WRF NUMERICAL MODEL SIMULATIONS OF THE FLORIDA SEA BREEZE AND ITS ASSOCIATED CONVECTION

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PROJECT MOTIVATION AND INTRODUCTION

- Difficulty of regional numerical weather prediction (NWP) models in simulating timing, location, and/or intensity of warm season convection$_1$, including Florida sea breeze (FLSB)
- NWP forecasting challenges due to grid size, initial/boundary conditions, microphysics (MP) entrainment effects, cumulus (CU) and planetary boundary layer (PBL) effects, etc.
- Study focuses on real-data numerical simulations' predictability to accurately forecast the FLSB and its associated convective initiation (CI) in the gray zone grid spacing
- WRF simulation experiments were conducted utilizing various model initialization times and input data, physics options, and parameterization schemes to study model sensitivity
- Simulation experiment results were verified against surface observations, Stage IV analysis, Climatology-Calibrated Precipitation Analysis (CCPA), and North American Regional Reanalysis (NARR) data to determine best results of the WRF simulations
- Best numerical results are further examined to understand dynamic and geophysical mechanisms controlling interactions between SB/CI in the gray zone grid spacing

WEATHER RESEARCH AND FORECASTING (WRF) MODEL

- Advanced Research WRF (ARW) Model v3.7.1$_2$
- Four nested domains
- 62 vertical eta levels (26 levels below 850 hPa)
- 50 hPa model top
- Horizontal resolutions (see Fig. 1):
  - 27 km (d01, color map)
  - 9 km (d02, white box)
  - 3 km (d03, red box)
  - 1 km (d04, white box)
- 120s time step, run for 48-24h (until 07/1200 UTC)

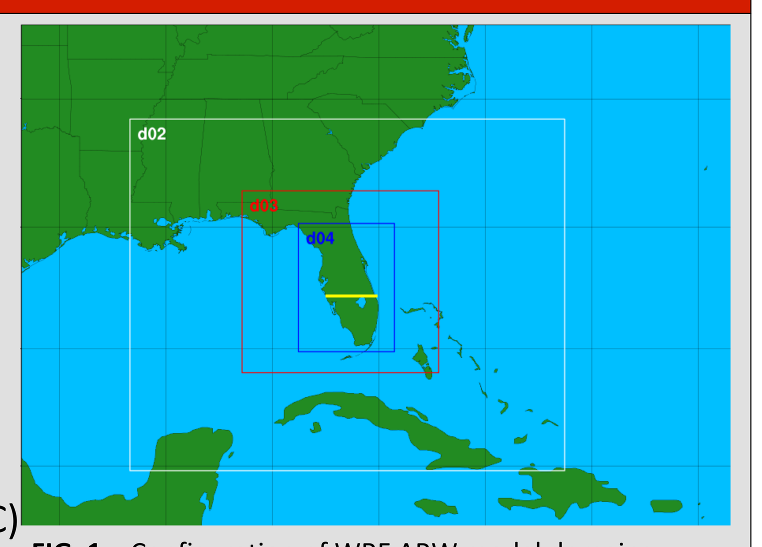

FIG. 1. Configuration of WRF ARW model domains.

FLORIDA SEA BREEZE CASE STUDY DESCRIPTION

- 6-7 Sep 2012 case study: Type 3 FLSB event with slight synoptic influence$_3$
- East coast and west coast sea breezes (ECSB/WCSB) initiated at 1320-1400 UTC; WCSB convection initiated at 1400-1500 UTC; ECSB convection initiated at 1600-1700 UTC
- SB fronts (SBFs) merge at 2030 UTC to produce strong squall line convection; convection ceases at 0500 UTC on 7 Sep 2012

