Data assimilation in NEMO shelf

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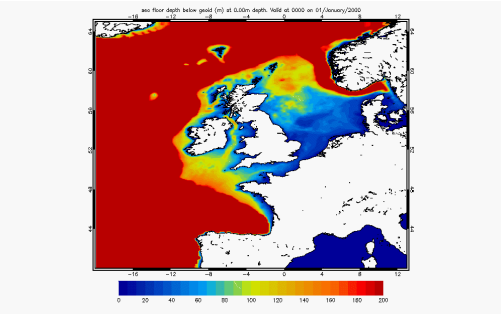
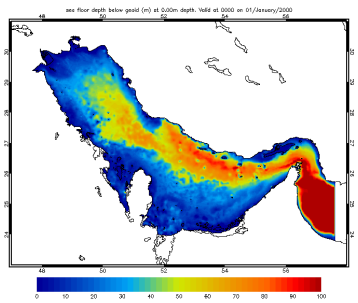
Introduction

Introduction

•The Met Office has 2 shelf sea models:

AMM7 (North West European Shelf)	**PGM4** (Persian Gulf)
	
•Operational •Uses ‘old’ data assimilation system	•In development. •Uses ‘new’ data assimilation system

•SST data is assimilated into both of these models.

Data assimilation in the AMM7

Data assimilation Method

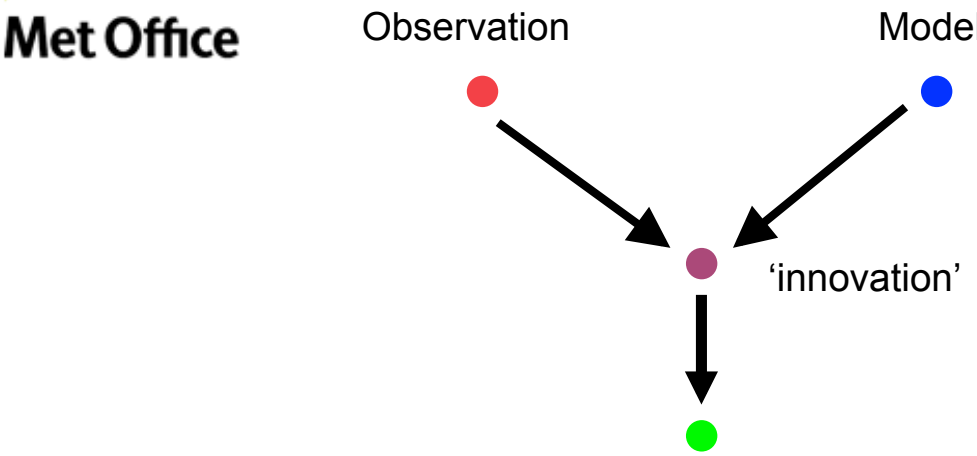
Overview

- The AMM7 uses an Analysis Correction method of Data assimilation. This is a simplified form of the Kalman Filter.
- Only SST data are assimilated.
- The scheme uses a First Guess at Appropriate Time (FGAT) method of comparing observations with the model.
- An Incremental Analysis Update (IAU) scheme is used to apply increments to the model

In essence, the assimilation proceeds as follows…

Data assimilation Method

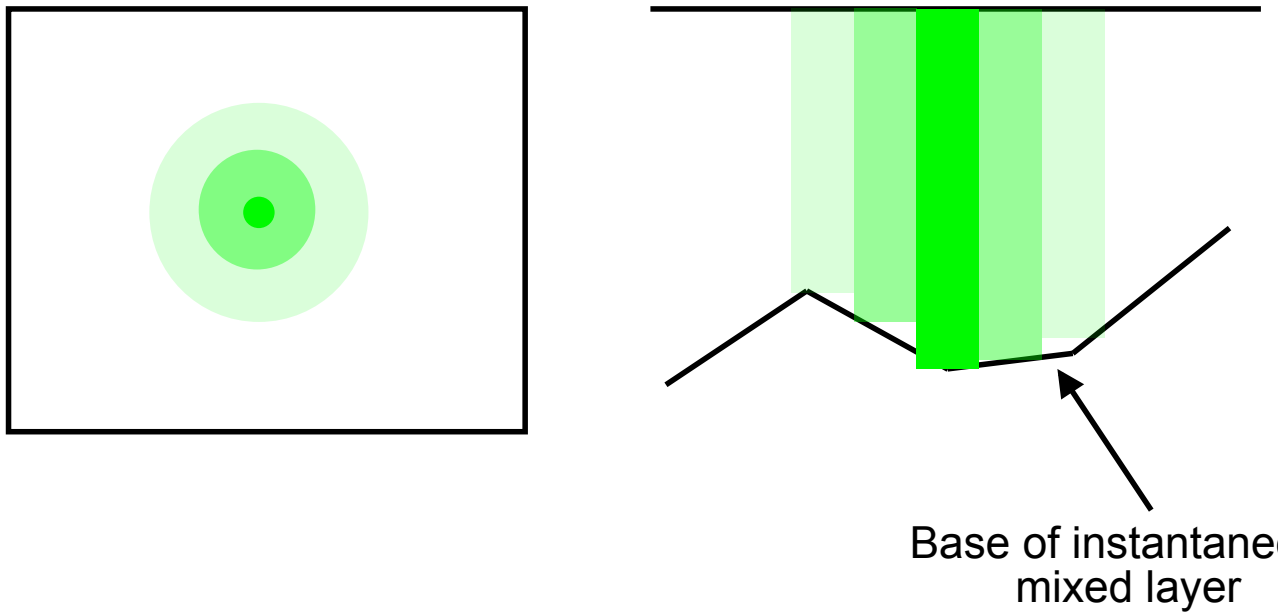
Example



For an observation find its model equivalent.

