Reanalysis needs for observations and analyses of sea surface temperature and sea ice: atmospheric perspective

Climate Change

Adrian Simmons

Consultant, Copernicus Climate Change Service, ECMWF

with acknowledgments to Hans Hersbach, Shoji Hirahara and the C3S reanalysis team

Copernicus Europe's eyes on Earth | European Commission | ECMWF

Reanalysis and data assimilation

Reanalysis applies a ***fixed*** modern data assimilation system to past observations.

The assimilation system blends information from different types of observation and a short "background" model forecast (or forecasts), using estimates of observational and background errors (including biases).

The model carries information from earlier observations forward in time; the model and background-error structures spread information in space and from variable to variable.

Atmospheric reanalyses have a very large number of users, with many different interests and requirements.

New comprehensive reanalyses tend to use a recent version of an assimilation system developed for numerical weather prediction, and the highest affordable resolution.

They typically go back 40-70 years in time, and are continued in close to real time for 5-10 years or more.

Climate Change

Use of SST and sea-ice data by atmospheric reanalysis

Use is usually via independent SST and sea-ice analyses

Differences in SST/sea-ice analysis are a cause of differences between reanalyses

A change in source of SST/sea-ice analysis may introduce discontinuity into a reanalysis

Efforts may be made to use sources that provide consistent values:

- the near-real-time SST/sea-ice analysis used by the parent NWP system is then a constraint
- and the near-real-time SST and sea-ice data may not be analysed by a fixed system

Also:

- quality control may still be needed in the reanalysis system
- there are requirements for accuracy and for temporal and spatial resolution as well as consistency over time
- there is an increasing requirement for temperature and ice analyses for lakes and inland seas

How well do we know the global surface air temperature?

Reanalyses give absolute temperatures

The HadCRUT4 analysis of monthly climate station data gives values relative to 1961-1990

Jones et al. (1999) estimate that the global-mean surface air temperature for 1961-1990 was 14.0^{O}C, “within 0.5^{O}C of the true value”

Average temperatures (^{O}C) for 1981-2010

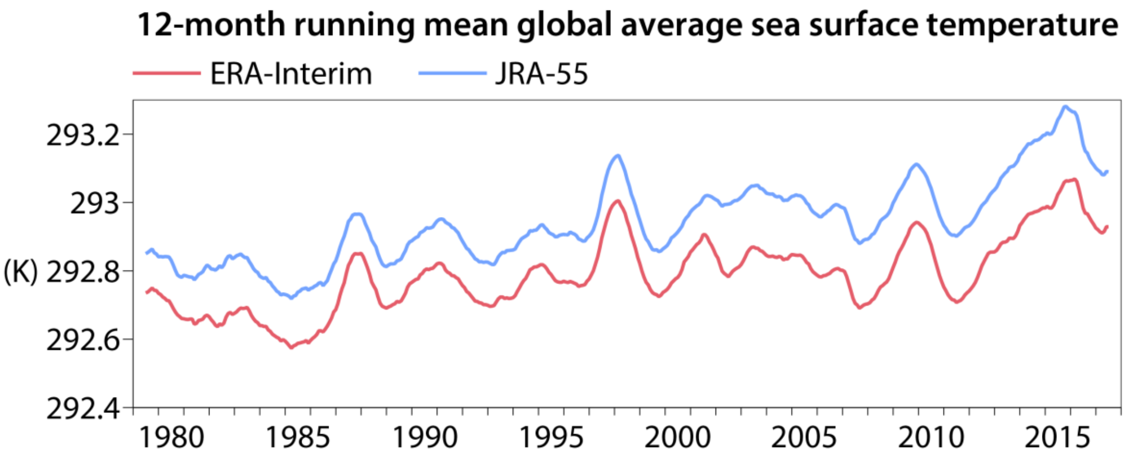
HadCRUT4+14.00	JRA-55	ERA-Interim
14.30	14.32	14.22

Average temperatures (^{O}C) for 1999-2017

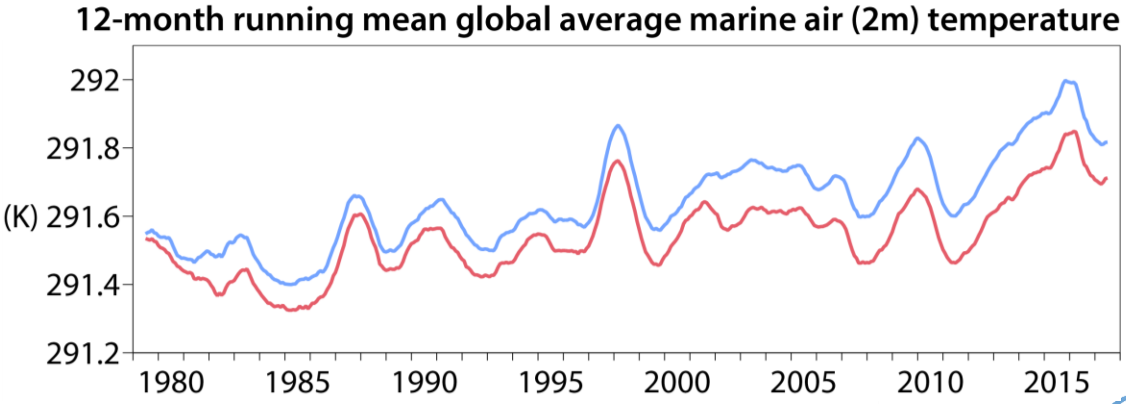
HadCRUT4+14.00	JRA-55	ERA-Interim	ERA5
14.52	14.55	14.47	14.42

Sea surface and marine air temperature analyses

Climate Change



The COBE SST analysis used by JRA-55 is generally warmer than the various SST analyses used by ERA-Interim

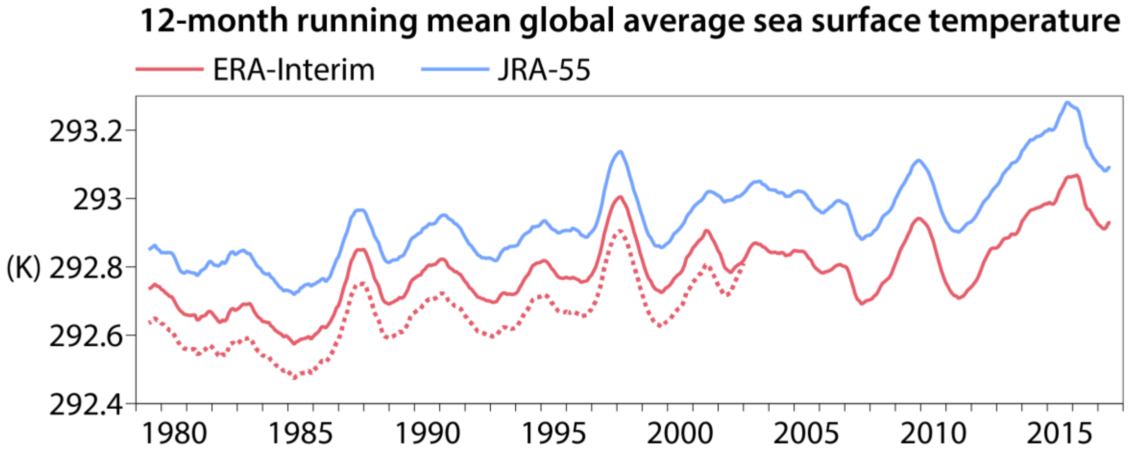


The corresponding background marine surface air temperatures are also warmer in JRA-55 than in ERA-Interim, although the difference is smaller

ECMWF Copernicus Europe's eyes on Earth European Commission

Sea surface temperature analyses

Climate Change



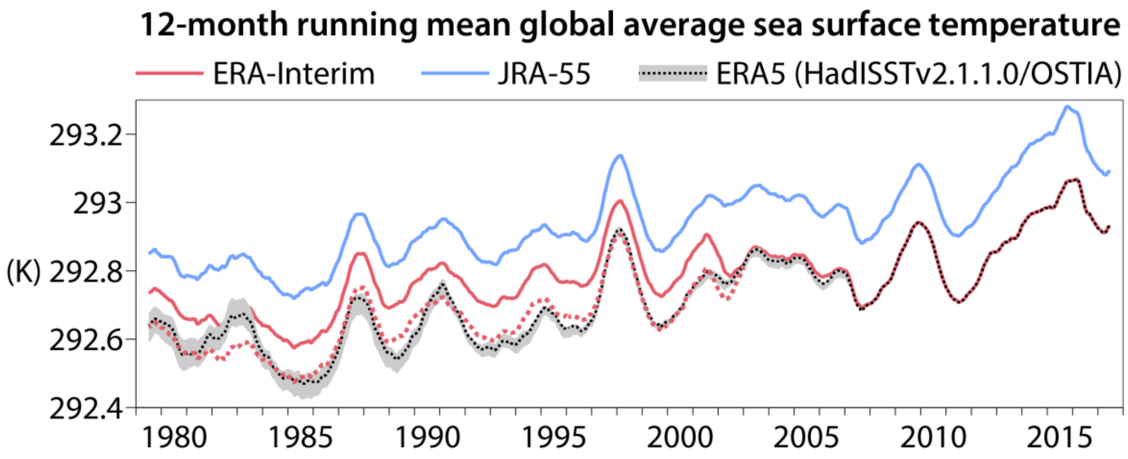
ERA-Interim used several sources of SST analysis. SSTs were consistently cooler by about 0.1°C after 2001, relative to other datasets such as JRA-55.

