Climate reanalysis and reforecast needs: An Ocean Perspective

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Summary

- Why needs SST/SIC and How to treat the information
- Uncertainty in SST/SIC analysis products
- SST and SIC in Ocean ReAnalysis
- Impact on reforecasts: medium-range to seasonal
- Recent development works at ECMWF

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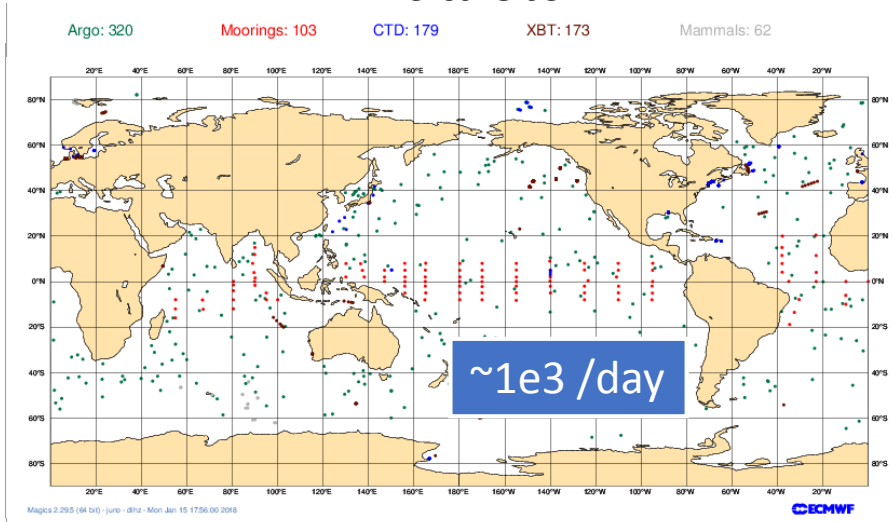
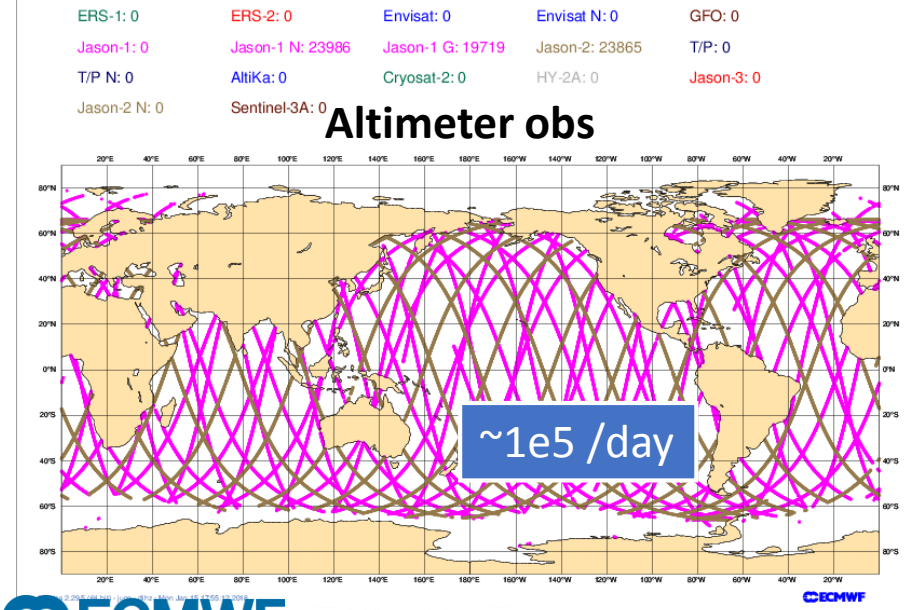
Important of satellite SST and sea-ice observations

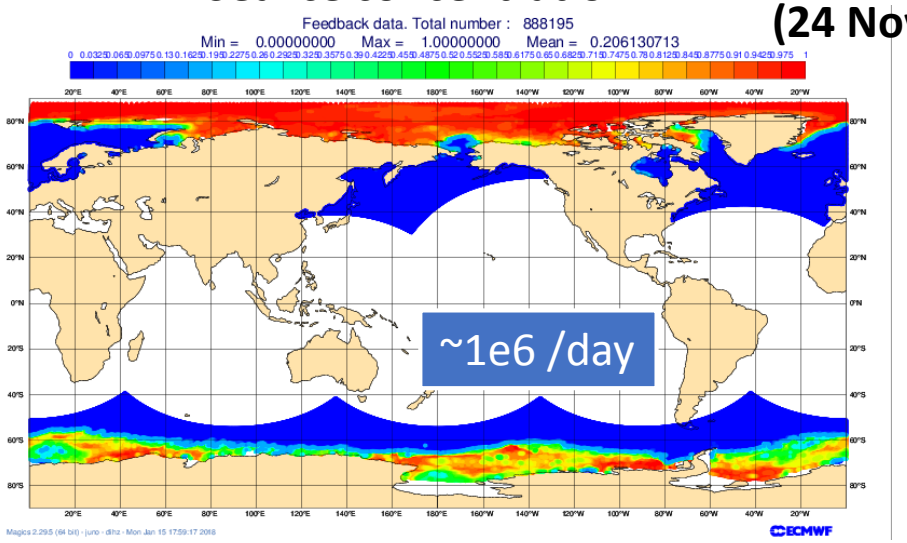
In-situ obs



Altimeter obs

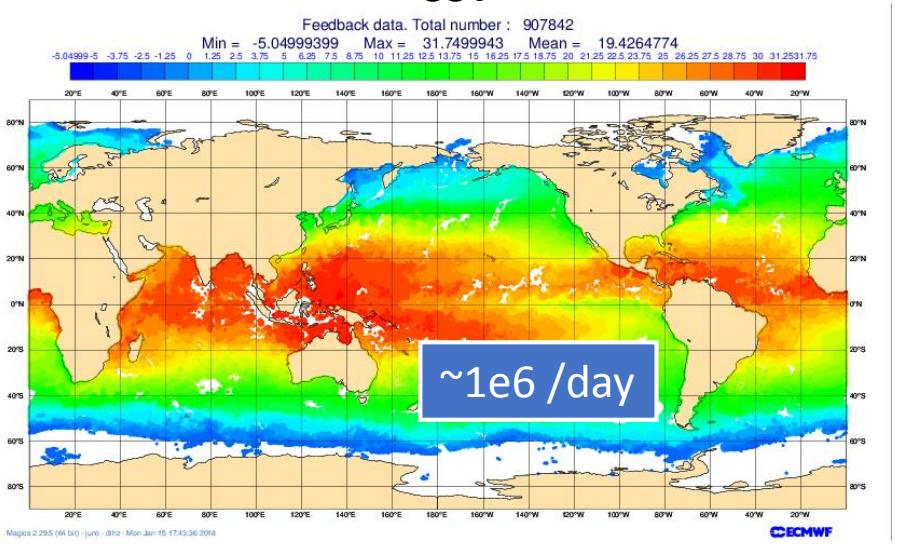


Sea ice concentration



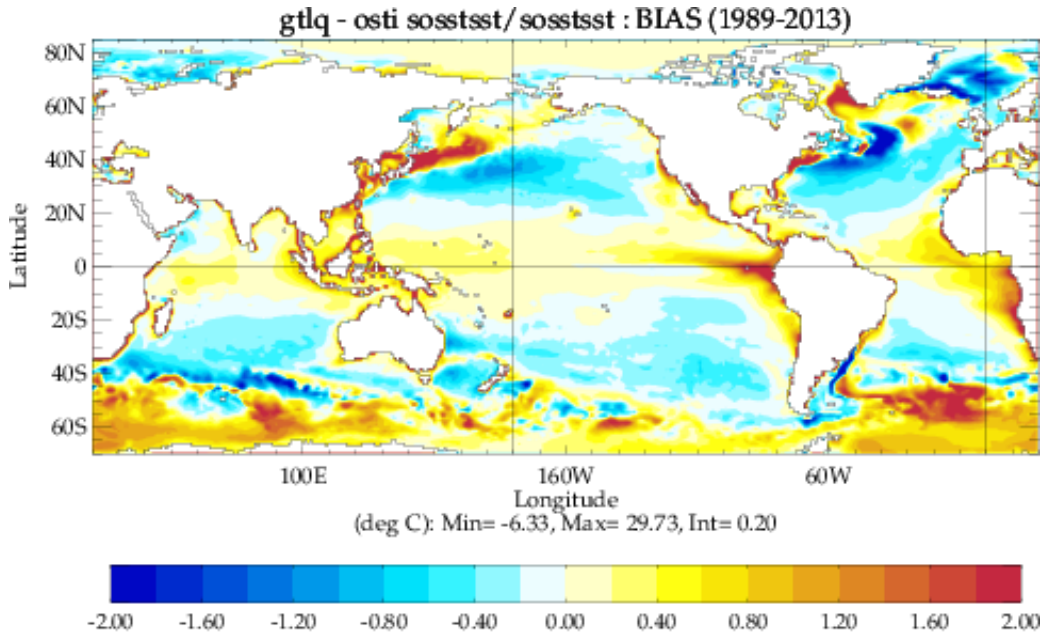
Daily available oceanic obs (24 Nov 2010)

SST

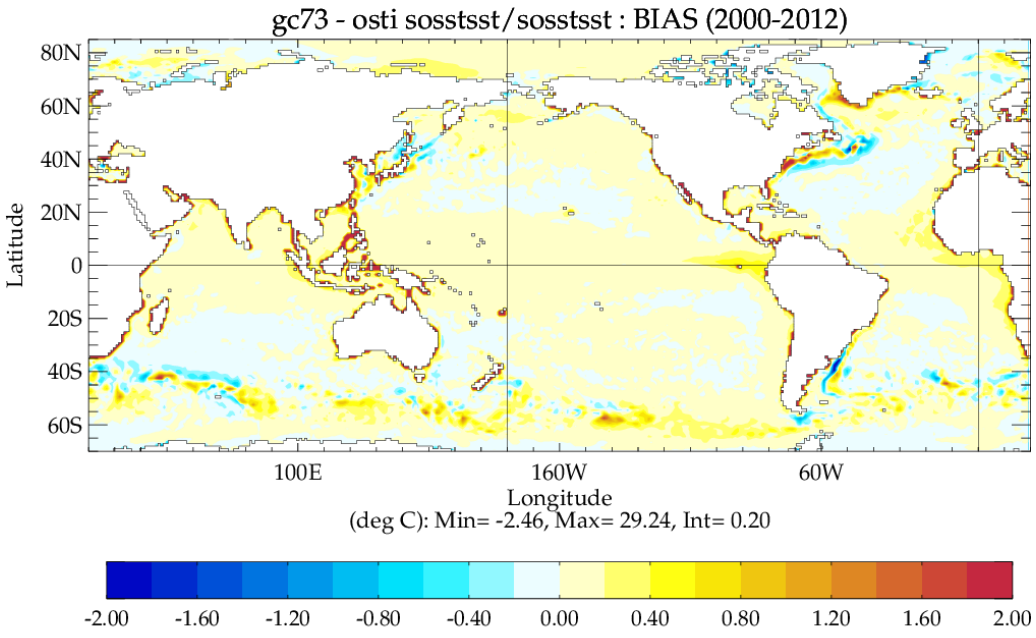


Model SST bias

SST: CNTL - OSTIA



SST: ORAS5 - OSTIA



Bias in Gulf Stream regions:

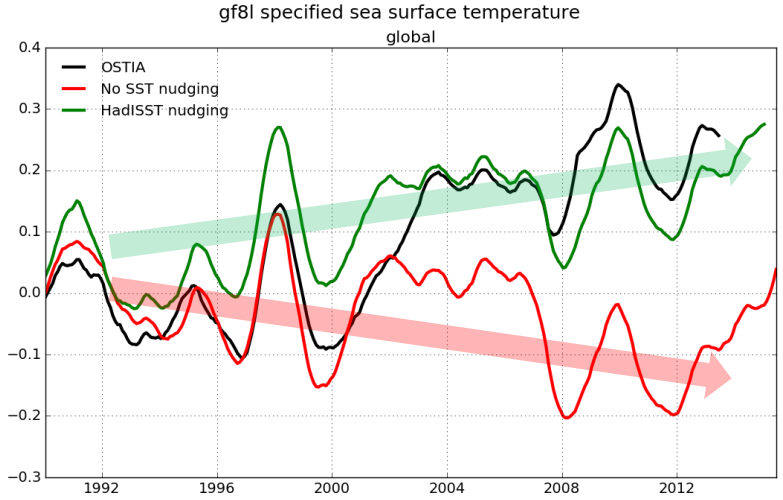
- Not enough resolution
- Inaccurate bathymetry
- Lack of A-O interactions
- Very weak constrain from in-situ observations (at contential shelf and near coast)

SST:

