Convective Initiation Sensitivity to the Presence of An Oceanic Barrier Layer

Sue Chen[1], Jerome Schmidt[1], Maria Flatau[1], James Richman[2], Tommy Jensen[2]

[1]Naval Research Laboratory, Monterey, California

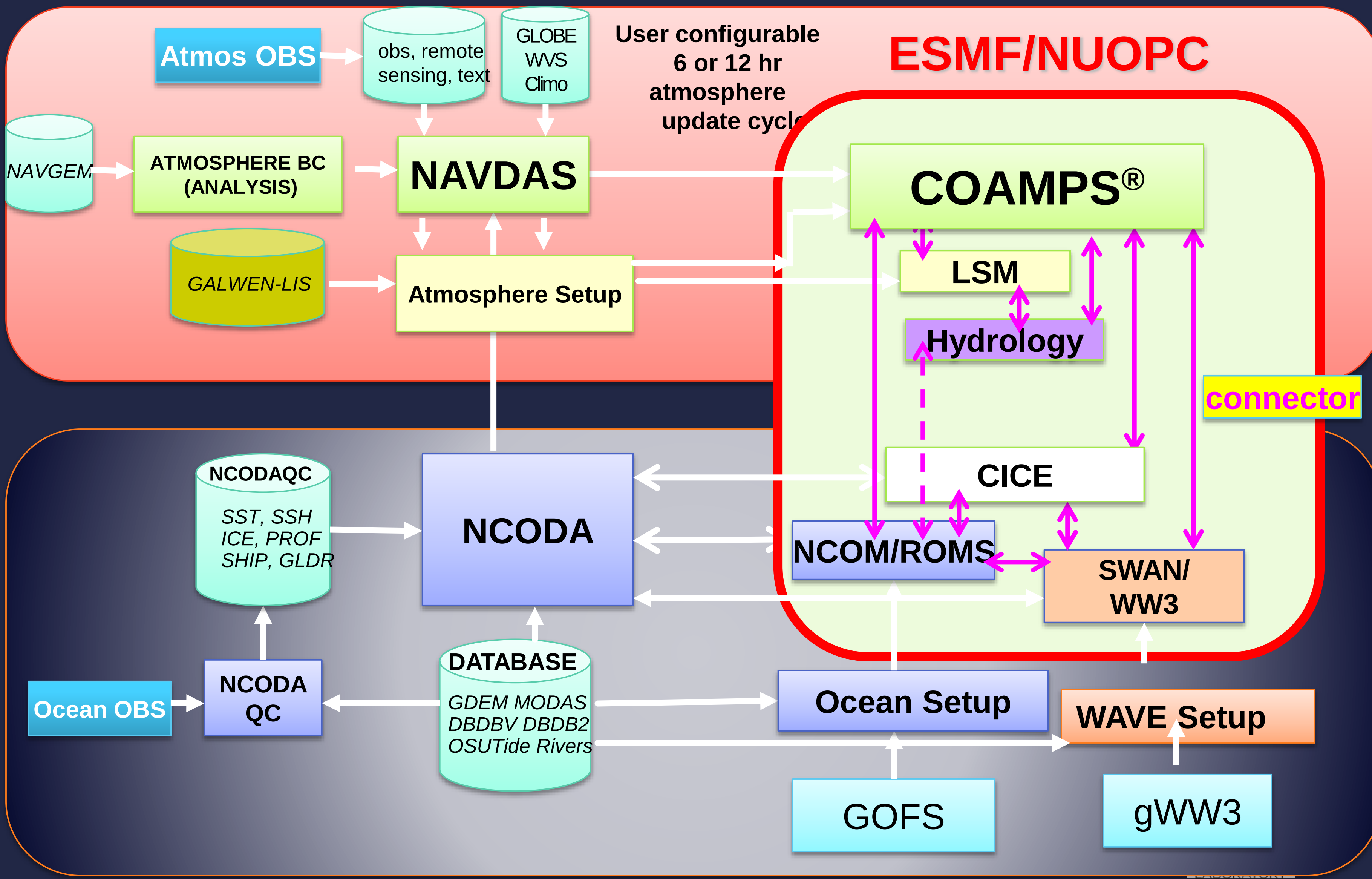
[2]Naval Research Laboratory, Stennis Space Center, Mississippi

Photo: Curtesy of N.-H. Chi

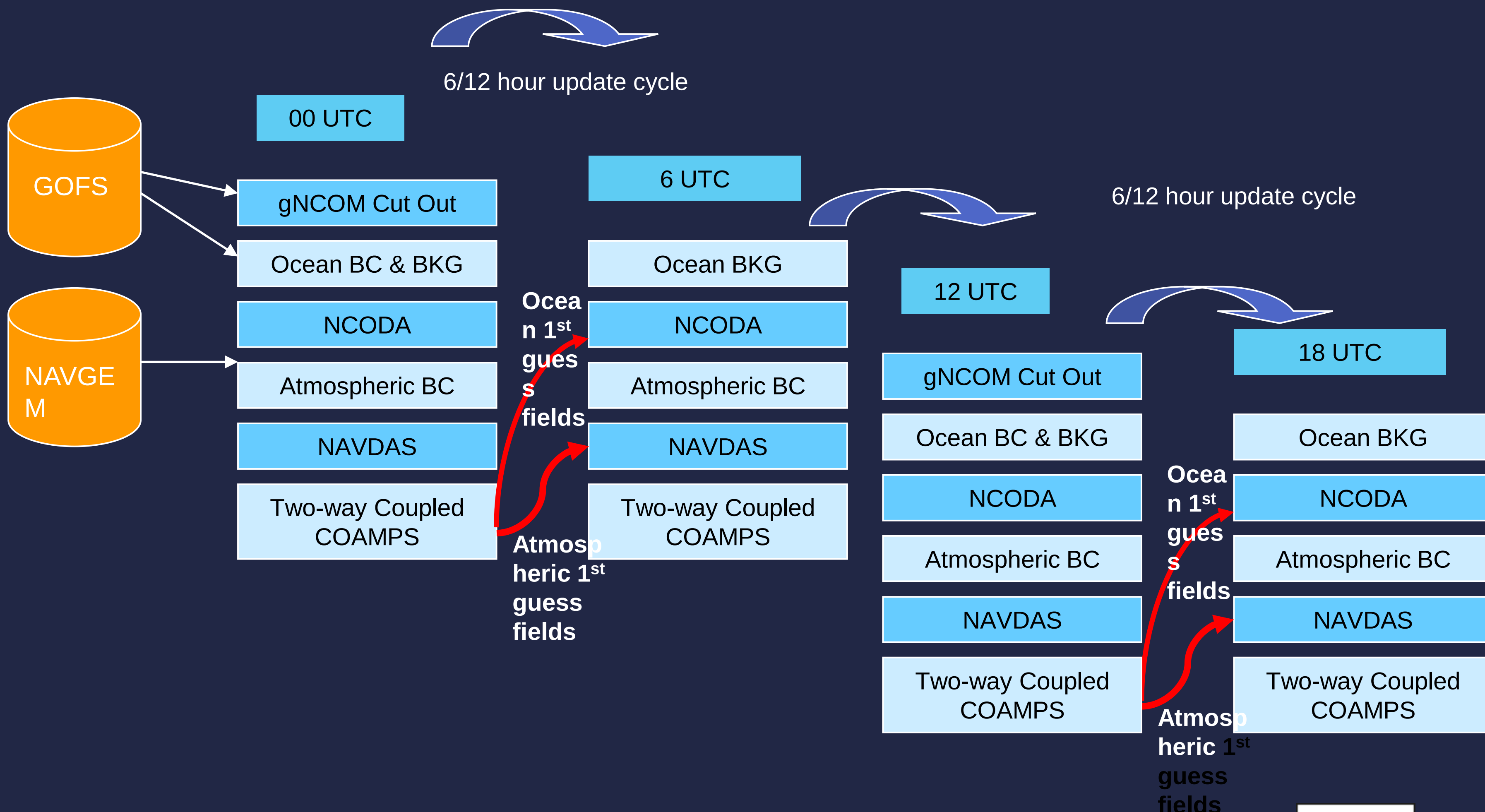
Motivation:

