AN ARCTIC SEA SURFACE TEMPERATURE CLIMATE DATA RECORD

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ABSTRACT

Daily fields of gap-free sea surface temperature observations from 1982 to 2010 have been constructed using the DMI_OI processing method, satellite SST observations from the ARC and Pathfinder projects, together with OSI-SAF sea ice reanalysis and ICOADS 2.5 observations. A thorough validation of the data set shows the overall performance with biases within 0.1 ^{o}C and standard deviations about 0.6^{o}C. The spatial and temporal validation shows small biases, with no apparent structures, except within the Marginal Ice Zone. Examples on regional SST time series are given, where the decadal warming is evident.

1. INTRODUCTION

The Arctic Ocean and adjancent waters are challenging regions for retrieving Sea Surface Temperature (SST) and generating SST analysis products. This is due to several factors, such as: persistent cloudiness, the presence of sea ice and a complex atmosphere, where summertime inversions are occurring frequently [1, 2]. In addition, there are few in situ observations in this regions and extended periods with twilight, or day and night only. All these factors put the cold regions among the most challenging regions to work with at present, in terms of SST observations. Global methods and algorithms have been demonstrated not to perform well in these regions [1, 3] and there is therefore a need for a regional level 4 (L4) gap free analysis with a specific Arctic focus.

2. OBSERVATIONS

The following data are used as input to the L4 processing system, called DMI-OI:

(A)ATSR Reprocessing for Climate (ARC). The AATSR Reprocessing for Climate (ARC) SST level 3 dataset v1.0 and v1.1 are used, for the period 01/2006-01/2010. Data are obtained through the NERC Earth Observation Data Centre (http://www.neodc.rl.ac.uk/browse/neodc/arc). The selected file types are i) Day-time dual-view 2-channel and ii) Night-time dual-view 3-channel SST retrievals. The data series include observations from the ATSR 1 instrument on board the ERS-1 satellite, ATSR 2 on board the ERS-2, satellite and the AATSR on board ENVISAT [4].

Pathfinder SST. The 4 km AVHRR Pathfinder Version 5 SST Project (Pathfinder V5.1) is a reanalysis of the AVHRR data stream developed by the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS) and the NOAA National Oceanographic Data Center (NODC). The Level 3 (L3) data series include observations from the AVHRR instruments on board NOAA 7, 9, 11, 14, 16, 17, 18 [5].

In situ SST data from drifting buoys, moored buoys and ship observations are obtained from the ICOADS project (version 2.5) and used for validation and bias correction of the Pathfinder observations from 1982 to 1991 [6].

Sea-ice concentration data: The Eumetsat Ocean and Sea Ice Satellite application Facility (OSI-SAF)[7] reanalysis data set has been used in the DMI-OI reprocessing.

A timeline with the input data is shown in the figure below

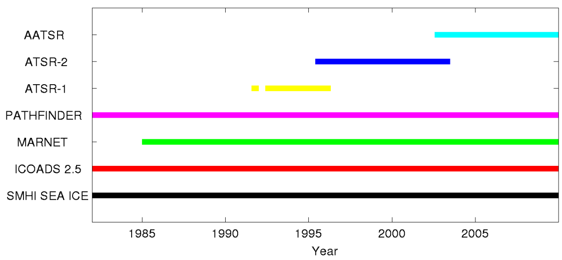

Figure 1. Timeline of the dataset included in the Level 4 reanalysis

3. QUALITY CONTROL AND PRE-PROCESING OF THE INPUT DATA

All satellite data valid for a particular day, within 24 hours from the analysis time are considered. The input L2/L3 SST data undergo various QC and processing steps to generate the individual level 3 products:

- Only Pathfinder satellite data which have a quality flag of 4 and higher are accepted
- Only ARC observations with an estimated error less than 0.8 ^{o}C are accepted.

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- Only in situ observations from the ICOADS data set passing all quality checks have been accepted.

- To avoid contamination from observations affected by diurnal warming, only local nighttime observations have been used for the Pathfinder data set.

- The ARC data have been adjusted to a depth of 1 m, which minimizes the contamination from diurnal warming. Therefore both day and night time products have been used.

