Improved surface fluxes for a coupled ocean-atmosphere model

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Introduction

- The project is concerned with the accurate estimation of global circulation with a coupled ocean-atmosphere data assimilation system;
- The objectives of the coupled framework:
  - to improve the quality of forecasts from the short to seasonal and interannual timescales;
  - Study mixed layer processes in ocean and atmosphere;
  - Take into account sea-ice interaction with the atmosphere;

Requirements

- A coupled model demands high-quality estimation of air-sea fluxes consistent with surface measurements and model physics;
- Surface fluxes remain one of the most important source of model error:
  - Bulk aerodynamic formulae contain large uncertain-ties in the transfer coefficients;
  - Discrepancies between modeled ocean SST and observations;

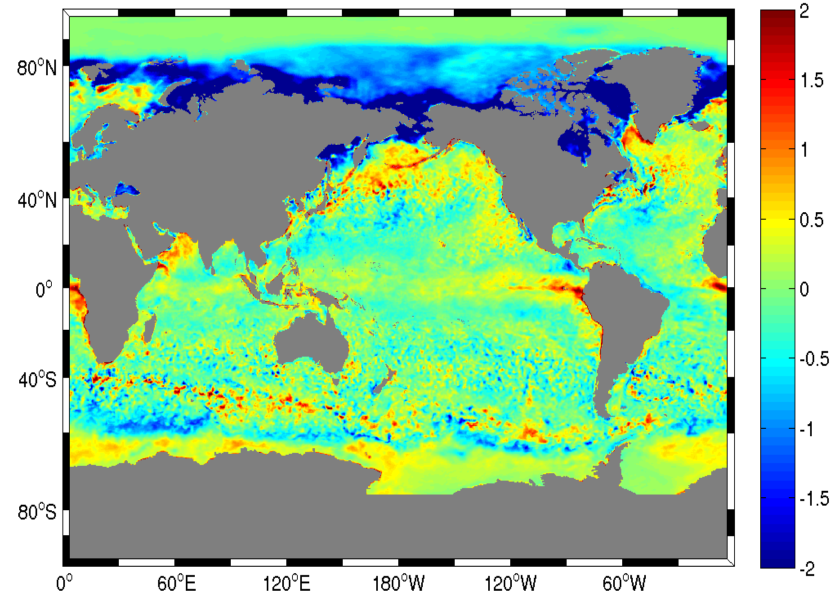
Objectives of Data assimilation

- Data assimilation is driven by the short-term forecast from the coupled model
  - maintains the model forecast close to observations;
- Assimilation can be used to estimate
  - Initial conditions of the atmosphere and ocean
  - model parameters for heat, momentum and humidity fluxes between the ocean and the atmosphere;

