The Met Office's new analysis system for diurnal SST

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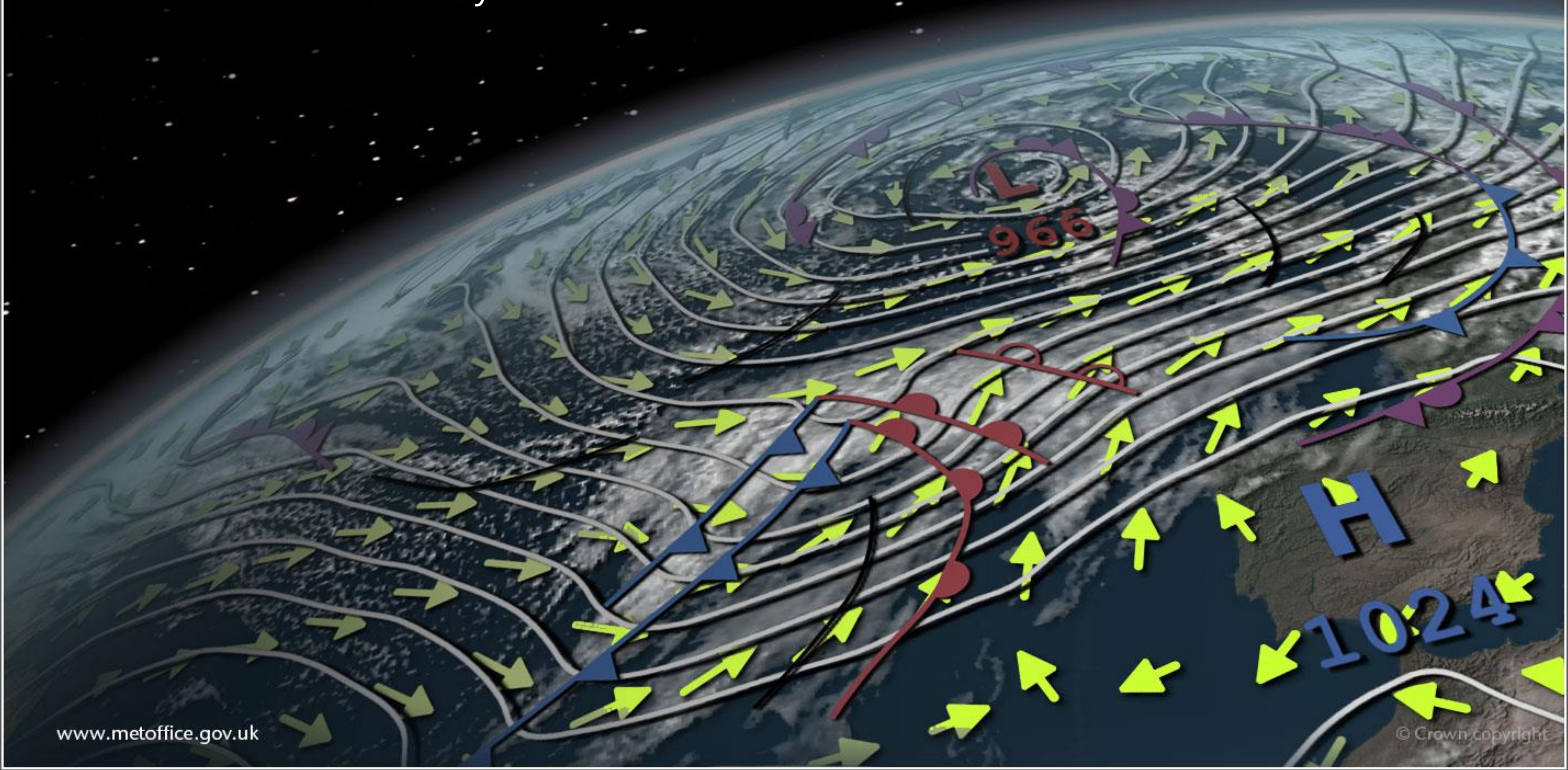
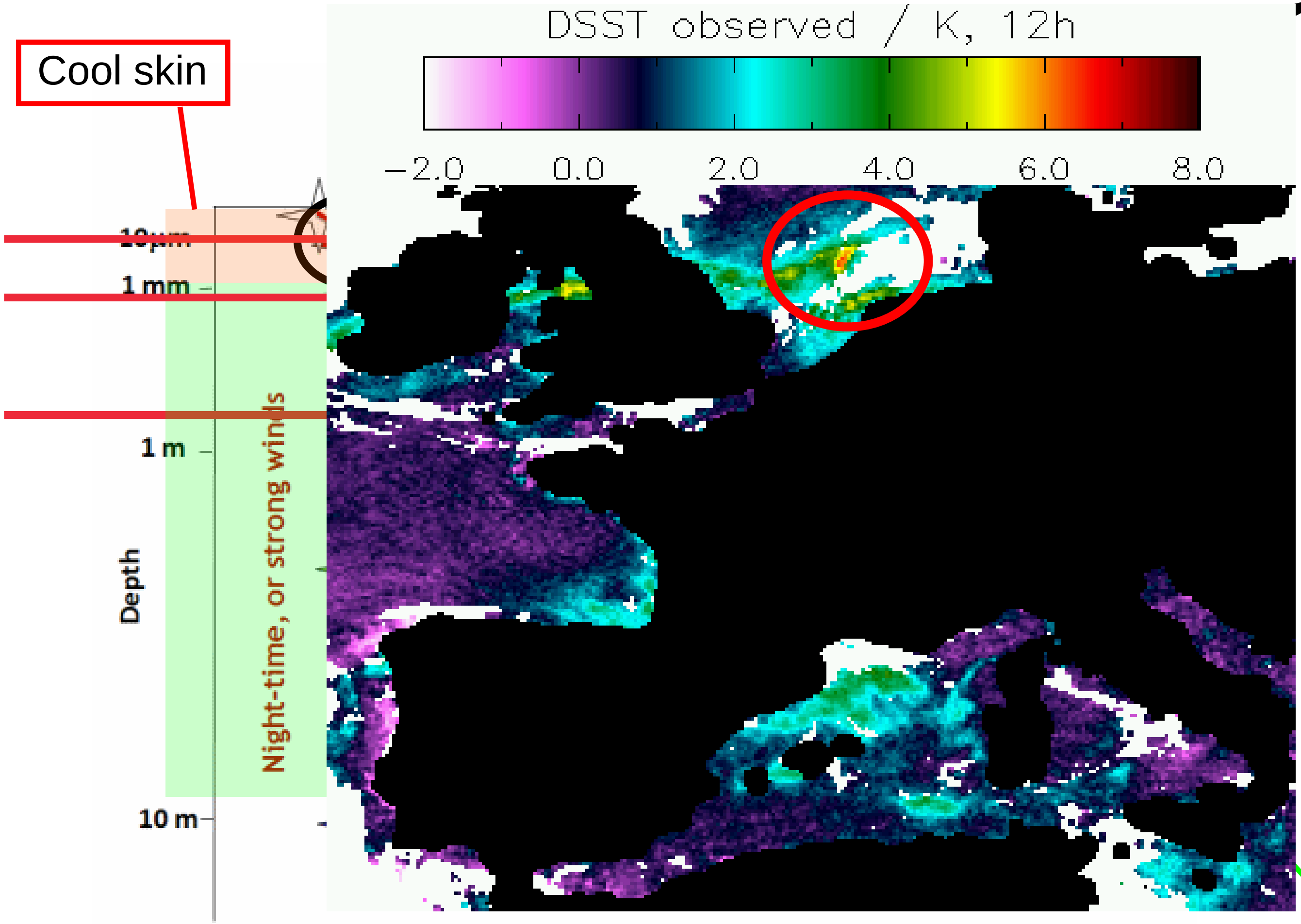
James While, Chongyuan Mao, Matthew Martin, Peter Sykes, Jonah Roberts-Jones, Alison McLaren