4. BIAS CORRECTION METHOD

Satellite data can be biased for several reasons, including: atmospheric water vapour; atmospheric aerosol (dust); surface changes (e.g. extreme roughness); instrument calibration problems [1]. These errors can lead to biases in the analysis if they are not treated in some way. The DMI-OI uses a bias correction method for the reprocessing, which has been developed specifically for minimizing high latitude biases. The dynamical bias correction method is described in [8] and is based upon aggregating observations within a temporal window and adjusting the satellite products to an accurate reference product. The method uses ICOADS (from 1982 to 1991) and (A)ATSR data (from 1991 to 2009) as to produce daily reference fields against which, the Pathfinder observations are corrected.

5. REPROCESSING SETUP

The DMI_OI reprocessing system is described in detail in [8, 9] and the reader is referred to these publications for further details. Fig. 2 shows a schematic of the processing system, including the preprocessing, the bias correction, the Optimal Interpolation and the output SST and associated error fields.

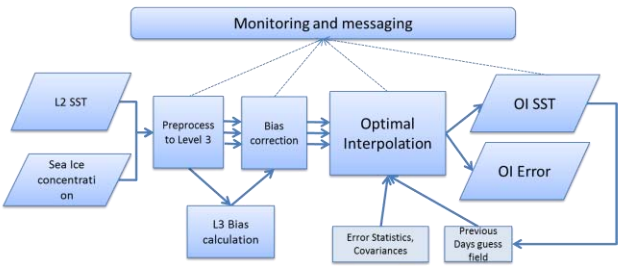


Figure 2. Schematic diagram of the DMI-OI reprocessing chain at DMI

Tab. 1 gives an overview of the grid specification and the region covered in this reanalysis.

Table 1. Details on the DMI_OI SST fields

Characteristics	Value
Spatial resolution	0.05 Degrees lat/lon
Grid	Regular lat/lon
Temporal resolution	Daily
Time span	Jan 1st, 1982 – Jan 1st 2010
Geographical domain	58^{o}N–88^{o}N, 180^{o}W-180^{o}E

6. EXAMPLE OF TIME SERIES

Fig. 3 shows an example of regional timeseries of SST from the Disko Bay area, The Nuuk Area and the Labrador Sea.

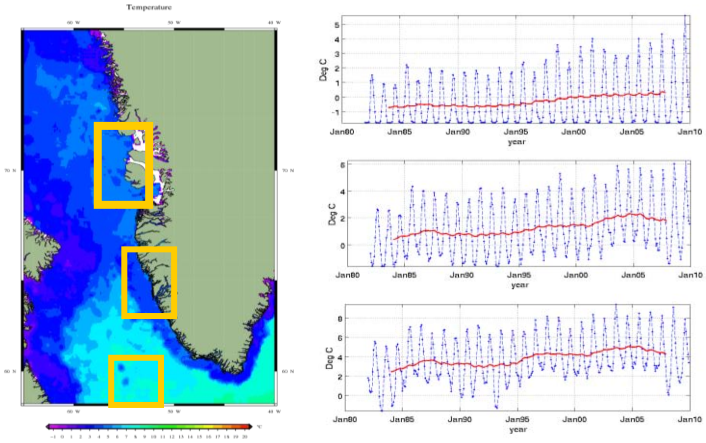


Figure 3.Monthly SST (blue) from the Disko area (upper), Nuuk area (middle) and Labrador Sea (lower). The red lines are smoothed versions of the blue curves.

The figure demonstrates the changes that have occurred over the last 30 years in the regions, with a significant warming of several degrees from 1982 to 2010. The Seasonal ice cover in the Disko Bay area gives a constant winter SST of -1.8^{o}C, whereas the summer temperatures in this region has increased by up to 3^{o}C.

7. VALIDATION OF DATA SET

The quality of the reanalysis has been assessed through a validation of the product against independent in situ observations of sea surface temperature, not included in the reanalysis.

