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Agenda Item: II.4

Other parameters and products

WORLD OCEAN SURFACE TEMPERATURE DERIVED FROM GEOSTATIONARY WEATHER SATELLITES – NEW GLOBAL METEOROLOGICAL PRODUCT

Summary and purpose of document

The present briefly describes the latest developments in the technique for the World ocean surface temperature (SST) retrieval from space – based IR radiance measurements in the ”atmospheric window” 10.5-12.5 microns from geostationary weather satellites Meteosat-7,-5, GMS, GOES-E and GOES-W for the latitude zone ±60 grad over the globe.

Action

None

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1. INTRODUCTION

Water surface temperature (SST) is one of key geophysical parameters indicating the state of the World Ocean. The regular generation of SST data sets on spatial scales ranging from local to global and on temporal scales of a few hours up to several days, months is of considerable interest for oceanography and climatology as well as for a lot of practical application areas (especially fishing).

There has been accumulated considerable experience in deriving SST from satellite data. The measurements of outgoing IR radiances in atmosphere window 10.5-12.5 μm from polar orbiting or geostationary meteorological satellites are commonly used for producing SST data sets. Monitoring the SST from geostationary satellites offers a number of advantages including: global coverage with high temporal resolution, reasonable accuracy and mutual consistency. Some deficiency of geostationary - based SST retrievals consists of reduced accuracy as compared with those produced from measurements of current polar orbiting satellites.

At present the IR data from ensemble of five “neighboring” geostationary satellites Meteosat-7,-5, GMS, GOES-E, GOES-W are regularly acquired at the satellite center “Planeta” in Moscow, using Meteosat PDUS station. It allows to regularly monitor zone ±60 grad the latitude over the globe and to perform the remote sensing of SST fields.

The objective of this paper is to describe concisely the technique for derivation SST data sets from geostationary – based IR radiance measurements. The single IR channel method is applied for analysis of satellite data and producing SST retrievals. The validation of SST retrievals, that has been accomplished through comparison to ground truth data, confirms the physical reliability and reasonable accuracy of satellite products. The examples of satellite derived SST maps are demonstrated.

2. METHOD

The methodology and technique of SST retrieval from geostationary – based IR radiance measurements have been developed and tested using data from Russian geostationary weather satellite GOMS/Electro N1, located at 76 grad East (1995-1998). Retrieval of SST of the reasonable quality requires careful attention to a number of problems:

- accurate absolute radiometric calibration of satellite IR data (if calibrated IR radiances are not available);
- detection and screening of cloud contaminated pixels;
- correction of atmospheric radiance attenuation;
- mapping SST fields at regular grid points.

The developed SST retrieval technique is applied separately to the individual IR imagery from each of five geostationary satellites. It can be briefly summarized as follows:

1. Initialize the navigation procedure. Perform the detection and screening of cloudy pixels.
2. Carry out vicarious radiometric calibration of IR imagery (except when Meteosat-7 IR data are analyzed).
3. Accomplish the correction of atmospheric radiance attenuation.
4. Assess the quality of SST retrievals and generate SST field map at regular grid points.

Some details of stages 2-5 realization.

Detection of cloud contaminated pixels at IR imagery and identification of clear-sky IR radiances (in terms of brightness temperatures, or original digital counts) is performed using simple one threshold procedure. Along with empirical threshold value for signal (inherent for each satellite) the well-known “spatial coherence” test is applied. To specify the threshold values for signal and its variance the histogram analysis is carried out for measured counts within whole imagery and within some predefined areas. The last ones are characterized by small variability of SST fields and mainly clear-sky conditions (selected starting from climatologic data). It is pertinent to note that the quality of cloud detection is better for data from Meteosat-7, since images in IR and VIS are available.

