

The increasing role of SST observation in ECMWF NWP and (Re)Analysis: An Ocean Perspective

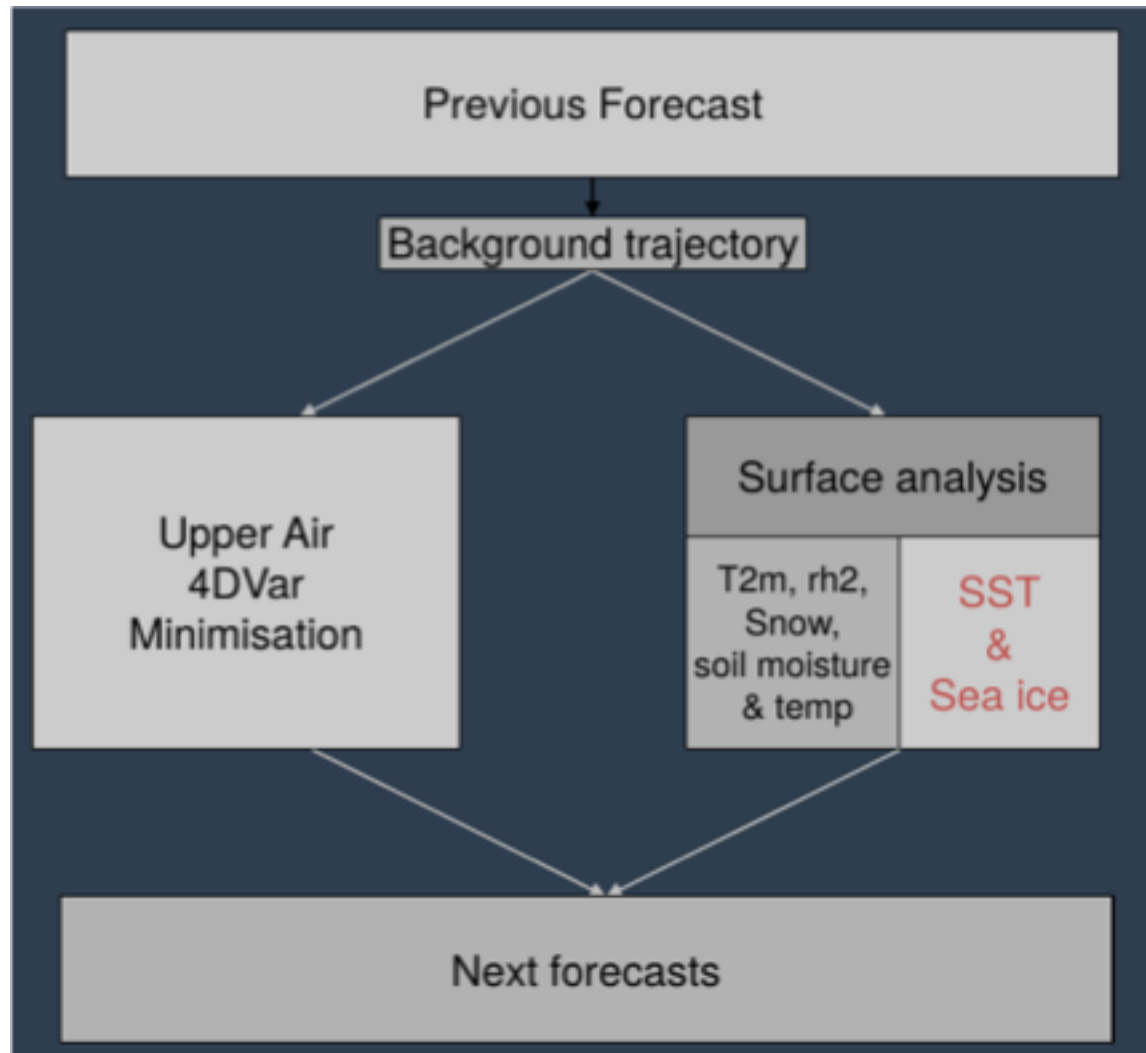
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ECMWF

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SST for ECMWF Atmospheric analysis



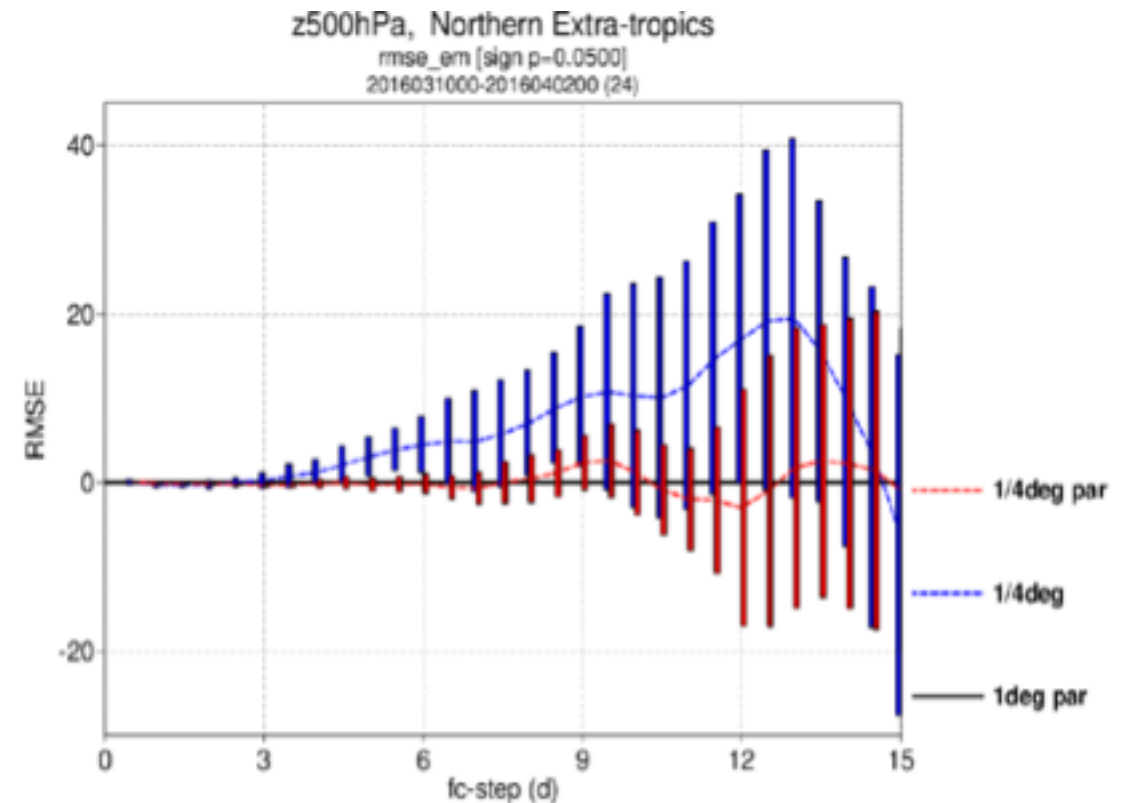
The SST and sea ice comes from external sources. Since 2008 we have been using the OSTIA operational product

- SST from the MetOffice
- Sea ice from EUMETSAT OSI-SAF
- CI<20% set to 0 (our choice)
- No consistency check between sea ice and SST

SST for ECMWF coupled forecasts

The ensemble prediction system (ENS) uses the coupled model: IFS + NEMO ocean model
A “partial coupling” scheme: The atmosphere sees the SST from atmospheric analysis (*OSTIA*) with added SST tendencies from the ocean model

- Preserves small scales structure of *OSTIA* in the SST field
- After 4 day we gradually switched to full coupling where the SST of the atmosphere and the ocean are consistent.



