Strategic Implementation Plan (SIP) for a Community-based Unified Forecast System

NGGPS Global Model Suites Planned for NCEP/EMC Operations

Presented by

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Presented at SIP Coordination Meeting

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NGGPS Global Model Suites
Project Milestone Accomplishments

- **SIP/EIP project accomplishments towards development of Unified Forecast System to date:**

  - **FV3-Global Deterministic Forecast System (FV3-GFS)**
    - FV3GFS Beta implementation is converted into full transition to operations
    - FV3GFS V1.0 (GFS V15) is on target for implementation in Q2FY19 (January, 2019),
    - FV3GFS V1.0 Public Release made in March 2018
    - Advanced version of FV3GFS V2.0 (GFSV16) is targeted for Q2FY20

  - **FV3-Global Data Assimilation System (FV3-GDAS)**
    - FV3-GFS is assimilating new satellite datasets (GOES-16, NOAA-20)
    - Preparing FV3-GDAS to accommodate increased vertical resolution and higher model top for Q2FY20 (FV3GFS V2.0) implementation

NGGPS Global Model Suites
Project Milestone Accomplishments

- **SIP/EIP project accomplishments to date:**
  - **FV3-Global Sub-Seasonal Ensemble Forecast System (FV3-GEFS/GEFS V12))**
    - Finalizing FV3-GEFS Reanalysis and Reforecast Configurations
    - FV3GEFS Reforecasts and operational implementation in Q2FY20 will include extension to weeks 3&4 using 2-Tier SST approach and stochastic physics
    - Global Wave Ensembles will be absorbed by GEFS in operations.
    - NGAC chemistry component will be integrated into GEFS Control Member
  - **FV3-Seasonal Forecast System (FV3-SFS)**
    - Benchmarked UGCS GSM+MOM5+CICE5 for sub-seasonal forecast evaluation
    - Benchmarked UGCS GSM+MOM5+CICE5 for sub-seasonal forecast evaluation
    - Developing FV3+MOM6+CICE5 coupled system using NEMS/NUOPC mediator.
    - Developed unified data assimilation for marine components including ocean, ice and waves using Marine JEDI
    - FV3-SFS Project is merged with S2S Coupled Model Development Project with initial target implementation for FV3-GEFS V2.0 (GEFS V13)

NGGPS Global Model Suites Accomplishments

FV3GFS V1.0 is being configured to replace spectral model (NEMS GSM) in operations in Q2FY19

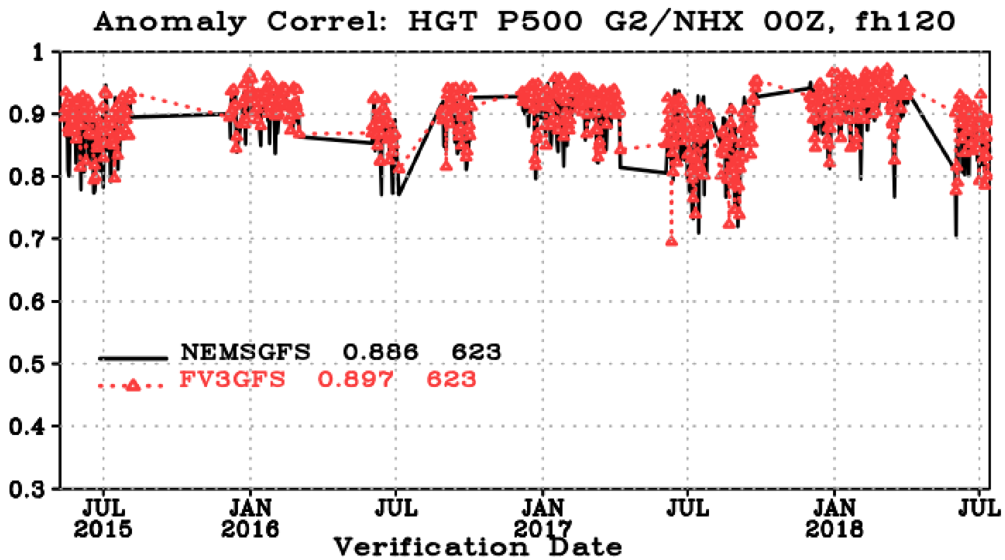
Configuration:

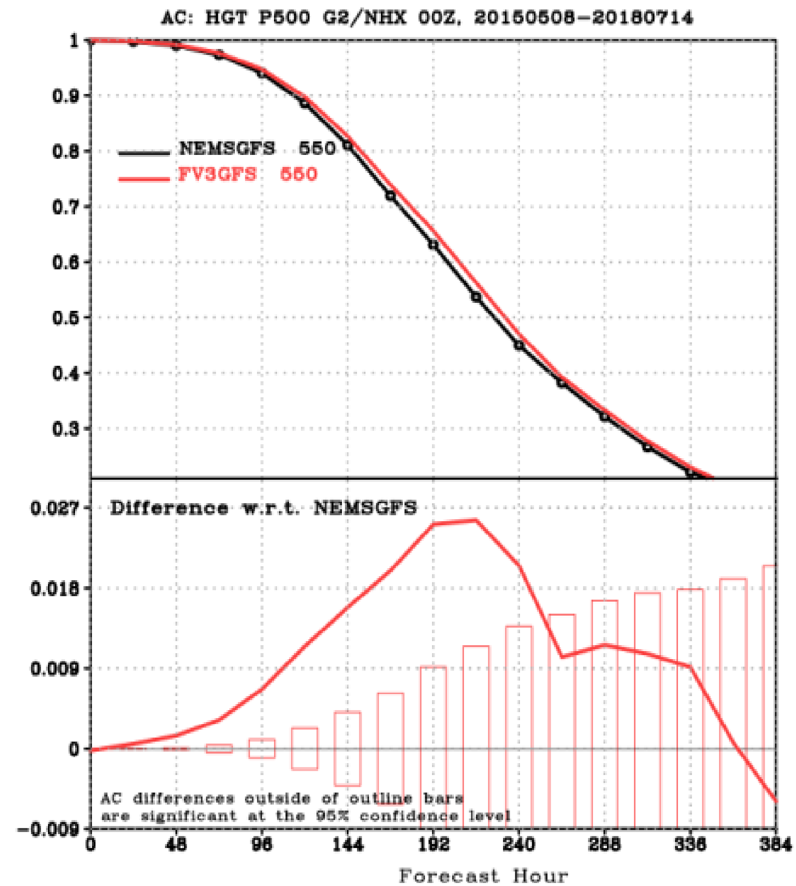
- **FV3GFS C768 (~13km deterministic);**
- **FV3GDAS C384 (~25km, 80 member ensemble);**
- **64 layer, top at 0.2 hPa;**
- **GFDL Microphysics + Rest of GFS Physics**
- **Uniform resolution for all 16 days**

Schedule:

- **3/7/18: code freeze of FV3GFS-V1 (GFS V15.0)**
- **3/30/18: Public release of FV3GFS-V1 code**
- **4/1 – 1/25/19: real-time EMC parallels**
- **5/25 – 9/10/18: retrospectives and case studies (May 2015 – September 2018; three summers and three winters)**
- **9/24/2018: Field evaluation due**
- **9/27/2018: OD Brief, code hand-off to NCO**
- **12/20/2018-1/20/2019: NCO 30-day IT Test**
- **1/24/2019: Implementation**

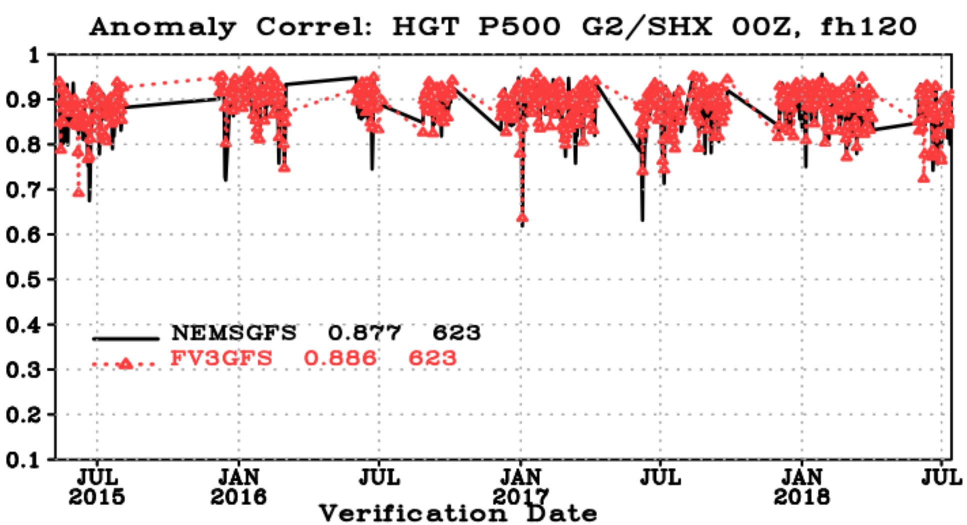
NGGPS Global Model Suites
Accomplishments

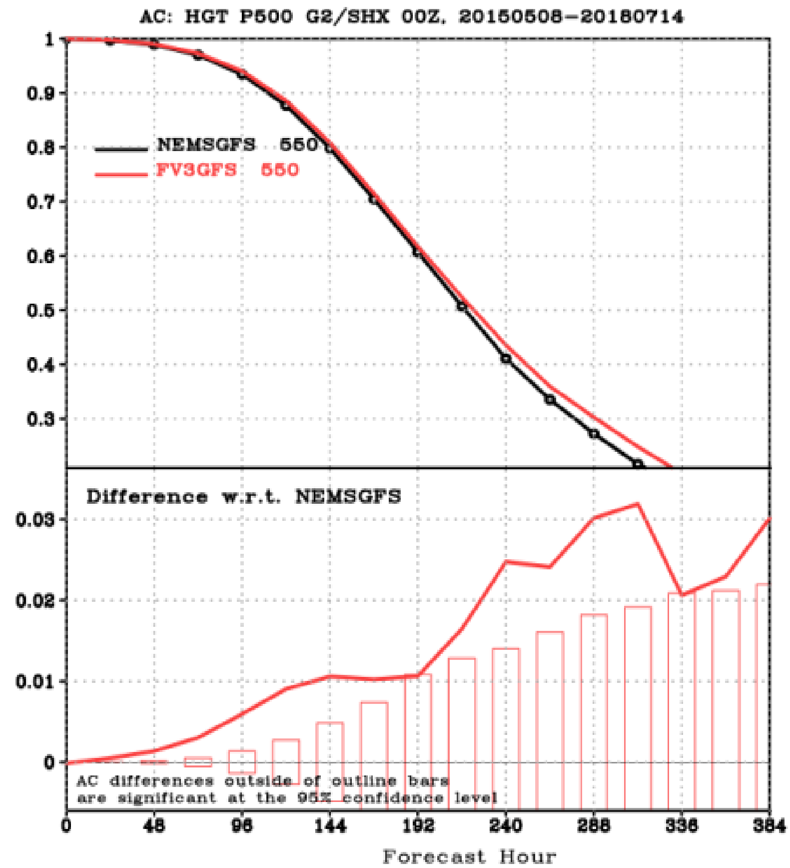




500-hPa HGT ACC, NH

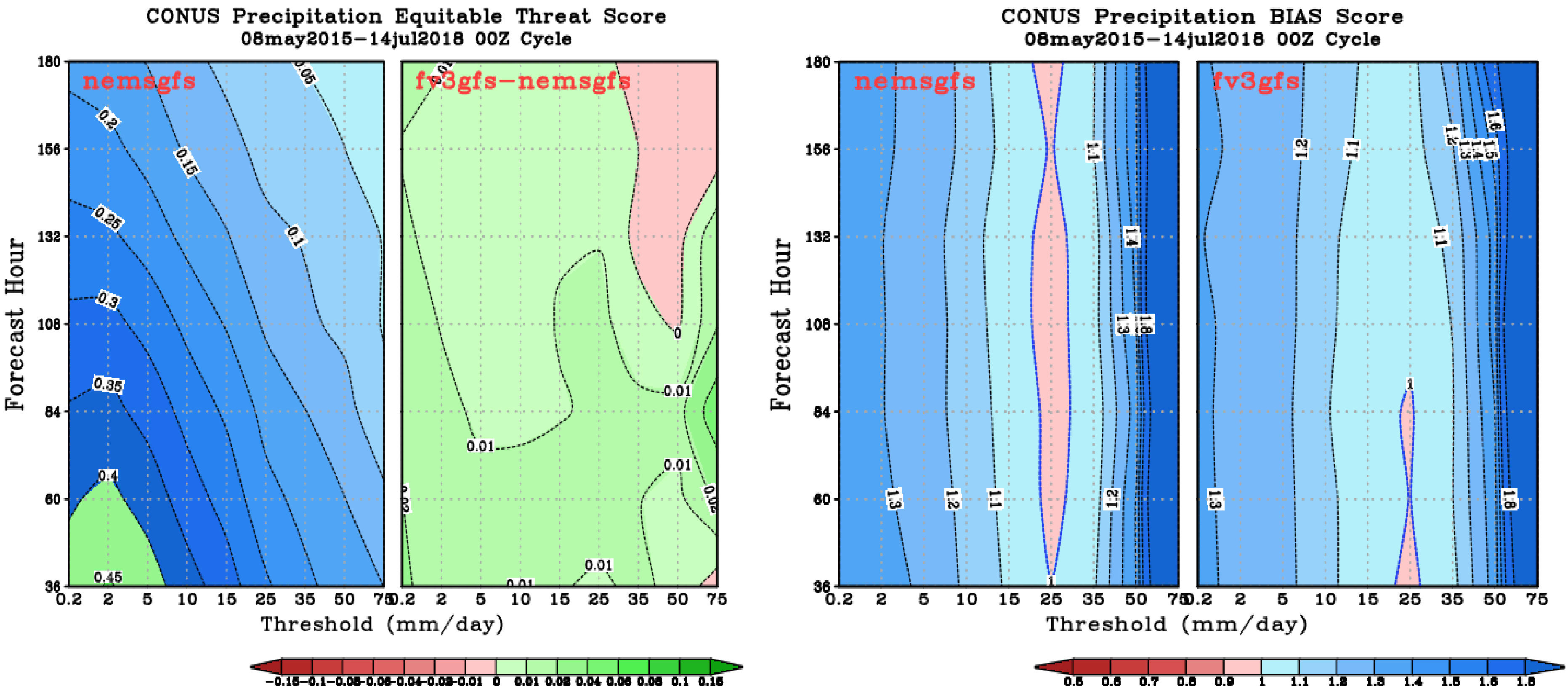
NGGPS Global Model Suites Accomplishments