Take the difference between the two to get the innovation.

Weight the innovation based upon the model and observation errors.
$0 \leq \text{weight} \leq 1$
less model error = less weight
less obs error = more weight



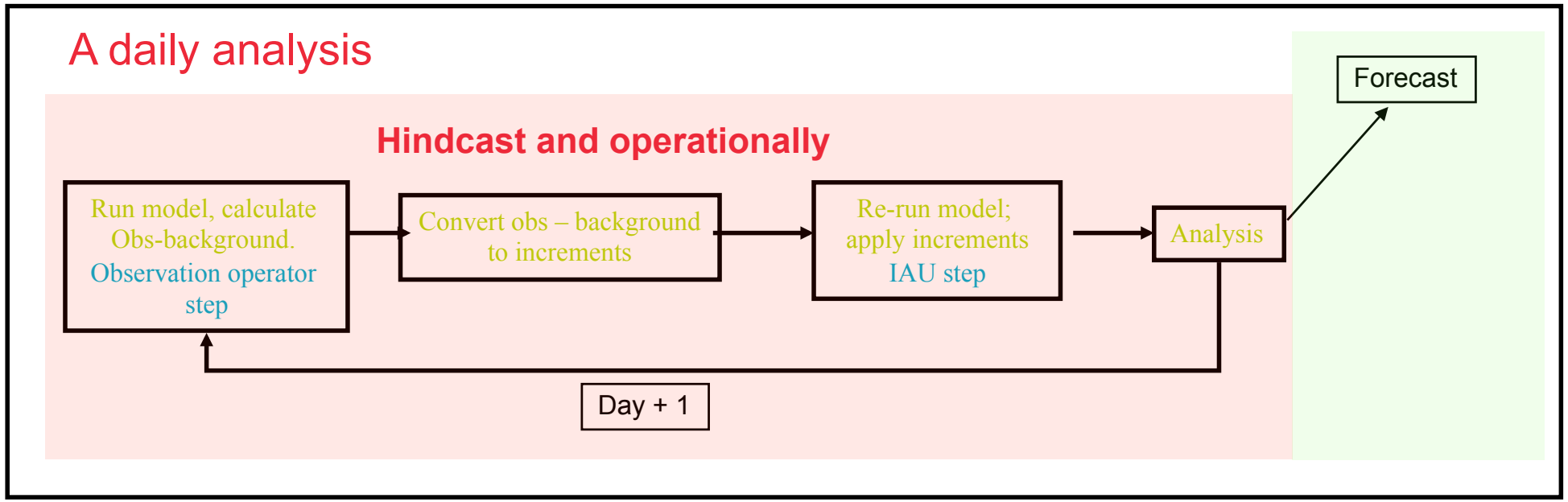
Based upon the model error covariances, spread the innovation

Repeat for all other observations and sum the result to get the increment.

Add the increment to the model to get the analysis.

Operational Implementation

Operational running



- Currently ran both operationally and in hindcast mode.
- Went operational on 16th March 2011.
- Providing products to the MyOcean2 consortium.

