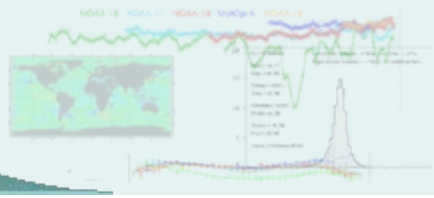
SST Quality Monitor Version 2 (SQUAM2)

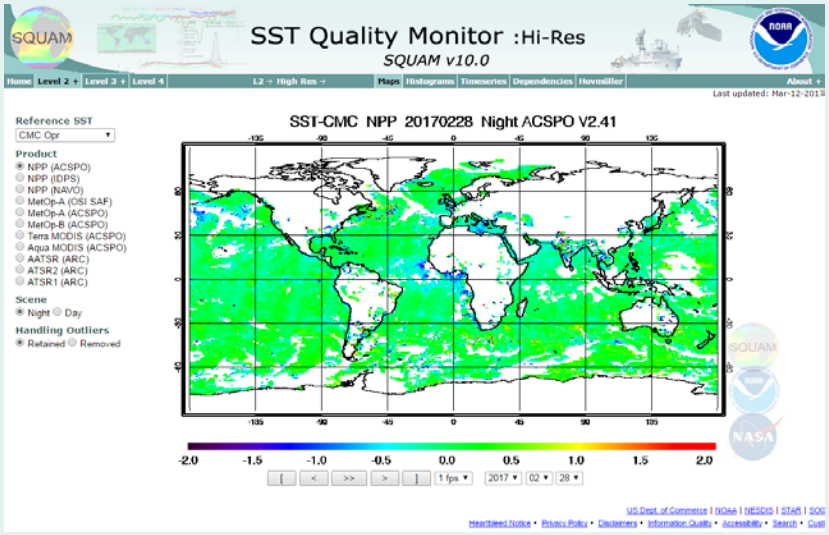


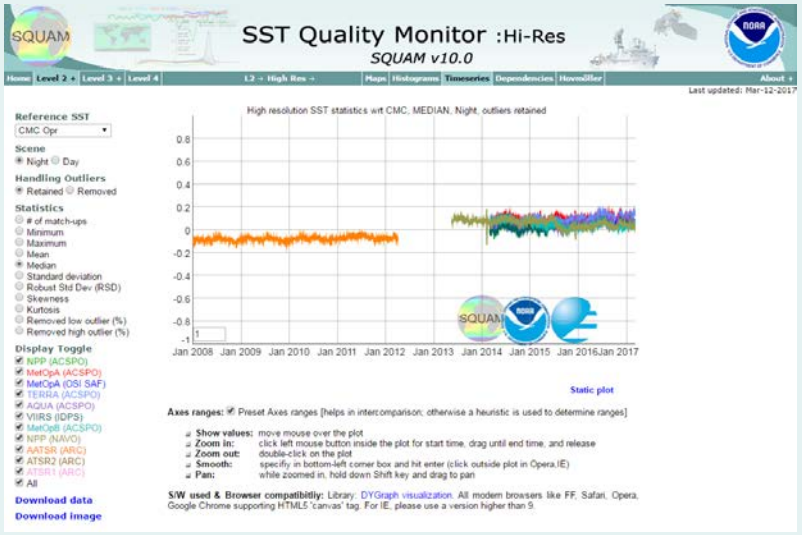
Kai He[1,2], Xinjia Zhou[1,3], Sasha Ignatov[1],
Maxim Kramar[1,2], Pransanjit Dash[4]

1. NOAA STAR; 2. GST, Inc.; 3. CIRA CSU; 4. EUMETSAT

SQUAM Background

- Development started in 2007 at NOAA. V1.0 released in 2009
- Today, SQUAM is a GHRSST resource for near real-time monitoring and validation of major global SST products produced by SST community
- Plots: Maps, histograms, time series, dependencies, Hovmöller diagrams
- Data monitored: community L2, L3, and L4 SSTs
- Web interface & interactive plotting





Methodology

- SQUAM analyzes **bias** of product SST *w.r.t.* reference SST

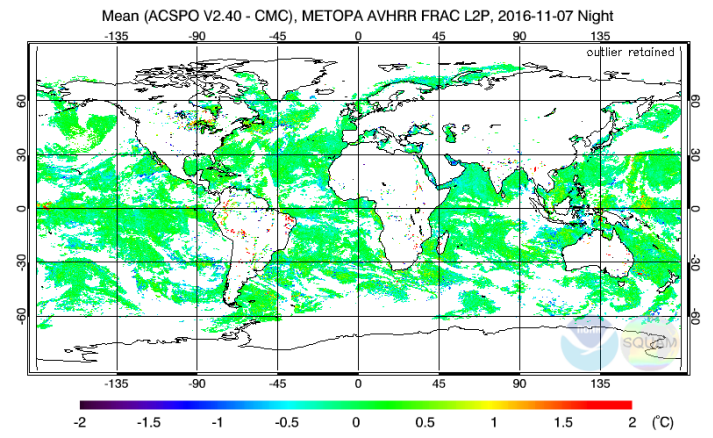
$$\Delta T = T_{product} - T_{ref}$$

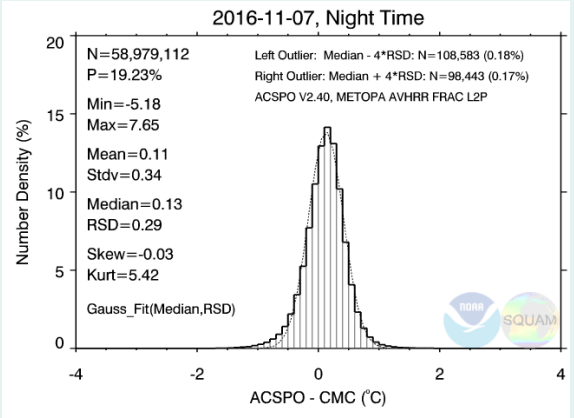
- Customarily, *in situ* SSTs are the natural choice of T_{ref} for SST validation. However, the global distribution is sparse and non-uniform in both space and time
- SQUAM supplements *in situ* validation with analyses against global L4 SSTs as reference
  - Higher coverage
  - Quality more uniform in space and time than *in situ* due to QC and bias adjustment in L4 production
  - Multiple L4 references, allowing sensitivity assessment to T_{ref} field
- The underlying assumption is that global distribution of ΔT is close to Gaussian
  - May be contaminated by outliers caused by sensor malfunction, suboptimal algorithm, cloud leakage, etc.
  - Statistical metrics of Gaussian can be used to monitor stability of SSTs and quality control them

Methodology

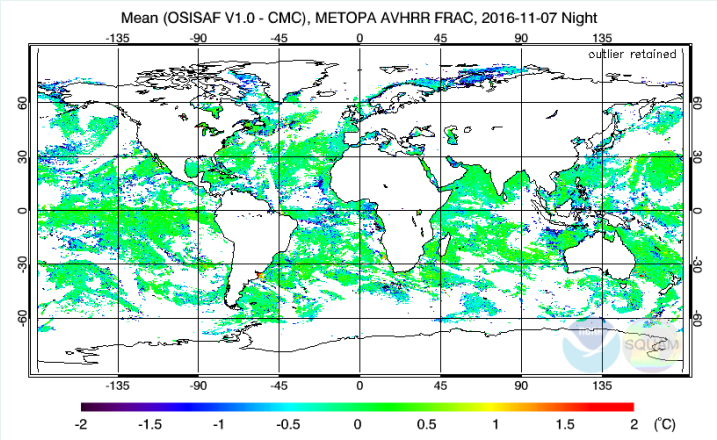
- *ΔT* should be small, centered at zero, and have a near-Gaussian distribution
- Left tail may be indicative of residual cloud and/or aerosol contamination

