

Ocean Coupling to Topographically-Enhanced Atmospheric Flow

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LONG-TERM GOALS

The goal of this project is to understand and predict oceanic and atmospheric processes in coastal areas where winds are topographically steered and strengthened.

OBJECTIVES

The proposed work aims to probe details of the interaction of mountainous island terrain with synoptic and intra-seasonal disturbances, and the associated ocean response and feedback. The research questions include:

- How do intra-seasonal and synoptic disturbances combine to generate spatial/temporal variability of the ocean and atmosphere on small time and space (e.g., operational) scales?
- How do terrain effects influence local precipitation and wind patterns during atmospheric episodes?
- How do warm wake waters surrounding islands impact the atmosphere during synoptic and intra-seasonal events? What is the evolution of atmospheric and oceanic boundary layers over the course of atmospheric passages, and what role do wind orientation and terrain play?

APPROACH

To accomplish these objectives we employ high-resolution (~1-3 km) two-way coupled ocean/atmosphere modeling to predict, interpret and improve the simulated boundary layer properties. The studies mine the rich datasets of observational programs including land-based meteorological data, satellite, moored and underway observations to form a more complete picture of circulation characteristics in the ocean and atmosphere in complex coastal mountainous regions. The project is a close collaboration with NRL partners on the modeling side (including James Doyle, Paul May and Sue Chen) and field team participants (including Pierre Flament of University of Hawaii, Arnold Gordon of Lamont-Doherty Earth Observatory, Janet Sprintall of Scripps, Craig Lee of University of Washington, and Cesar Villanoy of University of the Philippines).

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WORK COMPLETED

The Philippines national weather service (PAGASA) supplied 3-hourly meteorological station data at 50+ sites distributed throughout the Philippine islands. The dataset covers the 5-month time period 1 November 2007 – 31 March 2008 and consists of the following fields: wind speed, wind direction, temperature, dewpoint temperature, sea level pressure, rainfall, relative humidity, visibility, and cloud totals. This dataset is being compared with coupled COAMPS^{®1} simulations, and is being analyzed to examine regional patterns in key meteorological fields. The most recent completed work focused on examining rainfall totals and event-based precipitation statistics. This effort included comparison with shipboard measurements along with TRMM precipitation radar measurements from the same time period and from climatology.

During December 2007-February 2008 the Philippines experienced the greatest rainfall in 40 winters. We used a combination of observations (mentioned above) along with 3 km resolution two-way coupled COAMPS (May et al., 2011) to examine this anomalous season.

(¹ COAMPS[®] and COAMPS-OS[®] are registered trademarks of the Naval Research Laboratory.)

RESULTS

As expected from climatology, rainfall was greatest on the eastern side of the Philippines archipelago (Akasaka et al., 2007). Seasonal totals were extreme and exceeded 4000 mm in some locations (Figure 1). Discrete precipitation events delivered the bulk of the rain to the region. General patterns and magnitudes of rainfall produced by the two-way coupled model agreed with observations from land and from space, with the 3-km COAMPS nest more aligned with observations than the coarser 9 km resolution nest. In addition, shipboard measurements from January 2008 (collected by the ONR PhilEx program) reveal a fresh lens of water to the southwest of the island of Mindoro, which likely originated from river run-off (Pullen et al., 2011). The 3-km COAMPS produced precipitation in the mountainous areas of the Philippines that supports this hypothesis, although observations were limited in the mountains (Figure 2). TRMM data can be less reliable over complex terrain (Iguchi et al., 2000) so we are seeking additional land-based measurements in the mountains.

Manuscript in preparation: “Philippines extreme precipitation patterns from observations and two-way coupled modeling,” J. Pullen, J. Doyle, C. Villanoy and A. Gordon.

IMPACT/APPLICATIONS

I am a co-organizer of a special session at the American Meteorological Society 2013 as part of the “Symposium on the Coastal Environment.” The special oral presentation session is entitled: “Air/Sea Coupled Modeling: Processes & Operational Prediction”, which will examine the impact and prediction of these type of coupled processes throughout the world.

Insight into processes in coastal areas subject to topographically-enhanced winds are translatable to other regions of interest to the Navy. Such winds may influence Navy operations near important ports – e.g., Manila.

RELATED PROJECTS

This work is related to NRL-Monterey 6.1 projects within PE 0601153N that include studies of air-ocean coupling, boundary layer studies, and topographic flows and 6.2 projects within PE 0602435N that focus on the development of the atmospheric and coupled components of COAMPS. This work also draws on efforts conducted within the ONR PhilEx DRI and ONR OKMC DRI.

