ESA Climate Change Initiative Phase-II

Sea Surface Temperature (SST)

www.esa-sst-cci.org

Propagation of uncertainty information through levels of products

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Just to recap….

- Error and uncertainty are two different concepts:

Error

- Concept: How different is the measured value from the true value?

Uncertainty

- Concept: To what degree is the measured value in doubt?
- Quantification: “Standard Uncertainty” is the standard deviation of the (estimated) error distribution.

Objective for uncertainty information provision:

Users to have access to a standard uncertainty estimate….

- For every SST value given.
- At all levels (L2, L3, L4 and Obs4MIPS).
- At all spatial resolutions.
- For all types of SST provided (skin, 20 cm depth, daily mean values).

  (this presentation covers how we propagate uncertainties through these different levels of products)
- That is realistic for the context in which the SST is derived.
- That is validated so that users have confidence that it is realistic.

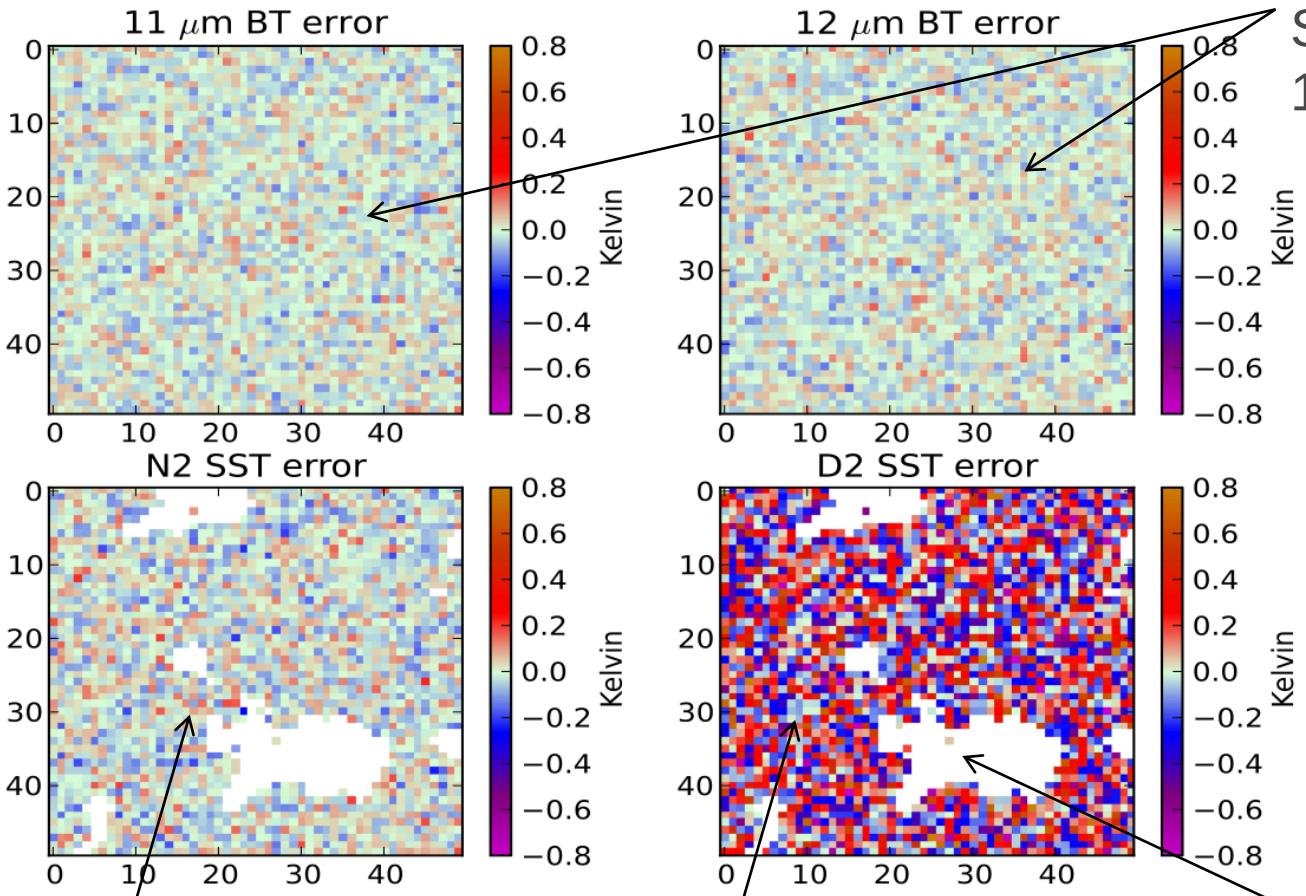
  (covered in Gary Corlett's presentation yesterday)