For monitoring global-mean temperature, ERA-Interim SSTs and the closely related surface air (two-metre) temperatures over sea are reduced by 0.1°C prior to January 2002 (red dotted).

ECMWF Copernicus Europe's eyes on Earth European Commission

Climate Change

Sea surface temperature analyses



ERA-Interim used several sources of SST analysis. SSTs were consistently cooler by about 0.1°C after 2001, relative to other datasets such as JRA-55.

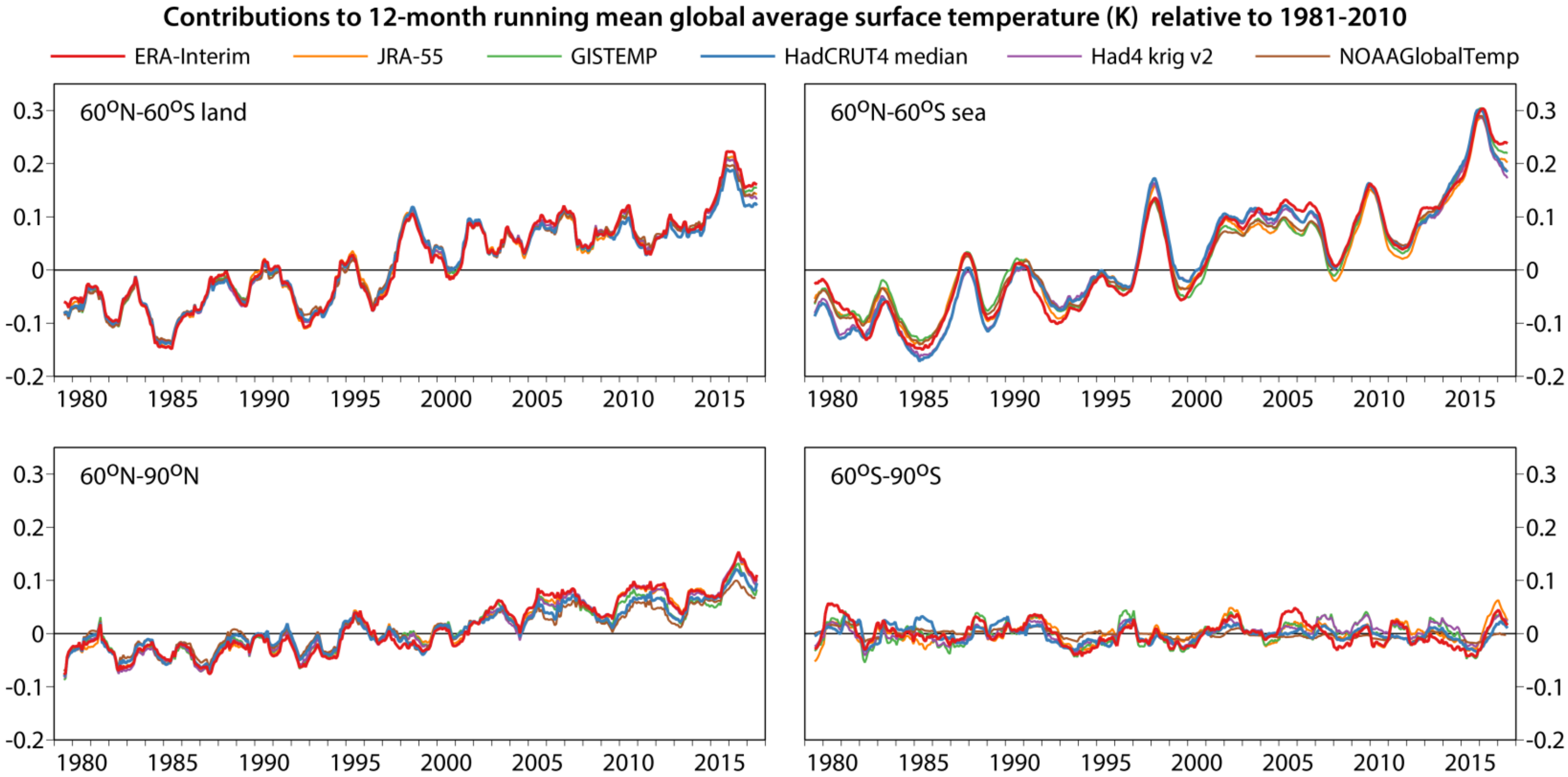
For monitoring global-mean temperature, ERA-Interim SSTs and the closely related surface air (two-metre) temperatures over sea are reduced by 0.1°C prior to January 2002 (red dotted).

The HadISST2 ensemble and OSTIA from September 2007 are being used in ERA5. The ensemble mean and 10-member range of HadISST2 are shown.

