CMMAP

Reach for the sky.

Timeline

November 2000	We begin working on a super-parameterized version of the CAM
Spring 2001	First results from the super-parameterized CAM
Summer 2001	We start to seriously consider proposing an STC
Late 2001	We decide to go for it, and we begin waiting for the NSF announcement to come out
February 2002	DR visits NSF to discuss the STC idea with Jay Fein
Spring 2002	We start drafting the STC proposal
October 2002	The Snowstorm Workshop at the Fort Collins Marriott
March 2003	The NSF announcement comes out
May 2003	Major planning Workshop

http://cmmap.colostate.edu/
(will become http://www.cmmap.org/)

Timeline

June 2003	The Pre-Proposal is submitted
October 2003	NSF invites us to submit a Full Proposal
Late 2003	Three more Workshops
February 2004	The Full Proposal is submitted
Early June 2004	NSF emails to say that we will be site-visited
October 2004	Site Visit
January 2005	Six of the twelve site-visited proposals are declined, but ours is not declined
April 2005	DR visits NSF to meet Margaret Tolbert
July 2005	The Limbo Workshop in Fort Collins

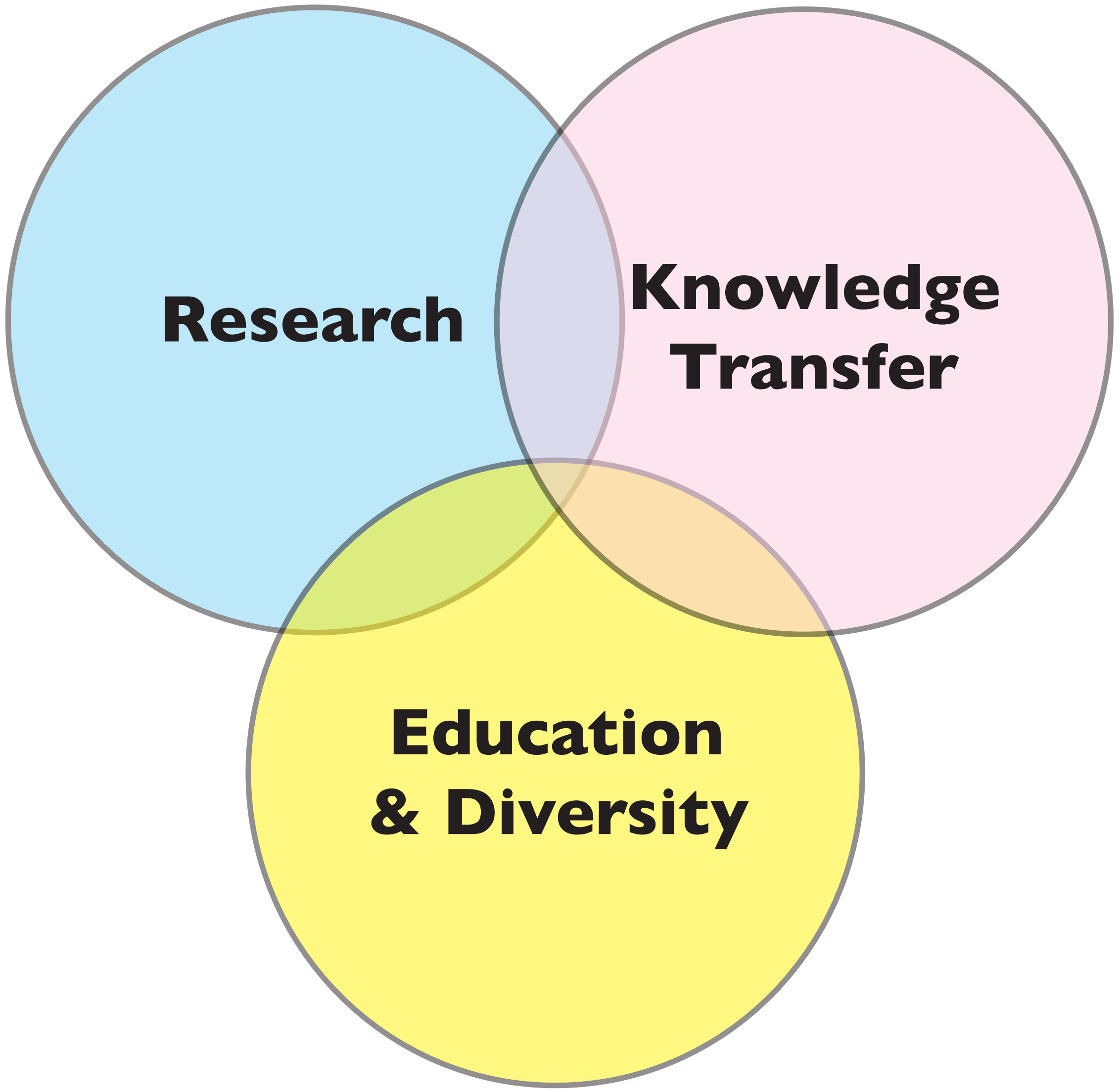
Timeline

December 2005	We get the word that NSF is "moving towards an award"
February 2006	Video conference
May 2006	Retreat
June 2006	Strategic Plan approved
July 2006	Award

