Remote Sensing of Environment 159 (2015) 288–306

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Six years of OSI-SAF METOP-A AVHRR sea surface temperature

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ARTICLE INFO

Article history:
Received 27 May 2014
Received in revised form 11 December 2014
Accepted 22 December 2014
Available online 18 January 2015

Keywords:
Sea surface temperature
METOP-A
AVHRR
Validation

ABSTRACT

The Ocean and Sea Ice Satellite Application Facility (OSI SAF) has been producing full resolution global Sea Surface Temperature (SST) from the METOP-A Advanced Very High Resolution Radiometer (AVHRR) since July 2007. The SST operational processing and the validation scheme have remained unchanged for more than 6 years. The global validation results against measurements are stable over time. Night-time METOP-A SSTs differ from drifting buoy SSTs by −0.05 K in average with a standard deviation of 0.44 K and the daytime values are respectively 0.09 K and 0.56 K.

Seasonal statistics have been calculated on a global regular 5-degree grid for a 6-year period to review the main biases and their characteristics. There is evidence of regional and seasonal biases, indeed the multispectral regression algorithms are known (to a various degree depending upon specific implementation) to have limitations in handling the variety of atmospheric absorption conditions encountered over the global ocean. This problem has been solved for the OSI SAF geostationary SST chain by adopting a Numerical Weather Prediction (NWP) profile based correction method. The same approach has been tested on a prototype chain ingesting METOP-A data and gives encouraging results. It will be used in the new polar orbiter chain under development at OSI SAF, that will process METOP-B data.

An application example of METOP-A SST time series is given by analyzing the inter-annual variability of Arctic Ocean SST in relation with the ice coverage variability in September. The METOP-A time series gives consistent results when compared to other observations or model outputs.

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1. Introduction

The Ocean and Sea Ice Satellite Application Facility (OSI SAF) of the EUropean Organization for the Exploitation of METeorological SATellites (EUMETSAT) has been producing global Sea Surface Temperature (SST) data from the METOP-A Advanced Very High Resolution Radiometer (AVHRR) since July 2007. The SST is calculated by multichannel algorithms (Barton, 1995; McClain, Pichel, & Walton, 1985; Walton, Pichel, Sapper, & May, 1998), where the coefficients have been derived from simulations.

The OSI SAF products are widely used in operational SST applications or international projects. The Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA, Donlon et al., 2012) has been ingesting high resolution METOP-A AVHRR SSTs since April 3rd 2008. Following the loss of the Advanced Along Track Scanning Radiometer (AATSR) onboard ENVISAT in April 2012, METOP-A SSTs have been used as a reference in OSTIA bias correction, since January 17th 2013 (Roberts-Jones, personal communication). The METOP-A SSTs have been used operationally by the Danish Meteorological Institute (DMI) SST analysis (Høyer, Karagali, Dybkjær, & Rasmus Tonboe, 2012) since 2010 and experimentally by the GHRSST Tropical Warm Pool Diurnal Variability Project in January–April in 2009 and 2010 (Beggs et al., in press).

The comparison between satellite SSTs and buoy measurements has been addressed on the global ocean (Gentemann, 2014; O'Carroll, August, Le Borgne, & Marsouin, 2012; O'Carroll, Saunders, & Eyre, 2008) or on specific regions, such the Arctic Ocean (Høyer et al., 2012). Drifting buoys are widely used because of their better geographical coverage and lower measurement depth, typically 20 cm depth against 1 m for moored buoys. Several authors have presented statistics for the different types of buoys. By a three-way analysis, Xu & Ignatov (2010) obtained a standard deviation of error of 0.26 for drifting buoys, 0.30 for tropical moored buoys and 0.39 for coastal moored buoys. The Castro, Wick, and Emery (2012) detailed study, which separates different types of buoy, day and night, open and coastal water and two matchup time values, concludes that no significant differences are found between drifting buoys and tropical moored buoys and that the largest deviations are observed with non-tropical moored buoys especially coastal ones.

The OSI SAF METOP-A SSTs are validated against drifting buoy measurements on a routine basis (Marsouin, Le Borgne, Legendre, & Péré, 2010). This paper presents a detailed study on a 6-year period using the drifting buoys on the global ocean and a complementary study using the tropical moored buoys. The obtained results can be useful for the users and for the future OSI SAF METOP-B AVHRR chain under

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http://dx.doi.org/10.1016/j.rse.2014.12.018
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development at Météo-France/Centre de Météorologie Spatiale (MF/CMS).

This text summarizes the SST operational processing (Section 2), the validation scheme (Section 3) and describes in detail the validation results (Section 4). Regional biases are discussed in Section 5, and operational solutions to this problem are briefly described. Finally, an example of application of these data in the Arctic Ocean is given in Section 6.

2. SST operational processing

The OSI SAF METOP-A SST chain includes the following main steps.

2.1. Preprocessing

The METOP/AVHRR full resolution radiometric L1B data are acquired at CMS through the EUMETSAT dissemination system EUMETCast. They are ingested in near real time for each METOP 3-minute granules. The threshold based MAIA cloud mask (Lavanant, 2007), is applied to these data.

