Perspectives from GATE, TOGA- COARE, and DYNAMO

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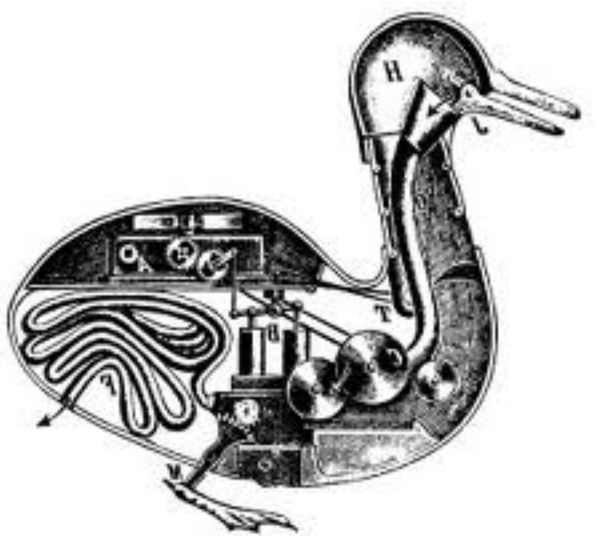
University of Washington and PNNL

Atmospheric Convection & Air-Sea Interactions over Tropical Oceans Workshop
Boulder, June 7, 2019

18th Century "Digesting Duck" of Jacques de Vaucanson, aka "Descartes Duck"

SCIENTIFIC REDUCTIONISM



SCIENTIFIC REDUCTIONISM is an approach to understanding the nature of complex things by reducing them to the interactions of their parts or to simpler or more fundamental entities

SCIENTIFIC HOLISM

HOLISM (from Greek word meaning *all*, *whole*, *entire*, *total*), is the idea that natural systems (physical, biological, chemical, social, economical etc.) and their properties, should be viewed as wholes, not as collections of parts.

HOLISM has lead to "systems thinking" and its derivatives, like the sciences of chaos and complexity. Systems in biology, psychology, or sociology are frequently so complex that their behavior is, or appears to be, "new" or "emergent": it cannot be deduced from the properties of the elements alone.

My point:

Reductionism was practiced in GATE, TOGA-COARE, and DYNAMO

By topic

- Convection
- Boundary layers
- Fluxes at sea surface
- Oceanography

and/or

By platform

- Soundings
- Radar
- Ships
- Aircraft

Bulletin American Meteorological Society
Vol. 55, No. 7, July 1974

GATE

International and Scientific Management
Group for GATE
Bracknell, U.K. and Geneva, Switzerland
World Meteorological Organization

final international scientific plans

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Vol. 73, No. 9, September 1992

TOGA COARE

Peter
Webster

Roger
Lukas

"Strategy"

- An *interface component,* in which the major emphasis will be the measurement and modeling of the interfacial fluxes between the atmosphere and the ocean over a wide variety of atmospheric and oceanic conditions.
- An *atmospheric component,* where the emphasis is on the measurement and modeling of those processes that determine the state of the atmospheric boundary layer, and, thus, influence the interfacial fluxes of heat, water, and momentum. It is anticipated that there will be observations taken over a full extent of weather conditions, ranging from the undisturbed trade-wind boundary layer to the disturbed boundary layer within a convective complexes.
- An *oceanographic component,* where the emphasis is on the measurement and modeling of the response of the upper ocean in order to assess the response to the varying fluxes at the interface that occur over the range of weather events and types encountered in the warm pools of the tropical oceans.

BAMS DECEMBER 2013

DYNAMO Components

Kunio Yoneyama

Chidong Zhang

Chuck Long

Sondes (i) two quadrilateral sounding arrays for adequate atmospheric budget estimates, embedded in a broad sounding network from East Africa to the Maritime Continent within 20°S and 20°N;

Radars (ii) multiple radars of different wavelength to sample the full spectrum of cloud population during all stages of MJO initiation;

Ships (iii) simultaneous and continuous observations of atmospheric and upper-ocean profiles to measure coherent and coupled air–sea variability at time scales from turbulence to the MJO;

(iv) identical twin sites in the IO (Addu Atoll) and western Pacific (Manus Island) to sample the same MJO event at its initiation and mature stages; and

Aircraft (v) an aircraft operation to sample the atmospheric and oceanic boundary layers and large-scale variability between atoll and ship sites.

Question:

What do we really *not* understand about convection forming over the tropical ocean?

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My answer:

How we get from no convection to non-precipitating convection, to deeper precipitating convection, to mesoscale organization

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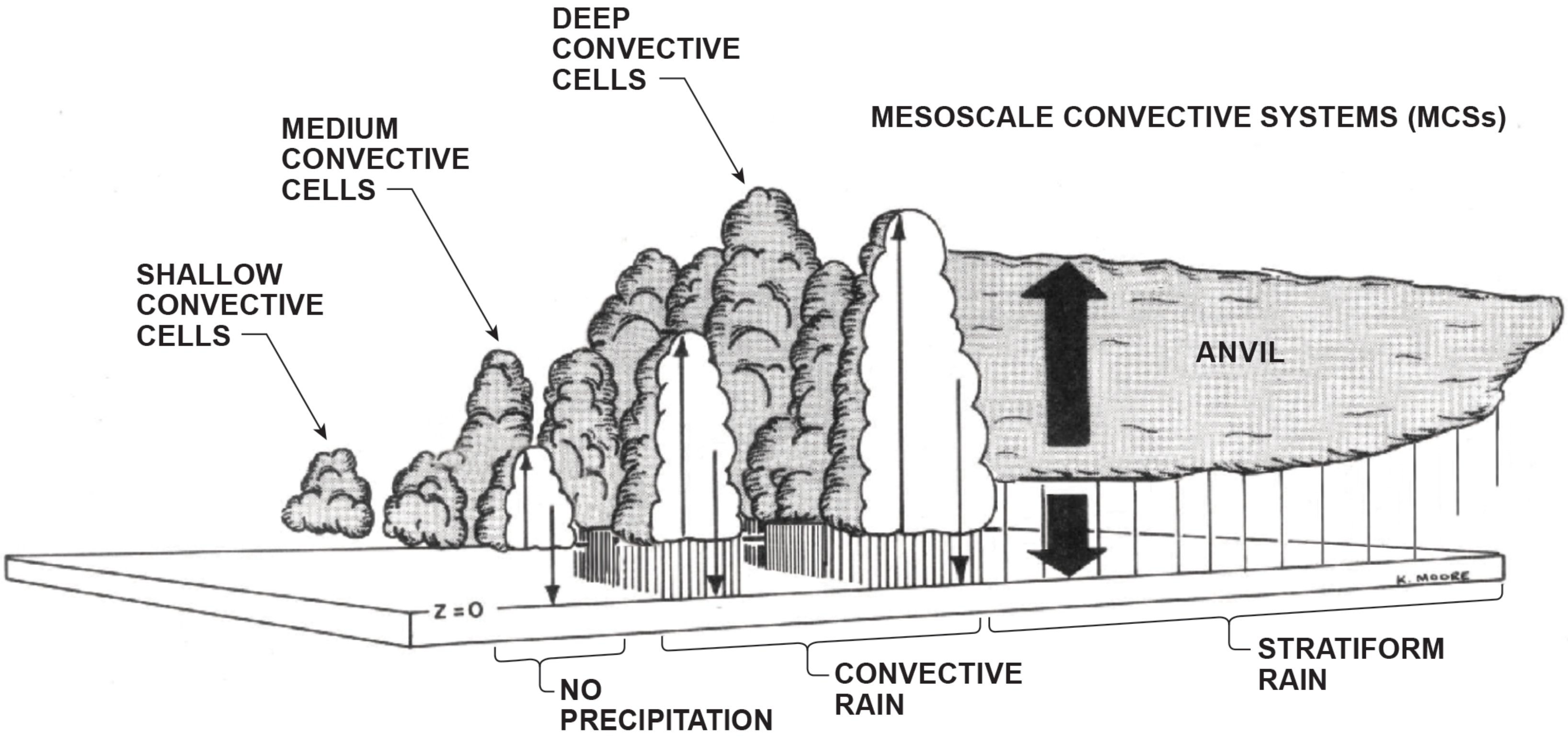
My premise:

