Zentrum für Geoinformationswesen der Bundeswehr

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Earth System Modelling at DWD: A Case Study of Hurricane Fiona

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The Earth System Modelling at the Weather scale (ESM-W) project, a collaboration between the German Meteorological Service (DWD) and GeoInfoDienst BW, aims to develop a coupled ocean-atmosphere forecasting system. This system integrates the ICON-O ocean model and the ICON-NWP atmospheric model for NWP time scales, aligning with the ICON-Seamless development goal of a time-scale independent, integrated modelling framework for both weather and climate applications.

Extreme weather events like Hurricanes can cause massive damage and endanger lives. E.g. the hurricane Fiona caused a damage of approximated 3.1B USD and 29 deaths in the Caribbean, the USA and Canada. Being able to warn of these dangers earlier promises to reduce such numbers in future cases. We present a case study of Hurricane Fiona from September 2022, incorporating weakly coupled data assimilation. We focus on comparing the modelled storm track with different observations and analysing additional physical quantities to assess the model's performance and the role of the coupled ocean. Additionally, we explore the influence of different technical configurations of the model on the hurricane's behaviour.

Model setup

We performed two coupled ICON simulations, a "high-res" (upper line in table) and a "low-res" (lower line) one. The low-res simulation started from a 1420 year climate simulation and was spun-up for 8 months using ARGO and OSTIA data. The high-res simulation started from an interpolated state in July 2022 which then was assimilated for 2 months.

Resolution atm/oce	Δt atm [min]	Δt oce [min]	Δt coup [min]
13/20 [km]	2	7.5	30
80/40 [km]	7.5	30	30

Atmospheric forecast

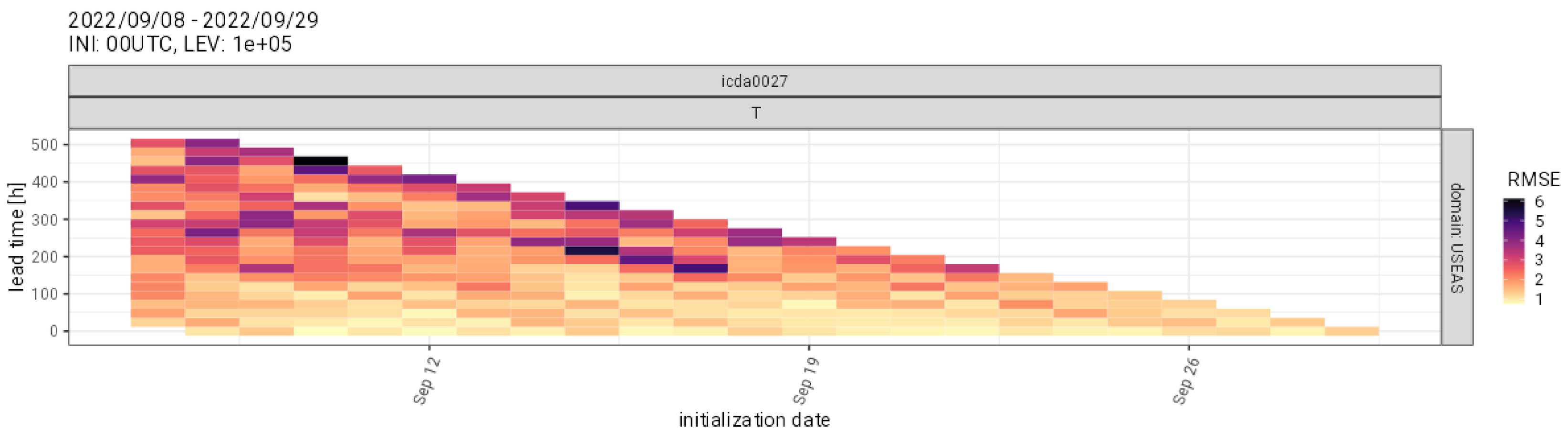

Figure 1: Verification of temperature against surface buoys for different lead times for the global domain (top) and the region affected by Hurricane Fiona (bottom). While the forecasting skill on a global scale shows a typical behaviour the regional part is heavily affected by the hurricane as can be seen by the outliers.

