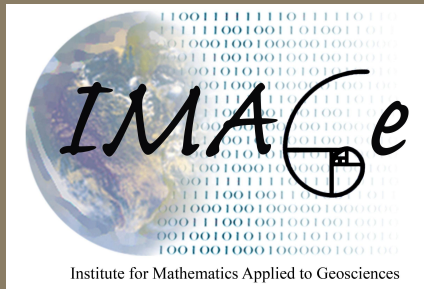# Institute for Mathematics Applied to Geosciences and the Theme of the Year

Douglas Nychka, Director and Senior Scientist

- What is IMAGe?

- Some things we do.

- Theme-of-the-Year:
  Past, Present, Future



Institute for Mathematics Applied to Geosciences



*WEB infomercial, May 2007*

## Institute for Mathematics Applied to Geosciences

- Turbulence Numerics Team / Geophysical Turbulence Program
- Geophysical Statistics Project
- Data Assimilation Research Section
- Computational Mathematics Group

*Vision:*

IMAGe brings mathematical models and tools to bear on fundamental problems in the geosciences

and will be a center of activity for the mathematical and geophysical communities.

# The Olive Tree and the Lexus

Note: We are a *team*, *program*, *project*, *section* and a *group*!

This reflects the independence among our science goals and different styles of research. But there are two main themes that organize IMAGe around its Vision.

*Icons for IMAGe culture*

# The Olive Tree



Traditional scientific investigation at its best

- Curiousity and creativity

- Unexpected and independent

- Productive and collaborative

# The Lexus



Tools and models for communities

- Deliberate and strategic
- Engaging and accessible
- Structured and predictable
- Productive and collaborative

# Turbulence Numerics Team (TNT) and Geophysical Turbulence Program (GTP)

 **Turbulence and multiscale processes**
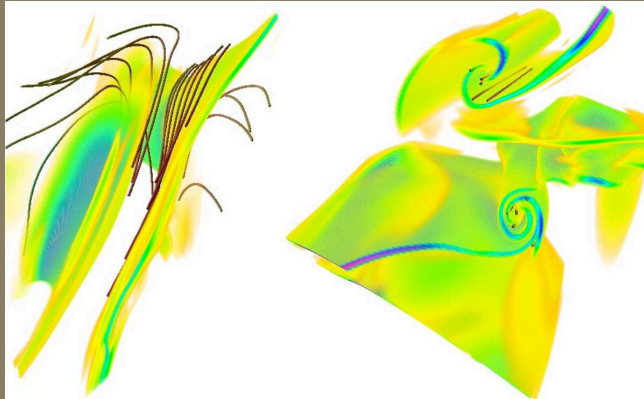Complexity and self organization in geophysical flows or astrophysical flows with magnetic fields.

 **Numerics for the direct simulation of turbulence**

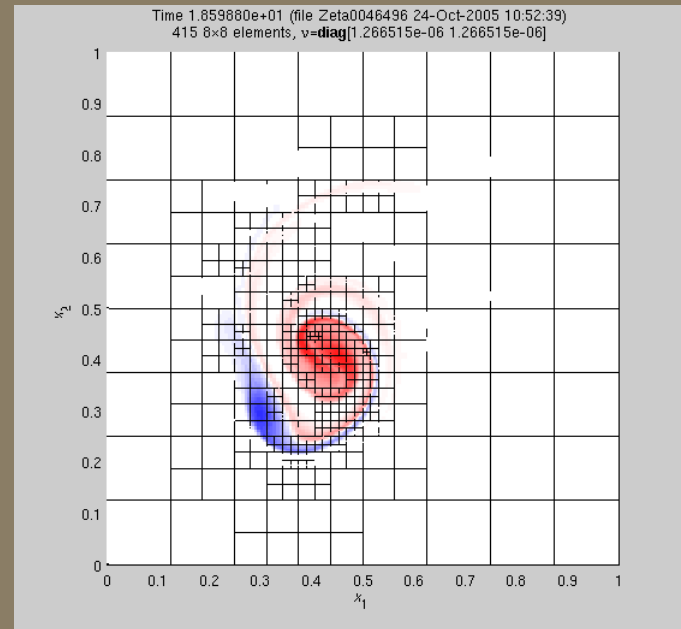*GASpAR:* Geophysical Astrophysical Spectral elements Adaptive Refinement

