# Model Biases in Precipitation and Air-Sea Fluxes in Tropical Cyclones

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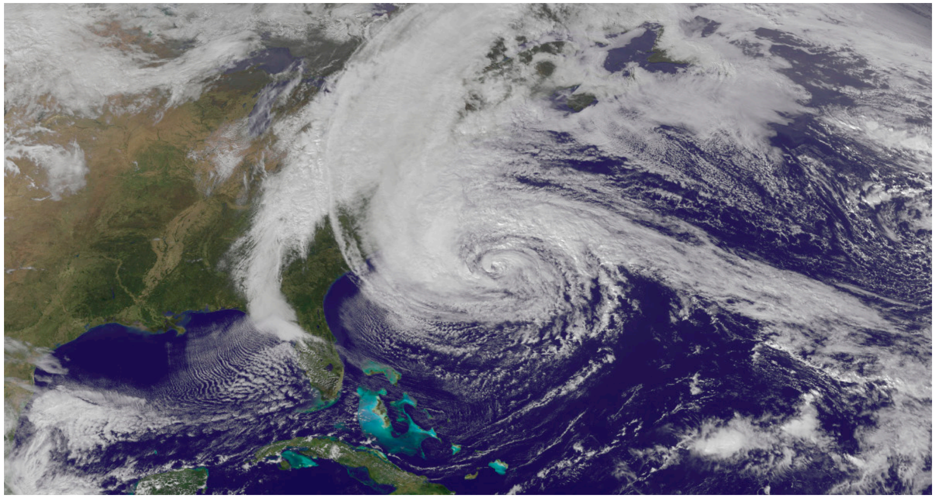


NATIONAL RENEWABLE ENERGY LABORATORY

National Oceanographic Partnership Program

GULF OF MEXICO RESEARCH INITIATIVE

UM Hurricanes and Coupled Modeling Group

University of Miami Rosenstiel School of Marine & Atmospheric Science

(WRF Users Workshop, 25 June 2014)

# Data and Model

- In situ air-sea latent and sensible heat fluxes using NOAA P-3 dropsondes and AXBTs data from DYNAMO, ITOP (typhoons), and Atlantic hurricanes.

- TRMM and CMORPH rainfall

- Airborne SFMR (Step Frequency Microwave Radiameter) surface wind

- WRF-ARW model (physics ensemble)

- UMCM (University of Miami Coupled Atmosphere-Wave-Ocean Model)

# University of Miami Coupled Model (UMCM)

- Weather Research and Forecasting (WRF-ARW) v3.5:

  12/4/1.3 km horizontal resolution with storm following nests, 36 vertical levels (phys: YSU PBL, Donelan+Garrat sfc., WSM5/6)

  Initial and boundary conditions from NCEP GFS/FNL
- University of Miami Wave Model (UMWM) v1.1:

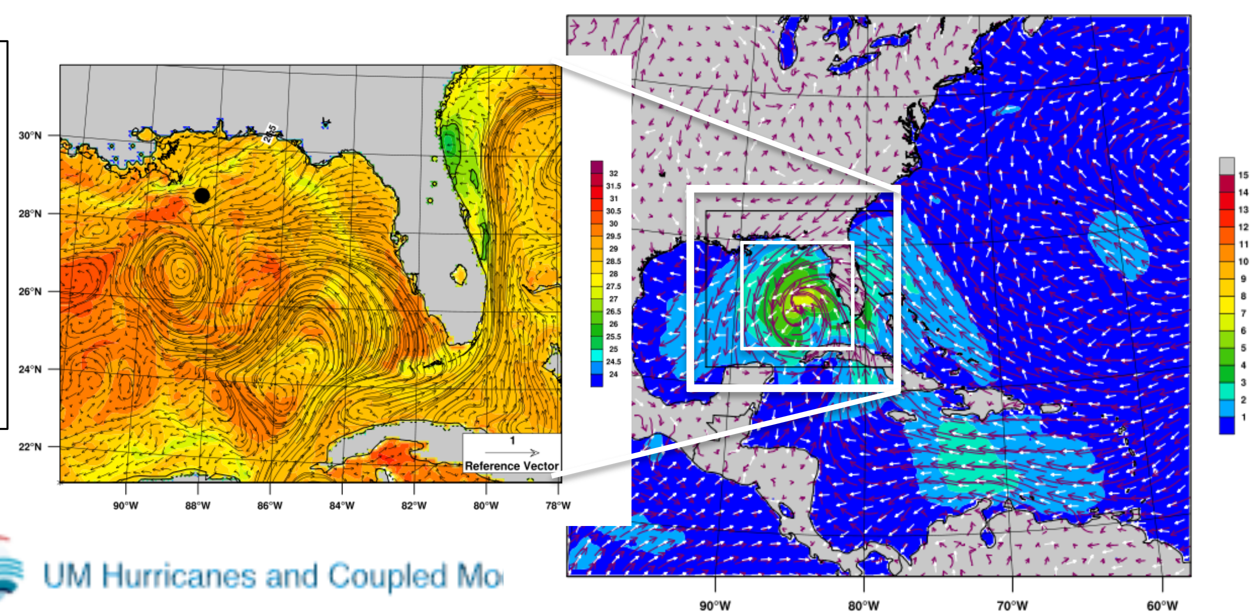
  4 km horizontal resolution, 36 directional bins and 37 frequency bins from 0.0313 - 2 Hz
- HYbrid Coordinate Ocean Model (HYCOM) v2.2.34:

  1/25 degree (~4 km) horizontal resolution, 32 vertical levels;

  Initial and boundary conditions from global 1/12 deg. HYCOM

**Experiments:**

- Uncoupled Atmos (**UA**)
- **Coupled** Atmos-Ocean (**AO**)
- Coupled Atmosphere-Wave-Ocean (**AWO**)

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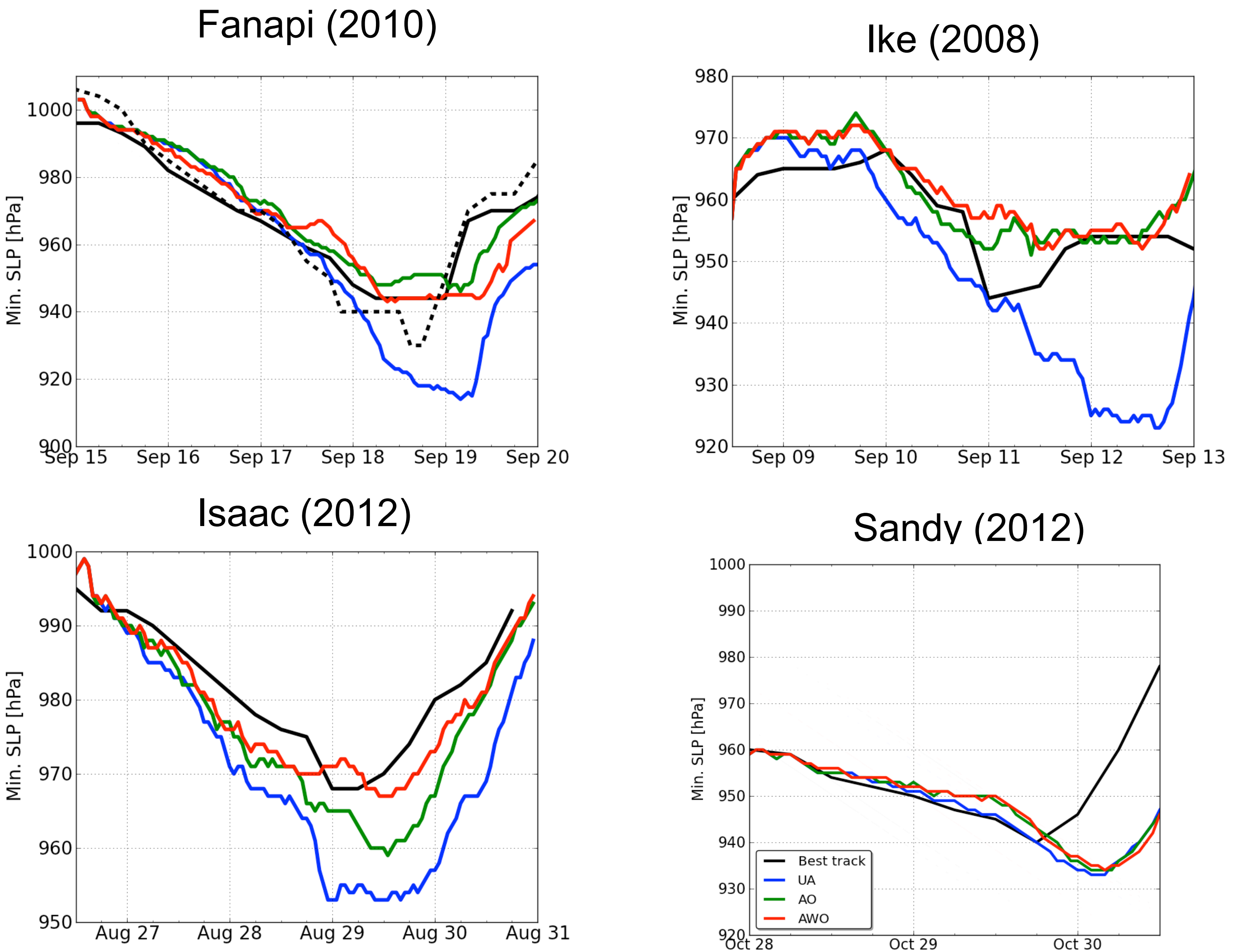


