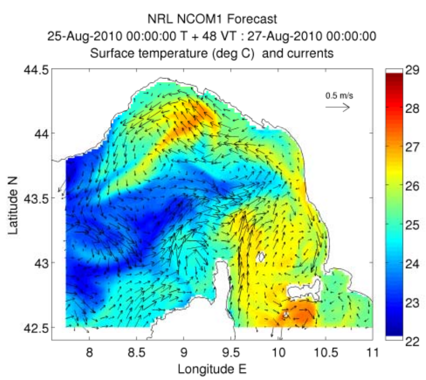
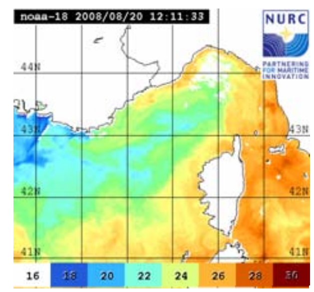
Uncertainty forecast by 3-D super-ensemble multi-model fusion in the ocean

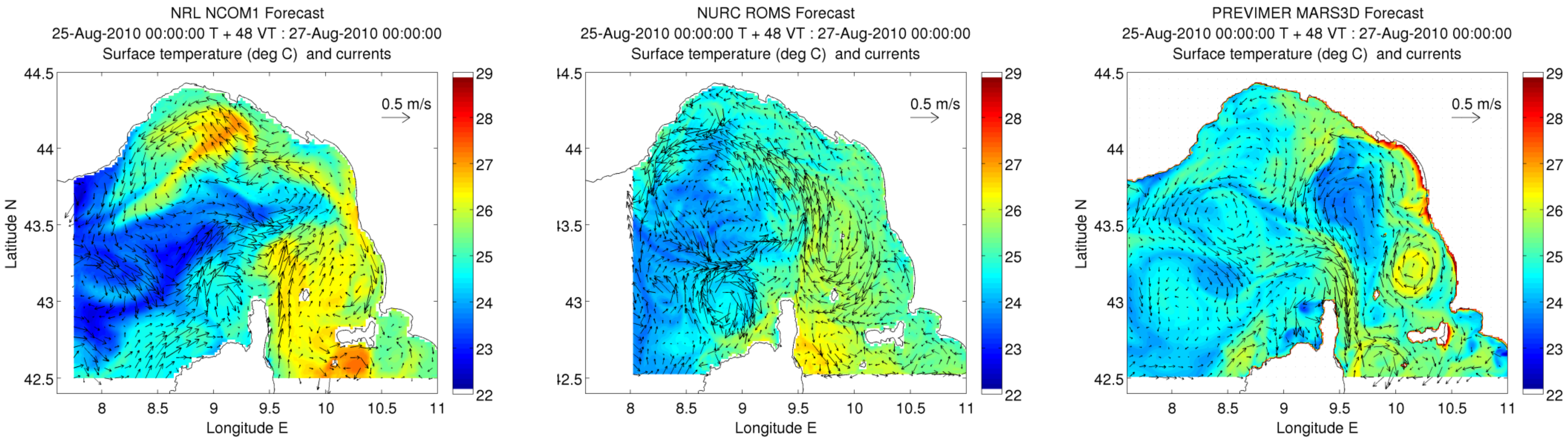




Baptiste Mourre, Jacopo Chiggiato, Fabian Lenartz and Michel Rixen
NURC, a NATO Research Centre, La Spezia, Italy

MREA10 conference, Tuesday 19 October 2010, Lerici

Context



In practice: multiple ocean forecasts available.

→ these forecasts differ ! … Which one to rely on ?

3D super-ensemble (3DSE)

Super-ensemble = fusion of multiple model forecasts with the aim of generating <u>one single improved forecast</u>.

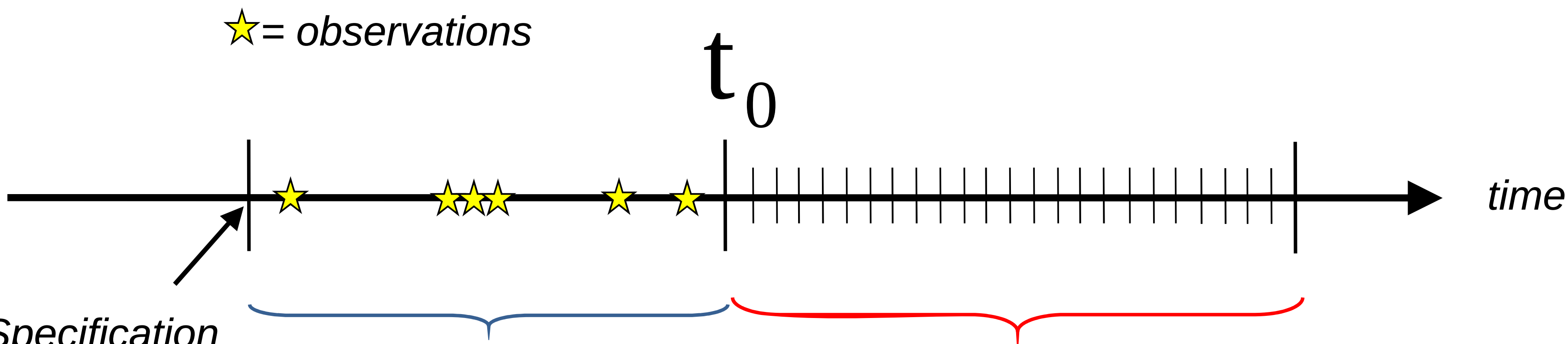
SE = linear combination of individual model outputs

$$\mathrm{T}_{SE}(x, y, z, t) = \sum_{i=1}^{\text{nb models}} w_i(x,y,z)\, \mathrm{T}_i(x, y, z, t)$$

3DSE: one weight per model and grid point $w_i(x,y,z)$

- 3-D ocean
- limited observation sampling
- spatially variable model skills

3D super-ensemble (3DSE)



