CMMAP

Reach for the sky.

Colorado State University

Knowledge to Go Places

http://www.cmmap.org/


Introductions

STSC Rationale and Goals

Caveats #1

We will try to minimize jargon.

We won't be completely successful.

If we use a term that you are not familiar with, or say anything that's confusing, please stop us to ask for an explanation.

Caveats #2

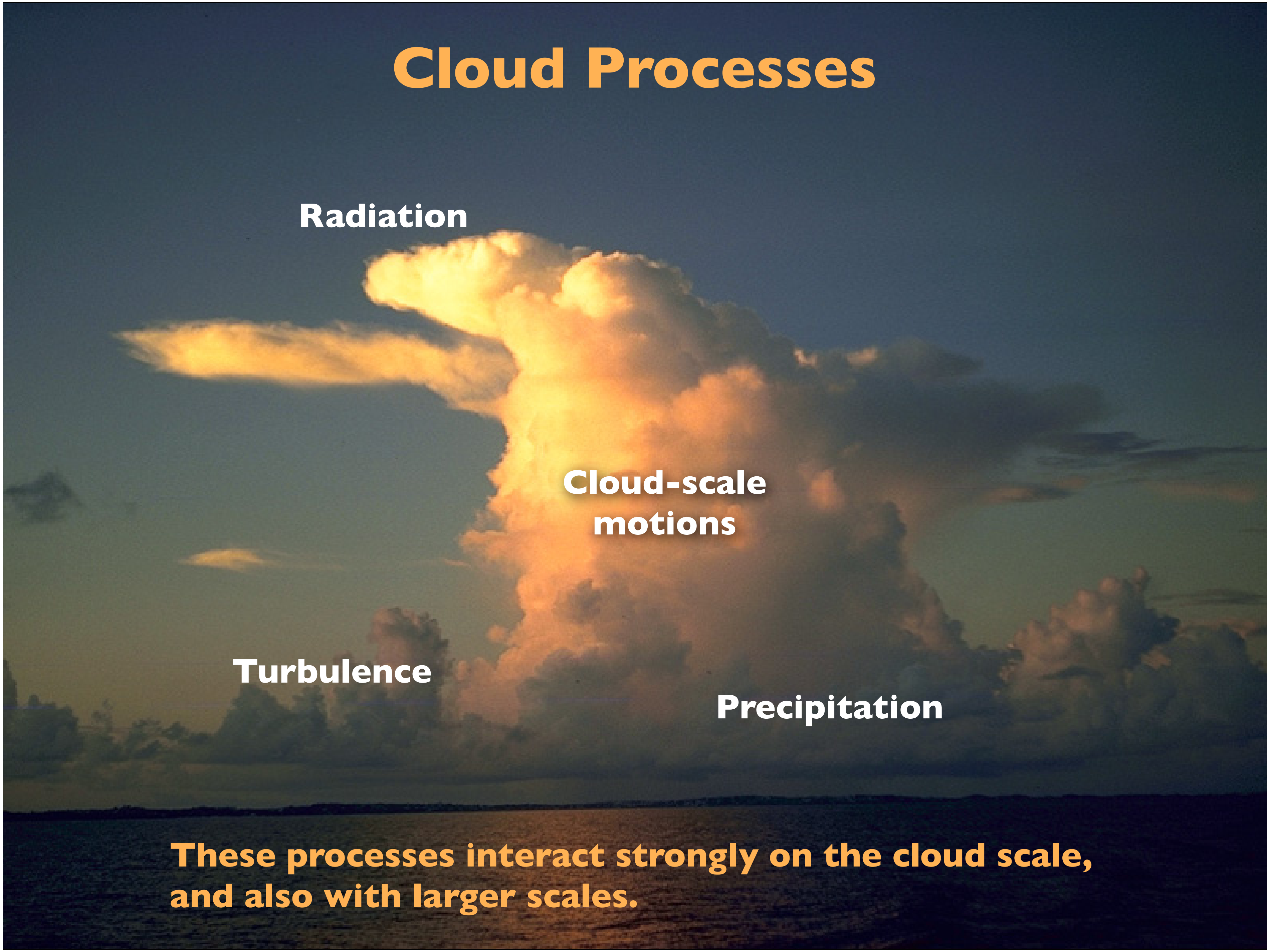
Given the time available,
it is impossible to cover everything,
or to go into detail on anything,
except in response to questions.