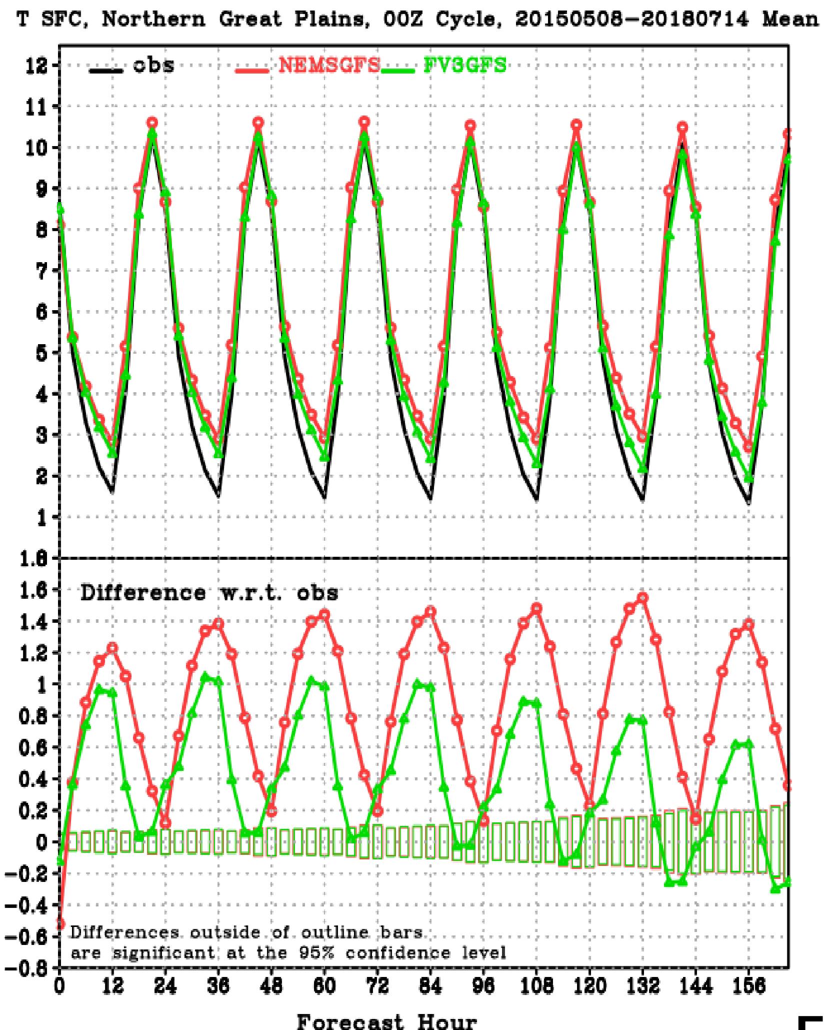
500-hPa HGT ACC, SH

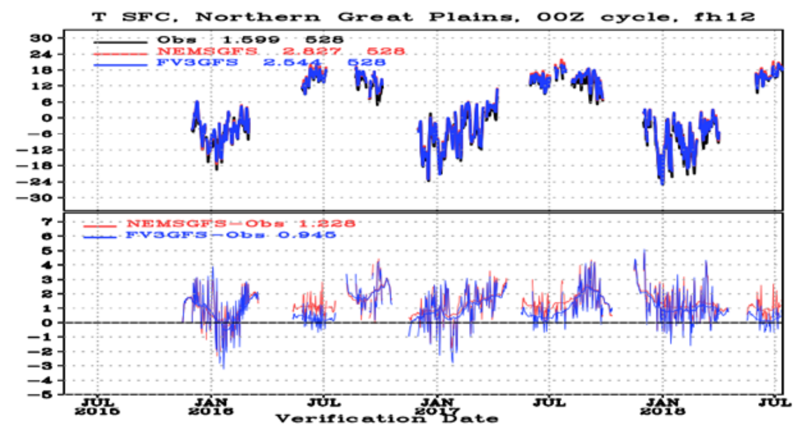
NGGPS Global Model Suites Accomplishments

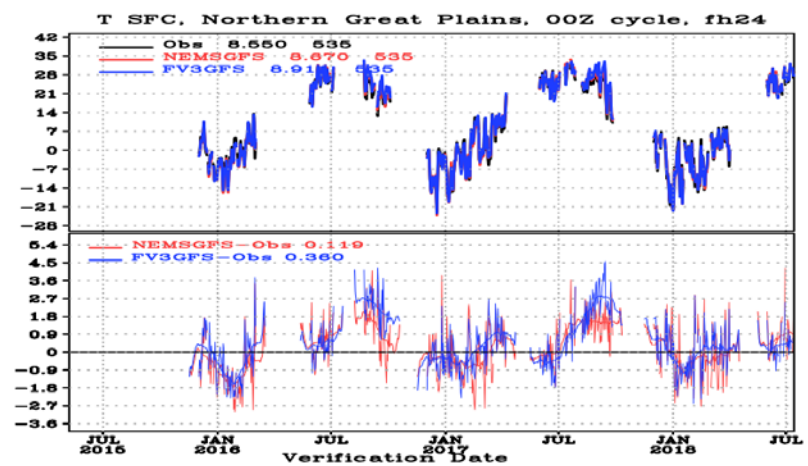


CONUS PRECIP ETS and BIAS Scores

NGGPS Global Model Suites
Accomplishments





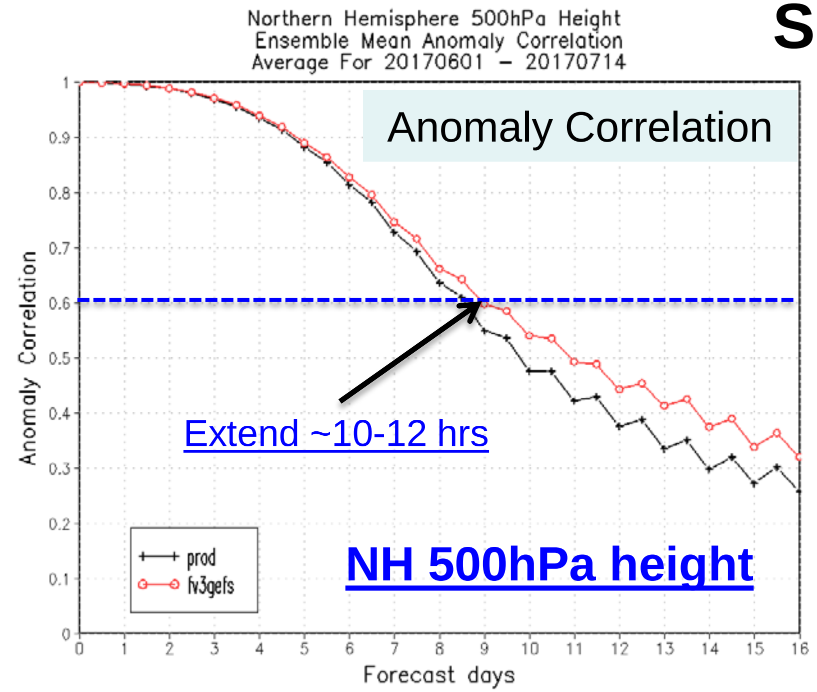


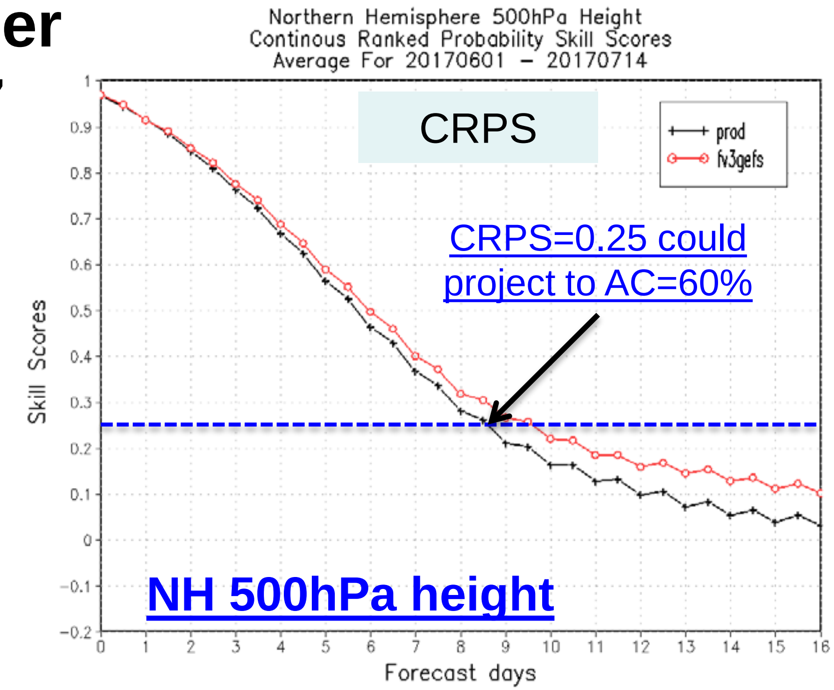
FIT2OBS, 2-m Temp, Northern Great Plains

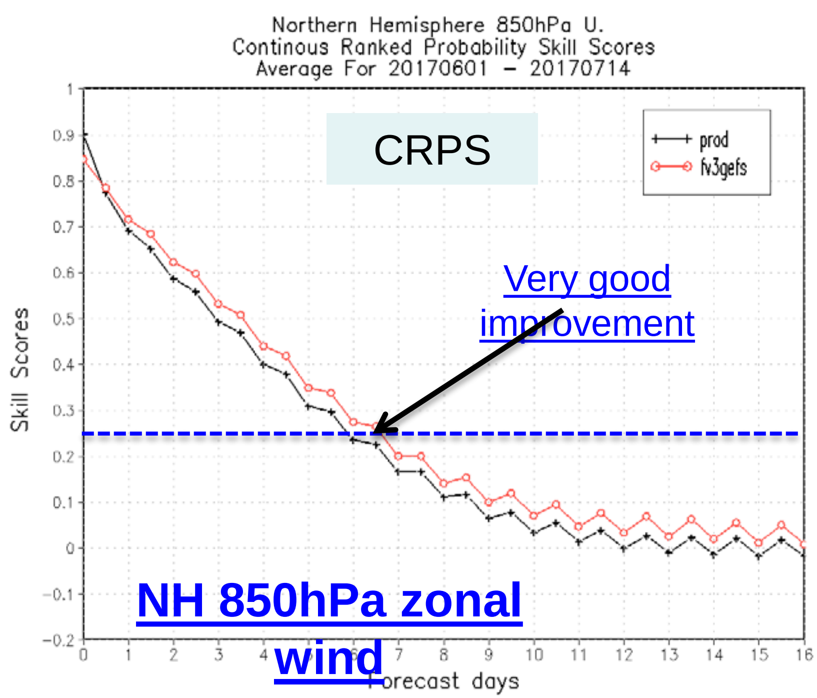
NGGPS Global Model Suites Accomplishments

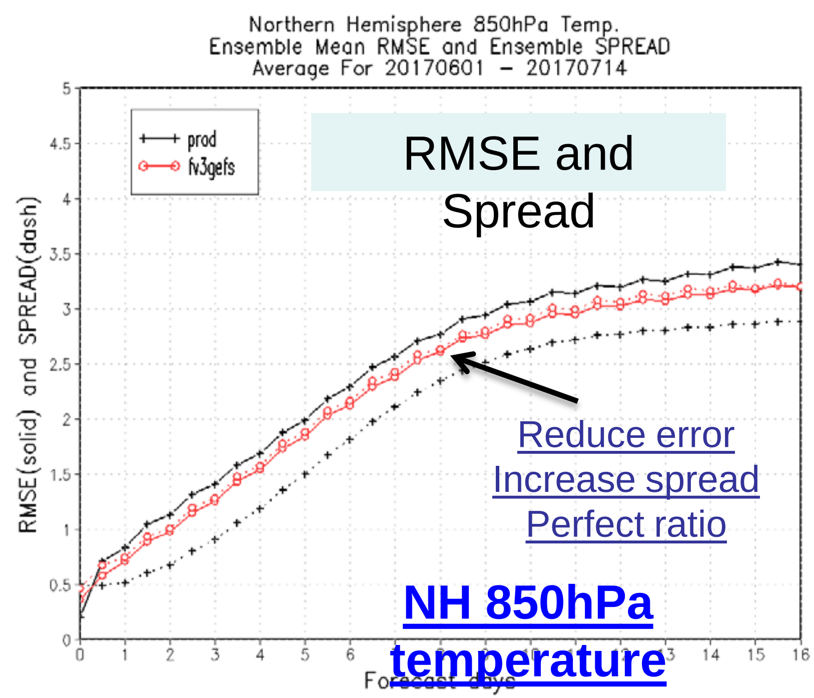
- **FV3-GEFS v12 is scheduled for implementation in Q2FY20**
- Resolution – C384 (~25km)
- **Lead time – 35 days**
- Ensemble members – 20 perturbed + 1 control
- Period: June 1 2017 – July 20 2017 (50 cases)
- Model and initial perturbations
  - Latest FV3GFS version with full cycle DA
  - GFS physics with GFDL MP
  - NSST – assimilate diurnal variation
  - EnKF f06 for ensemble initial perturbation
- Sciences
  - Three stochastic schemes (SKEB, SPPT and SHUM)
  - 2-tier SST
  - New SA convective parameterization scheme

Summer 2017

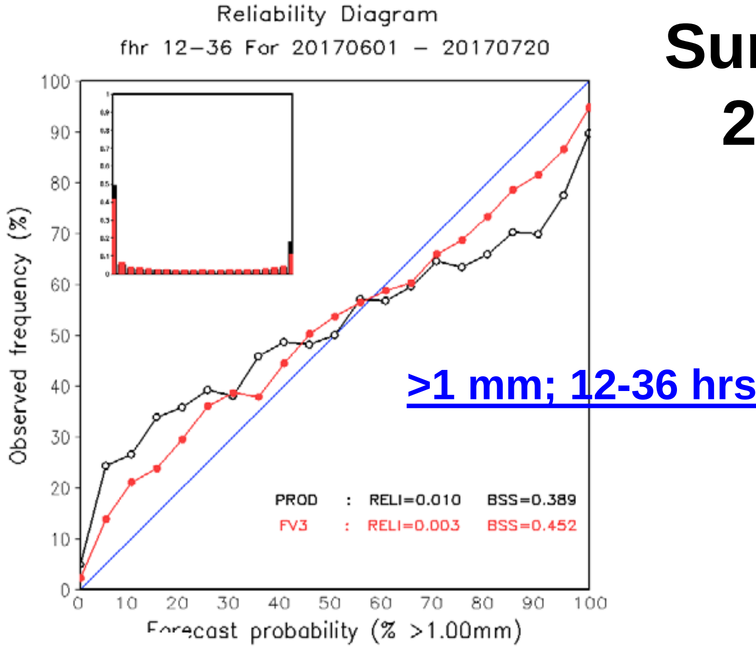

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For 20170601 – 20170714
Anomaly Correlation
Extend ~10-12 hrs
prod
fv3gefs
NH 500hPa height
Anomaly Correlation
Forecast days

