Request for SST Beta Maturity

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U. Miami - Peter Minnett, Bob Evans, Kay Kilpatrick; NAVO - Doug May, Jean-Francois Cayula; NRL/USM - Bob Arnone, Walt McBride; EUMETSAT/Meteo France - Pierre Le Borgne, Herve Roquet

NGAS - Sid Jackson; Raytheon - Bill Johnsen, Marian Hollingshead

Tracking

DR # 7050

CCR # 474-CCR-13-0871

DRAT discussion: Feb 27, 2013

AERB presentation: Feb 27, 2013

Acknowledgements

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- NPP Project Scientist – Jim Gleason
- JPSS DPA – Heather Kilcoyne, Janna Feeley, Bonnie Reed, Bruce Gunther, and others
- VIIRS Sensor Data Records (SDR; L1b) Team – Changyong Cao, Frank DeLuccia, Mark Liu, and others
- VIIRS VCM Team – Andy Heidinger, Tom Kopp, Denis Botambekov
- NESDIS/STAR JPSS Team – Ivan Csiszar, Laurie Rokke, Lihang Zhou, and many others

Outline

- **SST Stakeholders, Community, NOAA Mission, Users**
- **Beta Maturity Definition**
- **SST EDR Summary**
  - Inputs (SDRs & VCM), Algorithms & Product
- **SST Requirements & DRs**
- **SST EDR Evaluation**
  - VIIRS SST Imagery relative to MODIS
  - VIIRS Radiances (SDR): Stability/Consistency w/AVHRR/MODIS
  - EDR SST (VCM): Consistency w/ACSPO VIIRS/AVHRR/MODIS
- **Summary and Recommendation**
  - VIIRS Radiances are adequate for SST
  - Work underway with VCM Team to improve performance for SST
- **Remaining Tasks Towards Provisional**

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

VIIRS SST Users

- NCEP – Bob Grumbine, Avichal Mehra
- OPC, CPC – Joe Sienkiewicz
- NESDIS STAR Coast Watch – K. Hughes, Coral Reef Watch – M. Eakin, OSD NDE – T. Schott, OSPO – J. Sapper, NODC – K. Casey, NCDC – D. Reynolds/V. Banzon
- US Navy/FNMOC – Jim Cummings
- EUMETSAT – Simon Elliott
- Meteo France – Pierre Le Borgne, Herve Roquet
- Group for High Resolution SST – Peter Minnett
- UK Met Office – Matt Martin
- Japanese Met Agency – S. Ishizaki, D. Ichikawa
- Canadian Met Centre – Bruce Brasnett
- Bureau of Meteorology, Australia – Helen Beggs
- Sea and Atmosphere Inst., Lisboa, Portugal – A. Arriaga

Beta Maturity Definition

- Early release product
- Minimally validated
- May still contain significant errors
- Versioning not established until a baseline is determined
- Available to allow users to gain familiarity with data formats and parameters
- Product is not appropriate as the basis for quantitative scientific publication studies and applications

SST EDR Summary

Derived from SDRs in bands M12, M15, M16, and Geo

- ✓ Critically sensitive to accuracy and precision of SDRs
- ✓ Work closely with SDR Team to ensure adequate input

Relies on external VIIRS Cloud Mask (VCM) and ice mask

- ✓ Critically sensitive to accuracy and precision of VCM
- ✓ Work closely with VCM Team to ensure adequate cloud/ice masks

Retrieves 2 SSTs (skin, bulk) using regression algorithms

- ✓ New L1RD calls for one SST – skin; bulk is skin +0.17K
- ✓ IDPS regression formulations suboptimal, working to revisit

SST EDR defines internal SST Quality Flags

- ✓ Current QFs found suboptimal/overly restrictive, working to revisit

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.

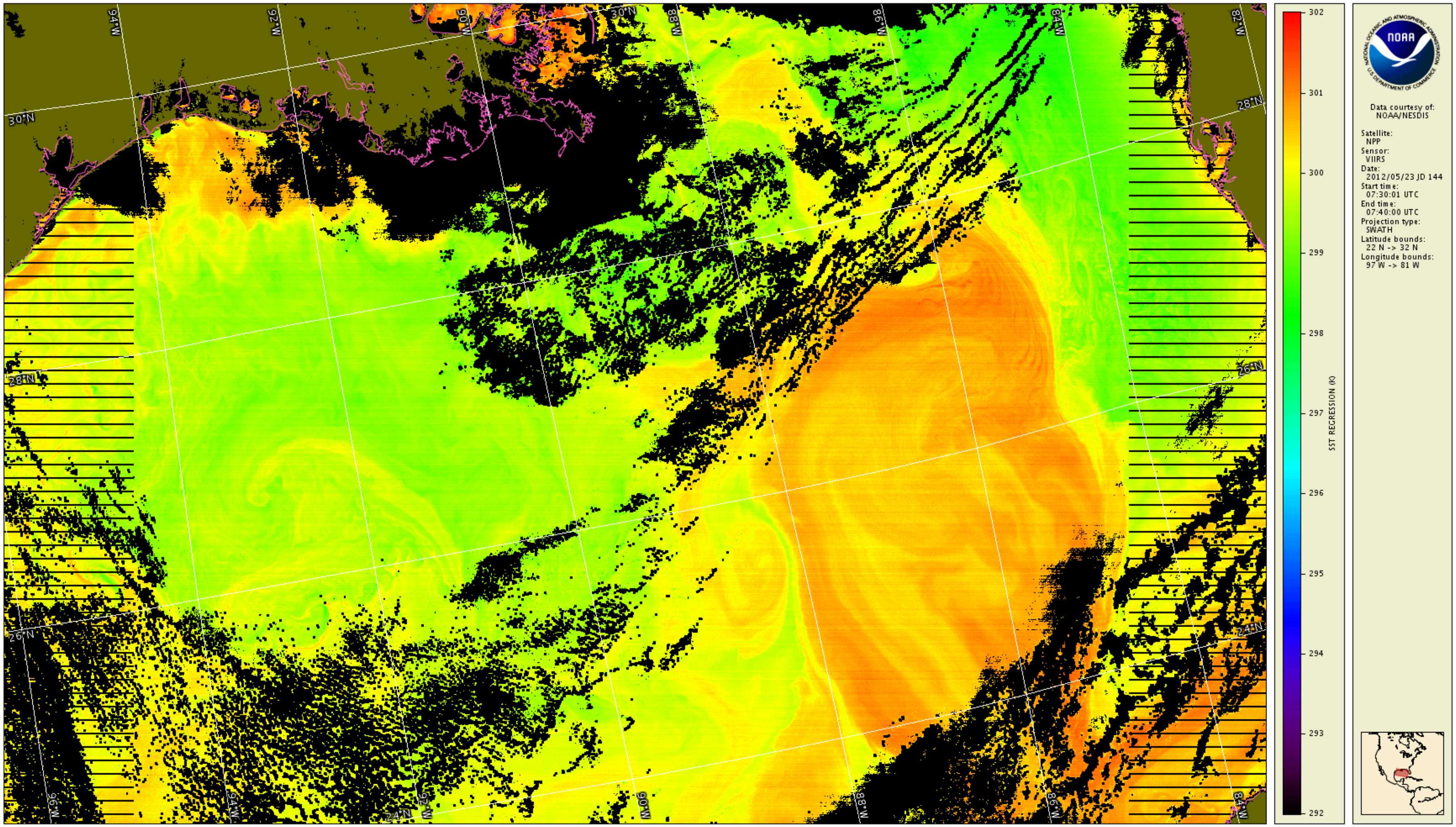
SST DRs

DR number	Short Description
4696	Fast-track SST EDR Tables
4727	Update FT VIIRS SST regression coefficients table
4748	algorithm needs to check cloud mask quality
4789	Remove/replace bulk SST data
4790	SST QFs code reorganization
4807	Change forms of SST equations
4844	SZA exclusion and SZA degradation flags affected by setting of cloudy/clear flags
4845	OAD for SST does not agree with code in PCR31250
4846	CDFCB vol IV part 3 SZA quality flag definition
4925	Unsatisfactory VCM Performance for SST
4947	SST to discontinue use of several ASFs
4948	Add VCM snow/ice flag to SST EDR
4965	1st Guess Skin Temp Change to SST product

Gulf of Mexico
23 May 2012 – Night

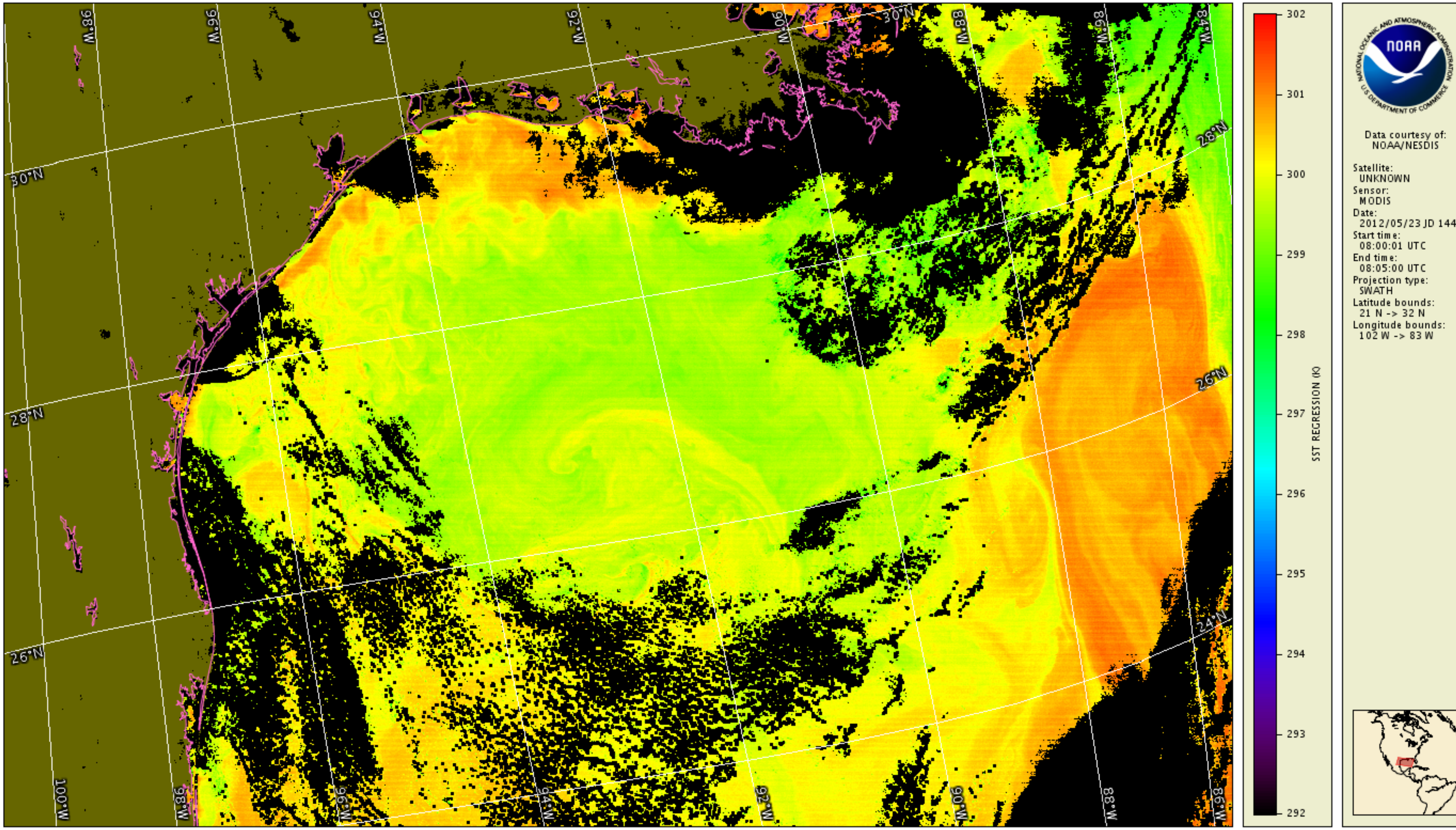
NPP/VIIRS ACSPO SST 23 May 2012
0730-0740 UTC – Night – Swath Projection