8th May 2015



What is diurnal SST?

Cool skin



Picture courtesy of the GHRSST consortium

We are most interested in the diurnal cycle at the ocean skin

IR Satellite

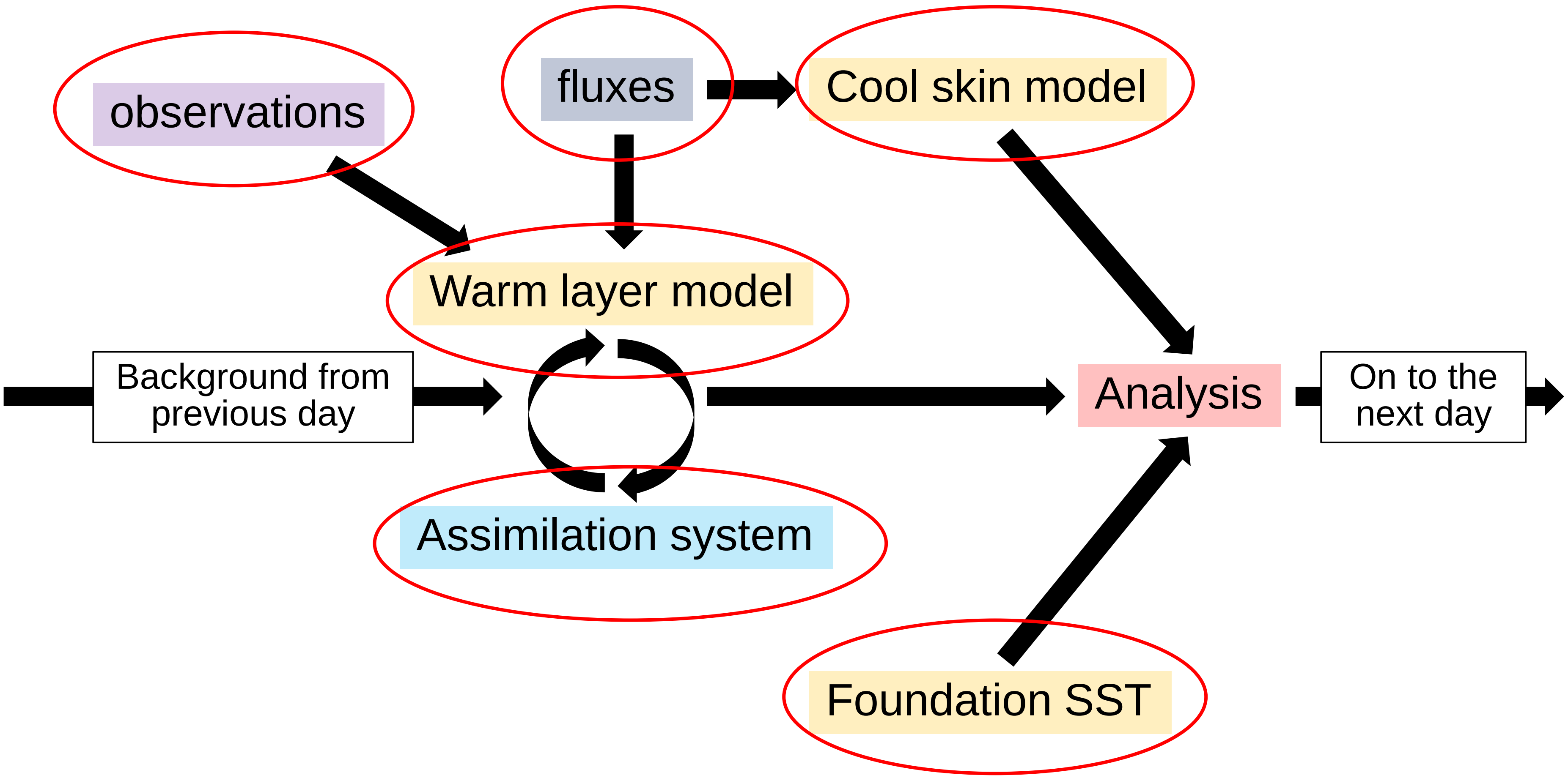
Microwave Satellite

In-situ measurements and ocean GCMs

Image reproduced with permission of Chris Merchant

Warm layer

Diurnal analysis system: a schematic



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Models

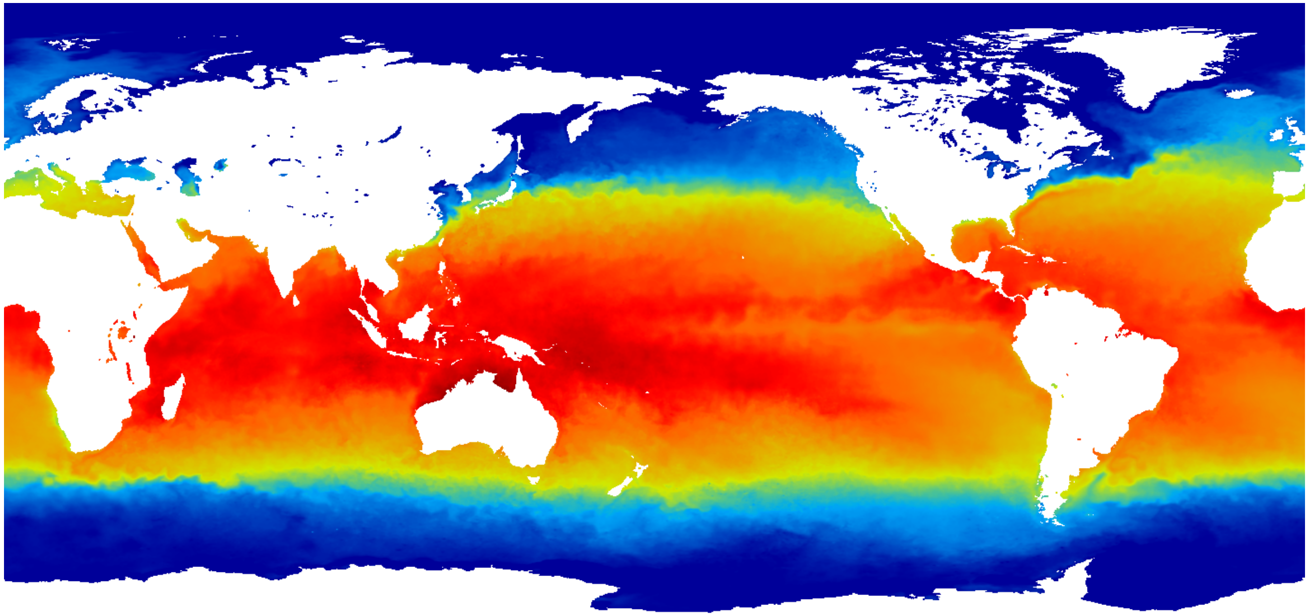
Foundation SST: OSTIA

Daily high-resolution (1/20°) analysis of SST and sea ice concentration.

SST analysis assimilates in-situ and satellite observations onto a background based on persistence. **No underlying physical model.**

OSTIA was developed to be used as a lower boundary condition in the Met Office atmospheric NWP model.

Produces an analysis of foundation SST, the temperature of the mixed-layer free of diurnal warming.



20130114–UKMO–L4HRfnd–GLOB–v01–fv02–OSTIA_1440.pp
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Cool Skin: Theory

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In NEMO we have implemented the Artale et al. (2002) cool skin model, which is based upon the Saunders equation.