Clouds Are Central to the Earth Sciences

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

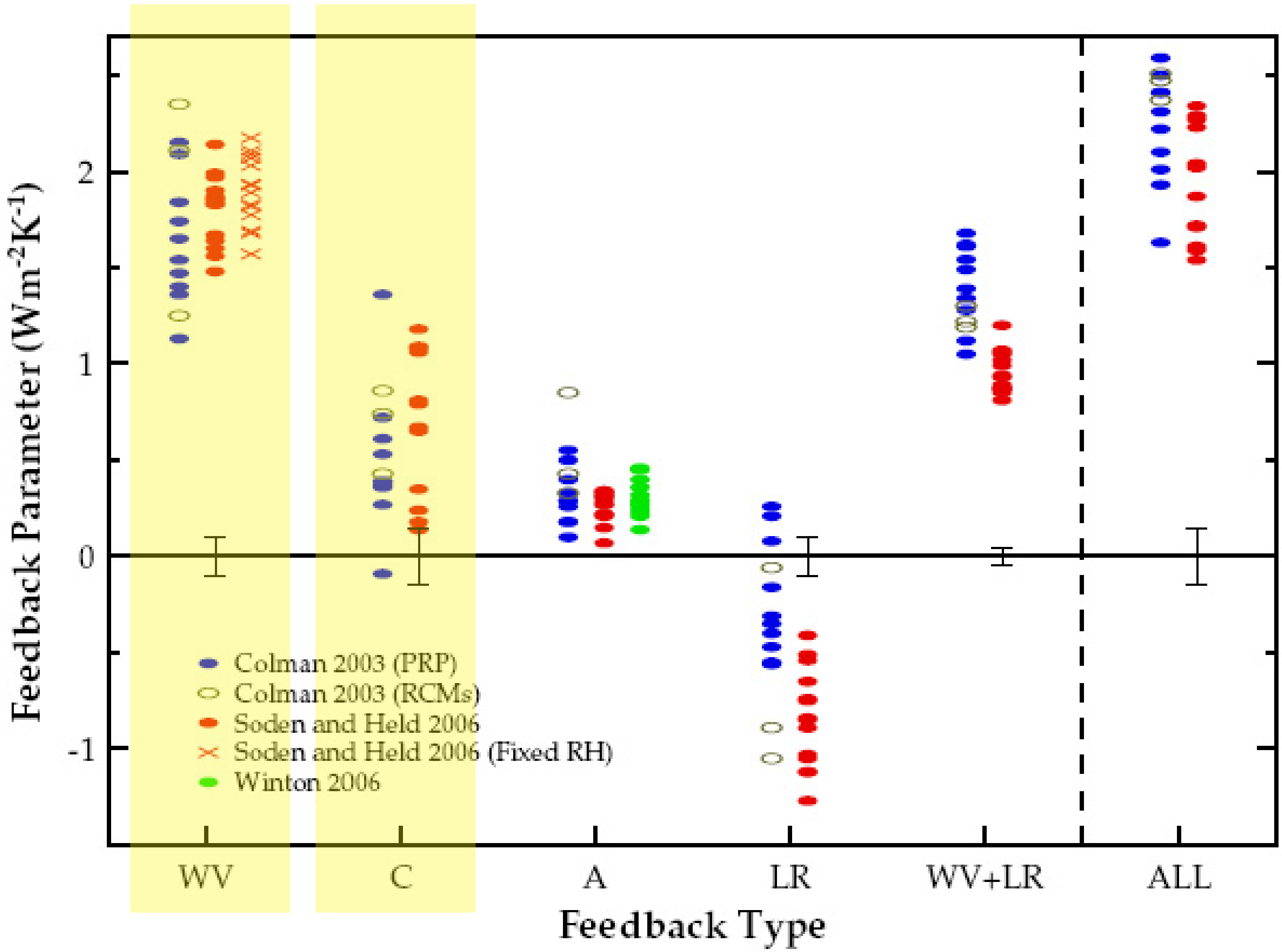
We are being held back in all of these areas by an inability to simulate the global distribution of clouds and their effects on the Earth system.

Cloud Processes



These processes interact strongly on the cloud scale, and also with larger scales.

Feedbacks in Climate Change Simulations



"Cloud feedbacks remain the largest source of uncertainty." -- IPCC AR4 SPM

"…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 unless we adopt a new approach it will still be true 30 years from now.


So, what's the problem?