As can be seen in Fig. 1, the forecasting error decreases with shorter lead-time (comparison against surface buoys). On the regional scale the RMSE gets much worse for Sep 25th onwards. This can be explained by the appearance of Hurricane Ian, which evolved on Sep 23rd and hit Cuba on 27th.

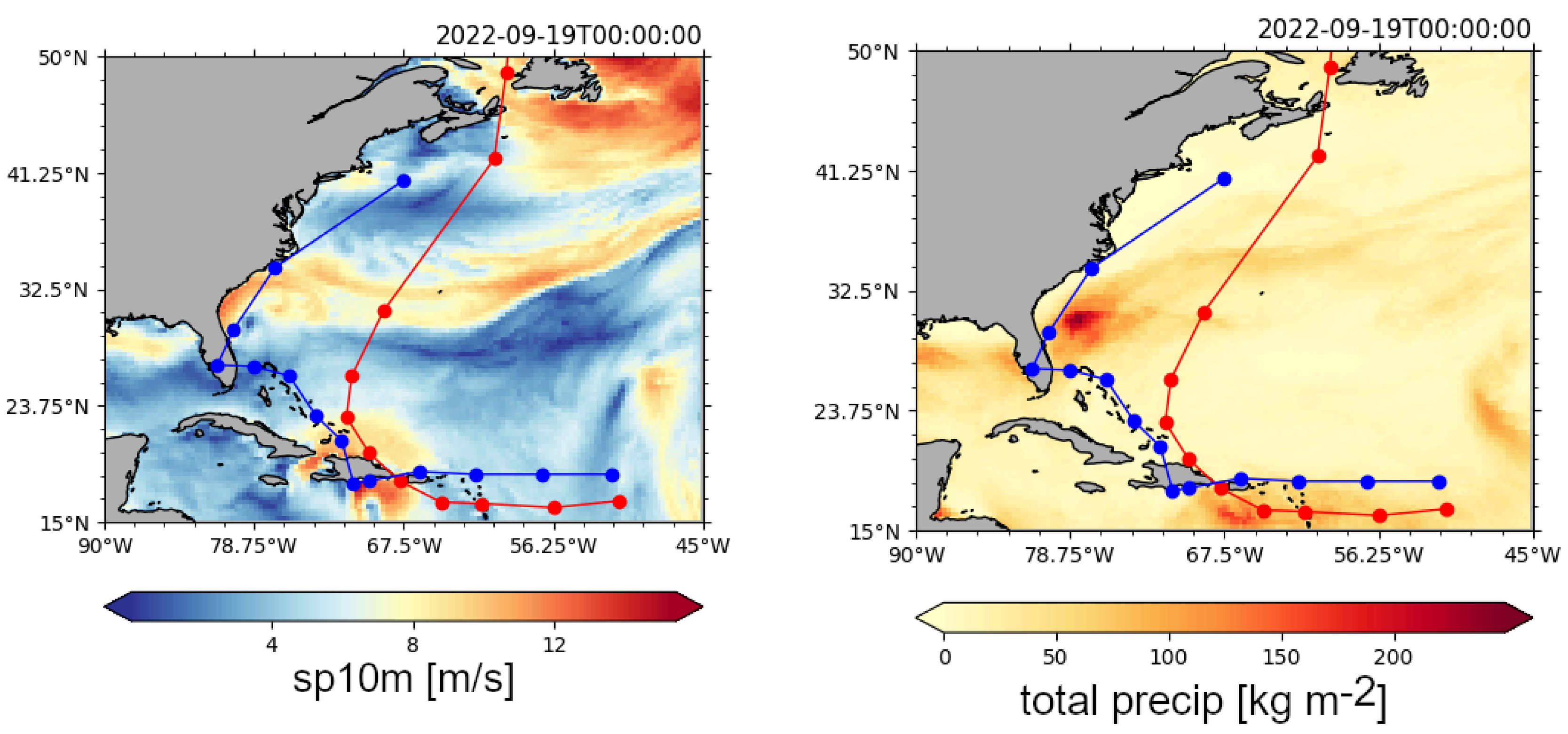

Figure 2: 10 Meter Wind speed (left) and precipitation (right) for Sep 19th. The forecast started on Sep 14th 00 UTC + 5 days lead time. While the hurricane's track (red = real track from NOAA [1], blue = calculated from max of 10m wind speed, dots indicate days starting from Sep 14th) is well predicted for the first 6 days the wind speed only amounts to approximately 40% of the real wind speed (~15 m/s vs 38.5 m/s).