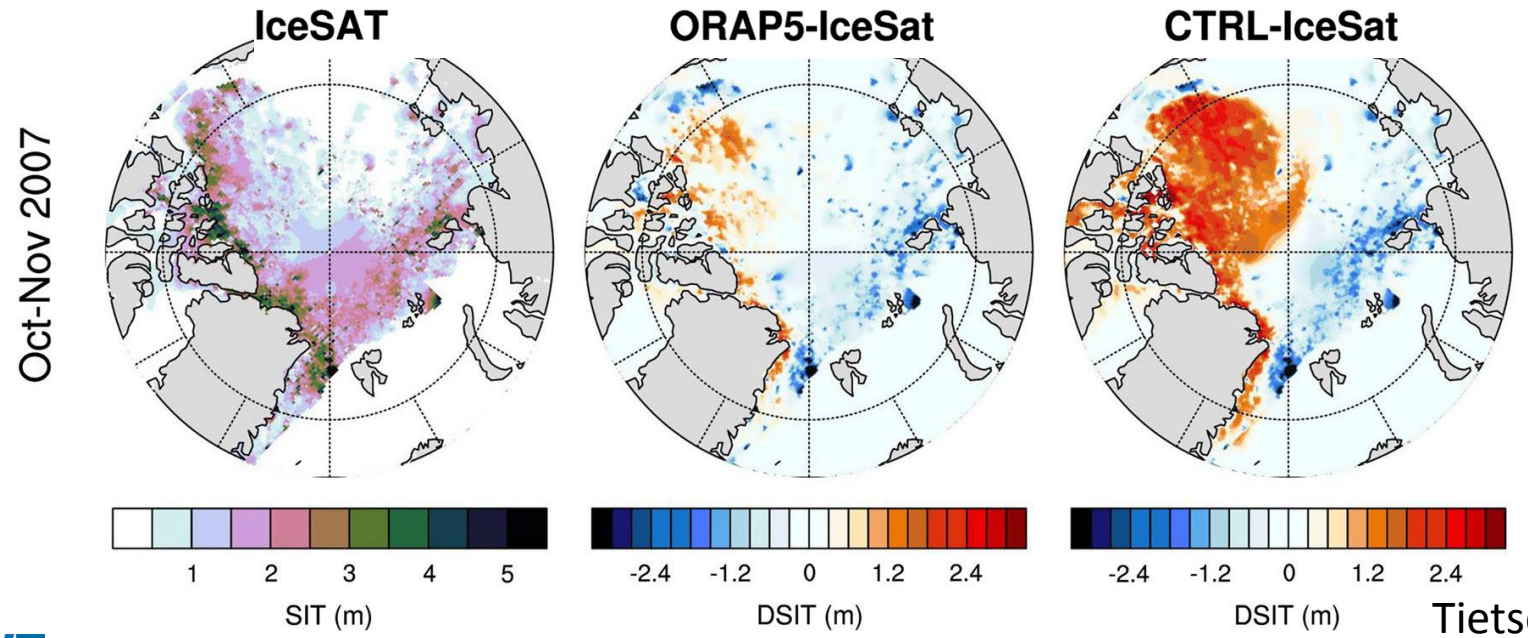
OSTIA

CNTL

+SST DA



Ice thickness:



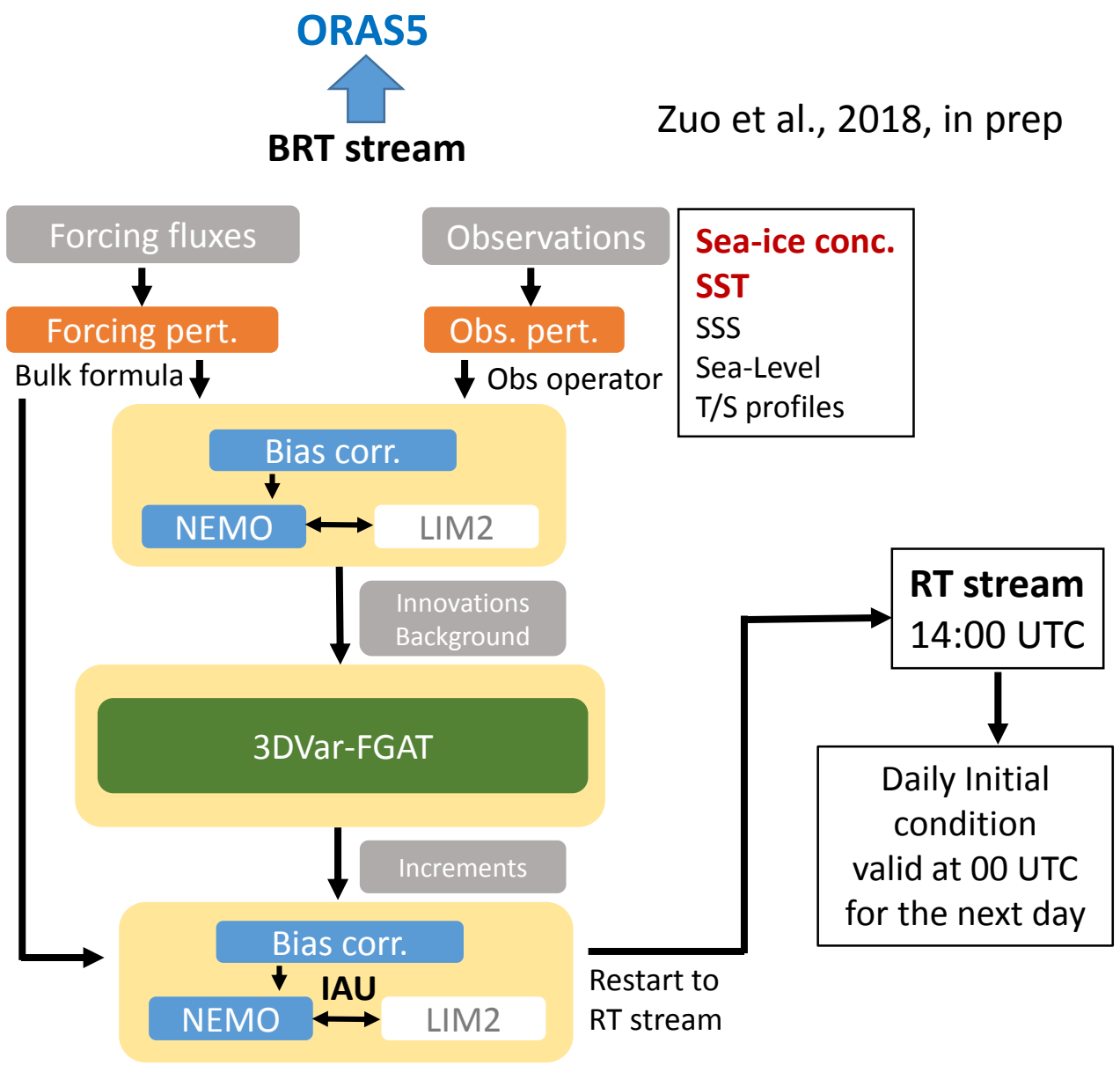
Tietsche et al., 2015

Use of SST/SIC obs in Ocean ReAnalysis

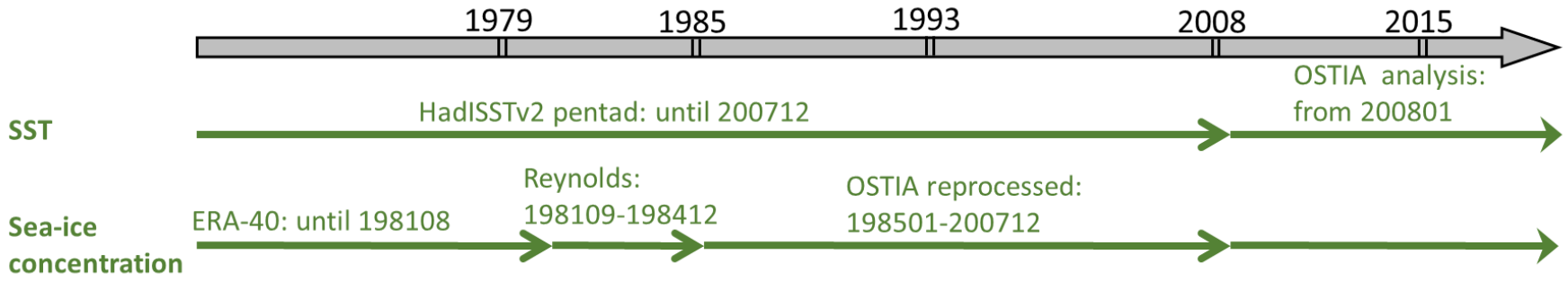
- Model: NEMOv3.4 + LIM2 (0.25 deg + L75)
- DA: 3DVAR-FGAT
- 5 ensemble members
- BRT+RT streams

OCEAN5 is used for initialising ocean and sea-ice components for

- ECMWF coupled forecasting systems
- Seasonal Forecasting System 5
- Atmospheric analysis: sea-ice



SST and sea-ice analysis products used in ORAS5



SST nudging scheme

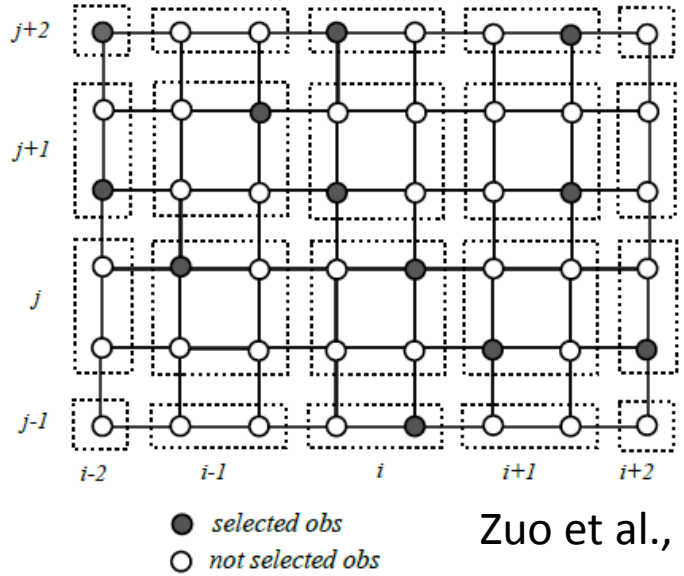
Haney 1917

$$Q_{ns} = Q^{o}_{ns} + \frac{dQ}{dT}(SST_{MODEL} - SST_{TARGET})$$

non-solar total heat flux

Fixed negative feedback coefficient

SIC ensemble sampling



Zuo et al., 2017

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Uncertainty in SST and SIC analysis products

SST and SIC L4 analysis products are commonly used in climate modelling, ocean (ECMWF ORAs) and atmosphere (ERAs) reanalysis, for the following reasons

- Gridded product without gap, make it very easy to use, e.g. for prescribing sea surface conditions for ERAs and surface nudging for ORAs (ORAS4, ORAS5).

- Normally consider to be more stable (no-gap, combined multiple sensors with homogeneity, bias corrected) than L2/L3 products, and less susceptible to instrumental failure due to the analysis procedure.

There are many SST and SIC analysis products available (OSTIA, ESA CCI, OIv2, HadISST2 …). However different SST/SIC analysis products are not always consistent, with large uncertainties (magnitudes varies from global/climate to regional/daily scales) in both SST and SIC among them.