Stems from the CINDY/DYNAMO hypothesis III which states: “The **barrier-layer**, wind- and shear-driven mixing, shallow thermocline, and mixing-layer entrainment all play essential roles in the MJO initiation over the Indian Ocean by controlling the upper-ocean heat content and sea surface temperature, and thereby surface flux feedback”

Air-Ocean-Wave-ICE-LSM-Hydro Coupled COAMPS Forecast and Data Assimilation System



Coupled Data Assimilation System
(COAMPS, NAVDAS, and NCODA)



Coupled Ocean/Atmosphere Mesoscale Convective System (COAMPS®)

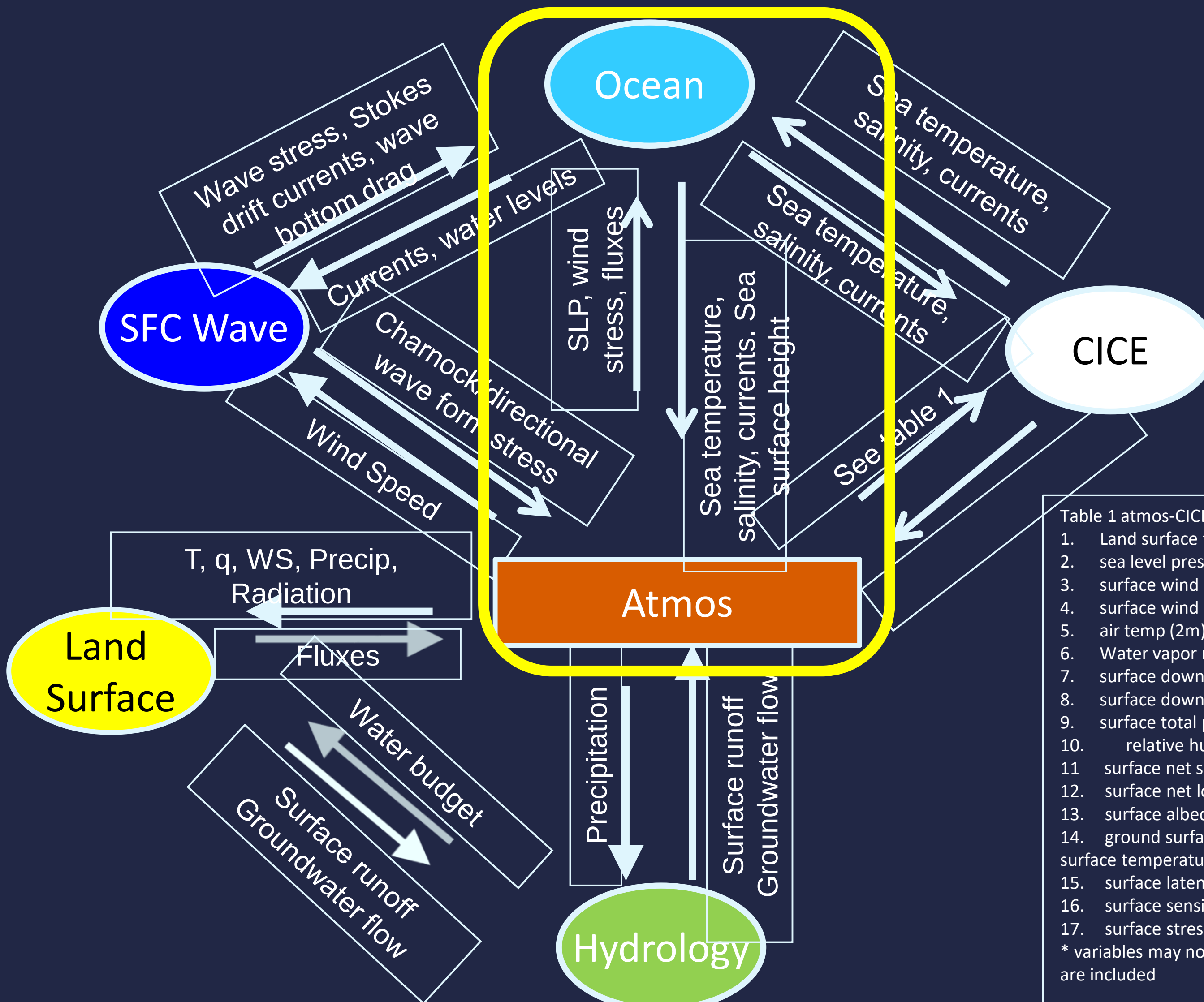
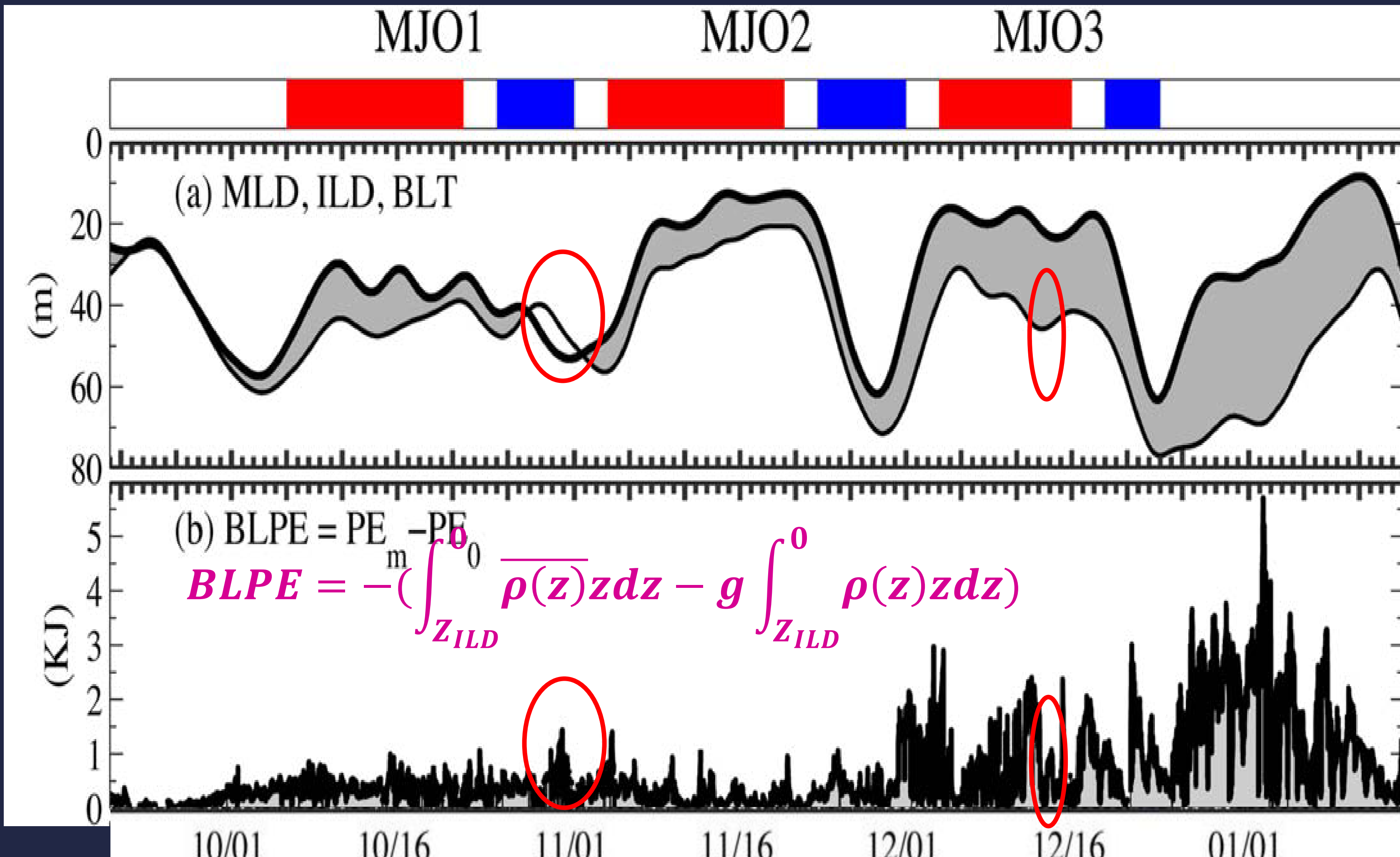


