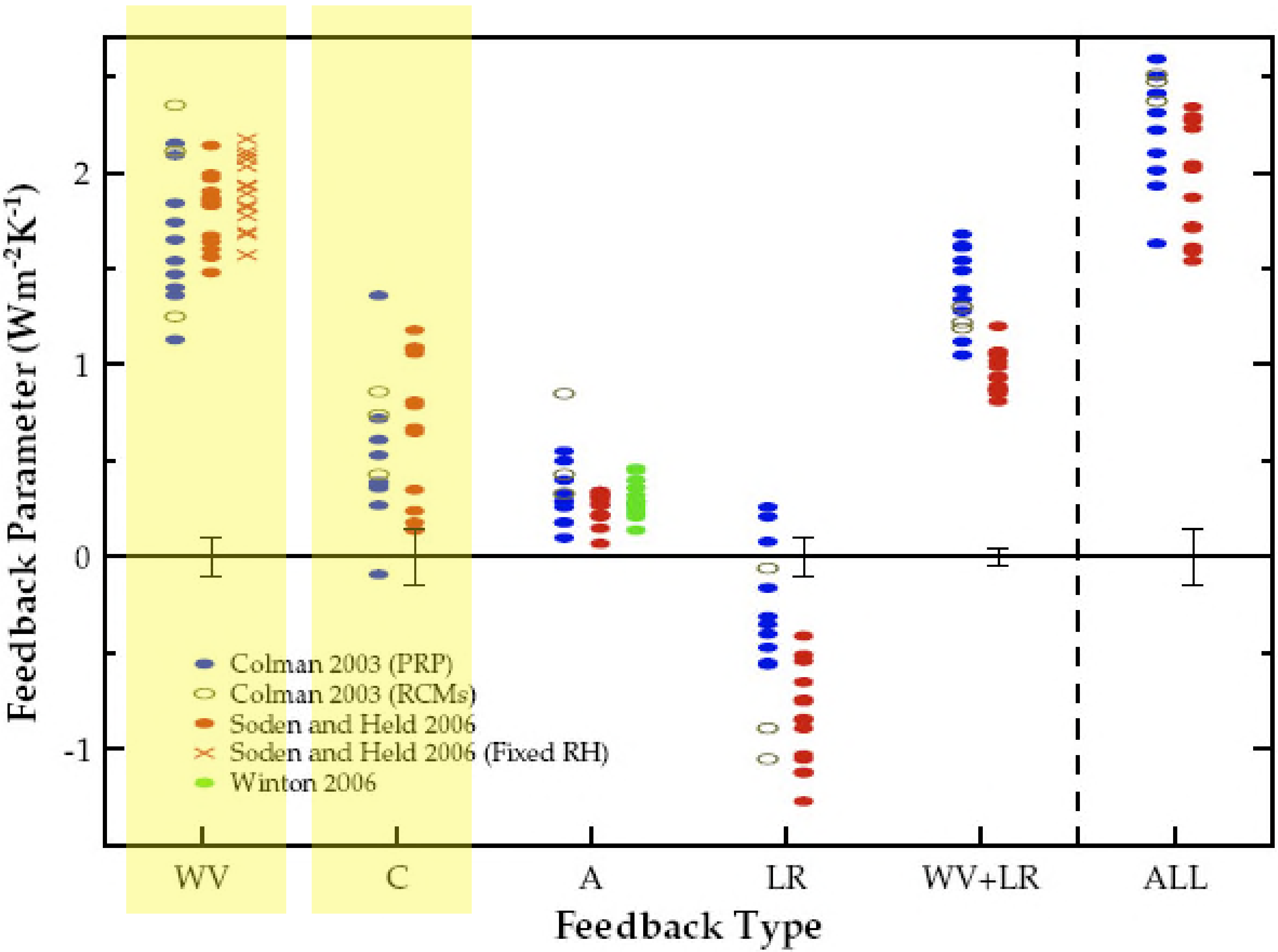
Research Plan & Discussion

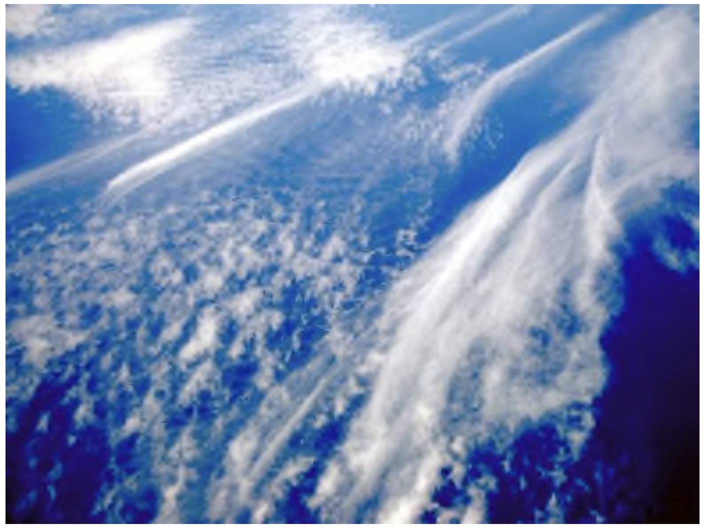
Wherein we do a little daydreaming

"Cloud feedbacks remain the largest source of uncertainty." -- IPCC 2007



So, what's the problem?

The problem is multiple scales.



