Center for Multiscale Modeling of Atmospheric Processes

MMAP

Acknowledgments

Support for this Workshop has been provided by CSU's Department of Atmospheric Science.

Thanks to Cindy Carrick for making all of the arrangements.

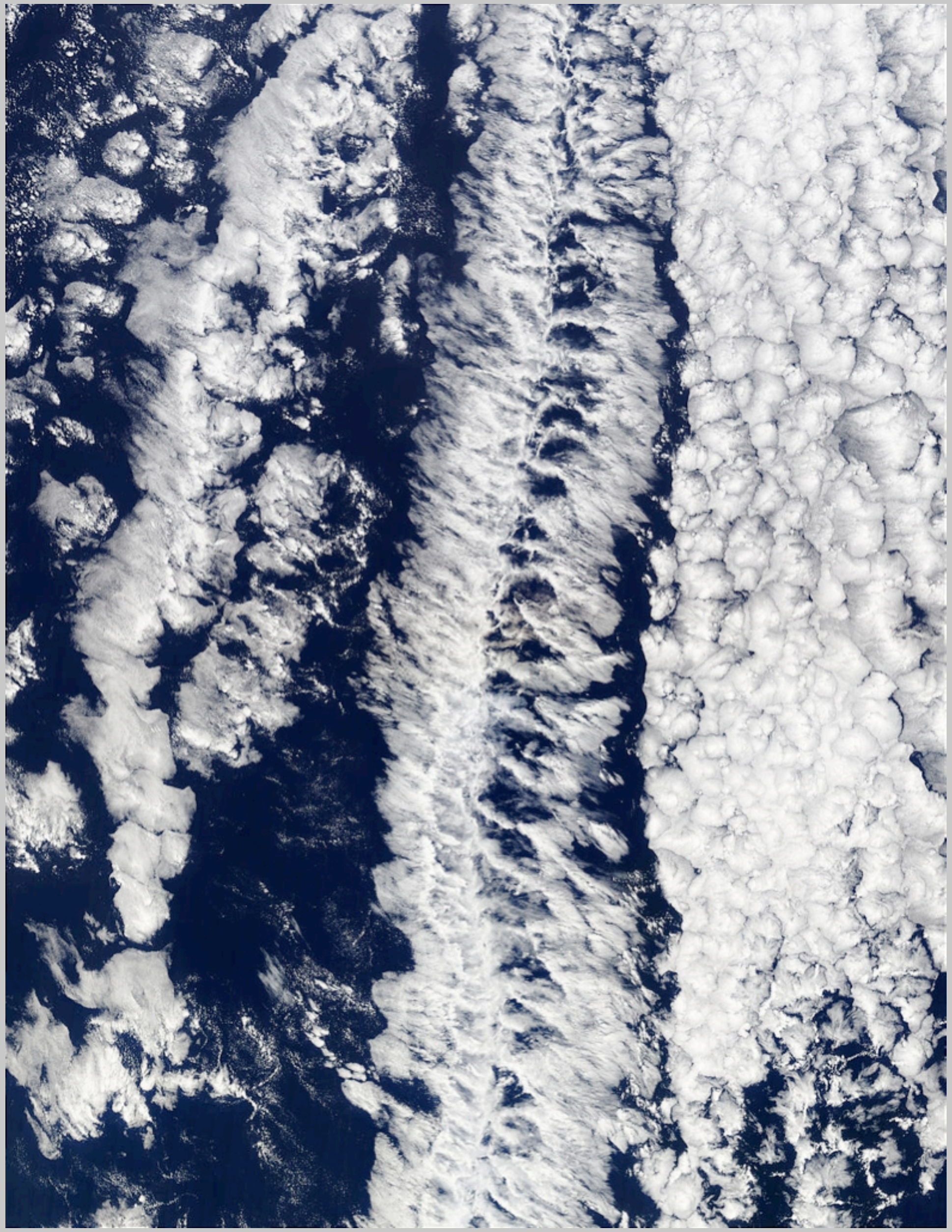
Who is here?

Logistics

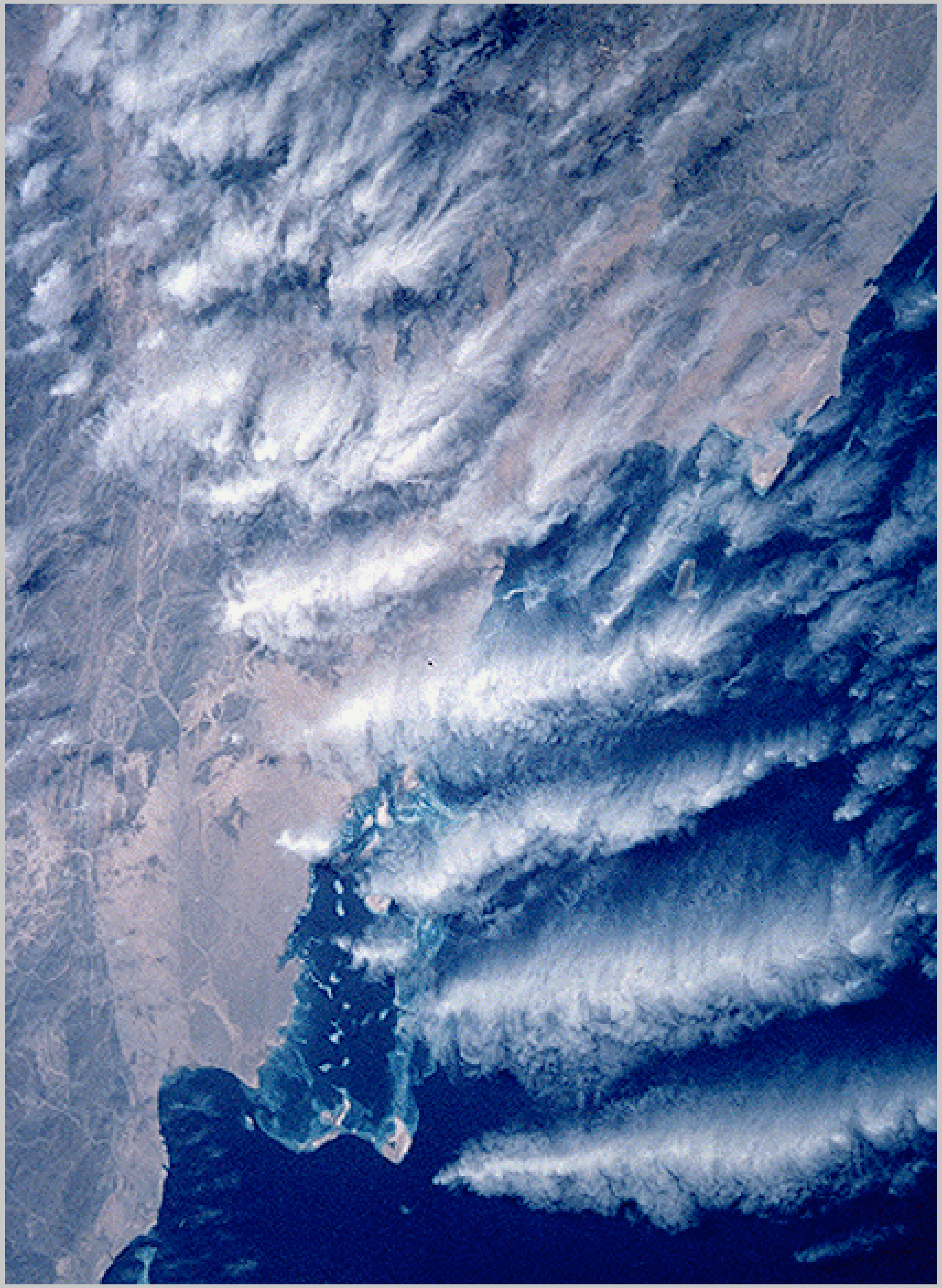
- Projectors
- Breaks
- Lunch
- Restaurant list
- Restrooms
- Other needs?

My goals for this talk

- Outline practical information about STCs
- Titillate
- Set up the following talks and discussion
- Presentation strategy:
  - Programmatics first
  - Science second



Science and Technology Centers



- **Funded from the top of NSF**
- **Academic lead institution, through which all funding flows**
- **Innovative research and education projects of national importance that require a Center mode of support to achieve their research, education, and knowledge-transfer goals**
- ***Partnerships* among academic institutions, national laboratories, industrial organizations, and/or other public/private entities**

