HadISST1 and the Reynolds et al. analysis

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Abstract

We discuss the SST and sea ice fields used in ERA40 (from HadISST1 and the NOAA 2DVAR), concentrating on the following aspects: sea ice fields, SST in the marginal ice zone, including comparisons with independent data, and how smooth is the transition between the two analyses used? A comment is made about the NOAA analysis and how it relates to the widely used OI.v2 (Reynolds et al., 2002). We focus on these elements as they have proved problematic in previous projects.

1. Introduction

SST and sea ice fields for ERA40 were taken from two data sets: HadISST1 (Met Office Hadley Centre, UK) and 2DVAR (NOAA/NCEP, USA). These data sets comprised fields of SST and sea ice on a 1° area resolution. To ensure a smooth transition at their boundary, both analyses used the same sea ice analysis and the same method of specifying SST in partially ice-covered grid boxes. HadISST1 is monthly and the 2DVAR is weekly, but both data sets were interpolated to dailies. HadISST1 was used through November 1981 and 2DVAR thereafter. It was found that no special processing was necessary to remove discontinuities prior to their use, unlike in previous projects using other data sets, so these two new data sets appear to fit together well.

Previously, adjustments were necessary between data sets to cope with differences in analysis approach. Figure 1 illustrates the zonal average SST anomaly from the amalgamated data set (created from the GISST2.2 (Rayner et al., 1996) and Reynolds and Smith (1994) OI data sets) used to force the AMIP-II integrations. Large discontinuities can be seen at the end of 1981 in the northern-most latitudes and in the

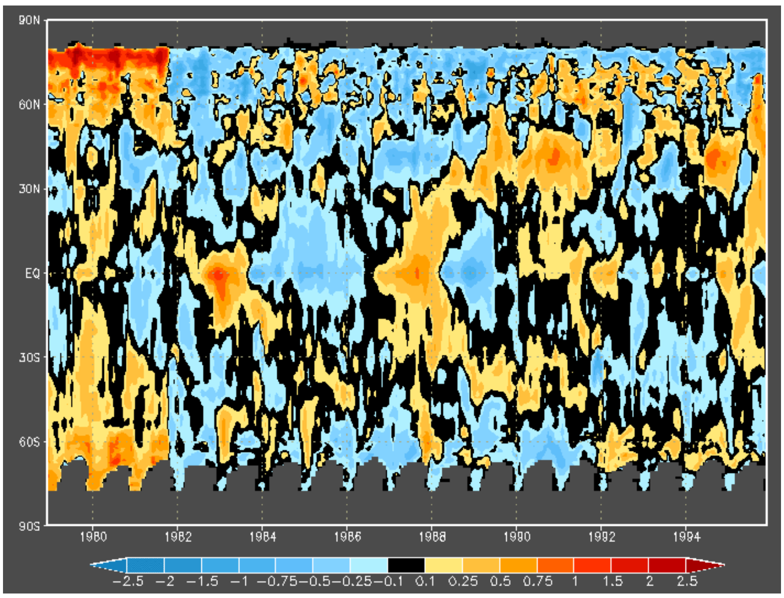

Figure 1 Zonal average SST anomaly (°C). GISST2.2 through Nov 1981, NCEP OI thereafter (courtesy Mike Fiorino, PCMDI (see http://www-pcmdi.llnl.gov/amip)).

Southern Ocean. Figure 2 shows the bias between these two data sets over a few years either side of the boundary at the end of 1981. GISST2.2 is generally warmer at high latitudes because the Reynolds and Smith analysis set SST to –1.8°C in grid boxes with sea ice concentration of at least 50%, whereas GISST2.2 used a seasonally and geographically-varying relationship between SST and sea ice concentration. There were also problems with discontinuities in their sea ice extent time series (not shown). For ERA40, data providers were asked to make the transition between their data sets as seamless as possible so as to avoid spurious "jumps" between the forcing data sets. To this end, a working group was set up to create a common sea ice data set and a common method of specifying SST in grid boxes with partial sea ice cover was agreed.