SST for ECMWF Ocean analysis

OCEAN5

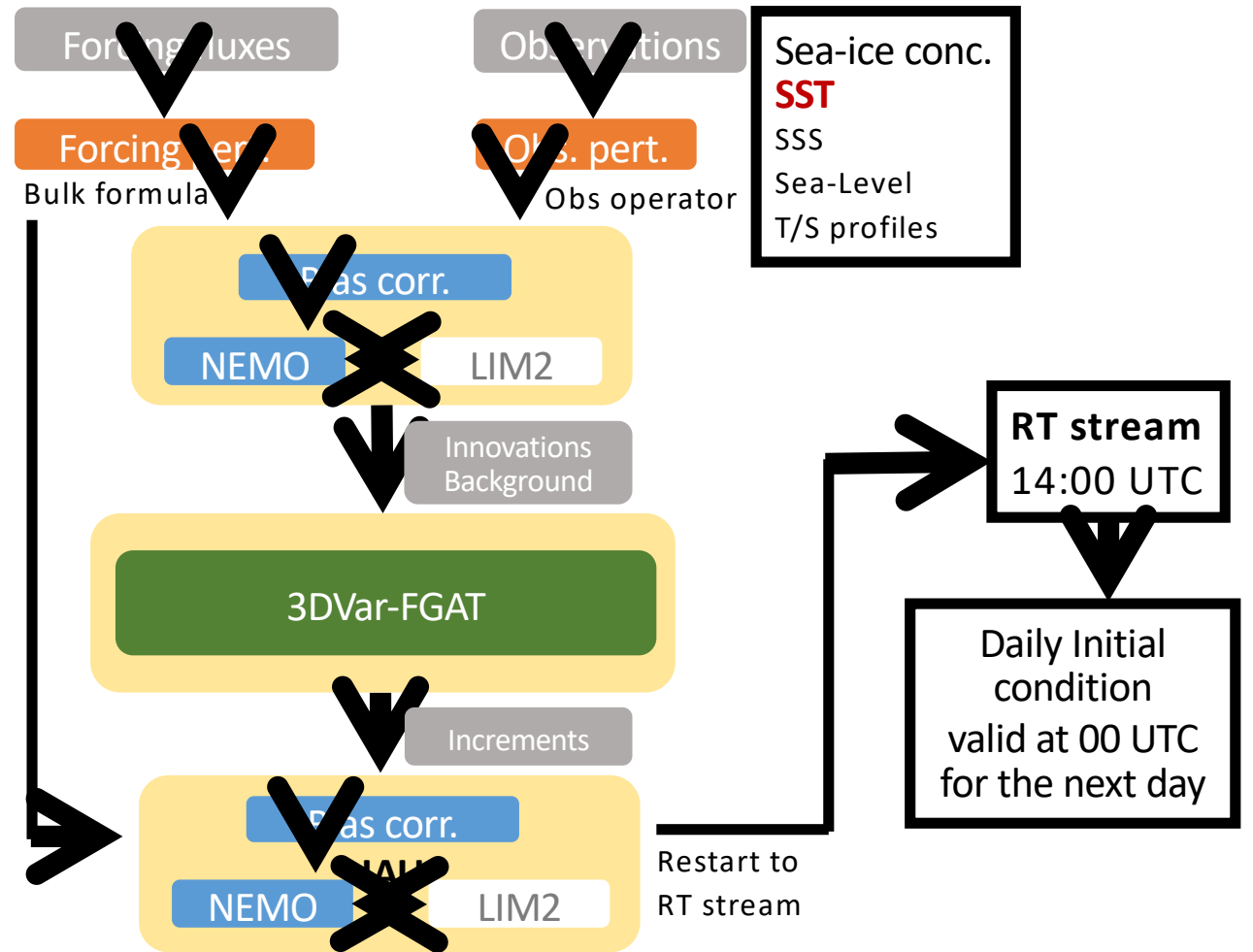
- Model: NEMOv3.4 + LIM2 (0.25 deg + L75)
- DA: 3DVAR-FGAT
- 5 ensemble members
- BRT+RT streams

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

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

ORAS5
BRT stream

Zuo et al., 2018



Use of SST obs in Ocean Data Assimilation

SST nudging scheme

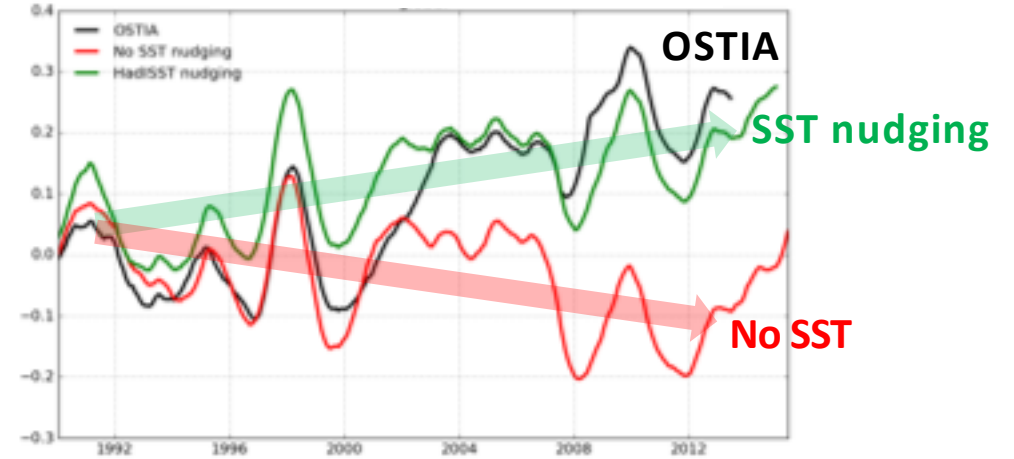
Haney 1917

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

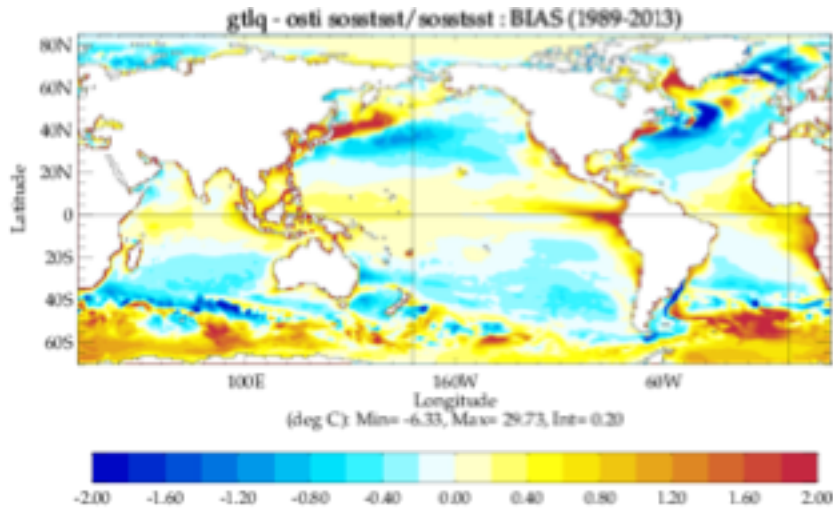
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non-solar total heat flux Fixed negative feedback coefficient