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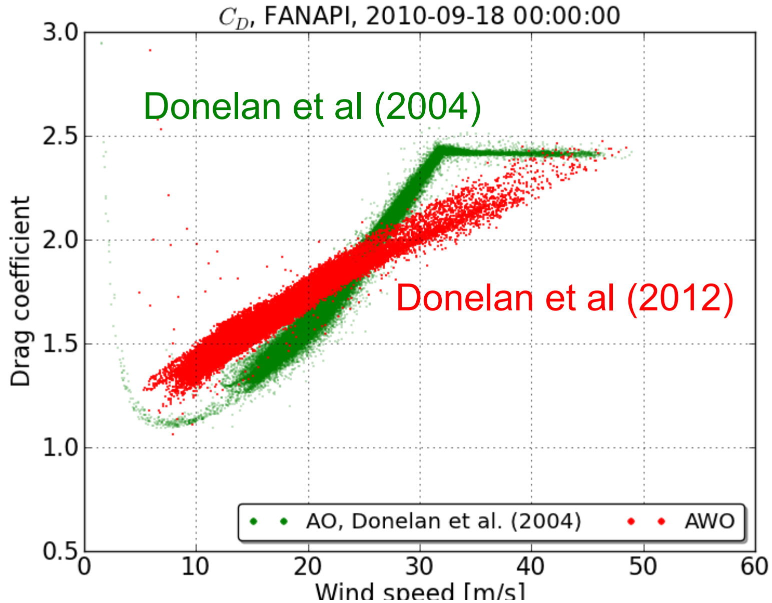
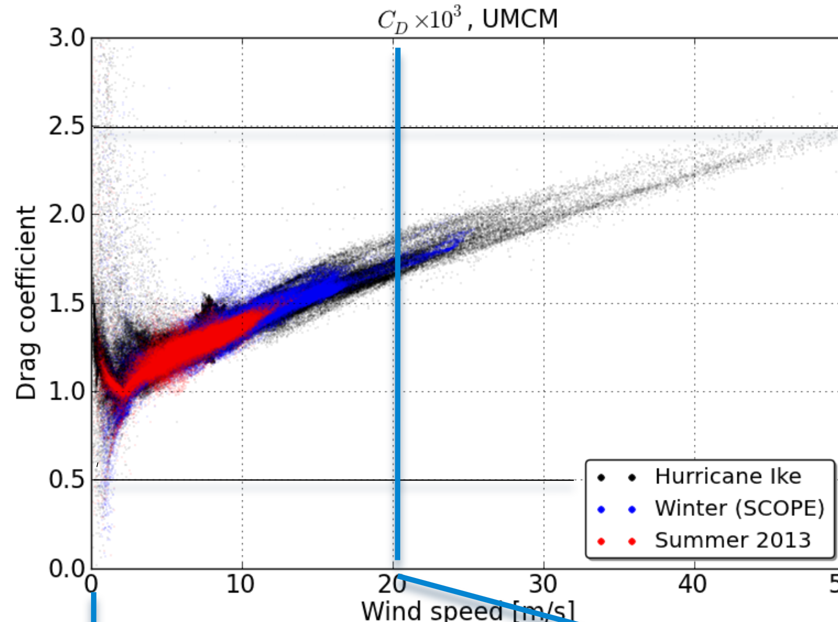
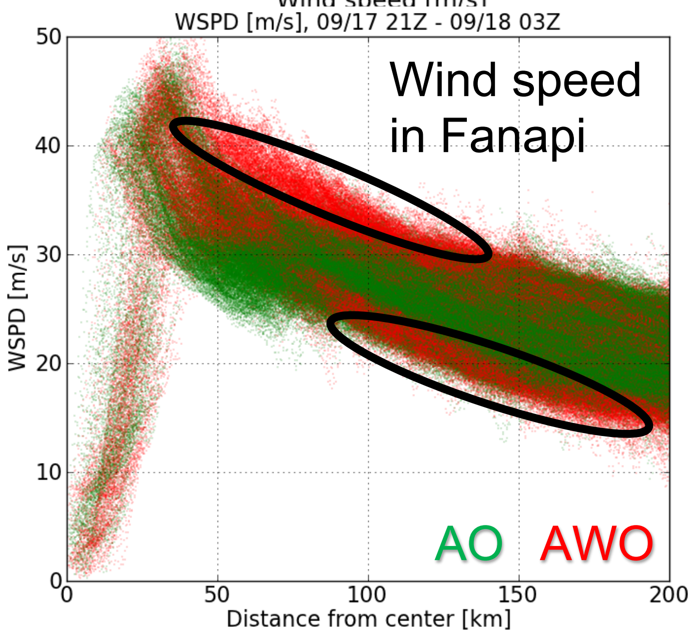
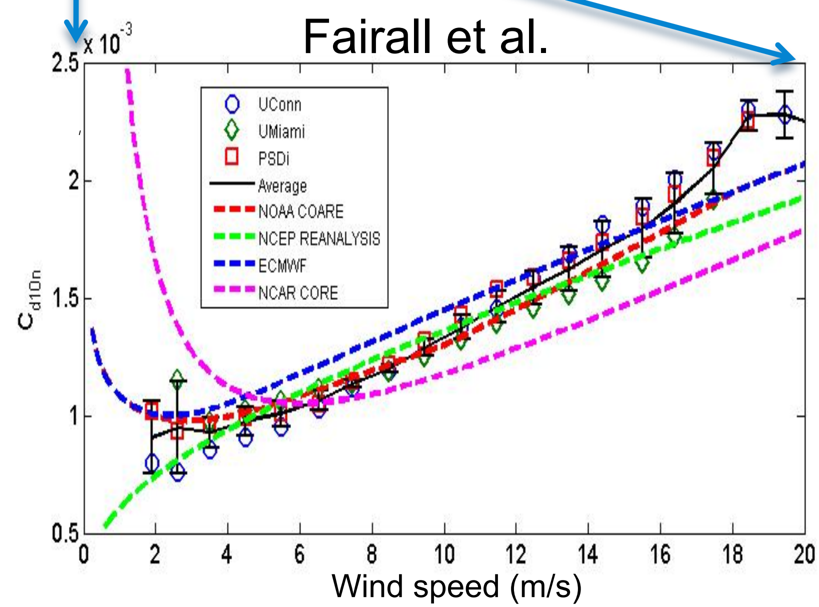
## Drag Coefficients: AO and AWO




## Drag Coefficient: AWO for all conditions

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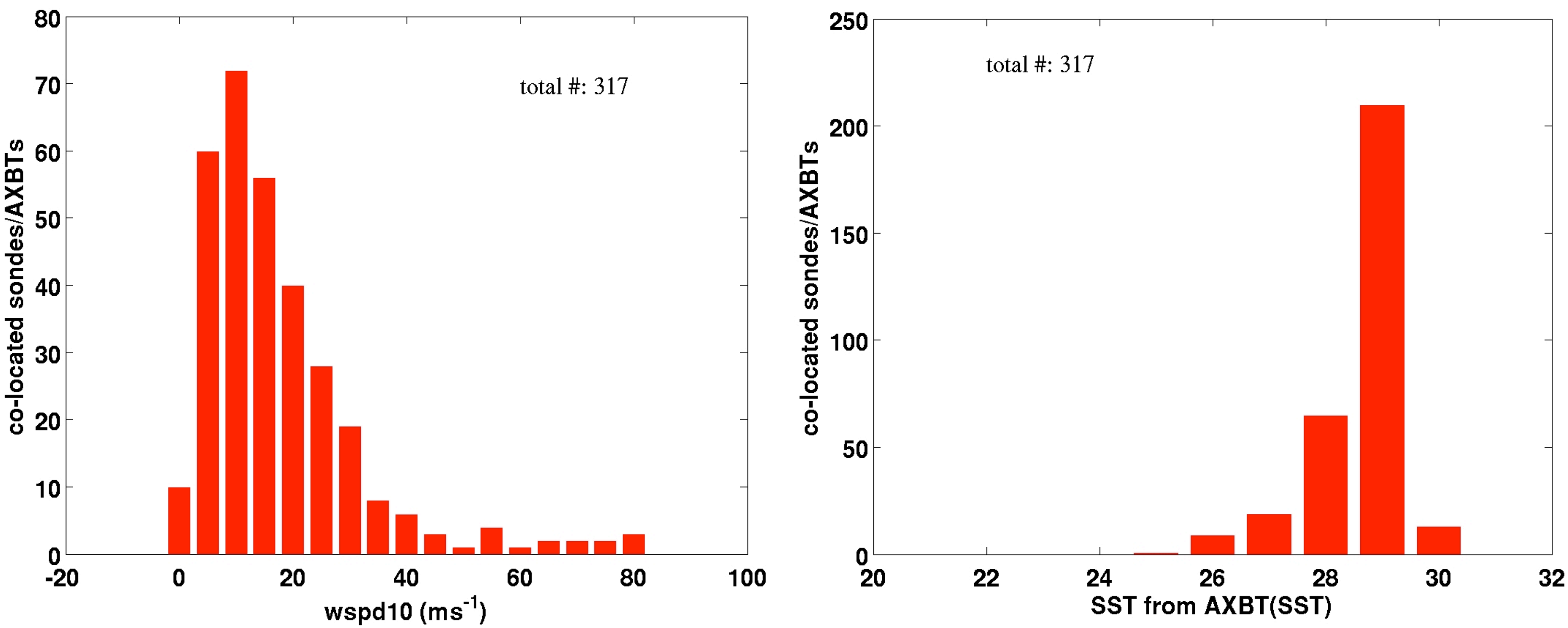
Chen et al. (2014): Coupled Observations and Air-Sea Fluxes in TCs.

What are the air-sea heat and most fluxes in tropical cyclones?

ITOP (Impact of Typhoons on Ocean in Pacific):
Co-located Dropsondes and AXBTs

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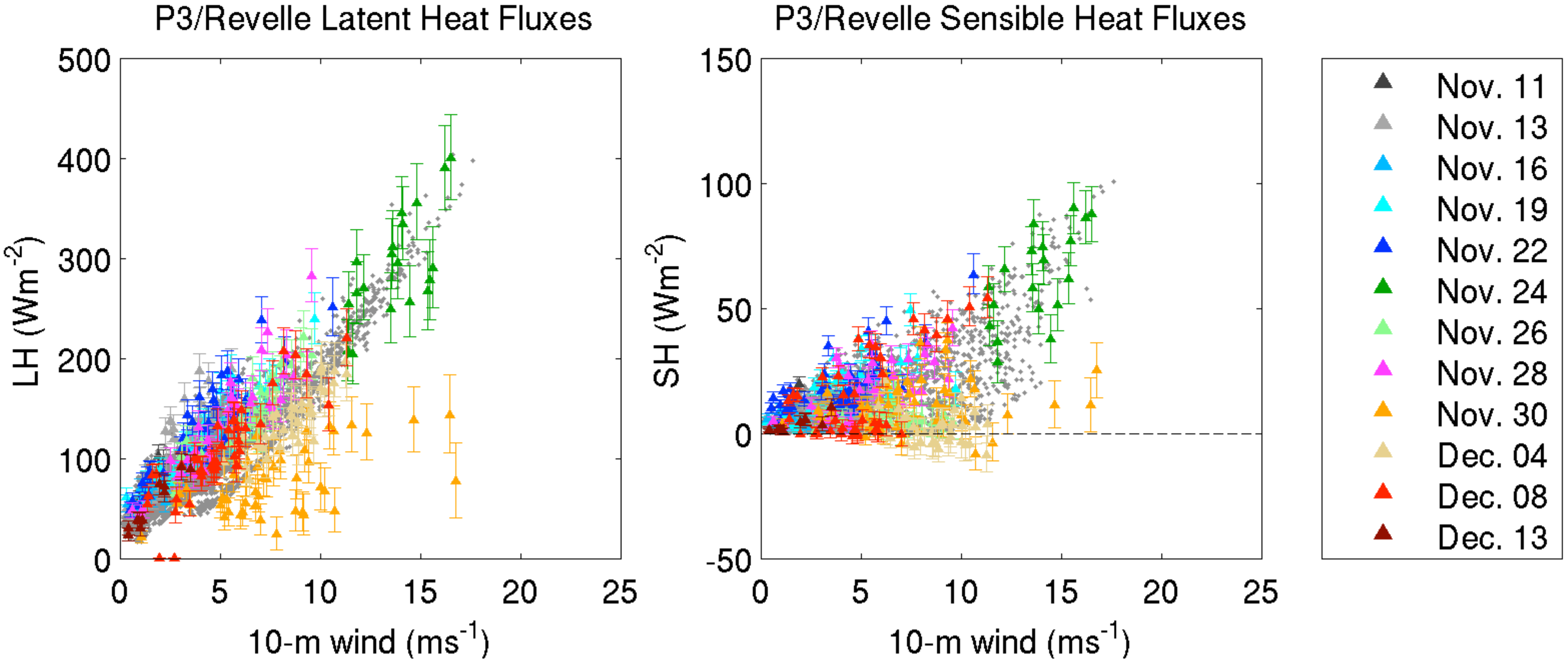
# Observation of Air-Sea Latent and Sensible Heat Fluxes in DYNAMO