According to Tu and Tsuang (2005), this model provides the best parameter values at both low and high wind-speed:

$$\Delta T_{cs} = \frac{Q_T \lambda \nu}{k_t u_*}$$

Layer thickness (~1mm)

$$\lambda = \frac{u_* k_t C}{\rho_w c_w h \nu \gamma}$$

$$\gamma = \begin{cases} 0.2u + 0.5, & u \le 7.5ms^{-1} \\ 1.6u - 10, & 7.5 < u < 10ms^{-1} \\ 6, & u \ge 10ms^{-1} \end{cases}$$

ΔT_{cs} = the skin and bulk difference

Q_t = Total heat flux (-ve in cool skin)

ν = kinematic viscosity of seawater

k_t = thermal conductivity of seawater

u_* = friction velocity of surface water $= \sqrt{\tau_u / \rho_w}$

τ_u = wind stress

ρ_w = seawater density

λ = a constant of proportionality

$C = 86400 s$ (number of secs in 1 day)

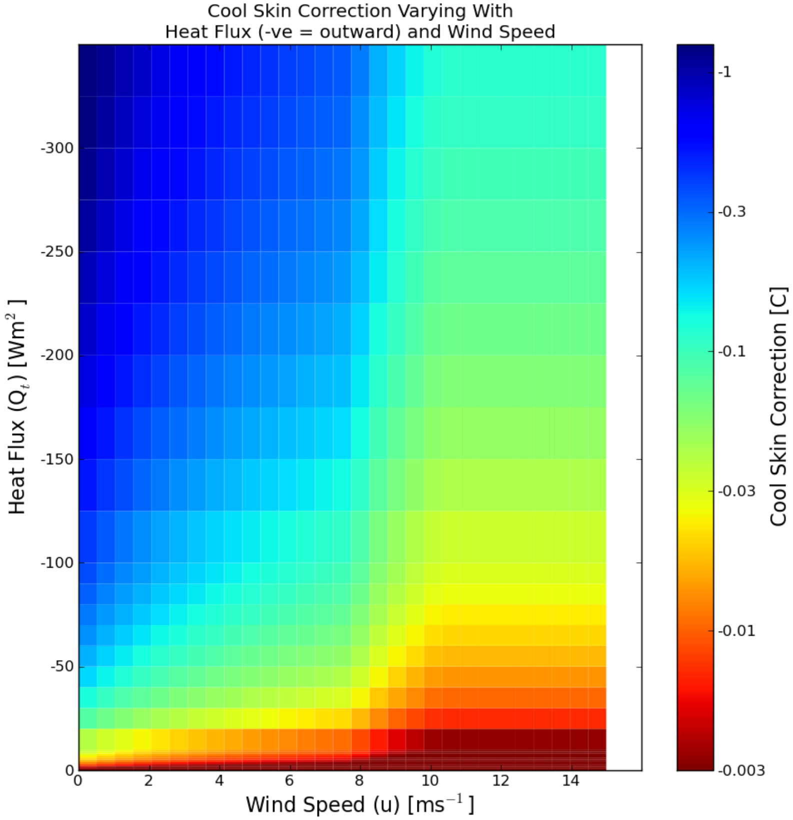
c_w = specific heat capacity of seawater at constant pressure

h = a reference depth

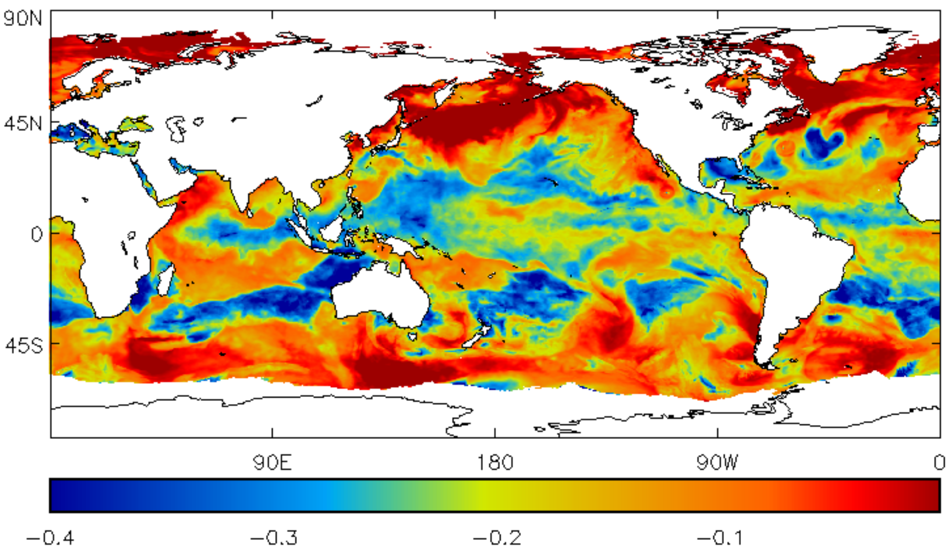
γ = dimensionless function of wind speed

u = wind speed

Cool Skin: output



Maximum cool skin: 15 July 2008



Note: Blue is large -ve

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Warm Layer Model: Theory

- We have also implemented a warm layer model within NEMO

- Based on the Takaya (2010) diurnal model.
  - Computationally cheap.
  - Continuous in time.