Absolute calibration of satellite IR observations which relates the observed radiometric (digital) counts to radiances or equivalent brightness temperatures is required for data from four spacecrafts, namely Meteosat-5, GMS, GOES-E, GOES-W. The procedure of absolute calibration being similar to that from (Gube at al., 1996) and commonly referred to as “vicarious calibration”, is based on the correlations between measured counts and calculated IR radiances in clear-sky conditions. It consists of the following steps:

- identification of cloud-free sea surface fragments and attribution of corresponding counts for blocks of 5x5 pixels (relating to the nodes of given 1° x 1° network within pre-selected area);

- calculation of “theoretic” radiances at the TOA using fast radiative transfer model (Weinreb and Hill, 1980) and ancillary information (SST, atmospheric temperature and humidity profiles and spectral response function for IR channel) as input data;

- formation the learning sample of pairs “calculated radiance – measured count” and derivation of regression coefficients in calibration equation;

- control of calibration quality.

The ancillary information on SST is extracted from special data set that contains monthly means and variances for regular grid points 1° x 1° over the World Ocean. Temperature and humidity profiles are extracted from “climatologic” data set of monthly averaged profiles given for regular global 5° x 5° network. As option, the NWP output, i.e. short-range forecast fields of temperature/humidity can be used in calibration procedure.

Further details of calibration procedure performance can be found in (Anekeeva at al., 1993). The performance of developed scheme and the quality of calibration have been evaluated for data collected during GOMS/Electro N1 operations. It should be noted that the calibration procedure might be repeated, if necessary (basing on the results of quality control).

Correction of measured clear-sky brightness temperatures and producing SST retrievals is accomplished using atmosphere "transfer function" technique. The transfer function (TF) is defined as the ratio of the radiance at TOA to that at the ocean surface. To adequately account for atmospheric radiance attenuation effects (water vapor absorption as principal factor) the catalogue of "climatologic" TFs has been generated for 1° x 1° latitude/longitude bins and for clear-sky aerosol-free conditions. The above mentioned climatologic data sets of mean temperature/humidity profiles and SSTs were used as input to TF calculation.

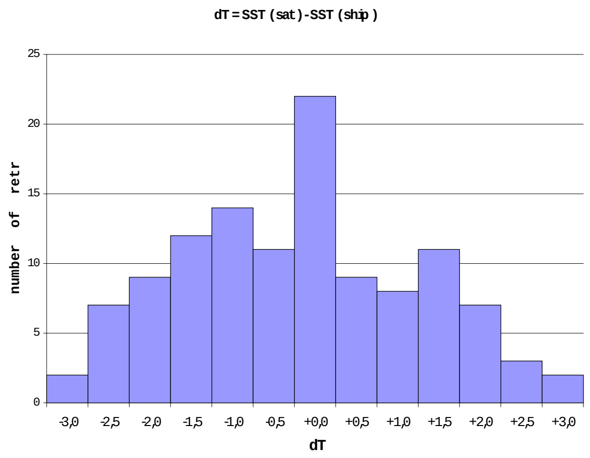
Preparation of SST maps. Satellite SST estimates as output product of stages 1 – 4 are subjected to "climatologic" control and filtering. In doing so they are compared with nearest (in space and time) "truth" values extracted from climatologic SST data set. If absolute difference between satellite and "truth" values exceeds 2σ (where σ is SST standard deviation) then corresponding satellite estimate is withdrawn as doubtful. In addition the test for spatial homogeneity of satellite SST field is executed: moving "window" of 4x4 pixels is applied to identify and to eliminate "outliers". After the filtering the SST estimates are used for creation the SST field map. The developed technique allows compiling SST maps either of regional or global coverage (using data from one or five satellites). For overlapping zones of two neighboring satellites special blending procedure is applied, based on median filtering. The output SST maps are generated for regular grid points with spatial spacing of 0.25 degrees.

3. RESULTS

The described technique is run operationally in SRC PLANETA during last half year. Output products include SST maps of regional coverage (one per day for each satellite) and global SST map (one map resulting from blended analysis of SST "regional" maps from five satellites during 5-10 days).