1. Bulk fluxes using P-3 dropsondes and AXBTs data (COARE 3.2)
2. Turbulence fluxes from *R/V* Revelle

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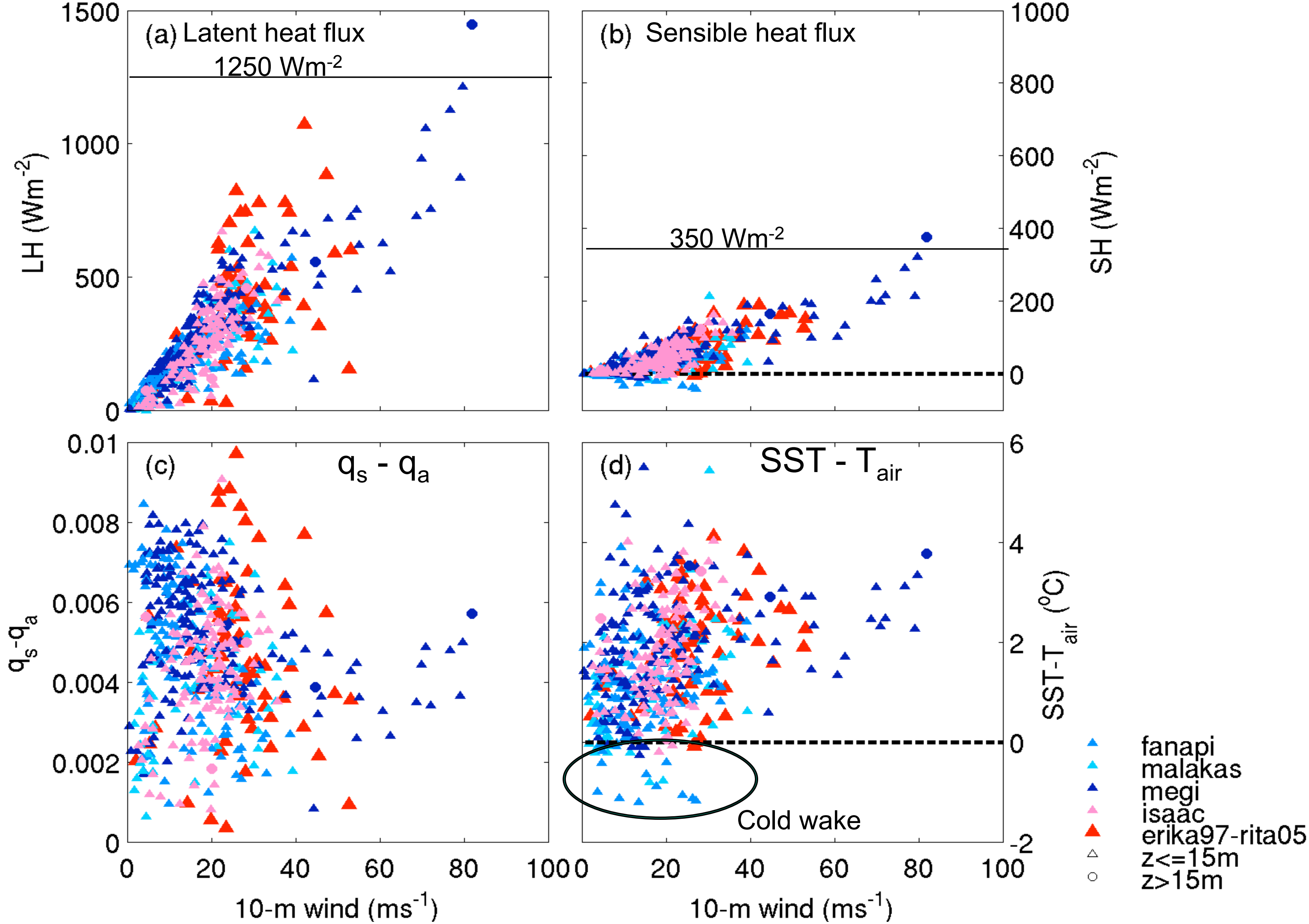
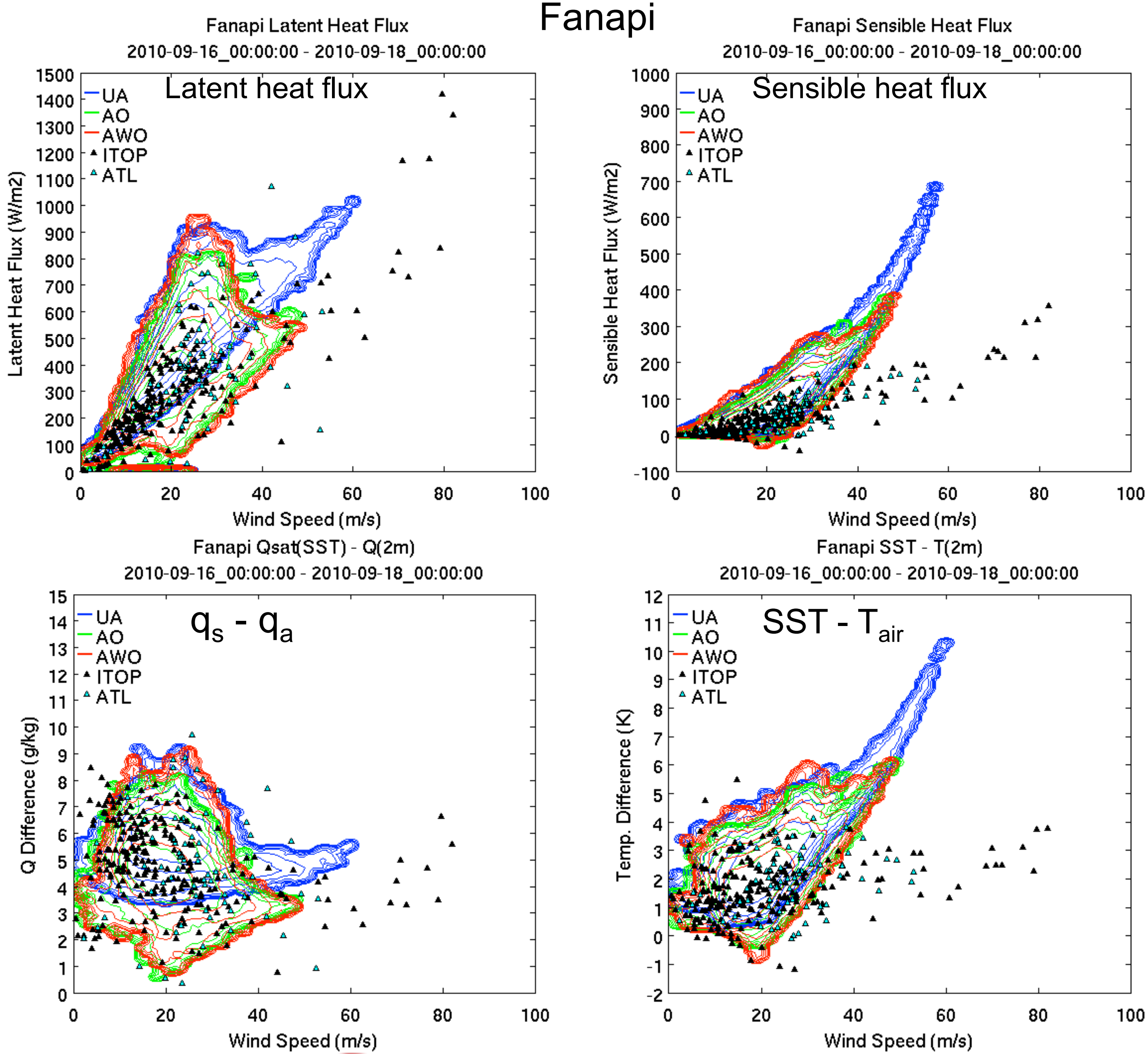
# LH & SH fluxes from ITOP and Atlantic Hurricanes (Isaac, Katrina, Rita, ...)



# Fanapi

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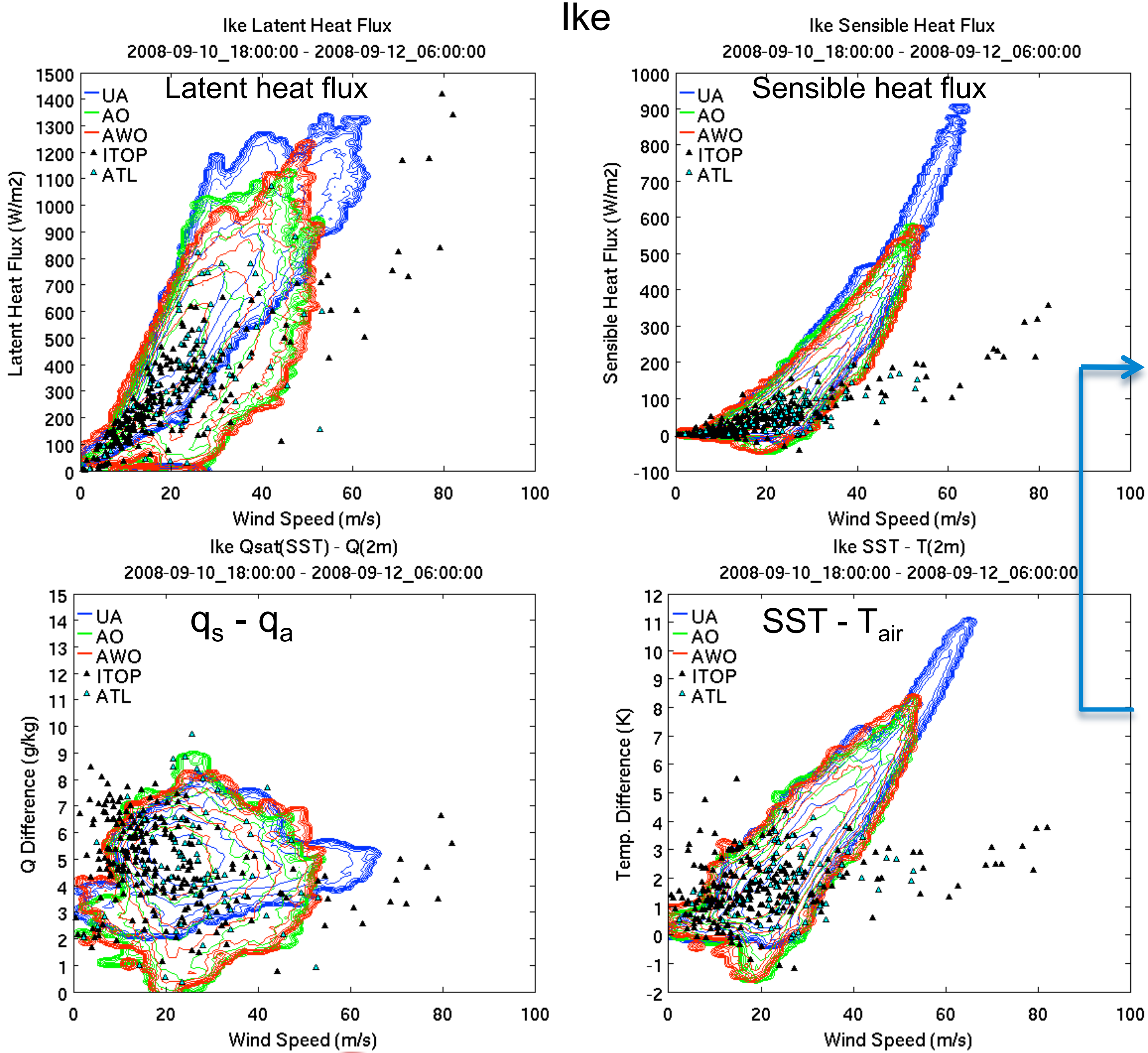
# Ike




