From FMS to FRE to Curator

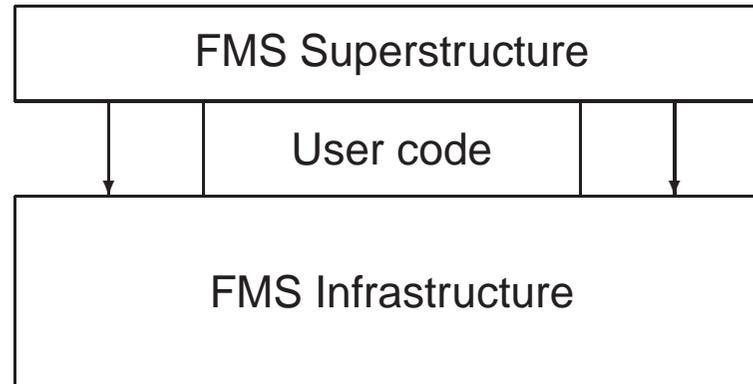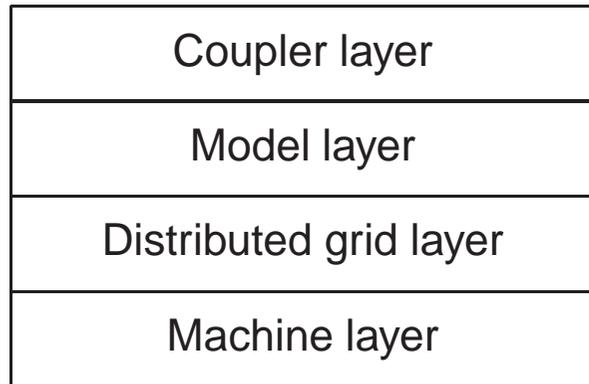**V. Balaji**

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FMS: the GFDL Flexible Modeling System

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- Develop high-performance kernels for the numerical algorithms underlying non-linear flow and physical processes in complex fluids;

- Maintain high-level code structure needed to harness component models and representations of climate subsystems developed by independent groups of researchers;

- Establish standards, and provide a shared software infrastructure implementing those standards, for the construction of climate models and model components portable across a variety of scalable architectures.

- Benchmarked on a wide variety of high-end computing systems;

- Run in production on very different architectures: parallel vector (PVP), distributed massively-parallel (MPP) and distributed shared-memory (NUMA).

Architecture of FMS

Coupler layer
Model layer
Distributed grid layer
Machine layer

FMS Superstructure
User code
FMS Infrastructure

FMS model components

- Models are free to choose grids independent of each other: for example, the ocean, shown on right, uses a *tripolar grid*. Several choices of ocean models are available, including idealized oceans and "data" oceans.

- Similarly several choices are available for the atmosphere, including a newly-developed finite-volume model on the *cubed-sphere* grid, shown at right. This model, which is available in both hydrostatic and non-hydrostatic forms, may well be the basis for future atmospheric climate models at many sites.

- Communication of data between models running concurrently on independent grids is through GFDL-pioneered "exchange grid" technology, which is the basis for development work underway in the ESMF project.
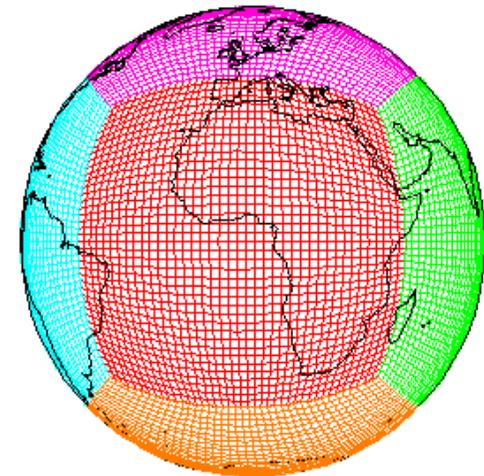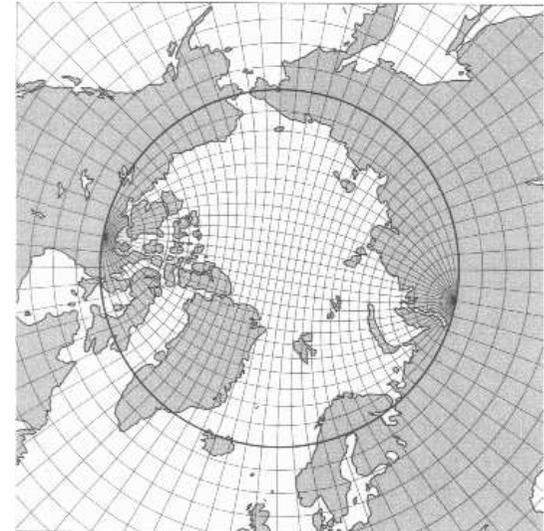
The FMS user interface: FRE

