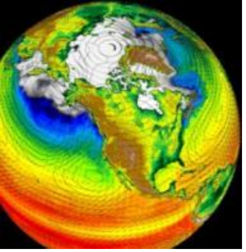
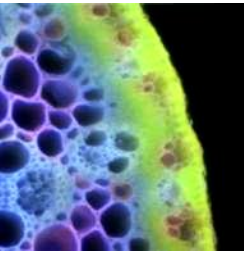
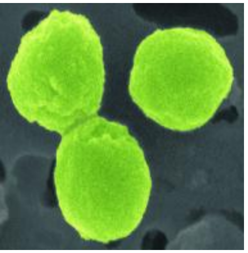


Earth System Prediction Capabilities

DOE interests/capabilities

AR5 Decadal prediction experiments

Dorothy Koch and Renu Joseph

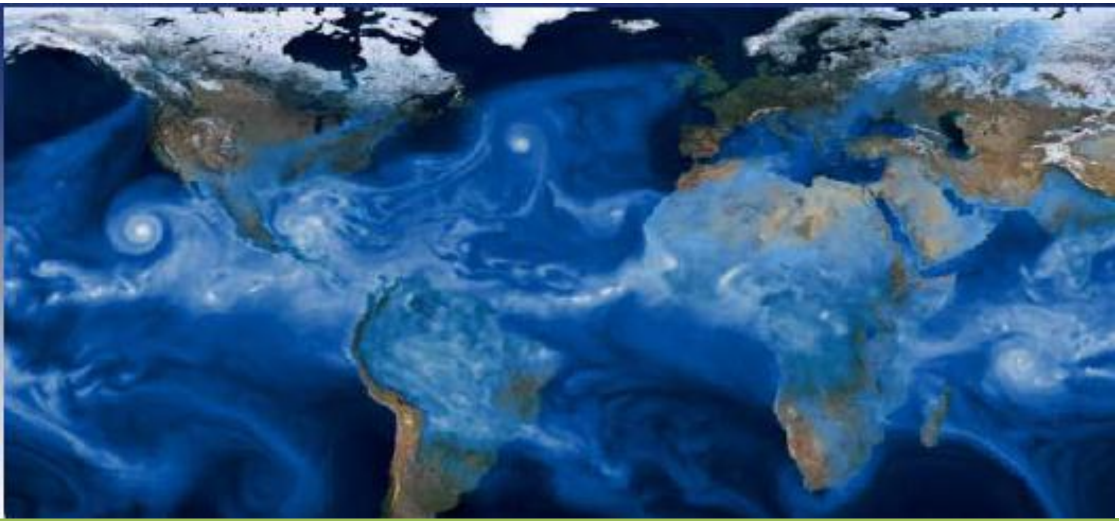
Climate modeling programs
Office of Biological and Environmental Research
U.S. Department of Energy

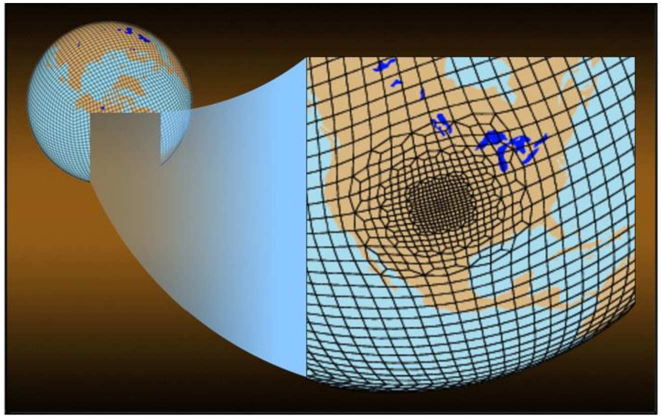
March 21, 2012

ESPC workshop, Silver Spring, MD

Outline

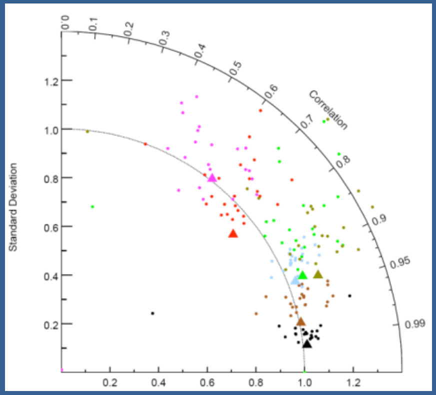
- DOE interests
- Synergistic DOE (CESM) activities
- AR5, PCMDI data archive
- ESGF/visualization tools (Dean Williams)

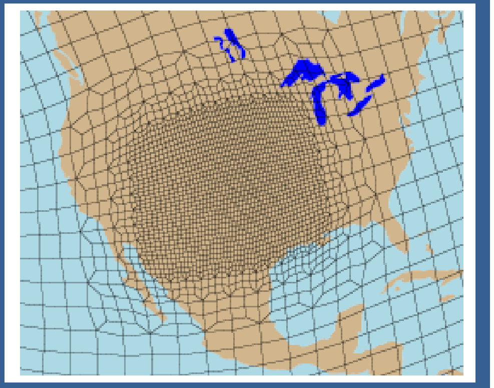


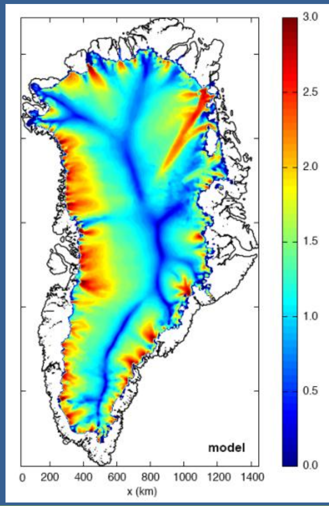


DOE modeling capabilities

- Earth System Modeling Program: Community Earth System Model and "testbed" development (Atmosphere, Oceans, Cryosphere, Land, Biogeochemistry)
- Regional and Global Climate Modeling program: Climate model analysis, diagnostics, metrics, and methods to obtain regional climate information
- Utilization of DOE computational capabilities
- DOE Laboratory and University support