Specification of initial model weights

$$\left(\frac{1}{\text{nb models}}\right)$$

& weight error correlations

Learning period

model weights are computed to minimize SE distance to observations

[2 days]

Forecast period

model weights are frozen and individual model forecasts are combined

[3 days]

3D super-ensemble (3DSE)

$$x = \begin{pmatrix} w_{11} \\ \cdots \\ w_{1p} \\ w_{21} \\ \cdots \\ w_{2p} \\ w_{31} \\ \cdots \\ w_{3p} \end{pmatrix} \begin{array}{l} \left.\vphantom{\begin{matrix} w \\ \cdots \\ w \end{matrix}}\right\} \text{Model 1} \\ \left.\vphantom{\begin{matrix} w \\ \cdots \\ w \end{matrix}}\right\} \text{Model 2} \\ \left.\vphantom{\begin{matrix} w \\ \cdots \\ w \end{matrix}}\right\} \text{Model 3} \end{array}$$

State vector = model weights (1 weight per model, variable and SE gridpoint)

→ Analysis error

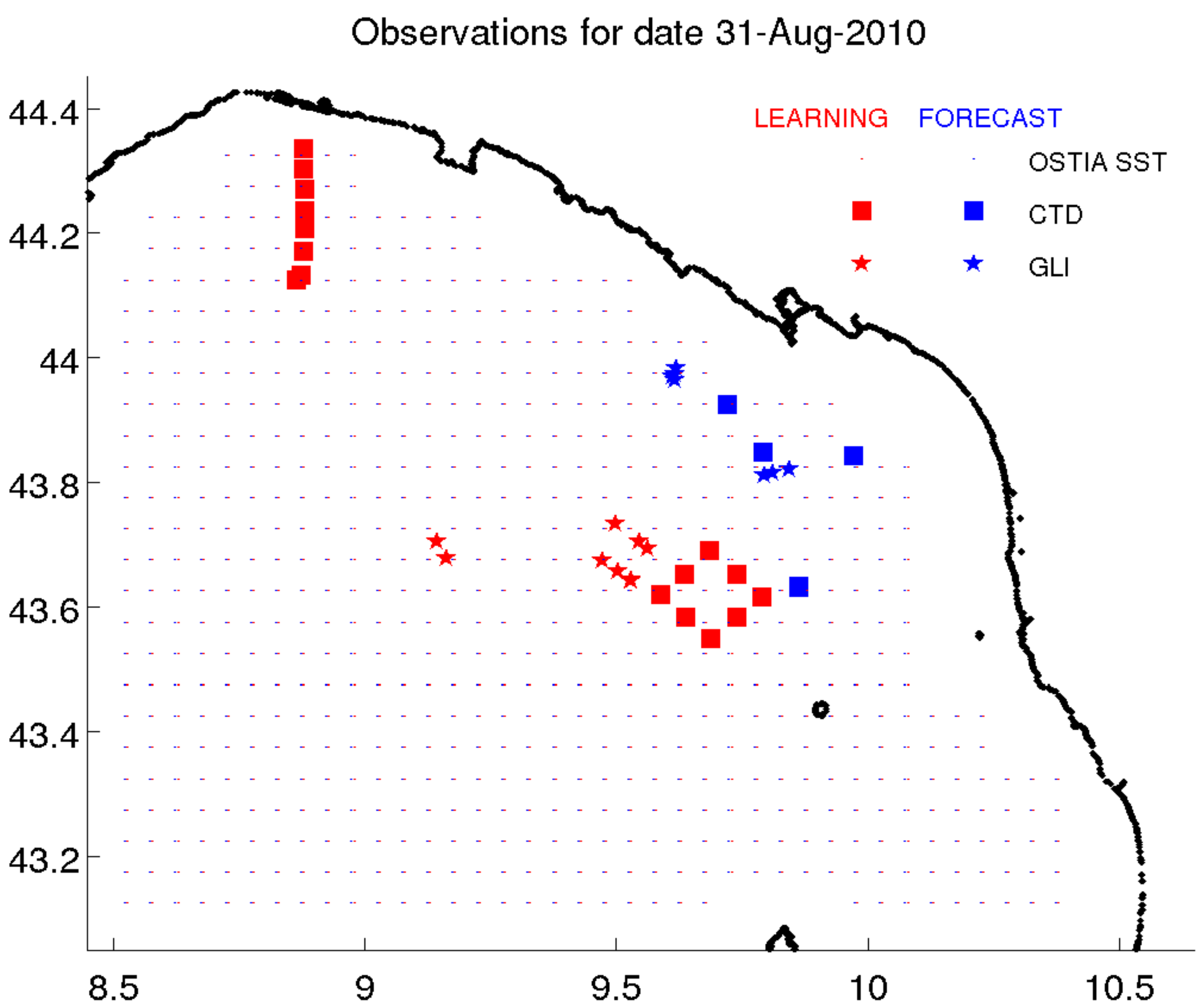
$$P^a(t_0)$$

Observation operator = model forecasts + interpolation at observation points

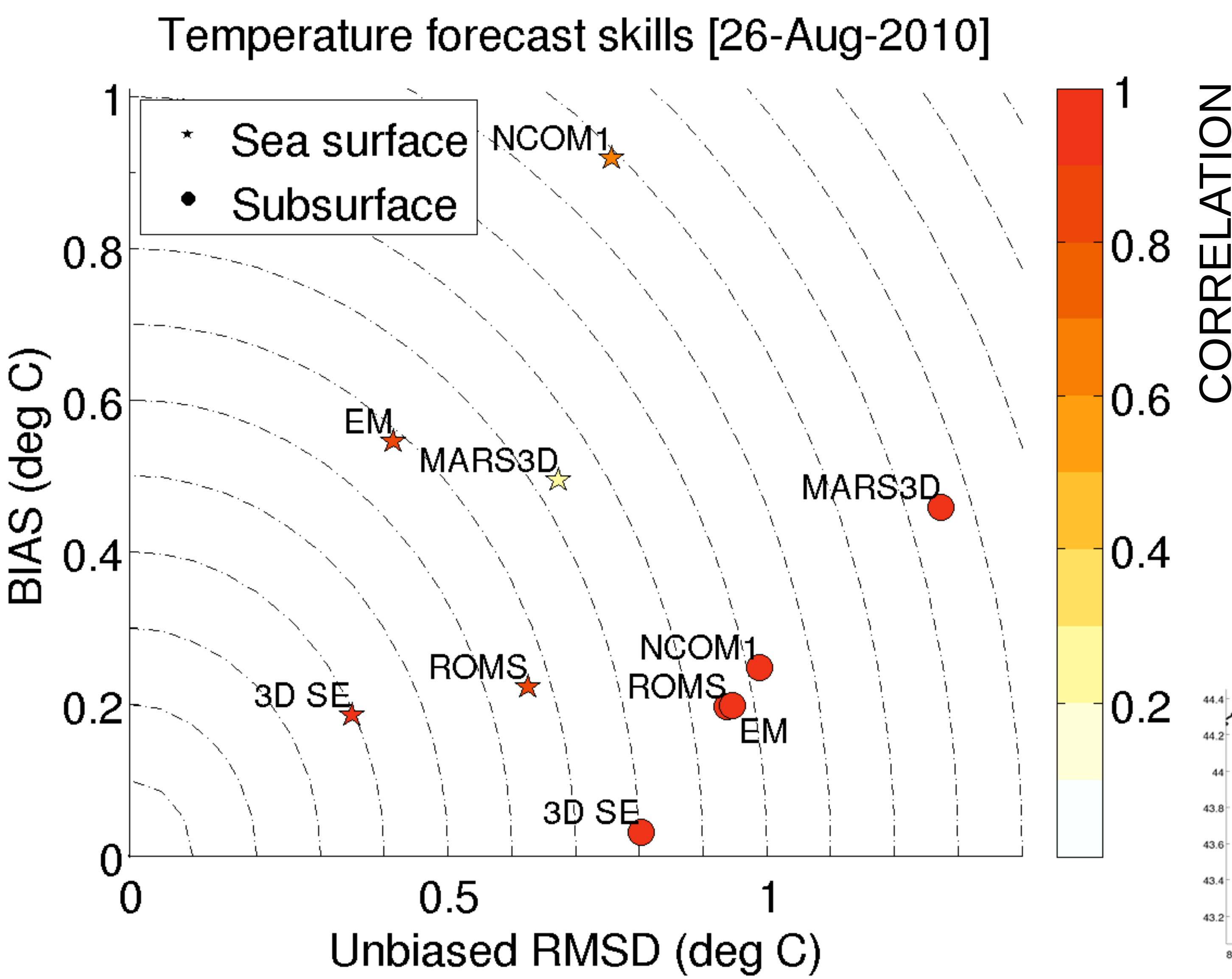
Weight error covariance matrix

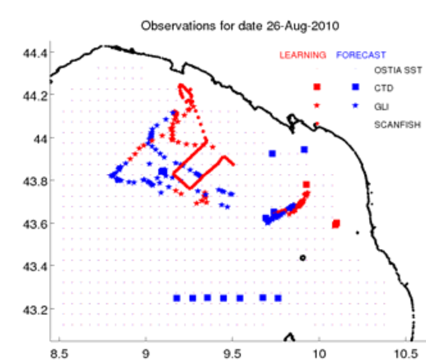
$$x^a = x^f + P^f H^T (HP^f H^T + R)^{-1} (y^o - Hx^f)$$