Cloud-scale processses
Well understood

→

Meso-scale statistics
Poorly understood

→

Global scale

This is where parameterization comes in.

CMMAP’s Vision for Research

Take advantage of rapidly increasing computer power to achieve major advances in our ability to understand and predict the effects of clouds on weather and climate

CMMAP's Research Goals

A. 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.

B. 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.

C. Apply the new models to develop an improved understanding of the role of clouds in the Earth system.

Objective	Actions Required	Time-frame	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	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	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	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	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	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	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	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	A
	Efficiently distribute model output and observational datasets to users		

What is multiscale modeling?

- Based on *resolution-independent physics:*
  - *Potentially covers scales from global to LES.*
  - *Necessarily involves a CRM?*
- Can combine CRMs with conventional global dynamical cores.
- Also includes global cloud-resolving models.
- Holds the promise of a truly unified, flexible multiscale modeling framework that *converges* (see next slide).

Convergence

At low resolution, a GCM represents cloudiness statistically -- thermodynamics.

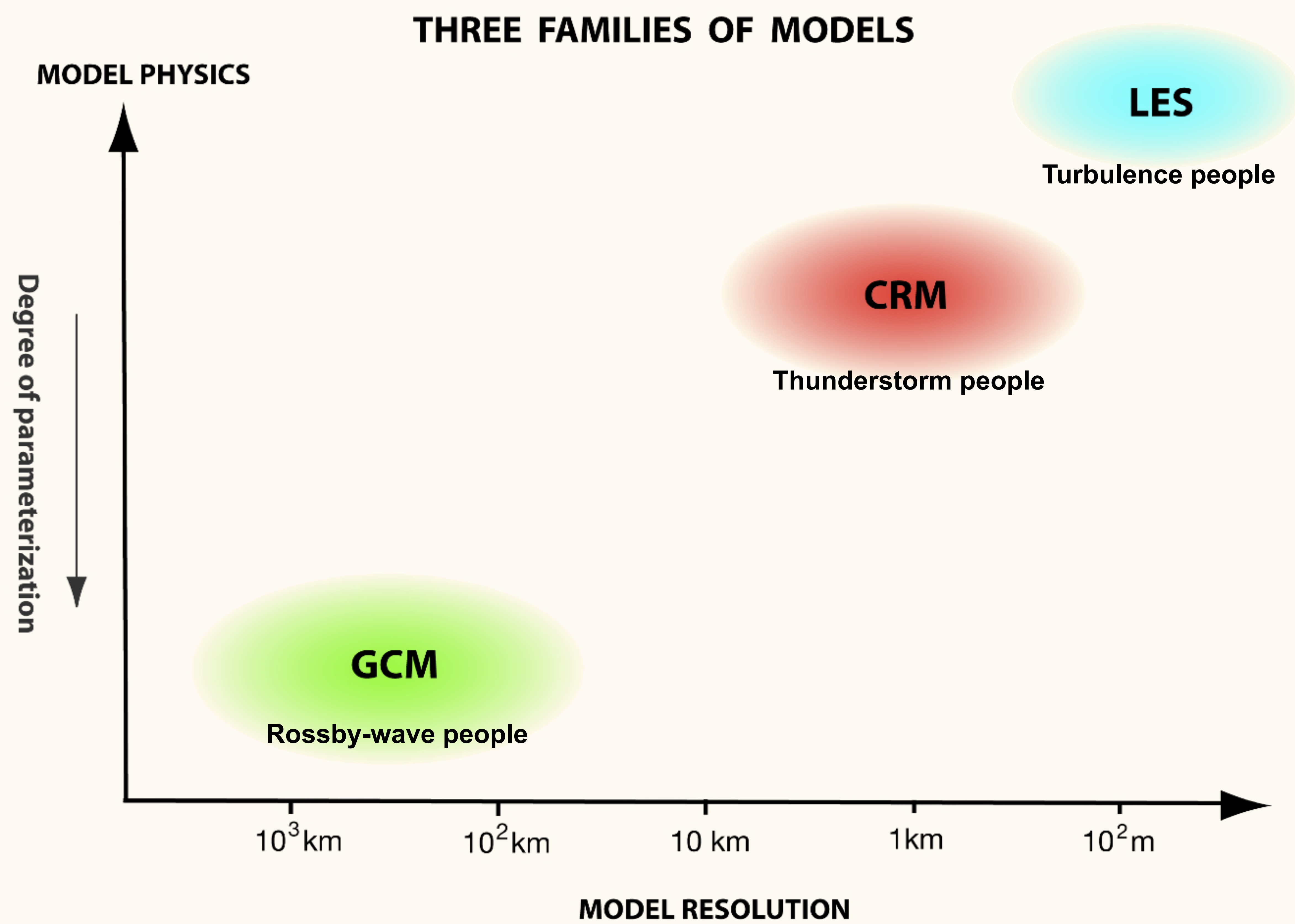
At very high resolution, the model should grow individual clouds -- molecular dynamics.

Therefore, as the model's resolution changes, its formulation should "adjust."

We must change not only the grid spacing, but the equations themselves.

This is both *physical* and mathematical convergence.

No existing global model has this convergence property.



