Suomi NPP SST Provisional Maturity

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U. Miami - Peter Minnett, Bob Evans, Kay Kilpatrick;
EUMETSAT/Meteo France - Pierre Le Borgne, Herve Roquet

JPSS JAM: Rosalie Marley; NGAS - Sid Jackson; Raytheon - Bill Johnsen, Marian Hollingshead

JPSS SST Team

Name	Affiliation	Funding	Tasks
Ignatov	STAR	NOAA	Lead, JPSS Algorithm & Cal/Val
Stroup, Kihai, Dash, Liang, Petrenko, Xu, Bouali, Zhou	STAR/CIRA STAR/STG STAR/GST STAR/GST	NJO	Quality Monitoring of VIIRS SSTs (SQUAM), Radiances (MICROS), and in Situ SSTs (*i*Quam) Data support; IDPS SST code, Match up, Cloud Mask, SST retrievals; Destriping L1b & SST
May, Cayula, McKenzie	NAVO	Navy, NJO	NAVO SEATEMP SST & Cal/Val VIIRS Cloud Mask evaluation
Minnett **Evans** Kilpatrick	U. Miami	NJO	Uncertainty & instrument analyses; SST Validation vs. drifters & shipboard radiometers; skin to sub-skin conversion (skin effect, diurnal heating); RTM
Arnone Fargion	USM/NRL UCSD	NJO	SST Algorithm Analyses, SST improvements at slant view zenith angles/swath edge
LeBorgne Roquet	Meteo France	EUMETSAT	Processing VIIRS and Cal/Val using O&SI SAF heritage; Comparisons with AVHRR/SEVIRI

Acknowledgements

- JPSS Program – Mitch Goldberg, Kathryn Schontz, Bill Sjoberg
- NASA SNPP Project Scientist – Jim Gleason
- NOAA NDE Team – Tom Schott, John Sapper, Dylan Powell, Bonnie Reed
- JPSS DPA – Eric Gottshall, Janna Feeley, Bruce Gunther
- VIIRS SDR & GSICS – Changyong Cao, Frank DeLuccia, Jack Xiong, Mark Liu, Fuzhong Weng
- VIIRS VCM – Andy Heidinger, Tom Kopp, Denis Botambekov
- NESDIS/STAR JPSS Team – Ivan Csiszar, Lihang Zhou, Paul DiGiacomo, Laurie Rokke, and many others
- NOAA CRTM Team – Yong Han, Yong Chen, Mark Liu

Criteria for Provisional Maturity Status

- Product quality may not be optimal
  - No requirement to demonstrate compliance with specifications
  - Product accuracy is determined for a broader (but still limited) set of conditions than Beta
- Incremental product improvements still occurring
- General research community is encouraged to participate in the QA and validation of the product, but need to be aware that product validation and QA are ongoing
- Users are urged to consult the EDR product status document prior to use of the data in publications
- Ready for operational evaluation

Recommend SST for Beta with Caveats
(23 Feb 2013 SST Beta Review)

- SST Data record available in CLASS from 22 Jan 2012 – onward is suboptimal and highly non-uniform
- As of this report, VIIRS SDRs have been verified and have reached a stable and accurate performance for SST
- As of this report, VCM and Ice Mask performance for SST remain non-uniform and suboptimal
- As of this report, SST EDR reports two SSTs – skin and bulk. Work is underway to exclude bulk
- SST Reveals strong limb cooling and degraded performance, due to suboptimal SST Regressions which are being revisited
- SST QFs are suboptimal and being revisited

SST DRs (1 or 2)

DR #	Description	Status
4696	Fast-track SST EDR Tables	Closed
4727	Update FT VIIRS SST regression coefficients table	Closed
4748	Algorithm needs to check cloud mask quality	Open
4789	Remove/replace bulk SST data	Closed
4790	SST QFs code reorganization	Open
4807	Change forms of SST equations	Open (Mx8.1)
4844	SZA exclusion and SZA degradation flags affected by setting of cloudy/clear flags	Open
4845	OAD for SST does not agree with code in PCR31250	Closed
4846	CDFCB vol IV part 3 SZA quality flag definition	Open
4925	Unsatisfactory VCM Performance for SST	Open
4947	SST to discontinue use of several ASFs	Open
4948	Add VCM snow/ice flag to SST EDR	Open

SST DRs (2 of 2)

DR #	Description	Status
4965	1st Guess Skin Temp Change to SST product	Open (Mx8.1)
7097	Daily Reynolds SST in IDPS (for SST)	Open
7098	Remove Bulk from SST Product	Open (Mx8.1)
7258	JPSS-1 Algorithm Improvements: Recommended: Sea Surface Temperature EDR	Open
7353	SST output metadata is showing "gracefully degraded"	Open
7385	Update to SST OAD and CDFCB documents as result of 474-CCR-13-1077 & 474-CCR-13-1137	Open (Mx8.1)
7417	VIIRS SST - Reference SST in the SST EDR does not always get output per 474-CCR-13-1137 implementation	Open (Mx8.3)

Remaining Work Towards SST Provisional (23 Feb 2013 SST Beta Review)

1. Work with VCM Team to fine-tune VCM and Ice Mask for SST

- ✓ Work with Andy Heidinger and Denis Botambekov to improve VCM

2. Redesign SST EDR per new L1RD

- ✓ Only keep skin SST, Exclude bulk, Reuse bulk layer for 1st-guess SST
- ✓ Reformulate SST regression equations, to improve SST statistics and remove limb cooling at swath edges
- ✓ Bring in superior 1st guess SST – Reynolds (instead of NCEP GFS) and redesign SST Quality Flags

3. Monitor VIIRS SST Radiances over an extended period of time

- ✓ Monitoring of IR Clear-sky Radiances over Oceans for SST (MICROS; www.star.nesdis.noaa.gov/sod/sst/micros/)

4. Monitor VIIRS SSTs over an extended period of time

- ✓ SST Quality Monitor (SQUAM; www.star.nesdis.noaa.gov/sod/sst/squam/)

1. Fine-tune VCM
SST Feedback to VCM (EDR Review, 7 Jan 2014)

- **Observations for both day and night VCM**
  - Improved since VCM Provisional @Jan'13: Larger domain, improved stats
  - Degraded performance is in part due to suboptimal IDPS SST algorithm (e.g., limb cooling at swath edges) – fixed in IDPS 8.1 (Feb'14)
- **Night**
  - IDPS domain +6% larger than ACSPO, and SST stats are degraded
  - IDPS SST close to meeting specs @new L1RD (ACSPO does meet specs)
- **Day**
  - IDPS domain now -4% smaller than ACSPO, but SST stats degraded
  - IDPS SST does not meet specs @new L1RD (ACSPO does meet specs)
- **VCM is thought to have fully realized its potential for SST. Further measurable VCM improvements for SST are deemed unlikely**
- **Remaining VCM leakages will be fixed, by redesigning SST QFs (pending bringing Reynolds SST in IDPS)**

2. Redesign SST EDR per new L1RD

- **Skin/Bulks SST (operational in build 8.1, Feb 2014)**
  - The new L1Rd only requires skin SST
  - Bulk SST was removed. Layer reused to store first guess SST (now NCEP GFS SST; will be replaced by Reynolds SST when available)
- **Reformulate SST regressions equations (build 8.1, Feb 2014)**
  - IDPS now uses EUMETSAT OSI SAF SST Equations
  - ACSPO has also switched to OSI SAF equations
  - JGR special issue manuscript in review
- **Bring in IDPS Reynolds SST & Redesign QFs (in progress)**
  - Bringing in Reynolds SST still in progress
  - QFs will be redesigned pending availability of Reynolds SST in IDPS
  - Hopefully will make to build 8.4, May 2014

3. Continuously Monitor VIIRS Radiances in MICROS

SST Feedback to SDR (SDR Review, 19 Dec 2013)

Overall, VIIRS is a very good, state of the art sensor for SST

- ✓ Radiances are stable and consistent w/AVHRR/MODIS (JGR, 2013)
- ✓ VIIRS imagery comparable or better than Aqua MODIS

Striping still affects SST

- ✓ Striping in VIIRS BTs is within specs and better than Aqua MODIS. However, it affects cloud mask, gets amplified in SST, and affects downstream SST products (gradients)
- ✓ SST Team works with SDR to reduce striping based on 1st principles
- ✓ Also, SST Team explores destriping in BTs to improve SST EDR. (JTECH, Jan 2014)