Reductionism is preventing us from reaching understanding of the interactive processes.

Tropical Oceanic Cloud Population

Idealized Oceanic Tropical Cloud Population



Houze et al. (1980)

Idealized Oceanic Tropical Cloud Population

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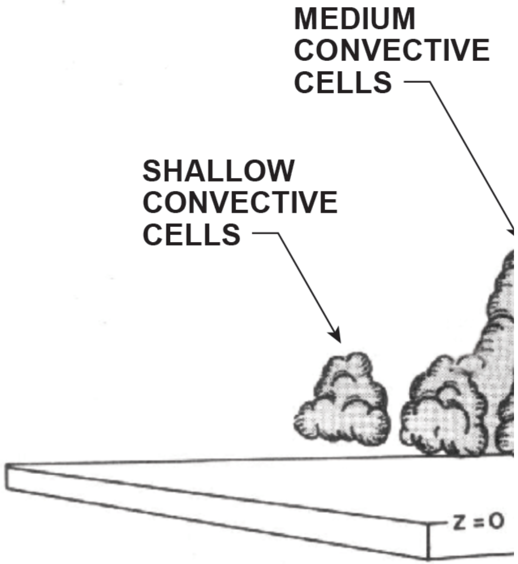
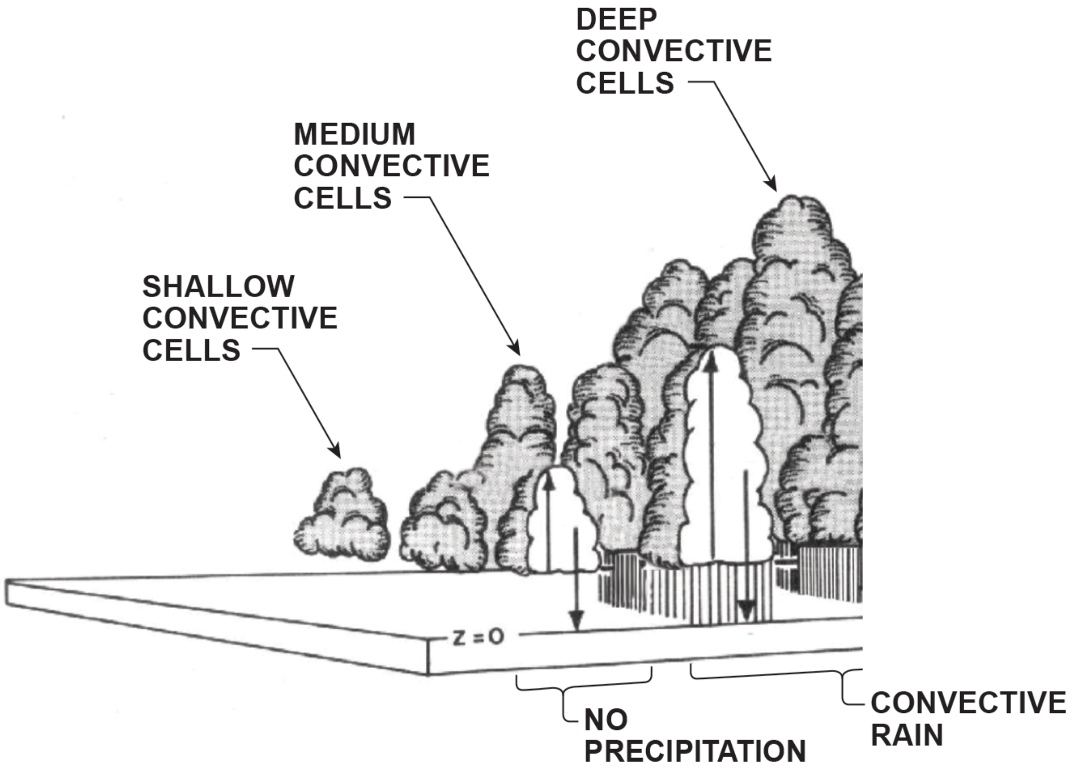
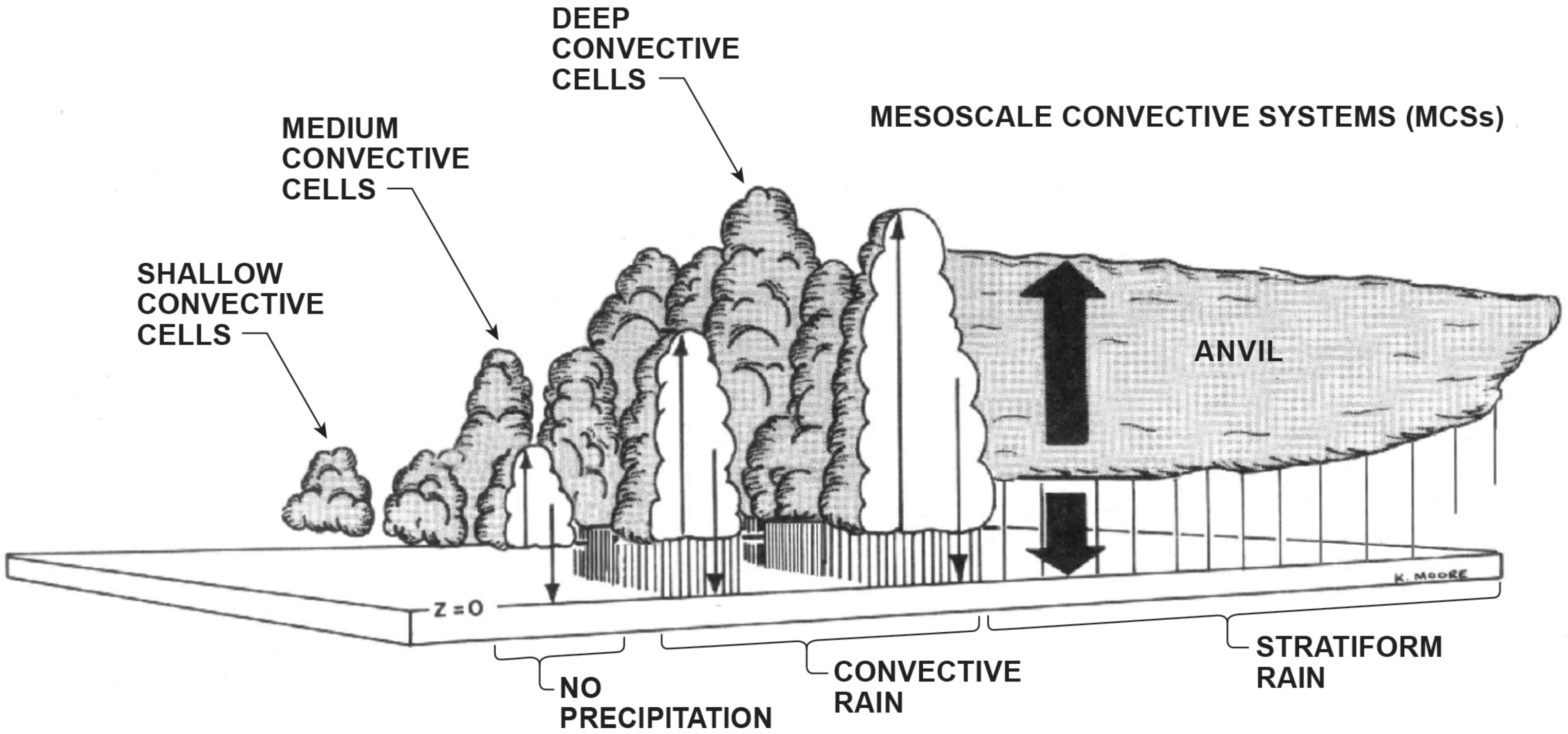