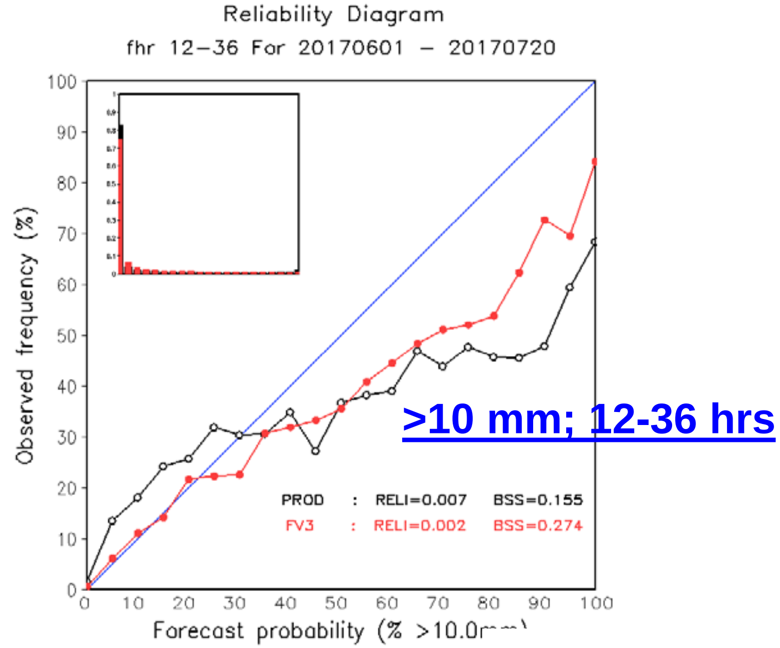

Northern Hemisphere 500hPa Height
Continous Ranked Probability Skill Scores
Average For 20170601 – 20170714
CRPS
prod
fv3gefs
CRPS=0.25 could project to AC=60%
Skill Scores
NH 500hPa height
Forecast days

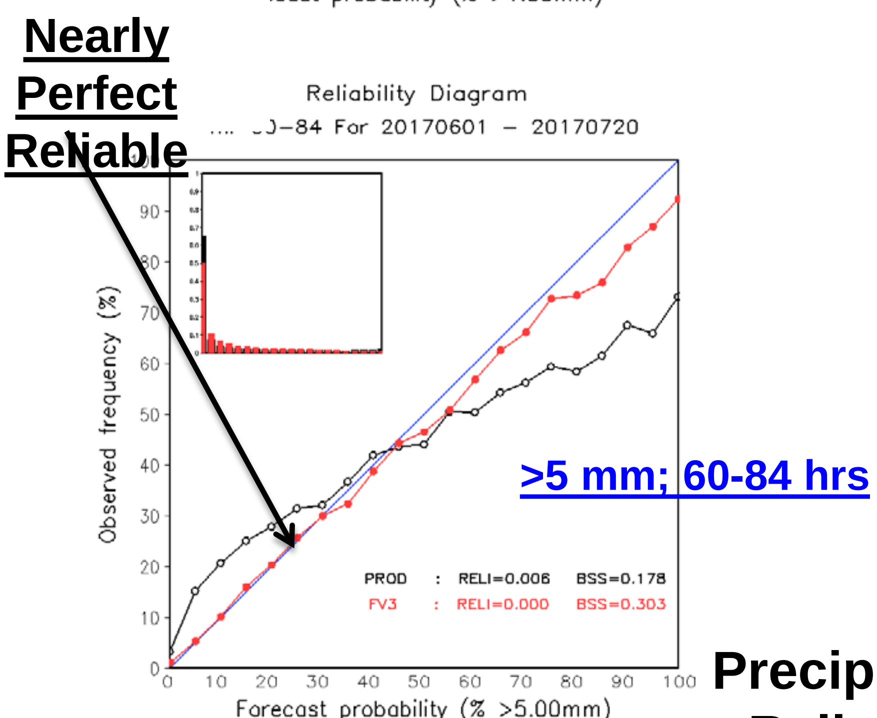

Northern Hemisphere 850hPa U.
Continous Ranked Probability Skill Scores
Average For 20170601 – 20170714
CRPS
prod
fv3gefs
Very good improvement
Skill Scores
NH 850hPa zonal wind
Forecast days

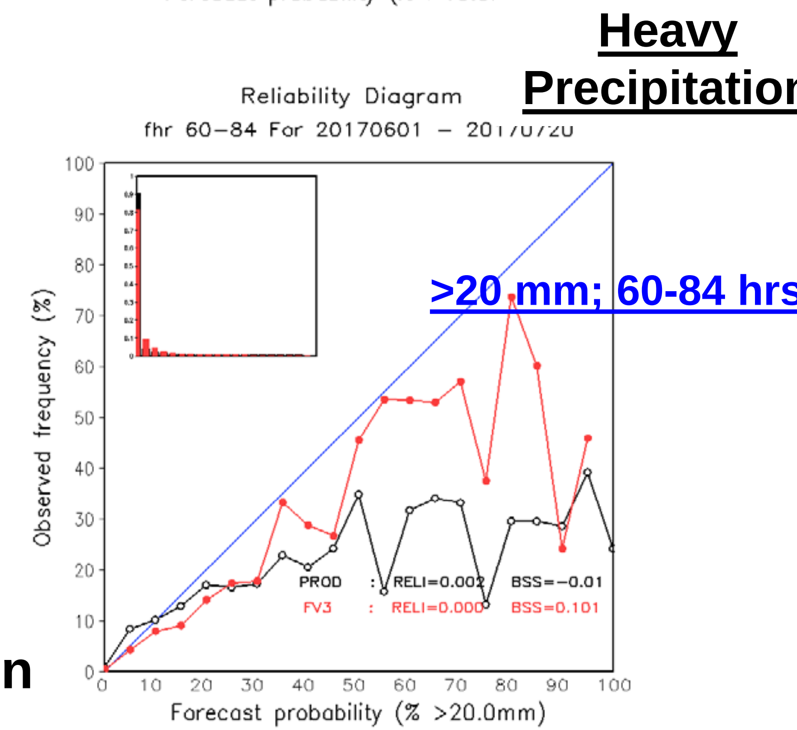

Northern Hemisphere 850hPa Temp.
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20170601 – 20170714
prod
fv3gefs
RMSE and Spread
RMSE(solid) and SPREAD(dash)
Reduce error
Increase spread
Perfect ratio
NH 850hPa temperature
Forecast days

Summer 2017

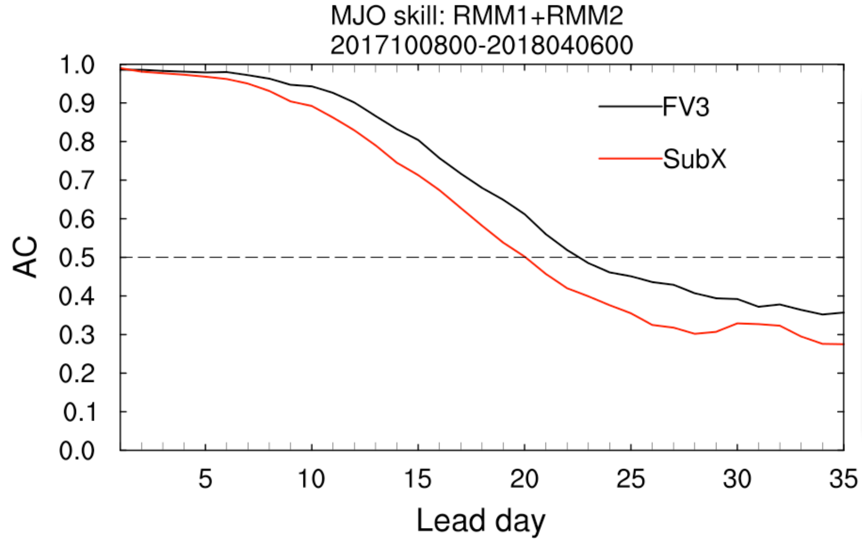








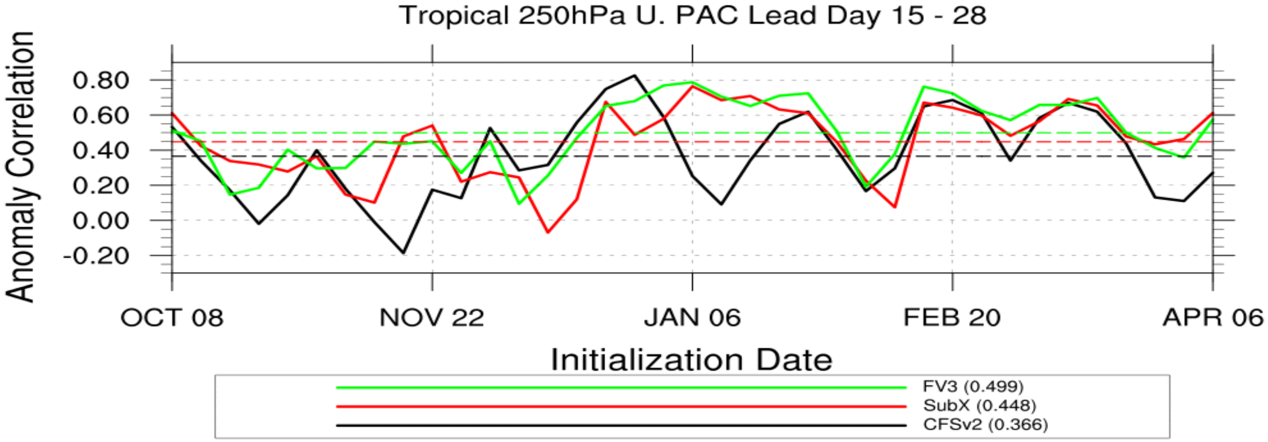
Precipitation Reliability



38 cases across six winter months (2017-2018)

Use operational initial conditions

Left: MJO skills
Bottom: Weeks 3&4 average AC

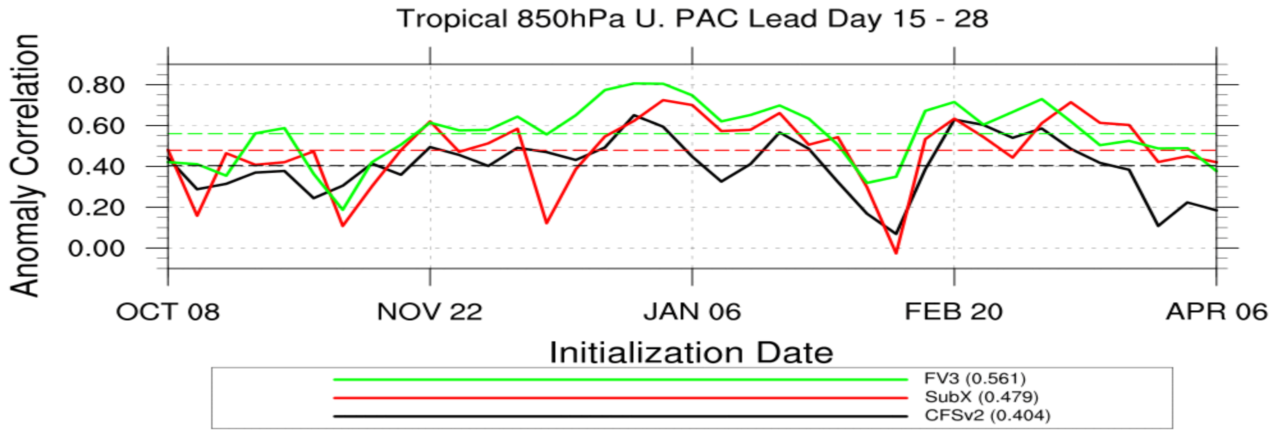


Tropical zonal wind
250hPa

CFSv2 --- 0.404
SubX --- 0.479
FV3 --- 0.561

Tropical zonal wind
850hPa

CFSv2 --- 0.366
SubX --- 0.448
FV3 --- 0.499



NGGPS Global Model Suites
Project Issues

- **SIP project issues:**
  - **FV3-Global Deterministic Forecast System (FV3-GFS)***
    - **Changing annual upgrade cycles to biennial period***
    - COMPUTATIONAL RESOURCES FOR Q2FY20 IMPLEMENTATION*
    - **Advanced physics development and testing at risk***
    - **Delayed development and readiness for CCPP*, CROW, and MET+**
  - **FV3-Global Data Assimilation System (FV3-GDAS)***
    - Increased vertical resolution and higher model top requires finalizing advance model configuration
    - **Delayed development and readiness for JEDI***
    - COMPUTATIONAL RESOURCES FOR Q2FY20 IMPLEMENTATION*

FV3GFS V2.0 Implementation Schedule is delayed to FY21

NGGPS Global Model Suites
Project Issues

- **SIP project issues:**
  - **FV3-Global Ensemble Forecast System (FV3-GEFS)***
    - Physics mods for sub-seasonal forecast extensions
    - <u>**Extremely slow progress on FV3 based coupled system development***</u>
  - **FV3-Seasonal Forecast System (FV3-SFS)**
    - Extremely slow progress on FV3 based coupled system development
    - Need accelerated development of Marine JEDI
    - Aerosol model development and data assimilation at risk
    - Lack of adequate resources

Coupled system for Sub-Seasonal Predictions delayed, will target to GEFS V13

NGGPS Global Model Suites
Team Coordination and Dependencies

- **General Team Coordination:**
  - Multiple meetings each week within EMC and with core partners
  - Weekly FV3GFS and FV3DA technical meetings
  - Bi-weekly Advanced Physics and Dynamics meetings
  - Regular interactions with GFDL, NASA/GMAO, ESRL GSD/PSD, DTC GMTB and CGD
  - Regular review of global modeling projects and coordination among various projects
  - Content and Project management through Vlab Redmine and Wiki/Forums

- **Dependencies**
  - Deliverables from almost all SIP WG and EIP Projects
  - JEDI, CCPP, CROW, MET+, Infrastructure, Software Architecture, code management and governance
  - Documentation and training

