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GLOBAL OPERATIONAL SST AND AEROSOL PRODUCTS FROM AVHRR: CURRENT STATUS, DIAGNOSTICS, AND POTENTIAL ENHANCEMENTS

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Introduction

AVHRR has been flown onboard NOAA satellites since 1978 and will continue to be in orbit through ~2020. NESDIS generates two operational products over ocean: Sea Surface Temperature, SST (from 1981), and Aerosol Optical Depth, AOD (from 1990). The two products are generated within the same processing stream after the common pre-processing (navigation, calibration, cloud screening, preliminary QC) done within the Main Unit Task (MUT) system. SST & AOD retrievals from daytime orbits of NOAA-16 and -17 are analyzed in this study.

Objective

1) Review and evaluate the current SST and AOD products
2) Identify strengths and weaknesses for coming MUT redesign

Data

- NOAA-16&-17 Aerosol Observations (AEROBS) 8-km data
- Anti-solar side of orbit; outside 40° cone glint angle
- AOD and SST (Daytime; Sub-sample of SST)
- 1 week of global data (3-11 Dec 2003)

NOAA Orbital Configuration

NOAA maintains two platforms in space: *morning* (equator crossing time at launch, EXT~0630/1830 local time) and *afternoon* (EXT~0200/1400). NOAA-17 is the first *mid-morning* platform (EXT~1000/2200). For the first time, morning platform has enough illumination for aerosol retrievals. Distribution of local time of observations in AEROBS data is shown in Fig.1. It deviates from the EXT due to cross-scanning. Additionally, EXT systematically changes with time (Fig.2-3). The SST and AOD products are thus highly non-uniform in local observation time.

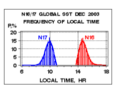

Fig.1. Frequency distribution of local time (LT) in the NOAA-16 and -17 SST/Aerosol files in December 2004.

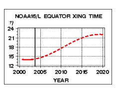

Fig.2. Local EXT for NOAA-16 (ascending/northbound node). Solid vertical line separates the past EXT prior to 2003, and its future projection beyond 2004.

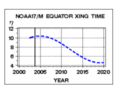

Fig.3. Local EXT for NOAA-17 (descending/southbound node; add 12h for ascending/northbound).

AVHRR Instrument

AVHRR/1 (flown onboard TIROS-N, NOAA-6, -8, -10) had two solar reflectance bands (SRB) centered at 0.63 and 0.83 µm (bands 1-2) and two Earth emission bands (EEB) at 3.7 and 11 µm (bands 3-4). AVHRR/2 (flown onboard NOAA-7, -9, -11, -12, -14) has an additional band 5 centered at 12 µm. This split-window enhancement was critically important for SST retrievals during daytime because of solar contamination in band 3. AVHRR/3 (flown onboard the current generation of NOAA-KLM satellites, NOAA-15 to -17, and to be flown on NOAA-N and three METOP platforms) has an additional SRB at 1.61 µm (termed 3A to differentiate it from band 3@3.7 µm that is now termed 3B). Also, AVHRR/3 has a refined sensitivity in the SRBs at low radiances, achieved through the concept of a "dual-gain". This feature is important for aerosol retrievals.

NESDIS MUT System

MUT system was set up at NESDIS in the early 1980s, and it has remained largely unchanged in its overall structure and functionality. It consists of two subsystems: the SST and aerosol observations (SST/AEROBS), which share much in common. The two products reside on the NESDIS Central Environmental Monitoring Satellite Computer System (CEMSCS) as rotating files, one per product and platform. Each file contains all AOD/SST retrievals during the last 8 days. The files are renewed automatically 4 times a day around 0100, 0700, 1300, and 1800 EST. In this study, we use two AEROBS files (NOAA-16 and -17), which also include SST.

Sample Definitions

For the analyses below, the 8-km AEROBS data from 3-11 Dec 2003 have been first averaged into 1day×(1°)^2 space-time boxes, resulting in N=62,197 (NOAA-16) and 56,054 (NOAA-17) grids. [The ~11% difference in a sample size between the AM and PM platforms may be due to a diurnal cycle in cloud cover. Or, it may result from the fact that calibration of the AVHRR SRBs used for cloud screening may be offset between the two platforms.] The NOAA-16 and -17 samples overlap in a sub-sample called *intersection* (in which both NOAA-16 and -17 data retrievals are available. There are N=17,728 1day×(1°)^2 such grids (~30% of the full samples).

SSTs

Parameters of the Non-Linear SST (NLSST) equations are tuned against buoy SSTs, *independently* for the platforms. The two SSTs are in excellent agreement. Cross-platform statistics (available in the *intersection* sub-sample only): R^2>0.99, bias 10^{-2}K, noise 0.7K.

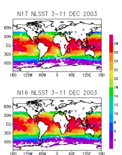

Fig.4. Global maps of SST derived from the AM (top: NOAA-17, EXT~1000) and PM (bottom: NOAA-16, EXT~1400) platforms.

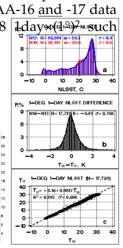

Fig.5. Global SST statistics: histograms of (a) T_{16} and T_{17} and (b) T_{16}-T_{17}; and (c) scattergrams T_{17} vs T_{16}.

