Overview of Research Objectives and Action Steps

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?

What is a "parameterization?"

The word "parameterization" is a contraction of "parametric representation."

A parameterization is a statistical theory that encapsulates our physical understanding of the interactions of small-scale processes (e.g., cloud processes) with larger-scale processes.

Parameterizations are not simply "curve fits" or collections of "adjustable numbers."

Parameterizations are necessary because of the huge range of scales in the Earth System.

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.

Help is on the way.

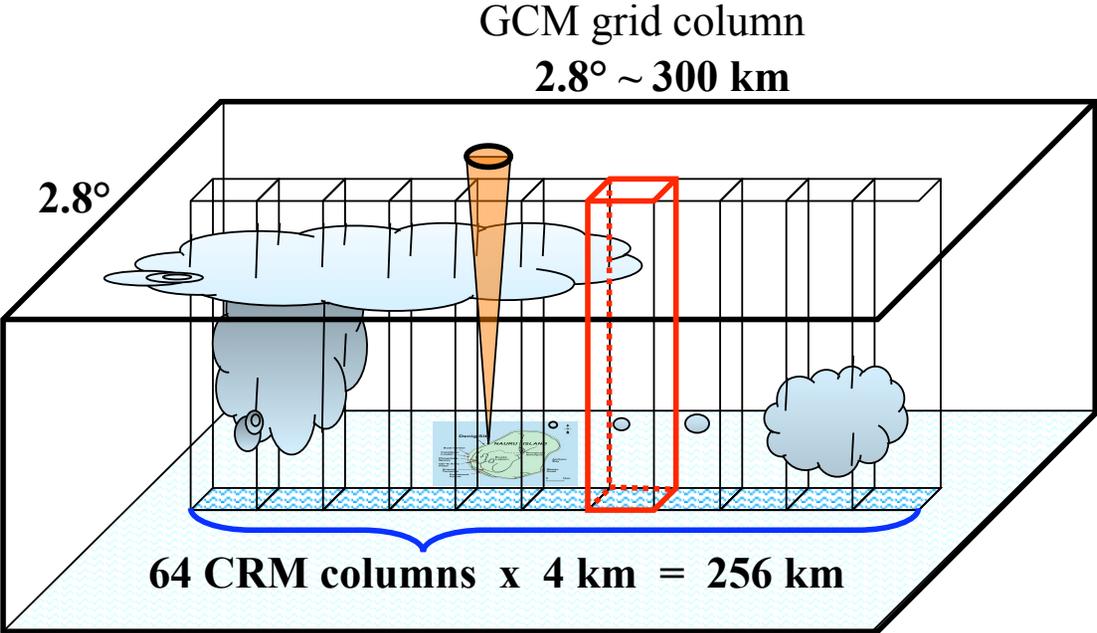We need a new approach to solving the cloud puzzle.

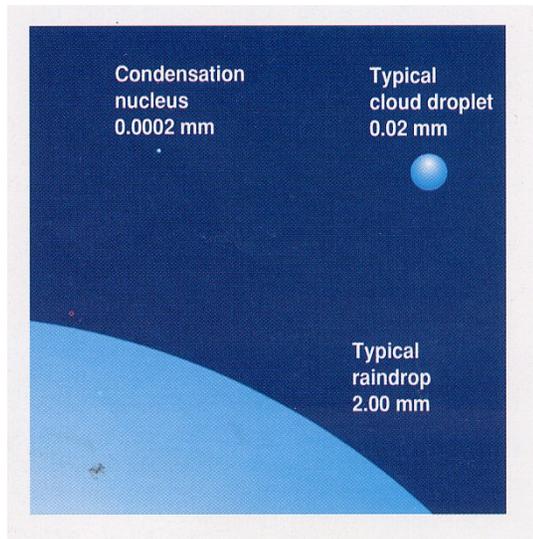Fortunately, a new approach has recently emerged through:
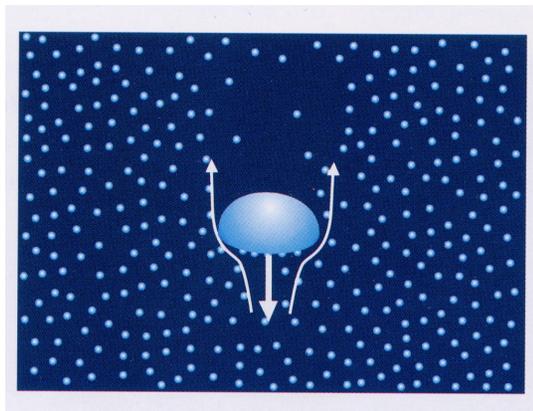

Advances in computing power

Super-Parameterization

GCM grid column
2.8° ~ 300 km

2.8°

64 CRM columns x 4 km = 256 km

Limitations (and Strengths) of CRMs

- Microphysics must still be parameterized.