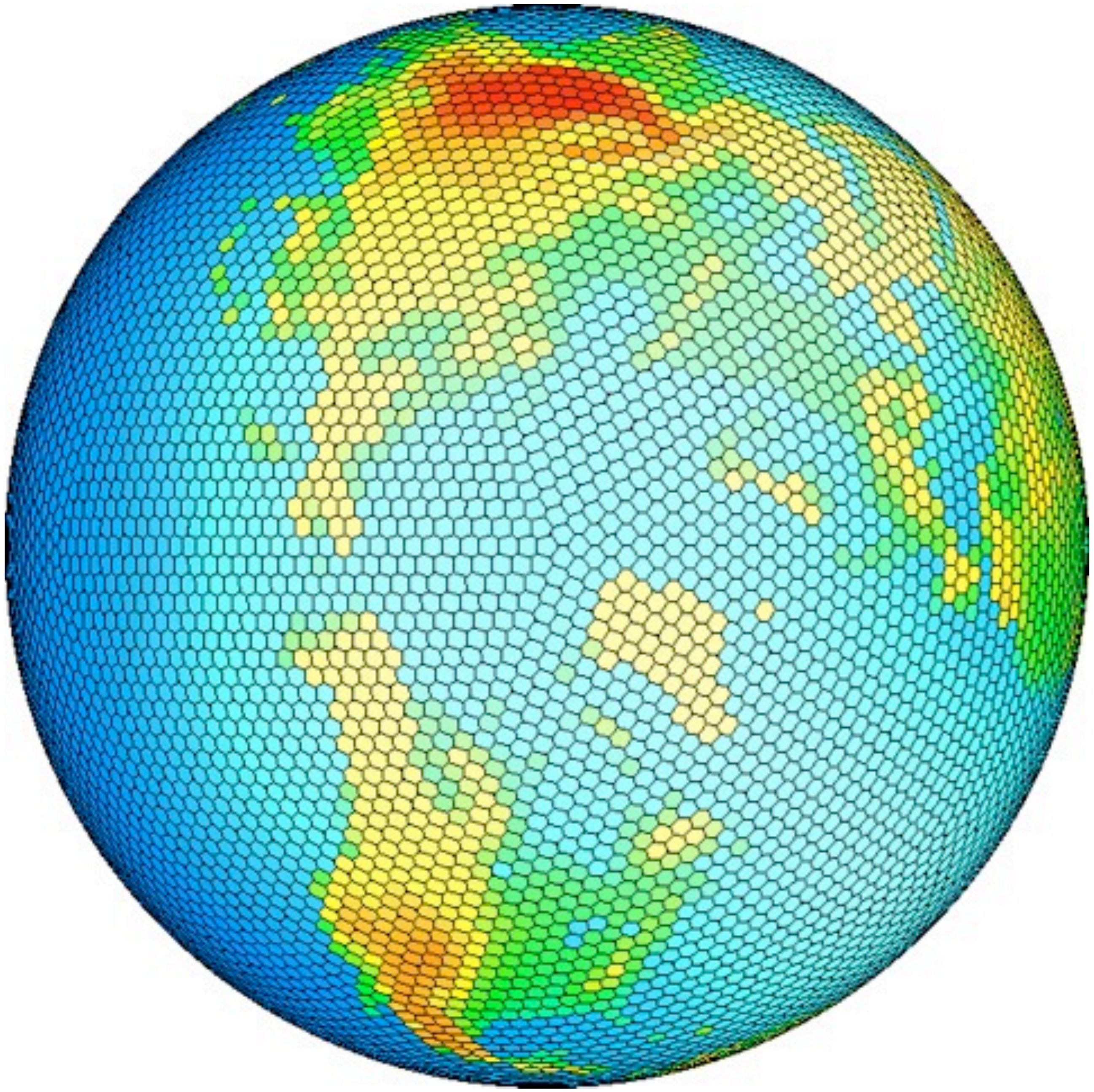
The long and winding road

- **Your Wildest Dreams**
- **Stairway to Heaven**
- **Sitting in Limbo**
- **Heaven’s Just a Sin Away**
- **Once in a Lifetime**


Excellent administrative work was absolutely essential to winning the STC award.


Research
Knowledge
Transfer
Education
& Diversity

Research



Clouds Are Central to the Earth Sciences

- Climate change
- Weather prediction
- The water cycle
- Global chemical cycles
- The biosphere

We are being held back in all of these areas by an inability to simulate the global distribution of clouds and their effects on the Earth system.

The Cloud Parameterization Deadlock

"...The modeling of clouds is one of the weakest links in the general circulation modeling efforts."

--Charney et al., National Academy Report, 1979

Deficiencies in the representation of cloud processes in climate models drive much of the uncertainty surrounding predictions of climate change.

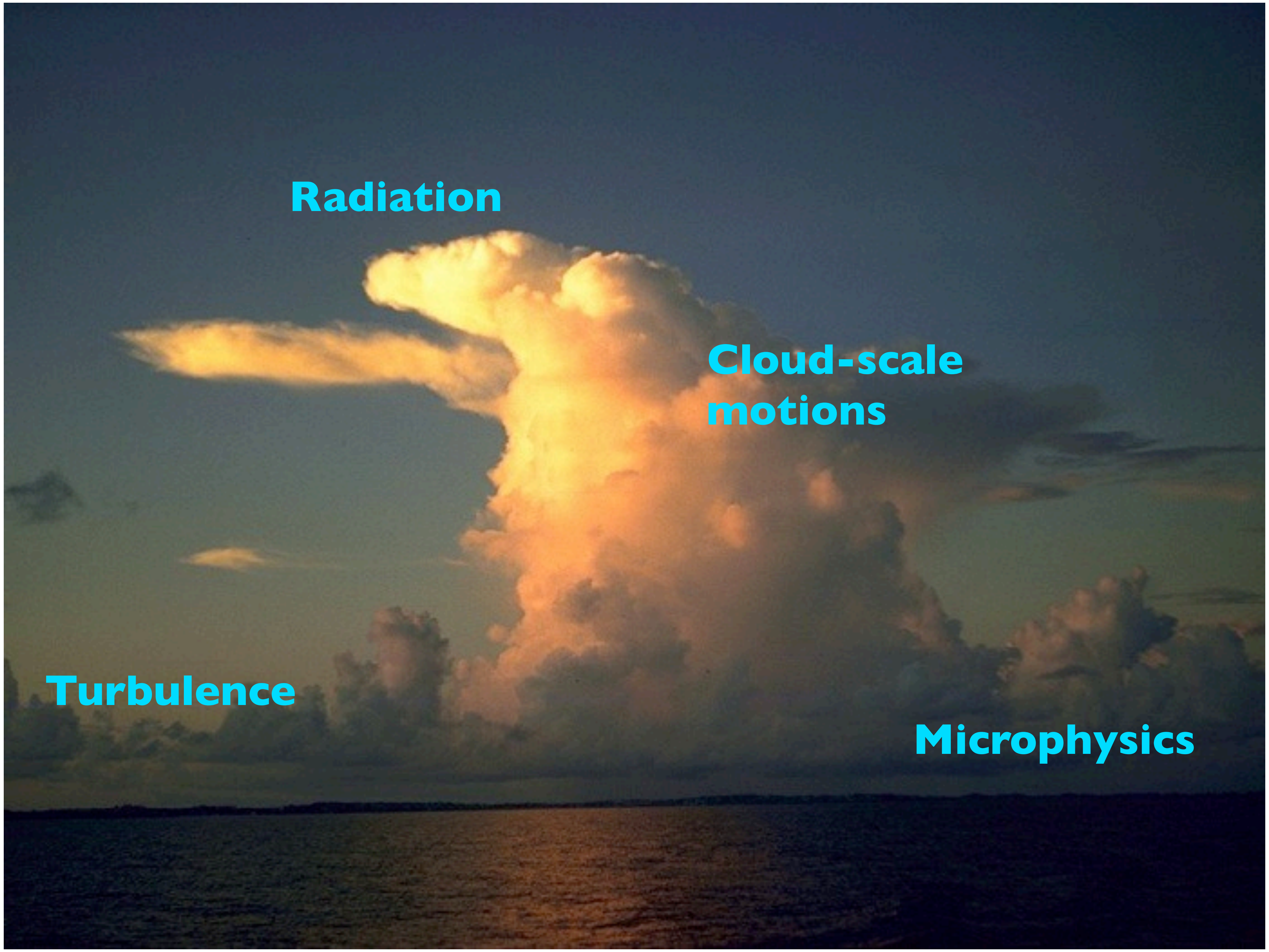
This was true 30 years ago, it's true now, and at the rate we are going it will still be true 30 years from now.

What can we do about it?

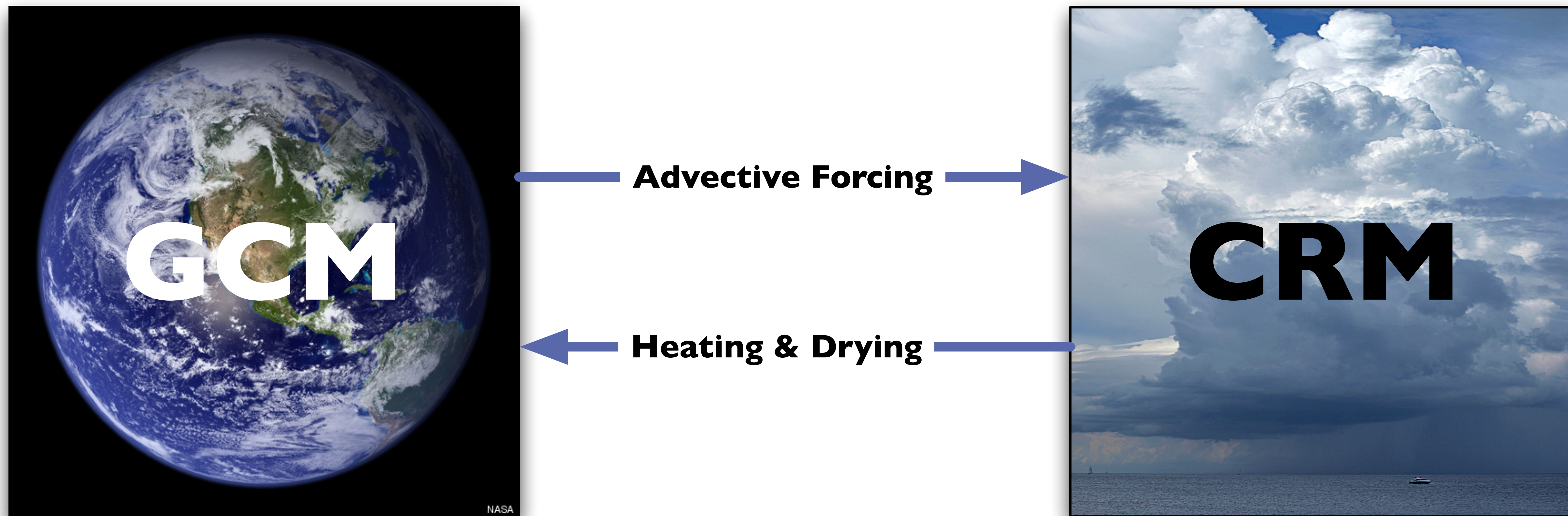
Climate Modeling

- Forty years old
- Physically based models
- Atmosphere, ocean, land-surface, sea ice, all coupled together
- Solve differential equations to predict mass, momentum, temperature, and moisture in spherical geometry
- Equations solved on a grid
- Smaller-scale processes “parameterized” using statistical theories

Clouds are complicated.