The Problem Is Multiple Scales

Cloud-scale processses
Well understood

Global scale

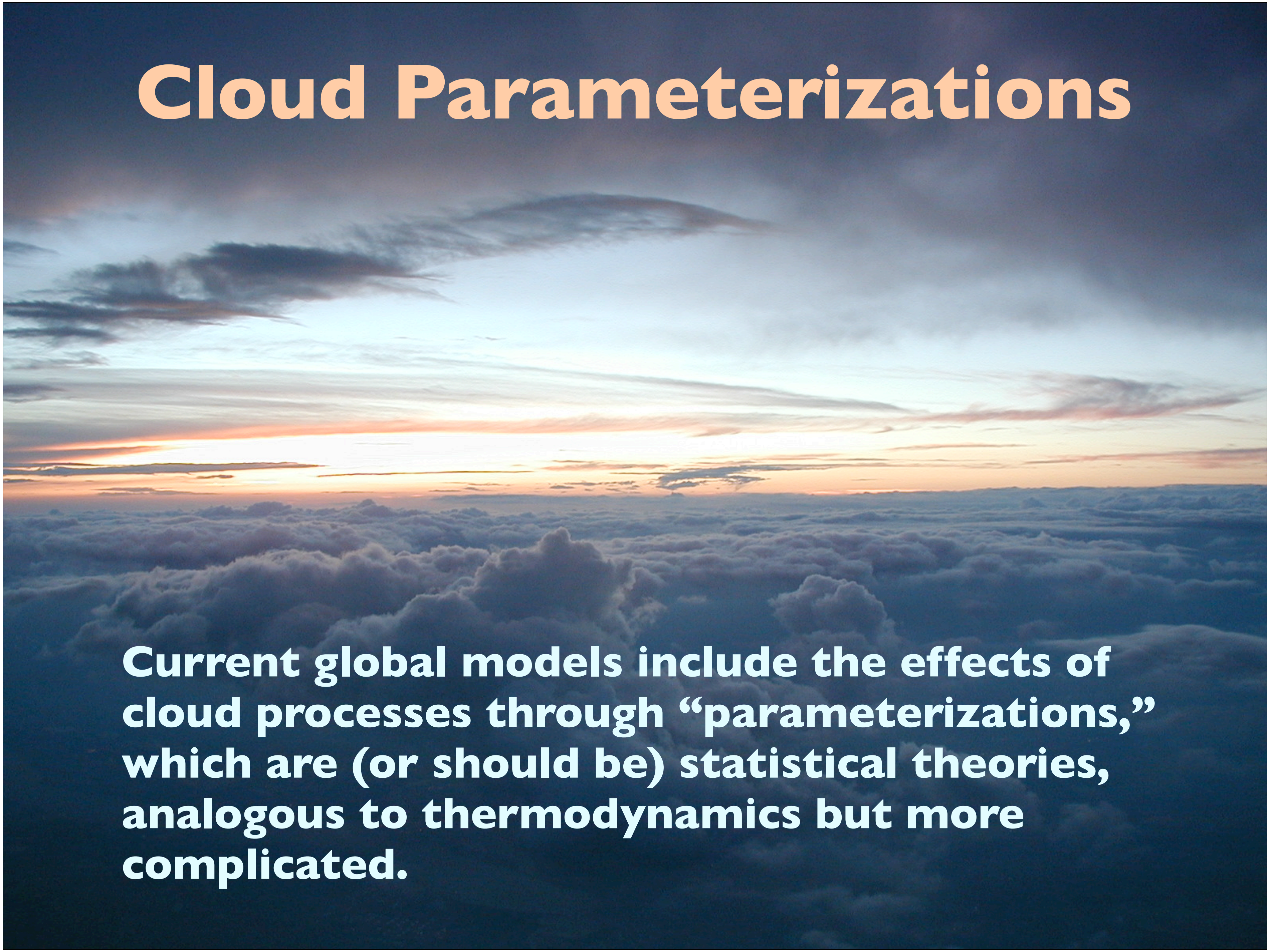
Bad news: Requires a very powerful computer.

Multiple Scales

Cloud-scale processses
Well understood → **Meso-scale statistics**
Poorly understood → **Global scale**

Global atmospheric models

- Conservation of mass, momentum, and energy
- Simulation of forced global-scale turbulence
- Resolved scales affected by unresolved scales
- Applications:
  - Prediction
    - Weather forecasting
    - Climate change simulations
  - Understanding
    - Numerical experiments
    - Learning by coupling


Cloud Parameterizations
Current global models include the effects of cloud processes through "parameterizations," which are (or should be) statistical theories, analogous to thermodynamics but more complicated.