SST in UA (too warm)

↓

Large LH & SH fluxes

↓

Strong convection (sfc wind)

↓

Large evaporative cooling ($T_{air}$)

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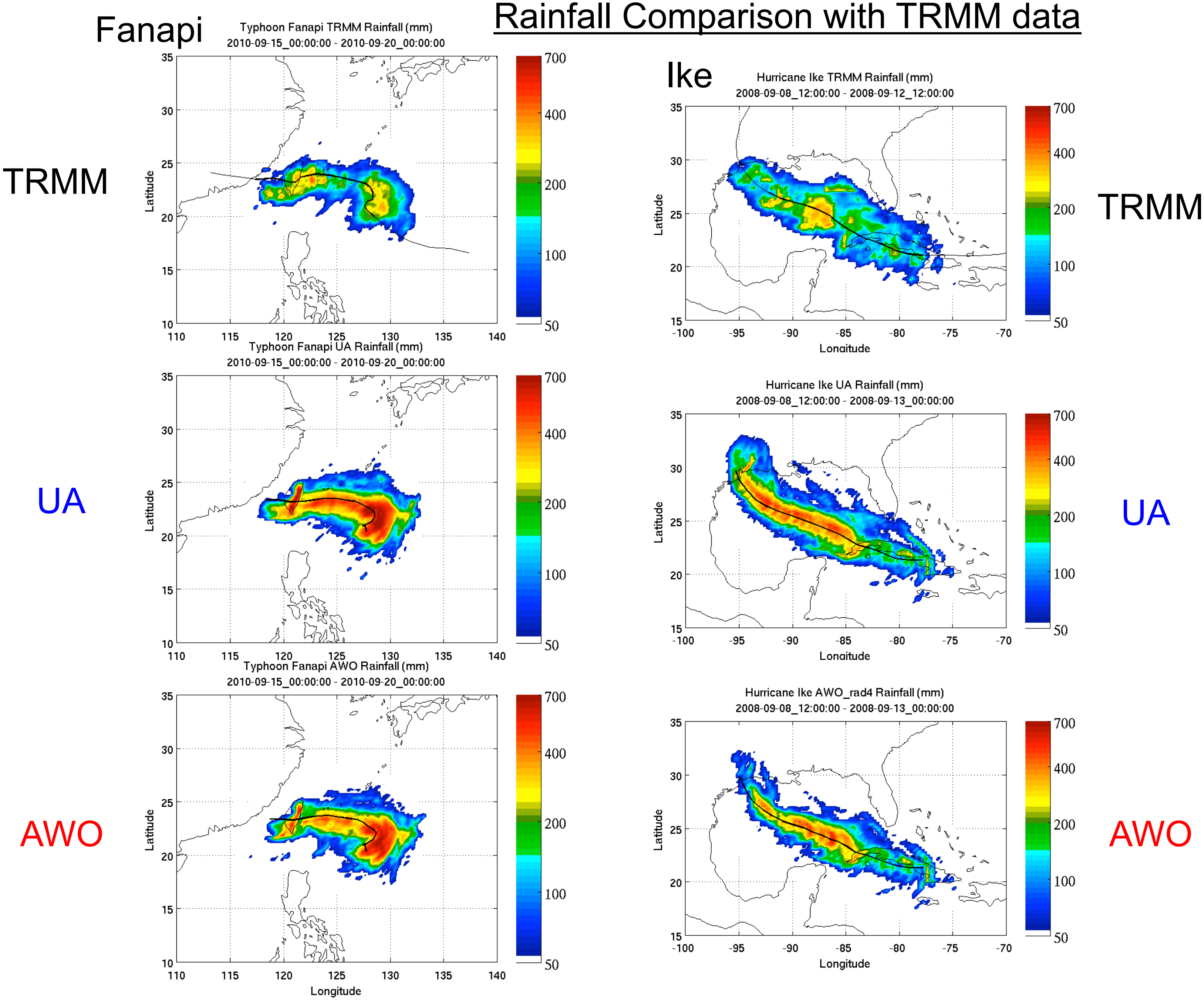
# Rainfall Comparison with TRMM data

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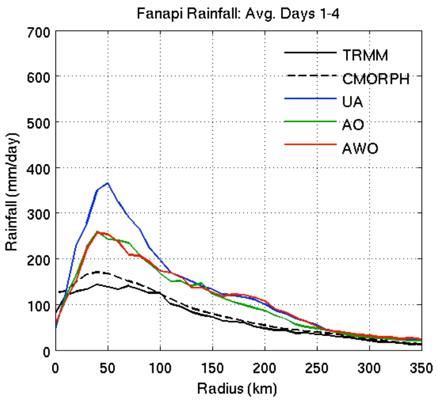
# Rainfall Comparison with TRMM

Fanapi

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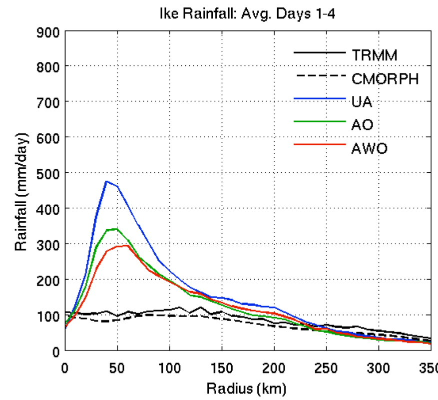


