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National Centers for Environmental Prediction (NCEP), NWS

AMS Annual Meeting, Seattle, WA
January 24, 2017
Outline

• Three-pronged Planning approach to enable change
  – Strategic plan/vision: High-end view, broader modeling enterprise
  – Roadmap: Where to go in 5-10 years, more detail, longer view
  – Strategic Implementation Plan: What to do right right now (next 2-3 years) to move towards vision of Strategic Plan and Roadmap

• Evolution of Community-based Unified Modeling System
  – What is NOAA’s vision for the community? How do you get involved?

• What’s next?
  – Upcoming model development/transitions: What’s on the horizon?
  – Environmental Model Center (EMC) strategic changes: How is EMC evolving to meet these challenges?

• Summary and Next Steps
Strategic Planning Approach for Unified Modeling

- Traditional approach would begin with long term vision codified in mature Strategic Plan, followed by Implementation Plan that lays out implementation details needed to execute the vision
- For challenges associated with unified modeling across spatial and temporal scales, a mature Strategic Plan is a long-term process
  - If we were to wait for a mature Strategic Plan before any implementation activities, many months or years would be lost towards the end goal
- Therefore we are taking a concurrent, parallel planning approach
  - **High-level/broad Strategic Plan** being led by NWS/OSTI (Hendrik Tolman)
    - High-level Strategic Plan + accompanying detailed Roadmap document
  - **Short-term (0 to ~2-3 years) Strategic Implementation Plan (SIP)** combines implementation activities with near-term strategic actions
    - Led by NWS/NCEP/EMC (Mike Farrar) with NOAA and external partners
Strategic Vision

Key Elements

• Focus on products supporting mission requirements
• Unified modeling and data assimilation
  – Coupled, ensemble based, reforecast and reanalysis
  – Including pre- and postprocessing, calibration, verification validation
• Focus on community modeling
• Evidence-driven decisions
• Same standards for all who contribute
• Transparent and robust governance
  – Service requirements
  – Technical requirements / solutions
  – Prioritization
Strategic Vision

Temporal Domains

Unified Coupled Model

Unified Data Assimilation

- Year+
  - (decadal-centennial)
- Year
  - (seasonal)
- Month
  - (outlook/sub-seas.)
- Week
  - (weather)
- Day
  - (rapid refresh)
- Hour
  - (Warn on Forecast)
- Now
  - (analyses)

<table>
<thead>
<tr>
<th>Global</th>
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<tr>
<td></td>
<td></td>
<td>Regional refinement</td>
<td>Regional refinement</td>
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<tr>
<td>Down-scaling</td>
<td>Down-scaling</td>
<td>Regional</td>
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Roadmap

Starting from the quilt of models and products created by the implementing solutions rather than addressing requirements . . .

... we will move to a product based system that covers all present elements of the productions suite in a more systematic and efficient way.
ESMF/NUOPC/NEMS architecture enables unified global coupled modeling and DA

Consistent with broader NOAA (UMTF) and US vision (National ESPC)

Courtesy Developmental Testbed Center
Roadmap

- What could the 5-10 year “end state” tentatively look like?
  - Living estimates below; corresponding resource needs on next slide

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<thead>
<tr>
<th>Element</th>
<th>Cadence</th>
<th>Range</th>
<th>Resol.</th>
<th>Ens.</th>
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<tr>
<td>SGS</td>
<td>7 d</td>
<td>9-15 mo</td>
<td>50 km (g)</td>
<td>28</td>
<td>4 y</td>
<td>1979-present</td>
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<tr>
<td>SSGS</td>
<td>24 h</td>
<td>35-45 d</td>
<td>35 km (g)</td>
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<td>20-25 y</td>
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<td>7-10 d</td>
<td>13 km (g)</td>
<td>26</td>
<td>1 y</td>
<td>3 y</td>
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<tr>
<td>RRGS</td>
<td>1 h</td>
<td>18 h</td>
<td>3 km (r)</td>
<td>26</td>
<td>1 y</td>
<td>TBD</td>
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<tr>
<td></td>
<td>6-12 h</td>
<td>30 h</td>
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<tr>
<td></td>
<td>6-12 h</td>
<td>60 h</td>
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<tr>
<td>WoFGS</td>
<td>5-15 min</td>
<td>2-4h</td>
<td>1 km (r)</td>
<td>26</td>
<td>1 y</td>
<td>TBD</td>
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</table>

