Using IMPOWR Field Data to Validate Warm Season Low-Level Jets in the WRF Model Offshore of Southern New England

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Background and Motivation

- Warm season coastal low level jets (LLJs) are common
- Models have been shown to have wind biases in this region (see Fig 1c)
- The **I**mproving the **M**apping and **P**rediction of the **O**ffshore **W**ind Resource project was a field study done with the goal of improving the treatment of the boundary layer winds in mesoscale models, such as the Weather Research and Forecast (WRF) model. A long EZ aircraft was used to collect atmospheric observations.
- This project focused around validating the WRF for lower level jets in the coastal waters of New England.

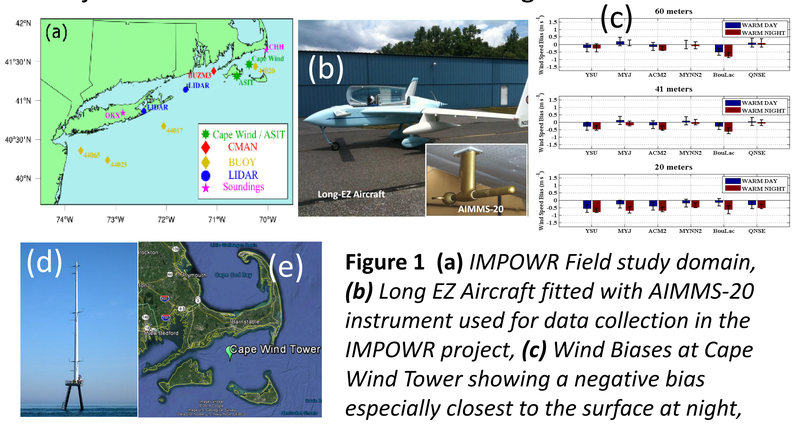


Figure 1 (a) *IMPOWR Field study domain,* ***(b)*** *Long EZ Aircraft fitted with AIMMS-20 instrument used for data collection in the IMPOWR project,* ***(c)*** *Wind Biases at Cape Wind Tower showing a negative bias especially closest to the surface at night,* ***(d)*** *Cape Wind Tower located inside Nantucket Sound just east of Martha's Vineyard* ***(e)****.*

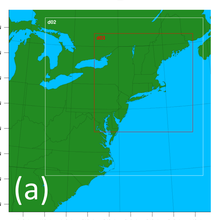
Research Questions

- What is the structure of the PBL in which these LLJs develop?
- What is the relative importance of model PBL physics and initial conditions?
- How steady are the winds during these LLJ events?

Weather Research and Forecasting Model (WRF v3.6.1) Set-up

WRF v3.6.1 Set up			
Initial/Boundary Conditions	RAP, GFS, NAM		
Vertical Resolution	38 Levels with 6 under 300m		
PBL Physics	MYNN2, YSU, ACM2		
Domains	Domain 1	Domain 2	Domain 3
Horizontal Resolution	12km	4km	1.33km

- 24 - hour sim by the WRF model. Initialized at least 18 hours before flight time.
- Prescribed NCEP 1/12th degree SST



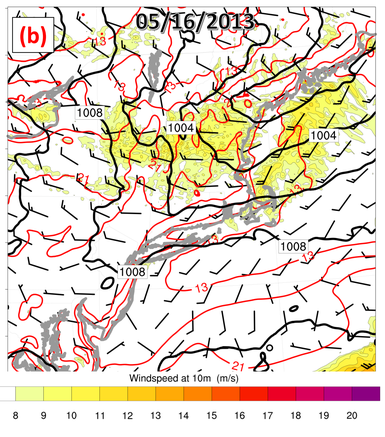
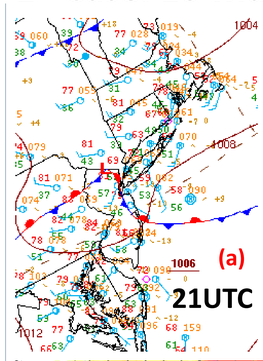


Figure 2 **(a)** WRF Domain setup, **(b)** 1.33km inner-most domain: May 16th, 2013 - SLP, 10m winds, and 10m temperatures at 21z

1st Case: 16-May-2013



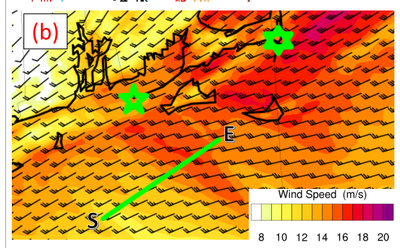
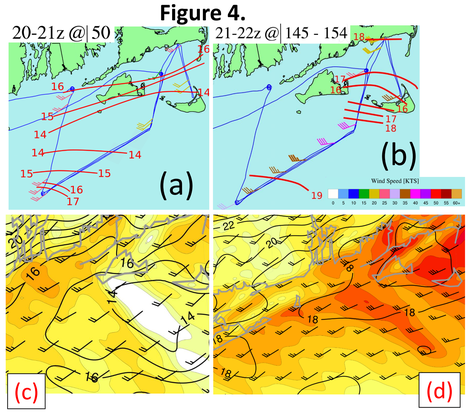


Figure 3. ***(a)*** *WPC surface analysis at 21z with a surface cyclone to the east. For comparison to WRF see Fig 2a.* ***(b)*** *Winds at 150m in the WRF indicating the location of soundings* ***(c)*** *at 1945z,* ***(d)*** *Chatham, MA* ***at*** *00z, Obs. cross section* ***(e)*** *and corresponding WRF cross section* ***(f)*** *taken between 2145 and 22z.*

Figure 4.