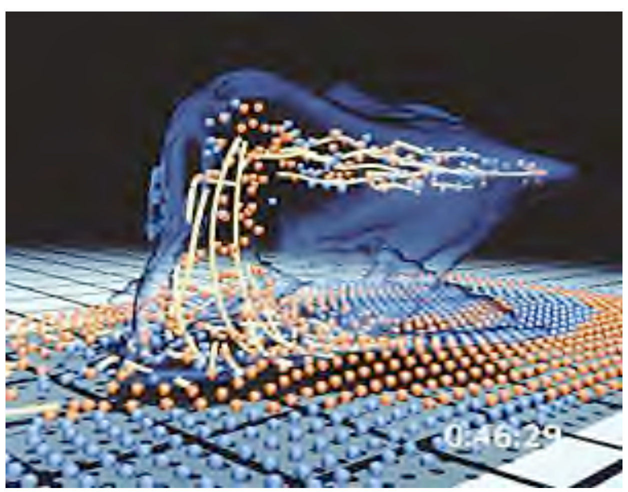
Slide from A Arakawa

A Multiscale Model Is A Scientific Water Hole.

GCRMs are very expensive.

Conventional GCMs depend on shaky parameterizations.

What's in between?



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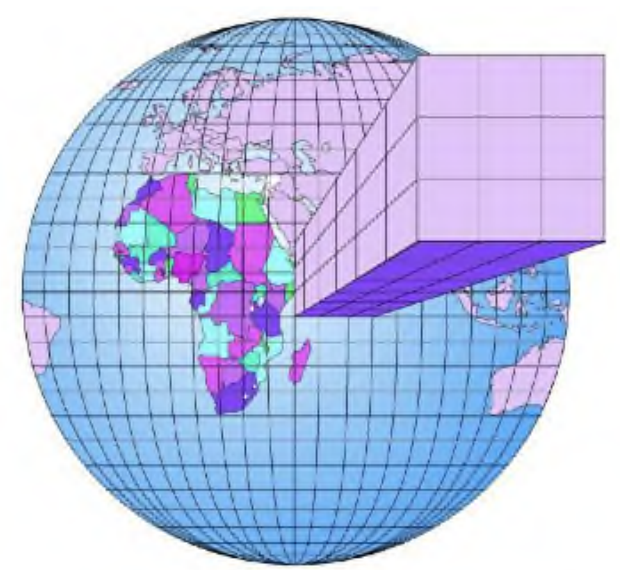

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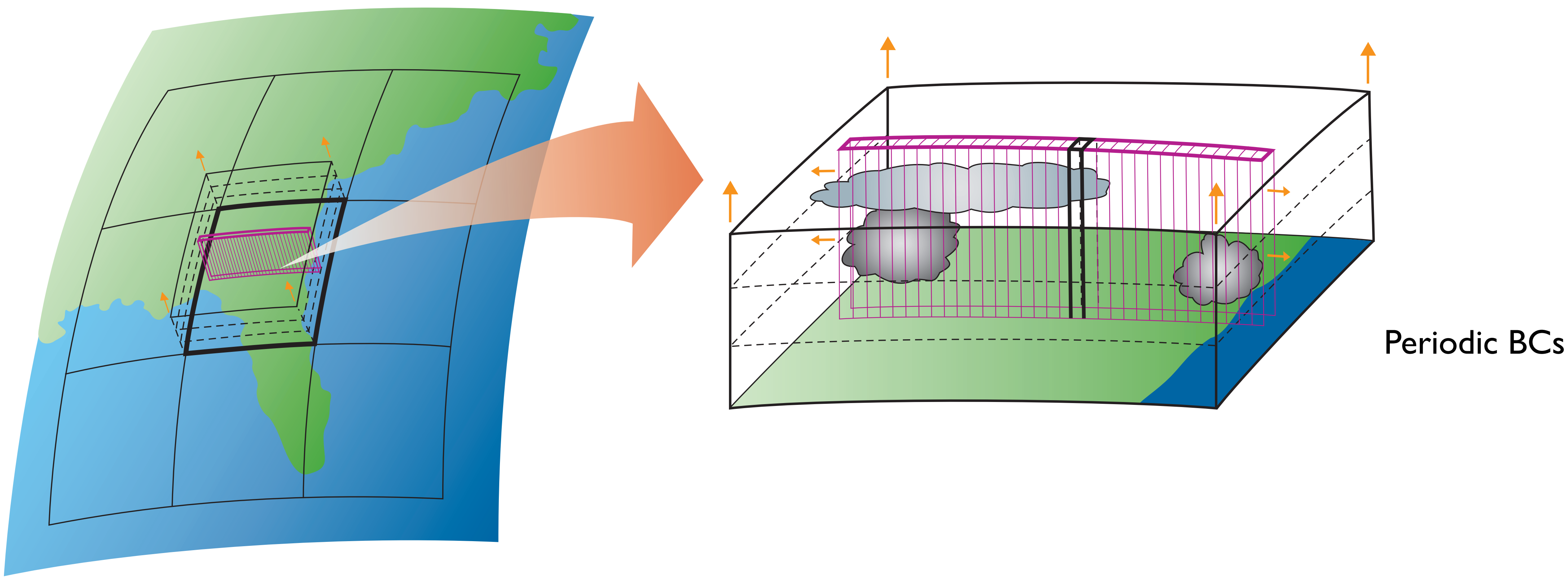
Super-Parameterization

