Advanced Surface Flux Parameterization

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LONG-TERM GOAL

The long-term goal is to understand the physical processes that critically regulate the coupling between the ocean and atmosphere boundary layers and develop advanced parameterizations of this interaction for a new generation of coupled ocean-atmosphere models.

OBJECTIVES

The objective of this research is to improve the surface flux and boundary layer turbulence parameterization in COAMPS™ for low- and high-wind events over the ocean in the context of air-sea interaction. Special emphasis will be placed on flux parameterizations in low-wind regimes in collaboration with CBLAST DRI (**C**oupled **B**oundary **L**ayer Layers/**A**ir-**S**ea **T**ransfer **D**efense **R**esearch **I**nitiative) community.

APPROACH

There are two complimentary and strongly interacted components in our study: modeling and observational efforts. Our first approach is to use COAMPS™ as a tool in understanding the physical processes, and developing new parameterizations for the surface and boundary layer turbulence mixing in the context of the air-sea interaction. We provide real-time COAMPS™ weather forecasts for each intensive operational period of CBLAST-Low field experiment, and therefore establish a focused model dataset which can be used, with the measurements, to evaluate the model physics and investigate the impacts of the interaction on the mesoscale weather prediction. We also use various single column versions of COAMPS™ and experiment data to study the detailed turbulence processes such as the large-eddy turbulent gustiness and the effects of skin SST, and develop the new parameterizations. The second approach is to collect turbulence data in Nantucket Island. These data are critical in the evaluation of the COAMPS™ forecast and development of the new parameterizations. They also provide a valuable data source for the process study of the air-sea interaction in that area.

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14. ABSTRACT
The long-term goal is to understand the physical processes that critically regulate the coupling between the ocean and atmosphere boundary layers and develop advanced parameterizations of this interaction for a new generation of coupled ocean-atmosphere models.

15. SUBJECT TERMS

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WORK COMPLETED

1. We evaluated CBLAST-2001 real-time forecast with data from CBLAST-Pilot-2001 field experiment. The time series of model surface variables are compared against the observation data at the locations of ASIMET and SecNavy moorings. The Probability Density Function analyses of the model errors are performed to identify possible processes which affect the forecast skills. The predicted boundary layer profiles are evaluated with the Rawindsonde data.

2. We reformulated the Louis surface flux parameterization to improve its performance over oceans and in the light wind conditions (Wang *et al*, 2002). To correct the weak stability dependence of the parameterization, we retuned the coefficients to fit results of the lately developed TOGA-COARE surface flux parameterization. The modified Louis scheme is evaluated against data obtained in various ocean/land surface field experiments.

3. We performed twice daily real-time forecasts for the CBLAST-Low-2002 experiments from 20 July – 6 September, 2002 using high resolution COAMPS™ (27, 9 and 3 km horizontal resolution) making use of the newly improved Louis surface flux parameterization developed this fiscal year. The forecasts have been presented in the website (www.nrlmry.navy.mil/shared-bin/CBLAST/cblast.cgi) to provide weather guidance for the CBLAST-Low-2002 experiment.

4. Supported by the supplemental award (# N0001402WR20210), we conducted ground-based measurements at the Nantucket site from July 31 to August 23, as part of CBLAST-Low 2002 field experiment efforts. The measurements include 2-4 times daily rawinsonde measurement; continuous SODAR measurements of boundary layer height and vertical profiles of turbulence variances; *in situ* high-rate sampling for turbulence fluxes; mean wind, temperature, and relative humidity at 5 and 10 m on a 10-meter mast; cloud base height from a laser ceilometer; and solar and IR radiation, pressure, wind speed, temperature, and humidity from a meteorological package.

5. We implemented a "cool skin/warm layer" parameterization for sea surface temperature (SST) in COAMPS™ to evaluate the sensitivity of the mesoscale weather prediction on the skin SST. The effort is focused on the surface fluxes and boundary layer development. Two 36-hours forecasts using this parameterization are performed over the CBLAST-LOW-2002 area and compared with those from the standard COAMPS™ forecasts.