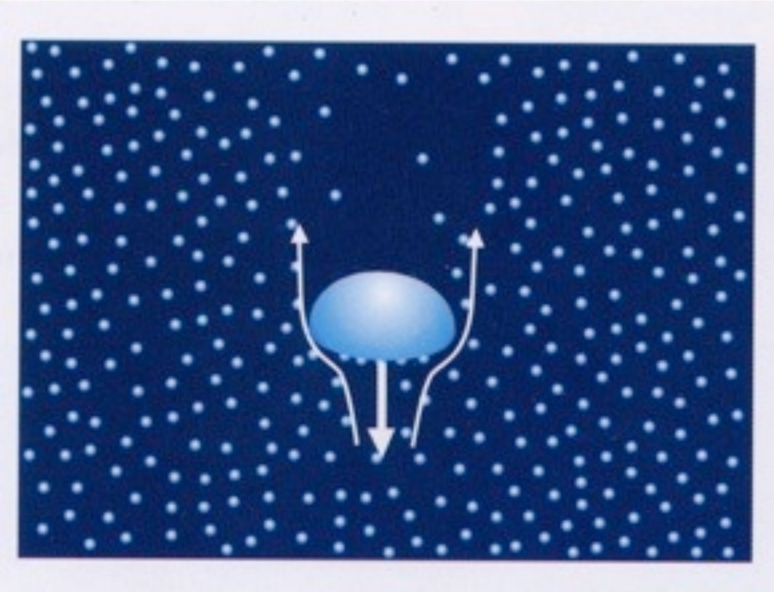
The Multiscale Modeling Framework



"Super-Parameterization"

- **Each CRM runs continuously.**
- **The CRMs do not communicate with each other.**

Limitations (and Strengths) of CRMs



- **Microphysics must still be parameterized.**
- **Radiative transfer must still be parameterized.**
- **Turbulence and shallow convection must still be parameterized.**

A door has swung open.

We have demonstrated the potential of the prototype MMF. ***This is a revolutionary, transformative new approach to understanding cloud processes.***

Now we need to use this new approach to better-understand the Earth System.

We need to establish MMF development and applications as a major new research activity, complementing but not replacing the older activities.

In order to do this, we need to engage the cloud parameterization enterprise, world-wide, through a ***multi-institutional collaborative effort with a centrally defined focus and an extended lifetime*****.**

This is CMMAP.


The design, testing, and application of an
improved MMF will be the central, organizing
component of CMMAP's research.

Education and Diversity

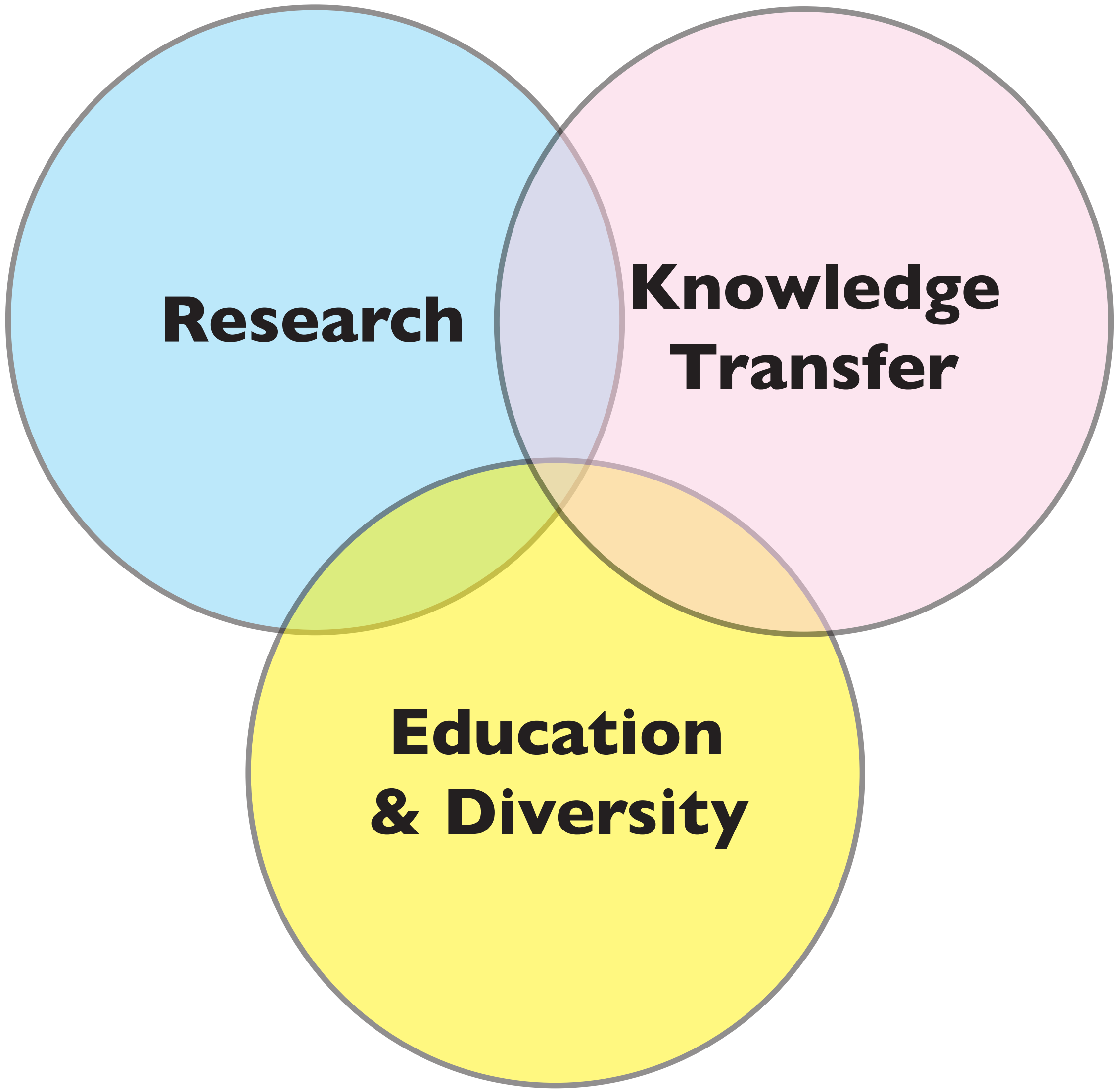
Education & Diversity Activities

- Teacher training workshop
- Colorado Climate Conference
- Graduate Student Colloquium
- Summer Interns Program
- Little Shop Activities
- Changing Climates
- Collaboration with SOARS
- Windows to the Universe
- Assessment

Knowledge Transfer

KT Activities

- Book
- Journal
- CESM collaboration
- Colorado Energy Council


Research
Knowledge Transfer
Education & Diversity

Ten years, and a cloud of dust

NATIONAL RESEARCH COUNCIL
DIVISION ON EARTH AND LIFE STUDIES
BOARD ON ATMOSPHERIC SCIENCES AND CLIMATE

A National Strategy for Advancing Climate Modeling

SUMMARY

Climate models are the foundation for understanding and projecting climate and climate-related changes and are thus critical tools for supporting climate-related decision making. This study will develop a strategy for improving the nation's capability to accurately simulate climate and related Earth system changes on decadal to centennial timescales. The committee will consider ways to improve the current climate modeling paradigm and whether there are other approaches with significant potential, identify the most important observations and research activities needed to support the development and validation of climate models, and discuss how to ensure that the nation's investments in modeling ultimately support decision making. The committee's report is envisioned as a high level analysis, providing a strategic framework to guide progress in the nation's climate modeling enterprise over the next 10-20 years.