ACSPO_V2.10_NPP_VIIRS_2012-05-23_0730-0740_20120526.053954.hdf



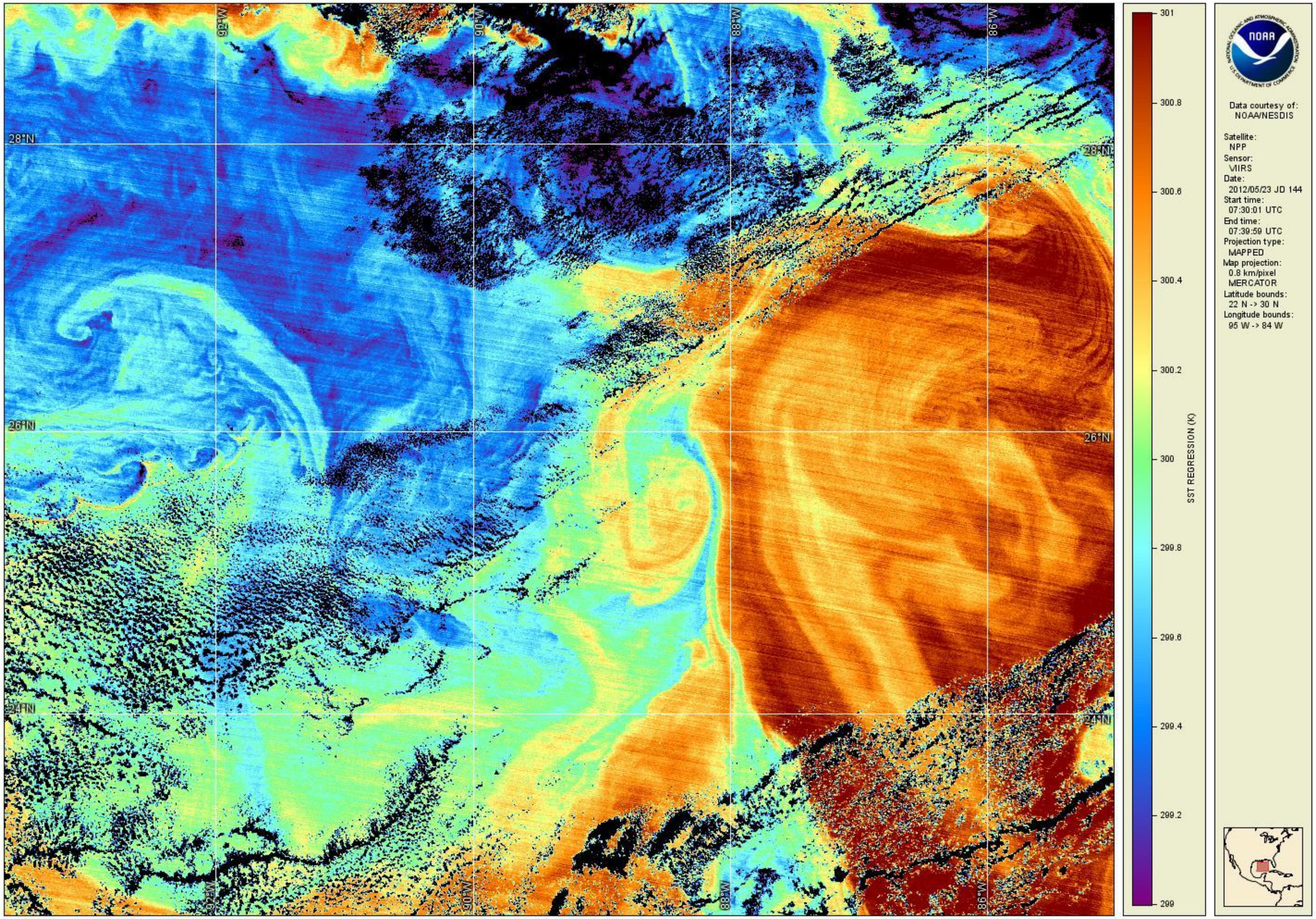
Aqua/MODIS ACSPO SST 23 May 2012 0800-0805 UTC – Night – Swath Projection

ACSPO_V2.10_AQUA_MODIS_2012-05-23_0800-0805_20120527.093405.hdf



NPP/VIIRS ACSPO SST 23 May 2012
0730-0740 UTC – Night – Mapped onto 0.8km grid

ACSPO_V2.10_NPP_VIIRS_2012-05-23_0730-0740_20120526.053954.hdf



Aqua/MODIS ACSPO SST 23 May 2012
0800-0805 UTC – Night – Mapped onto 0.8km grid

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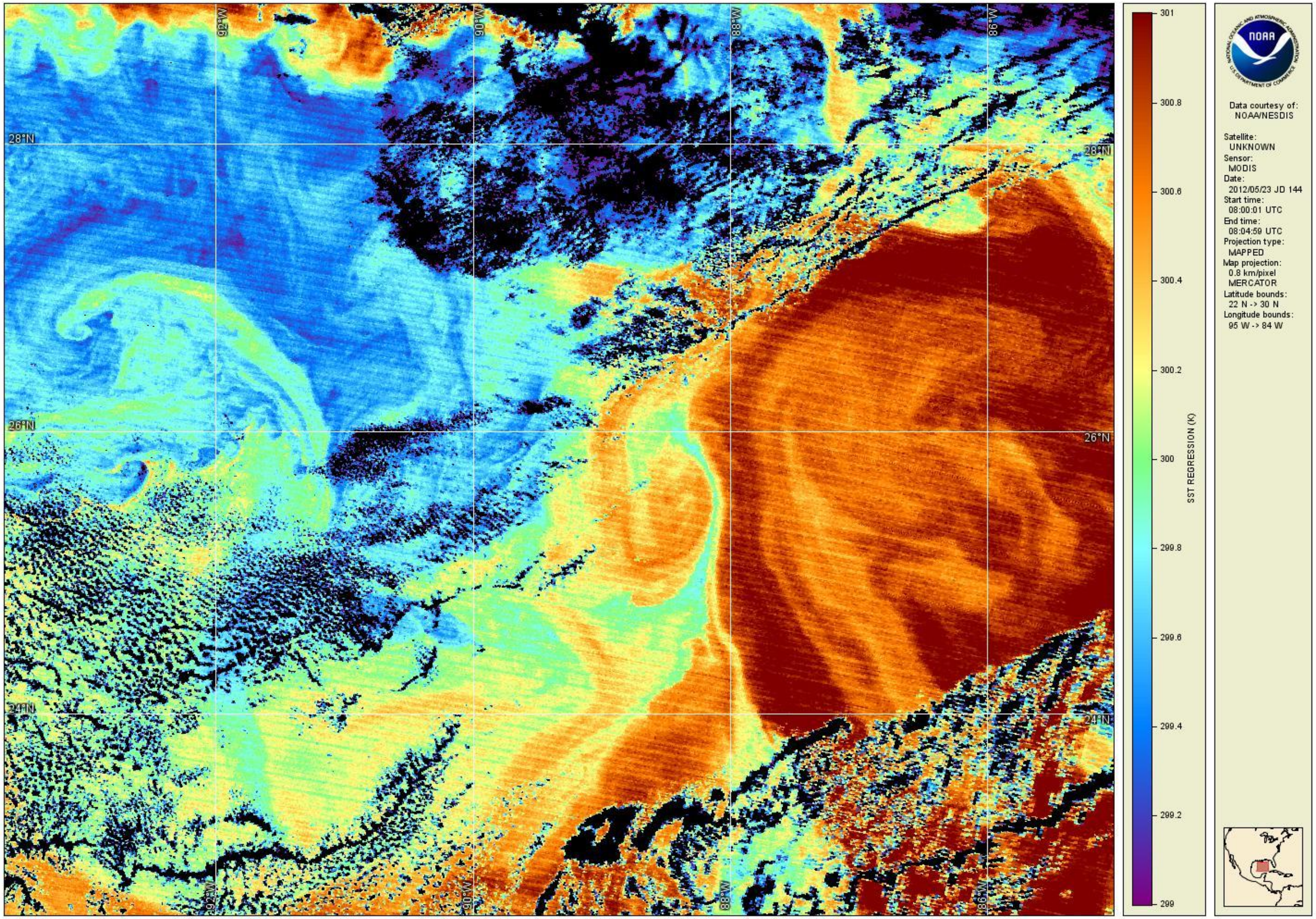
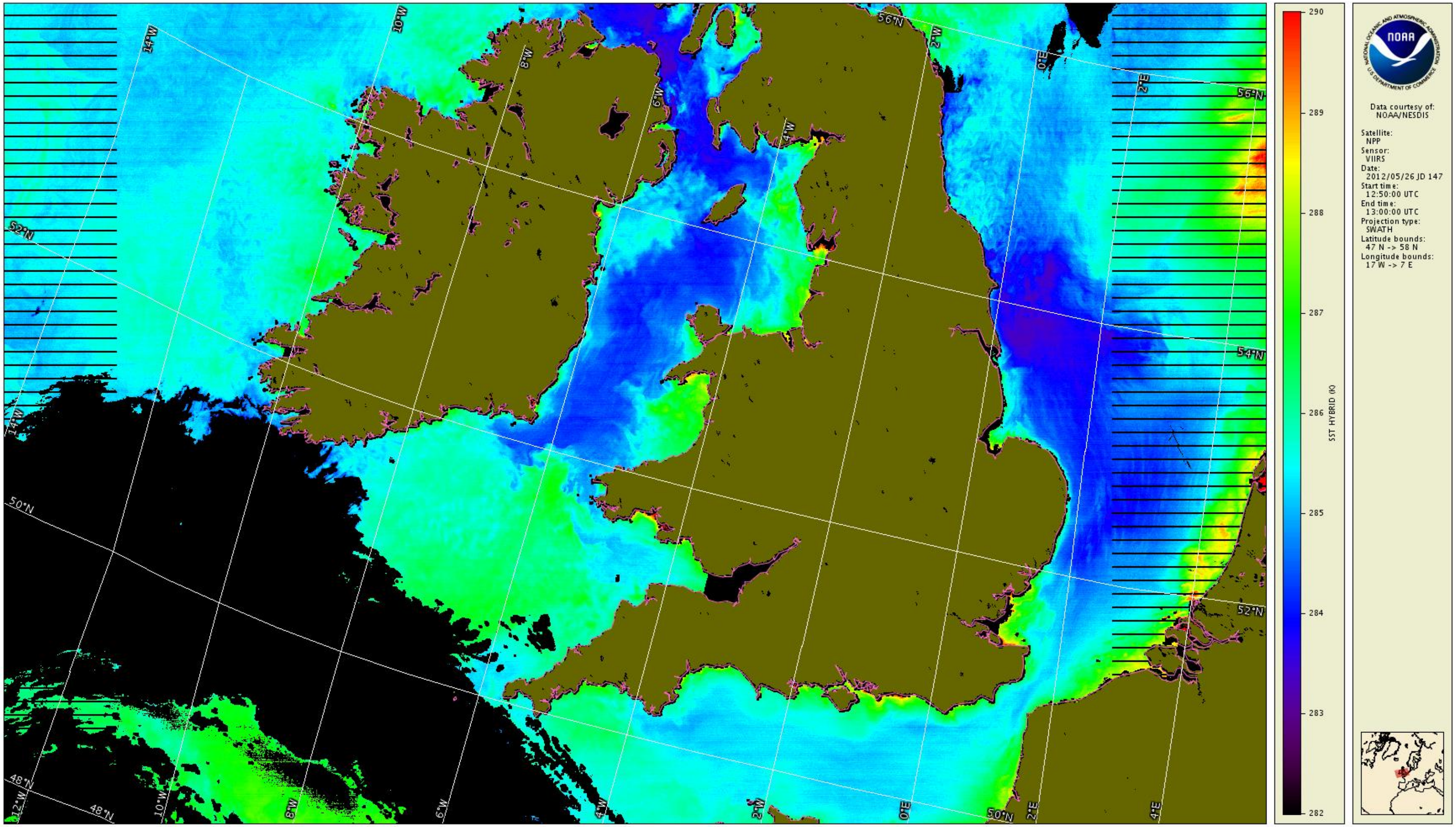