$$\frac{\partial T}{\partial t} = \frac{Q(\nu+1)}{D_T \rho c_p \nu} - \frac{(\nu+1)k u_w^* f(L_a)}{D_T \Phi\left(\frac{D_T}{L}\right)} T$$

Bulk thermal heating of a layer

Turbulent damping

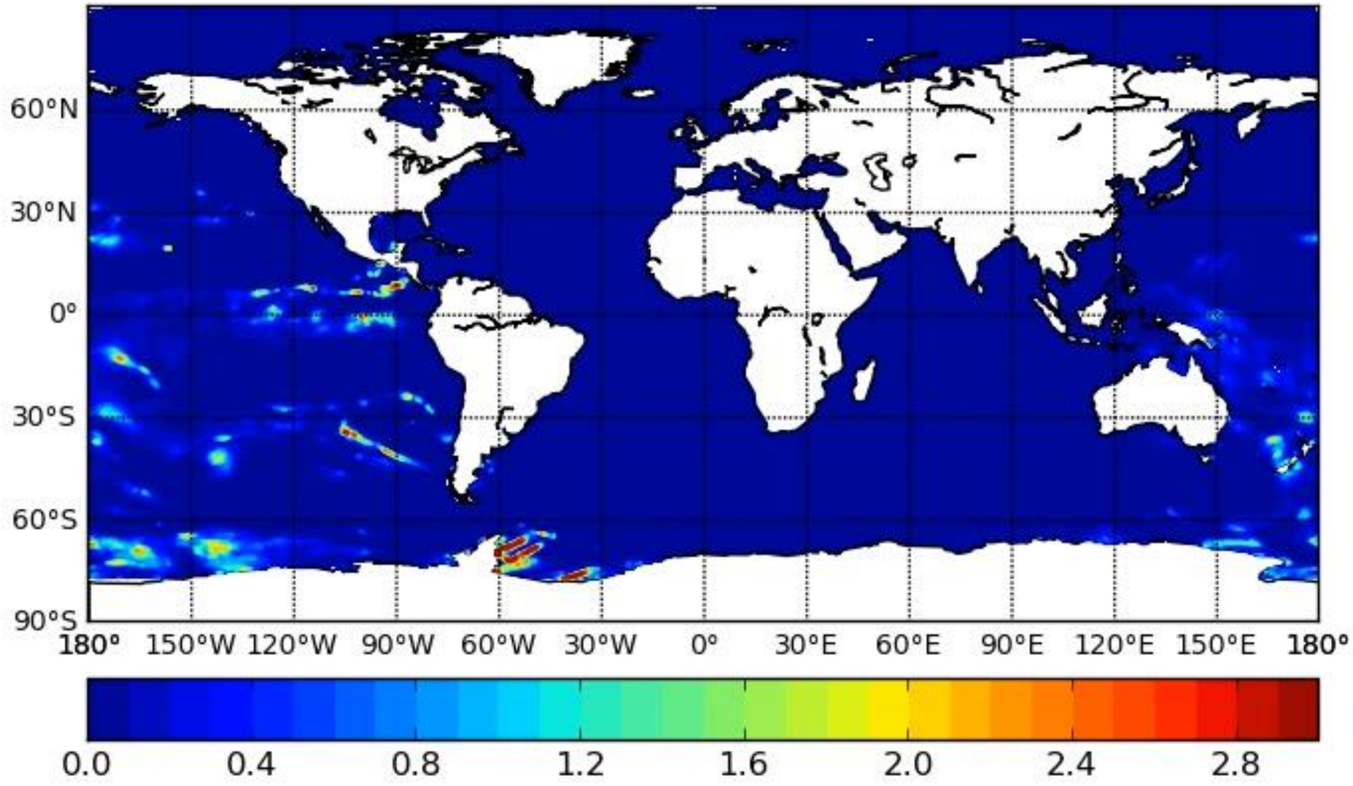
T:- ΔT_{WL}
t :- Time
Q:- Thermal energy flux
D_T:- Layer depth
ρ:- Water density
c_p:- Heat capacity
ν:- Structure parameter
u_w*:- Friction velocity
L_a:- Langmuir number
k:- Von Karman's constant
g:- Acceleration due to gravity
α_w:- Thermal expansion coefficient

$$f(L_a) = \max(1, L_a^{\frac{2}{3}}) \qquad L = \frac{\rho c_p {u_w^*}^3}{\kappa g \alpha_w Q} \qquad \Phi(\zeta) = \begin{cases} 1 + \frac{5\zeta + 4\zeta^2}{1+3\zeta+0.25\zeta^2} & (\zeta \geq 0) \\ (1-16\zeta)^{-\frac{1}{2}} & (\zeta < 0) \end{cases}$$