Table 1 atmos-CICE exchange fields

1. Land surface type
2. sea level pressure
3. surface wind U (10m)
4. surface wind V (10m)
5. air temp (2m)
6. Water vapor mixing ratio (2 m)
7. surface downward short wave flux
8. surface downward longwave flux
9. surface total precipitation
10. relative humidity (2m) *
11 surface net shortwave flux *
12. surface net longwave flux *
13. surface albedo *
14. ground surface temperature (i.e., sea surface temperature)*
15. surface latent heat flux *
16. surface sensible heat flux *
17. surface stress *

* variables may not be actually needed, but are included

DYNAMO Mooring



$$BLPE = -\left(\int_{z_{ILD}}^{0} \overline{\rho(z)}zdz - g\int_{z_{ILD}}^{0} \rho(z)zdz\right)$$

Chi et al. 2014, JGR ocean

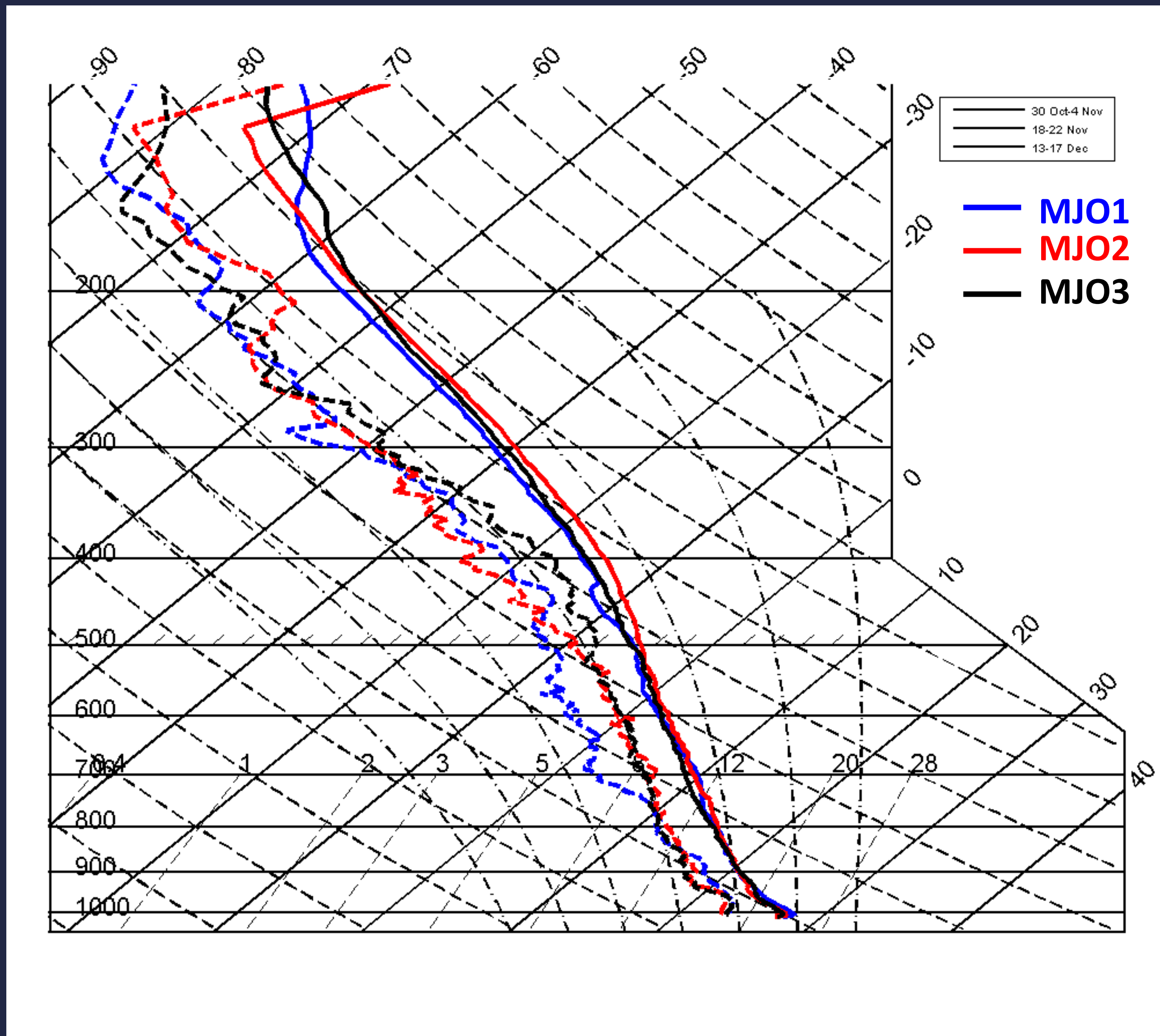
Hypothesis:

- Convective initiation is sensitive to the presence and the strength of an oceanic barrier layer

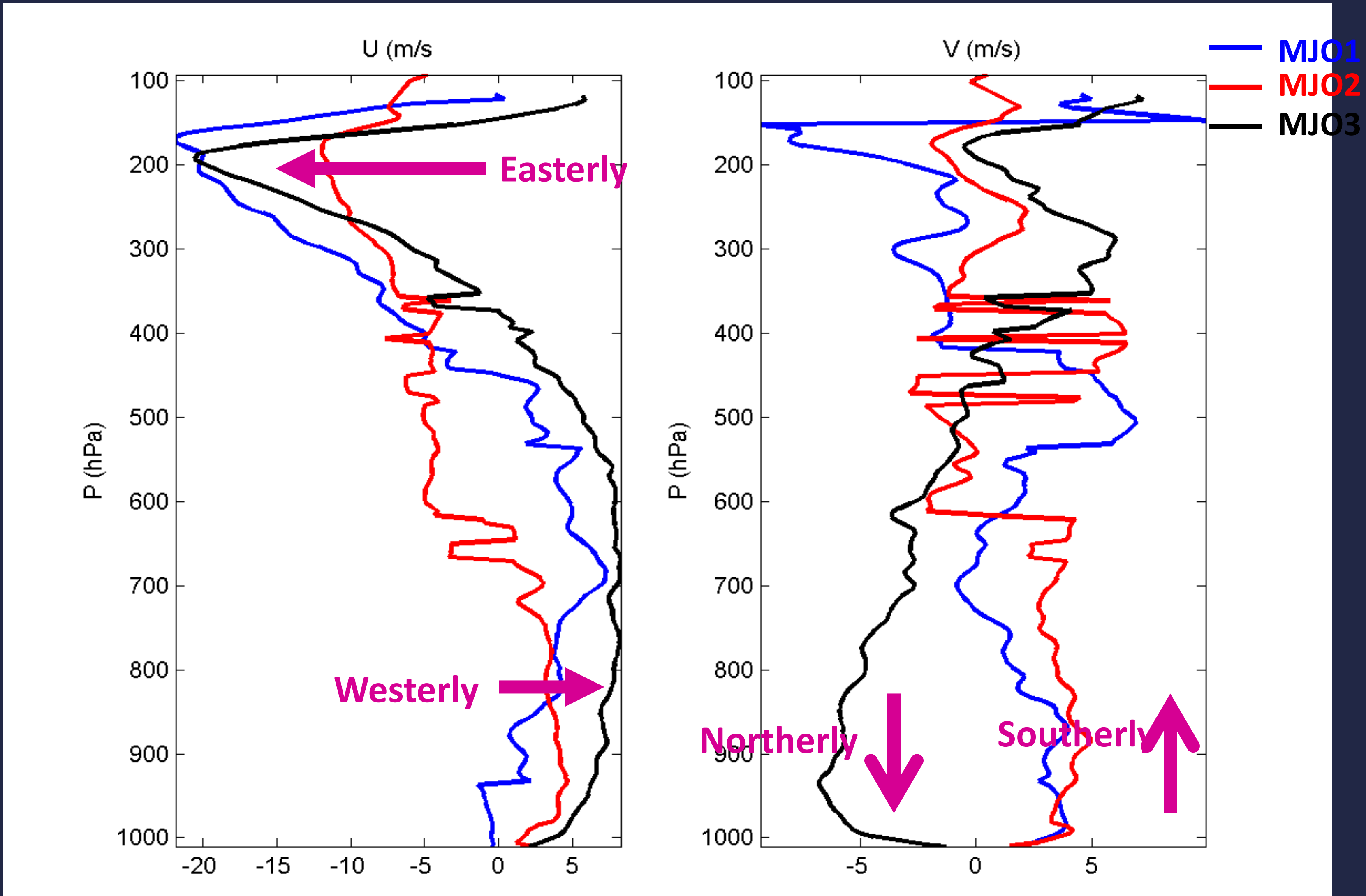
COAMPS Idealized Model Configuration

- Unstable atmospheric mean sounding from Gan
- Quiescent initial ocean (no initial currents)
- Initial ocean temperature and salinity profile from the DYNAMO mooring
- Model horizontal resolution - 1 km
- Model atmosphere is perturbed with 256 warm thermals that is 12 km wide and 2 km deep
- Simulation period: 38 h
- Control simulation: uncoupled
  - EXP1: coupled, ocean initial state from the 30 Oct T & S, barrier layer depth ~ 24 m
  - EXP2: As in EXP1, except S from 13 Dec, barrier layer depth ~ 56 m
- Horizontal homogenous initial SST for all three experiments: 29.8 °C