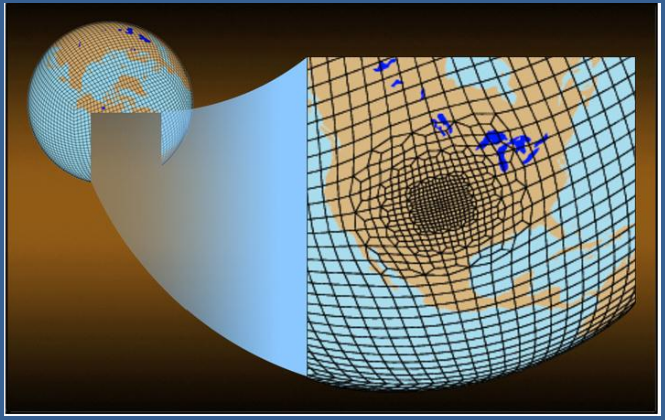






DOE Interests in ESPC

- Predictability for energy: solar, wind, temperature (extremes, energy grid), water
- Interagency (global) model intercomparison/collaboration
- Model validation, other science



Synergistic DOE Activities

Current, newer/potential Activities

- **Atmospheric (CAM) simulations, initialized, testing parameterizations; CAPT project; MJO simulations (LLNL)**
- **CESM Oceans (POP, MPAS) and sea-ice (CICE) simulations, including Data Assimilation (LANL)**
- **High, variable resolution CESM capabilities (ORNL, SNL, LANL)**
- **Climate Science for a Sustainable Energy Future (CSSEF) project, uses "forecast mode" and Uncertainty Quantification methods to test and calibrate model (multi-Lab)**
- **Regional Arctic Climate (System) Model (NPS)**
- **Impact of short-lived atmosphere species on decadal climate (PNNL, LLNL)**

Synergistic DOE Activities: CAM atmosphere

LLNL CAPT project:

CAM atmospheric simulation (fixed SSTs).

Climate run

Initialized with ECMWF , Day 2

Errors are similar and intrinsic to model

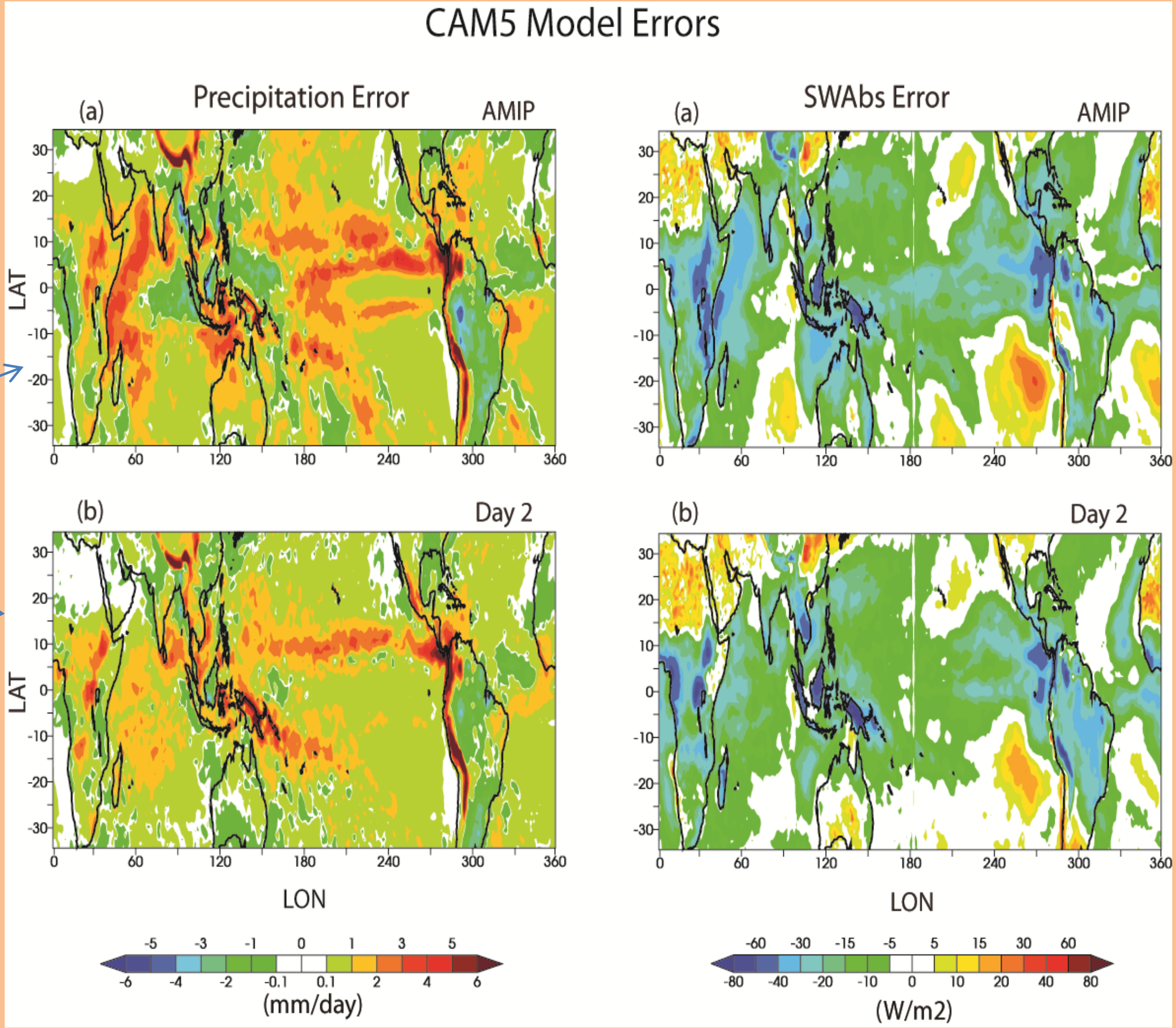


Figure courtesy of Steve Klein, LLNL

Synergistic DOE Activities: CAM MJO

LLNL CAPT project: CAM5 20 day hindcasts, initialized with ECMWF, 500 ensembles of perturbed parameter experiments. Most sensitive parameters are deep convective