- These equations are solved using an implicit scheme

Warm Layer Model: Example month

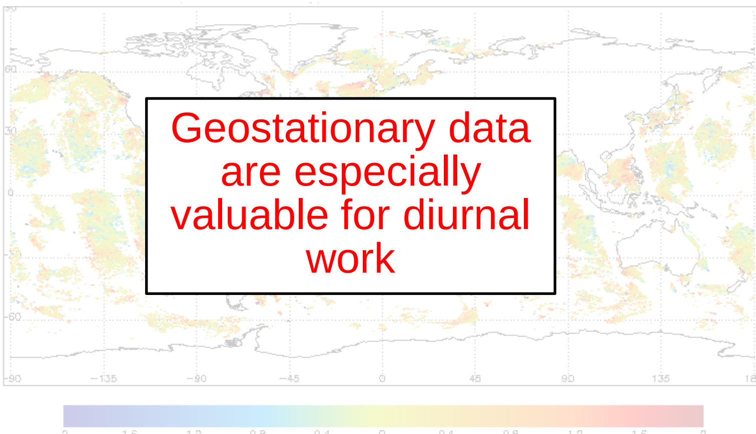
Jan 2011



Observations

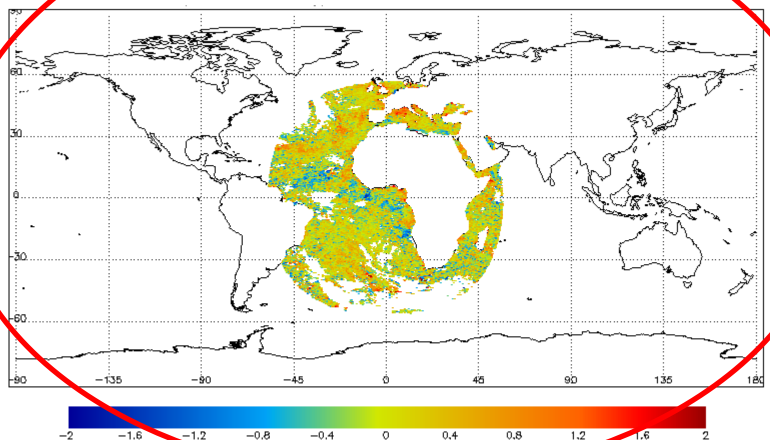
Observations

NOAA-AVHRR

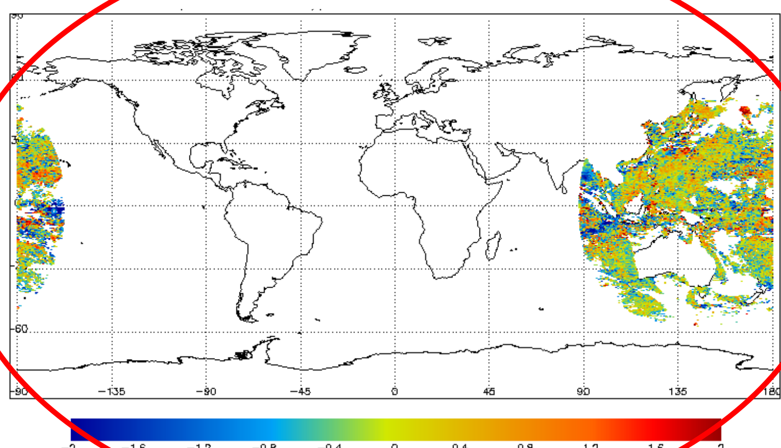


Geostationary data are especially valuable for diurnal work

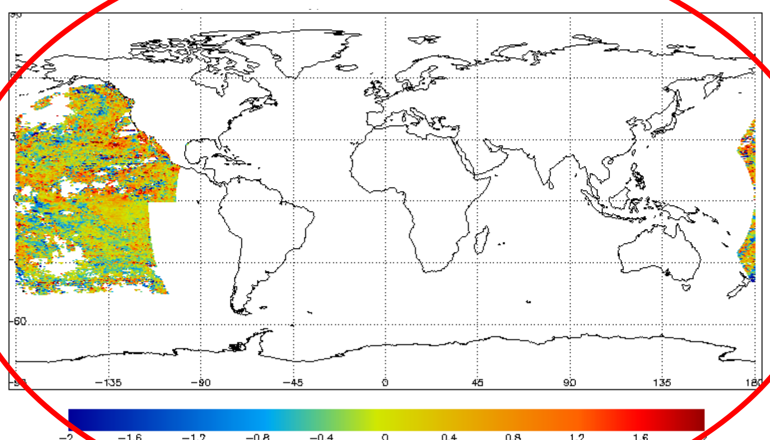
SEVIRI



MTSAT



GOES-West

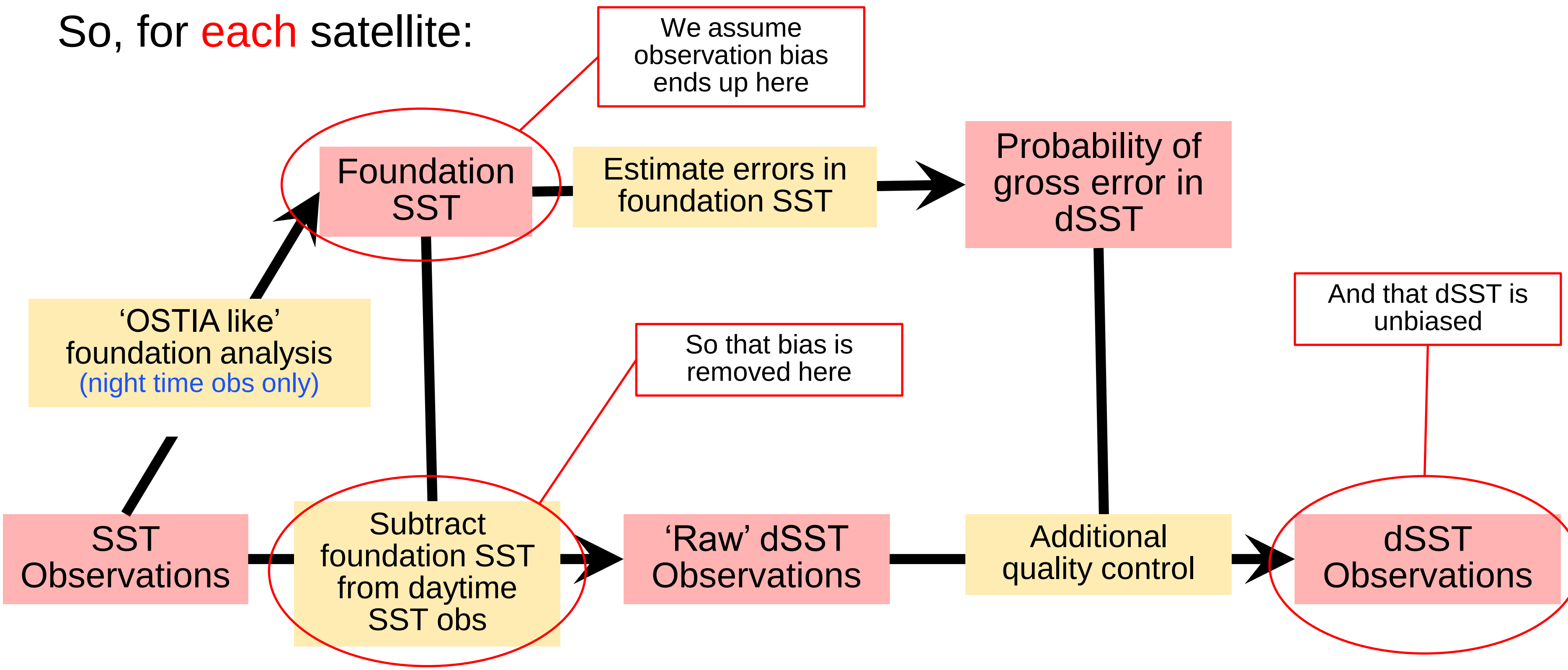


Observation are from 22/04/2015

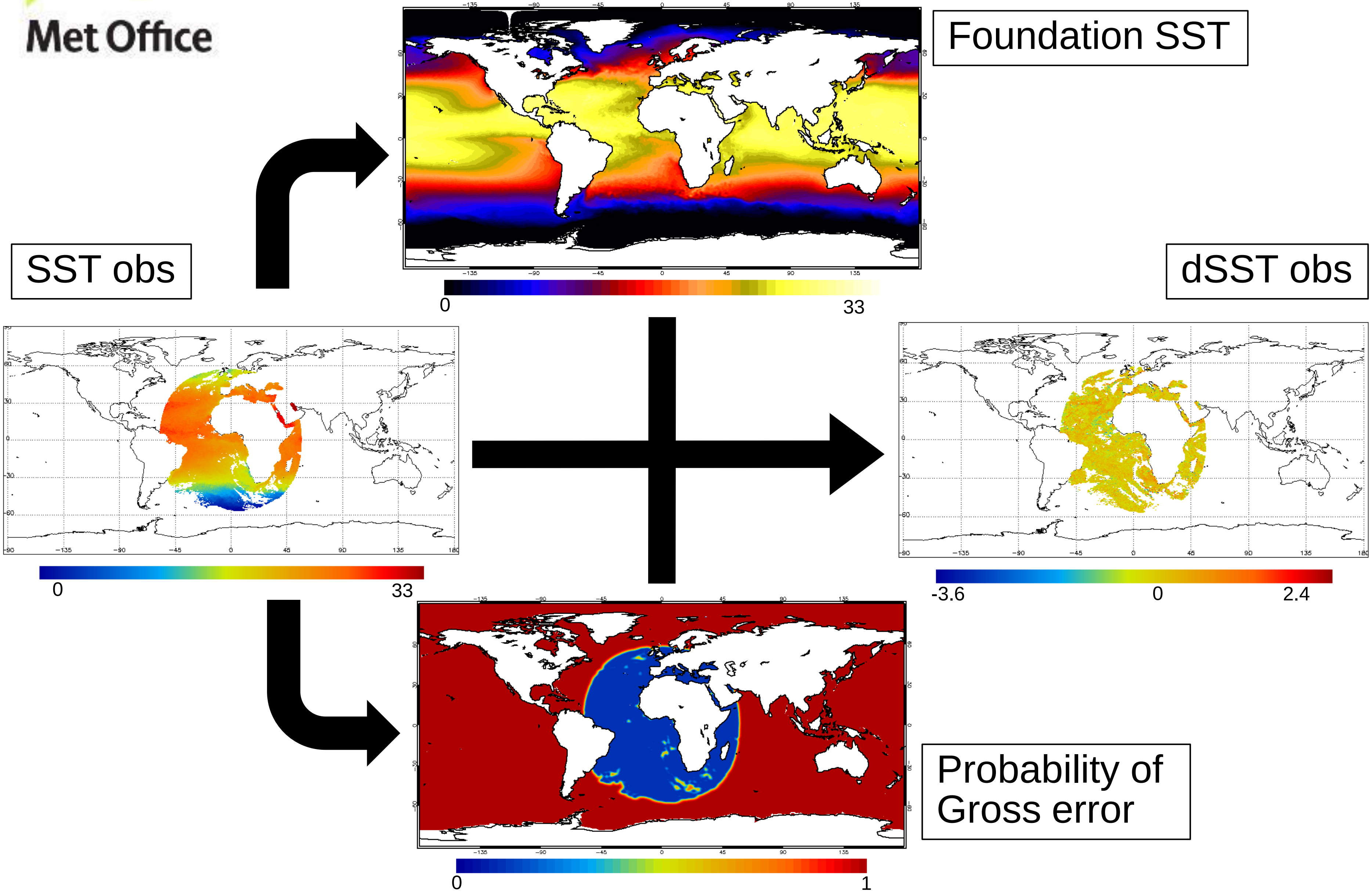
Observations: SST to dSST

The satellites provide us with observations of SST. These need to be converted to measurements of just the diurnal component (dSST).
i.e. the foundation component needs to be removed.

So, for **each** satellite:



Observations: SEVIRI example



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Data assimilation system

Data assimilation: Theory

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We assimilate the dSST observations into the warm layer model using a 3D version (latitude, longitude, and time) of 4DVar with 3 outer-loops.

Assimilation is done within the NEMOVAR assimilation framework.

Specifically we minimise the standard cost function:

$$J(\mathbf{x}) = 0.5(\mathbf{x}-\mathbf{x}^{\mathrm{f}})^{\mathrm{T}}\mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}^{\mathrm{f}}) + 0.5\,(\mathbf{y}-\mathbf{H}\mathbf{x})^{\mathrm{T}}\,\mathbf{R}^{-1}\,(\mathbf{y}-\mathbf{H}\mathbf{x})$$

With

$$\mathbf{x} = \begin{pmatrix} T_0 \\ Q_0 \\ Q_1 \\ \vdots \\ Q_N \\ u^*_{w_0} \\ u^*_{w_1} \\ \vdots \\ u^*_{w_N} \end{pmatrix}$$

T_0 is deliberately given a low weight in the assimilation.

If this is not done it is hard to get the initial dSST to balance with the flux driven dSST's

NOTE: We do not allow the assimilation to adjust the forcing at night.

Data assimilation: error covariances

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Error covariances, contained in **B** and **R**, allow the assimilation to spread the information from the observations.

R is assumed diagonal, but **B** allows for correlations in space and time.