Multiple Scales

Cloud-scale processses
Well understood

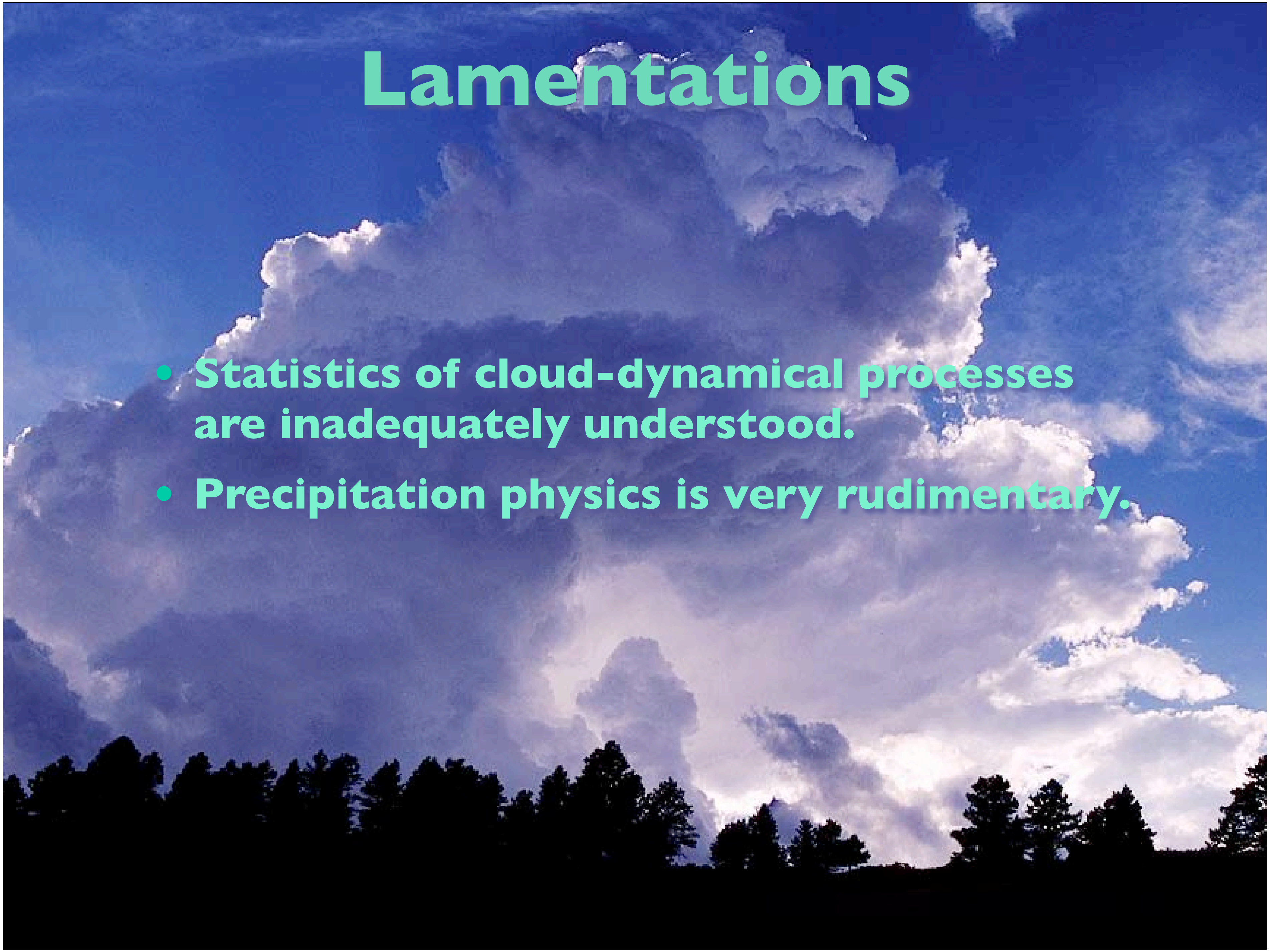
→

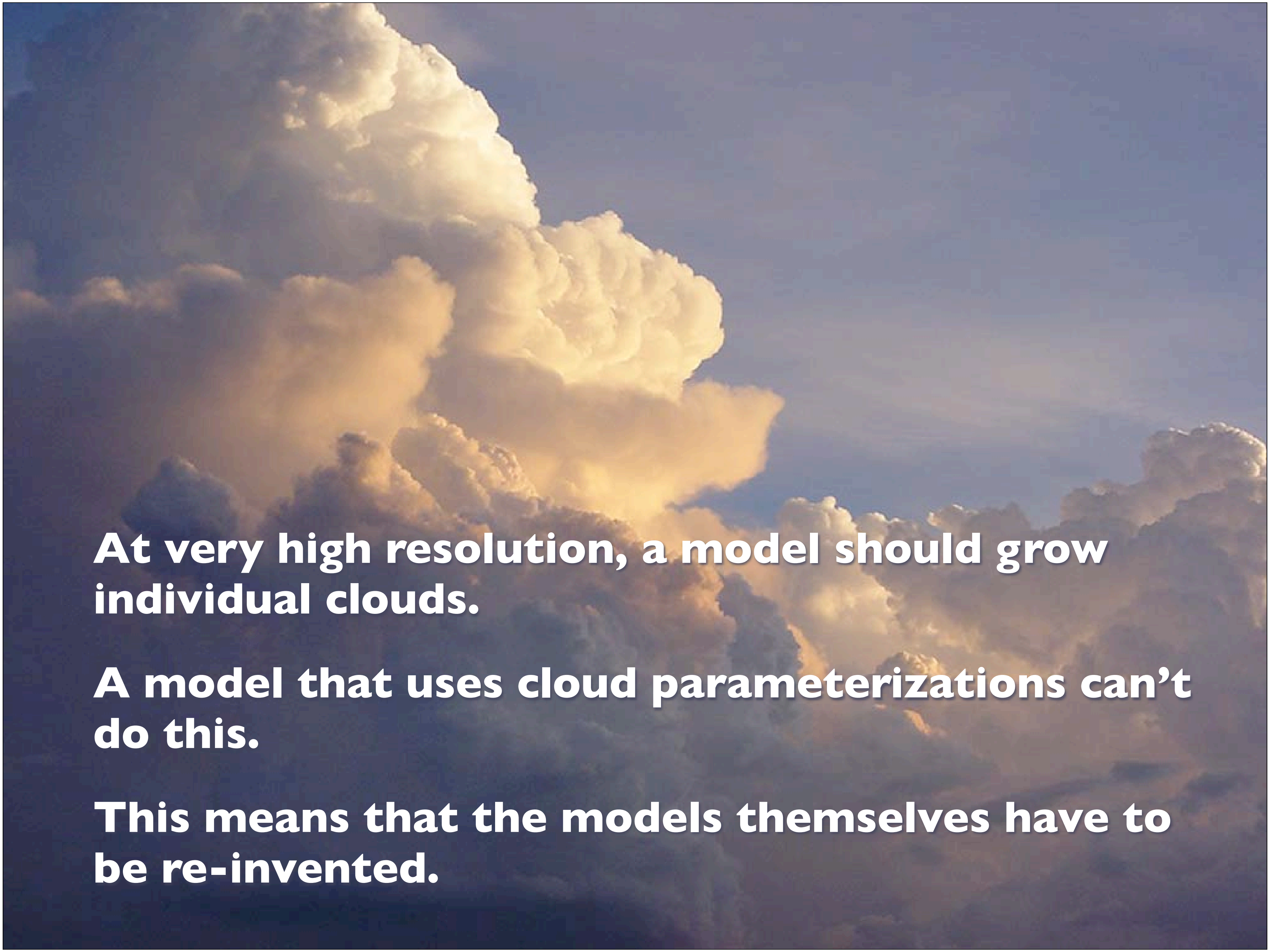
Meso-scale statistics
Poorly understood

→

Global scale

This is where parameterization comes in.


Lamentations
• Statistics of cloud-dynamical processes are inadequately understood.
• Precipitation physics is very rudimentary.