Precip Hovmöllers

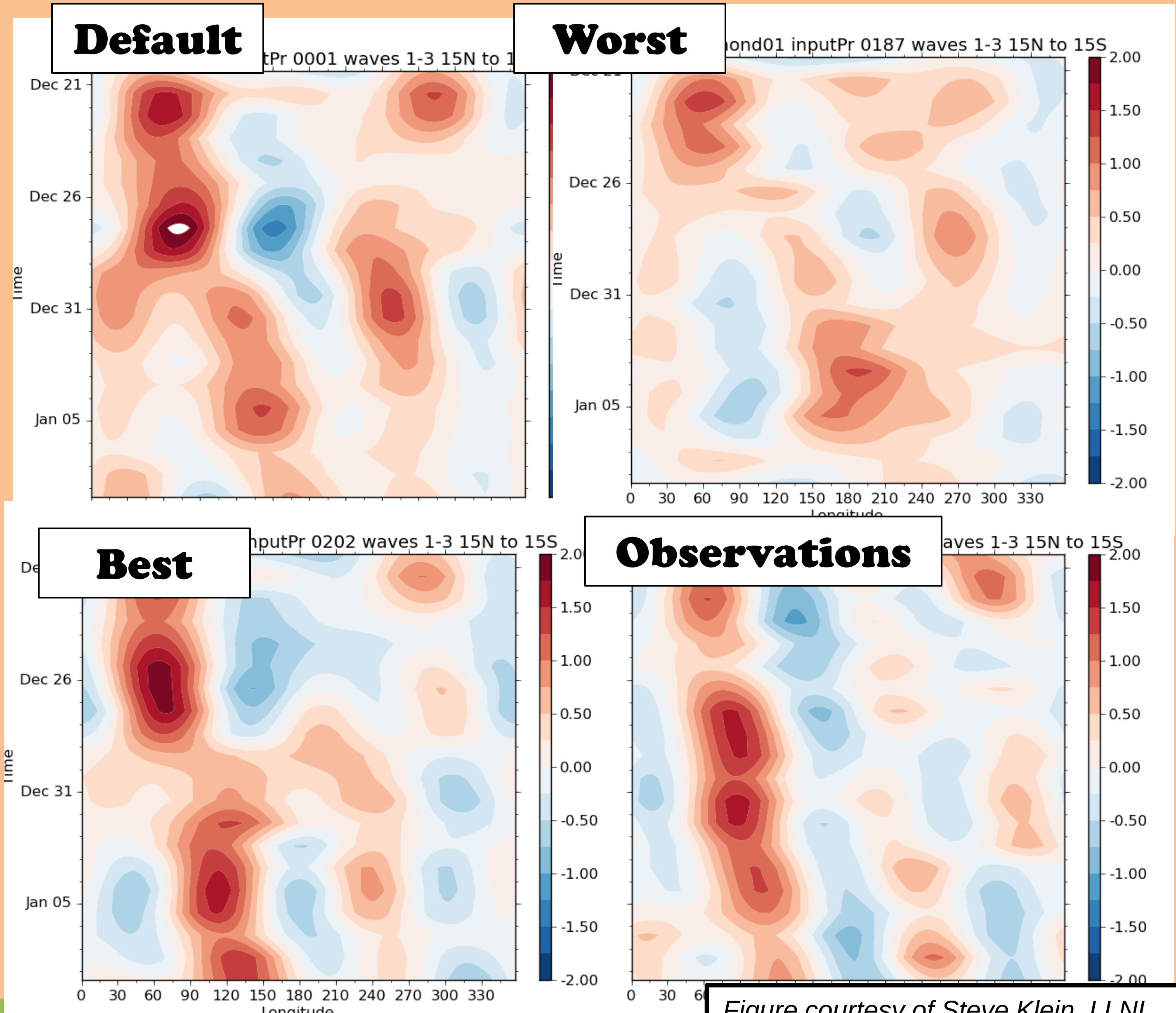


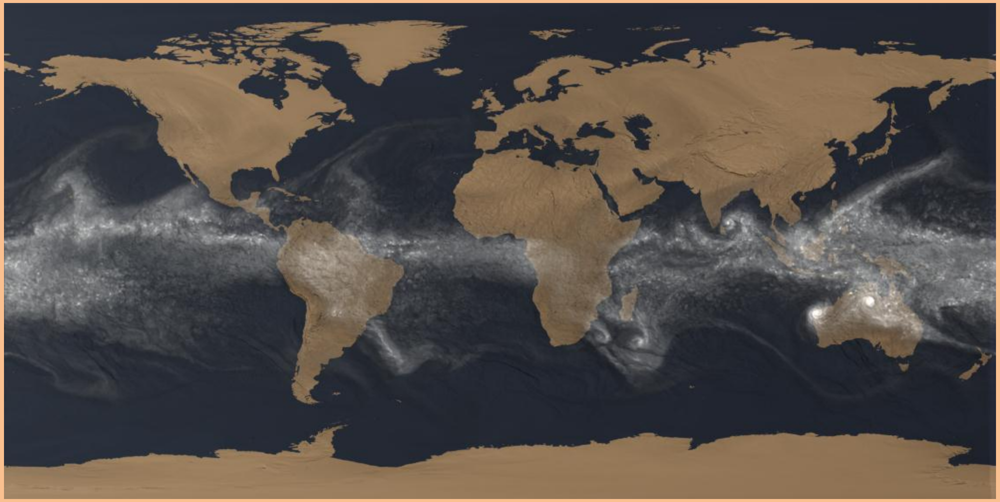
Figure courtesy of Steve Klein, LLNL

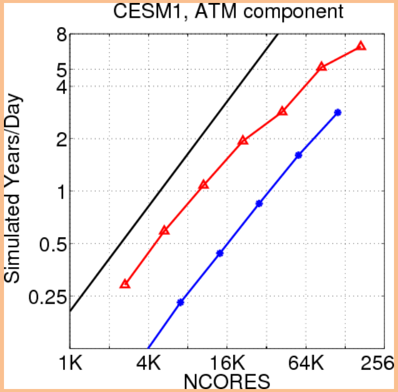
Synergistic DOE Activities: high/variable resolution, computational efficiency

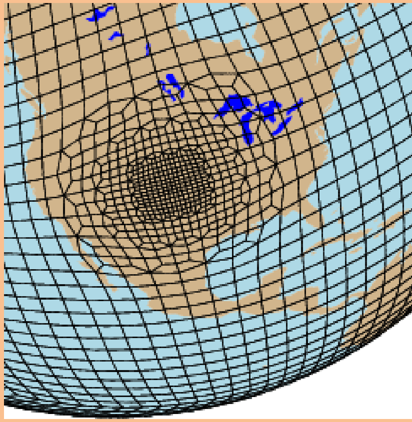
CESM next generation spectral element based atmospheric dynamical core for improved parallel scalability and variable resolution capability.