2.2. Cloud mask control

A series of tests that considers various quantities such as the local values of gradient, temperature, probability of ice, Saharan dust or aerosol has been defined. For each test, an indicator has been defined by comparison of the tested quantity (test_value) with a limit value (limit_value) and a critical value (critical_value). Outside this range of values either there is no problem, or the risk of errors is too high. The test indicator is defined as:

$$\text{test\_indicator} = 100 \times (\text{test\_value-limit\_value})/(\text{critical\_value--limit\_value}); \quad (1)$$

indicator values below 0, or above 100 are assigned to 0 and 100, respectively.

This approach enables the homogenization of the test results on a unique scale:0: no problem;]0–100[: potential problem; 100: critical problem (leading to masking the pixel).

The following indicators are used:

- Local temperature value indicator: this indicator is based on the pathfinder world SST 5-day climatology at about 0.04 degree resolution (Casey & Cornillon, 1999), which provides a mean SST, a minimum SST and a SST interannual deviation. The calculated SST is compared to the limit and critical values of the temperature obtained by adding margins to the local value of the minimum climatologic SST. These margins are a function of the interannual standard deviation of the temperatures, of distance to cloud and distance to coast.
- Gradient indicator: derived from the difference between the local 11 μm brightness temperatures (T_{11}) gradients and the corresponding maximum climatological values calculated from a world Atlas of thermal fronts (Andersen & Belkin, 2006). The limit value of this quantity corresponds to the T_{11} noise equivalent gradient value. The critical value is a plausible margin which is reduced in the vicinity of cloud, so that for a pixel close to a cloud the critical value is more easily reached than far from clouds. The gradient indicator is calculated from the limit and critical values according to Eq. (1). In the METOP-A chain, the gradient indicator is calculated at night only, because the use of visible channel allows in principle an efficient masking of the cloud edges and because diurnal warming may introduce local fronts that are not recorded in the climatology.
- Dust indicator: it is based on the use of the SEVIRI derived Saharan Dust Index (SDI, Merchant, Embury, Le Borgne, & Bellec, 2006) or the Navy Aerosol Analysis Prediction System (NAAPS, US NAVY, 2009) derived Aerosol Optical Depth (AOD) where the SEVIRI information is not available.
- Ice indicator: derived from the probability of ice calculated by applying the met.no ice probability method (Eastwood & Andersen, 2007), based on the use of the local value of the IR and visible channels.

The indicator calculation principles are shown in Fig. 1. For each indicator, the limit and critical values were adjusted by considering their impact on the preliminary validation results. A summary indicator ("cloud mask indicator") is computed as the mean of all test indicators but, if one indicator is equal to 100, the cloud mask indicator is assigned to 100. This synthesis is used, ultimately, to reflect the quality of the mask (see the Quality level determination section below).

2.3. Multi-spectral algorithm

The SST is calculated by classical multi-channel formulas, where the coefficients have been derived from simulations. A radiative transfer model has been applied to a data base of cloud free radio soundings and the coefficients have been calculated by multilinear regressions on simulated brightness temperatures (François, Brisson, Le Borgne, & Marsouin, 2002). The "NL" algorithm (Eq. 2, Walton et al., 1998) is used during the daytime and the "T37_1" algorithm (Eq. 3) at night.

$$\text{NL} \quad \text{SST} = a\,T_{11} + (b\,T_{CLI} + c\,S_\theta)(T_{11} - T_{12}) + d + e\,S_\theta \quad (2)$$

$$\text{T37\_1} \quad \text{SST} = (a + b\,S_\theta)T_{37} + (c + d\,S_\theta)(T_{11} - T_{12}) + e + f\,S_\theta \quad (3)$$

where:

- T_{11}, T_{12} and $T_{3.7}$ are brightness temperatures (BTs) at 11.0, 12.0 and 3.7 μm, respectively.

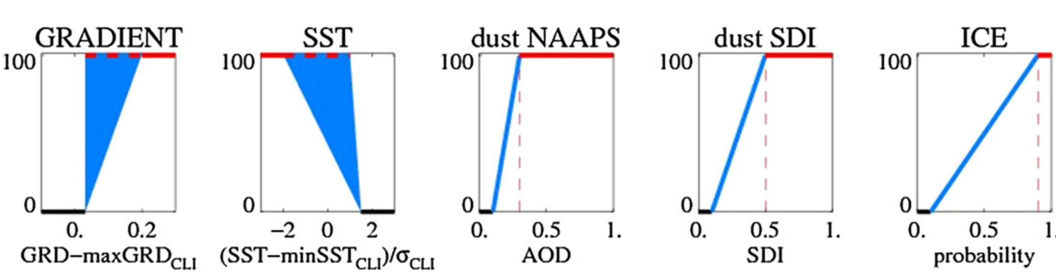

Fig. 1. Simplified scheme of the cloud mask indicators. On each plot, the values below the limit value are in black, those above the critical value are in red and those in between are in blue. In the case of the gradient indicator and local temperature value (SST) indicator, the critical value varies with respect to the distance to cloud, the transition from limit to critical value is an area rather than a line. The distance to coast has been ignored in these plots. $maxGRD_{CLI}$ is the maximum climatological T_{11} gradient (derived from a SST gradient climatology), $minSST_{CLI}$ is the minimum climatogical SST, AOD (the dust aerosol depth) and SDI (the Saharan Dust Index).

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