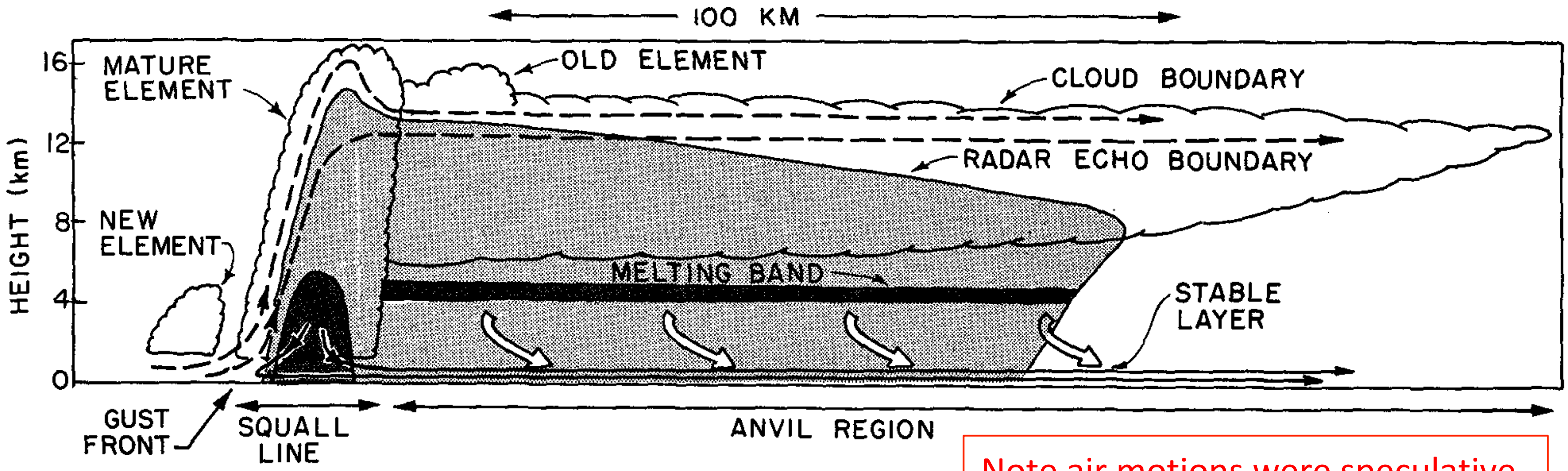

DEEP
CONVECTIVE
CELLS
MEDIUM
CONVECTIVE
CELLS
SHALLOW
CONVECTIVE
CELLS
z = 0
NO
PRECIPITATION
CONVECTIVE
RAIN


DEEP
CONVECTIVE
CELLS
MESOSCALE CONVECTIVE SYSTEMS (MCSs)
MEDIUM
CONVECTIVE
CELLS
SHALLOW
CONVECTIVE
CELLS
ANVIL
Z=O
K. MOORE
NO
PRECIPITATION
CONVECTIVE
RAIN
STRATIFORM
RAIN

GATE

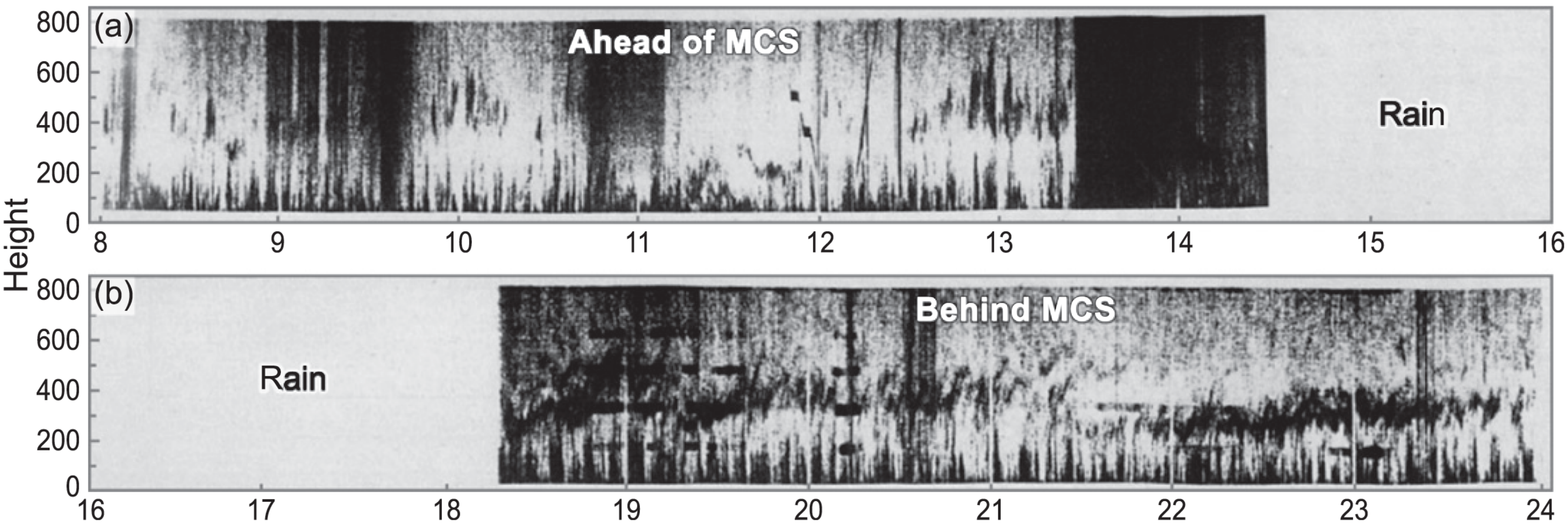
GATE Shipboard Radars
3D Reflectivity structures, but without Doppler or dual-polarimetric capability