ECMWF Copernicus Europe's eyes on Earth European Commission

Contributions to global mean surface air/sea temperature

Climate Change

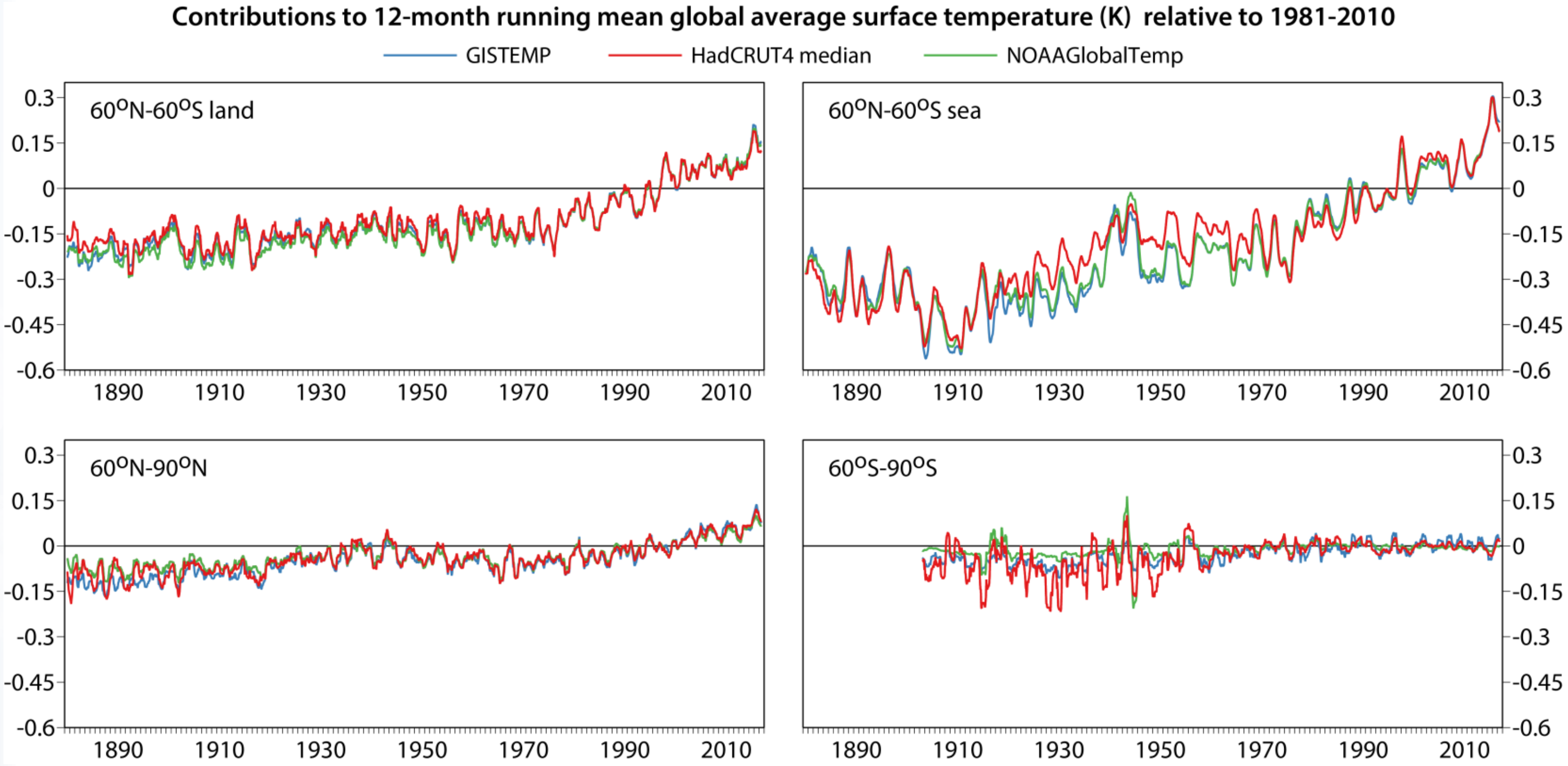


ERA-Interim uses the Met Office's OSTIA from February 2009 onwards; HadCRUT4 uses HadSST3; NOAAGlobalTemp uses ERSSTv4; GISTEMP uses ERSSTv5

ECMWF Copernicus Europe's eyes on Earth European Commission

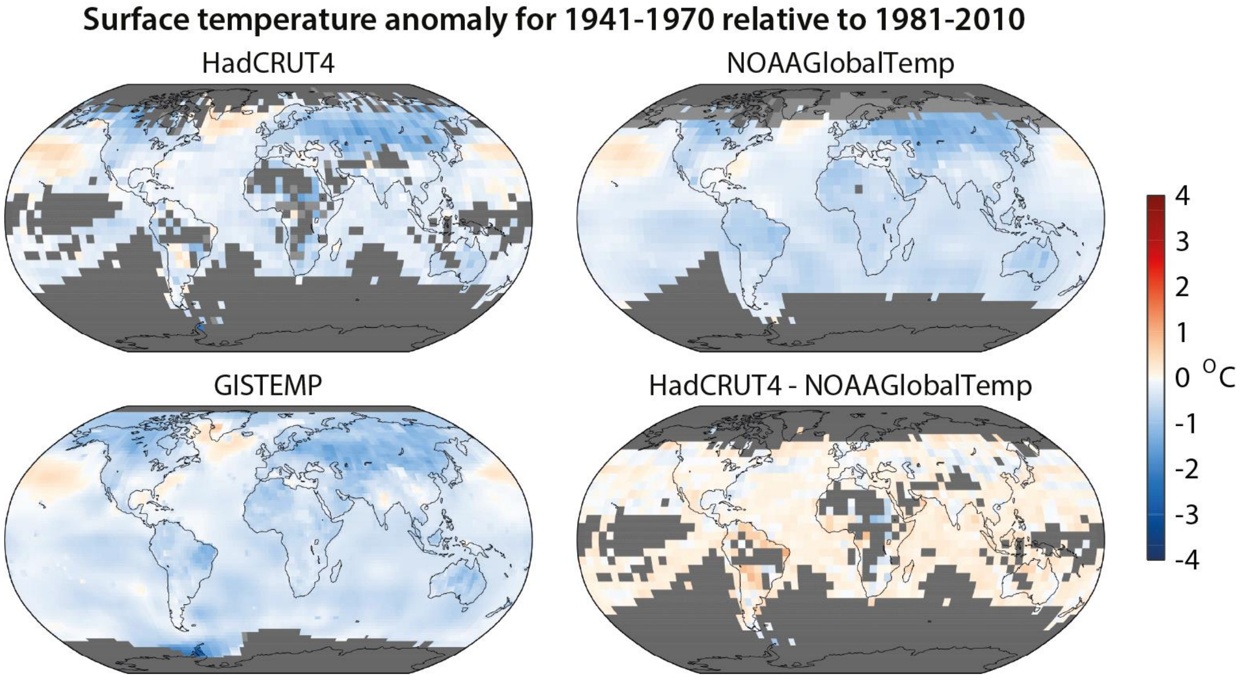
Contributions to global mean surface air/sea temperature

Climate Change



HadCRUT4 uses HadSST3; NOAAGlobalTemp uses ERSSTv4; GISTEMP uses ERSSTv5

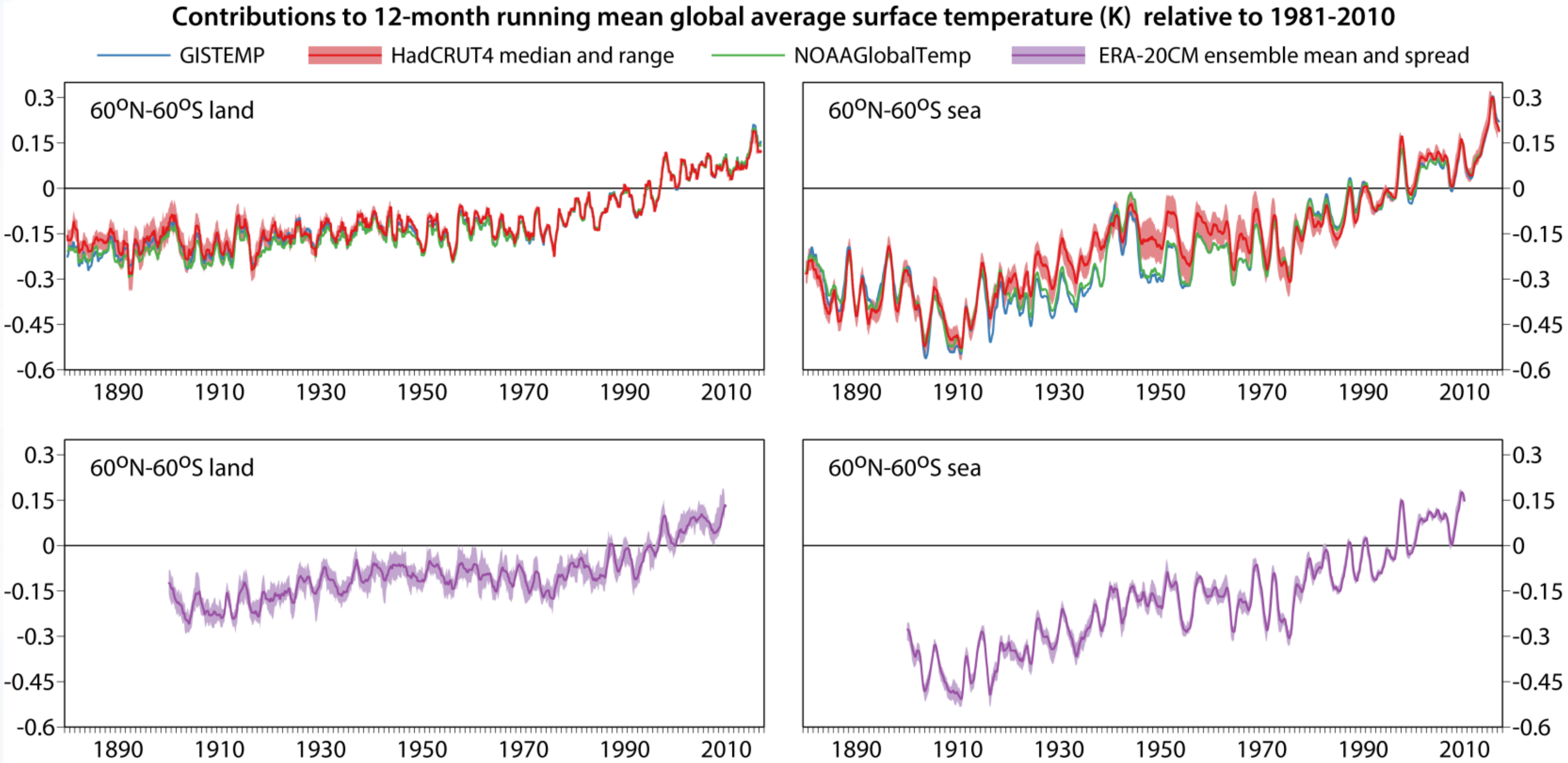
GISTEMP, HadCRUT4 and NOAAGlobalTemp



Mid 20th century SSTs are generally warmer relative to 1981-2010 for HadSST3 as used by HadCRUT4 (and for the COBE SST) than for the ERSST versions used by GISTEMP and NOAAGlobalTemp. This is consistent with differences in the bias adjustment of ship data (Huang *et al.*, 2015).

