Recent Developments at NOAA/GFDL

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Outline

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GFDL Strategic Plan: 2012-2016

- Basic climate processes and their representations in models.
- Comprehensive modeling of climate system variability and change.
- Understanding, detection and attribution, and prediction of extreme events.
- Understanding, detection and attribution, and predictability of modes of climate variability.
- Cryospheric amplification of climate change and sea-level rise.
- Understanding the Earth system including biosphere and human activities.
- Climate science, impacts and services.

Google “GFDL Strategic Science Plan”.

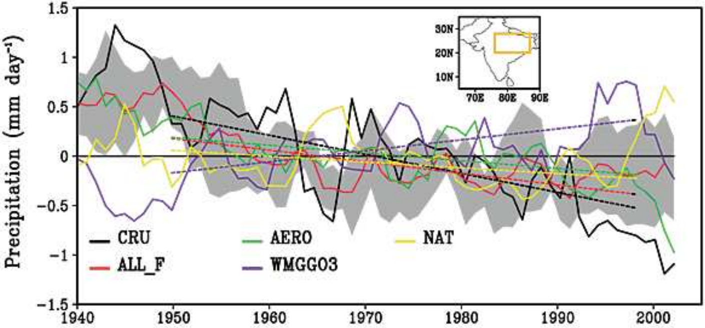
Current suite of GFDL models

- CM3: comprehensive tropospheric and stratospheric chemistry, aerosol-cloud feedbacks.
- ESM2M and ESM2G: free-running carbon cycle.
- DECP: decadal prediction models at various resolutions with advanced initialization (ECDA).
- C180, C360: atmospheric models with AM3 physics optimized for tropical storm “permitting” simulations (HiRAM).
- Cloud-resolving models with bulk microphysics.

All models built on common framework and run within a single distributed workflow.

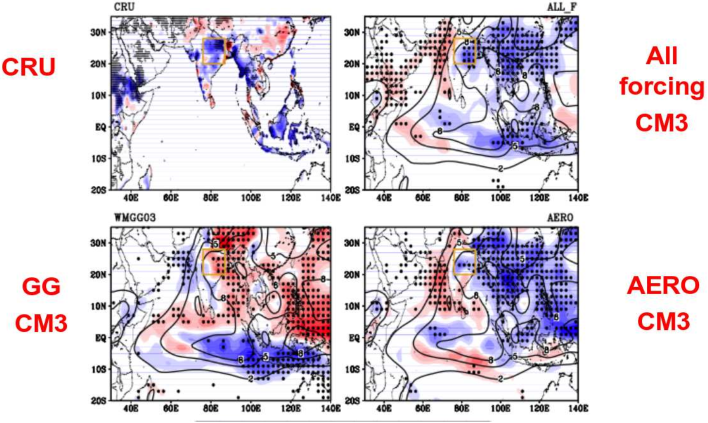
Outline

Aerosol indirect effects weaken South Asian monsoon



Cloud-aerosol feedbacks induce a weakening of the Indian monsoon (Figure courtesy Bollasina et al., **Science** 2011).

Aerosol indirect effects weaken South Asian monsoon: summer monsoon spatial pattern



Cloud-aerosol feedbacks induce a weakening of the Indian monsoon (Figure courtesy Bollasina et al., **Science** 2011).

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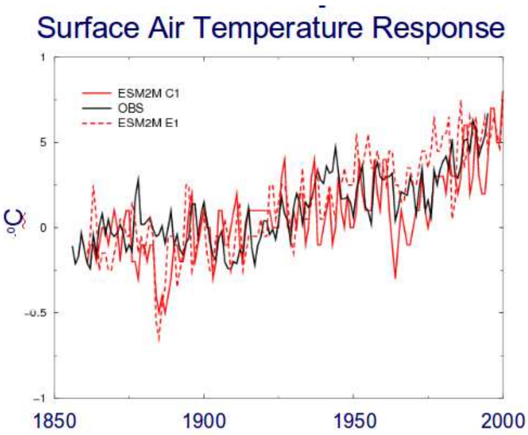
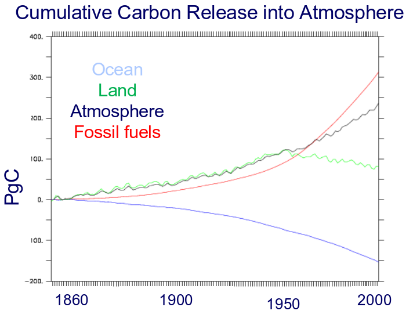
ESM2M: free-running carbon cycle



Free-running carbon cycle in ESM2M. Emissions-driven runs comparable to concentration driven runs (and to observations.) Figure courtesy Ron Stouffer, NOAA/GFDL; pre-publication.