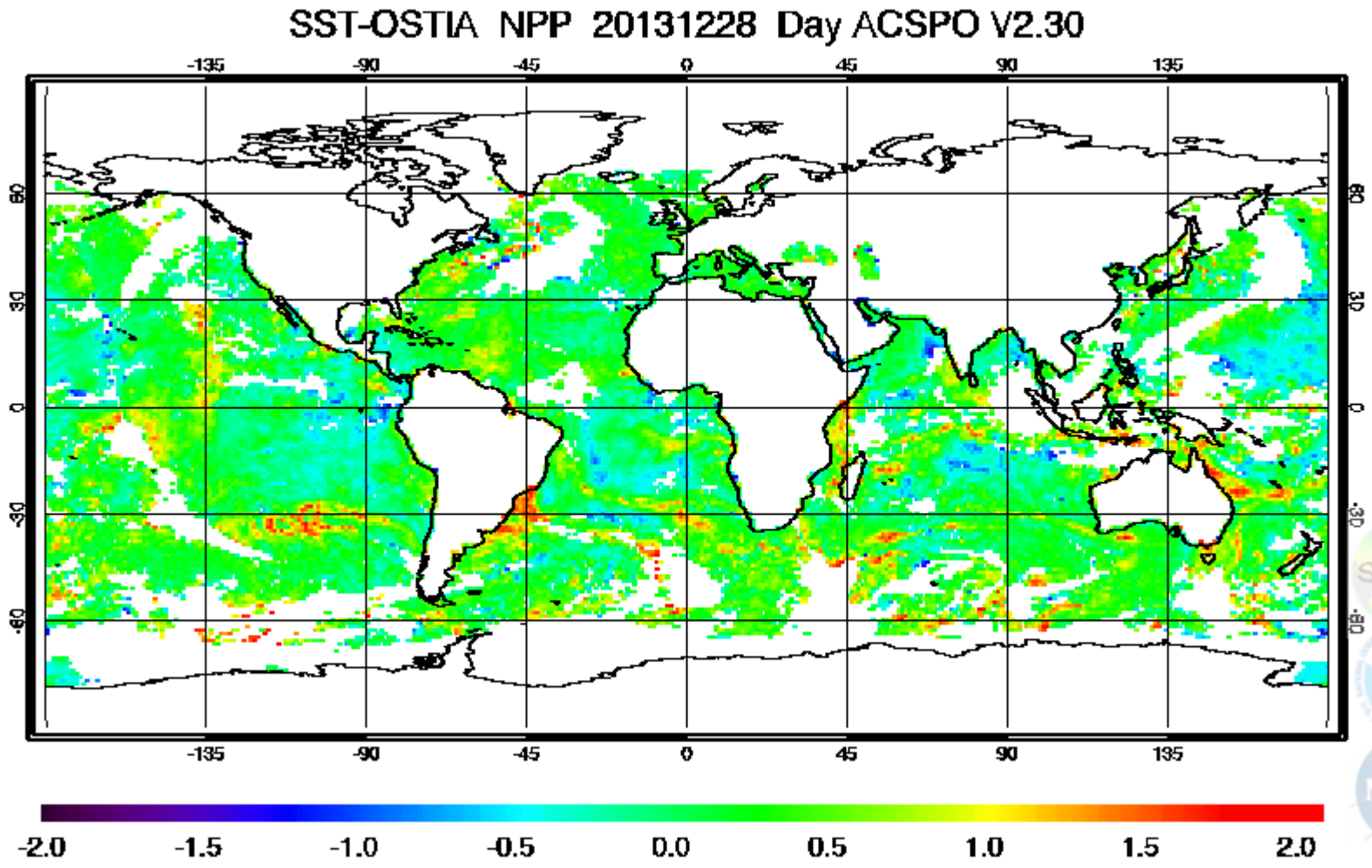
Suggested Improvement

- ✓ Fill in radiances in bow-tie areas. (Currently, filled in with NaNs – suggest put real numbers, while keeping the “bow-tie” flag on)

4. Continuously Monitor VIIRS SSTs in SQUAM

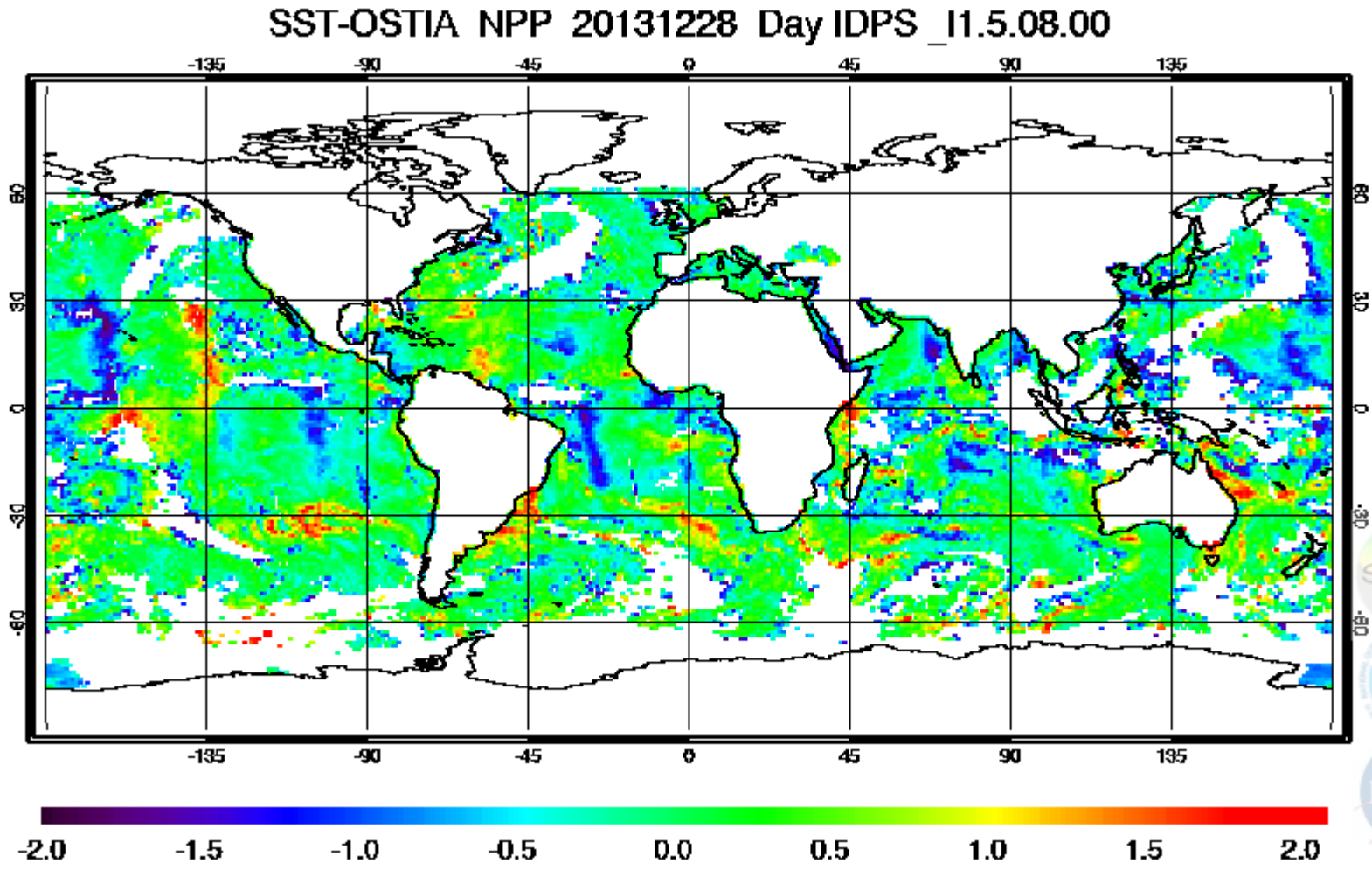
- **IDPS SST continuously monitored since 8 Mar 2012 against**
  - Global analysis fields (L4 – OSTIA, Reynolds)
  - Quality controlled in situ data
- **Other community SST Products monitored in SQUAM**
  - NOAA heritage Advanced Clear-Sky Processor for Oceans (ACSPO) products from SNPP VIIRS, NOAA/Metop AVHRRs, Terra/Aqua MODIS
  - OSI SAF (Metop AVHRR) and NAVO (NOAA and Metop AVHRR) SSTs
- **IDPS SST performance**
  - Nighttime SST is largely in-family and close to meeting specs
  - Daytime SST is “out-of family” and does not meet specs
  - The reasons are mostly cloud and ice masks, and suboptimal SST algorithms

DAY: ACSPO L2 minus OSTIA L4
28 December 2013



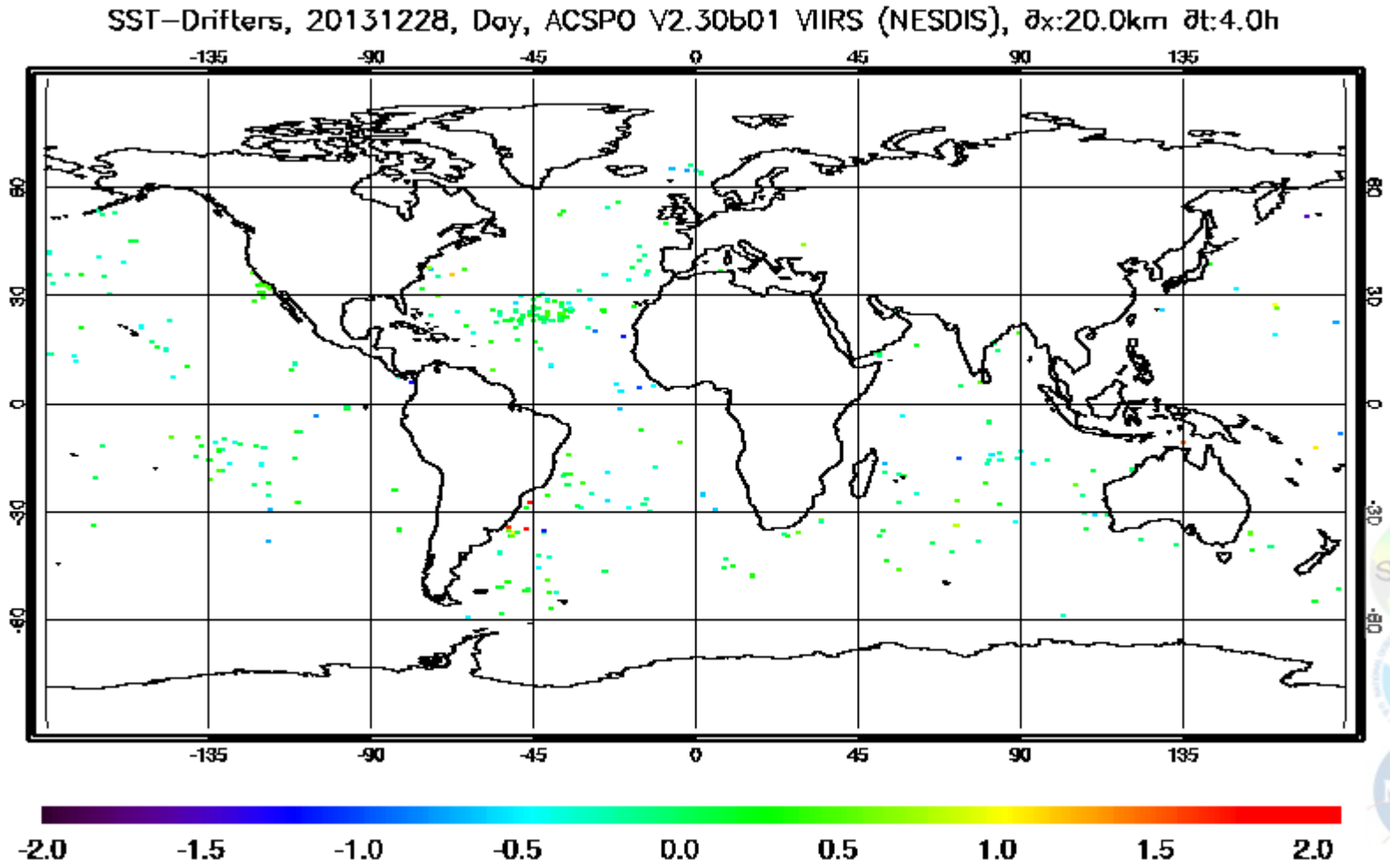
- ***Deviation from Reference SST is flat & close to 0***
- ***Residual Cloud/Aerosol leakages seen as cold spots***
- ***Warm spots show areas with diurnal warming during daytime***