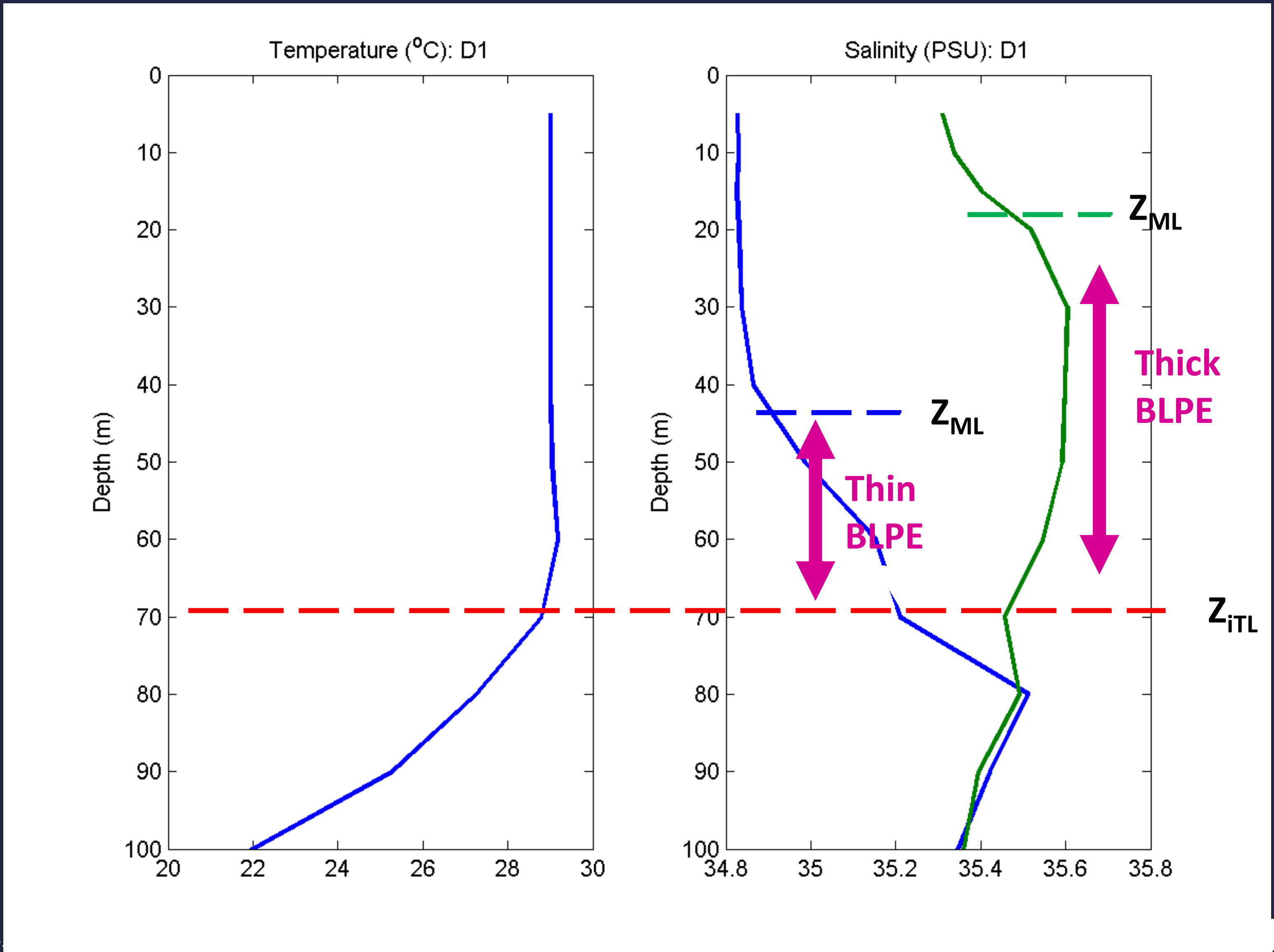
Mean Gan soundings prior to MJO1, MJO2, and MJO3 initiation



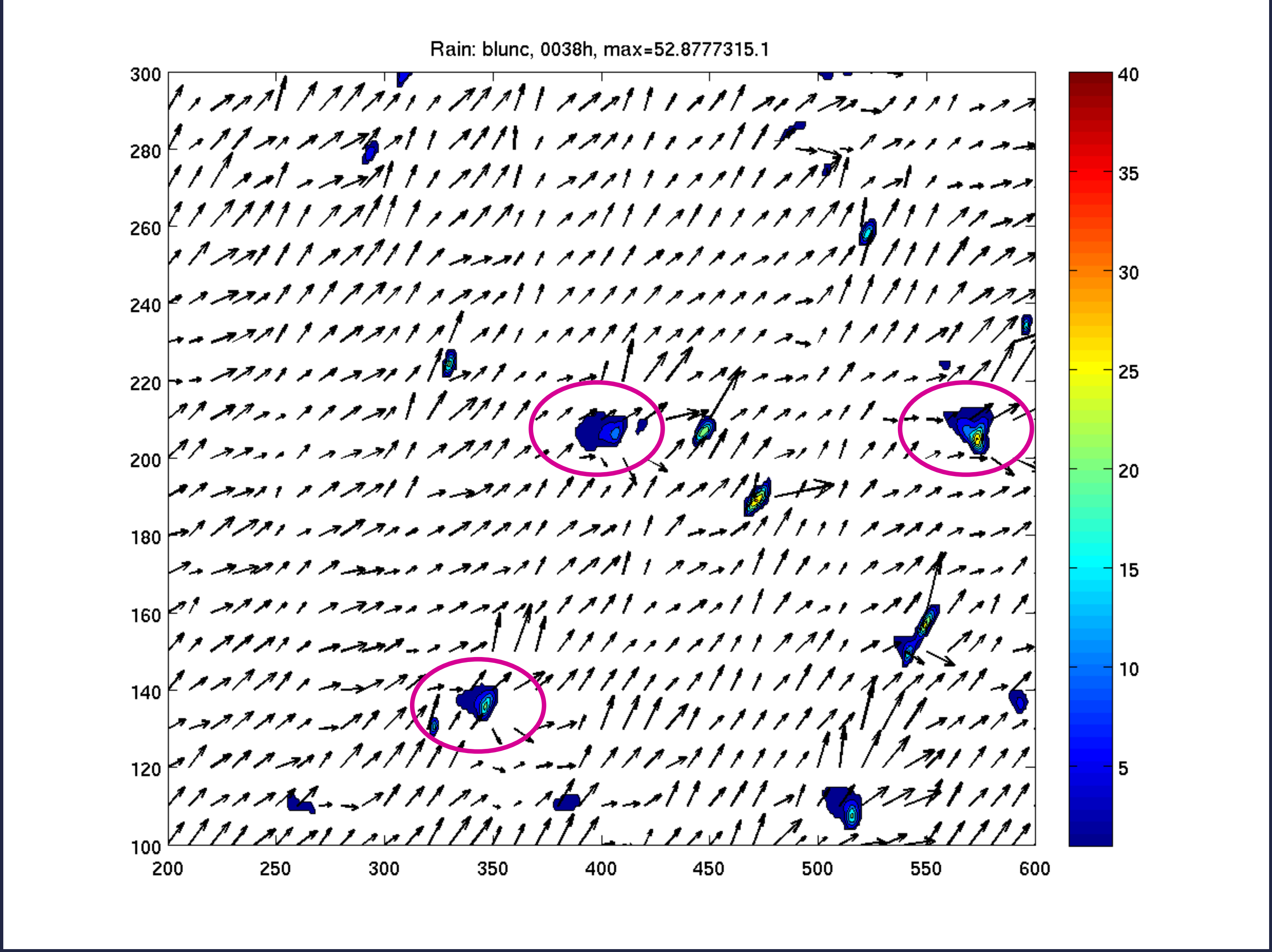
Mean Gan U and V Profiles Prior to MJO1, MJO2, and MJO3 Initiation



