NUMERICAL STUDIES PERTAINING TO AIRFLOW ON THE WEST COAST OF THE US

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LONG TERM GOALS

The long term goal of this project is to improve our understanding and forecasting of coastally trapped disturbances (CTD) that occur along the west coast of the U.S. in spring and summer. The passage of a CTD is generally associated with a sudden change in the local weather from clear skies to dense stratus clouds.

OBJECTIVES

During this last year we have focused our investigations on two outstanding questions regarding the processes that maintain the amplitude of CTDs as they propagate northward along the west coast. The first question is how CTDs maintain their strength while propagating around the coastal bends and across the gaps in the Pacific Coast Ranges. The second question is how CTDs persist without losing their energy though the generation of upward propagating gravity waves.

APPROACH

Our investigation has employed a hierarchy of numerical models and analytic theory. A three-dimensional nonhydrostatic model for the simulation of stratified air flow over topography has been used to study the propagation of CTDs along both a smoothed profile of the actual west coast topography and more idealized ridges. Shallow-water models have been used to investigate the horizontal structure of disturbances propagating along both straight and curved side-walls. Analytic theory has been used to describe the small-amplitude response of the fluid in idealized environments. These approaches are coordinated in an effort to arrive at the simplest physical description of the phenomena that is consistent with the available observations.

WORK COMPLETED

The observations of Ralph, et. al., (1997, hereafter R97) show that the northward propagating CTD is immediately preceded by a deepening of the marine layer near the

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southern California coastal mountains. Our co-investigators (Rotunno and Klemp) have have conducted numerical simulations to yield a schematic model of the processes leading up to the development of a CTD that mimics the one observed in R97. In particular, they showed that a CTD is triggered when sufficient cold stable air is piled up against the coastal mountain range. The results from these observations and numerical simulations suggest that the process of CTD initiation can be modeled by starting with a deepened marine layer in southern California. The resulting ``damn-break'' problem produces a CTD that behaves similarly to the ones in more complex simulations initialized with more realistic synoptic forcing.

Although this earlier work appears to have established the basic dynamical processes responsible for the development and propagation of CTDs, several fundamental questions remain unanswered. In particular, it is not clear how the propagation of the CTD is influenced by gaps and bends in the coastal topography or why the CTD does not decay as the result of energy lost to vertically propagating gravity waves. In order to address these questions a three-dimensional nonhydrostatic primitive equation model has been modified to include the realistic topography of the west coast and this model has been used to simulate the propagation of CTDs along the Pacific coast. The numerics of this model have also been improved so that they better capture the evolution of poorly resolved waves and steep gradients. This improvement was required in order to simulate CTD initialized with a "dam-break" and to better describe the the temperature structure in the elevated inversion at the top of the coastal marine layer.

A series of simulations were conducted using different atmospheric structures. Structures that received particular attention where (1) two neutrally stratified layers separated by a jump in potential temperature, which is the closest analog to a shallow water model, (2) a neutrally stratified layer with a capping inversion topped by a deep layer of stably stratified fluid (which is an approximate model of the actual well-mixed layer and overlying troposphere off the Pacific Coast), and (3) a uniformly stratified layer.

RESULTS

In their climatological study of CTDs along the western coast of the United States, Bond et al. (1996) documented a number of cases in which CTDs continue to propagate past significant bends and gaps in the coastal orography. Observations of the 1994 ARI field program analyzed by R97 provide a particular example of this; the CTD they studied rounds a bend in the coastline at Point Conception and propagates past the gap in the orography at Monterey Bay.

Figure 1 shows the results of a numerical simulation of a CTD with a slightly smoothed representation of the actual California topography. (The topography is contoured at 200 m intervals.) The CTD is distinguished by the region of strong southerly winds (indicated by the vectors) and colder temperatures (indicated by darker shading) near the coast. After ten hours, the CTD has arrived at the southern end of Monterey Bay. After twenty hours the CTD has continued to propagate northward and passed the gap at Monterey Bay without major disruption. In contrast, the CTD experiences significantly more modification as it passes the entrance to San Francisco Bay. Although the CTD does continue to propagate northward beyond San Francisco Bay, its amplitude is weaker north of the bay. There is also a component of westerly flow that channels cold marine air into the central valley.

These results show that the influence of coastal bends and topographic gaps on the propagation of CTD depends on the character of the gaps and bends. One important difference between Monterey bay and San Francisco Bay is the length of the gap in the coastal orography. Further investigations are necessary to determine the response as a function of key nondimensional parameters such as the ratio of the gap width to the Rossby radius of deformation. Nevertheless, it is clear that these simulations can help elucidate the role played by coastal orography in regulating the northward propagation of CTD.