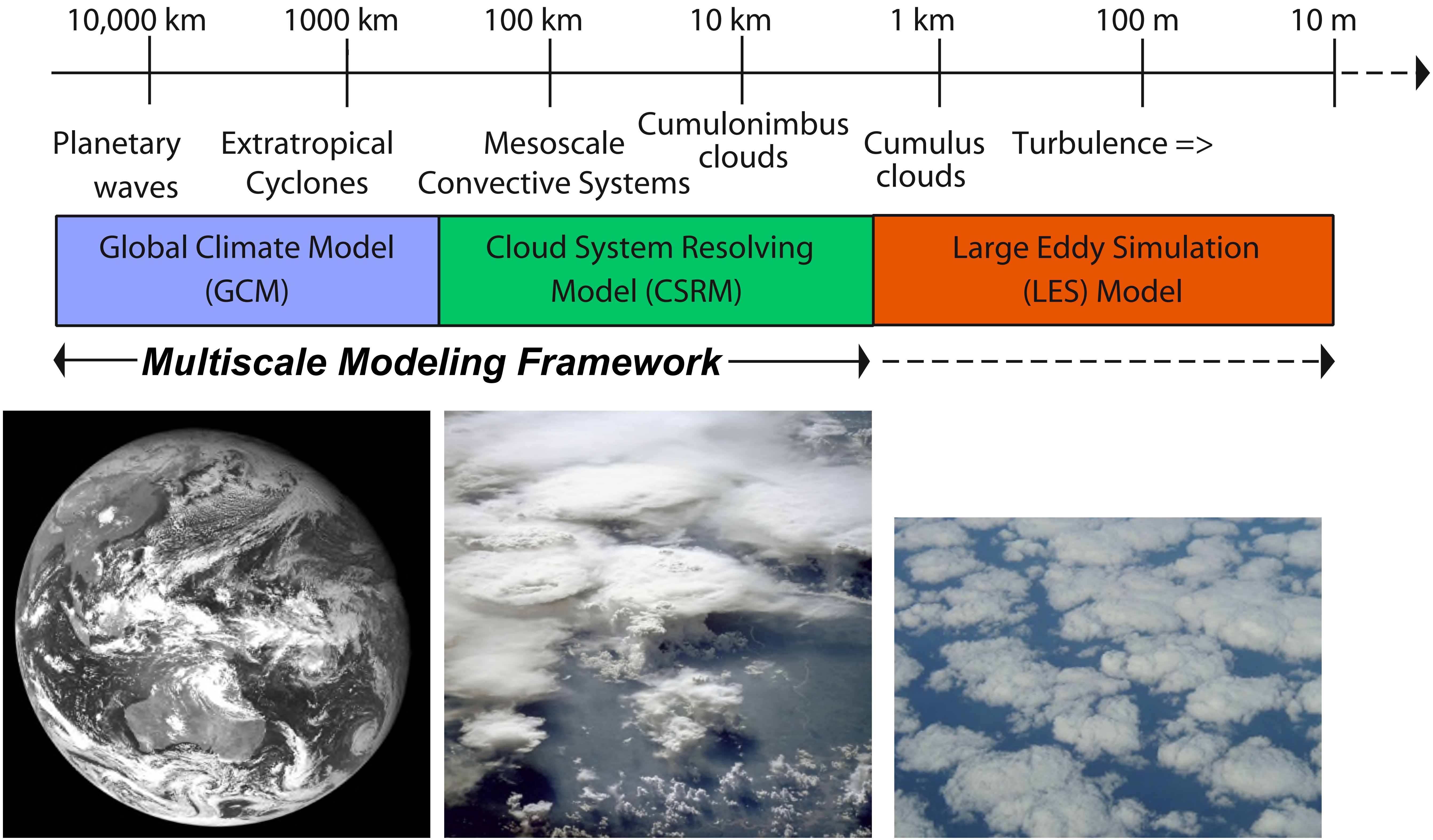
(a.k.a. the Multiscale Modeling Framework, or MMF)



A super-parameterized climate model is about 250 times slower than a conventional GCM with climate resolution.