Examples ACSPO VIIRS and MODIS SST Imagery

Great Britain and Ireland
26 May 2012 – Day

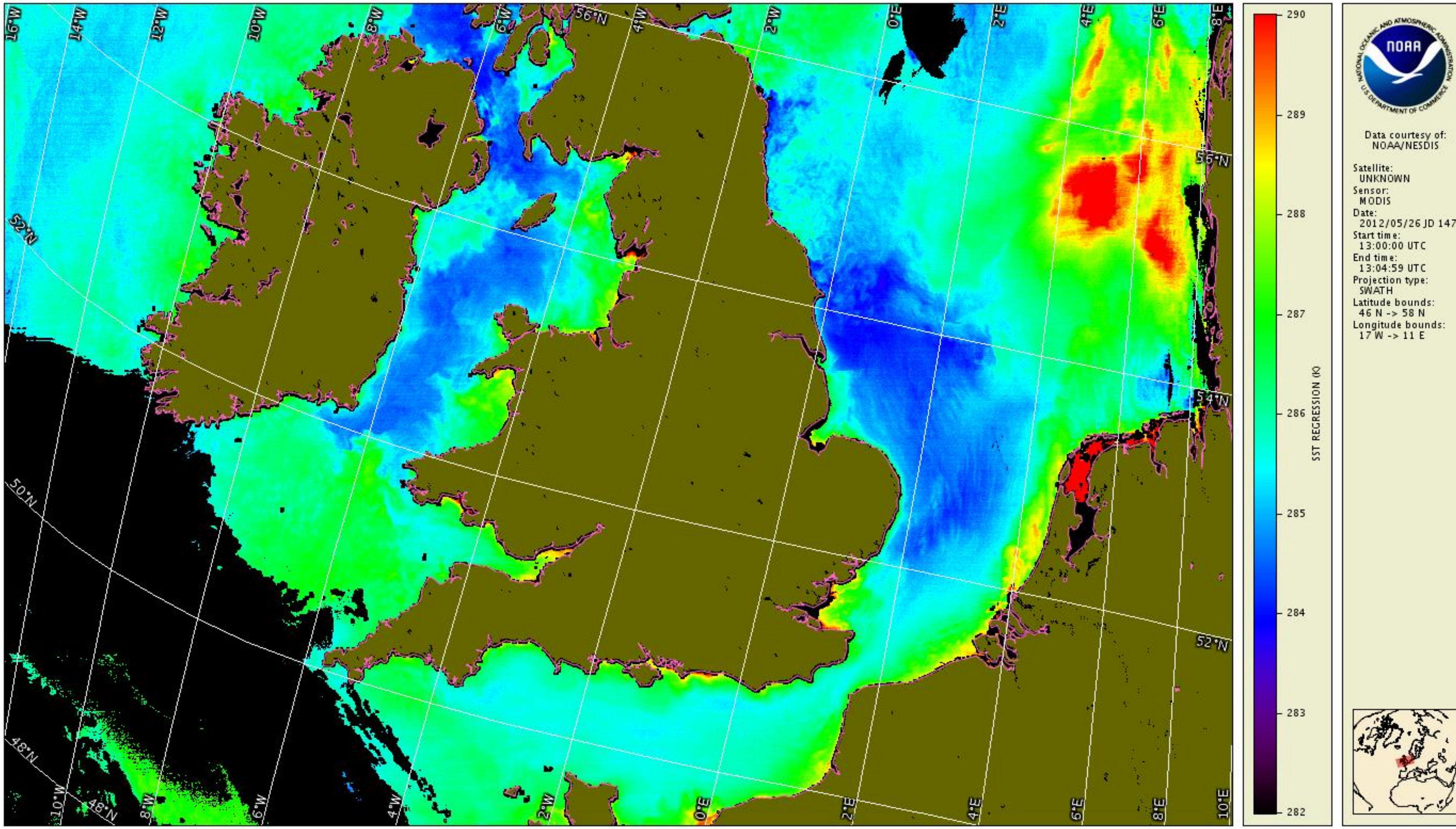
NPP/VIIRS ACSPO SST 26 May 2012 1250-1300 UTC – Day – Swath Projection

ACSPO_V2.10_NPP_VIIRS_2012-05-26_1250-1300_20120529.075657.hdf



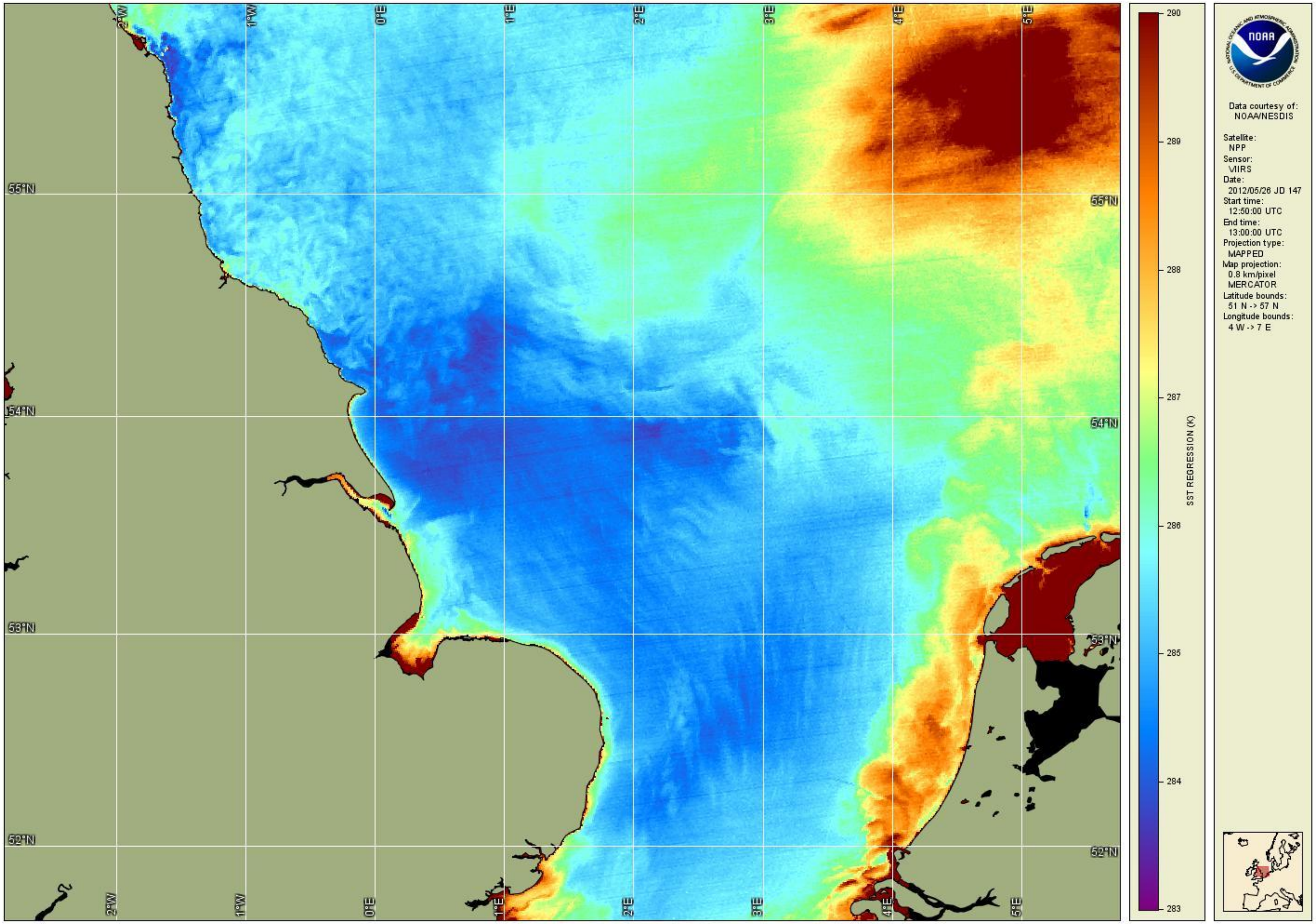
Aqua/MODIS ACSPO SST 26 May 2012 1300-1305 UTC – Day – Swath Projection