Analyses

- Trad. 6-24 h --- Var. (g) --- 6 mo ---
- RUA 15 min --- TBD (r) --- 6 mo ---

SGS = Seasonal Guidance System
SSGS = Sub-Seasonal (Outlook) Guidance System
WGS = Weather Guidance System
RRGS = Rapid Refresh Guidance System
WoFGS = “Warn on Forecast” Guidance System

(g) Global
(r) regional
Red: uncharted territory
Roadmap

• “End state” is associated with cost
• Requirement focus will shift high % of compute needs to CAM models.
• Total machine size needed for all element except for Warn on Forecast Guidance System (WoFGS) is approximately 37 PFlop
  – Peak performance, accounting for all elements in production suite and for fractional machine use.
• Data storage and access critical

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<thead>
<tr>
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<th>SGS</th>
<th>SSGS</th>
<th>WGS</th>
<th>RRGS</th>
<th>WoFGS</th>
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<tr>
<td>PFlop</td>
<td>0.19</td>
<td>0.33</td>
<td>4.98</td>
<td>9.17</td>
<td>89.1a</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.91b</td>
</tr>
<tr>
<td>Fraction</td>
<td>1.3%</td>
<td>2.2%</td>
<td>34%</td>
<td>63%</td>
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</table>

\(^a\) Assuming same spatial coverage as RRGS
\(^b\) Assuming 10% of spatial coverage as RRGS
\(^c\) State before implementation of WoFGS
Strategic Implementation Plan (SIP) for Unified Modeling

- **Goal:** Single plan that integrates R&D, testing/eval, R2O and implementation activities of NOAA + external partners in common goal of building National unified modeling system across temporal and spatial scales
  - Use Next Generation Global Prediction System (NGGPS) as foundation to build upon
- **Community:** Engage community on several levels for varying roles:
  - **Researchers, Users, Stakeholders:** Conducts research and testing on publicly available model baseline; long-term science contributions; builds next-gen STEM workforce
  - **Trusted Super-users:** Select R&D users that test/evaluate prototype models under development by core development partners prior to baselining and public release
  - **Core Development partners:** Orgs actively involved in development of next-gen operational unified modeling system. Orgs include NOAA ops, R&D and program offices; NCAR; NASA/GMAO; Navy/NRL; JCSDA
  - **Operations:** Centers that own/operate operational version of unified modeling system. For NOAA, this equates to the NCEP Production Suite
- **Approach for SIP development:** Begin with existing core R&D partners to quickly draft SIP components via functional area Working Groups; then bring together broader community in public workshop to begin building SIP version 1.0
Strategic Implementation Plan (SIP)

Working Groups

- **Governance**
  - Decision making, roles/responsibilities, advisory boards, org. alignment

- **Communications and Outreach**
  - Common messaging strategy

- **Convective Allowing Models (CAMs)**
  - Intermediate steps to CAM ensembles, Warn on Forecast; test/eval w/community

- **System Architecture**
  - NEMS evolution; community approach

- **Infrastructure**
  - Standards/doc; CM; code repository; etc.

- **Testing and Testbeds**
  - Role of testbeds; regression testing; etc.

- **Verification & Validation (V&V)**
  - V&V of ops forecasts vs. R&D testing/eval; unified/standard tools and data formats

- **Dynamics and Nesting**
  - FV3 transition on global wx/S2S/climate; moving nests for hurricanes

- **Model Physics**
  - Common Comm. Physics Pkg (CCPP); stochastic, scale-aware physics

- **Data Assimilation**
  - FV3 integ. between NOAA, NASA; Joint Effort for DA Integ (JEDI); coupled DA

- **Ensembles**
  - Strategy across scales; model uncertainty

- **Post-Processing**
  - Comm. PP infrastructure; std formats/tools

- **Component Model sub-groups**
  - Marine models + NOS coastal/bay models
  - Aerosols and Atmospheric Composition
  - Land Sfc Models (LSMs) + hydrology (OWP)

- **New WG or addition**
- Augmentation of existing NGGPS group
Strategic Implementation Plan (SIP)

Schedule

- Nov 2016: SIP Planning Meeting at ESRL (Boulder, CO)
- Dec 2016: Establish Working Group membership and co-chairs
- Jan 2017: Brief approach at AMS Town Hall Meeting (Seattle, WA)
- Mar 2017: WGs initial recommendations/findings/SIP inputs due
- Apr 2017: Community Workshop (College Park, MD)
  - More on next slide ... “How can you get involved?”
- ~ Summer/Fall 2017: Meeting to draft SIP v1.0 (location TBD)
  - Incorporate Community inputs; SIP v 1.0 will be initial, “living” document
- Potential for forums at upcoming major conferences
  - AGU (Dec 11-15, 2017; New Orleans)
  - AMS (Jan 7-11, 2018; Austin TX)
  - Any others? Seeking additional ideas from the community...
Mission of FV3 Community: Improve environmental modeling forecast capability unified across time and space for both research and operations
  • Develop the next generation of scientists
  • Conduct research for improved scientific understanding and innovation
  • Engage with community to improve transition of research to operations
  • Build the world’s best operational capability