Satellite-derived SST may contain errors of different nature and be relatively unreliable under certain conditions such as optically thin clouds, wrong pixel assignment (marked as "sea" instead "land") etc. It means that the validation and quality monitoring of SST retrievals are mandatory. The verification of satellite derived SST can be performed through comparison to ground-truth data, namely: routine coincident buoy or ship measurements (access via GTS or INTERNET); SST gridded fields produced by NCEP or Hydrometeorological Center of Russia. At present the first option is executed routinely. Comparison of SST estimates with collocated in-situ observations (matchups of satellite and ship data) over the Atlantics and Indian Ocean areas gives small systematic biases and rms errors in the range 1.5-2.0 grad C. These figures are close to examples of error statistics that are given at fig.1.

(a)



(b)

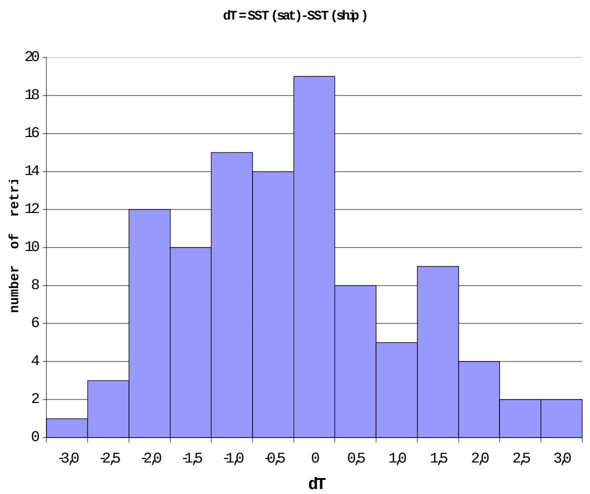
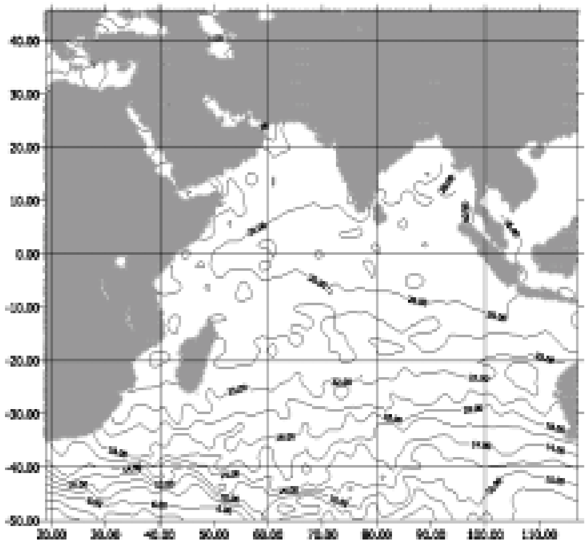


Fig 1. Histogram of the SST retrieval errors:
(a) Atlantic Ocean, METEOSAT-7, 12.07-17.07.2000, rmse=1.64, bias=-0.23 °C, N=117
(b) Indian Ocean, METEOSAT-5, 12.07-17.07.2000, rmse=1.56, bias=-0.34 °C, N=104

Here the error histograms are shown for a week period relating to Atlantics (fig. 1a, Meteosat-7 data) and Indian Ocean (fig. 1b, Meteosat-5 data). The accuracy of SST retrievals for Indian Ocean is found to be slightly better than those for Atlantics in spite of the fact that available Meteosat-5 data are not calibrated. Two reasons can explain this fact: difference in cloud coverage for Atlantics and Indian Ocean; SST field for Indian Ocean is more conservative and stable.

In conclusion two examples of SST products are given below: SST field for Atlantics and Indian Ocean (fig. 2) and global SST composition map (fig. 3).

