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NASA Project Progress Report

"Sea Breeze-Induced Mesoscale Systems and Severe Weather"

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One of the goals of this funded research is to determine the extent to which thunderstorm activity during the summer months along coastal regions of the Atlantic and Gulf coasts can be attributed to the dry sea breeze circulation. This subject will be the focus of this project report. Satellite composites of thunderstorm activity for synoptically undisturbed conditions have been obtained for south Florida for a series of days in the summer of 1983. These data were catalogued into different low level synoptic flow regimes. Five synoptic flow regimes were found from the data. They were: light southeasterly, strong southeasterly, strong easterly, very light and variable, and strong southwesterly low level synoptic flows. A three-dimensional mesoscale numerical model was used for each synoptic flow regime to quantitatively predict the location of enhanced thunderstorm activity. This model includes a parameterization of vegetation and soil moisture feedbacks as well as a sophisticated planetary boundary layer representation.

Using the results of the satellite image composites, spatial and temporal characteristics of deep convective cloud patterns and their variation with synoptic flow have been described. The results from the numerical model have provided explanations for the observed patterns. Figures 1 and 2 give an example of the results from the south Florida cloud study. Shown are the deep convective cloud composites at 1200, 1400, 1600 and 1800 LST for the light southeast synoptic flow class. The model predicted vertical velocities for the light southeast synoptic

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class at the corresponding time of day are shown next to each composite image.

To summarize for each synoptic flow class, first, for light southeasterly flows, the composite satellite imagery and mesoscale model predictions documented that deep convective clouds developed along the east coast sea breeze and along the southern tip of Florida early in the day. By mid afternoon convection forms along the west coast sea breeze and moves inland. Convection is highly organized along both sea breeze fronts with the most preferred regions of convective activity located near the convex curved coastline along the west coast and east of Lake Okeechobee where the east coast sea breeze convergence is enhanced by the lake breeze flow. (The percentage of frequency of occurrence of this deep convection for all of our composites has been calculated and will be provided as part of our next progress report). By late afternoon convection in the south has advanced further west in the direction of the low-level flow. The east coast sea breeze convection to the east of the lake has dissipated. By early evening, clouds in the southern peninsula have dissipated with new development forming just north of Lake Okeechobee where the east coast sea breeze flow interacts with the divergent flow which was formed over Lake Okeechobee but has been advected to the northwest.

For strong southeast flow, convection moves further inland from the east coast than for light southeasterly. Convection develops later on the west coast with particularly preferred regions found along the southwest coastline. Another preferred region in the afternoon is found north of Lake Okeechobee along the intersection of the east coast sea breeze and lake breeze. By evening this region is translated further north by the prevailing flow. The southern convective areas dissipates by evening. This class illustrates less convective organization with more convective areas in many portions of the peninsula than was the case for the light southeast composite.

For strong easterly flow, convective activity started later than for the southeasterly classes. By early afternoon, well-pronounced preferred areas of convection are found along the southwest coastline with no activity along the southeast coast. The model also predicts the strongest peninsula scale forcing by this time along the west coast. The most preferred regions of convective activity remain anchored along the west coast sea breeze and do not move inland. By late afternoon convective activity is also found along the east coast sea breeze which has moved rapidly to west of Lake Okeechobee. By early evening preferred areas of convection are advected offshore and are found further north than earlier. The early evening convection lies along an enhanced convergence area where the west and east coast sea breeze, and the lake breeze interact, as predicted by the model.

Light and variable convective activity is very suppressed throughout the day. The model predicted vertical velocities are less than the other classes as the weak synoptic flow did not add convergence to the downwind coastline by opposing the onshore flow. Some convection had formed along the east coast sea breeze just east of Lake Okeechobee and along the southwest coast, but by early evening the southern convective areas had dissipated while some spotty deep convection had developed to the north, where the east coast sea breeze had advanced inland.

For the strong southwesterly class, only one satellite case was available. Early in the afternoon the strongest convection had developed along the convex curved part of the southwest coast with shallow convection along the east coast sea breeze convergence region. The west coast sea breeze convection clouds had moved inland with the front by late afternoon. Widespread deep convective clouds had developed also near the southern tip of the peninsula. In the early evening, as with all the cases, cirrus created by the convection associated with the sea breeze helped to dissipate the cumulus activity. Well north and inland where the east and west coast sea breezes met, convection had developed by the end of the day.