Upcoming Events

Through workshops, symposia, and other meetings (either as part of our studies or as separate activities), the Division serves as a hub for exchange among policy-makers, members of industry, scientists, and the general public to discuss timely issues.

A National Strategy for Advancing Climate Modeling

Workshop

April 27, 2011 - April 28, 2011

National Center for Atmospheric Research Boulder CO

Map

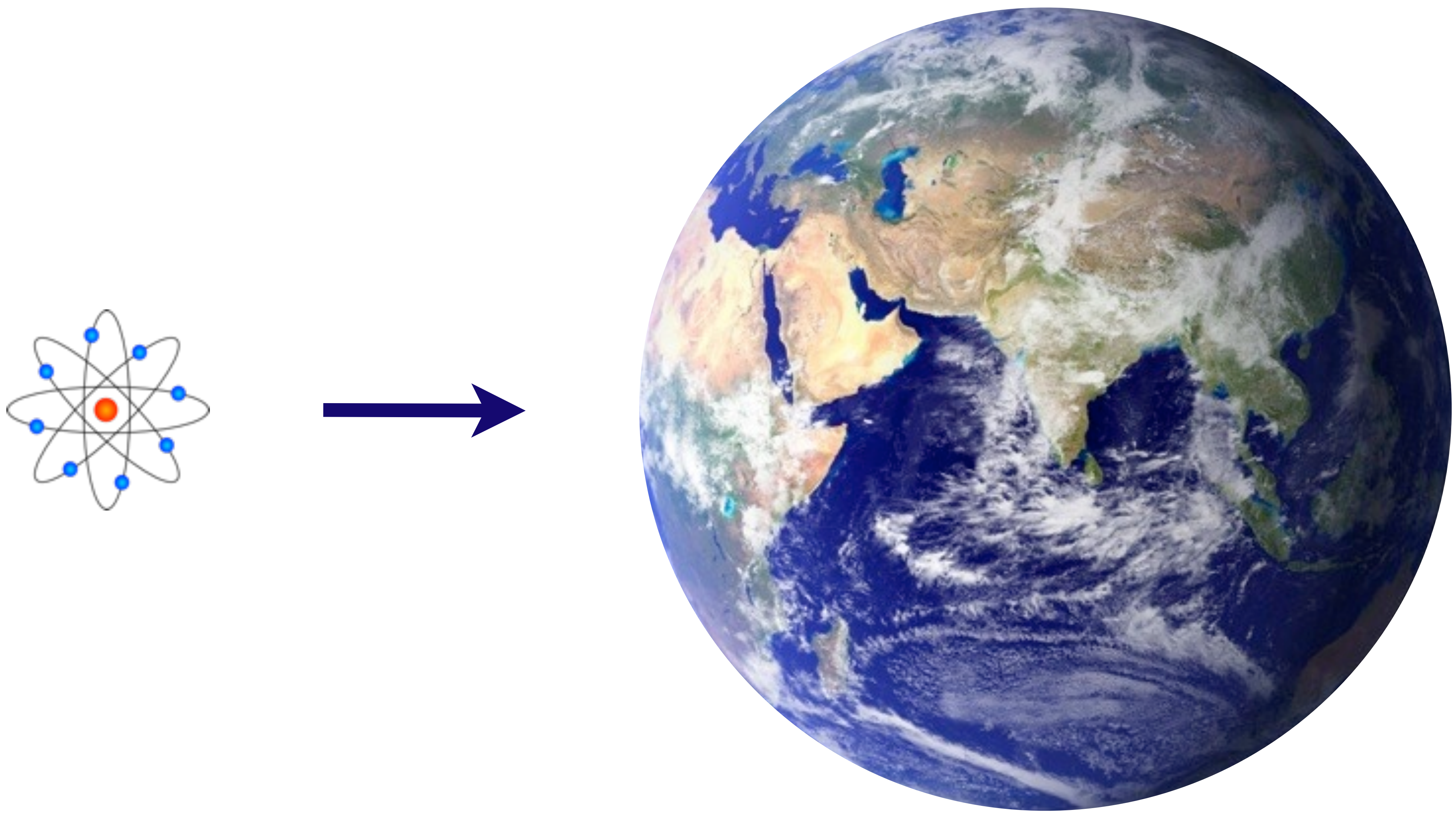
Climate models are the foundation for understanding and projecting climate and climate-related changes and are thus critical tools for supporting climate-related decision making. This study will develop a strategy for improving the nation's capability to accurately simulate climate and related Earth system changes on decadal to centennial timescales.

Improving the fidelity of climate models

(with emphasis on the atmosphere)

Ab initio climate modeling

A "reductionist" program



The physics that we understand well applies at a point.

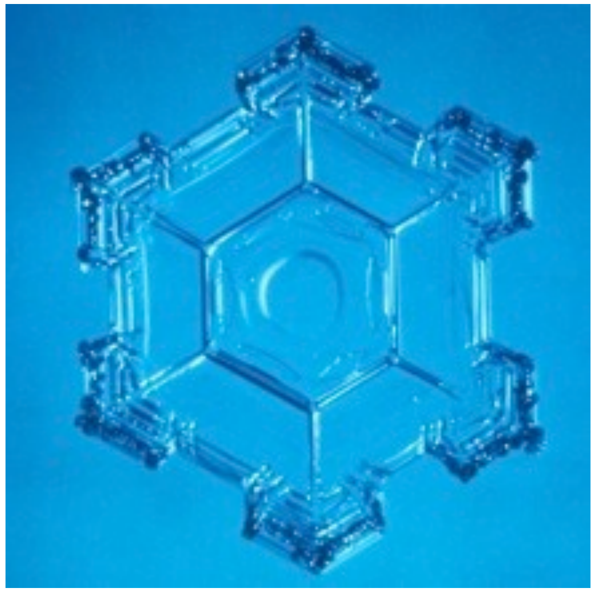
It does not apply to a grid cell.


The surface area of the Earth is about 100 million times larger than the area covered by a middle-sized cloud.

