Convective-Stratiform-Anvil Transition (CStAT)
Focus Group White Paper

Motivation

Accurate simulation of deep convective systems, and their associated stratiform rain and ice-phase anvil cloud components are still a challenge for cloud resolving, regional, and global models. Stratiform regions and anvil clouds and their associated air motions affect the large-scale circulation via radiative and latent heating feedbacks and transports of moisture and momentum. One of the challenges to modeling these systems is to understand the environmental, dynamical, and microphysical processes that control the transition of mesoscale cloud systems from a collection of convective updrafts to mature systems exhibiting mesoscale circulations, stratiform precipitation, and extensive anvil clouds. The CStAT mission is to advance the observational description and model simulation of this transition.

Background

In their early stages of development convective cloud systems consist of buoyant cumulonimbus elements rising from the boundary layer to the upper troposphere. Groups of cumulonimbus clouds merge into mesoscale regions of multiple updrafts and downdrafts. These groups induce mesoscale circulations on which the convective-scale elements are superimposed. The convective region of the cloud system is a combination of this upward mesoscale circulation and the superimposed convective elements. Depending on wind shear of the environment, these mesoscale circulations feed buoyant air into the mid-to-upper troposphere and form an active stratiform precipitation producing cloud that can occupy a large fraction of the cloud system and account for roughly half the cloud system's precipitation. Extending outward from both the active convective region and the stratiform region are nonprecipitating anvil clouds composed of ice-phase hydrometeors. The convective regions of cloud systems contain localized strong updrafts, which advect snow and ice particles upward and slow the fallout of hail and graupel. The stratiform regions mostly lack strong upward air motions and ice particles of all types drift downward, melt (producing a radar bright band) and fall to the surface as stratiform rain. Surrounding anvil cloud regions contain ice particles that are too light to fall out rapidly.

Each of these structural components (convective region, stratiform rain region, and anvil cloud) has distinct macrophysical and microphysical characteristics that impact the vertical structure of their associated radiative and latent heating profiles. Environmental conditions can be considered to dictate the patterns of structural organization. The familiar curved convective squall line trailed by stratiform precipitation and preceded and trailed by anvil cloud is one form, determined by the combination of thermal stratification and wind shear in the environment.

Researchers are actively working to establish how the distribution of areas covered by convective structural components impacts radiative fluxes, latent heating rate profiles, meso-scale dynamics, global circulation, and climate sensitivity. Currently, across cloud-resolving, regional and climate models, there is a persistently large spread in convection-generated ice and rain microphysical properties predicted under the same meteorological or climatological conditions. In other words, cloud dynamics and microphysics schemes in current models are challenged to faithfully reproduce the relevant properties of convection-generated cloud structural components, as well as their associated process impacts.

Science Questions

1. What are the relative roles of large-scale meteorological conditions, aerosol, wind shear, and small scale variability in determining the morphological and microphysical properties of convection-generated clouds?
2. What are the most relevant properties that models should reproduce to predict the convective lifecycle, including all of the structural components of convective systems? To what degree of accuracy?
3. How do errors in simulated microphysics and their impacts on radiative and latent heating affect prediction of the large-scale circulation?

Objectives

1. Develop important observational targets by model type
    a. Cloud-resolving models (CRMs)
    b. General circulation models (GCMs)
    c. Single-column models (SCMs)
2. Identify key differences in the structural and microphysical properties of the convective, stratiform, and anvil clouds across models and observations and the processes in the models driving these differences
3. Identify key measurements, retrievals, or improvements to model simulators needed to make further progress

Approaches

1. Close collaboration between modelers and observationalists to identify science questions and develop observational case studies
2. Use multi-observation approaches, including advanced forward calculations and collocated ground and satellite measurements
3. Develop IOP comparative case studies from MC3E, AMIE, and TWP-ICE
4. Constrain model dynamics, cold pools, hydrometeor size spectra, ice properties, condensation versus fusion latent heating, radiative fluxes under varying thermodynamic and aerosol states
5. Constrain specific parameterization assumptions (CRM to GCM)

6. Organize breakout sessions at the ASR meetings, as well in major open conferences.

Metrics

In 5 years, the goal of this focus group is to achieve (1) improved understanding of the factors controlling the transition from convective updrafts to stratiform precipitation to anvil, and (2) improved model simulations of deep convective cloud systems in all model types (see objective 1).

Leadership

Researchers interested in participating in this group include Xiquan Dong, Jiwen Fan, Zhe Feng, Ann Fridlind, Wojtek Grabowski, Robert Houze, Mike Jensen, Sally McFarlane, Courtney Schumacher, Wei-Kuo Tao, Adam Varble, Christopher Williams, Ping Zhu, and Edward Zipser. Many are already committed to other leadership duties. Ann Fridlind and Sally McFarlane are willing to lead.