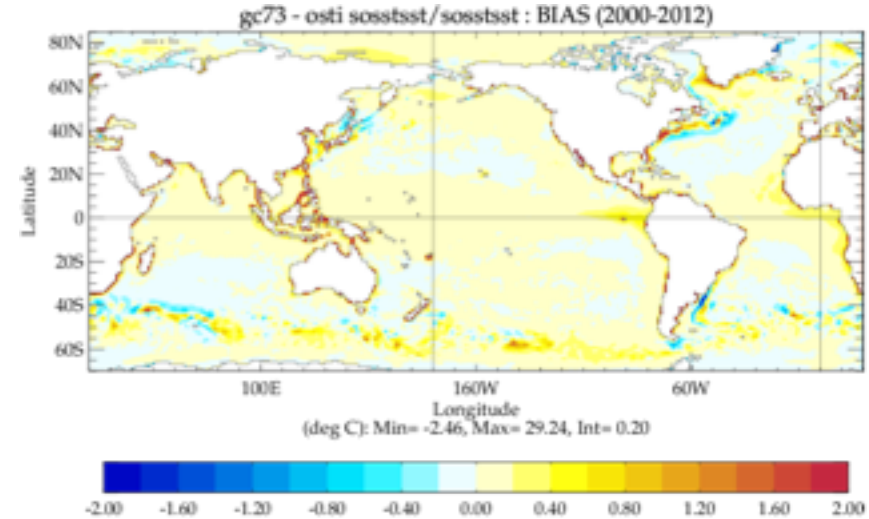
Global mean SST



SST bias: Control - OSTIA

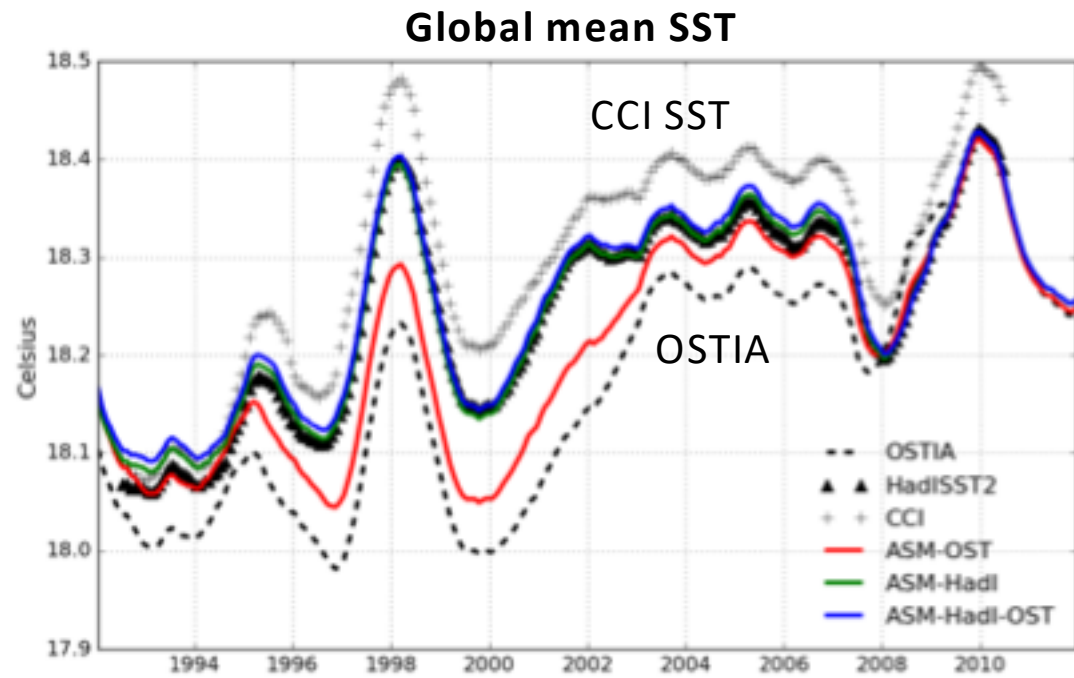


SST bias: ORAS5 - OSTIA



Impact of SST obs in Ocean ReAnalysis

Reforecasts and Climate Monitoring



Zuo et al., 2018

DA experiments with different products

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

AMOC transports in ocean reanalyses



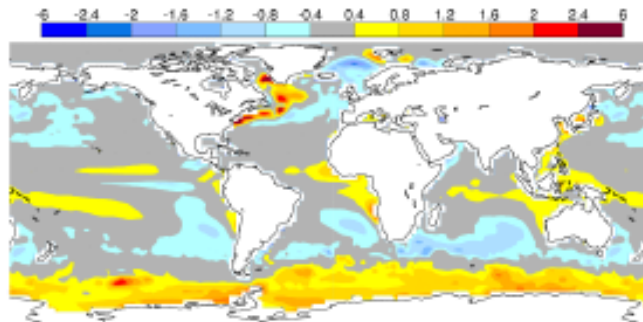
Use of SST obs: Model calibration and skill assessment

Both calibration and skill assessment require a set of reforecast over a sufficiently long period. These reforecast are initialized from reanalyses.

Assessment:
SST forecasts in DJF
Month 2-4, 1981-2010

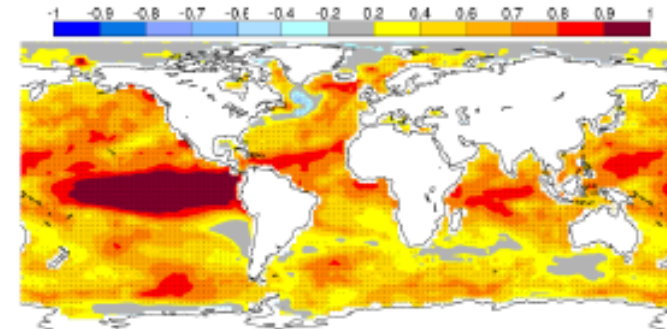
Bias

Bias (model minus reference) for ECMWF S5 with 25 ensemble members
Sea Surface temperature (°C)
Hindcast period 1981-2010 with start in November average over months 2 to 4

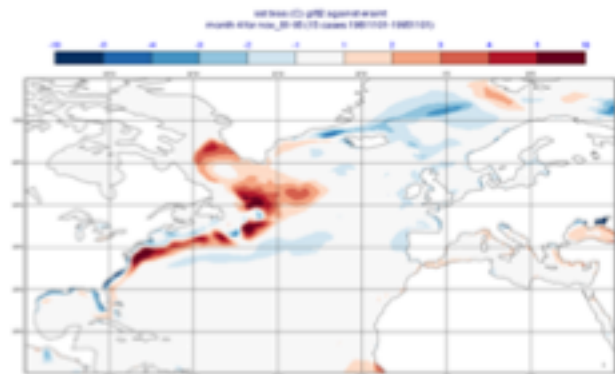


Anomaly Correlation

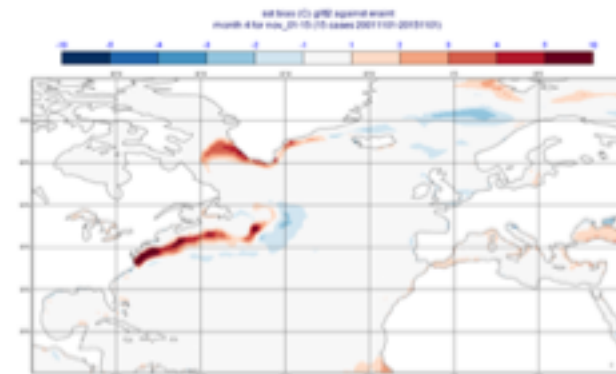
Anomaly Correlation Coefficient for ECMWF S5 with 25 ensemble members
Sea Surface temperature (°C)
Hindcast period 1981-2010 with start in November average over months 2 to 4
Black dots for values significantly different from zero with 95% confidence (200 samples)