The normal reference network for validating satellite SST products is the observational network of drifting buoy observations. However, ship observation and moored buoys are also available. We therefore decided to include validation statistics from ships and moored buoys, calculated separately. SST observations from ships typically have larger errors than traditional drifting buoy observations. This can also be seen in the validation statistics in Fig. 4.

The overall validation of the reanalysis is seen in Fig. 4 showing biases within 0.1^{o}C and standard deviations of the differences of about 0.6^{o}C, when compared to drifting and moored buoys, whereas the ship observations have larger bias and standard deviations.

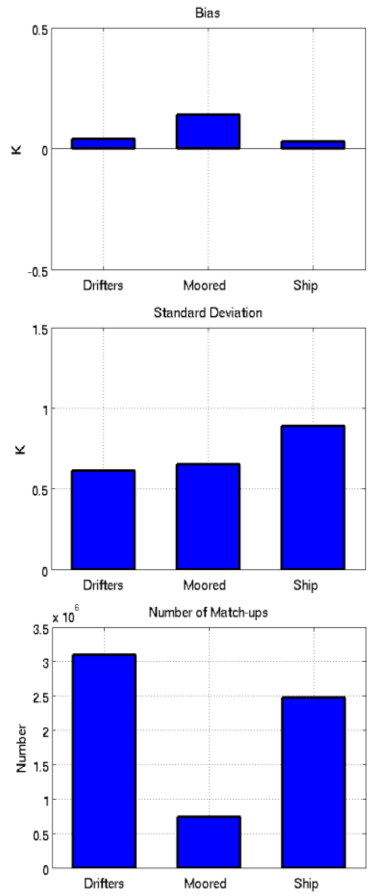
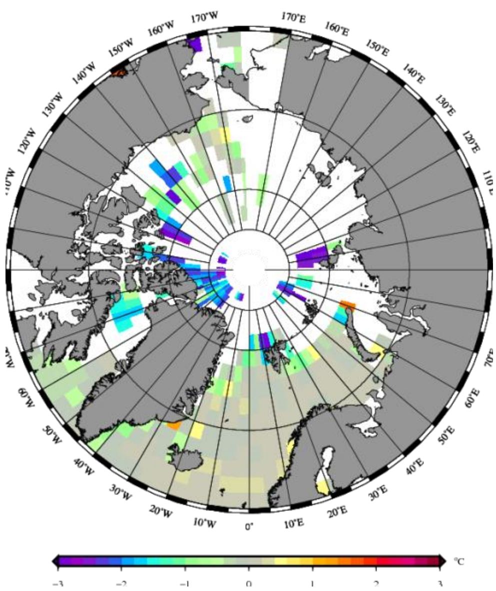
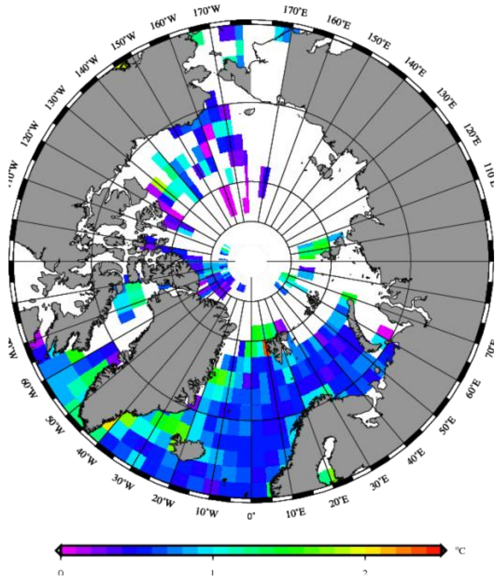


Figure 4. Bias (top), Standard deviation (middle) and Number of Matchups for the full time series from 1982 to 2010. The statistics is derived using in situ observations not included in the analysis (In situ – satellite)

The spatial validation results, shown in Fig. 5, demonstrate that the biases are relatively uniform throughout the Arctic. Exceptions are very close to the ice in the Marginal Ice zone, where there is a tendency for a cold bias of up to 0.5^{o}C.