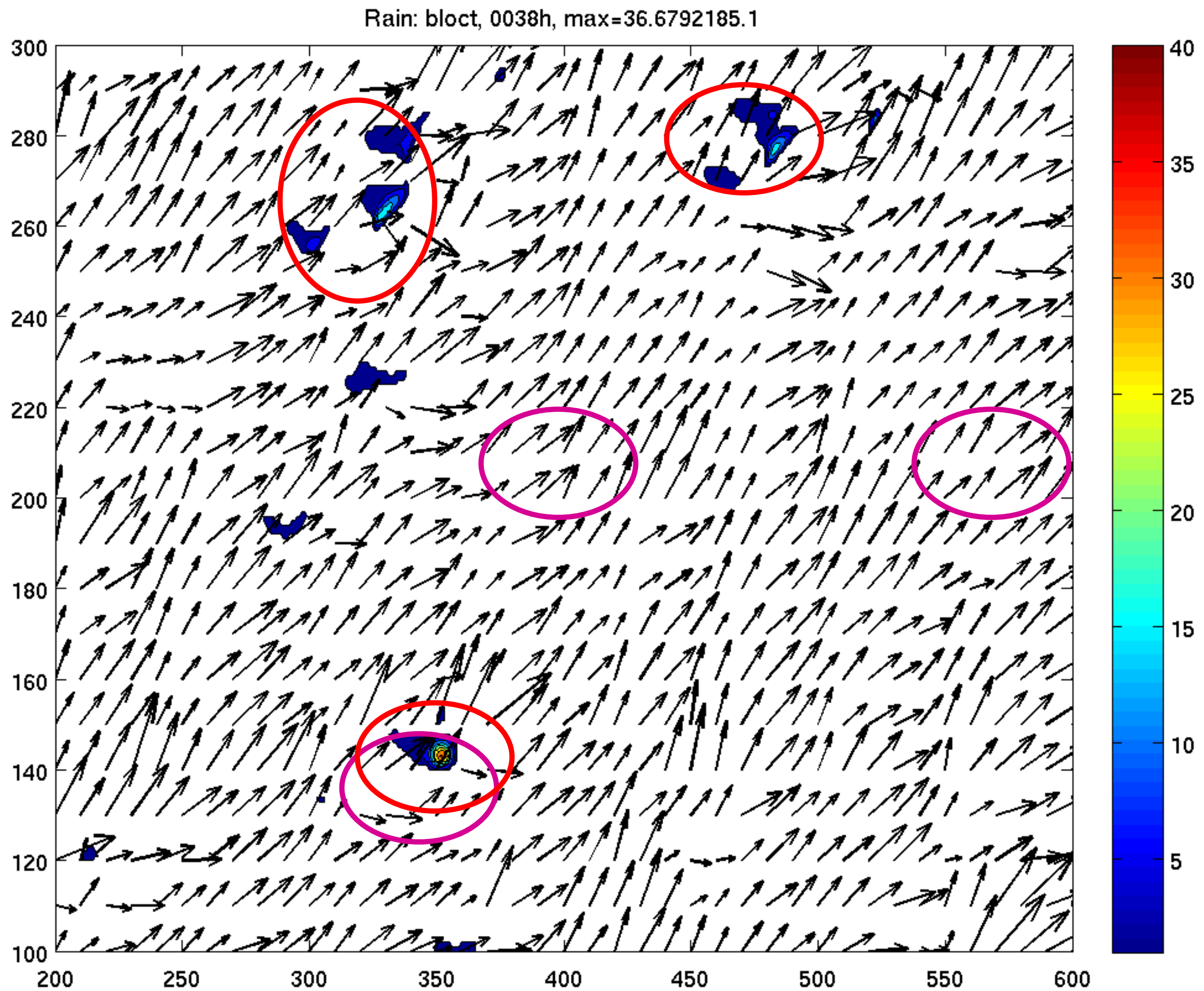
COAMPS Initial Ocean T&S Profiles



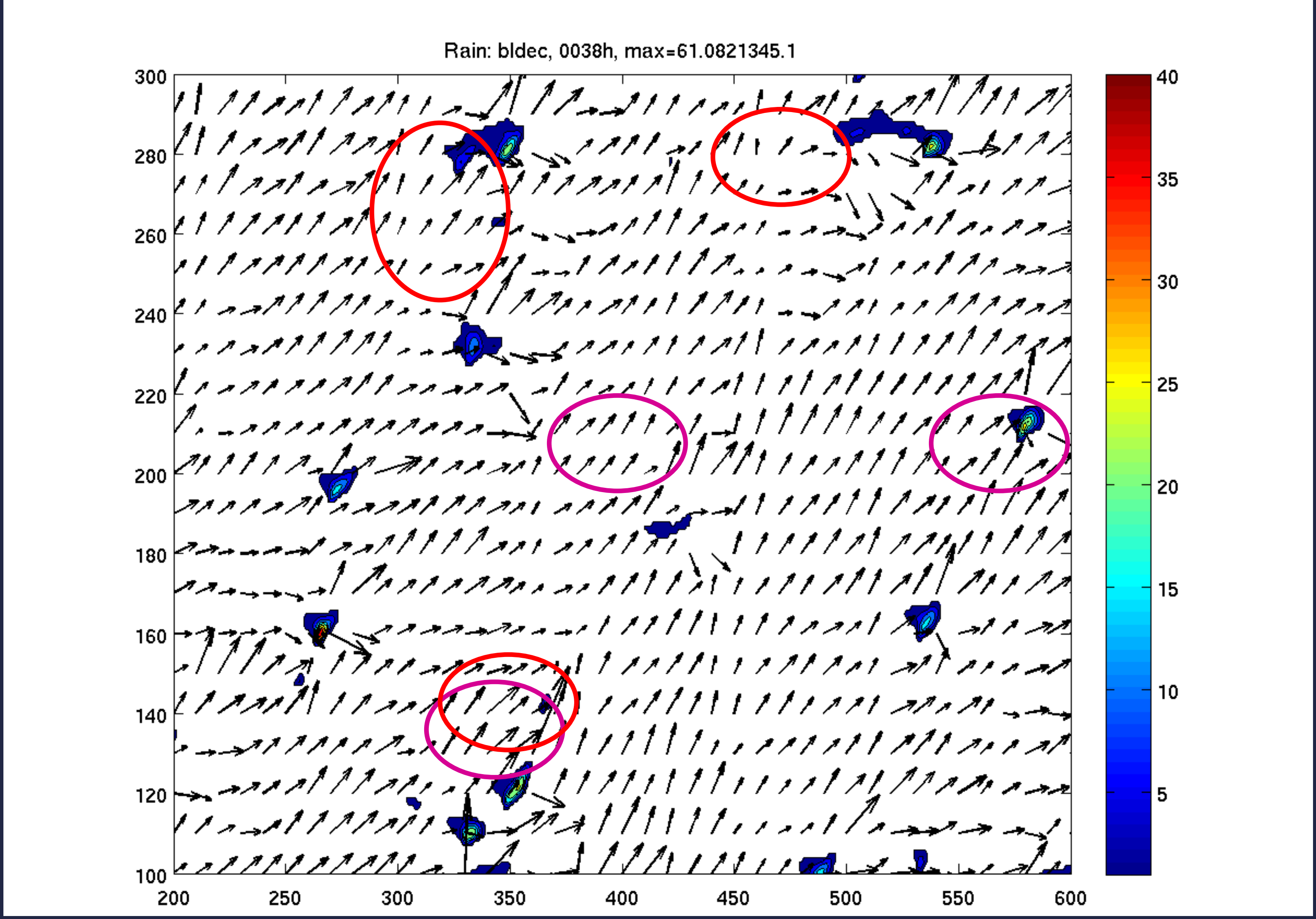
38 h: 2 pm LT, uncoupled, maximum rain rate: 53 mm/h