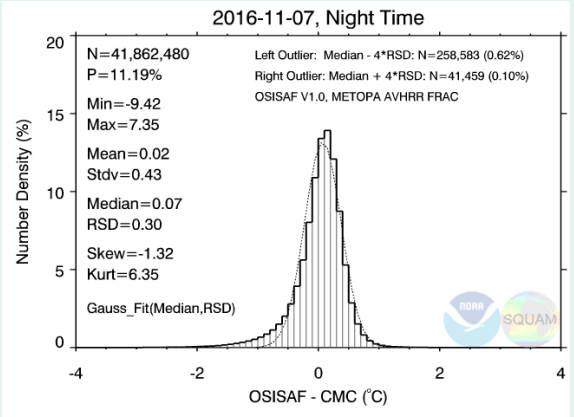
ACSPO





OSI-SAF

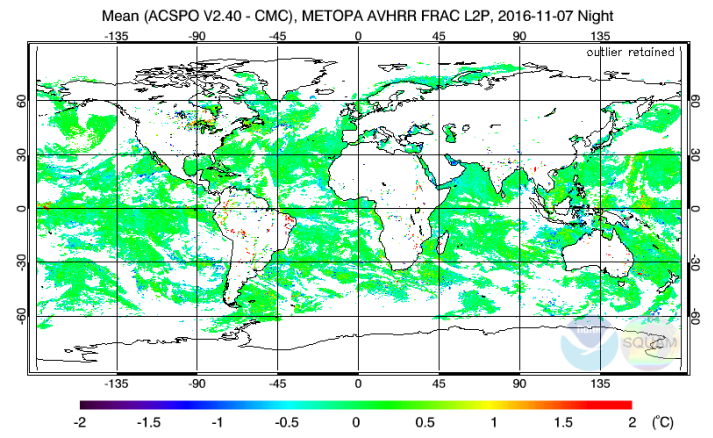


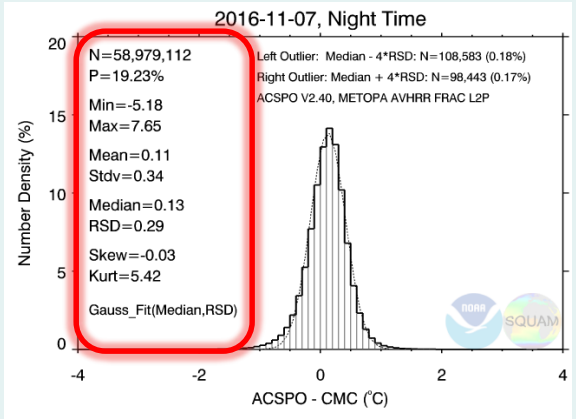


Methodology

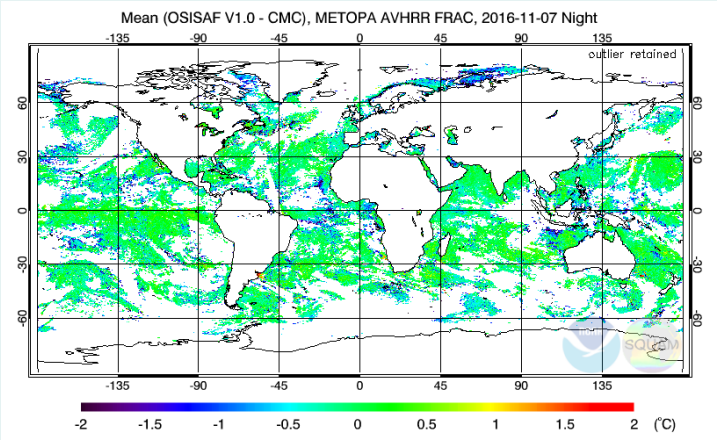
- Maps & Histograms vs. L4 provide a global “snapshot” for daily diagnostics

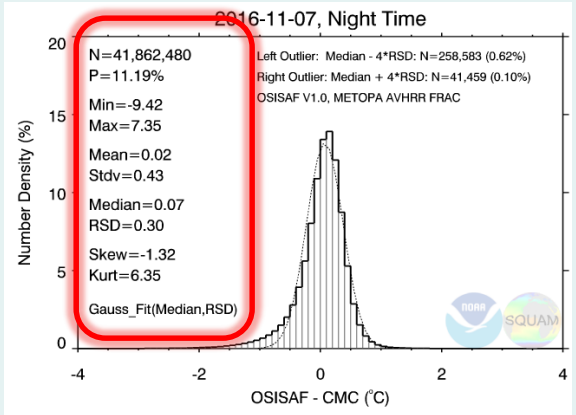
ACSPO





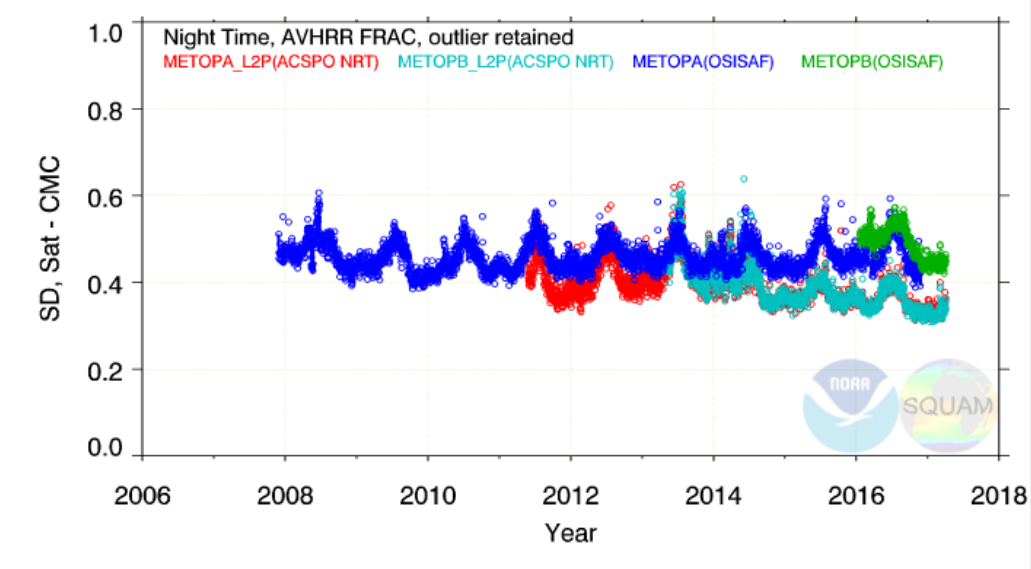
OSI-SAF

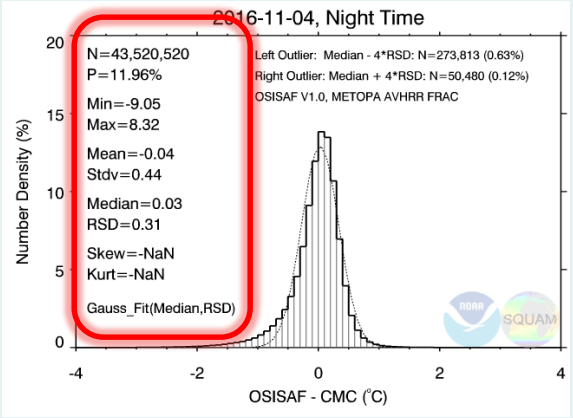




Methodology

- Maps & Histograms vs. L4 provide a global “snapshot” for daily diagnostics
- Time series of statistics of ΔT are generated to monitor stability and cross-platform consistency

