The future of coupled modeling at NWS

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Overview

Planning at NWS

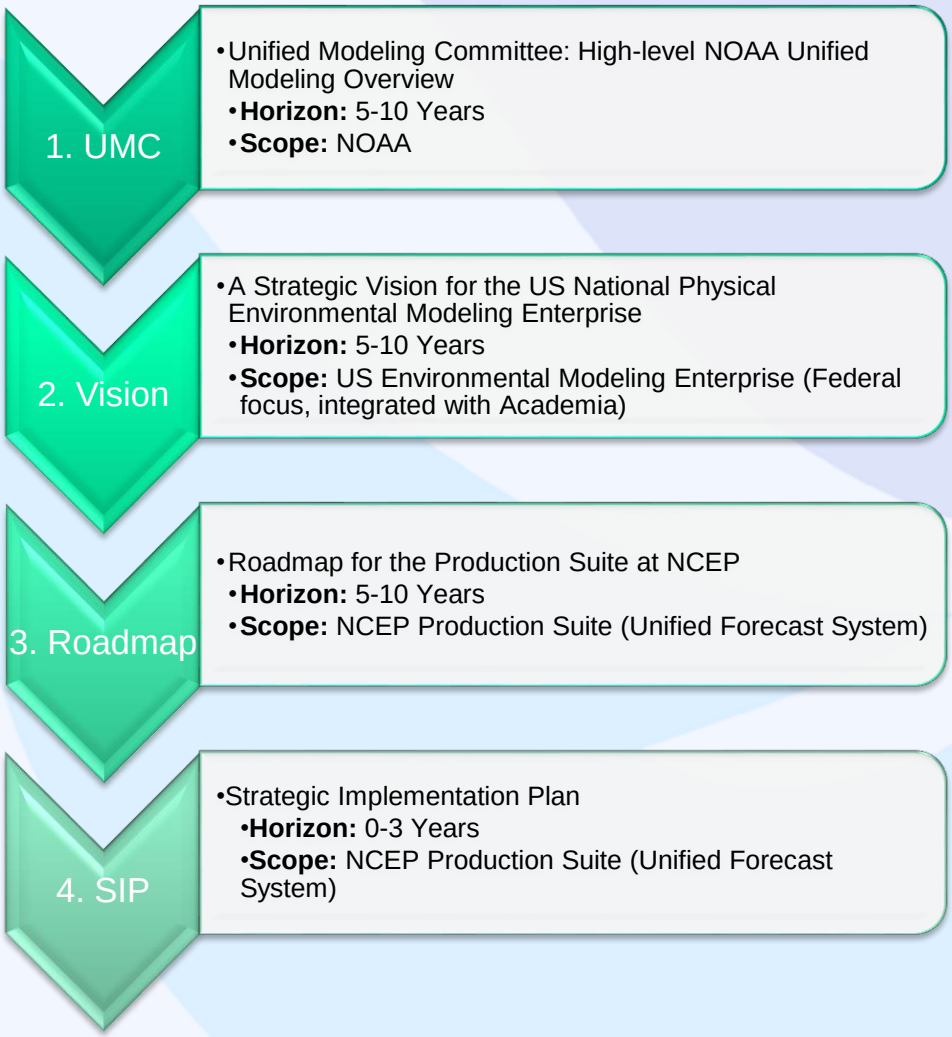
- Coupled ensemble modeling
  - NOAA Unified Modeling Committee whitepaper
  - A Strategic Vision for NOAA's Physical Environmental Modeling Enterprise
  - 2017-2018 Roadmap for the 2017-2018 Roadmap for the Production Suite at NCEP
  - Strategic Implementation Plan
- NOAA – NCAR Memorandum of Understanding (MoA)

Coupled modeling

- The present and past
- The approach
- The progress

Planning Overview

A Hierarchy of Plans



(1) A broad "strategy document" from the NOAA Unified Modeling Committee (UMC; under the auspices of the NOAA Research Council); spans the entirety of the NOAA modeling enterprise, inclusive of bio-geo-chemical, social and physical.

(2) The NWS and OAR are developing a Strategic Vision Document looking out 10 years and bridging US Physical Environmental Modeling Enterprise with the higher level NOAA UMC effort.

(3) Also emanating from an NWS-OAR partnership, is a Roadmap document that lays out how we can move the NCEP Production Suite towards the vision described in the Vision Document.

