Convective Initiation Sensitivity to the Presence of An Oceanic Barrier Layer

Sue Chen\textsuperscript{1}, Jerome Schmidt\textsuperscript{1}, Maria Flatau\textsuperscript{1}, James Richman\textsuperscript{2}, Tommy Jensen\textsuperscript{2}

\textsuperscript{1}Naval Research Laboratory, Monterey, California
\textsuperscript{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

**ESMF/NUOPC**

**User configurable 6 or 12 hr atmosphere update cycle**

**NAVDAS**

- Atmos OBS
  - Atmosphere Setup
  - NAVGEM
  - GALWEN-LIS
  - ATMOSPHERE BC (ANALYSIS)

**NCODA**

- NCODA QC
  - Database:
    - SST, SSH, ICE, PROF, SHIP, GLDR
- Ocean OBS
  - GLOBE WVS Climo
  - Obs, remote sensing, text

**COAMPS®**

- CICE
- Hydrology
- LSM
- BOB
- WAVE Setup
- gWW3
- SWAN/WW3
- Ocean Setup
- NCOM/ROMS

**DATABASE**

- GDEM MODAS
- DBDBV DBDB2 DBDB2
- OSUTide Rivers

**NCODA QC**

- SST, SSH, ICE, PROF, SHIP, GLDR

**Ocean OBS**

- NAVGEM
- GALWEN-LIS
- ATMOSPHERE BC (ANALYSIS)
Coupled Data Assimilation System
(COAMPS, NAVDAS, and NCODA)

- GOFS
- NAVGEM
- gNCOM Cut Out
- Ocean BC & BKG
- NCODA
- Atmospheric BC
- NAVDAS
- Two-way Coupled COAMPS

6/12 hour update cycle

- 00 UTC
- 6 UTC
- 12 UTC
- 18 UTC

- Ocean BKG
- Atmospheric BC
- NAVDAS
- Two-way Coupled COAMPS
- NCODA
- gNCOM Cut Out
- Ocean BC & BKG
- Atmospheric BC
- NAVDAS
- Two-way Coupled COAMPS
- NCODA
- Atmospheric BC
- NAVDAS
- Two-way Coupled COAMPS
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 (2m)
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

9/27/2017 Coastal Hydrology and Surface Processes linked to Air/Sea Modeling: 1st community of users workshop, Madeira, Portugal
Chi et al. 2014, JGR ocean

Coastal Hydrology and Surface Processes linked to Air/Sea Modeling: 1st community of users workshop, Madeira, Portugal
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

Temperature (°C): D1

Salinity (PSU): D1

Depth (m)

Temperature

Salinity

Z

ML

Z

ML

Z

iTL

Z

 thinner BLPE

Z

 thinner BLPE

Z

iTL
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
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
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 examine 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 examine 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 examine 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 examine the barrier layer influence on the convective cloud and radiative equilibrium.
- Expand the current work to include more parameter space such as different large-scale environment, barrier layer strength, and ocean mixing.