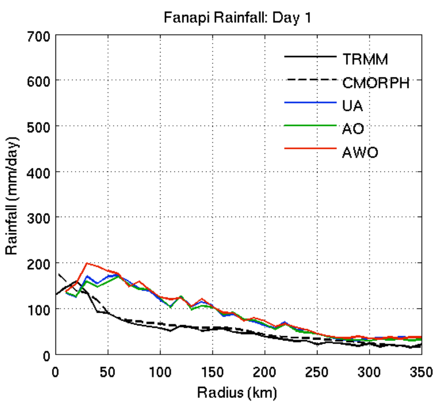


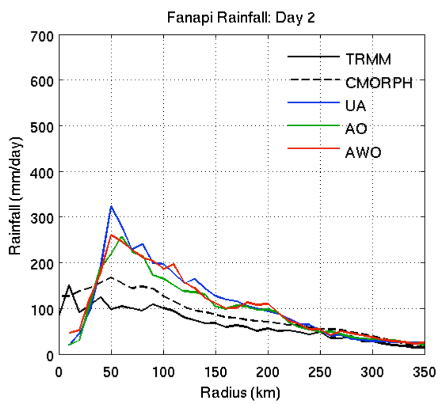


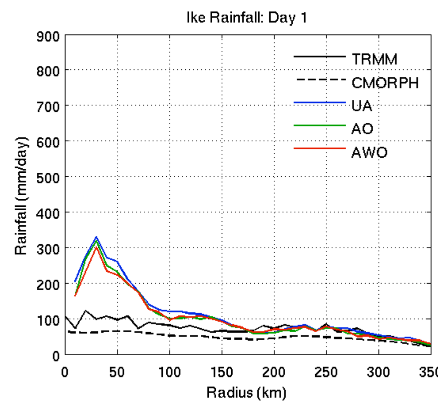


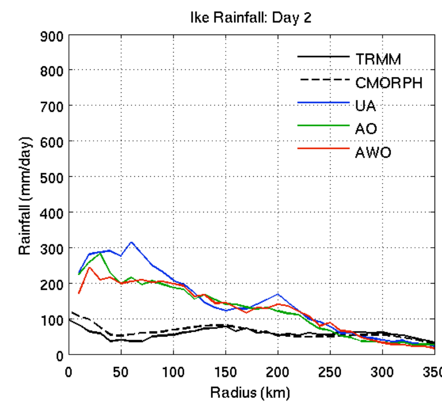


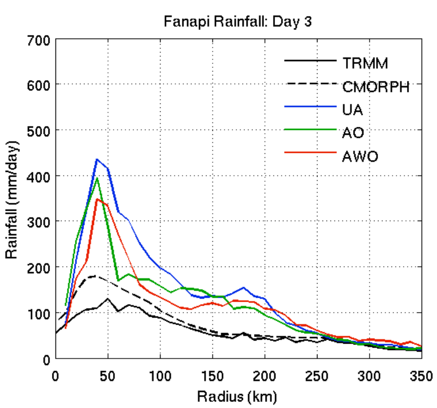


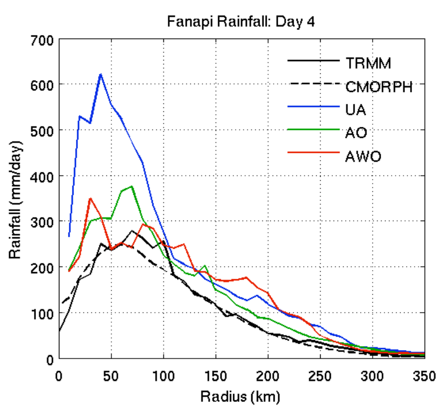


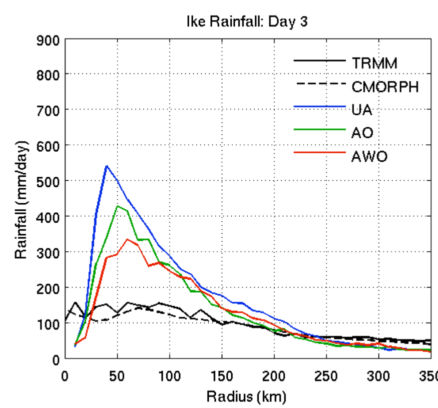


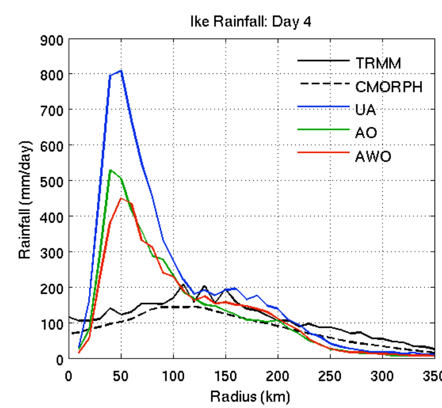


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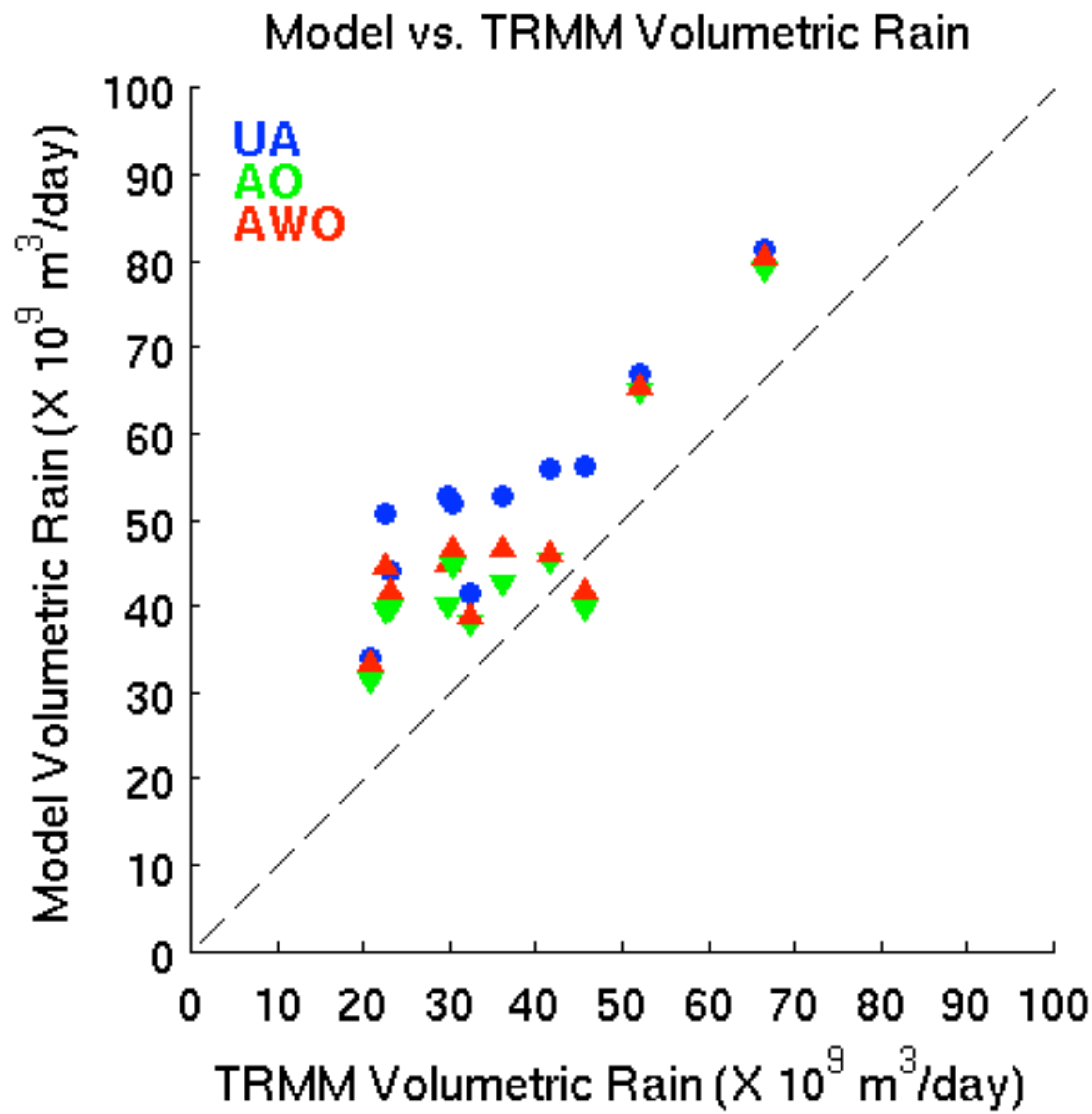


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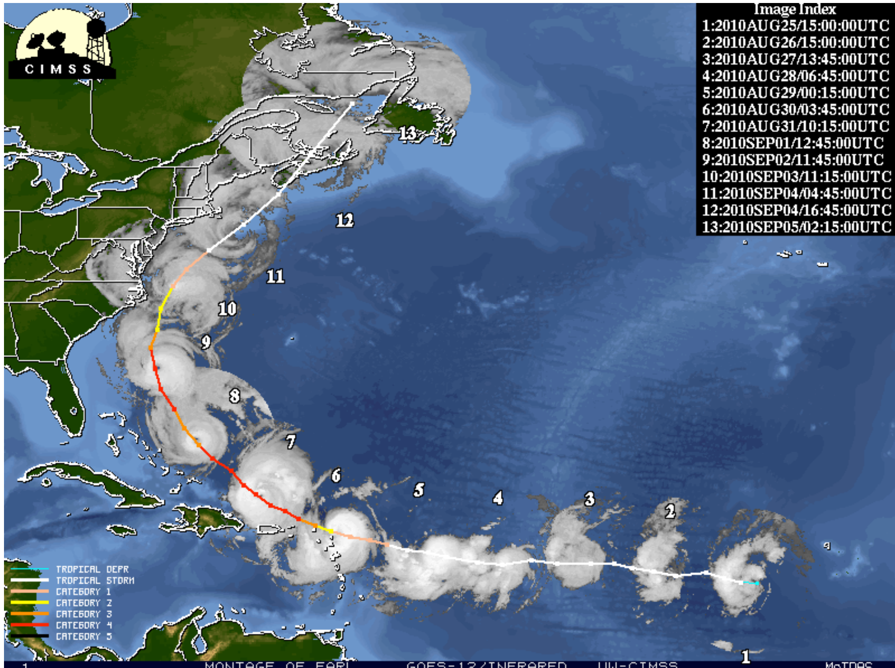
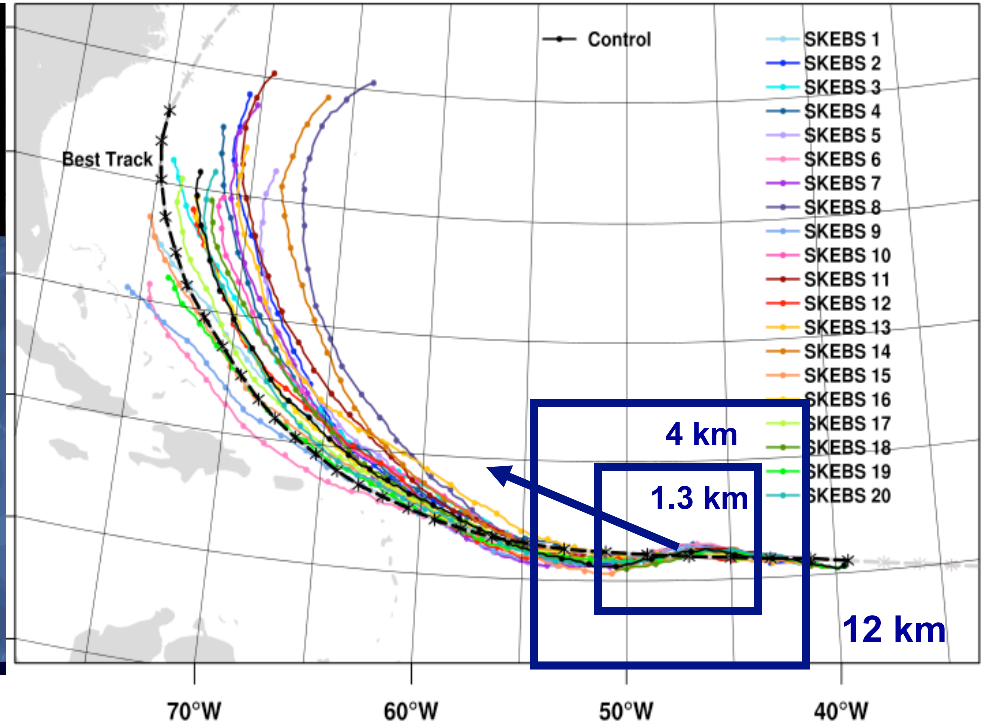
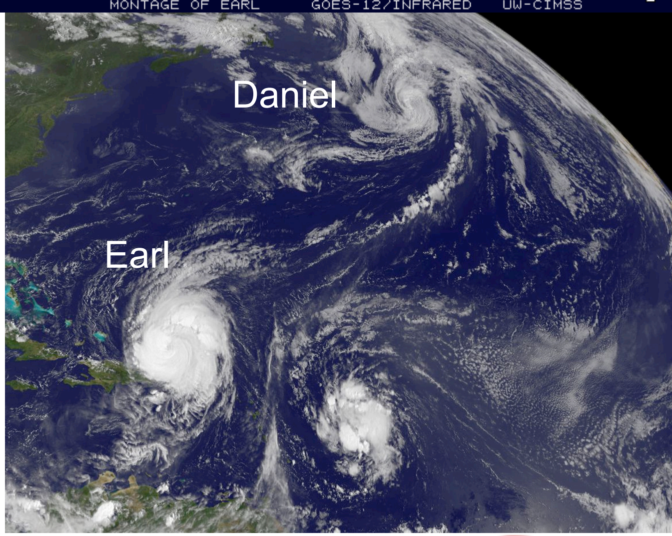
# Hurricane Earl (2010)




WRF-ARW model with triply nested grids




Earl is an Ideal candidate:
- favorable environment
- long lasting
- non-landfalling
- full lifecycle (TS->RI->MH)

# Ensemble Forecasts Using WRF-ARW Model (nested grids 12/4/1.3 km)

1) **Physics parameterization ensemble (Control+19 members)**
   *- Generated by using various physical parameterizations of cloud microphysics (9), surface fluxes (7) and PBL (3) schemes*

2) **Stochastic Kinetic Energy Backscatter (SKEBS) ensemble (5 ensembles, each with 20 members)**
   *- Adding small, stochastic perturbations to (u,v) and T tendencies (Berner et al. 2005, 2011)*