(4) At a practical level, the Strategic Implementation Plan (SIP), describes NOAA's concrete steps over the next 3 years to build the Next Generation Global Prediction System based on the Unified Forecast System, beginning with numerical weather prediction across scales and in partnership with with the community (all stakeholders).

Unified Modeling Committee

NOAA-wide, long term

Under NOAA Research Council

Policy rather than requirements

* ftp://ftp.library.noaa.gov/noaa_documents.lib/NOAA_UMTF/UMTF_overview_2017.pdf

Strategic Vision

Physical modeling at NOAA, 5-10 year vision

AA level approval

Effort pre-dates UMC

Finalized, awaiting signatures

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

- Operations ***and*** research

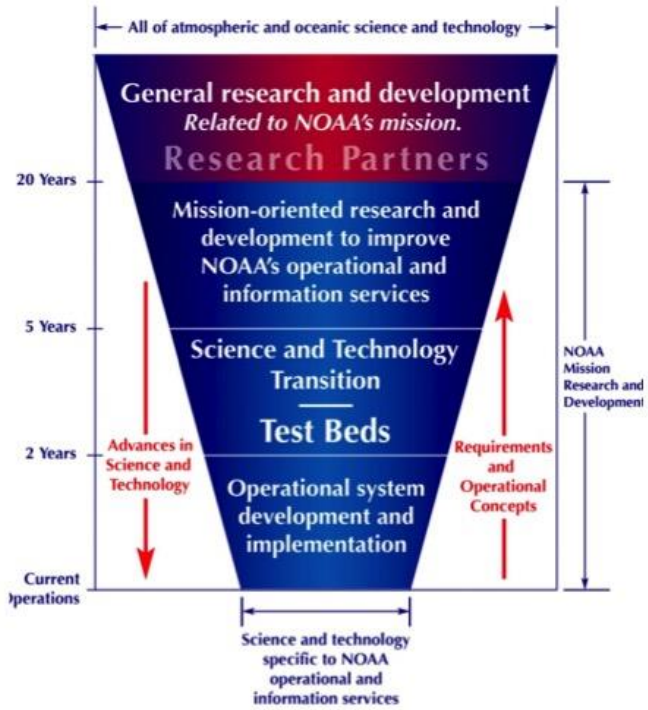
Evidence-driven decisions

- Same standards for all who contribute

Transparent and robust governance

- Service requirements
- Technical requirements / solutions
- Prioritization

See SIP for community governance

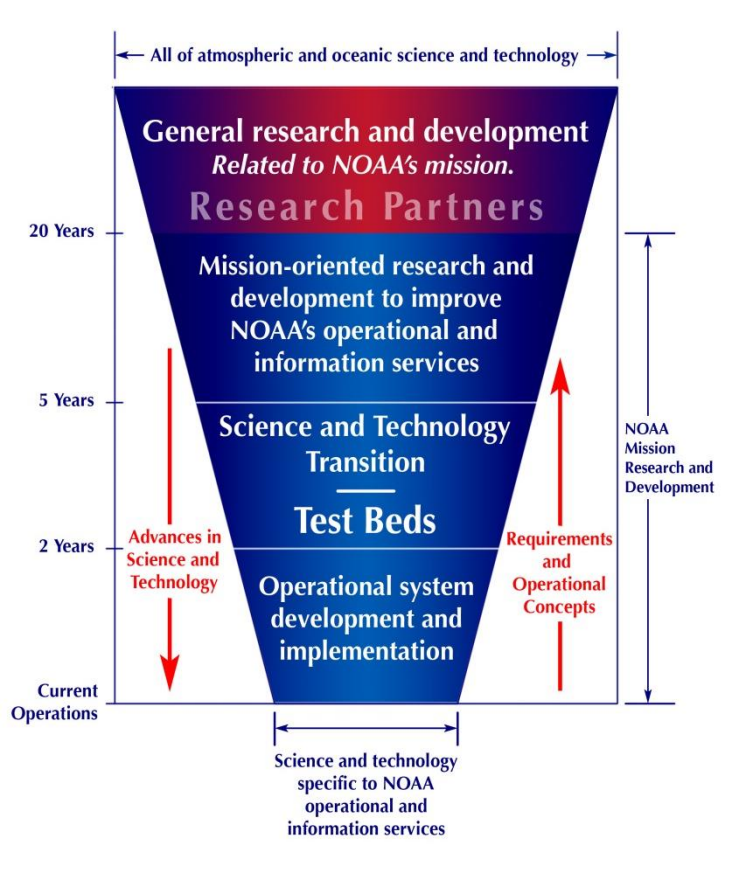


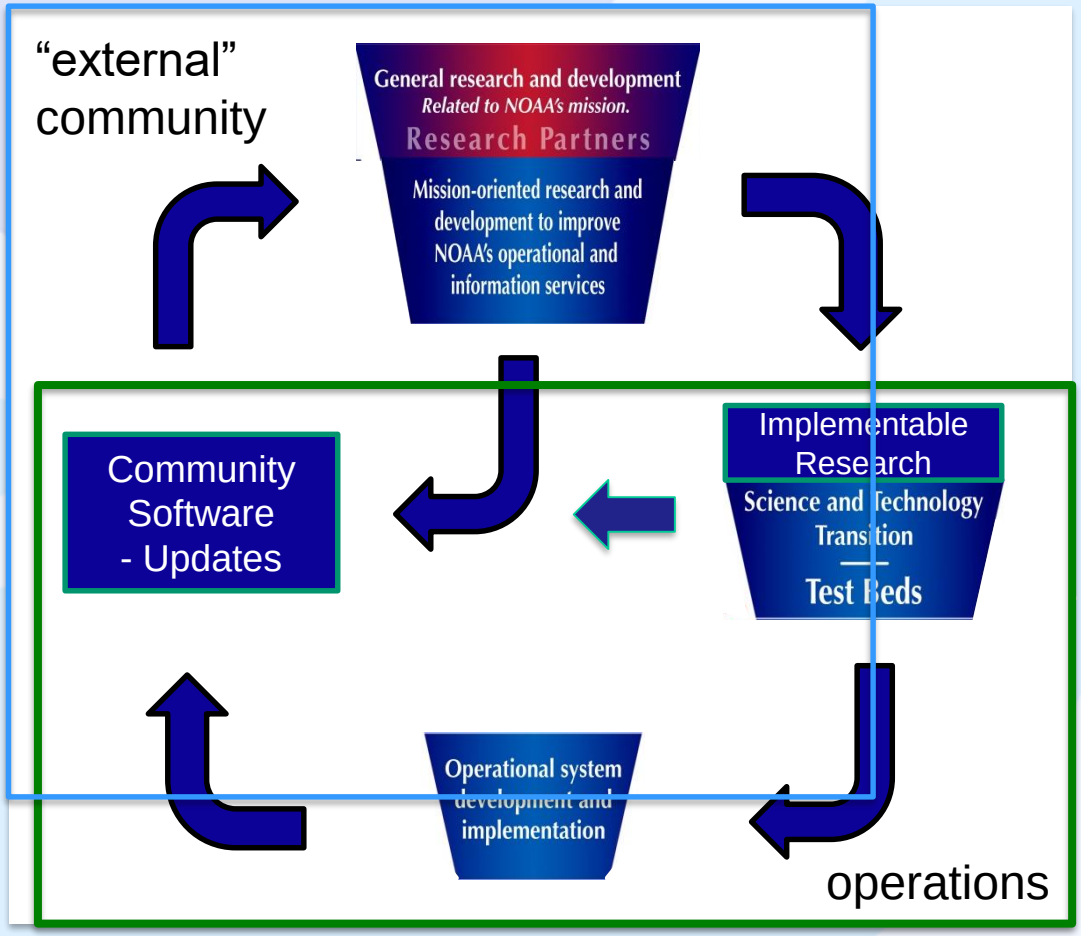
Courtesy Louis Uccelini

Strategic Vision Fig. 1

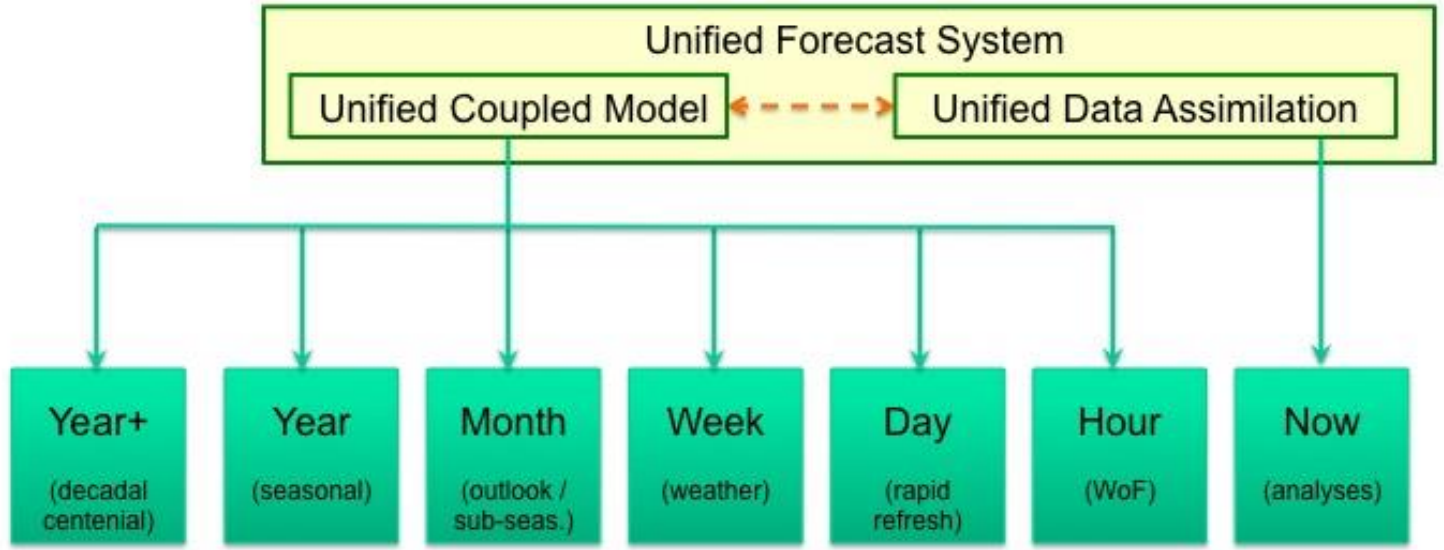
Deconstructing the funnel

Past → Future





Strategic Vision: Temporal Domains



Global	Global	Global	Global			Global
		Regional refinement	Regional refinement			
Down-scaling	Down-scaling			Regional	Regional	Regional