The FV3 community will be guided by:
  • Shared goals, objectives and “ownership” with transparent governance
  • Inclusive and collaborative development, testing and evaluation
  • Balance of operational, research and end-user needs and priorities
  • Scientific capability and credibility
  • Strong partnership between research and operations

Community Engagement: Upcoming April 2017 Workshop open to all

Unprecedented opportunity to develop and advance a world-class unified modeling system for the Nation!
NOAA NGGPS FV-3-based Unified Modeling System: Vision for Community

- Operations
- Core Developers
- Researchers, Users & Stakeholders
- “Super Users”

Shared Infrastructure, Support & Governance

Inclusive of Public, Private, and Academic Sectors
Evolution of Community-based Unified Modeling System

*How do YOU get involved?*

- **Community Modeling Workshop**: College Park, MD (April 18-21, 2017)
  - Refinements of community vision; input on how community will engage;
  - How community-based unified modeling *will actually work*
  - Governance, code repositories, testing and evaluation, etc.
  - Priorities on development of unified system + how it impacts schedule
  - Further information at: https://www.weather.gov/sti/stimodeling_nggps

- **Get involved in Strategic Implement. Plan (SIP) Working Groups**
  - Working Groups seeking members from broad R&D community
  - To inquire, contact: michael.farrar@noaa.gov

- **Participate in NGGPS calls for proposals**
  - Anticipate initiating next Federal Funding Opportunity in Fall 2017 for Summer 2018 award
## GFS Changes Implemented/Planned (FY15-20)

*(Blue represents significant upgrade)*

<table>
<thead>
<tr>
<th>GFS Implementation</th>
<th>Q2FY15 GFS V12.0</th>
<th>Q3FY16 GFS V13.0</th>
<th>Q3FY17 GFS V14.0</th>
<th>Q3FY18 GFS V15x (beta)</th>
<th>Q3FY19 GFS V15.0</th>
<th>Q3FY20 GFS V16.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resolution</strong></td>
<td>T1534 (13 km) L64</td>
<td>T1534 (13 km) L64</td>
<td>T1534 (13 km) L64</td>
<td>C768 (13 km) L64</td>
<td>C1152 (9 km) L128</td>
<td>C1152 (9 km) L128</td>
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<tr>
<td><strong>Physics</strong></td>
<td>RTG SST RRTMG McICA Hybrid EDMF PBL GLDAS/Noah LSM</td>
<td>Noah LSM Upgrades</td>
<td>NSST Noah LSM Scale-aware SAS TKE Moist EDMF PBL</td>
<td>NUOPC Physics Driver</td>
<td>Advanced Physics TBD</td>
<td>Advanced Physics (TBD)</td>
</tr>
<tr>
<td><strong>Dynamics</strong></td>
<td>- Semi-Lagrangian - Tracer fixer - Gravity wave drag</td>
<td>None</td>
<td>None</td>
<td>FV3</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td><strong>DA</strong></td>
<td>- T574 Ensemble - CRTM v2.1.3 - SSMIS, MetOp-B IASI - GOES hourly AMVs</td>
<td>- All-sky radiances - 4D Hybrid</td>
<td>JPSS, CrIS and GOES-R Ready SEVIRI IR; VIIRS GOES WV Winds GPSRO RARS &amp; DBNET</td>
<td>GSI for FV3 - GOES-R &amp; JPSS data</td>
<td>- JEDI/Unified forward operator</td>
<td>DA on FV3 grid</td>
</tr>
<tr>
<td><strong>Products</strong></td>
<td>- Frozen precipitation fraction</td>
<td>- Hourly output - Five more levels</td>
<td>1/8 degree products</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
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<tr>
<td><strong>Significant Component</strong></td>
<td>Semi-Lagrangian 13 km Improved Physics</td>
<td>4D EnVAR LSM upgrades</td>
<td>NEMS/ESMF LSM upgrades</td>
<td>GFS/FV3 (prototype only)</td>
<td>Operational GFS/FV3</td>
<td>- Advanced Physics/CCPP - DA on FV3 grid</td>
</tr>
</tbody>
</table>