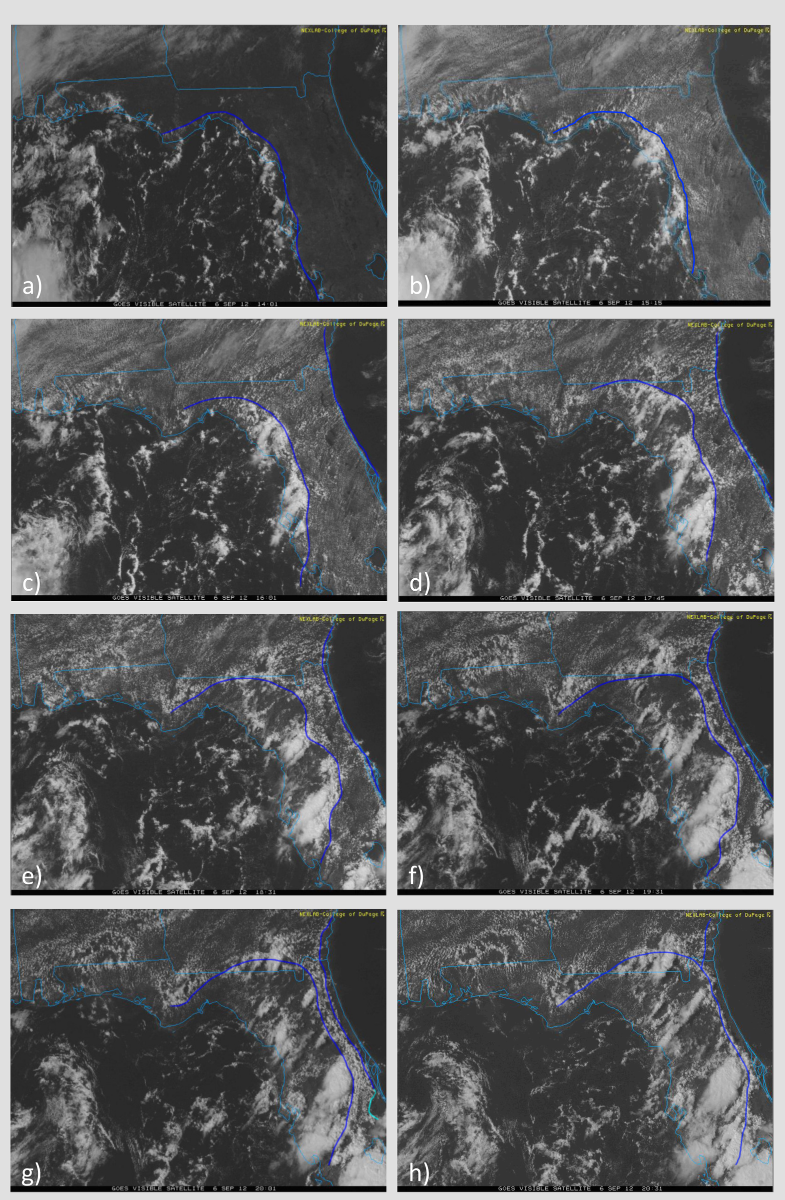

FIG. 2. GOES-E visible satellite images of convective cloud cover over the Florida peninsula at a) 1401 UTC, b) 1515 UTC, c) 1601 UTC, d) 1745 UTC, e) 1831 UTC, f) 1931 UTC, g) 2001 UTC, and h) 2031 UTC 6 Sep. Blue lines indicate the locations of the west coast and east coast sea breeze fronts. Images courtesy of College of DuPage and Carl Jones.