Calibration of SEAS5:
SST bias



Before 2000

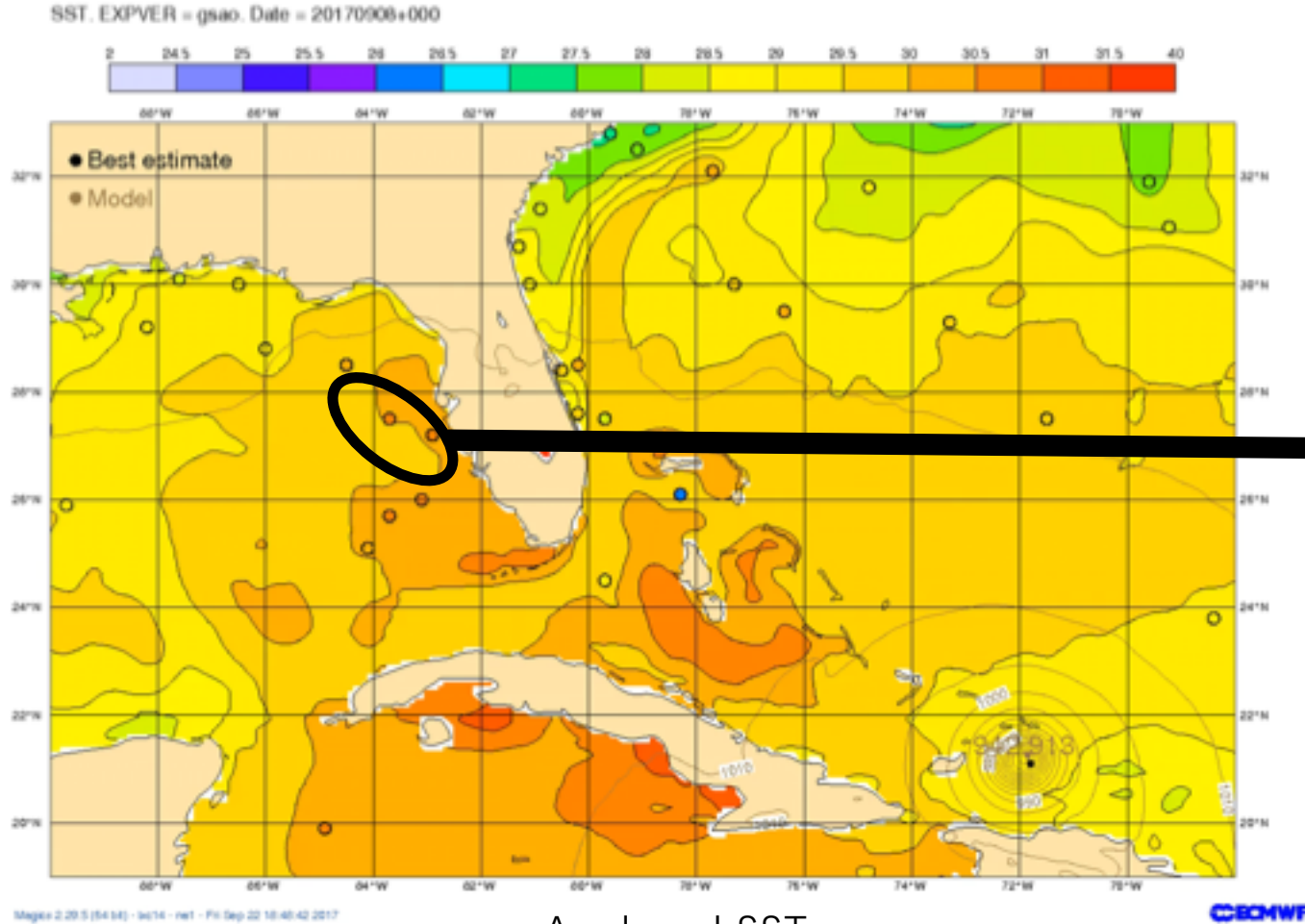


After 2000

GHRSSST XIX

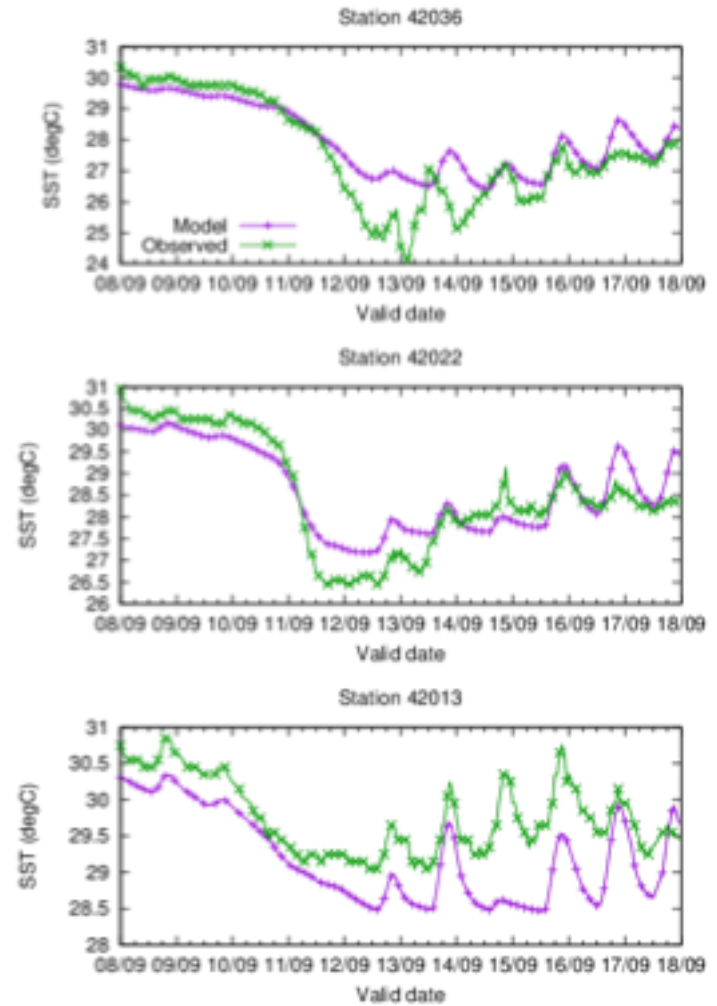
Use of SST obs: Model evaluation

Hurricane Irma



Analyzed SST

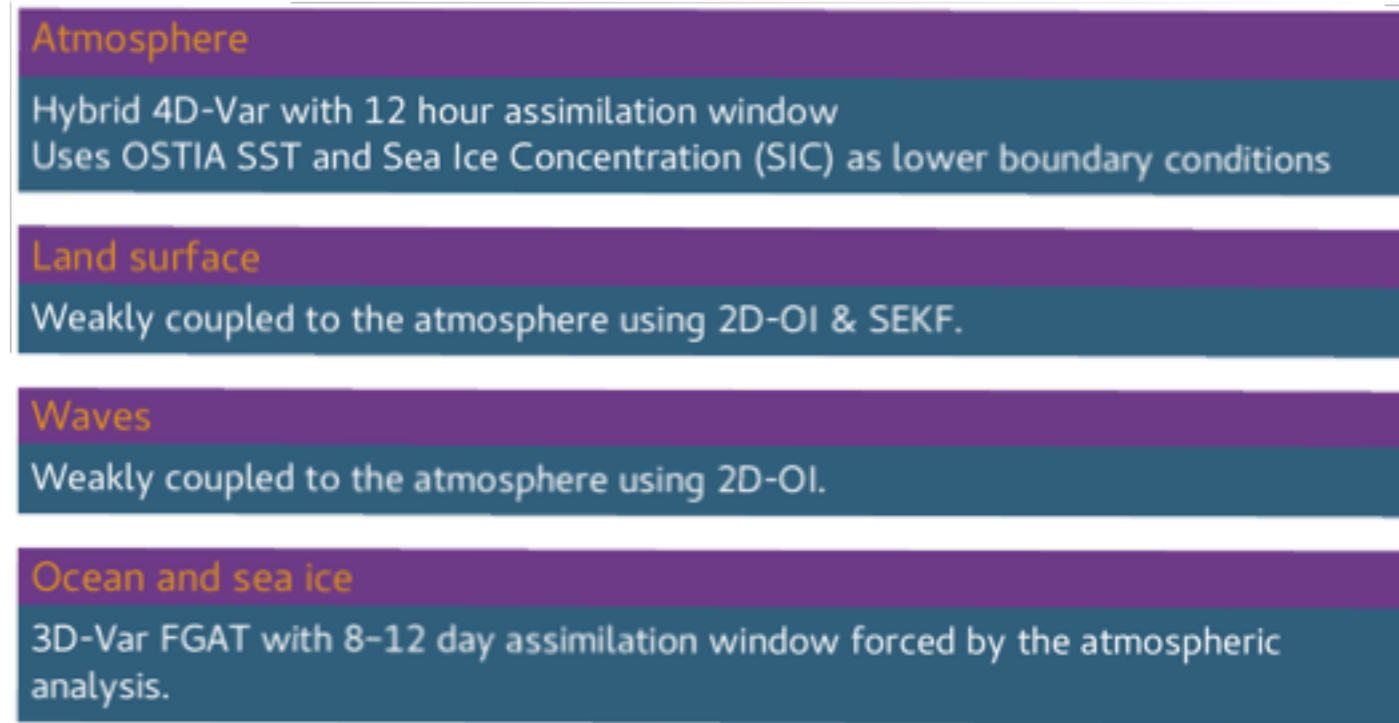
SST from Obs and coupled model forecasts



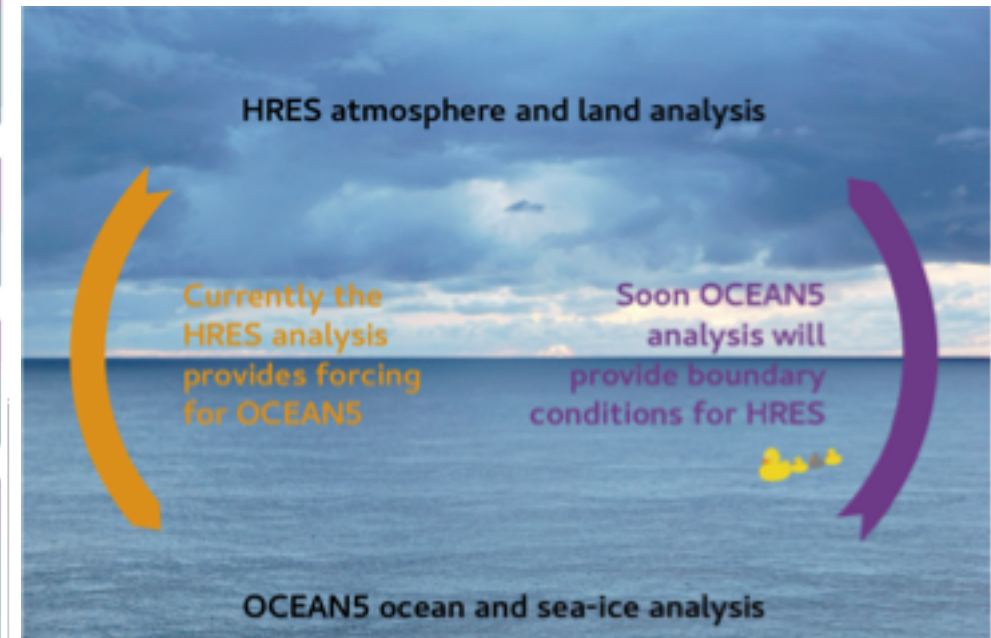
Courtesy of Kristian Mogensen

WCDA system development at ECMWF

Current DA system at ECMWF



Weakly Coupled ocean-atmosphere DA



Courtesy of Phil. Browne

Planned changes of SST/sea-ice for ECMWF NWP system in 2018

CY45R1:

