Sea Surface Temperature Measurements from the VIIRS Instrument During NPOESS

John M. Jackson[1] , Robert Evans[2], Doug May[3] and Peter Minnett[2]

[1]Northrop Grumman Space Technology, [2]Rosenstiel School of Marine and Atmospheric Science, University of Miami, [3]Naval Oceanographic Office

Introduction

Abstract:
The National Polar-orbiting Operational Environmental Satellite System [NPOESS] is being developed to replace the current NOAA Polar Orbiting Environmental Satellite (POES) and the DoD Defense Meteorological Satellite Program (DMSP) systems. The instruments generally will represent significant improvements over the current operational sensors. For example the Visible-IR Imager Radiometer Suite [VIIRS] with 22 channels will be replacing the 6-channel Advanced Very High Resolution [AVHRR] on the POES system and the 3-channel Operational Linescan System [OLS] on the DMSP system. Measurements of the sea surface temperature from NPOESS, will come from the VIIRS and Microwave Imager Sounder instruments. The VIIRS sea surface temperature Environmental Data Record (EDR) will be derived from the moderate resolution thermal emissive channels covering the short-wave and long-wave infrared spectral regions (3.7 to 12.05 μm). Both skin and bulk sea surface temperature will be retrieved. The VIIRS sea surface temperature retrieval algorithm will be described and performance results using both simulated and MODIS proxy data will be presented.

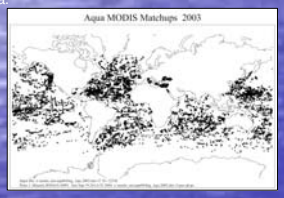
The VIIRS Instrument

SST Requirements:
Sea surface temperature (SST) is defined as a measurement of the temperature of the surface boundary layer (skin) and upper 1 meter (bulk) of ocean water. Retrievals are made using separate relations for skin and bulk SST. The requirements below apply only under clear conditions unless otherwise stated. A horizontal cell is considered to be clear for this EDR if the cloud mask indicates "confidently clear" for that cell and the cells adjacent to it, and if the thin cirrus detection flag is not set for that horizontal cell. This EDR will be produced under the "probably clear" and "probably cloudy" conditions indicated by the cloud mask or under Exclusion conditions, but without performance specifications.

Paragraph	Subject	Specified Value	KPP Exclusion
	1. *Horizontal Cell Size*		
ID.2.4.3	1. *Nadir, Clear*	0.75 km	
ID.2.4.6	2. Worst Case, Clear	1.5 km	
ID.2.4.9	3. Horizontal Reporting Interval	HCS	
ID.2.4.9	3. Horizontal Coverage	Ocean	
ID.2.4.9	3. Measurement Range	271 K - 313 K	
	4. *Measurement Uncertainty (Bias)*		
ID.2.4.9b	**1. *Satellite Zenith Angle < 45 degrees***	**0.4 K**	
ID.2.4.9b	**2. *>45 degrees < Satellite Zenith Angle <50 degrees***	**0.7 K**	
	5. Measurement Uncertainty (Bulk)		
ID.2.4.10a	1. *Nadir, Clear* (Bulk Sea Surface)	0.1 K	
ID.2.4.10b	2. *>45degrees < Satellite Zenith Angle <53 degrees*	0.3 K	
	6. Measurement Accuracy (Skin and Bulk)	0.1 K	
	7. Mapping Uncertainty, 3 Sigma		
ID.2.4.12	1. Nadir	0.4 km	
ID.2.4.12	2. Worst Case	1.5 km	
	8. Measurement Value Average Period Time		
ID.2.4.13a	1. Clear	9 hrs	X
ID.2.4.15	9. Long Term Stability	0.1 K	
ID.2.4.17	10. Latency	NPP - 140 min NPOESS - 29 min.	
	1. Measurement Uncertainty Degradation Contributors (Skin and Bulk)		
ID.2.4.21	1. SST Measurement above 305 K	0.8 K	
ID.2.4.29	2. Aerosol Optical Thickness exceeding 0.5 Sea	1.0 K	
ID.2.4.30	3. Satellite Zenith Angle > 50 degrees	0.7 K	
	5. Measurement Uncertainty Exclusion Conditions		
ID.2.4.35a	1. Aerosol Optical Thickness > 1.0		

Testing with MODIS Match-up Data

MODIS Aqua and MODIS Terra match-up data has been provided by Rosenstiel School of Marine and Atmospheric Science, University of Miami. The data was collected for MODIS SST validation. Five years worth of match-up data from both Terra and Aqua has been collected and quality controlled. More than 290,000 bulk SST match-up data points and more than 2,000 skin SST match-up data points were collected for Aqua, and more than 85,000 bulk SST match-up data points and more than 3,000 skin SST match-up data points were collected for Terra.



Testing with Terra and Aqua match-up data shows consistent results. Performance at night is better than daytime performance for both data sets (although the improvement is more significant for Aqua). The triple window algorithm, used only at night, takes advantage of data from the 3.7 μm band to provide improved performance a higher temperatures. The global performance of the two algorithms is generally better than NPOESS requirements, but is not uniformly better than requirements over the entire temperature range. Testing with MODIS data does not show much performance difference in the Nadir and EOS stratifications. However, the VIIRS instrument is expected to perform better at Nadir due to improved NEdT due to multiple pixel aggregation.

