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Wetter und Klima aus einer Hand
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Zentrum für Geoinformationswesen der Bundeswehr

Evaluation of preliminary results using the ICON-based Earth System Model of DWD

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The project "Earth System Modelling at the Weather scale" (ESM-W) by DWD in cooperation with GeoInfoDienst BW aims to develop a global coupled ocean-atmosphere forecasting system based on the ocean model ICON-O and the atmospheric model ICON-NWP including a weakly coupled data assimilation. We initially conducted a full-year cycled experiment (icda0024) incorporating ocean observations. These observations included in-situ vertical profiles from ARGO floats, combined with sea-surface temperature and salinity data derived from satellite products (OSTIA and SMOS). The assimilation cycle was performed three-hourly for the atmosphere and daily for the ocean. Subsequently, we conducted a three-month forecast experiment (icda0024-main). In this poster, we present evaluations of the first guess and forecast results compared against Mercator and Ocean5 analyses.

I. Introduction

Our primary focus is on a global coupled model. The ICON (ICOsahedral Nonhydrostatic) model in its NWP configuration, utilized for numerical weather prediction at Deutscher Wetterdienst (DWD), constitutes the global atmospheric component of this system. It is coupled to the ICON-O[1] ocean model via the YAC coupler, which facilitates the exchange of the conserved quantities.
The current configuration employs a mean resolution of 80 km (R2B5) for the atmospheric model and 40 km (R2B6) for the ocean model. Figure 1 illustrates a typical assimilation cycle. For detailed information on the assimilation setup of the coupled model, refer to the oral presentation by M. Sprengel et al..

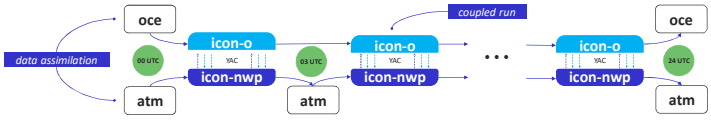

Figure 1: Data assimilation cycle employed for the coupled ocean-atmosphere system.

II. Evaluation of cycled results

The preliminary results of the ICON-based Earth System Model, derived from experiment icda0024, were obtained from a 2022 run. This experiment utilized a weakly coupled analysis system, incorporating a three-hourly atmospheric and daily ocean data assimilation cycle. In this study, we compared the daily outputs of icda0024 from September 2022 with those of Mercator[2] and Ocean5[3] separately.

The comparison of the RMSE (Root Mean Square Error) for SST (Sea Surface Temperature), SSS (Sea Surface Salinity), and SSH (Sea Surface Height) revealed similar distributions between icda0024 versus Mercator and icda0024 versus Ocean5. Specifically, for the RMSE of SST, the similarities may be attributed to the use of common OSTIA data but icda0024 has the lowest resolution (1/12° in Mercator and 1/4° in Ocean5). Discrepancies are observed in SSS in the arctic, likely due to differences in sea ice models and no data assimilation performed at high latitudes in icda0024. The SSH differences are mostly in active regions due to the lower resolution in icda0024.

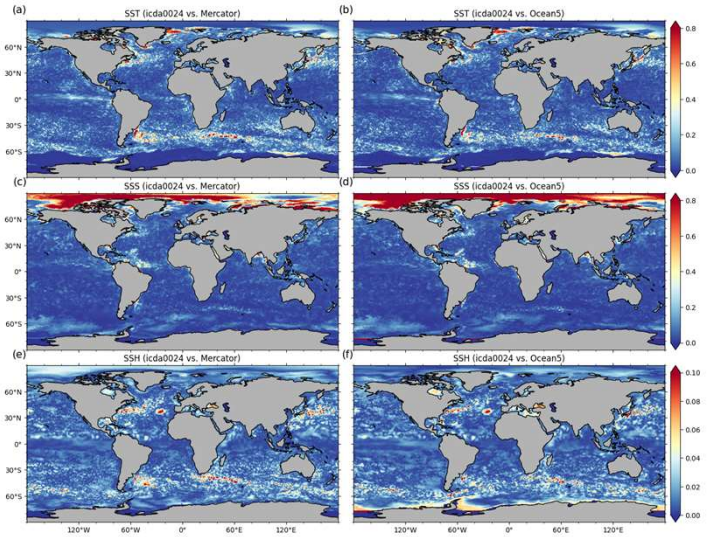

Figure 2: The monthly RMSE of SST (a,b; K), SSS (c,d; psu) and SSH (e,f; m) for icda0024 compared with Mercator and OCEAN5 in September 2022.