DAY: IDPS L2 minus OSTIA L4
28 December 2013



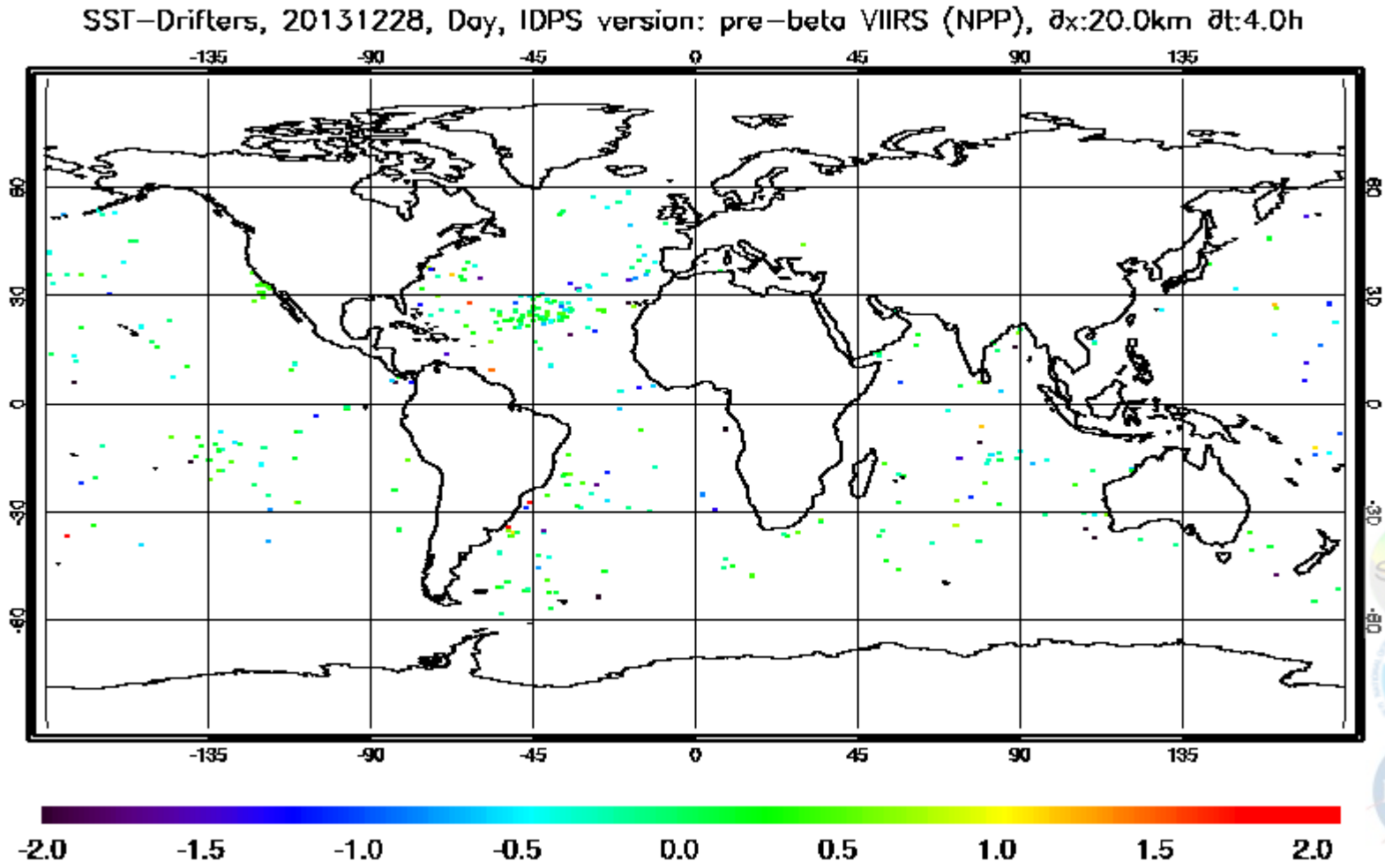
- *More Cloud leakages than in ACSPO*
- *"Limb Cooling" – due to suboptimal SST equations (fixed in build 8.1, Feb 2014)*

DAY: ACSPO L2 minus in situ SST
28 December 2013



- *Much fewer match-ups with in situ data than with L4*
- *Validation statistics may not be globally representative*
- *Daily validation statistics may not be accurate and stable*

DAY: IDPS L2 minus OSTIA L4
28 December 2013



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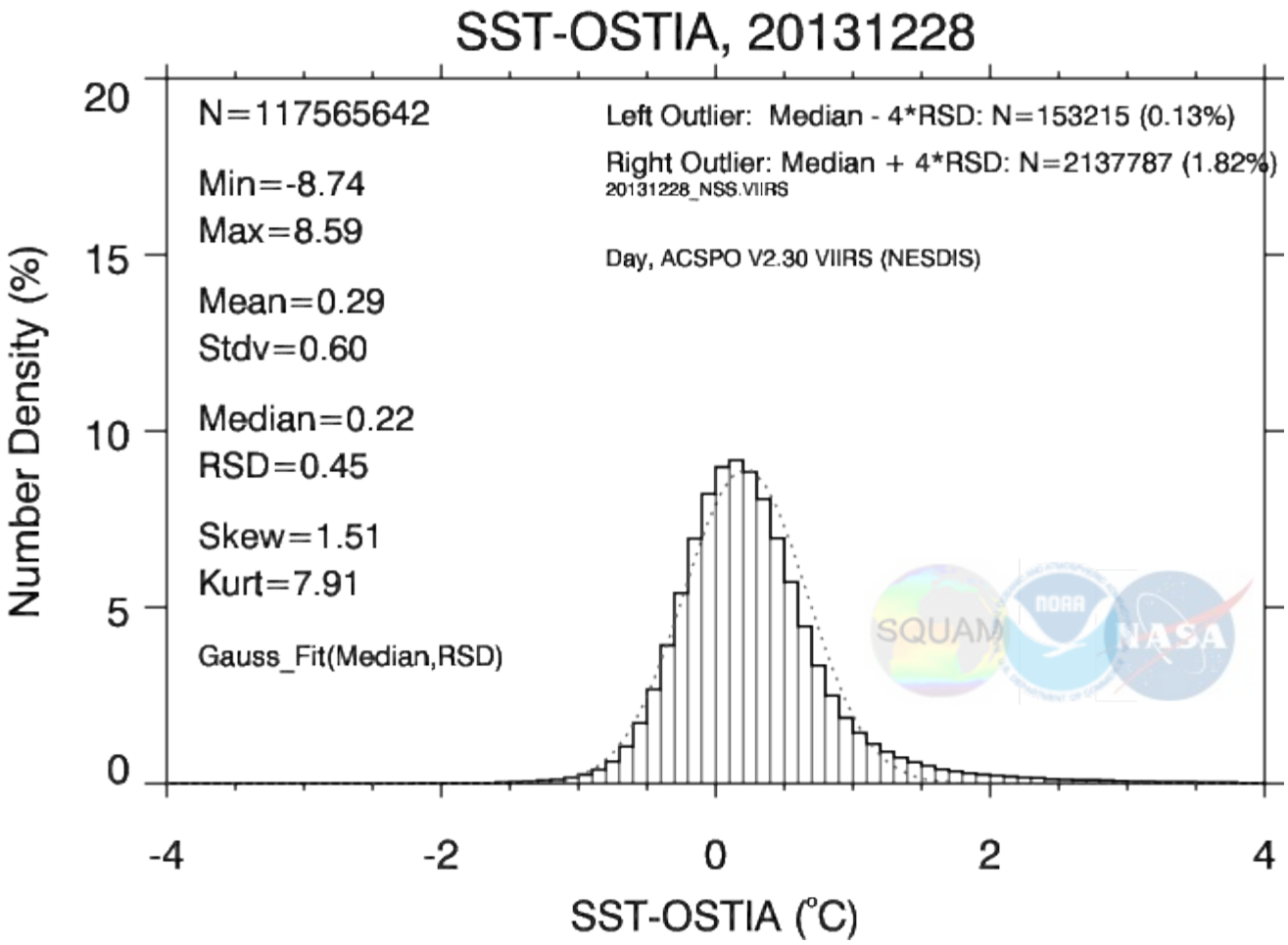
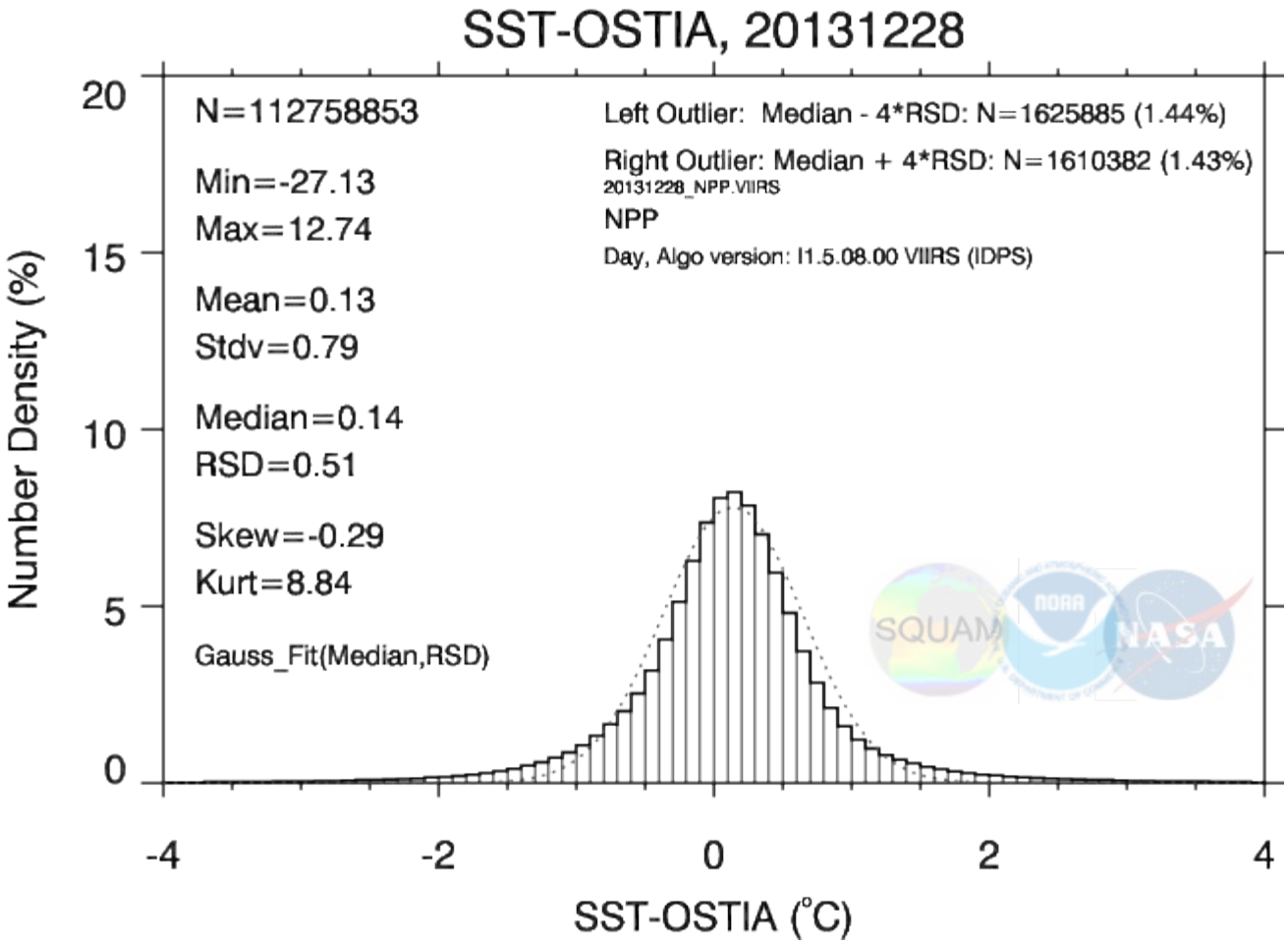