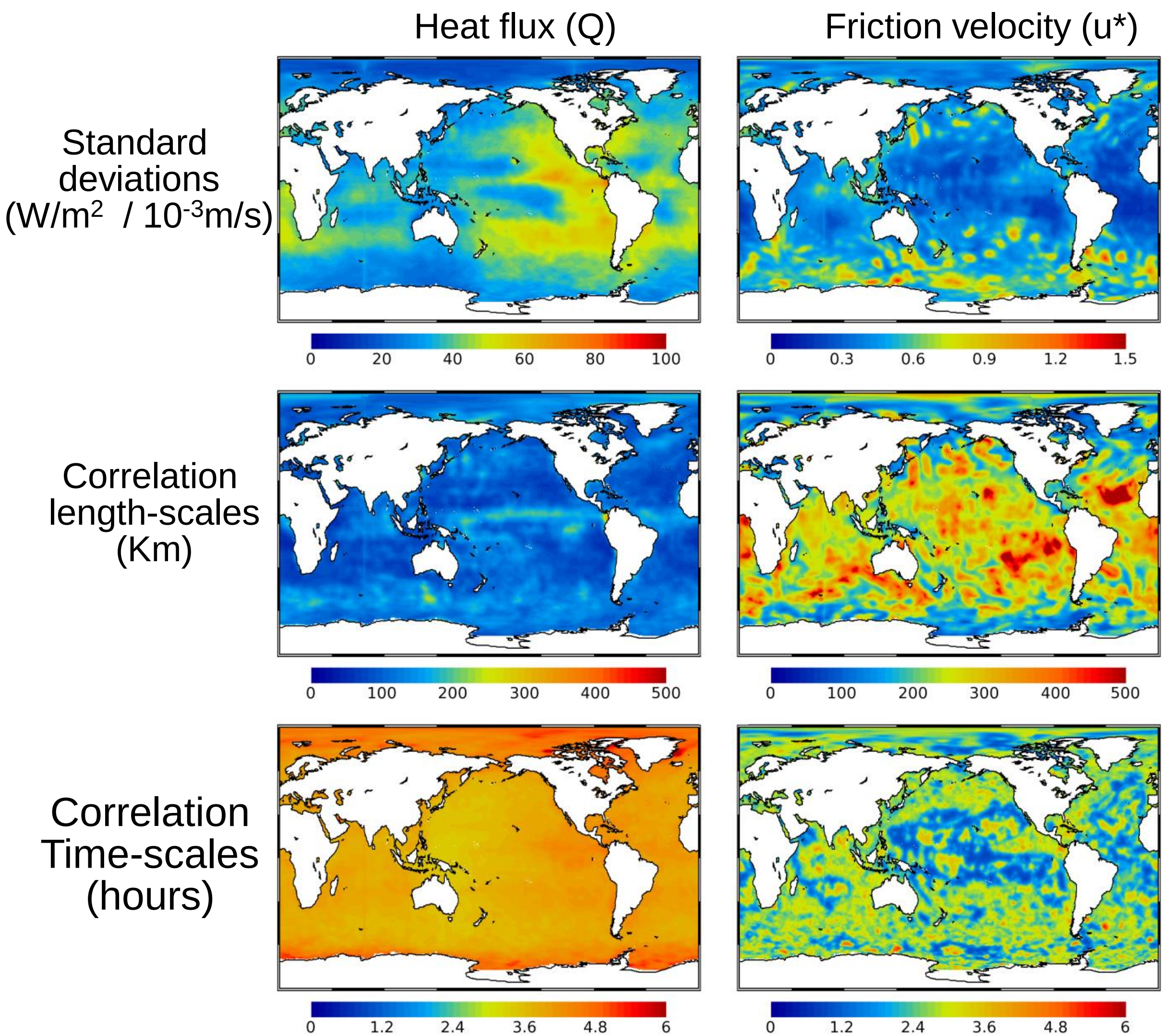
Correlations are modelled using a Gaussian function.

NMC analysis, shown right, indicates significant structure in the correlations.

However, at the present time variances and correlations are assumed constant:

Variable	STD	Length -scale	Time-scale
T_0	0.01 K	155 km	N/A
Q	55 W/m^2	111 km	4 hrs
u*	6×10^{-4} m/s	178 km	3.4 hrs
obs	0.7 K	0	0

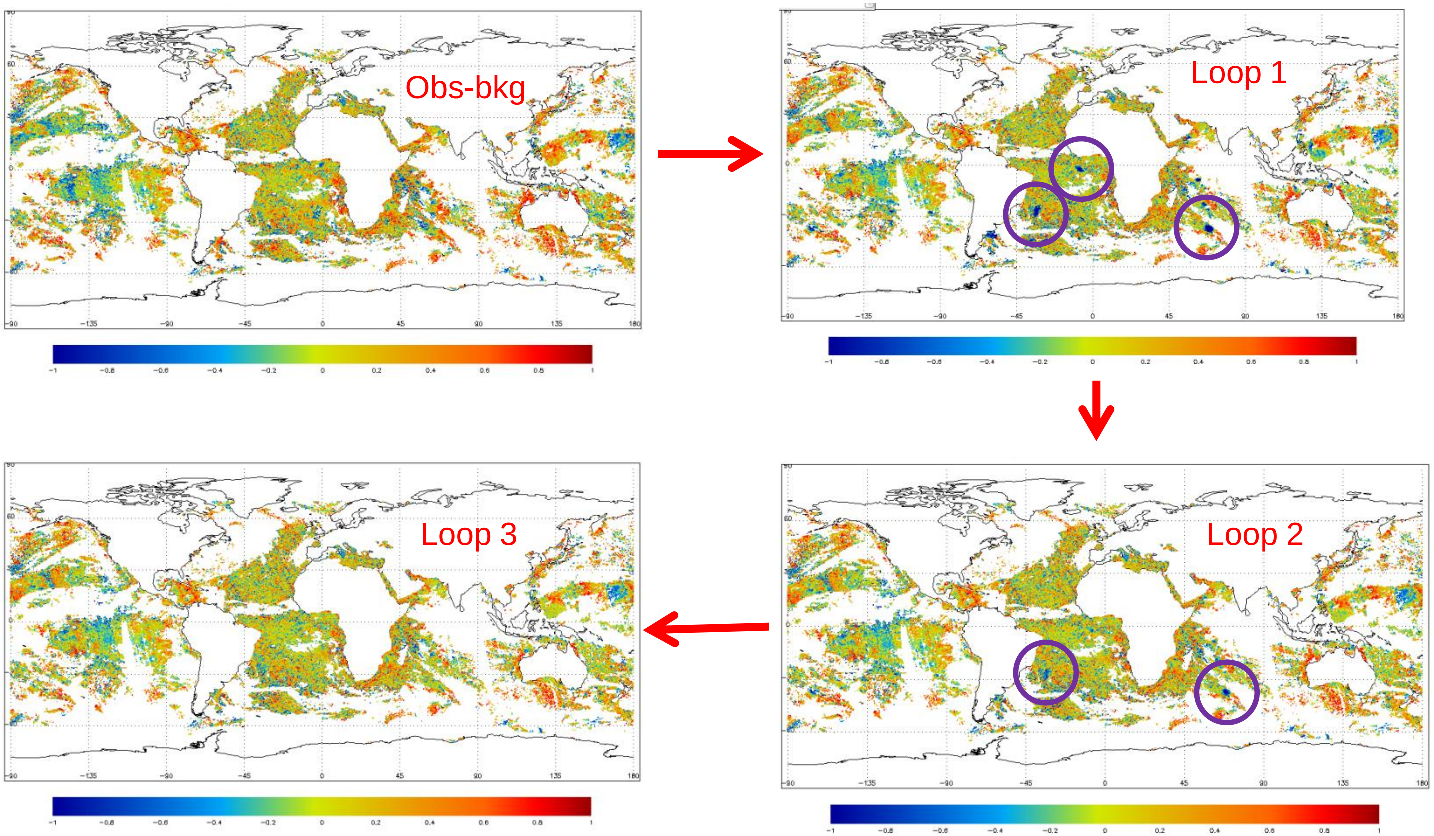
Spatially varying covariances will be implemented in a future update to the system



Data Assimilation: Outer-loops are vital!