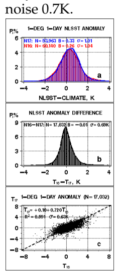

Fig.7. Same as in Fig.5 but for the SST anomalies.

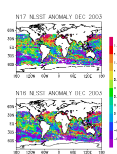

Fig.6. Same as in Fig.4 but for the SST anomalies.

SST Anomalies

More appropriate is performing analysis in SST anomalies. Bauer-Robinson (1985) SST climatology was subtracted from NLSST. Cross-platform bias is still within ~10^{-2} K, and noise ~0.7K. But the R^2 dropped down to ~0.69. The RMS anomaly ("signal" we are after) in Fig.7a is about 1K. Noise is $\sqrt{0.7^2/2}$~0.5K. The signal-to-noise ratio is ~2.

View Angle and Cloud trends in SST

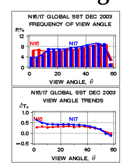

Fig.8. View zenith angle: (a) frequency distribution, and (b) trends in the mean anomalies for NOAA-16 and -17.

View angle dependence in NLSST treated empirically. Trends consistent for the two platforms: cold bias at θ>40°.

Cloud biases consistent. May be real (surface cooler under cloudy conditions) or residual cloud. Check w/ surface data.

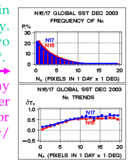

Fig.9. Count of clear-sky pixels within 1day×(1°)^2: (a) frequency distribution, and (b) trends in the mean δT_S.

Aerosol

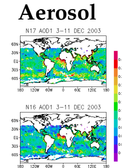

Fig.10. Global distribution of aerosol optical depth in AVHRR/3 band 1, τ_1 (λ_1=0.63 µm), in December 2003.

band1

band2

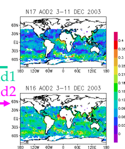

Fig.11. Same as in Fig.10 but for AOD in AVHRR/3 channel 2, τ_2 (λ_2=0.83 µm).

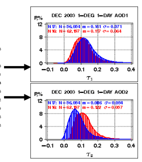

Fig.12. Global histograms of AODs in AVHRR channels 1 and 2, τ_1(λ_1=0.63 µm) and τ_2(λ_2=0.83 µm).

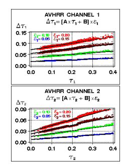

Fig.14. Error in AOD, Δτ, caused by error in calibration slope, ε (after Ignatov 2002.)

Cross-platform differences are due to lack of onboard calibration of AVHRR solar reflectance bands.

AOD errors are amplified in calculating the Angstrom exponent.

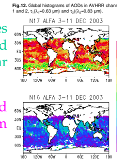

Fig.15. Global distribution of the Angstrom exponent derived as α=-ln(τ_1/τ_2)/ln(λ_1/λ_2).

In NOAA operations, the aerosol model cannot be estimated from AVHRR bands 1 and 2. Band 3A is not always available. Thus NOAA continues to use single-channel aerosol algorithm.

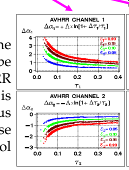

Fig.17. Calibration slope-induced error in the Angstrom exponent (after Ignatov 2002.)

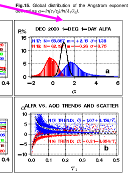

Fig.16. Histograms of the Angstrom exponent, α, and scattergrams of α vs τ.

Aerosol/SST

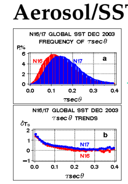

Fig.18. (a) Histograms of slant-path AOD in AVHRR channel 1, $\tau_1$secθ, and (b) trends in SST anomalies.

SST anomaly is negatively and non-linearly correlated with slant-path AOD.

AOD positively correlated with ambient cloud amount (May be related to the negative correlation "SST-cloud" in Fig.9.)

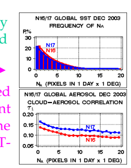

Fig.19. (1) Count of aerosol pixels within [1day×(1°)^2] boxes, N_A (centered at ΔN_A=1), and trends in τ_1.

Conclusion

SST is derived from AVHRR Earth emission bands, which are well-calibrated onboard. As a result, it is relatively accurate, and well-reproducible from the two platforms. In a global sense, the errors in the SST product are mainly random (although they may be localized regionally and/or seasonally), with noise σ_N~0.5K. SST reveals view angle-, cloud- and aerosol-related biases. Diurnal signal is not seen because platforms are calibrated against buoys *independently*.

The aerosol product, on the other hand, is derived from the solar reflectance bands which are not calibrated onboard. As a result, the AVHRR aerosol product is subject to significant systematic errors (up to Δτ~(3-5)×10^{-2} in band 1), which may additionally change in time as the calibration slopes in the AVHRR solar reflectance bands degrade. Aerosol model cannot be estimated in the operational reality, and thus single-channel retrievals will be continued.

Plans

The MUT processor and SST algorithm are currently under a fundamental redesign, in preparation for METOP era with 1-km global resolution. CLAVR-x will be used as a front end. Satellite data will be merged with NCEP files to facilitate skin-to-bulk SST conversion and atmospheric correction. Comprehensive self- and cross-consistency checks of the SST/Aerosol products will

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