Enables ultra high resolution simulations on petascale platforms: 1/8° CESM time-slice simulations running well on 170K cores (ORNL Jaguar), achieving 4.6 SYPD. Scaling to O(500K) cores expected.

Examples: cubed-sphere grid for uniform high resolution (left), scaling to 170K cores at global 1/8° (middle), a global 1° grid smoothly transitioning to 1/8° over the SGP ARM site (right).

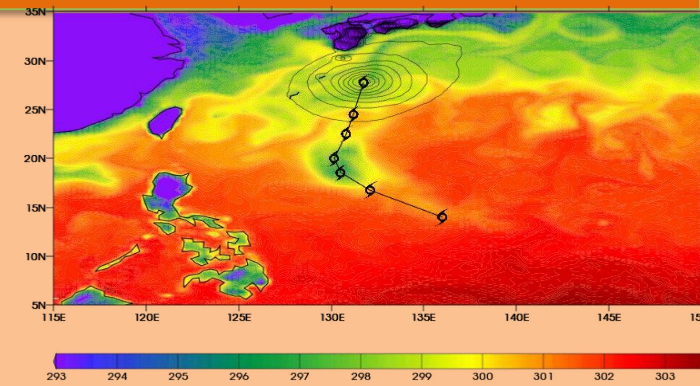




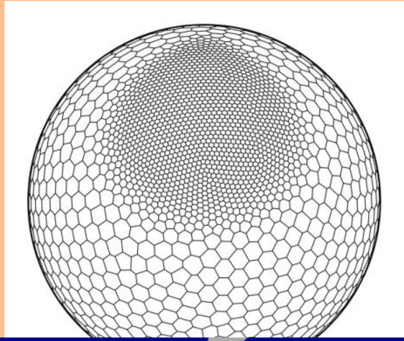


Synergistic DOE Activities: COSIM Develops Ocean/Ice Models, used in CESM

- Parallel Ocean Program (POP)
  - New multi-scale (MPAS) ocean GCM
  - High res (1/10 deg ocn)
  - Eddy-resolving ocean modeling
  - AMOC
- Los Alamos Sea Ice Model (CICE)
- Ice sheet model (Glimmer-CISM)
  - Ice-ocean interface
  - Sea-level rise
- High performance computing
- Publicly available
  - http://climate.lanl.gov

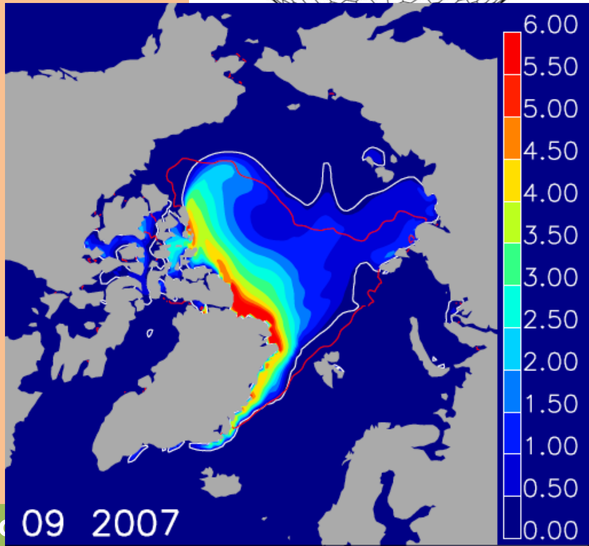


Tropical storm path from high-res

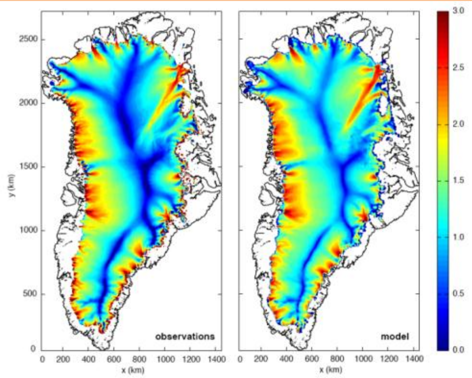


Variable-resolution MPAS ocean

2007 ice minimum from CICE simulation



Dynamic ice sheets; variable mesh grids



Synergistic DOE Activities: Regional Arctic model

Regional Arctic Climate (System) Model

9 Institution consortium for high-resolution Arctic modeling

Many of same components as CESM (CLM/VIC, POP (<10 km), CICE, WRF (<50 km), GLIMMER/CISM)