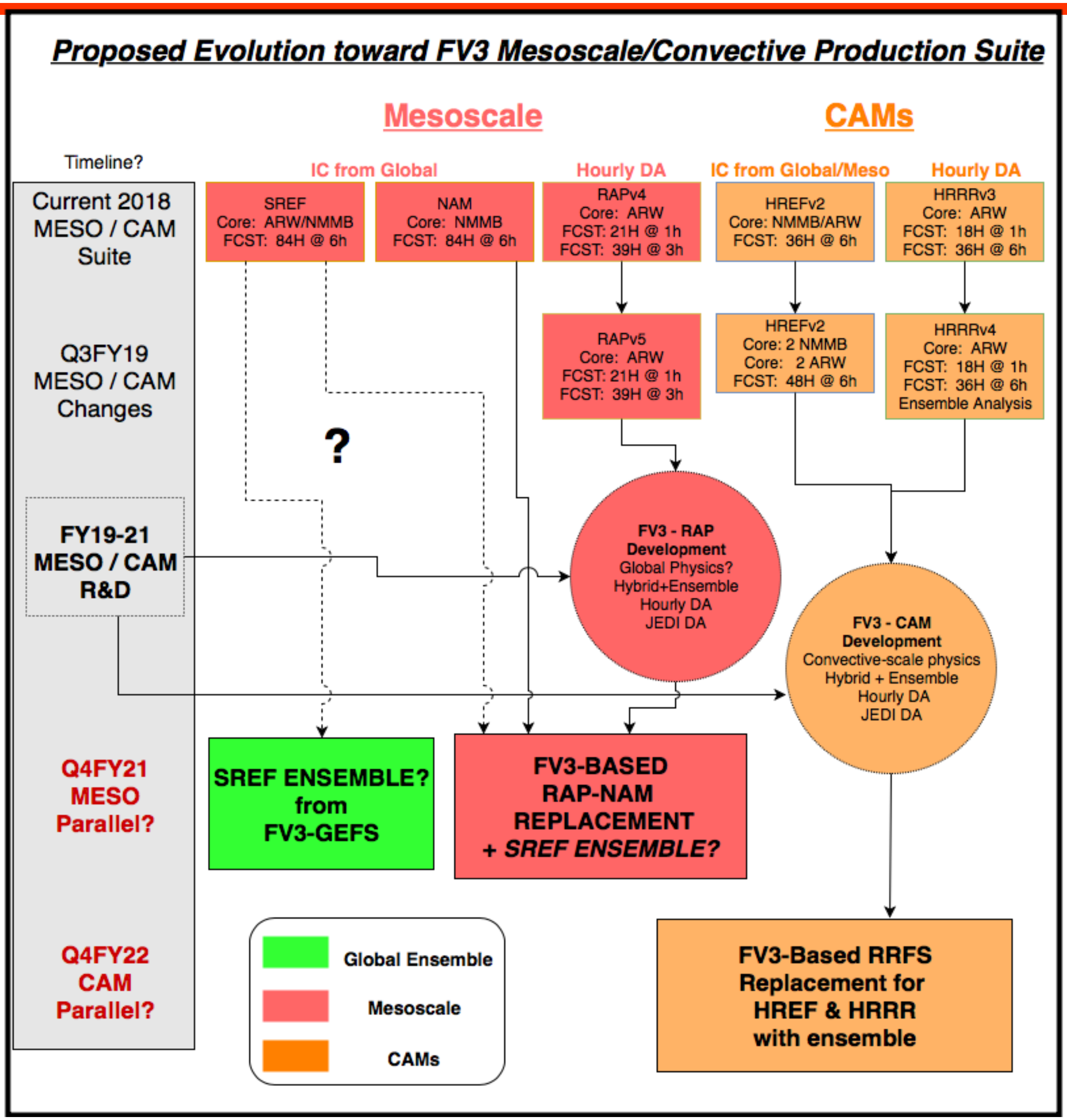
Connection to CAM from Global Model Suite

- **Unification of NAM/RAP/SREF with GFS/GEFS**
  - Current operational NAM and RAP (parent domains) have similar resolution as that of GFS, and GEFS is approaching the resolution of SREF
  - Coordination with CAM WG in determining the needs for CAM-scale initializations using GFS and GEFS
  - GFS continues providing initial and boundary conditions for various downstream applications including Hurricane Models
  - Global model with high-resolution nest(s) over CONUS and other areas of interest is a possibility within the UFS framework
  - Development of moving nests within the global model is planned for Hurricane Analysis and Forecast System (HAFS) under Hurricane Supplemental, active coordination with Dynamics and Nesting WG.
- **Other priorities for global-meso unification**
  - Common repositories for development of FV3 Stand-alone Regional Model within the FV3GFS framework
  - Physics unification is planned using high-resolution RAP/HRRR physics as an option for Advanced Physics configuration considered for FV3GFS V2.0
  - JEDI to provide DA capabilities for all applications including CAM and CAM ensembles
  - MET+ to cater to verification needs for all applications
  - T&E of Global Model Suites need to take into account CAM dependencies

Unification of Mesoscale/ CAM Production Suite

How does this plan fit into planned Global Model Suite upgrades?

Need a common strategy for coordinated development of FV3CAM and Global Model Suites.



Update on Coupled model development for S2S Scales

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SIP Aug 1 – 3 2018

Contributors

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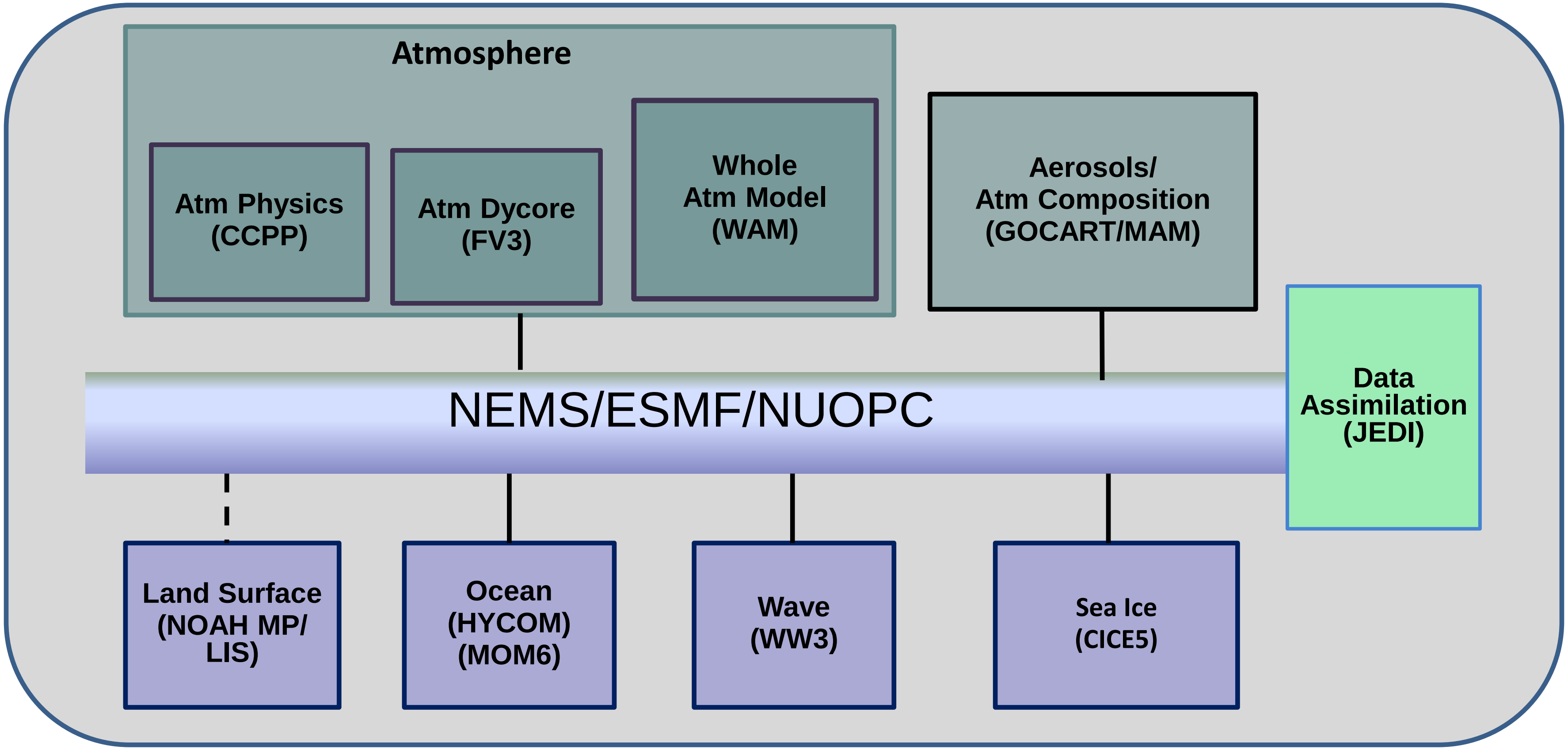
  - *Jun Wang, Bin Li, Jessica Meixner, Jiande Wang, Samuel Trahan, Xingren Wu, Denise Worthen, Hyun Chul Lee, Partha Bhatacharjee, Shrinivas Moorthi, Suranjana Saha, Patrick Tripp, Andre Vander Westhuysen, Ali Abdolali, Avichal Mehra, Robert Grumbine, Yuejian Zhu, Xiaqiong Zhou, Mark Iredell, Li Pan, Jeff McQueen, Yan Xue, Arun Kumar, David Dewitt, Arun Chawla, Vijay Tallapragada*
- NOS
  - *Saeed Moghimi, Ed Myers*
- ESRL
  - *Shan Sun, Rainer Bleck, Benjamin W. Green, Ning Wang, Georg Grell*
- NESII
  - *Tony Craig, Fei Liu, Cecelia DeLuca, Robert Oehmke, Gerhard Theurich*
- GFDL
  - *Rusty Benson, Brandon Reichl, Stephen M. Griffies, Robert Hallberg, Alistair Adcroft*
- UCAR/NCAR
  - *Mariana Vertenstein, Rocky Dunlap, Dave Bailey*

UFS



- UFS consists of fully coupled components representing different parts of the Earth system (solid lines represent functioning connections that have been made to the NEMS mediator)
- All components are based on community codes with authoritative repositories
- NEMS infrastructure allows flexibility to connect instantiations of the repositories together to create a coupled model.

NEMS Infrastructure

- NEMS infrastructure consists of
  - NUOPC caps for each component (connects the components to the overall infrastructure)
  - ESMF libraries
  - NEMS mediator for exchanging fluxes
  - Overall driver
- The following components have tested NUOPC caps [Note: Development of these caps will be an ongoing process as we identify new fields to exchange across components]
  - FV3GFS
  - WW3
  - MOM6
  - CICE5
  - GOCART
  - HYCOM
  - ADCIRC
- The functionality of the NEMS mediator has been tested with multiple coupled apps
- Parallel effort is on going to develop the CMEPS community mediator
- A nightly regression test package runs to ensure that new developments do not break existing capability

Coupled Applications

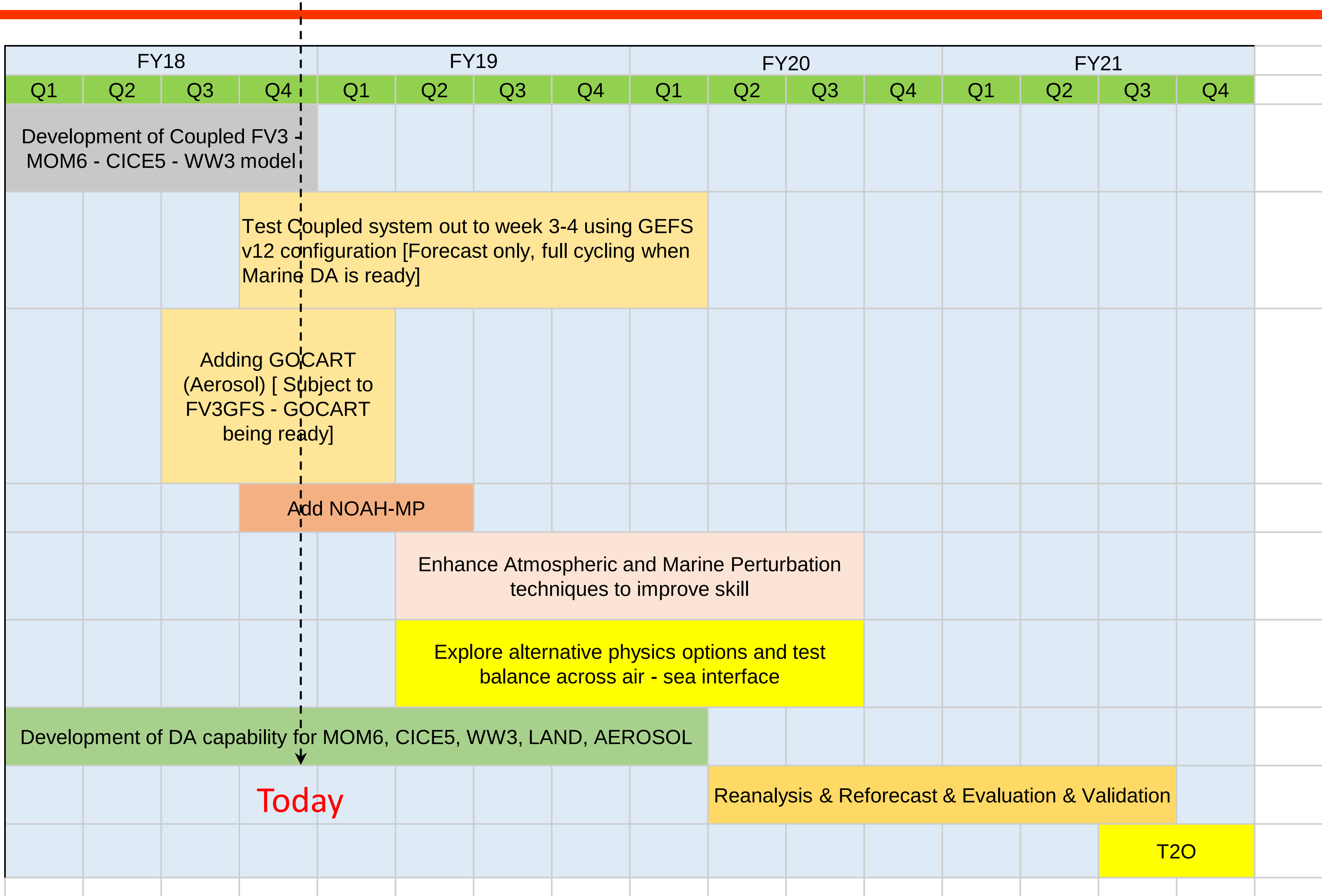
- The coupled applications repositories use an "umbrella repository" which point to authoritative repos for the components
- Application repos allow for concurrent developments
- Examples
  - FV3_MOM6_CICE5
  - FV3_WW3
  - FV3_CHEM
- Code managers for components, specific apps and overall NEMS infrastructure
- Regression tests are conducted nightly (any application compset can be added to regression test suite)

Current Developments

Each of these is a working coupled system being actively tested

Application	Code Manager	Description	Target operational System
NEMSFV3GFS	Jun Wang	Weather app that connects physics driver with FV3 dycore	GFS GEFS SFS
FV3-WW3	Jessica Meixner	Wave atmospheric stresses	GFS GEFS
FV3-MOM6-CICE5	Bin Li	Prototype coupled system for S2S scales	GEFS SFS
FV3-MOM6-CICE5-WW3	Jessica Meixner	S2S system + wave - ocean langmuir mixing	GEFS SFS
FV3-CHEM	Li Pan	Atmosphere - aerosol interactions	GEFS SFS
ADCIRC - WW3	Andre VanderWesthuysen	Wave - surge interactions	COASTAL ACT (for now)
HYCOM-CICE5	Denise Worthen	ocean - ice interactions at weather scales	RTOFS