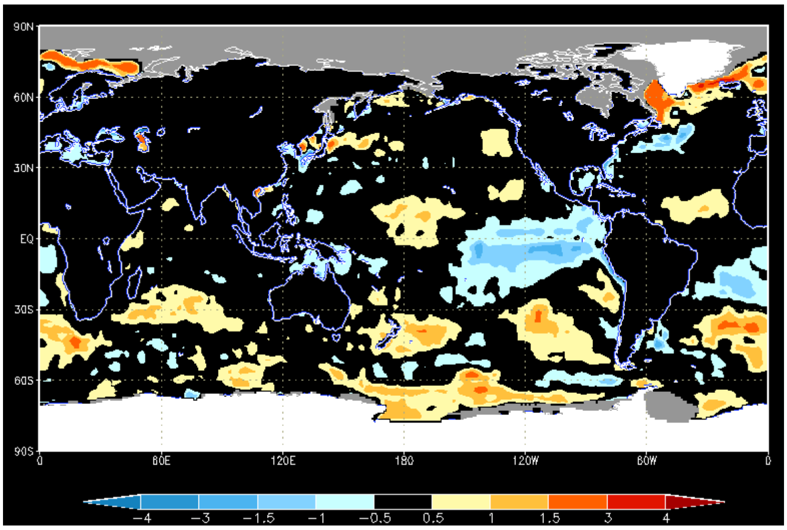

Figure 2. GISST2.2 (1978-81 avg.) - NCEP OI (1982-84 avg.), January (courtesy Mike Fiorino, PCMDI (see http://www-pcmdi.llnl.gov/amip)).

Here we outline these efforts and demonstrate that the new data sets (HadISST1 and the 2DVAR) have smaller discontinuities between them than did earlier data sets. Details of the improved analysis methods can be found in Rayner et al, 2002 and Reynolds et al, 2002 respectively.

2. Sea ice analysis

Available sea ice data are heterogeneous, because sea ice has been observed using a variety of methods and in very different levels of detail through the historical record. Although many data sets may provide an approximately homogeneous record of sea ice extent, i.e. the total size of the region at least partly covered by sea ice, the important parameter from the perspective of forcing a climate model is the variation in sea ice concentration, i.e. the relative fraction of sea ice in each grid box. This is more likely to be heterogeneous. Satellite-borne passive microwave retrievals of sea ice concentration are not consistent with fields derived from digitized charts. The satellite-based data give a detailed picture of concentration variations within the ice edge in winter, but have problems in the summer (especially in the Arctic) through the effect of surface melting on the passive microwave retrievals. The chart-based data are detailed in areas of operational interest, but contain less information about the inner ice pack. So these heterogeneous records must be manipulated to provide a self-consistent history of observed sea ice concentration without unrealistic trends or discontinuities. This was done in collaboration with a group of international experts brought together by ECMWF to produce a homogenized sea ice data set for input to ERA40. Because of time constraints, it was necessary to adopt compromises to produce a workable (but inevitably still imperfect) data set.

For the most part sea ice extents were left as in the input data sets. To the best of our knowledge, we used all the hemispheric-scale digitized information readily available at the time; chart-derived data from Walsh and

Chapman (2001) and the National Ice Center (Knight, 1984) and satellite-borne passive microwave data from NASA Goddard (Cavalieri et al., 1997), the Bristol algorithm data set (Hanna and Bamber, 2001) and the operational fields from NCEP (Grumbine, 1996). Prior to 1973 in the Southern Hemisphere, we had no access to interannually-varying data, so relied upon a climatology found in a Russian hydrographic Atlas for 1947-62 (Tolstikov, 1966). Between 1962 and the start of monthly-varying data in 1973, we linearly interpolated the anomaly fields. Additional data have become available for the Northern Hemisphere since the data set was created and some still reside in historical archives.

