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ERA-CLIM2 WP2 introduction

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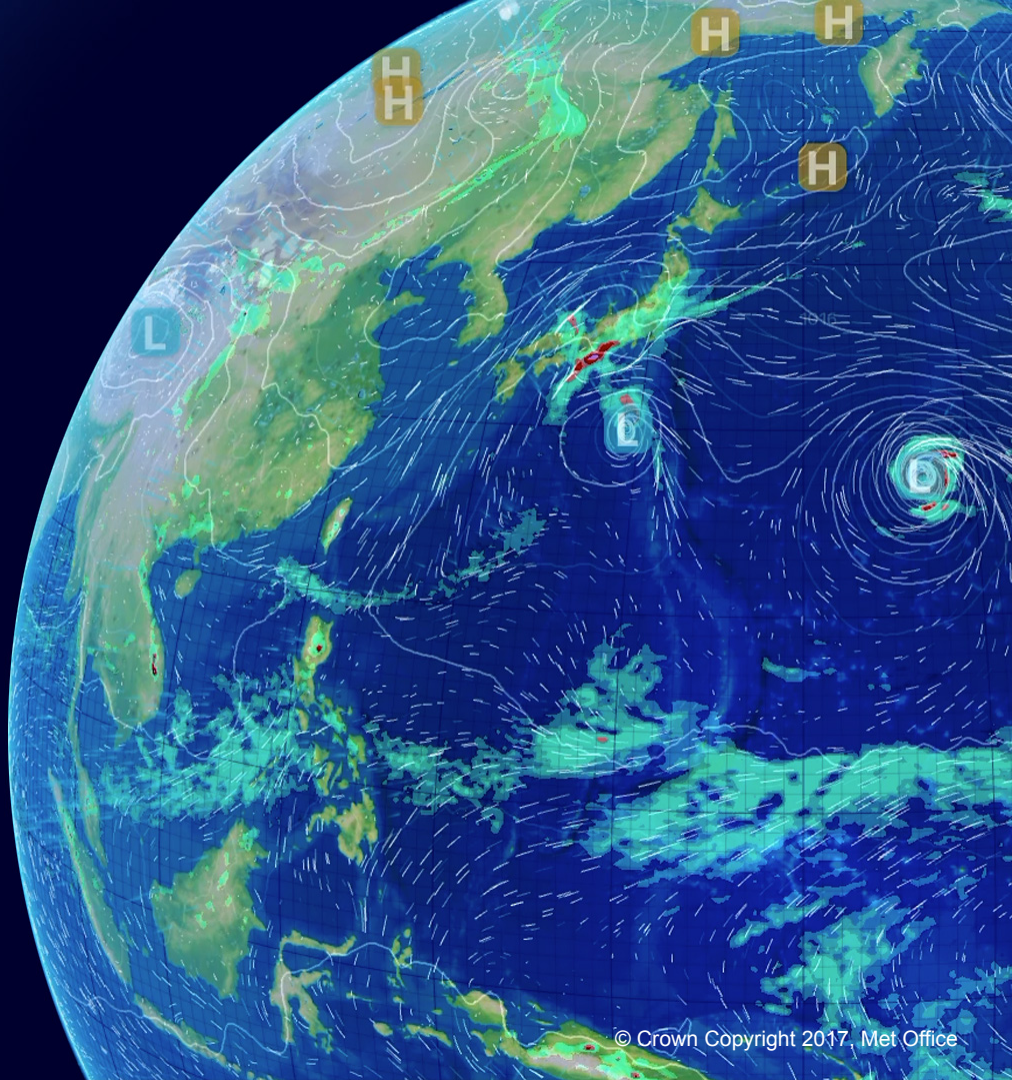


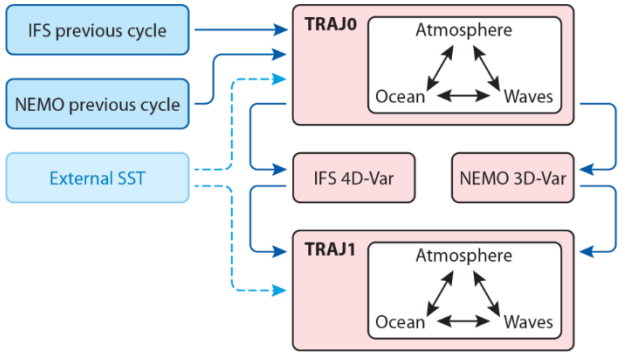
WP2 objectives
Future coupling methods

Research and development in coupled data assimilation for climate reanalysis, and work on development of the carbon component.