Modeling Across Scales

Global circulation

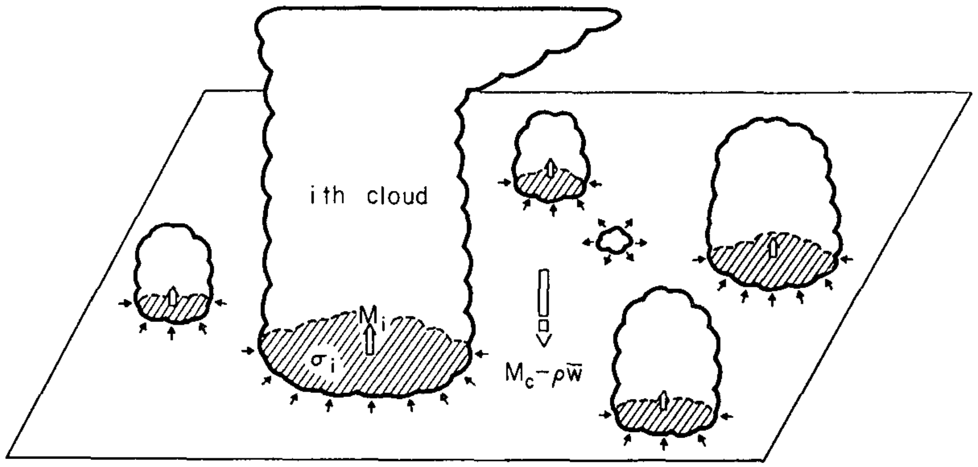
Cloud-scale &mesoscale processes



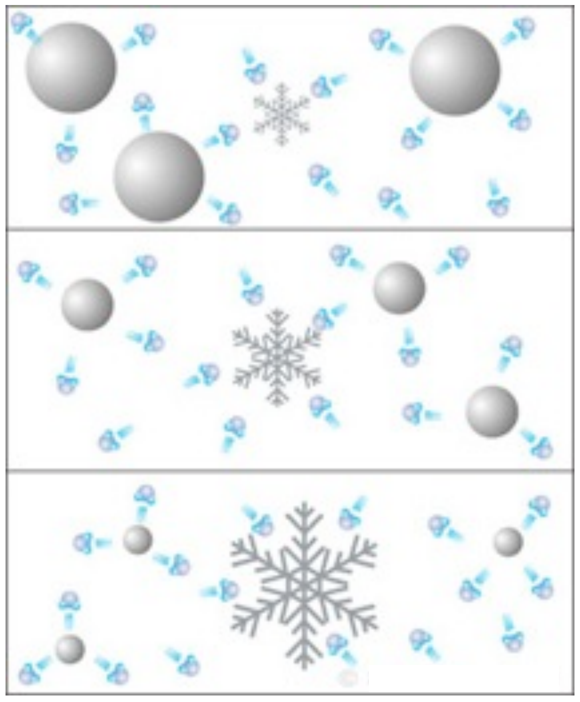
Radiation, Microphysics, Turbulence

Parameterized

Toy models



Toy updrafts & downdrafts

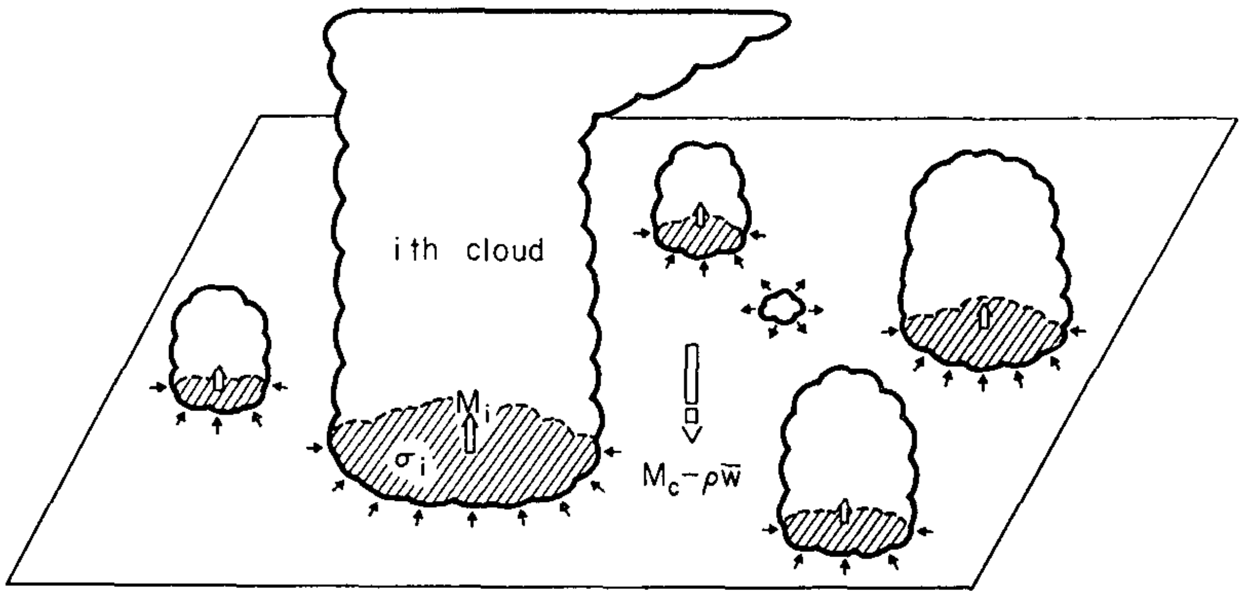


Toy microphysics

So, what's the problem?

- Closure assumptions
- Missing processes
- Improperly coupled processes
- Inadequate sample size

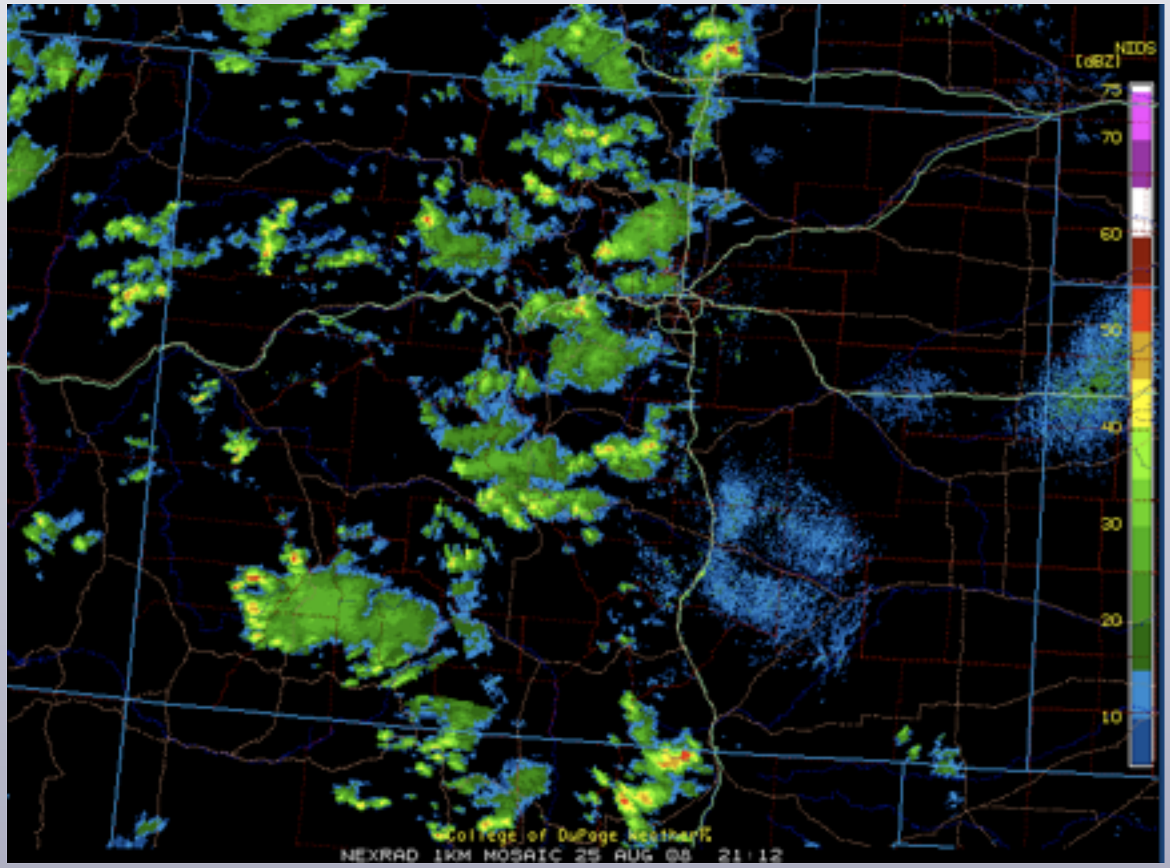
Scale Separation



"Consider a horizontal area ... large enough to contain an ensemble of cumulus clouds, but small enough to cover only a fraction of a large-scale disturbance. The existence of such an area is one of the basic assumptions of this paper."

