Modeling Aerosol Effects on the Formation of Pockets of Open Cells in Marine Stratocumulus Using WRF Modeling System

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Introduction

- Satellite imagery shows the recurrence of Pockets of Open Cells (POCs) in marine stratocumulus (Sc) (e.g. Fig 1d in the blue box);
- POC regions are optically thin, affecting the Earth's radiation budget;
- POCs are often associated with precipitation, which may be susceptible to aerosol loading;
- Evaporative cooling in POCs produces "cool pools" that may affect mesoscale organization.

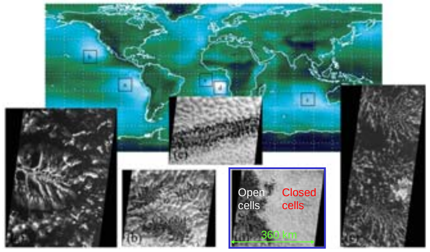


Fig. 1: MISR images of actinoform (radial structure) clouds (black & white); Color map from International Satellite Cloud Climatology Project (ISCCP) showing 1983-2001 mean annual low-cloud amount. (Source: Garay et al. 2004)

Objectives and Method

- To examine factors that control macro/microphysical properties of Sc, particularly, over POC region;
- To examine aerosol effects on the formation and evolution of POCs and on precipitation in POCs;
- Traditional large-eddy simulation (LES) domain (up to 25x25 km^2) limits its ability to study POCs with dimension of 100s km and each cell at 10s km;
- WRF modeling system:
  - 2-moment microphysics (Feingold et al. 1998)
  - 1-way/2-way grid nesting; online chemistry.
- LES nested in mesoscale grids:
  - aerosol effects and dynamical feedbacks on POCs
  - large-scale forcing on POCs.

Preliminary Results

- WRF-LES is used to model Sc in clean and polluted environments ($\Delta x = \Delta y = 240$ m; $\Delta z = 30$ m). Cloud albedo fields at different times are compared in the following figure; The initial profiles are based on measurements made during the Second Dynamics and Chemistry of Marine Sc (DYCOMS-II) experiment off the coast of California.

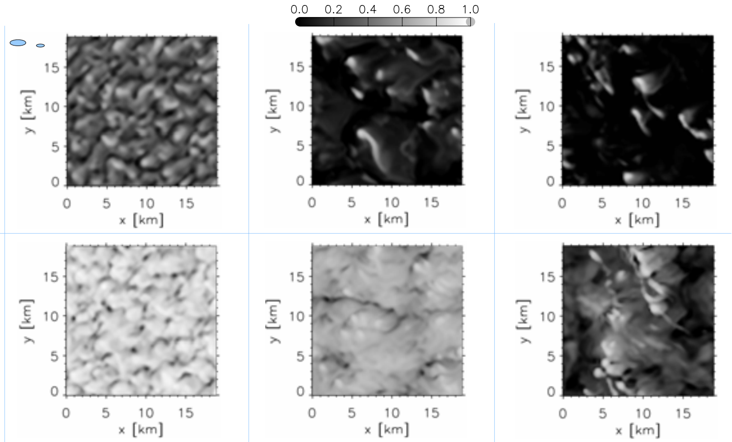
Cloud Albedo

Clean case: Cloud Condensation Nucleus (CCN) =65 cm^{-3}

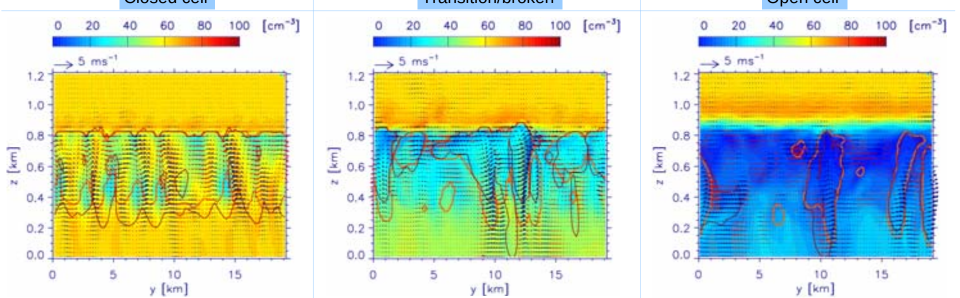
Closed-cell Sc sheet starts breaking up after about 2 hrs; Then gradually patchy and cumulus-like cells are formed and aligned along the wind.

Polluted case: CCN=300 cm^{-3}

Polluted clouds are brighter; The cellular structure of Sc changes with time but the Sc sheet does not break up during the 8-hr simulation.



- Vertical cross-sections of total particle (CCN + drop) number concentration (shaded colors), perturbation wind vectors (updrafts and downdrafts), cloud outline (0.001 g kg^{-1}) and drizzle water (0.001 g kg^{-1}) to show different stages of the evolution of Sc from closed cells to open cells.

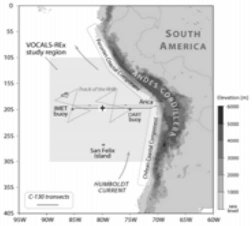


Closed cell	Transition/broken	Open cell
Cloud tops are well defined; Eddies mix air through the Boundary Layer (BL); Particles in cloud layer are decreasing, but CCN are vented into clouds from below; Drizzle drops are transported downward in the downdrafts, but do not reach the surface.	Cloud-top radiative cooling and surface heating enhance convective instability and strengthen in-cloud circulations; Lower-level air is moistened and cloud layer deepens; Drizzle can now reach the surface; Sc sheet is broken and patchy; Small cumuli start forming;	Sc sheet breaks up into cumulus-like clouds that are maintained by surface heat and moisture supply; Cloud base is further lowered ; Particles in the BL are significantly depleted; Some CCN are entrained from above cloud but not many;

Summary and Future Work

- Simulation results support the hypothesis that precipitation in clean air is critical to the breakup of a closed-cell Sc sheet;
- A combination of cloud thickening due to dynamical forcing and low drop concentrations may trigger and accelerate the breakup of Sc sheet;
- Cumulus updrafts driven by surface heating transport water vapor and CCN from the mixed layer to the cloud layer, maintaining the 'wall' of open cells;
- The simulation results need to be evaluated against observations.

VOCALS-REx (VAMOS Ocean-Cloud-Atmosphere-Land Study Regional Experiment)



When: October 2008

Where: South-east Pacific

- VOCALS-REx (Chile) will collect datasets supporting further modeling work on this topic:
  - Embedding LES in mesoscale grid (varying large-scale forcing, mesoscale organization, surface forcing)
  - Adding CCN sources from direct aerosol emission, secondary particle formation, and nucleation;

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