6. We made a preliminary study on the role of the wave-induced surface stress in the momentum flux parameterization using routine measurements from buoys of the National Data Buoy Center (NDBC). In this study, the COARE surface flux scheme were used in an offline mode while three newly developed schemes for surface roughness length was used. These roughness schemes directly involve surface wave properties, such as significant wave height and peak wavelength measured by the NDBC buoys. The objective is to understand the sensitivity of the buoy-derived surface momentum fluxes to surface roughness parameterization and understand the range of applicability of the three schemes.

7. We made more intensive COAMPS™ simulations to understand the scale-dependence of surface flux and boundary layer parameterizations in high- resolution mesoscale models in comparison with observational data from the Japan/East Sea (JES). This study enhanced our understanding of the resolvable and the subgrid scale turbulence statistics in a mesoscale model.

RESULTS

Evaluation of CBLAST-2001 Real-Time Forecasts: The comparison between the forecast and the buoy data consistently indicate a mean warm temperature bias and a deficit in the predicted downward longwave radiation at the surface. Furthermore, there exist bi-modal distributions of the temperature bias. The mode of the cold bias appears to be related to cloud prediction. This finding is interesting as operational COAMPS^{TM} forecast consistently demonstrates a mean cold temperature bias as opposed to the warm bias found here. The consistent deficit in the COAMPS^{TM} longwave radiation field also points to the deficiency of the coupling of the radiation and atmosphere moisture/clouds fields.

CBLAST-Low-2002 Real-Time Forecast: The real-time forecast is a success as it promptly provided the weather forecasts for the measurement groups in the CBLAST-Low-2002. One particular success is the COAMPS^{TM} ability in predicting the local mesoscale circulation such as sea breeze as it may significantly modify the coastal turbulence field. As an example shown in Figure 1, the sea breeze front (indicated by the temperature gradient and wind shear) is located about 20 km inland at 8:00 pm LST on August 7. The predicted surface fluxes and air temperature at the mooring location changed significantly as the sea breeze was developing. The marine boundary layer structure is expected to undergo significant modification as well due to the change in the surface stability. Because the prediction of wind, turbulence, temperature and clouds fields in coastal areas are particularly challenging due to the complex interaction among coastal dynamics, turbulence field and cloud microphysics, the measurement and real-time forecast provide excellent datasets for both process and parameterization studies.