A comparison between the real track (red) and the simulated track (blue, calculated from a forecast starting at Sep 14th 00 UTC) shows, that the hurricane sticks too close to land and stays there for too long. The cause for this behaviour is yet to be determined. Also, the wind speed is lower than in reality, which might be caused by the hurricane losing strength near land. Thus, the track was well simulated for the first 7 days until Fiona moved back to open waters. Additional results hold for the precipitation rate. The location of the maximum in the simulation fits reality well, but the maximum is much smaller (180 kg/m² vs 508 kg/m²).

Oceanic forecast

Here, we present and compare the performance of two forecasts at the sea surface with observational data. During the period from Sep. 18-27 2022, there is a clear reduction of SST in the region and high surface velocity.

In Fig. 3, the high-resolution forecast is seen to accurately capture Hurricane Fiona's impact on SST and surface velocity, showing detailed changes and strong velocity patches. The low-resolution forecast (not shown) fails to simulate these features.

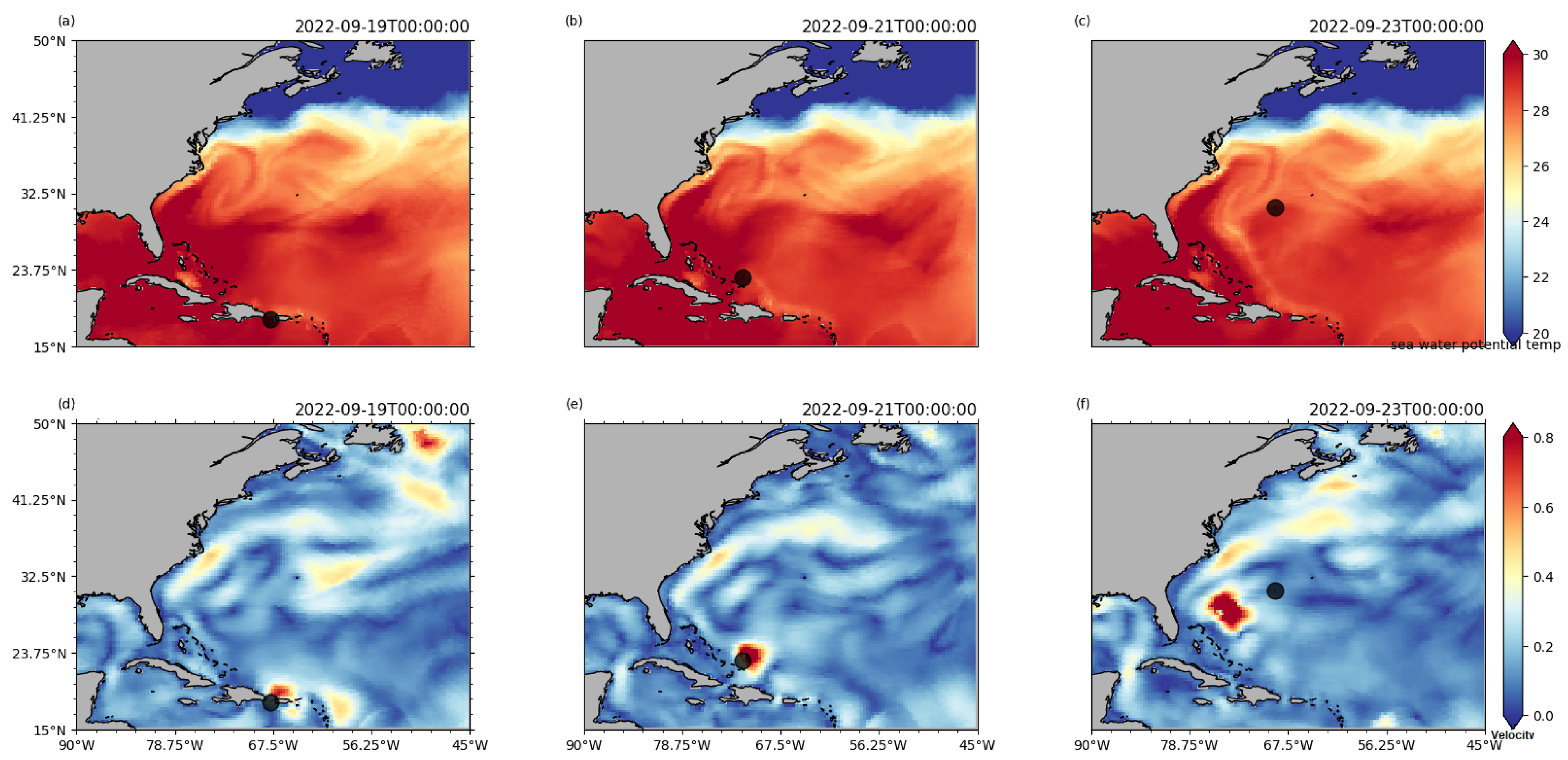

Figure 3: The evolution of SST (top) and surface velocity (below) during the hurricane Fiona on September 19th, 21st and 23rd 2022, separately. The black cycles denote the track of Hurricane Fiona , as documented by NOAA [1].