38 h: 2 pm LT, coupled, thin BL, maximum rain rate: 37 mm/h



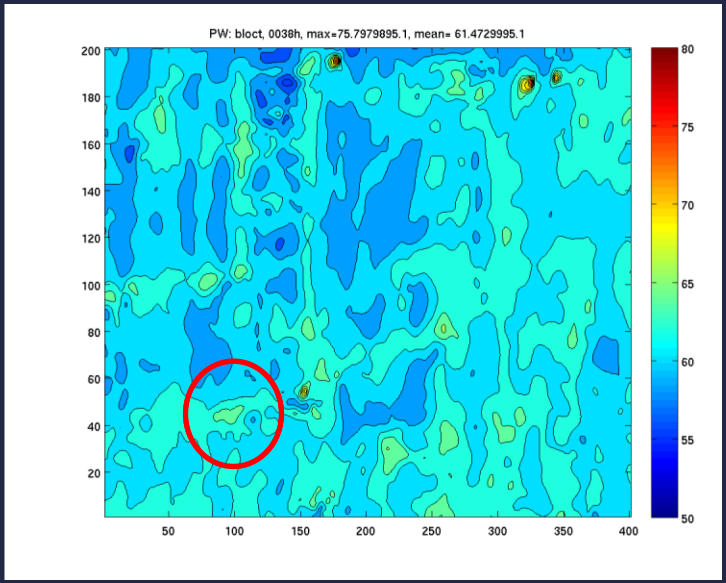
38 h: 2 pm LT, coupled, thick BL, maximum rain rate: 61 mm/h



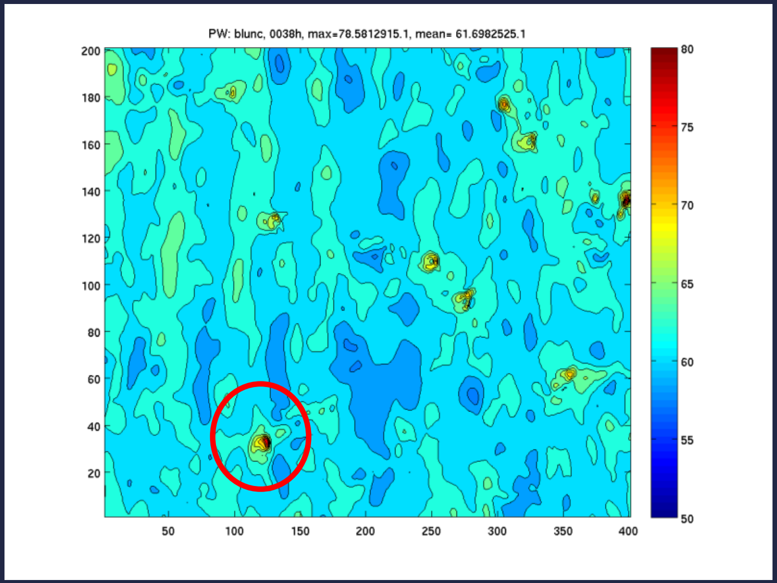
- The convection in the thick BL experiment is stronger and the rain is heavier than the thin BL and the uncoupled experiments

Atmospheric Moisture Change

38 h: Thin BL, max PW=76 mm, mean PW=61.5 mm

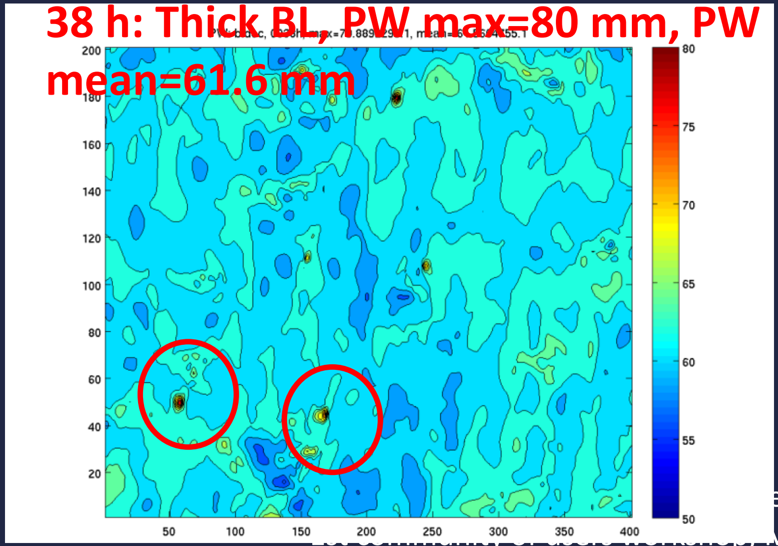


38 h: Uncoupled, PW max=79 mm, PW mean=61.7 mm



Initial PW is 62.4 mm

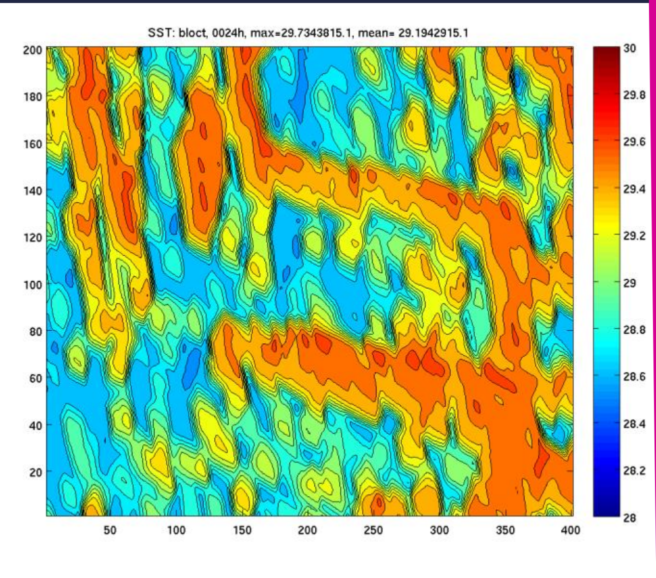
38 h: Thick BL, PW max=80 mm, PW mean=61.6 mm



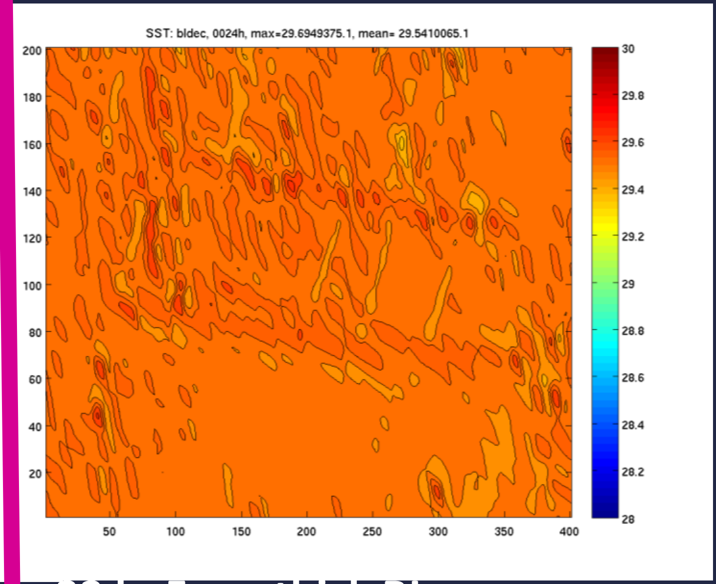
- **All three experiments remove the atmospheric moisture from rain fallout**
- **The thick BL experiment has the highest local increase of PW value compared to the other two experiments**