Difference between CONCEPTS forecasts and CMC SST

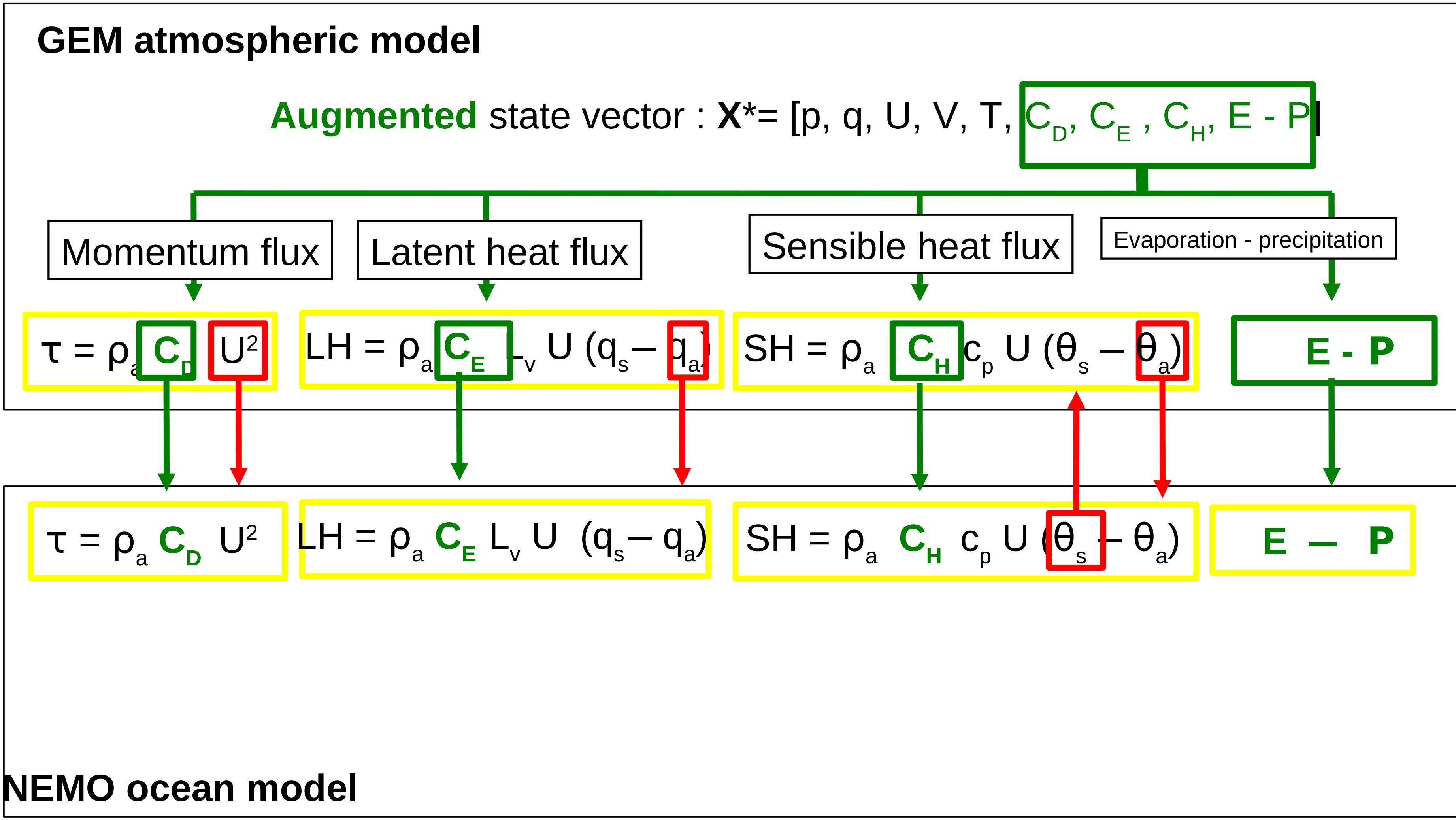
- Produce weekly 10d forecasts using ORCA025
- Important differences from CMC SST analysis can be seen
- Differences from PSY3V2R2 also present…

CONCEPTS - CMCSST for day 10 Average of forecasts from 20090520 to 20090819



(Greg Smith, François Roy)

Parameter estimation



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GEM 4D-Var data assimilation system with **parameter estimation**

- Estimation problem is expressed as the minimization of the cost function

$$J(\mathbf{X},\mathbf{p})=\frac{1}{2}\left(\mathbf{X}-\mathbf{X}_b\right)^T\mathbf{B}_X^{-1}\left(\mathbf{X}-\mathbf{X}_b\right)+\frac{1}{2}\left(\mathbf{p}-\mathbf{p}_b\right)^T\mathbf{B}_p^{-1}\left(\mathbf{p}-\mathbf{p}_b\right)$$
$$+\frac{1}{2}\left(\mathbf{HM}\left(\mathbf{X},\mathbf{p}\right)-\mathbf{Y}\right)^T R^{-1}\left(\mathbf{HM}\left(\mathbf{X},\mathbf{p}\right)-\mathbf{Y}\right)$$

- **Augmented** state vector :

  X= [p, q, u, v, T],

  p = [C_D, C_E , C_H, E - P]

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Characteristics of the assimilation