ACSPO_V2.10_AQUA_MODIS_2012-05-26_1300-1304_20120527.215350.hdf



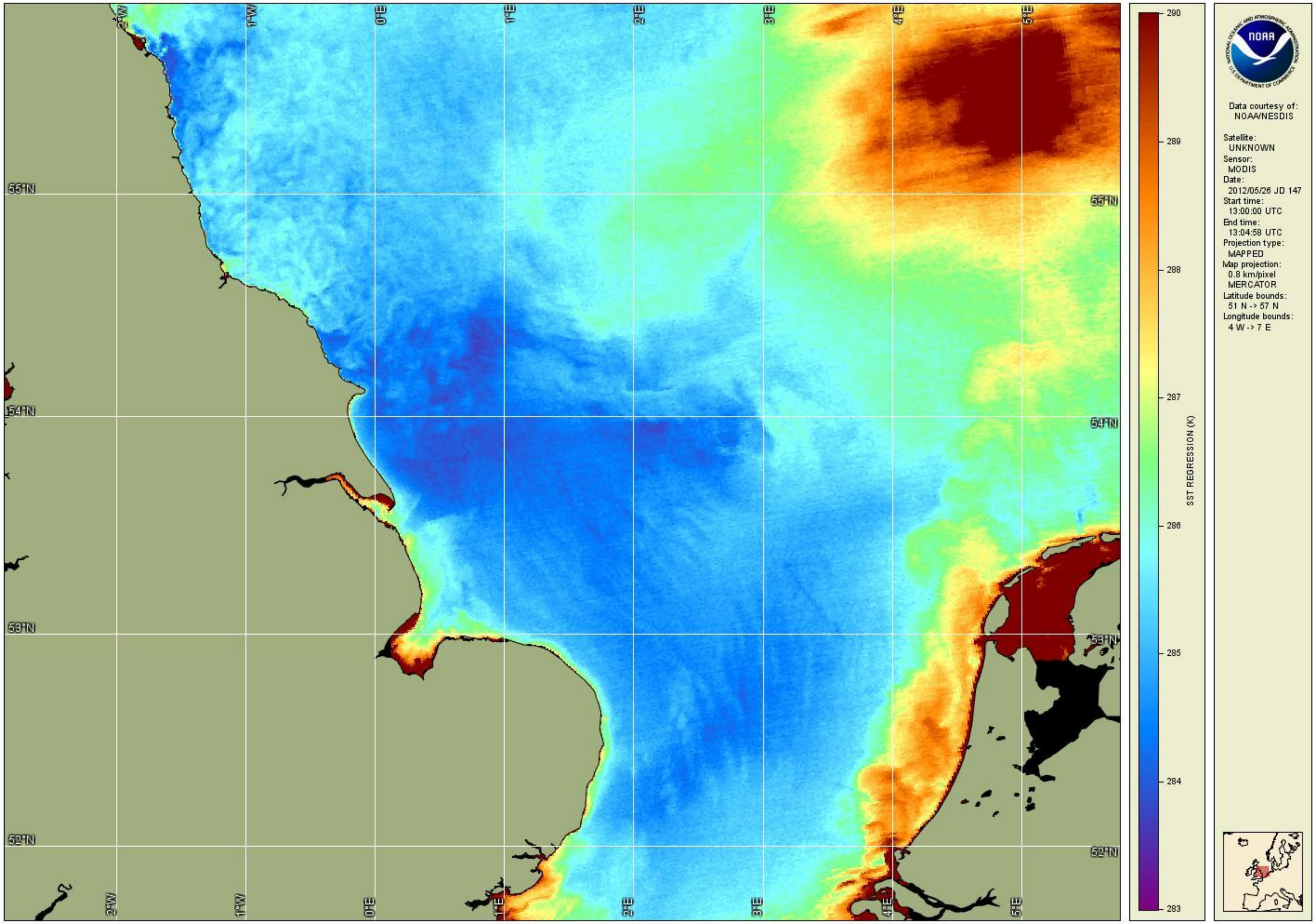
NPP/VIIRS ACSPO SST 26 May 2012
1250-1300 UTC – Day – Mapped onto 0.8km grid

ACSPO_V2.10_NPP_VIIRS_2012-05-26_1250-1300_20120529.075657.hdf

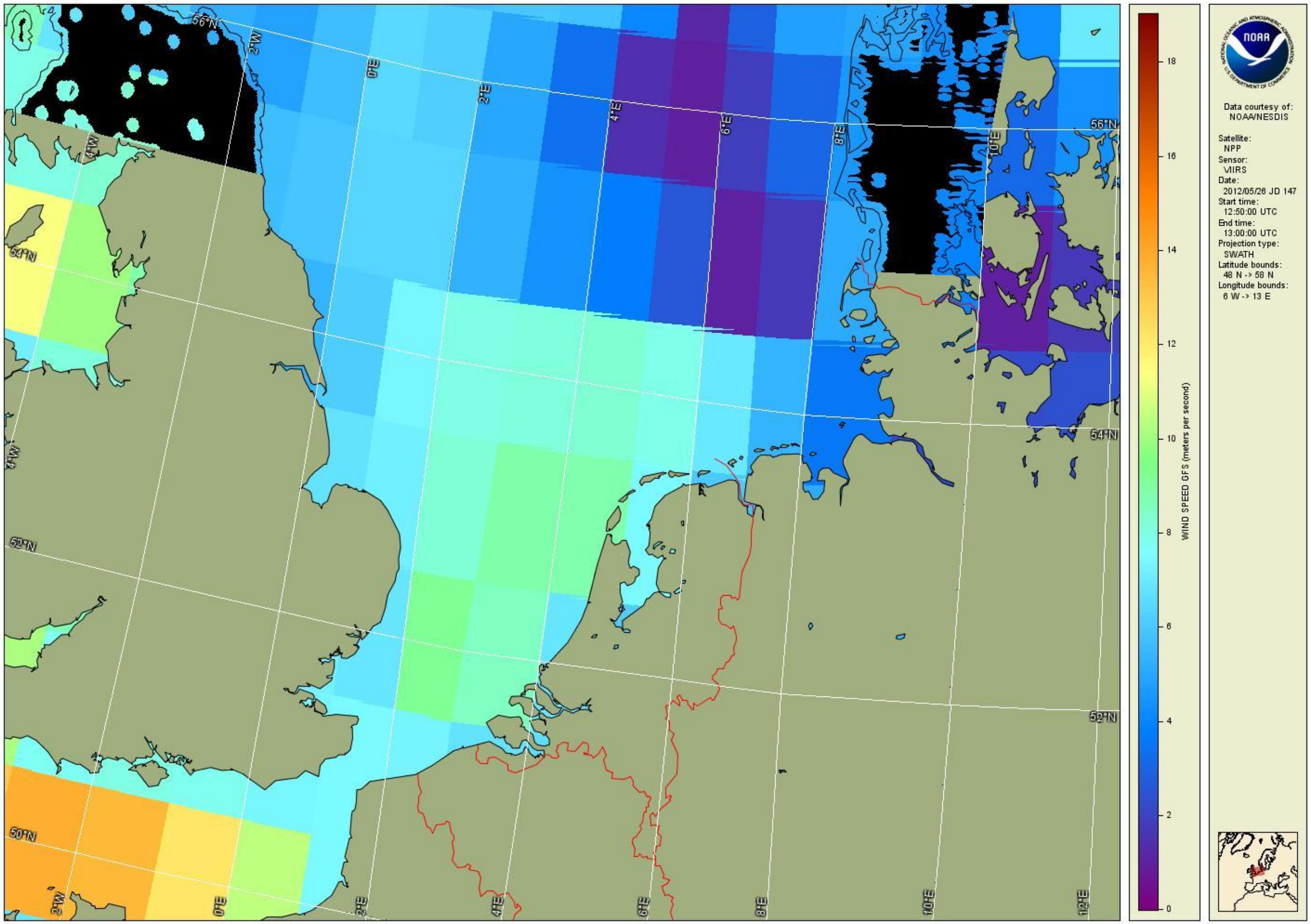


Aqua/MODIS ACSPO SST 26 May 2012
1300-1305 UTC – Day – Mapped onto 0.8km grid

ACSPO_V2.10_AQUA_MODIS_2012-05-26_1300-1304_20120527.215350.hdf



Wind Speed
26 May 2012 – Day – 1° gridded NCEP GFS



VIIRS, MODIS, and AVHRR Radiance Monitoring in MICROS

www.star.nesdis.noaa.gov/sod/sst/micros/

M-O Biases and Double Differences (“DD”)