Level 1 Products

Sources of Uncertainty

- Errors from random effects (unknown) from radiometric noise.
  - These can be propagated in L2 products using NEdT uncertainty estimates looking at the black bodies and instrument model.
- Locally systematic effects.
  - Eg. Intermittently determined calibration parameters.
- Systematic effects.
  - Eg. Spectral response function error.
  - Eg. Emissivity error.

Level 2 Products: Noise propagation



Simulated error in the 11 and 12 μm channels.

Error propagation:

$e_{ret}=\Sigma(a_i e_{yi})$

Where:

e = error

a = coefficient

y = brightness temperature

Nadir 2-channel retrieval simulated error.

Dual-view 2-channel retrieval simulated error.

Cloud fields overlaid.

Level 2 Products: Retrieval uncertainty

Ambiguity in / limitations of the retrieval mean that there is a further error which varies with the state of the atmosphere, therefore:

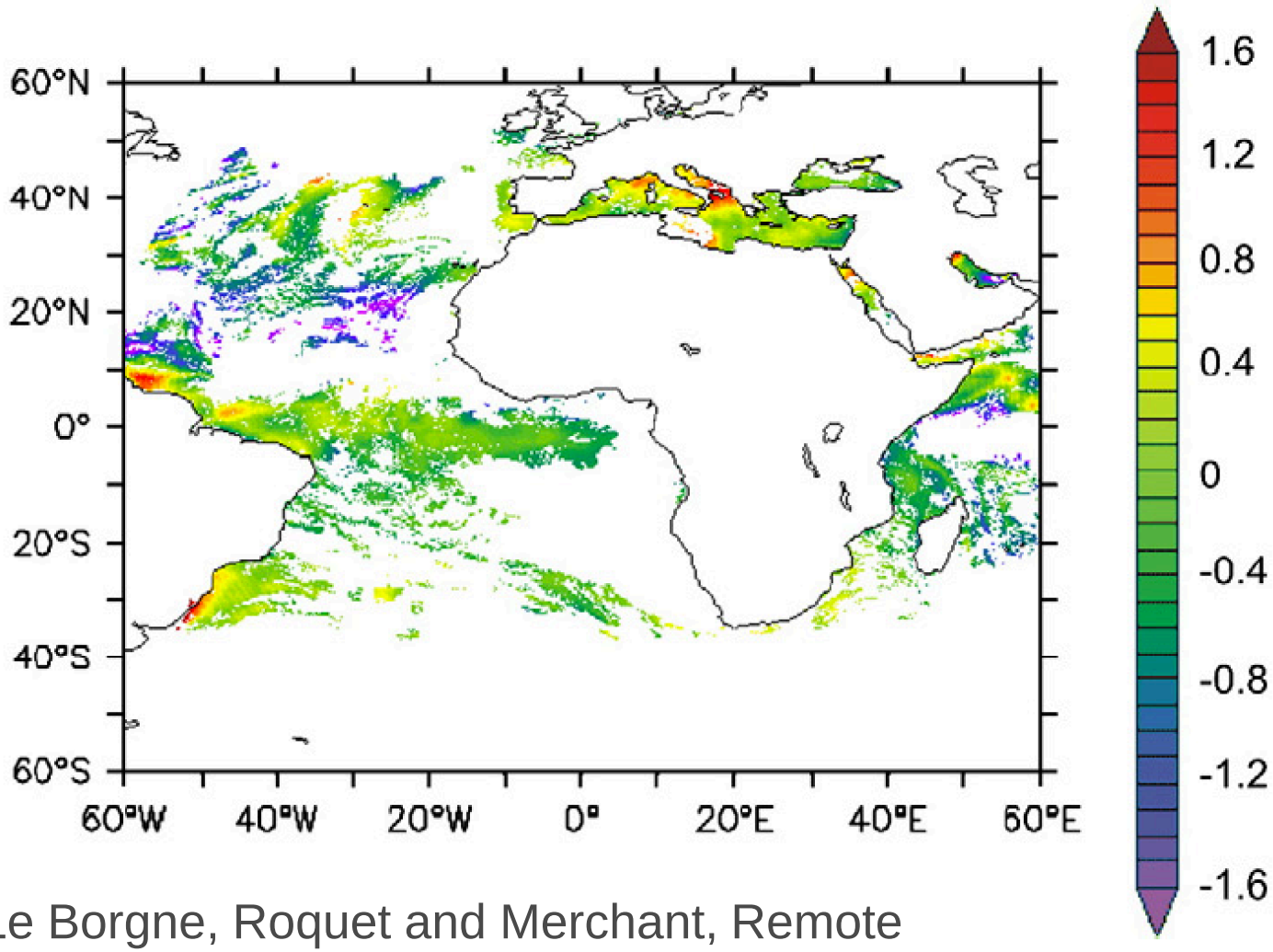
- It is correlated in space.
- It is correlated in time.
- Space/time correlations are on synoptic scales.