- Different SST definitions
- Different data sources
- Difference bias correction strategies
- Different analysis procedures

Summary of some L4 SST/SIC analysis products

Only products utilized satellite observations and with a global coverage

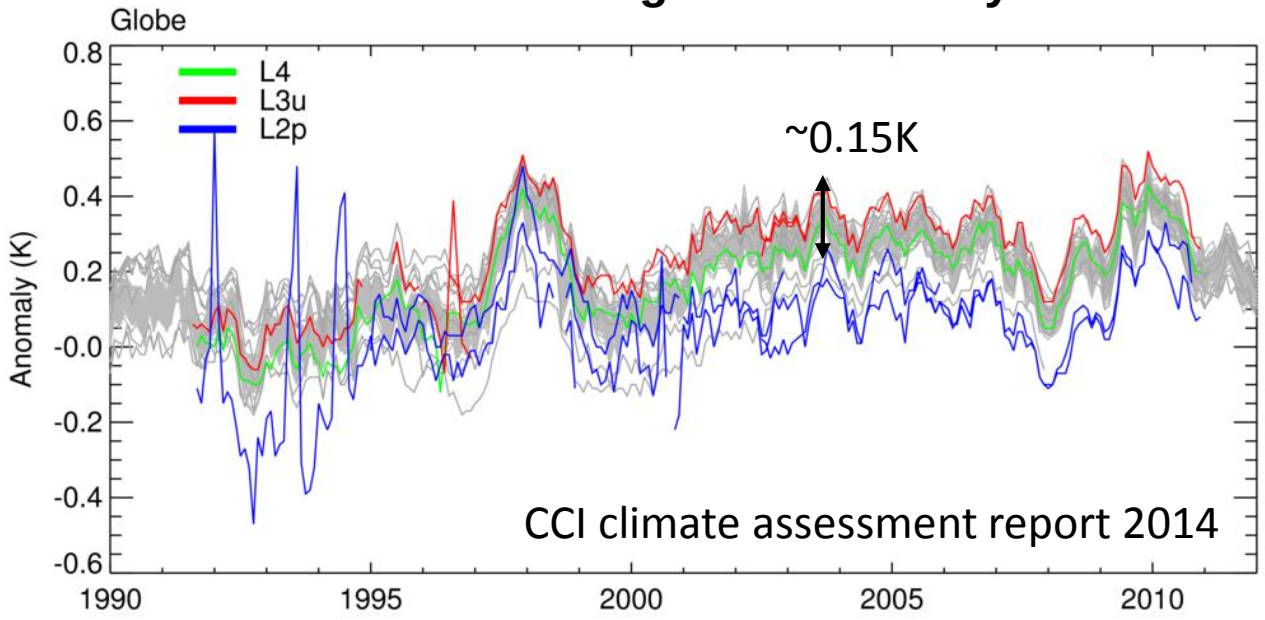
products	Data sources	SST definition	Bias correction	member	resolution	period
OIv2d (NOAA)	AVHRR, AMSR, in-situ	bulk SST (~0.5 m depth)	Bias corr. against in-situ (ship-based and buyo)	OI 1 member	Daily, 0.25 deg	1981-NRT
OSTIA (UKMO)	(A)ATSR, AVHRR, in-situ Oper. only: TMI, AMSR-E, NAR, SEVIRI	Foundation temperature (night time only), at ~ 4-10 m depth	Bias corr. against AATSR and in-situ (drifting buyo)	OI 1 member	Daily, 0.05 deg	1985-NRT
HadISST2 (Hadley Centre)	ATSR, AVHRR, in-situ	Night time only for AVHRR and ATSR		OI 10 ens	Pentad, 0.25 deg	1961-2010
CCI-SST (ESA)	ATSR (ref), AVHRR	Daily mean SST at 0.2 m	No BC against in-situ	OI 1 + uncert.	Daily, 0.05 deg	1991-2010

ATSR: the Along-Track Scanning Radiometers
AATSR: Advanced Along Track Scanning Radiometer
AVHRRs: Advanced Very High Resolution Radiometers

AMSR-E: Advanced Microwave Scanning Radiometer-EOS
TMI: Tropical Rainfall Measuring Mission Microwave Imager
SEVIRI: Spinning Enhanced Visible and Infra-Red Imager

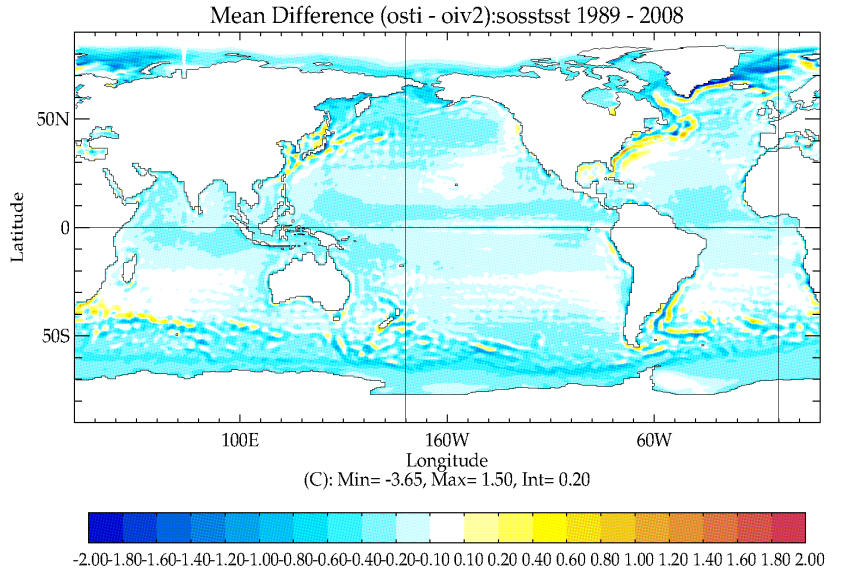
Uncertainty in SST analysis

Global average SST anomaly

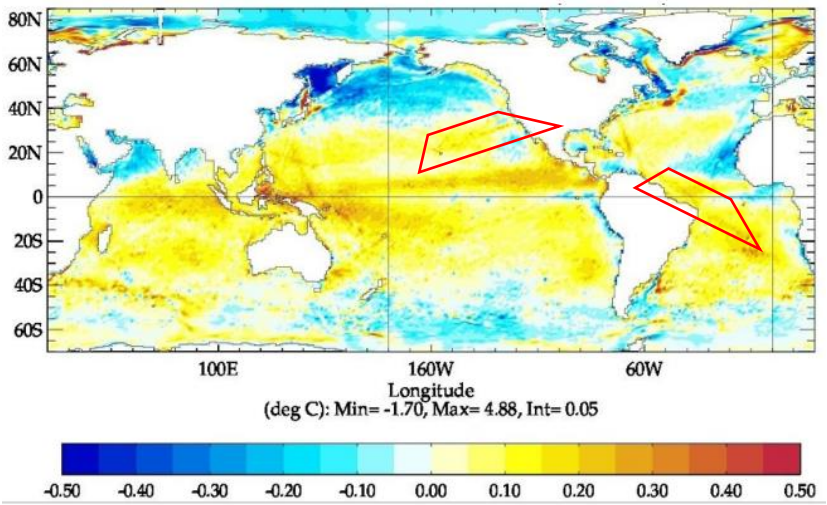


Relative to OSTIA climatology, for different SST analysis products (OIv2, HadISST, OSTIA … in grey) and the ESA-CCI SST (green)

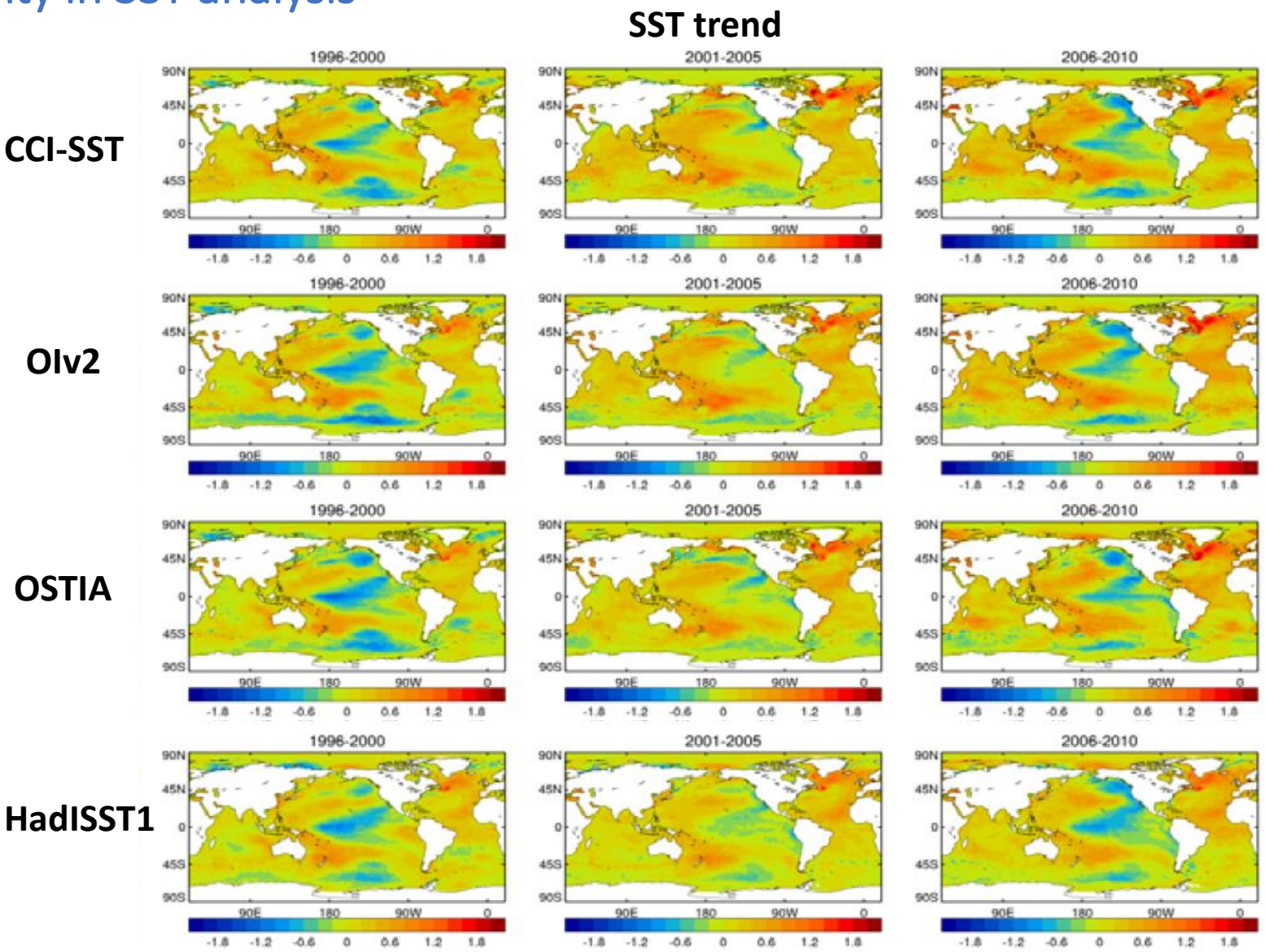
SST: OSTIA-OIv2 (1989-2008)



SST: ESA CCI-HadISST2 (1992-2010)