Carbon sources and sinks



- Land carbon fluxes dominant before 1960; then trend changes sign.
- Fossil fuels dominant contemporary source.
- Ocean uptake scales with pCO_2.

Figure courtesy Ron Stouffer, NOAA/GFDL; pre-publication.

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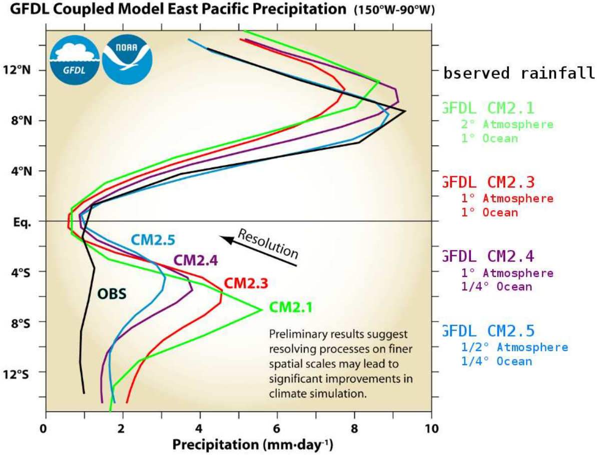
Resolution as a cure for key model biases



The “double-ITCZ problem” appears to be improved by adding resolution (Figure courtesy Gabe Vecchi, NOAA/GFDL).

Annual mean SST bias in CM2.5 control

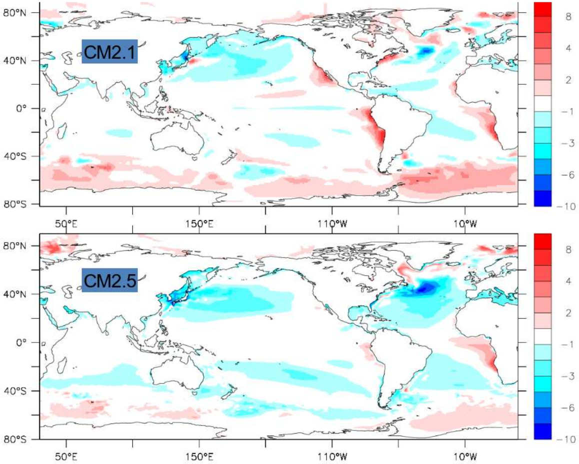
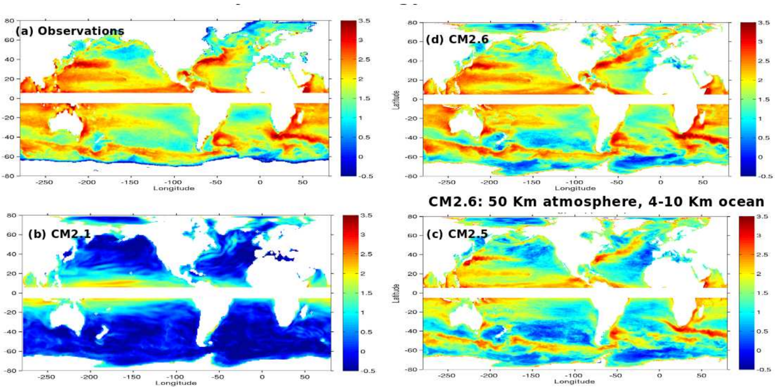


Figure courtesy Delworth et al (2012).

Ocean Eddy Kinetic Energy in CM2.5 and CM2.6



CM2.6: 50 Km atmosphere, 4-10 Km ocean

CM2.1: 200 Km atmosphere, 100 Km ocean

CM2.5: 50 Km atmosphere, 10-25 Km ocean

EKE patterns show marked improvement in the progression toward “eddy-permitting” and “eddy-resolving” ocean models. (Delworth et al 2012).