Model minus Observation (“M-O”) Biases

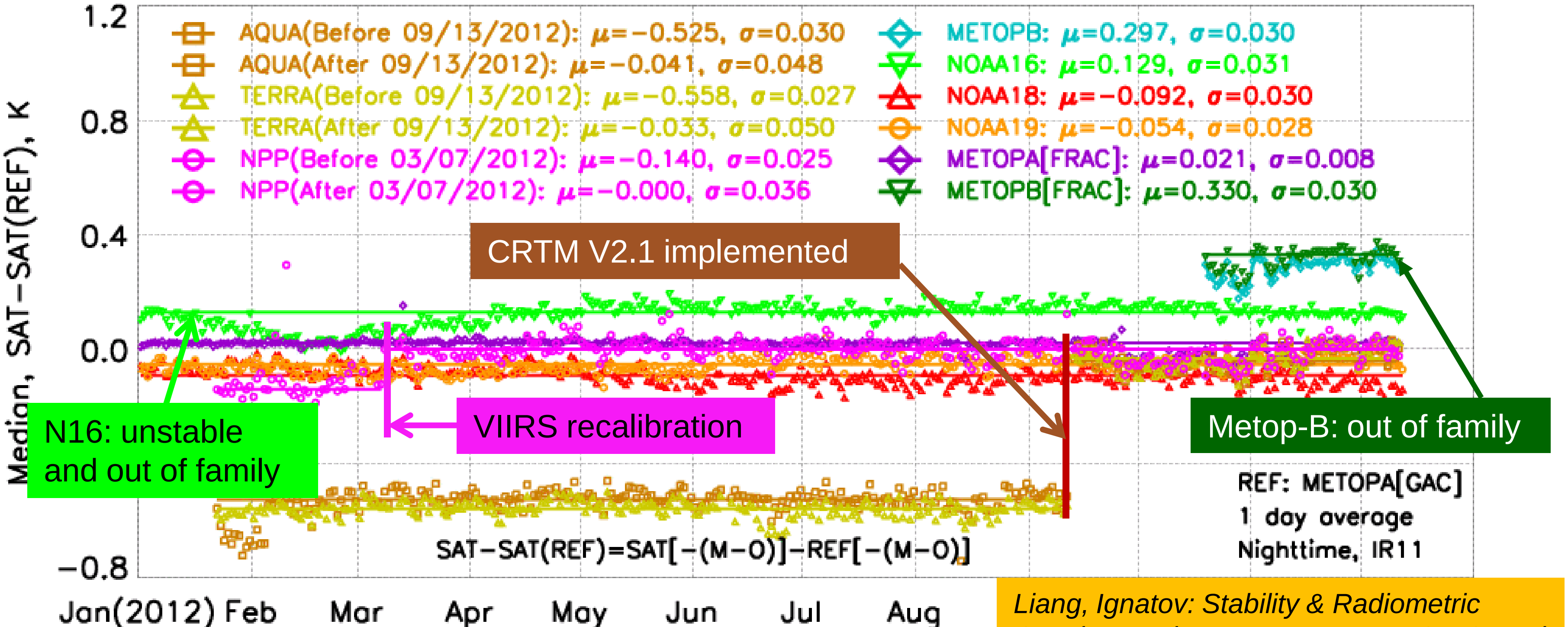
- **M (Model)** = Community Radiative Transfer Model (CRTM) simulated TOA Brightness Temperatures (w/ Reynolds SST, GFS profiles as input)
- **O (Observation)** = Clear-Sky sensor (AVHRR, MODIS, VIIRS) BTs

Double Differences (“DD”) for Cross-Platform Consistency

$$SAT - REF = SAT[-(M - O)] - REF[-(M - O)]$$

- “M” used as a “Transfer Standard”
- DDs cancel out/minimize effect of systematic errors & instabilities in BTs arising from e.g.
    - Errors/Instabilities in Reynolds SST & GFS
    - Missing aerosol
    - Possible systemic biases in CRTM
    - Updates to ACSPO algorithm

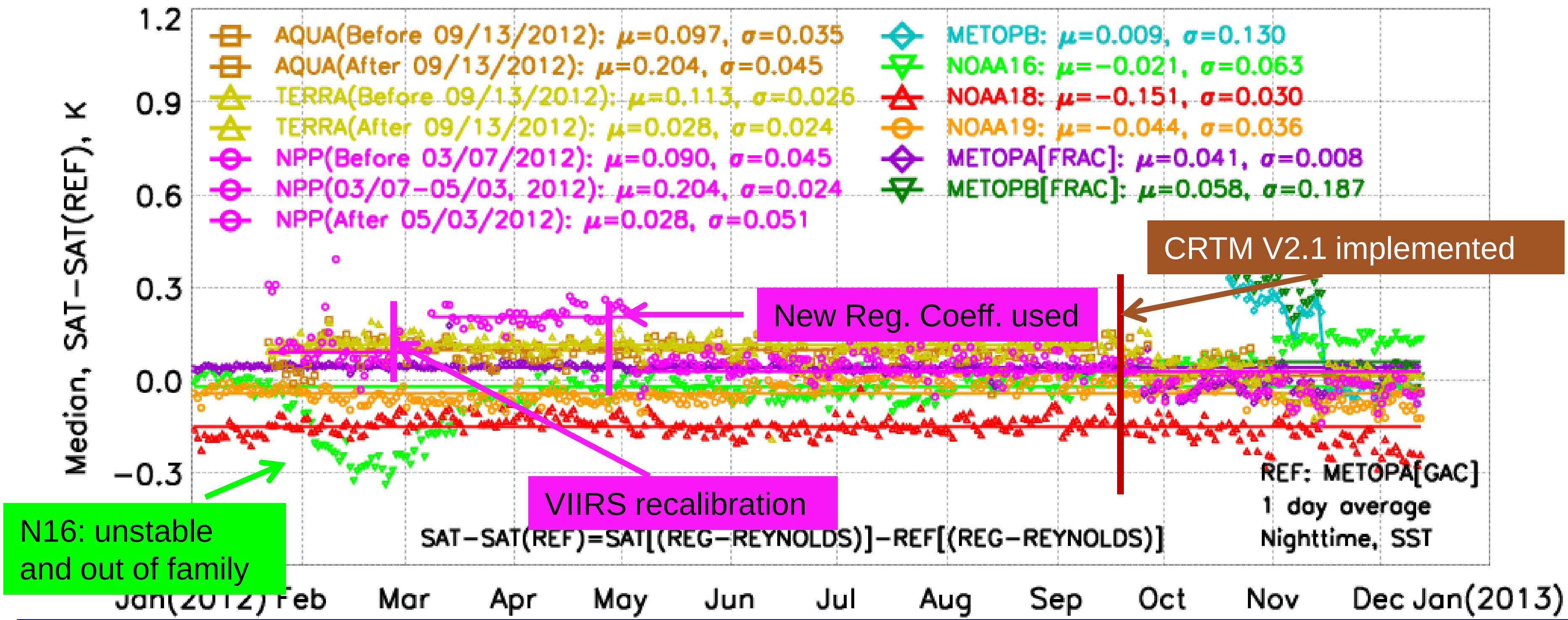
Double Differences in IR11 (VIIRS M15)



Liang, Ignatov: Stability & Radiometric Consistency between AVHRR, MODIS, and VIIRS in SST bands. JGR, 2013, submitted

- **All AVHRRs and NPP/VIIRS are consistent to within ±0.1K**
- **VIIRS Cal change 7 Mar 2012 reset BT@M15 by +0.14K – now better in family**
- **Terra and Aqua/MODIS out of family by 0.6K – due to suboptimal CRTM coefficients in V2.02**
- **Both were back in family after CRTM V2.1 implemented on Sep. 13, 2012**
- **Metop-B is inconsistent with Metop-A by ~0.3 K, due to suboptimal CRTM coefficients used in CRTM V2.1**

Double Differences in SST



- **All AVHRRs, MODISs and NPP/VIIRS SSTs are consistent to within ±0.1K**
- **VIIRS Cal Change 7 Mar 2012: SST +0.10K – Out of family**
- **New SST coefficients implemented 3 May 2012: SST -0.15K – Back in family**
- **CRTM update resulted regression SSTs more noise, and the new coefficients have been implemented since Dec. 2012. More data is needed to understand their performance**

Summary to Imagery and Radiance Analyses

VIIRS SST Imagery

- ✓ Is of comparable quality to Aqua MODIS or exceeds
- ✓ Crisp, and nicely resolves fine surface structure
- ✓ Striping is comparable to Aqua MODIS or exceeds

VIIRS is a good instrument for SST

- ✓ MICROS captured the 0.14K increase in BTs on 7 Mar 2012
- ✓ MICROS also captured the WUCD event (~7K) in Feb 2012
- ✓ Provided feedback to SDR Team, worked to improve SDRs
- ✓ Radiances are Stable & consistent with AVHRRs/MODISs

MODIS

- ✓ All MODIS bands were out of AVHRR/VIIRS family by 0.3-0.6K. Sensor was fine, but CRTM coefficients were in error. Provided feedback to CRTM Team, fixed in CRTM v2.1.
- ✓ MODIS Terra-Aqua 3.7 µm still inconsistent by 0.3K – working to fix

IDPS and ACSPO SST Monitoring in SST Quality Monitor (SQUAM)

www.star.nesdis.noaa.gov/sod/sst/squam/

VCM and Ice Mask for SST in SQUAM

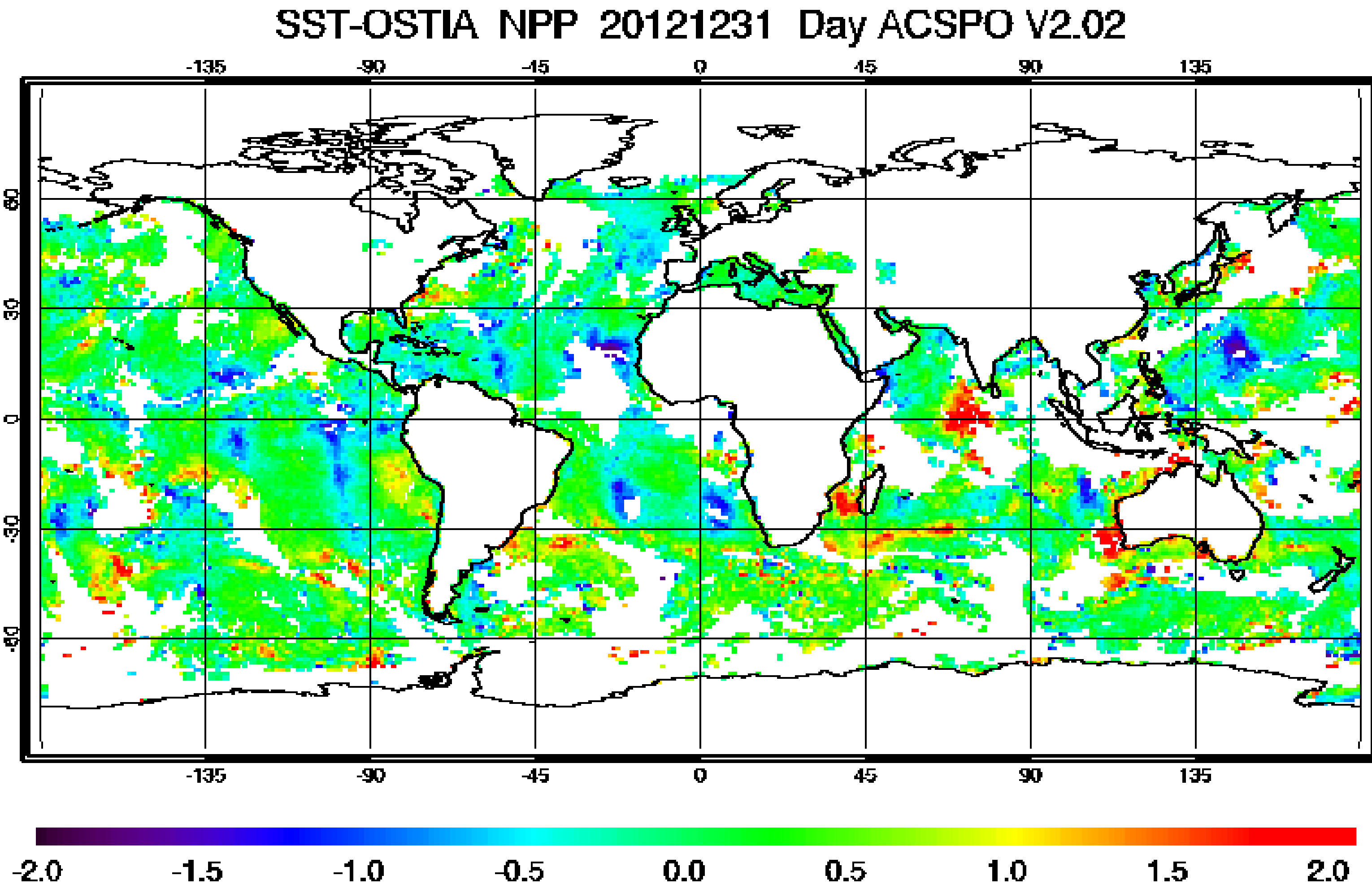
- STAR analyses use VCM Confidently Clear data only (consistent with VCM Beta Review Analyses, Apr’2012)
- SST QF have been analyzed & Discussed at several SST Telecons in Mar’2012
- Based on these analyses, SST QFs were found too restrictive.
- They are not used in the SST Analyses presented here, pending QF redesign