STC Program History

Late 1980s and early 1990s: 25 STCs

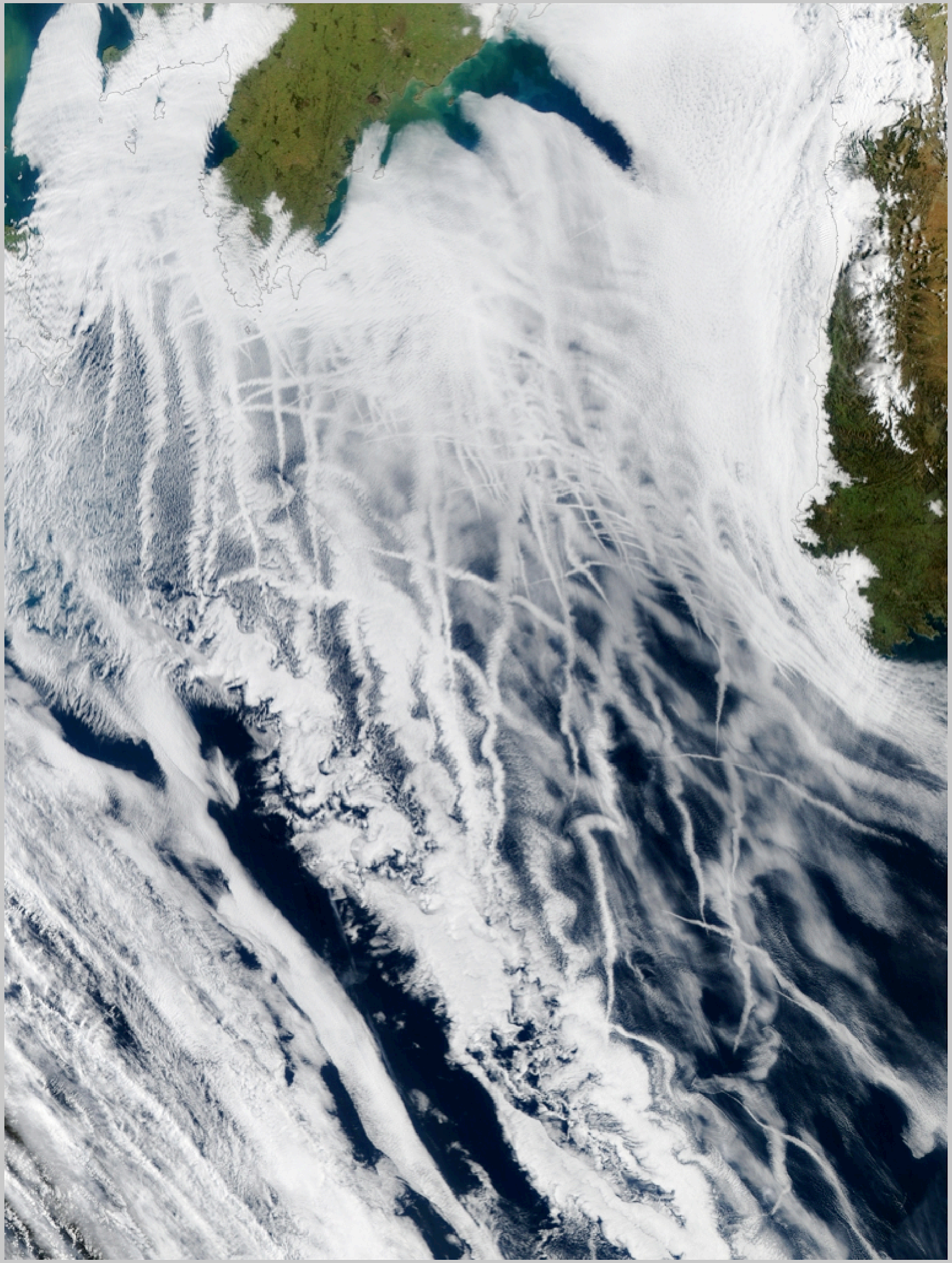
C^4 and CAPS

1999: Five new STCs created

2002: Six new STCs created

Current total: 11 STCs.

The eleven current STCs



Center for Behavioral Neuroscience

Center for Embedded Networked Sensing

Center for Advanced Materials for Water Purification

The Nanobiotechnology Center

National Center for Earth-Surface Dynamics

Center for Integrated Space Weather Modeling

Sustainability of Water Resources in Semi-Arid Regions

Center for Adaptive Optics

Center for Biophotonics Science and Technology

Center for Environmentally Responsible Solvents and Processes

Center on Materials and Devices for Information Technology Research

The process

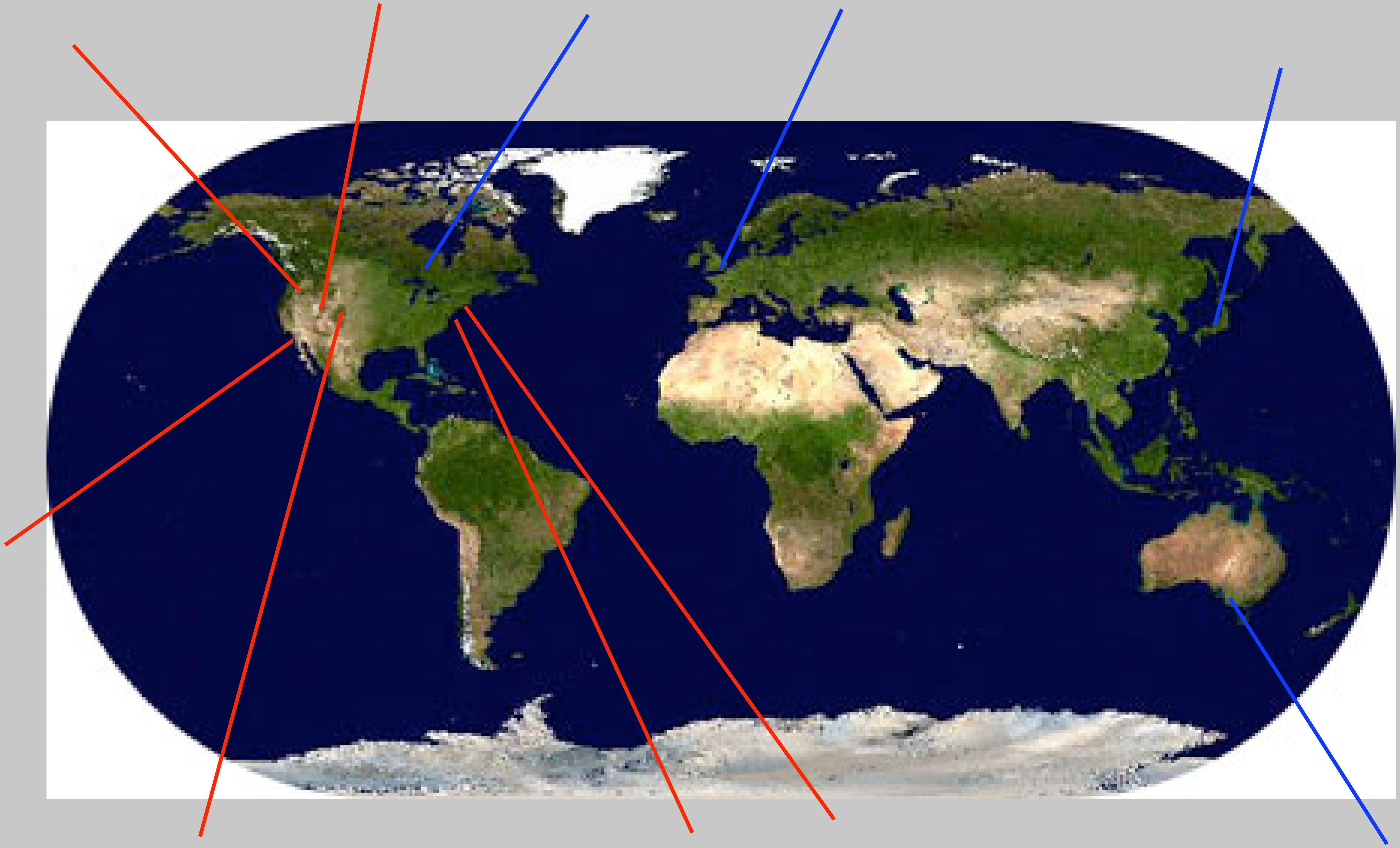
- We started planning for our STC proposal in early ‘02.
- The triggering event was the realization that what we are working on will require an STC.
- I visited NSF in February ‘02.
- At about the same time, Steve Rutledge and I began working to organize CSU support.
- We had a first planning Workshop in Fort Collins during a snowstorm in late October ‘02.
- NSF issued the “Announcement of Opportunity” in March ‘03.

In May '03, we held a second Workshop.

The process, contd.

- Kau’ai workshop, May ‘03.
- Pre-Proposal submitted, June ‘03.
- Randall and Helly presentation at NSF, August ‘03.

Investigators



Management team

- David Randall, Director
- Chin-Hoh Moeng, Deputy Director
- Scott Denning, Associate Director for Education and Outreach
- Wayne Schubert, Associate Director for Knowledge Transfer
- John Helly, Associate Director for Computing

Research

- The subject of today's meeting
- To be outlined later in this presentation

Education and Outreach

- K-12
  - Poudre and Thompson public schools
  - Little Shop of Physics
  - Catamount Institute
  - Susan Foster, UCAR
- Undergraduate
  - SOARS
  - Colorado College
  - CSU Math and Physics
  - Catamount Institute
- Graduate
  - CSU Atmospheric Science
  - UCLA Atmospheric Sciences
  - University of Washington Atmospheric Science
  - SOARS
- Postdoctoral
- Assessment

Knowledge Transfer

- **Research partners**
  - **Climate change: *CCSM, CCSR, GISS, BMRC***
  - **NWP: *NCEP, ECMWF, GSFC, CAPT ,JMA, BMRC,***
- **New all-electronic open-access journal on global environmental modeling**
- **Book on the history of climate modeling**

All of this had to fit in 10 pages.

Budget

- The Pre-Proposal had to include a fairly detailed budget.
- The total is very close to the upper limit of $4 M per year.
- Breakdown by category
  - Research and Knowledge Transfer~70%
  - Education/Outreach~30%
- 30% cost-sharing

We made the playoffs.

- NSF received 164 pre-proposals.
  - Four bounced.
  - One was withdrawn.
  - Thirty-seven were selected for further consideration.
- We were selected.
- Ultimately 6 or 7 will be funded.

What happens next?