The magnitude of these uncertainties can be evaluated on the basis of a simulation study of the retrieval process.

- ‘True’ SST field and simulated brightness temperatures.
- Retrieve SST using the simulated brightness temperatures as input.
- Retrieval algorithm uncertainty is the difference between the retrieved and ‘true’ SST.

Calibration of the sensor means that there is also a systematic error.

Simulated Retrieval Errors

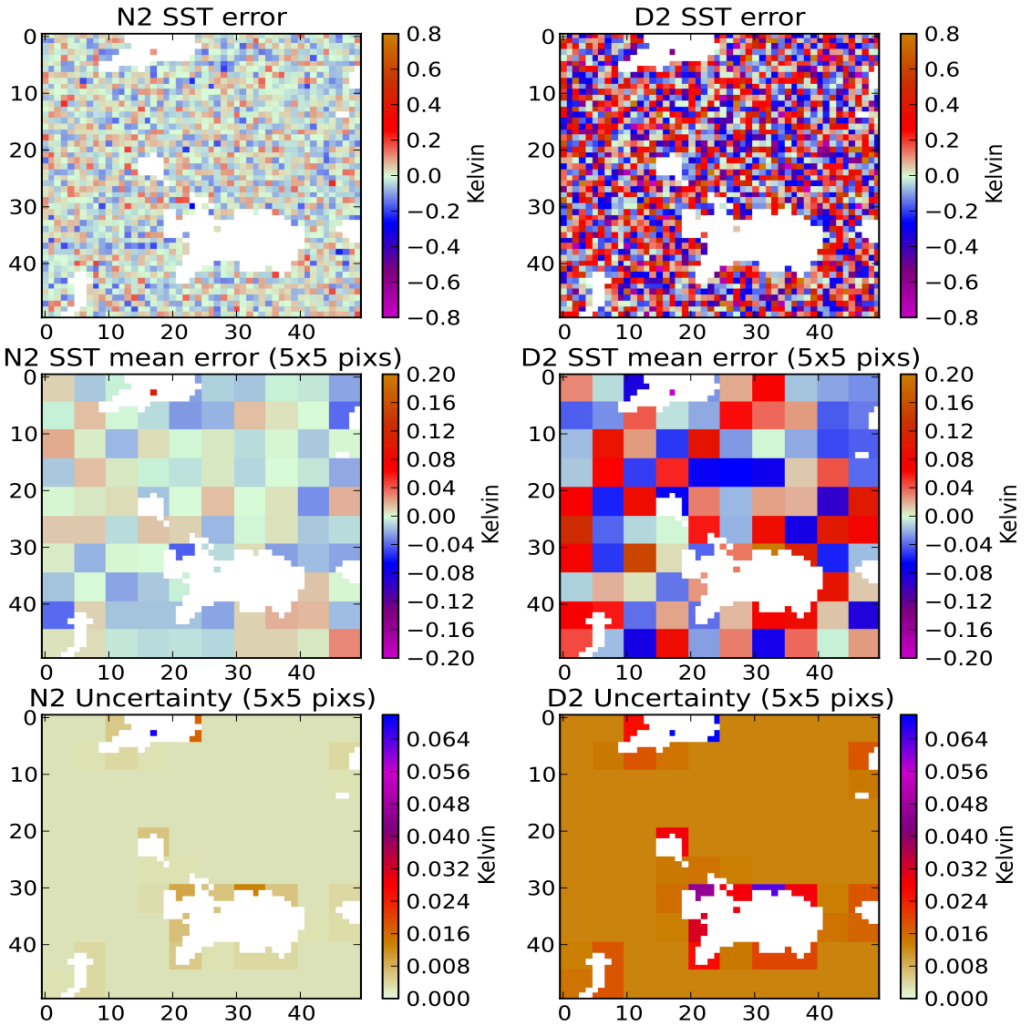


Example:

Simulated retrieval errors for SEVIRI SST.