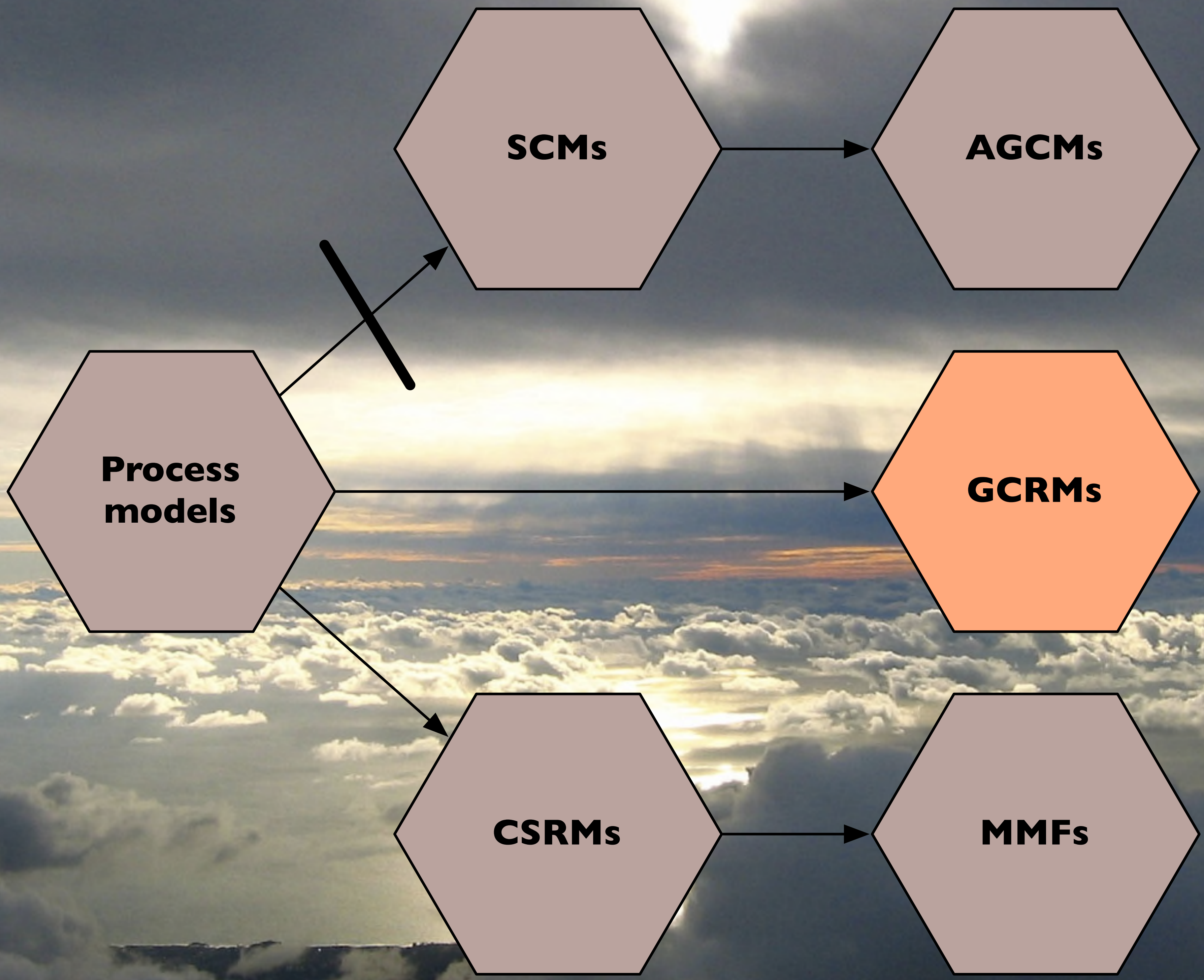
It is more flexible and less expensive, but also more complicated, than a global cloud-resolving model.