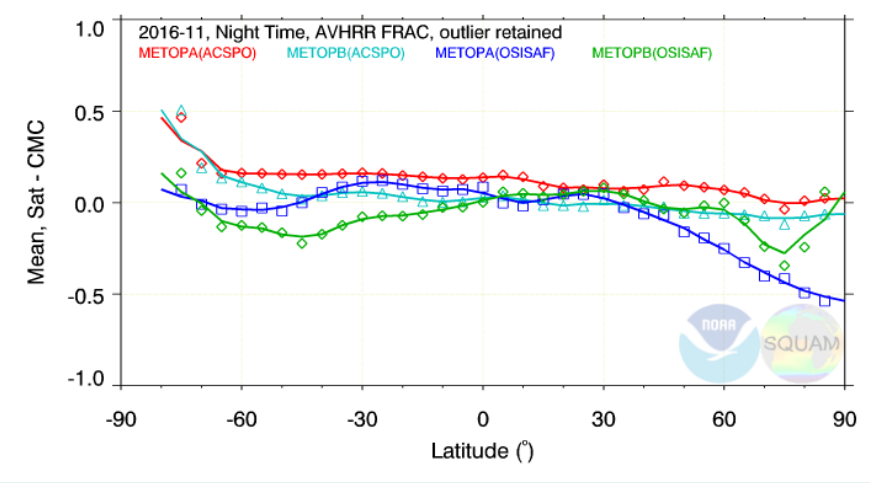




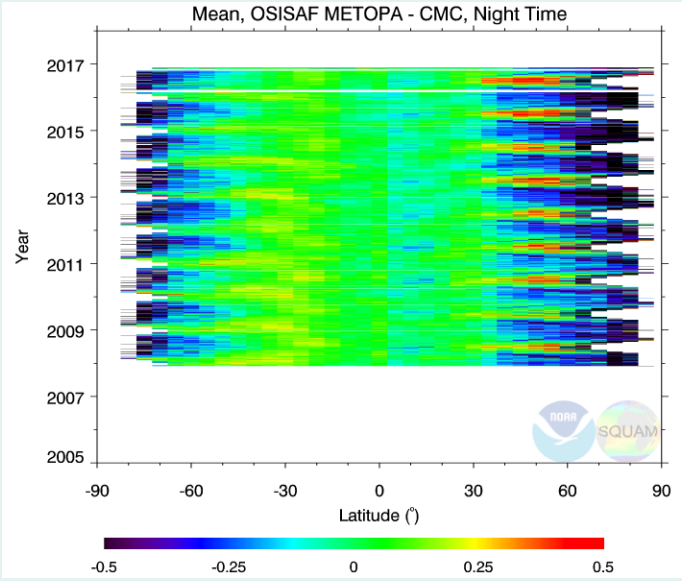
Methodology

- Maps & Histograms vs. L4 provide a global “snapshot” for daily diagnostics
- Time series of statistics of ΔT are generated to monitor stability and cross-platform consistency
- Dependencies & Hovmöller plots help to identify and understand outliers & instabilities

Mean - Latitude



Latitude dependence



Motivation for Redesign

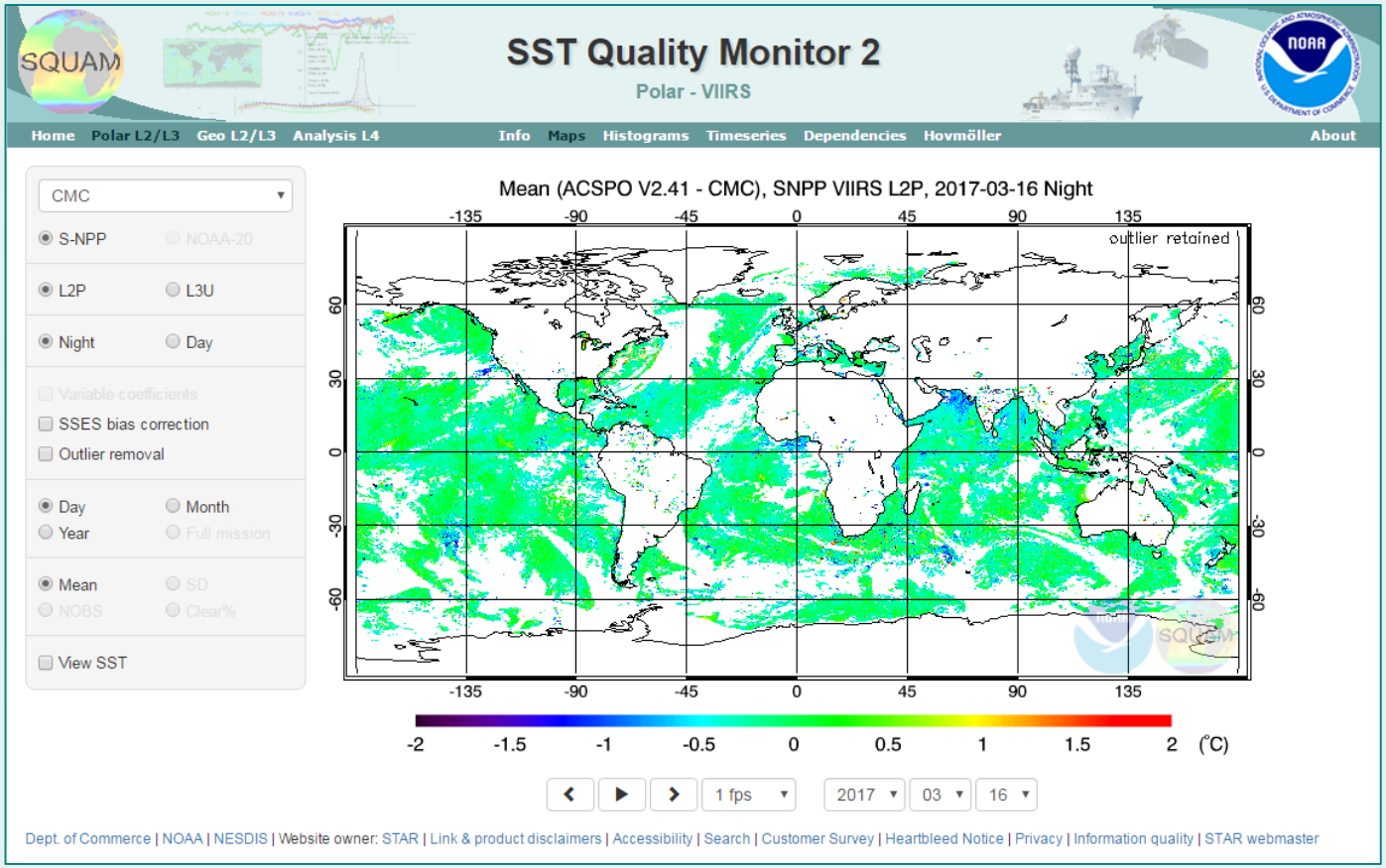
- Challenging data volumes and demand of computing resources
  - New gen polar: VIIRS onboard SNPP and future J1 – J4; AVHRR FRAC onboard Metops; MODIS onboard Terra and Aqua
  - New gen geo: ABI onboard G16 and future GOES-S/T/U, AHI onboard Himawari-8/9
  - Reanalyses (RAN): AVHRR GAC and VIIRS, future FRAC, MODIS, etc.
- Need for adding new functionalities
  - SSES bias correction
  - Variable regression coefficients (for ACSPO RAN SSTs)
  - SQUAM processing improvements: time aggregation, match-up, etc
- Need for updating the 8-year-old web interface
  - Room for improvement with new web tech (graphic, interactivity, speed, etc.)