Tendencies: $\Psi'(x,y,t) = rD(x,y,t)\psi'(x,y,t)$ ~O($10^{-4}$ m/s, $10^{-9}$ K/s)

backscatter ratio

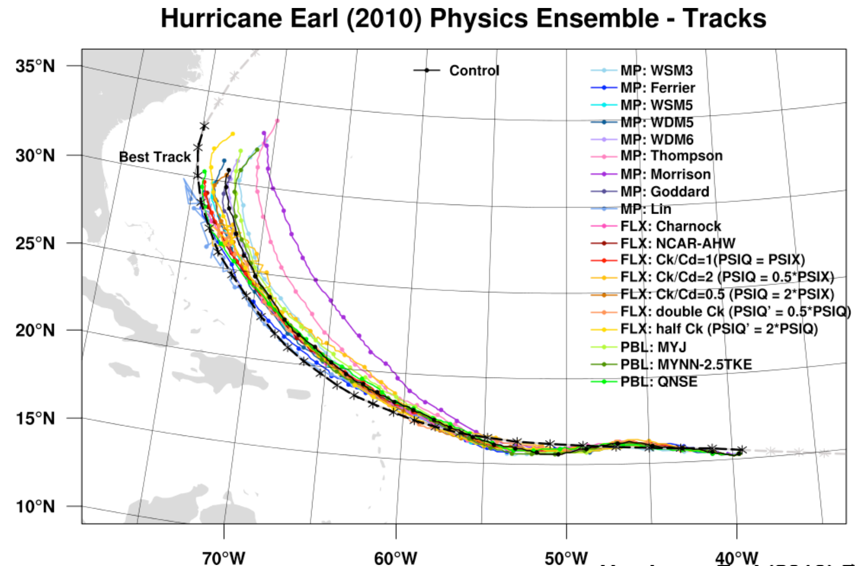
dissipation rate

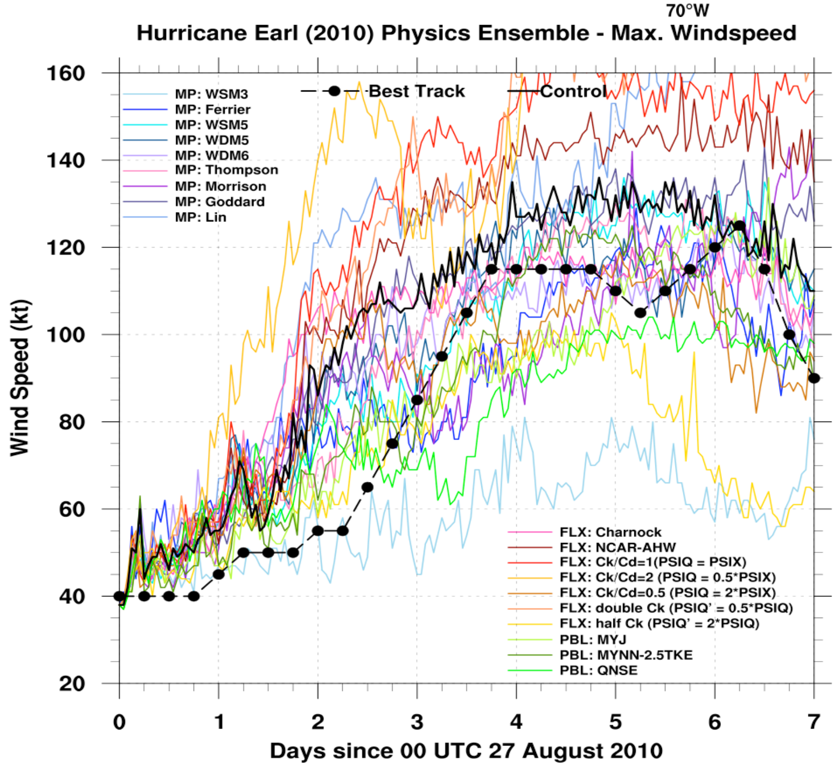
stream function

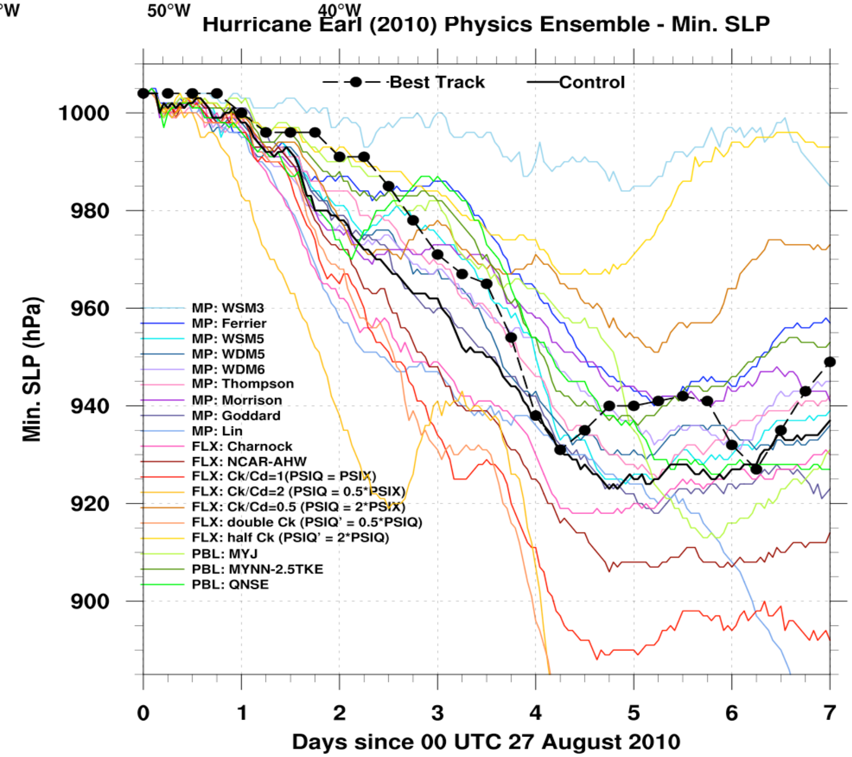
**Perturbations as a function of spatial scale:**

| | | |
|---|---|---|
| Ensemble 1: | All-scale perturbations | |
| Ensemble 2: | Synoptic-scale perturbations+BL | = 525 – 4200 km |
| Ensemble 3: | Synoptic-scale perturbations | = 525 – 4200 km |
| Ensemble 4: | Mesoscale perturbations | = 24 – 200 km |
| Ensemble 5: | Convective scale perturbations | = 2 – 11 km |

# Physics ensemble

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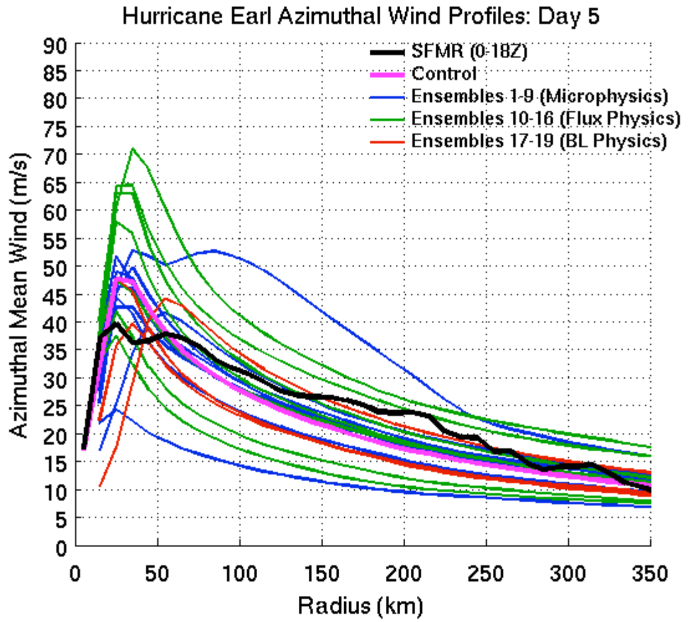
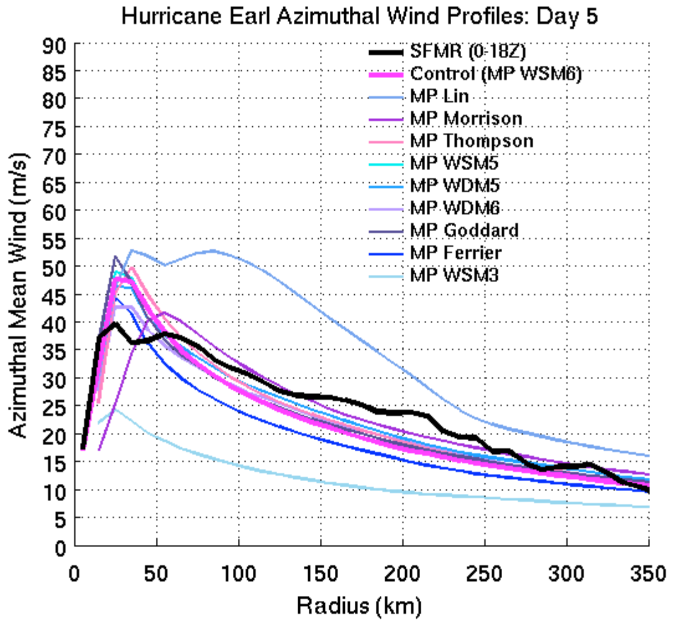
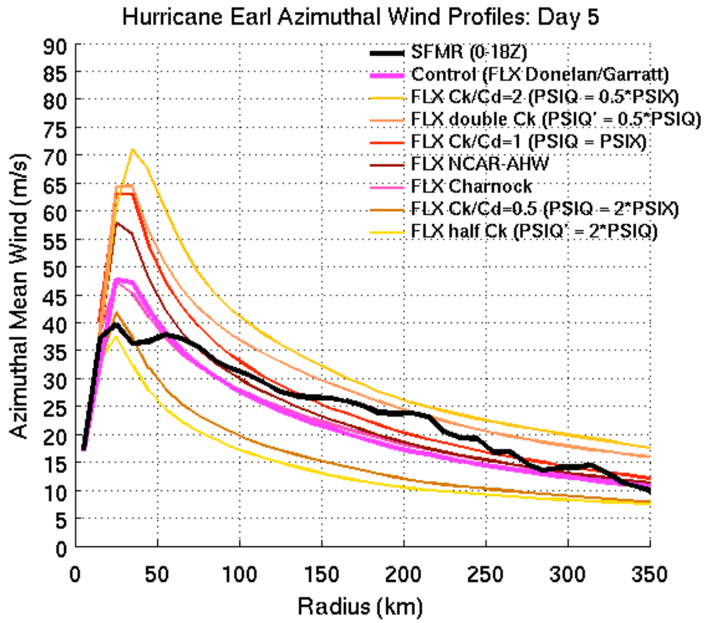
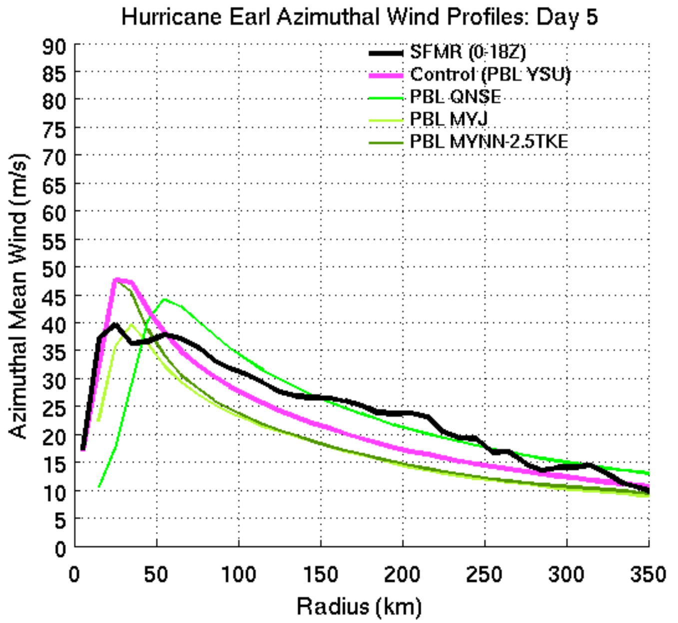
# Day 5