- HRES coupled to NEMO (0.25 degree) for the long forecast
 - This means that all forecasts issued by ECMWF will be using a coupled model
- Introduction of full coupling in the tropics
 - OCEAN5 from day 0 in the tropics
 - This will be done for both HRES and ENS
- Using of OCEAN5 sea-ice in the atmospheric analysis system
 - Increases the coupling between the atmosphere and the ocean in the analysis system

CY46R1:

- Use the SST from OCEAN5 in the tropics merged with OSTIA in the extra-tropics in the atmospheric analysis system is been investigated
 - Increases the coupling between the atmosphere and the ocean in the analysis system yet another step

Impact of SST in uncoupled forecasts - HRES

Control forecasts: OSTIA SST + climatological tendency (OSTIA)

New forecasts: OCEAN5 SST + climatological tendency (OSTIA)

Impact on Geopotential

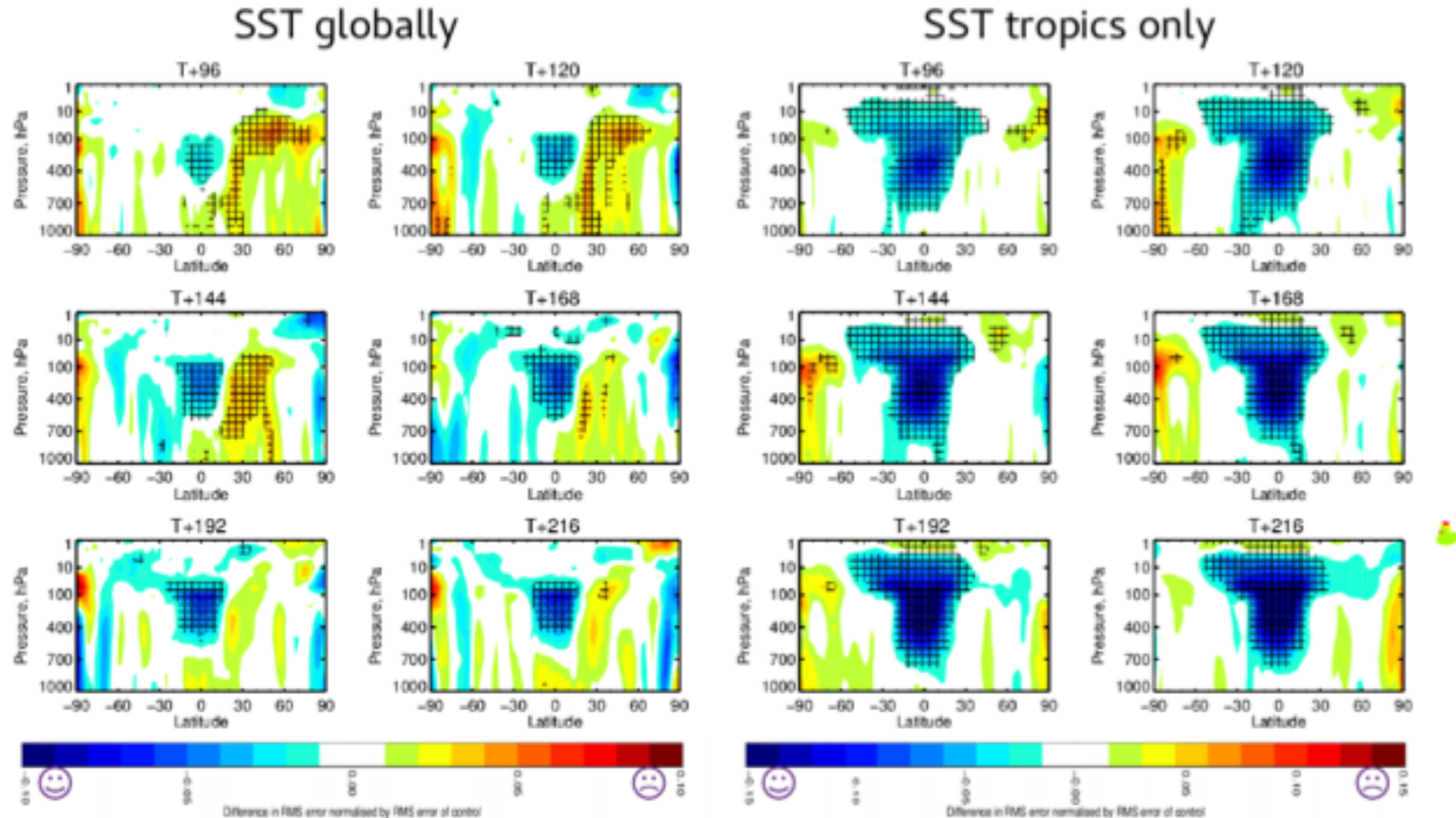


Figure by
Phil. Browne

Impact of SST in coupled forecasts - HERS

WCDA SST in the Tropics

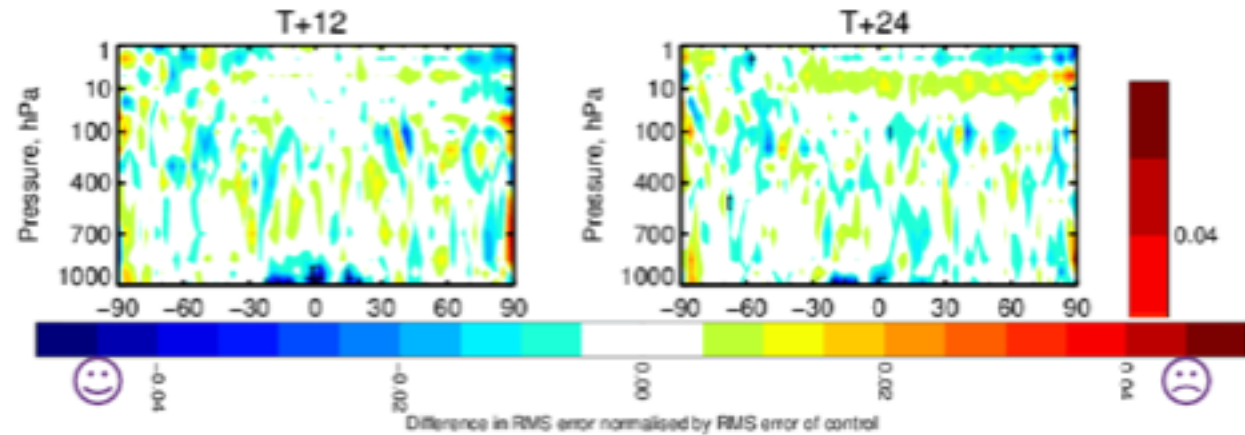
- Ocean and Atmospheric analysis are produced with WCDA
- The control Atmospheric analysis is uncoupled (prescribed with OSTIA)
- Improvement comes from improved Atmospheric analysis by WCDA through SST coupling in the Tropics.

Figure by Phil. Browne

Impact on humidity and Temperature

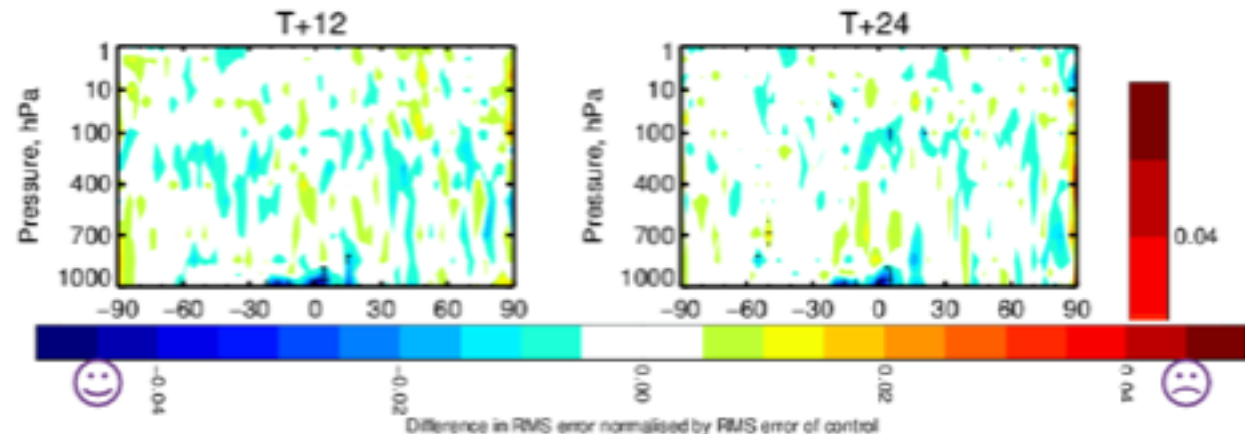
Change in error in R (Summer analysis blended SST-control)

6-Jun-2017 to 31-Aug-2017 from 154 to 173 samples. Cross-hatching indicates 95% confidence. Verified against own-analysis.