S2S Development Schedule



Test Plan for S2S Development

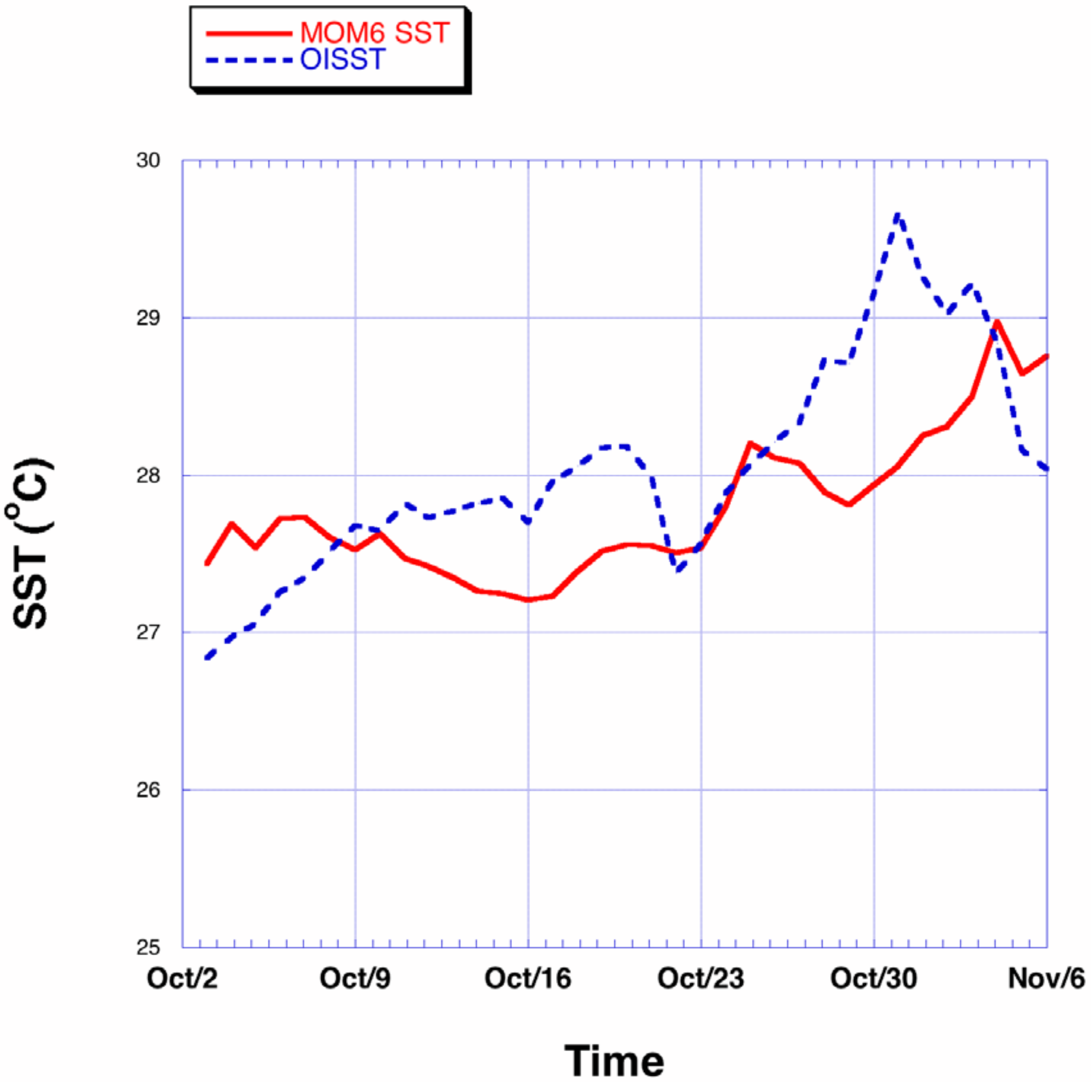
- A good Test plan needs the following
  - to be thorough enough to include multiple important cases (so as to remove the element of chance in getting the right answer)
  - Be short enough that we can test multiple things
- The following is a tentative test plan EMC has developed for S2S deterministic component development
  - Initialize model forecast runs from the 1st and 15th of each month
  - Repeat for all months from 2012 to 2018
  - This covers important El-Nino / La-Nina years as well as years of very low Arctic ice
  - In the absence of a DA system the components will be initialized by operational initial conditions [GDAS for atmosphere, NCODA for ocean and ice, restart files for WW3]
  - Skill metrics will be computed with CPC's S2S validation system + additional metrics

FV3-MOM6-CICE5

1) Air-sea fluxes are computed in FV3 if sea ice fraction is 0.
2) Air-sea fluxes are computed in the mediator if sea ice fraction >0.
3) Regridding from FV3 to MOM6 is done without using FV3's land-sea mask.
4) SST from MOM6 is used in FV3.
5) Sea ice fields from CICE5 are used in FV3.
6) Length of run: 35 days (from 00:00 UTC 03 Oct 2016 to 00:00 UTC 07 Nov 2016).
7) Grids : FV3 – C96 ; MOM6 – ¼ deg ; CICE5 – ¼ deg

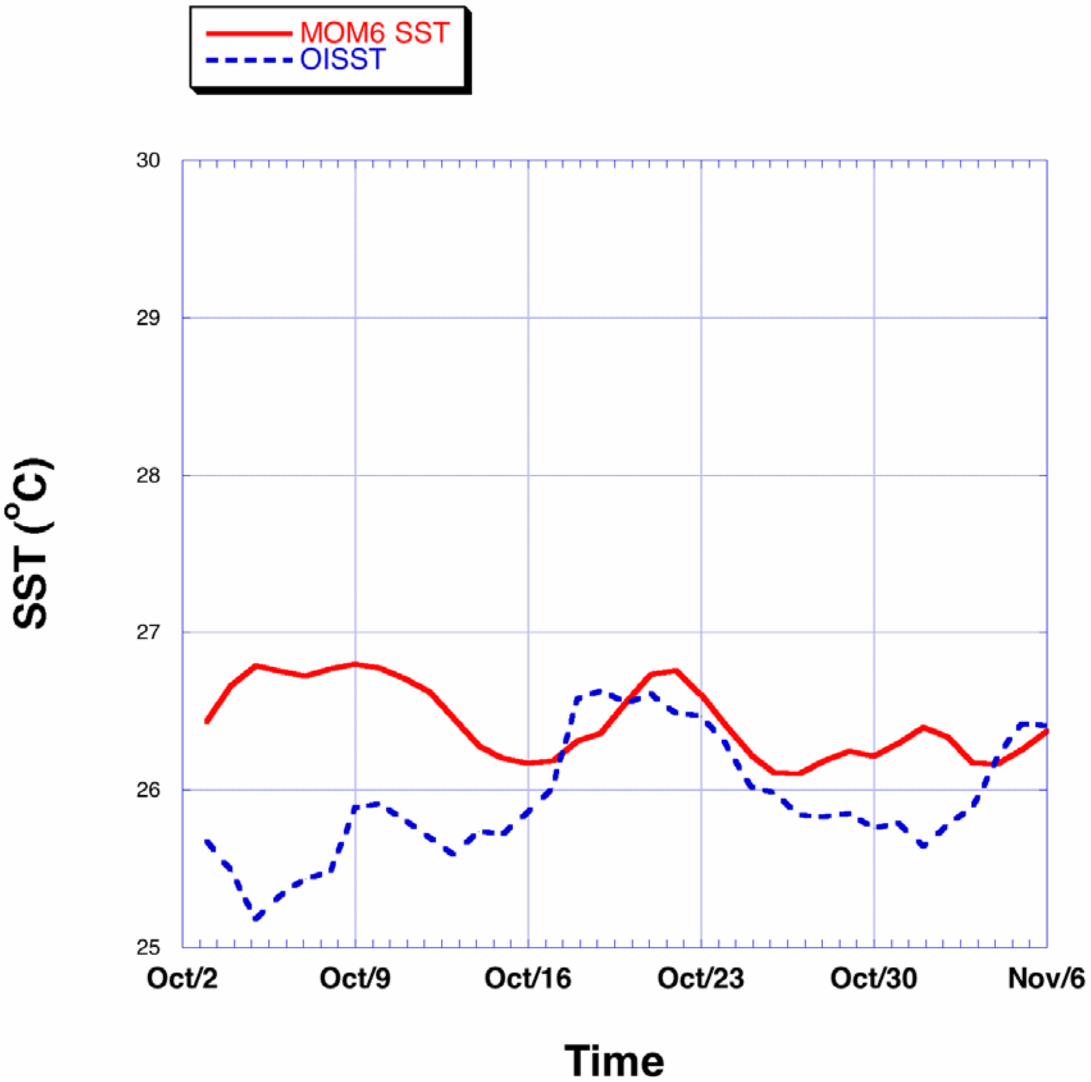
Comparisons with OI SST

Equatorial Indian Ocean (50°E,0°N)



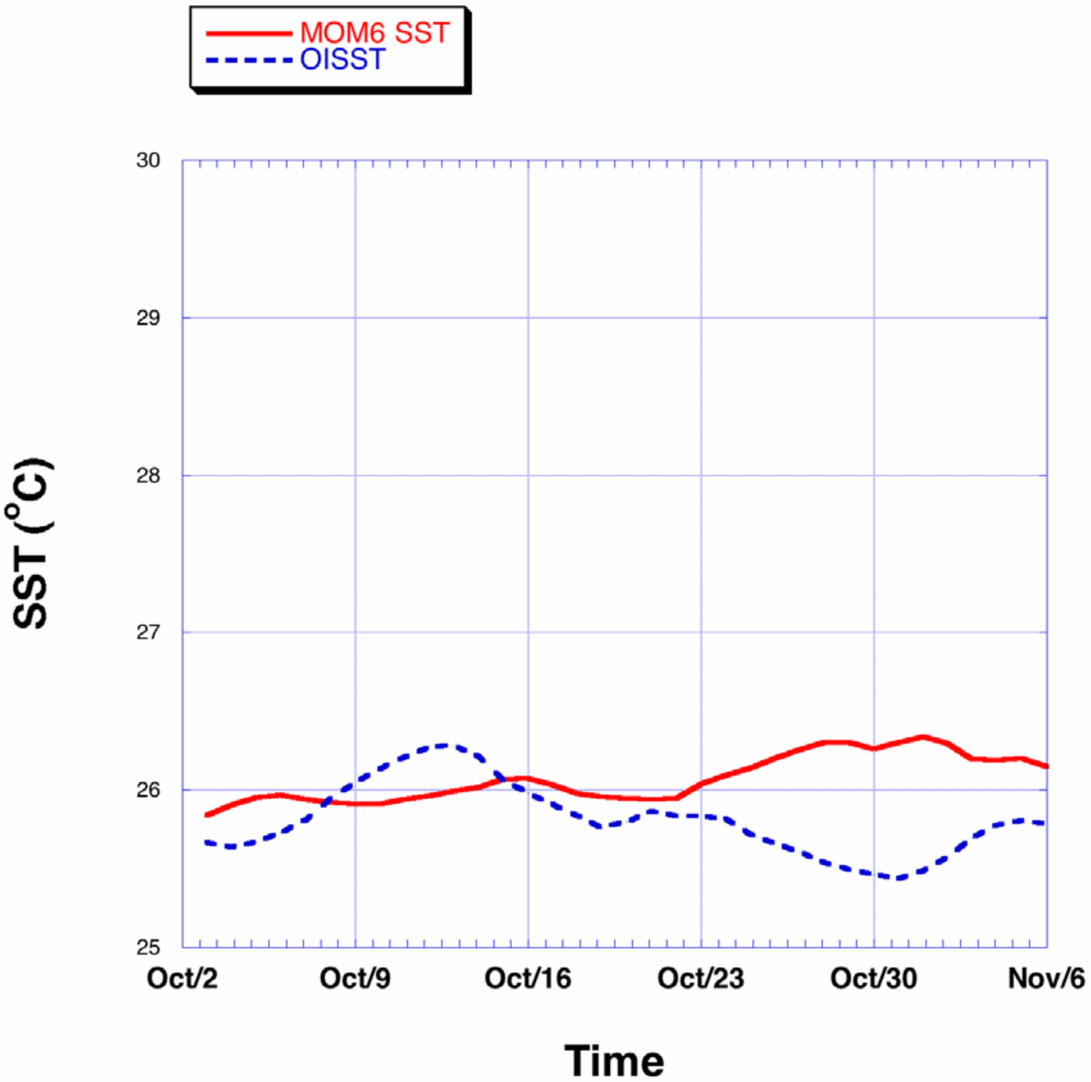
Comparisons with OI SST

Equatorial Atlantic Ocean (20ºW,0ºN)

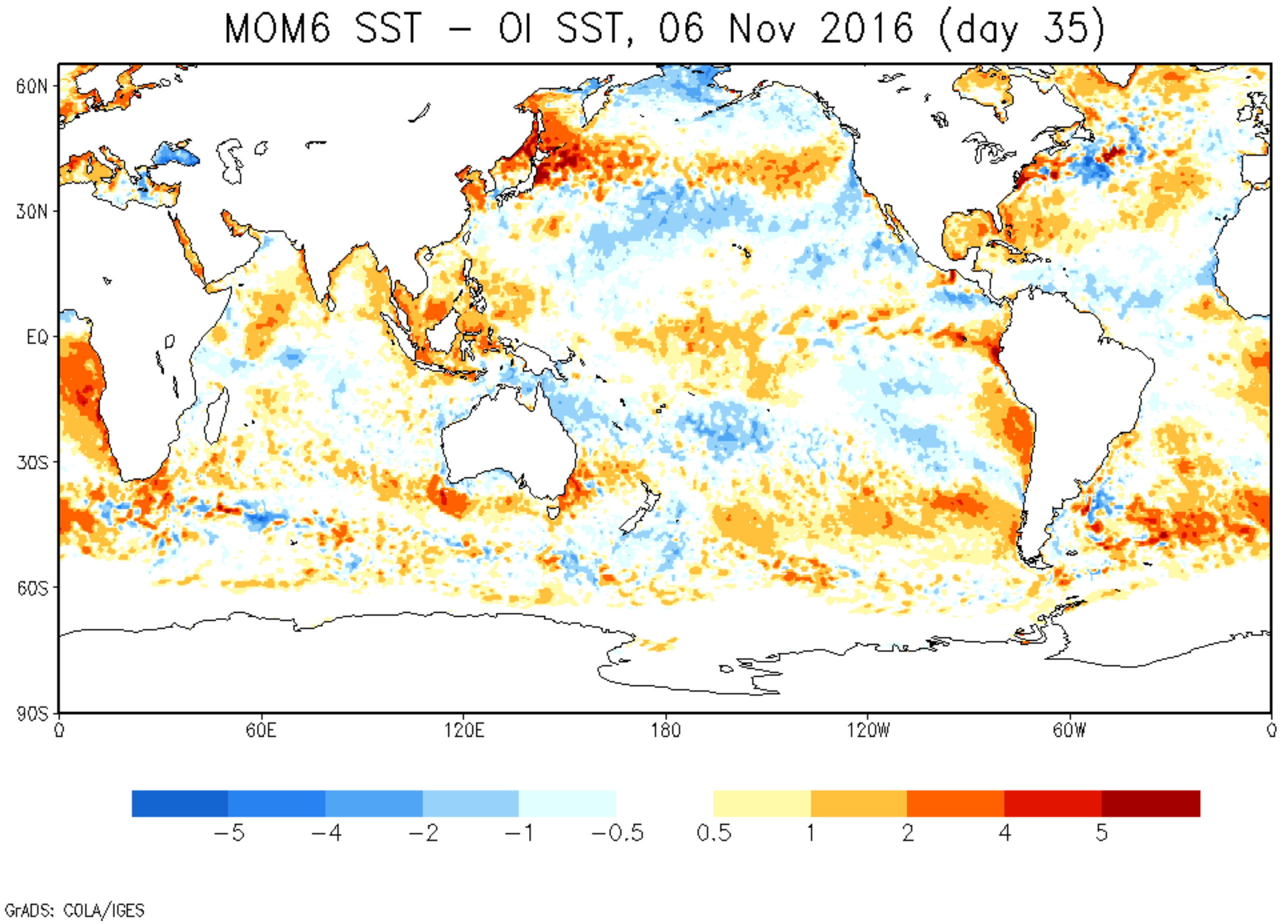


Comparisons with OI SST

NINO3.4 (170°W-120°W,5°S-5°N)