The results of the numerical model and the satellite cloud composites have shown the importance of the low level synoptic flow in developing sea breeze convergence patterns, and, therefore, in controlling the onset and subsequent position of deep convective clouds. This dominance of the sea breeze in climatologically influencing and focusing rainfall over south Florida (and, undoubtedly, for other similar subtropical and tropical areas) when the flow is dominated by synoptic scale high pressure has been clearly established. This dominance is being quantified and will be reported in our next progress report.

One area, however, where the model predicted convergence has consistently disagreed with the observed convective cloud activity during the early afternoon was along the southern tip of the peninsula where a strong preference for convective clouds was found. As discussed by McCumber (1980), the model predicts less convergence over south Florida in the west and south coast sea breezes where marshes and wet soils are located since the ground will remain cooler and the thermal contrast between sea and land will be less. The model predicts strong convergence to the north where dry, warmer sands are located, with a resultant larger heat contrast between sea and land. A comprehensive evaluation of the aforementioned soil characteristics effect are given in Ookouchi et al. (1984) and Kessler et al. (1984).

Despite the fact that peninsula scale convergence is smaller in the southern tip, the lower tropospheric environment for convective clouds would be favored along the southern coast if the environment had higher amounts of low level moisture, due to the wetter soils, so that the available buoyant energy would be greater. As shown from the statistical results of this study (which we will report more on in our next report) and by other works, low level moisture is the only statistically significant, positively correlated large scale thermodynamic variable which is related to the daily averaged percentage of deep convective clouds over south Florida. The model output is currently being examined to ascertain if through mesoscale readjustments of the thermodynamic field, the low level atmosphere is more favorable over the southern tip of the peninsular, than further north. Over the drier soils to the north, in spite of the warm surface layer, the low level moisture supply is lacking, as suggested by the model results. This spatial variability in buoyant energy, as obtained by the model, is currently being evaluated.

The degree of organization of convection along the sea and lake breezes decreased from 1400 EST to 1600 EST as seen from our satellite image composites. Some convective clouds began to move away from the sea breeze fronts by 1600 EST. This result is supportive of the results of Cooper et al. in which there is a decrease in peninsula scale forcing but an increase in cumulus development forced by the convective scale downdrafts. The decrease in the first forcing may be accelerated by the cloud shading effect (e.g. Gannon, 1978; Segal et al., 1984). Shading contrasts may also force local circulations supporting clouds formation along the contrast line (e.g. Purdom, 1982; Segal et al., 1984). Despite the increase in convective scale forcing, however, convection still remained near their initiation regions along the sea breeze front, apparently a result of the preconditioning and enrichment of the atmosphere by the horizontal convergence of moisture, heat, and cumulus cloud themselves within the convergence zones of the sea breeze.

Finally, in the references to this progress report are listed papers which were supported fully or in part by the current NASA grant.

References

Blanchard, D. O., and R. E. López, 1984: Variability of the convective field pattern in south Florida and its relationship to the synoptic flow. NOAA Tech. Memo. ERL ESG-4. U.S. Dept. of Commerce, Boulder, Colorado 80303, 77 pp.

Cooper, H. J., M. Garstang, and J. Simpson, 1982: The diurnal interaction between convection and peninsular-scale forcing over south Florida. Mon. Wea. Rev., 110, 486-503.

Frank, N. L., P. L. Moore, and G. E. Fisher, 1967: Summer shower distribution over the Florida peninsula as deduced from digitized radar data. J. Appl. Meteor., 6, 309-316.

Gannon, Sr., P. T., 1978: Influence of earth surface and cloud properties on the south Florida sea breeze. NOAA Tech. Rep. ERL 402 - NHEML 2. U.S. Dept. of Commerce, Boulder, Colorado 80303, 91 pp.

Kessler, R. C., D. Eppel, R. A. Pielke, and J. McQueen, 1984: A numerical study of a large sandbar upon sea breeze development. Arch. Met. Geoph. Biokl. (accepted).