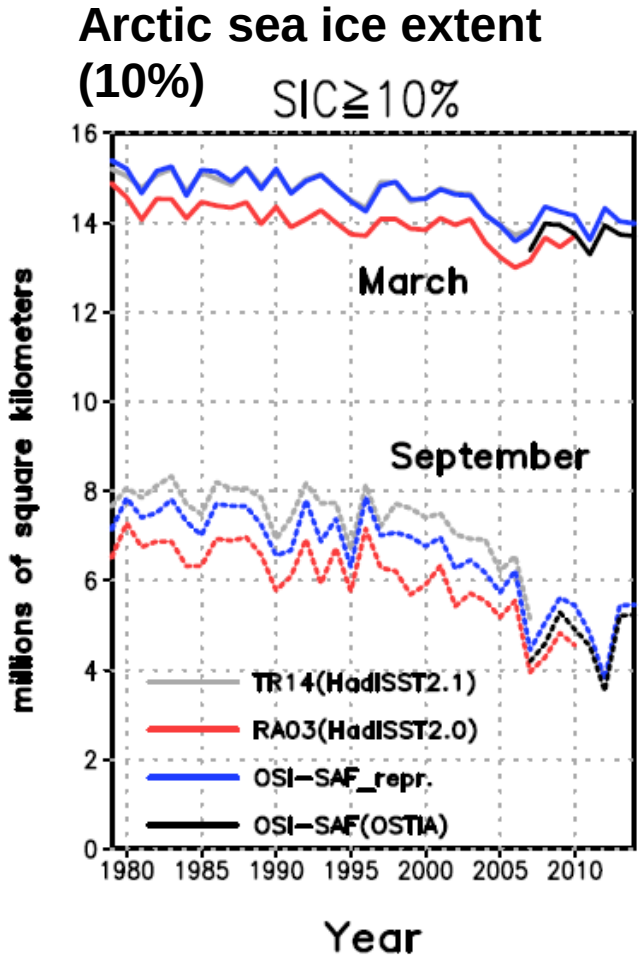


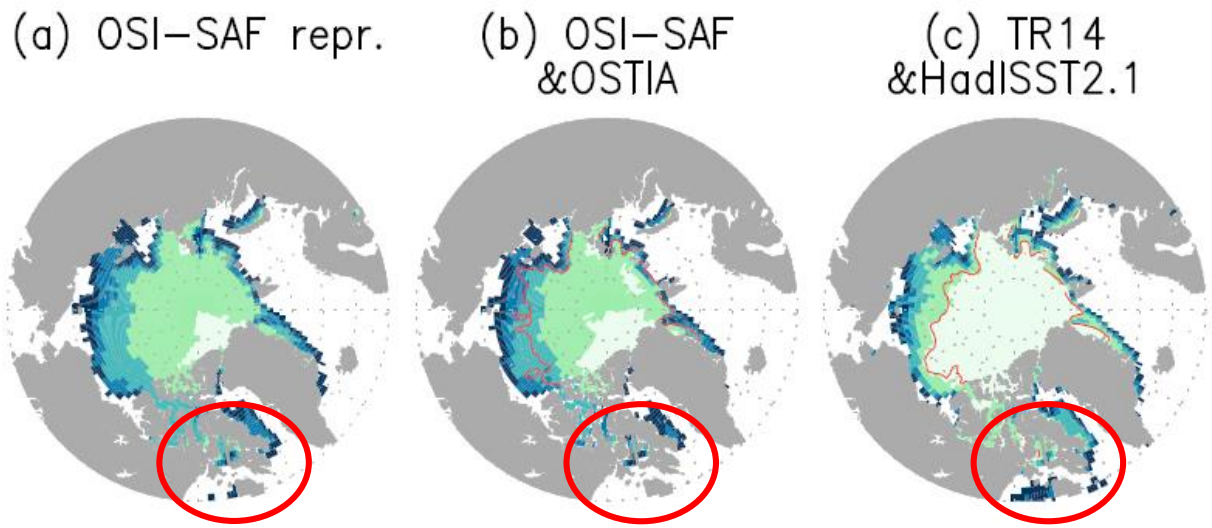
Uncertainty in SST analysis



CCI climate assessment report 2014

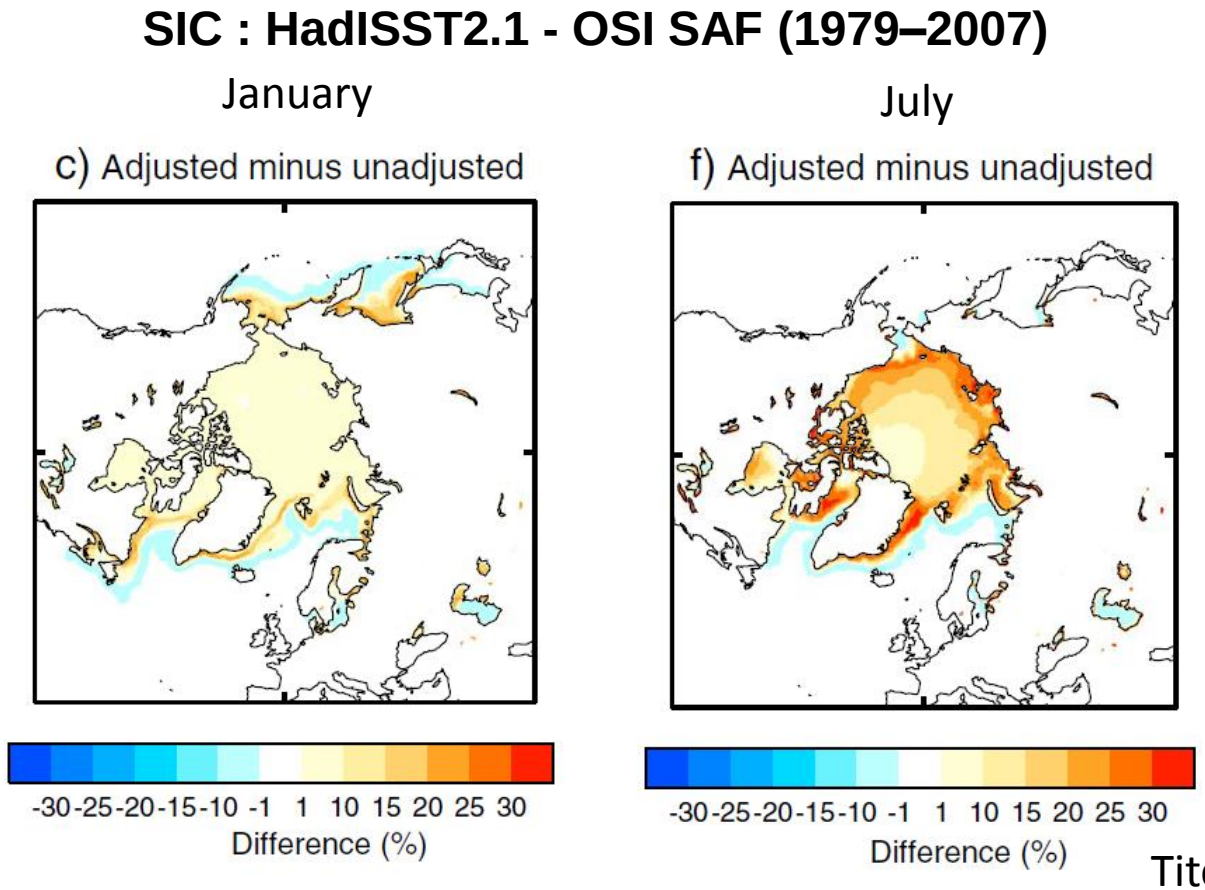
Uncertainty in sea-ice concentration analysis





Hirahara et al, 2016

Uncertainty in sea-ice concentration analysis



HadISST.2.1 SIC was adjusted against NIC ice charts. As a result, it contains more ice than OSI-SAF

Titchner et al., 2014

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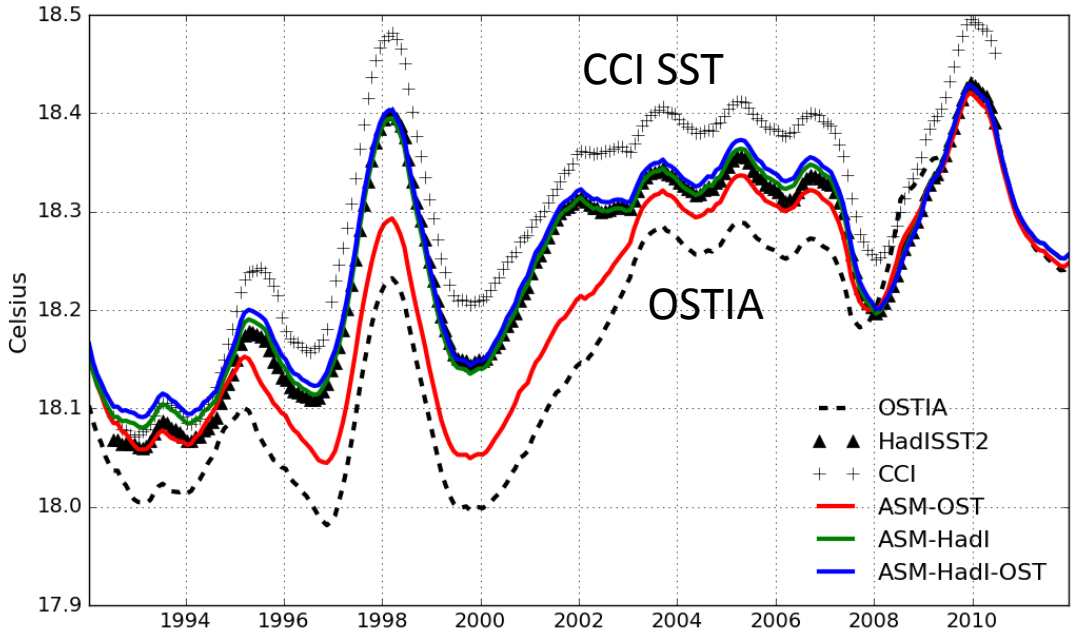
Sensitivity to SST and SIC products

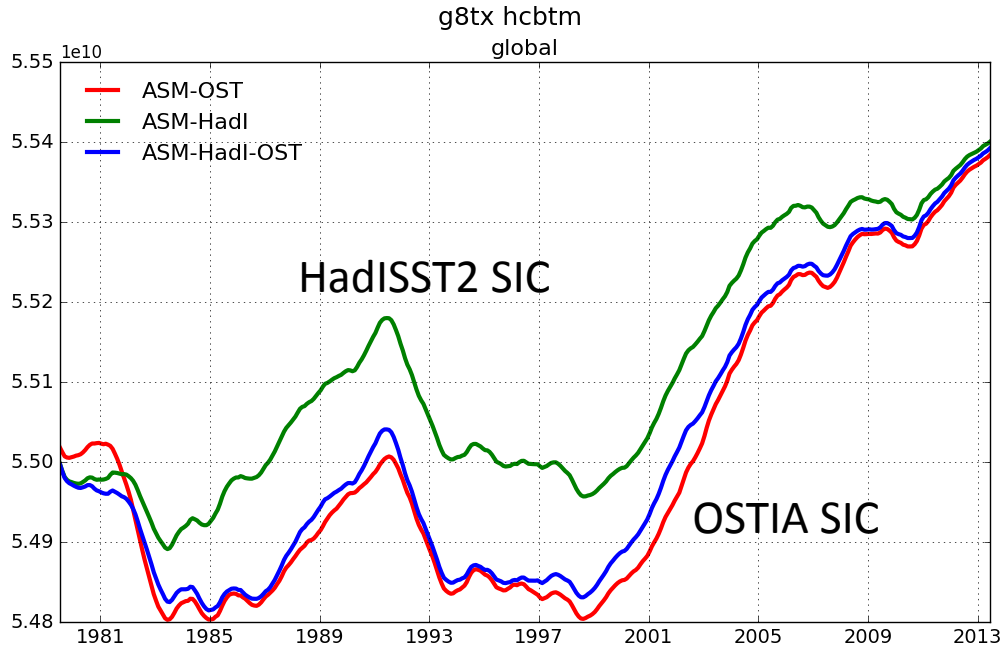
DA experiments with different products

Name	SST	SIC
ASM-OST	OSTIA	OSTIA
ASM-HadI	HadISST2.1	HadISST2.1
ASM-HadI-OST	HadISST2.1	OSTIA

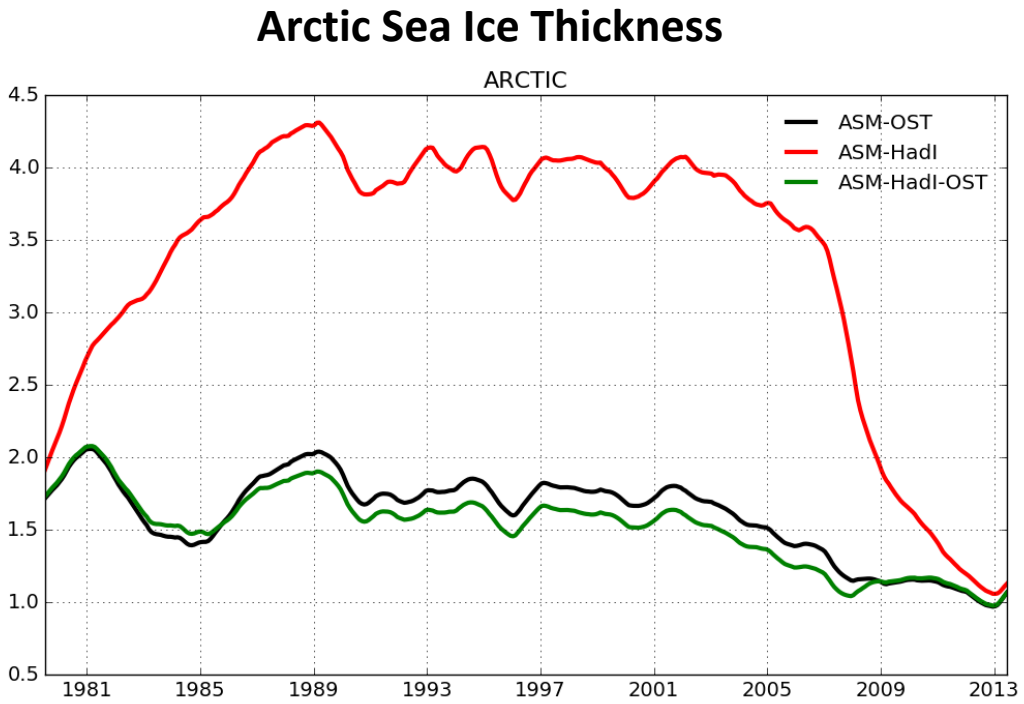
Global mean SST



Global Ocean Heat Content (1.e10 J/m2)

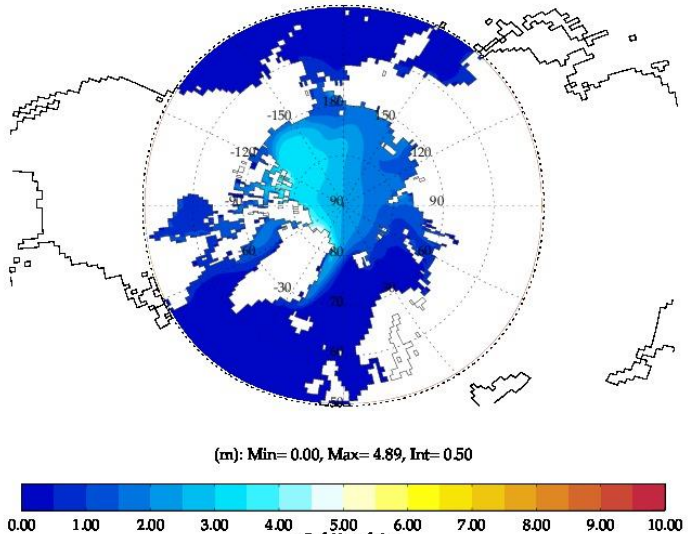


Sensitivity to SST and SIC products



ASM-HadISST SIC overestimated Arctic sea-ice thickness in general, and particularly at the north of Greenland and in the Beaufort Sea.