The lower curve in Figure 3 for the Northern Hemisphere illustrates the problem associated with following a chart-derived data set from Walsh with a passive microwave-derived data set from Cavalieri et al. There is an obvious discontinuity in the July time series which results from depressed concentrations retrieved using the passive microwave instrument through the effects of melting on the surface of the sea ice. The winter time series appears consistent, but notice the generally higher extents in the National Ice Center chart data. We corrected for the effect of surface melt on the passive microwave-derived data sets and added this corrected variability to the Walsh data set, because it has 100% ice poleward of the marginal ice zone and we wanted to parameterise the effects of open areas of water in the ice pack. Figure 3 also shows the result, here HadISST1. The jump in the summer time series has been removed without removing the overall downward trend in the sea ice area. The wintertime curve is much the same, with the additional area coming from the inclusion of a Caspian Sea climatology. Note that the extent of the GSFC data has not been changed which explains why the change in area is modest and nowhere near the area of the NIC fields.

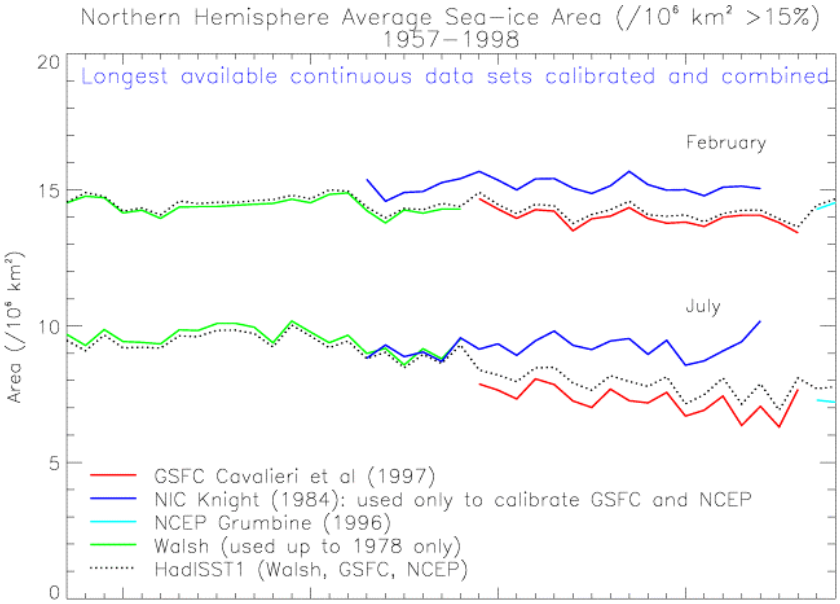

Figure 3 Northern Hemisphere average sea ice area ($10^6 km^2$), 1957-98

In the Southern Hemisphere (Figure 4), the differences between the data sets are greatest in the winter. Here, the ice retreats to the coast in many places in summer and ponding on top of the ice is an issue in relatively few places. It is known that this version of the Goddard data set contained generally low concentrations in the Southern Hemisphere and since we assembled the data set, a new algorithm has been produced. However, at the time, we only had this data set, so we used the Bristol algorithm data set to adjust it. These data agreed closely with the NCEP fields that were to update the analyses and are found to agree well with *in situ* measurements. We used these corrected fields to reduce the NIC concentrations which were assessed as being too high. In Figure 4, we can see that the HadISST1 curve tracks the Bristol time series and is about halfway between the GSFC and NIC curves in the winter month.