- **Education/Outreach Workshop, Fort Collins, Dec 2.**
- **Research Workshop in Silver Spring on Dec 15.**
- **Another Research Workshop in Fort Collins on Dec 18.**
- **DR to Tokyo, mid January.**
- **Full proposal due on *February 10*. It can be 2.5 times as long as the Pre-Proposal.**

Participants in this week's workshops

DC

Jim Abeles
Jeff Amthor
Robert Atlas
Anning Cheng
Jiun-Dar Chern
Zachary Eitzen
Jay Fein
Wanda Ferrell
Arthur Hou
Marat Khairoutdinov
Frank Li
Steve Lord
Hua-Lu Pan
David Randall
Tsengdar Lee
Pam Stephnens
Wei-Kuo Tao
Bruce Wielicki
Kuan-Man Xu
Minghua Zhang
Milija Zupanski

Fort Collins

Tom Ackerman
Maike Ahlgrimm
Howard Barker
Jim Benedict
Mark Branson
Chris Bretherton
Cindy Carrick
Giri Chukkapalli
Bill Collins
Don Dazlich
Charlotte DeMott
Paul DeMott
Scott Denning
Henk Dijkstra
Phil Duffy
Laura Fowler
Wojciech Grabowski
Jim Hack
Ross Heikes
John Helly
Andy Heymsfield
Brian Jones
Marat Khairoutdinov
Celal Konor
Sonia Kreidenweis
Steven Krueger
Cara-Lyn Lappen
Don Middleton
Chin-Hoh Moeng
Mitch Moncrieff
Norm Wood
Jim Thomas
Joon-Hee Jung
Kelley Wittmeyer
Bill Pennell
Robert Pincus
David Randall
Todd Ringler
Steven Rutledge
Wayne Schubert
Richard Somerville
Mike Toy
Takanobu Yamaguchi
Dusanka Zupanski
Milija Zupanski

Agency partnerships (non-NSF)

- DOE
  - ARM
  - CCPP
  - PNNL
  - Livermore
- NASA
  - GSFC
  - LaRC
- NOAA
  - NECP
  - CIRES

Changes in the full proposal

- Whatever is necessary and no more
  - Add specifics
  - React to reviews
- True global CSRM
- Adjustments to Education and Outreach plans
  - Change of Associate Director
  - Addition of assessment
  - Some cuts to compensate

And then...

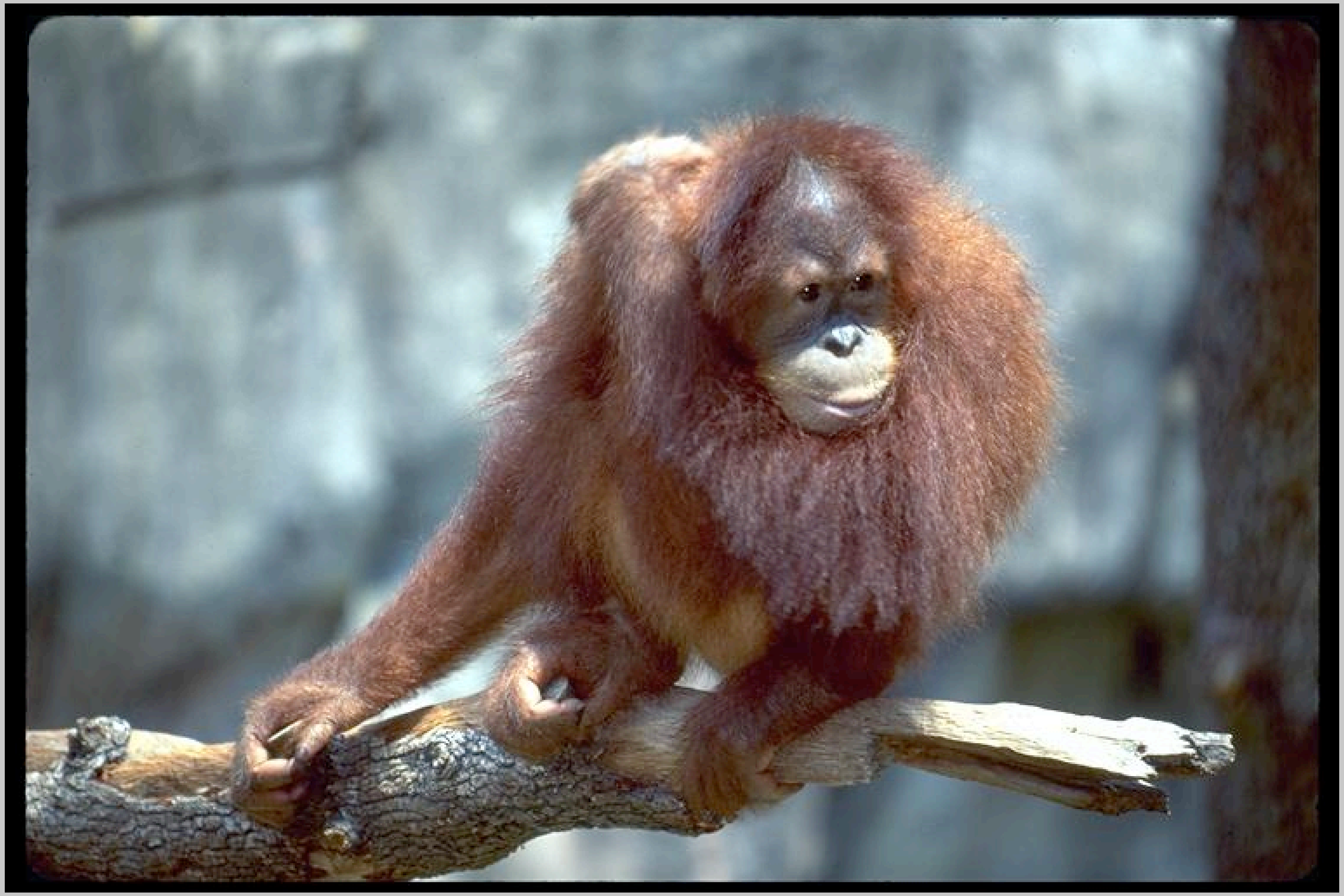
- There will be another cut in May.
- If we pass the next cut, we will be site-visited in the fall.
- Six or seven new STCs will be awarded in January 2005.
- Funding will begin in summer 2005.

Goals of this workshop

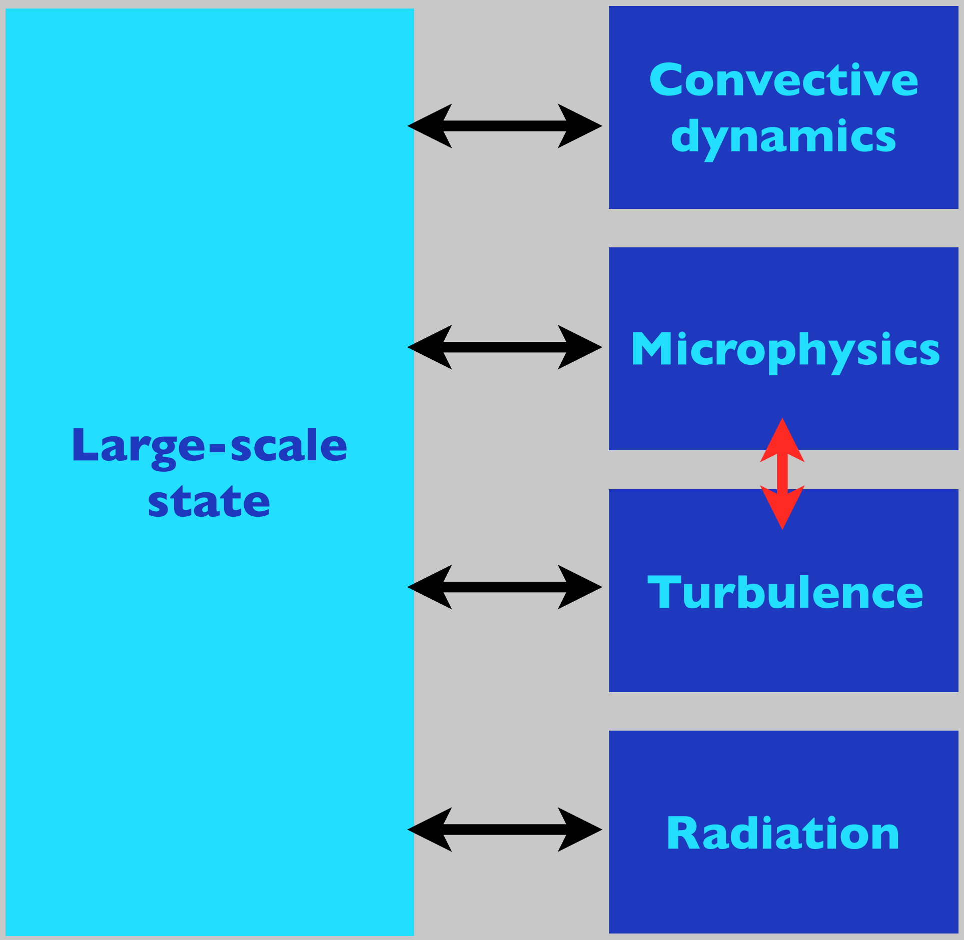
- **Maximize our changes of success**
  - ***Identify ways to strengthen the research component of the full proposal***
  - ***Generate input for the full proposal***
- **Communicate among ourselves so that everyone knows what is being proposed and how their work fits in the bigger picture**

The parameterization zoo

- Cumulus clouds
- Stratiform clouds
- Boundary-layer turbulence and clouds
- Mesoscale organization
- Turbulence in the free atmosphere
- Radiation
- Gravity waves