# Some TNT activities



Folding and rolling of current sheets in idealized MHD



GASPAR: Adaptive, high order numerics





Time 1.859880e+01 (file Zeta0046496 24-Oct-2005 10:52:39)
415 8×8 elements, $\nu=$**diag**[1.266515e-06 1.266515e-06]

# Data Assimilation Research Section (DAReS)

 New methods for combining observations with numerical models for prediction and understanding physical processes

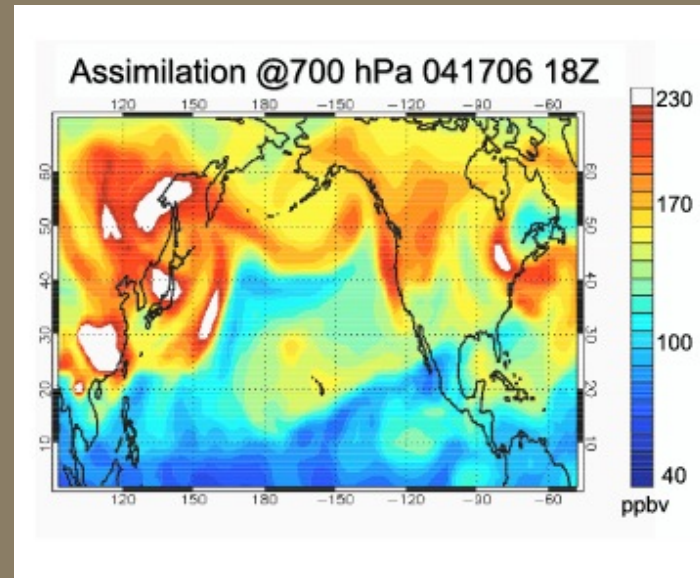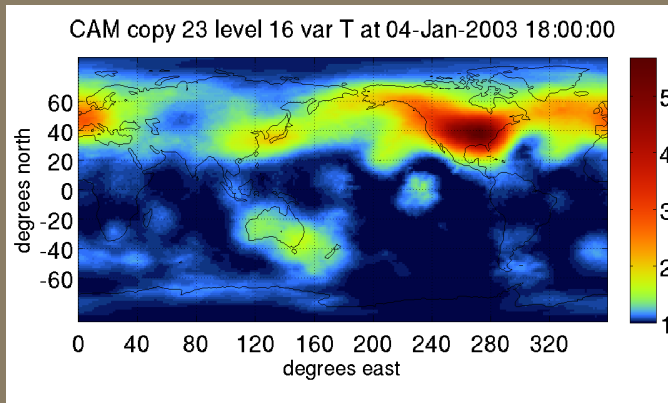 Data Assimilation Research Testbed(DART)

# Some DAReS Activities



Adaptive inflation to stabilize the Kalman filter



Assimilating satelite observations of CO using CAM

# Computational Mathematics Group

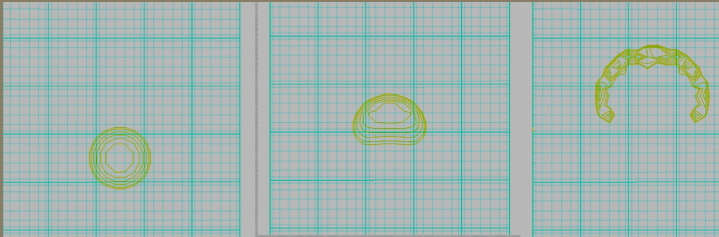 New algorithms and representations for solving geophysical models

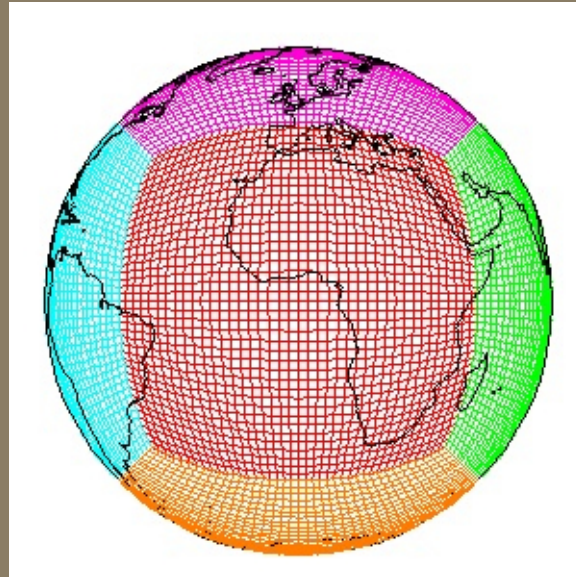 Contributions to High Order Methods Modeling Environment
(HOMME)

