NU-WRF-LIS Coupled Simulation Experiments of Tropical Storm Kelvin (2018) and the Brown Ocean Effect

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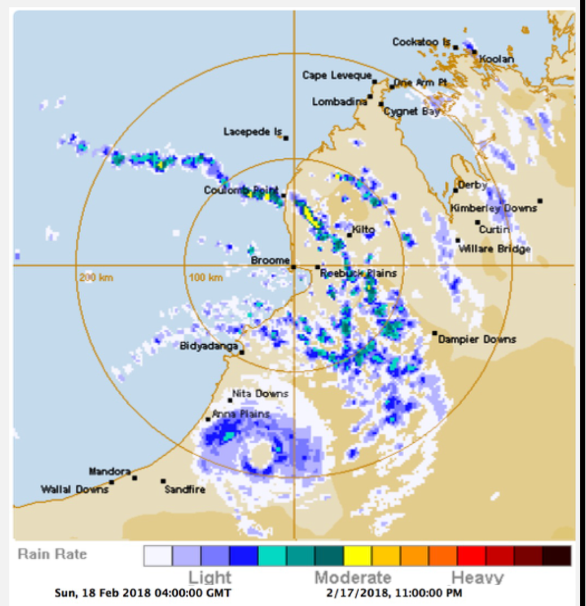
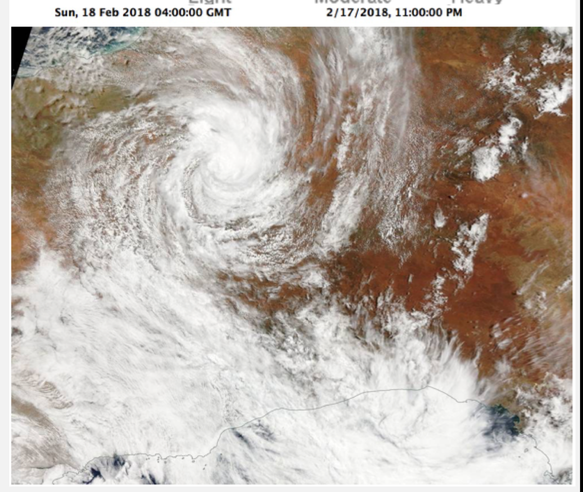
Probing for the Brown Ocean Effect

Tropical cyclones (TCs) develop over ocean and landfalling TCs undergo weakening process over land due to various reason such as loss of sufficient moisture flux, increased friction, and increased baroclinicity in general. However, there have been TCs that were able to maintain their strength or even to intensify inland away from the coast. **Previous studies suggested that these TCs were fueled by moisture and energy fluxes from the ground, which is known as the 'brown ocean' effect** (Anderson and Shepherd 2014).

Recently, Tropical Storm Kelvin (2018) made its landfall in the evening on Feb 17, 2018 over northwest of Australia. At about its landfall, its strength was increased from Category 1 to Category 2 and it survived until Feb 19, 2018 when it became a Tropical Low. **A set of numerical simulations of Tropical Cyclone Kelvin has been conducted using the NASA Unified Weather Research and Forecasting (NU-WRF) coupled with the NASA Land Information System (LIS)** to understand the contributions of the soil moisture and surface fluxes quantitatively during the intensification period of the storm over the land.





NU-WRF Simulations & LIS Spinup

- The NASA Land Information System (LIS; Kumar et al. 2008) is coupled to the NASA Unified WRF (NU-WRF;Peters-Lidard et al. 2014) model so that the WRF model can benefit from the enhanced land surface conditions that the LIS provides, including extended offline land surface model spinups over a five-year period using both the GDAS and MERRA2 datasets as its meteorological forcing.
- NU-WRF-LIS Coupled Model Experiment Suite:
  - WRF(GDAS)-LIS(GDAS)
  - WRF(GDAS)-w/oLIS
  - WRF(MERRA2)-LIS(MERRA2)
  - WRF(MERRA2)-LIS(GDAS)
  - WRF(ERA-I)-w/oLIS
- Noah Land Surface Model version 3.6
- 1 km high resolution simulation over a 1200 km by 1200 km domain over northwestern Australia with the integration time step of 6 sec.