A weakness of current parameterizations



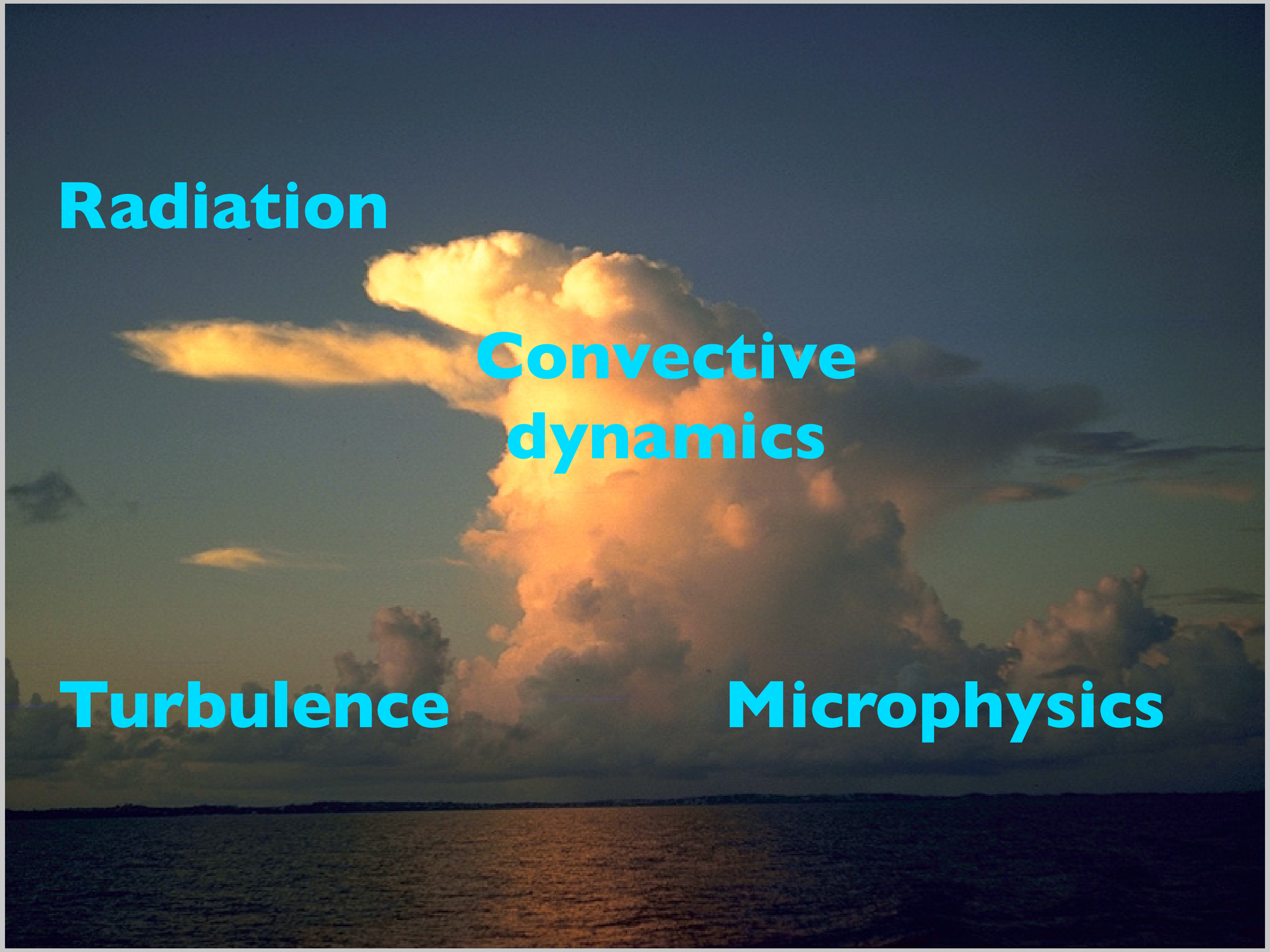
With just a few exceptions, current GCMs permit parameterized processes to interact only indirectly, through the large-scale state.

We need a framework for the representation of direct, cloud-scale process interactions in GCMs.

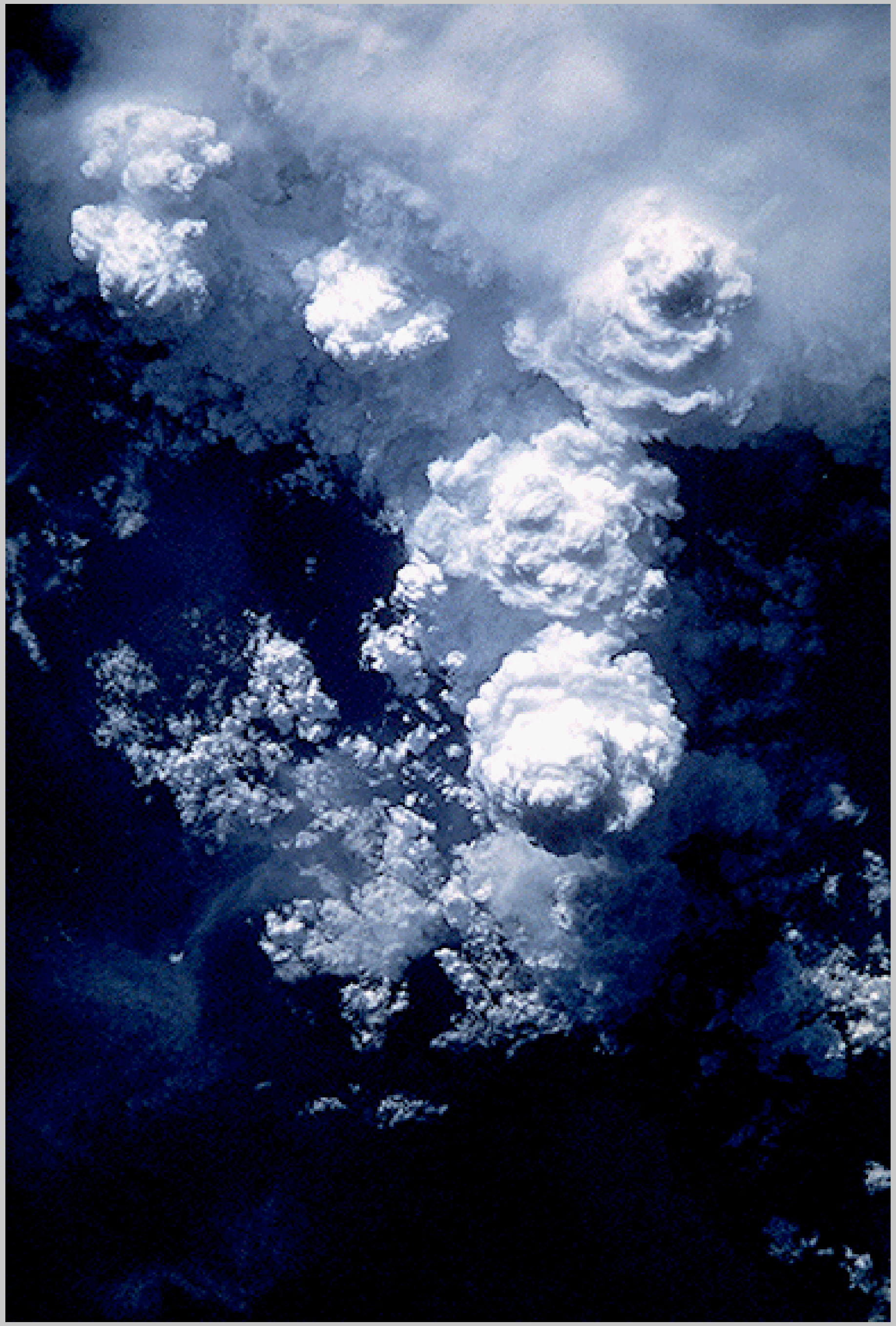
CSRMs represent direct, cloud-scale process interactions through a non-statistical approach.

Challenges for statistical theories

- **Processes talk to each other on small space and time scales. Because of this, parameterizations *must be unified*.**
- **Parameterizations *must scale* with resolution and *must converge* to cloud models at high resolution.**



Cloud-system resolving models

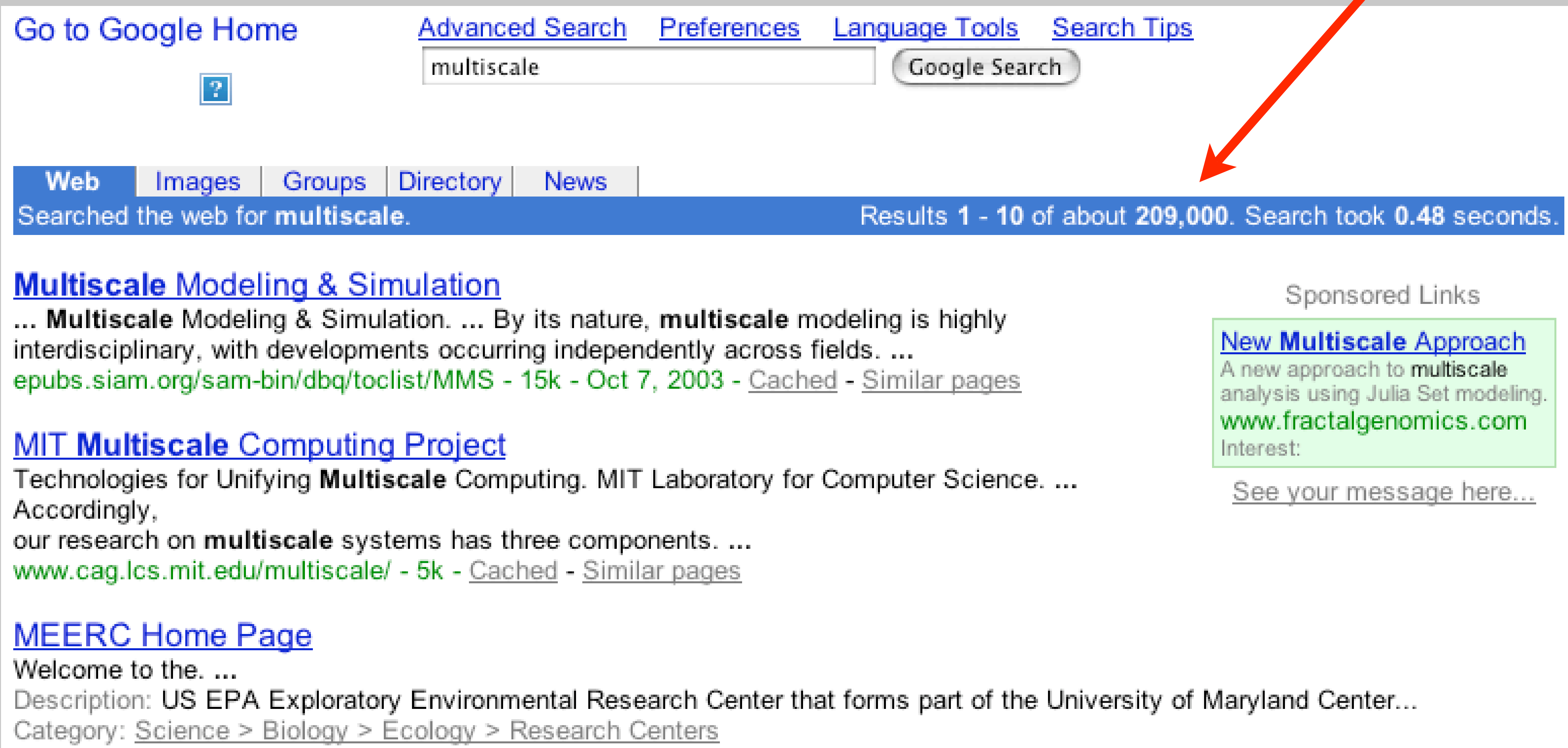


- Cloud-scale dynamics are directly simulated.
- Microphysics, radiation, and turbulence are parameterized.
- Applications:
  - Simulation of case studies and comparison with single-column models (GCSS)
  - Experiments aimed at exploring basic physics
  - Super-Parameterizations

Terminology

- The cloud model is called a CSRM.
- Inside the GCM, the CSRM acts as a Super-Parameterization.
- The combination of the GCM and the CSRM is called a Multi-Scale Modeling Framework (MMF).