Subsurface temperature drift corrected by eddy dynamics

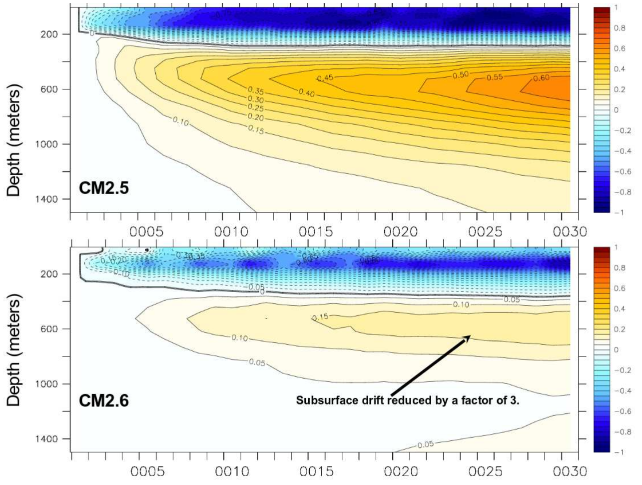


Figure courtesy Delworth et al (2012).

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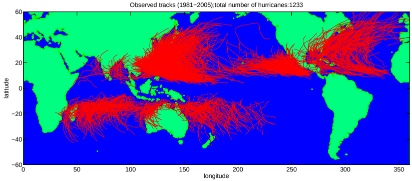
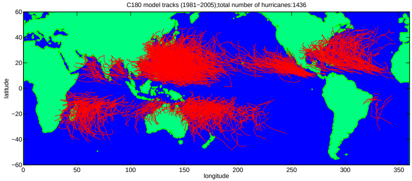
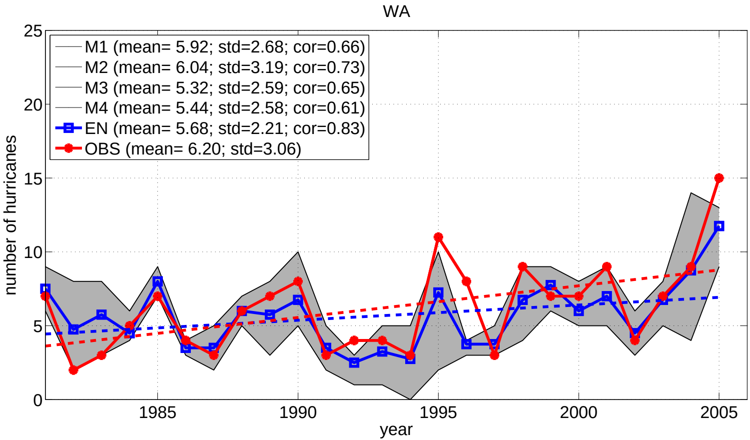
Hurricane statistics from global high-resolution atmosphere models





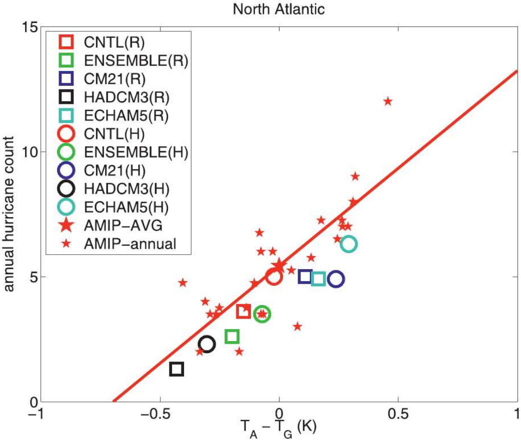
Observed and modeled hurricane tracks from 1981-2005 in a global 50 km (C180) atmospheric model forced by observed SSTs. (Figure courtesy Ming Zhao and Isaac Held, NOAA/GFDL).