Comprehensive website for all information and documentation:
http://www.gfdl.noaa.gov/~fms

- Source code maintenance under CVS; browse over the net using webCVS.

- Model configuration, launching and regression testing encapsulated in XML;

- Relational database for archived model results;

- Standard and custom diagnostic suites;

The FMS Runtime Environment (FRE) describes all the steps for configuring and running a model jobstream; archiving, postprocessing and analysis of model results.

fremake, frerun, frepp, frecheck, ...

The Regression Test Suite (RTS) is a set of tests that are run continuously on a set of FMS models to maintain and verify code integrity.

The IPCC AR4 archive at PCMDI

The IPCC data archive at PCMDI is a truly remarkable resource for the comparative study of models. Since it came online in early 2005, it has been a resource for ∼300 scientific papers aimed at providing consensus and uncertainty estimates of climate change, from ∼20 state-of-the-art climate models worldwide.

| Model	Modeling Center
BCCR BCM2	Bjerknes Centre for Climate Research
CCCMA CGCM3	Canadian Centre for Climate Modeling & Analysis
CNRM CM3	Centre National de Recherches Meteorologiques
CSIRO MK3	CSIRO Atmospheric Research
GFDL CM2_0	Geophysical Fluid Dynamics Laboratory
GFDL CM2_1	Geophysical Fluid Dynamics Laboratory
GISS AOM	Goddard Institute for Space Studies
GISS EH	Goddard Institute for Space Studies
GISS ER	Goddard Institute for Space Studies
IAP FGOALS1	Institute for Atmospheric Physics
INM CM3	Institute for Numerical Mathematics
IPSL CM4	Institut Pierre Simon Laplace
MIROC HIRES	Center for Climate System Research
MIROC MEDRES	Center for Climate System Research
MIUB ECHO	Meteorological Institute University of Bonn
MPI ECHAM5	Max Planck Institute for Meteorology
MRI CGCM2	Meteorological Research Institute
NCAR CCSM3	National Center for Atmospheric Research
NCAR PCM1	National Center for Atmospheric Research
UKMO HADCM3	Hadley Centre for Climate Prediction
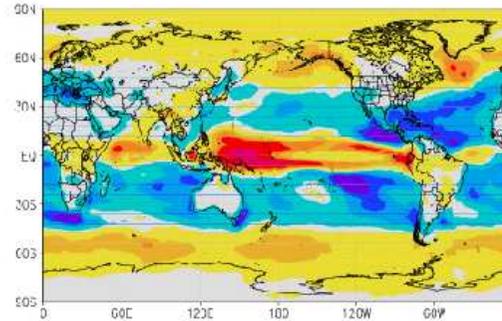
This figure, from Held and Soden (2005), is a composite analysis across the entire IPCC archive.

Computational load at GFDL:
- 5500 model years run.
- Occupied half of available compute cycles at GFDL for half a year (roughly equivalent to 1000 Altix processors).
- 200 Tb internal archive; 40 Tb archived at GFDL data portal; 4 Tb archived at PCMDI data portal.