Unified Forecast System = Coupled Ensemble + Reanalysis + Reforecast

Strategic Vision Fig. 2

Roadmap

Production Suite, 5-10 years

AA level approval

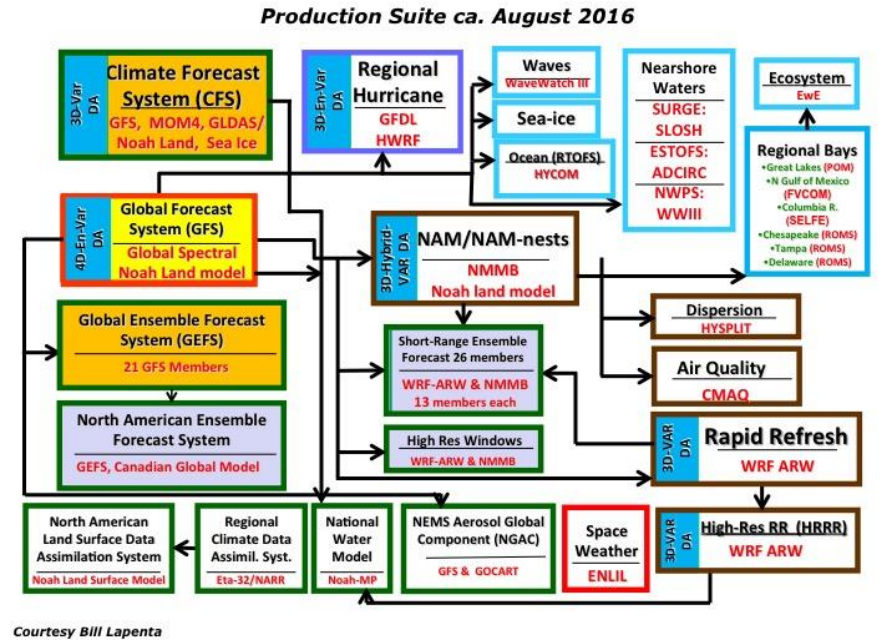
Effort pre-dates UMC

Finalized, awaiting signatures

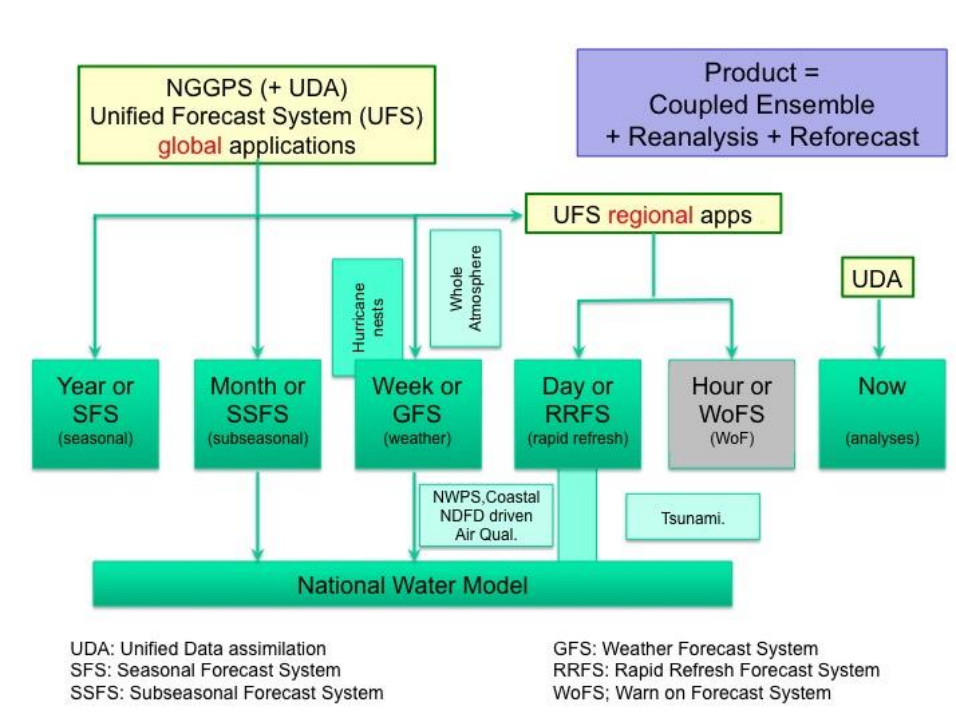
Roadmap: Big Picture

Moving from atmosphere focus to holistic environmental approach

Roadmap Fig. 1



… we will move to a product based system that covers all present elements of the productions suite in a more systematic and efficient way



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

Roadmap Fig. 2

Roadmap: 5 year "end state"

Focus on transition to Unified System

Roadmap Table 2

Element	Cadence	Range	Resol.	Ens.	Update	RR
SFS	7 d	9-15 mo	50 km (g)	28	4 y	1979-present
SSFS	24 h	35-45 d	35 km (g)	31	2 y	20-25 y
GFS	6 h	7-10 d	13 km (g)	26	1 y	3 y
RRFS	1 h 6-12 h 6-12 h	18 h 30 h 60 h	3 km (r)	26	1 y	TBD
WoFS	5-15 min	2-4h	1 km (r)	26	1 y	TBD
Analyses						
Trad.	6-24 h	---	Var. (g)	---	6 mo	N/A
RUA	15 min	---	TBD (r)	---	6 mo	