3DSE: REP10 temperature forecast

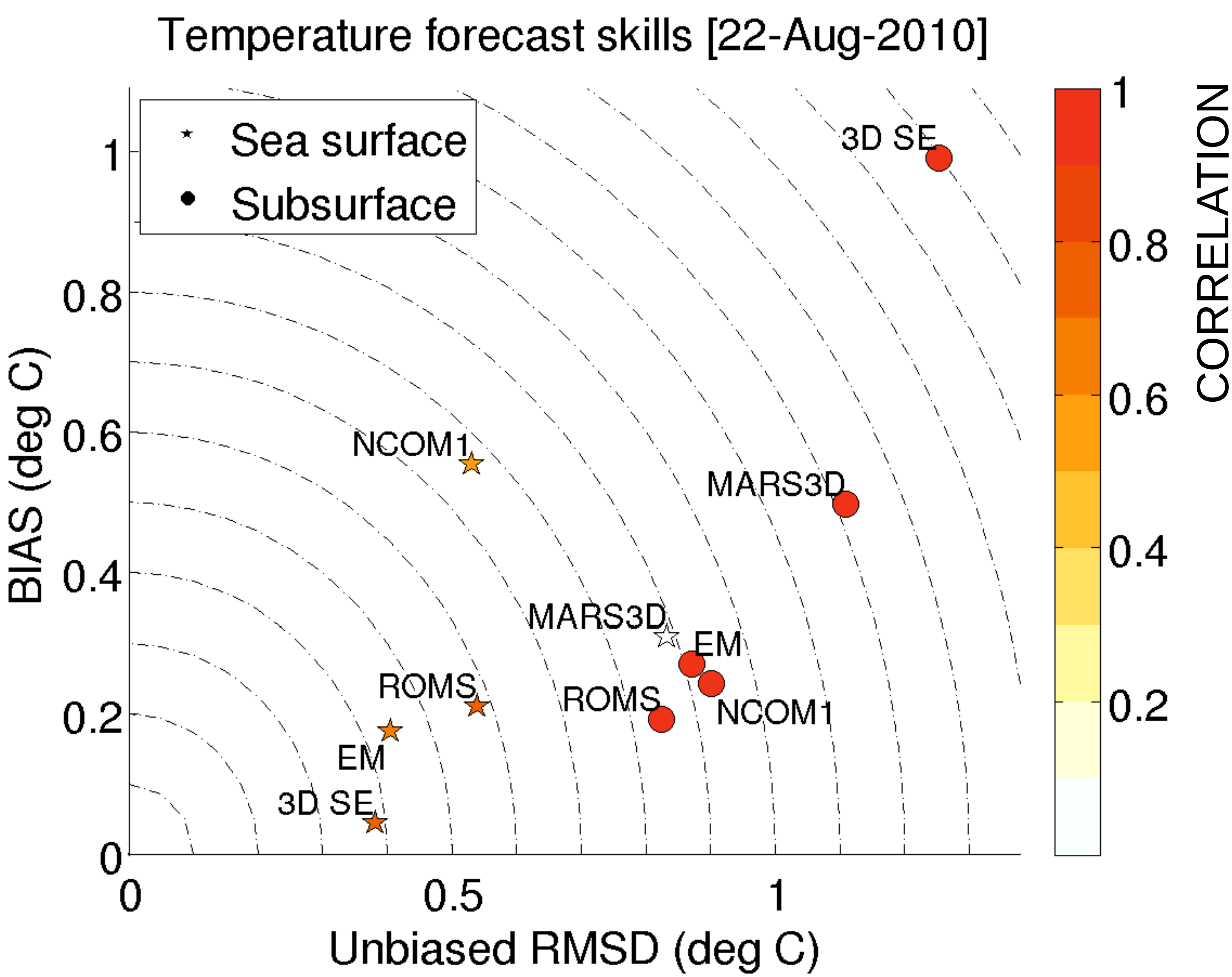


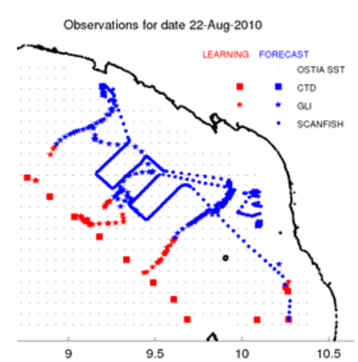
3DSE: REP10 temperature forecast



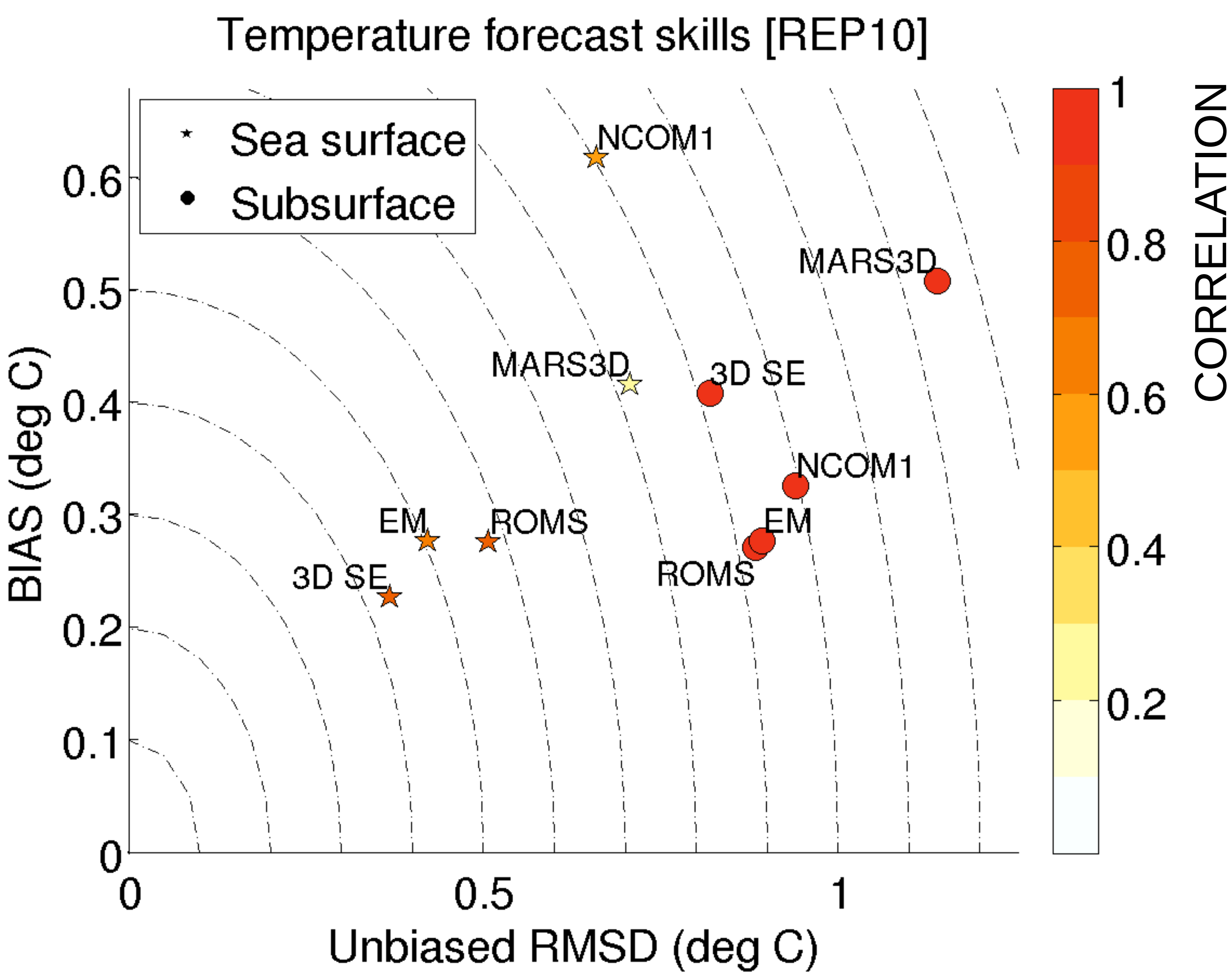


3DSE: REP10 temperature forecast

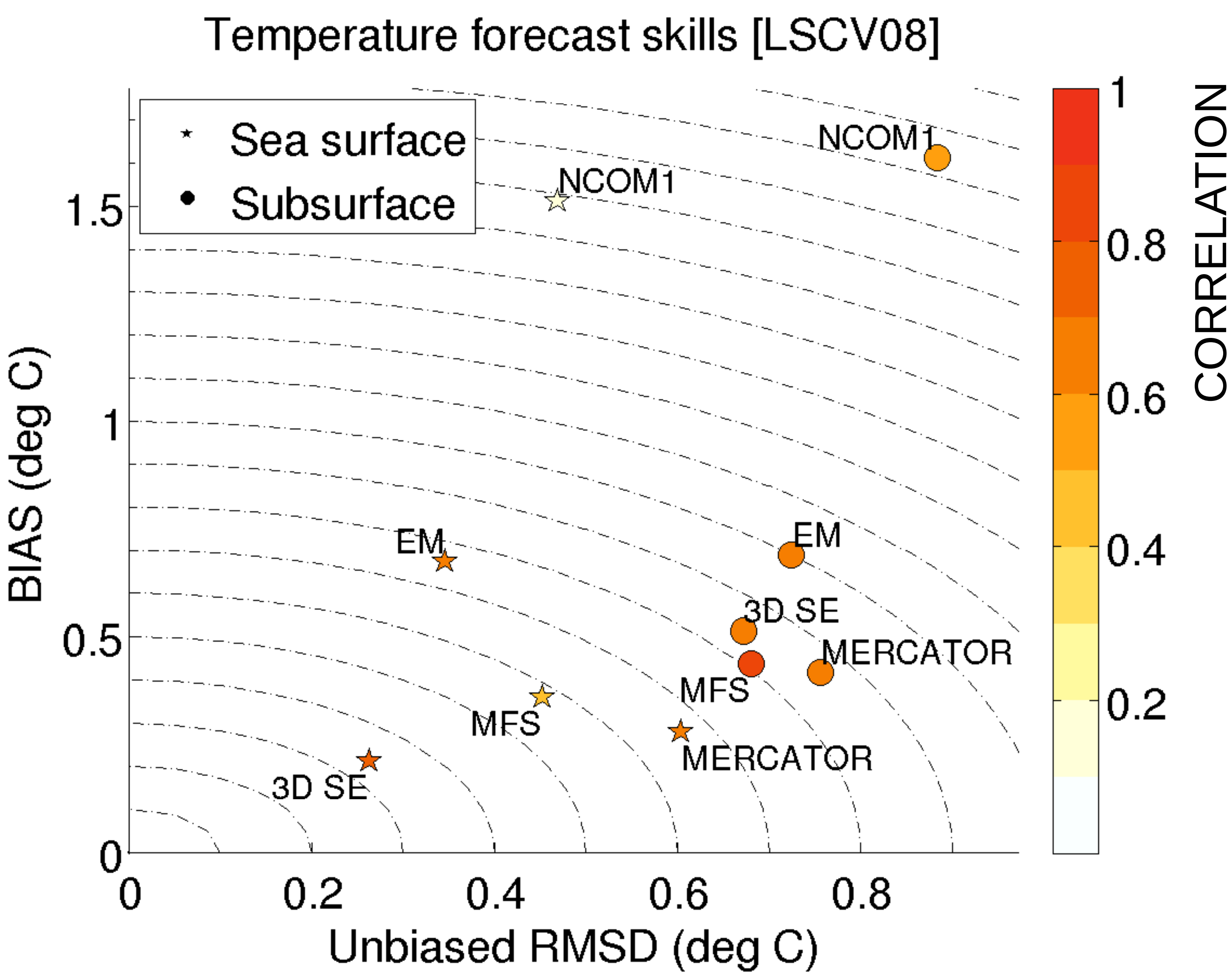




3DSE: REP10 temperature forecast



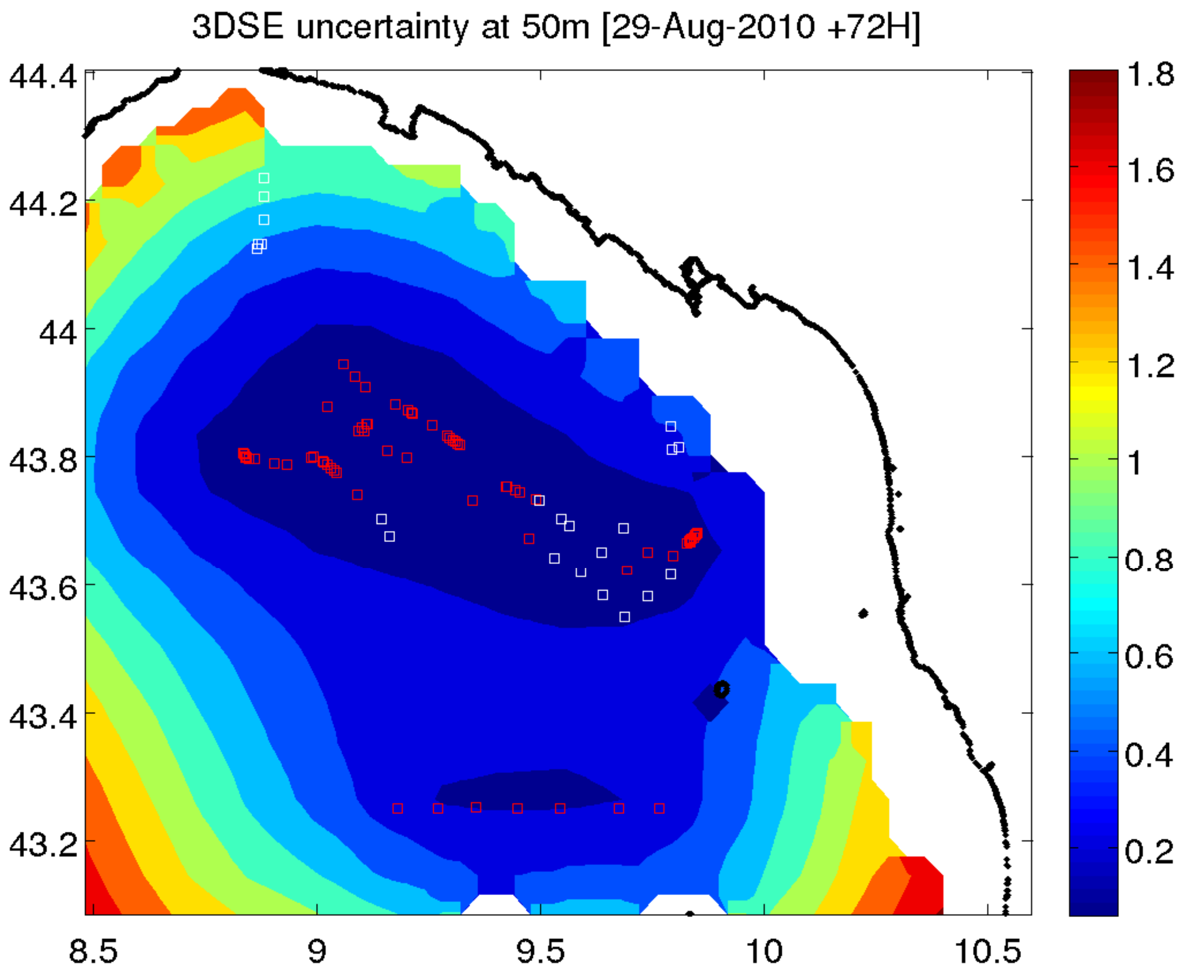
3DSE: LSCV08 temperature forecast



3DSE uncertainty

