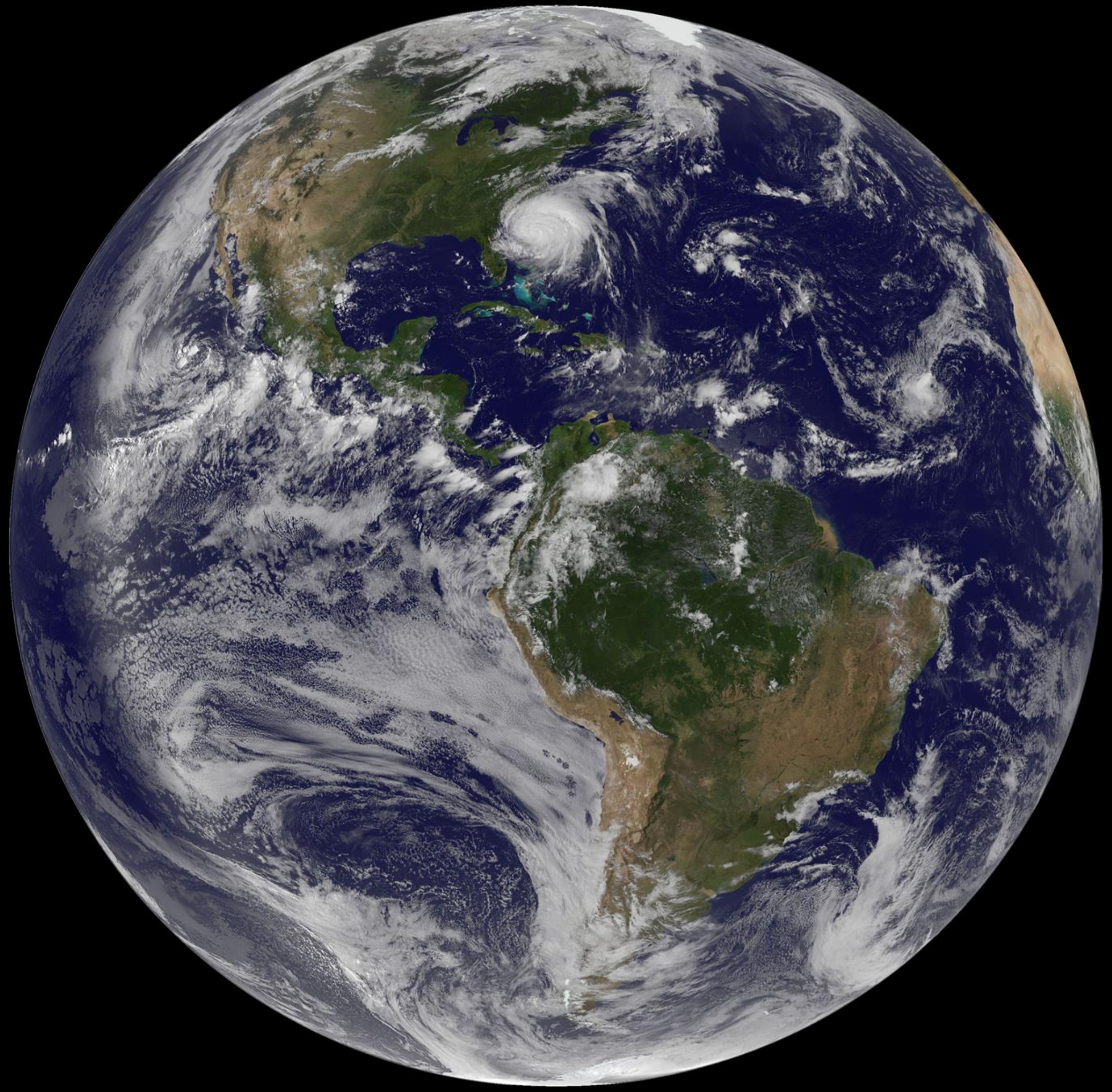
Coupled Modeling Infrastructure Capabilities

NOAA CIRES / NESII

August 2, 2017

NGGPS PI workshop



Hurricane Irene/NASA GOES-13 satellite image/August 26, 2011

Goals of the Project

- Continue maintenance and development of the Earth System Modeling Framework (ESMF) and National Unified Operational Capability (NUOPC) Layer
- Support the mutually beneficial partnership between the ESMF development team and the Community Earth System Model - CESM (in partnership with EMC, GFDL, and others…)
- Implement the ESMF-based coupling software for the atmosphere-ocean-land-sea ice-wave modeling system that is a candidate for the next Climate Forecast System (CFS) version (CFSv3)
- Improve the data access and collaboration environment for the Coupled Model Intercomparison Project (CMIP) and other projects through extensions to the ESGF; these include a user-friendly front end for ESGF called Earth System CoG, and software utilities based on metadata and data standards.