- 4D-Var assimilation for the atmospheric component only
  - Temperature observations near the surface will contribute to the estimation of the parameters (ships, buoys, etc.)
  - *Ad-hoc* error statistics for the parameter C_E: constant variance with homogeous and isotropic Gaussian correlations (L_c= 200 km)
- SST used is that provided by a separate ocean reanalysis
- Resolution of the atmospheric model is ~100 km
- Assimilation over a period of 7 days
- Preliminary results

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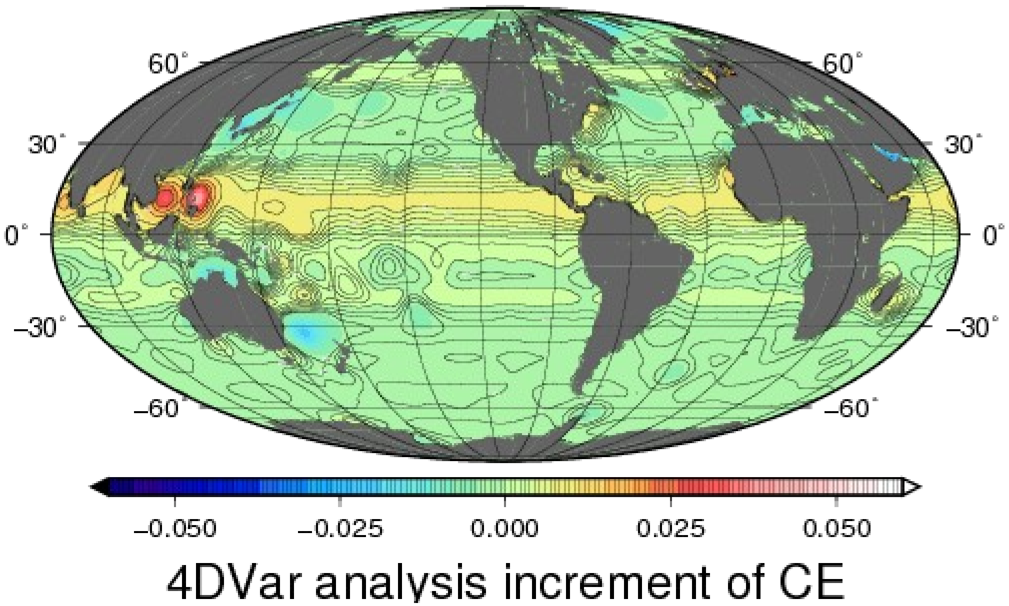
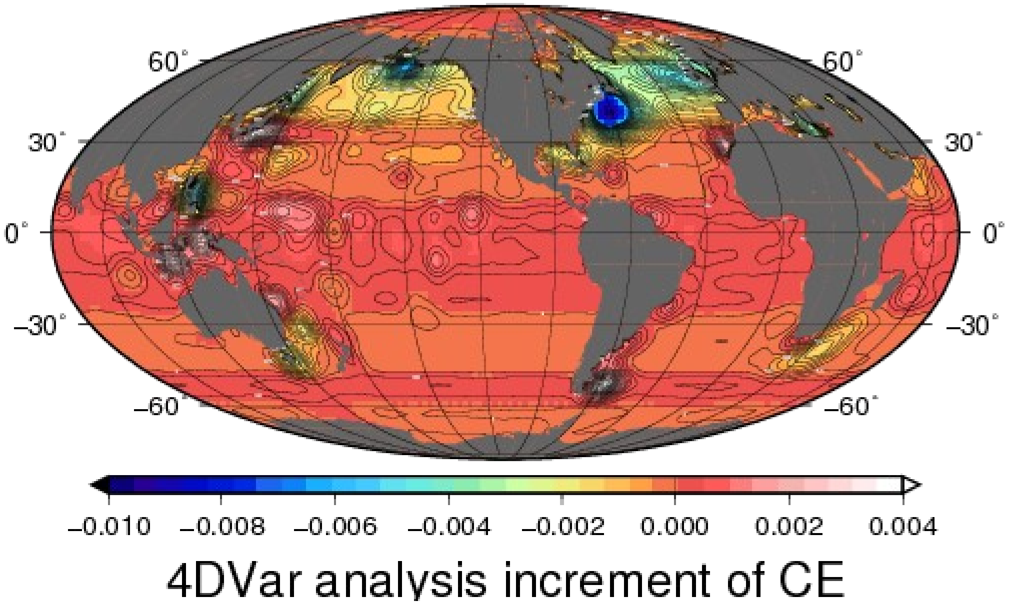
4DVar analysis *parameter* increments: CE

