Precipitation formation in Trade Cumulus: Remote Sensing and Modeling

Graham Feingold

NOAA Environmental Technology Laboratory

U of Miami/CIRES/NOAA-ETL proposal:
Albrecht, Kollias/Hare, White/
Fairall, Feingold, Hill

- **Shipboard component**
  - Cloud Radar(s): W-band, K-band
  - Microwave radiometer
  - Doppler Lidar (2 μm, high resolution)

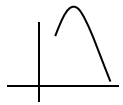
- **Modeling Component**
  - Large Eddy simulations + bin aerosol/cloud microphysics
  - Rainshaft model
  - Parcel models (inorganics and organics)

Objectives

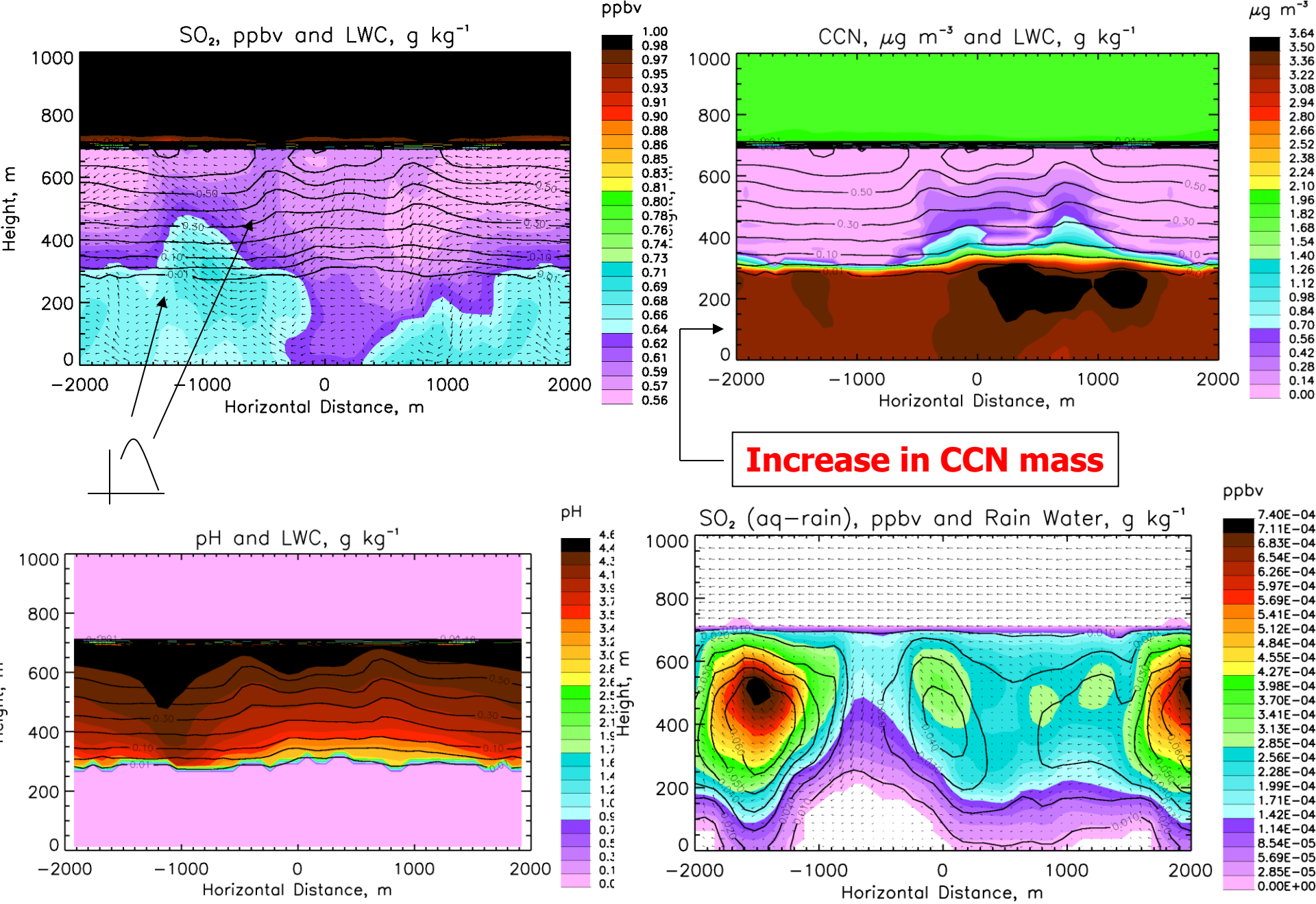
- Document dynamical and microphysical structures in trade-wind cumuli under various dynamical and aerosol conditions;
- Investigate microphysical / dynamical factors and time scales involved in the production of large drops;
- How do the raindrop size distributions evolve from the initial to mature precipitating stages of shallow cumuli?
- How is the marine boundary layer altered by precipitation from trade-wind cumuli?
- What are the statistical properties of precipitating trade-wind cumuli from the cloud to mesoscale scale?