DECEMBER 1977 ROBERT A. HOUZE, JR. 1543



Note air motions were speculative, microphysics not indicated

GATE Shipboard Acoustic Sounders Detected Boundary Layer Turbulent Plumes

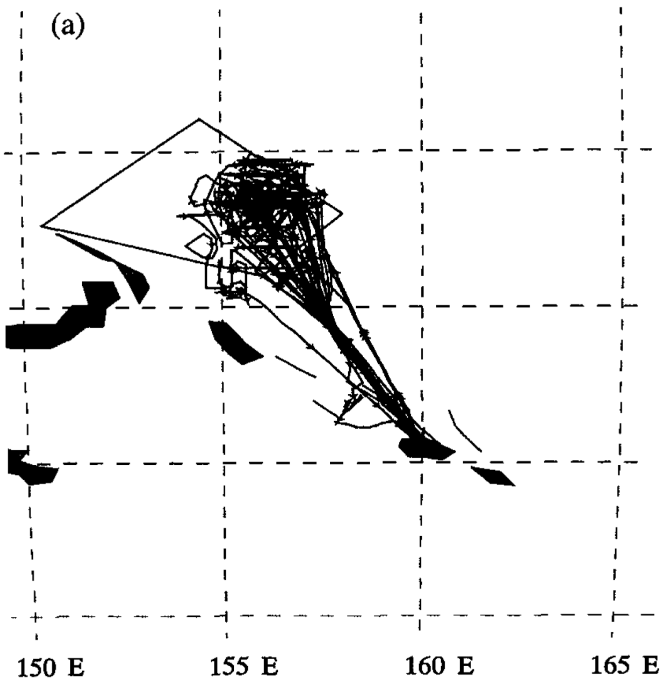


TOGA COARE

TOGA COARE Flights

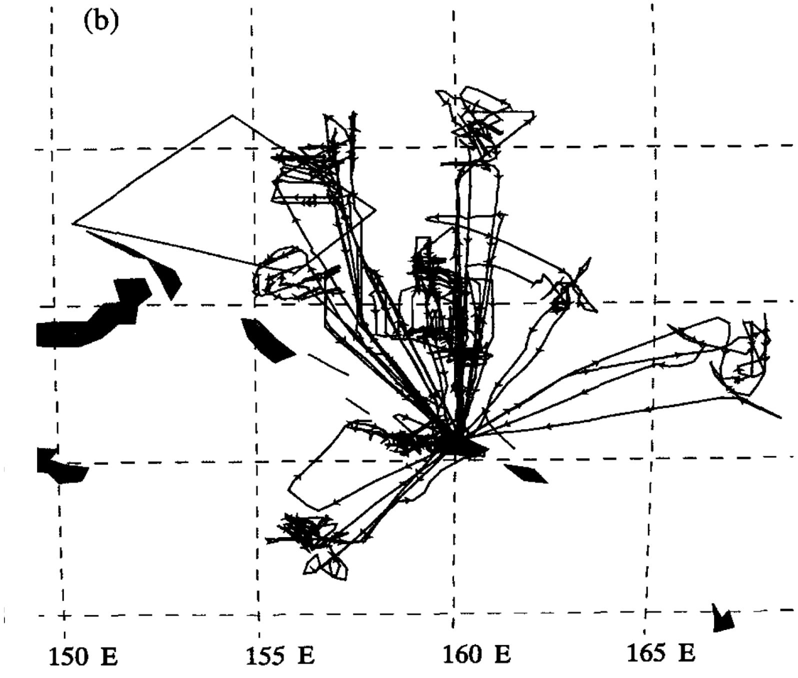
Small cumulus flights

Measured boundary layer properties



Large convection flights

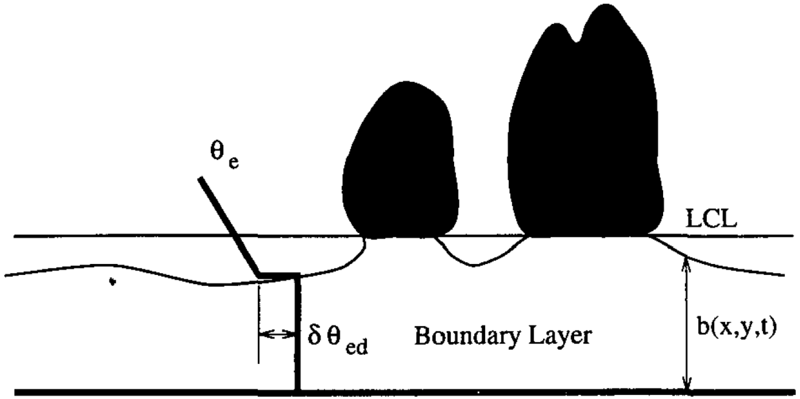
Measured air motions and radar reflectivity



TOGA COARE Shallow Convection Flights

Raymond (1995)

Analyzed and interpreted theoretically the aircraft data from the class 1 flights



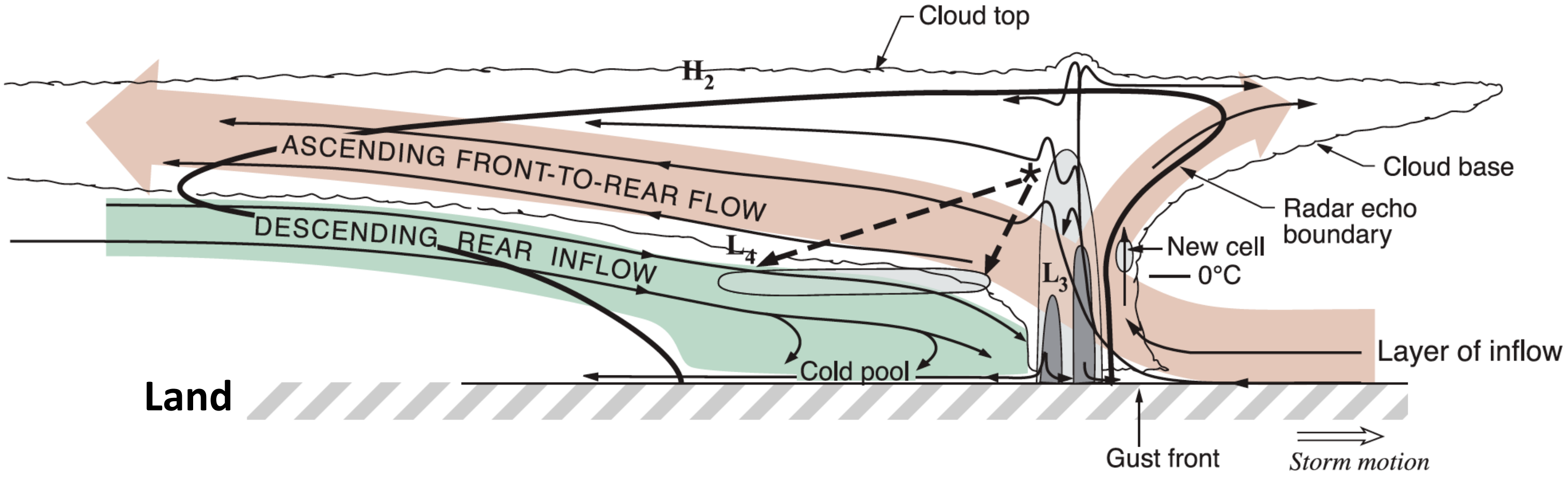
- Convection can only occur when the boundary layer θ_e exceeds a threshold
- Surface fluxes increase θ_e
- Downdrafts decrease θ_e
- Boundary layer equilibration takes about a day
- Convection not controlled by low-level convergence