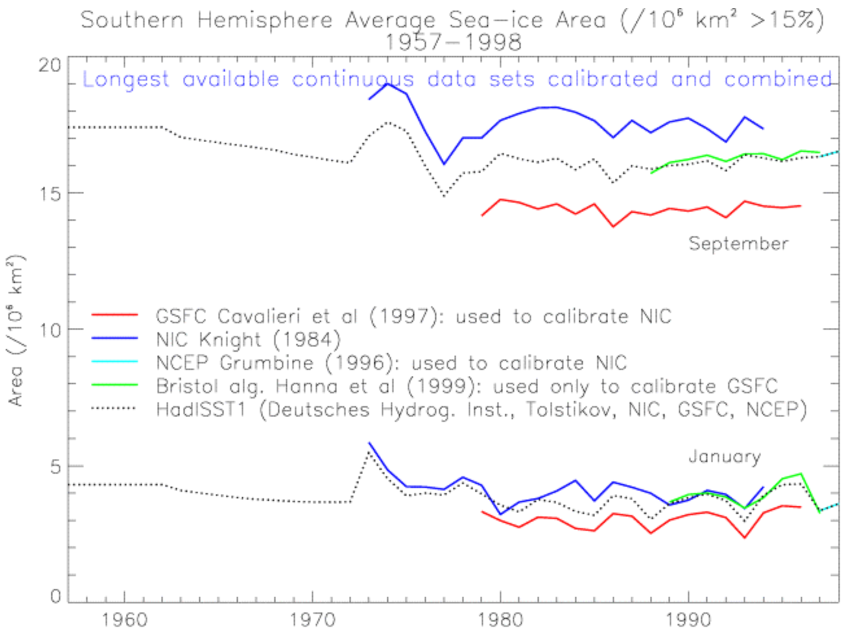

Figure 4 Southern Hemisphere average sea ice area ($10^6 km^2$), 1957-98

3. SST in the Marginal Ice Zone

SST values in partially ice-covered grid boxes were specified using sea ice concentration. Monthly- and geographically-varying relationships between SST (in situ and bias-adjusted AVHRR) and sea ice concentration were developed using coincident pairs of data. Separate relationships for each calendar month were developed using 12 overlapping 3-month seasons. Hemispheres were split into 360 31°-longitude sectors; peripheral regions were separated from areas of contiguous sea ice coverage. Relationships of the following form were fit to the data in a least squares sense:

$$SST = a\,(ICE)^2 + b\,(ICE) + c\ ,$$

where

$$-1.8°C = a\,(0.9)^2 + b\,(0.9) + c$$

(in the Laurentian Great Lakes this was set = 0°C).

If fewer than 100 data pairs were available, coefficients were linearly interpolated from neighbouring sectors or months. SST was specified using the relationship centred on the target longitude and the sea ice concentration in the target grid box.

Figures 5 and 6 show the results of this process in the Arctic and compare our SST fields against those of the Global Digital Environment Model (GDEM) climatology (Teague et al., 1990). The fields are very similar in January, as would be expected when the sea ice cover is extensive. The SST in HadISST1 to the east of Svalbard appears to follow the shape of the sea ice edge better than in the GDEM, so it is more likely to be the GDEM which is in error here. The differences between the fields are more extensive in July. Baffin Bay appears to be a particularly difficult area where the SST differences are rather large. The GDEM could be based on very few data here, so it is hard to tell which is right. There is some indication that our sea ice corrections may have led to SST biased cold in the Canadian Archipelago, but this requires further investigation.