Focusing on the hurricane-affected region, we compare the mean SST from different resolutions with observations from the Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA, Fig. 4). Both experiments yield lower forecast values compared to observations; however, the mean SST from the experiment with high resolution more closely matches the observed data.

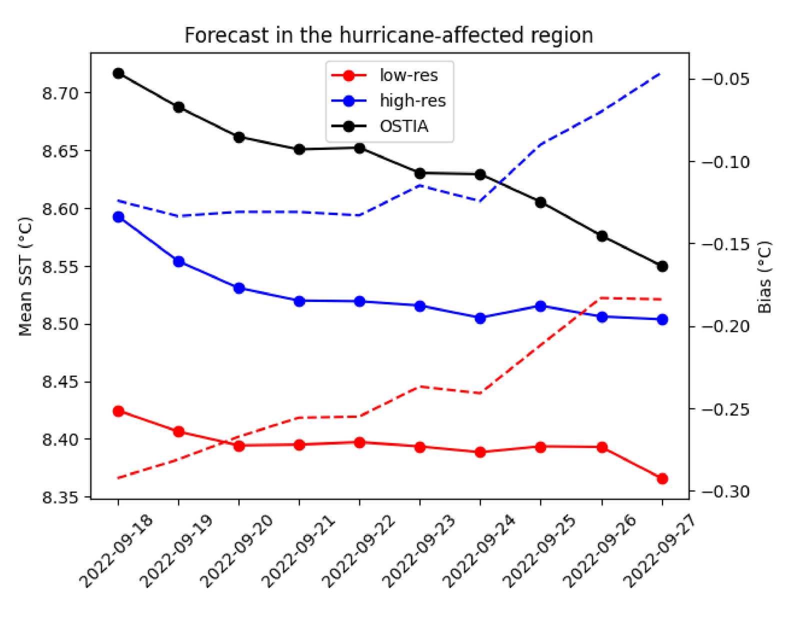

Figure 4: Comparison of the mean (solid lines) and bias (dash lines) of SST between two 10-day forecasts and OSTIA observations in the region affected by the Hurricane Fiona.

Conclusions

- The hurricane track can be calculated on a scale for 5-7 days both for atmosphere and ocean;
- High resolution enhances the ability to capture extreme events such as hurricanes, resulting in simulations that closely align with real-world observations;
- Our hurricane sticks too much to land, the maxima of variables are too weak.

Outlook

- Analyse and improve hurricane's behaviour at landfall
- Investigate the process of ocean mixing and upwelling in the hurricane

1) National hurricane center tropical cyclone report, Hurricane Fiona (AL072022), https:www.nhc.noaa.gov/data/tcr/AL072022_Fiona.pdf

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