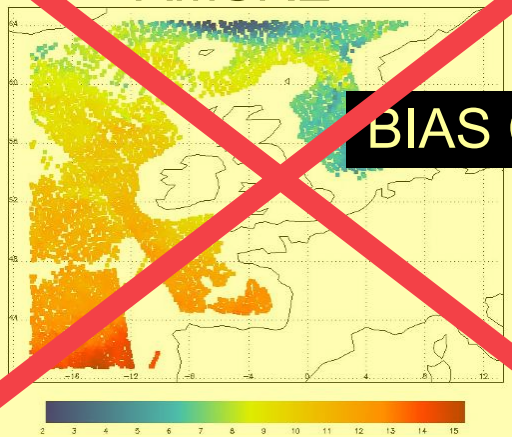
Operational implementation

Observations

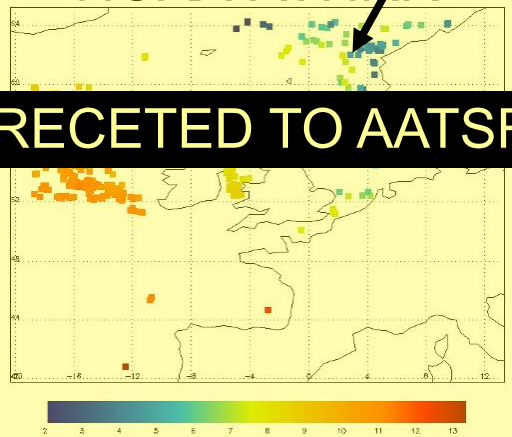
Recently incorporated NOAA-19 Satellite

Recently switched to hourly data

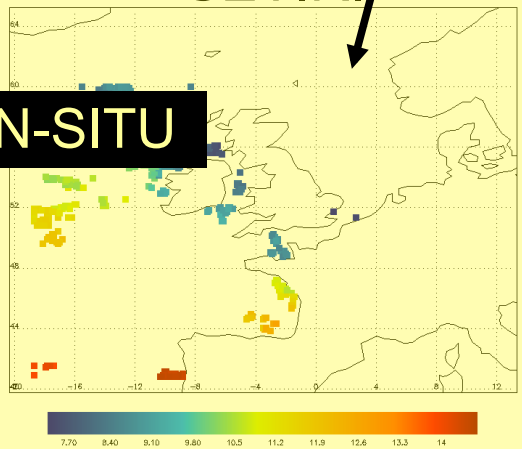
AMSRE



NOAA-AVHRR

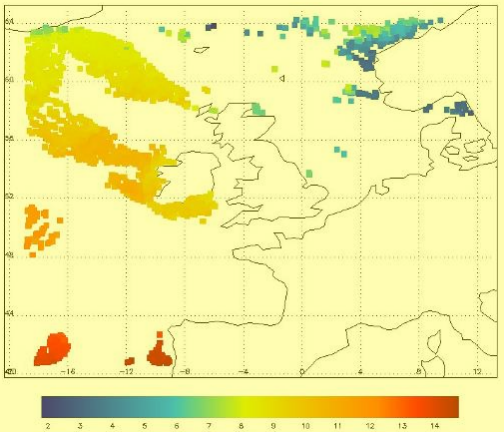


SEVIRI

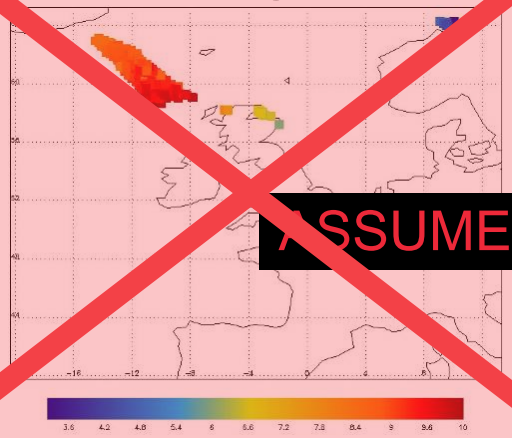


BIAS CORRECETED TO AATSR & IN-SITU

METOP-AVHRR

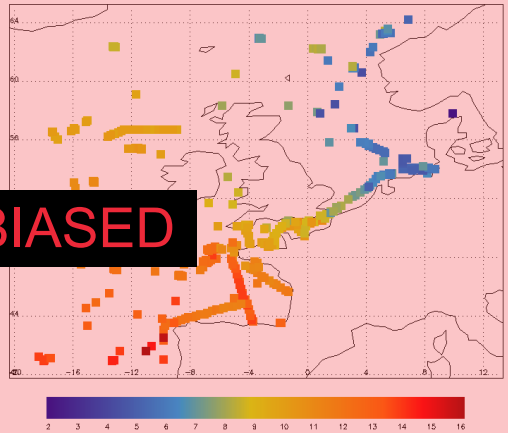


AATSR



ASSUMED UNBIASED

IN-SITU



Results

Statistics

Control

RMS error = 0.78 K