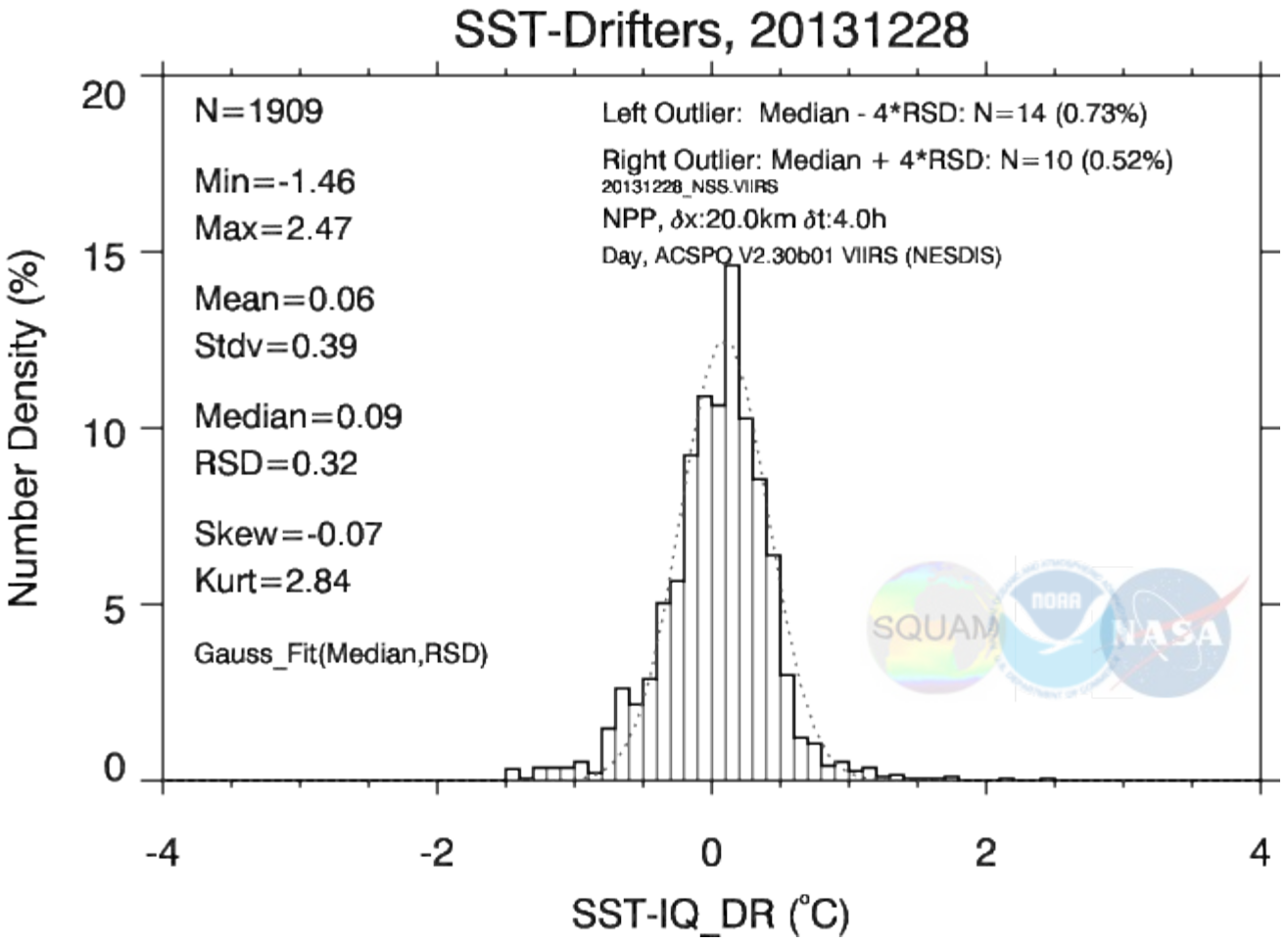
- ***Shape close to Gaussian but skewed positively due to diurnal warming***
- ***Domain & Performance Stats close to expected***

DAY: IDPS L2 minus OSTIA L4
28 December 2013



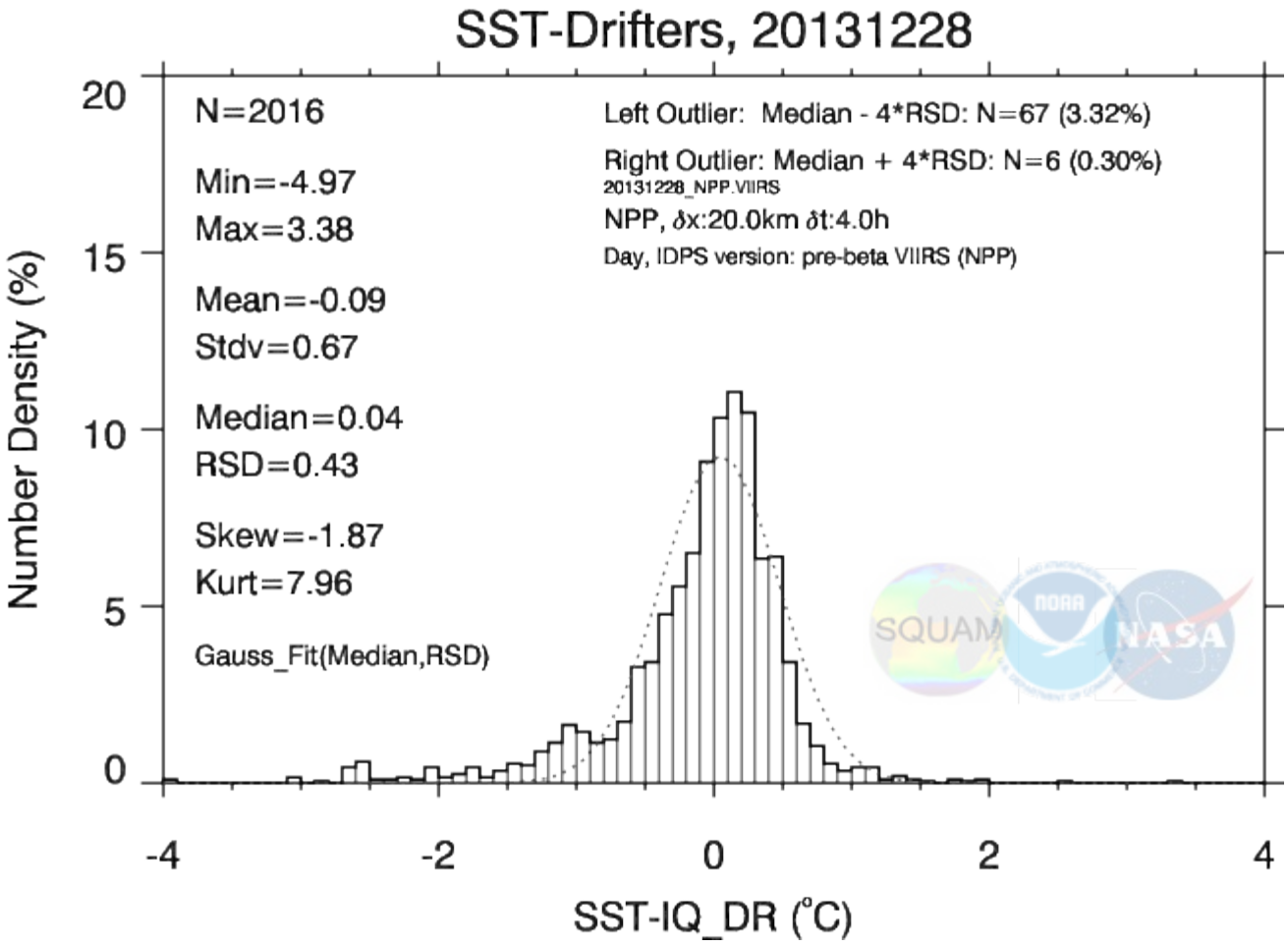
- ***IDPS sample -4% smaller compared to ACSPO***
- ***Degraded Min/Max, STDV/RSD & Larger fraction of outliers***