SST differences



FV3-MOM6-CICE5-WW3

Grids

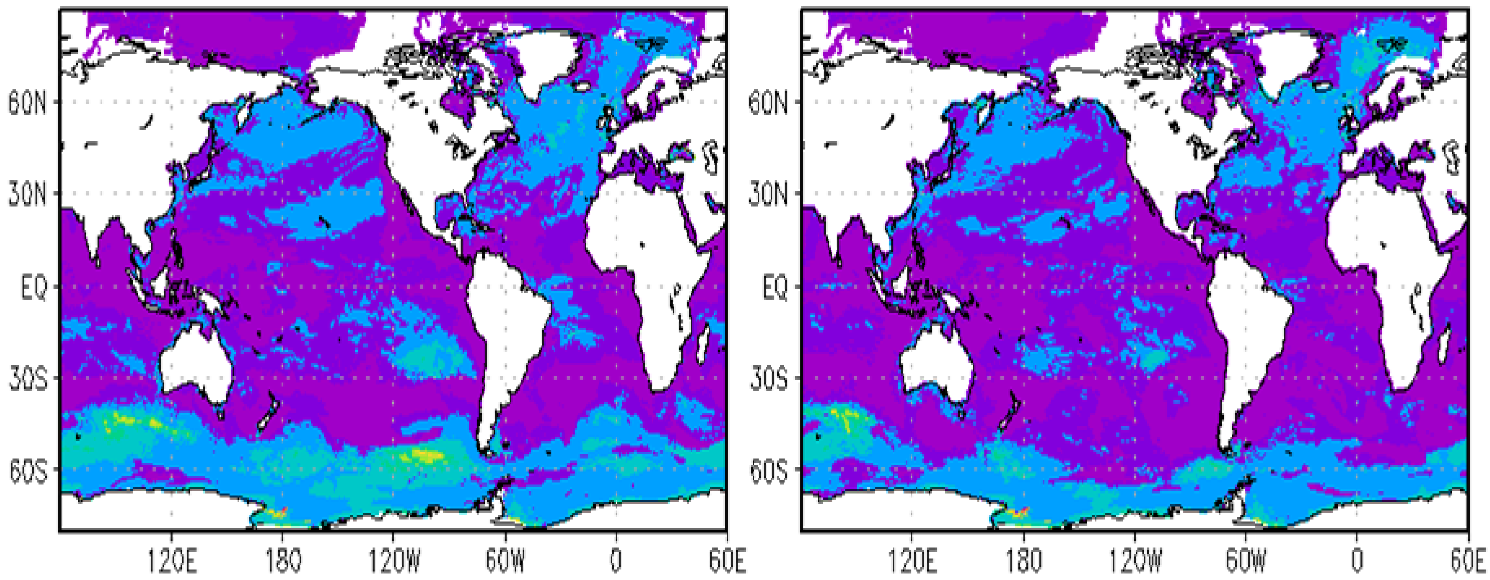
- FV3
  - C96 (~100km)
- MOM6 & CICE5
  - ¼ degree tripolar
- WW3
  - ½ degree regular lat/lon

Initial Conditions

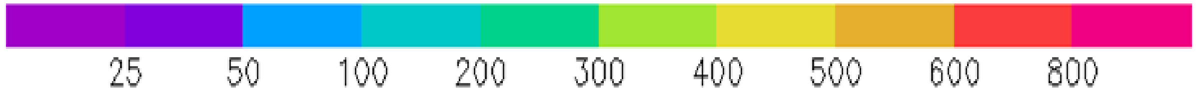
- FV3, MOM6 & CICE5
  - Same as FV3-MOM6-CICE5 tag 1.0.3
- WW3
  - From rest

Coupled

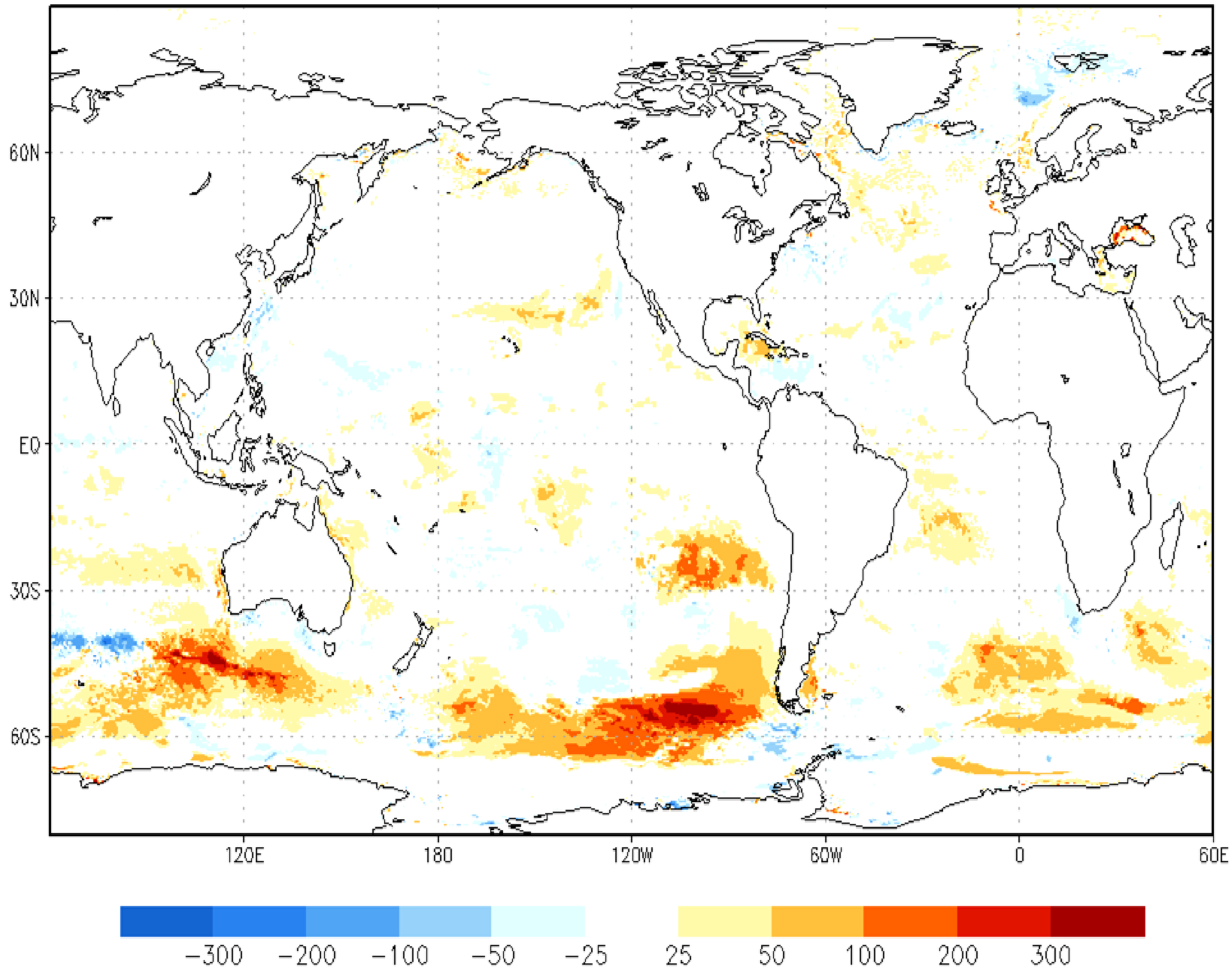
Uncoupled



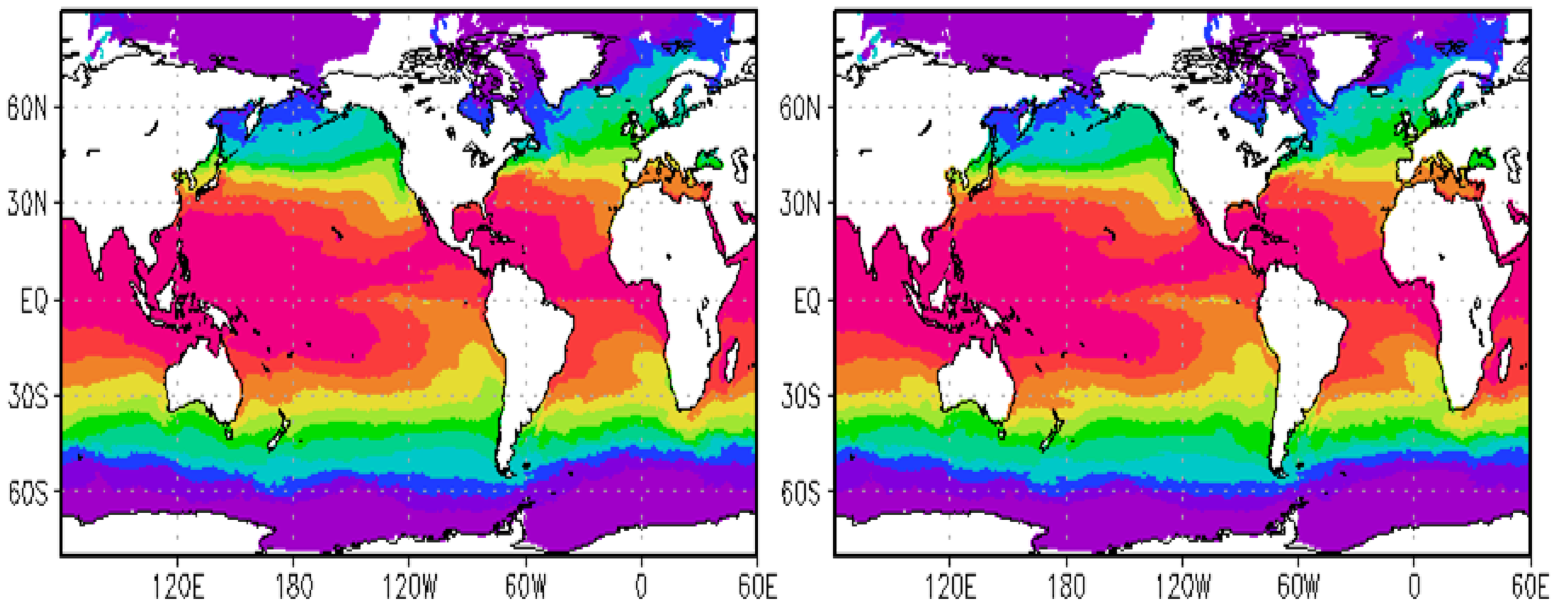
Mixed Layer Depth [m]



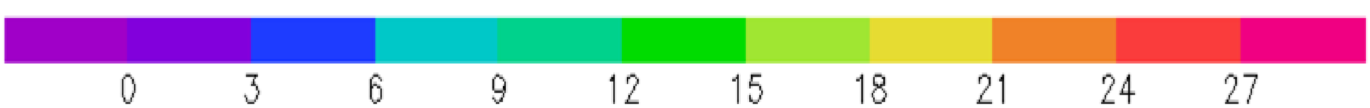
Mixed Layer Depth Difference [m]



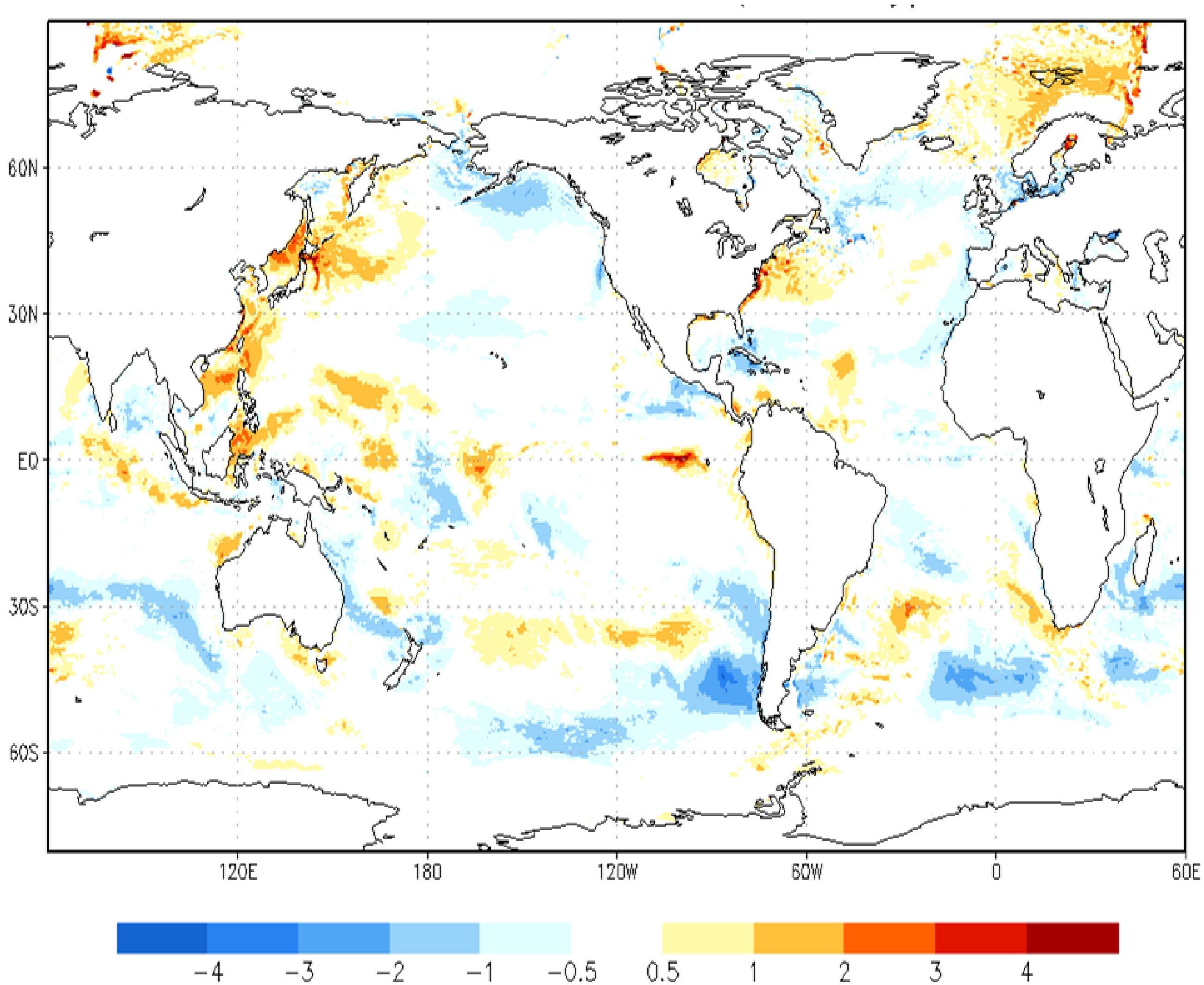
Coupled Uncoupled



Sea Surface Temperature [deg C]