Overview of next release (7.1.0)

Anticipated summer 2017

- Implementation of higher order conservative grid remapping (Bob Oehmke/CIRES)
- New shortcuts for cubed sphere grid creation (Bob Oehmke/CIRES)
- Support for component hierarchies in the NUOPC Layer (Gerhard Theurich/NRL)
- Completion of DOE MOAB (Mesh Oriented database) as an option for the underlying finite element mesh framework for grid remapping (Ryan O'Kuinghttons and Bob Oehmke/CIRES)
- Extension of the ESMF virtual machine to recognize, allocate to, and begin to negotiate for heterogeneous resources such as accelerators (Jayesh Krishna/ANL)
- Implementation of dynamic masking during the application of interpolation weights (Gerhard Theurich/NRL)
- Extrapolation of points that lie outside the source grid (Bob Oehmke/CIRES)

Second Order Conservative Regrid Method

- Destination cell value is combination of values of intersecting source cells modified to take into account **source cell gradient:**

  $$d = \sum(s_i + \nabla s_i \cdot (c_{si} - c_d))$$

  Where:

d	= destination value	s_i	= intersecting source cell value
c_d	= destination centroid	c_{si}	= intersecting source cell centroid
		∇s_i	= intersecting source cell gradient

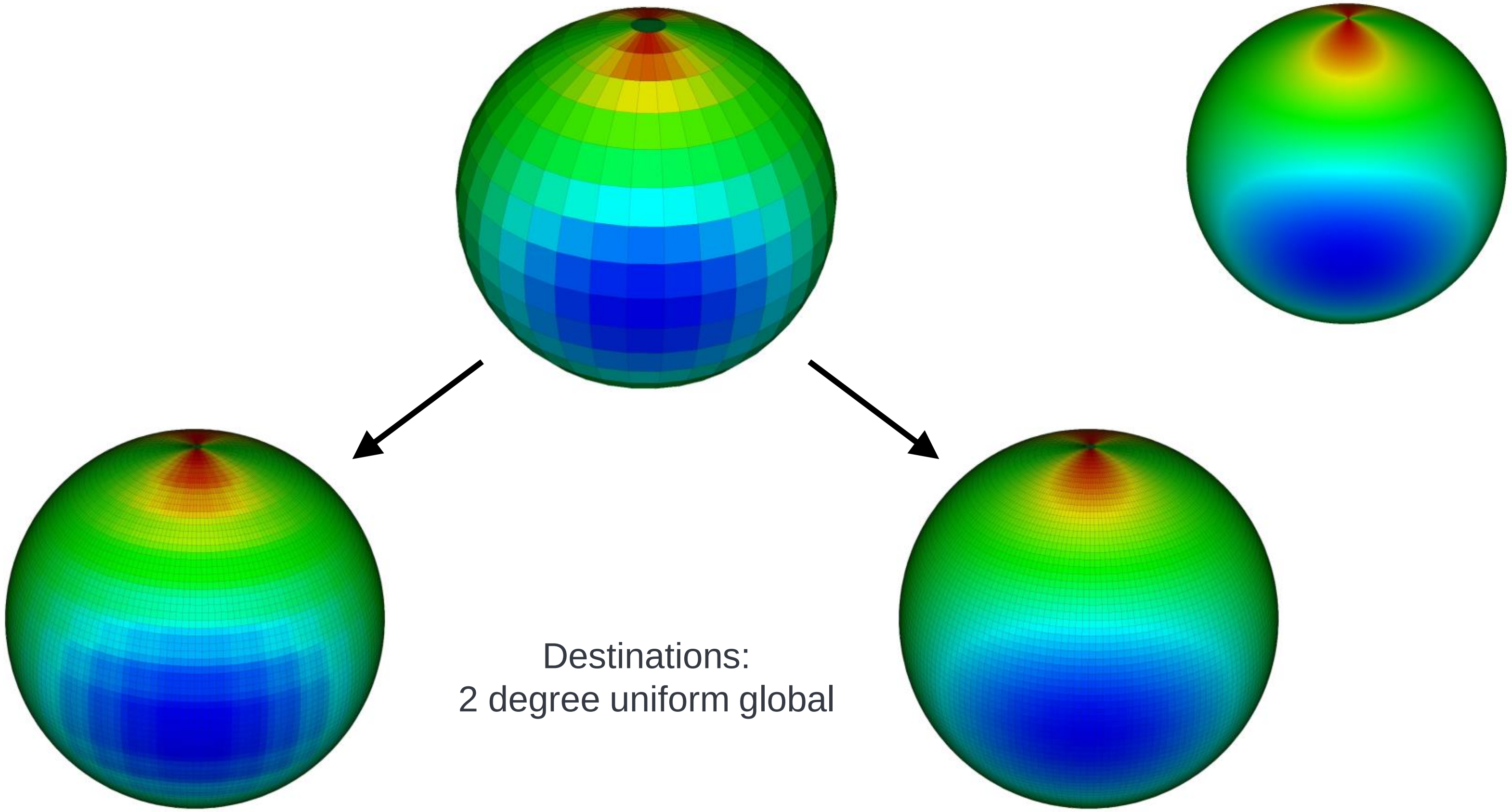
- Requires a **wider stencil** and more computation, so more expensive in terms of memory and time than first-order