Facing the need for reorganization and redesign

- Development of SQUAM2 started in 2016

SQUAM 2: A Snapshot

www.star.nesdis.noaa.gov/sod/sst/squam2/ (Current URL)



SQUAM 2: Organization

	Polar L2/L3	Geo L2/L3	Analysis L4
High Resolution	**S-NPP VIIRS** ACSPO L2P ACSPO L3U **AVHRR FRAC** ACSPO L2P OSISAF L2P	**Himawari-8 AHI** ACSPO L2P **GOES-16 ABI** ACSPO L2P	MUR (JPL)
Low Resolution	**AVHRR GAC** ACSPO		CMC (Environment Canada) OSTIA (Met Office) GMPE (Met Office) Reynolds (NOAA) GAMSSA (Bureau)

SQUAM 2 Polar

- VIIRS, AVHRR FRAC, AVHRR GAC
- Reference SST:
  - L4: CMC, OSTIA, Reynolds
  - *In situ* (iQuam v2): drifters + tropical moorings, ARGO floats
- ACSPO L2P & L3U
  - Currently a mix of RAN and NRT data (seamless records)
  - RAN: 01 Mar 2012 -- 05 Dec 2015
  - NRT: 06 Dec 2015 – present
- Day & Night
- **SSES bias correction**
- Outlier removal (currently defined as >±4RSD)
- Time aggregation: day, month, year, full mission (future)
- Maps & histograms
  - View SST (in addition to *ΔT)*
- Time series
  - Stats include: NOBS, clear ratio, min/max, mean/median, sd/rsd, skew/kurt, low/high outlier ratio
- Dependencies plots & Hovmöller diagrams
  - Sat view angle, solar zen angle, lat/lon, SST, SST- air temperature, wind speed, total precipitable water, glint angle, scattering angle

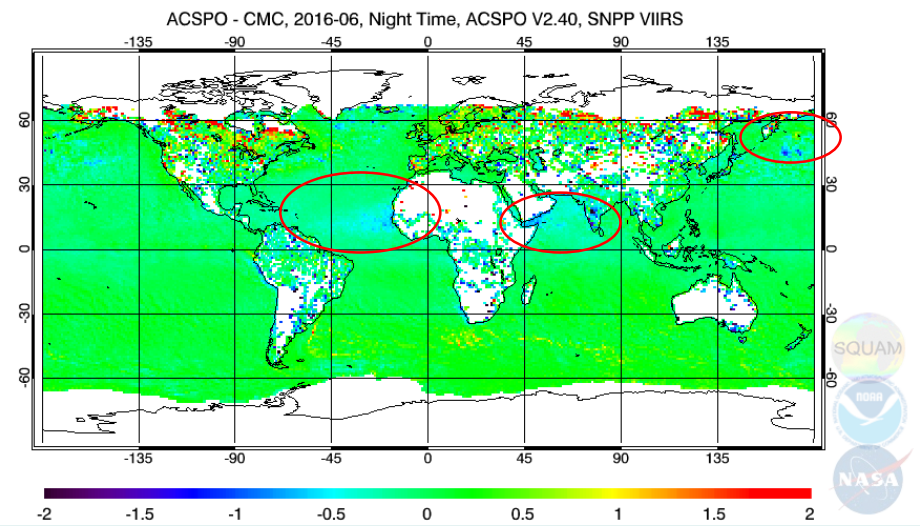
SQUAM 2 Polar

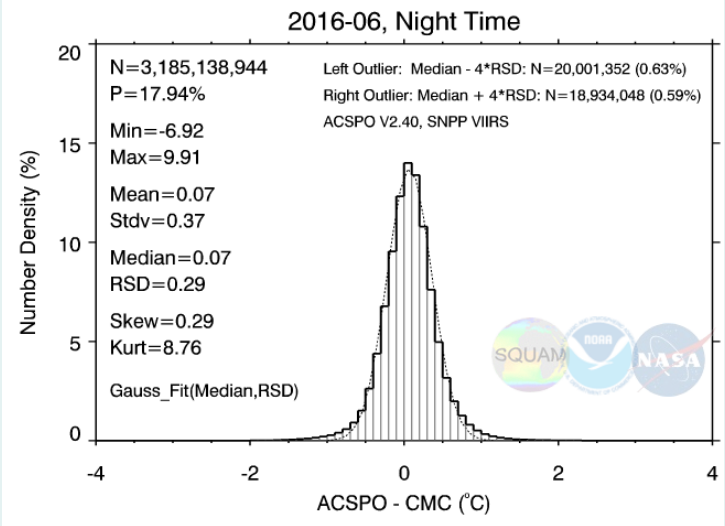
Example: SSES bias

- Using maps & histograms to show SSES bias correction on aerosol effect (link)
  - VIIRS L2P, ACSPO – CMC L4
  - Jul 2016, monthly aggregated, nighttime
- Cold bias in typical areas affected by aerosols
  - Tropical eastern Atlantic, Indian ocean, north-west Pacific