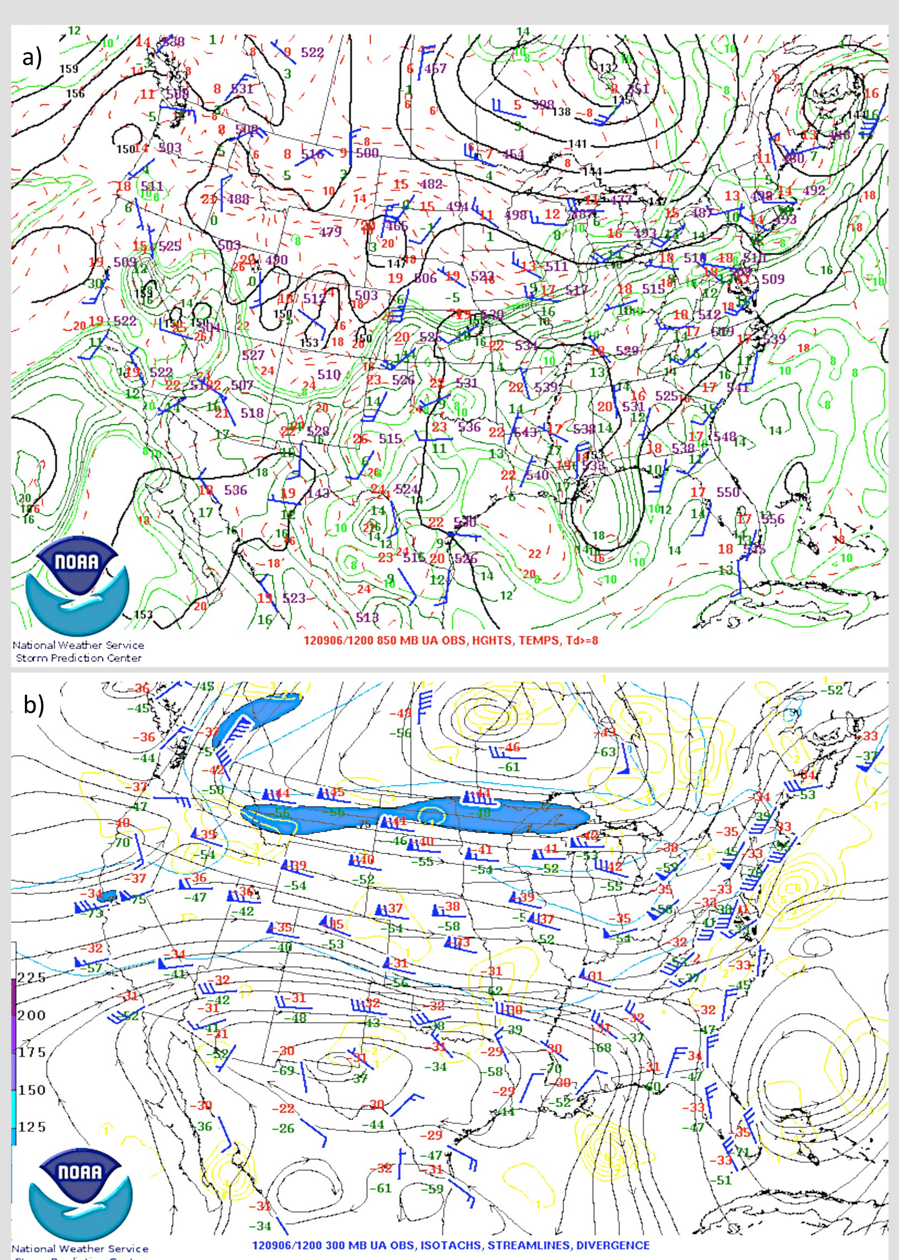

FIG. 3. Upper air analyses at 1200 UTC 6 Sep for a) 850 hPa obs, heights (black contours), temps (red contours), and dew point temps (green contours) and b) 300 hPa obs, streamlines (black contours), divergence (yellow contours), and isotachs (blue shading).

TABLE 1: WRF EXPERIMENT LIST AND CI TIMING RESULTS

WRF Exps	WRF Initialization, Parameterization, and Physics Options*							CI Event Timing*** (Mins)				
	Initialization Data/TIme	Nesting Feedback	CU** Param	MP Param	PBL Param	Sfc Layer	Land Sfc	Strt NW	Strt SW	Strt SE	Strt NE	End
Cntrl	NAM 06/00Z	1-way	KF	Thompson	YSU	MM5	Noah	-120	✓	+180	+60	✓
N0512	NAM 05/12Z	1-way	KF	Thompson	YSU	MM5	Noah	-180	-180	+300	-120	✓
N0518	NAM 05/18Z	1-way	KF	Thompson	YSU	MM5	Noah	-120	-180	+60	✓	✓
N0606	NAM 06/06Z	1-way	KF	Thompson	YSU	MM5	Noah	+60	+60	+180	+120	✓
N0612	NAM 06/12Z	1-way	KF	Thompson	YSU	MM5	Noah	+180	+120	+120	+60	+60
G0600	GFS 06/00Z	1-way	KF	Thompson	YSU	MM5	Noah	-60	✓	+180	+60	✓
2way	NAM 06/00Z	2-way	KF	Thompson	YSU	MM5	Noah	-120	-60	-120	✓	✓
CU1	NAM 06/00Z	1-way	GF	Thompson	YSU	MM5	Noah	+60	✓	+180	+60	+60
CU2	NAM 06/00Z	1-way	G3	Thompson	YSU	MM5	Noah	-60	✓	+120	+60	+240
CU3	NAM 06/00Z	1-way	NSAS	Thompson	YSU	MM5	Noah	-60	✓	+120	+60	+120
CU4	NAM 06/00Z	1-way	NT	Thompson	YSU	MM5	Noah	-60	+60	+120	+60	✓
MP1	NAM 06/00Z	1-way	KF	Lin	YSU	MM5	Noah	-60	✓	+180	+60	+60
MP2	NAM 06/00Z	1-way	KF	WSM6	YSU	MM5	Noah	-120	✓	✓	+60	+60
MP3	NAM 06/00Z	1-way	KF	Morrison	YSU	MM5	Noah	-60	+60	+180	+60	✓
MP4	NAM 06/00Z	1-way	KF	SBU-YLin	YSU	MM5	Noah	-180	✓	-180	+60	+120
PBL1	NAM 06/00Z	1-way	KF	Thompson	MYJ	MO-JE	Noah	✓	✓	✓	+60	+60
PBL2	NAM 06/00Z	1-way	KF	Thompson	MYNN3	MYNN	Noah	✓	-60	+180	+120	+60
PBL3	NAM 06/00Z	1-way	KF	Thompson	ACM2	PX	PX	+60	+120	+240	+180	+60
PBL4	NAM 06/00Z	1-way	KF	Thompson	QNSE	QNSE	Noah	+300	+120	+180	+60	+120
PBL5	NAM 06/00Z	1-way	KF	Thompson	GBM	MM5	Noah	+120	+120	+240	+120	-60
GPBL1	GFS 06/00Z	1-way	KF	Thompson	MYJ	MO-JE	Noah	✓	✓	+120	+60	✓