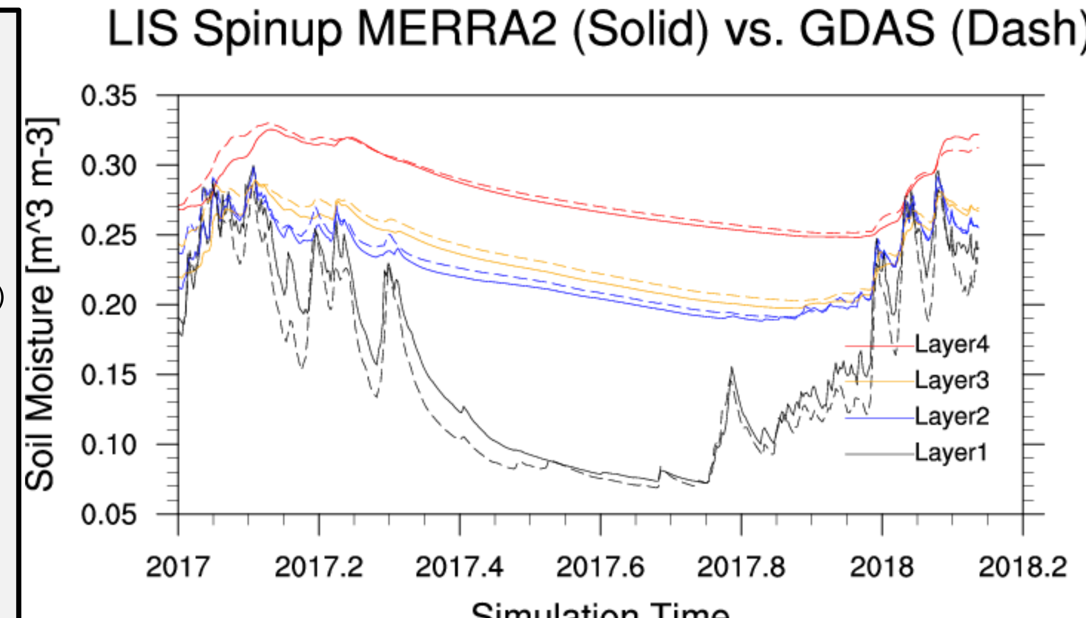
Physics Options
NU-WRF vs. WRF Tropical

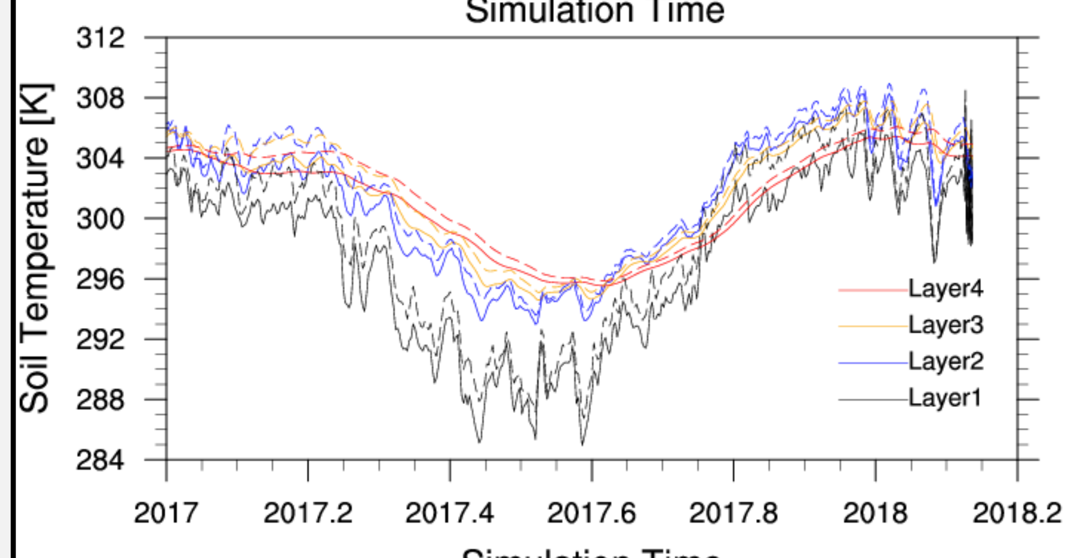
mp: Goddar 4ICE (56) vs. WSM6 (6)
cu: 0 vs. 0
ra_lw: Goddard 2017 (57) vs. RRTMG (4)
ra_sw: Goddard 2017(57) vs. RRTMG (4)
bl_pbl: MYNN2 (5) vs. YSU (1)
sf_sfclay: MYNN2 (5) vs. MM5 Simil. (91)
sf_surface: LIS Noah3.6 (55) vs. Noah (2)

SST updated using the sea surface temperature (SST) analyses (Infra-Red) produced by Remote Sensing Systems (http://www.remss.com) for the entire experiments.