Developments will be available for implementation in the CERA (Coupled ECMWF Reanalysis) framework developed at ECMWF.

The work package addressed special requirements for the pre-satellite data-sparse era and the requirement to maintain a consistent climate signal throughout the entire reanalysis period.

- T2.1: Coordination and management
- T2.2: To include SST and sea-ice assimilation in NEMOVAR
- T2.3: To improve the ocean analysis component including use of ensembles and 4D-VAR
- T2.4: Development of the carbon component of coupled earth system reanalysis
- T2.5: Towards development of fully coupled data assimilation



T2.2 SST and sea-ice assimilation

- SST bias correction scheme:
  - Developed a new scheme based on a variational bias correction, where some un-biased reference data types are used to provide “observations-of-bias”.
  - In idealised experiments, new scheme shown to be more robust to changes in the observing system than other schemes.
  - Implemented in NEMOVAR and tested in 3-year reanalysis.

- EOF-based data assimilation:
  - Scheme to improve the assimilation of sparse historical observations by using global-scale covariances from EOFs implemented in NEMOVAR.
  - Tests in monthly objective analysis system showed improvements compared to standard assimilation. Tests in cycling ocean reanalysis system showing some promising signs.

- Sea-ice assimilation
  - Improvements to assimilation of sea-ice concentration and using SIC to change the sea-ice thickness.
  - Tested scheme to transform the sea-ice to a Gaussian variable using anamorphosis.

T2.3 improve the ocean analysis component including use of ensembles and 4D-VAR

- Developments to enable NEMOVAR to make use of ensemble information in a hybrid ensemble-variational scheme:
  - Code re-written to implement hybrid DA options: one in which the parameters of the error covariance model estimated from the ensemble; one in which the ensemble is used directly but with localisation. Code made available and tested at ECMWF.
  - Efficiency improvements made to the diffusion operator which is important for various aspects of modelling the background error covariances.

- 4D-Var tested in the CERA framework:
  - Tests in CERA-20C didn't show much impact whereas in CERA-SAT there was some improvement from 4D-Var vs 3DVar-FGAT (due to higher resolution and assimilation of SSH).
  - Simplified tangent-linear and adjoint model (resolution and in the equations) provides some benefits for lower cost.

- Ensemble error covariances and linear balance relationships in coupled DA:
  - Linearised versions of the bulk formulae developed and tested compared to ensemble estimates.
  - Scheme demonstrates ability of strongly coupled DA to directly transfer information from ocean to atmosphere and vice-versa.

T2.4 Development of the carbon component of coupled earth system reanalysis

- Various options for how to produce an ocean biogeochemistry reanalysis:
  - Best option was to use the atmospheric forcing from a previous reanalysis (CERA-20C), and run the coupled physical-biogeochemical ocean model separately.
  - Avoids issues related to the spin-up of different streams in CERA-20C and also issues related to the vertical motions induced by the physical ocean DA.
  - Assessment of this long experiment shows good quality reanalysis for the main biogeochemical variables and the carbon flux.

- Land carbon DA used to improve the parameter settings in the model:
  - Various data-sets used to tune the parameters for different aspects of the model in a sequential method.
  - Final settings shown to improve the overall representation of the land carbon system.

T2.5 Towards development of fully coupled data assimilation

- Methods for estimating coupled error covariances tested:
  - Innovation-based method useful for getting information related to the true errors but results restricted mainly to moorings which measure ocean/atmosphere near-surface variables.
  - Ensemble-based method provides information everywhere and has been used to provide insight into the relationships between ocean and atmosphere near-surface variability.
- Bias correction in coupled DA system tested:
  - Ocean DA in CERA-20C didn't have bias correction.
  - Using an on-line bias correction (which accounts for biases in T/S and pressure at the equator) seemed to provide most of the benefit (vs including an off-line component).
  - The impact of the ocean bias correction also propagated to atmospheric variables – further work needed to assess whether these changes were improving the atmospheric state.
- Strongly coupled DA methods in idealised single-column model (in OOPS):
  - A collection of 4DVar cost functions were proposed, penalising the flux consistency and/or controlling the interface conditions. Convergence of minimisation of the algorithms (including CERA) studied.
  - Flux consistency can be improved, moderately at a small additional cost or significantly at a huge additional cost. Global (outer) convergence can also be improved compared to CERA, so more benefit can be expected from the first outer iterations