*Orange indicates changes to Cntrl (gray); RRTM LW & Dudia SW radiation schemes used for all exps
**Cumulus parameterization schemes applied only to outermost domains (d01 & d02)
***Timing error color codes for d03 results: Blue negative Red positive Green zero

RESULTS AND DISCUSSION OF "BEST" (PBL1) SIMULATION

- ECSB and WCSB initiated at 1340-1420 UTC (20 mins after observations) and reach max depth of 700-900m; WCSB propagates at avg speed of 6 ms^{-1}, ECSB at 2-3 ms^{-1}
- WCSB convection initiated at 1400-1500 UTC (same as observations); ECSB convection initiated at 1600-1800 UTC (0-1 hour after observations); SBFs merge at 2030-2100 UTC (same as observations) to produce an enhanced convective squall line; convection ceases at 0600 UTC (1 hour after observations)
- Timing and location of SB convection is best early in the simulation (until 06/2200 UTC), while after this time, the orientation of the simulated convection becomes much worse: this is due to the simulation weakening the synoptic winds too soon, allowing the ECSB to penetrate further inland than the observations

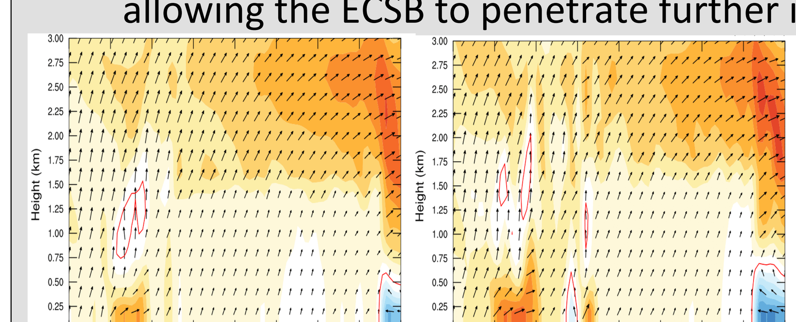

FIG. 3. Cross section (yellow line in Fig. 1) of d03 PBL1 WRF zonal winds (shading: red east, blue west; units m s^{-1}) and total horizontal wind vectors (black arrows, reference vector 10 m s^{-1}) at: 1700 UTC (left) and 1800 UTC (right) 6 Sep 2012.