The simulation shown in Figure 1 is for an atmospheric structure consisting of two neutrally stratified layers separated by an elevated inversion which is a first-order approximation to the climatological structure associated with the summertime marine layer off the California coast. We were surprised to obtain very similar results even when this atmospheric structure was modified to include stratification in the upper layer (which is an even better model of the summertime climatological conditions off the West Coast). The stratification permits vertically propagating gravity waves to carry energy aloft and this energy transport might be expected to weaken the disturbance. Similar CTD were even generated in additional idealized simulations in which the low-level inversion was removed and there was a uniform stratification from the surface to the top of the numerical domain. Together with our co-PI's, Rich Rotunno and Joe Klemp, we are investigating the dynamical processes that maintain the CTD in an environment in which the upward propagation gravity waves can potentially radiate energy away from the disturbance. Our hypothesis is that nonlinear wave steepening maintains the sharp front of the CTD and counteracts the energy loss through vertical wave propagation.

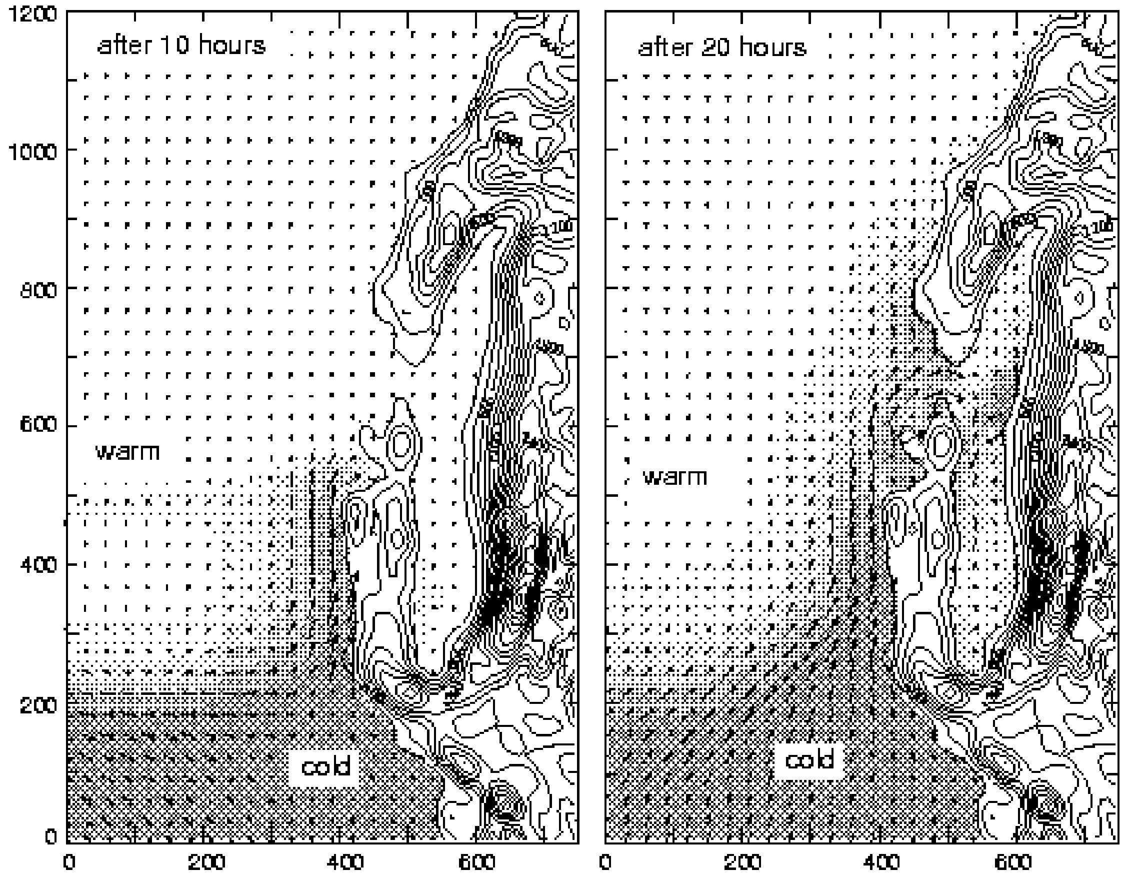

Figure 1.

IMPACT

Disturbances are observed to propagate along the margins of significant topographic features at many locations throughout the world, including the eastern slope of the Rocky Mountains and the southern coast of South Africa. The fundamental issues concerning the propagation and maintenance of these disturbances that we are addressing in this research should ultimately help improve the forecasting of these features at several locations throughout the world.

RELATED PROJECTS

This is a joint project with co-investigators Richard Rotunno and Joseph Klemp at the National Center for Atmospheric Research (NCAR). The funding for our co-investigators has been provided via a separate ONR grant to NCAR entitled "Numerical Studies Pertaining to Airflow on the West Coast of the U.S."

REFERENCES

Bond, N. A., C. F. Mass, and J. E. Overland, 1996: Coastally trapped wind reversals along the United States west coast during the warm season, Part I: Climatology and temporal evolution. Mon. Wea. Rev. 124, 430-445.

Ralph, F. M., L. Armi, J. M. Bane, C. Dorman, W. D. Neff, P. J. Neiman, W. Nuss, and P. O. G. Persson, 1997: Observations and analysis of the 10-11 June 1994 coastally trapped disturbance. To be published in Mon. Wea. Rev.