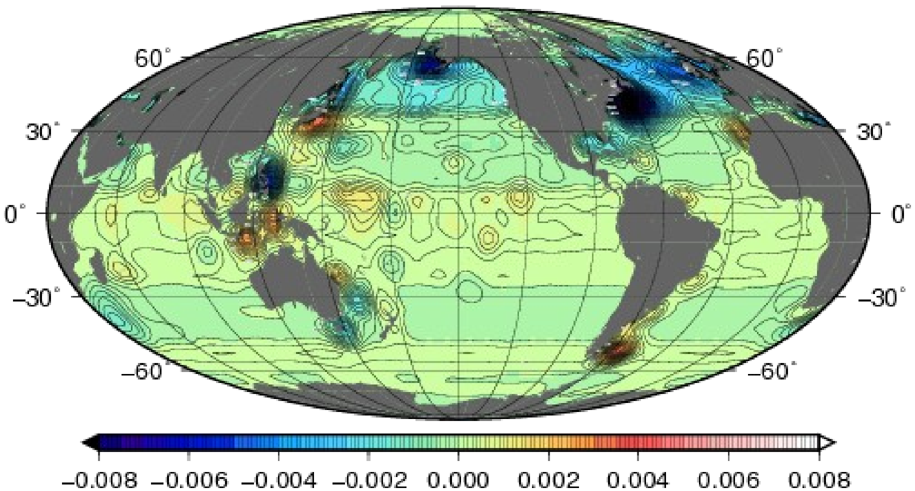
Boreal summer
Single case:
June 22, 2008



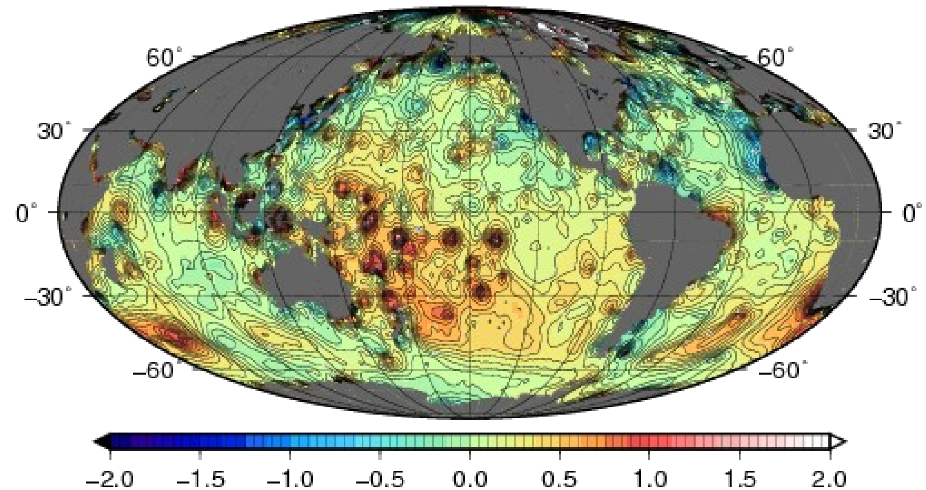
Boreal winter
Single case:
December 21, 2006