Sea Ice Thickness: OSTIA SIC



Sea Ice Thickness: HadISST2 SIC

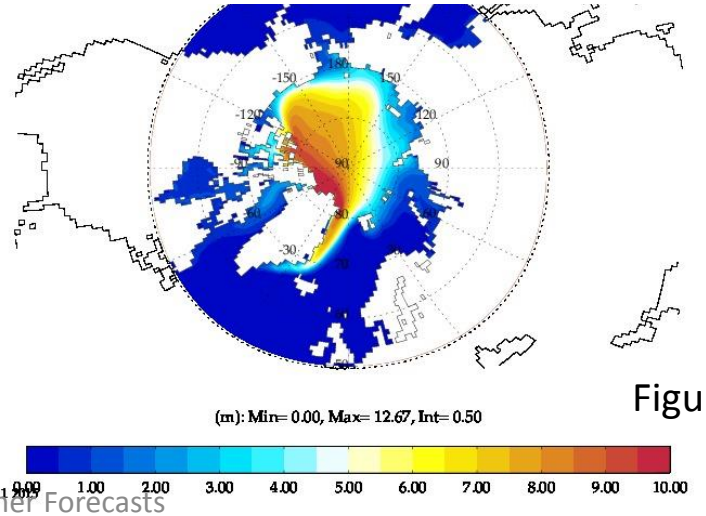


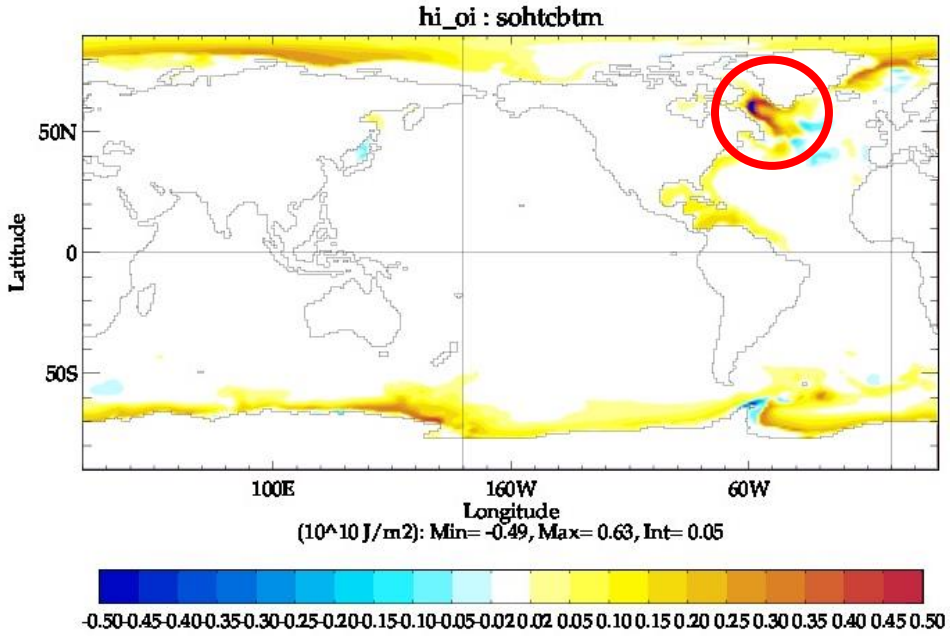
Figure by Magdalena

Sensitivity to SST and SIC products

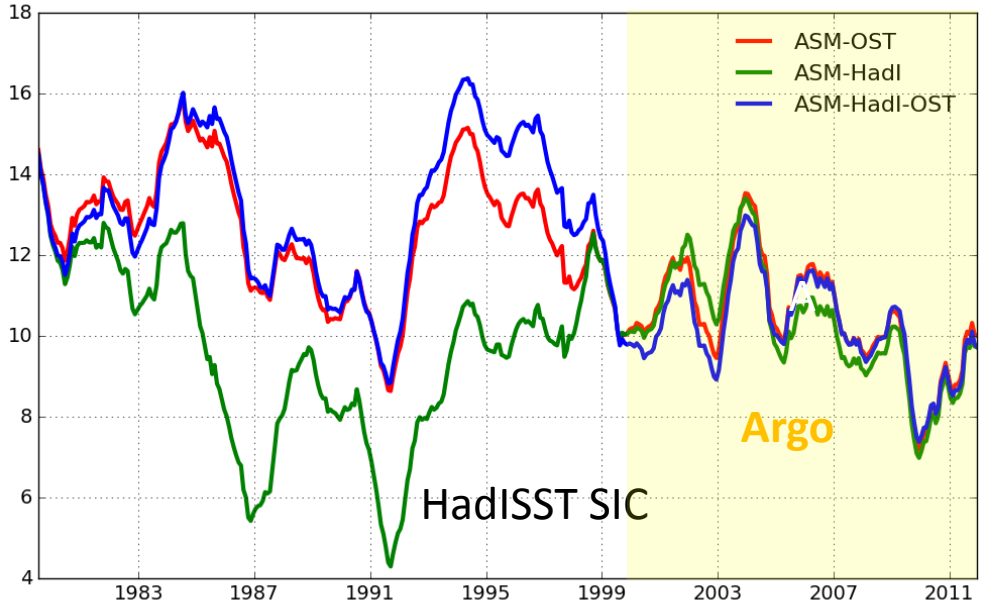
High sea-ice concentration in the HadISST2 analysis

- Too much fresh water export → Insulates the ocean from cooling in winter
- Increased OHC
- Weakening deep water formation in the Labrador Sea
- Produces a reduction of AMOC

OHC: ASM HadSIC – OSTIA SIC



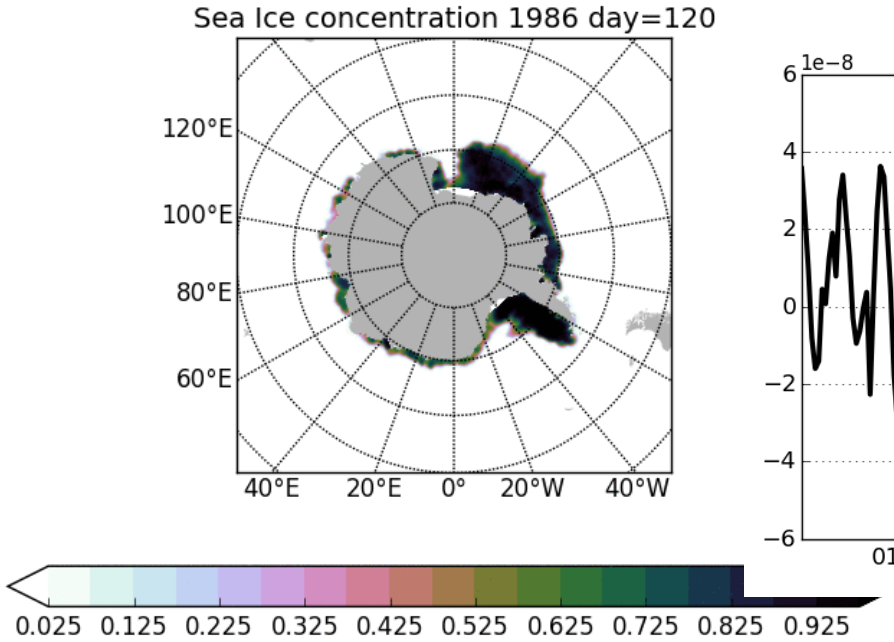
AMOC at 26N (Sv)



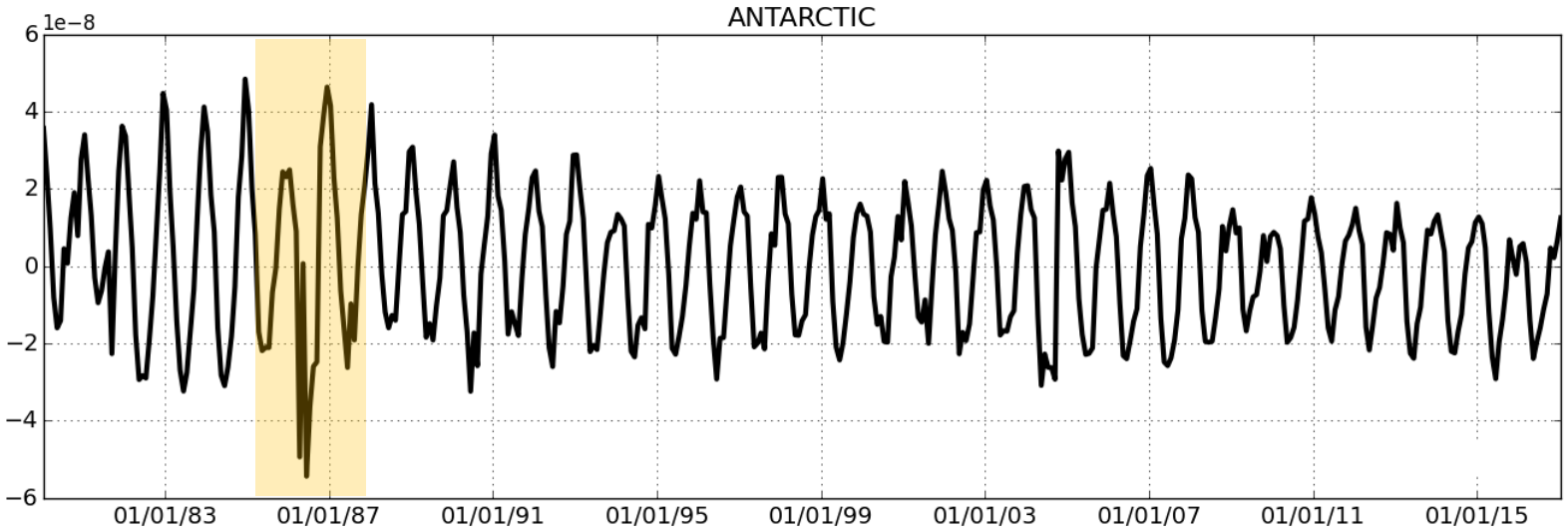
Consistency in analysis product

Filling the temporal gap in SIC analysis

OSTIA SIC: March to April 1986



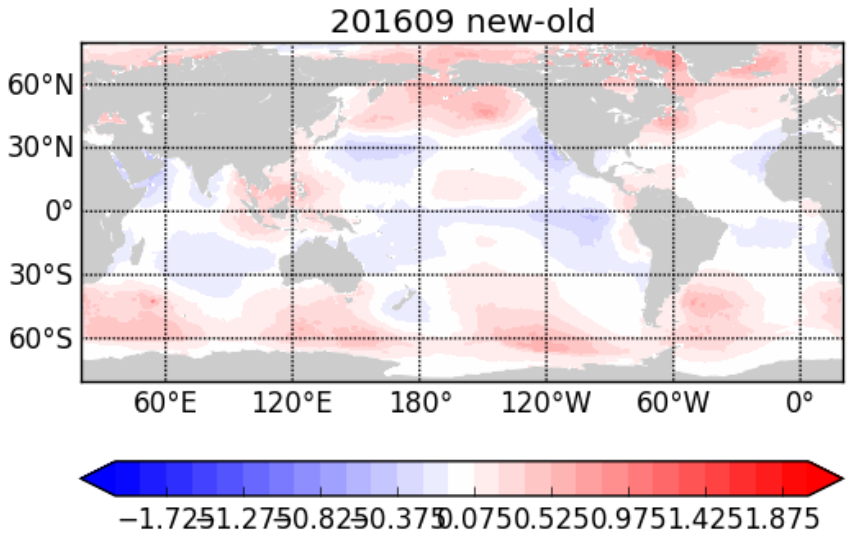
ORA Antarctic SIC



Antarctic sea-ice concentration show historical low in 1986 March-April, which was contaminated by missing observations in this period.

