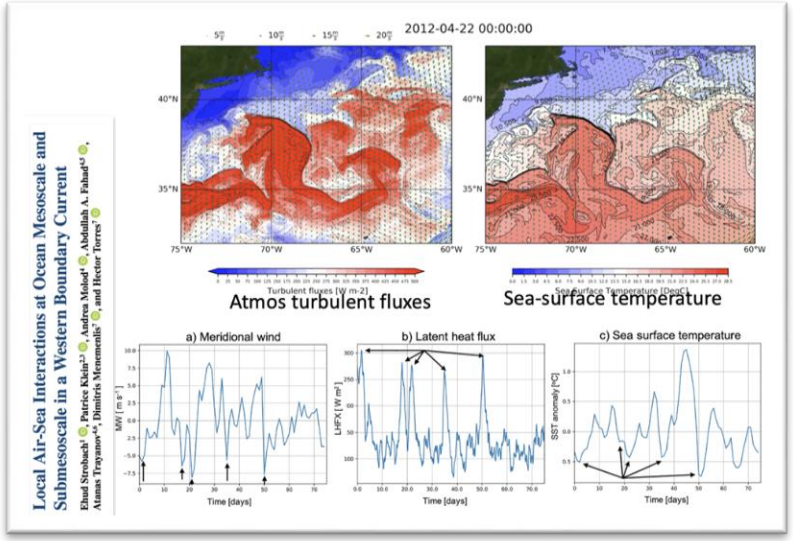
ECCO 2023 - Technical developments

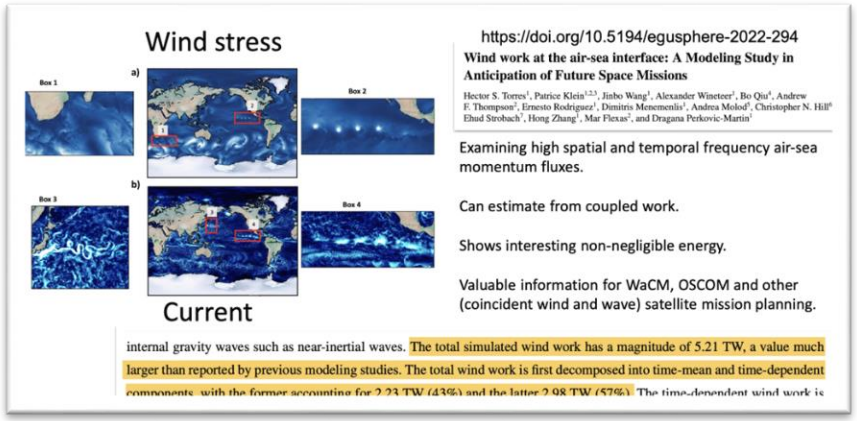
Chris Hill

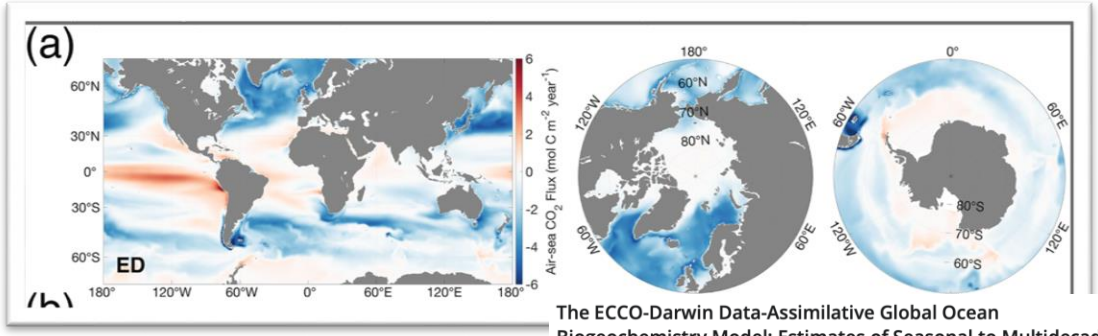
- Coupling
- GPUs performance, memory v compute tradeoff; floating point precision again.
- Emulator based acceleration of optimization - fit obs, parameter values

