SST analysis for coupled atmosphere-ocean-ice data assimilation in the Canadian global prediction system.

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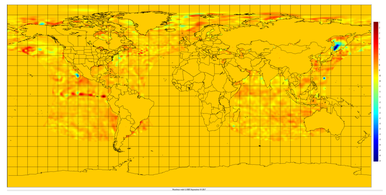
Abstract

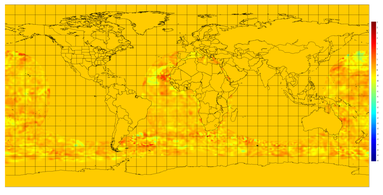
A first prototype of a weakly coupled atmosphere-ocean data assimilation system was recently tested at Environment and Climatic Change Canada. The current system is built on four independent atmospheric, ocean, SST and sea-ice data assimilation components, where only the atmospheric and ocean data assimilations are weakly coupled, i.e. sharing common model background states from the coupled atmosphere-ocean model to compute two independent analyses. One of the key elements of this system is the current uncoupled daily SST analysis computed using the optimal interpolation (OI) method. This system estimates an SST that represents the "foundation" temperature, which is not affected by the diurnal cycle. Our goal in progressing towards strongly coupled data assimilation systems is to use the same data assimilation software as the atmospheric system to compute the SST analysis every 6h (instead of daily), i.e. the same frequency as the atmospheric analysis. To be more suitable for the assimilation of surface-sensitive atmospheric radiance observations, the new SST analysis should include a surface skin temperature that resolves the diurnal cycle in addition to the "foundation" temperature.

Methodology. Towards stronger coupling

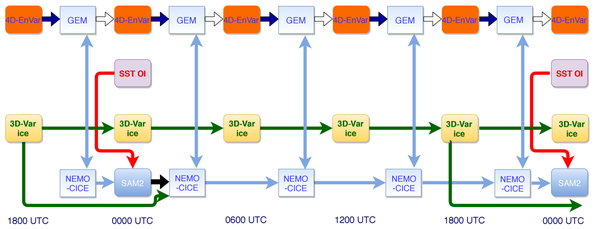
Implement SST analysis using the atmospheric 4D-EnVar DA system in the 3DVar mode:

- Background error covariance matrix is estimated using the diffusion operator;
- Foundation SST;
- Using observations and quality control from the current operational OI data assimilation system;
- Two separate 3D-Var analyses on the Yin-Yang grids to compute correctly the diffusion operator on the poles

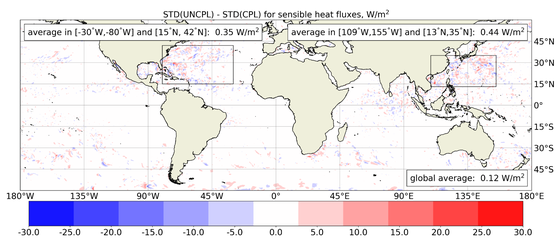




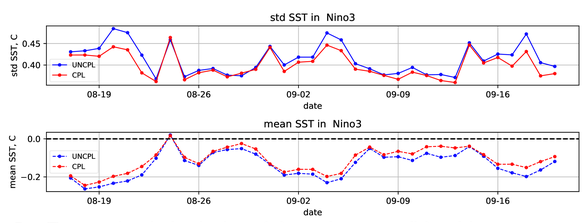
Weakly Coupled Data Assimilation system



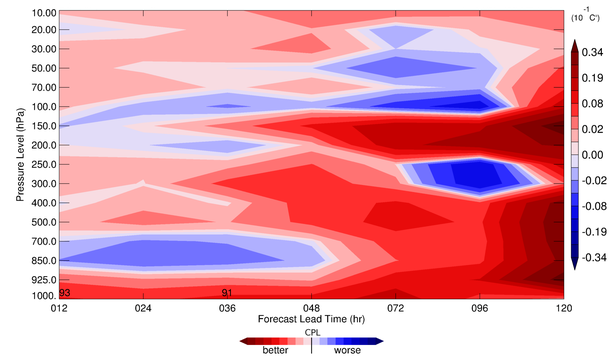
Weakly coupled data assimilation (DA) system scheme. The atmospheric 4D-EnVar DA component computes analyses every 6 h. The SST OI DA component computes daily analyses valid at 00:00 UTC, which are assimilated using the daily SAM2 ocean DA component at 00:00 UTC. The3D-Var sea ice analyses are computed every 6 h. The 3D-Var sea ice analysis computed at 18:00 UTC provides the initial condition for the computation of fully coupled atmosphere–ocean background states at 00:00, 06:00, 12:00 and 18:00 UTC. The separate atmospheric and ocean analyses are propagated in space and time using the fully coupled GEM–NEMO–CICE model