Objectives contd..

- Can we find evidence for cloud processing of aerosol in the observed size distributions?
- Can we detect changes in cloud microphysics under different aerosol loadings?

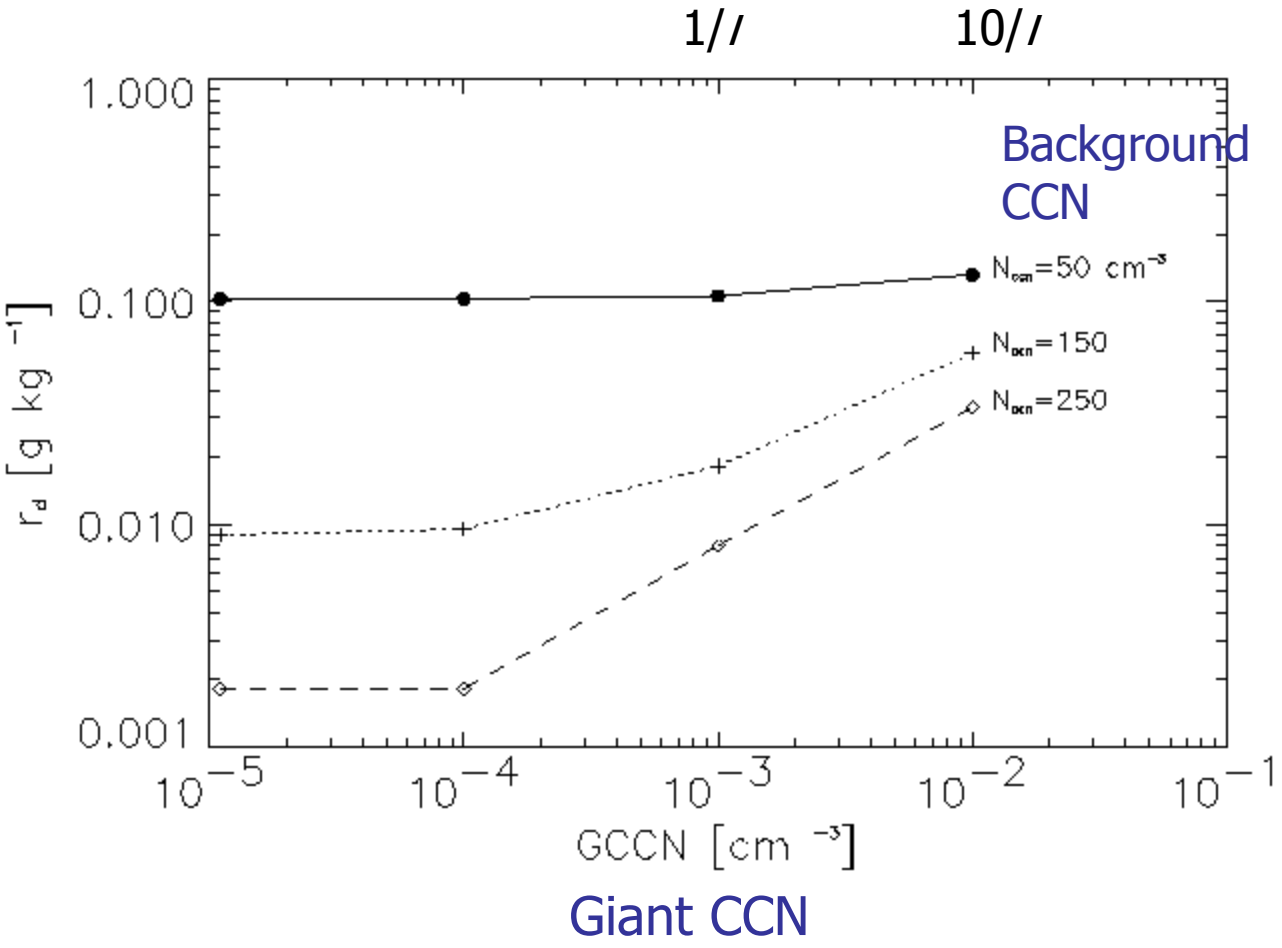
- Large Eddy Simulation (LES)
  + microphysical model 
  + aqueous chemistry model