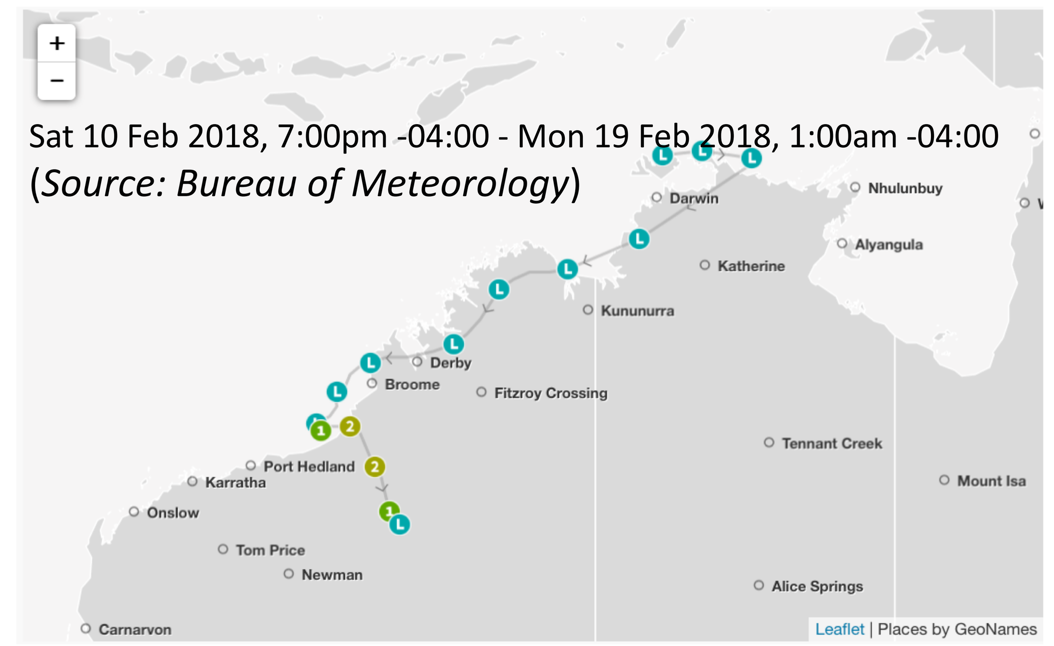
Note: WRF-LIS coupled simulations used NU-WRF physics options while WRF without LIS simulations used WRF physics options which is the 'tropical' physics suite in the WRF v.3.9.

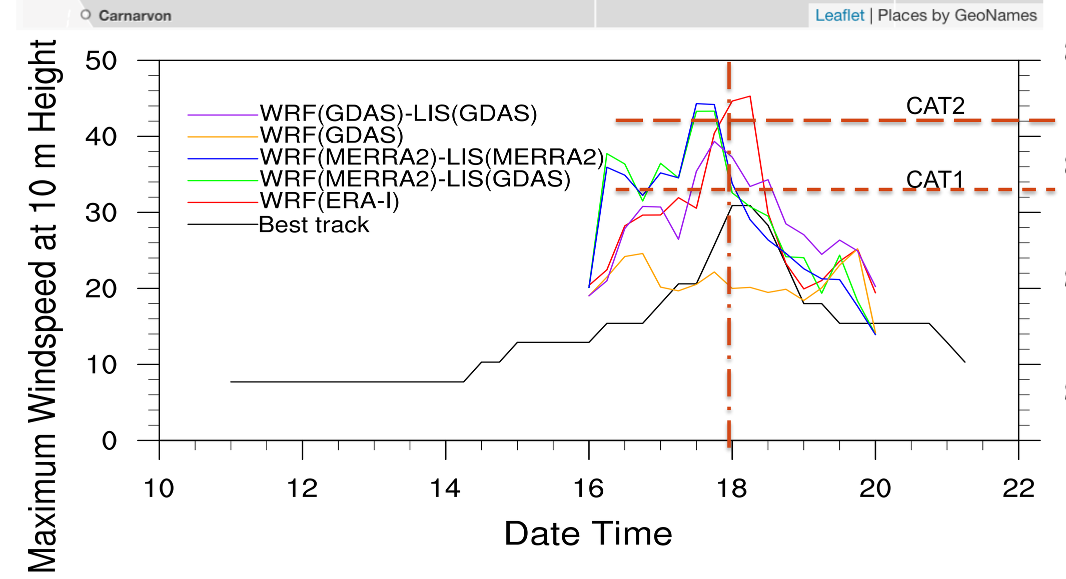
LIS Spinup MERRA2 (Solid) vs. GDAS (Dash)