DAY: ACSPO L2 minus *in situ* SST
28 December 2013



- ***Shape close to Gaussian***
- ***Domain & Performance Stats better than spec***

DAY: IDPS L2 minus *in situ* SST
28 December 2013



- ***IDPS match-up data set +6% larger compared to ACSPO***
- ***Increased Min/Max, STDV/RSD & Larger fraction of outliers***

DAY 28 December 2013 – Summary

ΔT = "VIIRS minus OSTIA" SST (expected ~0)

	NOBS (%ACSPO)	Min/ Max	Mean/ STD	Med/ RSD	Skew/ Kurt
ACSPO	117.6M (100%)	-8.7/ +8.6	+0.29/0.60	+0.22/0.45	+1.5/ +7.9
IDPS	112.8M (96%)	-27.1/+12.7	+0.13/0.79	+0.14/0.51	-0.3/ +8.8

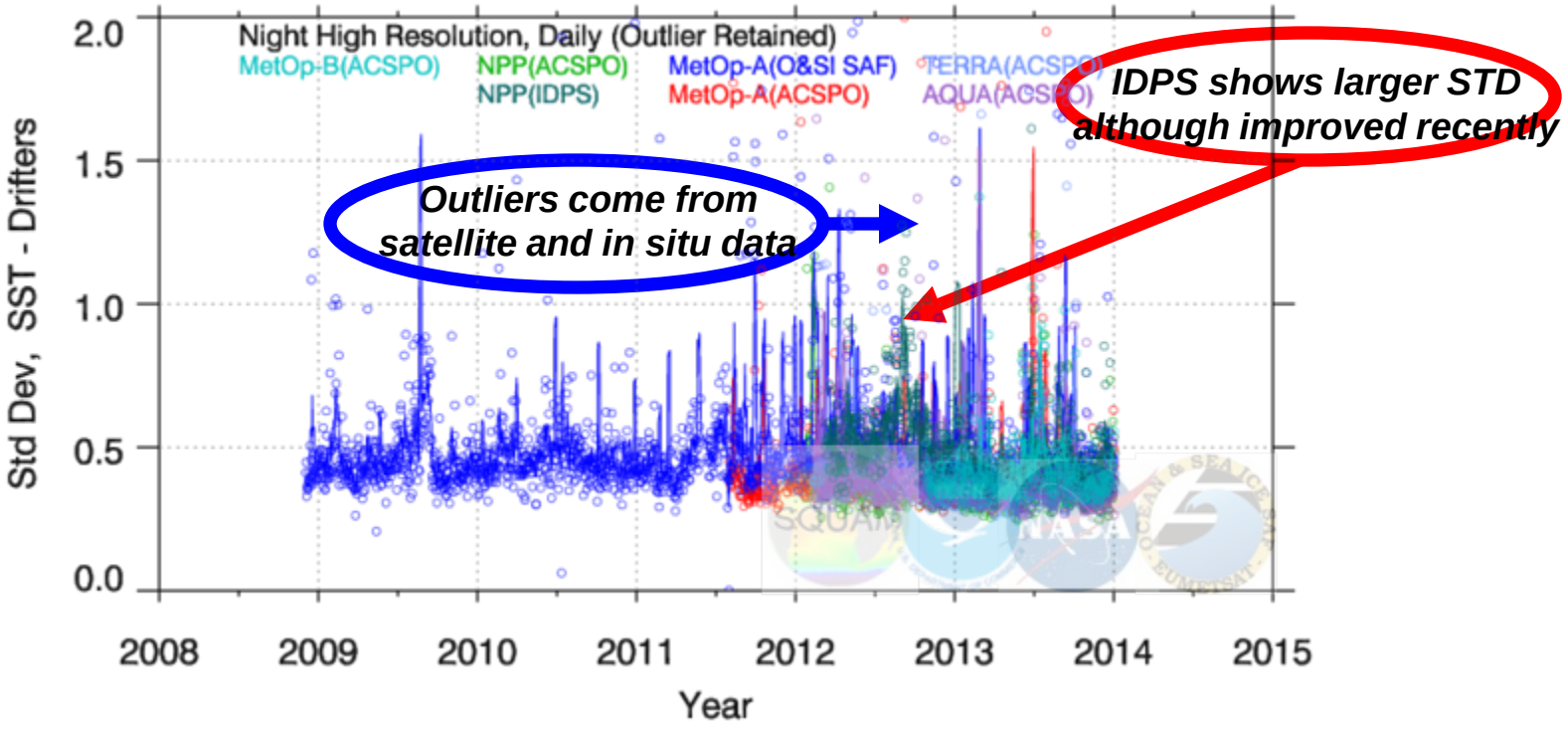
- *IDPS SST domain -4% smaller but all Stats degraded, compared to ACSPO*
- *Gap between Conventional and Robust stats wider in IDPS - More outliers*

ΔT = "VIIRS minus in situ" SST (expected ~0)

	NOB (%ACSPO)	Min/ Max	Mean/ STD	Med/ RSD	Skew/ Kurt
ACSPO	1,909 (100%)	-1.5/ +2.5	+0.06/0.39	+0.09/0.32	-0.1/ +2.8
IDPS	2,016 (106%)	-5.0/+3.4	-0.09/0.67	+0.04/0.43	-1.9/ +8.0

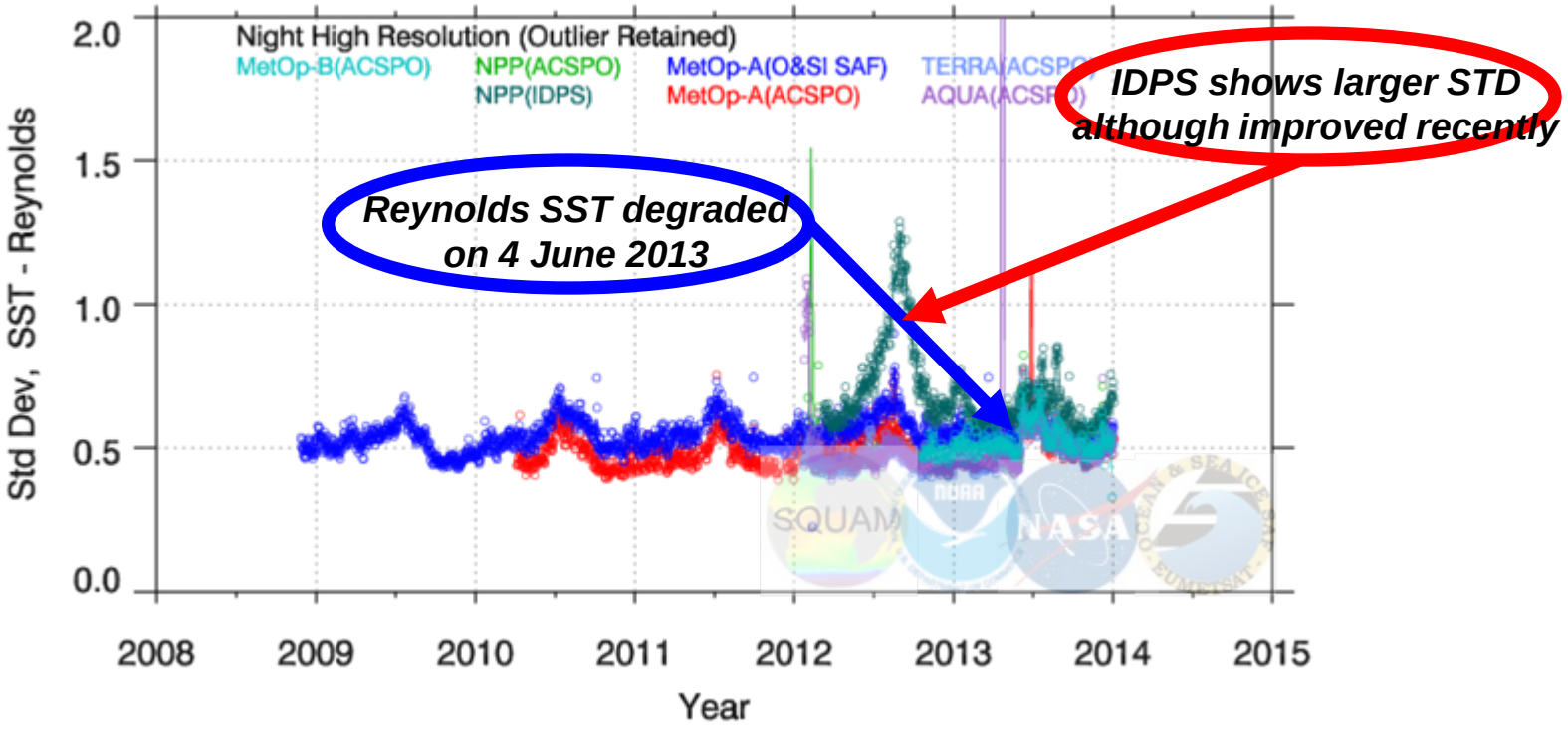
- *IDPS SST domain is +6% larger but all Stats degraded, compared to ACSPO*
- *Gap between Conventional and Robust stats wider in IDPS - More outliers*