Mahrer, Y. and M. Segal, 1984: On the effect of islands geometry and size on inducing sea breeze circulation. Mon. Wea. Rev. (in press).

McCumber, M. C., 1980: A numerical simulation of the influence of heat and moisture fluxes upon mesoscale circulations. Ph.D. Dissertation, Dept. of Environmental Sciences, The University of Virginia, Charlottesville, 255 pp.

McPhearson, R. D., 1970: A numerical study of the effect of a coastal irregularity on the sea breeze. J. Appl. Meteor., 9, 767-777.

⊗McQueen, J. T., 1985: A numerical and climatological investigation of deep convective cloudiness patterns in south Florida. M. S. thesis, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, 120 pp.

Ookouchi, Y., M. Segal, R. C. Kessler and R. A. Pielke, 1984: Evaluation of soil moisture effects on the generation and modification of mesoscale circulations. Mon. Wea. Rev. (accepted).

Pielke, R. A., 1974: A three-dimensional numerical model of the sea breezes over south Florida. Mon. Wea. Rev., 102, 115-139.

Purdom, J. F. W., 1982: Subjective interpretation of geostationary satellite data for Nowcasting. Nowcasting, Ed. Browning, K. A., 149-166.

⊗Segal, M. and R. A. Pielke, 1984: On the effect of water temperature and synoptic flows on the development of surface flows over narrow-elongated water bodies. J. Geophys. Res. (in press).

⊗Segal, M., R. A. Pielke and Y. Mahrer, 1984: Evaluation of surface sensible heat flux effects on generation and modification of mesoscale circulations. Proceeding of the Second International Symposium on Nowcasting, European Space Agency, Norrköping, Sweden, 3-7 Sept., 263-269.

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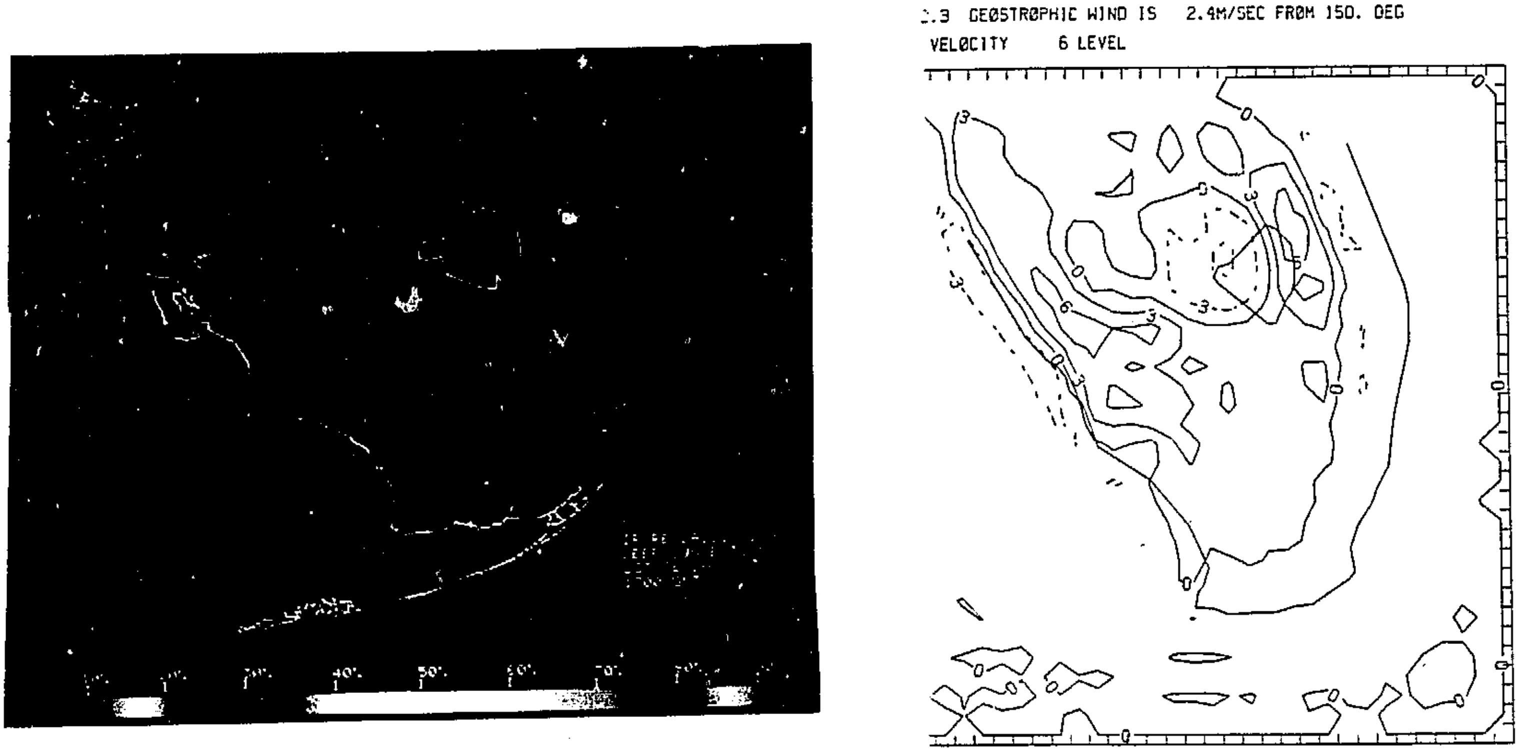