TOGA COARE Deep Convection Flights

Note in 18 years since GATE, technology had advanced

Doppler radar technology over land had been showing how air overturns in the big MCSs

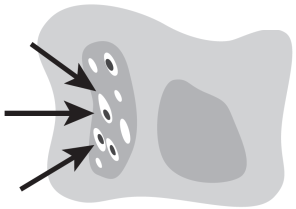
By 1992, Doppler radars had shown this structure in squall lines over land



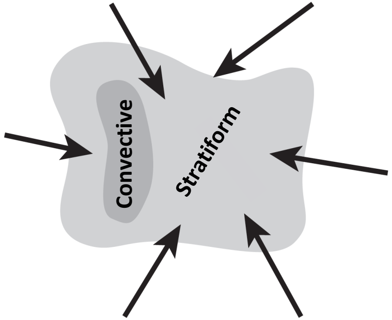
Houze et al. 1989

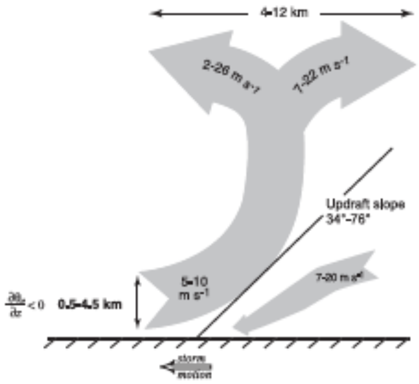
TOGA COARE airborne Doppler radars showed similar mesoscale circulation…but in 3D

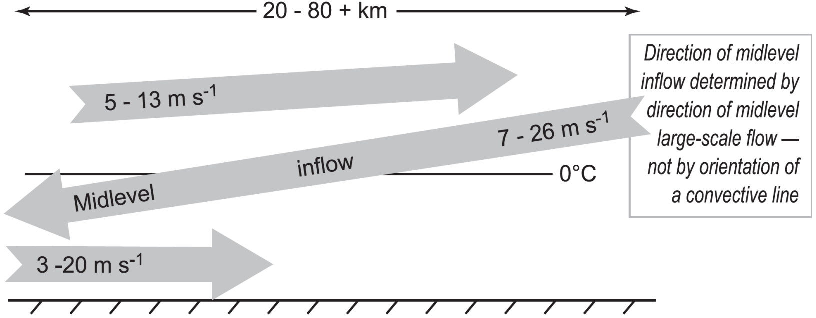
Low-level inflow



Midlevel inflow







Kingsmill and Houze 1999

Note:

The TOGA CORE shallow cloud and deep cloud studies were carried out separately and never integrated with each other (reductionism)

Results from DYNAMO

In the 18 years following TOGA COARE, there were further advances in instrument technology

GATE—reflectivity

- 3D precipitation structure

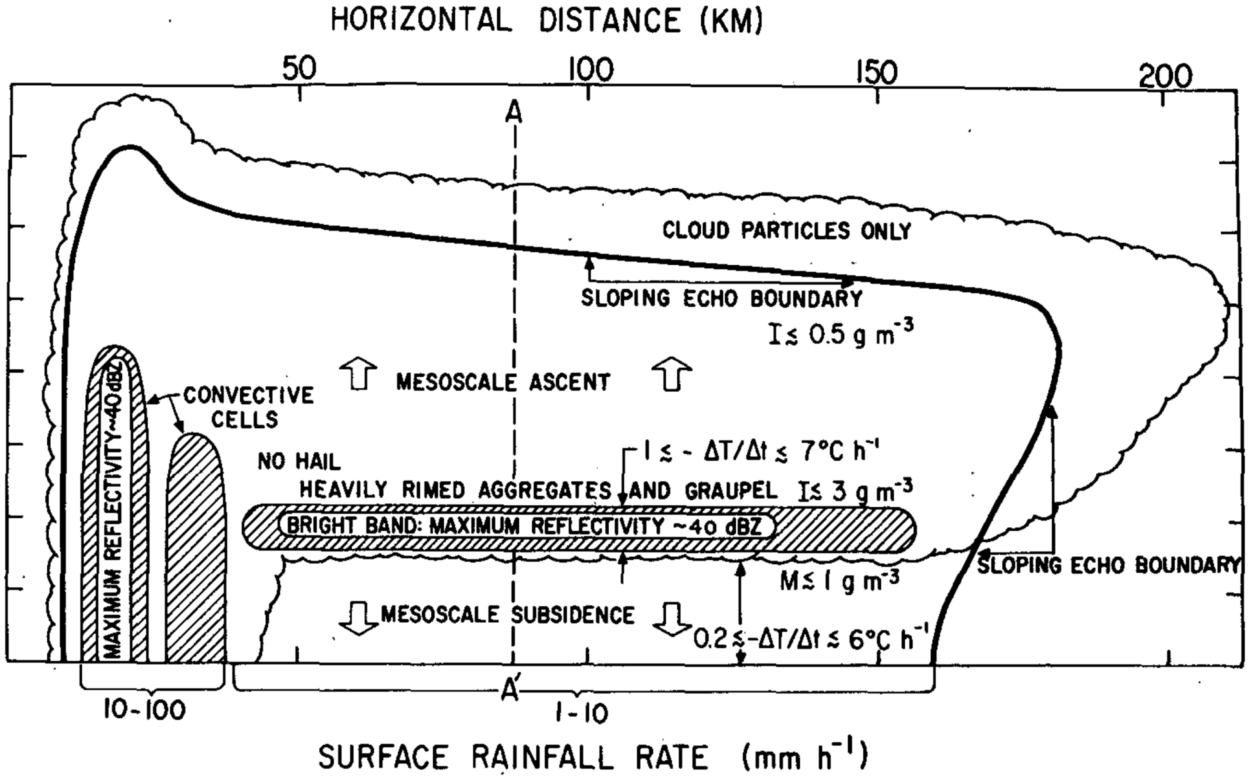
TOGA COARE—reflectivity, Doppler

- 3D precipitation structure
- Mesoscale air motions

DYNAMO—reflectivity, Doppler, dual-polarization, power

- 3D precipitation structure
- Mesoscale air motions
- Cloud microphysics
- Non-precipitating clouds
- Boundary layer structure

Leary and Houze 1979
….analyzing GATE shipboard radar and drop size data inferred