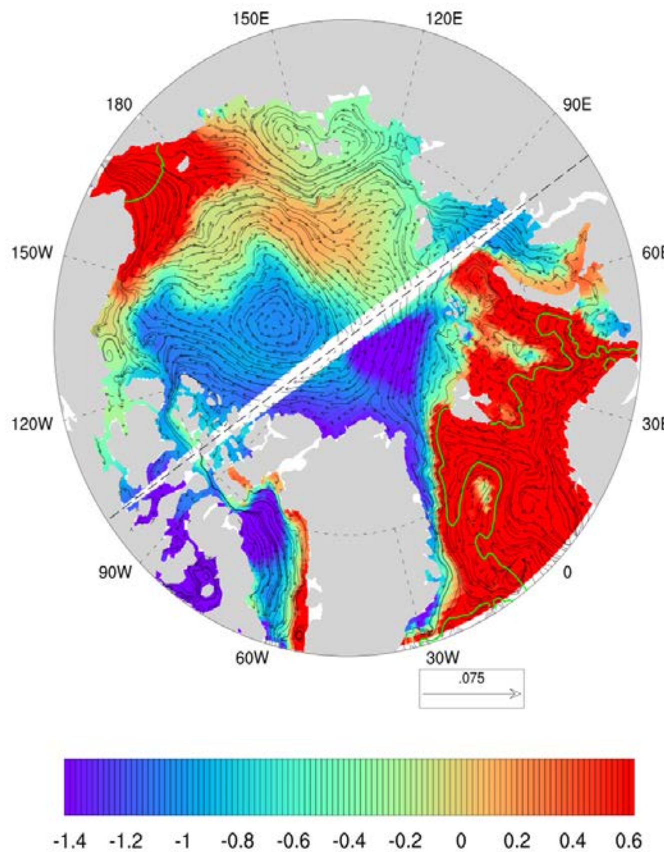


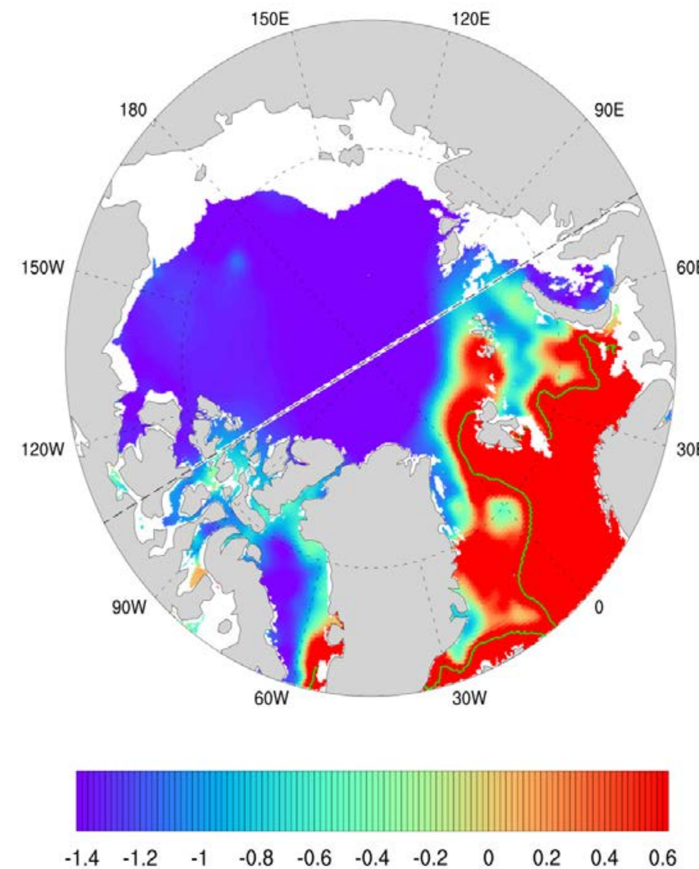
SST Difference [deg C]



MOM6 Initial conditions derived from CFSRv2

October climatology from GDEM3

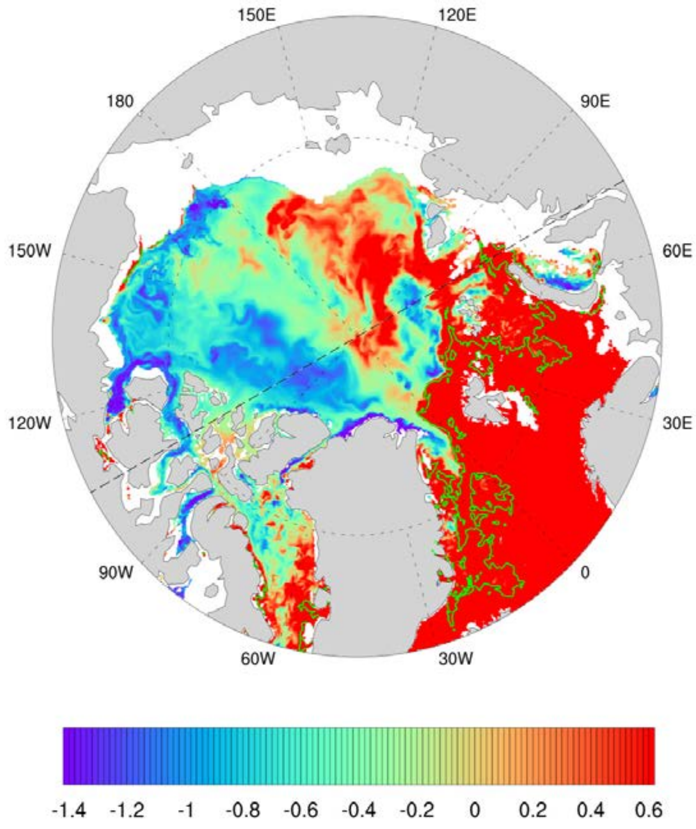


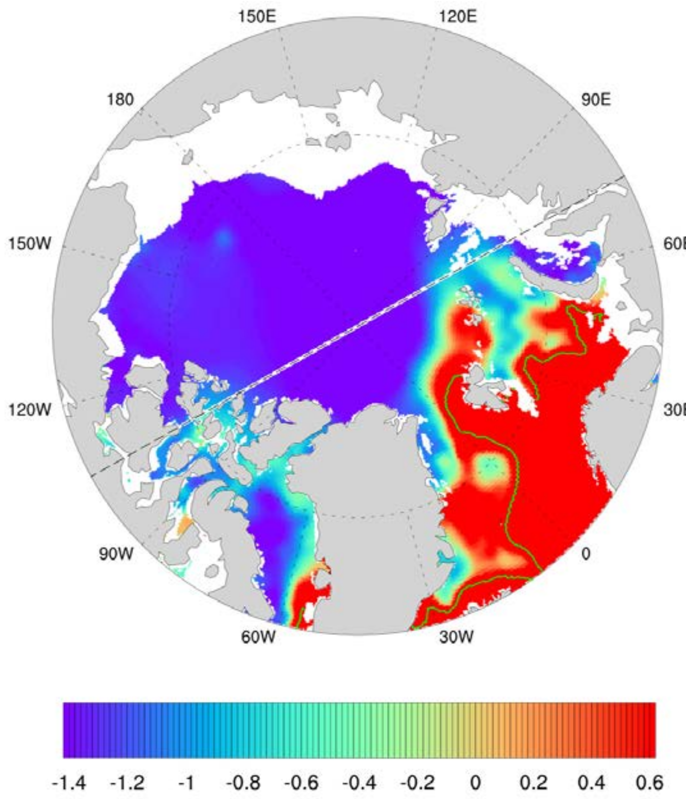


At 100m, MOM6 initialized from CFSRv2 exhibits both artifacts from the tripolar grid (seam) and an unrealistically strong inflow at Bering Strait. The Eurasian shelves and Bering Strait are too deep. There is a weak Atlantic inflow signal with primarily recirculation at Fram Strait, as indicated by the 1.8 ^{o}C contour line shown in green.

GRTOFS

October climatology from GDEM3





At 100m, GRTOFS shows a stronger temperature signal for the Atlantic inflow along the Barents Sea and Eurasian shelves. No tripole seam anomalies are present.

Work towards fractional mask at GSD

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Steps needed to use fractional land mask

Finished uncoupled FV3 (code is committed to repository branch "NEMSfv3gfs_GSD_fractional_landmask")

1. Modify uncoupled FV3 code to allow for composites of surface variables over water (ocean and lake are treated the same way now, "wet"), land, and ice
2. Separate ice (not static) from land/water mask (static): **make use of existing "fice" variable to determine if there is any sea/lake ice**
3. Three tests with different coastlines in uncoupled FV3 mode
   1) backward-compatible test: **passed** regression test when non-fractional land mask is used;
   2) changed a single land point on FV3 grid into a mixture of ocean/land/ice type (slide 3);
   3) used fractional land mask based on MOM6 bathymetry (slide 4).
4. Ocean and lake fraction are added to orography dataset (slide 5).

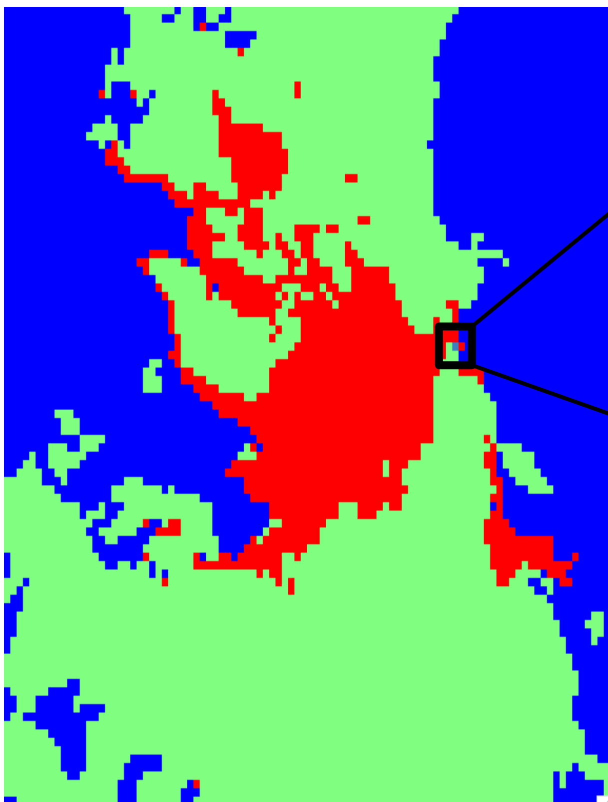
Next coupled FV3:

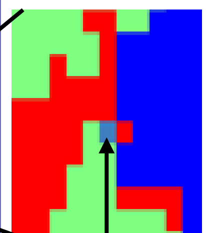
5. Run the same FV3 code with fractional land mask in coupled mode: work closely with EMC team and NESII group

Test 2 - Changing 1 point: result from older version of code:

- General idea: Pick a **single point** along Arctic coastline at ice edge, change from non-fractional mask to fractional mask (land + open water + sea ice); rest of globe remains non-fractional
- At the end of first physics call (say, 7.5 minutes), there should only be differences at the test point, as shown on the right below.

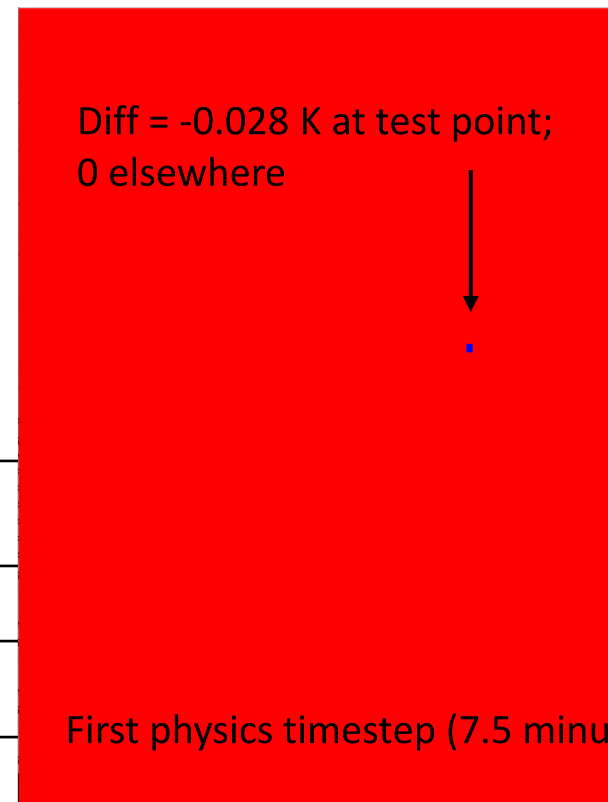
slmsk on FV3 tile 3, modified for one fractional test point





	Original	Changed
Land (%)	100	50
Open ocean (%)	0	21 = (100-50)*(100-58)
Sea ice (%)	0	29 = (100-50)*58

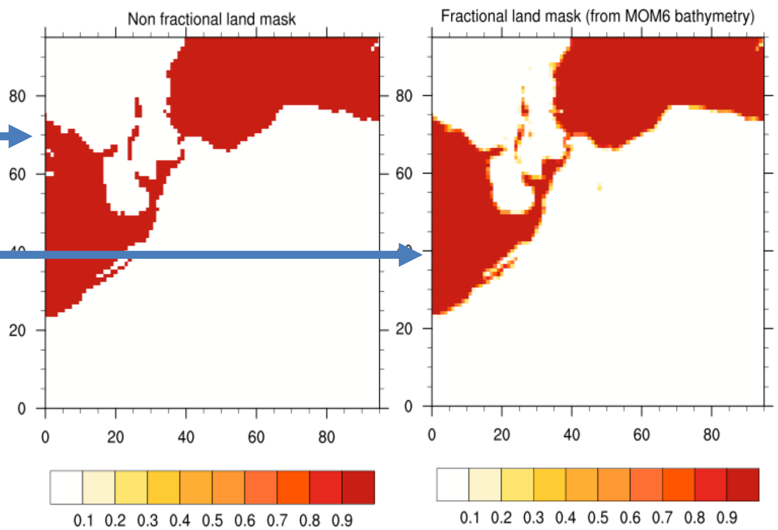
TSFC (**test – control**) at this point on FV3 tile 3