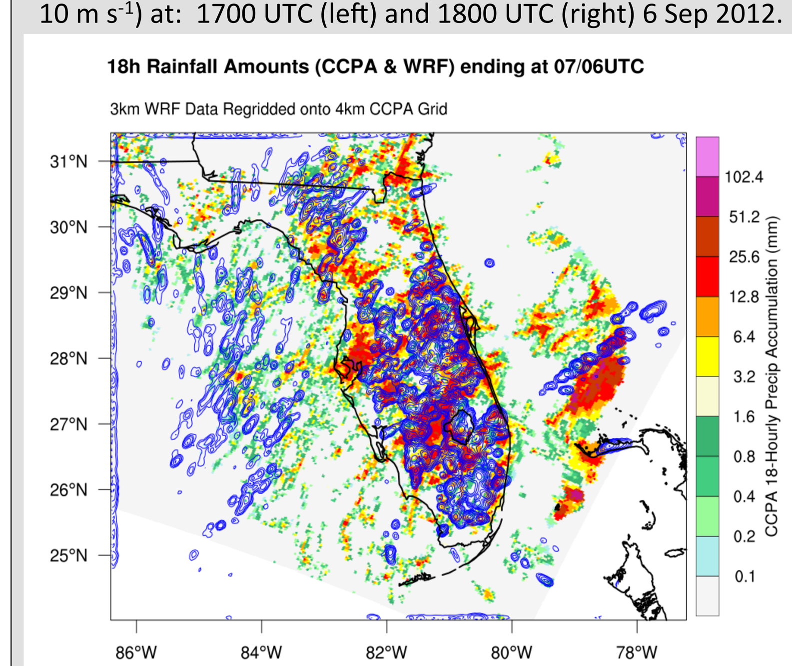

FIG. 4. 18-h rainfall accumulation from 1200 UTC 6 Sep to 0600 UTC 7 Sep for CCPA data (shading; units mm hr^{-1}) and d03 PBL1 WRF simulated data (blue contours; units mm hr^{-1}).

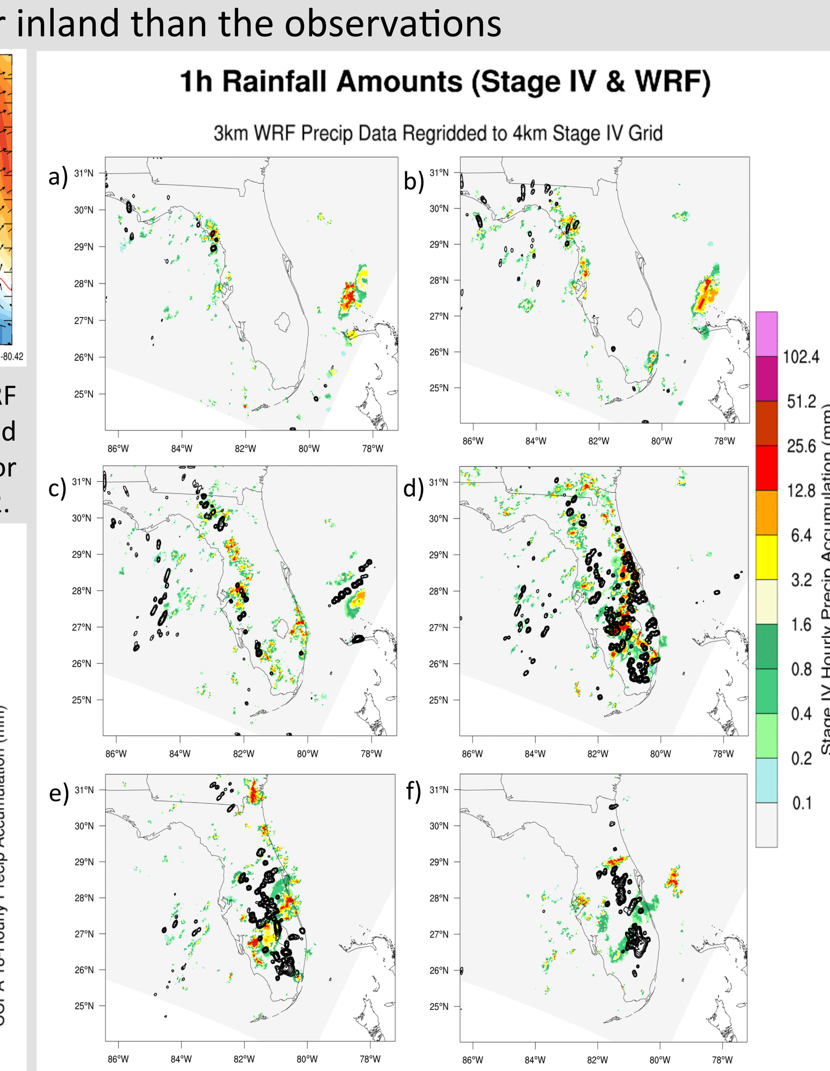

FIG. 5. D03 PBL1 WRF hourly precipitation accumulation (black contours; units mm hr^{-1}) and Stage IV precipitation analysis (color contours; units mm hr^{-1}) at: a) 1400 UTC, b) 1600 UTC, c) 1800 UTC, d) 2100 UTC, e) 2300 UTC on 6 Sept 2012 and f) 0100 UTC on 7 Sept 2012.