Le Borgne, Roquet and Merchant, Remote Sensing of Environment, 2011.

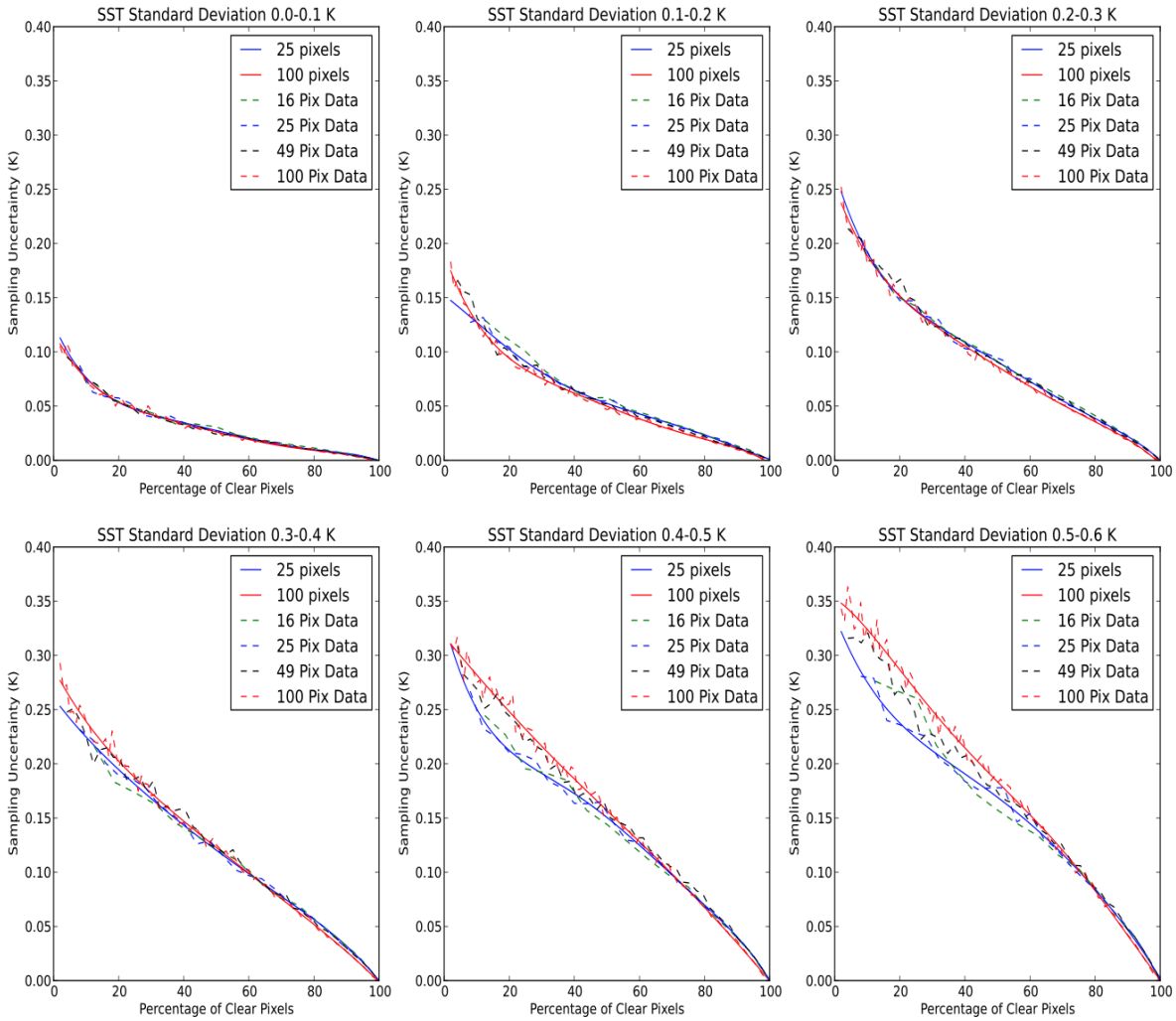
Noise propagation to L3 Gridded Products



Many SST users want data at 0.05 degrees or coarser so we generate gridded products:

- Mean errors over gridded products do not average down.
- Uncertainty from random effects reduces as $1/\sqrt{n}$.

