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INFLUENCE OF COASTAL UPWELLING ON THE INDIAN MONSOON

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1. INTRODUCTION

During Northern Hemisphere summer, strong surface winds parallel to the eastern coast of Africa (the Somali jet), cause widespread upwelling and cooling in the Indian Ocean. Coastal waters are up to 5° C colder than open ocean at the same latitude, and upwelling sea surface temperature effects can extend as far out as 12 degrees (~1350 km) from the coast (fig 1 shows deviations from zonal mean). In addition to the large-scale east-west temperature gradient, smaller scale SST features like cold tongues and small areas of intense upwelling occur intermittently throughout the season.

These smaller-scale features are not captured by the SST data sets commonly used in mesoscale and global modeling applications, such as the Reynolds SST analysis included in the NCEP reanalysis. However, the features are clearly visible in satellite-derived SST's such as those from the Pathfinder mission. This raises a natural question: how sensitive are the dynamics of the Indian Monsoon to localized temperature gradients? The purpose of this research has been to explore this question, as well as to find out more about what role the basin-wide temperature gradient in the Indian Ocean plays.

2. METHODOLOGY

Mesoscale model (MM5) simulations are conducted using high-resolution (74 km), coarse resolution (274 km), and zonally averaged SST data sets, to understand how the cool SSTs associated with coastal upwelling influence the Indian monsoon.

MM5 was modified and tested for a domain centered on the North Indian Ocean to make it an appropriate choice for mesoscale modeling of the Indian Monsoon. The three model simulations were identical in all respects except for the sea surface temperature inputs. 1999 AVHRR Multi-Channel Sea Surface Temperature (MCSST) data was interpolated to 274 km resolution to create a coarse data set. After being averaged to 274 km resolution, the coarse data set was reinterpolated before being inputted into MM5, while the high resolution data set was interpolated directly to the 74 km MM5 grid. A zonal mean data set was created by zonally averaging within the simulation domain.

All simulations were integrated from mid-April 1999 through September 1999, using boundary conditions from the NCEP reanalysis, the RRTM radiation scheme, simple-ice moisture scheme, and the Kane-Fritsch cumulus parameterization.

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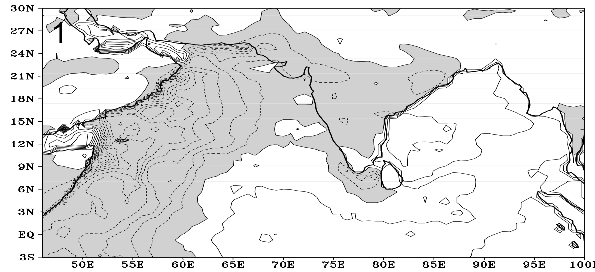

Figure 1: July 1999 SST deviations from the zonal mean. Contour interval 0.5 C (shaded regions have temperature below the zonal mean). Source: July 1999 MCSST data

3. VALIDATION

All three MM5 simulations produce a simulation of the Somali jet, and the Indian monsoon that is more realistic than those generally found in global model simulations. The structure of the modeled precipitation field is similar to that found in both the GPCP observations and the Legates climatology (fig 2a,b shows July precipitation and Legates climatology). Low level winds are also similar to observations, showing a Somali jet of similar strength and location to that in the NCEP reanalysis (see fig 2 a,b).

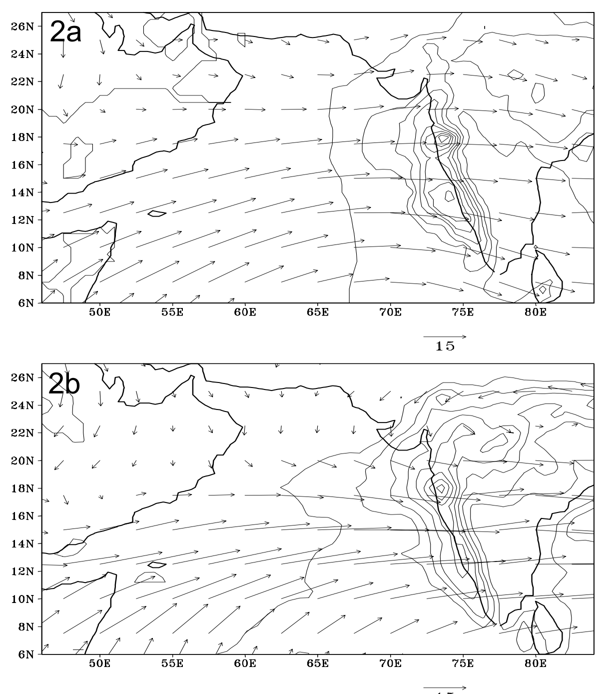

Figure 2 validation: July 1999 850mb winds and precipitation (contour interval 3mm/day, arrow corresponds to 15 m/s winds) Figure 2a: NCEP reanalysis winds, and July precip. climatology from Legates. Figure 2b: MM5 output for coarse resolution run, winds and precipitation

4. RESULTS

When higher resolution SSTs are used, the monsoon simulation over India changes.