III. Hurricane track

In September 14-27 2022, Hurricane Fiona was characterized as a large, powerful, and destructive tropical cyclone. It holds the distinction of being the most costly and intense tropical or post-tropical cyclone to have impacted Canada on record[4] .
In this study, we selected a specific day (2022.09.22) in the mature period of tropical cyclones, during which strong wind occurred in the region, to evaluate the capability of tracking Hurricane Fiona among icda0024, Mercator, and Ocean5. The hurricane core (indicated by a black triangle) and the surface current are depicted in Fig. 3a, 3b, and 3c. The strong currents generated by Hurricane Fiona are distinctly visible in icda0024 and Ocean5, whereas no such strong signals are observed in Mercator. Additionally, the spatially averaged RMSE comparison for the full month of September 2022, reveals substantial variations in SST and SSS (Fig. 3d).

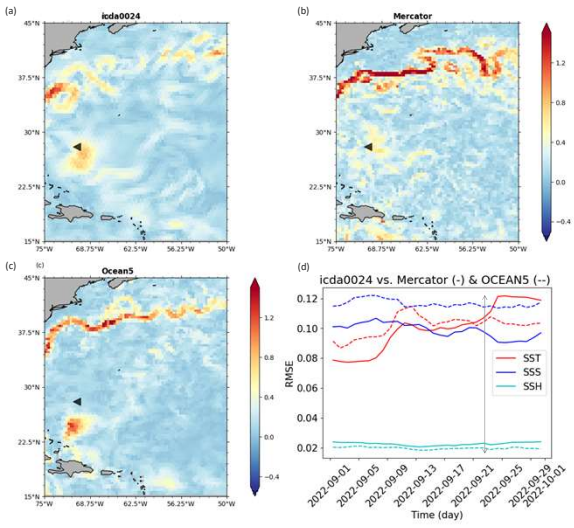

Figure 3: The surface current (m/s) of icda0024 (a), Mercator (b) and Ocean5 (c) on 2022-09-22. The location of the Hurricane core is indicated by a black triangle. The spatial RMSE for icda0024 vs. Mercator (solid line) and vs. Ocean5 (dash line) of SST (K), SSS (psu) and SSH (m) within the region are depicted in panel (d). The vertical double arrow line indicates the date of 2022-09-22.

IV. Evaluation of forecast results

The RMSE of the forecast against Mercator and Ocean5 analyses in September 2022 are shown in *Figure 4*. As expected, the error increases with lead-time. The RMSE against Ocean5 *(bottom)* is larger than the RMSE against Mercator *(top)* and decreases during the experiment period as the hurricane is captured better when more data is available for the assimilation.

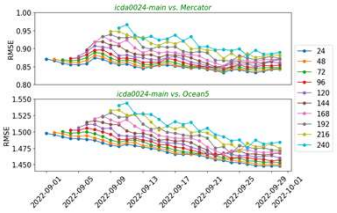

Figure 4: The RMSE of forecast SST for icda0024-main forecast against Mercator (top) and OCEAN5 (bottom) in September 2022. Units are in Kelvin.

Conclusion

- The weakly-coupled ICON-based earth system model shows good preliminary results compared with the Mercator and Ocean5 data reanalysis;
- The system could simulate the extreme Hurricane event;
- The forecast experiment against Mercator and Ocean5 demonstrates a reduction in RMSE over the time of the experiment, alongside an increase in error over lead times extending up to 10 days.

1) P. Korn *et al* (2022), Journal of Advances in Modeling Earth Systems, 14, e2021MS002952, https://doi.org/10.1029/2021MS002952
2) Mercator, Global Ocean Physics Analysis and Forecast, Global Ocean Physics Analysis and Forecast | Copernicus Marine Service
3) ORAS5, Climate Data Store. https://doi.org/10.24381/cds.67e8eeb7
4) R. Pasch *et al*, Hurricane Fiona (AL072022), (2023), https://www.nhc.noaa.gov/data/tcr/AL072022_Fiona.pdf

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