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SURFACE FLUXES AND STRATOCUMULUS CLOUDS IN DECS: A MODELING STUDY

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1. Introduction

It is well known that stratocumulus clouds in California central coast area undergo strong diurnal variation. During late evening and night, stratocumulus clouds develop over the land area. The clouds dissipate after the sunrise, a process called "morning burnoff". This phenomenon was frequently observed in Development and Evolution of Coastal Stratocumulus (DECS) project (Kalogiros and Wang, 2001a and b). Fig 1 shows the observed diurnal variations of the cloud top and base heights over land on 6 July, 1999. The cloud base height maintained more-or-less constant at 350m from 11:00 pm to 7:00 am, and increased to 500m at 12:00 pm. Then there was clearly cloud breakup period around 01:00 pm, and after 03:00 pm. It is interesting to note that the inversion-base height decreased with the rise of the cloud base height.

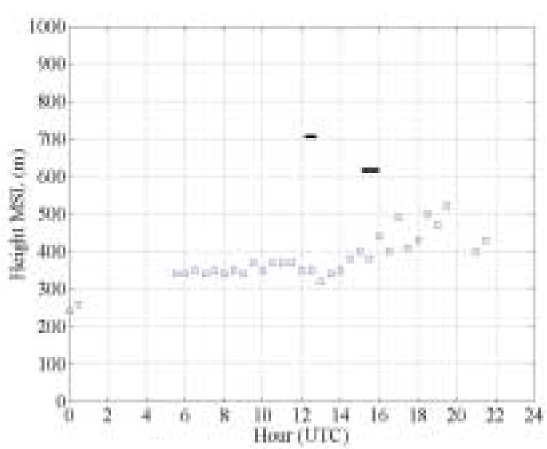

Fig. 1. Ceilometer measurement of cloud base heights (dot), and rawinsonde derived inversion base height (horizontal bars), 6, July, 1999.

Although the solar radiation is clearly involved in the processes responsible for the variation, other variables such as mesoscale circulation and land-sea surface inhomogeneity need to be considered. Furthermore, the detailed process that leads to the cloud breakup has yet to be offered. Because the phenomena involves both turbulence-cloud-radiation fine scales and coastal mesoscale flows, we take two different approaches: an idealized Lagrangian cloud modeling and a mesoscale model reanalysis.

2. Idealized Lagrangian cloud modeling

Two dimensional version of the LES model described by Stevens et al. (1999) was initialized over water with typical soundings of FIRE. The model was integrated with constant SST until the simulated air column reached the land at about 12:00 pm. Five simulations have been copnducted as demonstrated in Fig. 2. This Lagrangian approach is based on the observations that on-shore flows frequently exist. A major weakness in this method is that the mesoscale flows are specified.

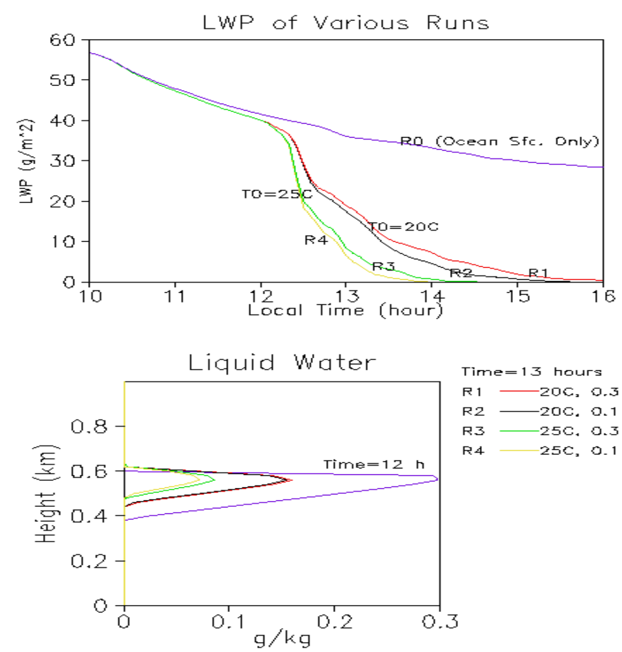

Fig. 2. Various simulations: T0 is land surface temperature; R1-5 are different runs with different T0 and moisture availability specified to the right of the plots.