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

SFS= Seasonal Forecast System
SSFS= Sub-Seasonal (Outlook) Forecast System
GFS= Global Forecast System
RRFS= Rapid Refresh Forecast System
WoFS = "Warn on Forecast" System

Changing use of WCOSS
Needing ~ 37 PFlop machine

Resolutions for atmosphere, other component models may have different resolutions

Roadmap: 10 year “best system”

Focus on becoming best in the world

Roadmap Table 4

Element	Cadence	Range	Resol.	Ens.	Update	RR
S3FS	7 d	12 mo	15 km (g)	200	TBD	1979-present
	24 h	45 d		100		
GFS	1? - 6 h	7-10 d	5 km (g)	50	1 y	3 y
RRFS	1 h 3 h 6 h	24 h 48 h 72 h	1.5 km (r)	50	1 y	TBD
WoFS	5 min	2h	0.5 km (r)	50	1 y	TBD
Analyses **Trad.** **RUA**	 6-24 h 5 min	 --- ---	 Var. (g) TBD (r)	 --- ---	1 y	N/A

S3SFS= (Sub-) Seasonal Forecast System
GFS= Global Forecast System
RRFS= Rapid Refresh Forecast System
WoFS = “Warn on Forecast” System

SFS / SSFS use single model
Needing ~ 730 PFlop machine

Resolutions for atmosphere, other component models may have different resolutions