ACSPO (NOAA heritage) vs. IDPS SSTs

Objective: Ensure comparable SST performance in comparable SST domain

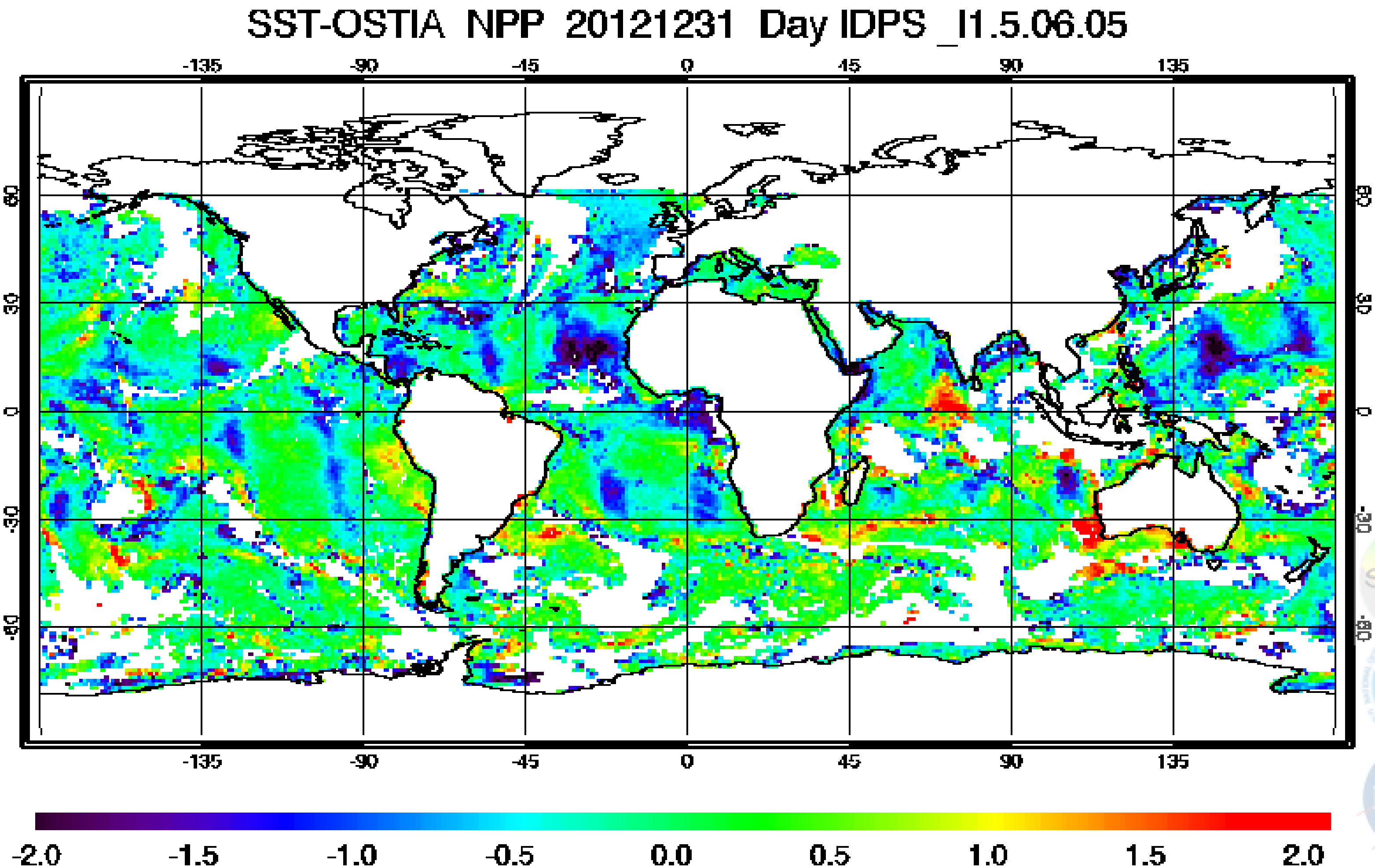
Analysis of one representative day of data
– 31 December 2012 in SST Quality Monitor (SQUAM)
www.star.nesdis.noaa.gov/sod/sst/squam/

DAY: ACSPO L2 minus OSTIA L4
31 December 2012



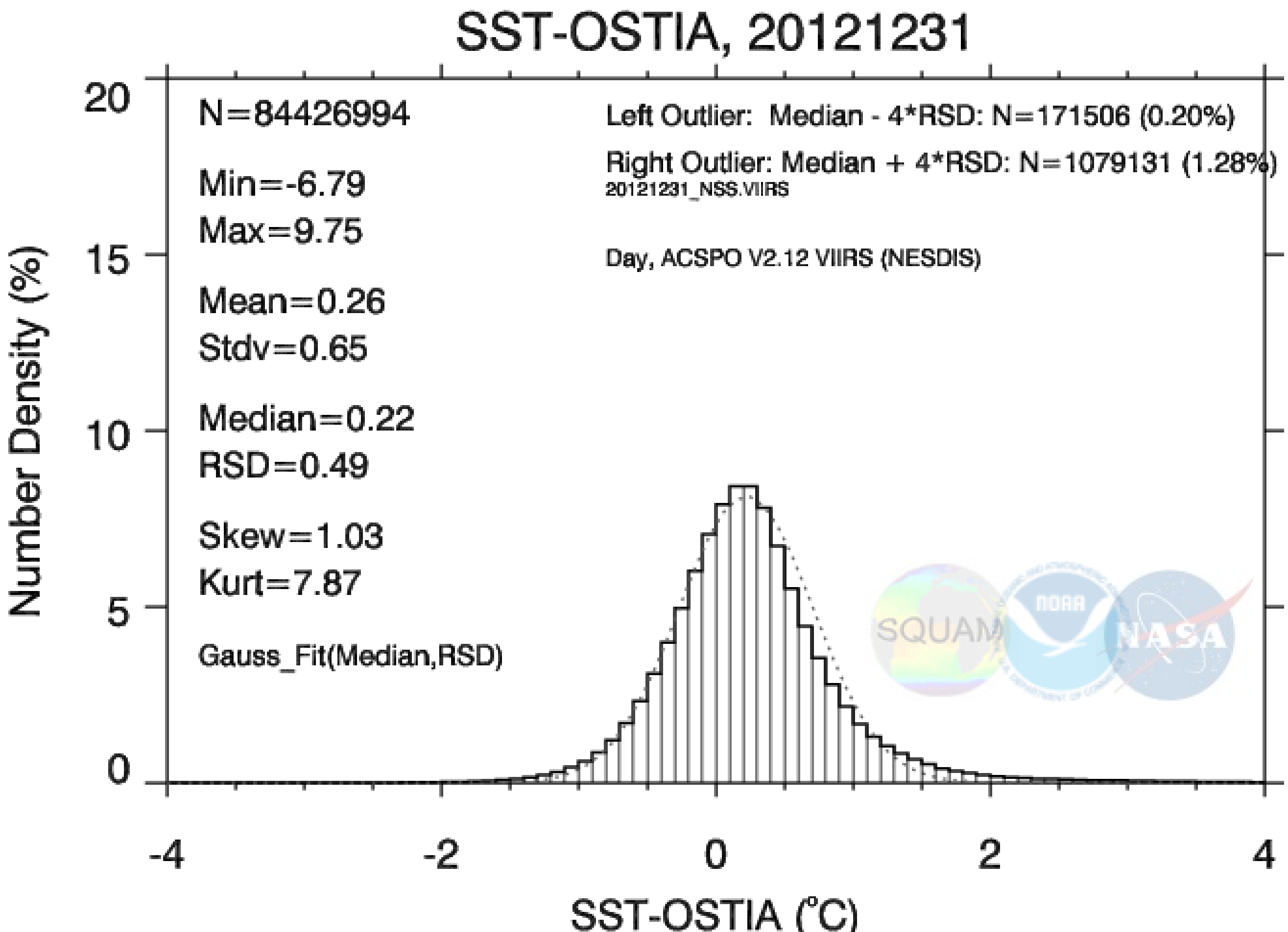
- ***Deviation from Reference SST is flat & close to 0***
- ***Residual Cloud/Aerosol leakages seen as cold spots***