It is seen from Fig. 2 that after the landing of the air column, the cloud rapidly dissipates particularly for higher land surface temperature T0. The buoyancy flux profiles (Fig. 3) at the different time show considerable warming due to the surface heat and cloud-top entrainment fluxes after the landing of the column. Particularly, the negative buoyancy flux at the cloud base (400 m) significantly increases from 12.25 to 12.5 hours, indicating that the enhanced entrainment may be causing decoupling of the well-mixed PBL. It is also

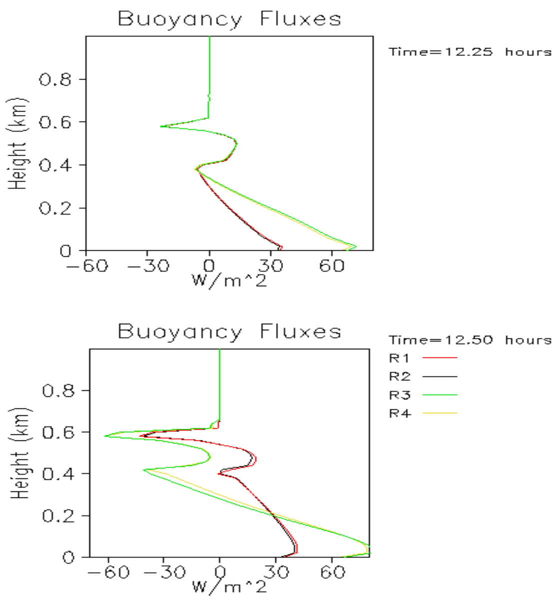

Fig. 3. Profiles of buoyancy fluxes at different times for different runs.

noticeable that the change of buoyancy flux starts from the surface and extends upward. TKE profiles shown in Fig. 4 demonstrate impacts of significantly increased surface buoyancy flux. Particularly, the maximum just below the inversion increases significantly, indicating the occurring strong entrainment. The above Lagrangian cloud modeling results can be summarized as follows:

Solar incoming flux $\uparrow \Rightarrow$ Ground temperature $\uparrow$

$\Rightarrow$ Surface heat flux $\uparrow \Rightarrow$ Buoyancy flux $\uparrow$

$\Rightarrow$ TKE $\uparrow$ $\Rightarrow$ Cloud-top entrainment $\uparrow$

$\Rightarrow$ Clouds warmed up $\uparrow \Rightarrow$ Cloud breakup

3 COAMPS regional modeling

A number of weakness exist in the above idealized cloud simulation. One of them is the lack of definition of realistic mesoscale flow pattern. The other is the prescribed ground temperature.

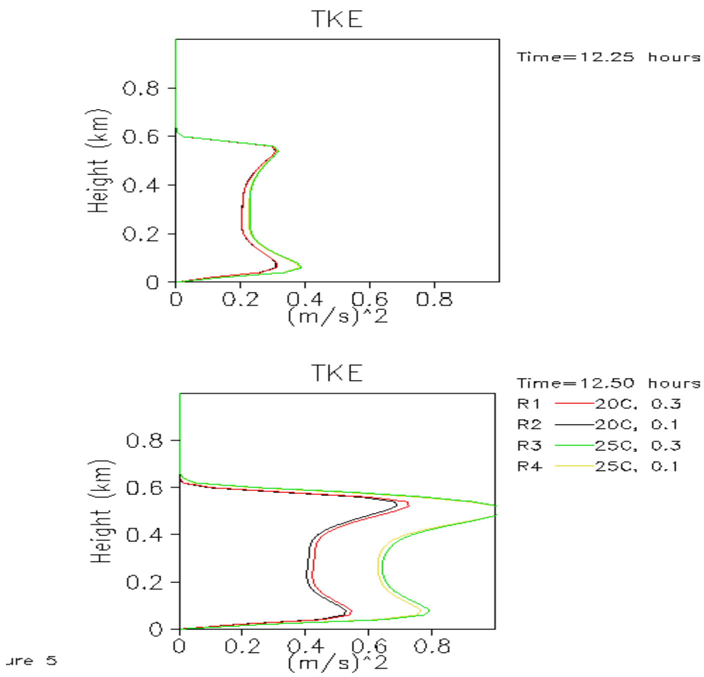

Fig. 4. TKE profiles.