Change in error in T (Summer analysis blended SST-control)

6-Jun-2017 to 31-Aug-2017 from 154 to 173 samples. Cross-hatching indicates 95% confidence. Verified against own-analysis.



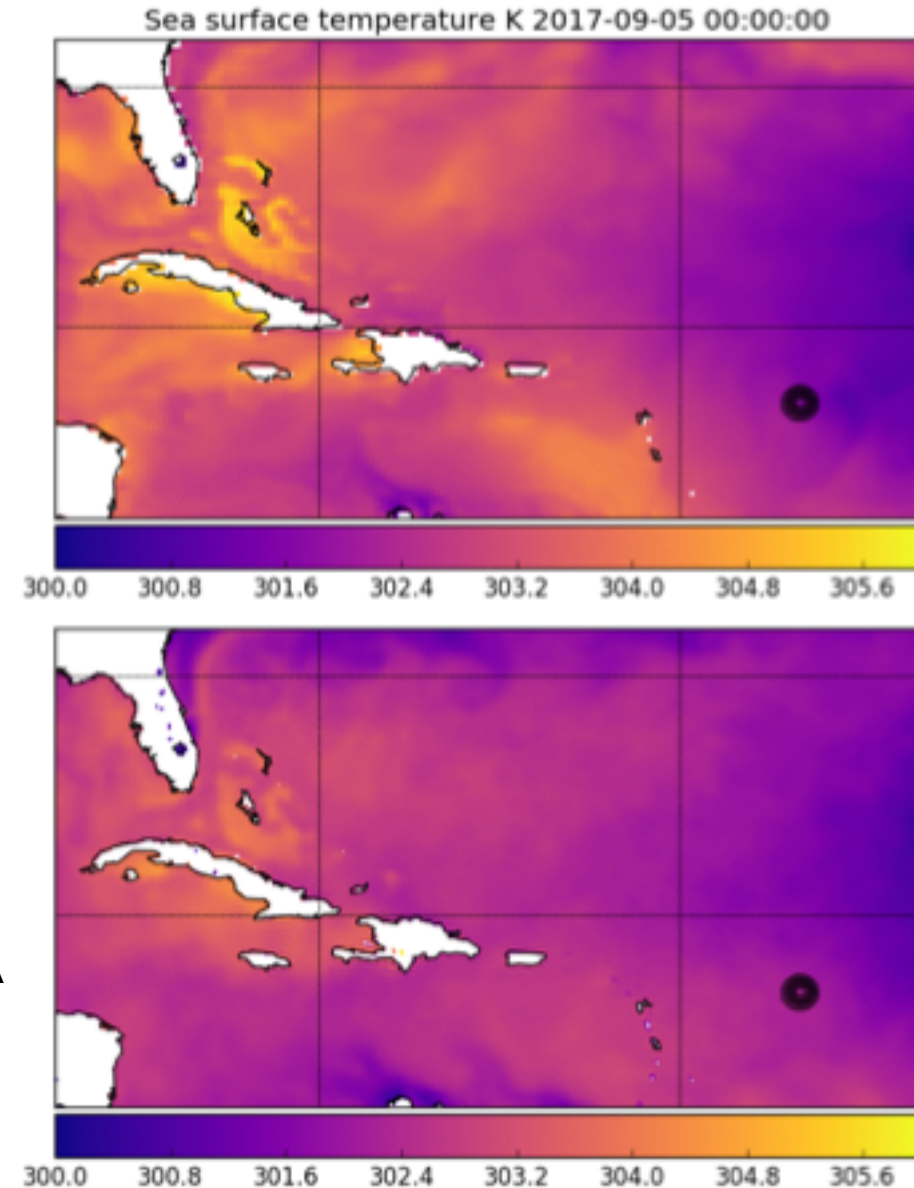
SST in coupled VS un-coupled analysis

Quasi-Strongly Coupled DA analysis

- Better representation of the rapid ocean cooling process
- However hard to obtain satellite observations following Hurricane pathways
- In-situ obs is vital

Uncoupled analysis: OSTIA
Normally with 1-2 day delay

Hurricanes Irma and Jose



Courtesy of
Phil. Browne

Impact of timeliness of OSTIA SST

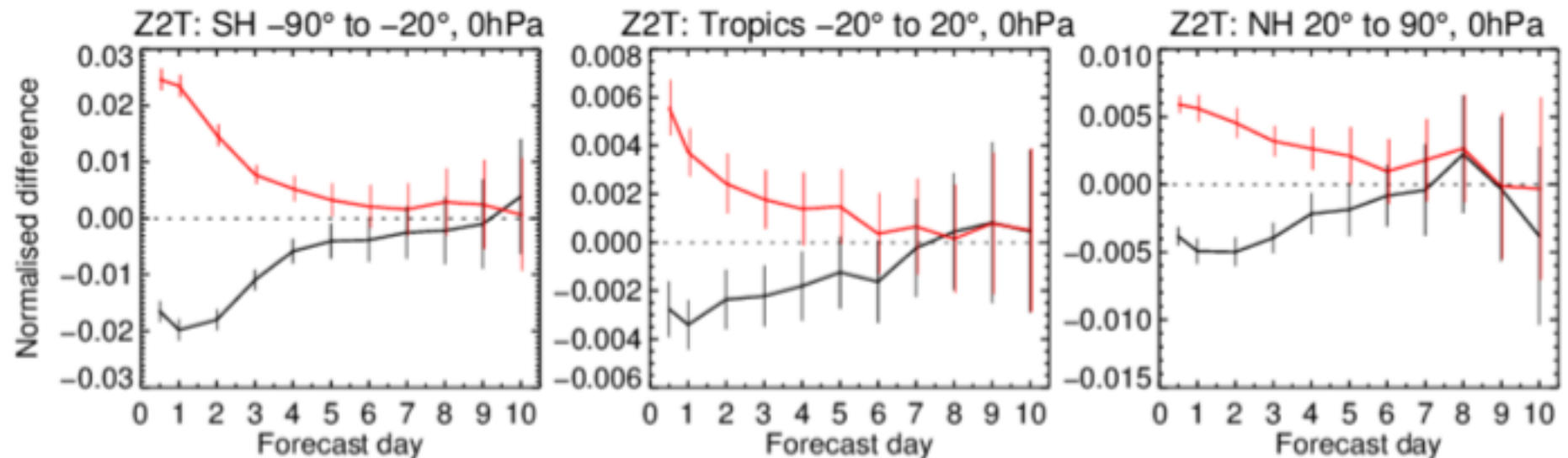
Current OSTIA SST used in 4DVar (Atmosphere) is with up to 57 hours delay
in 3DVar (Ocean) is with 24 hours delay

Research on timeliness of SST observations

- Use OSTIA from yesterday as operational (control)
- Use OSTIA at the right day (Delay + 1)
- Use OSTIA from the day before yesterday (Delay -1)

1–Dec–2014 to 30–Nov–2015 from 356 to 365 samples. Verified against 0001.

Confidence range 95% with AR(1) inflation and Sidak correction for 8 independent tests