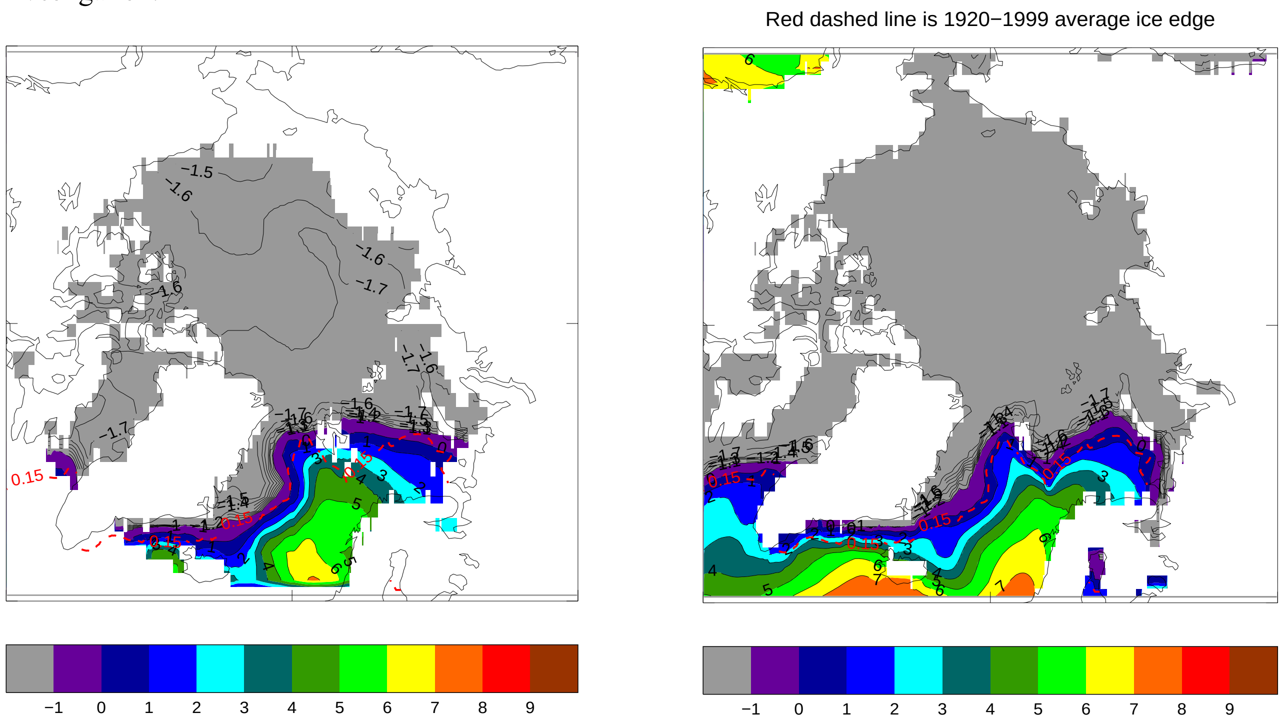

*Figure 5 Arctic SST (°C) climatology, 1900-1998, January. Left: GDEM, right: HadISST1 (here a combination of open water SST and –1.8˚C*fraction of sea ice in each grid box)*

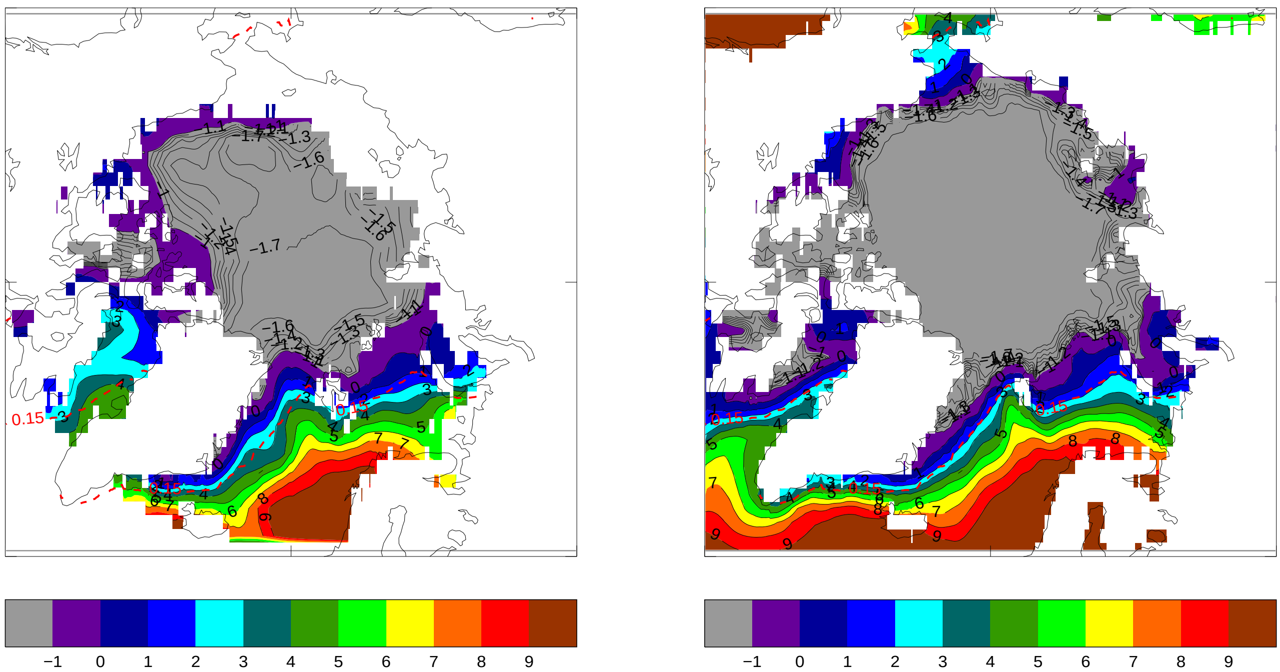

*Figure 6 Arctic SST (°C) climatology, 1900-1998, July. Left: GDEM, right: HadISST1 (here a combination of open water SST and –1.8˚C*fraction of sea ice in each grid box)*