Testing with VIIRS Synthetic Data

A global synthetic data set was created for testing the VIIRS algorithms. The parameters of the data set relevant to testing the VIIRS SST algorithm are summarized below.

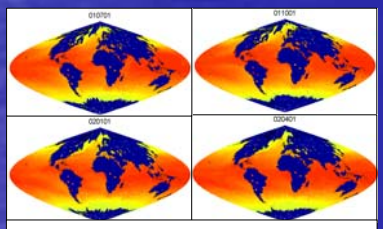
Spacecraft:
- NPP, 1330 orbit (no spacecraft pointing error effects)

Sensor model:
- Based on EDU test data and allocations

Atmospheric truth:
- Tropospheric temperature and moisture profiles from NCEP AVN FNL
- Tropospheric aerosols
  - MODTRAN aerosols rescaled to MODIS 8 day average values
- Stratospheric aerosols
  - MODTRAN background levels

Surface truth:
- Ocean BRDF computed using
  - Wind speed (NCEP)
  - Wind direction (NCEP)
  - Chlorophyll concentration (Bricaud database)
- Surface temperature (NCEP)

RTM:
- MODTRAN4+, v3, R1 with the 16-stream DISORT option



Global SST for four of the twelve months in the data set

Overview of the SST Algorithm

VIIRS SST Non-linear Split Window Algorithm

$$SST = a_0 + a_1 T_{11} + a_2 (T_{11} - T_{12})(RSST + a_3 (T_{11} - T_{12})(\sec(z) - 1))$$

a0, a1, a2, a3: Regression coefficients
T11: Brightness temperature at 11 μm
T12: Brightness temperature at 12 μm
RSST: Model sea surface temperature
z: Sensor zenith angle

This algorithm is stratified by T11-T12 with a switch point at 0.8 K. For the range of 0.6 K to 1.0 K results from the two stratifications are linearly interpolated.

The Non-linear Split Window Algorithm will be used for daytime VIIRS SST retrieval and as a back-up algorithm at night. This algorithm is heritage from AVHRR and MODIS.

VIIRS SST Triple Window Algorithm

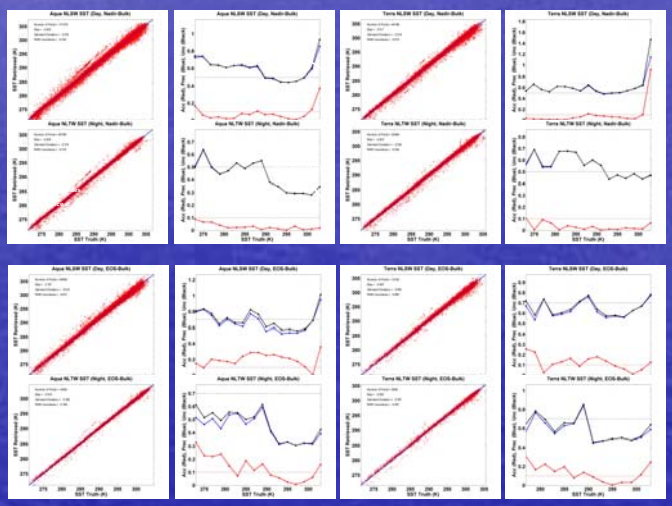
$$SST = a_0 + a_1 T_{11} + a_2 (T_{37} - T_{12})(RSST + a_3 (\sec(z) - 1))$$

a0, a1, a2, a3: Regression coefficients
T11: Brightness temperature at 11 μm
T3.7: Brightness temperature at 3.7 μm
T12: Brightness temperature at 12 μm
RSST: Model sea surface temperature
z: Sensor zenith angle

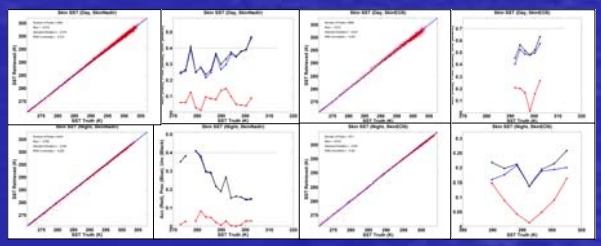
There are no stratification for this algorithm.

The Triple Window Algorithm will be used as the primary algorithm at night. This algorithm is heritage from AVHRR.

Performance Results from MODIS Match-up Data



Performance Results from VIIRS Synthetic Data



Testing with VIIRS global synthetic data shows very good performance for skin SST. The non-linear split window algorithm, used during the day, shows some performance degradation at the high end of the temperature range, but overall the skin SST will meet or exceed NPOESS requirements.

Conclusions

The VIIRS Sea Surface Temperature algorithm will satisfy NPOESS system requirements on a global basis by using the heritage non-linear split window algorithm for day retrievals and the heritage triple window algorithm for night retrievals. However, the limitations of the non-linear split window algorithm will cause degraded performance during daytime when sea surface temperatures exceed 302 K.

Special thanks to Alexander Ignatov of NOAA - NESDIS and Kay Kilpatrick of the University of Miami.