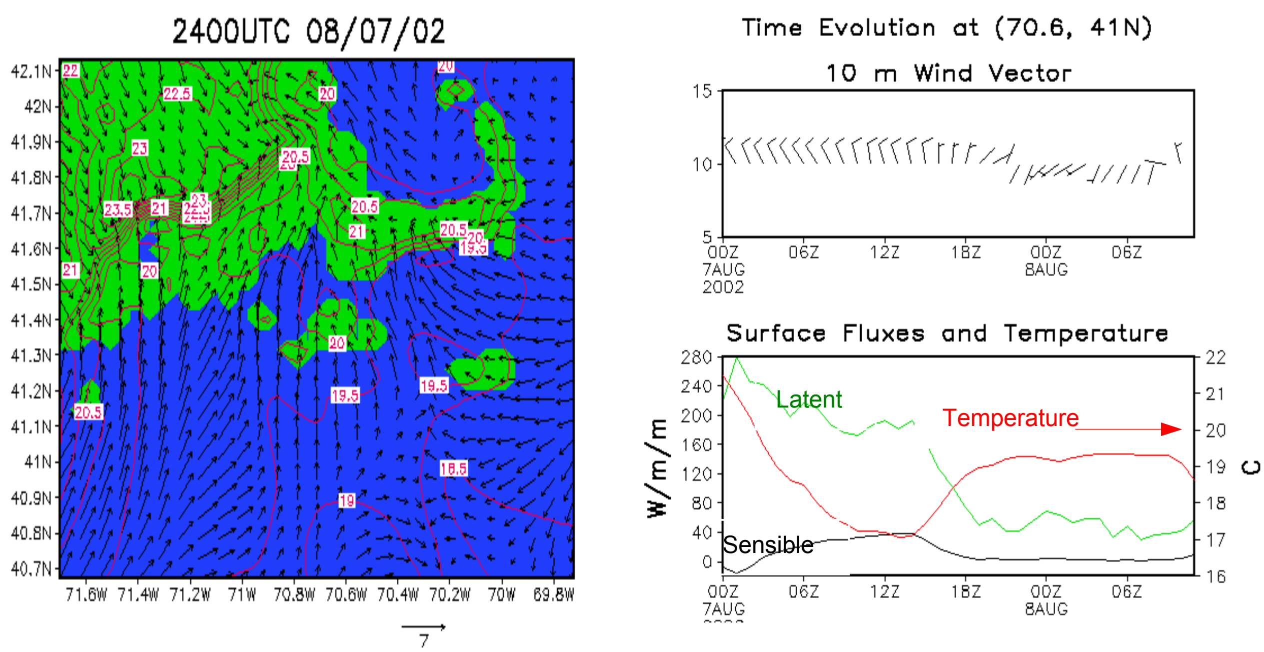

Figure 1. Sea breeze episode on 7 Agust,2002 [Left: Wind vectors and temperature field at 10 m. Land: green, ocean: blue; Right: Time series of wind vector, the fluxes and temperature]

Improved Surface Flux Parameterization in COAMPS™: The effort is made to reformulate the Louis scheme used in COAMPS™. We first eliminate the "gustiness" factor in the scheme, retune the coefficients to fit the TOGA-COARE surface parameterization (Fairall *et. al*., 1996) and introduce new formulation to handle with the difference between momentum and heat roughness length. The modified scheme particularly improves the wind stress calculation as compared with data as shown in Figure 2. Consequently, it significantly improves the near-surface wind prediction as the wind-speed bias is reduced by half during noon time over land areas.

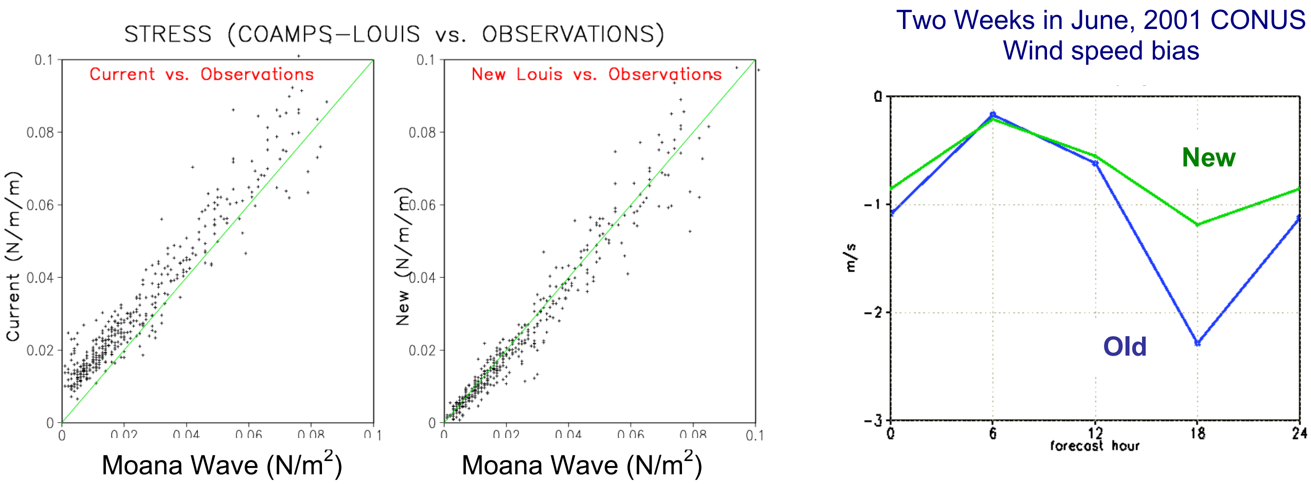

Figure 2. Comparison of the current and modified COAMPS surface flux parameterization. [Left: stress, COAMPS vs. observation; Right Low-level wind speed bias]