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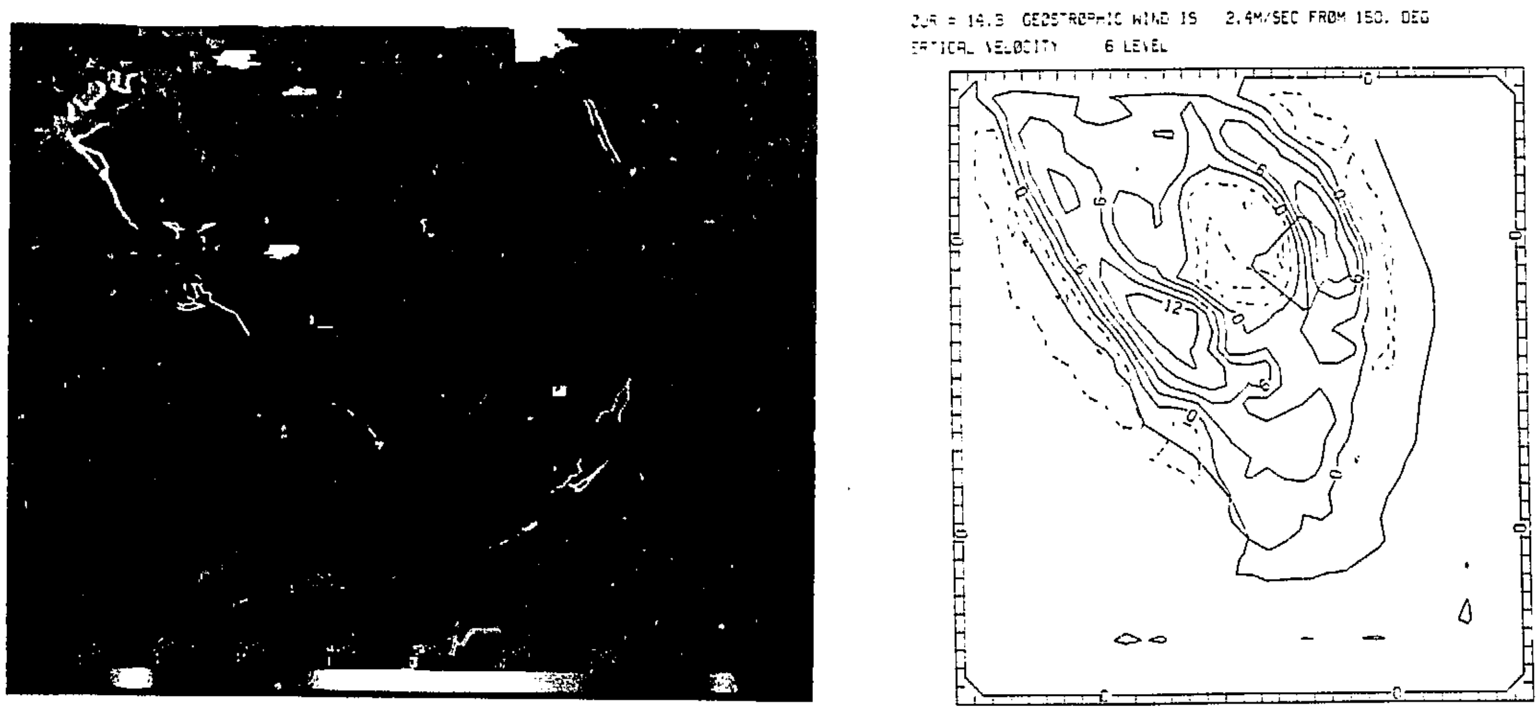