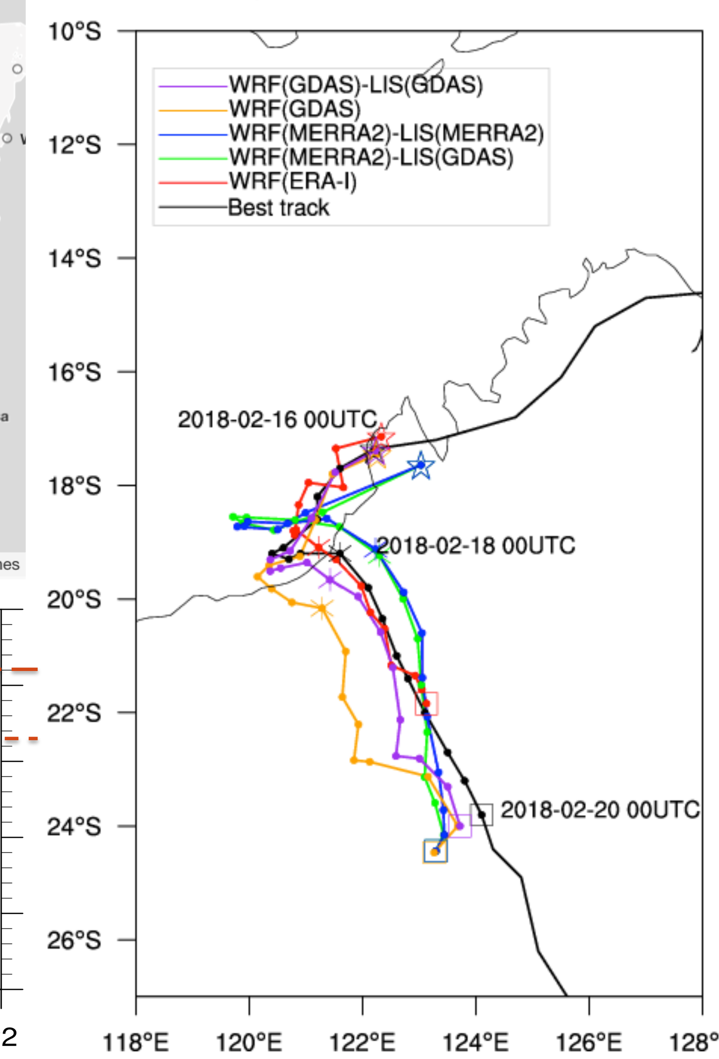


Results

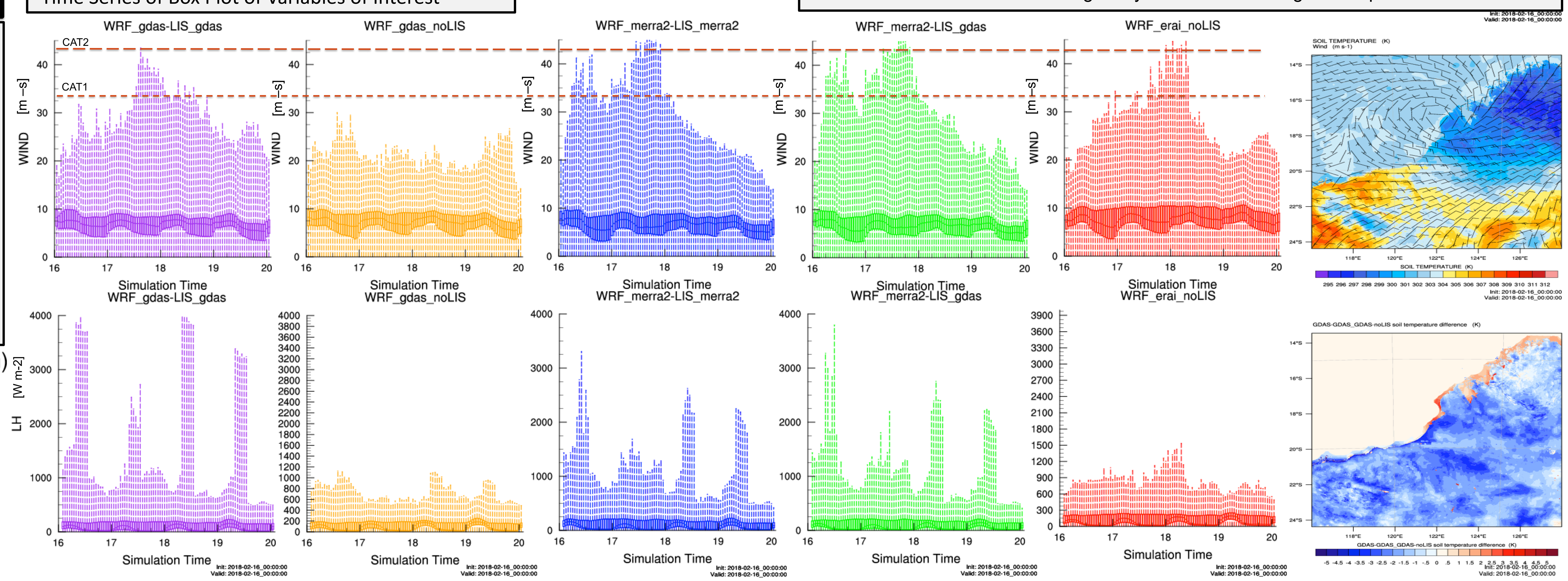


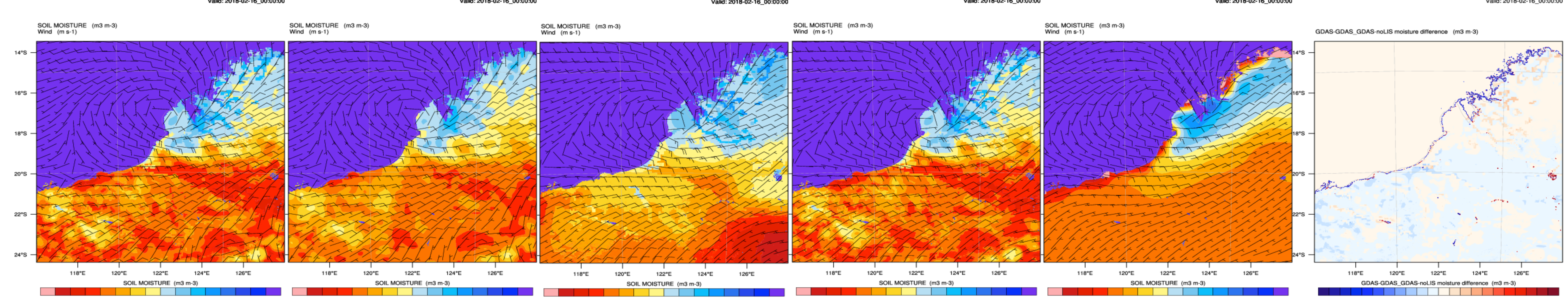


Cyclone Kelvin (2018)



Time Series of Box Plot of Variables of Interest





Summary

- The WRF-LIS coupled simulations with NU-WRF physics, including the LIS spinup, reproduced more realistic life cycles of the storm both in track and intensity changes than the WRF simulations using the 'tropical' physics suite (WRF v.3.9) without the LIS spinup. The WRF(GDAS)-LIS(GDAS) coupled simulation produced the closest track and intensity trend to the observation amongst the simulation experiments.
- Compared to those of WRF 'Tropical' without the LIS spinup, the WRF-LIS coupled simulations using NU-WRF physics options generated much enhanced Latent Heat (LH) flux during the daytimes, the mean of which is associated with that of the wind speed (diurnal cycle). The explosive LH fluxes during the daytime of Feb. 16 allowed the storm to reorganize over the shore. After its landfall on Feb. 17, successive LH fluxes intensified the storm, making Cat 2 TC over the land on Feb. 18. Without further enhanced LH flux event, Kelvin went into decay rather rapidly.
- The LIS spinup nearly saturated the bottom soil layer by the beginning of February. Mid-February, GDAS-forced LIS produced slightly drier soil moisture in the upper and lower layers, which corresponded with higher soil temperatures throughout the profile versus that of MERRA2. These differences, however, do not seem to impact the WRF(MERRA2) coupled simulations in terms of TC intensity and track.
- Top layer soil moisture condition driven by the LIS using the MERRA2 are wetter (drier) than that by using the GDAS over the coastal region (inland region) creating higher contrast in soil moisture between the two regions than the GDAS. Spatial distribution of top soil moisture (temperature) within the "off-the-shelf" GDAS dataset are comparable with (warmer than) that spun up by the GDAS-forced LIS for five years while lacking details. The initial soil moisture distribution within the ERA-I displays the wettest soil condition over the northern coastal region with potentially 'artifacts' along the coast and somewhat homogeneity over the inland region compared to the others.

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