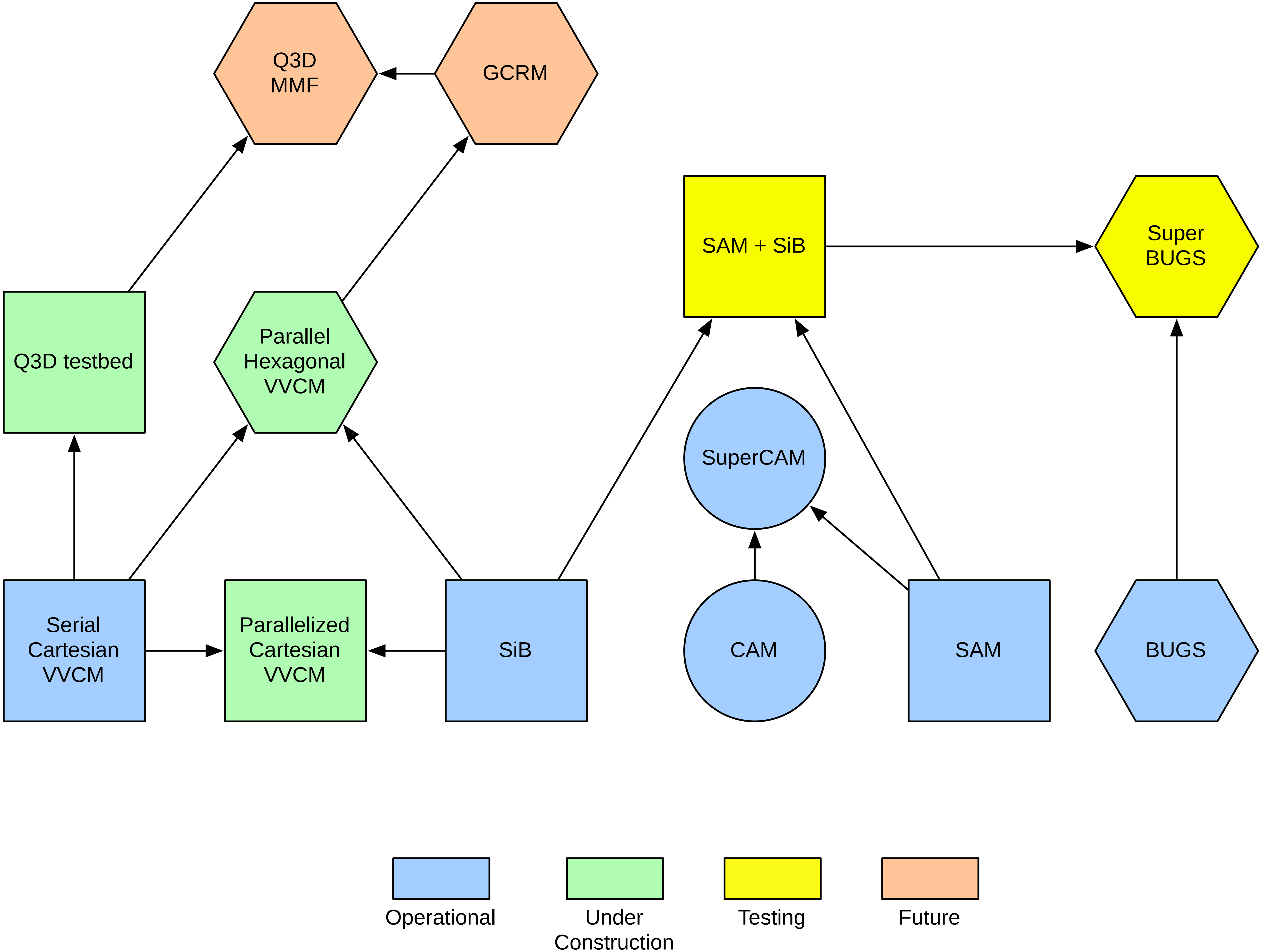
Scales of Atmospheric Motion



Slide from Steve Krueger

A modeling hierarchy




Q3D
MMF
GCRM
SAM + SiB
Super
BUGS
Q3D testbed
Parallel
Hexagonal
VVCM
SuperCAM
Serial
Cartesian
VVCM
Parallelized
Cartesian
VVCM
SiB
CAM
SAM
BUGS
Operational
Under
Construction
Testing
Future

Model Status

Model	Status	Comments
SuperCAM	Operational	Still evolving
SuperBUGS	Testing	PBL and LSM in CRM
SAM	Operational	Test physics here
SAM + SiB	Testing	
VVCM	Late testing	Test physics here
Hex VVCM	Under construction	
Q3D testbed	Under construction	
Q3D MMF	Future	
GCRM	Future	

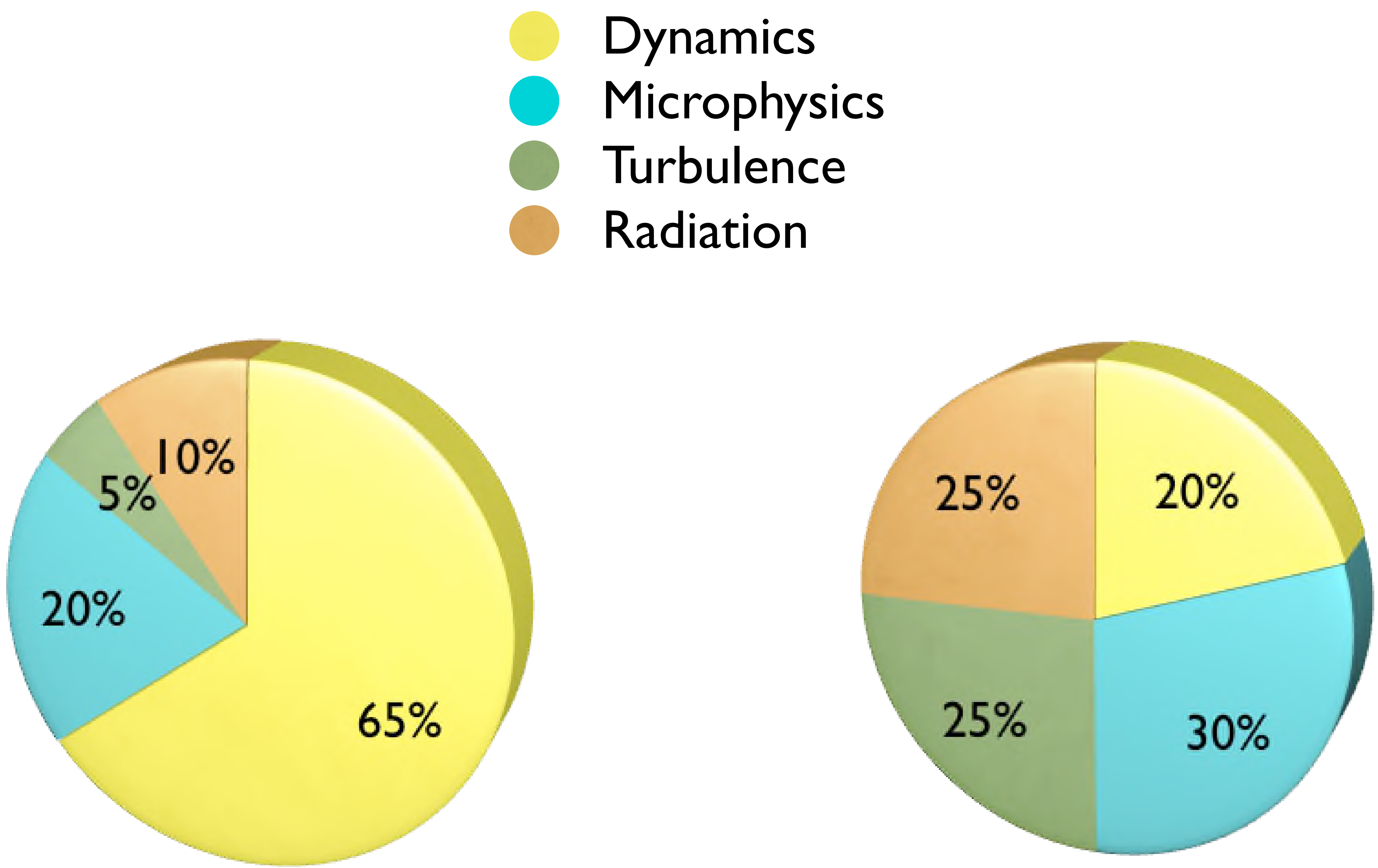
SAM

- Marat's creation
- Anelastic, well parallelized
- Widely shared
- Supported in an organized way
- Now in version 6.6
- Testbed for microphysics, turbulence, and radiation parameterizations
- Incorporated into SuperCAM and SuperBUGS