Mean error = -0.27 K

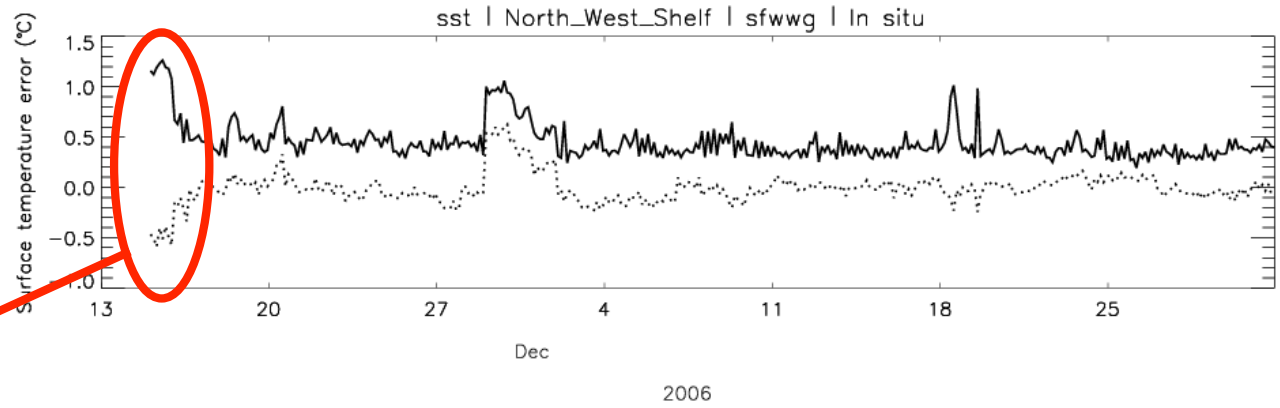
Assimilating run

RMS error = 0.47 K
Mean error = -0.06 K

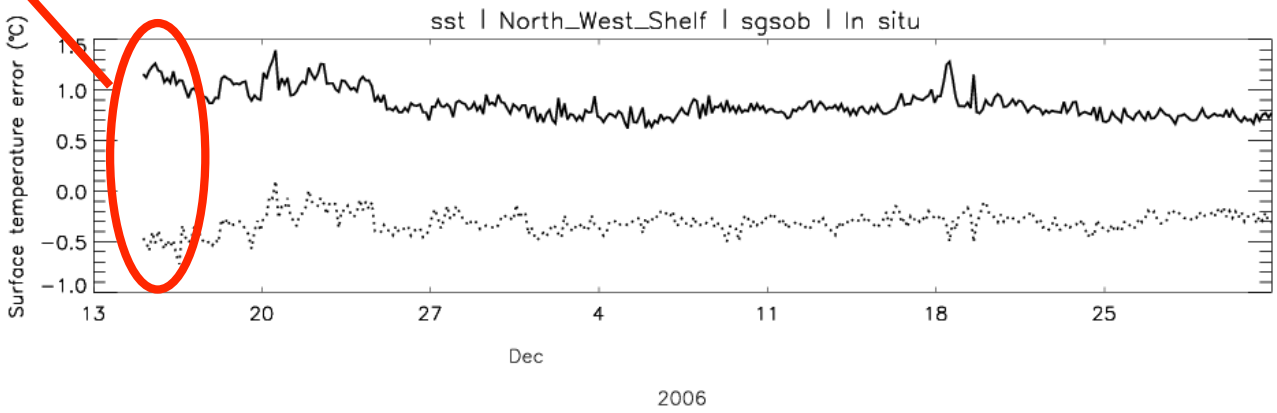
Model was spun up for 2 years before assimilation began.

Large initial reduction in error

Assimilating run

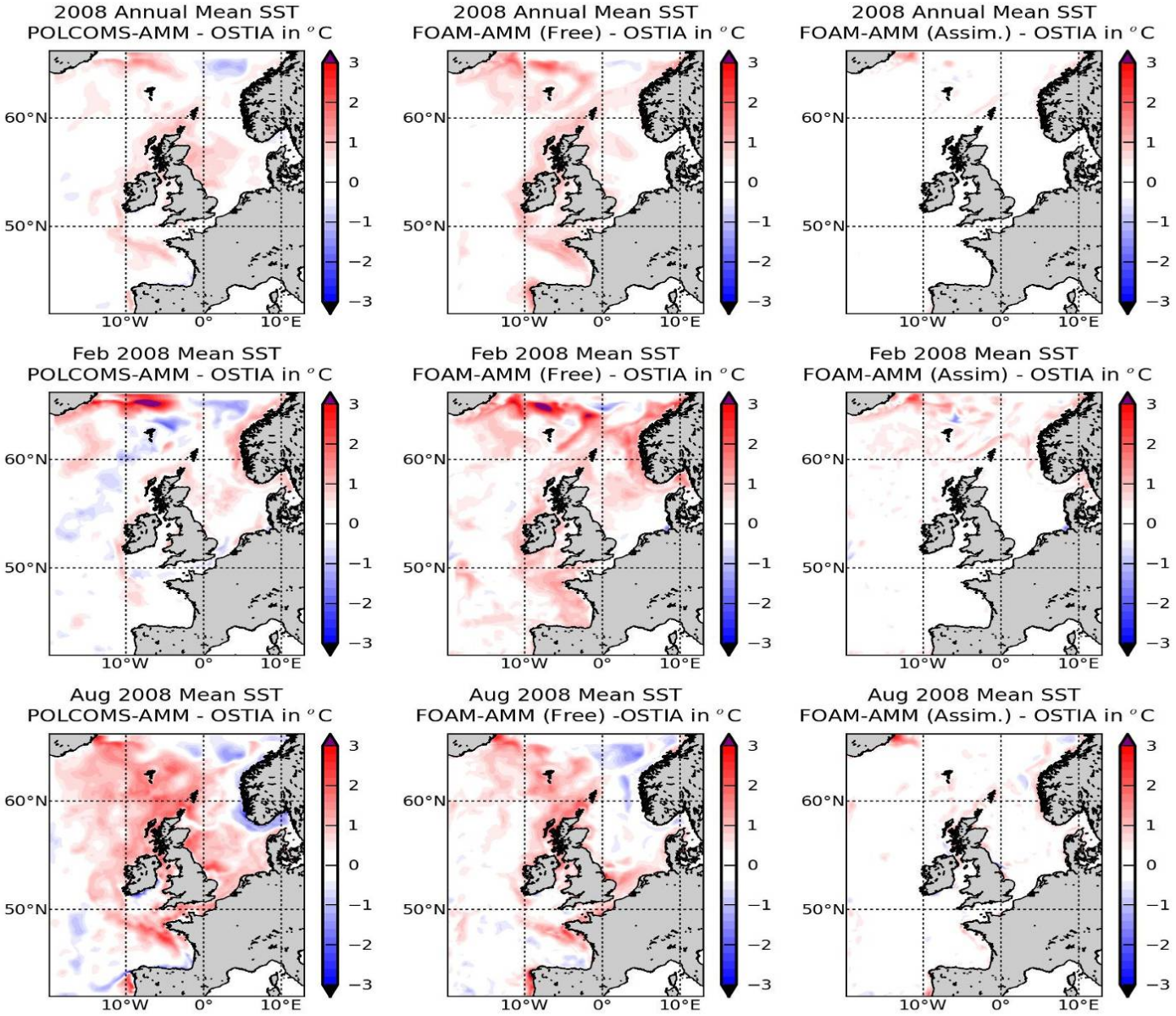


Control



Results

Mean difference to OSTIA (2008)



Data assimilation in the PGM4

Data assimilation method

Overview

- PGM4 used a 3DVar method of data assimilation based on the NEMOVAR set of code.