Contributions to global mean surface air/sea temperature

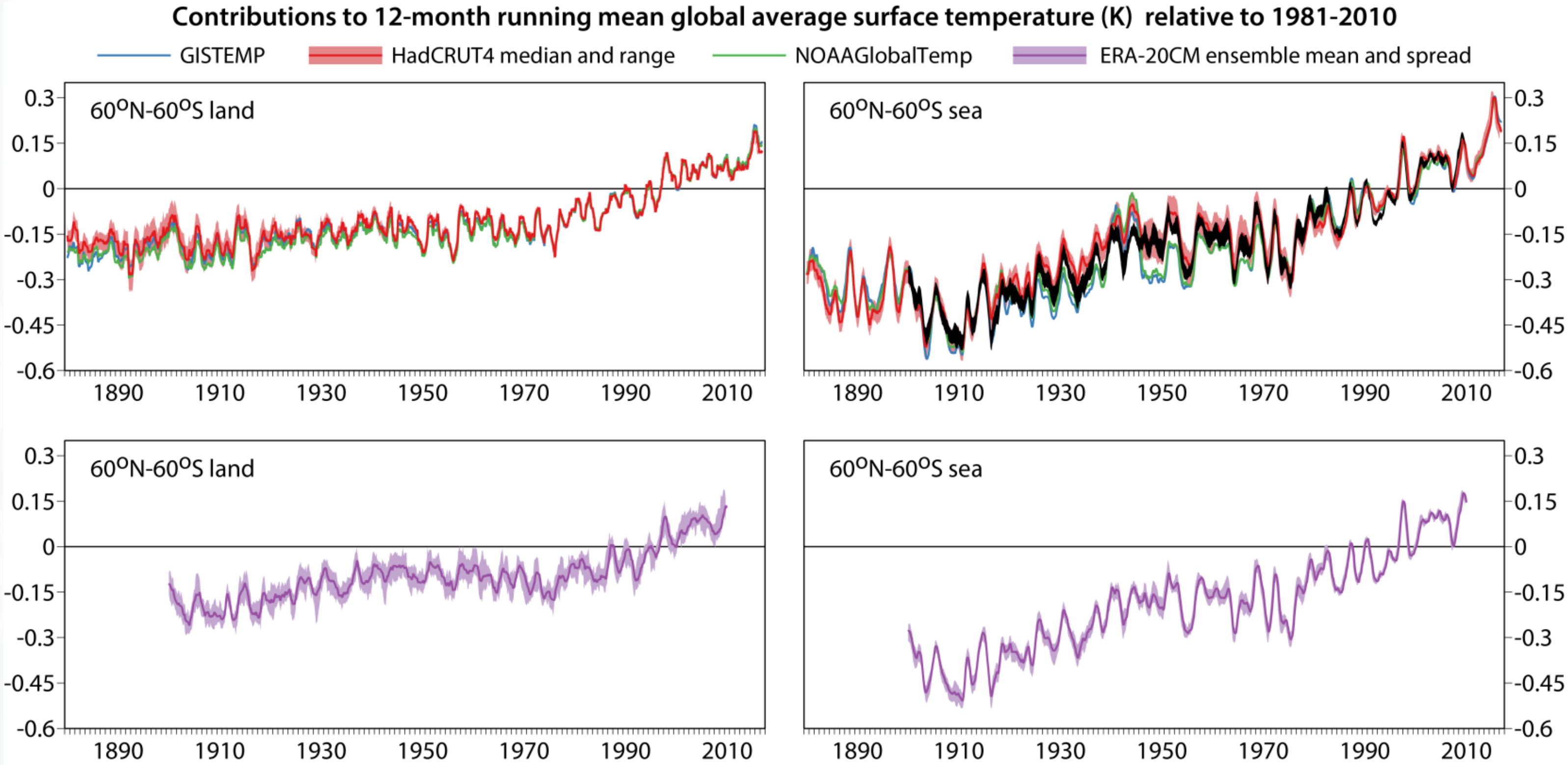
Climate Change



ERA20-CM uses HadISSTv2.1.0.0. Its SST is closer to HadSST3 than to ERSSTv4 or v5

Contributions to global mean surface air/sea temperature

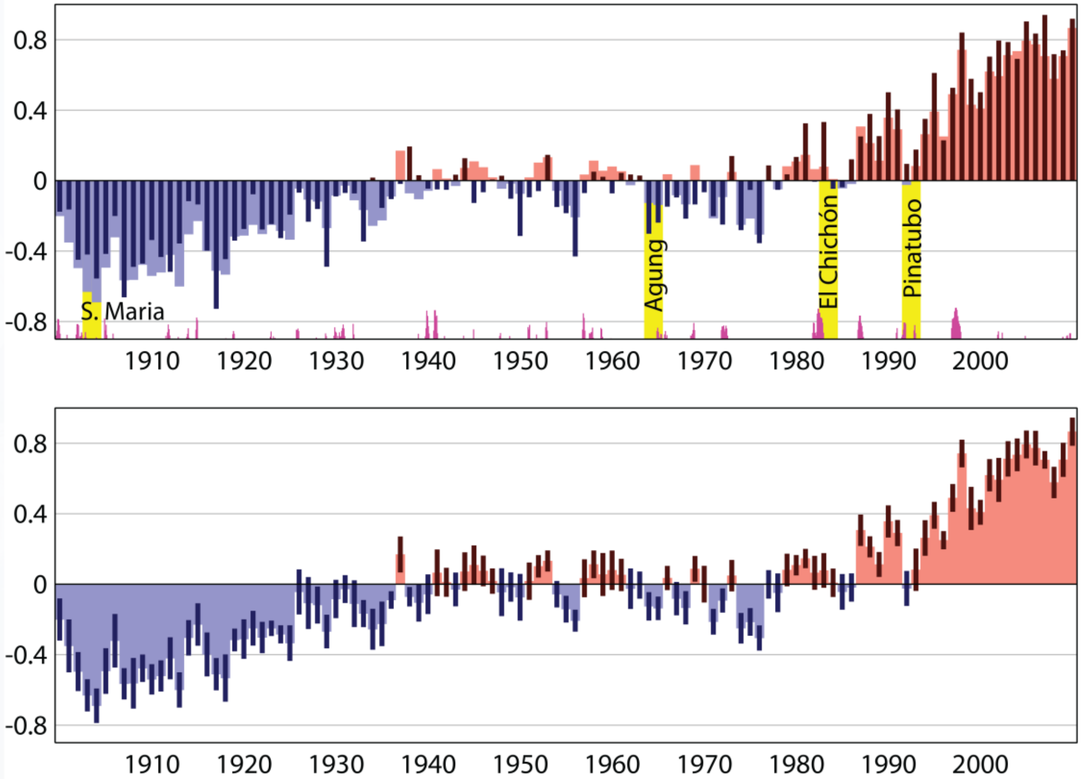
Climate Change



ERA20-CM uses HadISSTv2.1.0.0. Its SST is closer to HadSST3 than to ERSSTv4 or v5

SST and sea ice influence model background over land

Surface air temperature anomalies (^oC) relative to 1961-1990 averaged over all land points where CRUTEM4 provides values