# Some CMG Activities



Numerics for a nonhydro-static fluid,
hot bubble test case



HOMME: Discontinuous Galerkin dynamical core on cube sphere geometry

# Geophysical Statistics Project

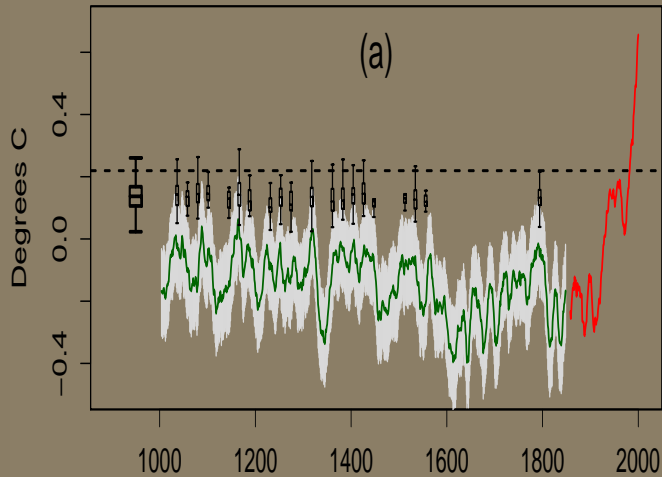 Statistical theory and new statistical models for geophysical data

 High level statistical software, Applied statistics at NCAR
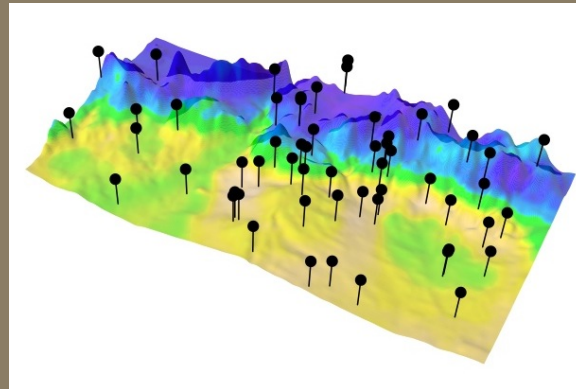
# Some GSP Activities



Uncertainty (boxplots) in the reconstructed decadal maxima for Northern Hemisphere Temperature



Packages in the *R* data analysis environment



*Fields:Tools for spatial data*

# Globalization



*Mathematics Centers and Institutes as partners*

# Theme-of-the-Year

A year long focus on a particular topic that integates some mathematical science with an NCAR science topic.

Typically this is a series of workshops and schools along with additional visitors.

- *TOY$_\epsilon$ '05 Data Assimilation in the Geosciences*
  J. Anderson

- *TOY '06 Models for Multi-scale Geophysical Processes*
  J.Tribba & A. Majda (Courant)

- *TOY '07 Statistics for numerical models*
  S.Sain, M. Fuentes (NCSU) & D. Bignham (Simon Fraser)

- *TOY '08 Geophysical Turbulence: Observations, Computation and Theory*
  A. Pouquet & K. Julien (CU)

TOY '09 ?

# TOY06: Emerging Mathematical Strategies for Multi-Scale and Stochastic Modeling of the Atmosphere and Climate

Four workshops:

- I. Multi-scale Interactions in the Tropics to Midlatitudes: Mathematical Theory, Observations and Numerical Models

- II. Multi-Scale Interactions in a GCM grid box: Mathematical Theory, Numerics and Parameterization

- III. Stochastic and Statistical Parameterization of Unresolved Features in the Atmosphere and Upper Ocean

- IV. Multi-Scale Processes for Low Frequency Variability, Climate, and Climate Change Response