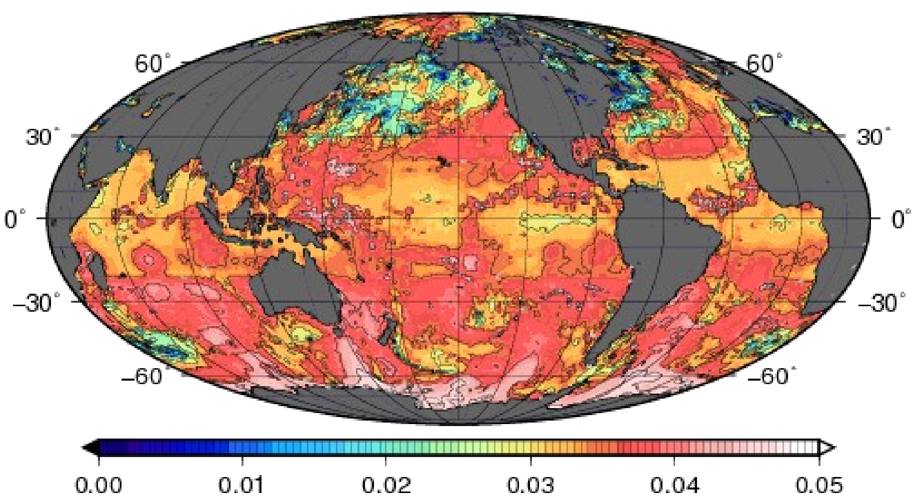
4D-Var analysis increments.