At very high resolution, a model should grow individual clouds.
A model that uses cloud parameterizations can't do this.
This means that the models themselves have to be re-invented.

Multiple Scales

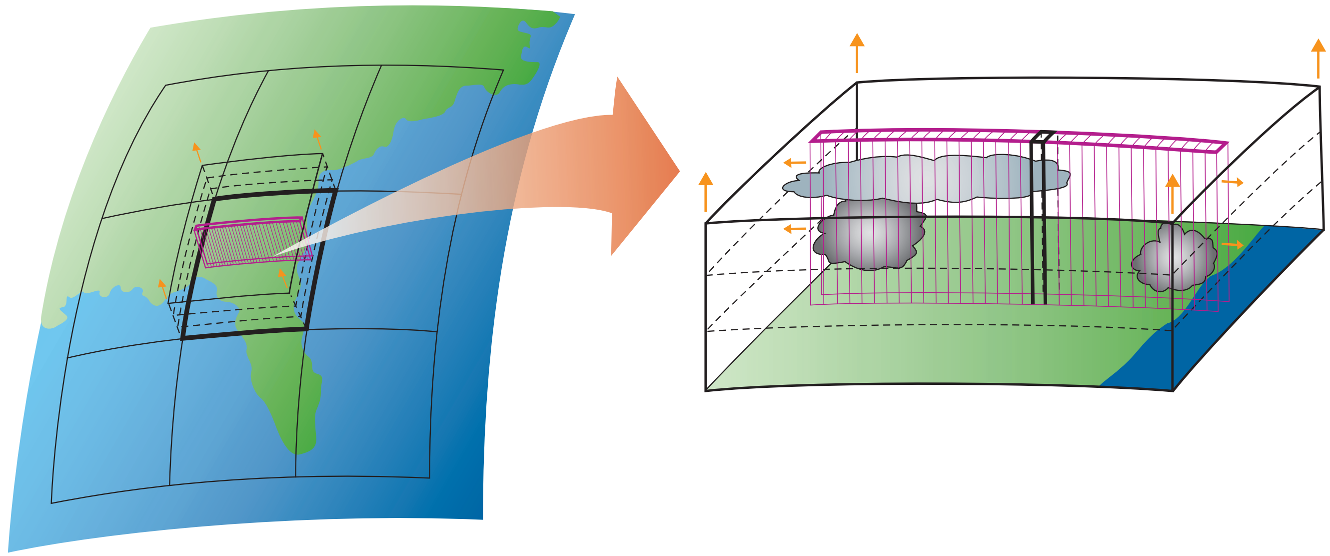
Cloud-scale processses
Well understood

Global scale

Good news: We now have very powerful computers.

Not quite powerful enough, though...