Interannual variability of hurricane frequency



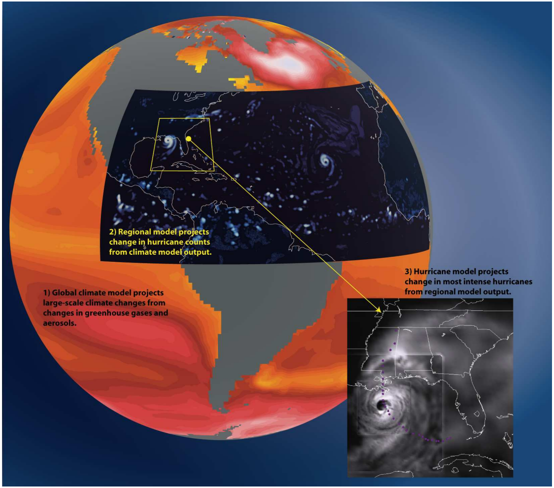
Interannual variability of W. Atlantic hurricane number from 1981-2005 in the C180 runs. (Figure courtesy Ming Zhao and Isaac Held, NOAA/GFDL).

A simple predictor of hurricane counts?



Difference between Atlantic surface temperature T_A and mid-tropospheric global temperature T_G dtermines hurricane generation rate. From Zhao et al (2009).

Nested models for hurricanes and climate change



From Bender et al, *Science*, 2010.

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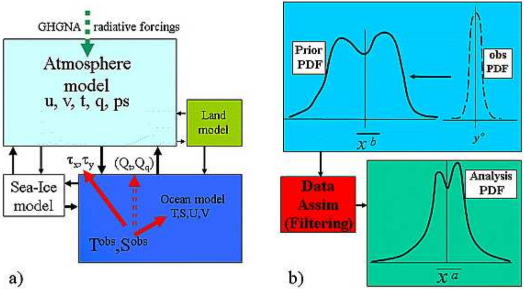
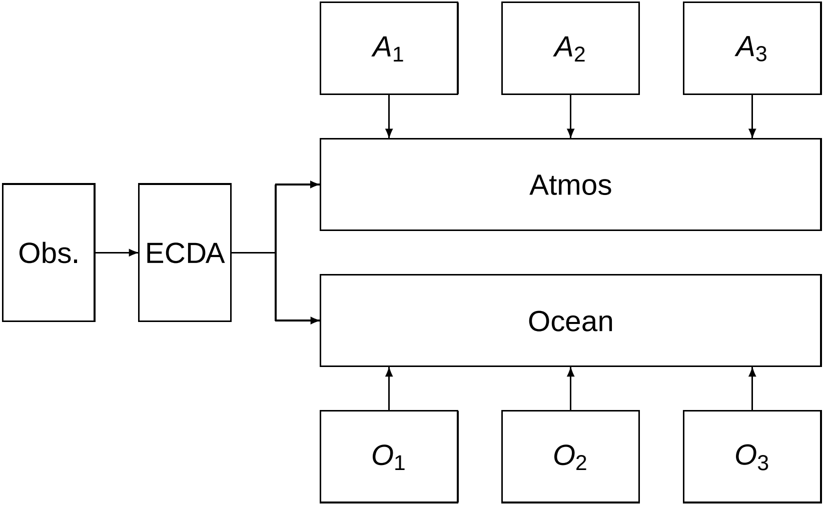
Data assimilation

Zhang - 2008JC005261



Data assimilation uses ensembles to find likely model trajectory taking into account model error and observational error. (Figure courtesy Zhang et al 2008).

Ensemble Coupled Data Assimilation (ECDA)