Early in the season (May), differences between the coarse and high resolution simulations are localized along the eastern coast of India, near a small region of upwelling. As compared to the coarse resolution run, the fine resolution simulation has an anomalous anticyclone, consistent with these temperature differences in the input data (Fig 3a, b). The surface pressure perturbation field is similar to the geopotential heights shown. Some anomalous drying occurs in the high resolution case in the region of the anticyclone, due to decreased wind convergence.

When comparing the coarse and high resolution simulations in the middle of the monsoon season (July), the simulations suggest that there may be a more basin-wide effect occurring due to the enhanced zonal temperature gradient along the western coastline of the Arabian Gulf in the high resolution run (Fig 4a, b). Associated with the small-sclae SST changes, the Somali Jet strengthens further north (and weakens in the south). Precipitation patterns near Bombay change, with some areas receiving more rainfall, others less, due to changes in wind and moisture convergence.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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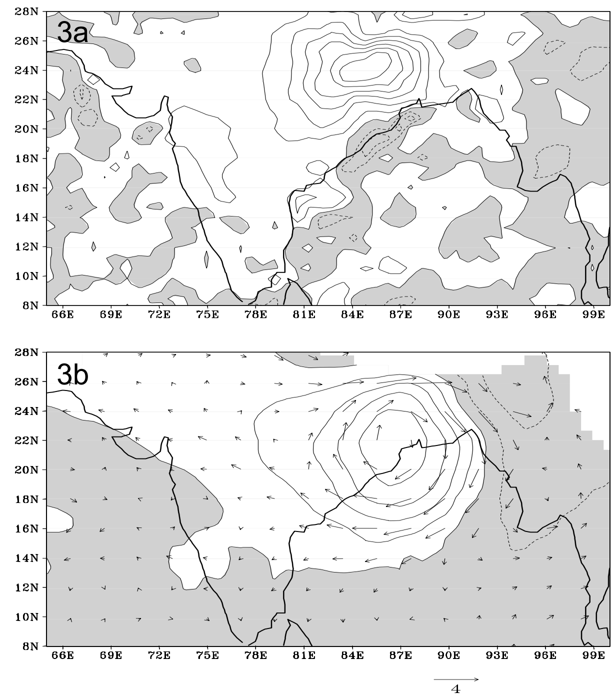

Figure 3: May 1999 simulation differences: high resolution run – coarse resolution run.
Figure 3a: surface temperatures differences, contour interval 0.2 C, shaded regions are negative.
Figure 3b: 870mb geopotential height and wind differences, contour interval 2 gpm, arrow corresponds to 4 m/s, shaded regions negative.

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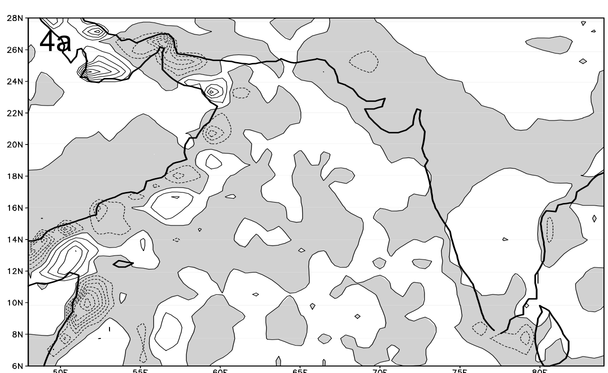

Figure 4a: July 1999 SST difference between high resolution (74 km) and coarse resolution (274km) run, contour interval .5, shaded regions where high resolution SST colder.

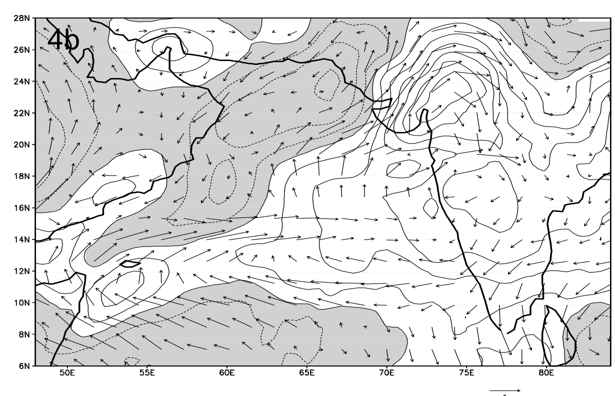

Figure 4b: July 1999 870mb geopotential height differences and winds (high resolution – coarse resolution), contour interval 2 gpm, reference wind vector 1 m/s.