NIGHT STD DEV wrt. In situ SST



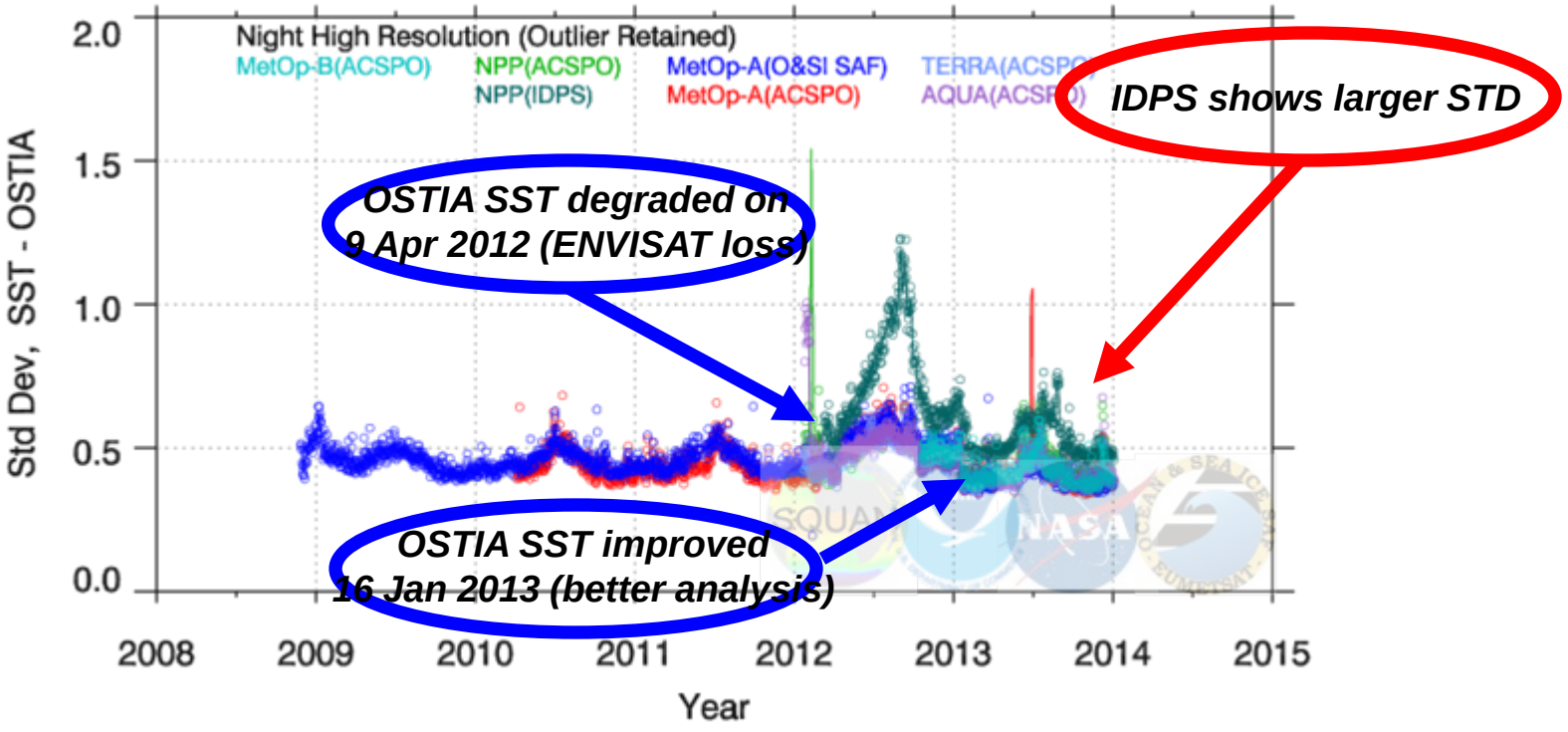
- Daily val against in situ SST is noisy due to small match-up sample & lack of global coverage
- IDPS SST has been out of family earlier in the mission, but improved in 2013

NIGHT STD DEV wrt. Reynolds L4



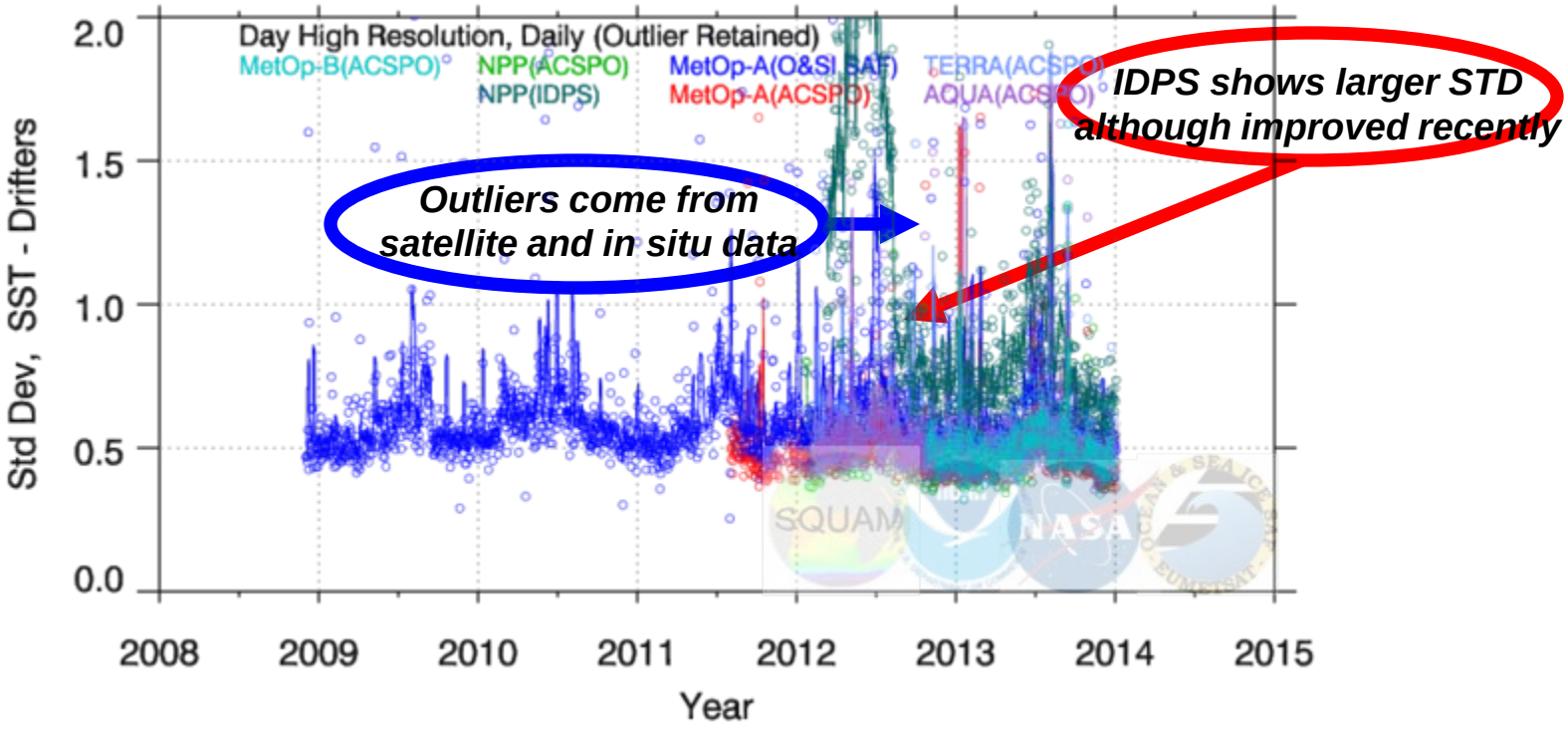
- Comparisons with global L4s are “crispy” but subject to L4 artifacts - E.g., Reynolds L4 degraded on 4 June 2013, resulting in increased STD for all products
- IDPS SST has been out of family but improved in 2013, now on the upper envelope of “family”