Sampling Uncertainty in L3 Products



SST CCI Phase 2 development work:

- Sampling uncertainties are introduced where the gridded domain is not fully observed (eg. partially cloud covered).
- These uncertainties can be modeled as a function of domain size, clear sky percentage and SST variability.

Obs4MIPS-style L3 data

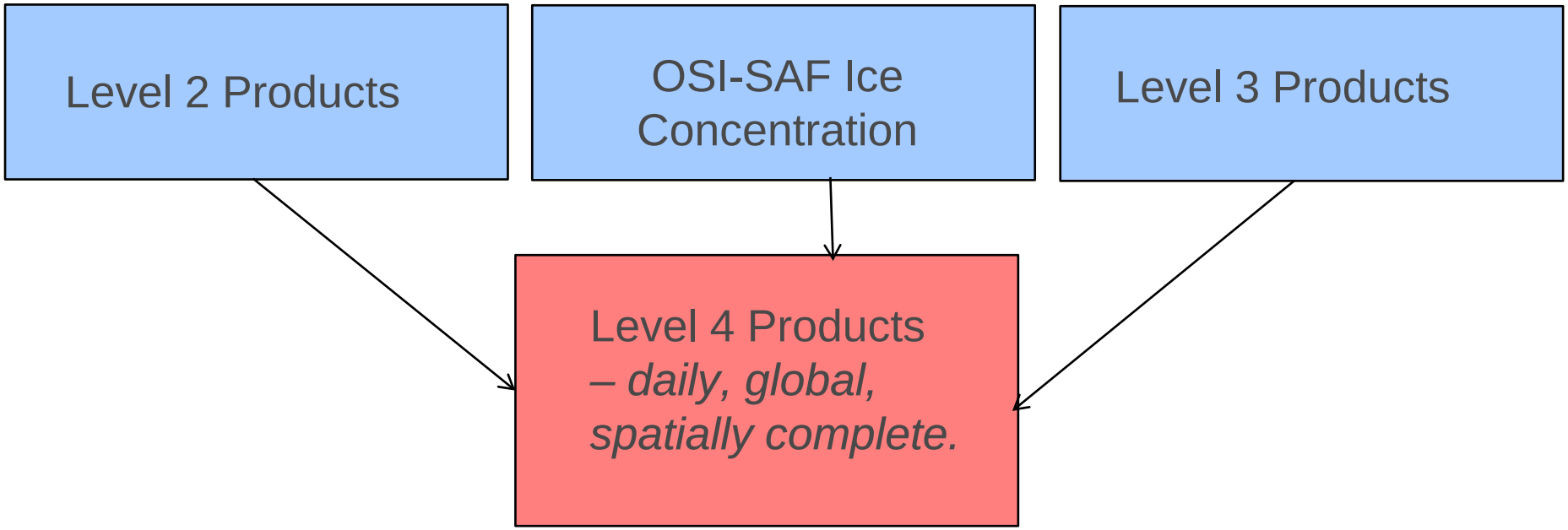
- Gridded products at 1 degree resolution, monthly data generated from L2P and L3U datasets.
- This case is complicated as the scales averaged are longer than synoptic scales, and locally correlated uncertainties average down a certain amount, but not by as much as $1/\sqrt{n}$. We need to take into account the number of constituent grid boxes and synoptic areas in the average.

$$\sigma = \sqrt{\sum_{p=1}^{n}\sum_{q=1}^{n}\frac{r_{pq}\sigma_p\sigma_q}{n^2}}$$

$$r = \exp\left(-1/2\left(\frac{d_{xy}}{l_{xy}} + \frac{d_t}{l_t}\right)\right)$$

- d_{xy} – spatial separation of each observation pair.
- d_t – temporal separation of each observation pair.
- l – correlation length scales.