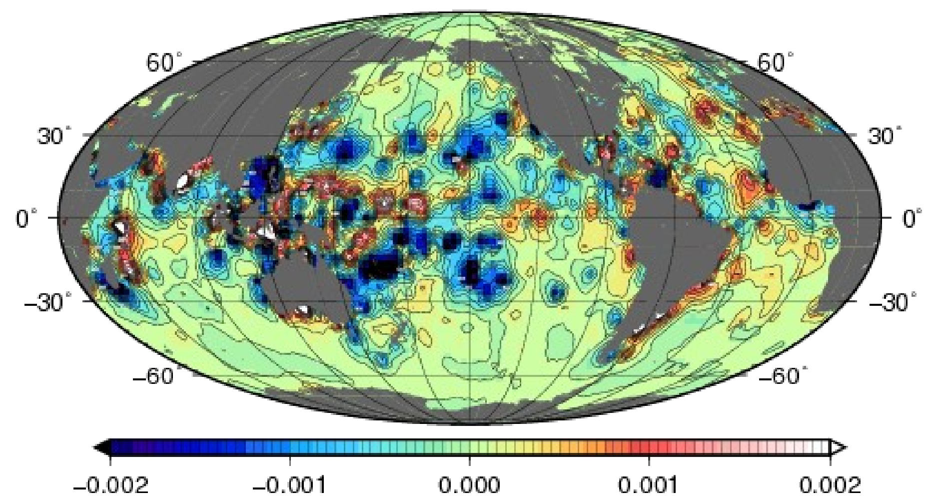
CE analysis increment



TT analysis increment



CE bulk formulation



HU analysis increment

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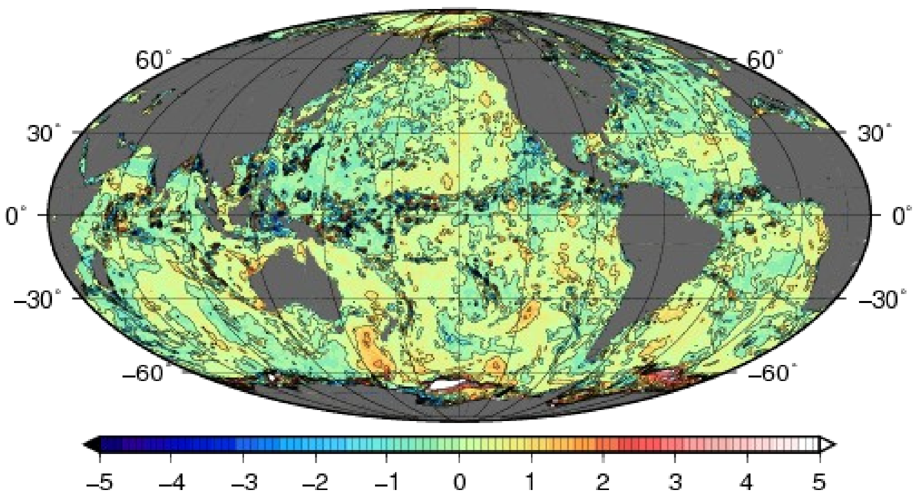
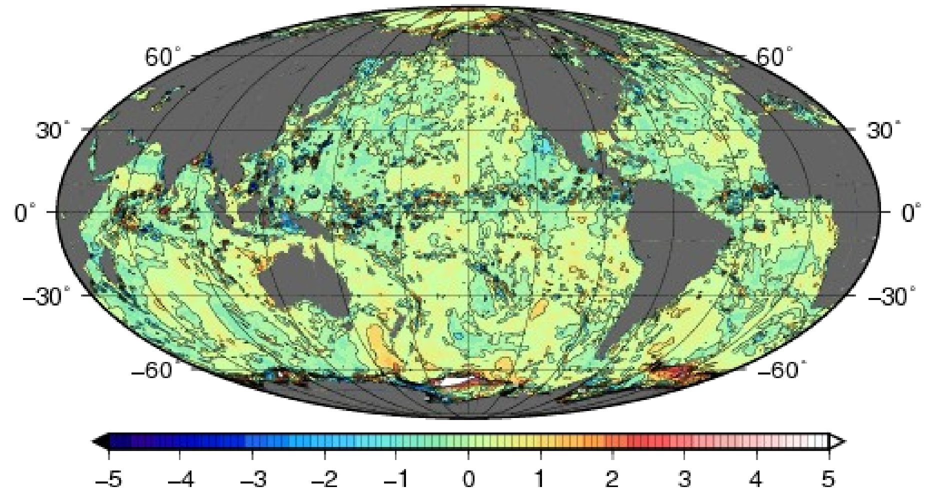
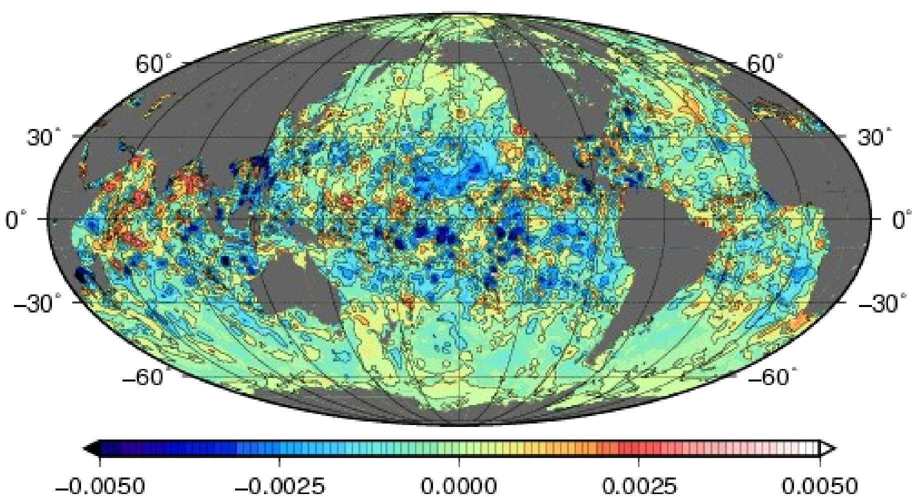
Improvement on GEM forecasts