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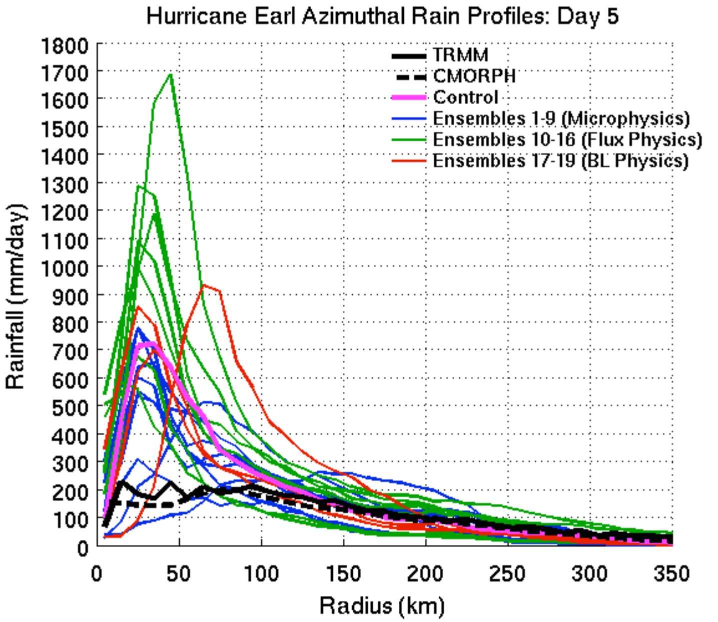


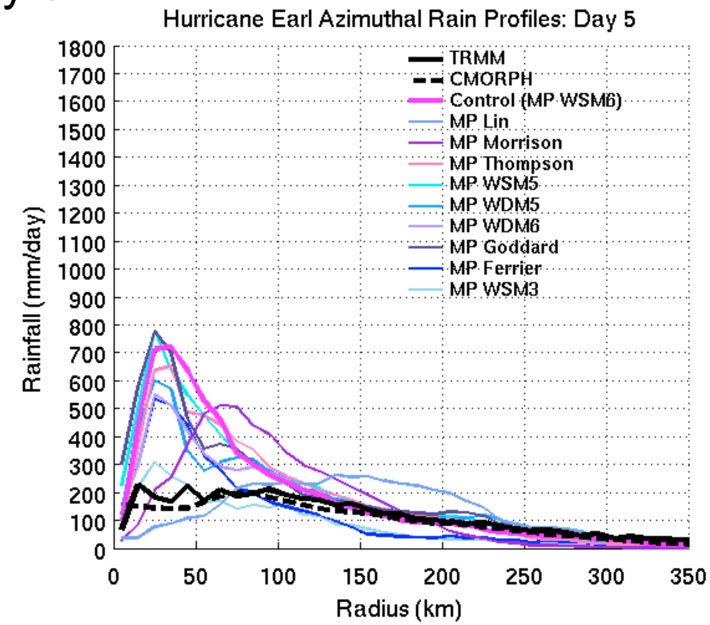


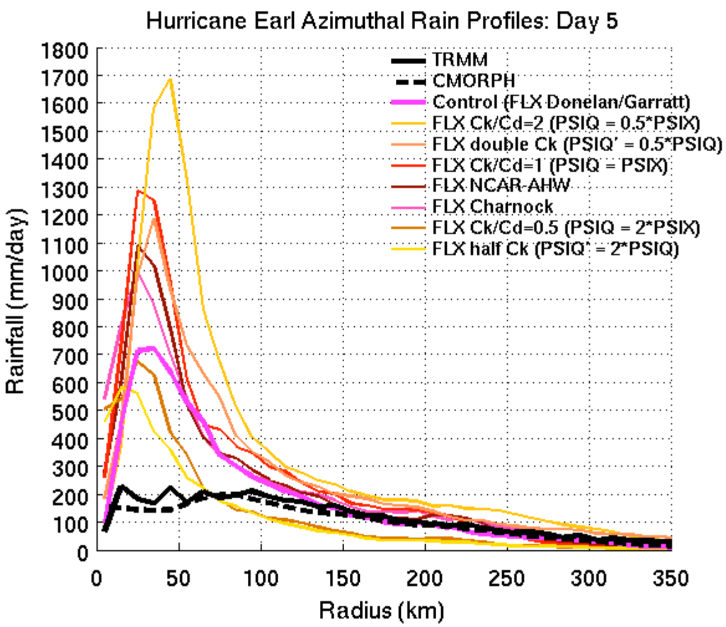


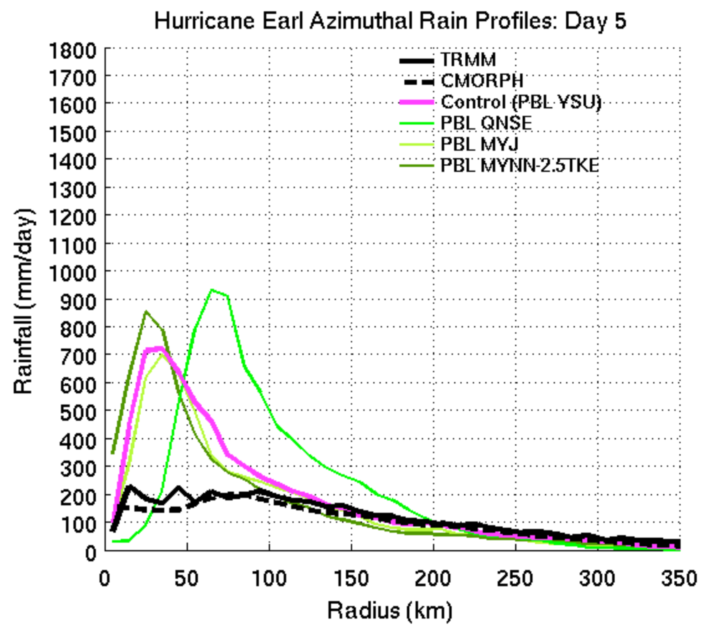


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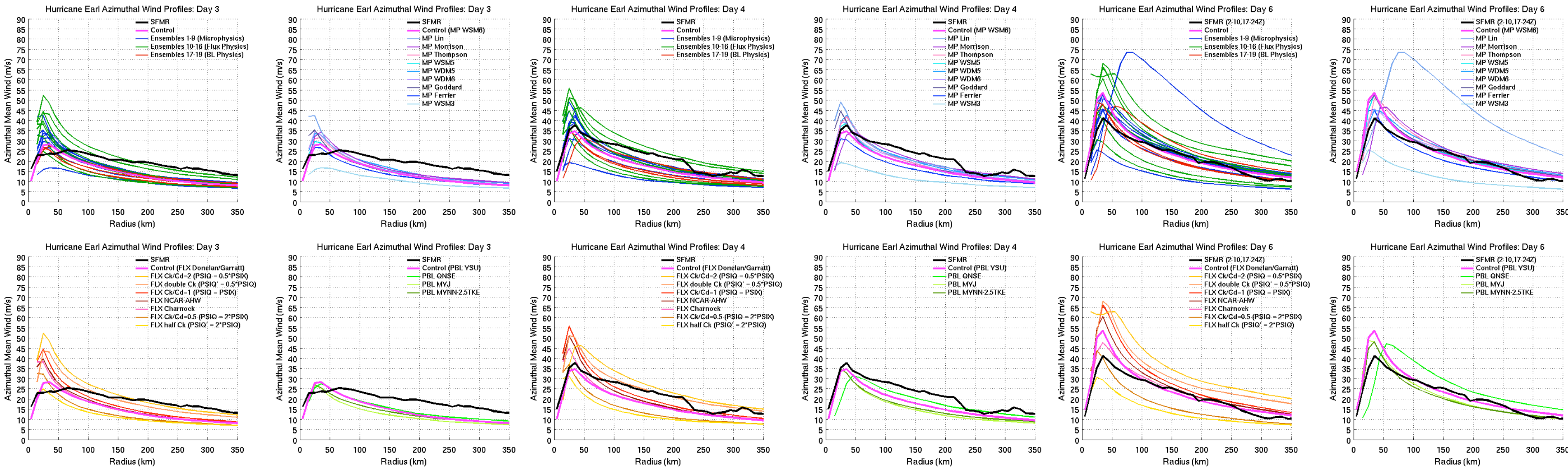
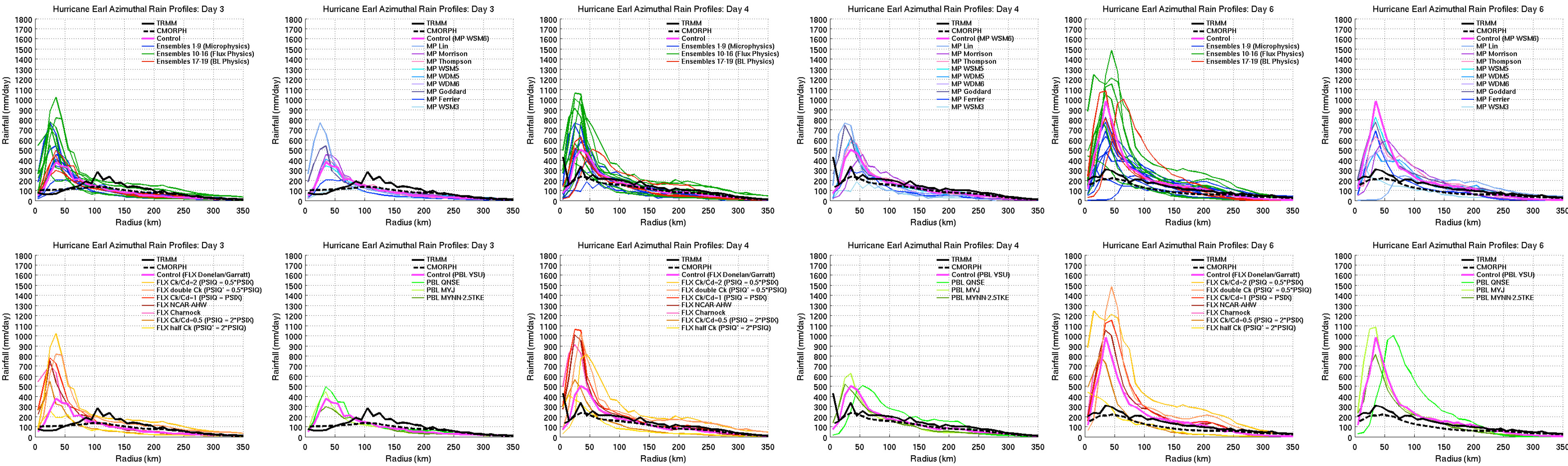
# Day 3 Day 4 Day 6