- Preserves integral of field across interpolation, but gives **smoother results than first-order** (especially when going from coarser to finer grids)

Comparison of Conservative Methods

Source:
10 degree uniform global

Analytic field:
F = 2+cos(lon)^2 * cos(2*lat)

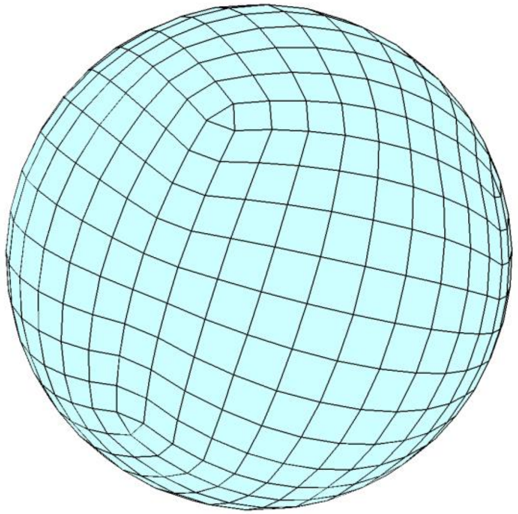


Destinations:
2 degree uniform global

First-Order Conservative

Second-Order Conservative

Cubed Sphere Shortcuts



- Two ways to represent cubed sphere grids in ESMF:
  1. **Unstructured Mesh**
     - data fields are 1D
     - more efficient for calculating regridding weights
     - Better fit for irregular HOMME grids

  1. **Multi-tile Grid**
     - data fields are 2D which more naturally matches shape of tiles
     - Better fit for regular FV3 grids
- Both representations can be regridded to other ESMF geometry types (i.e. Grids, Meshes, and Location Streams)
- Three **new APIs** to allow easier creation of cubed spheres in ESMF:

  ESMF_MeshCreateCubedSphere(tileSize, ...)

  ESMF_GridCreateCubedSphere(tileSize, …)

  ESMF_GridCreateMosaic(filename, ...)

  (Create from GFDL Gridspec format mosaic file)

Integration of MOAB

- Underneath ESMF_Mesh and ESMF grid remapping code is a custom built 3D finite element code

- The idea is to replace that code with an externally developed finite element code (DOE's MOAB - Mesh Oriented dAtaBase) to:
  - Get new capabilities:
    - Higher-order elements (elements with data on more than just corners and centers)
    - Data on edges
    - More flexible internal fields

  - Follow development advances

Status:

- Can optionally create an ESMF_Mesh built on MOAB internally
- Can compute ESMF conservative and regridding weights using these Meshes
- Close to complete for bilinear and other methods

Community Mediator for Earth Prediction Systems - CMEPS

A new effort is creating a community coupler using NUOPC software:

Goal is to replicate CESM and GFDL coupling strategies, and offer
- During-run grid remapping
- Easily reconfigurable run sequence
- Support for coupling hierarchies
- Compliance checking and development tools
- Greater interoperability with other NUOPC components