4. Homogeneity of SST and sea ice fields

Figures 7-9 (Fiorino, 2001) demonstrate that the SST and sea ice fields from HadISST1 and the 2DVAR are sufficiently homogeneous to use in ERA40 without the need for bias-adjustments of the kind used for AMIP-II. Figure 7 shows zonal average SST within partially ice-covered grid boxes. The agreement is generally good across the boundary between HadISST1 and the 2DVAR, but winter SSTs in the Southern Hemisphere are colder in the 2DVAR. This could be a result of this analysis being a weekly mean and HadISST1 being a monthly mean. There are no obvious discontinuities in the SST fields away from sea ice (Figure 8). The percentage of open water in grid boxes with partial sea ice cover is also quite consistent in the two data sets (Figure 9) and not outside the general variability.

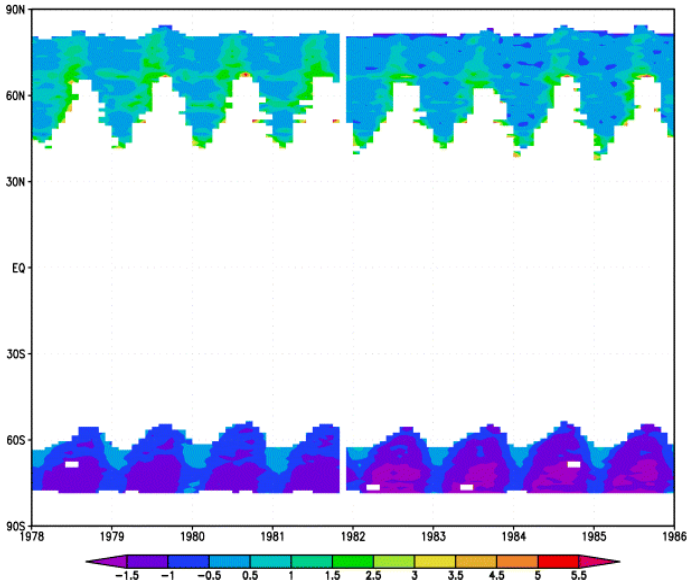

Figure 7 ERA40 SST (˚C) where sea ice conc. > 10% and < 80% (Fiorino, 2001)

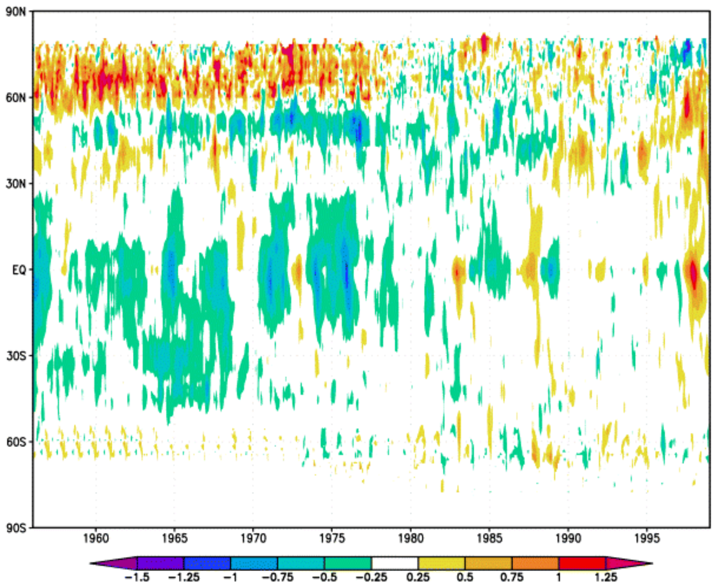

Figure 8 ERA40 SST anomaly (°C, relative to 1982-98) away from sea ice (Fiorino, 2001).