— sstoffset=+1 – control
— sstoffset=-1 – control

Development of L2 SST assimilation

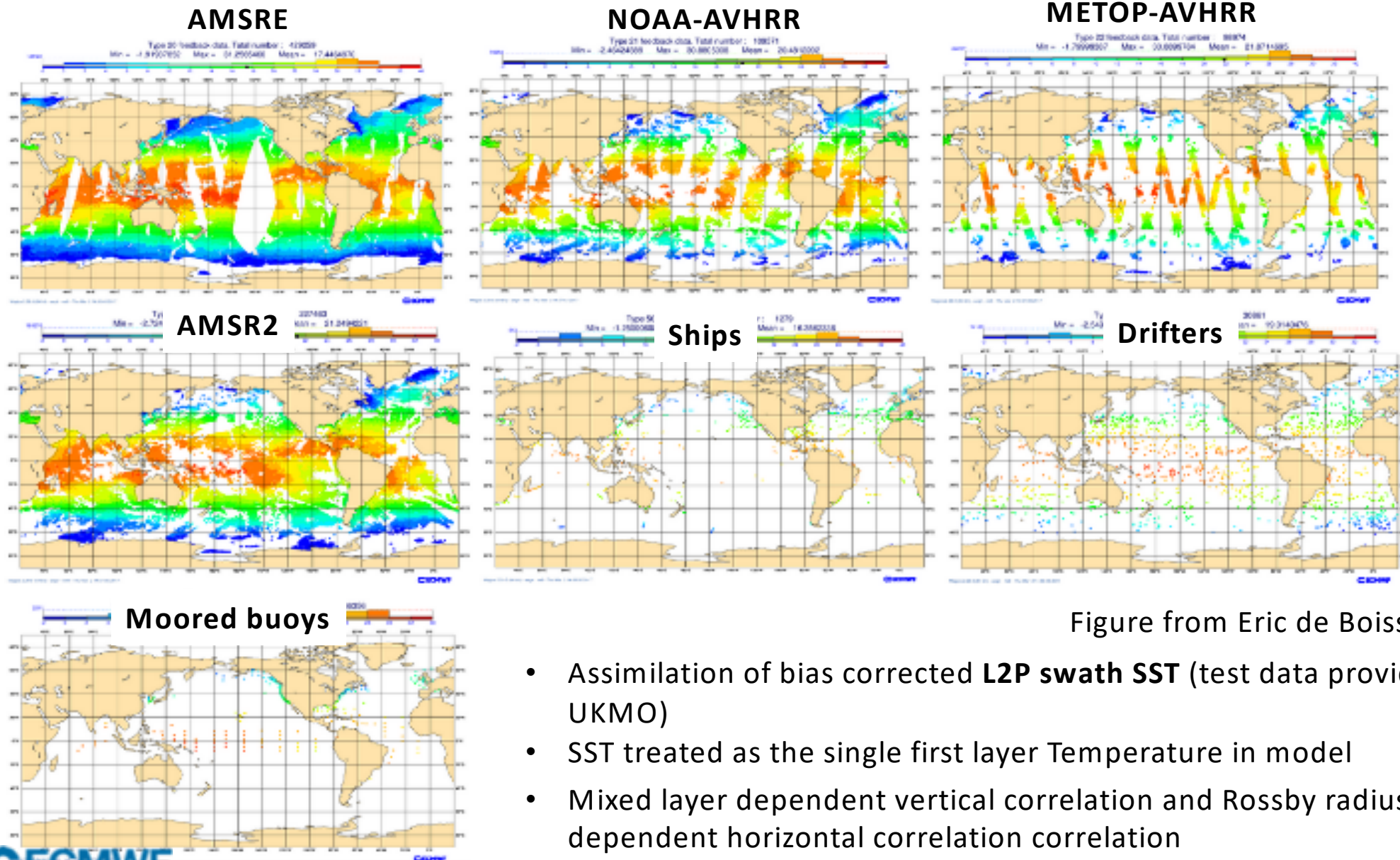


Figure from Eric de Boisseson

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

Workshop on observations and analysis of sea-surface temperature and sea ice for NWP and Climate Applications

22 – 25 January 2018

- The way forward for the use of observations of SST and sea-ice
- To advise ECMWF on how to best exploit the observational information.
- To identify areas where significant improvements and progress can be made



Outcome of SST/Sea-ice workshop

Vision of using SST/Sea-ice information at ECMWF in 10 years:

ECMWF was encouraged to follow an evolution towards the **assimilation of radiances (L1 data) for the constraint of SST and sea-ice in the context of running fully coupled systems.**

- Coupled DA and modelling has demonstrated benefits and should be further developed independent on decisions on the assimilation of L1 data.
- Fully coupled L1-DA is aspirational, but at this stage speculative. A stepwise approach needs to be followed as science and resources allow
- Forward models should be shared by community and provided/supported by central facility.
- The fitness of the individual model components (ocean, sea ice, land, ocean surface waves)
- and their respective DA schemes for the purpose of assimilating L1 data needs to be developed and evaluated.
- ECMWF should seek to exploit opportunities, campaigns and collaboration as they arise
- (GHRSSST, SAFs, ESA, EUMETSAT, all existing partnerships).

Outcome of SST/Sea-ice workshop

(a) Recommendations for improving the use of L4

- Actively engage with GHRSSST to optimise the properties of SST observations for NWP applications.
- Make use of diurnal cycle SST information in addition to foundation temperature
- Uncertainty information in the L4 product should be used when provided.
- Validation of SST forecasts should be done against foundation temperature, drifting buoy depth and skin temperature SST analyses

b) Recommendations for transition to L3-L2

- Initially use OSI-SAF L3 and then L2 products of SST and sea ice for assimilation into the ocean model.
- This will improve timeliness, allow using latest NWP input data and enable using QC information.
- This step will require consistent L2-L3 reprocessing for reanalyses. It will also require improving the methodology for assimilation of surface information into the ocean/sea-ice models.

Summary

SST observation is essential for NWP (calibration, assessment of forecasts) and (Re)Analysis (Data assimilation, evaluation of reforecasts, climate monitoring).

- L4 SST analysis prescribed the lower boundary condition in Atmospheric analysis
- L4 SST data is used to produce ocean analysis
- SST observation is routinely used for calibration seasonal forecasting system, and assessment of the forecasts skill
- The quality of SST product used influences the quality of the NWP forecasts

As ECMWF moving towards more coupling (both in model and DA system) in NWP, the role of SST observation becomes increasingly important. And our requirement for SST data also changes

- Faster and more frequent delivery of data
- Include uncertainty information for QC
- Moving from L4 towards L3/L2 level data
- Consistency between SST and sea-ice observations

The 2018 SST/Sea-ice workshop provides ECMWF with guide and recommendations for ECMWF 10 years' strategy regarding to use of SST and sea-ice information

- ECMWF will embark on assimilating L1 radiance with fully coupled system
- ECMWF has started working on assimilated L2P SST data

Extra slides

Important of SST observations in OOS

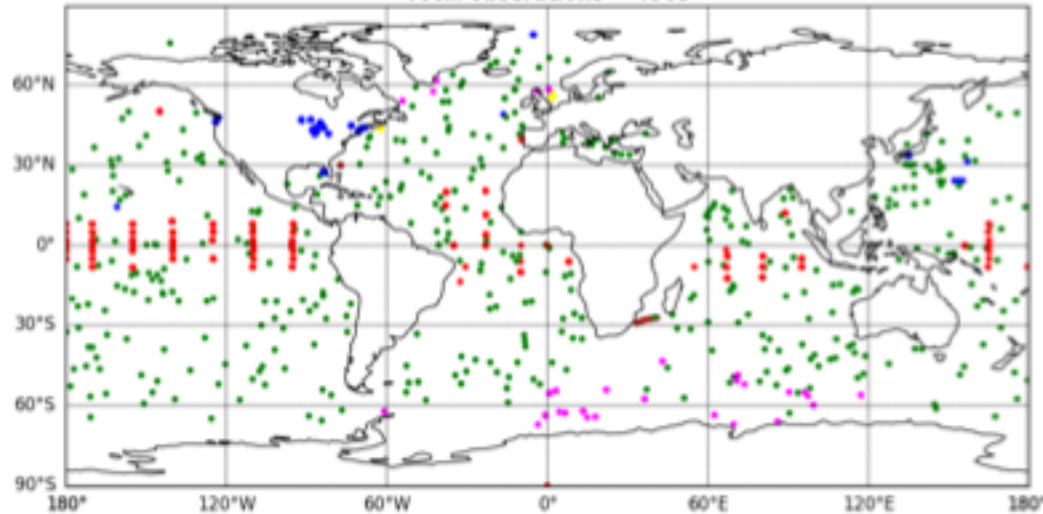
Daily available oceanic observations

Ocean In-situ obs (exclude drifters)

CTD:2233 APB:0 UOR:0 Seaglider:68 hres CTD:0
Argo:440 XBT:26 Mammals:66 Mooring:1730 MBT:0