(analysis) weight error covariances P^a

3DSE error covariances HP^aH^T



3DSE uncertainty calibration

theoretical 3DSE uncertainty estimate $\mathrm{HP}^{\mathrm{a}}\mathrm{H}^{\mathrm{T}}$

observed error $\mathrm{y}^{\mathrm{o}} - \mathrm{Hx}^{\mathrm{a}}$

Calibration by amplification of
the weight error covariance matrix:

$$\mathrm{P}^{\mathrm{a}^{[\mathrm{ampl.}]}} = \alpha^2 \mathrm{P}^{\mathrm{a}}$$

Temporal dependency:

$$\alpha(t)\,?$$

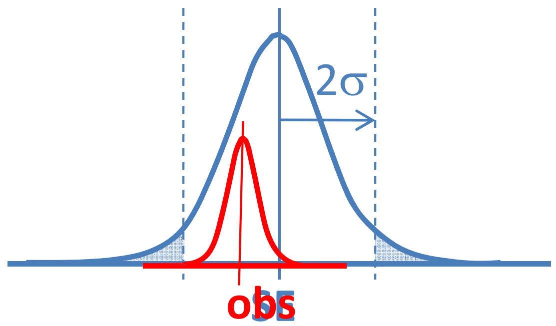
3DSE uncertainty calibration

$$\mathrm{P}^{\mathrm{a}^{[\mathrm{ampl.}]}} = \alpha^2 \mathrm{P}^{\mathrm{a}}$$

2 ways to estimate α :

- based on the rms difference (over the number of observations) between 3DSE uncertainty and observed error

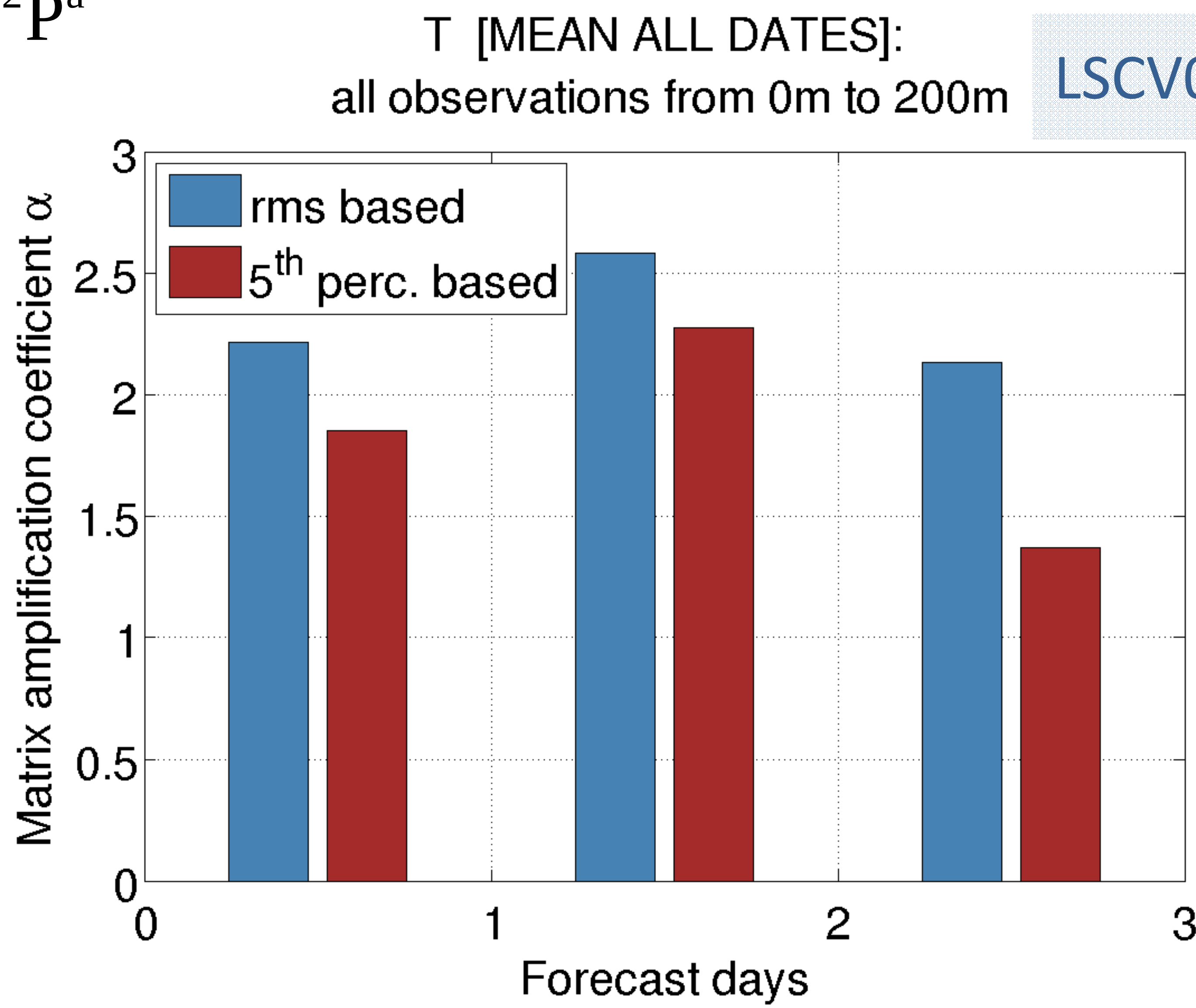
- based on the 5th percentile of the error distribution