BEFORE applying SSES bias correction

S-NPP VIIRS, 2016-06, Bias=0.07K SD=0.37K





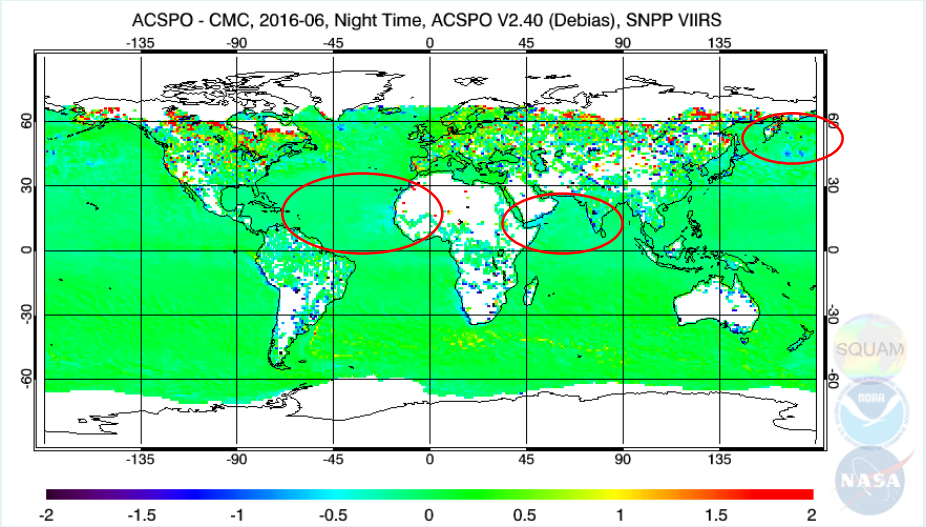
SQUAM 2 Polar

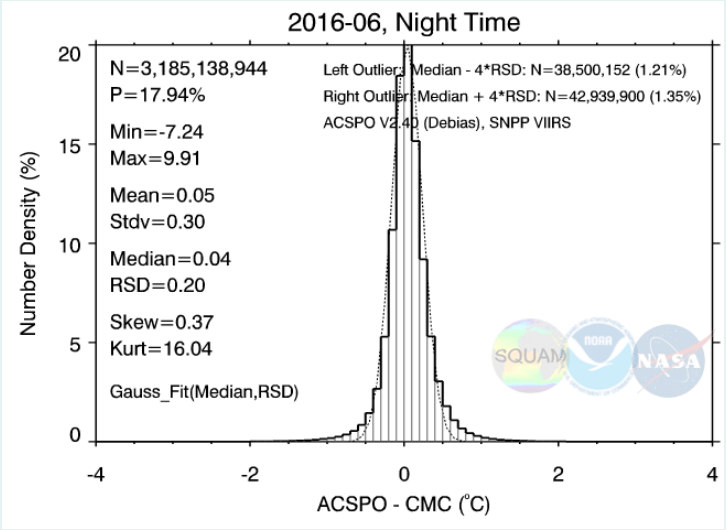
Example: SSES bias

- Using maps & histograms to show SSES bias correction on aerosol effect (link)
  - VIIRS L2P, ACSPO – CMC L4
  - Jul 2016, monthly aggregated, nighttime
- Cold bias in typical areas affected by aerosols
  - Tropical eastern Atlantic, Indian ocean, north-west Pacific

AFTER applying SSES bias correction

S-NPP VIIRS, 2016-06, Bias=0.05K SD=0.30K





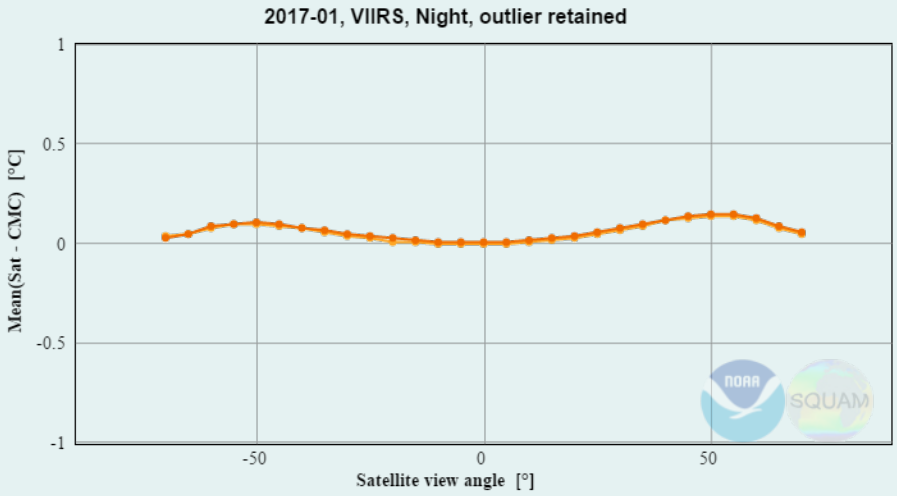
SQUAM 2 Polar

Example: SSES bias

- Using dependency plots and Hovmöller diagrams to show how SSES mitigates biases related to dependence variables (link)
  - VIIRS, ACSPO – CMC L4
  - Dependence variable: satellite view angle

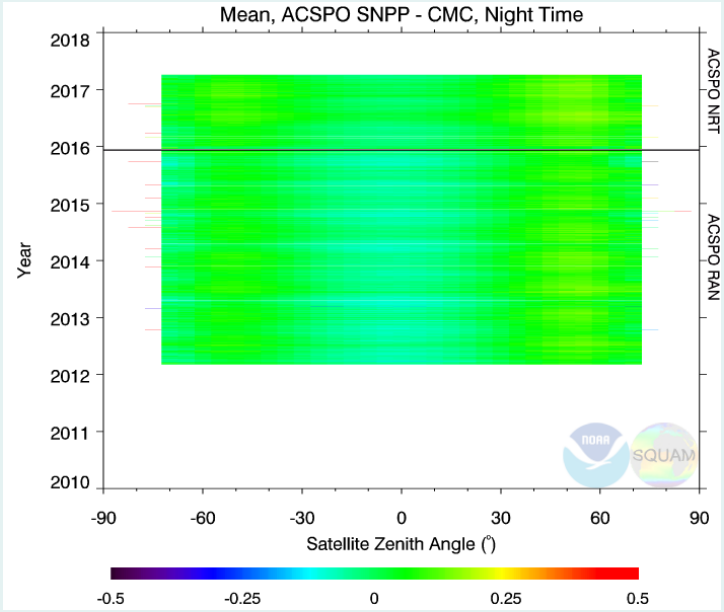
BEFORE applying SSES bias correction

Dependency – 2017-01, monthly, night



– SNPP L2p – SNPP L3U

Hovmoller – SNPP L2P, daily, night



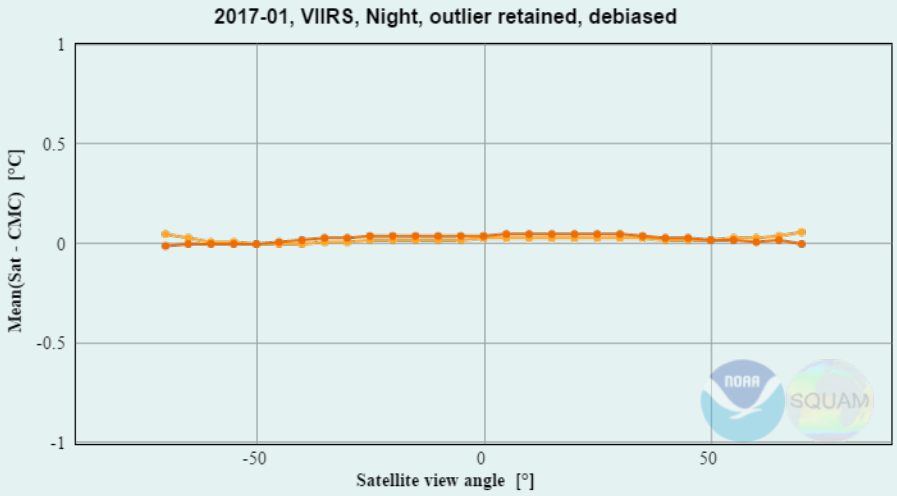
SQUAM 2 Polar

Example: SSES bias

- Using dependency plots and Hovmöller diagrams to show how SSES mitigates biases related to dependence variables (link)
  - VIIRS, ACSPO – CMC L4
  - Dependence variable: satellite view angle