Model drift in decadal prediction

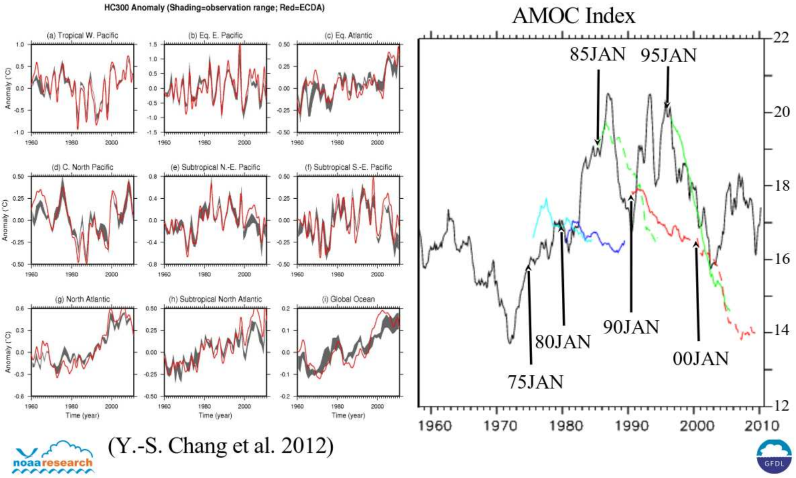
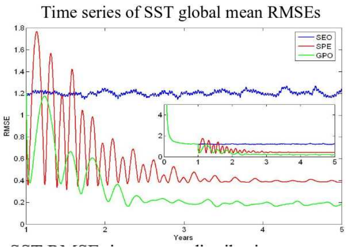
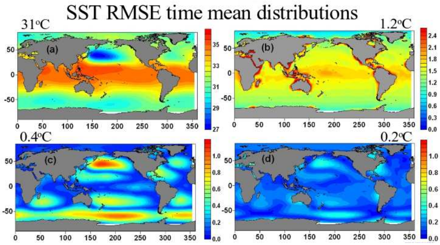


Figure courtesy Shaoqing Zhang and You-Soon Chang, NOAA/GFDL.

Adapting ECDA for parameter estimation





- Intermediate coupled model with 10 free parameters, all biased.
- SEO: State Estimation Only.
- SPE: Single Parameter Estimation, single-valued.
- GPO: Single Parameter Estimation, geographically dependent parameter optimization.
- Does not deconvolve structural uncertainty from parameter uncertainty.
- Can also be used for multi-parameter optimization (see Wu et al 2012a, 2012b).

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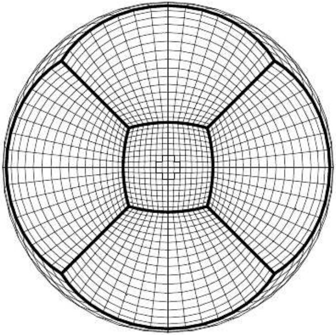
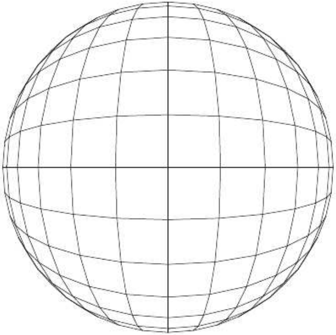
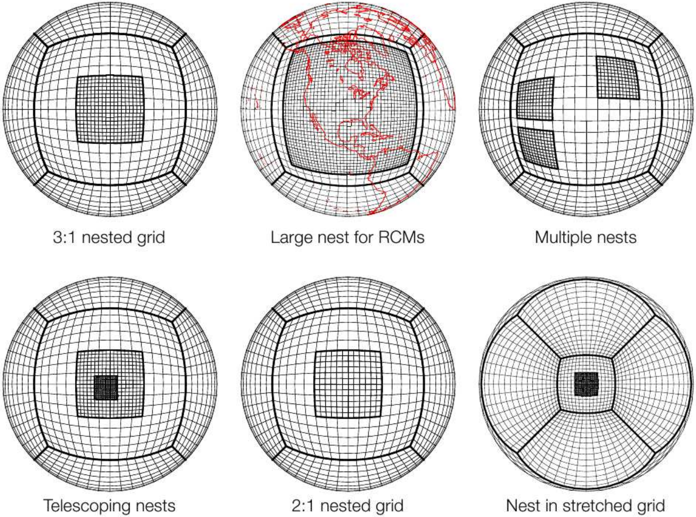
Stretched grids





- Opposing face gets very coarse
- Discontinuities in slope
- Scale-aware parameterizations required

