OBSERVATIONS AND CLOUD-RESOLVING MODEL SIMULATIONS OF CIRRUS ANVIL SPREADING AND DECAY

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Introduction
Observations show that cirrus clouds often result from the life cycle of convective cloud systems. Machado and Rossow (1993), using satellite imagery, found that relatively thin high clouds constitute a large part of the area covered by such systems, especially when considering the system’s entire life cycle.

Idealized Simulations
The EU-CRM specifications included a 200 m grid size in both the horizontal and vertical directions and a spatial domain 51.2 km long and 18.2 km high. We represented the generation of cirrus anvils by detrainment from deep convection by adding (‘injection’) cloud ice in a layer between 9 to 11 km height and in a sub-region of the domain over a time period of 6 hours. The horizontally averaged rate of ice addition was 0.007 kg m⁻² s⁻¹ for most runs. We ran each simulation for a total of 18 hours.

The Problem
From a GCM perspective, convectively generated cirrus anvils originate from concentrated substrates. In order to more realistically represent both radiative and microphysical processes in anvil clouds in GCMs, the cloud fraction due to anvil clouds should be included by representing, in a simplified fashion, the physical processes that form, maintain, and dissipate anvil clouds. The fraction of a grid cell occupied by anvil clouds is largely determined by the history of the clouds, so that a prognostic cloud fraction parameterization is appropriate. Such an approach has been developed by Tiedtke (1993), and extended by Randall and Fuehrer (1999). To date, these methods have not been examined using cloud-resolving models (CRMs) or tested against observations except indirectly using global, monthly averaged datasets.

The Approach
We are using the 2D University of Utah CRM to study the cirrus clouds that result from the life cycle of convective cloud systems. (1) We are performing idealized 18-h CRM simulations of the life cycle of anvil clouds to study the physical processes that determine the cloud fraction of anvil clouds. (2) We are analyzing a 29-day simulation based upon Case 3, a joint GISS and ARM intercomparison project. (3) We are using GOES cloud products provided by Pat Minnis et al. to determine how cloud amount and ice mass are related and to compare the retrievals to the CRM simulations.

Case 3 Simulation
This simulates the cumulus convection (and attendant creation of cirrus) observed at the Southern Great Plains Cloud and Radiation Testbed site during the 1997 Summer IOP of the ARM program. As such, a rich variety of cloud property observations are readily available for comparison. The panel to the right shows sample hourly reflectivity snapshots of all hydrometeors (black is >20, color range is >0 to >20) for part of a Case 3 simulation (512 km x 16 km) with interactive radiation.

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References

These Hovmuller diagrams of T2O show the spread of anvil cloud for 8 idealized simulations. They show that:
- There is no spread without radiation, except when vapor instead of ice is injected.
- Mesoscale motions are required for spreading.
- Cloud-scale motions and/or turbulence are NOT required for spreading.
- Solar radiation does not reduce the spreading.

Observations
As part of our DOE ARM research, we used Minnis et al.’s pixel-level cloud products (for the DOE ARM SGP site) which are the same as those available for CRYSTAL-FACE, to provide observational insight into the relationships between cloud amount, large-scale IWP, and cloud-radiative forcing for cirrus clouds; and to provide data for model evaluation. We will analyze the corresponding CRYSTAL-FACE cloud products similarly.

Time series of large-scale OLR (clear-sky and all-sky), clear-sky fraction, and IWP for a 14-h day period during Case 3 from Minnis et al.