-- AS 74

A summer afternoon in Colorado

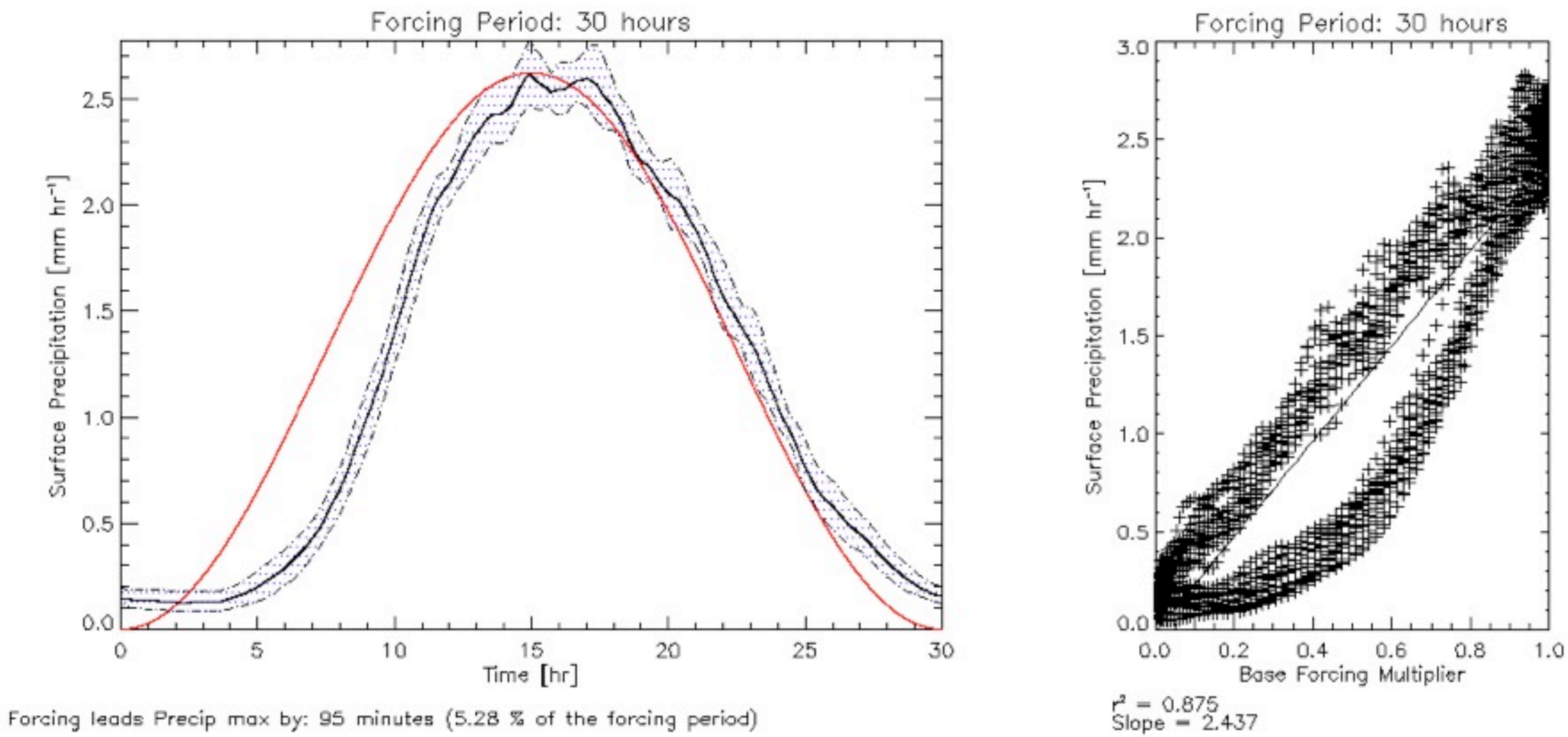


A parameterization calculates the “expected” collective effect of many clouds over a large area.

One of the issues is that the sample size is not very large.

The space scales are not sufficiently separated.

Delayed response



The time scales are not sufficiently separated.

Slide from Todd Jones

Where technology is leading us

- **Higher resolution**
- **More simulations (e.g., larger ensembles)**
- **Longer ~~simulations at fixed~~ resolution**

Increasing resolution

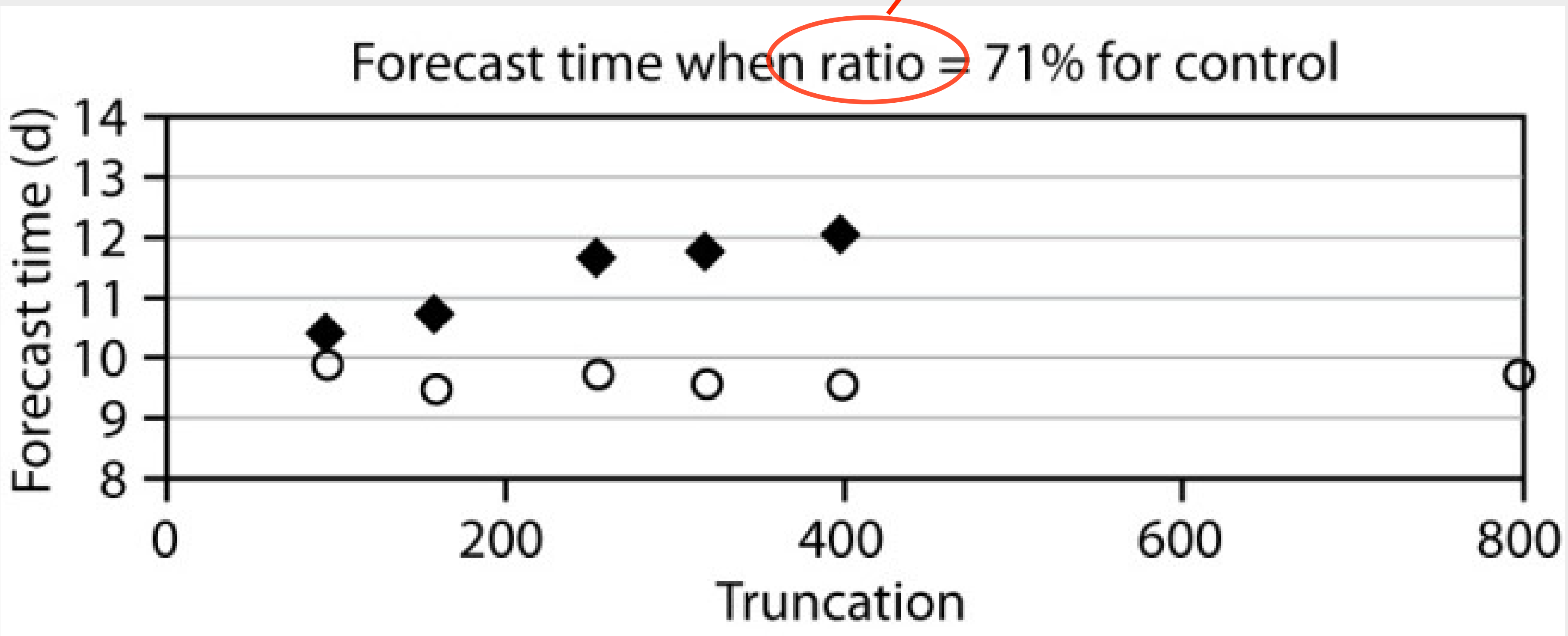
- Incremental improvements
  - Mountains
  - Tropical cyclones
  - Ocean basins
- Qualitative changes
  - Eddy-permitting ocean models
  - Convection-permitting atmosphere models

Higher resolution

- Gradualist approach: dx gradually decreases, without changing parameterizations
  - OK for NWP, not so good for climate
  - No qualitative change until dx~5 km
- Aggressive approach: dx~5 km right now
  - Currently too expensive for climate
  - Super-parameterization as a compromise

Does increased resolution improve the results?

“Ratio” refers to the ratio of forecast error to its saturation value. Black diamonds for the T799 “perfect model,” white circles for real forecasts.