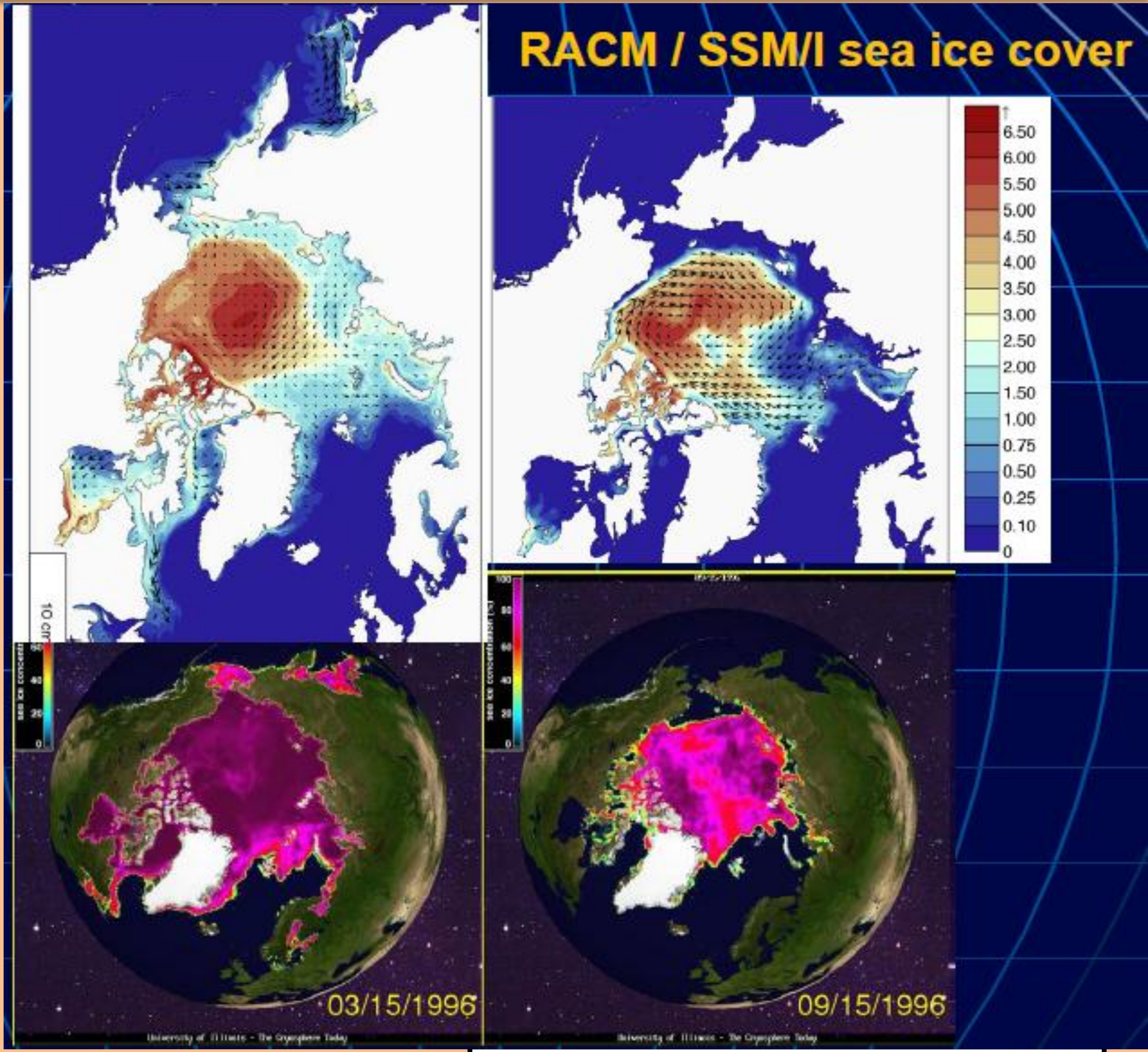
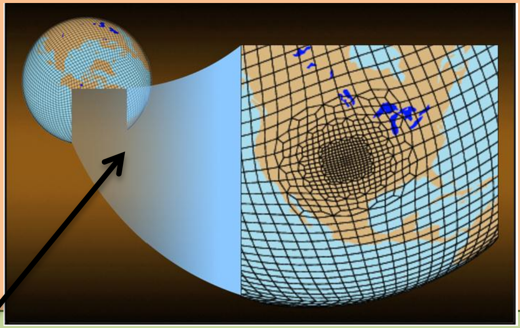


Figure courtesy of Wieslaw Maslowski, NPS

Synergistic DOE Activities: Climate Science for a Sustainable Energy Future (2010-)

3 Science Themes:
- Numerics
- Testbeds
- Uncertainty Quantification

3 Components:
- Atmosphere
- Land
- Ocean and Sea-Ice



9 Labs:
ANL
BNL
LANL
LBNL
LLNL
ORNL
PNNL
SNL
NCAR

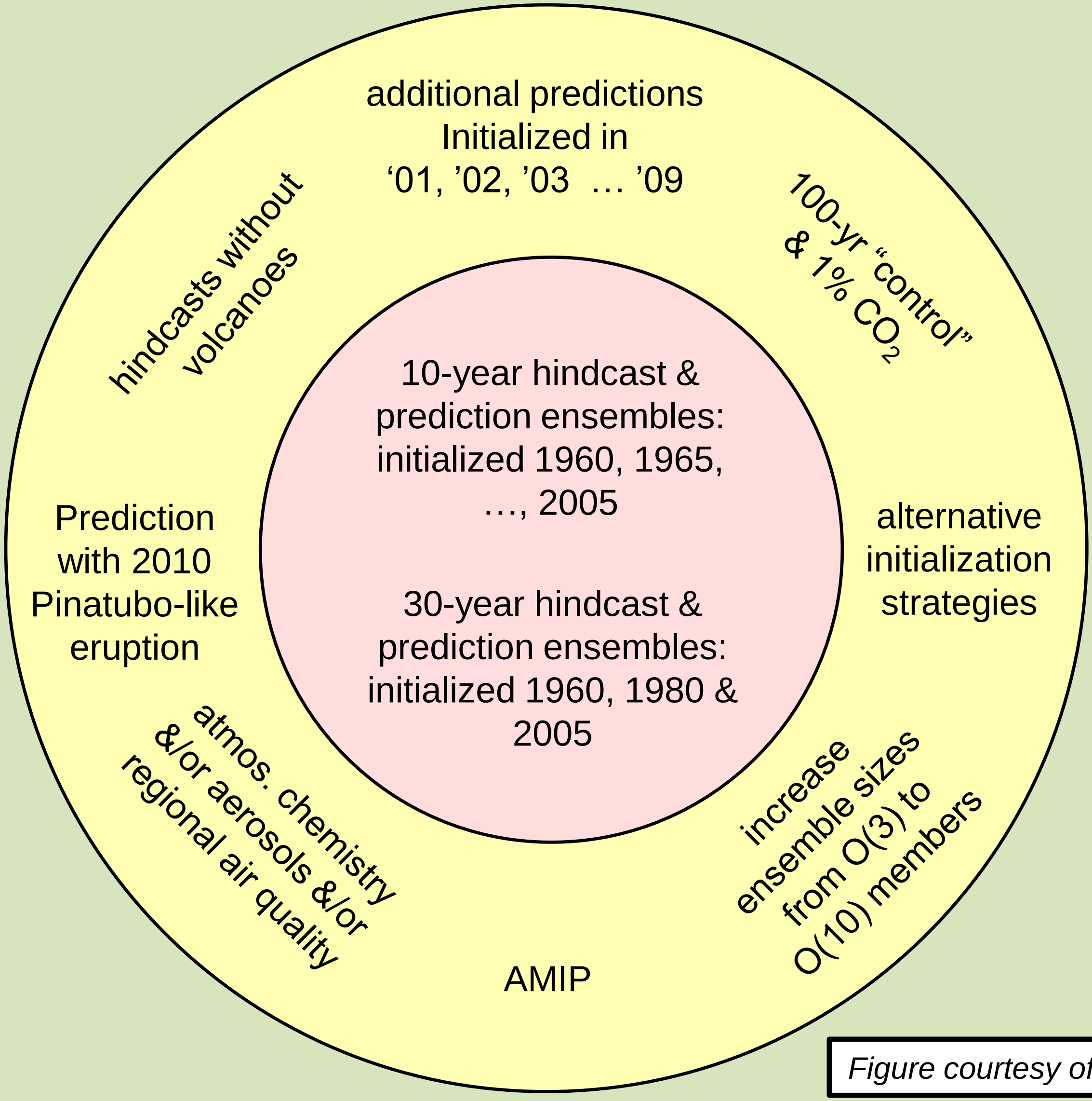
Task example:
- **Variable-resolution, centered on ARM observation site**
- **Initialize model to facilitate comparison with data**
- **Apply uncertainty quantification to test and calibrate**
- **Improve hydrologic simulation**