Exploring whether the community coupler can replace the NEMS mediator

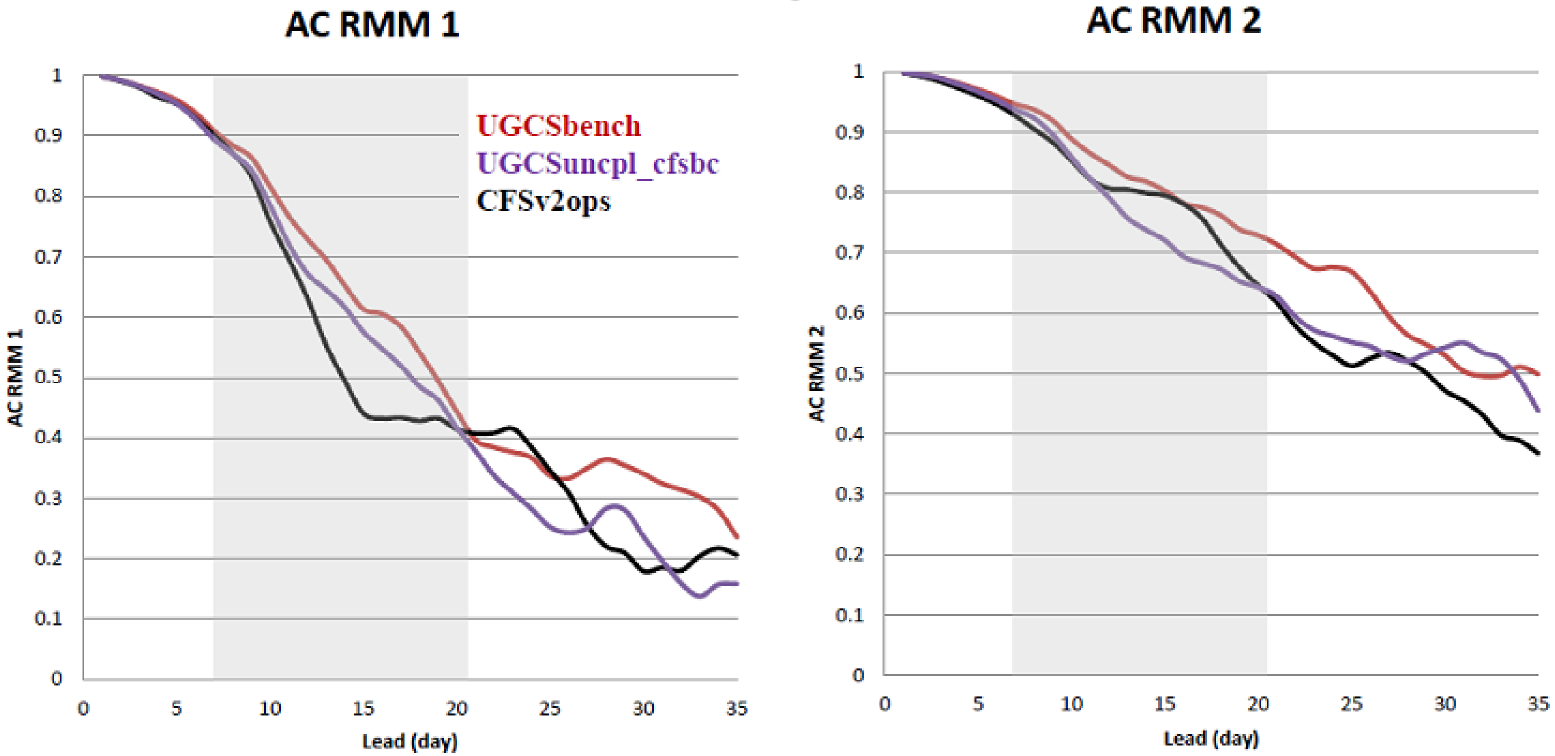
Unified Global Coupled System – S2S

- Delivered development version (0.4) of the Unified Global Coupled System – Seasonal (UGCS-**Seasonal**) running under NEMS in spring 2017, with fully coupled GSM, MOM5, and CICE components, initialized for a cold start and optimized for comparable performance with CFSv2.
- For more information, see: https://esgf.esrl.noaa.gov/projects/couplednems/

Unified Global Coupled System – Subseasonal Initial Benchmark

MJO Anomaly Correlation Skill

(144 cases covering 04/2011-03/2017)