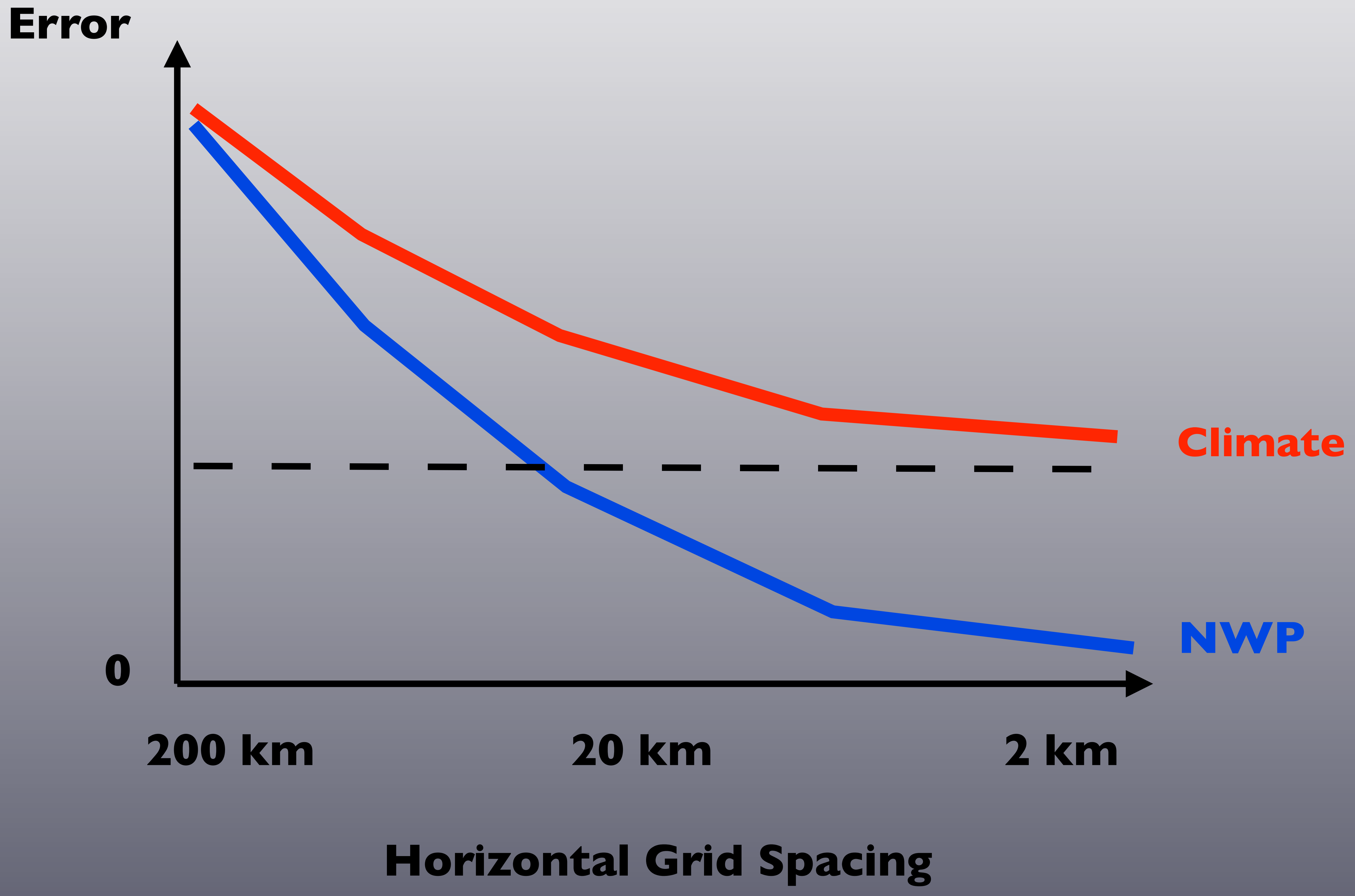


Buizza 2010:

“…although further increases in resolution are expected to improve the forecast skill in the short and medium forecast range, simple resolution increases without model improvements would bring only very limited improvements in the long forecast range.”

Error versus resolution

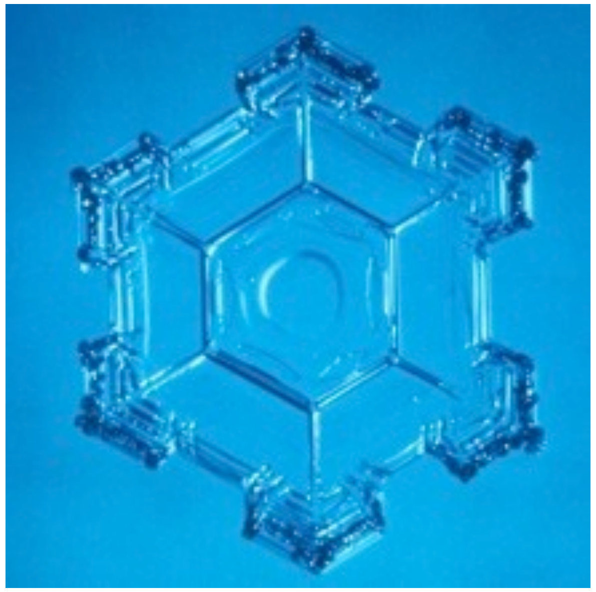
without changing the parameterizations



Parameterize less.

Global circulation

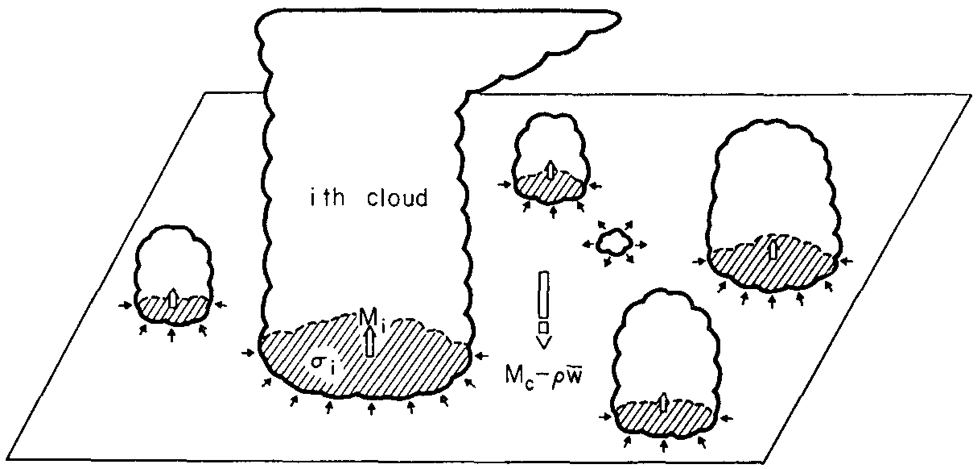
Cloud-scale
&mesoscale
processes



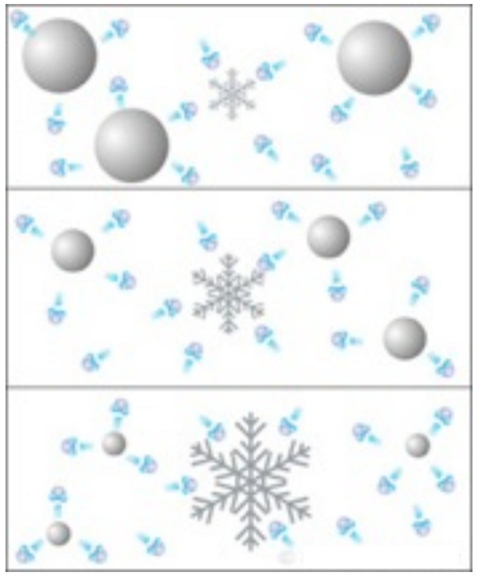
Radiation,
Microphysics,
Turbulence

Parameterized

Parameterize Different.