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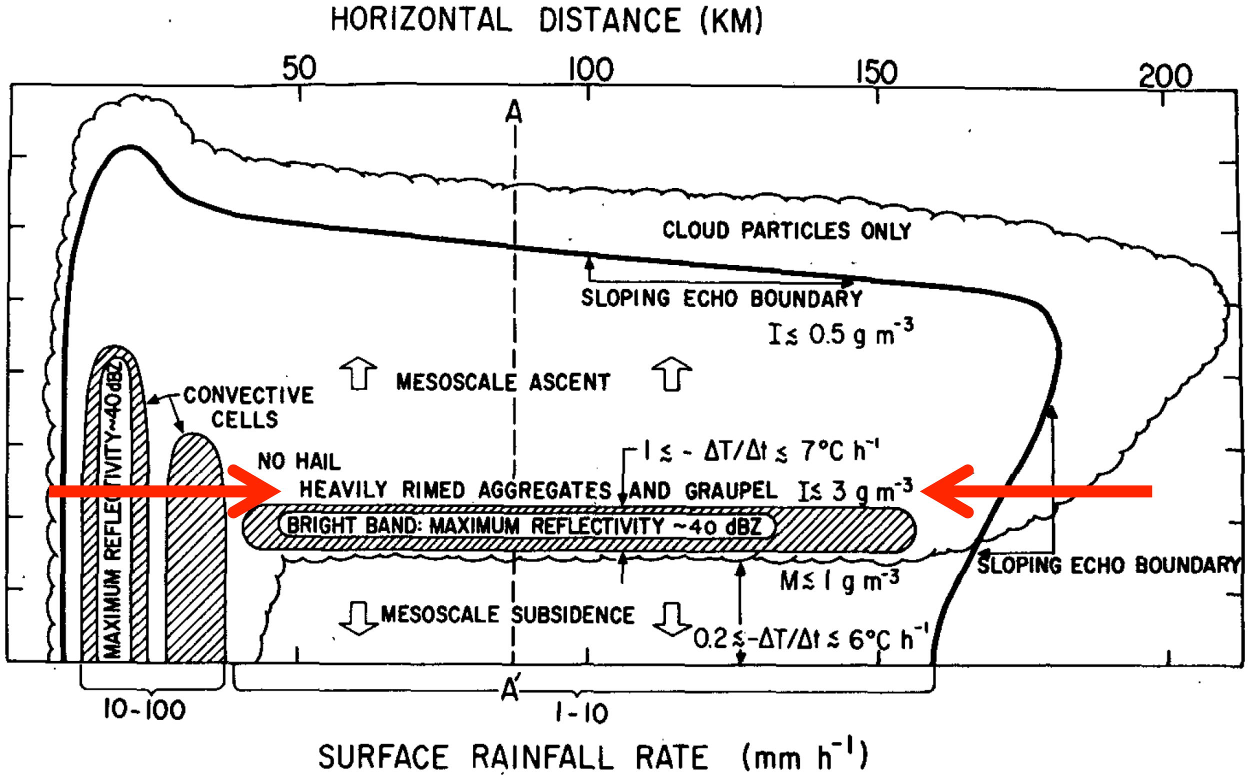
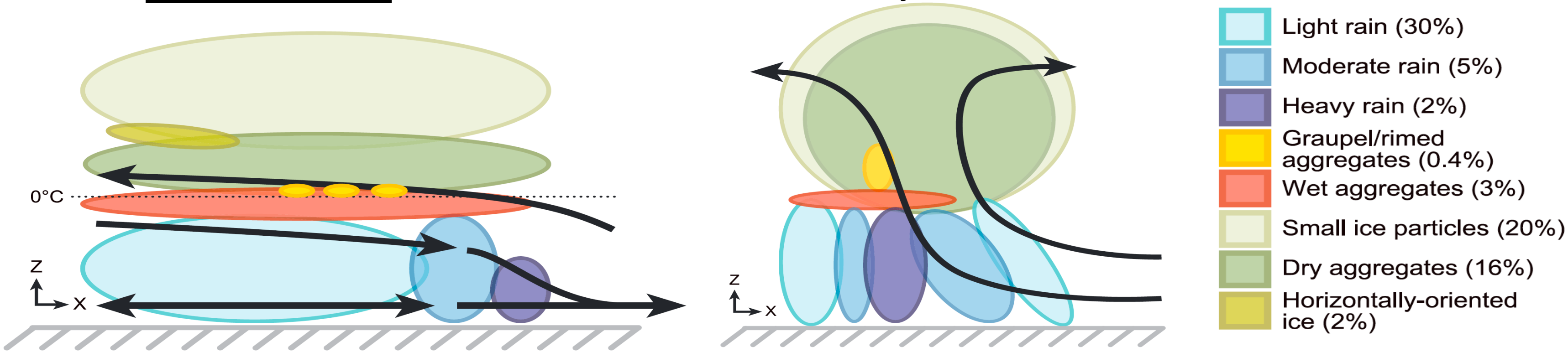


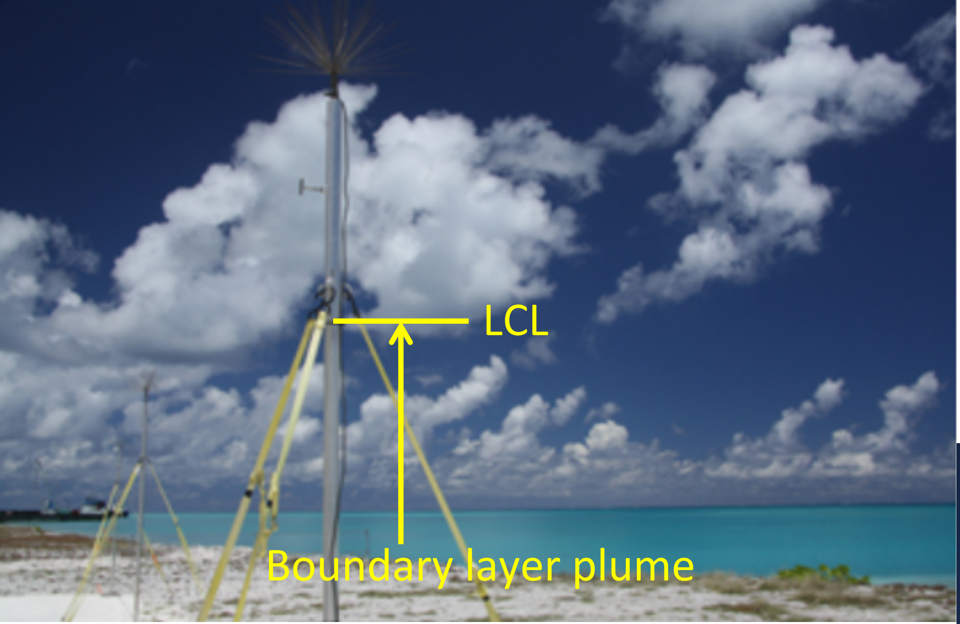
Barnes and Houze 2014 analyzed DYNAMO dual-polarization radar data