Level 4 Products

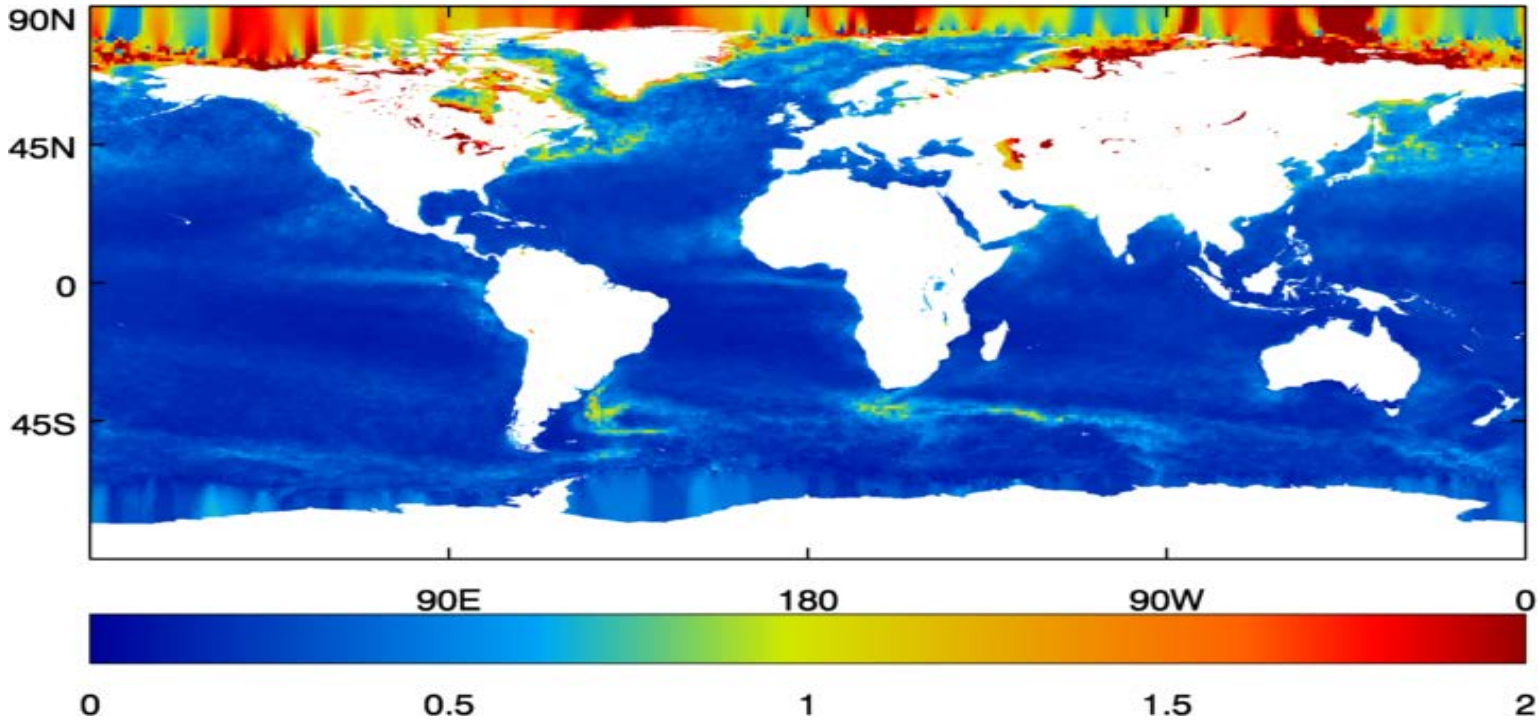


- L4 OSTIA products (Operational Sea Surface Temperature and Ice Analysis).
- L2 and L3 uncertainties are used as part of the weighting of SST inputs when generating the SST data field using optimal interpolation assimilation.

Uncertainties given in L4 Products

- The uncertainty field in the L4 product is currently stored in the ‘analysis error’ variable.

- Example SST CCI analysis uncertainty estimates (K) (30 June 2002).



Level 4 Uncertainty Estimates (1)

$$\varepsilon_i^a = \sqrt{B_i[\alpha + \beta(1-\varepsilon_i^o)]}$$

- Pre-defined field of background error covariance estimates.
- Estimated from previous OSTIA SST reanalysis.
- Includes uncertainty due to e.g. lack of observations and a limited ability to resolve mesoscale features.

- Uncertainty is given by the background error weighted by the influence of the observations on the analysis.