~1e3 /day

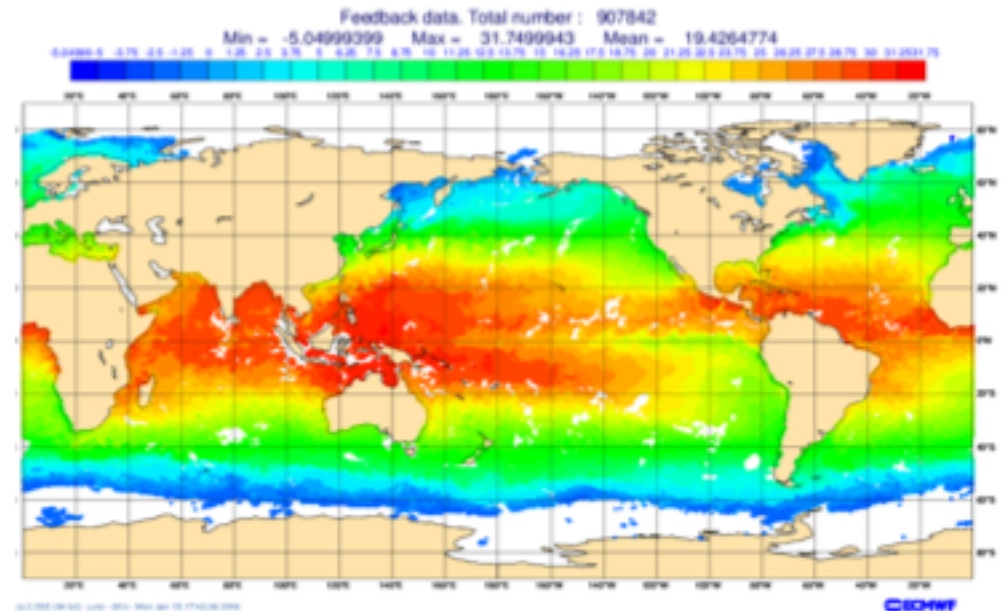
Total observations = 4563



26 May 2018

SST (GHRSSST L2P)

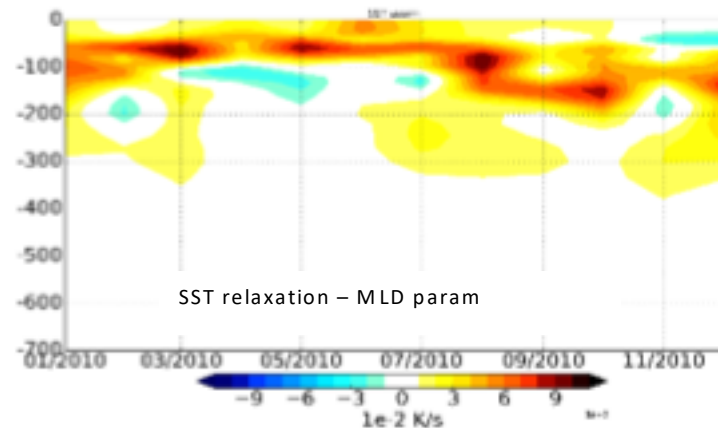
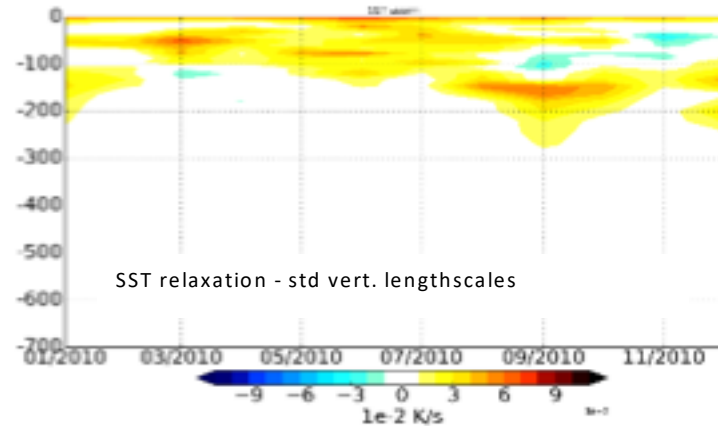
~1e6 /day



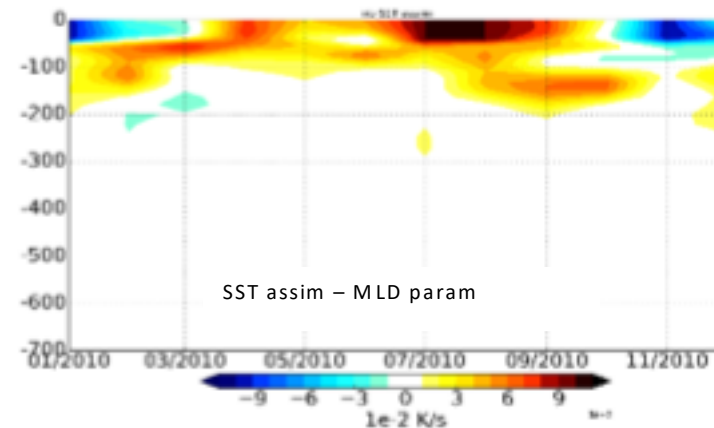
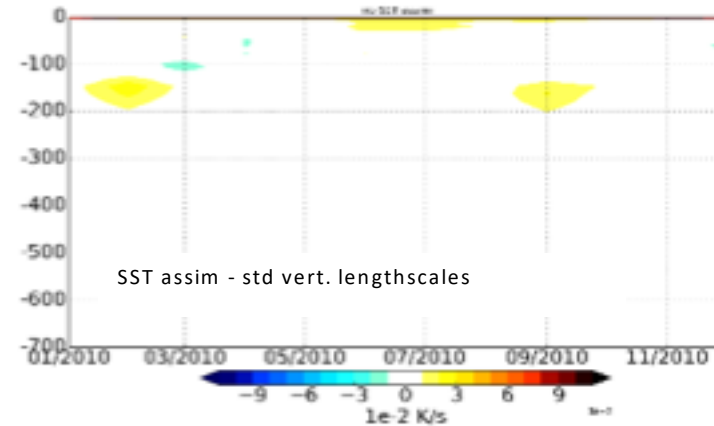
Development of L2 SST assimilation

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

Development of L2 SST assimilation

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

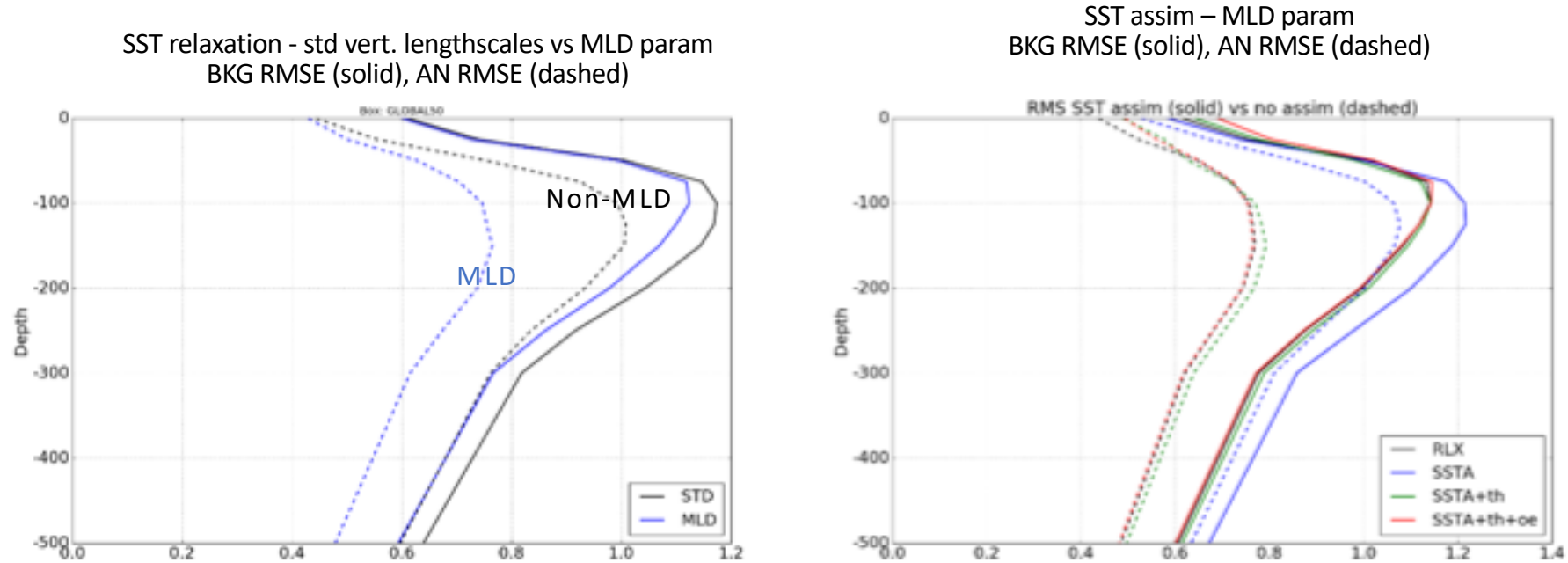


Figure from Eric de Boisseson

- 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.

Uncertainty in SST observation products

SST 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 analysis products available (OSTIA, ESA CCI, OIv2, HadISST2 ...). However different SST analysis products are **not always consistent**, with **large uncertainties** (magnitudes varies from global/climate to regional/daily scales).

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

Summary of some L4 SST analysis products

Products utilized satellite observations and with a global coverage

products	Data sources	SST definition	Bias correction	member	resolution	period
Olv2d (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