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TRMM/PAGASA rain gauge total
(1 Nov 2007 - 31 Mar 2008)

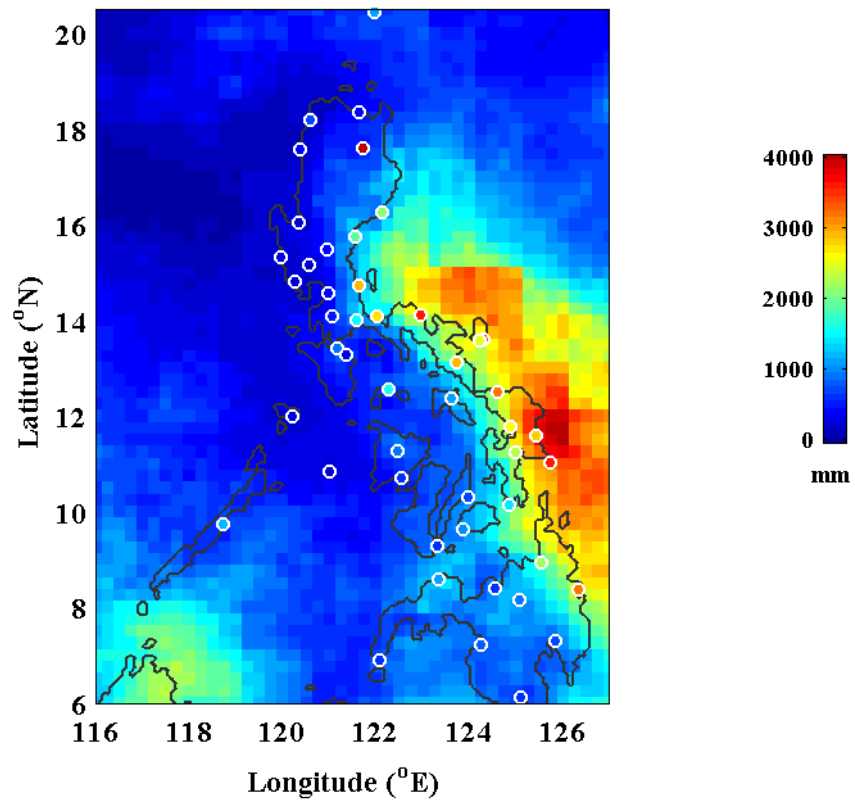


Figure 1: TRMM measurements of rainfall total (in mm) for 1 November 2007 – 31 March 2008 with rain gauge totals from 48 meteorological stations shown with colored circles.

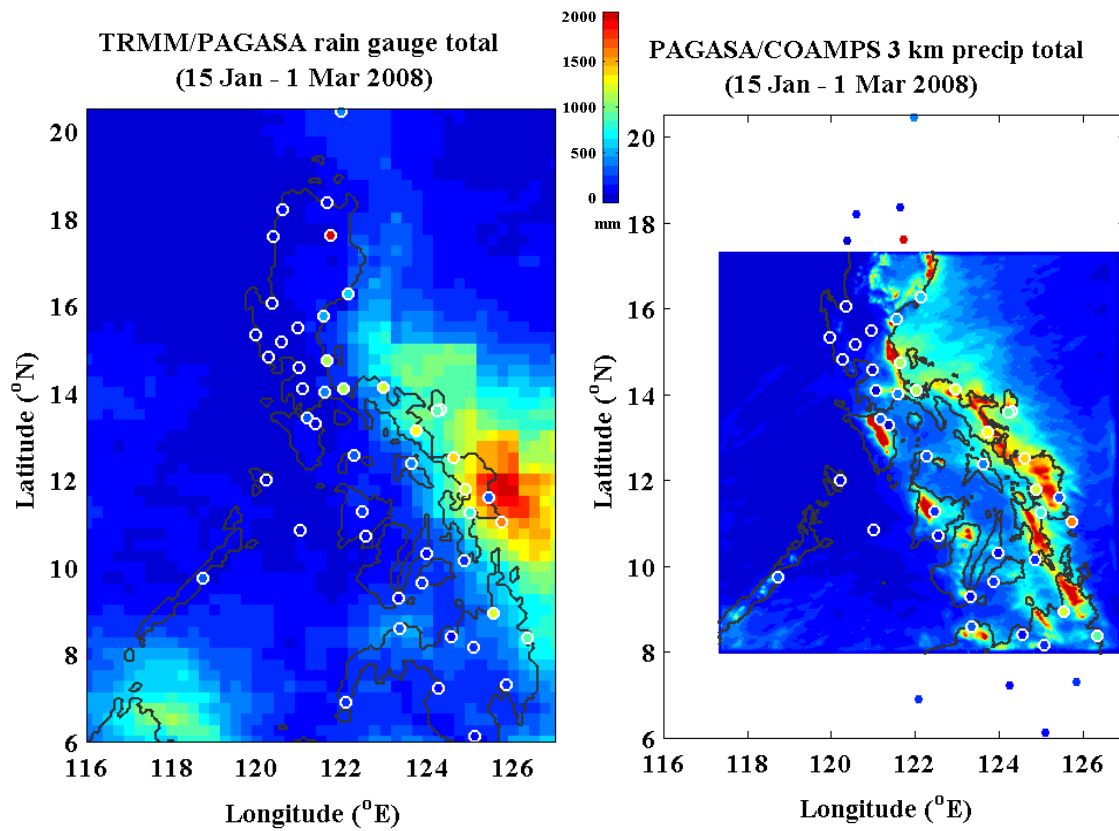


Figure 2: As in Figure 1, but for a reduced time period (15 January – 1 March 2008) when 3 km resolution coupled COAMPS was run (right panel).