→ <u>confirmed</u> GATE results of Leary and Houze 1979



→ and also the air motion results of TOGA COARE

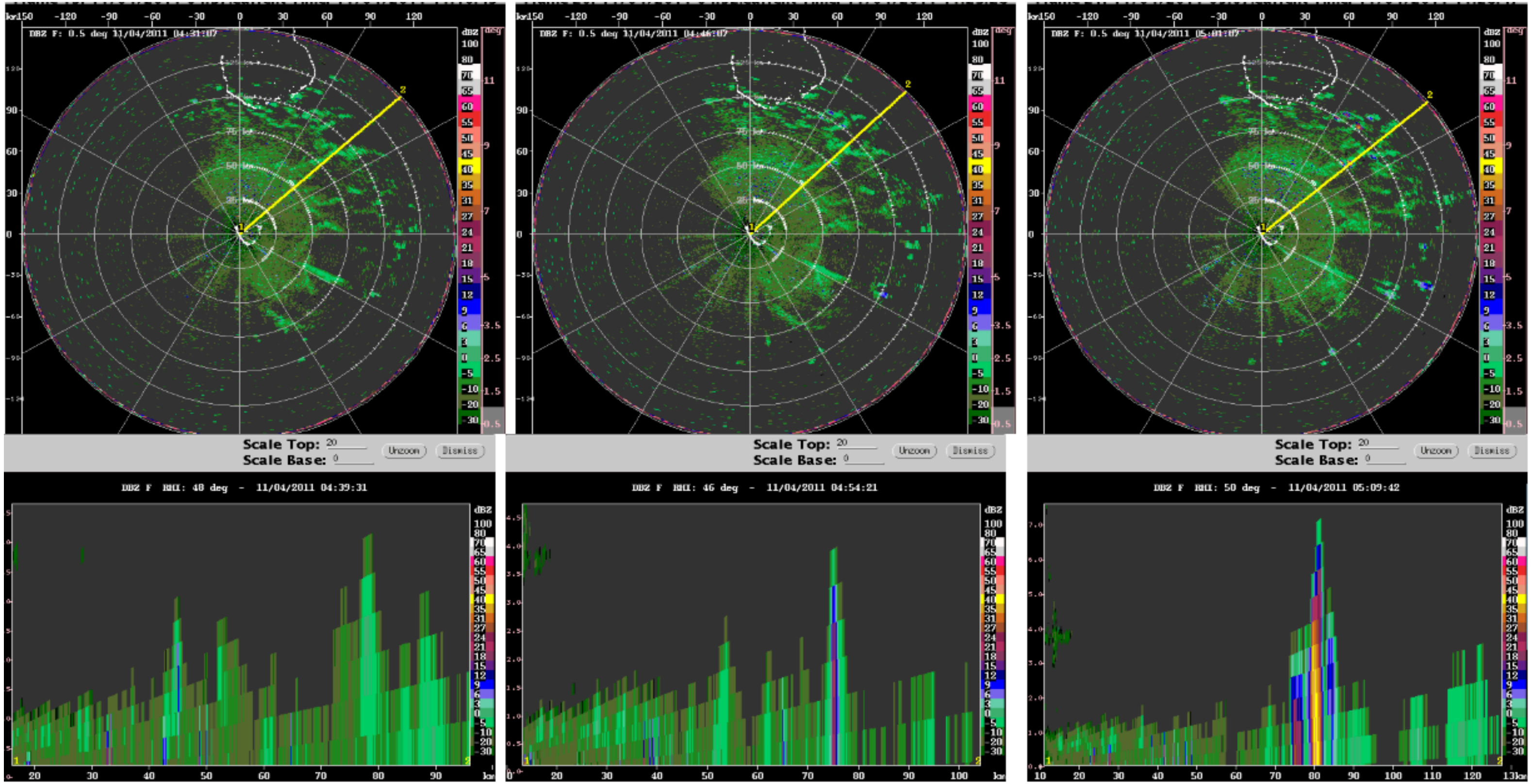
Barnes and Houze 2014)



Non
precipitating
cumulus
In DYNAMO
4 Nov 2011

Later in the day,
one cloud forms a
rain shower

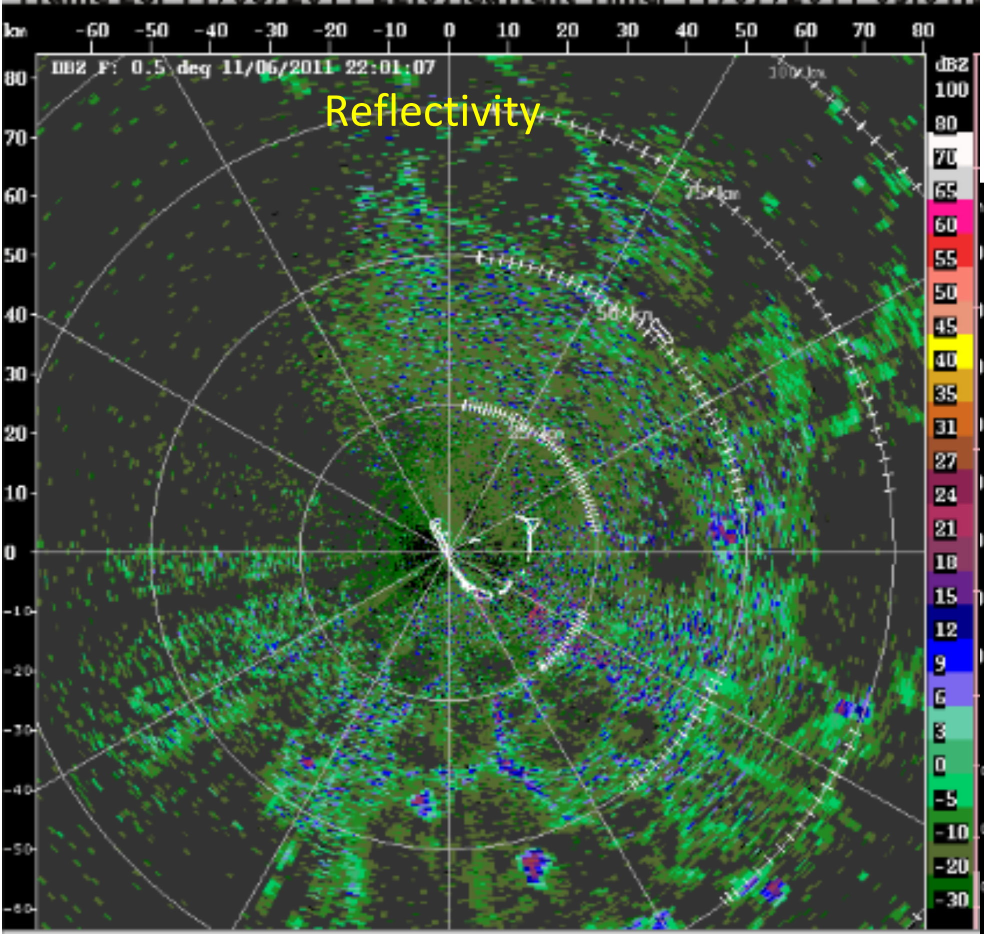
Brute Power in DYNAMO → non-precipitating clouds