- Radiative transfer must still be parameterized.

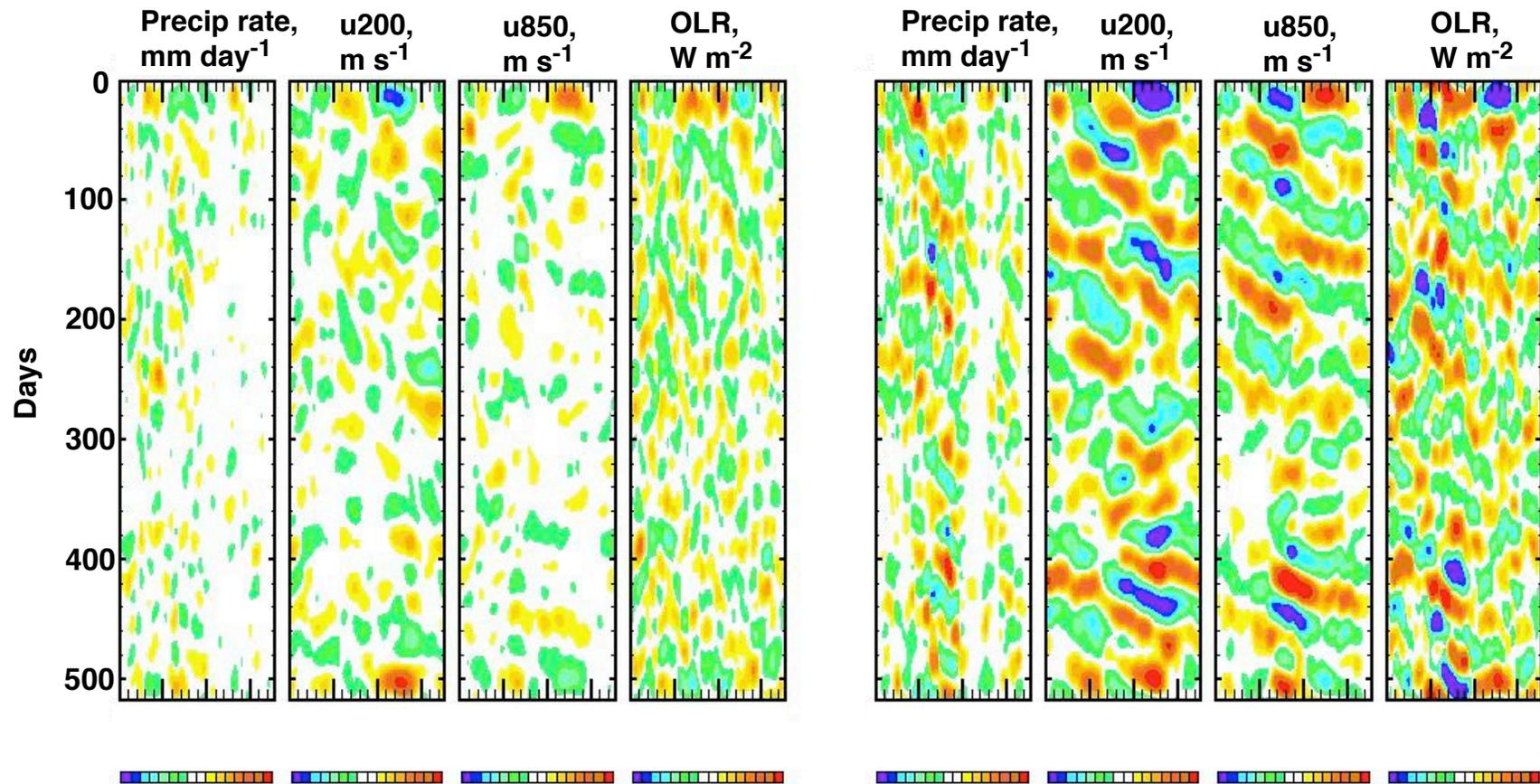- Turbulence and shallow convection must still be parameterized.

A summary of our adventures to date

- The prototype MMF produces substantially improved simulations of tropical variability on a range of time scales.

- The prototype MMF produces substantially improved simulations of both low and high cloudiness.

- The periodic boundary conditions and two-dimensionality of the prototype MMF cause some problems.