- This scheme has a number of advantages over the AMM7 scheme:
  - More efficient minimisation - faster!.
  - Diffusion based correlation functions.
  - More flexibility in specifying error covariance relationships.

- Nonetheless, there are many similarities with the AMM7 scheme:
  - only SST data are assimilated.
  - Still a FGAT system.
  - Increments are added down to the base of the mixed layer
  - Increments are added to the model over 1 day with a IAU scheme.

Data assimilation method

How 3DVar works

In 3DVar we find **x** (the analysis) that minimises:

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

But in words this is just:

Cost = Difference from model prediction^2 + Difference from observations^2

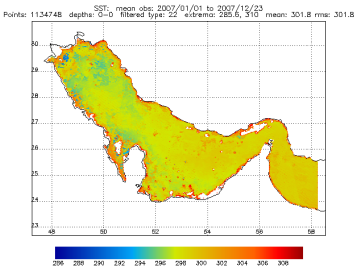
The matrices **B** and **R** act as weights between the two terms, and also serve to spread the information in space.

Data assimilation method

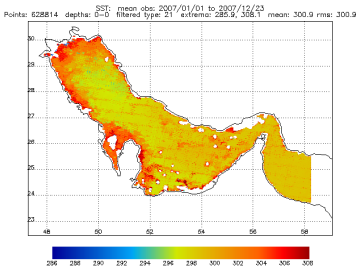
Observations

Observations assimilated into the PGM4 model are the same as the AMM7 model.

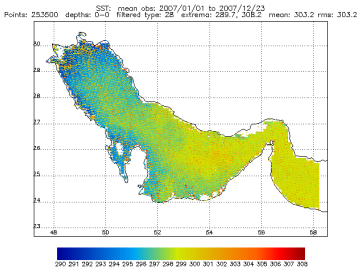
AATSR



NOAA-AVHRR



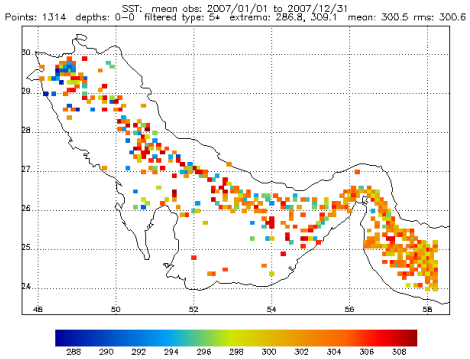
MetOP-AVHRR



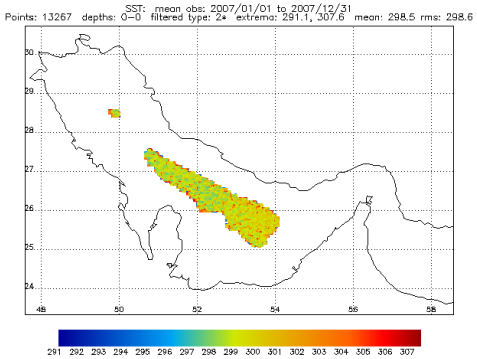
Except…

No AMSRE or SEVIRI data

All in-situ data comes from ships, only ~2 observations a day.



We have observations from the TMI microwave instrument



Results

Stats (against AATSR)