Increasing resolution



GCM

CRM

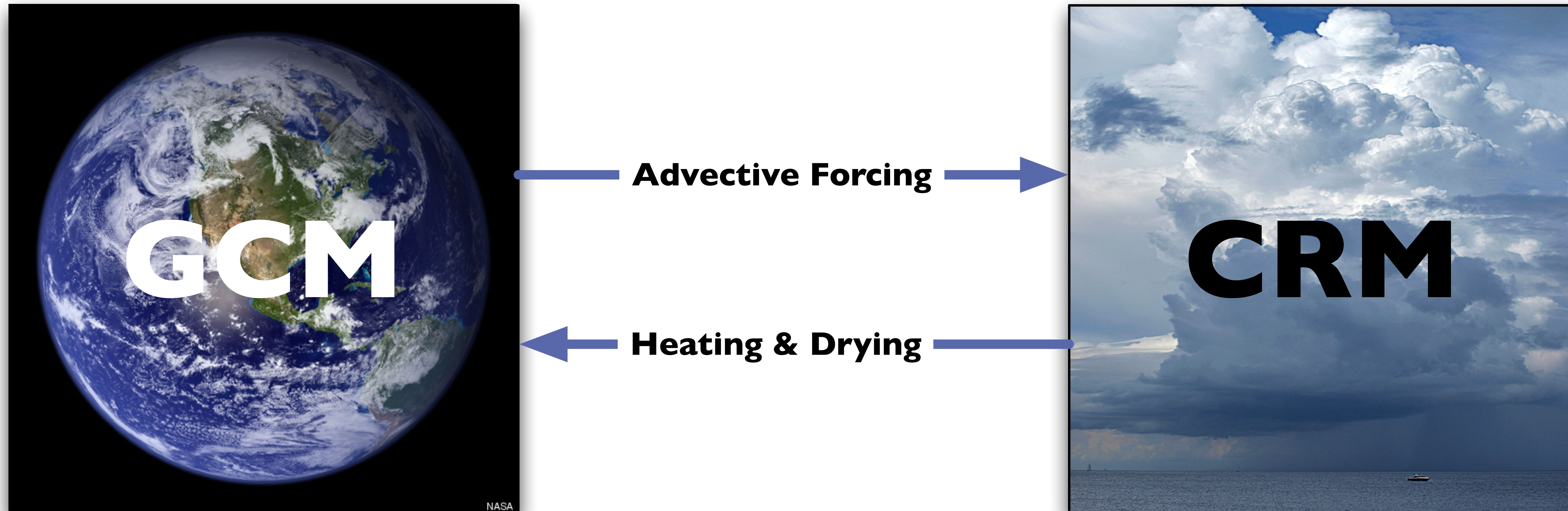
Parameterizations for low-resolution models are designed to describe the collective effects of ensembles of clouds.

Parameterizations for high-resolution models are designed to describe what happens inside individual clouds.

Expected values --> Individual realizations

Different input, different output

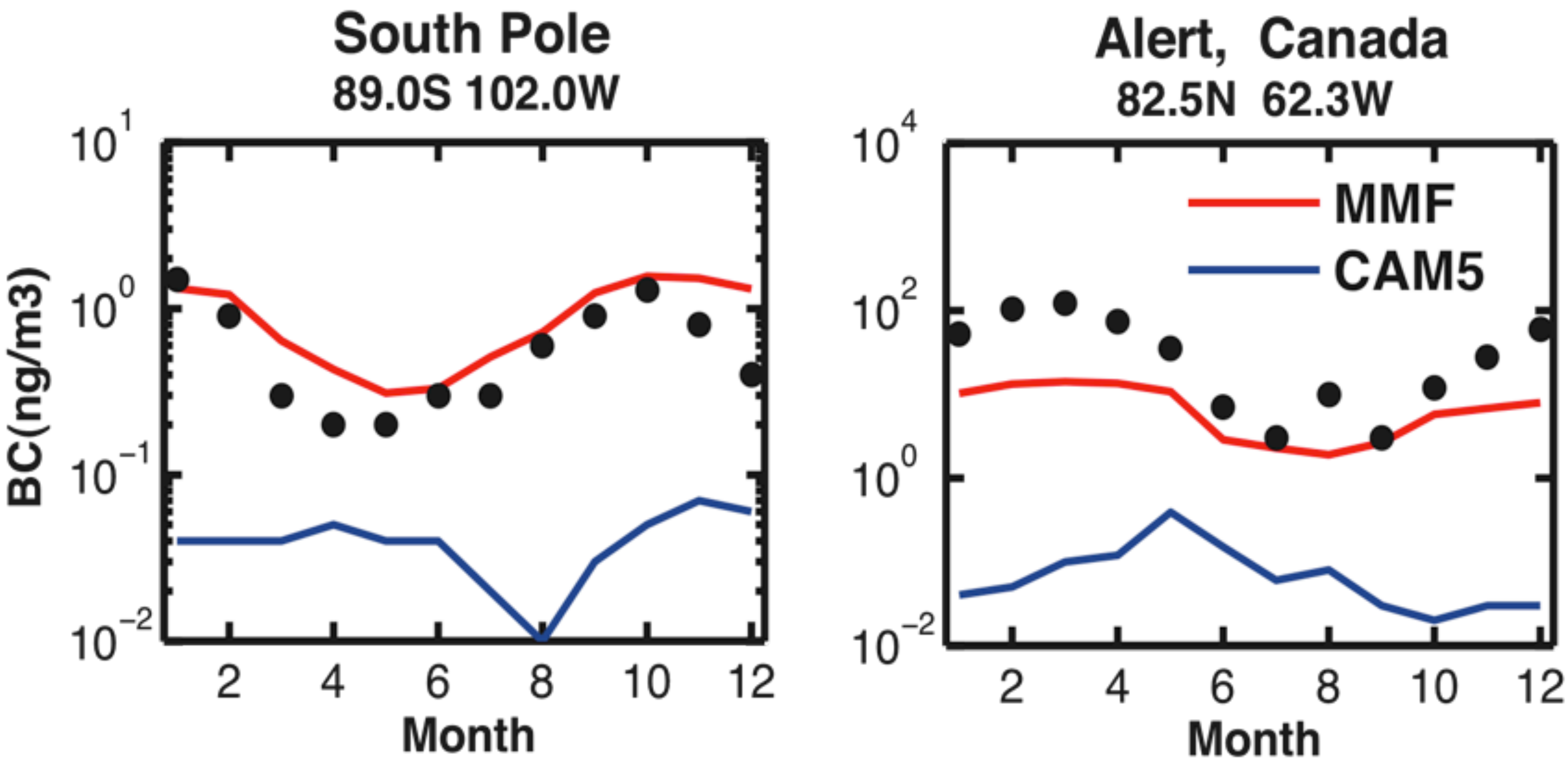
The Multiscale Modeling Framework



"Super-Parameterization"

- **Each CRM runs continuously.**
- **CRMs behave "stochastically.**
- **The CRMs do not communicate with each other.**
- **MMFs are much faster than GCRMs.**

Black carbon concentrations in the polar regions



The two models share the same dynamical core and aerosol parameterization.

Only the parameterized aerosol transport is different.

Slide from Minghuai Wang of PNNL

Types of Complexity

- **Coupling Complexity**
  - **Adding components**
- **Numerical Complexity**
  - **Emergent behavior**
- **Conceptual Complexity**
  - **Emergent behavior “inside” parameterizations**

Very high-resolution models are conceptually simpler, but numerically more complicated.

Local coupling of processes

- Parameterizations of individual processes are formulated separately, by different people -- often with different expertise and interests.
- Coupling among processes does not get enough attention, and is less successful.
- Modularity is good from a programming point of view, but in nature processes are not modular.
- However, high-resolution physics is more modular than low-resolution physics.

Social networks

- Dynamical core builders
- Cloud & turbulence parameterizers
- Aerosol people
- Vegans
- etc...

We need a Facebook for modelers.

Take-Home Messages

By representing processes on their native scales, we get:

- The equation of motion ("*ab initio*" physics)
- Stochastic behavior
- Improved results from the remaining parameterizations
- More revealing comparisons with observations
- Increased (potential) modularity

CMMAP

Reach for the sky.