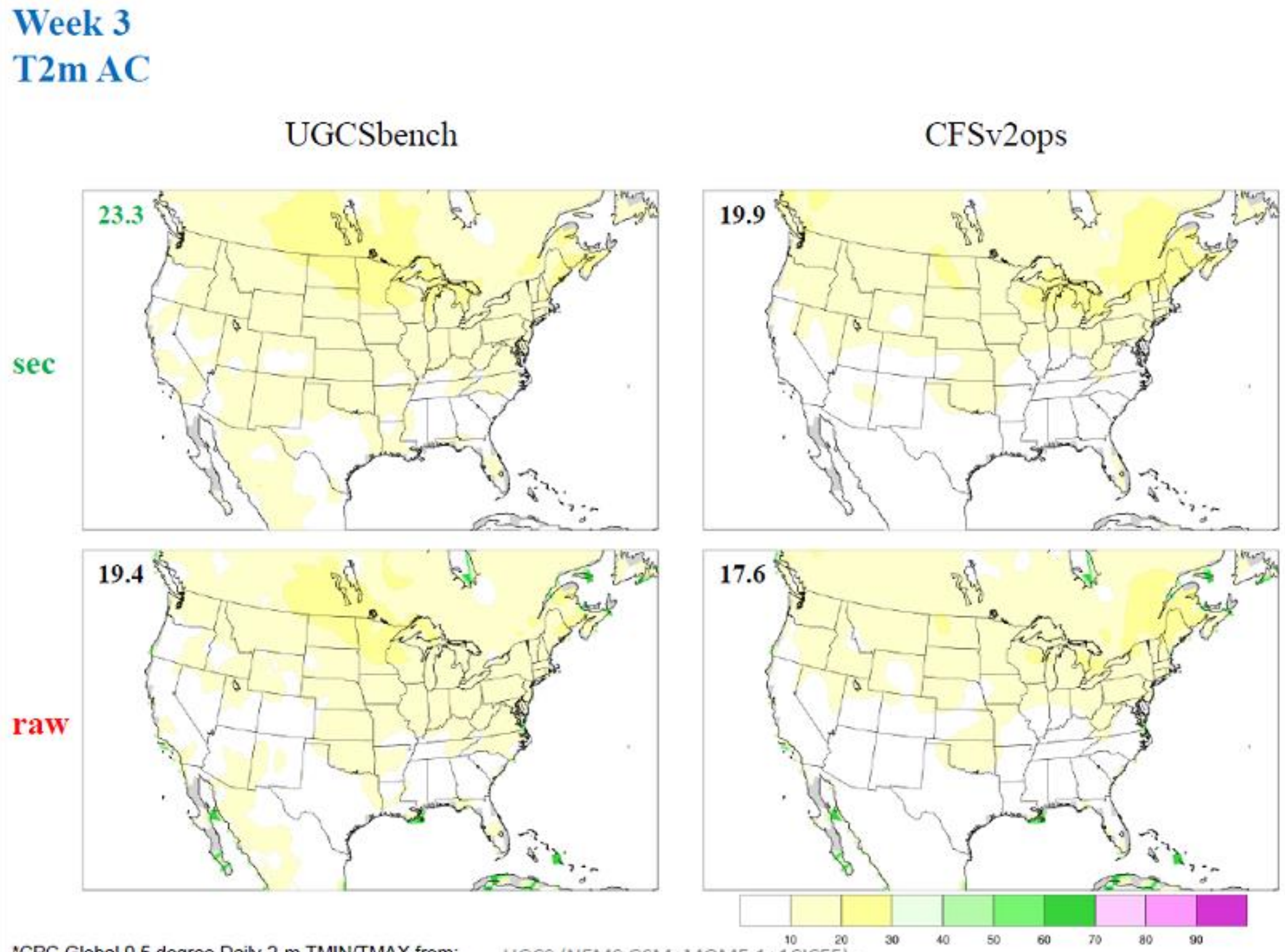
Week 2 & 3: UGCSbench generally has higher skill than uncoupled and CFSv2

All-seasons MJO's two leading modes (RMM1 and RMM2) of the combined timeseries of OLR, U850 and U200 equatorial anomalies. RMM1 series has the largest amplitude in the Maritime Continent and (negative) in the West. Hem. and Africa; RMM2 has largest amplitude in the Western Pacific and (negative) in the Indian Ocean.

CFSR verification u200,u850 and OLR

UGCS (NEMS GSM+MOM5.1+1CICE5) - Saha, Melhauser, Pena et al.