Super-Parameterization: A Multiscale Modeling Framework



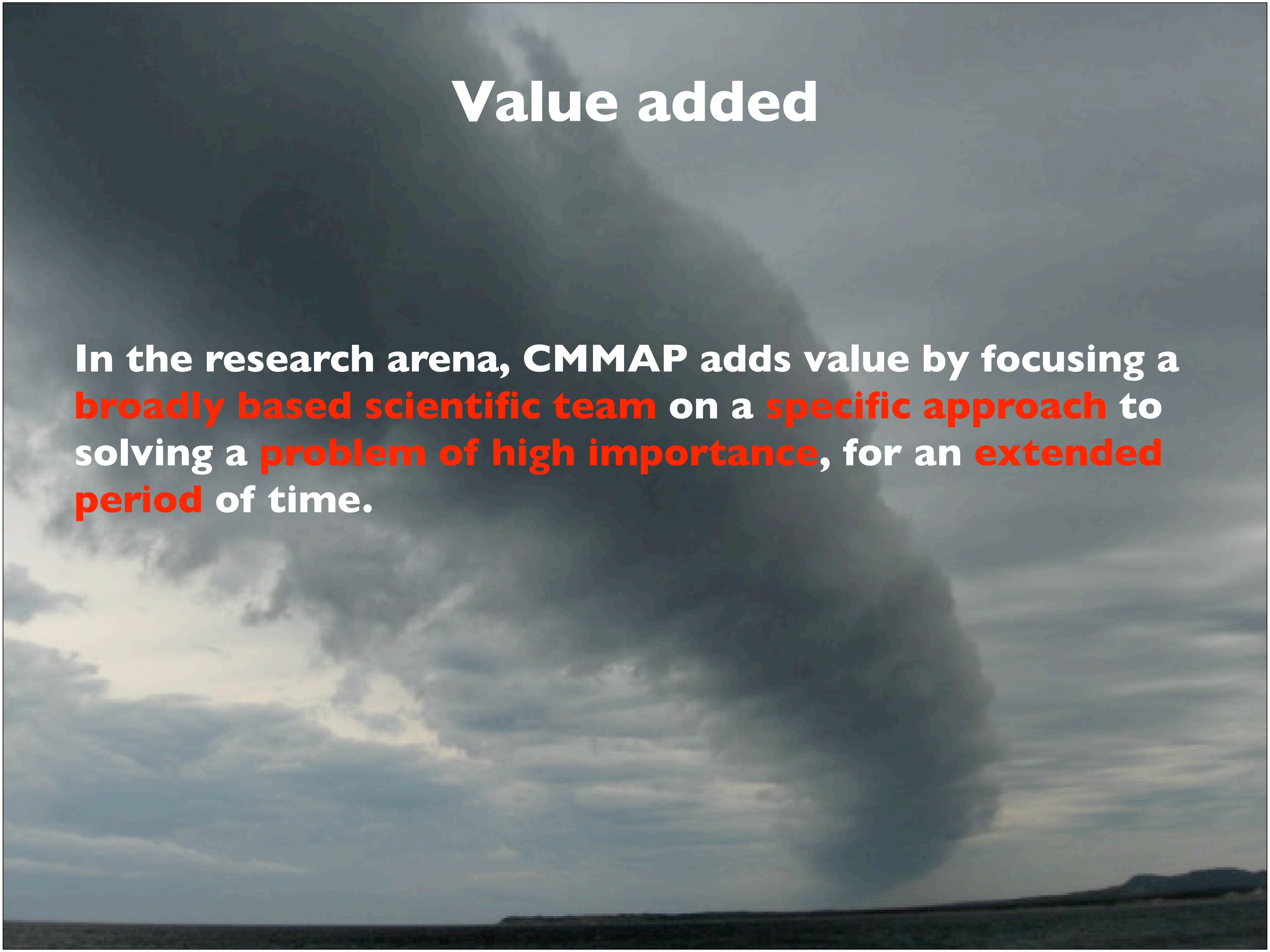
This idea was proposed and first tested by Wojciech Grabowski.


CMMAP's Vision for Research
Take advantage of rapidly increasing computer speed to achieve major advances in our ability to understand and predict the effects of clouds on weather and climate