Nested grids



Lee vortices off Hawaii under two-way nesting

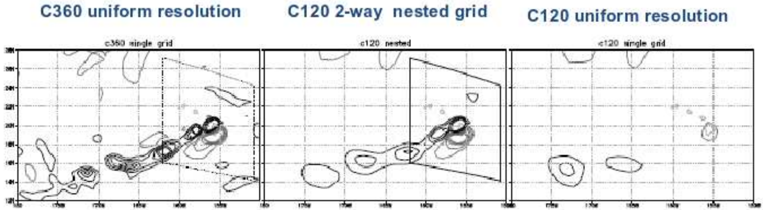


FIG. 15. Surface vorticity (contour interval 10^{-5} s^{-1}, negative values in gray, values above 5×10^{-5} s^{-1} not plotted) at $t = 72$ h in simulations initialized at 0000 UTC on 1 August 2010. Hawaii is at center-right in each panel. Dotted line in left-most panel shows where the nest would be in the nested-grid c120 simulation.

Figure courtesy Harris and Lin 2012.

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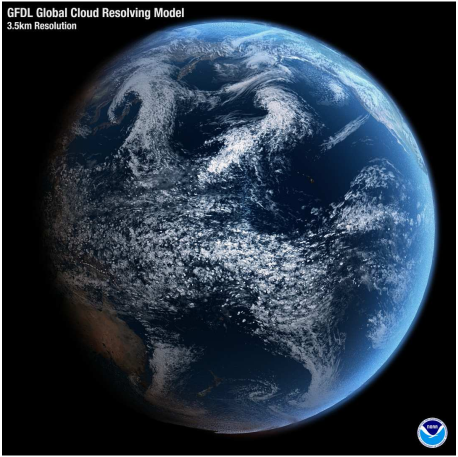
C2560: 3.5 km resolution global cloud-resolving model



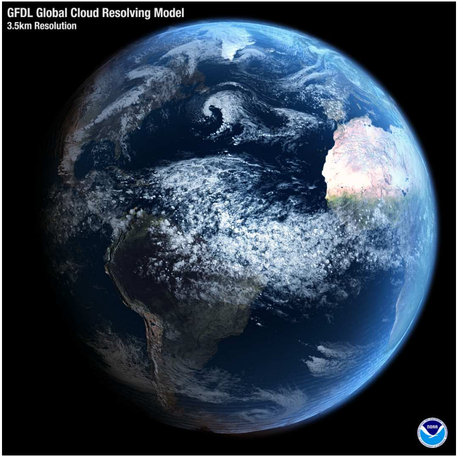


Figure courtesy S-J Lin and Chris Kerr, NOAA/GFDL.

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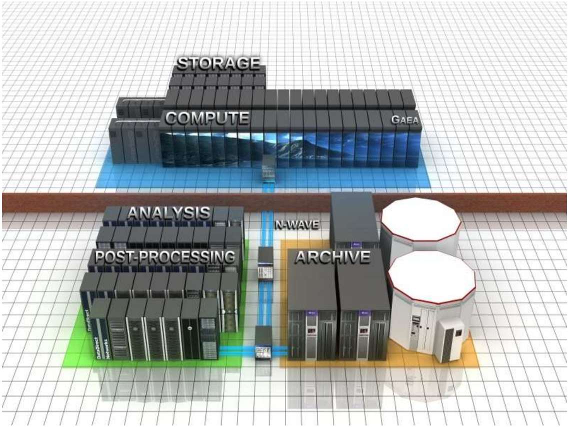
Gaea

The NOAA Climate Modeling and Research System *Gaea*. Being extended in 2012 to include GPU capabilities.

Gaea and GFDL



FRE and other elements in the GFDL modeling environment manage the complex scheduling of jobs across a distributed computing resource.

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Summary

- GFDL Strategic Plan: process studies; development of comprehensive models; climate extremes; experimental prediction; downstream science.
- Experimental seasonal to decadal prediction, including high-resolution fully coupled ensemble Kalman filter for data assimilation
- Continued development of extremely high-resolution atmosphere models using state of the art dynamical core
- Unification of ocean model development through MOM5 and MOM6 (incorporates capabilities from GOLD model into MOM, incorporates results of Climate Process Teams)
- Development of next generation climate model(s) CM4: convergence of multiple model branches into a few “trunk” models, through a Model Development Team led by Isaac Held.
- Increased integration of NOAA modeling across climate research and extended-range forecasting.