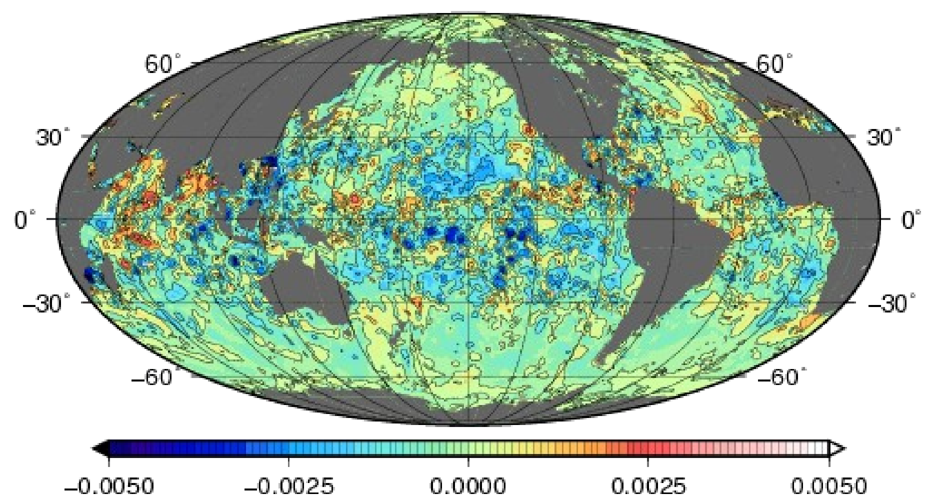
TT REF Forecast – Analysis



TT PE Forecast – Analysis



HU REF Forecast – Analysis



HU PE Forecast – Analysis

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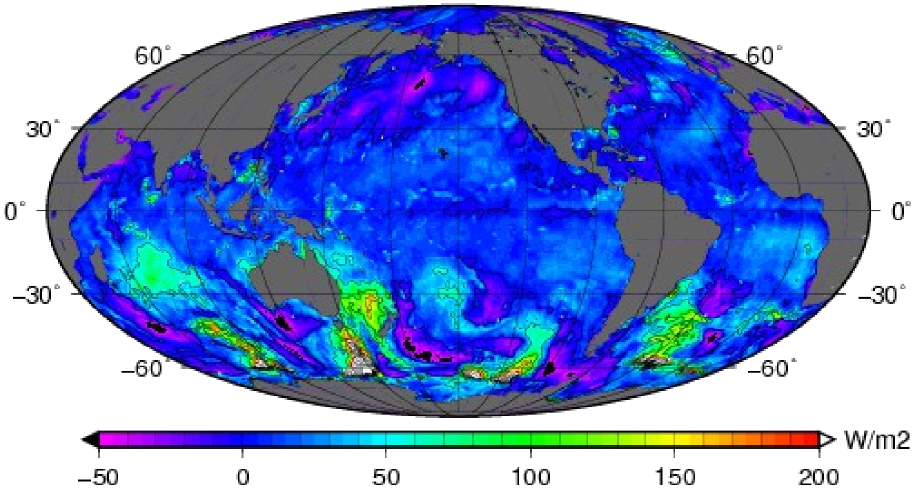
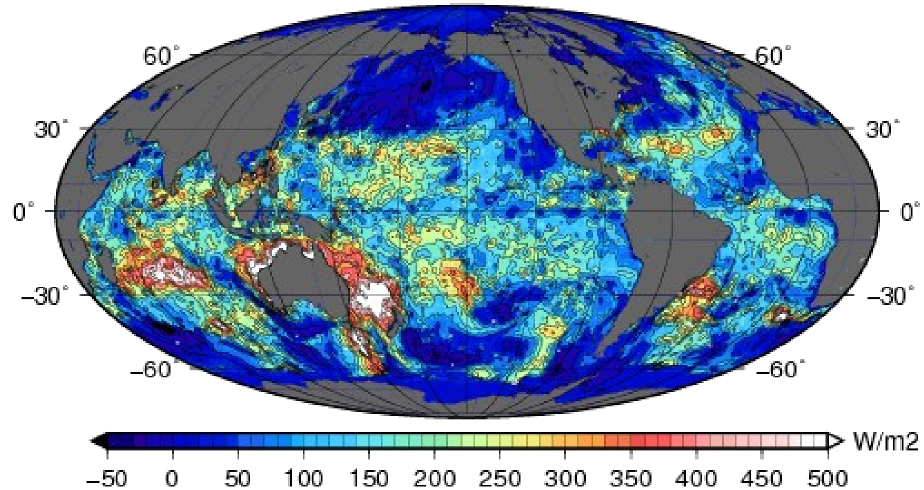
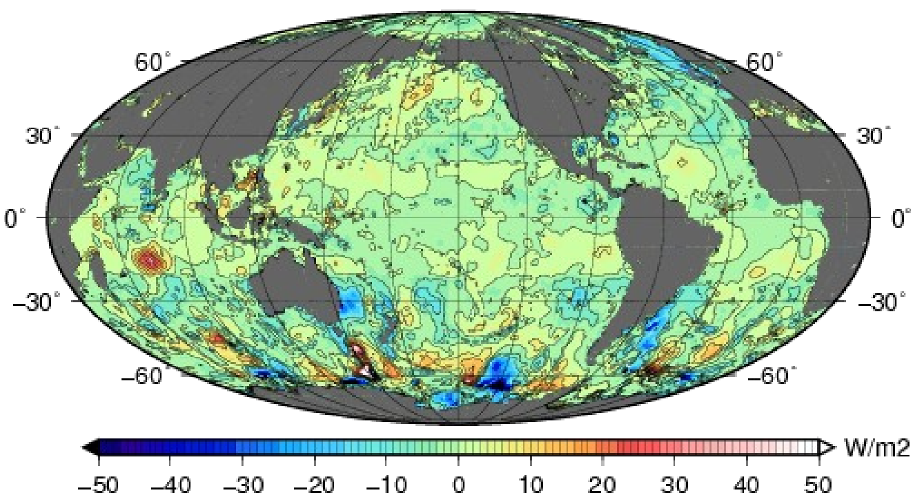
Corrected surface fluxes