Strategic Implementation Plan

SIP, execution at NCEP 1-3 year

Execution level approval / planning

Annual upgrade through SIP working groups

https://www.weather.gov/sti/stimodeling_nggps_implementation

NGGPS Goals and Objectives[1]

Next Generation Global Prediction System

Design/Develop/Implement NGGPS global atmospheric prediction model

- Non-hydrostatic scalable dynamics

Improve data assimilation and physics

Position NWS for next generation high performance computing

Engage community in model/components development

Reduce implementation time

Increase effectiveness of product distribution

- Post-processing, assessments, and display

World's Best Global Forecast Guidance

[1]From NWS Budget Initiative proposal to OMB

SIP for Unified Forecast System

Common Goal: Single integrated plan that coordinates activities of NOAA + external partners in common goal of building a national unified modeling system across temporal and spatial scales

- NGGPS: foundation to build upon
- Activities include R&D, testing/eval, V&V, R2O, shared infrastructure, etc.

Approach for SIP development:

- Began with existing core R&D partners to organize in functional area Working Groups (WGs) responsible for drafting respective functional SIP components
- End product (in final coordination) will be SIP version 1.0, a 3-year plan (FY 2018-2020)
- FY18 and following : SIP to be rolling 3-year plan to be updated annually

SIP Working Groups

Unified Forecast System (UFS) Steering Committee

Go…es,

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.
- 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

New WG or addition (wrt NGGPS)
Augmentation of existing NGGPS group

Dynamics and Nesting
- FV3 transition on global wx/S2S/climate
- Nests for hurricanes (moving?)

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

Data Assimilation
- NOAA, NASA integ. w/FV3; coupled DA
- Joint Effort for DA Integration (JEDI)

Ensembles
- Strategy across scales; model uncertainty

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

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

NOAA – NCAR MoA

NCAR - NWS – OAR

NCAR – NOAA MoA

Letter of Intent for collaboration between NCAR, NWS and OAR signed July 28, 2017

- “to develop a Memorandum of Agreement (MOA) that will describe how both organizations will work collaboratively toward the design and construction of a community unified modeling infrastructure. “
- Identified benefits include
  - Synergies
  - Common repositories
  - Access to NOAA operational models

Team for writing MoA formed in November 2017

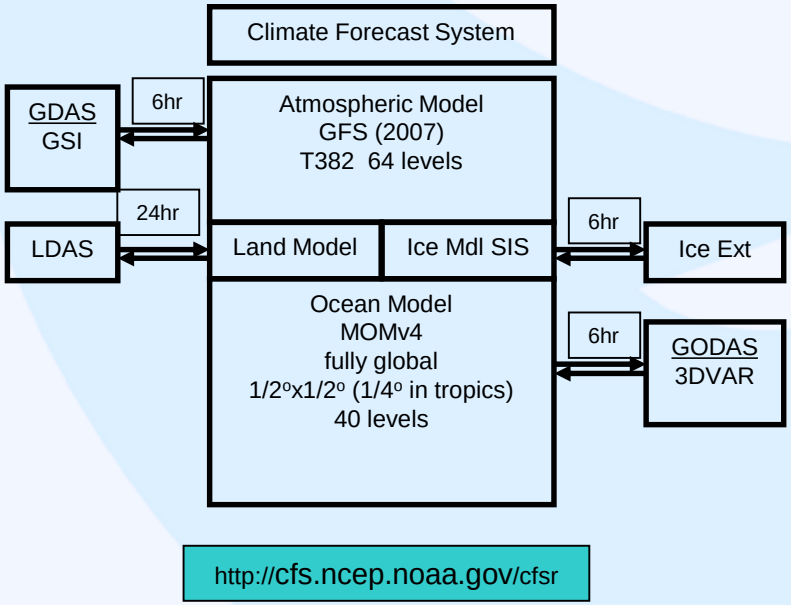
- Full MoA text agreed upon by all three organization
- Now in NOAA final legal review