## Wind: model and SFMR




## Rain: Model and TRMM/CMORPH

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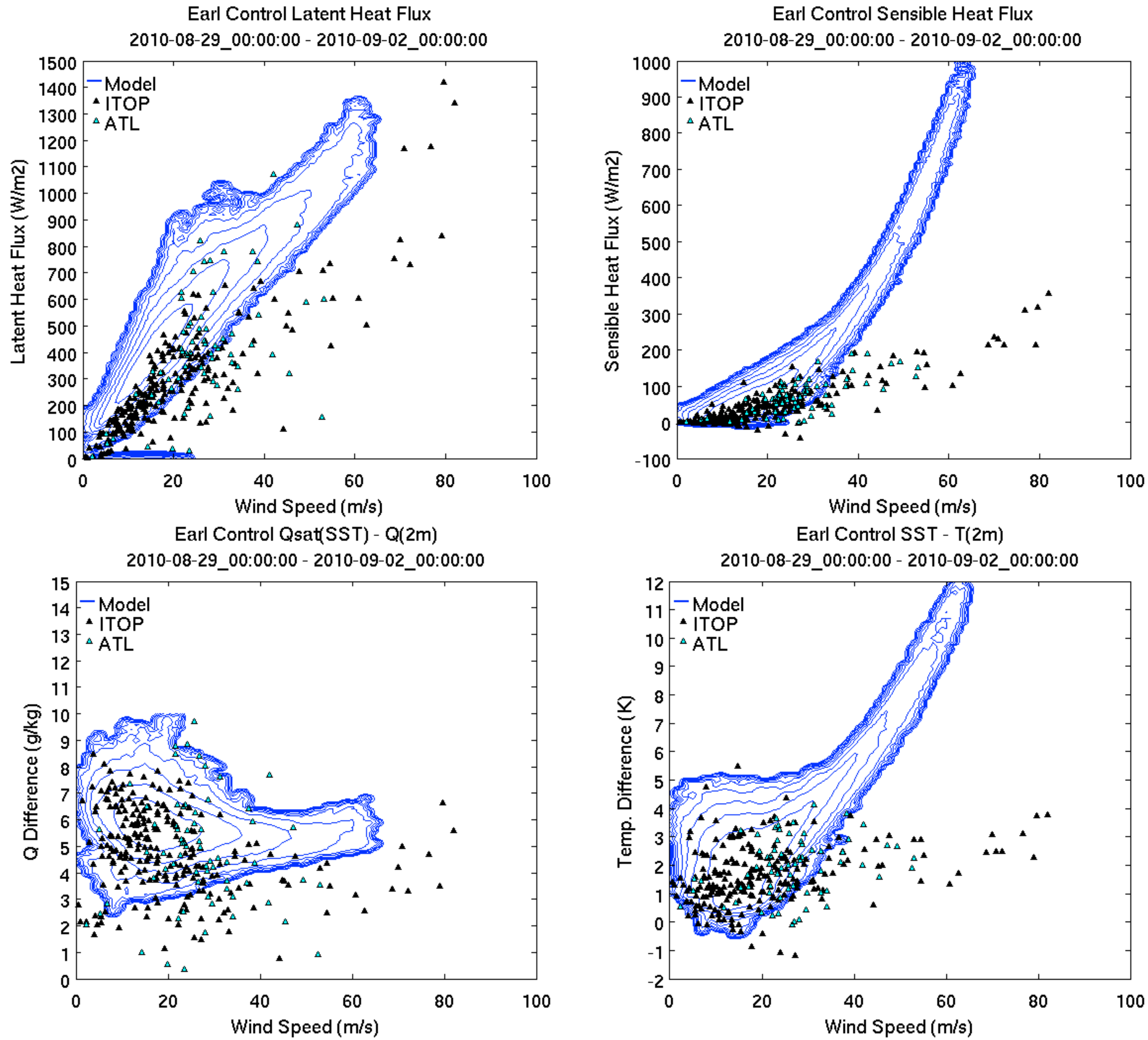
# Control: YSU PBL

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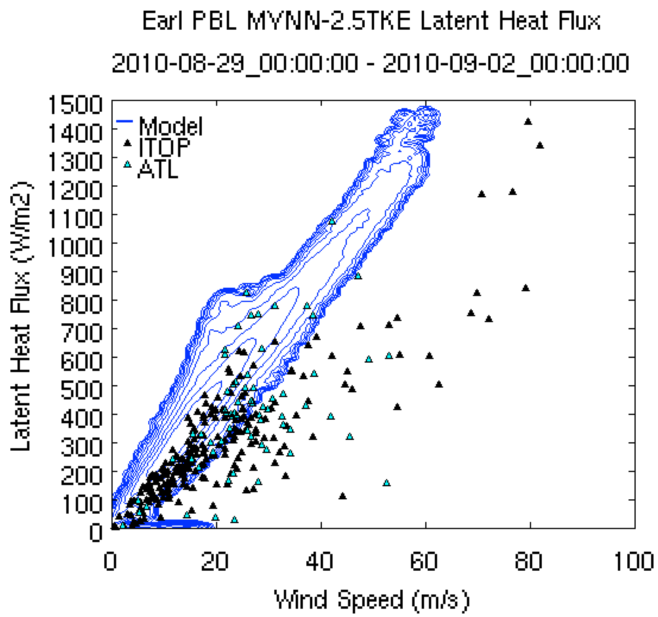
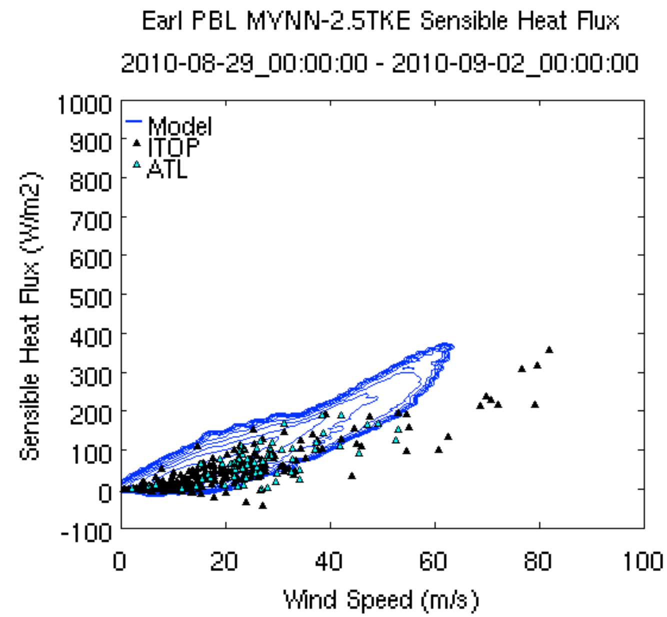
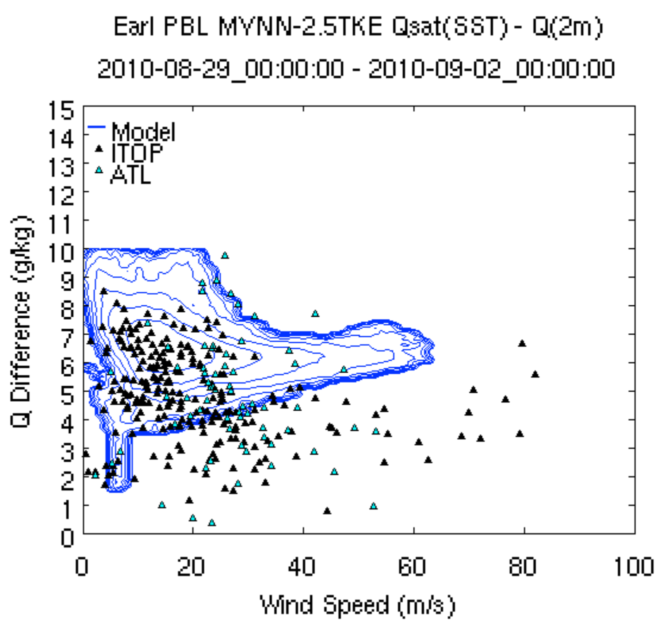
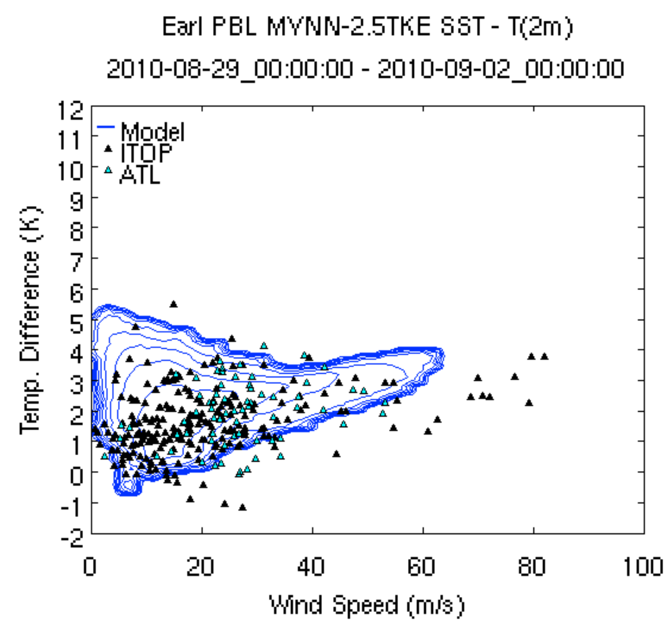
# MYNN-2.5TKE PBL

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# Summary

- Uncoupled atmospheric model (UA) with unrealistically warm SST produces excessive surface latent and sensible heat fluxes, which lead to a vicious cycle:

  Excessive heat/moisture fluxes -> more rain/stronger convection -> large evaporative cooling and stronger wind -> larger heat/moisture fluxes

- Coupled atmosphere-ocean (AO) and atmosphere-wave-ocean (AWO) can correct a significant part (but not all) of the model biases in air-sea fluxes and rainfall, which is a good starting point to break up the vicious cycle

- Physics ensembles reveal general problems in rain and air-sea fluxes (extreme high biases) in WRF

- Rain and fluxes (& TC intensity) are more sensitive to PBL and surface layer physics than microphysics

- Need to build better NWP models with sound energetics from the bottom up!