# Some follow through:
## IMAGe postdoc, Christian Franzke

Origin of nonlinear signatures
in planetary wave dynamics
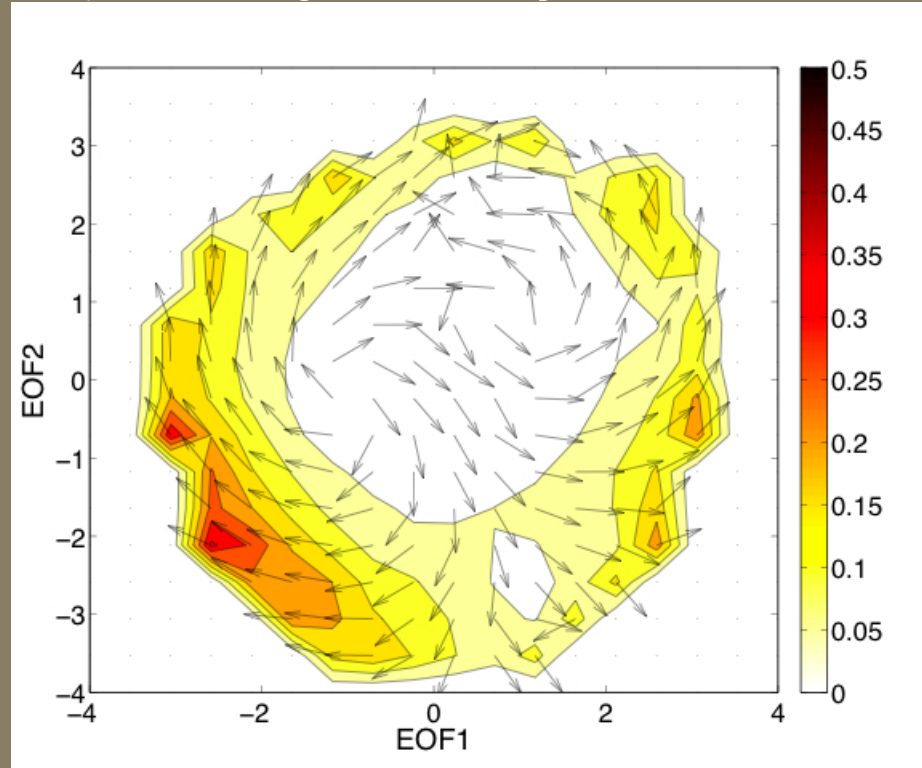


(with G. Branstator and A.Majda)

# TOY07 Statistics for Numerical Models

## *Goal*

Engage statisticians at SAMSI and NCAR with several geo-physical models that have substantial scientific import.

Some NCAR and related models:

- Upper atmosphere (TIEGCM) (A. Richmond), Magnetosphere (M. Wiltberger)

- Boundary layer column model (J Hacker)

- Turbulence (P. Mininni)

- Coupled global and regional climate models (NARCCAP and PRUDENCE groups )

# Program outline

- Kick off meeting at SAMSI,
  9/07 with formation of SAMSI and NCAR working groups.

- *Geophysical Models at NCAR: Scoping and Synthesis.*
  13-14 November 2006.

- Application of Random Matrices Theory and Methods.
  7-9 May 2007

- Application of Statistics to Numerical Models: New Methods and Case Studies.
  21-24 May 2007

- Summer Graduate Workshop on Data Assimilation for the Carbon Cycle.
  8-13 July 2007

# Prudence regional climate experiments

Functional analysis of variance for multi-model regional climate experiments.

Cari Kaufman
IMAGe/SAMSI
postdoc
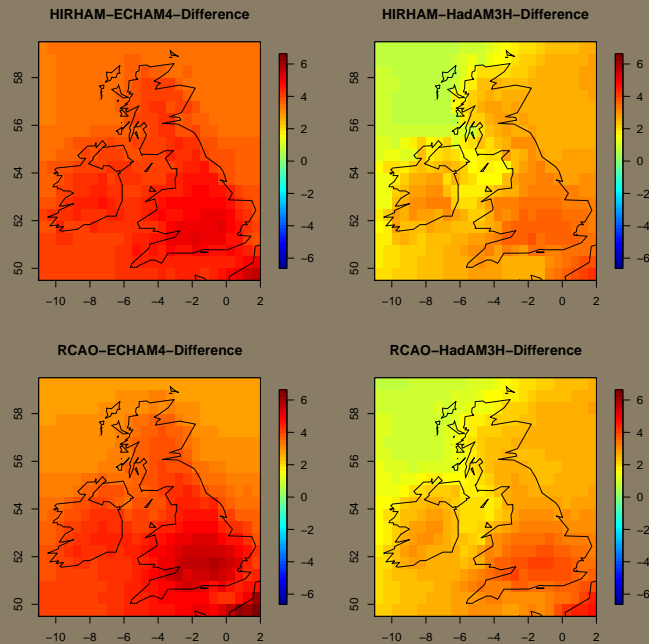
# Summary

- Healthy balance between science and broader community contributions.

- TOY has been successful and is growing in scope.

- Many growing connections to the NSF Math Centers.