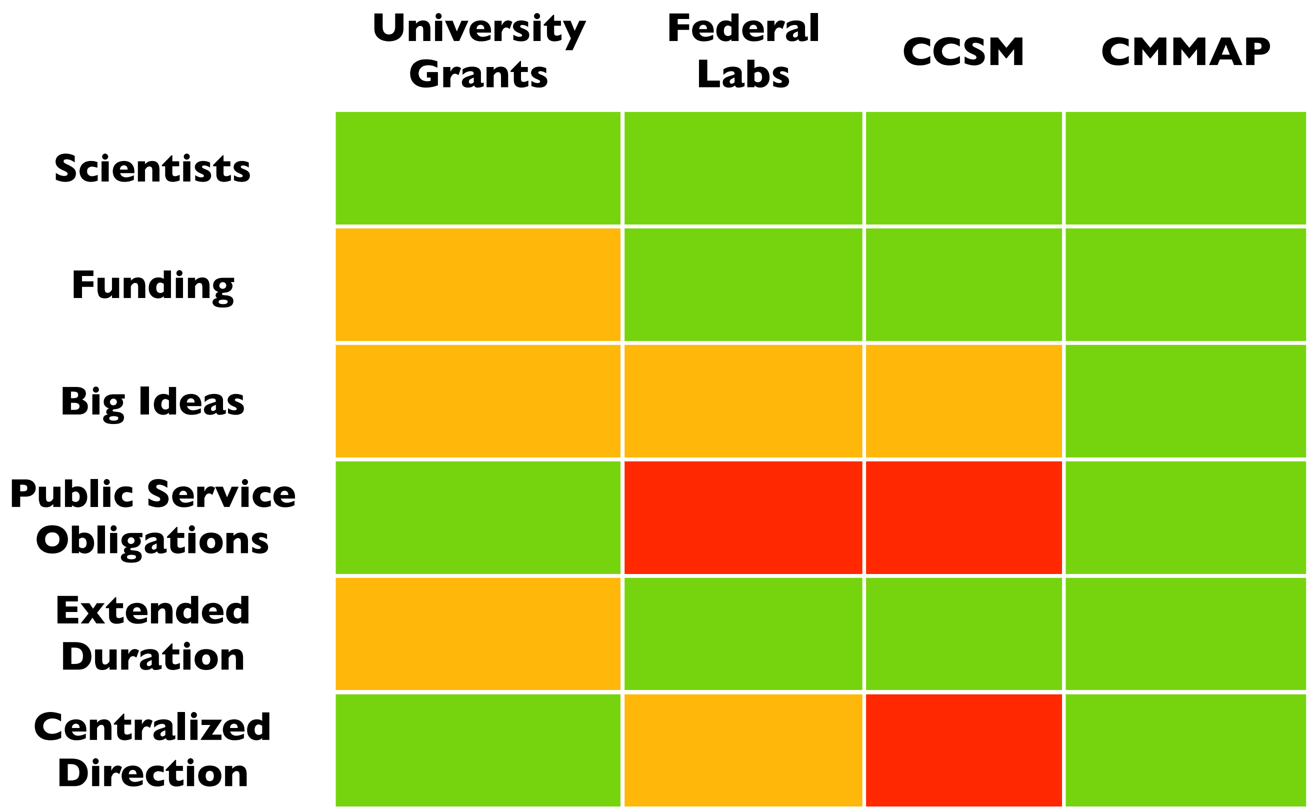
CMMAP's Research Goals

- Create radically new models that take advantage of petascale computers to produce dramatically improved simulations of the interactions of clouds with the global circulation of the atmosphere.
- Identify, analyze, and understand the strengths and weaknesses of the new models using a variety of state-of-the-art observational datasets, derived from in situ observing systems, as well as both ground-based and satellite-borne remote sensors.
- Apply the new models to develop an improved understanding of the role of clouds in the Earth system.

Objective	Actions Required	Time-frame	Team Leader	Location	Supports Goal #
1. Extensions, evaluations and applications of the prototype MMF	Perform and analyze AMIP (Atmospheric Model Intercomparison Project) simulations with the prototype MMF	Year 1	Khairoutdinov	CSU	A
	Perform and analyze coupled ocean-atmosphere simulations with the prototype MMF	Year 2			
	Create and test a geodesic version of the prototype MMF	Year 2			
2. Development of a second-generation MMF	Develop and test improved numerical representation of cloud-scale dynamics	Year 2	Arakawa/ Randall	UCLA	A
	Develop and test a global cloud-resolving model	Year 2			
	Develop and test Quasi-3D MMF	Year 3			
3. Develop and test improved microphysics parameterizations for MMFs and GCRMs	Develop new microphysics parameterization and test in CSRM	Year 3	Krueger/ Kreidenweis	UU	A
	Test new parameterization in MMF and GCRM	Year 4			
4. Develop improved parameterizations of boundary-layer clouds and turbulence for use in MMFs and GCRMs	Develop new boundary-layer cloud and turbulence parameterization and test in CSRM	Year 3	Bretherton/ Moeng	UW	A
	Test new parameterization in MMF and GCRM	Year 4			
5. Test sensitivity of CSRMs to more detailed radiation calculations	Develop new radiation parameterization and test in CSRM	Year 3	Barker	MSC	A
	Test new parameterization in MMF and GCRM	Year 4			
6. Innovative analysis, evaluation and interpretation of MMF results using emerging datasets	Acquire and adapt in situ and ground-based remotely sensed datasets for use in evaluating the MMF	Ongoing	Rossow	CCNY	B
	Acquire and adapt satellite datasets for use in evaluating the MMF				
	Develop and apply advanced, non-linear, multi-variate analysis methods to enable diagnosis of multi-scale atmospheric processes.				
7. Accelerating improvement of conventional parameterizations	Develop and test improved parameterizations of cumulus convection	Ongoing	Stevens	CSU	A & C
	Develop and test improved parameterizations of stratiform clouds				
	Develop and test improved parameterizations of the boundary layer				
8. Optimal use of computational and data storage resources	Port the MMF and GCRM to a variety of computing platforms including those associated with NSF's petascale initiative	Ongoing	Helly	UCSD	A
	Efficiently distribute model output and observational datasets to users				


Value added
In the research arena, CMMAP adds value by focusing a broadly based scientific team on a specific approach to solving a problem of high importance, for an extended period of time.

Cloud-Climate Research Machines



A door has swung open.

The Multiscale Model is a revolutionary, transformative new approach to understanding and simulating cloud processes on the global scale.

We need to establish multiscale model 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 through a *multi-institutional collaborative effort with a centrally defined focus and an extended lifetime.*

This is CMMAP.

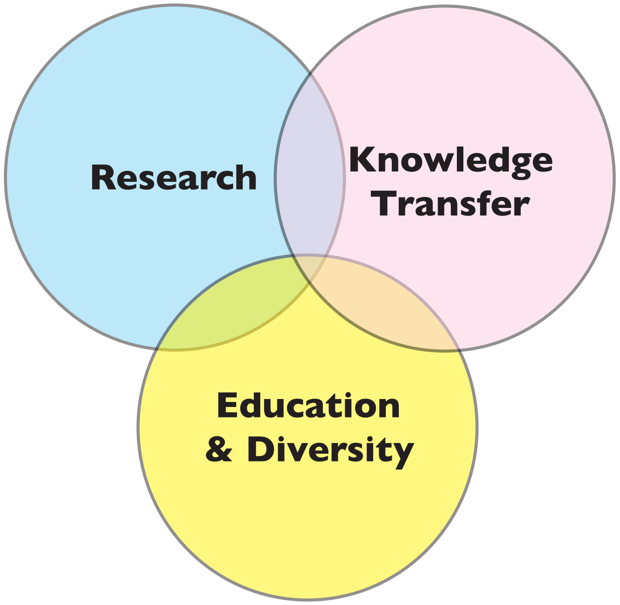
Research is about learning new things.
We do research in the context of education.