Coupling

- Already discussed at meeting (Dimitris talk) – key technical points
  - Ocean-atmosphere frontal coupling at kilometer scale resolution, and kilometer-scale air-sea momentum coupling terms are significant
  - Current high-resolution applications reinforce case for better representation of air-sea feedbacks/fully-coupled
  - A lot of the interesting feedbacks are across quite wide time and space scales. Ideally need ways to
    - **more formally downscale to optimize initial conditions**
    - **translate kilometer scale processes upscale into parameterizations**







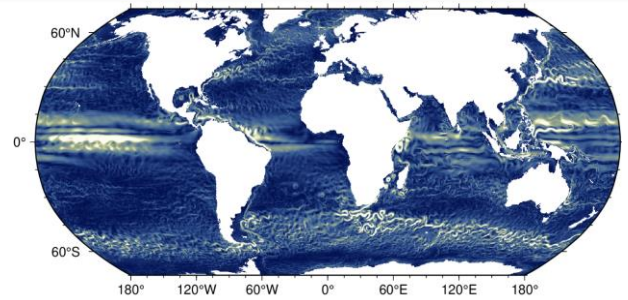
The ECCO-Darwin Data-Assimilative Global Ocean Biogeochemistry Model: Estimates of Seasonal to Multidecadal Surface Ocean pCO_2 and Air-Sea CO_2 Flux

Coupling (as well as interest in higher resolution ocean only assimilation) present sizable computational challenges that ➔ two interesting, somewhat linked, technical directions

- **GPU/GPU-like** and “refactoring” MITgcm finite volume simulation engine
  - Compute using GPUs can speed up computations significantly
  - Potentially goes hand-in-hand with ”refactoring” (fancy word for re-writing!) how memory is used so that very small model state – all geometry etc.. recomputed on fly.

- **Emulators**/surrogates*
  - Some remarkable/intriguing surrogate model results in weather forecast (and elsewhere) using specific flavors of deep-neural networks
    - Learn “latent model” (statistical emulator) in Fourier/modal space
    - Target time-stepping models with lots of training data sample solution space

* and surrogates do “back propagation”

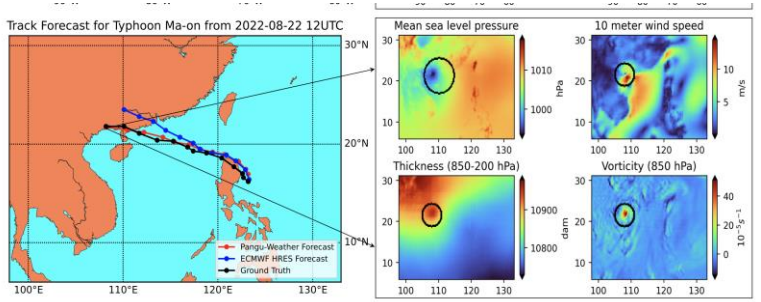


¼ quasi-global 10 years per day, single GPU.
1/12 quasi-global 5 months per day, single GPU.

can achieve similar on CPU cluster, but
➔ GPU potentially 100x less $$ cost in compute hardware than CPU for same computation
Key pieces – GPU architecture **and** memory model refactoring

ECMWF ERA5 1979-2017 training, 2019-2022 test

builds on Fourier mode based DNN (FOURCASTNET, Pathak et al)