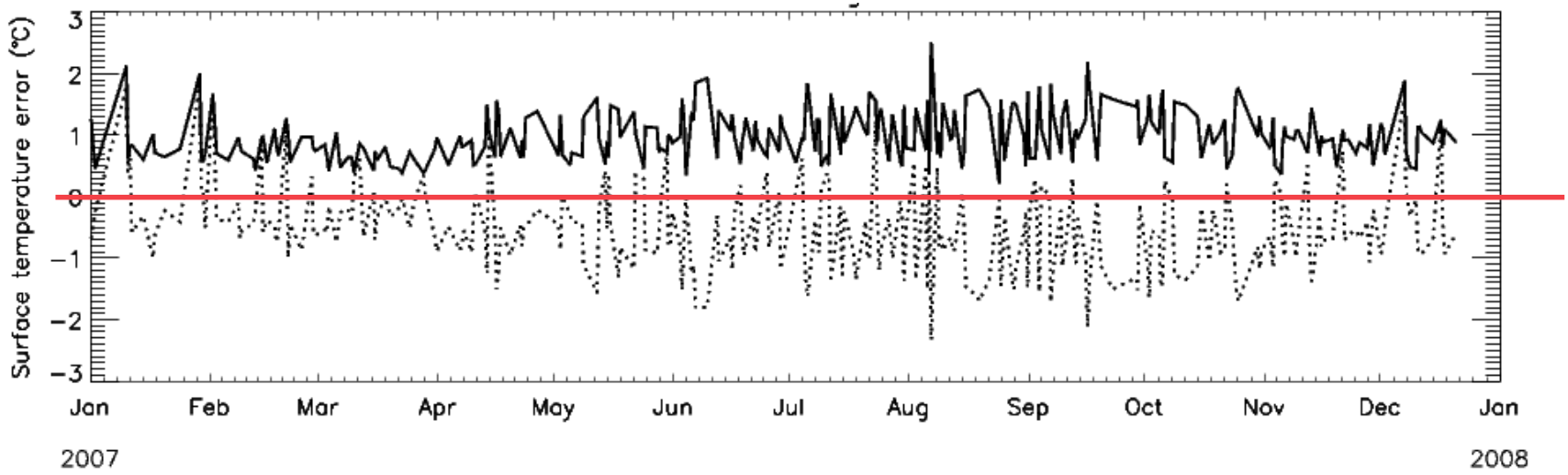
Control

RMS error = 1.16 K
Mean error = -0.69 K

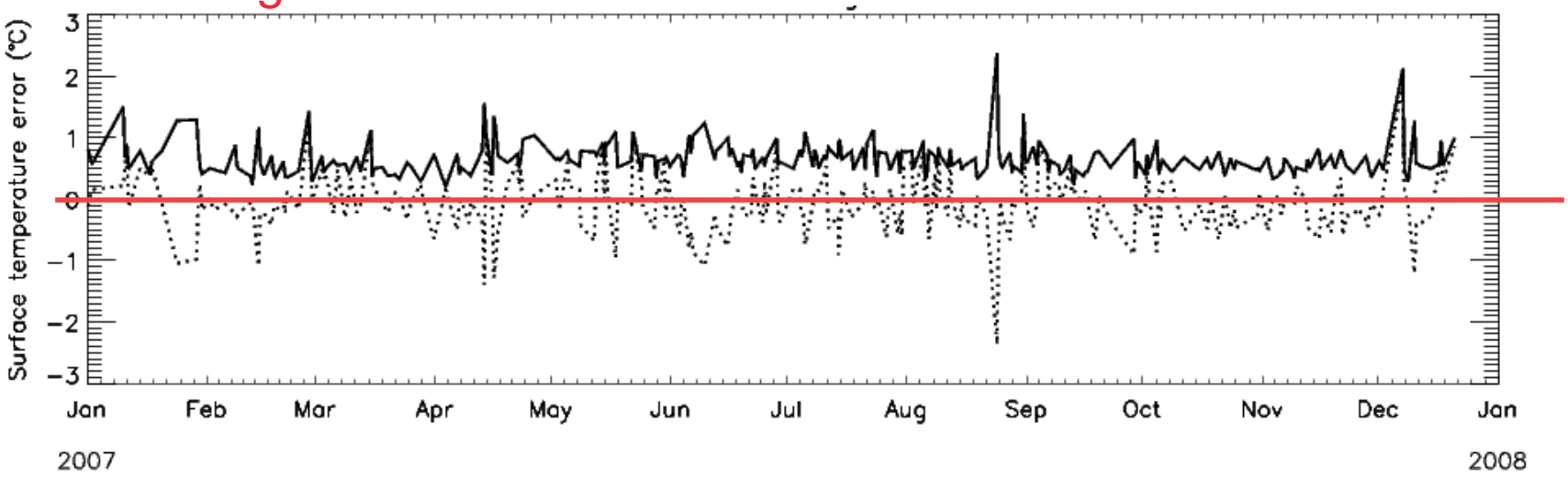
Assimilating run

RMS error = 0.74 K
Mean error = -0.09 K

Control



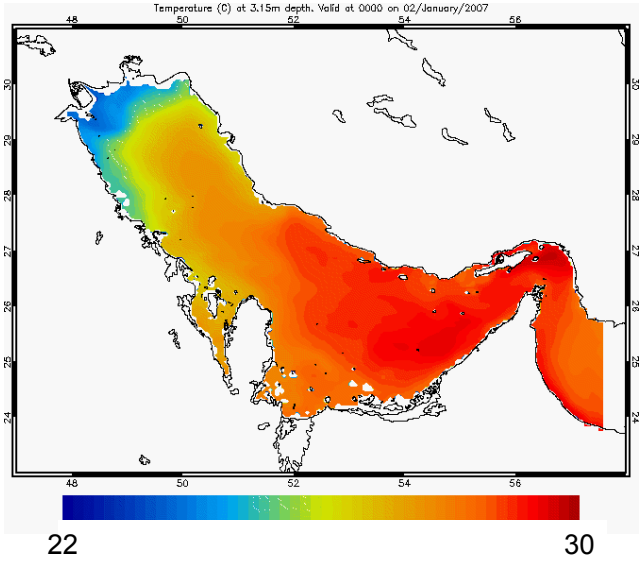
Assimilating run



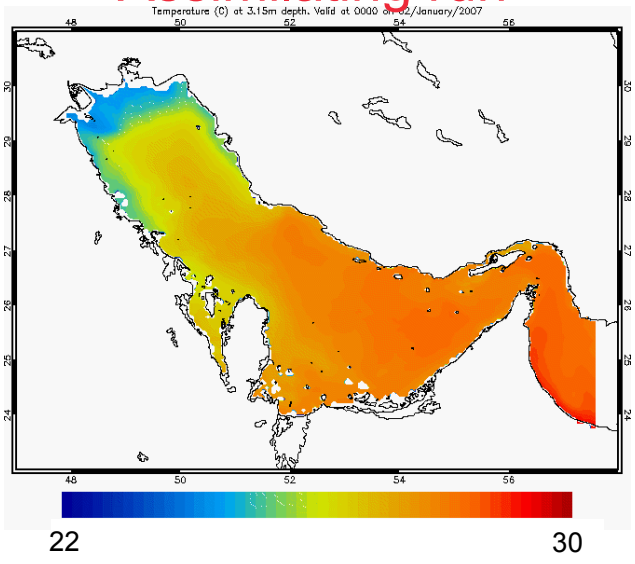
Results

Temperature (ºC)