Therefore, we performed a mesoscale simulation using COAMPS (Hodur, 1997) which has detailed topography and the ability to predict ground surface temperature. Three nested grids were used, 5km, 15km and 45km, in the one-week simulation from 5 July, 12 July, 1999.

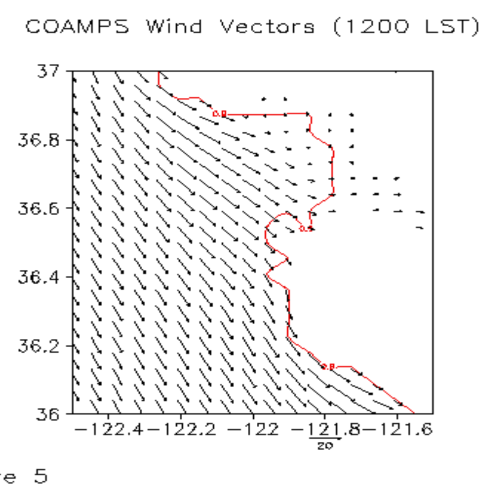

Fig. 5 displays the flow pattern at 50m relative to the coast line, indicating onshore flow for Monterey bay area and justifying the approach of Lagrangian simulation. Temporal variation of clouds and surface variables are shown in Fig. 6. Both ground surface temperature and surface heat flux increase significantly after the sunrise (~0600 LST). The maximum liquid water content of clouds decrease from 0.7 g kg^{-1} at 11:00 am to 0.2 g kg^{-1} at 4:00 pm, starts to increase at 6:00 pm, a pattern consistent with our experience, although clouds

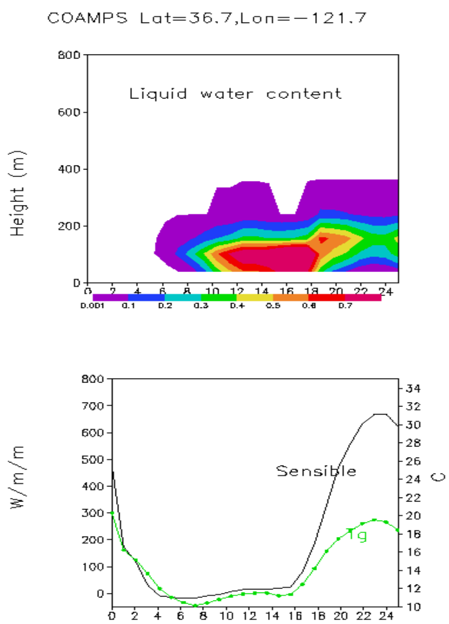

Fig. 6 Diurnal variation of clouds (above) and ground temperature (Tg) and surface sensible heat flux, 6 July.

did not completely disappear. The COAMPS simulation is consistent with the idealized cloud modeling in that both predict cloud dissipation with the significant increase of surface sensible heat flux. However, the decrease of the PBL height observed in rawinsonde measurements as shown in Fig. 1 was not present in either of the simulations. We speculate that the decrease is related to the reduced cloud-top radiative cooling resulting from cloud solar warming and the cloud dissipation process.

4. Summary

A cloud model and a mesoscale model (COAMPS) have been used to study the diurnal variation of stratocumulus in the California central coast. The results show that a major controlling factor is the surface sensible heat flux, which increases significantly during daytime resulting from surface heating and enhances the cloud-top entrainment. The clouds dissipate due to this enhanced entrainment. Several physical processes are currently under investigation: cloud layer solar warming, mesoscale circulation and drizzle. Because the cloud dissipation process is closely related to the surface sensible heat flux, we are also improving the flux parameterizations in COAMPS to realistically predict the cloud diurnal evolution.

Acknowledgment

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