- The prototype MMF uses about 250 times more computer power than a conventional global model.

- Analysis of results obtained with the prototype MMF is already teaching us new things about the Earth system, and about conventional parameterizations.

Control

Precip rate, mm day⁻¹ · u200, m s⁻¹ · u850, m s⁻¹ · OLR, W m⁻²

Prototype MMF

Precip rate, mm day⁻¹ · u200, m s⁻¹ · u850, m s⁻¹ · OLR, W m⁻²

Filtered to show only periods of 20-100 days.

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 MMAP.

1. Vision Statement for Research

To understand and predict the effects of clouds on a wide range of Earth-system processes.

2. Mission Statement for Research

The research mission of MMAP is to develop a new kind of global atmospheric model that can represent the effects of clouds on weather and climate with greatly improved realism; to evaluate the new model by comparison of model results with observations; and to apply the model to understand the interactions of clouds with other components of the Earth system, including the atmosphere, the vegetated land surface, and the oceans.

Objective	Action Steps	Responsible Person & Team	Location	Time-frame
Extensions, evaluations and applications of the prototype MMF	Perform and analyze AMIP simulations with the prototype MMF	Khairoutdinov DeMott Ackerman	CSU CSU PNNL	Year 1
	Perform and analyze coupled ocean-atmosphere simulations with the prototype MMF	Khairoutdinov	CSU	Year 2
	Create and test a geodesic version of the prototype MMF	Dazlich Khairoutdinov	CSU CSU	Year 2
Development of a second-generation MMF	Develop and test Quasi-3D MMF	Arakawa Jung Konor	UCLA CSU CSU	Year 3
	Develop and test a global cloud-resolving model	Arakawa Jung Konor Khairoutdinov	UCLA CSU CSU CSU	Year 3
Development of improved parameterizations for use in the MMF	Develop and test improved microphysics parameterization for CSRMs	Grabowski Bretherton Kreidenweis Tao Krueger Heymsfield	NCAR UW CSU GSFC UU NCAR	Ongoing
	Develop improved turbulence parameterizations for use in CSRMs	Moeng Lappen Stevens	NCAR CSU UCLA	Ongoing
	Test sensitivity of CSRMs to more detailed radiation calculations	Barker Collins Stephens	AES NCAR CSU	Ongoing