  - Captures the large eddies containing most of the boundary layer energy
  - Resolves aerosol and drop size distributions on fixed size grids (includes giant CCN)
  - Simulates aqueous chemistry
  - Carries soluble material inside drops
  - Coupled radiation model
  - Radiatively-active aerosol


SO2, ppbv and LWC, g kg-1
Height, m
Horizontal Distance, m
ppbv
CCN, μg m-3 and LWC, g kg-1
μg m-3
Horizontal Distance, m
Increase in CCN mass
pH and LWC, g kg-1
pH
Horizontal Distance, m
SO2 (aq−rain), ppbv and Rain Water, g kg-1
ppbv
Horizontal Distance, m

Prior work: Effect of Giant CCN on drizzle formation in SCu for different background CCN

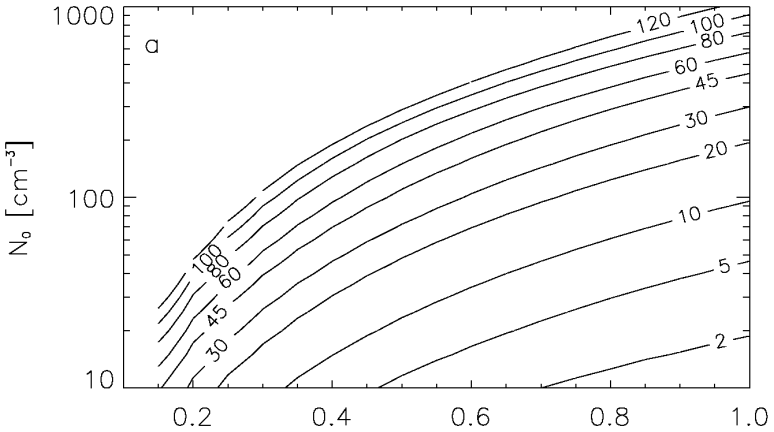
Stronger relative effect at high [CCN]