3DSE uncertainty calibration

$$\mathrm{P}^{\mathrm{a}^{[\mathrm{ampl.}]}} = \alpha^2 \mathrm{P}^{\mathrm{a}}$$

LSCV08



Conclusions

• The 3D super-ensemble produces a skilful reconciliation of multiple model forecasts, without requiring any a priori knowledge of individual model errors.

Prediction skills: surface RMSD 0-72h: 0.4°C

subsurface RMSD 0-72h: 0.9°C

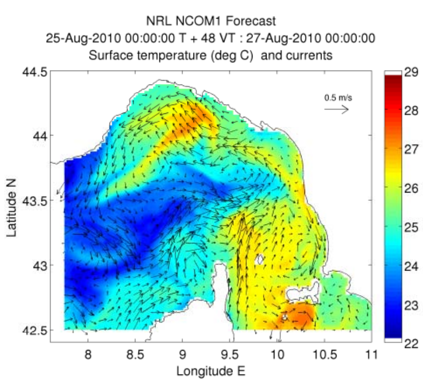
• Reliable associated uncertainty forecast likely to be further refined by empirical calibration.

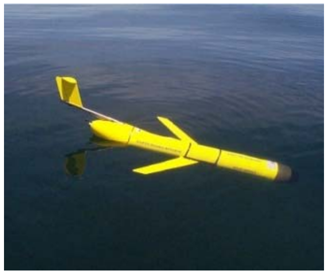
Publication:

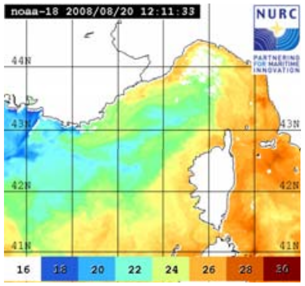
Enhanced ocean temperature forecast skills through 3-D super-ensemble multi-model fusion.

Lenartz F., Mourre B., Barth A., Beckers J.-M., Vandenbulcke L. and M. Rixen. Geophysical Research Letters, 2010, in press.

Thank you for your attention !