### Dates

- Jan 14, 2015 Done
- May 11, 2016 Done
- May 10, 2017 Planned
- Planned
- Planned
- Planned

*Today*
### Implementation Plan of FV3GFS (FY17-FY19)

<table>
<thead>
<tr>
<th>FY 17</th>
<th>FY 18</th>
<th>FY 19</th>
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<tbody>
<tr>
<td>Q1</td>
<td>Q2</td>
<td>Q3</td>
</tr>
<tr>
<td>Evaluate FV3 structure and document FV3 modeling system</td>
<td>Implement FV3 dycore in NEMS@</td>
<td>Couple FV3 to GFS physics (NUOPC physics driver) perform forecast-only experiments, tuning and testing</td>
</tr>
</tbody>
</table>

@ The targeted FV3GFS resolution is ~10km L128 with model top ~80 km.
& New physics: Scale-aware convection and PBL, Double-moment cloud and aerosol-aware microphysics, Unified convective and orographic gravity wave drag etc
% ~25km L128 4D-EnVAR data assimilation

Early experimental implementation of FV3GFS (~13km L64) w/cycled DA

Code delivery, NCO Parallel & operations

NEMS/ FV3GFS in operations
FV3-GFS
Development/Implementation Plan

- After Q3FY17 NEMS/GSM implementation (last spectral model upgrade), *all resources are diverted to FV3 implementation task*

- Benchmark FV3GFS with fully cycled DA to match or exceed the skill of operational GFS

- Experimental *early (parallel) implementation* of FV3GFS in Q2FY18

- Simultaneous development and testing of *advanced physics and higher resolution* for FV3GFS

- *First official implementation of FV3GFS in Q2FY19*
Proposed Plan for FV3-based GEFS v12
(sub-seasonal ensemble system)
with reanalysis and reforecast

Proposed changes: 1) Start producing FV3-based reanalysis for GEFS v12 in ~Q1 FY18, using the configuration of FV3GFS. 2) Reforecasts will commence soon after starting the reanalysis, uncoupled*, with 2-tier SST approach, and will include extension to 35 days.
GEFS Implementation Plans

Implications of Changes

- GEFS v12 implementation will use **FV3 dycore**, in close coordination with the FV3 deterministic GFS development
- GEFS v12 implementation will be **consistent** with EMC’s global modeling strategies of **unified system**
- Reanalysis production is performed with **FV3** system, not the obsolete spectral dycore
- ESRL reanalysis team participates in bringing FV3-based assimilation system **online more quickly** and **testing** an FV3-based GEFS,
  - Reduces **risk of delays** with FV3GFS implementation
Environmental Modeling Center (EMC) Strategic Changes

How is EMC evolving to meet new challenges?

- **Instill Project Management (PM) discipline**
  - PM training for all federal employees and contractor team/area leads
  - Quarterly PM Reviews for all EMC development and implementation projects

- **Shift model development resources from legacy models to FV3**
  - Next NAM and GFS (GSM) implementation will be the last, then freeze (port to Cray)
  - GFDL and EMC working early prototype parallel runs for FV3-GFS: already underway!
  - All global and meso model developers have FV3 as first element in FY17 Perf. Plans

- **EMC reorganization**
  - Old org structure (separate Global, Meso, and Marine Branches) built around legacy architecture of independent models; *reorganize around unified modeling system*
  - Consolidate science in single **Modeling & DA branch**: all work together inside unified framework; break down old global vs. meso stovepipes
  - New **Verification, Post-Processing, and Production Generation branch**: consolidate resources for efficiency and consistency; verification independent from development
  - New **Systems Engineering and Implementation branch**: consolidate resources for efficiency and consistency; greater focus on NEMS and community systems arch
Summary and Next Steps

- NGGPS provides golden opportunity; foundation to build upon to unite the ops and R&D communities with a next-generation National unified modeling system
- Strategic planning organized around 3-pronged approach
  - Strategic Plan: Broad, high-level strategic vision
  - Roadmap: More detailed evolution over 5-10 year time frame
  - Strategic Implementation Plan (SIP): Short-term (2-3 years) to move toward vision
    - Detailed planning broken down into Working Groups, now underway
- Community workshop (April 2017) to begin building approach and draft SIP v1.0
- NOAA already moving to replace legacy models (e.g., Global Spectral Model) with new FV3-based NGGPS modeling system; migration underway!
- NCEP/EMC taking concrete steps to evolve to unified modeling paradigm
  - PM discipline; Reorg around unified system; freeze legacy models, working on FV3

**NOAA and partners are working with broad community to build towards a National unified modeling system across time/space scales...join us!**