(a)



(b)

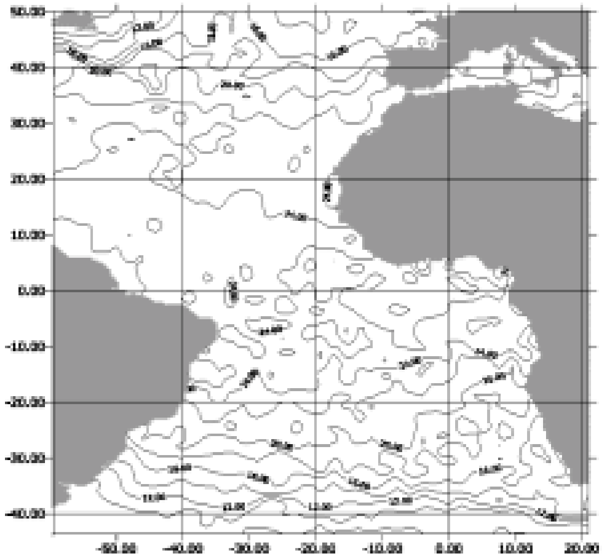


Fig 2. Satellite-derived sea surface temperature maps:
(a) Indian Ocean METEOSAT-5, July 2000
(b) Atlantic Ocean METEOSAT-7, July 2000

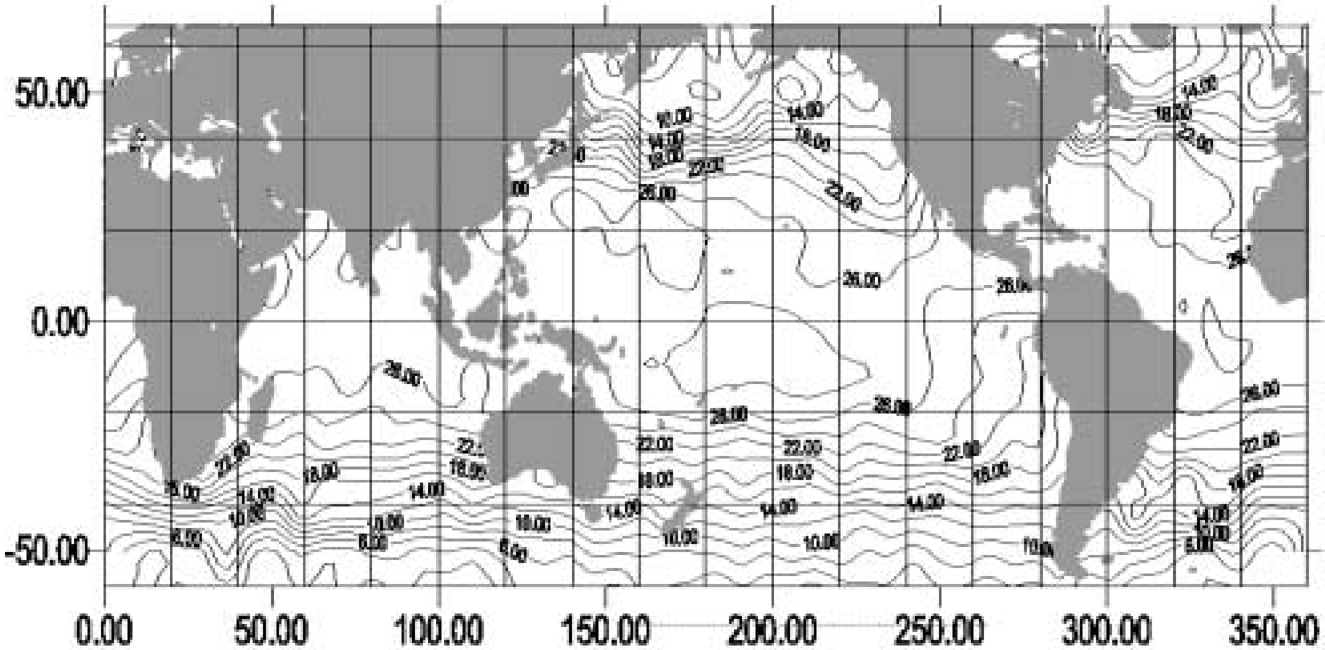


Fig 3. Satellite-derived sea surface temperature global map
18.06 – 25.06.2000, METEOSAT-7, METEOSAT-5, GMS, GOES-E, GOES-W