Unified Global Coupled System – Subseasonal Initial Benchmark



*CPC Global 0.5 degree Daily 2-m TMIN/TMAX from:
ftp://ftp.cpc.ncep.noaa.gov/precip/wd52ws/global_temp/
e.g., CPC_GLOBAL_T_V0.x_0.5deg.lnx.YYYY

UGCS (NEMS GSM+MOM5.1+1CICE5) -
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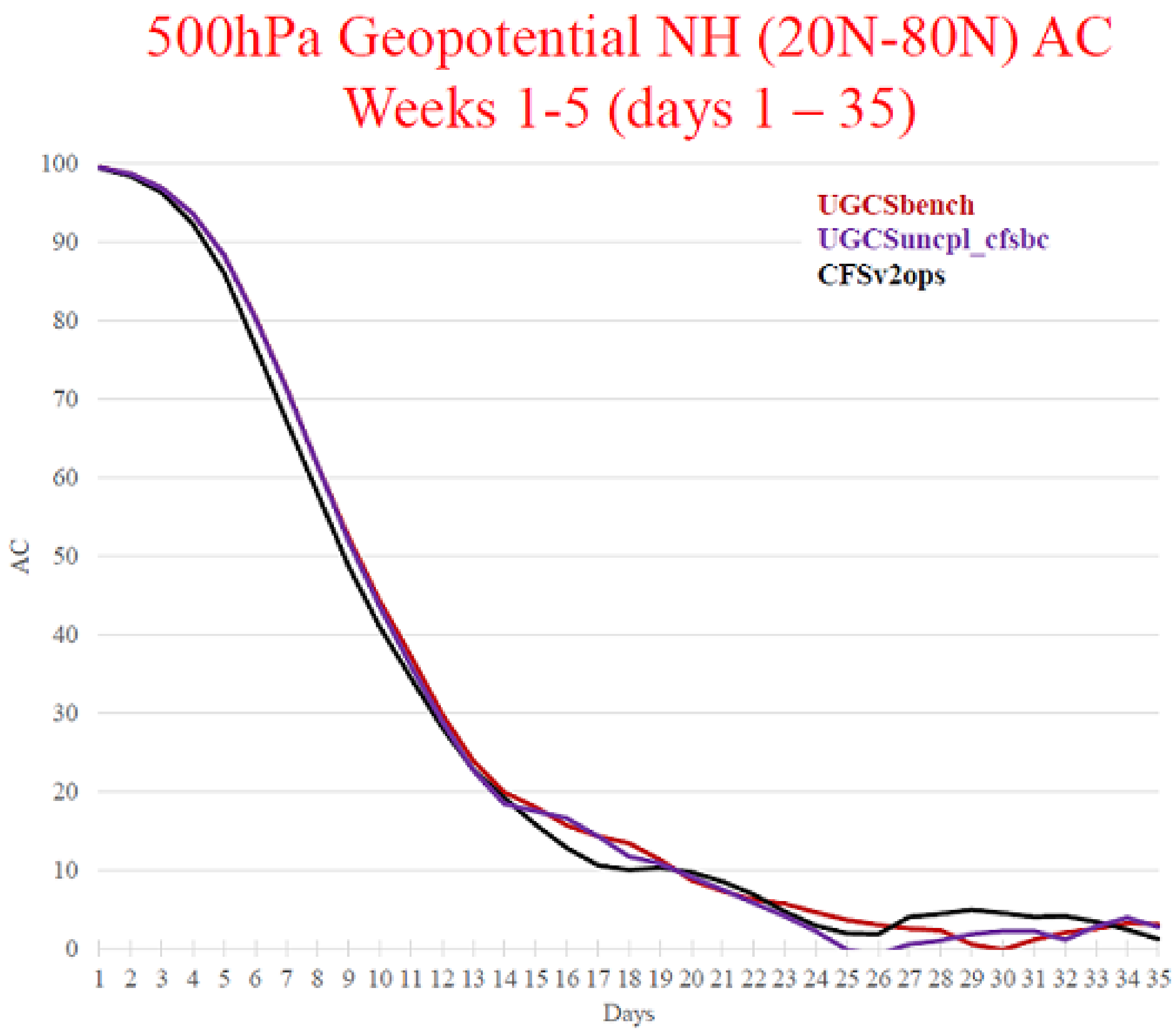
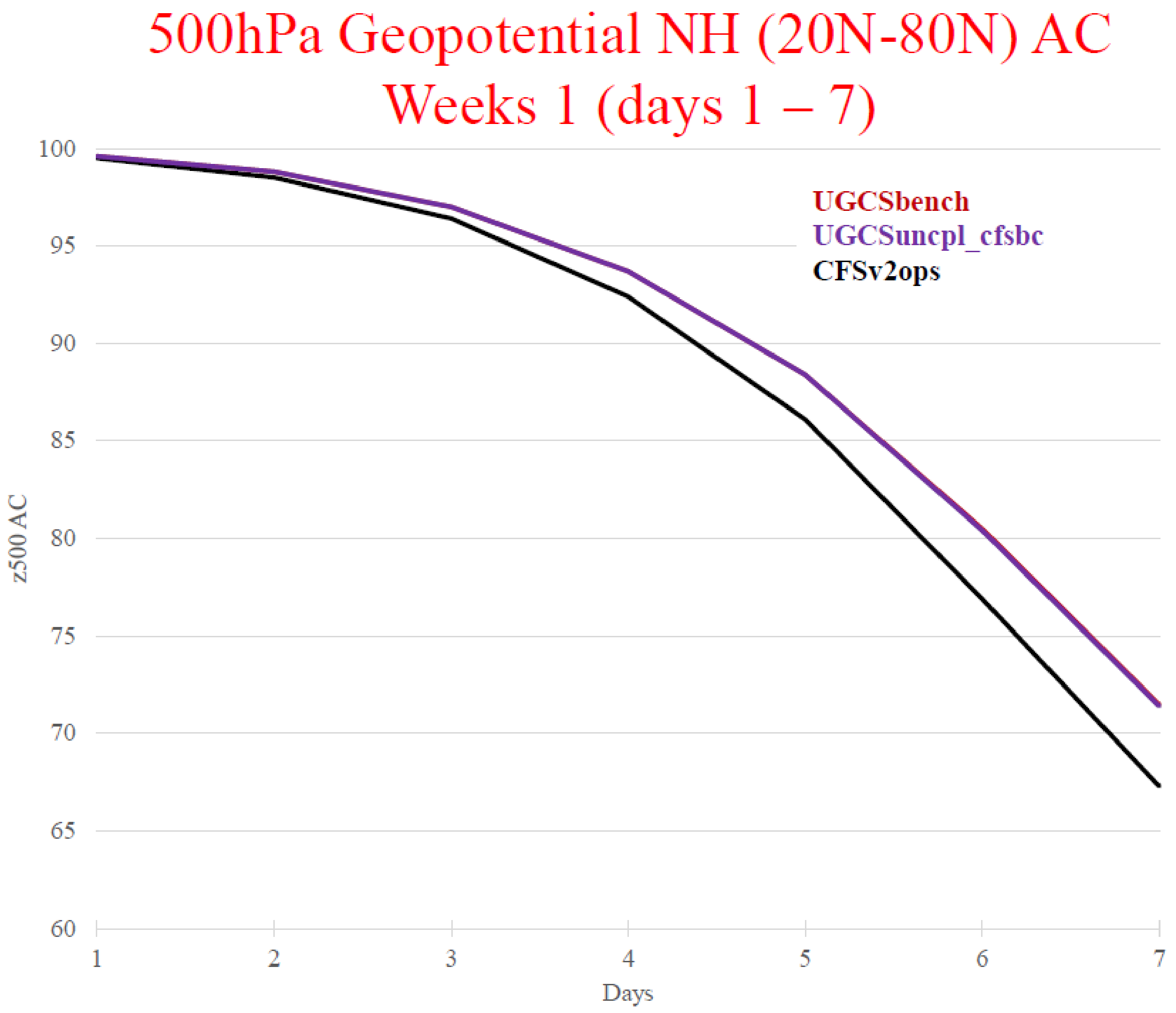