Apropos but pedestrian



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multiscale — Google Search

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Searched the web for **multiscale**. Results **1** - **10** of about **209,000**. Search took **0.48** seconds.

[**Multiscale** Modeling & Simulation]

... **Multiscale** Modeling & Simulation. ... By its nature, **multiscale** modeling is highly interdisciplinary, with developments occurring independently across fields. ...
epubs.siam.org/sam-bin/dbq/toclist/MMS - 15k - Oct 7, 2003 - Cached - Similar pages

[MIT **Multiscale** Computing Project]

Technologies for Unifying **Multiscale** Computing. MIT Laboratory for Computer Science. ... Accordingly,
our research on **multiscale** systems has three components. ...
www.cag.lcs.mit.edu/multiscale/ - 5k - Cached - Similar pages

[MEERC Home Page]

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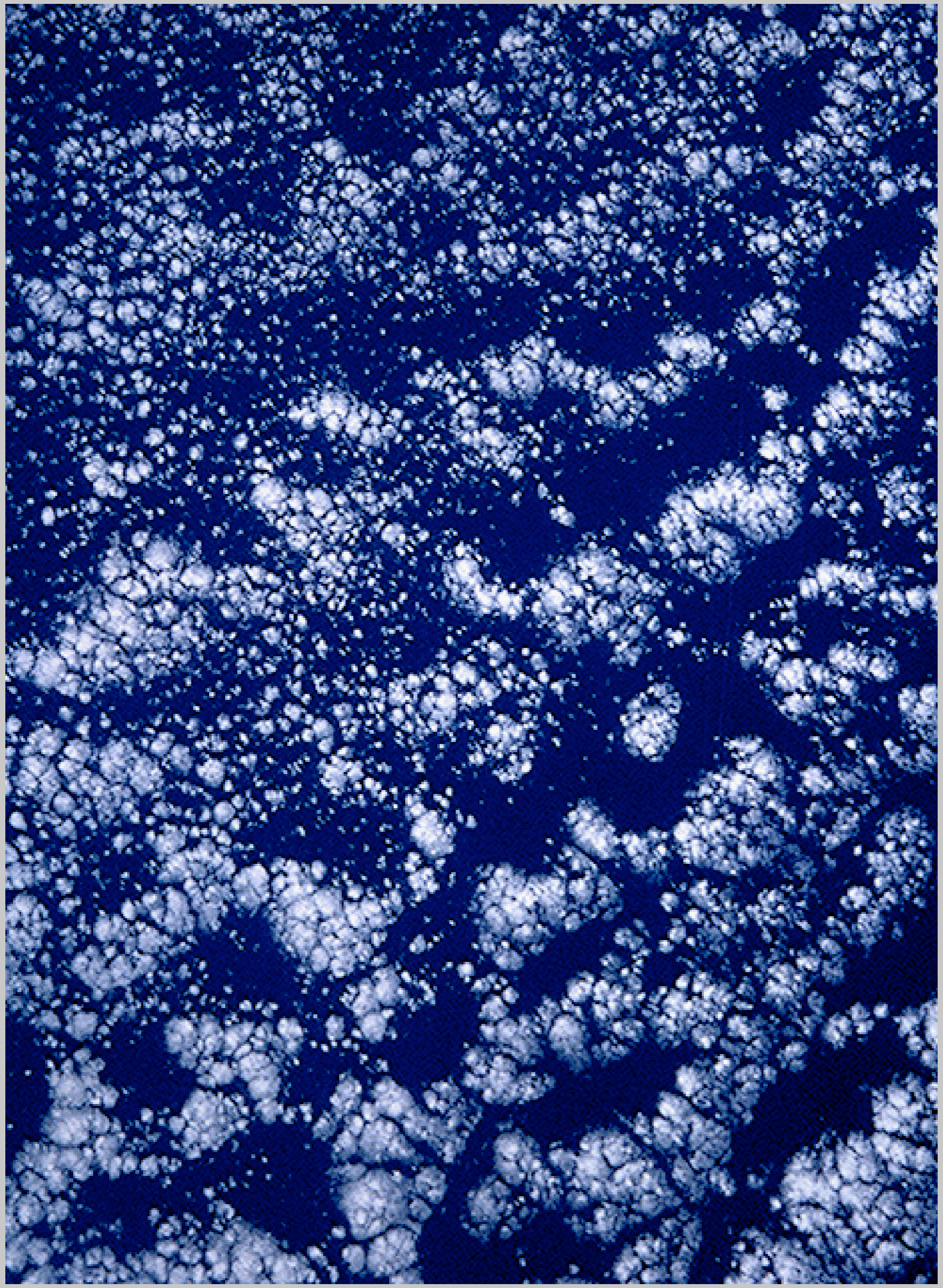
Category: Science > Biology > Ecology > Research Centers

Sponsored Links

[New **Multiscale** Approach]
A new approach to multiscale analysis using Julia Set modeling.
www.fractalgenomics.com
Interest:

See your message here...

In a nutshell



- Conventional parameterizations can do everything eventually (we hope), but for now we are frustrated by their limitations.
- Many of these limitations can be avoided through the use of an MMF.
- Increasing computer power is rapidly making MMFs a practical option.
- MMFs were not possible until essentially now.

What do we get?

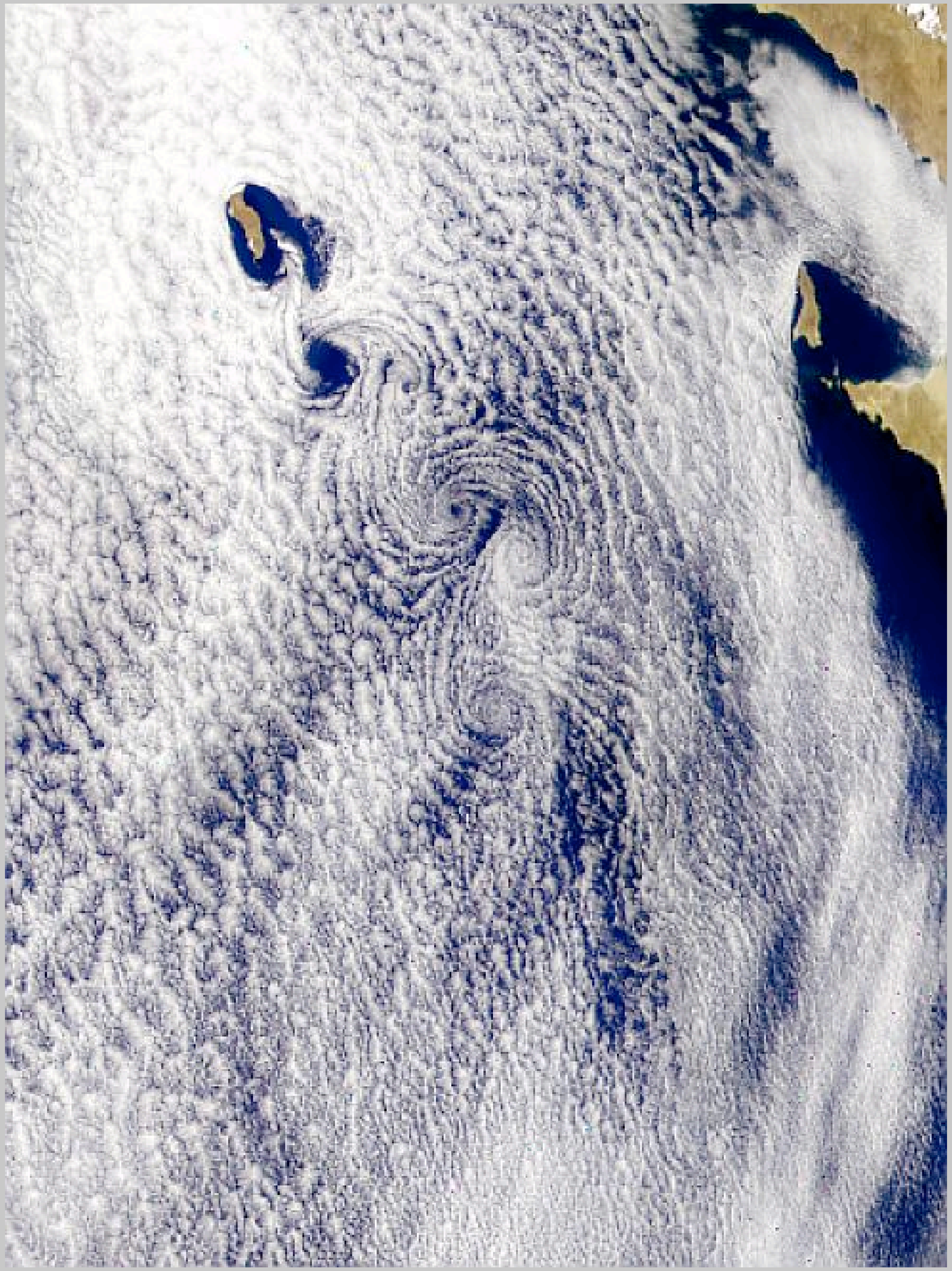
- Explicit deep convection, including mesoscale organization (e.g., squall lines), downdrafts, anvils, etc.
- Explicit fractional cloudiness
- Explicit cloud overlap in the radiative sense
- Explicit cloud overlap in the microphysical sense
- Convective enhancement of the surface fluxes
- Possible explicit multi-dimensional cloud-radiation effects
- Convectively generated gravity waves

What do we get? 2

- The ability to compare global model results on the statistics of mesoscale and microscale cloud organization with observations from new platforms such as CloudSat
- The ability to assimilate cloud statistics based on high-resolution observations
- The ability to compare results obtained with the MMF to results obtained with conventional parameterizations

A summary of some results to date

- Intra-seasonal, synoptic, and diurnal variability are more realistic with the MMF.
- Cloud-scale interactions between radiation and other processes are quite important for both low and high clouds.
- The MMF produces excessively strong precipitation systems over the tropical Western Pacific in the northern summer -- the GRS.
- The MMF is sensitive to the parameterized ice microphysics.