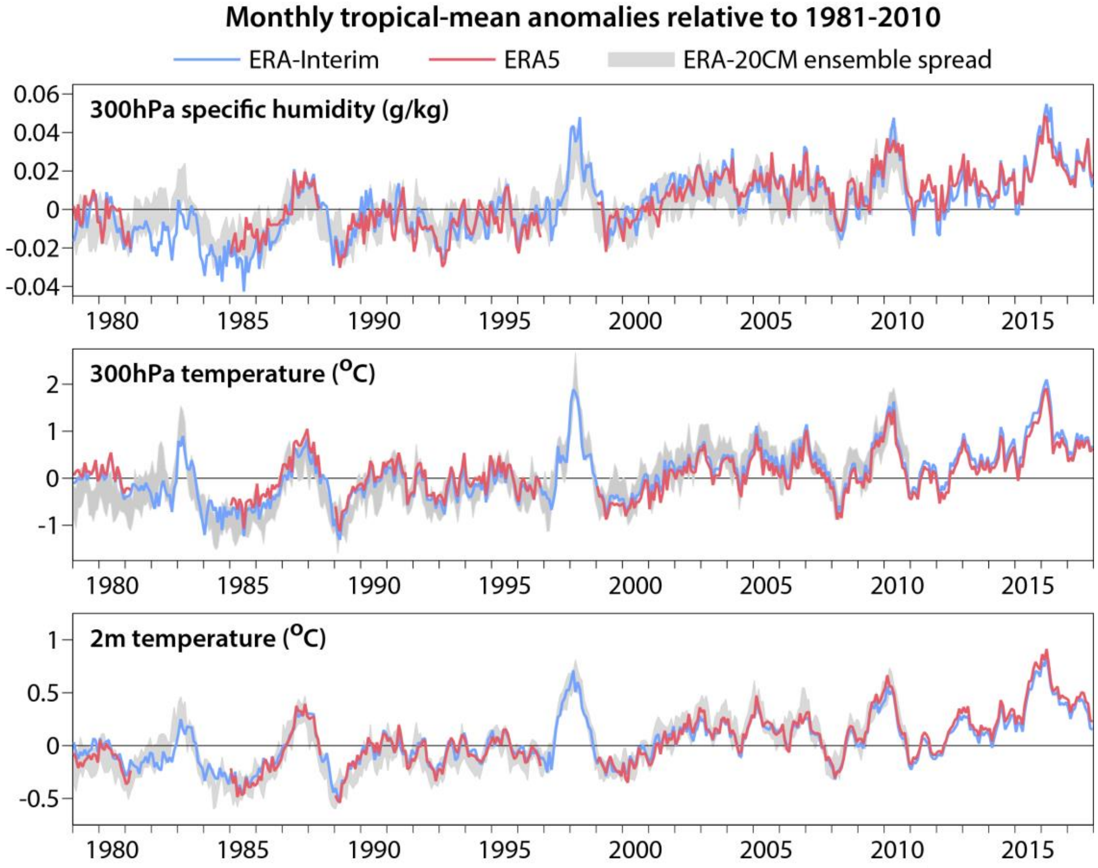
Dark bars show annual CRUTEM4 values

Light bars are the averages of ten ERA-20CM simulations using a recent version of the ECMWF model with CMIP5 forcings and different SST estimates

Dark bars show ± one standard deviation of the values from individual simulations

Upper tropospheric temperature and humidity variability

Climate Change

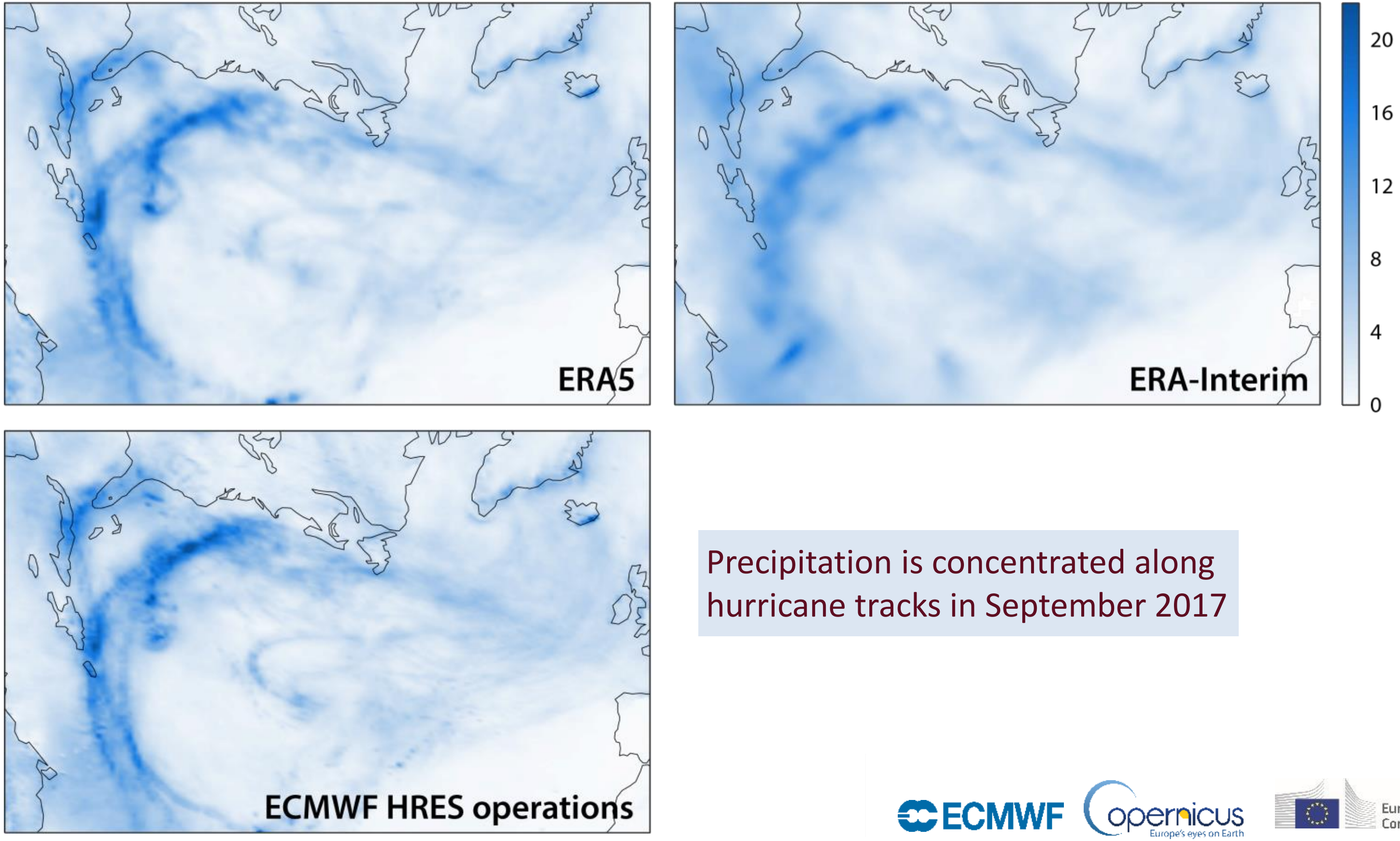


Sea-surface temperature variations are reflected in temperature variations throughout the troposphere, particularly in the tropics, where there is a substantial increase in amplitude as height increases

Climate Change

Impact of SST on evaporation and rainfall

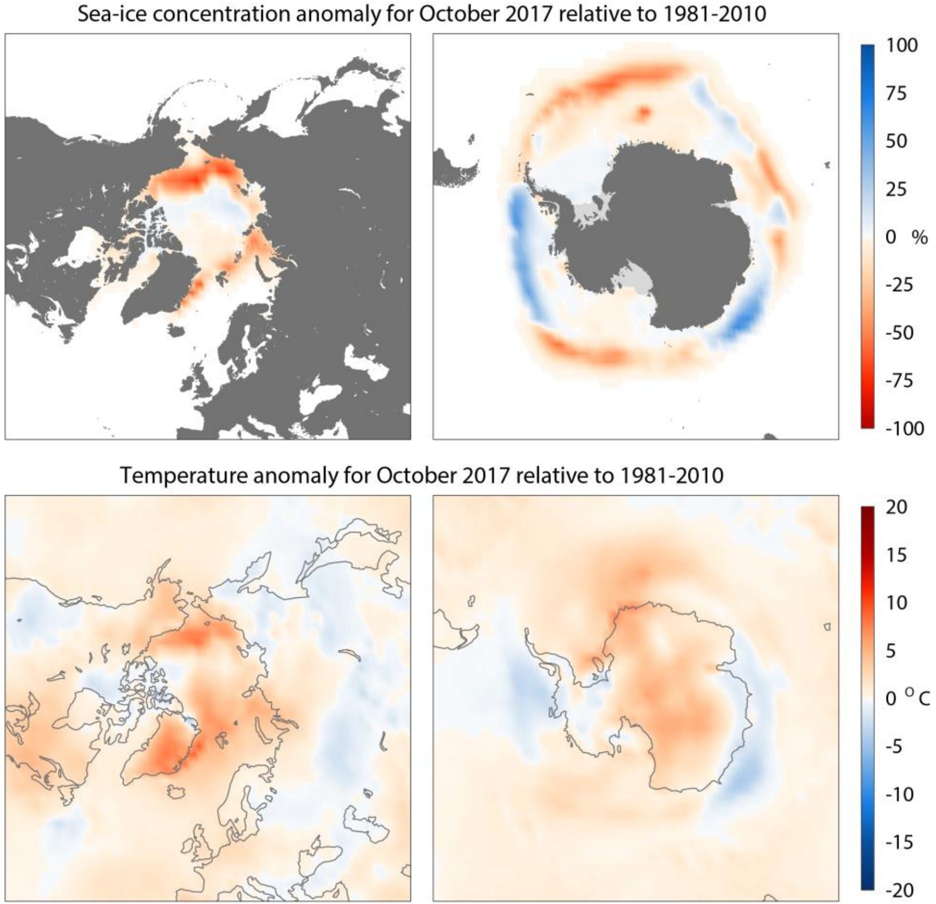
Mean precipitation rate (mm/day) for September 2017