SuperCAM

- Studied by CSU, Barker-Cole, PNNL/ U. Washington, BMRC, and LLNL groups, so far
- Still has lots of potential for good science:
  - MJO studies (ongoing)
  - Coupling with an ocean
  - Further experiments with a 3D CRM
  - Improved microphysics, turbulence, and radiation parameterizations
  - Tests with higher horizontal and vertical resolution
  - Alternative ways of coupling the GCM and CRM
- Computer time available through CMMAP

Where does the time go?



Present

Future?

VVCM

- Tests:
  - Joon-Hee Joong and Akio Arakawa
  - Chin-Hoh Moeng
  - Grant Firl
  - Todd Jones
- Parallelization in progress
- Physics upgrades needed
  - Turbulence
  - Microphysics
  - Radiation
  - Land surface
- Infrastructure needed

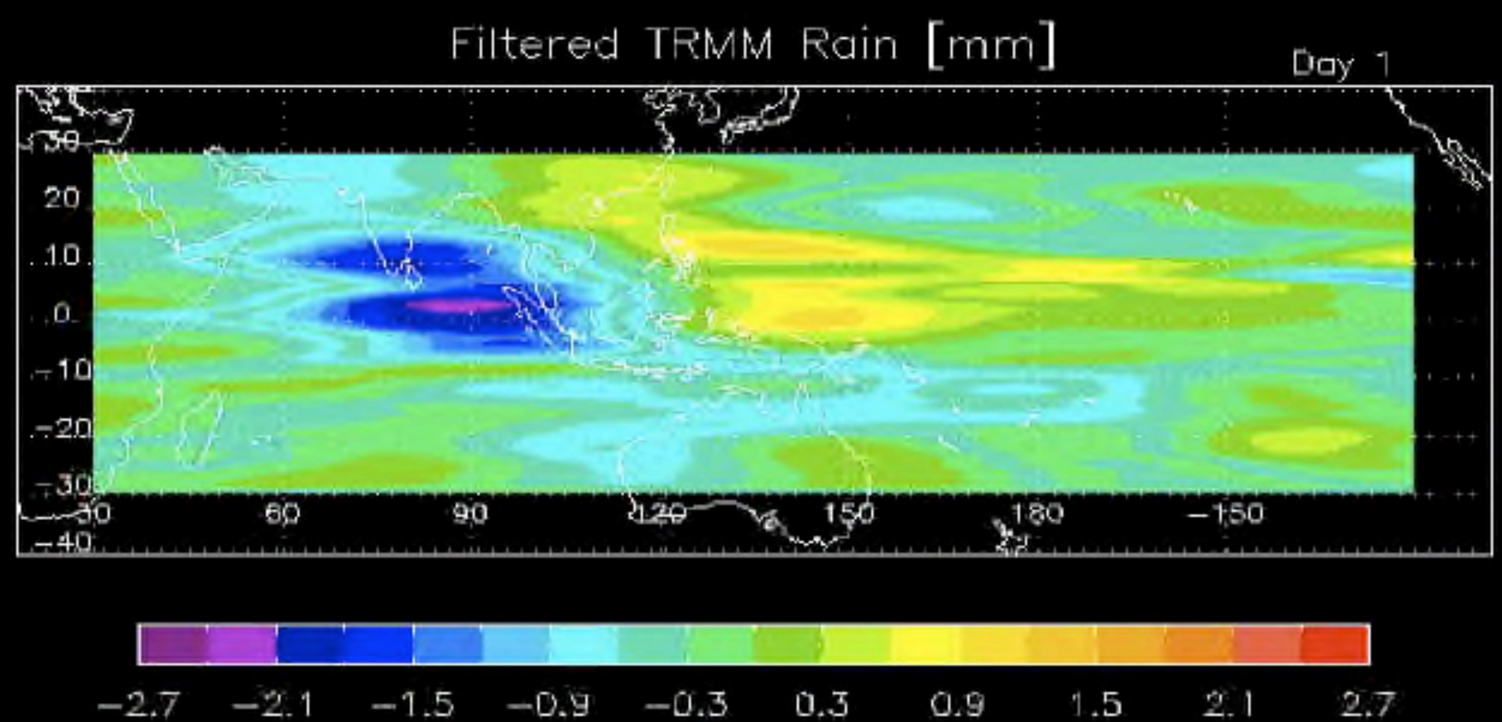
Research Themes

- Future tools, aka Q3D and GCRM
- MJO
- Deep and shallow convection, and turbulence, aka "Deep and shallow"
- Low-cloud feedbacks

Each theme benefits from model development, and needs large computing resources.

