Strongly Coupled Assimilation of a Hypothetical Ocean Current Observing Network within a Regional Ocean-Atmosphere Coupled Model: Horizon2020 An OSSE Case Study of Typhoon Hato

Phillipson, L., Li, Y., and Toumi, R. (2021). Strongly Coupled Assimilation of a Hypothetical Ocean Current Observing Network within a Regional Ocean–Atmosphere Coupled Model: An OSSE Case Study of Typhoon Hato. *Monthly Weather Review* 149, 5, 1317-1336

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- Tropical cyclone intensity predictions improving at a rate of about 1/3 to 1/2 compared to track predictions for 24–72 h.
- Why is intensity predictions comparatively harder to improve?





 Hurricane intensity is critically dependent on the initial vortex structure, intensity, and moisture content.



All models are wrong :(



Zн

What else could be used?



A tropical cyclone can exert a huge wind stress on the ocean!

Drives surface currents!

\*poor rubber ducks :(



\*poor rubber ducks :(

What if we could track these rubber ducks?

Maybe we could use these ocean observations to help constrain the atmosphere.

Extra observations!

### Weakly vs Strongly Coupled DA system



Zhang, S., Liu, Z., Zhang, X. *et al.* Coupled data assimilation and parameter estimation in coupled ocean–atmosphere models: a review. *Clim Dyn* **54**, 5127–5144 (2020)

#### Weakly Coupled DA

Rubber duck assimilation would only impact the ocean model initially. O2A fluxes are could in turn impact the atmos but are limited. (SST 2 ATMOS).

#### **Strongly Coupled DA**

Rubber duck assimilation could directly impact the atmos model!

# How can does SCDA work?



**Ensemble DA with a Local Least Squares Framework** 

Anderson, J. L. (2003). A Local Least Squares Framework for Ensemble Filtering. *Monthly Weather Review* 131, 4, 634-642



# How can does SCDA work?





We have adjusted the ocean state using an ensemble DA method! (EAKF)

Represents an assimilation increment i.e. the difference between after and before assimilation.



# How can does SCDA work?





2

Regress this observationspace increment onto model winds (WRF U10)!



Both models have been adjusted!



### How can does SCDA work?





3

Repeat for every single ensemble member, and over any model variable you choose to update!

Say WRF Surface Pressure or ROMS SST

#### Ocean Surface Current Observations (not rubber ducks)

#### **HF** Radar



~150-200 km sampling from shore ~10km horizontal resolution ~ hourly sampling rate

#### Drifters

(a)

(b)



~ **15 min** sampling rate

The average horizontal current in the upper 60 cm



### Coupled Model Ensemble



The Weather Research and Forecasting (WRF) model

Regional Ocean Modelling System (ROMS)



x n ensemble members

Coupled-Ocean-Atmosphere-Wave-Sediment Transport (COAWST) Modelling System



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#### **Geophysical Research Letters**

#### **RESEARCH LETTER**

10.1029/2018GL079677

#### Key Points:

- A strongly coupled data assimilation system is developed for tropical cyclone forecast
- Synthetic coastal surface currents are assimilated

#### Improved Tropical Cyclone Intensity Forecasts by Assimilating Coastal Surface Currents in an Idealized Study

#### Yi Li<sup>1</sup> and Ralf Toumi<sup>1</sup>

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- Promising idealised results!
- TC metrics all improved in 7 idealised cyclones.
- What's the next step? More realistic set-up!



### Coupled Ensemble South China Sea Model

- WRF ARW 6km horizontal resolution, 40 vertical levels. GFS 1/4 degree res boundaries.
- ROMS 4km Horizontal resolution (rotated grid), 20 vertical levels. HYCOM boundaries.
- 34 Ensemble Members



## Case Study: Typhoon Hato

- Rapid motion and intensification (~30 hPa decrease < 24 hours).
- 7 observation system simulation experiments (OSSEs) using a 'truth' simulation of Hato & CNTRL



Surface Currents (m/s)

- 1. HF 2. DRIFT
- 3. HF+DRIFT 4. HF+DRIFT (WC)
- 5. **PMIN**
- 6. PMIN+HF+DRIFT 7. PMIN+HF+DRIFT (WC)

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## How it performs?



 Peak intensity example for the HF + DRIFT Experiment. i.e. no atoms observations!

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### **General Results**



- On average all SC experiments perform better than the CNTRL
- SC Experiments performs better than WC

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•We use a SCDA to showcase how an ocean observing system could hypothetically improve estimates of Typhoon Hato.

 Tropical cyclone metrics are all improved. Track improvements are especially promising.

#### Imperial College London

### Limitations

- It's not a 'fully' strongly coupled system. We can only assimilate surface currents.
- This actually has some advantages -We avoid having to formally define cross-model correlation length-scales. This is arguably the hardest aspect to a SDA system.
- Linear regression cannot correctly capture extreme wind regime correlation (super Typhoon winds >100 knots).