Precipitation is concentrated along hurricane tracks in September 2017

Sea-ice concentration and surface air temperature

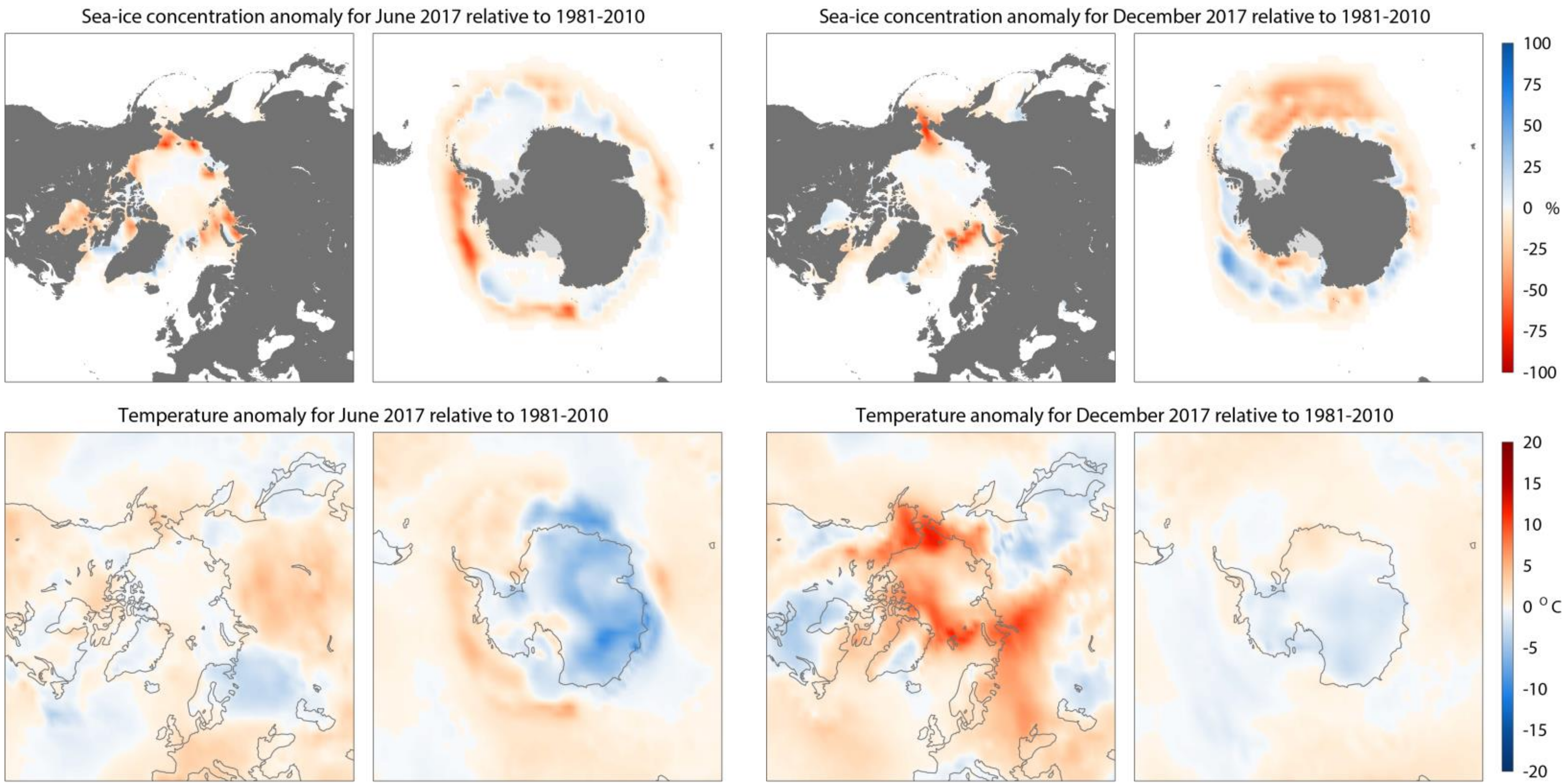
Climate Change



Cold-season anomalies in sea-ice concentration tend to correlate negatively with anomalies in surface air temperature

Sea-ice concentration and surface air temperature

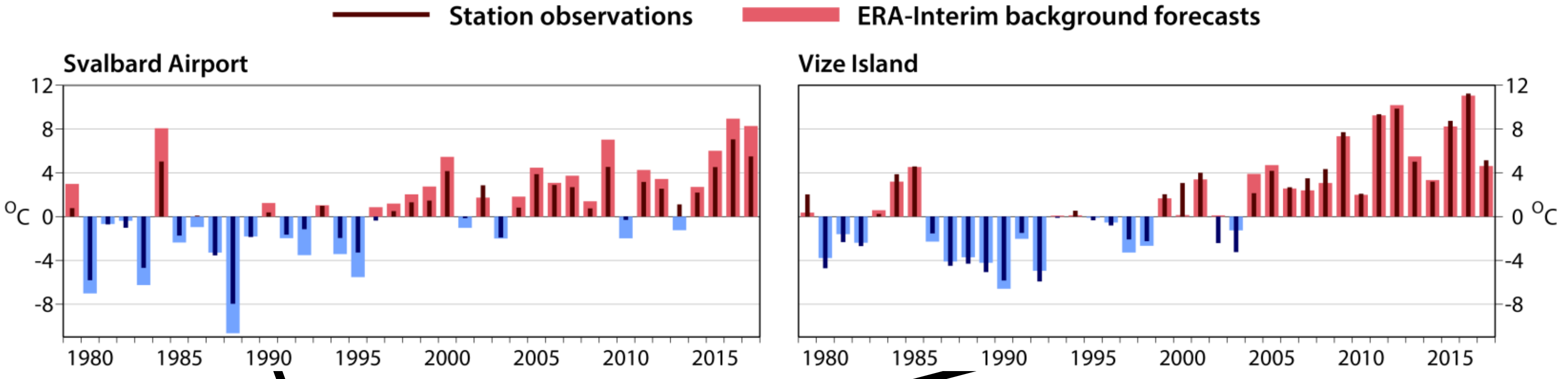
Climate Change

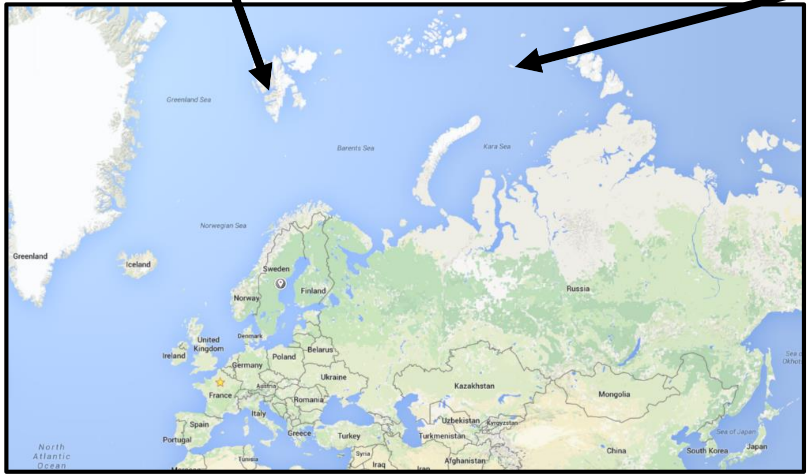


ECMWF Copernicus Europe's eyes on Earth European Commission

Oct-Dec surface air temperature anomalies wrt 1981-2010

Climate Change





Large warm surface air temperature anomalies occur in autumn, winter and spring where sea-ice cover is anomalously low