SST Change

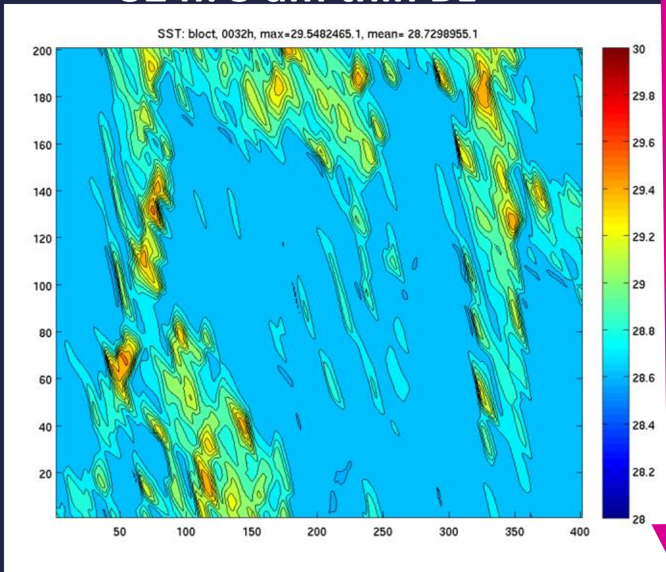
24 h: 11 pm, thin BL



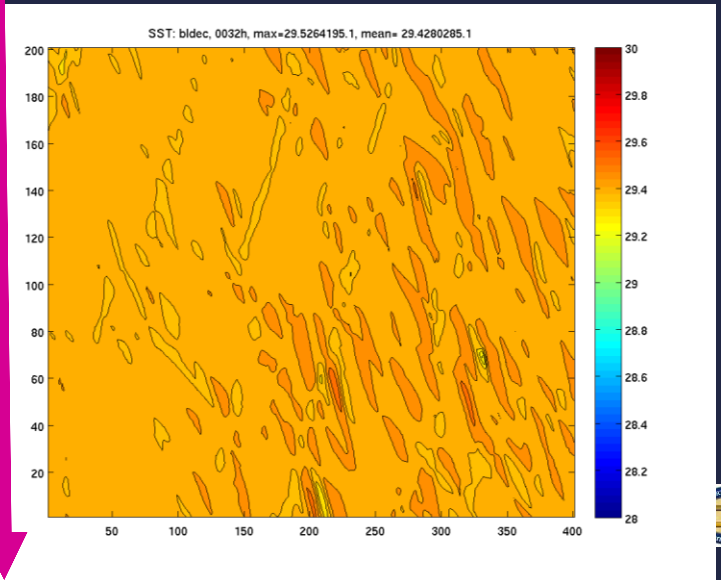
24 h: 11 pm, thick BL



32 h: 5 am thin BL



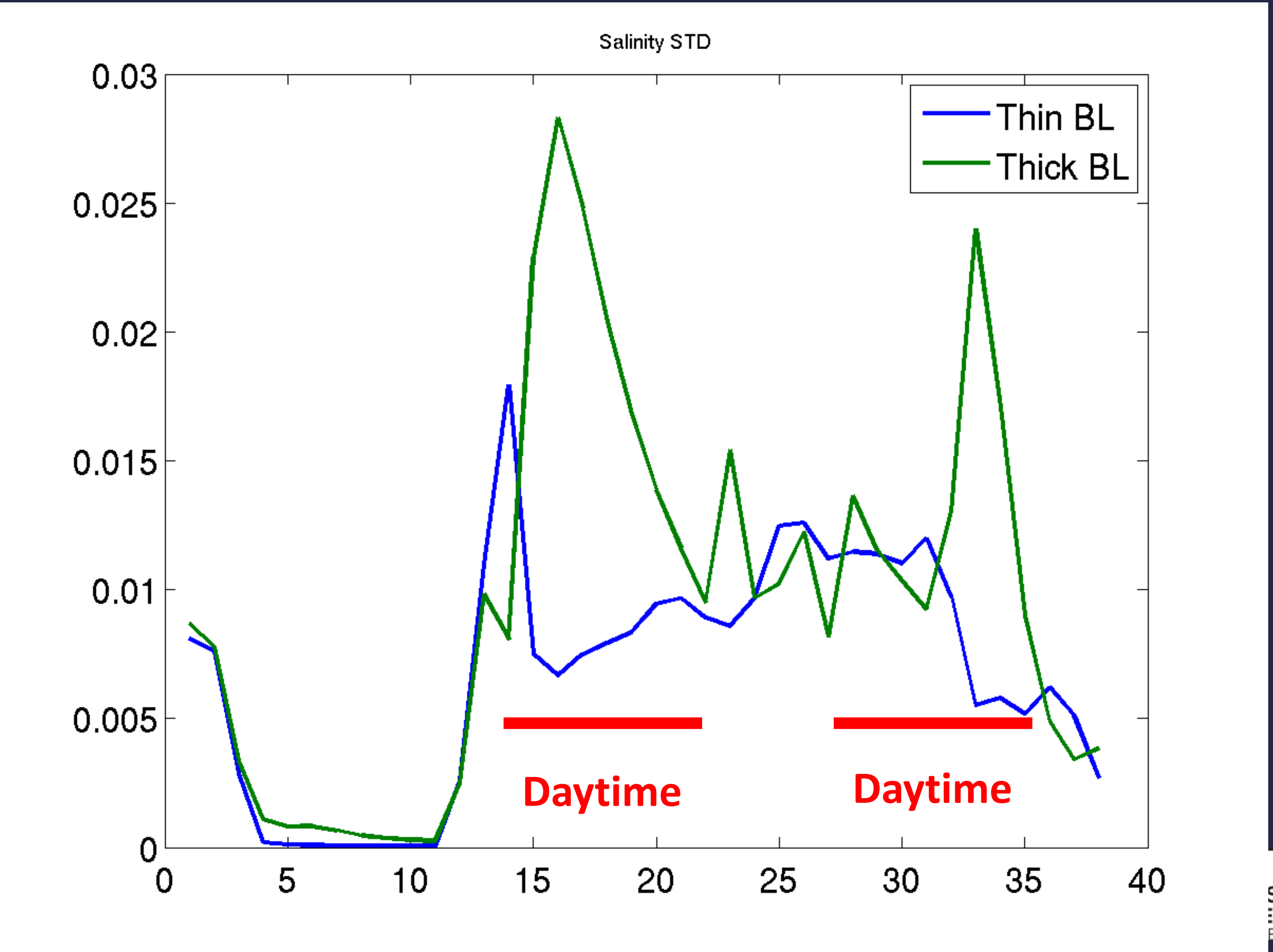
32 h: 5 am thick BL



- SST in the thick BL experiment remains 0.5 C° warmer than the thin BL experiment at nighttime

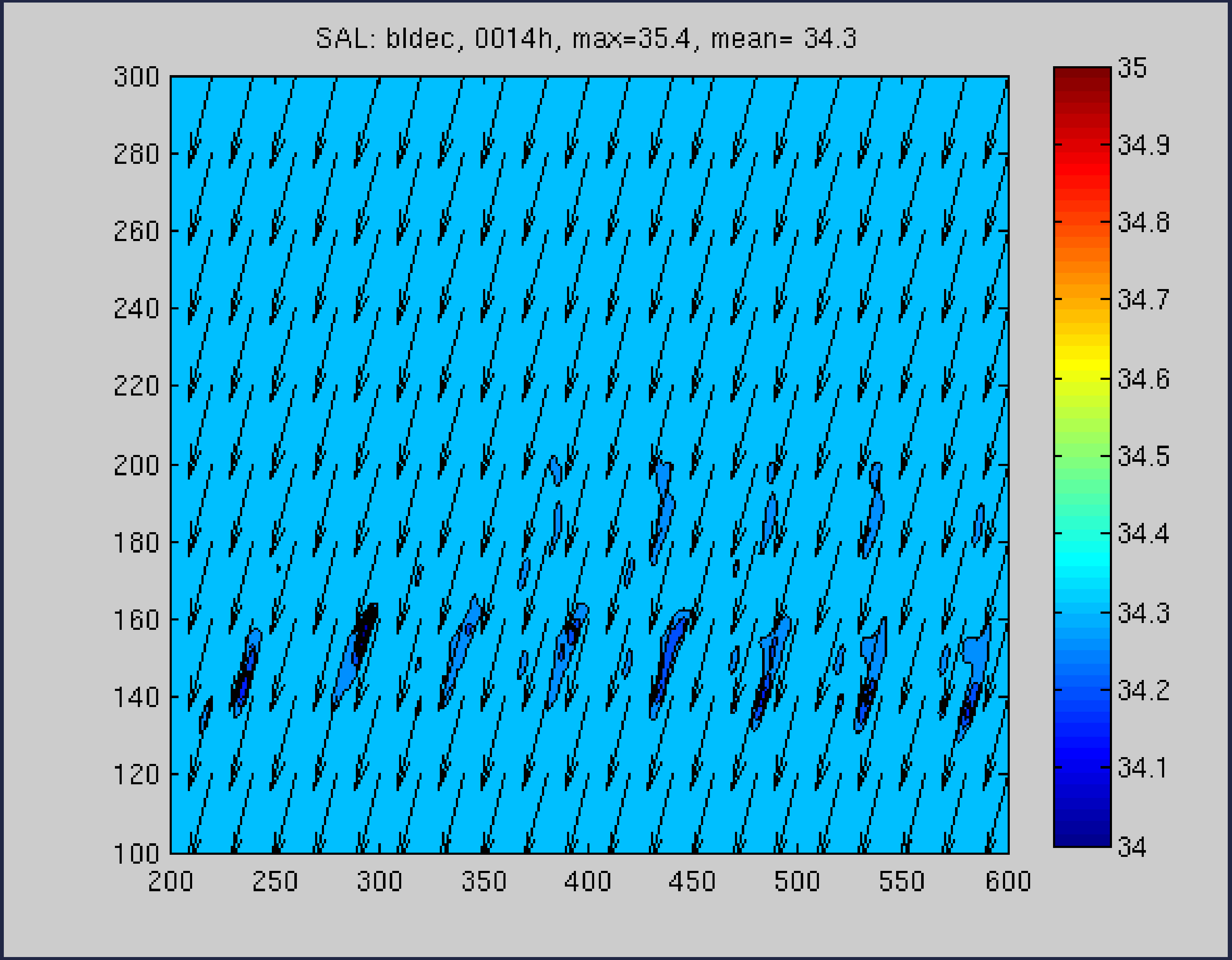
Surface Salinity Change: Rain+Evaporation