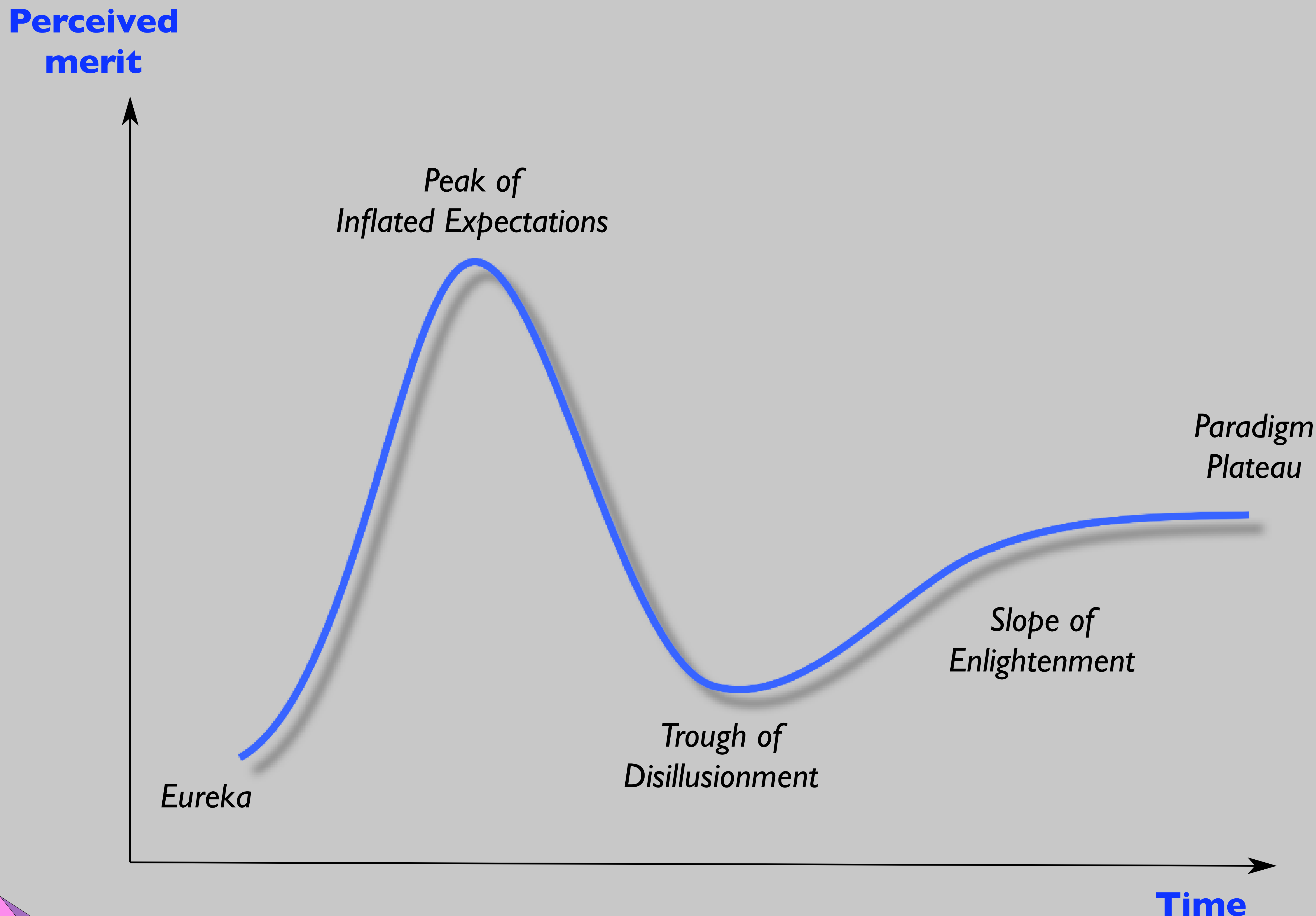


Why build an MMF?

Because we can learn a lot by doing so.

- How does nature work?
- How do closure assumptions break down?
- How can we unify our parameterizations?
- How can we make scalable parameterizations?

Trajectory of an idea

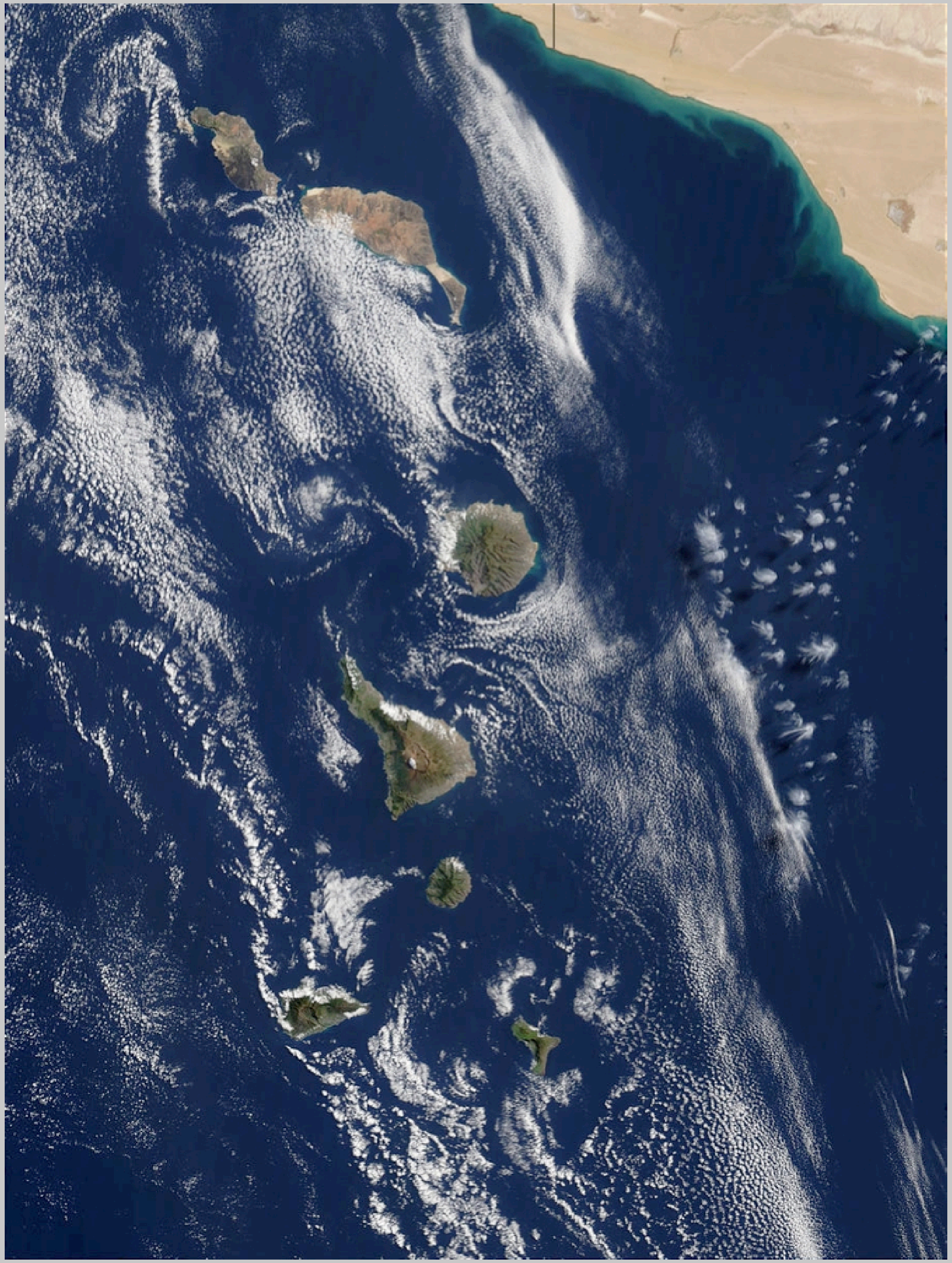


Issues

- Super-parameterizations
  - Coupling methods -- relevant to GRS problem?
  - PBL clouds
  - Momentum transports
- Conventional parameterizations
  - Unification
  - Scaling and convergence
- NWP and data assimilation
  - Model evaluation
  - Analyses and forecasts pe se
- Model evaluation
- Cloud and water vapor feedbacks
- Computation
  - Cycles
  - Data management
  - Visualization

Outline of the research

- Extension, evaluation and application of the prototype MMF
- Development of an improved MMF
  - Improved coupling methods
  - Improved parameterizations
- Ongoing evaluation and interpretation of MMF results
  - Emerging datasets
  - Theory
- Tests of a true, global, 3D CSRM
- Computational issues
  - Performance
  - Data management
  - Visualization
- Continuing development of "classical" cloud parameterizations
- Scientific applications of the MMF