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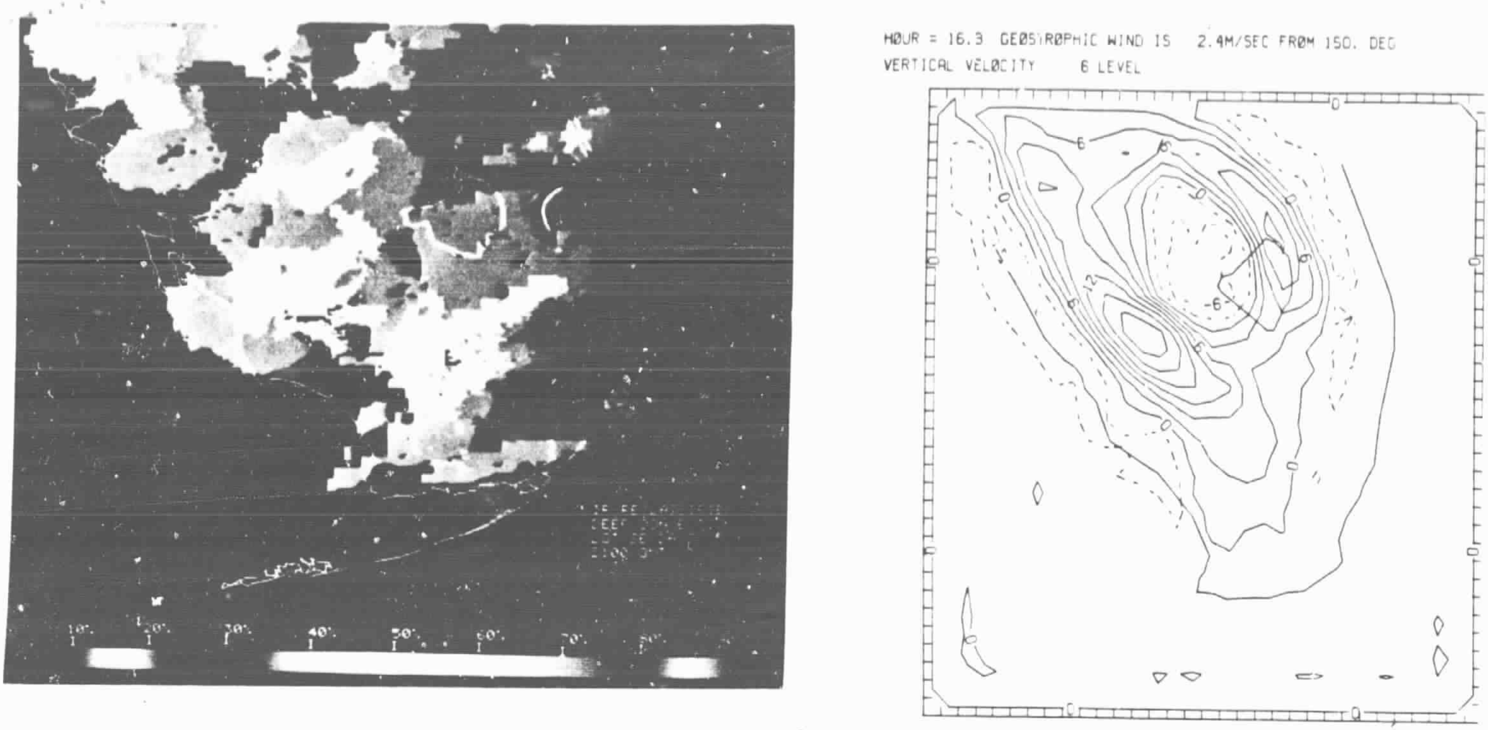
Figure 1. Deep convective cloud satellite image composite and model predicted vertical velocities for south Florida at: (A) 1200 LST, (B) 1400 LST. Color bar on the bottom of each satellite composite relates deep, convective cloud frequencies to color. Vertical velocities are shown at 1 km and the contour interval is 3 cm/sec.