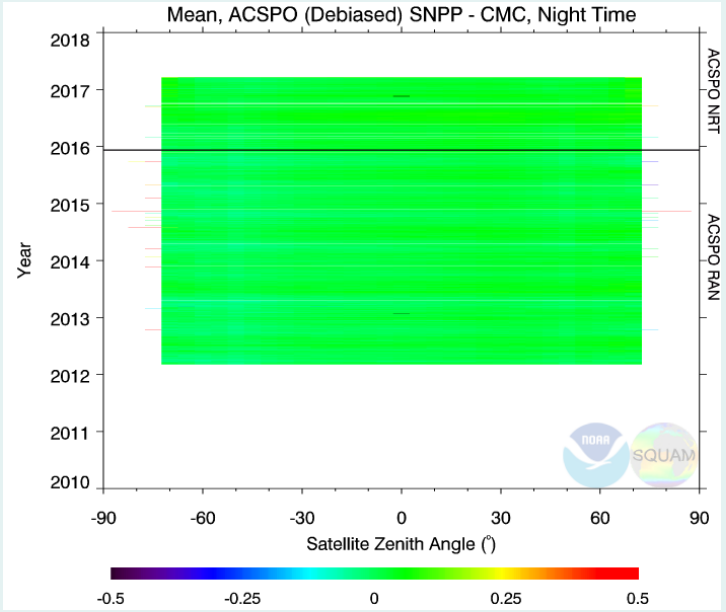
AFTER applying SSES bias correction

Dependency – 2017-01, monthly, night



– SNPP L2p – SNPP L3U

Hovmoller – SNPP L2P, daily, night



SQUAM 2 Polar

- VIIRS, AVHRR FRAC, AVHRR GAC
- ACSPO RAN
- PM & AM families (seamless records for each; two platforms at a time)

NOAA-16	PM	30 Aug 2002 – 06 Jun 2005
NOAA-18	PM	07 Jun 2005 – 21 Feb 2009
NOAA-19	PM	22 Feb 2009 – present
NOAA-17	Mid-AM	30 Aug 2002 – 22 Nov 2006
Metop-A	Mid-AM	23 Nov 2006 -- present

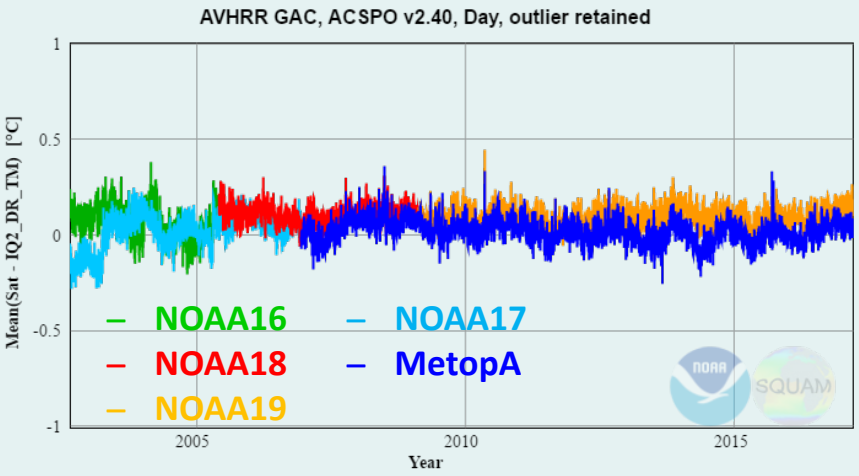
- Variable regression coefficients
  - Ex: time series of mean bias against *in situ*.
- Time series of double difference
  - Daytime – nighttime, satellite – AM ref satellite, satellite – PM ref satellite

SQUAM 2 Polar

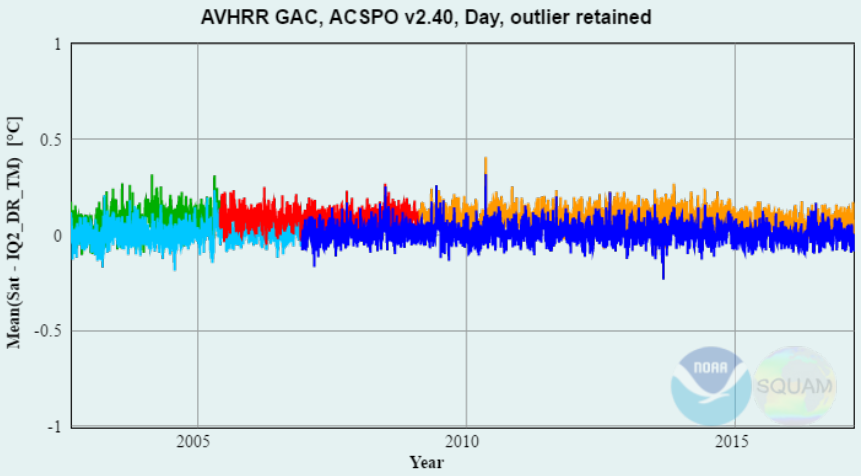
Example: variable coefficients

- AVHRR GAC SSTs are unstable due to brightness temperature (BT) artifacts, which are caused by suboptimal calibration, drifting orbits, etc.
- Without a “stable version” of BT, variable regression coefficients are employed in ACSPO RAN
- Variable regression coefficients are dynamically derived using a 90-day moving window
- fixed coefficients vs. variable coefficients in GAC RAN time series (link)
  - Validated against drifters + tropical moorings
  - Mean, day time
- Greatly suppress the variations, especially in NOAA16 & NOAA17

Fixed coefficients



Variable coefficients



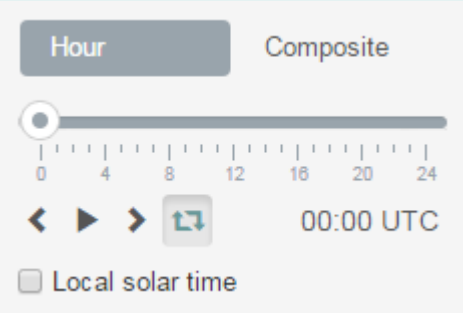
SQUAM 2: Geo

- Hamawari-8 AHI, GOES-16 ABI (upcoming)
- Reference SST:
  - L4: CMC, OSTIA
  - *In situ* (iQuam v2): drifters + tropical moorings, ARGO floats
- ACSPO L2P
  - 14 Apr 2015 – present
- SSES bias correction, outlier removal, time aggregation
- Hour & local solar time, and composite
  - Hour: specify hour of day (HOD) in both UTC and local solar time (LST)
  - Composite: daytime/nighttime, button to compare to VIIRS
- Maps & Histograms
  - Satellite view (default) and equiangular projection
- Time series
  - View all hours or by individual hour (in both UTC and LST)
- Dependencies & Hovmöller
  - Local hour dependency