Consistency in analysis product

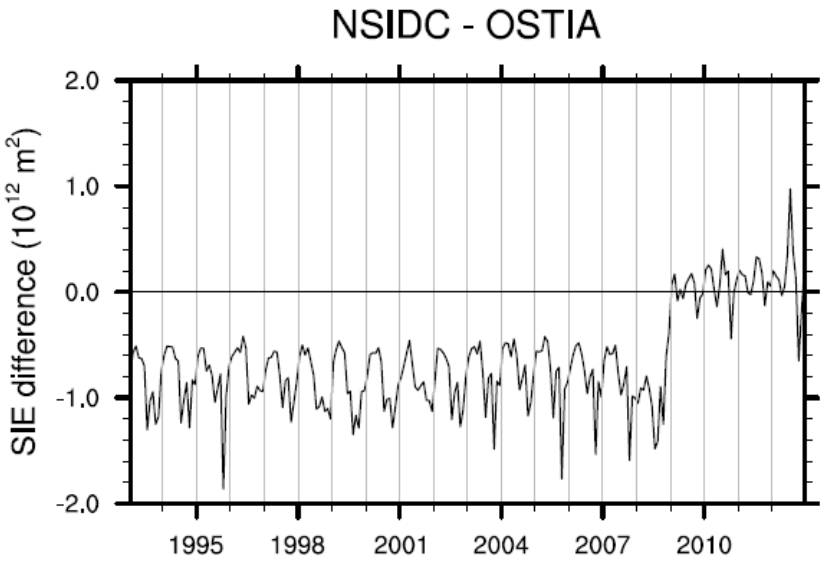
OSTIA SST: new – old



Global: 0.05K

New (from Nov 2016): ACSPO VIIRS for bias correction
Old: MetOp-A AVHRR for bias correction

Arctic sea ice extent



Tietsche et al., 2014

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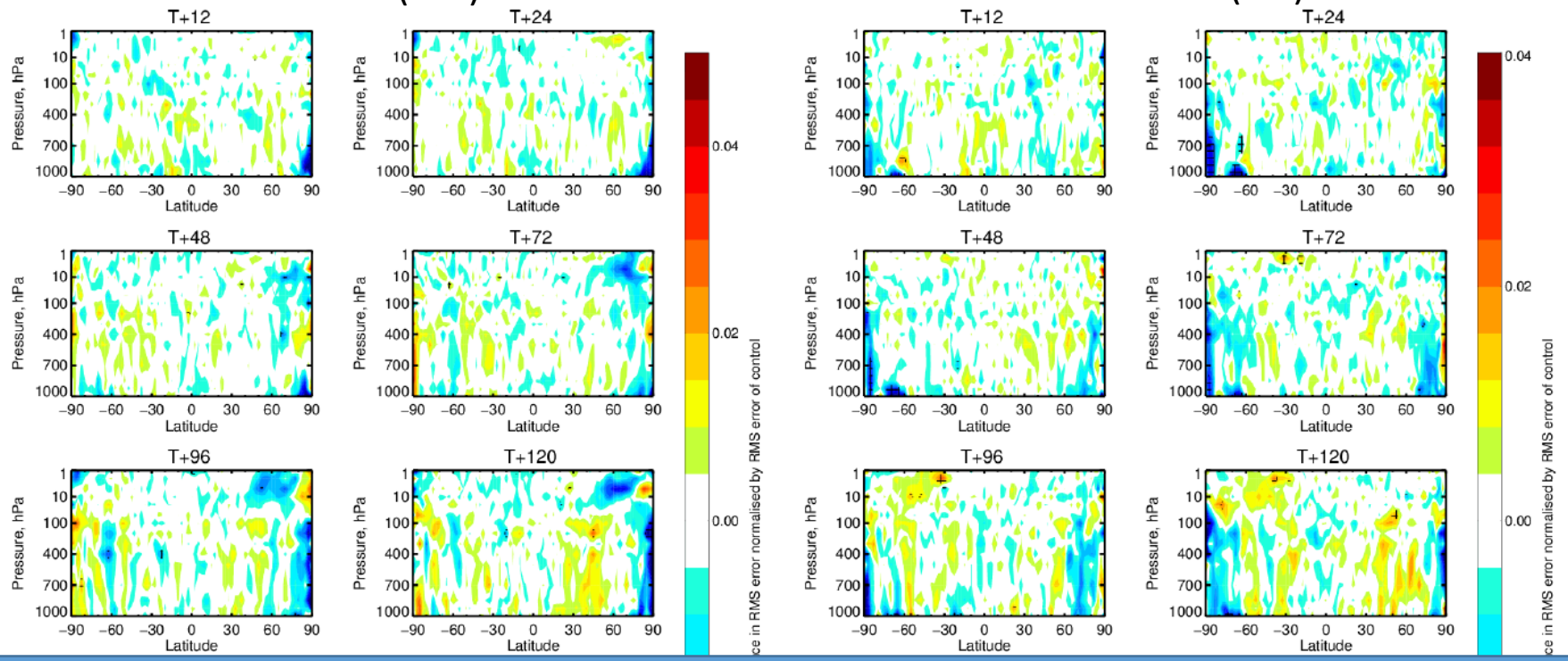
Impact of sea-ice condition in coupled forecasts - medium range

Normalised differences in T errors : OCEAN5 CI - OSTIA CI
at T+12 and T+24 hours

Figure by Phil. Browne



- OSTIA CI used is with 1-day delay
- OCEAN5 CI is more realistic due to additional constrains from atmospheric forcing and other obs types (in-situ, SST)
- OCEAN5 provided CI is more consistent with coupled forecasting model, which share the same ocean model configuration as OCEAN5

Impact of sea-ice condition in coupled forecasts - medium range

Normalised differences in SKT RMS: OCEAN5-OSTIA at T+12 and T+24 hours

WINTER (DJF)

SUMMER (JJA)

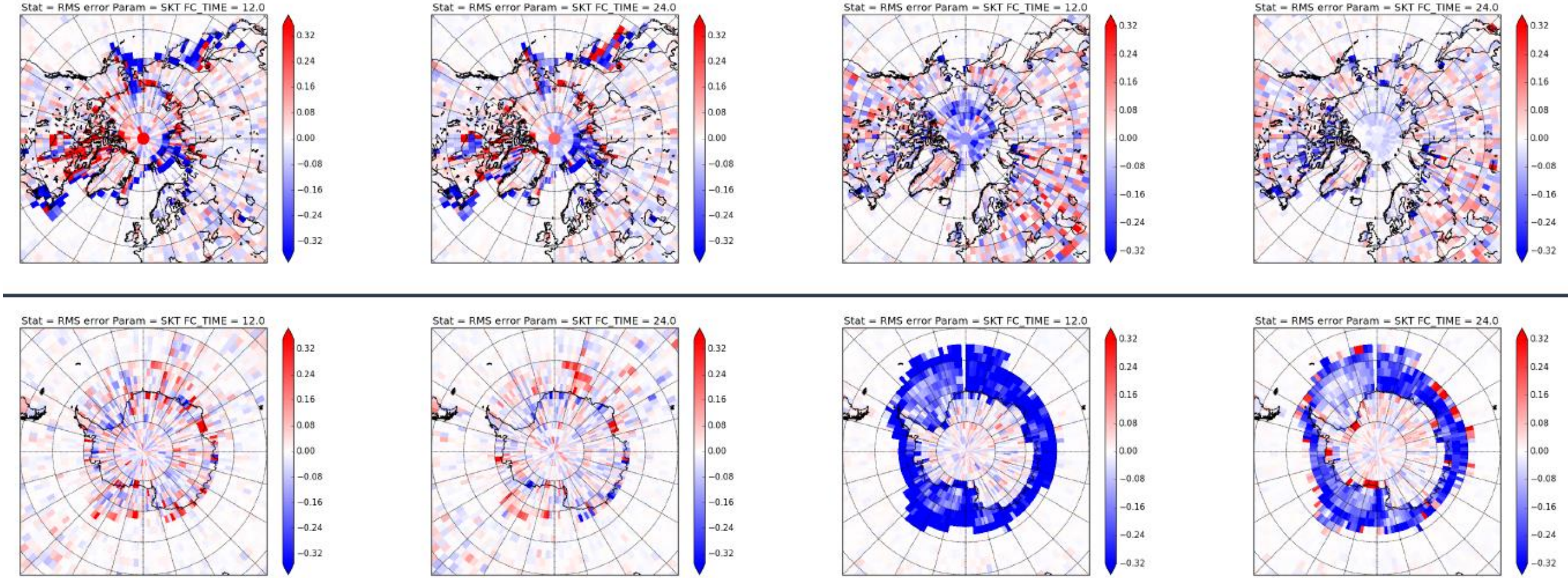
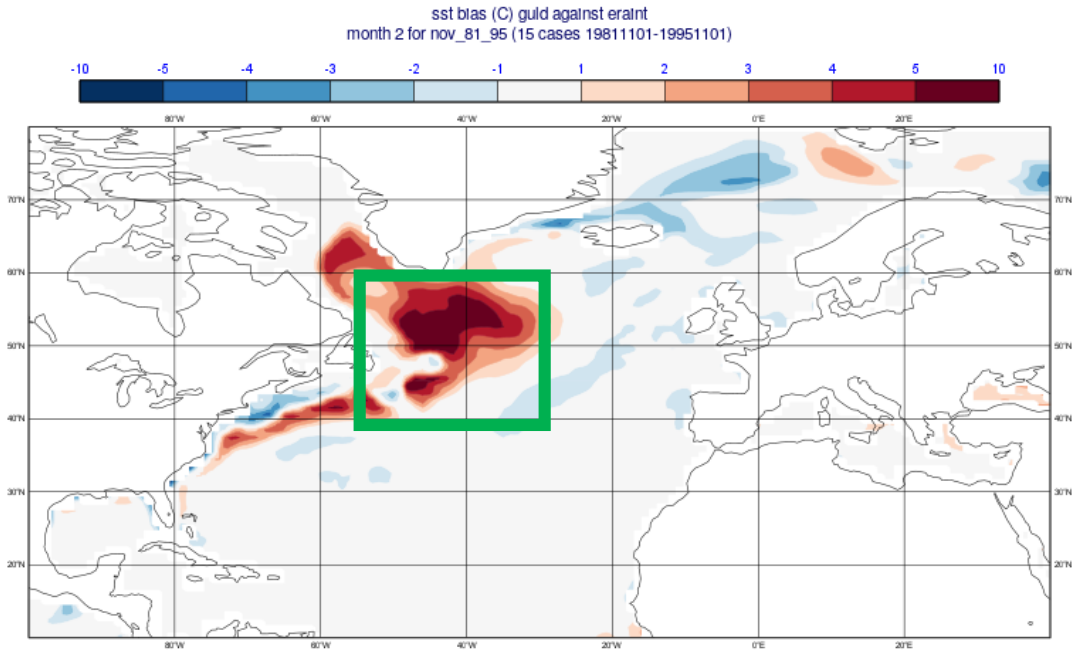