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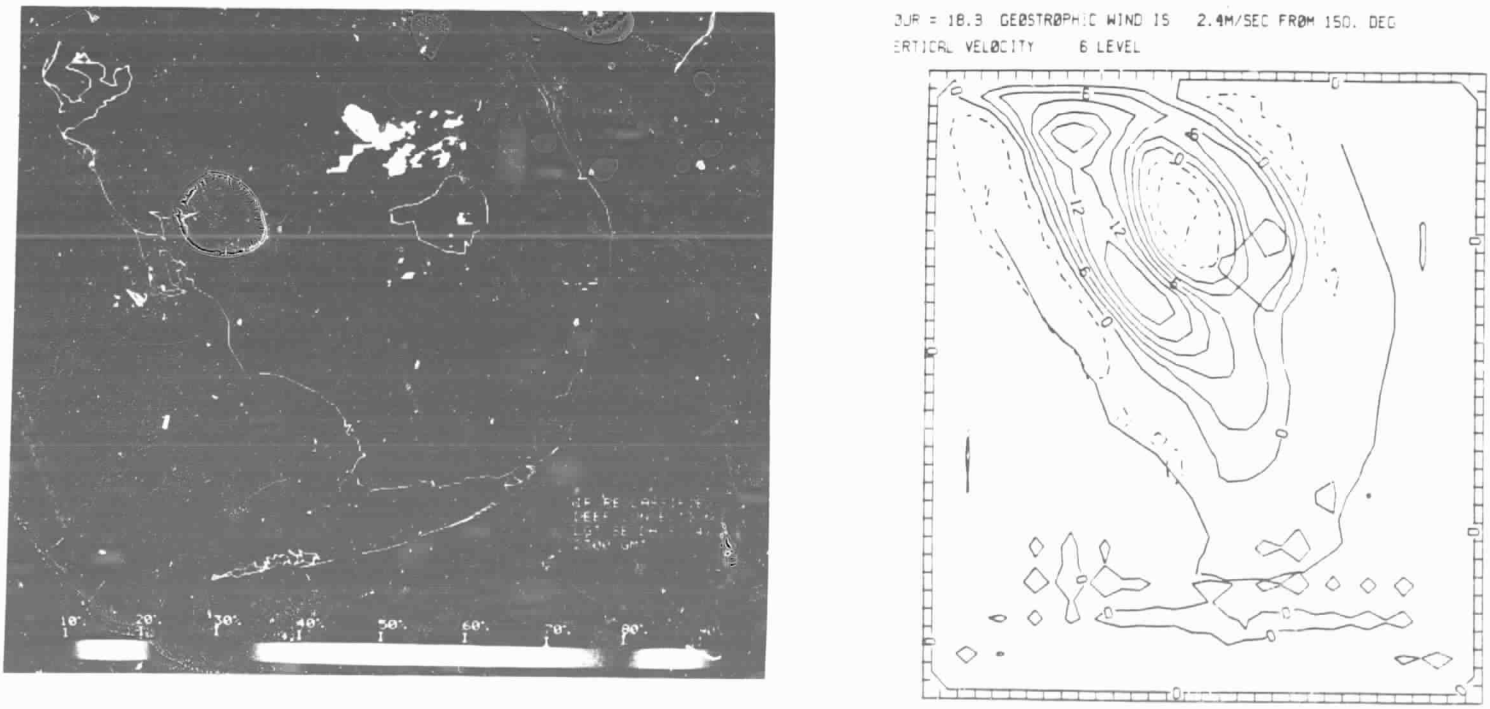

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Figure 2. Same as Figure 1 except for (A) 1600 LST, and (B) 1800 LST.