DAY: IDPS L2 minus OSTIA L4
31 December 2012



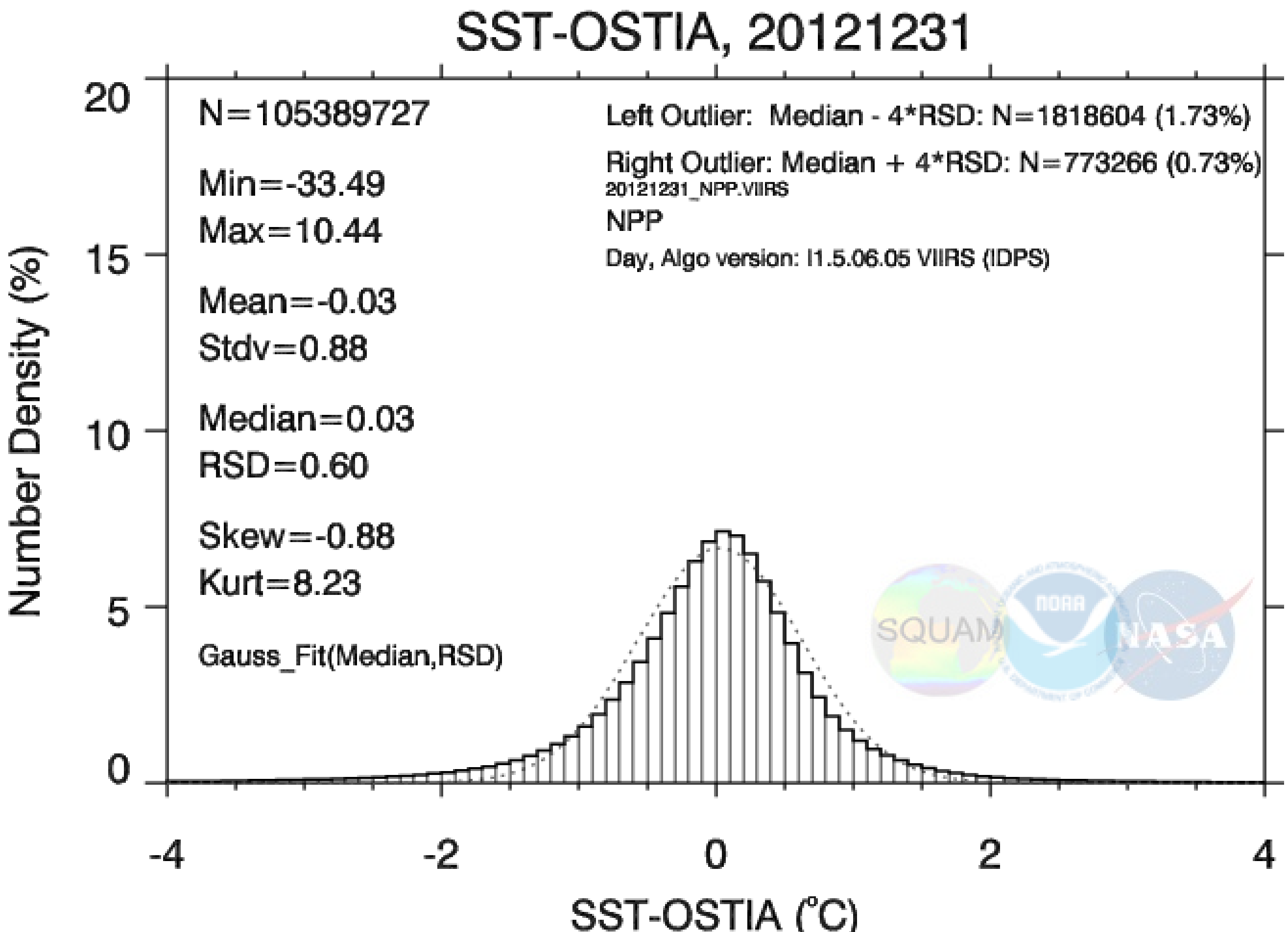
- ***More Cloud leakages in IDPS than in ACSPO***
- ***"Limb Cooling" – due to SST equations/coefficients***

DAY: ACSPO L2 minus OSTIA L4
31 December 2012



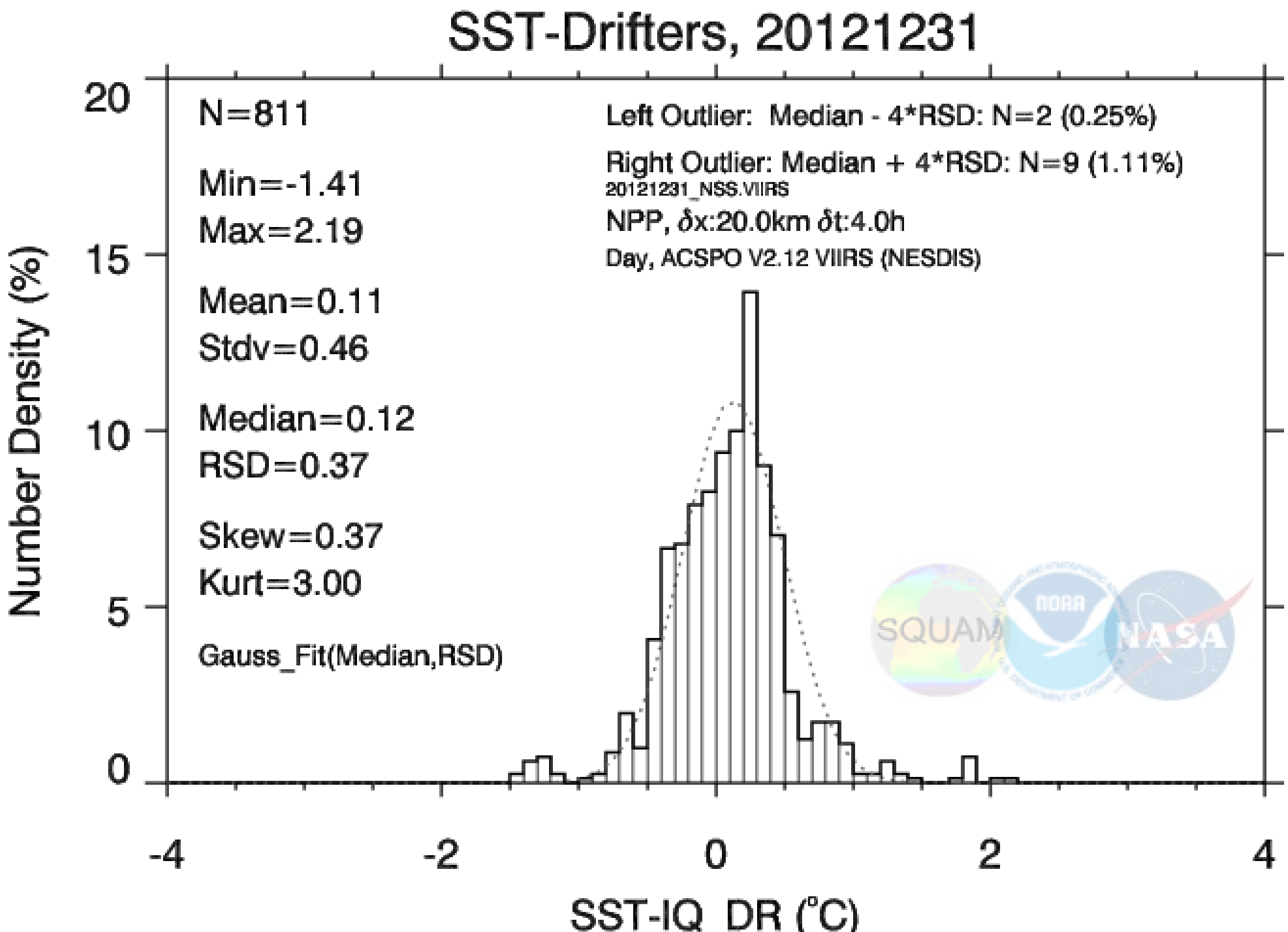
- ***Shape close to Gaussian***
- ***Domain and Performance Stats close to expected***

DAY: IDPS L2 minus OSTIA L4
31 December 2012



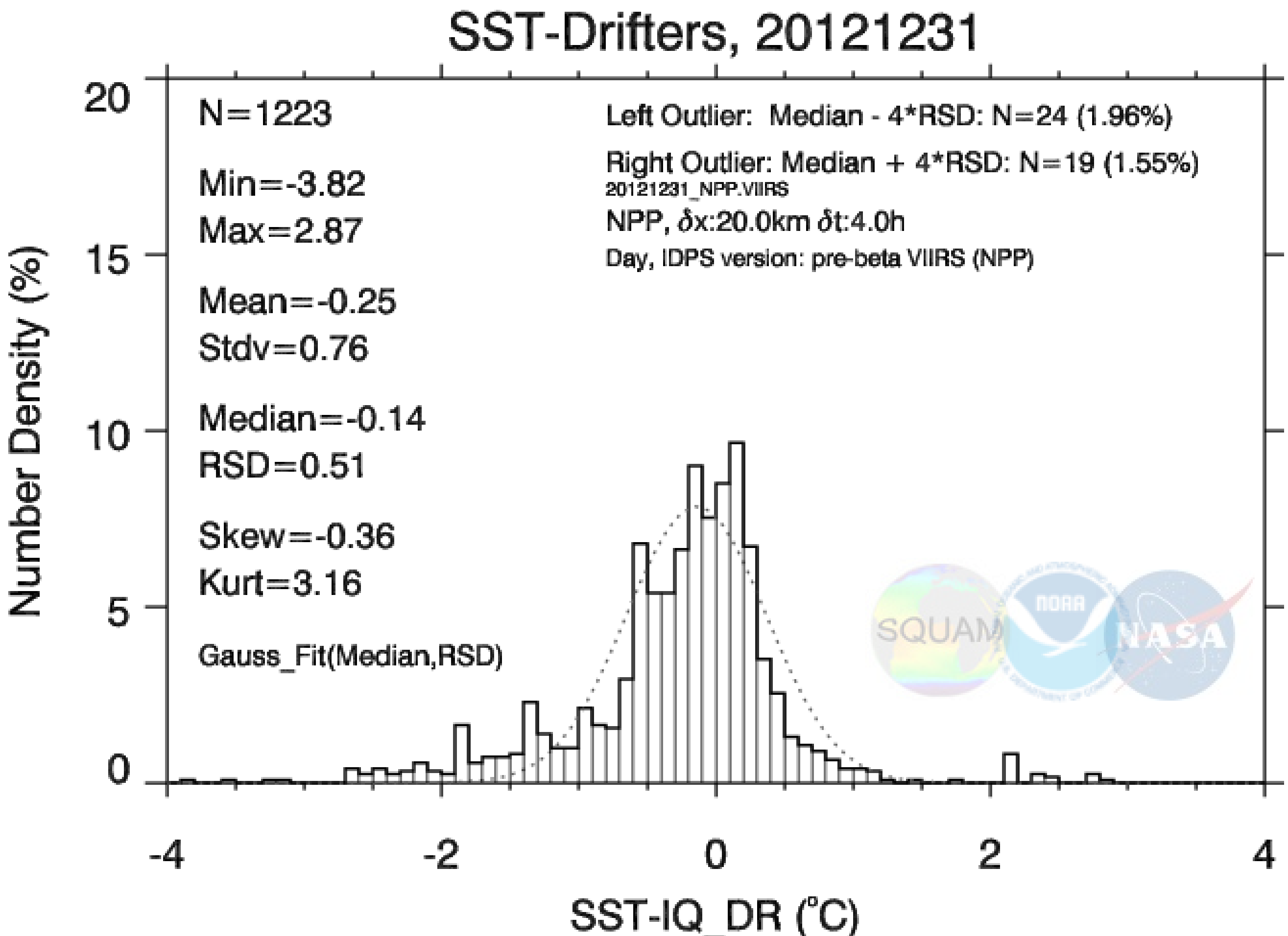
- ***IDPS sample +25% larger compared to ACSPO***
- ***increased Min/Max, STDV/RSD & Larger fraction of outliers***