CMIP5: Expected 24 centers; 50+ models;
5 Feb 2012: 19 centers, 38 models)
11 groups have done decadal prediction experiments

Primary Group	Country	Model
CAWCR	Australia	ACCESS 1.0
BCC	China	BCC-CSM1.1
GCESS	China	BNU-ESM
CCCMA	Canada	CanESM2, CanCM4, CanAM4
NCAR	USA	CESM1, CCSM4
RSMAS	USA	CCSM4(RSMAS)
CMCC	Italy	CMCC- CESM, CM, & CMS
CNRM/CERFACS	France	CNRM-CM5
CSIRO/QCCCE	Australia	CSIRO-Mk3.6
EC-EARTH	Europe	EC-EARTH
LASG, IAP	China	FGOALS- G2.0, S2.0 & gl
FIO	China	FIO-ESM
NASA/GMAO	USA	GEOS-5
NOAA GFDL	USA	GFDL- HIRAM-C360, HIRAM-C180, CM2.1, CM3, ESM2G, ESM2M
NASA/GISS	USA	GISS- E2-H, E2-H-CC, E2-R, E2-R-CC, E2CS-H, E2CS-R
MOHC	UK	Had CM3, CM3Q, GEM2-ES, GEM2-A, GEM2-CC
NMR/KMA	Korea / UK	HadGEM2-AO
INM	Russia	INM-CM4
IPSL	France	IPSL- CM5A-LR, CM5A-MR, CM5B
MIROC	Japan	MIROC 5, 4m, 4h, ESM, ESM-CHEM
MPI-M	Germany	MPI-ESM- HR, LR, P
MRI	Japan	MRI- AGCM3.2H, AGCM3.2S, CGCM3, ESM1
NCC	Norway	NorESM1-M, NorESM-ME, NorESM1-L
NCEP	USA	CFSv2-2011