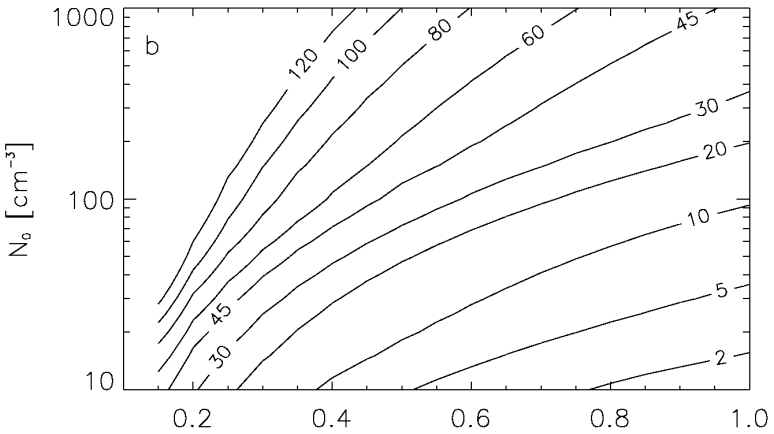


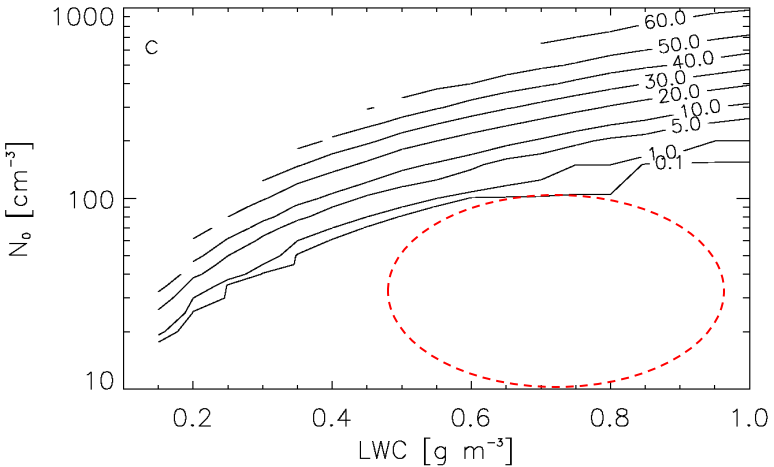
Water in Drizzle drops

Feingold et al. JAS 1999

Will there be sufficient range of background aerosol to investigate the relative effect of giant aerosol?







Time required for 10% of LWC to be transferred to drizzle

No Giant CCN

With Giant CCN

% difference between a and b

Questions to be addressed with LES

- role of dynamics (e.g. recirculation) in large drop production
  - superimpose radar reflectivity and Doppler velocity fields to identify zones of large drop production;
  - Perform similar analyses with the LES

- Effect of precipitation on BL dynamics
  - Remote sensors
  - LES

Questions to be addressed with LES

- The role of giant CCN in initiating precipitation
- the role of precipitation in removing aerosol and soluble gases
- role of cloud processing in influencing precipitation formation and boundary layer dynamics
  - Aqueous chemistry
  - Coalescence scavenging

Direct/Indirect effect studies

Can we find evidence for cloud processing of aerosol?

- Surface and airborne aerosol measurements
- LES

collision-coalescence:

reduction in N_a

Runaway process??

Hoppel

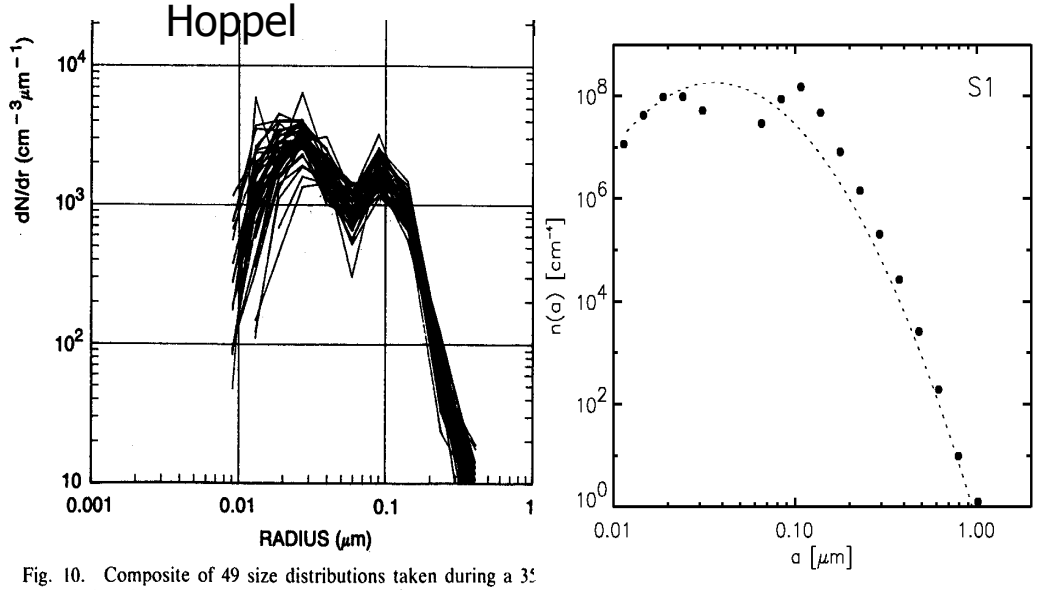
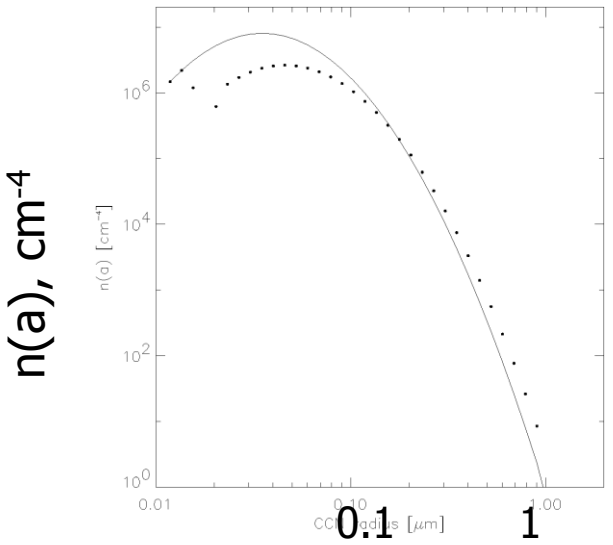