NIGHT STD DEV wrt. OSTIA L4



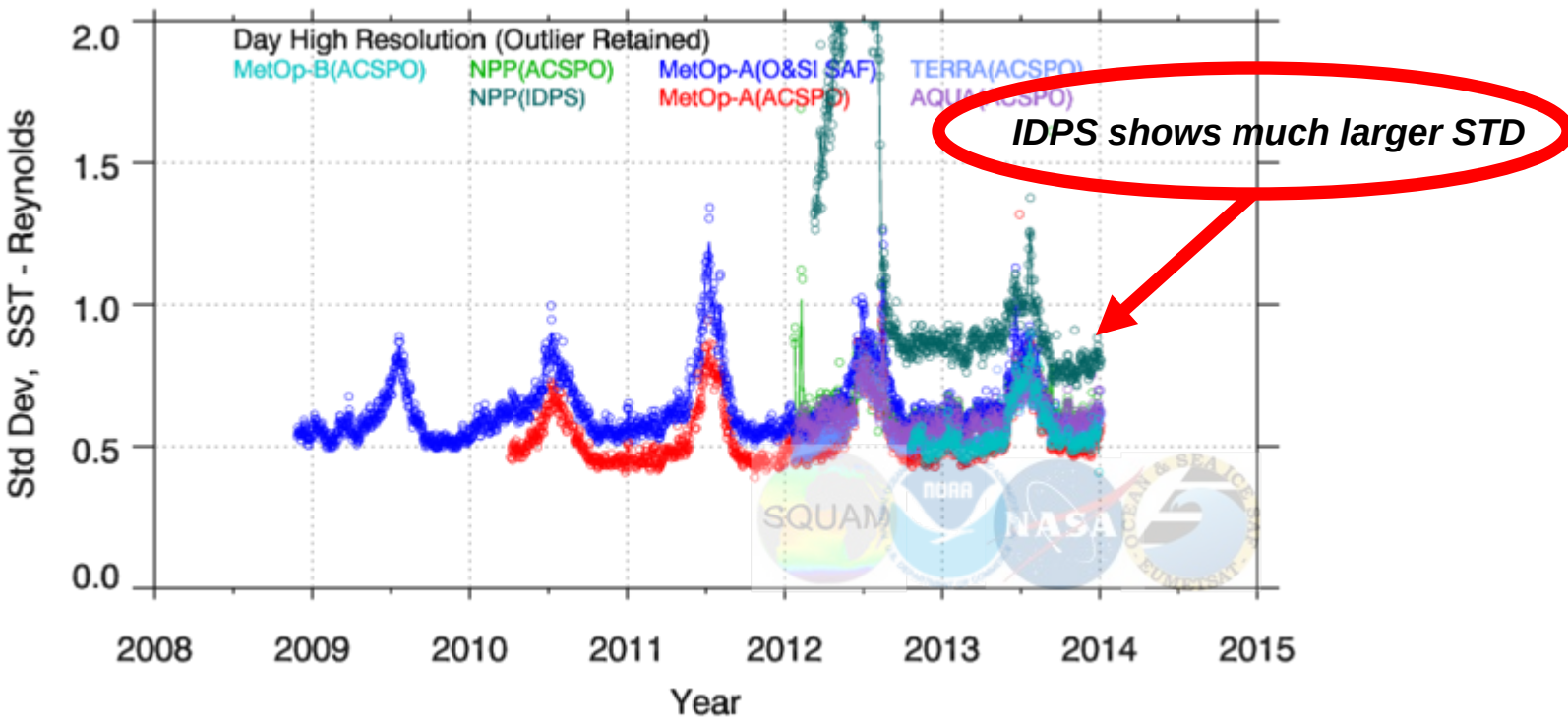
- OSTIA more accurate than Reynolds SST – STDs consistently smaller, for all satellite products
- OSTIA degraded on 9 Apr 2012 (loss of AATSR on ENVISAT, used to anchor OSTIA SST) and improved on 16 Jan 2013 (due to improvements in analysis)
- IDPS SST has been out of family but improved in 2013, now on the upper envelope of “family”

DAY STD DEV wrt. In situ SST



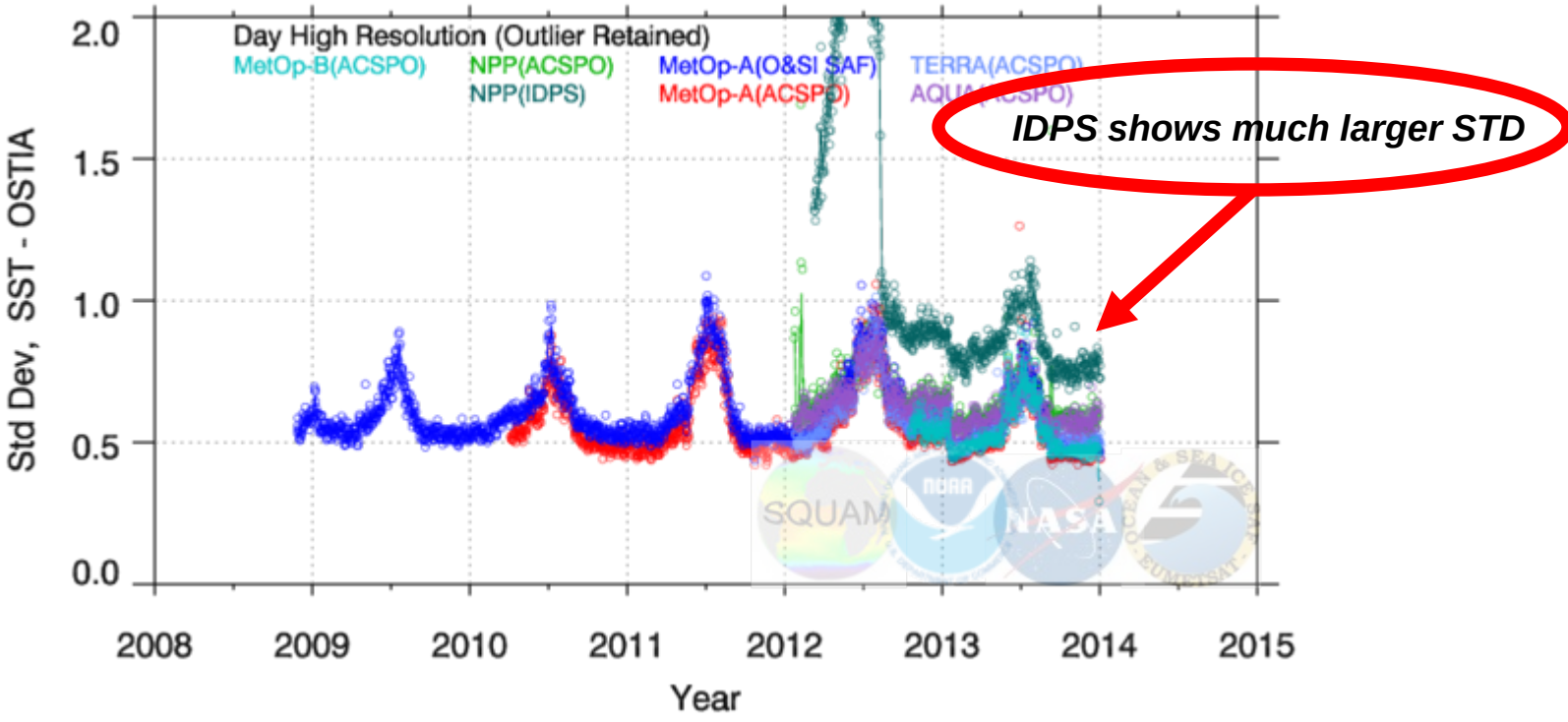
- Daily val against in situ SST is noisy due to small match-up sample & lack of global coverage
- IDPS SST improved recently but has been out of family for the full 2 years of monitoring

DAY STD DEV wrt. Reynolds L4



- IDPS SST has been out of family but improved in mid 2012. Still significantly deviates from family, but less than earlier in the mission

DAY STD DEV wrt. OSTIA L4



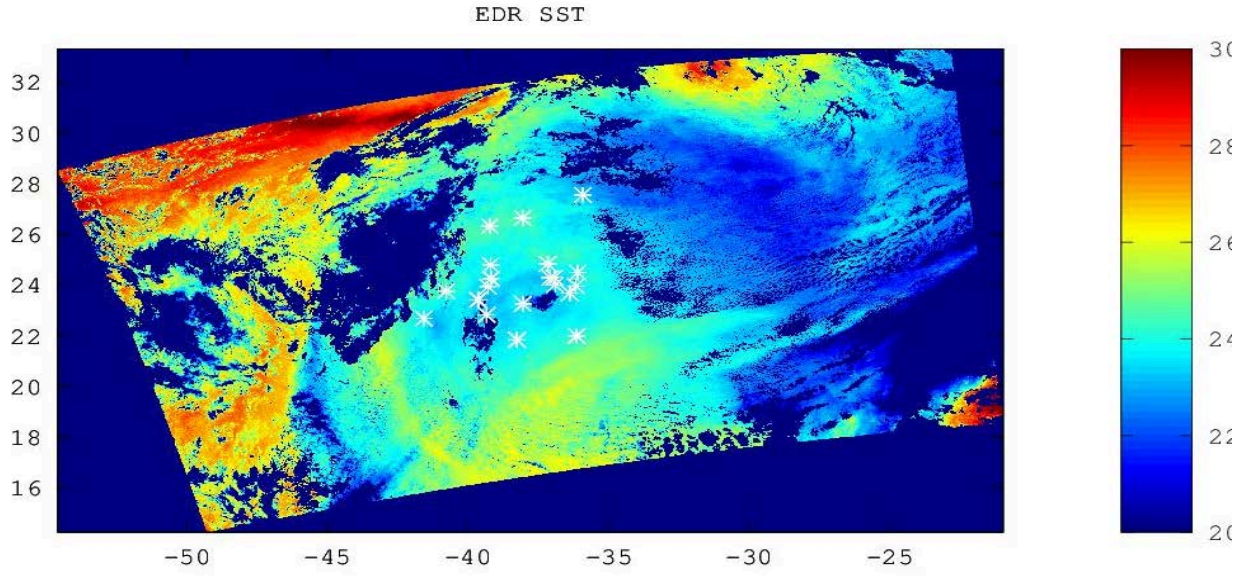
- Comparison with OSTIA SST suggest the same qualitative observations as against Reynolds and in situ, although quantitatively, comparison statistics may differ

NAVO/USM summary

- Best quality (very restricted) domain IDPS EDR SST Falls within specs with RMS errors lower than 0.45°C for daytime and 0.29°C at night.
- Best quality domain can increase with implementation of EUMETSAT OSI/SAF SST equations scheduled for build 8.1.
- Some cloud leakage, aerosol contamination can be significant. Standard SST “cloud detection” usually flags aerosol contamination.