Because of the non-linear behaviour with respect to wind speed, we have been forced to use multiple outer loops in the analysis.

Early loops improve the wind/heat flux, but can cause the dSST to overshoot



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Validation

Validation using moored buoys

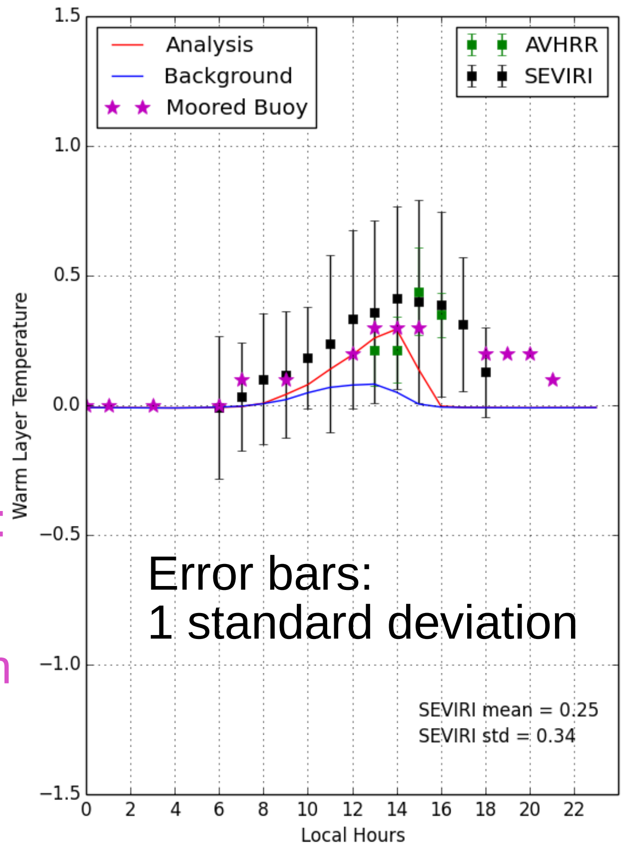
Example point

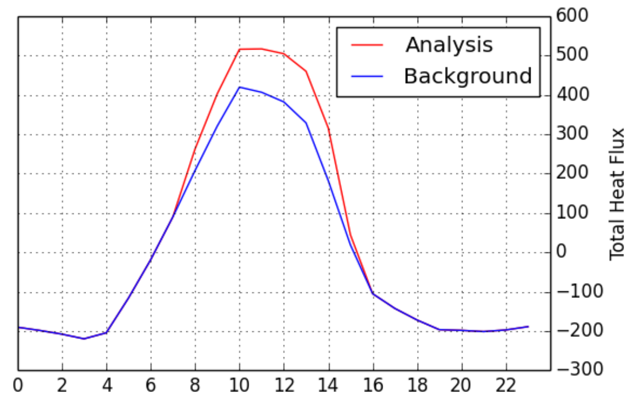
Diurnal cycle and fluxes at Lon = -37.9 and Lat = 20.0 on 25 Oct

Green square: AVHRR observation

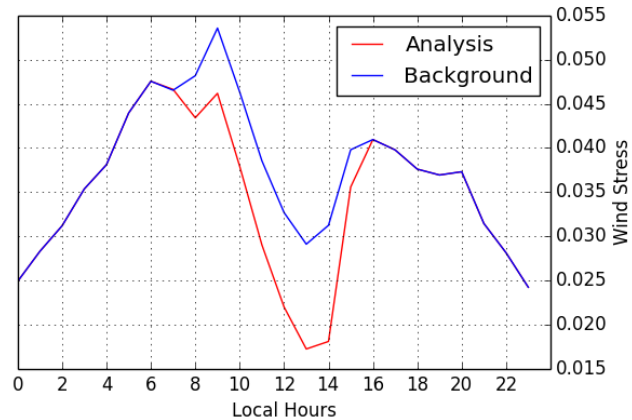
Black square: SEVIRI observation

Magenta stars: Moored buoy observation, with foundation SST removed





Total heat flux



Wind Stress

All blue lines: warm layer without data assimilation

All red lines: warm layer with data assimilation

Validation using near surface Argo profiles for large diurnal events (>0.4°C)

$ARGO_{dSST}$ = ARGO(0.5m) — ARGO(4m)

For more validation please see the poster by Chongyuan Mao

Poster No. 18

Results are the average of 32 profiles

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Conclusions

Conclusions

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- The Met Office has developed and implemented an analysis system for skin SST.
- The system includes both a warm layer model and a cool skin model, with the warm layer model constrained using ‘4DVar’ data assimilation with 3 outer-loops.
- In order to be used in the assimilation, SST observations are converted to dSST using a foundation removal technique with additional quality control.
- The match to independent ARGO data is improved by the assimilation. Obs minus analysis statistics are also improved compared to the background (see the poster by Chongyuan Mao).
- The diurnal analysis is now available through Copernicus CMEMS

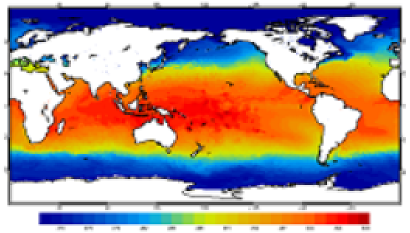
GLOBAL OCEAN OSTIA DIURNAL SKIN SEA SURFACE TEMPERATURE

Satellite-observation, Temperature, Sea-ice, Near-real-time, Global-ocean

SST_GLO_SST_L4_NRT_OBSERVATIONS_010_014

For the Global Ocean- the OSTIA diurnal skin Sea Surface Temperature product provides daily gap-free maps of:

- Hourly mean skin Sea Surface Temperature at 0.25° x 0.25° horizontal resolution, using in-situ and satellite data from infra-red radiometers.



MORE INFO

ADD TO CART

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Questions?