Fig. 10. Composite of 49 size distributions taken during a 35 hour period on March 18 and 19, typical of conditions when there was no continental influence.

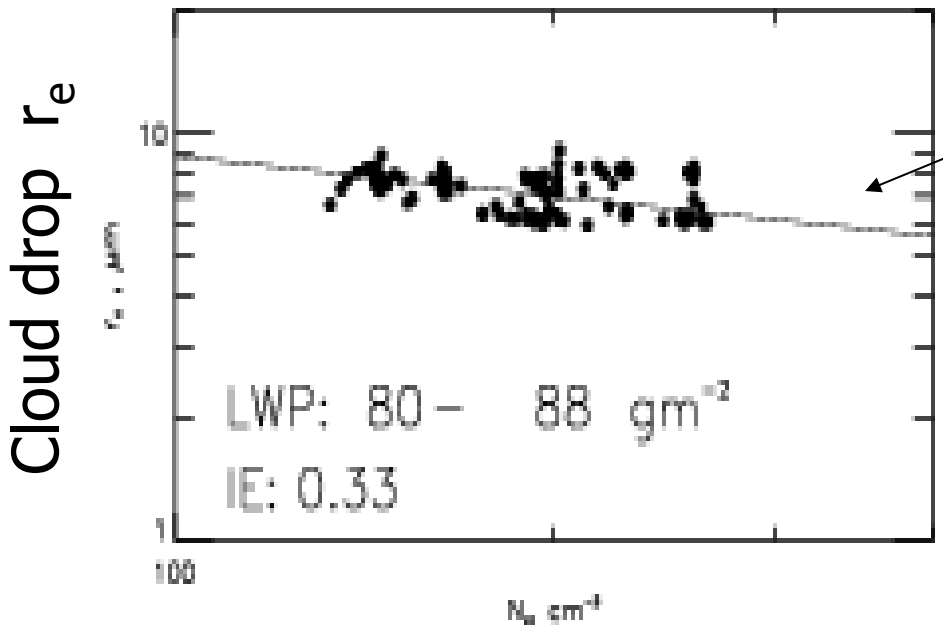


Aqueous chemistry processing

Indirect effect studies

Can we detect changes in cloud microphysics under different aerosol loadings?

- Surface-aerosol measurements
- Drop size retrievals from radar/μwave radiometer



Theoretical Value for slope ~ 0.23-0.33

Surface aerosol concentration (>0.15 μm)

NOAA ETL PACS Cruise, Nov 2003