GEOPHYSICAL CONTROLS ON SB CONVECTION IN THE GRAY ZONE

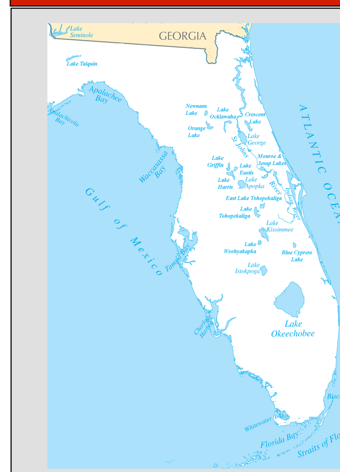

FIG. 6. FL water bodies, including lakes greater than 25 km².

- Sensible heating, synoptic winds, coastline shape, and low-level moisture are prime ingredients in initiating the lift, inhibition, dilution, and buoyancy$_4$ needed to generate convection in our best simulation
- Previous studies$_3$ have shown Lake Okeechobee (1,825 km²) to be able to produce lake breezes that impact FLSB CI in numerical models
- In the d03 WRF simulation, mid-sized lakes (between 200-50 km²) produced lake breeze (LB) effects; small lakes (between 50-12 km²) produced no discernable lake breeze, however they were able to produce perturbations in winds, pressure, and temperature downwind of their locations (see Fig. 6)
- Interactions of the SBs with the LBs or the interactions of the LBs with each other in the simulation were important locations for CI (Fig. 7)
- Convective cold pools produce moisture and temperature effects within the center and outer regions of the outflow, that can interact with the environmental air to produce buoyancy effects (Fig. 8)
- Outflow boundaries colliding with SB and LB boundaries will produce lift effects to aid in convective initiation (Fig. 8)

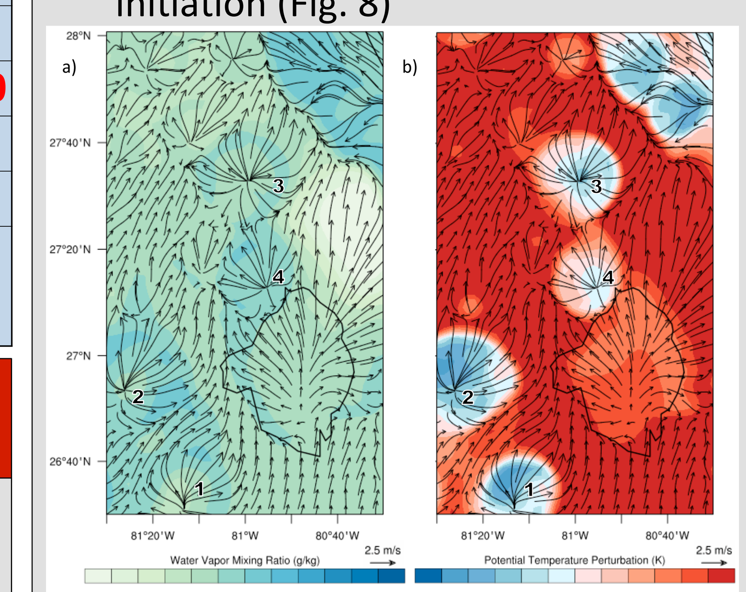

FIG. 8. D03 PBL1 WRF 100-m AGL a) water vapor mixing ratio (g kg^{-1}) and theta perturbation (K) at 2000 UTC 6 Sep. Convective outflow cold pools numbered.