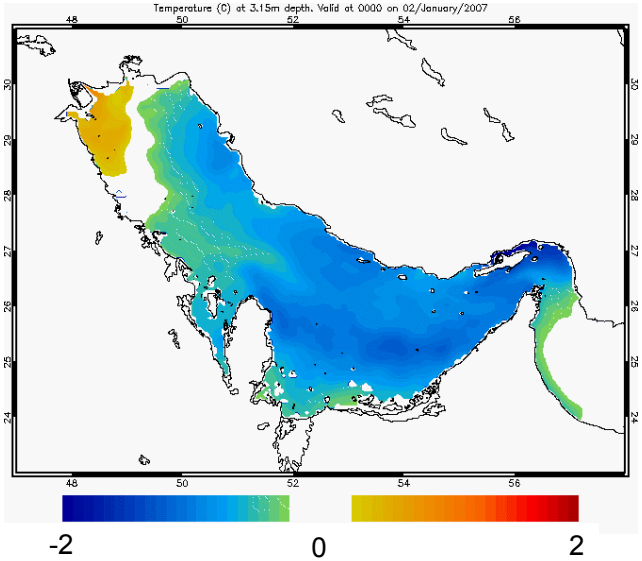
Control



Assimilating run



Assim minus control



Summary

Summary

- The Met Office has two shelf seas models that include data assimilation:
- The AMM7 is the Met Office model of the North West Shelf
  - It was the Met Office's first shelf seas model to include data assimilation, but only of SST.
  - Data assimilation is conducted with a FGAT Analysis Correction scheme, with an IAU step.
  - Assimilation of SST does improve the near surface temperature.
  - In the near future we will move to a 3DVar data assimilation system (NEMOVAR) and begin assimilating T&S profiles and altimeter data.
  - We plan to significantly improve the specification of error covariances by making them depend on the bathymetry and SST gradients.
- The PGM4 is the Met Office's model of the Persian Gulf
  - It uses fundamentally the same code as the AMM7, but has different bathymetry and forcing.
  - Data assimilation is conducted with a FGAT 3DVar scheme, with an IAU step, but is (again) only of SST.
  - Assimilation of SST does improve the near surface temperature, and removes some significant biases.

Questions?

Data assimilation Method

Error covariance relationships (1)

The model & observation errors and error covariances specify how we weight and spread the innovations.

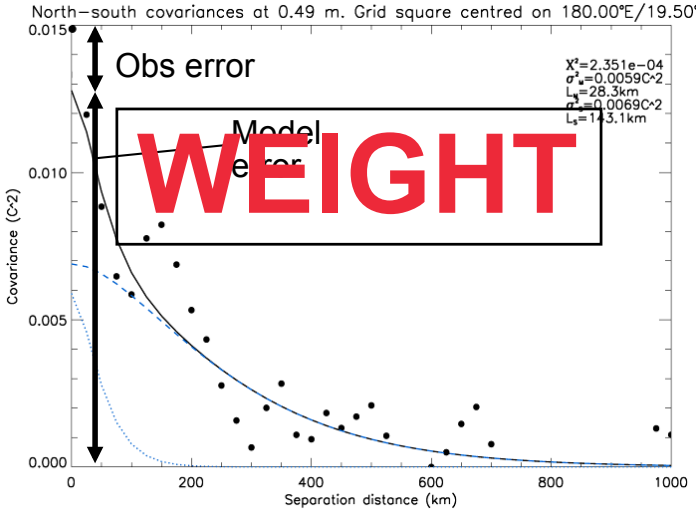
The errors and error covariances are unknown and impractical to specify exactly.

In consequence, we use a function fitting approach to model the error covariances

For the AMM7 we use 2 methods to find the parameters of our functions:

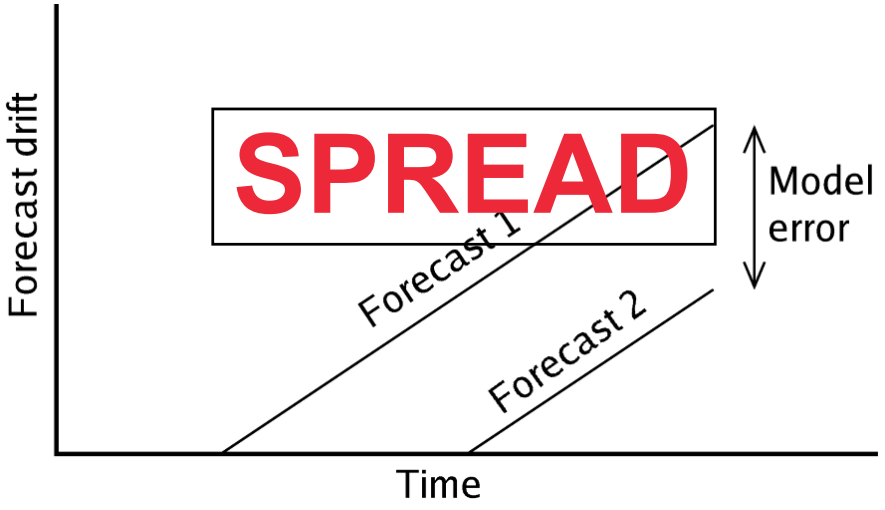
Hollingsworth & Lönnberg (1986) Method

- Based on observations-background statistics
- Correlations all assumed to be in the model
- Observation + model error
- Accurate magnitudes
- Low resolution.