NSF

CMMAP
Reach for the sky.

As academics...

- We learn.
- We teach (and advise).
- We "transfer" what we have learned to the larger culture.



Education Goals

- Enhance the climate science workforce of the future
- Enhance teaching and learning of Earth System Science at all levels
- Disseminate CMMAP science results to the public and to climate stakeholders

Atmospheric scientists are not diverse.

There are very few African-Amerian, Native American, or Hispanic atmospheric scientists.

Although we have many female graduate students, there are not many female faculty.

Diversity Goals

- **Support and matriculate graduate students whose gender and ethnic makeup reflect those of the US population.**
- **Improve understanding of the structural barriers to gender and ethnic balance in science.**
- **Encourage participation in science and engineering by women, minorities and persons with disabilities, at all academic levels.**

Knowledge Transfer Goals

- Enable improved climate models
- Enable improved weather forecasts
- Capture and record the history of global modeling
- Create an appropriate venue for the publication of scientific papers on global environmental modeling
- Create an appropriate venue for the publication of review articles directed toward policy planners and the scientifically informed public

Management Goals

- Create and nurture a new community of researchers and educators with a strong focus on the Research, Education, Diversity and Knowledge Transfer goals of the Center.
- Foster collaborative relationships between the Center and other institutions.
- Create synergistic relationships with non-NSF funding sources and national and international partners.

CMMAP is "Integrative" on multiple levels

- Our research is creating a more natural way for global modelers to interact with other groups within atmospheric science.
- We are integrating research and education.
  - Researchers provide content for use by K-16 educators
  - Researchers train students to do research
- We are working to diversity the ethnic and gender make-up of the climate science work force.

The Global Model As A Scientific Water Hole

A Disconnect at the Water Hole

- What cloud-observers measure, global models don't simulate.
- What cloud-resolving models simulate, global models don't simulate.

Addressing the disconnect

- **Tests with SCMs, CRMs, and LESMs, through case studies based on field experiments**

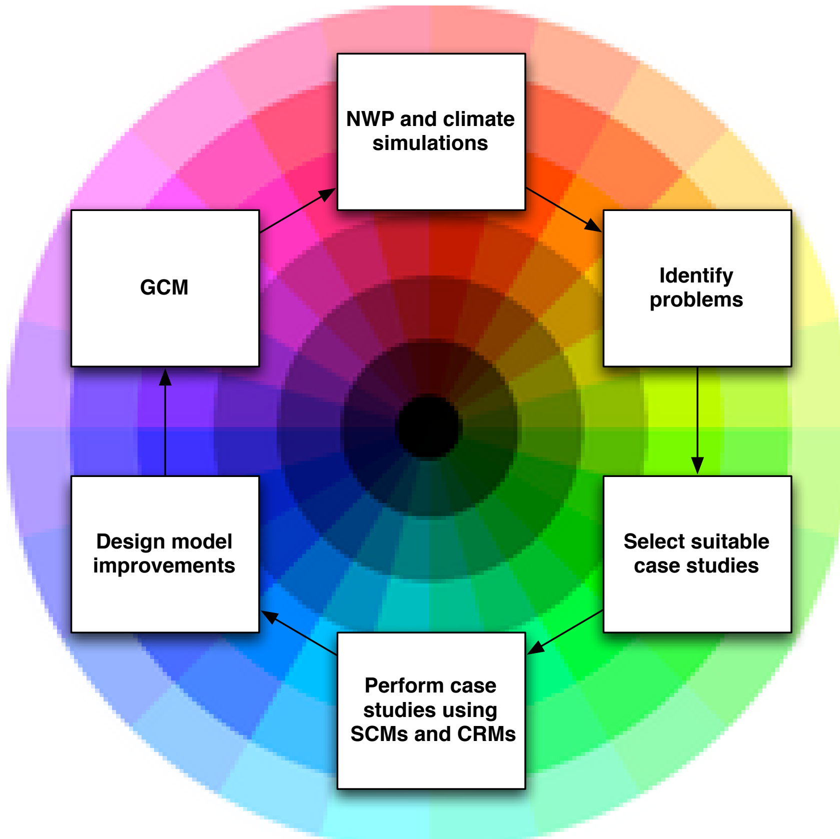


Diagram from Christian Jakob

- **A harmonic convergence of GCMs and CRMs**

Changing the world...

Major advances in our ability to understand and predict the effects of clouds on weather and climate

A climate science workforce enhanced by CMMAP's inspiration and education of students of all levels, policymakers, and the public.

A climate science workforce enhanced through CMMAP's diversity of culture and life experience which draws from the whole US population.

An internationally recognized resource for research and education in climate simulation, numerical weather prediction, and scientific publications dealing with global environmental modeling.

Questions?