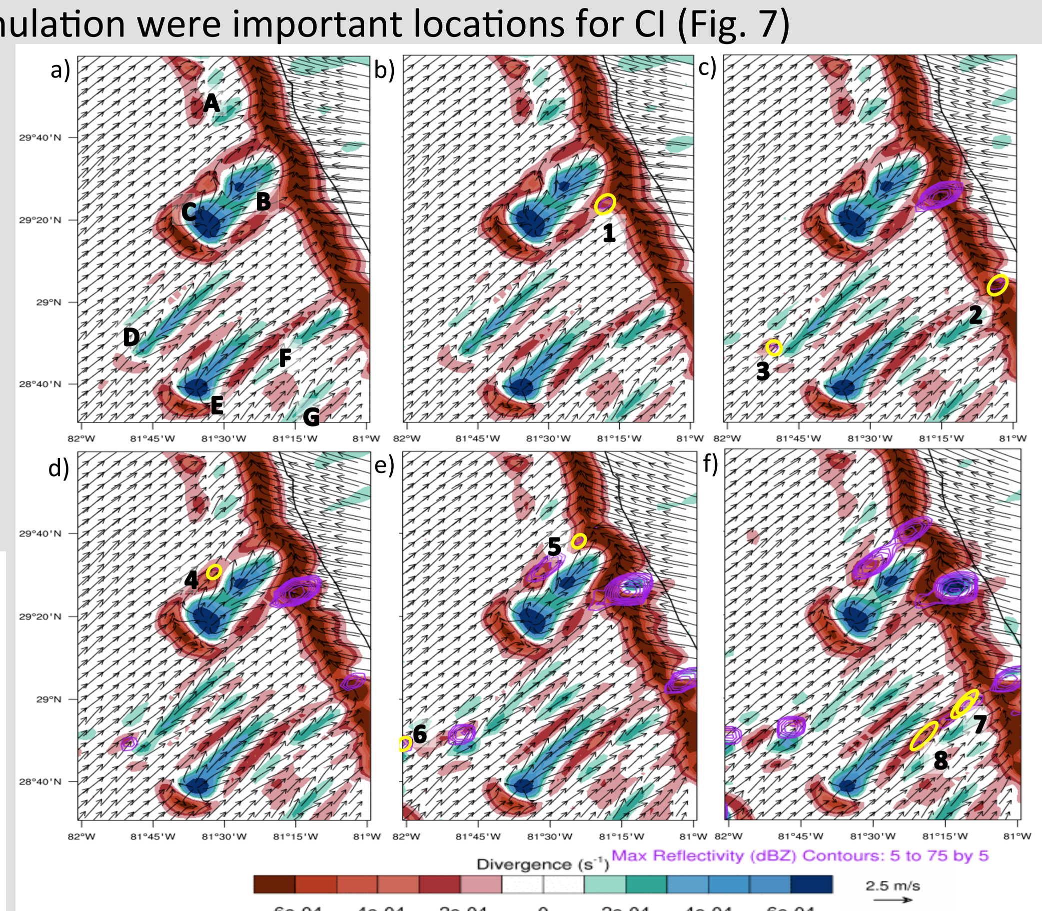

FIG. 7. D03 PBL1 WRF divergence (shaded contours; units s^{-1}), max reflectivity (yellow/purple contours; units 5 dBZ) and total wind vectors (black arrows; reference vector 2.5 m s^{-1}) at: a) 1820 UTC, b) 1825 UTC, c) 1840 UTC, d) 1845 UTC, e) 1900 UTC, and f) 1910 UTC 6 Sep. Yellow reflectivity contour lines indicate convective cell's first appearance in the simulation and are numbered accordingly in b-f); thereafter, reflectivity contours are purple. a) indicates river/lake effect divergence from: A – St John's River, B – Crescent Lake, C – Lake George, D – Lakes Griffin, Harris, and Eustis, E – Lake Apopka, F – Lakes Monroe, Jesup, and Harney, G – East Lake Tohopekaliga.

SUMMARY AND CONCLUSIONS

- All WRF experimental simulations successfully produced SB and convection for the case study
  - Significant differences in timing, location, and intensity of SB convection produced
- Experiments show the model sensitivity to physical parameterizations schemes (especially PBL) and initialization times/data in producing the sea breeze and its associated convection
- "Best" simulation is most accurate for CI prediction at/before 2200 UTC before it weakens the synoptic winds too much compared to observations
- Geophysical factors, lake effects, and SB-CI interactions heavily influence the main ingredients of instability, lift, moisture, and CAPE/CIN in generating/maintaining SB convection
- Preferred areas of CI were regions where the sea breeze collided with other external boundaries such as another sea breeze, lake breeze, or a convective gust front/cold pool
  - Increased gray zone resolution allowed smaller Florida lakes (between 200-50 km²) to generate lake breeze effects (not often seen in previous FLSB studies)

FUTURE WORK

- Compare parameterization/initialization "ensemble" results to results from an ensemble of WRF experiments using the Stochastic Kinetic-Energy Backscatter Scheme (SKEBS) in WRF to generate random perturbation fields and random boundary conditions
- Compare above Type 3 SB case results to results from Type 1 and Type 2 SB cases$_3$

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