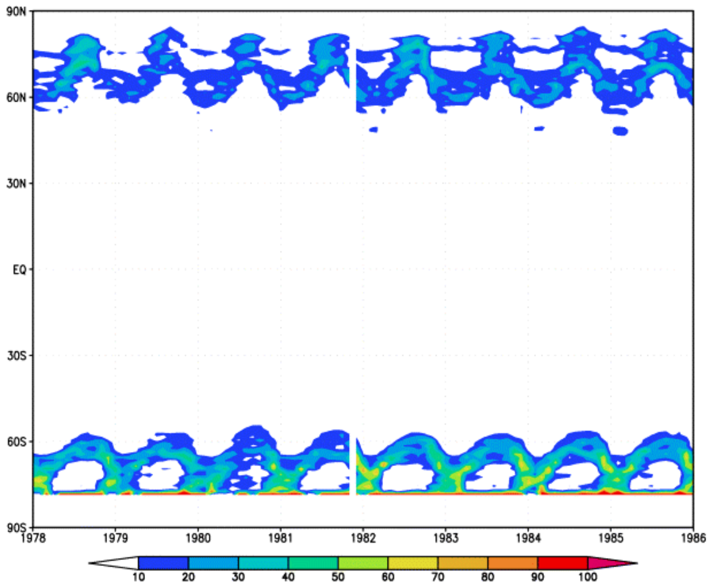

Figure 9Percentage of open water where sea ice conc. > 10% and < 80% in ERA40 lower boundary (Fiorino, 2001).

5. Reynolds et al. analysis

As previously discussed, ERA40 is forced by the NOAA 2DVAR analysis. Since the data were provided to ECMWF, this has been superseded at NOAA by the OI.v2 (Reynolds et al., 2002). Improvements in this analysis are: better correlation structure used in the SST analysis and improved AVHRR bias-correction, especially in the Southern Ocean. The overall difference in SST between the two NOAA analyses is not large (see Figure 10). The ERA40 team have chosen to stay with the 2DVAR.

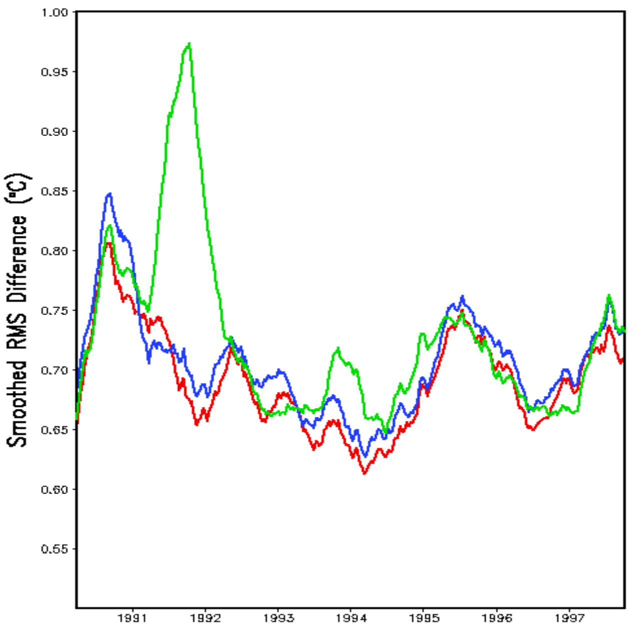

Figure 10 Analysis - buoy SST RMSD (°C) 1990-1997, averaged 65°S-80°N. Red: OI.v2, blue: 2DVAR, green: OI.v2, but without AVHRR bias-correction step (Reynolds et al., 2002).

6. Summary

Sets of SST and sea ice fields have been provided for ERA40 which are more homogeneous across data set boundaries than those used to force previous simulations or reanalyses. The sea ice fields are also internally more homogeneous in time, despite their varied input data.

Acknowledgements

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