CFSR used for verification

Unified Global Coupled System – Subseasonal Initial Benchmark



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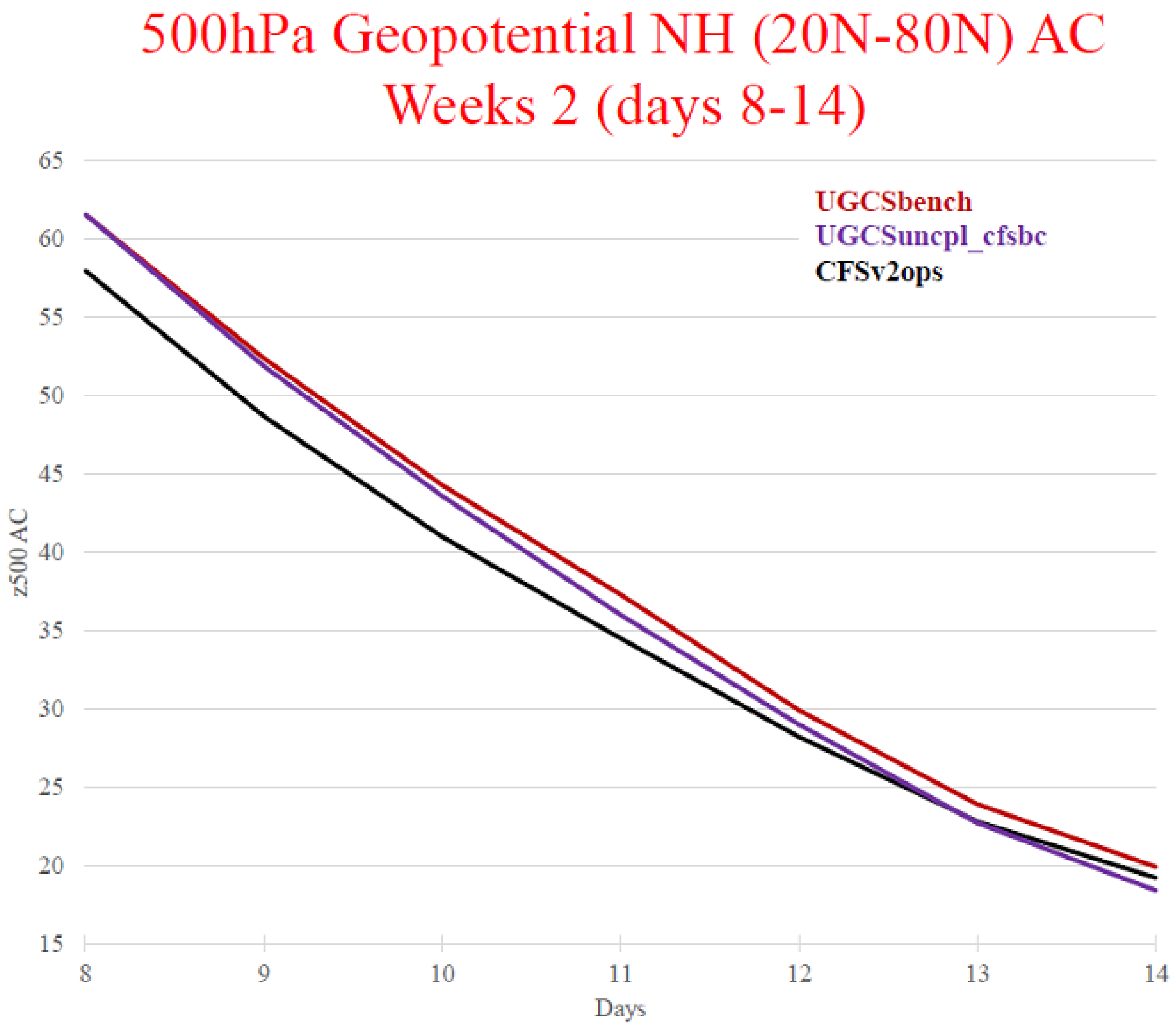

NEMS Open Issues and Next Steps

The current NEMS implementation uses a CESM-like central mediator with explicit coupling. Is this the right approach?

The evolution of infrastructure for NEMS requires answering the questions:

- Which processes need to able to run concurrently or on different grids? How should components be sequenced?
- Should we use an exchange grid?
- Should we couple some components implicitly?
- Where and how should we compute fluxes?
- Which interpolation methods and options should we use?

To answer these and other questions, a System Architecture Working Group (SAWG) has been assembled by EMC director Mike Farrar. In addition to EMC, the working group engages experts in the integrative science of building coupled applications, from GFDL, ACME, CESM, NASA, Navy, and other centers. Jim Kinter and Cecelia DeLuca are the co-chairs.

First report: https://esgf.esrl.noaa.gov/site_media/projects/sawg/System_Architecture_31Mar2017.pdf

Thank you! Comments or questions?