The IPCC data pipeline at GFDL
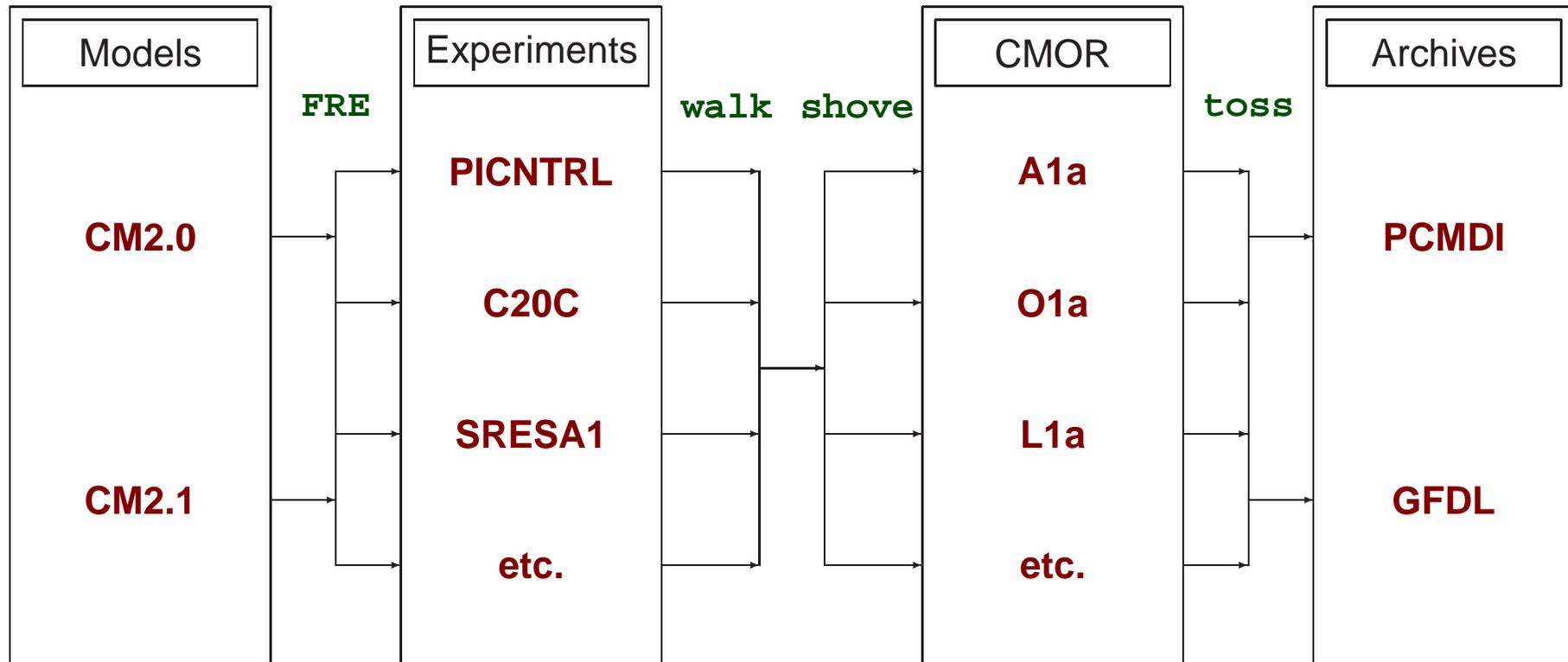
The process was time- and data-intensive, with multiple access episodes for the same datasets. Clearly it would be ideal if FRE already produced compliant data.

FMS and community standards

- FMS authors are now active participants in the design of the Earth Systems Modeling Framework (ESMF) community-wide modeling standard and framework, for which FMS is a design prototype. ESMF prototype v2.0 is currently released to the public. **(http://www.esmf.ucar.edu)**

- GFDL is also central in the development of community standards for data through the CF Conventions.

- We follow a similar path for public delivery of models and data: community models like MOM4 are delivered as "ESMF components" to partners that request it; similarly publicly accessible data (e.g IPCC) is delivered according to the standards established by such experiments.

- All of these steps are being automated through the FRE Curator.