Coupled Air-Sea Modeling for Improved Coastal Dispersion Prediction

Julie Pullen
& Marine Meteorology Division,
Naval Research Laboratory
Outline

► SST impacts on NYC region during sea breezes

► 2-way air/sea feedback in the Adriatic during strong wind events
Air-Sea Interaction in NYC: Mesoscale Modeling for CB Threats

Julie Pullen & Teddy Holt
Naval Research Laboratory
Monterey, CA

with Alan Blumberg, SIT
Brian Colle, SUNY-Stony Brook
& Marty Leach, LLNL
Mesoscale Overview

- COAMPS®: data-assimilation modeling system
- 5 nests (36 km to 0.444 km)
- urbanization and time-varying (hourly) realistic SSTs on nests 4 (1.33 km) & 5 (0.444 km)

sea breeze forecast (nest 5)
NYC Mesoscale Modeling

- Common horizontal grid configuration among modeling groups (NRL, LLNL, SUNY-Stony Brook, SJSU)

(Nest 3 (4 km))

(Nest 2 (12 km))

(Nest 1 (36 km))

(5 nests: 36 km to 0.444 km)

(Nest 4 (1.33 km))

(Nest 5 (0.444 km))
NYC Mesoscale Modeling

Realistic High-Resolution SST’s

COAMPS nest 4 (1.33 km)
00 UTC 5 July 2004

COAMPS® nest 5 (0.444 km)

Observed SST

analyzed

model

analyzed

model
Surface temperature (color shading, K)

10-m wind arrows

Concentration (1 mg m$^{-3}$ isosurface)

Continuous 2-m release of 200 kg s$^{-1}$ starting at 12 UTC 4 July 2004 at 6 sites

Model SST (varied hourly)

UCP
Classic sea breeze
Northerly to southerly wind shift
Temperature decrease
Dew point increase

Sea breeze-NW wind interaction

Southerly synoptic flow with sea breeze enhancement

Sea breeze with afternoon and evening precipitation

LaGuardia (LGA) 1-12 Aug 2004

01 Aug 02 Aug 03 Aug 04 Aug 05 Aug 06 Aug

01 Aug 02 Aug 03 Aug 04 Aug 05 Aug 06 Aug

07 Aug 08 Aug 09 Aug 10 Aug 11 Aug 12 Aug

 Courtesy of Michael Reynolds, BNL
NYC Mesoscale Modeling

COAMPS® NYC Nest 5 (0.444 km): LaGuardia (LGA)

Observations
COAMPS forecasts

2-m air temperature (C)

bias = -0.51
rmse = 1.54

10-m wind direction (deg)

bias = -17.5
rmse = 51.2

2-m dew point depression (C)

bias = 0.68
rmse = 2.54

10-m wind speed (m s⁻¹)

bias = -1.44
rmse = 2.08

NYC Mesoscale Modeling

COAMPS forecasts

Hourly model SST UCP
COAMPS® NYC
Hourly model SST versus analyzed SST

12-hr mean 0.44 km COAMPS 2-m air temperature
- Uses analyzed SST
- Uses NYHOPS varying SST

Mean air temperature difference

24-h forecast from 2004070400
12-h daytime period from 2004070412 to 2004070500
COAMPS® NYC

Hourly model SST versus analyzed SST

12-hr mean 0.44 km COAMPS 10-m wind speed

uses analyzed sst

uses NYHOPS varying sst

Mean wind speed difference

24-h forecast from 2004070400
12-h daytime period from 2004070412 to 2004070500
COAMPS® NYC
Hourly model SST versus analyzed SST

Std dev of 0.44 km COAMPS 10-m wind speed

uses analyzed sst

uses NYHOPS varying sst

Difference of 10-m wind rms vector amplitude

24-h forecast from 2004070400
12-h daytime period from 2004070412 to 2004070500
Two-Way Air-Sea Coupling: Studies of the Adriatic

Julie Pullen and James Doyle
Naval Research Laboratory–Monterey

Richard Signell
NATO Undersea Research Center, ITALY

(in press, MWR)
Adriatic Circulation Patterns

Pullen et al. (JGR-oceans, 2003):
- documented the bora-induced generic double gyre in the ocean
- evaluated one-way coupled model using ocean and atmosphere velocity observations
- quantified the importance of high-resolution atmospheric fields for forcing ocean models
Model Set-up

- 2-km resolution ocean model (NCOM)
- 4-km resolution atmosphere model system (COAMPS)

One-Way Coupling
- 12 hour incremental update cycle
- MVOI
- 6 hour atmosphere forecast
- analyzed SST
- ocean forecast with hourly forcing

Two-Way Coupling
- 12 hour incremental update cycle
- MVOI
- 6 hour atmosphere forecast
- modeled SST
- ocean forecast with hourly forcing
Boundary Layer & Surface Fluxes

During a Bora Event

(29 September 2002 6Z)

Potential Temperature

Latent Heat Flux

Sensible Heat Flux

2-Way Coupled

1-Way Coupled
Post-Bora SST Evaluation

(1 October 2002)

Basic Statistics

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Boundary Layer Evolution
During a Bora Event
Acqua Alta (over-water site near Venice)

Richardson Number

Potential Temperature

2-Way Coupled

2-Way – 1-Way
Wind & Temperature Evaluation
(23 September – 23 October 2002)

2-Way Coupled Mean SST

& Near-Surface Winds

Acqua Alta Ocean Temperature

Wind Speed Statistics

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Acqua Alta Ocean Temperature

Wind Speed Statistics

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Atmospheric Stability Difference
(23 September – 23 October 2002)

Mean 30 m Richardson Number
2-Way Coupled

Mean 30 m ΔRichardson Number
2-Way – 1-Way
Point Statistics

- 2-way TKE is reduced by 20% in the lower ABL
- 2-way TKE is less vertically coherent
EOFs & Correlations

- Analyzed SST EOF 1
  - Variance: 95.32%

- 2-way coupled SST EOF 1
  - Variance: 85.85%

Amplitude times series of SST EOF 1:
- 2-way
- Analyzed

1-way 10-m air temperature correlation

2-way 10-m air temperature correlation
Using satellite MCSST data and in situ ocean temperature observations to evaluate model-derived SST, the 2-way coupled simulation had lower mean bias and RMSE error compared to the 1-way coupled simulation.

At gas platforms in the northern Adriatic, the 2-way coupled model produced lower mean wind speeds that accorded better with measurements than did the values from the 1-way coupled model.

Cooler SSTs represented in the 2-way coupled simulation stabilize the atmosphere relative to the 1-way coupled simulation, leading to reduced (more realistic) wind speeds in the 2-way coupled simulation.

2-way coupling impacts the correlation structure of atmospheric variables such as TKE and air temperature.
Back-Up Slides
Five continuous passive tracer releases at 2-m 10 mg m$^{-3}$ concentration isosurface

Rockefeller Center
Financial District
Ft. Wadsworth
Ft. Tilden
Sandy Hook

Cold start MVOI CODA Urban Canopy Param