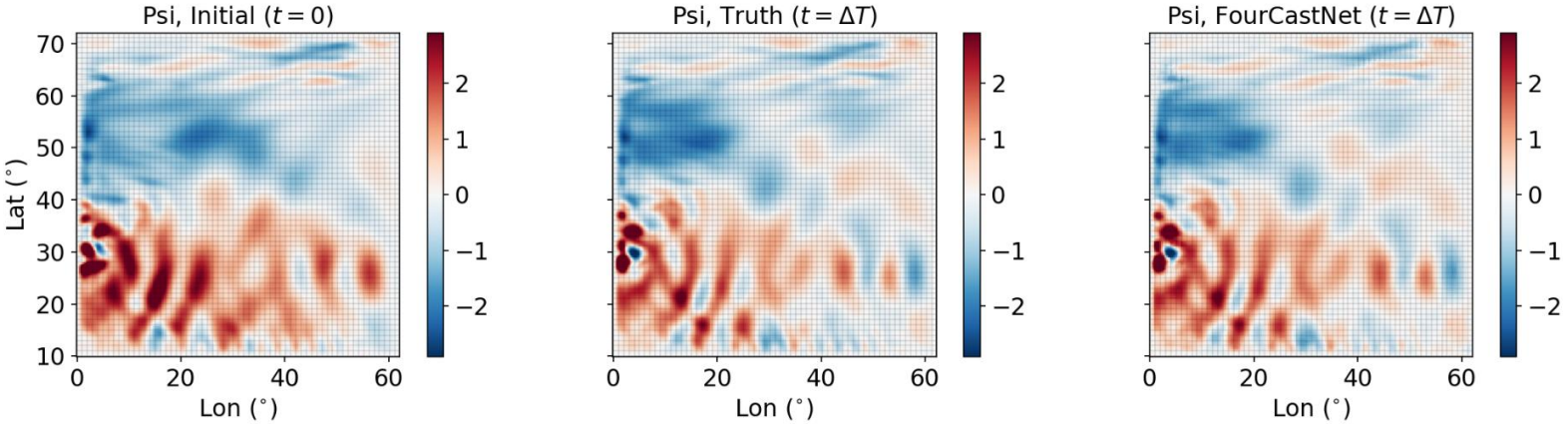
Typhoon-Ma 2022

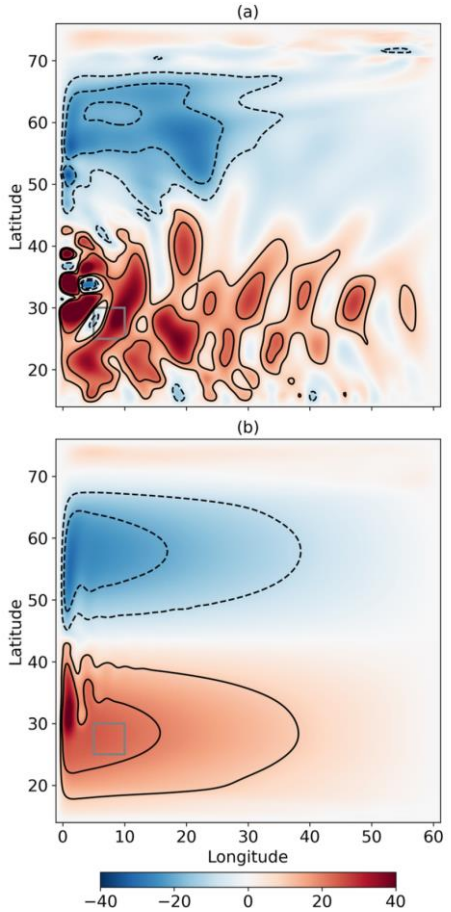
5-day ”forecast”, 1.4 secs, single GPU, 256 million parameter trained emulator x10,000 v IFS

Pangu-Weather: A 3D High-Resolution System for Fast and Accurate Global Weather Forecast

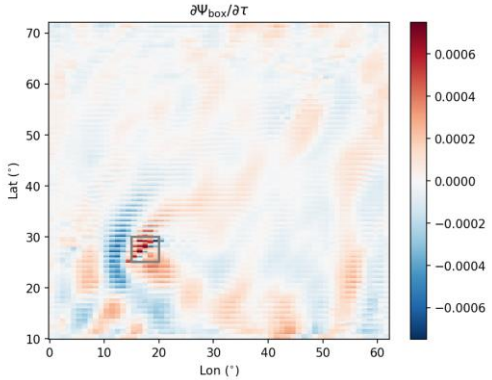
Could/should we use many GPUs to generate large amounts of synthetic data for many scenarios, train emulators **and** optimize emulator controls to obs

- First twin experiments with double gyre
  - Emulation





  - Back propagation
    - in progress



  - Optimization

Summary

- Two new technologies, GPU and maturing DNN
  - GPU potentially allows for many ensembles at interesting resolutions
  - Sufficient ensembles can be used to create emulator/surrogate with some skill
  - DNN emulator has, in principle, back propagation of partial derivatives with respect to weights and any “inputs” (initial conditions, boundary terms, parameters)
  - Potentially can accelerate both overall global data fit and parametrization fitting
  - Can still validate in physics based overall framework
  - Lots of possibilities
  - Not going to replace adjoint – but maybe approx., compressed adjoint on your laptop

Chris + ECCO + Suyash, Bjorn, Simone, Andre, Kamyar, Raf, Milan, ….