Reference FC



Reference FV



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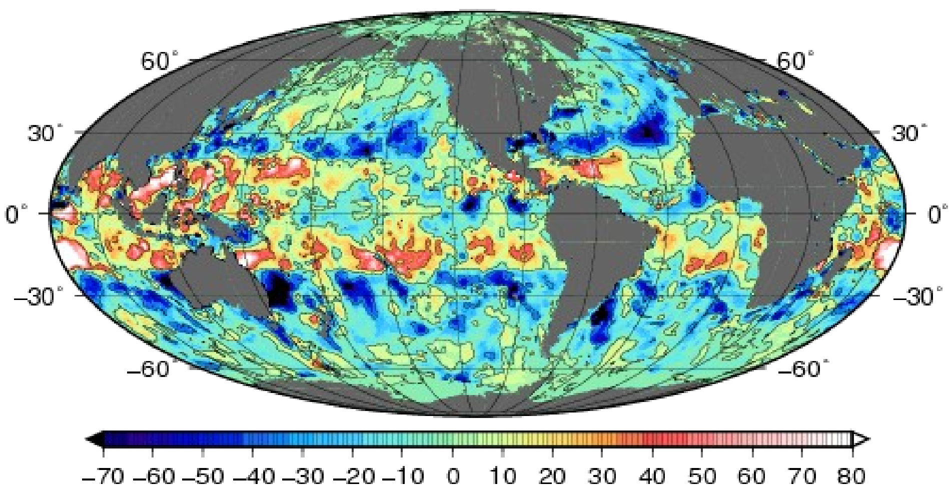

FV. PE – REF

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Conclusions

- Parameter estimation scheme has been implemented within GEM-4DVar atmospheric data assimilation model;
- Turbulent transfer coefficient governing the calculation of heat surface fluxes is estimated within the assimilation itself;
- The scheme improves the estimation of surface heat fluxes and the quality of model forecast at short time scales;

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Future work

- Observability of model parameters should be further studied;
- These preliminary results shoud be validated by independent reanalyses and observations;
- Further studies of the method :
  - 1-way coupling (NEMO ocean model forced by GEM fields);
    - Study the impact on the ocean forecast of the changes to the representation of surface fluxes
  - future fully coupled system (GEM-NEMO interaction) which should be previously tuned (mixed layer parametrization, wind stresses, horizontal interpolation of transferred fields, accurate masks, accurate sea-ice model / analyses)
  - Assess the impact on other aspects of the forecasts
    - Revisit cloud parameterization and global radiative balance for instance
    - Altering surface fluxes may upset the global balance that exists in the model
    - May require to include other aspects of the parameterizations in the parameter estimation
    - Current framework may be easily extended to add other parameters