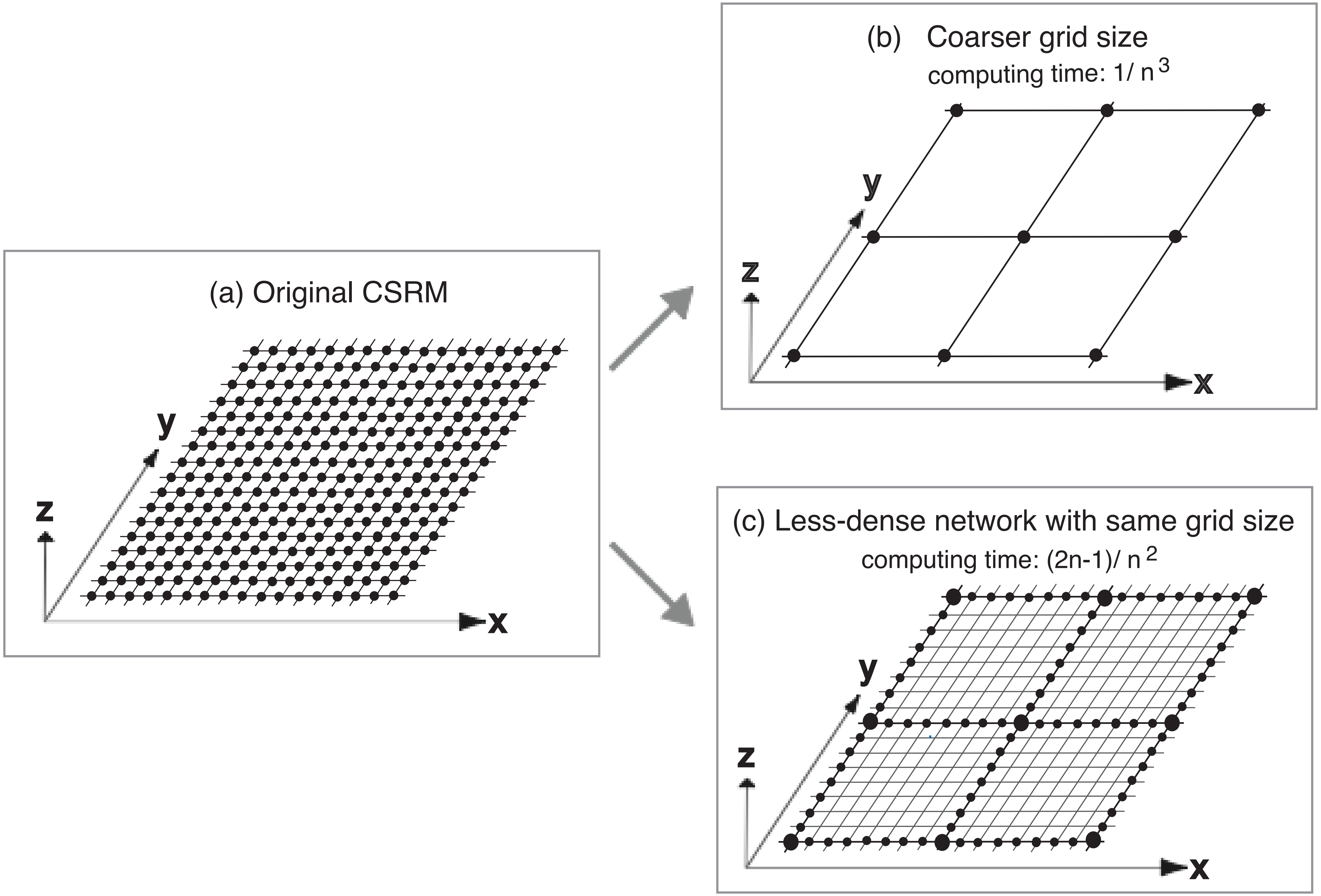
Applications

- Using the model to understand something about nature
  - Physics of the MJO
  - Effects of cloud-scale radiation
  - Diurnal cycle
  - Transports of CO_2 and other tracers
  - Aerosol physics with cloud-scale dynamics in the context of the global circulation
  - Effects of mesoscale organization on the global circulation
  - Cloud and water vapor feedbacks
- Climate change simulations
- Numerical weather prediction and data assimilation
  - Comparison with new data (e.g., CloudSat)
  - Improved simulations of weather systems

Conceptual weaknesses of the first-generation MMF

- **Due to the use of cyclic lateral boundary conditions, CSRMs in neighboring GCM grid boxes can communicate only through the GCM;**
- **Due to the use of cyclic lateral boundary conditions, each CSRM converges to a 1D cloud model with no vertical velocity as the GCM grid size approaches the CSRM grid size;**
- **The two dimensionality of the CSRM is obviously artificial.**

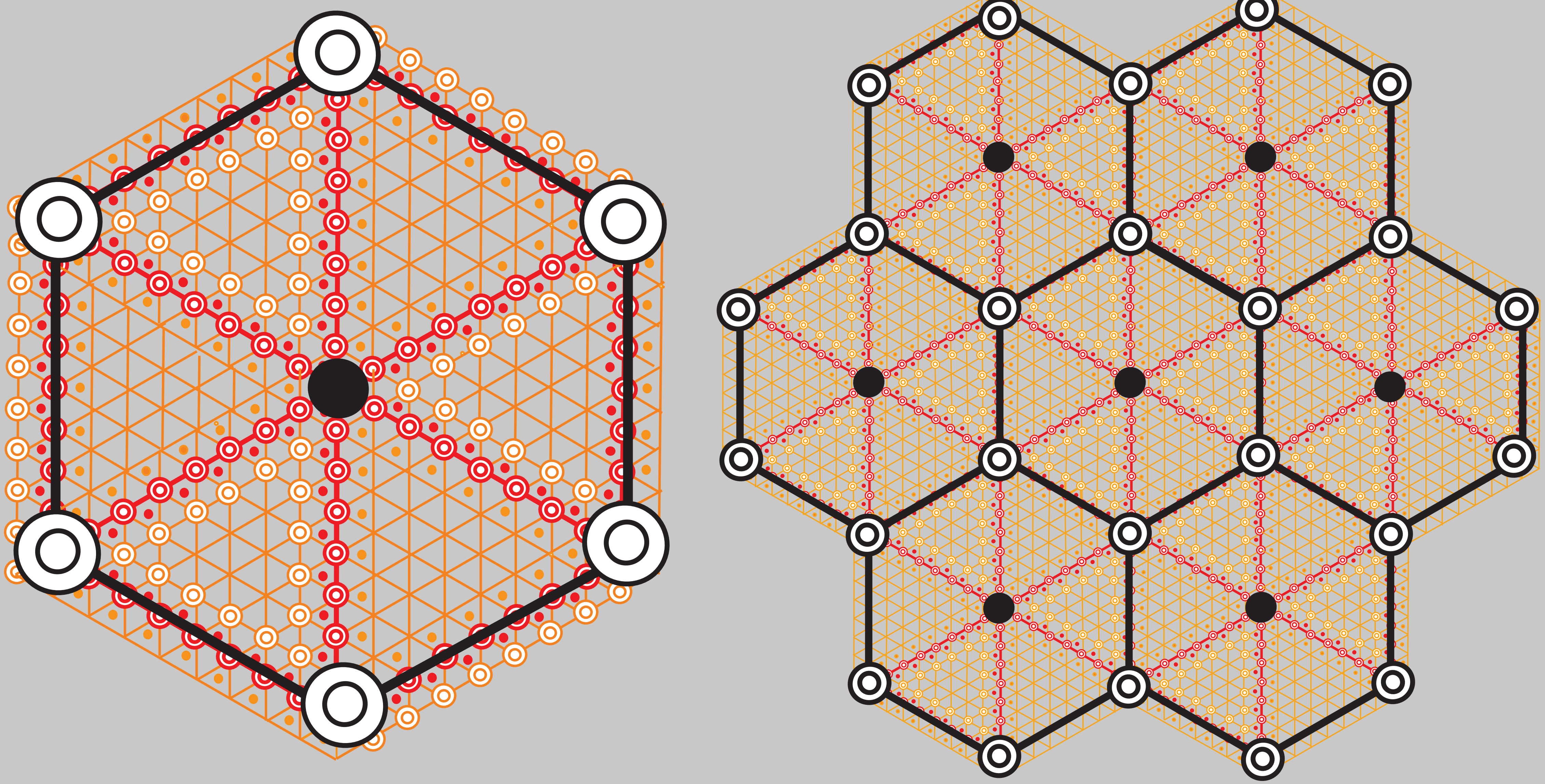
Arakawa's Quasi-3D approach



Why is quasi-3D better?

- 2D is replaced by quasi-3D, and the orientation problem goes away.
- Convective systems can propagate from one GCM grid column to the next.
- Geographically realistic topographic forcing can be used.
- The formulation of the quasi-3D model is "resolution-independent."
- A quasi-3D global model *converges* to a global CSRM.

A future geodesic MMF



This will be a pretty exotic beast.