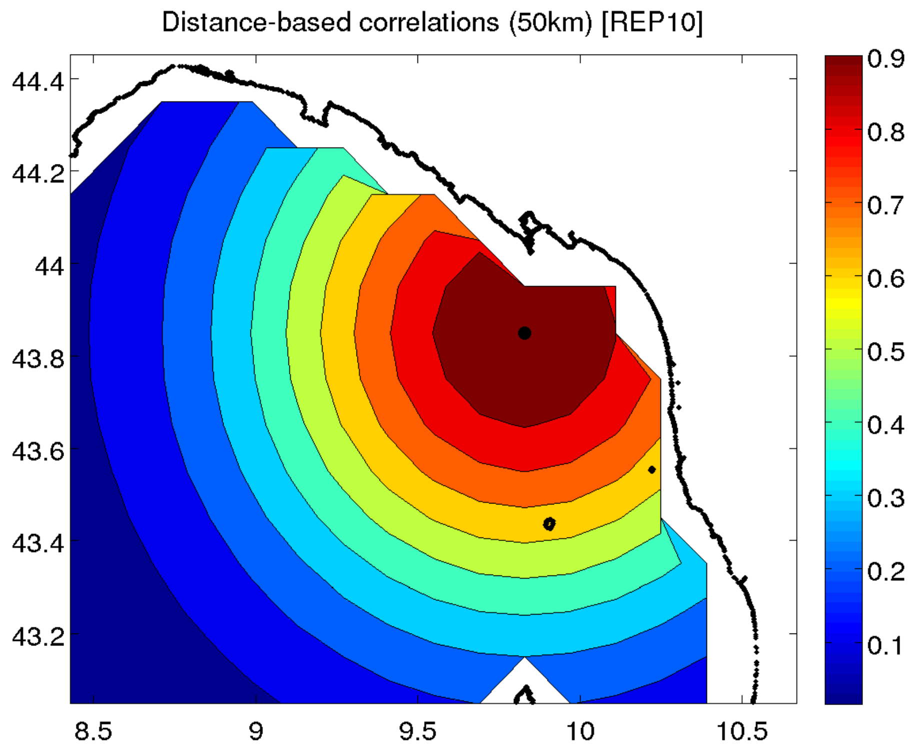


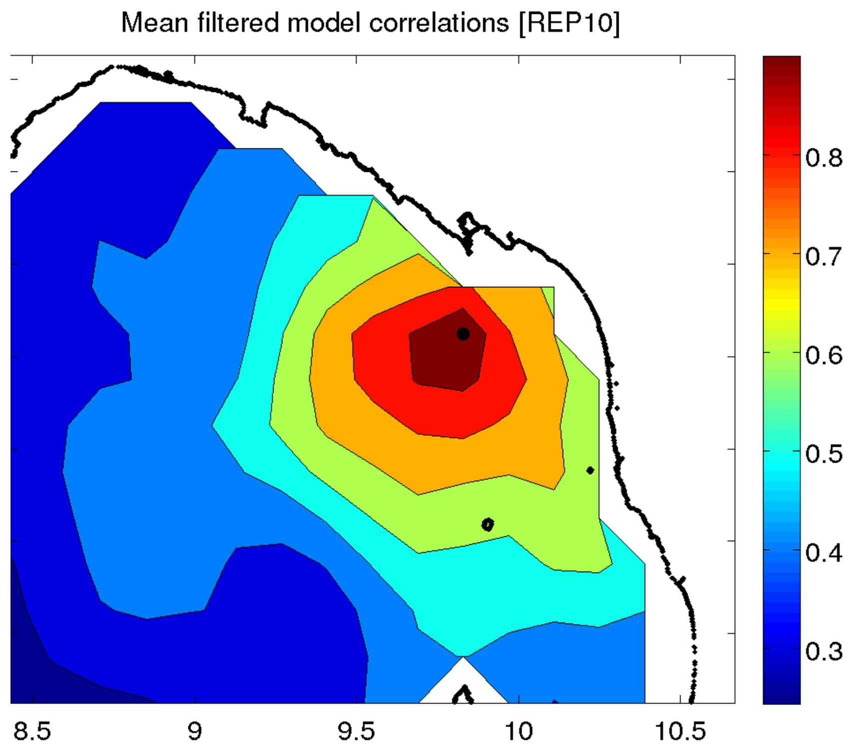




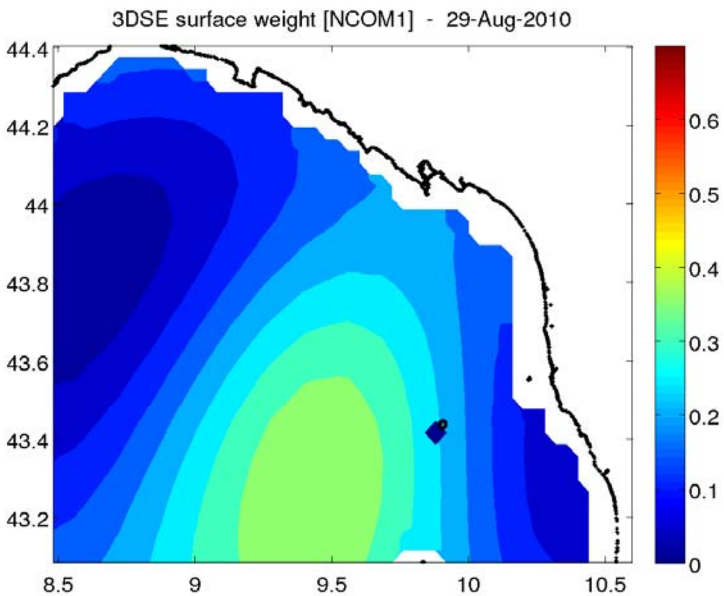
Additional material

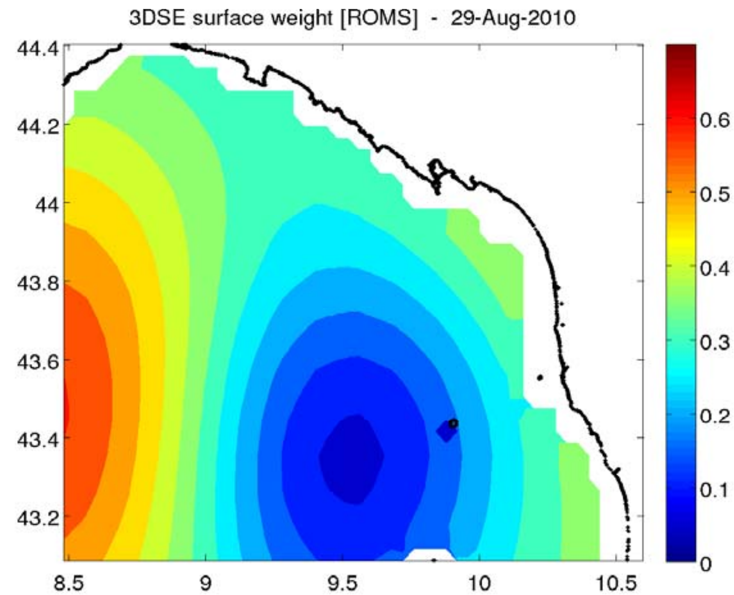
Weight error correlations

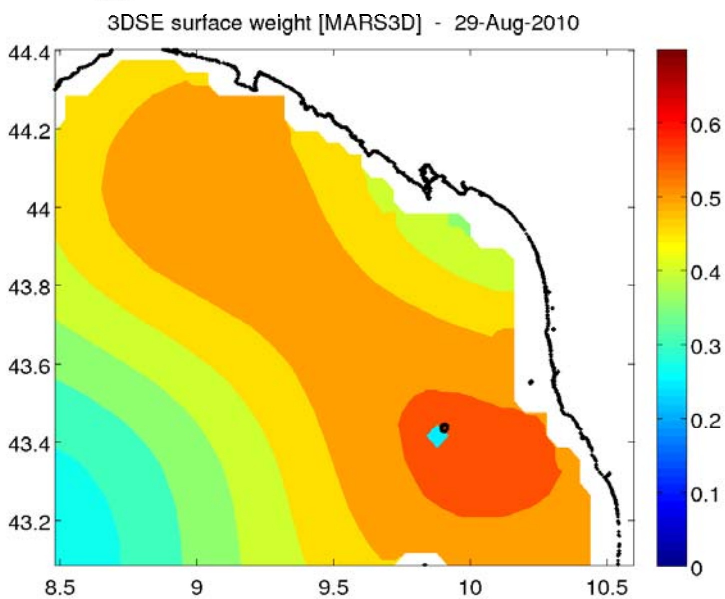




3DSE model weights







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Temporal dependency:

$$\alpha(t)\,?$$

Spatial dependency:

$$\mathrm{P}^{a^{[\text{ampl.}]}} = \mathrm{AP}^{a}\mathrm{A}\,?$$

diagonal matrix