Figure by Phil. Browne

Impact of SST nudging in Seasonal Reforecasts

SST reforecast bias (month=3): 1981-1995

from CTRL with SST nudging



from CTRL without SST nudging

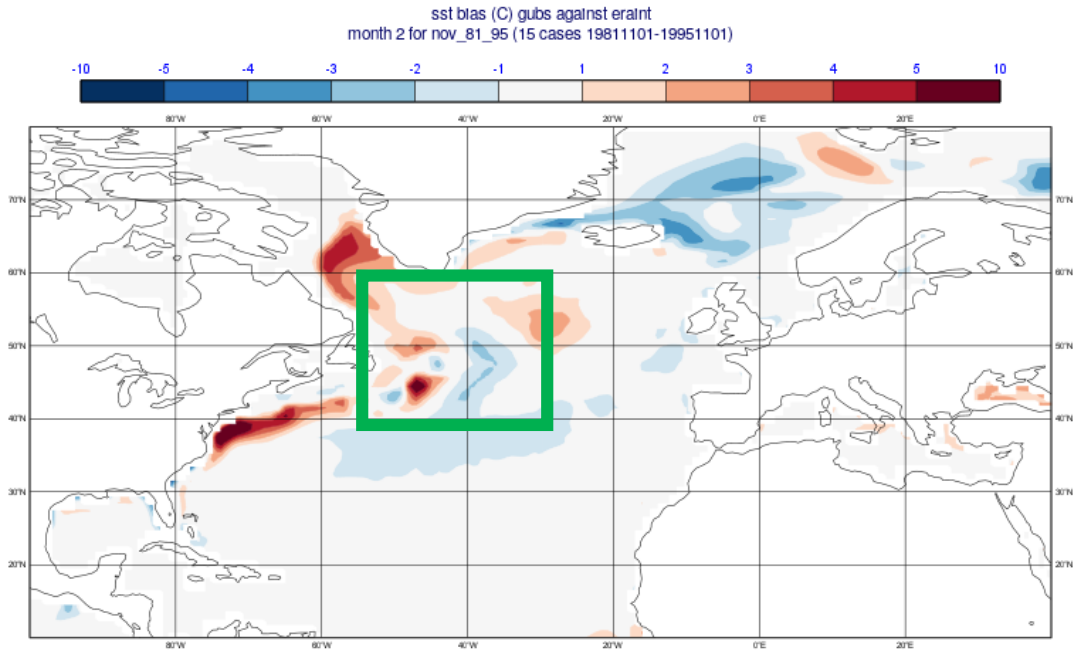
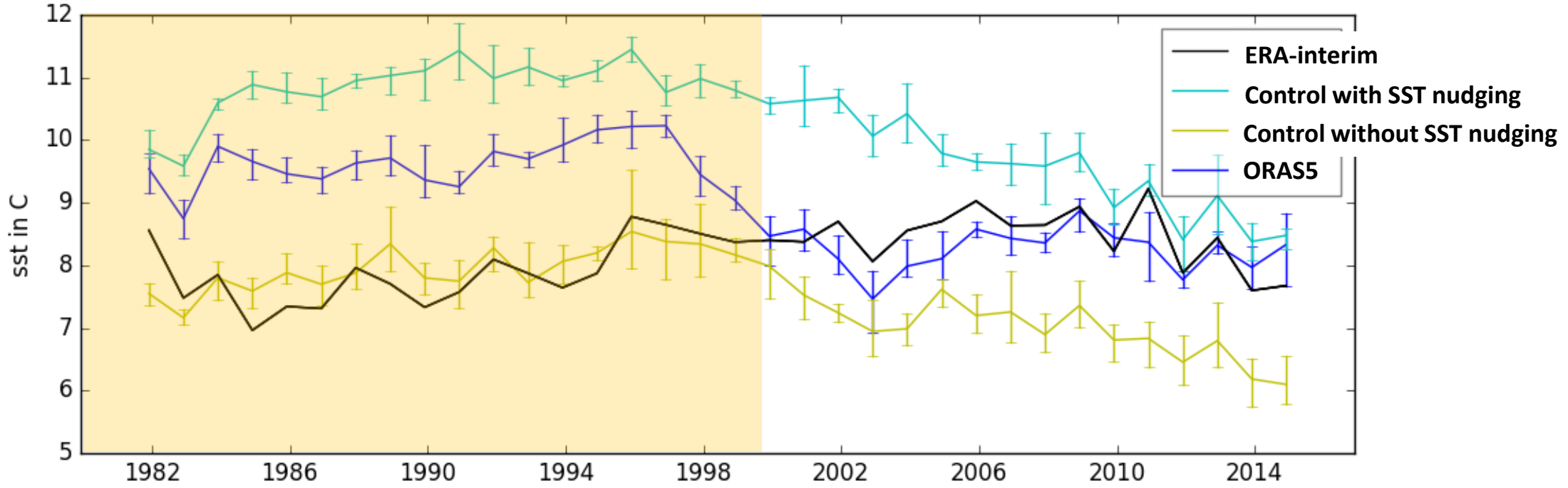


Figure by Steffen Tietsche

Conclusion: SST restoration may be too strong for the early period (pre-2000)

Impact of SST nudging in Seasonal Reforecasts

Time series of forecast ensemble means and ERA-I verification



November initialization and reforecasts for month 3

Figure by Steffen Tietsche

Skill of seasonal forecasts is very sensitive to SST nudging and ocean data assimilation

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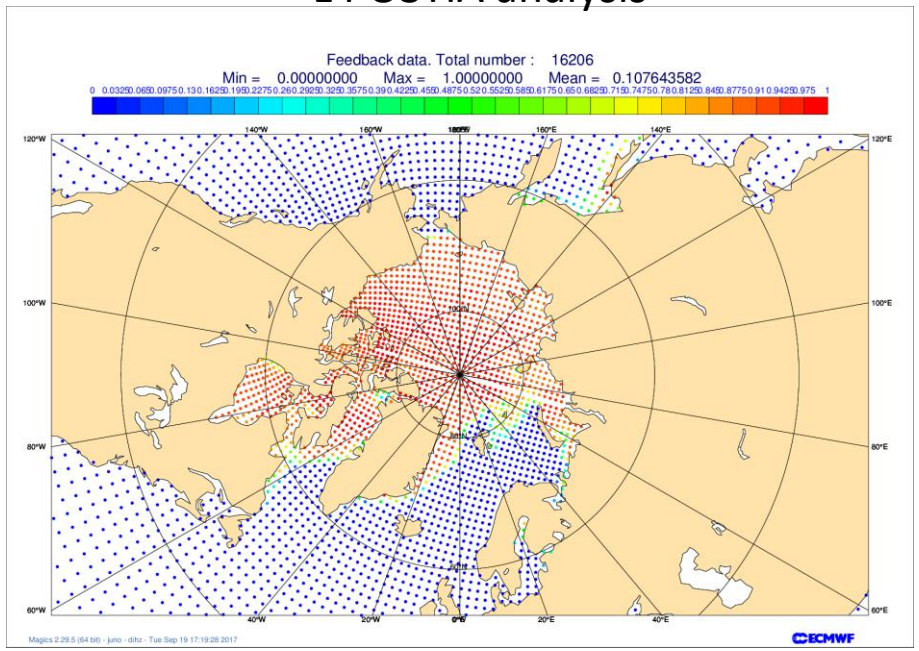
Development of L3 SIC assimilation

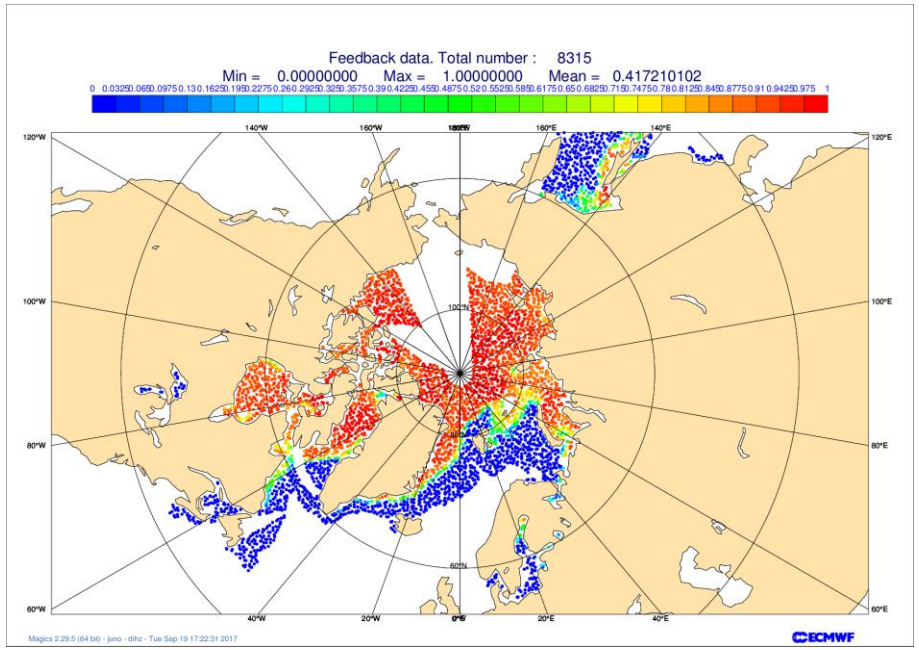
Daily assimilated SIC on 20130118

L4 OSTIA analysis



L4 analysis: with filtering, masking, extrapolation to produce a gap-free product

L3 OSI SAF



with 10km resolution there is ~1 milion obs per day from L3 OSI-SAF, obs reduced to ~10,000 per day with a thinning boxes of ~0.5X0.5 degree

Impact on ORA: L3 OSI-SAF VS L4 OSTIA

ORA SIC differences (2005-2015)
OSI-SAF (L3) – OSTIA (L4)

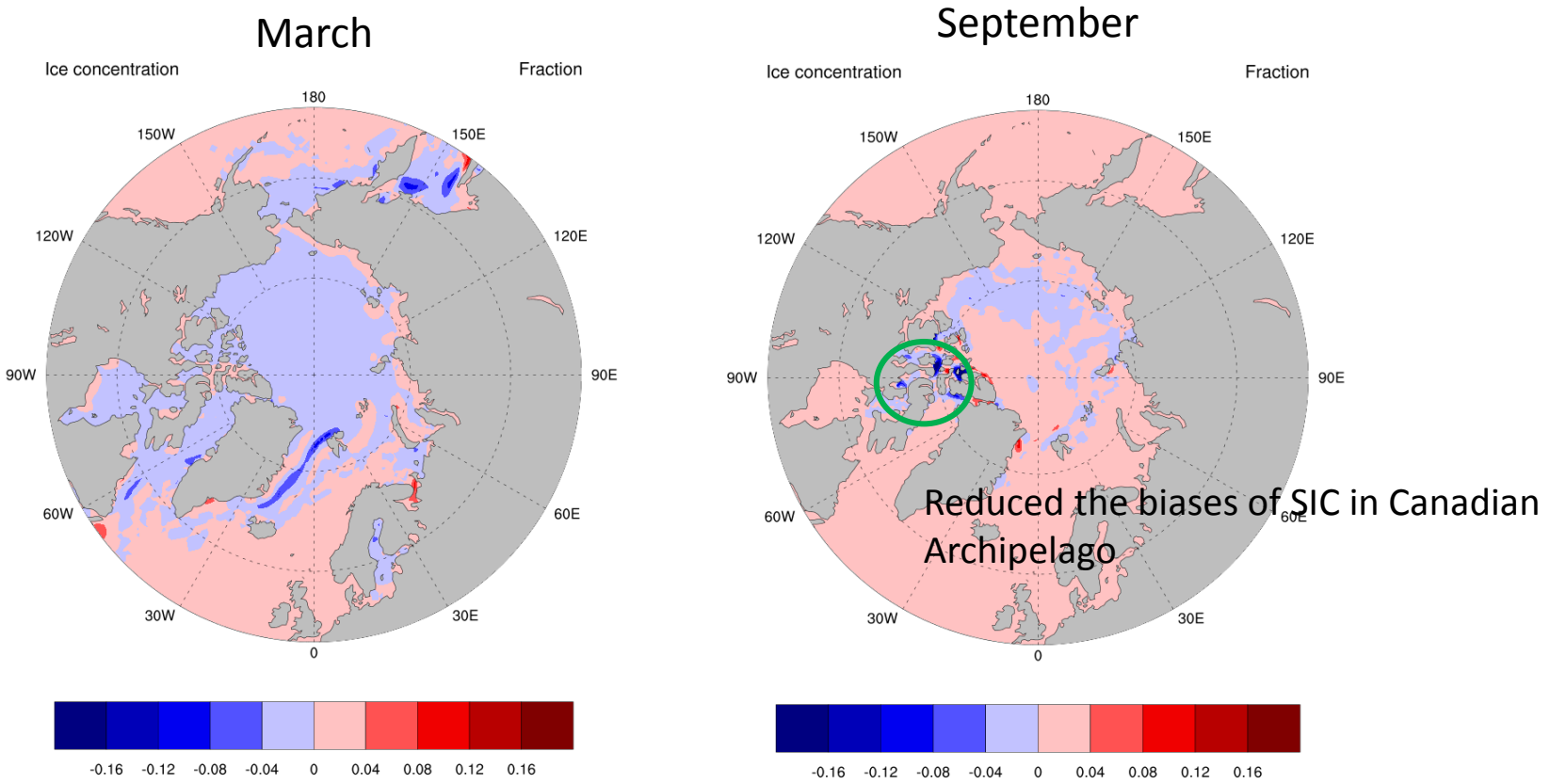
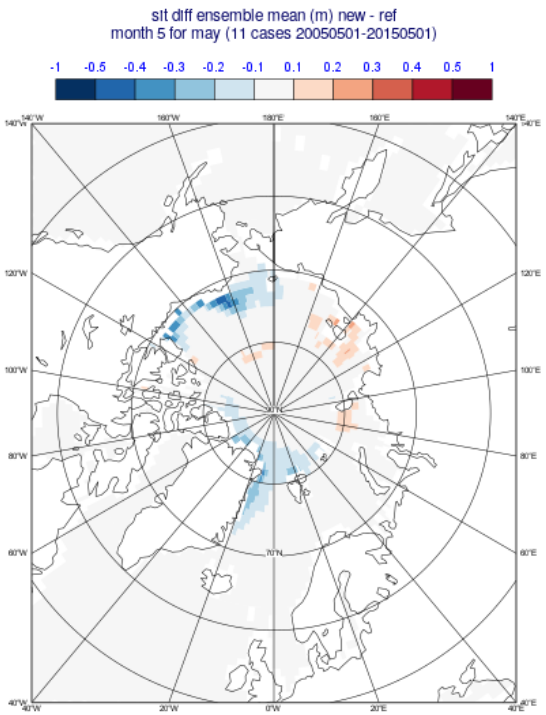


Figure by Beena B. Sarojini

Impact on reforecasts: L3 OSI-SAF VS L4 OSTIA

Reforecasts differences: September (May start)
OSI-SAF (L3) – OSTIA (L4)

Sea Ice thickness (m)