The design, testing, and application of an improved MMF will be the central, organizing component of MMAP's research.
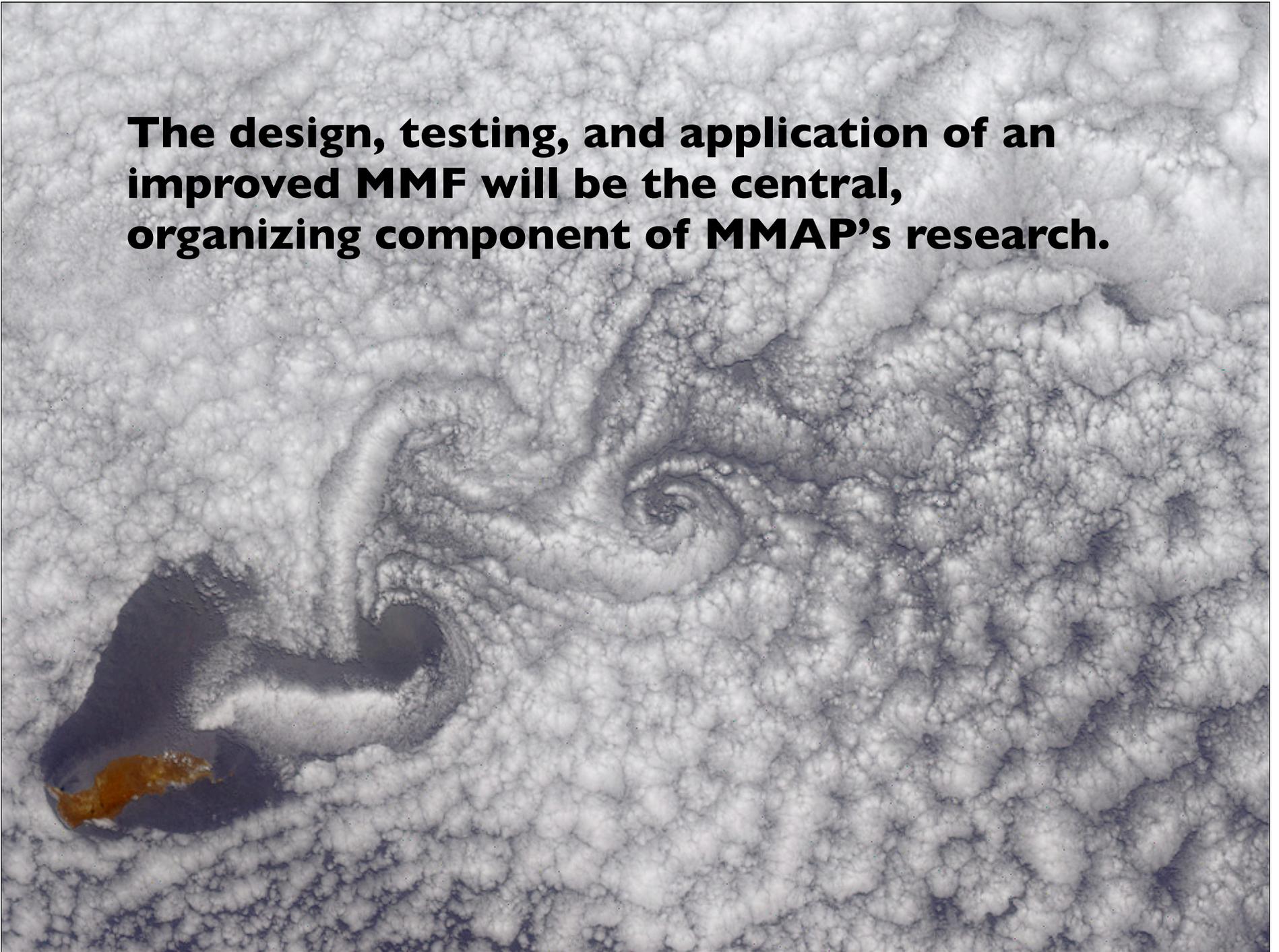
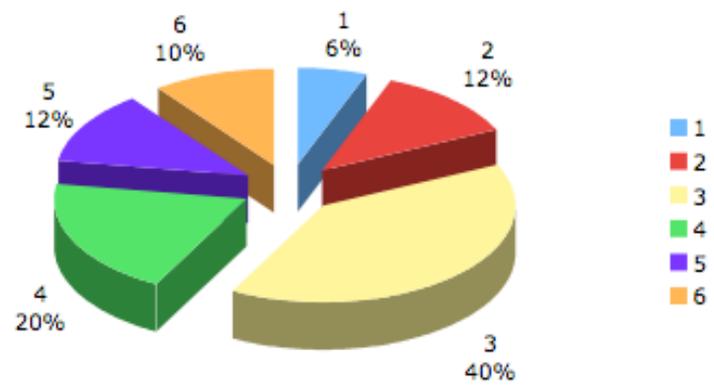| Objective	Action Steps	Responsible Person & Team	Location	Time-frame
The evaluation and interpretation of MMF results using emerging datasets	Acquire and adapt in situ datasets for use in evaluating the MMF	Ackerman Heymsfield	PNNL NCAR	Ongoing
	Acquire and adapt satellite datasets for use in evaluating the MMF	Stephens Rossow Kummerow	CSU CCNY CSU	Ongoing
Continuing development of conventional parameterizations	Cumulus convection	Randall Hack	CSU NCAR	Ongoing
	Stratiform clouds	Randall	CSU	Ongoing
	Boundary layer	Lappen Randall Bretherton	CSU CSU UW	Ongoing
Optimal use of computational and data storage resources	Port the MMF and GCRM to a variety of computing platforms	Helly Khairoutdinov Dazlich	UCSD CSU CSU	Ongoing
	Efficiently distribute model output and observational datasets to users	Helly	UCSD	Ongoing

Comparison with Observations
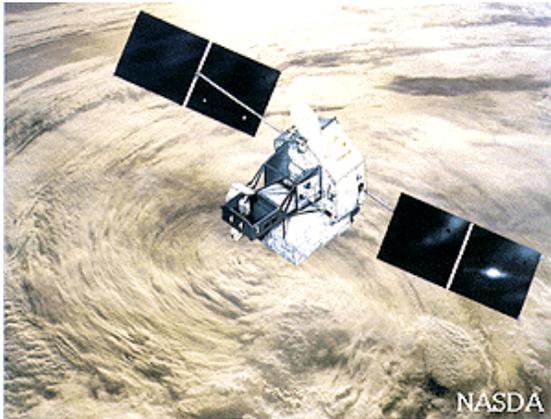
TRMM/GPM

ARM

CloudSat

Chill

Research Objectives

1
6%

2
12%

3
40%

4
20%

5
12%

6
10%

1
2
3
4
5
6

Questions?