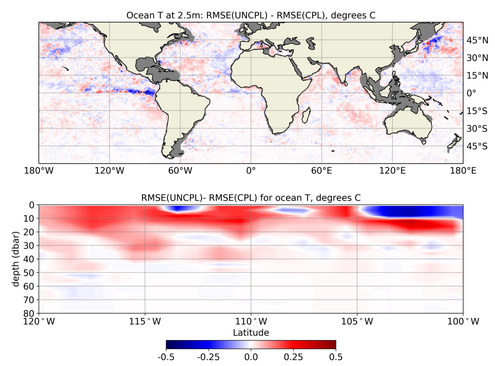
Difference (W/m^2) between the standard deviation of uncoupled and weakly coupled data assimilation systems for the turbulent surface sensible heat flux computed using 12 h coupled forecasts during September 2017.



OmF standard deviation (a) and mean (b) with respect to the gridded foundation SST field from the ocean SAM2 DA component for the Niño3 region situated within the latitude–longitude box defined by [150, 90 °W] and [5 °S, 5 °N]. The statistics are computed using 24 h forecasts.

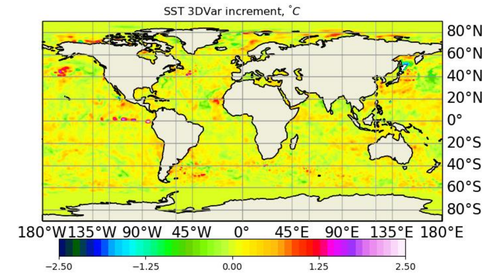


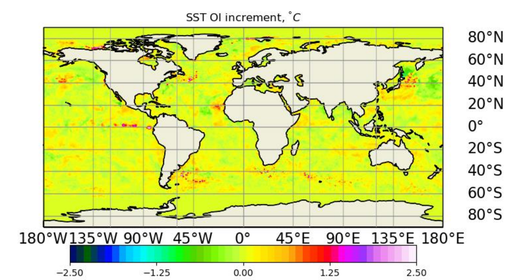
Difference in the standard deviation of the air temperature (°C) against the mean analysis as a function of the forecast lead time. The statistics are computed for weakly coupled data assimilation and the uncoupled data assimilation in the northern extratropics region between 20 °N and 60 °N. Positive values (red) mean that the standard deviation produced by the weakly coupled data assimilation system is smaller, whereas the negative values (blue) mean the converse. Numbers show the area where the difference between the weakly coupled DA and uncoupled DA is statistically significant with confidence level above 90%.

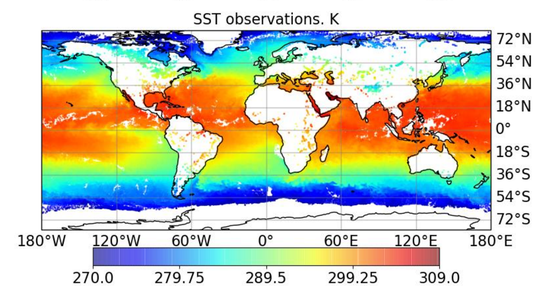


Difference between the uncoupled DA and weakly coupled DA (24 h forecasts) RMSE (°C) with respect to the Argo ocean temperature measurements in September 2017. Positive values (red) indicate that the RMSE produced by weakly coupled DA is smaller, whereas negative values (blue) mean the converse. (a) The RMSE difference for ocean temperature at 2.5m of depth. The grey areas show the regions where Argo measurements were not taken. (b) The temperature vertical section through 1.5 °N latitude in the eastern tropical Pacific Ocean between 120 and 100 °W.

Results







Conclusion

- 3D-Var foundation SST analyses are implemented using atmospheric data assimilation system;
- Background error covariance matrix is estimated using the diffusion operator;
- 3D-Var SST increments are similar to the current operational SST OI analysis increments;
- Proper validation of the 3D-Var SST analyses with respect to the current operational system is needed

References

Skachko, S., Buehner, M., Laroche, S., Lapalme, E., Smith, G., Roy, F., Surcel-Colan, D., Bélanger, J.-M., and Garand, L.: Weakly coupled atmosphere–ocean data assimilation in the Canadian global prediction system (v1), Geosci. Model Dev., 12, 5097–5112, https://doi.org/10.5194/gmd-12-5097-2019, 2019.