SQUAM 2: Geo

Hourly analysis

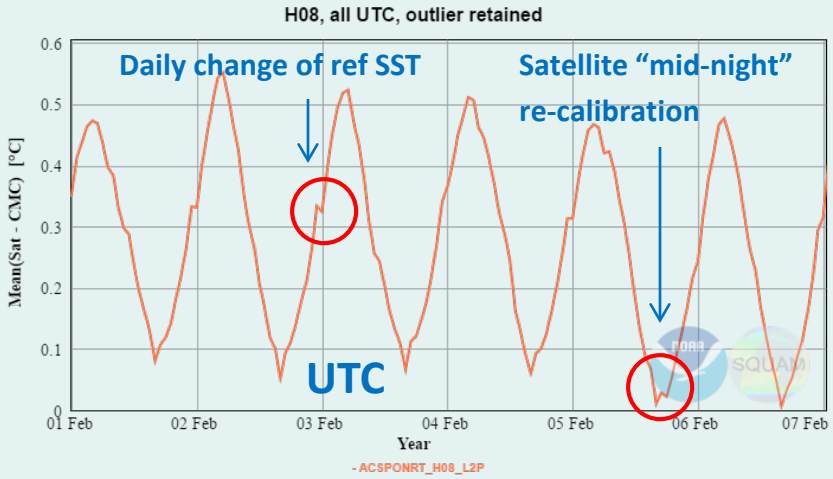
- Hourly analysis in SQUAM Geo
  - H08 AHI temporal frequency: every 10 min (GOES-16 ABI: 5 or 15min)
  - SQUAM picks 1st full disk image in a 1-hour interval
  - Compatible with time aggregation (month, etc.)
- UTC based (default)
  - For monitoring sensor performance
- Local solar time based
  - For scientific analysis, since physics are based on local time, such as diurnal cycle effect.
  - LST results are computed by splitting full disk images based on LST hour and regrouping.
- Interactive control
  - Hour slider
  - Navigation bar
  - Toggle between “looping” and “rolling”
    - Pressed (looping): constrained to 24 hrs UTC/LST
    - Unpressed (rolling): allow crossing onto the adjacent day/month

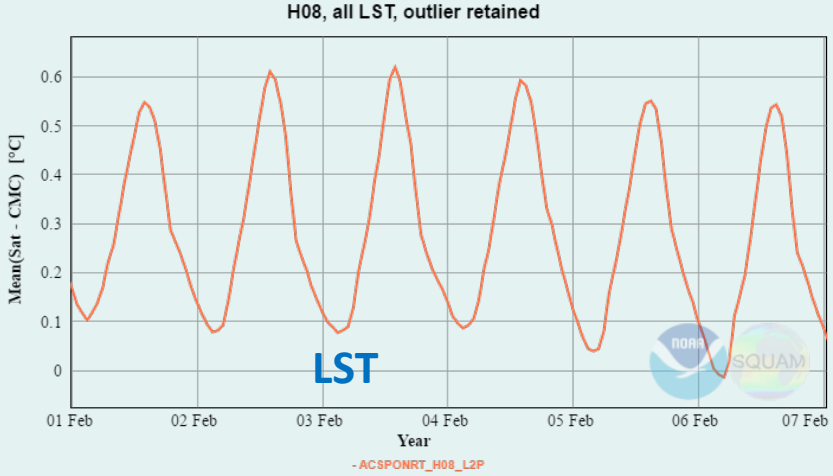


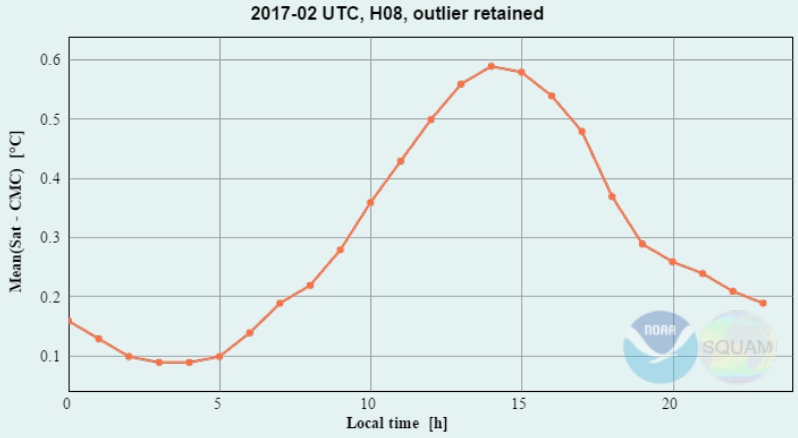
SQUAM 2: Geo

Example: diurnal cycles

- In SQUAM time series (link)
  - Mean bias, H08 against CMC
  - Local solar time
  - 01 Feb – 07 Feb, 2017
- Also in SQUAM dependency plots with time aggregation (link)
  - Dependence variable: local time
  - Feb 2017, monthly aggr.
- min ~ 0.1K @03:00 LST, max ~ 0.6K @14:00 LST

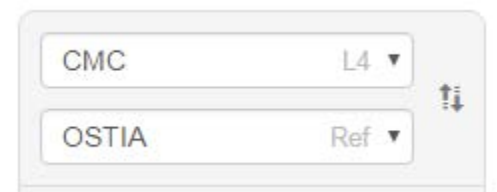






SQUAM 2: Analysis (L4)

- L4 SSTs: CMC, OSTIA, GMPE, Reynolds, GAMSSA, MUR
- *in situ* reference in addition to L4: drifters + tropical moorings, ARGO floats
- Interactive controls
  - L4 box & Ref box
  - Not simply interchangeable: L4 SST is mapped to the grids of the Ref SST
  - Swap if selecting identical ones, or clicking “swap” button