- The surface salinity variability for the thick BL experiment is larger than the thin BL experiment

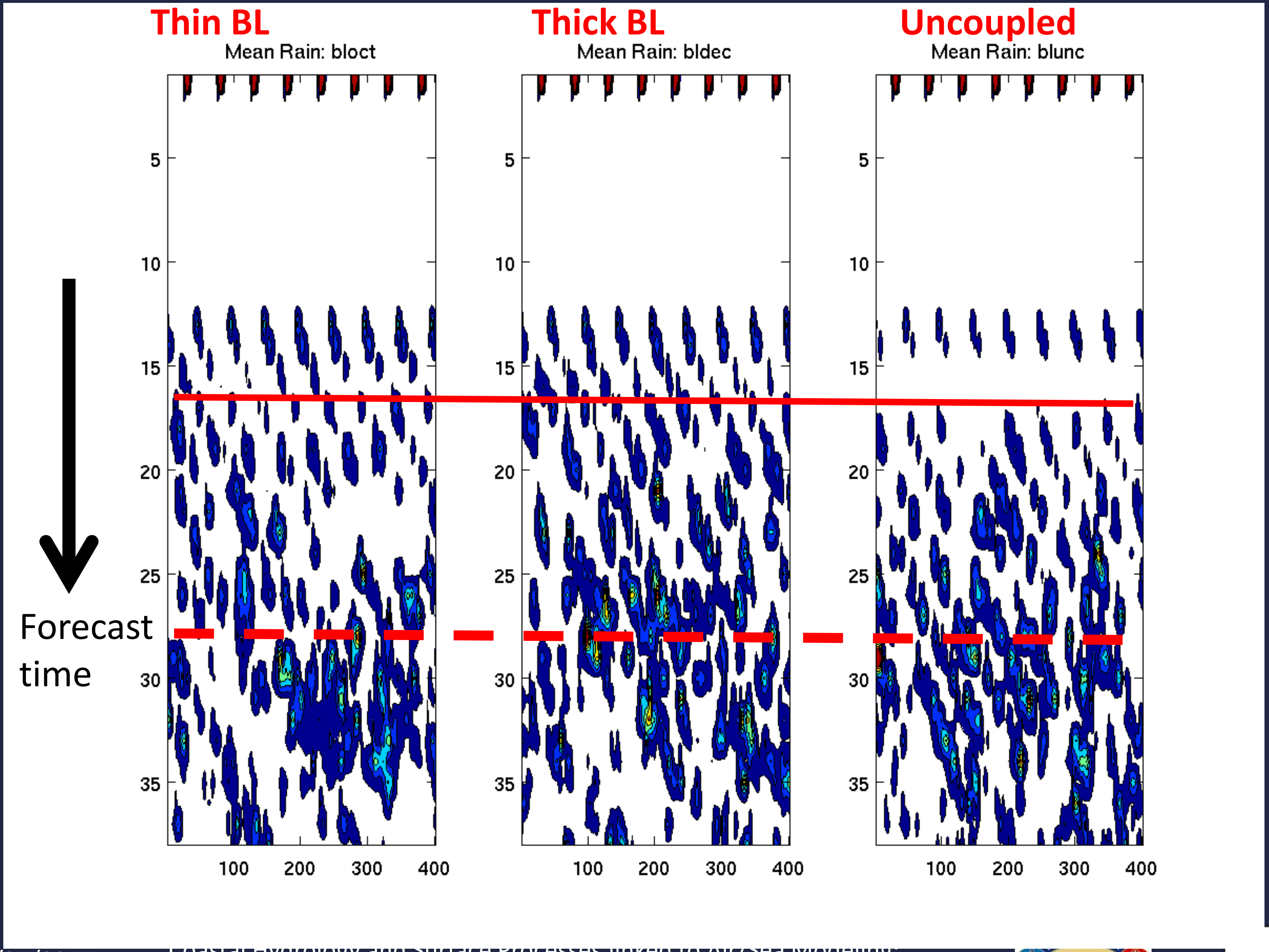


S.NAVAL
ESEARCH
BORATORY

Thick BL Surface Salinity Movie



- **The thick BL experiment has the strongest convection initiated few hours before the other two experiments**



Summary

- High-resolution coupled idealized COAMPS simulations are conducted to systematically exam the sensitivity of convective development in the absence of large-scale synoptic forcing to the presence of an oceanic barrier layer (BL) and the strength of BL

Summary

- High-resolution coupled idealized COAMPS simulations are conducted to systematically exam the sensitivity of convective development in the absence of large-scale synoptic forcing to the presence of an oceanic barrier layer (BL) and the strength of BL
- The thick BL experiment has the highest local increase of PW value compared to the other two experiments due to stronger convective transport of moisture

Summary

- High-resolution coupled idealized COAMPS simulations are conducted to systematically exam the sensitivity of convective development in the absence of large-scale synoptic forcing to the presence of an oceanic barrier layer (BL) and the strength of BL
- The thick BL experiment has the highest local increase of PW value compared to the other two experiments due to stronger convective transport of moisture
- **The surface salinity variability for the thick BL experiment is larger than the thin BL experiment**

Summary

- High-resolution coupled idealized COAMPS simulations are conducted to systematically exam the sensitivity of convective development in the absence of large-scale synoptic forcing to the presence of an oceanic barrier layer (BL) and the strength of BL
- The thick BL experiment has the highest local increase of PW value compared to the other two experiments due to stronger convective transport of moisture
- The surface salinity variability for the thick BL experiment is larger than the thin BL experiment
- **The thick BL experiment has a 0.1 mm increase of PW after 38 h forecast compared to the thin BL experiment**

Summary

- High-resolution coupled idealized COAMPS simulations are conducted to systematically exam the sensitivity of convective development in the absence of large-scale synoptic forcing to the presence of an oceanic barrier layer (BL) and the strength of BL
- The thick BL experiment has the highest local increase of PW value compared to the other two experiments due to stronger convective transport of moisture
- The surface salinity variability for the thick BL experiment is larger than the thin BL experiment
- The thick BL experiment has a 0.1 mm increase of PW after 38 h forecast compared to the thin BL experiment
- **The time-longitude plots of the rain showed the initiation of strong convection occurs ~ 2 h earlier than the thin BL experiment**

Hypothesis is validated

- Convective initiation is sensitive to the presence and the strength of an oceanic barrier layer

Future Work

- Extend the simulation time to exam the barrier layer influence on the convective cloud and radiative equilibrium

Future Work

- Extend the simulation time to exam the barrier layer influence on the convective cloud and radiative equilibrium
- Expend the current work to include more parameter space such as different large-scale environment, barrier layer strength, and ocean mixing