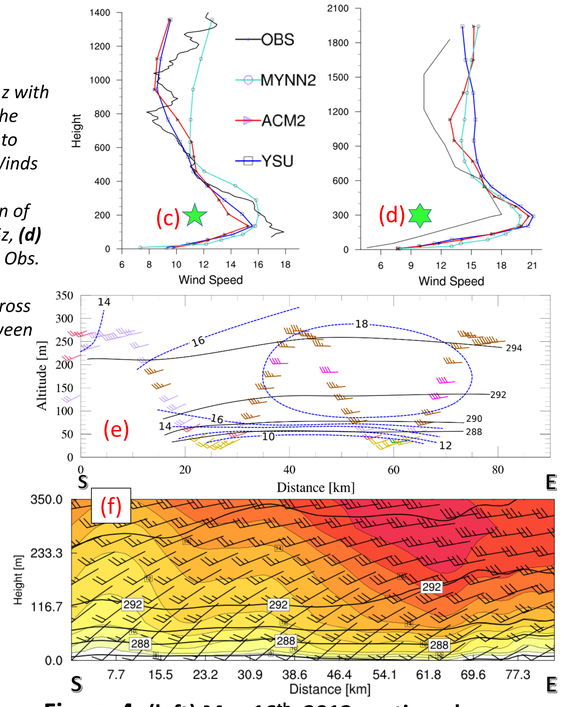


Figure 4. (left) May 16th, 2013 continued.
Flight track wind/temp observations from the aircraft at ***(a)*** *50m between 20 and 21z,* ***(b)*** *150m between 21 and 22z. (bottom) Corresponding WRF spatial plots at* ***(c)*** *50m (2030z) and* ***(d)*** *150m (2130z).*

Summary

- WRF winds weak by 1-3 ms^{-1} offshore/early in run (fig. 3c) but strong onshore/late in run (fig. 3d)
- Max winds sit atop most stable layer (fig. 3e)
- WRF weak by ~ 1 ms^{-1} in jet core but up to 4 ms^{-1} elsewhere due to narrow WRF jet
- Cold pool present near opening to Nantucket sound in obs. is weaker in WRF leading to a weaker temp gradient in places

2nd Case: 12-May-2014

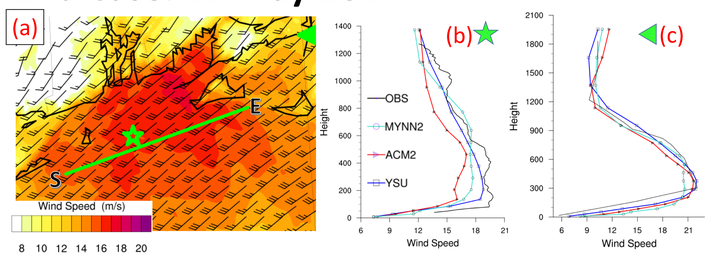
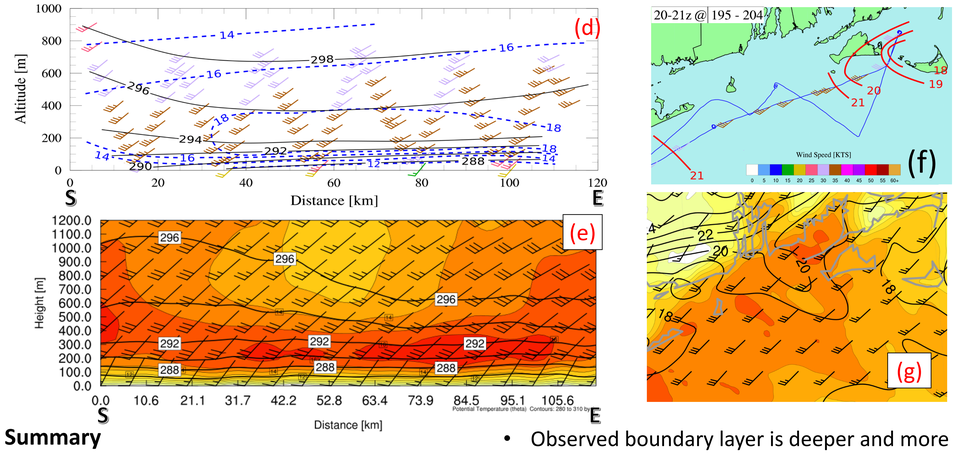