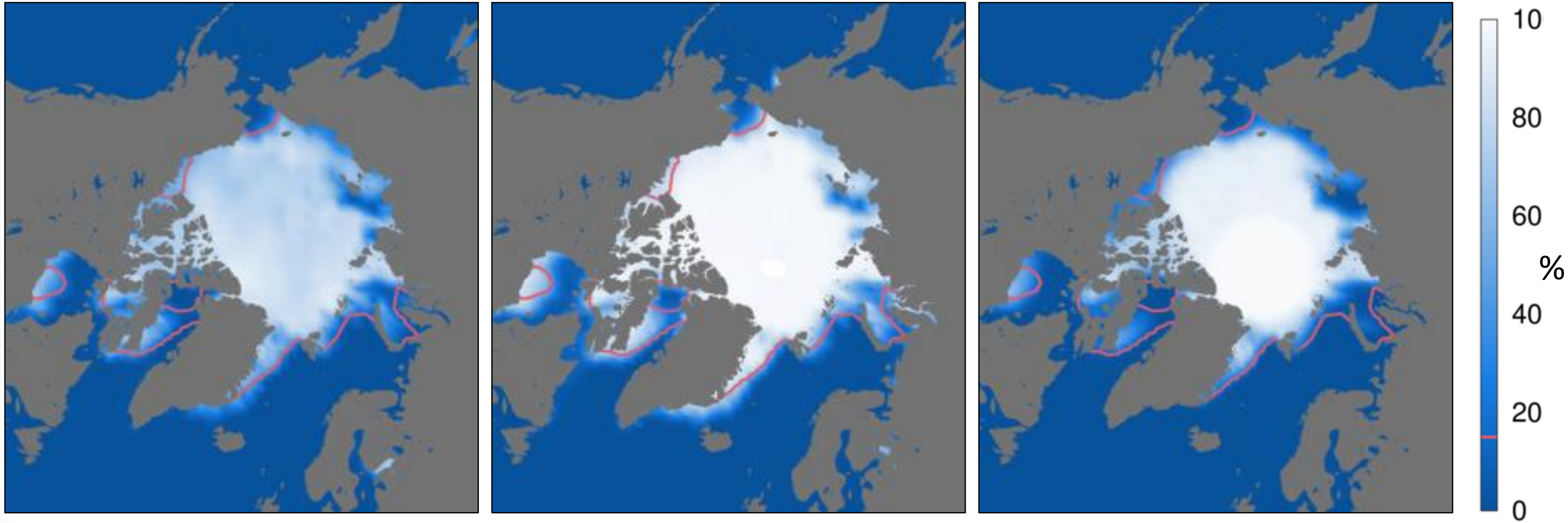
They are quite well captured by ERA-Interim, but values may be subject to error due to limited resolution of coastal and orographic effects

ECMWF | Copernicus Europe's eyes on Earth | European Commission

Climate Change

Mean sea-ice concentration for July 2000

Initial ERA5 production OSI SAF v1 reprocessing	HadISST2	ERA-Interim HadISST1



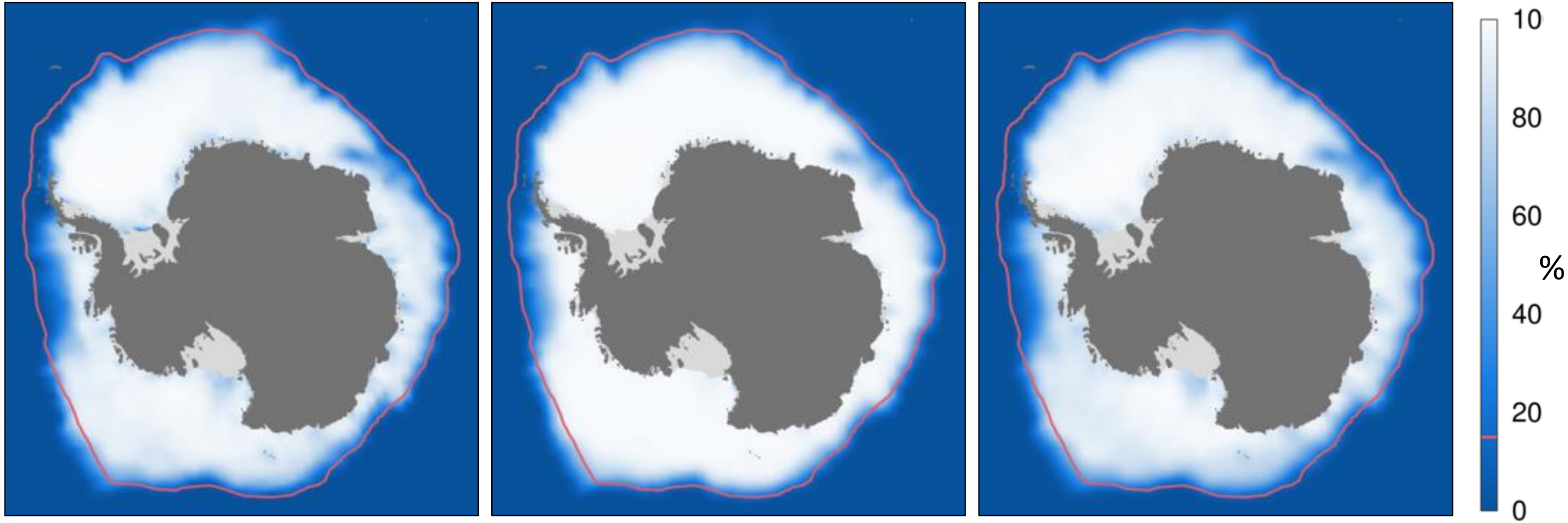
Spurious ice in Gulf of Finland	Spurious ice on Lake Ladoga Concentrations are generally higher than those of OSI SAF product	Set by ECMWF to 100% north of 82.5^{O}N More different in marginal zones than the other two

Red line is 1981-2010 climatological 15% contour from ERA-Interim

Mean sea-ice concentration for July 2000

Climate Change

Initial ERA5 production OSI SAF v1 reprocessing	HadISST2	ERA-Interim HadISST1

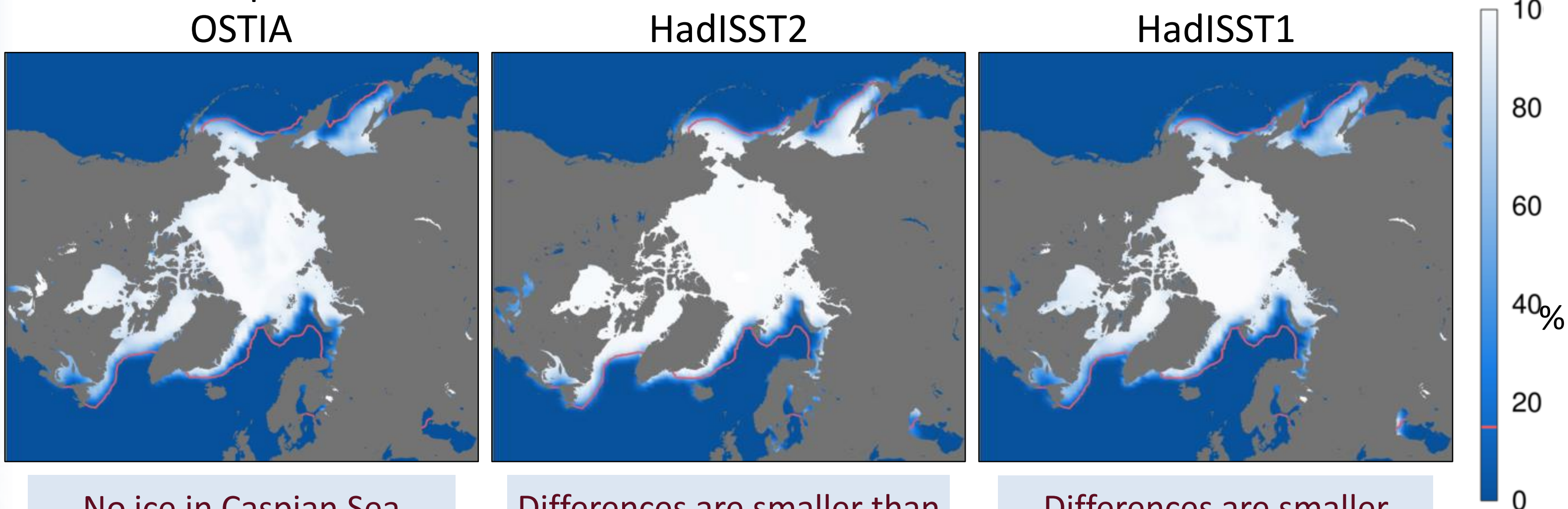


Generally more similar this month than for the Arctic; concentrations are a little higher in HadISST2