Figure courtesy of Karl Taylor, LLNL

CMIP5 decadal experiments: models initialized with observations



Adapted from Taylor *et al.*, BAMS, 2011

Figure courtesy of Karl Taylor, LLNL

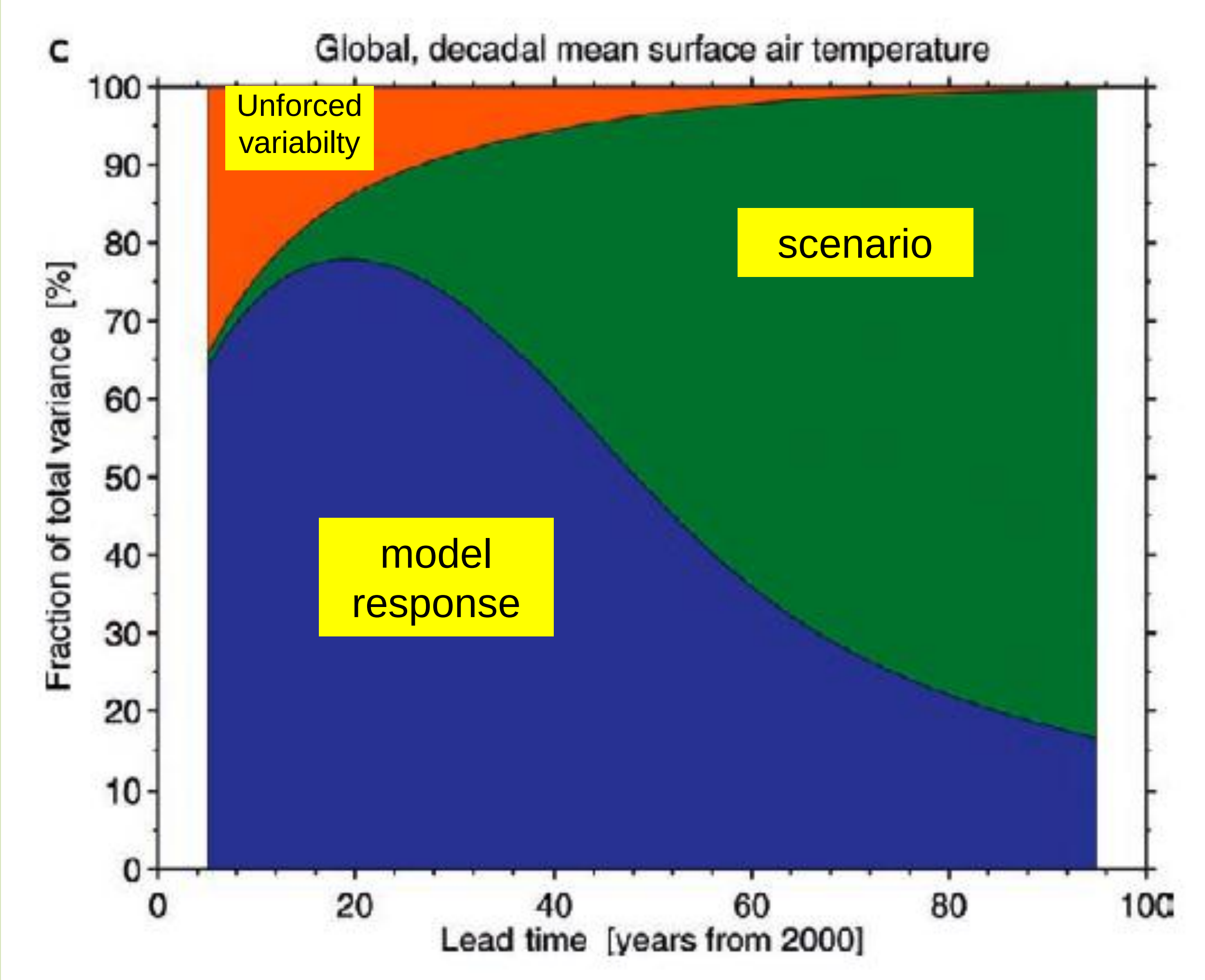
CMIP5 decadal experiments contributions

** Core simulations (# available as of 5 Feb 2012)*

Experiment(s)	Number of models
*Hindcasts and predictions	18 (11)
AMIP	3 (2)
Volcano-free hindcasts	3 (1)
2010 “Pinatubo-like” eruption	1 (1)
Initialization alternatives	5 (?)
Pre-industrial control	10 (7)
1% CO2 increase	9 (6)

Figure courtesy of Karl Taylor, LLNL

Projection ranges are initially dominated by model “uncertainty”, but eventually are dominated by scenario



Hawkins & Sutton, *BAMS*, 2009

Figure courtesy of Karl Taylor, LLNL

Decadal (initialized) simulations pose challenges

- Initial state (from observations) is inconsistent with model equilibrium climate state
- Model initially adjusts rapidly toward its natural equilibrium
- Sophisticated "bias" corrections must be applied to remove this artifact of the initialization procedure.
  - More complex than normal drift correction because it involves multiple time-scales, all of which are of interest to decadal prediction
- Modeling groups will "bias correct" only for near-surface air temperature, surface temperature, precipitation rate, and sea level pressure.
- All other fields should probably be considered only by specialists

Figure courtesy of Karl Taylor, LLNL

“Decadal” predictability

<u>Best :</u>

- Surface temperature over ocean (N. Atlantic, N. Pacific (ENSO+External forcing), S. Oceans
- Arctic sea ice (couple years for thick ice)

<u>Decent</u> in theory but data issues are limiting:

- AMOC (decadal)
- Subsurface ocean temperature

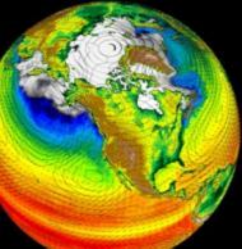
<u>Poor</u>:

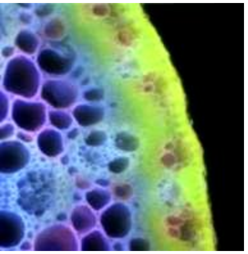
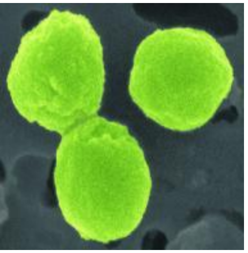
- Air temperature over land
- Precipitation

Most decadal skill is from forcing not initialization

3 challenges:

1. Limited data for initializing
2. Initialization methods
3. Model limitations



Thank you!

Dorothy Koch
Dorothy.Koch@science.doe.gov
Renu Joseph
Renu.Joseph@science.doe.gov

http://www.climatemodeling.science.energy.gov/

Climate and Environmental Sciences

Atmospheric Science

- Atmospheric System Research
- Atmospheric Radiation Measurement (ARM) Climate Research Facility

Climate and Earth System Modeling

- Regional & Global Climate Modeling (Renu Joseph)
- Earth System Modeling (Dorothy Koch)
- Integrated Assessment (Bob Vallario)

Environmental System Science

- Terrestrial Ecosystem Science
- Terrestrial Carbon Sequestration Research
- Subsurface Biogeochemical Research
- Environmental Molecular Sciences Laboratory

Climate & Environmental Sciences Division Strategic Goals

1. **Synthesize new process knowledge and innovative computational methods advancing next generation, integrated models of the human-earth system.**

- **Human dimension, sea-level rise, variable-grids**

2. **Develop, test and simulate process-level understanding of atmospheric systems and of terrestrial ecosystems extending from bedrock to the top of the vegetative canopy.**

- **Indirect effects, carbon cycle, water cycle, cloud feedbacks, precipitation; Arctic, tropics**