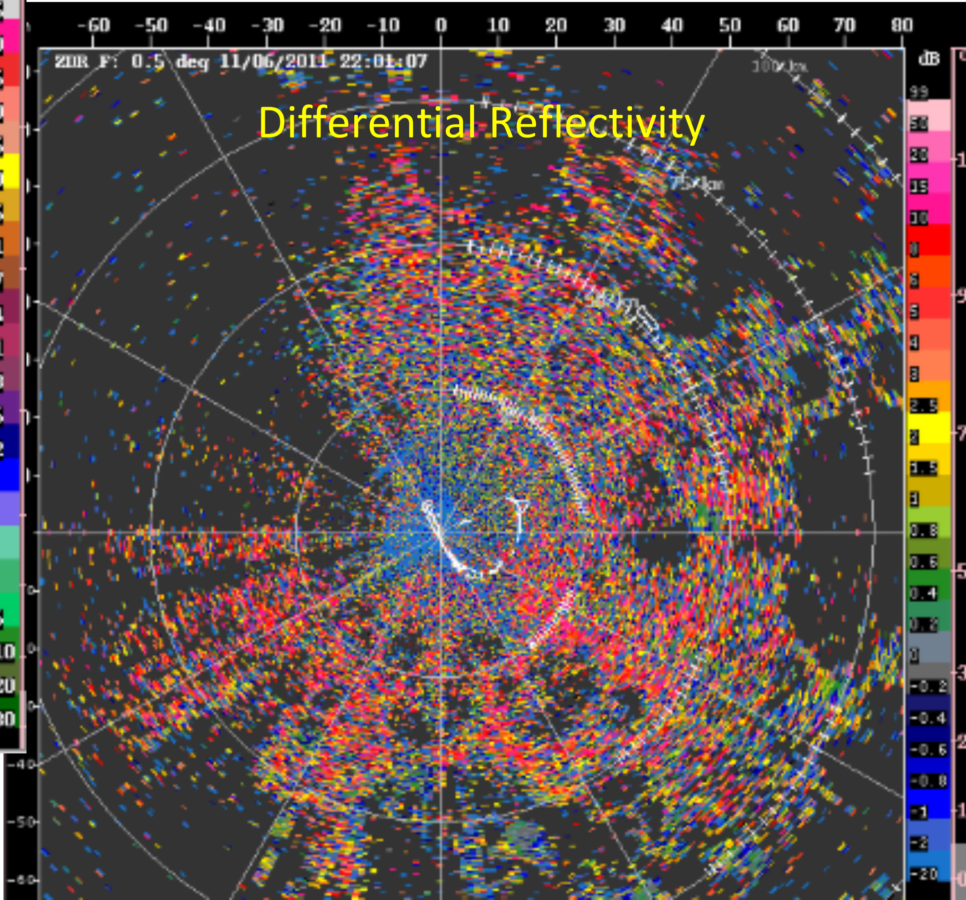


4 Nov 2011

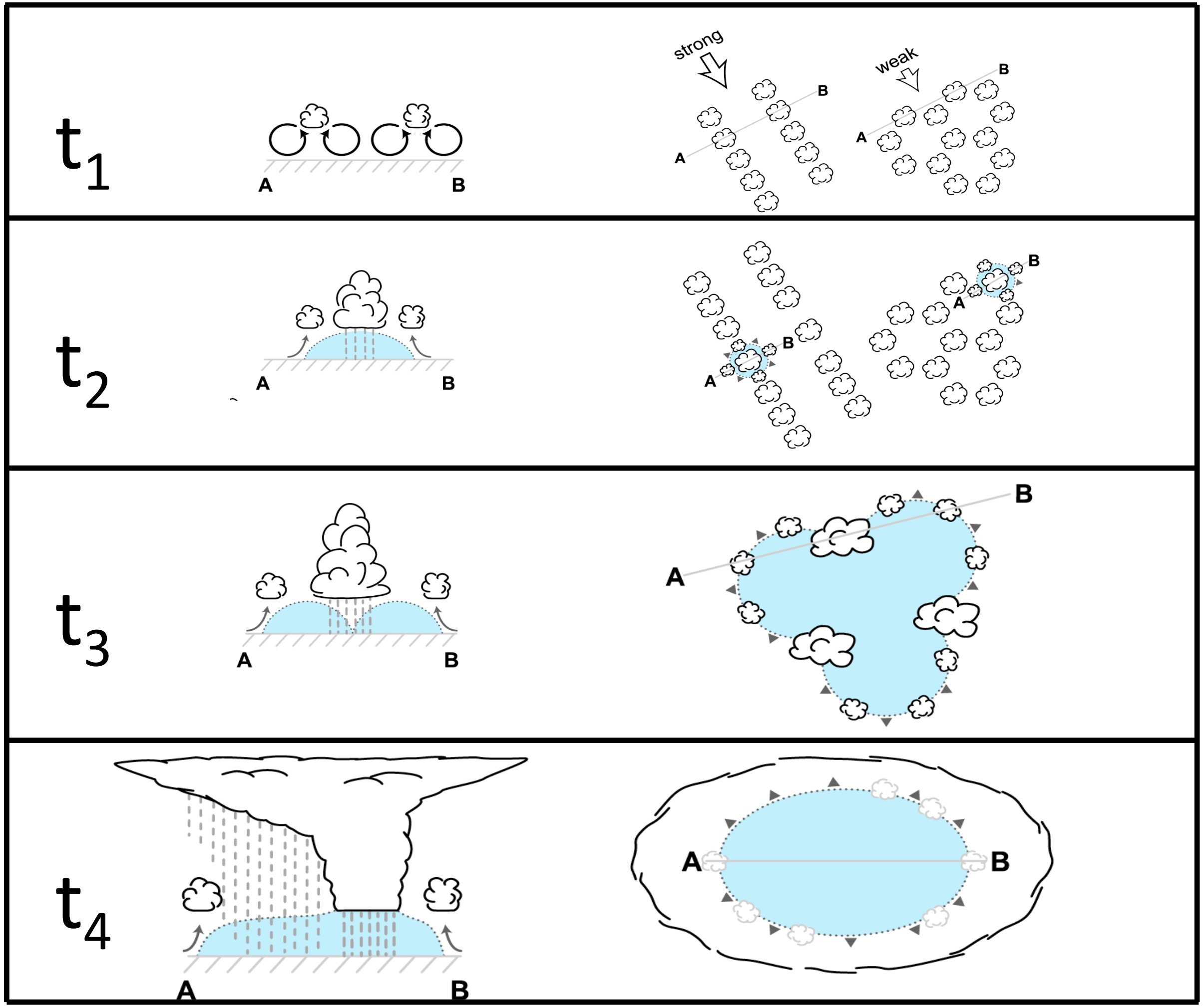
Rainshower

Cold pool signatures in DYNAMO
6 Nov 2011





Hypothesized sequence of Rowe and Houze 2015



Lessons from GATE, TOGA COARE & DYNAMO

Need more holism less reductionism!

- First identify processes that need to be understood
- Coordinate <u>all</u> resources on those processes in a singular plan
- Make maximum use of technological advances as platform availability decreases
- Use remote sensors to map processes holistically


Good Luck!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