Sea Ice concentration

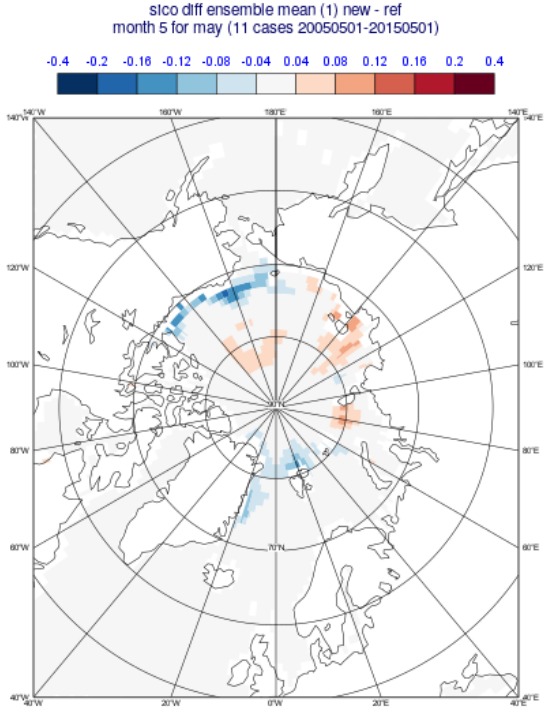
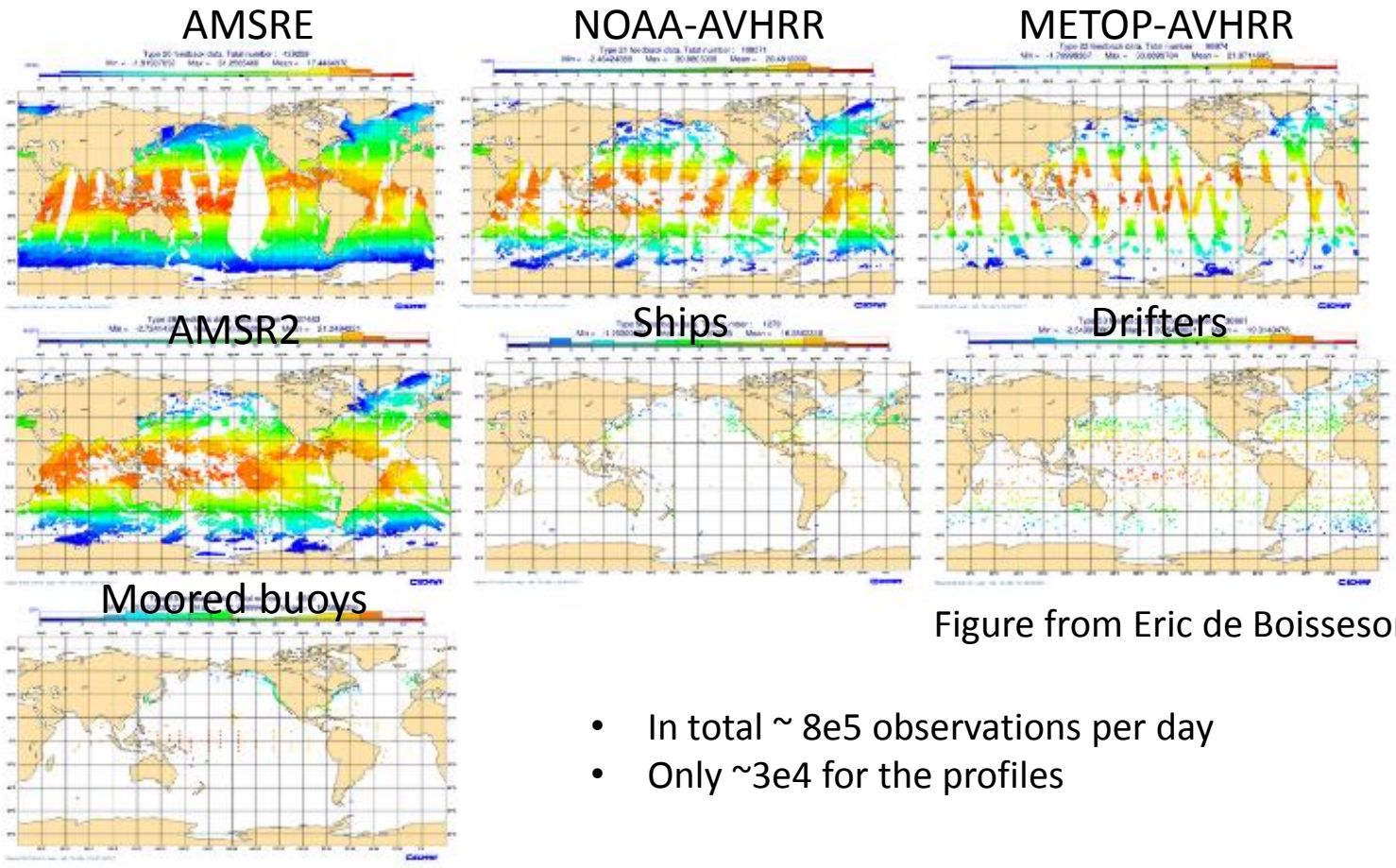


Figure by Beena B. Sarojini

ECMWF

Development of SST assimilation

- Assimilation of bias corrected L2P swath SST (Kindly provided by UKMO)
- SST treated as the single first layer Temperature in model
- Mixed layer dependent vertical correlation and rossby radius dependent horizontal correlation



L2P: Level 2 Pre-Processed Product. SST retrievals on the same grid as the source satellite observations. Typically the satellite projection for one orbit

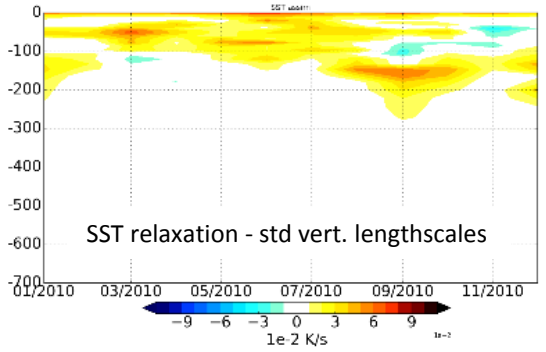
Figure from Eric de Boisseson

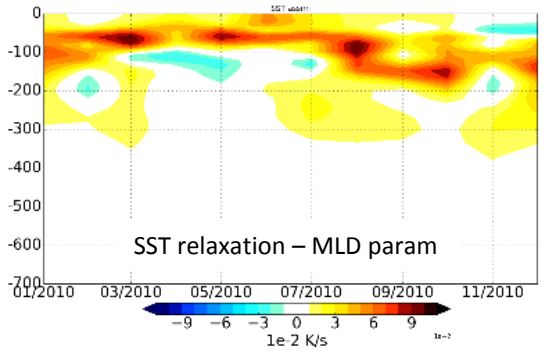
- In total ~ 8e5 observations per day
- Only ~3e4 for the profiles

SST assimilation VS nudging

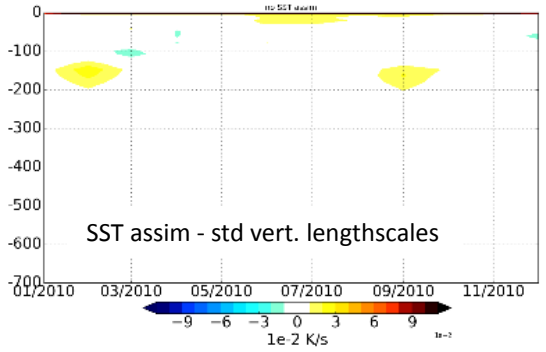
T increments

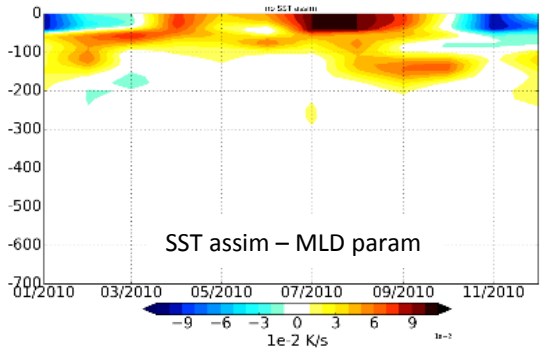
Nudging L4





DA L2P





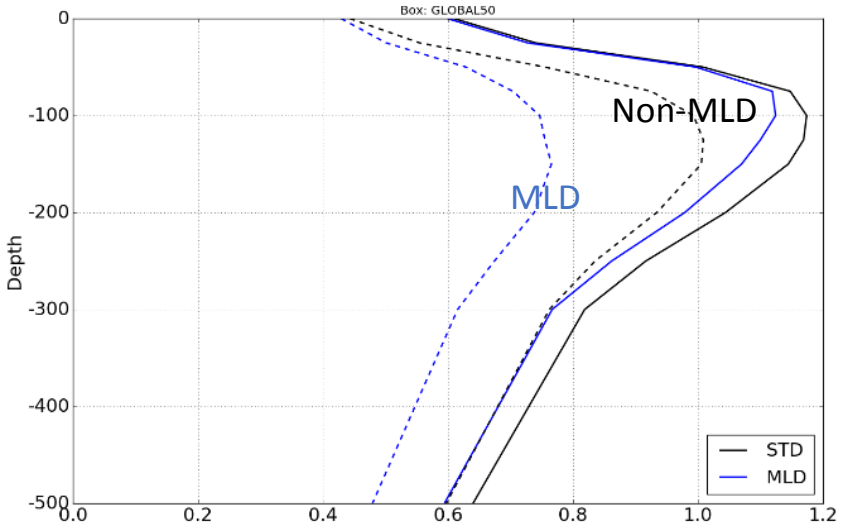
- MLD param allows the propagation of the T incr. down to the thermocline
- Further thinning and increased SST OE reduce the weight given to SST obs. wrt to profiles

Figure from Eric de Boisseson

SST assimilation VS nudging

First results encouraging. Work still ongoing to find the best configuration: convergence, MLD param, OE, bias correction…

SST relaxation - std vert. lengthscales vs MLD param
BKG RMSE (solid), AN RMSE (dashed)



SST assim – MLD param
BKG RMSE (solid), AN RMSE (dashed)

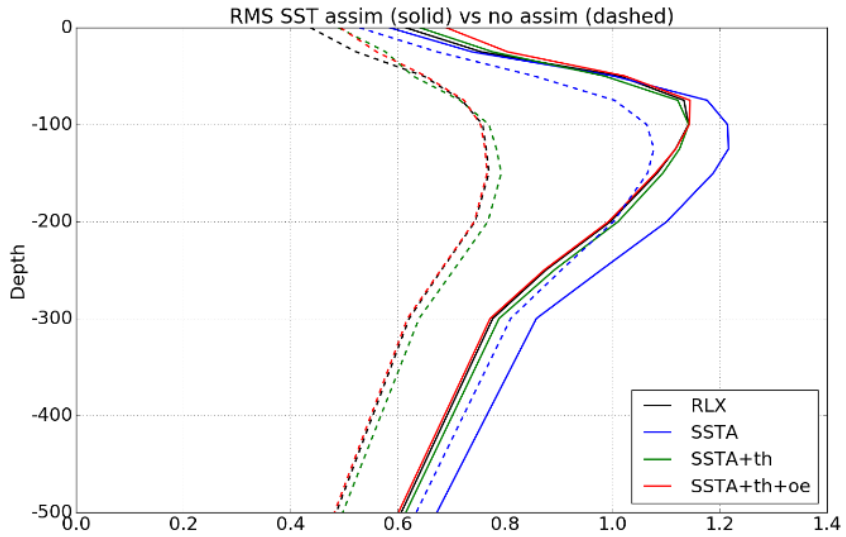


Figure from Eric de Boisseson

- SST relaxation: fit to profiles greatly improved with MLD param. But much more expensive.
- SST assim with MLD param: assimilating all the data improves the bkg in the first levels but degrades the fit in the thermocline and at depth. Thinning and increasing the OE sdv for SST help reducing the degradation at depth but first levels still worse.

Summary

- SST and sea-ice observation is essential for climate monitoring and reanalysis/reforecasts application
  - Much more (1e3 times) SST/SIC observation available than ocean in-situ observations
  - Ensure accurate reproduction of various Essential Climate Variables (ECVs): OHC, sea-level, Transports, Overturning circulations, et al
- There is large uncertainty (0.1-0.15K) in SST analysis products due to different data sources, SST definitions, bias correction and analysis strategies.
- Ocean reanalysis is sensitive to the assimilated SST/SIC products. At the same, consistency in SST/SIC product is crucial for ORA and climate application.
- Both SST and SIC assimilations have an impact on (re)forecasts, which is not always positive.
- ECMWF is developing assimilating L2P SST and L3 SIC data.