Garden-variety
parameterizations

Continuing roles for "classical" cloud parameterizations

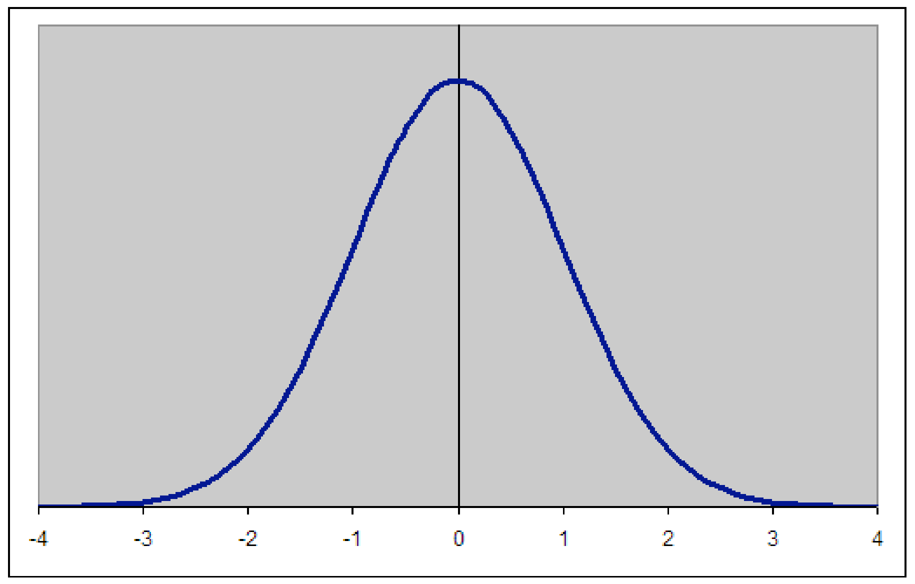
- **Classical parameterizations are still needed as encapsulations of our (gradually improving) understanding of how clouds interact with the large-scale circulation.**

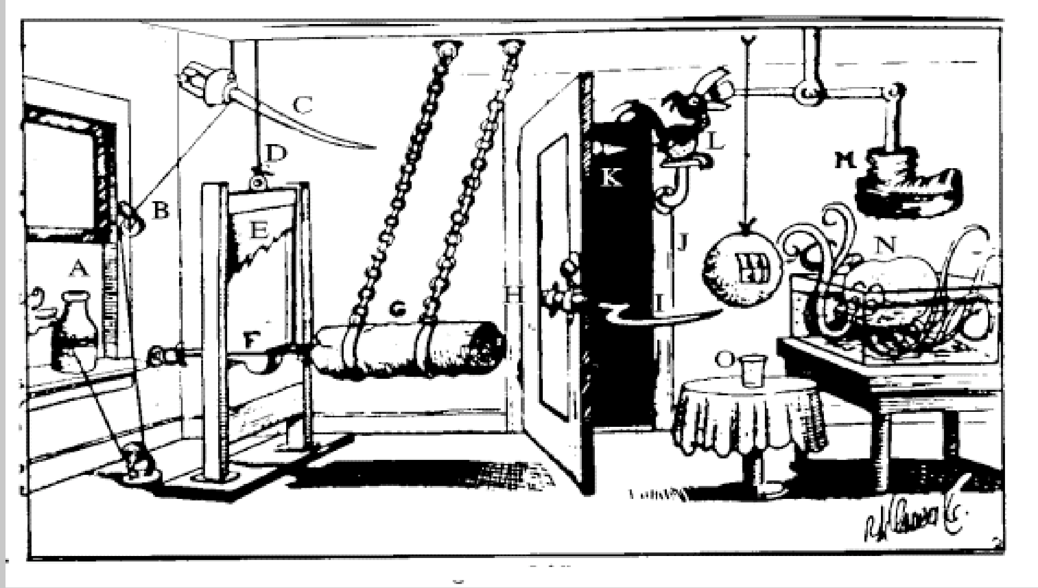
- **Classical parameterizations can be improved by studying the results obtained with super-parameterizations. The improved classical parameterizations "capture" what we learn from the super-parameterization.**

- **Classical parameterizations will still be used wherever very large computing resources are not available, and especially for very long simulations, e.g. of Milankovich cycles.**

The future of conventional parameterizations

- **Less modular -- Unified**
- **More prognostic**
- **More complicated**
- **Partly statistical and partly mechanistic**





Two freeways to the future

MMF

“Classical” Parameterizations

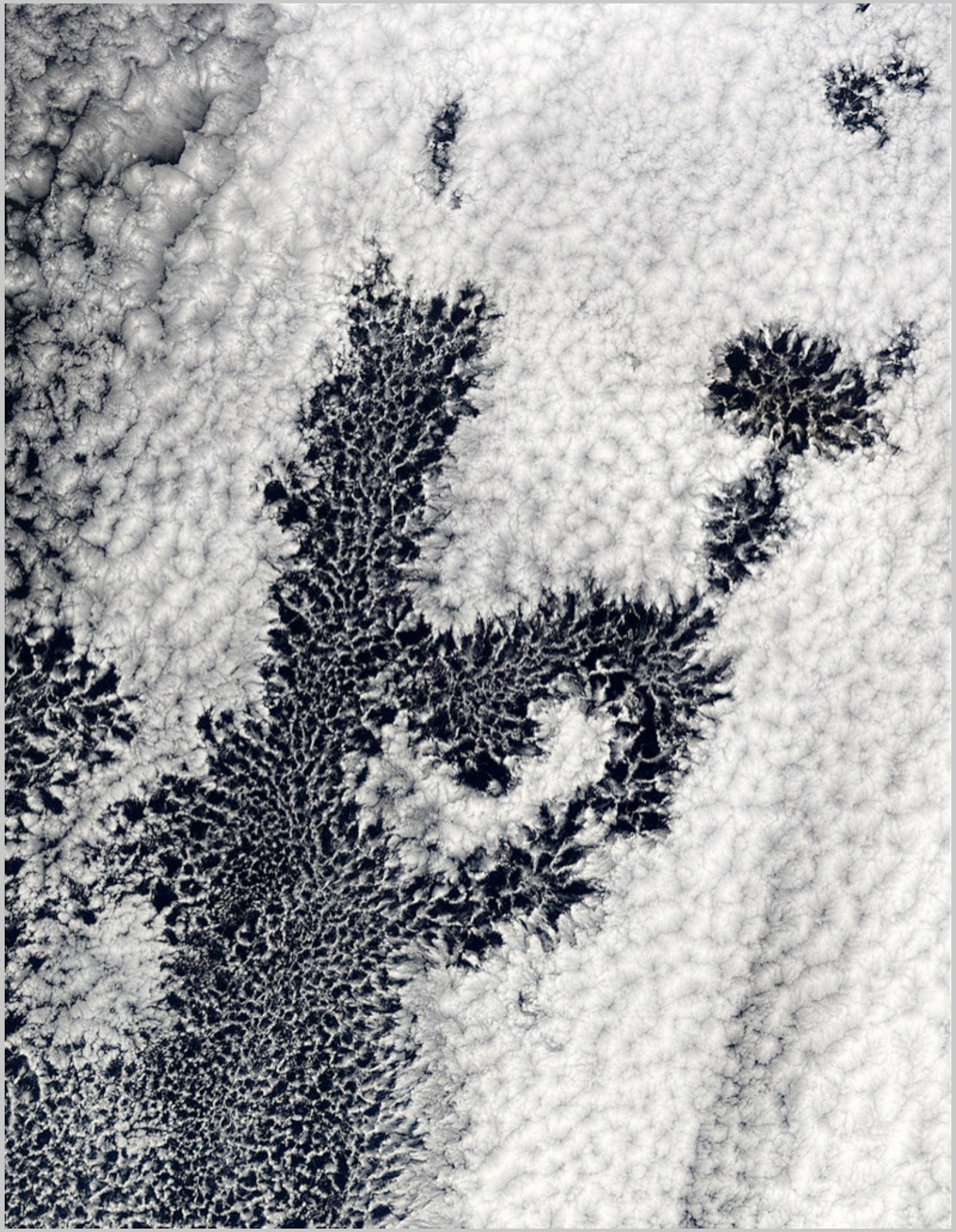
The MMF can help us to make progress with the classical approach.

Near-Future Plans

- **Change the dynamical core from semi-Lagrangian to finite volume -- *Already done.***
- **Port CCSM's Land-Surface Model into SP -- *Work under way.***
- **3D "big-brother" experiments -- *Work under way.***
- **Test with higher-resolution CSRM -- *At PNNL.***
- **Extend CSRM domains around full latitude circles**
- **AMIP2 simulation**
- **Cloud-feedback runs with specified SSTs**
- **A short (~ 1-year) coupled simulation**
- **Test Arakawa's idea for a "Quasi-3D model"**

One, two, three, many

- **NCAR MMM**
- **CSU**
- **UCLA**
- **MSC and Penn State**
- **PNNL**
- **LLNL**
- **U. Utah**
- **GSFC**
- **LaRC**



The STC as a research partnership

- We have a common set of goals.
- We have a "primary" research path.
- There can be other paths running in parallel.
- Everything must evolve, including the primary path.

FC Agenda, STC Planning Workshop

8:30	David Randall	Welcome and Introductions
8:40	David Randall	STC Overview
9:40	Marat Khairoutdinov	Recent super-parameterization research at CSU
10:00	Break	
10:20	Wojciech Grabowski	Super-parameterization and mesoscale dynamics
10:40	Mitch Moncrieff	Organized convection in the context of MMAP
11:00	Bill Collins	Multi-scale modeling and the CAM
11:20	John Helly	Computing overview
11:40	All	Break-out groups
12:00	Lunch, including lunch-time discussions	
1:15	Charlotte DeMott	Analysis of super-parameterization results
1:35	Joon-Hee Jung	Experiments with MMF coupling
1:55	Steve Krueger	On MMF coupling methods
2:15	Howard Barker	Cloud-scale radiation and the global circulation
2:35	Robert Pincus	Using MMF to help improve garden-variety cloud parameterizations
2:55	Break	
3:15	All	Discussion, wrap-up, and action items
5:00	Adjourn	

Break-out groups

Topic	*Lead*	*Rapporteur*
Evaluation and further development of the MMF	**Randall**	
Developing improved parameterizations for use in the MMF	**Krueger**	
The evaluation and interpretation of MMF results, including theoretical aspects	**Grabowski**	
Computational issues	**Helly**	
Classical parameterizations and applications via partners	**Schubert**	

This is not meant to be a rigid plan. Do what makes sense.

Breakout discussion, Group I

"Evaluation and further development of the MMF"

Randall, Carrick, C. DeMott, Jung, Moeng, D. Zupanski

- **Coupling methods**
- **Great Red Spot --**
  - **MK's interpretation--the squall line that keeps coming back**
  - **WG's interpretation-- the importance of momentum transport**
- **Evaluation**
  - **Coupled modeling**
  - **Data assimilation for model evaluation**
- **Scalability versus parameterization**
- **Aerosols**