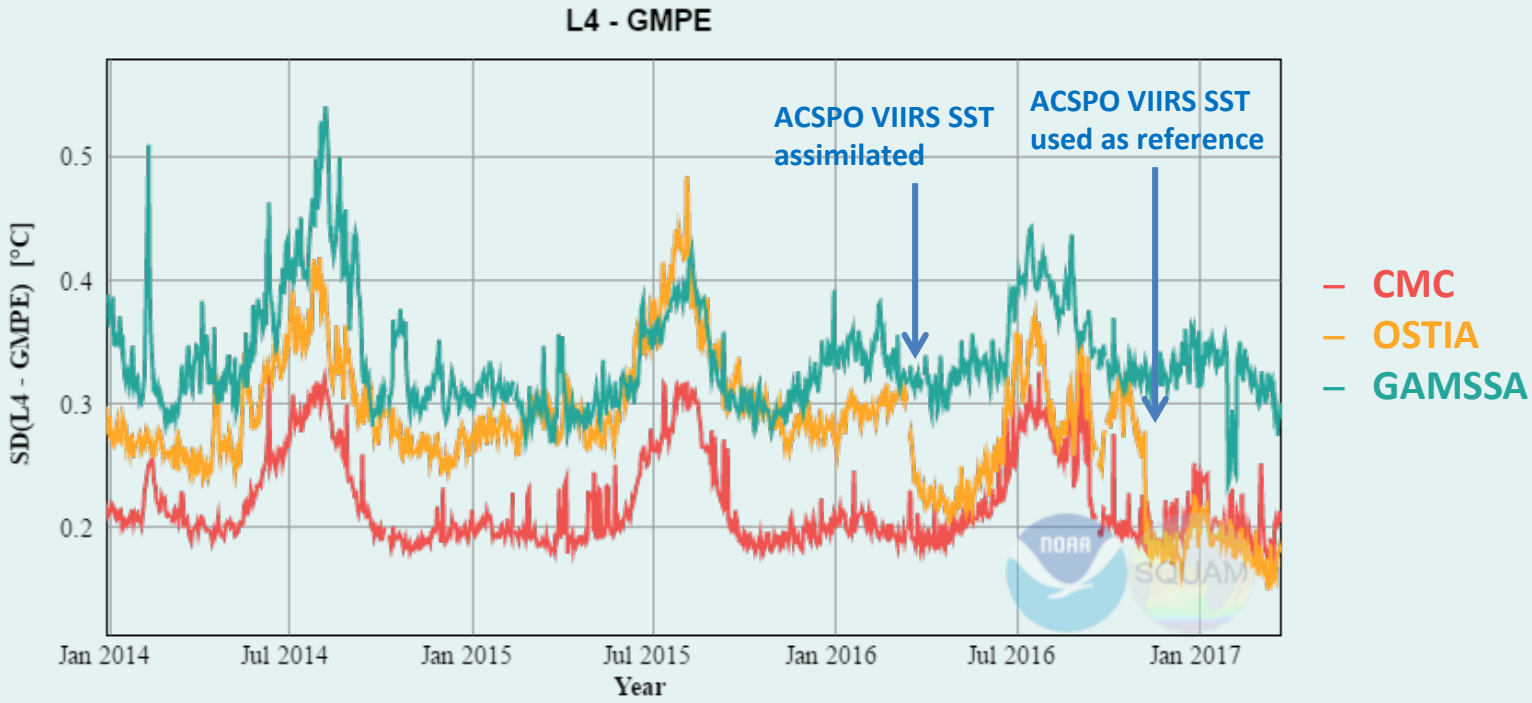


- Time aggregation
- Maps & histograms
  - Ice and/or land mask in “view SST” mode
- Time series
- Dependencies & Hovmöller
  - Dependence variables: latitude, SST

SQUAM 2 L4

Example: OSTIA

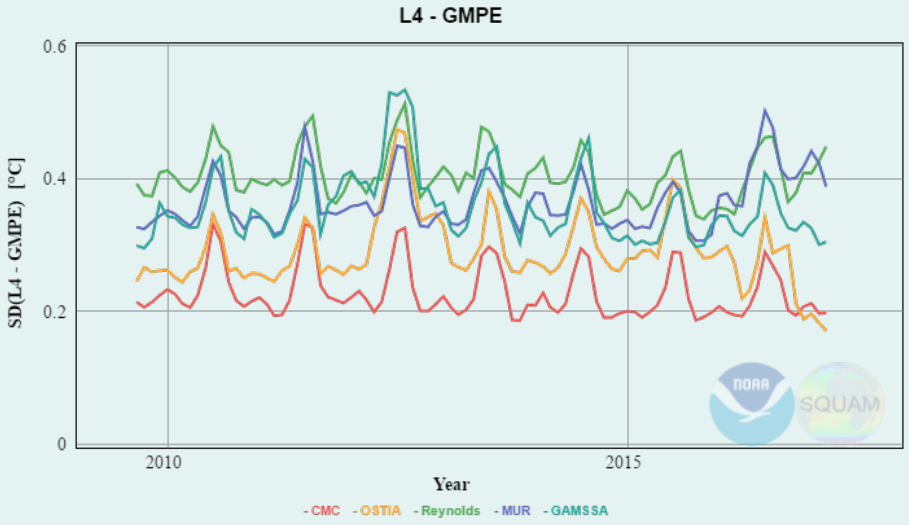
- OSTIA had made two changes in 2016 (link)
  - Mar 2016, SD(OSTIA – GMPE) decreased from ~0.3K to ~0.23K (OSTIA started to assimilate ACSPO VIIRS SST)
  - Nov 2016, SD dropped from ~0.27K to ~0.20K (OSTIA started using ACSPO VIIRS as reference)
  - OSTIA SD is now comparable with CMC, which has been assimilating ACSPO VIIRS SST since May 2014
- GAMSSA SD remained pretty much at the same level as the "pre-ACSPO" OSTIA
- This case study gives an idea of potential room for improvement in GAMSSA

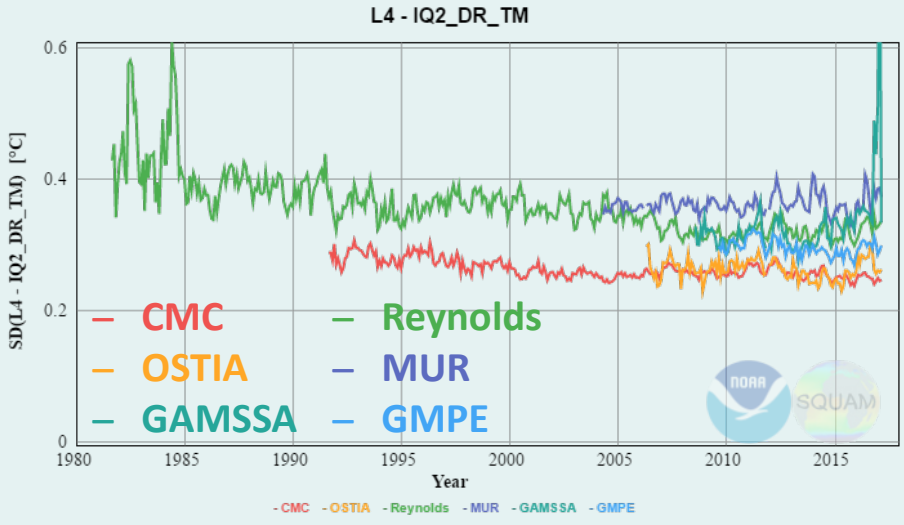


SQUAM 2 L4

Example: against *in situ*

- The results of “L4 – GMPE” and “L4 – in situ” are not fully consistent
- This is because *in situ* data have been assimilated in all L4 analyses (except GMPE), more aggressively in some L4s than in the others
- CMC (and more recently, OSTIA too) are on the lower envelope of points against both GMPE and in situ, suggesting overall better performance





SQUAM 2
Web functionality

- Web-based features

Permalink	URL stores all tab and button selections, easy for bookmarking and sharing
Session caching	Polar, Geo, and Analysis memorize their tab & button selections independently
Interactive plots	Available in time series and dependencies, powered by DYGraph JS library. Both image and data are export-able.

- interactive plot cheat sheets

Zoom in	Hold your click and drag
Reset zoom	Double click or check “Axis range: preset”
Pan	Hold Shift key and drag
Show values	Hover on the data point
Smooth	Enter *n* in the left corner box for *n*-point mean filtering
Toggle dataset visibility	Check/un-check “Display toggles” boxes
Download	Press button for data download or image export

SQUAM 2
Summary

- SQUAM has been upgraded and redesigned to
  - Meet challenging demands of data volume and computing resource due to new platforms and products
  - Stay more centric to NOAA ACSPO products
  - Support new techniques (SSES, variable coefficients, etc)
  - Improve processing algorithms and efficiency
  - Enhance web interface and functionality
- We are committed to support SQUAM2 for our community users and partners. Ongoing development and improvements are based on user needs and feedback
  - Opinions on the current contents, functionality, features?
  - Suggestions of wanted features? Feedback is appreciated & improvements will be made
- We plan to release SQUAM2 in place of heritage SQUAM by the GHRSST Meeting in June 2017

Thank you!