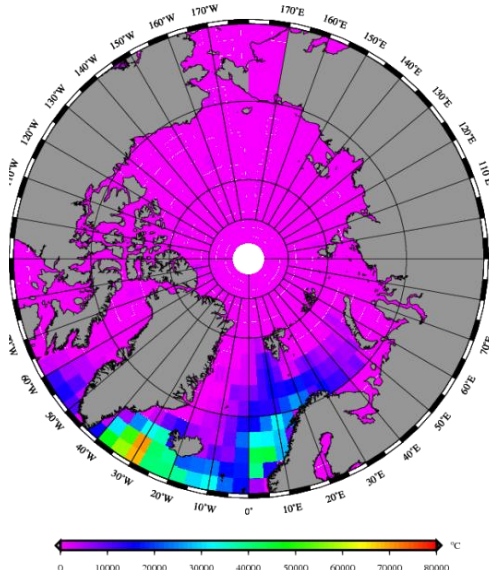


Figure 5: Spatial bias (top), standard deviation (middle) and Number of in situ – satellite match-ups (bottom) for bins of 4 degree longitude and 2 degrees latitude

Similarly, the standard deviation results are also spatially uniform, with enhanced standard deviations in the Marginal Ice Zone associated with the East and West Greenland Current. Note that the statistics from the region north of Greenland is based upon very few matchups and the numbers are therefore not as reliable as the well sampled areas in the Nordic Seas.

The validation statistics from 1982 to 2010 (Fig. 6) show a stable performance when the product is compared against moored and drifting buoy

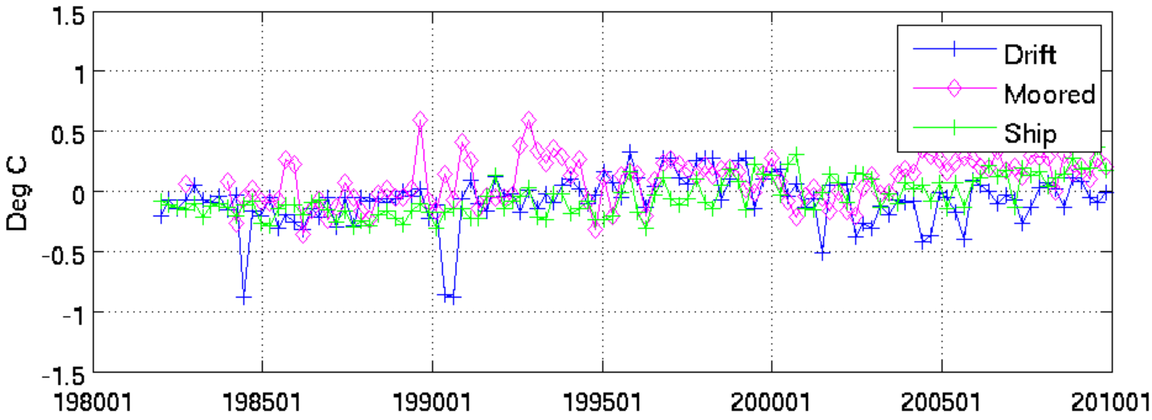


Figure 6 Bias (satellite – in situ) of the L4 time series, from 1982 to 2010 for the three types of in situ observations: drifting buoys, moored buoys and ship observations.

observations with typical seasonal biases within 0.2 °C. Note that the number of in situ observations available for validation is very low in the beginning of the record and much larger by the end of the record. This is especially true for the drifting and moored buoy observations and thus the yearly validation statistics is less reliable in the beginning of the period.

8. CONCLUSIONS

Daily SST level 4 fields have been constructed from 1982-2010 for the Arctic region. The algorithm used to construct the SST fields has been developed with a specific focus on Arctic SST obsevations, which is also reflected in the validation of the data set. Comparison against in situ observations not included in the L4 analysis showed very small biases < 0.1 °C and standard deviations ~0.6 °C with small temporal variations. In addition, the spatial patterns of bias and standard deviations showed a uniform performance throughout the region except within the Marginal Ice Zone, where elevated standard deviations and negative biases are present. From the results above, we can therefore conclude that a robust Arctic SST reanalysis has been reconstructed, which can be used for climate change studies by itself or in combination with numerical ocean and atmospheric models.

9. REFERENCES

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