NMC method: Parrish & Derber (1992)

- Based on the difference between forecasts of different lengths
- Only gives model error
- Underestimates magnitudes
- High resolution (model grid scale)



Data assimilation Method

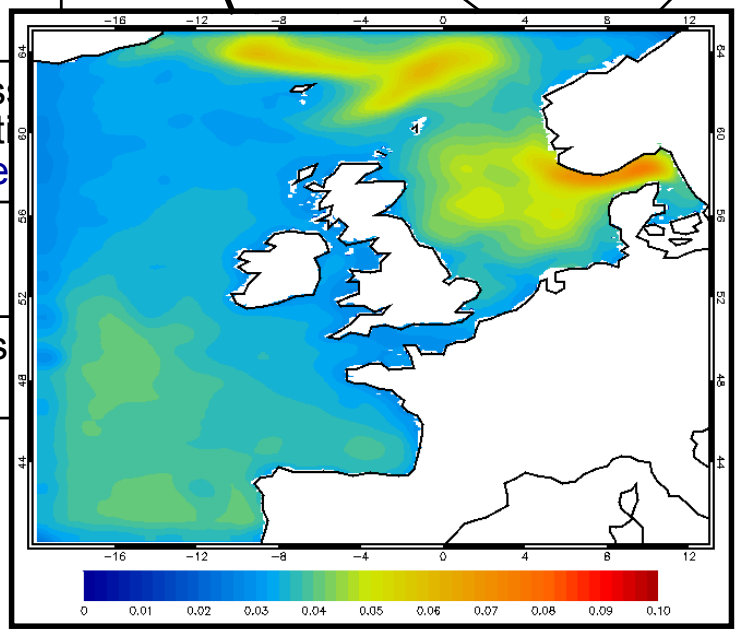
Error covariance relationships (2)

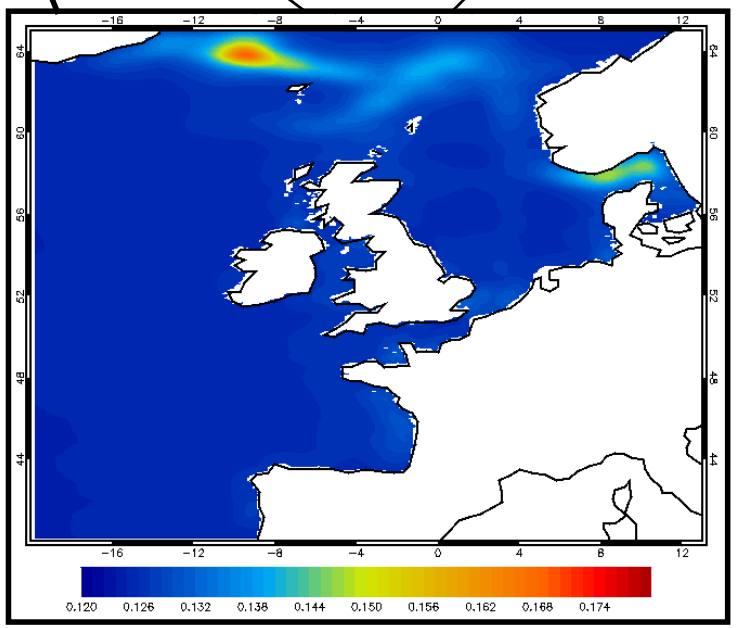
V_{syn}:- synoptic scale variability
V_{mes}:- mesoscale variability
L_{syn}:- synoptic length scale
L_{mes}:- meso length scale
r:- grid point separation
β:- cross-variable correlation

$$B_{ij} \approx \beta_{ij} \left(V_{\mathrm{syn}} \left(1 + \frac{r_{ij}}{L_{\mathrm{syn}}} \right) \exp\left(-\frac{r_{ij}}{L_{\mathrm{syn}}} \right) + V_{\mathrm{mes}} \left(1 + \frac{r_{ij}}{L_{\mathrm{mes}}} \right) \exp\left(-\frac{r_{ij}}{L_{\mathrm{mes}}} \right) \right)$$

cross
correlati
Balance

Only ass
$\beta_{ij}=\delta_{ij}$





Data assimilation Method

Mathematically the process on the previous slide is given by:

Analysis, Forecast, Kalman gain

h: Observation operator
H: linearised *h*

$$\mathbf{x}^{\mathrm{a}} = \mathbf{x}^{\mathrm{f}} + \mathbf{K}\left(\mathbf{y} - h(\mathbf{x}^{\mathrm{f}})\right)$$

$$\mathbf{K} = \mathbf{B}\mathbf{H}^{\mathrm{T}}\left(\mathbf{H}\mathbf{B}\mathbf{H}^{\mathrm{T}} + \mathbf{R}\right)^{-1}$$

Model error covariance
Constant in our scheme

Observation error covariance
Assumed Diagonal

$\left(\mathbf{y} - h(\mathbf{x}^{\mathrm{f}})\right)$:- Innovation
(also used for assessment)

$\Delta\mathbf{x}^{\mathrm{a}} = \mathbf{K}\left(\mathbf{y} - h(\mathbf{x}^{\mathrm{f}})\right)$:-analysis increment

These equations assume that **y** and **x** are unbiased