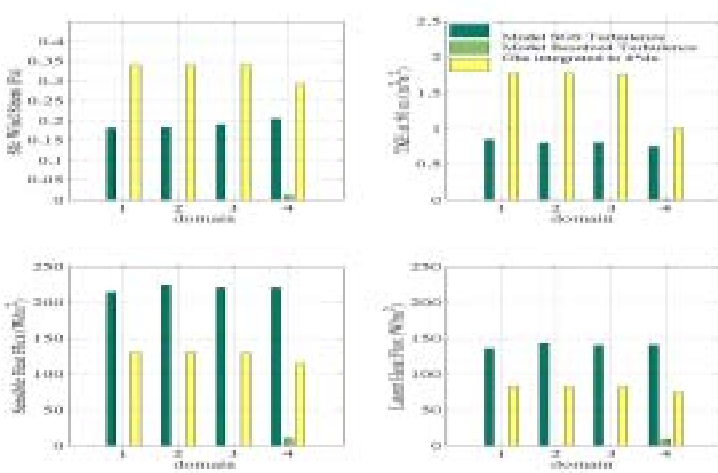

Figure 3. Comparison of model SGS parameterized and resolved surface fluxes and TKE interpolated to a height of 50 m with fluxes/TKE calculated from aircraft observations. [Domain number 1 to 4 has horizontal resolution of 13.5, 4.5, 1.5, and 0.5 km, respectively.]

Scale dependence of surface fluxes in sub-kilometer resolution mesoscale models: Our results showed that it is unlikely that the lowest resolvable scales up to 10Δx can be realistically resolved in a mesoscale model due to the inherit diffusive properties of the model. The parameterized fluxes and TKE (turbulence kinetic energy), on the other hand, are insensitive to model grid resolution (Figure 3). Here, the model represented surface fluxes and TKE (resolved and parameterized) differs significantly from the observed values. This result indicates that the SGS (**s**ub**g**rid-**s**cale) parameterization should not only depend on grid resolution, but also should be tailored to the diffusive property of the model's numerical scheme in order to compensate for the contributions not being represented by the smallest resolvable scales in the range of turbulent eddies.

IMPACT/APPLICATIONS

The modified surface flux parameterization is shown to significantly improve the low-level wind prediction in the selected COAMPS™ simulations. It is expected that the eventual transition to the FLEET Numerical Meteorology and Oceanography Center (FNMOC) will improve the wind forecast skill of COAMPS™ in general.

TRANSITIONS

The improved surface flux parameterization has been transitioned to 6.4 programs (PE 0602435N and PE 0603207N) for applications within COAMPS™ and for subsequent transition to FNMOC and regional Naval Meteorology and Oceanography Centers for operational use.

RELATED PROJECTS

Related 6.2 projects within PE 0602435N are BE-35-2-18, for the *Mesoscale Modeling of the Atmosphere and Aerosols*, BE-35-2-19, and for the *Exploratory Data Assimilation Methods*. Related project at NPS is Award # N0001402WR20176 for COAMPS™ evaluation using aircraft measurements.

SUMMARY

We have developed an improved surface flux parameterization for COAMPS™ through data analysis and COAMPS™ model simulations. The Nantucket turbulence measurement and real-time forecast provide the valuable model and observation datasets for the further air-sea interaction studies. The COAMPS™ evaluation, the SGS scale analysis and the boundary layer mixing modification provide more insight of the model physics, which will help the development of turbulence and surface flux parameterizations.

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PUBLICATIONS

Wang, S., Q., Wang, and J. Doyle: 2002; Some improvement of Louis surface flux parameterization. *15th Symposium on Boundary layers and Turbulence*, American Meteorological Society, 15-19, July 2002, Wageningen, the Nettherland. 547-550.

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