Level 4 Uncertainty Estimates (2)

$$\varepsilon_i^a = \sqrt{B_i[\alpha + \beta(1 - \varepsilon_i^o)]}$$

Low observation influence

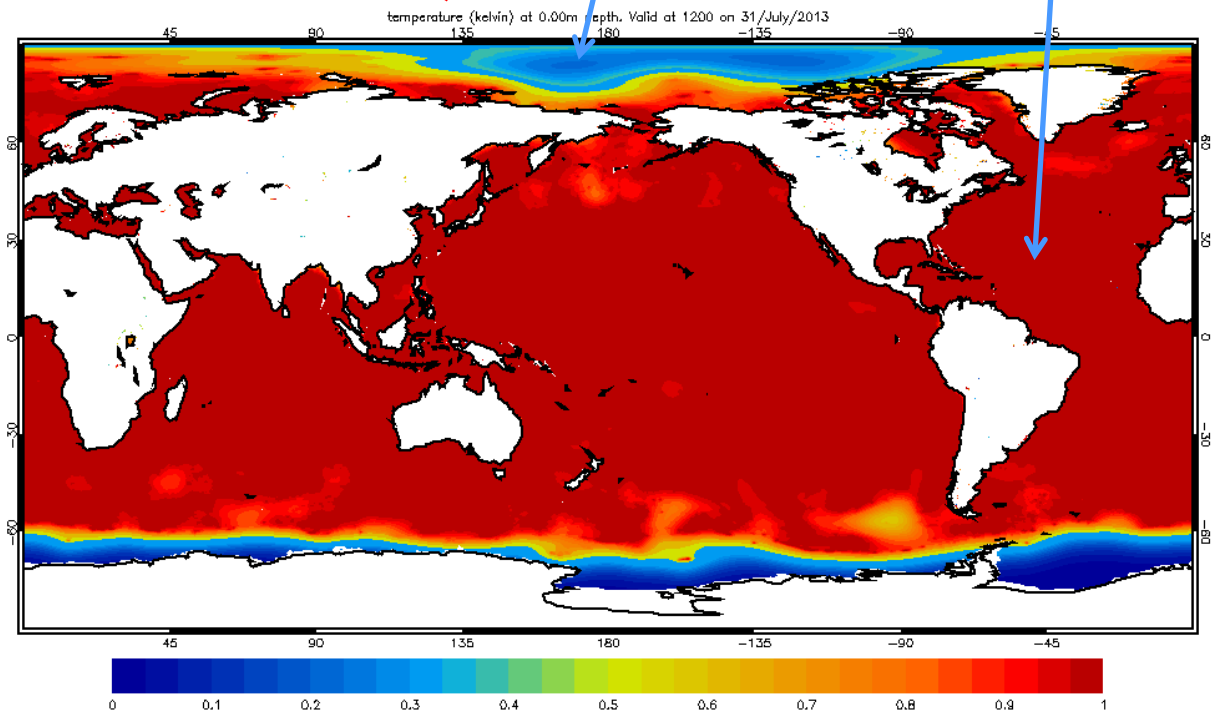
High observation influence

- ε_i^o is calculated using optimal interpolation where:

  observations = 1

  analysis background = 0

- The weight previously given to the observations in the SST analysis is preserved.



Operational example field, 31st July 2012

Level 4 Uncertainty Estimates (3)

$$\varepsilon_i^a = \sqrt{B_i[\alpha + \beta(1 - \varepsilon_i^o)]}$$

- α and β are tunable parameters.
- Values of α = 0.5 and β = 4.0 are used based on comparisons between the OSTIA analysis uncertainty and SST uncertainties in comparison with in-situ observations.

Where observations are given full weight:

$$\varepsilon_i^a = \sqrt{0.5B_i}$$

Where observations are given no weight:

$$\varepsilon_i^a = \sqrt{4.5B_i}$$

- Larger uncertainties in regions with fewer observations.

Development of Level 4 Uncertainties

- Level 2 and Level 3 product uncertainties are currently used in the SST estimate and the uncertainty calculation.
- An assumption is made that the observational uncertainties are not spatially correlated.
- The Level 2 and Level 3 products contain a breakdown of the different uncertainty components which could be propagated into the Level 4 product.
- SST CCI Phase II work will address how to do this and how to include correlation information in the uncertainty estimate.