WP2 status of deliverables

Deliverable number	Deliverable title	Delivery date	Type
D2.1	Assimilation of sea-surface temperature observations [METO]	27 => 39	Code + documented results
D2.2	Assimilation of sea-ice observations [MERCO]	27 => 39	Code + documented results
D2.3	Ensemble-based covariance estimates [CERFACS]	34 => 46	Code + documented results
D2.4	Ensemble-based covariances in coupled data assimilation [CMCC]	24 => 36	Report
D2.5	4D-Var in NEMOVAR [INRIA]	27 => 39	Report
D2.6	Optimised model parameters for the carbon cycle [UVSQ]	34 => 46	Report
D2.7	Alternatives for coupling ocean biogeochemistry [MERCO]	34 => 46	Report
D2.8	Weakly coupled assimilation methods [UREAD]	18	Report
D2.9	Covariances from weakly coupled data assimilation [METO]	18	Report
D2.10	Coupled-model drift [UREAD]	34 => 46	Report
D2.11	Fully coupled data assimilation [INRIA]	34 => 46	Report
D2.12	Status report WP2 [METO]	8	Report

- All deliverables completed, reviewed and submitted.

Code developments:

- All relevant code developments have been made available in the NEMOVAR code repository hosted at ECMWF.
- A new version of the NEMOVAR code (v5), containing all the ocean DA developments made in ERA-CLIM2 is about to be released.

Papers:

- 13 papers related to WP2 have been published, submitted or in preparation.

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ERA CLIM 2

Thankyou for listening

WP2 papers

1. Feng, X., et al., 2017 Coupling of surface air and sea surface temperatures in the CERA-20C reanalysis, Quart. J. Roy. Met. Soc.
2. Feng, X., and K. Haines, 2017 Atmospheric response and feedback to sea surface temperatures in coupled and uncoupled ECMWF reanalyses, In preparation.
3. Lea, D. J., et al., 2015: Assessing a New Coupled Data Assimilation System Based on the Met Office Coupled Atmosphere-Land-Ocean-Sea Ice Model. Monthly Weather Review, 143, 4678-4694, doi: 10.1175/MWR-D-15-0174.1.
4. Mulholland, D. P., P. Laloyaux, K. Haines and M.-A. Balmaseda. Origin and impact of initialisation shocks in coupled atmosphere-ocean forecasts. Mon. Wea. Review.
5. Mulholland, D. P., Haines, K. and Balmaseda, M. A. (2016), Improving seasonal forecasting through tropical ocean bias corrections. Q.J.R. Meteorol. Soc., 142: 2797-2807.
6. Pellerej, R., et al, 2016. Toward variational data assimilation for coupled models: first experiments on a diffusion problem.. CARI 2016, Oct 2016, Tunis, Tunisia. 2016
7. Peylin, P., et al.: A new stepwise carbon cycle data assimilation system using multiple data streams to constrain the simulated land surface carbon cycle, Geosci. Model Dev., 9, 3321-3346.
8. Storto, A., et al. Strongly coupled data assimilation experiments with linearized ocean-atmosphere balance relationships, submitted to MWR.
9. Storto, A., et al., 2017. Constraining the global ocean heat content through assimilation of CERES-derived TOA energy imbalance estimates. Geophysical Research Letters, 44.
10. Storto, A., et al., 2016, Sensitivity of global ocean heat content from reanalyses to the atmospheric reanalysis forcing: A comparative study, Geophys. Res. Lett., 43, 5261–5270.
11. Weaver AT, et al., 2016. Correlation operators based on an implicitly formulated diffusion equation solved with the Chebyshev iteration. Q. J. Roy. Meteorol. Soc., 142: 455-471.
12. Weaver A. T., et al. 2017. "Time"-parallel diffusion-based correlation operators. Technical Memorandum 808, ECMWF, Reading, UK.
13. While, J., M.J. Martin, 2017. Variational bias correction of satellite sea surface temperature data incorporating direct observations of the bias. In preparation.