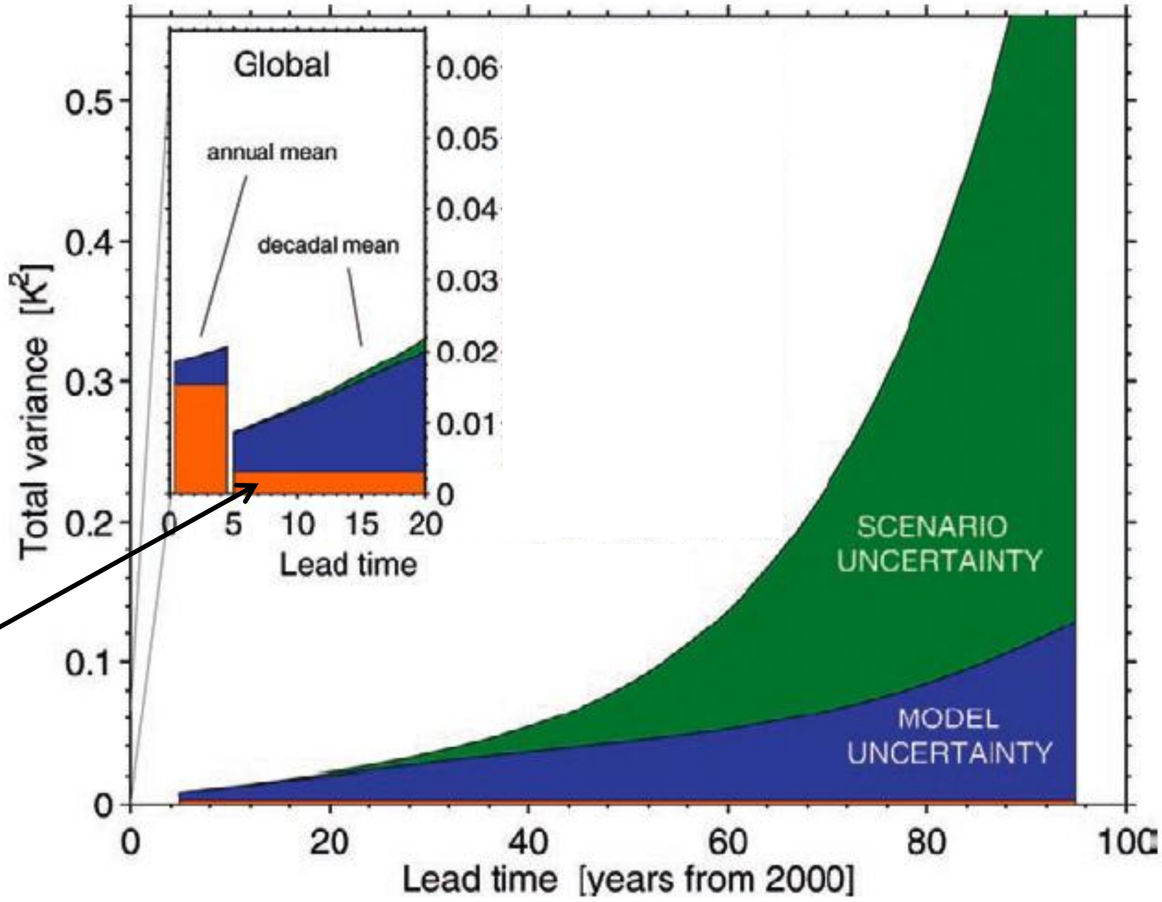
4. **Enhance the unique capabilities and impacts of BER community resources to advance the frontiers of climate and environmental science.**

- **Testbeds, diagnostics, UQ, tools for PCMDI/ESGF**

5. **Identify and address science gaps that limit translation of CESD fundamental science into solutions for DOE's most pressing energy and environmental challenges.**

- **"Use-inspired" development of capabilities to use models for energy applications (e.g. water availability, extremes)**

Total range of future climate change estimates depends on scenario, model, and unforced variability



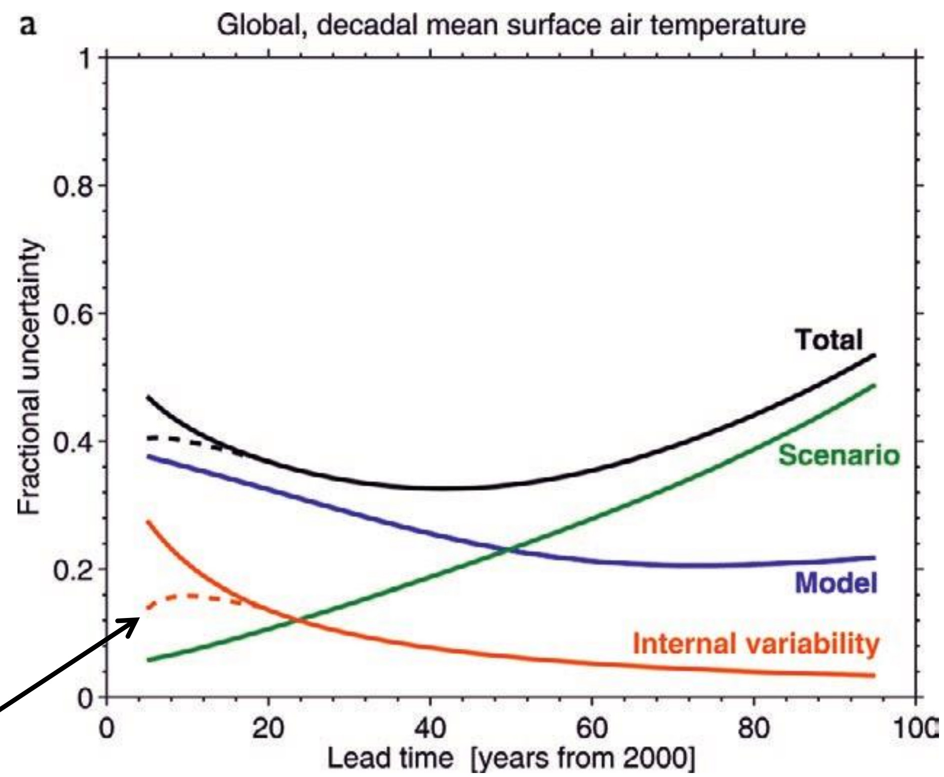
Unforced variability is important only in the near-term.

Hawkins & Sutton, *BAMS*, 2009

Figure courtesy of Karl Taylor, LLNL

CMIP5 will also include models initialized with the observed climate state (particularly, the upper ocean)

- The hope is that through initialization the models will be able to predict the actual trajectory of "unforced" climate variations.
- The hypothesis is that some longer time-scale natural variability is predictable if the initial state of the system is known



The deviation from observations caused by unforced variability can potentially be reduced through initialization.

Hawkins & Sutton, 2009

Figure courtesy of Karl Taylor, LLNL