Figure 5. ***(a)*** *WRF winds at 150m indicating location of soundings* ***(b)*** *at 2145z,* ***(c)*** *Chatham, MA at 00z, obs. cross-section* ***(d)*** *at 2040z, and corresponding WRF cross-section* ***(e)*** *at 2045z. Flight-track wind/temp obs.* ***(f)*** *between 20 and 21z and corresponding 200m WRF spatial plot* ***(g)*** *at 2030z.*



Summary

- WRF does better onshore and later in the run than offshore and earlier in the run (fig. 5b & c)
- Again, jet sits just above very stable layer and is strongly sheared (fig. 5d)
- Observed boundary layer is deeper and more stable than WRF and the observed jet is stronger by 2-3 ms^{-1} (fig 5d & e)
- Temperature gradient at 200m is weaker in WRF than Obs. due to cooler temps in WRF offshore (fig 5f & g)

Vertical Profiles of Potential Temperature

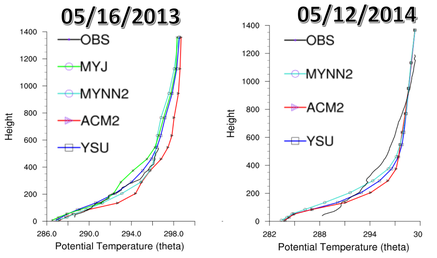
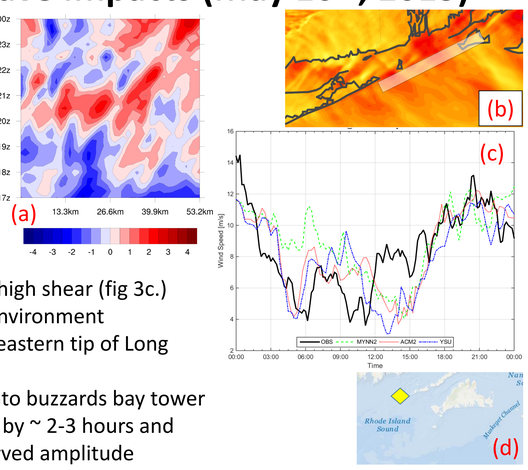


Figure 6. ***(a)*** *May 16th, 2013 theta profile inside Nantucket Sound,* ***(b)*** *May 12th theta profile at eastern edge of cross section (see fig 5a.)*

- Stable boundary layer
- Sensitivity to PBL schemes small
- MYNN2 & YSU did well for 16th
- All BLs too shallow for 12th case, most of all ACM2

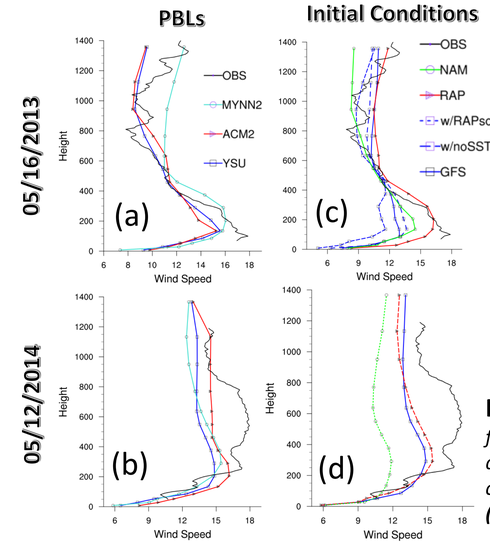
Gravity Wave Impacts (May 16th, 2013)

Figure 7. ***(a)*** *Hovmoller plot for wind speed at 28m ASL (RAP – YSU),* ***(b)*** *WRF winds at 28m indicating the location of Hovmoller box* ***(c)*** *Buzzards Bay time series* ***(d)*** *Buzzards Bay tower location (yellow diamond)*



- Stable BL (fig 6a.) & high shear (fig 3c.) provide conducive environment
- Waves originate off eastern tip of Long Island's south fork
- Propagate directly into buzzards bay tower
- WRF late with onset by ~ 2-3 hours and doesn't match observed amplitude

Sensitivity to PBL Physics vs Initial Conditions



- For 16th case GFS ICs also run using RAP soil moisture/temp & with GFS skin temp (very low res) as SST
- RAP outperformed both GFS and NAM consistently
- PBL harder to say

Figure 8. *PBL comparison for* ***(a)*** *May 16th,* ***(b)*** *May 12th and Initial Conditions comparison for* ***(c)*** *May 16th,* ***(d)*** *May 12th*

Conclusions

- 2 LLJ cases observed during IMPOWR, with winds 14-20 m s^{-1} centered around 200 m ASL
- WRF under-predicted magnitude of LLJs by 2-5 m s^{-1} and the WRF LLJ altitude is often too low
- WRF under-predicted temperature differences between inland and ocean
- Wind speeds are highly variable due to presence of gravity waves
- This variability is late to develop and under predicted by WRF simulations leading to, at times, large errors
- Simulations are more sensitive to initial conditions than PBL parameterizations