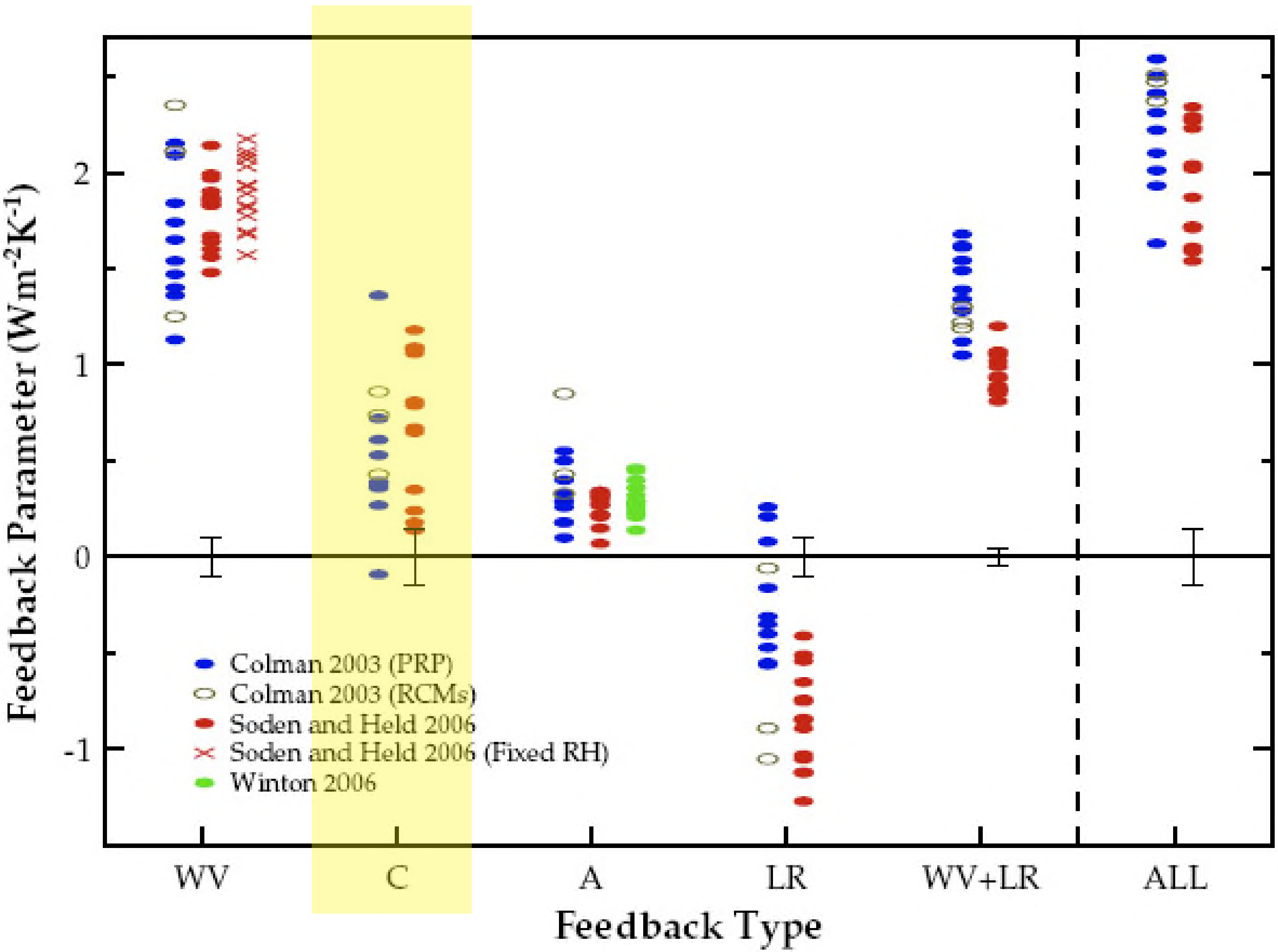
Each theme involves individual efforts, and also coordinated multi-investigator analyses of large calculations.

The Madden-Julian Oscillation (MJO)



This problem is going to be solved in the next few years.

Low-Cloud Feedbacks



Deep and Shallow

- Improved turbulence parameterizations are essential for the improvement of cloud-resolving models.
- Inexplicably, there is very little work on the interactions of deep convection with the PBL.

Relationships between themes and objectives

Objective	Relevant Research Theme(s)
1. Extensions, evaluations and applications of the prototype MMF	All
2. Development of a second-generation MMF	Future Tools
3. Develop and test improved microphysics parameterizations for MMFs and GCRMs	All
4. Develop improved parameterizations of boundary-layer clouds and turbulence for use in MMFs and GCRMs	All
5. Test sensitivity of CSRMs to more detailed radiation calculations	All
6. Innovative analysis, evaluation and interpretation of MMF results using emerging datasets	All
7. Accelerating improvement of conventional parameterizations	MJO Low-cloud feedback Conv and Turb
8. Optimal use of computational and data storage resources	All

Continuing roles for conventional cloud parameterizations

- **Conventional parameterizations will always be needed as encapsulations of our (gradually improving) understanding of how clouds interact with the large-scale circulation.**
- **Conventional parameterizations can be improved by studying the results obtained with the MMF**

Value added

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

- **Scientific expertise**
- **A big idea**
- **Funding**
- **Extended duration**
- **Focus, focus, focus**
- **Centralized direction**

Conclusions

- Our modeling tools are at various stages of maturity.
- New parameterizations must be tested in the VVCM, SuperCAM, and SuperBUGS -- not only in SAM.
- The SuperCAM still has a lot of potential to teach us new things.