Example of aerosol contamination

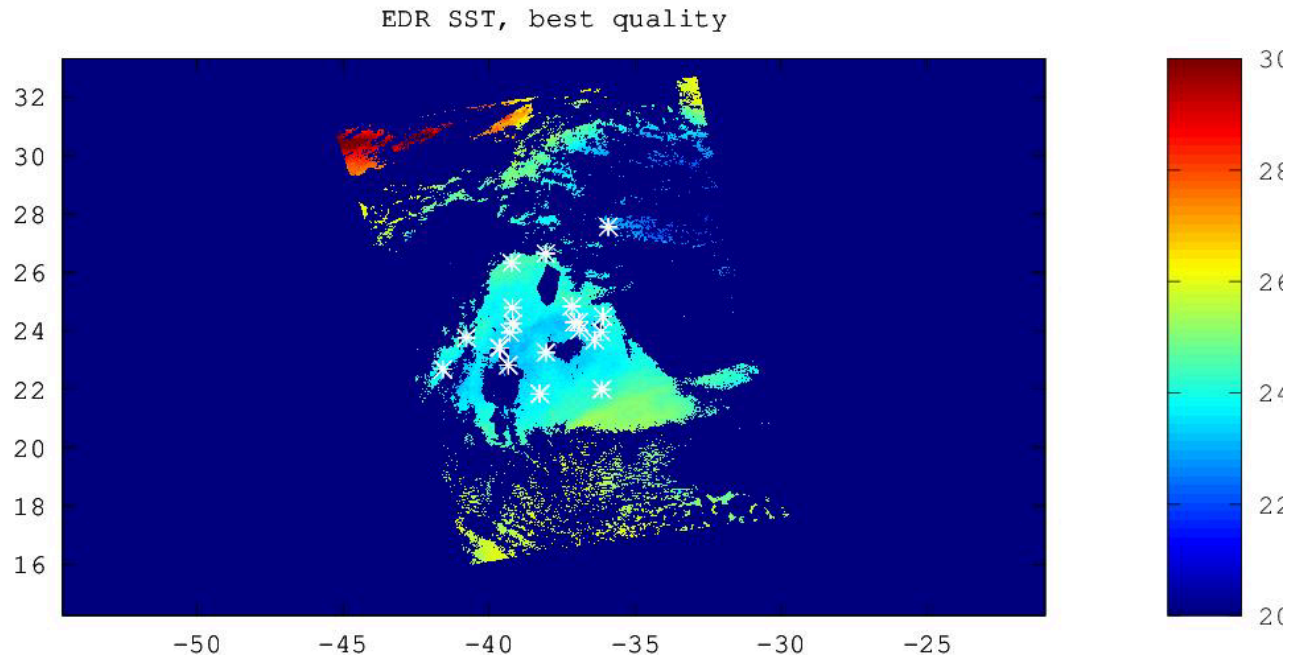
North Atlantic West of Africa



IDPS EDR SST (all categories) 52W to 32W and 20N to 30N on September 4 between 15:35-15:40. Buoys (white crosses) show an average negative SST bias of 2.4^{0}C.

Example of aerosol contamination

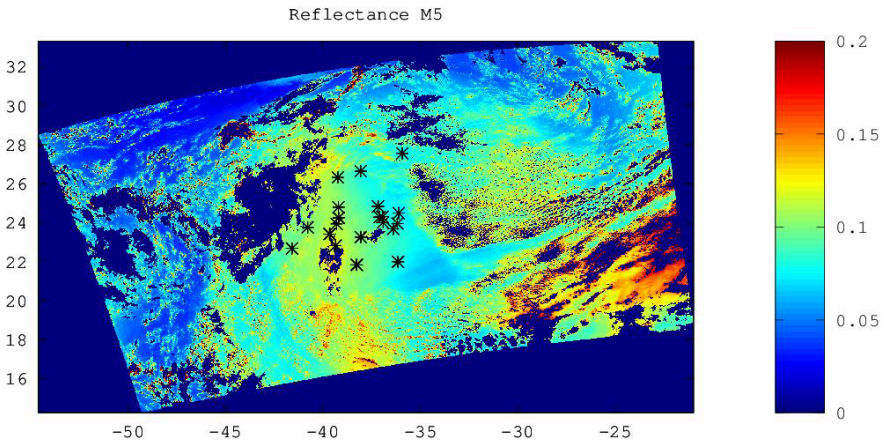
North Atlantic West of Africa

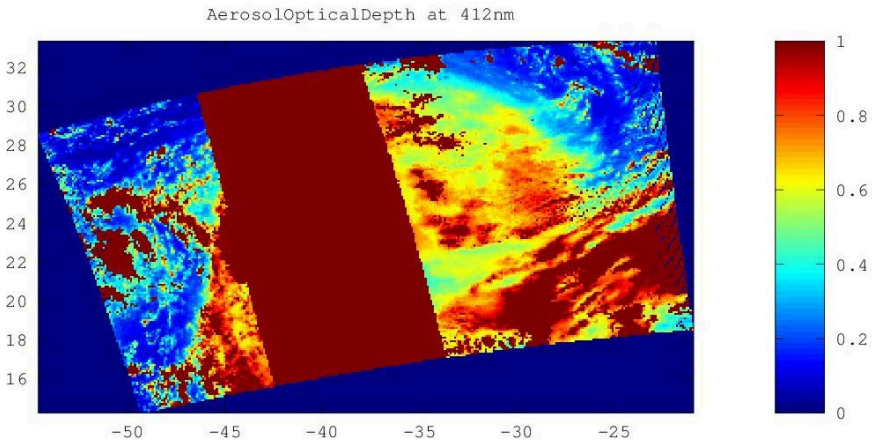


IDPS EDR SST (best category only). Buoys (white crosses) show an average negative SST bias of 2.4^{0}C.

Example of aerosol contamination

North Atlantic West of Africa





M5 reflectance shows potential contamination.

AOD field (Aerosol EDR) is missing data in ROI but surrounding areas show potential aerosol contamination

Recommend IDPS SST for Provisional

- SST Data record is available in CLASS from 22 Jan 2012 – onward
- IDPS SST has been extensively validated for the complete period of availability
- Accuracy and precision of the products has been non-uniform
- Nighttime IDPS SST EDR has been close to meeting L1RD requirements from ~Feb 2013 onward, although still remains slightly inferior to the community products – ACSPO and OSI SAF
- Daytime IDPS SST EDR remains suboptimal. More work is needed to bring it back in community family, and meet L1RD specs

Remaining Work Towards Validated

1. Fix VCM leakages within SST EDR (especially, daytime)

- ✓ Bring in IDPS higher quality first guess SST (Reynolds)
- ✓ Redesign EDR QFs to compensate for VCM leakages. This will require porting parts of ACSPO cloud masking code, into IDPS
- ✓ NAVO to look into minimizing aerosol contamination in IDPS SST

2. Continue monitoring VIIRS SST Radiances

- ✓ Monitoring of IR Clear-sky Radiances over Oceans for SST (MICROS; www.star.nesdis.noaa.gov/sod/sst/micros/)

3. Continue monitoring VIIRS SSTs

- ✓ SST Quality Monitor (SQUAM; www.star.nesdis.noaa.gov/sod/sst/squam/)

4. Design IDPS reprocessing capability to generate a uniform EDR. The current EDR is very non-uniform. Nighttime data before Feb 2013, and daytime data until present, remain suboptimal

Users' Readiness

Stakeholders, User Community, NOAA Mission

- **Stakeholders**
  - NWS (NCEP, CPC, OPC, JCSDA)
  - NESDIS (Coast Watch, Coral Reef Watch, NCDC, NODC, OSPO)
  - NMFS/NOS/OAR (Coast Watch)
  - DOD/Navy
- **User's Community**
  - Climate
  - Weather
  - Oceanography
  - Operational Ocean Forecasting
  - Fisheries and Shipping
  - Academia
- **NOAA Mission Goals supported**
  - Weather and Water
  - Climate
  - Ecosystem

NOAA VIIRS SST Users

- NCEP – Bob Grumbine, Avichal Mehra
- POES/GOES Blended – Eileen Maturi
- Coral Reef Watch – Mark Eakin
- OPC/CPC – Joe Sienkiewicz
- NOS/NESDIS – Chris Brown
- Coast Watch – Kent Hughes
- NCDC – Viva Banzon
- NODC – Ken Casey, Deirdre Byrne
- NMFS – Cara Wilson
- NCDC – CLASS

External VIIRS SST Users

- EUMETSAT – Simon Elliott
- UK Met Office – Matt Martin
- Canadian Met Centre – Bruce Brasnett
- Japanese Met Agency – S. Ishizaki, D. Ichikawa
- PO DAAC – Ed Armstrong

Users Product Preferences

NOAA Users

- No NOAA users expressed interest in IDPS SST product
- All listed expressed interest in ACSPO SST
- Operational NDE ACSPO Production will commence in Jan 2014
- Formats are either BUFR (NCEP) or netcdf4

External Users

- EUMETSAT, UKMO, CMC interested in NDE ACSPO SST
- JMA did not specify their preference

Current status

- NOAA JPSS SST Team works with NOAA and external users, to finalize distribution mechanisms and preferred data formats

Back Up Slides

SST (Skin) Requirements (new L1RD)

EDR Attribute	Threshold	Objective
a. Horizontal Cell Size (Res)	1.6km[1]	0.25km
b. Mapping Uncertainty, 3σ	2km[1]	0.1km
c. Measurement Range	271 K to 313 K	271 K to 318 K
d. Measurement Accuracy[2]	0.2K	0.05K
e. Measurement Precision[2]	0.6K	0.2K (<55° VZA)
f. Refresh Rate	12 hrs	3 hrs
g. Latency	90 min	15 min
h. Geographic coverage	Global cloud and ice-free ocean; excluding lakes and rivers	Global cloud and ice-free ocean, plus large lakes and wide rivers

[1]Worst case scenarios corresponding to swath edge; both numbers are ~1km at nadir

[2]Represent global mean bias and standard deviation validation statistics against quality-controlled drifting buoys (for day and night, and in full VIIRS swath and range of atmospheric conditions). Uncertainty is defined as square root of accuracy squared plus precision squared. Better performance is expected against ship radiometers.

IDPS vs. ACSPO Summary

Both are derived from Geo & SDRs in M12, M15, M16

- ✓ IDPS has no heritage; ACSPO is NOAA heritage system

Both retrieve skin SST using regression algorithms

- ✓ New L1RD calls for one SST – skin (bulk=skin+0.17K)
- ✓ Both use OSI SAF formulations

Cloud Mask (CM)

- ✓ IDPS: “one-size-fits-all” VCM; ACSPO: CM optimized for SST

Ice Mask (IM)

- ✓ IDPS: VIIRS-based; ACSPO – additionally uses external IM

Quality Flags

- ✓ ACSPO sets no QFs other than CM; IDPS QFs are suboptimal, and being redesigned to minimize VCM leakages