DAY: ACSPO L2 minus *in situ* SST
31 December 2012



- ***Shape close to Gaussian***
- ***Domain and Performance Stats close to expected***

DAY: IDPS L2 minus *in situ* SST
31 December 2012



- ***IDPS sample +51% larger compared to ACSPO***
- ***increased Min/Max, STDV/RSD & Larger fraction of outliers***

DAY 31 December 2012 – Summary

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

	NOBS (%ACSPO)	Min/ Max	Mean/ STD	Med/ RSD	Skew/ Kurt
ACSPO	84.4M (100%)	-6.8/ +9.8	+0.26/0.65	+0.22/0.49	+1.0/ +7.9
IDPS	105.4M (125%)	-33.5/+10.4	-0.03/0.88	+0.03/0.60	-0.9/+8.2

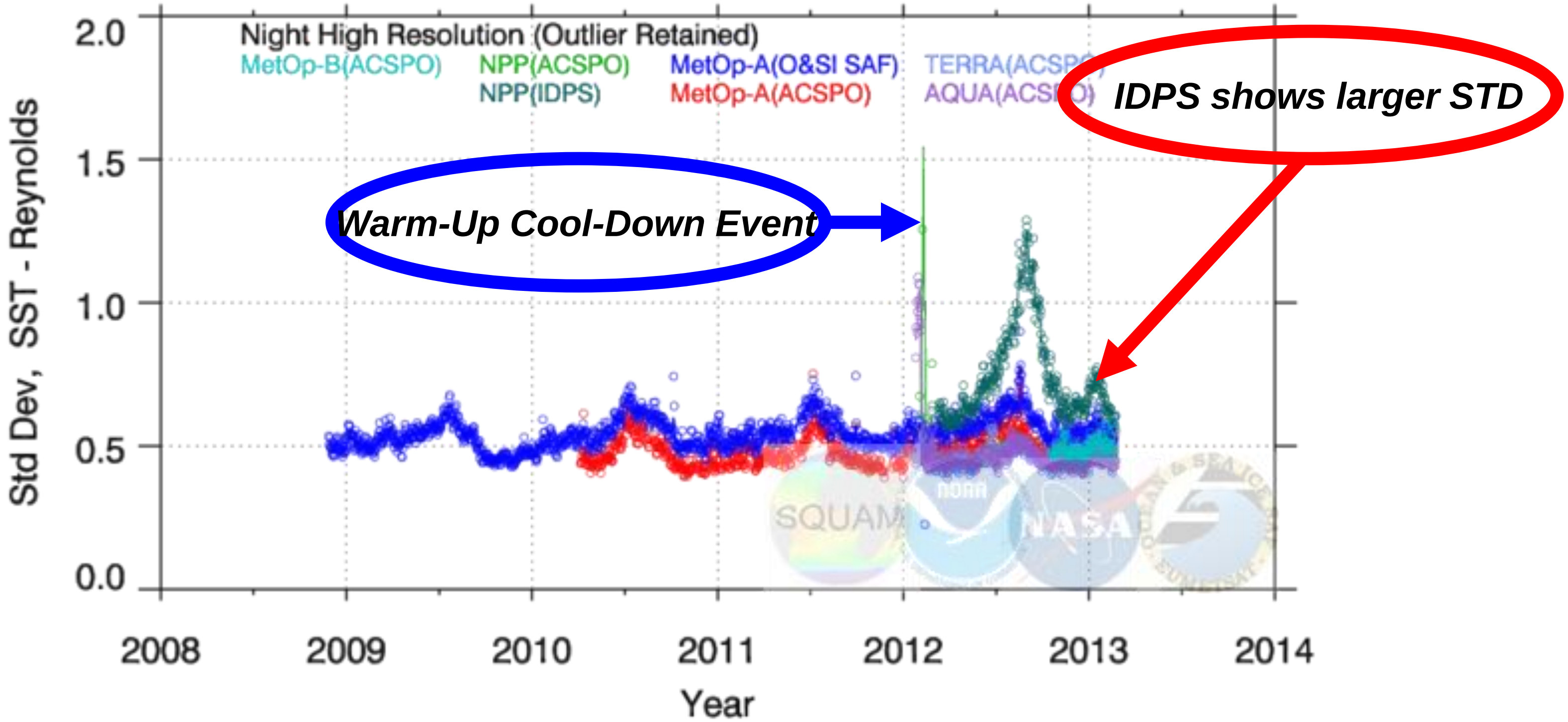
- ***IDPS SST domain +25% larger but all Stats degraded, compared to ACSPO***
- ***Gap between Conventional and Robust stats wider in IDPS - More outliers***

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

	NOBS (%ACSPO)	Min/ Max	Mean/ STD	Med/ RSD	Skew/ Kurt
ACSPO	811 (100%)	-1.4/ +2.2	+0.11/0.46	+0.12/0.37	+0.4/ +3.0
IDPS	1,223 (151%)	-3.8/+2.9	-0.25/0.76	-0.14/0.51	-0.4/+3.2

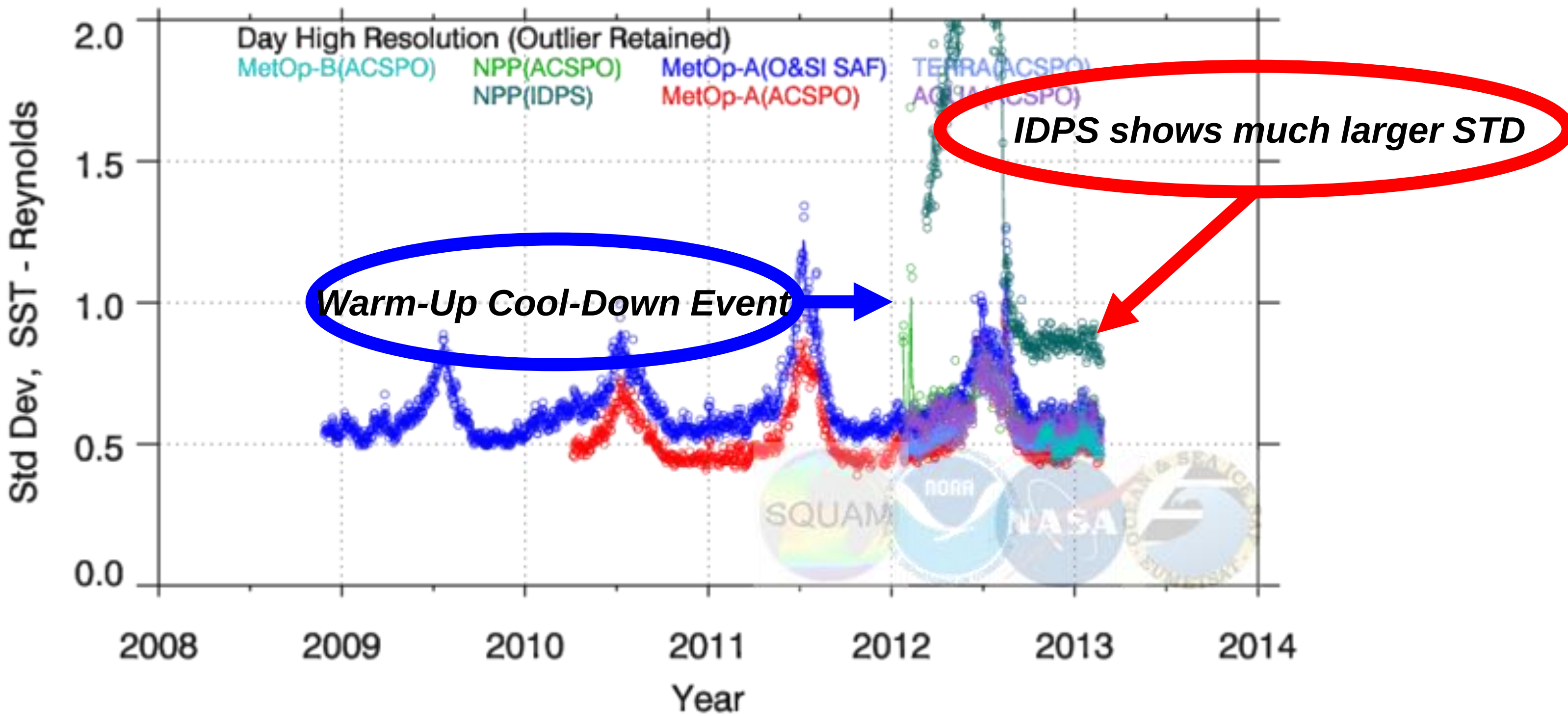
- ***IDPS SST domain is +51% larger but all Stats degraded, compared to ACSPO***
- ***Gap between Conventional and Robust stats wider in IDPS - More outliers***

NIGHT STD DEV wrt. Reynolds L4



- ***AVHRR & MODIS SSTs are consistent***
- ***ACSPO VIIRS is consistent with MODIS & AVHRR***
- ***VIIRS EDR shows larger STD, out of spec***
- ***Large peaks due to suboptimal performance of Ice Mask***

DAY STD DEV wrt. Reynolds L4



- ***AVHRR & MODIS SSTs are consistent***
- ***ACSPO VIIRS is consistent with MODIS & AVHRR***
- ***VIIRS EDR shows much larger STD, out of spec***
- ***Large peaks due to suboptimal performance of Ice Mask***

Summary to VCM and IM Analyses in SQUAM

VCM Performance for SST Remains Suboptimal

- ✓ IDPS domain larger than ACSPO, but SST statistics degraded
- ✓ SST specs are not met (including revisited in new L1RD)
- ✓ Improvements are needed in both day (more problematic) and night (less problematic) VCM
- ✓ Suboptimal SST performance is in part due to SST algorithms (e.g., limb cooling at swath edges) – work is underway to revisit

Work is underway with VCM Team at U. Wisconsin (Andy Heidinger and Denis Botambekov) to fine tune VCM for SST

Recommend SST for Beta with Caveats

- SST Data record available in CLASS from 22 Jan 2012 – onward is suboptimal and highly non-uniform
- As of this report, VIIRS SDR has been verified and has 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

Remaining SST Work Towards Provisional

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

- ✓ Work underway with UW Andy Heidinger and Denis Botambekov

Redesign SST EDR per new L1RD

- ✓ Only keep skin SST, and exclude bulk SST
- ✓ Reuse bulk SST layer to store first-guess SST
- ✓ Reformulate SST regression equations, to improve SST statistics and remove limb cooling at swath edges

Redesign SST Quality Flags

- ✓ Current SST QFs are too restrictive – SST domain too small
- ✓ Work is underway to revisit