Mean sea-ice concentration for February 2008

Climate Change

Initial ERA5 production OSTIA	HadISST2	ERA-Interim HadISST1



No ice in Caspian Sea

High concentrations in Great lakes

Differences are smaller than in summer example

Concentrations tend to be higher in marginal zones

Differences are smaller than in summer example

Concentrations tend to be closer to OSTIA than HadISST2 in marginal zones

Lake values are from modelling in ERA5, and from lagged ERA-40 temperatures in ERA-Interim

ECMWF Copernicus Europe's eyes on Earth European Commission

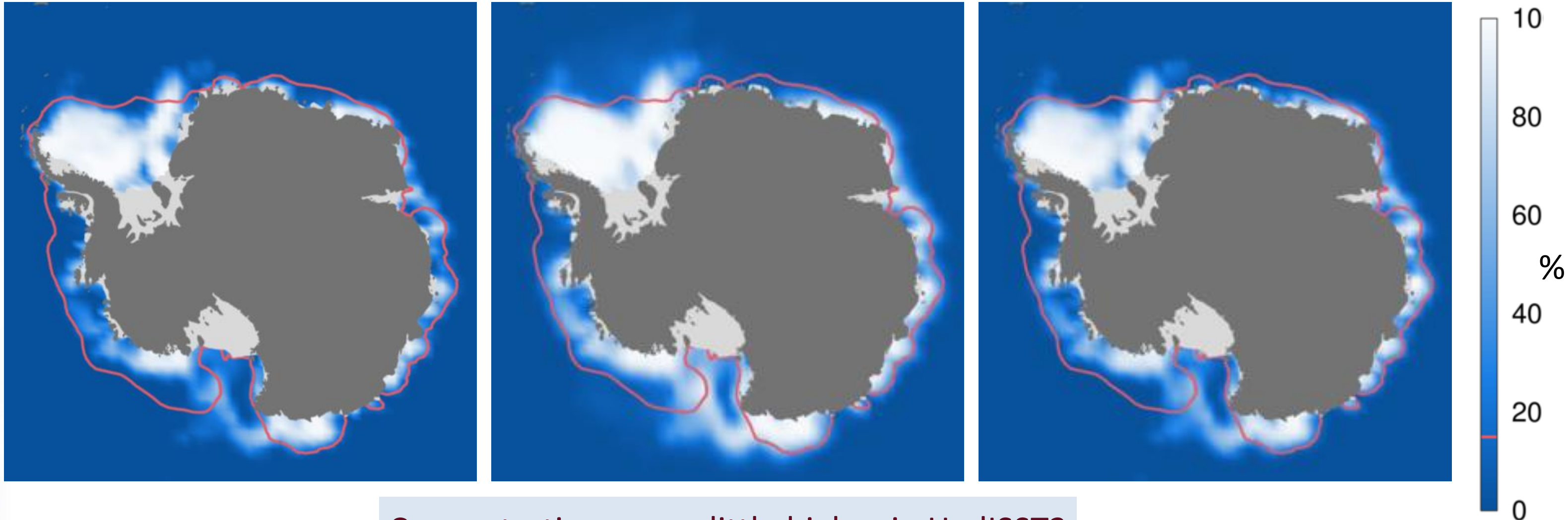
Climate Change

Mean sea-ice concentration for February 2008

Initial ERA5 production
OSTIA

HadISST2

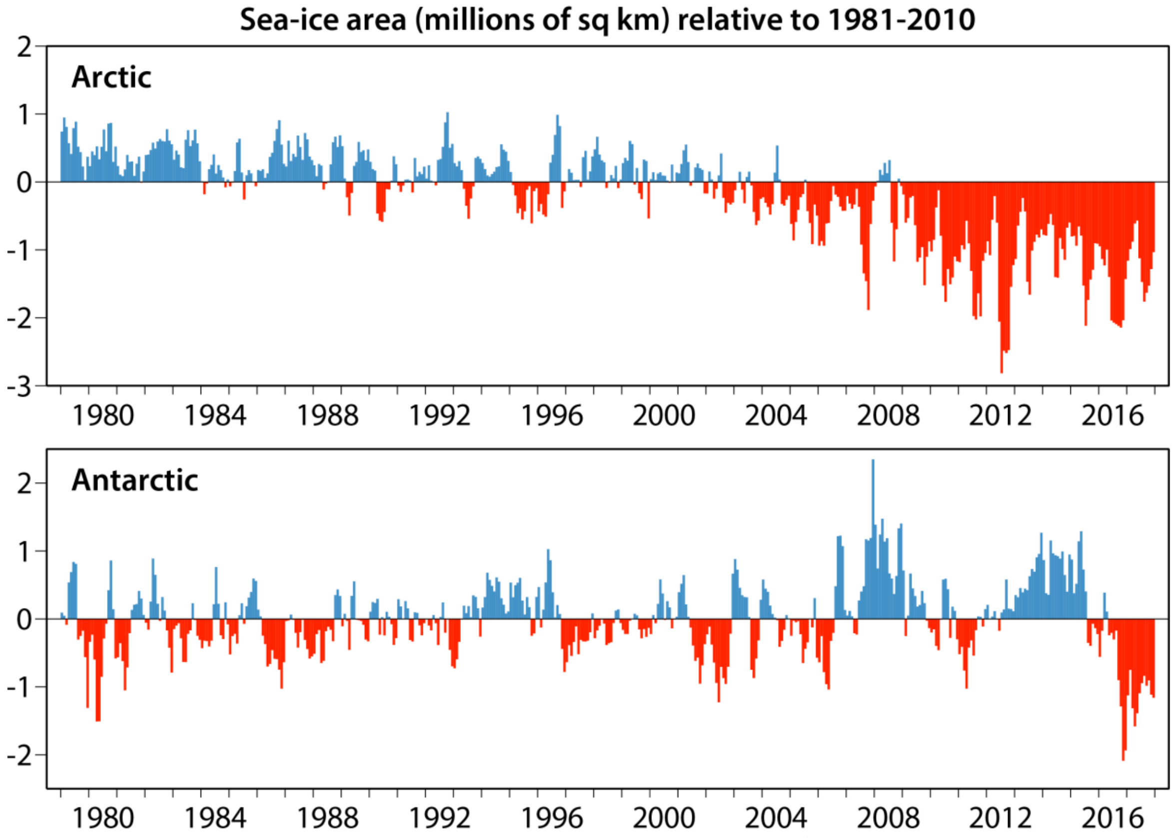
ERA-Interim
NCEP operational product



Concentrations are a little higher in HadISST2

Climate Change

Sea-ice area from analyses used by ERA-Interim



ECMWF Copernicus Europe's eyes on Earth European Commission

Climate Change

To conclude

Reanalysis has been served reasonably well by the SST and sea-ice products it has used

- enabling it directly to produce reasonable near-surface trends and variability
- assisting the assimilation of upper-air data to characterize trends and variability

But we are not yet close to where we want to be. Requirements are for

- reduced uncertainty in SST analyses
- reduced uncertainty in sea-ice analyses for interior regions and marginal zones
- better quality control of sea-ice analyses
- a near-real-time SST/sea-ice analysis that follows the reanalysis principle of using a fixed processing system
- an historic SST/sea-ice analysis that is consistent with the near-real-time analysis
- a more extensive treatment of lakes and inland seas