Test 3 – using fractional land mask from MOM6

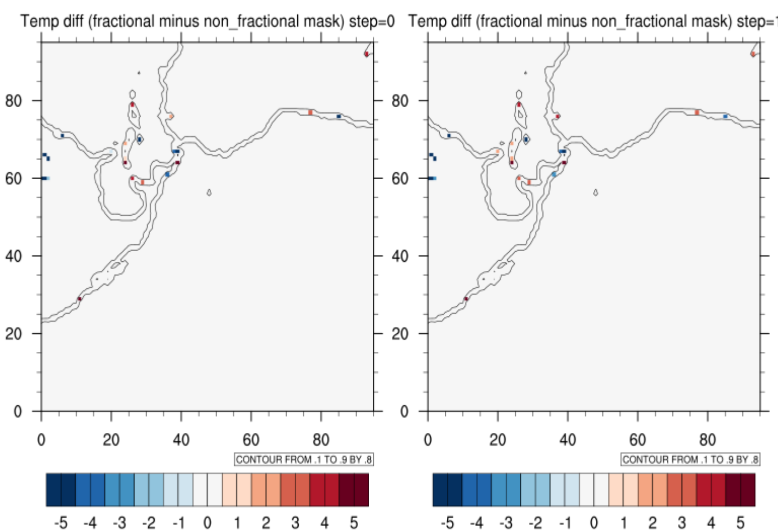
Two experiments:

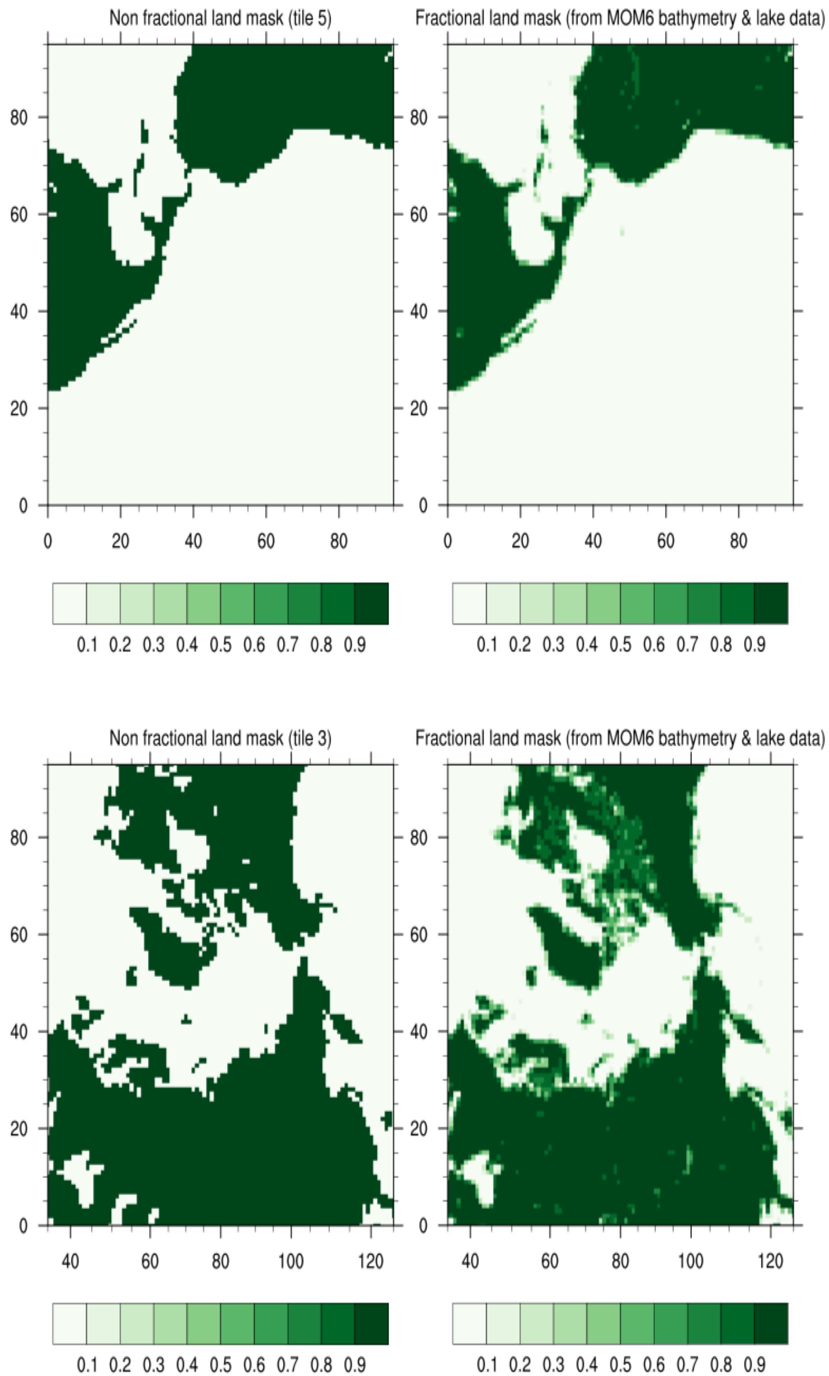
1. chgres reads NEMSIO data and creates FV3 ICs using current non-fractional land mask;
2. Same as in (1), except using fractional land mask from MOM6.



Results:

1. Two land masks are very similar except along coastline (contour lines of 0.1 and 0.9);
2. Surface temperature differs only along coastline, both initially and at step 1.



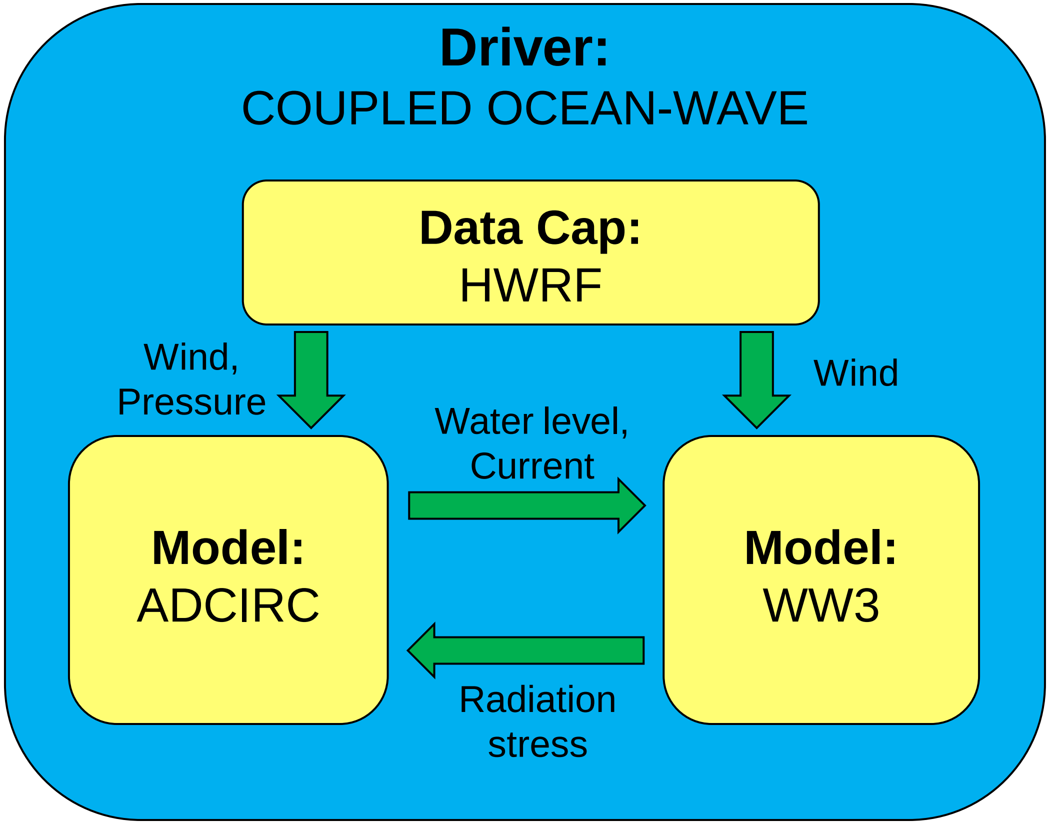


Lake fraction is included on the FV3 grid (right column). Upper: tile 5; lower: tile 3.

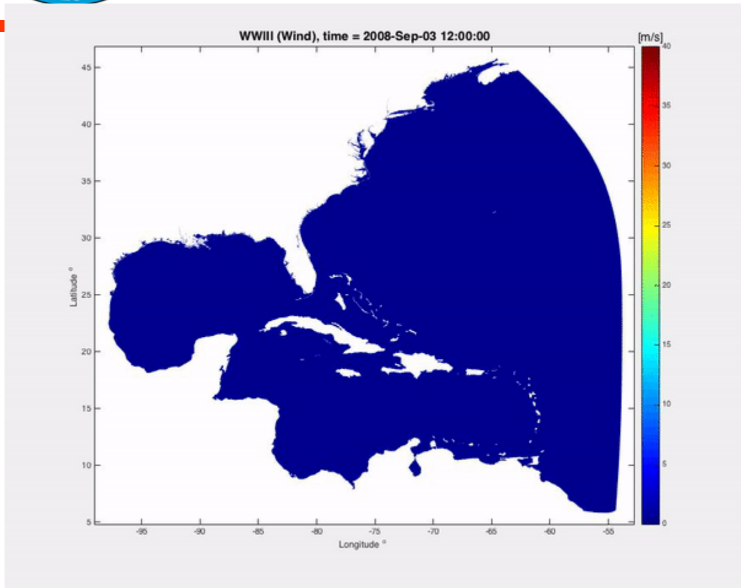
Note the lake dataset has no info on Caspian Sea!

Wave - Surge Coupling (COASTAL ACT)

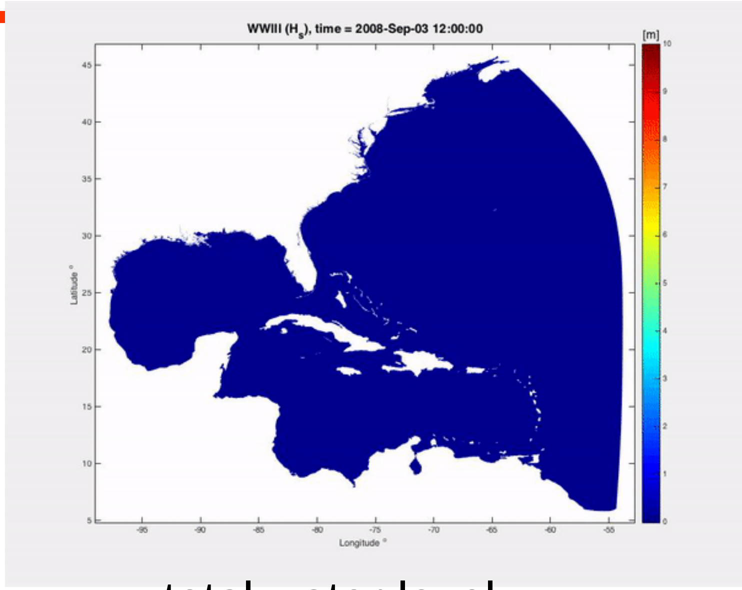
- NOS / EMC Collaboration
- Wave model updated to
  - implicit propagation
  - domain decomposition
- Wave cap updated to handle unstructured grids
- NUOPC cap for ADCIRC (NOS)
- Verified import and export fields between wave and surge models



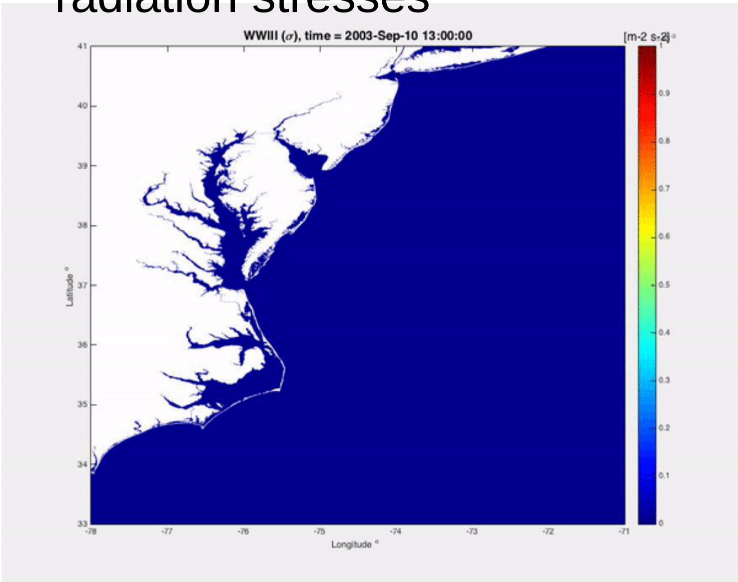
wind speed



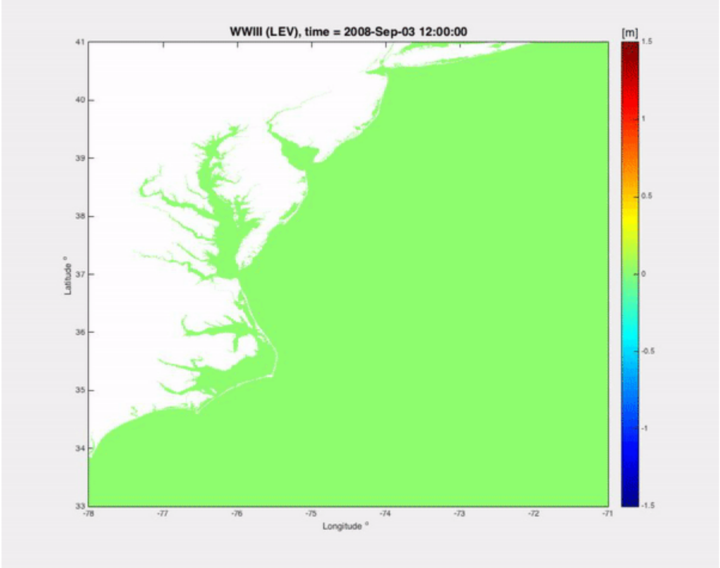
sig. wave height



radiation stresses



total water level



Moving Forward (Order will depend on availability)

- Finalize the coupled wave atmosphere configuration for GEFS v 12 (it will be one way for this implementation)
- Connect the fractional land sea mask development at ESRL with our coupled system and conduct conservation tests
- Begin benchmark tests for the coupled (FV3-MOM6-CICE5-WW3 model)
- Replace NEMS with CMEPS (when available)
- Update the S2S coupled system with GOCART (when ready)
- Develop the coupled wave atmosphere system for next GFS and GEFS implementations
- Finalize the land model for the coupled S2S system (potentially NOAH-MP)
- Replace the ice model with the ice consortium community model
- Begin tests of coupled S2S model in GEFS configurations for GEFS v13