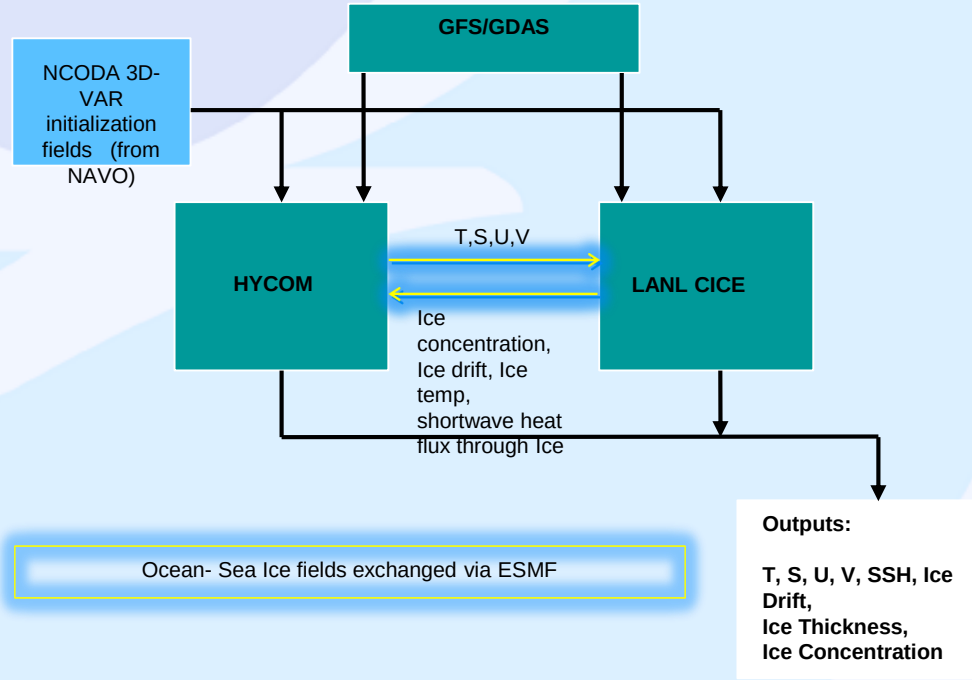
The Present and Past

present

Coupled systems

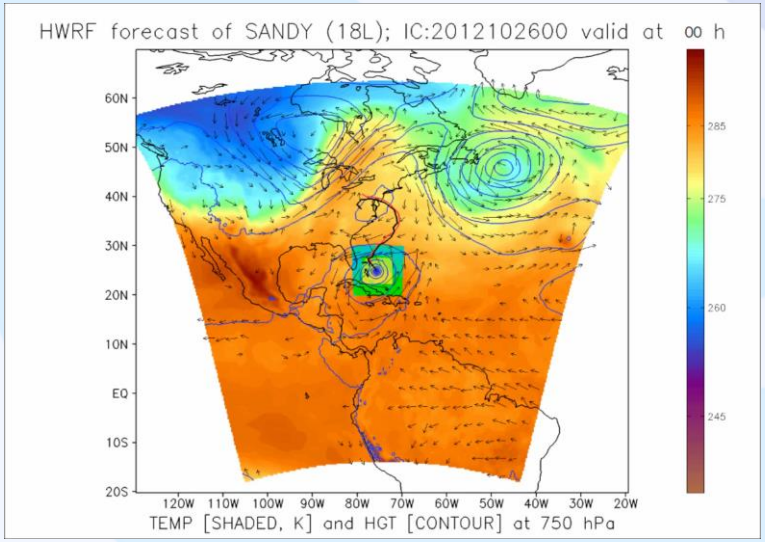
- Climate Forecast System (CFS v2)
- HYCOM – CICE coupling
- Hurricane models (GFDL, HWRF)



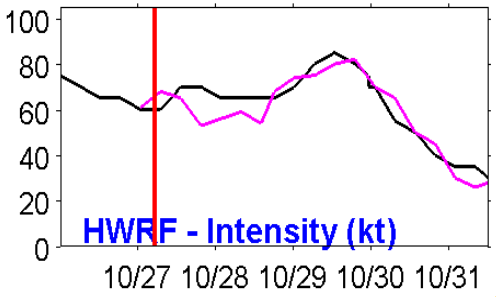


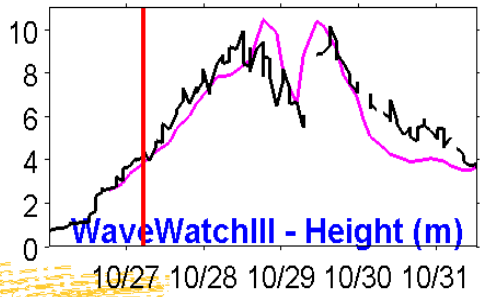
Operational HWRF

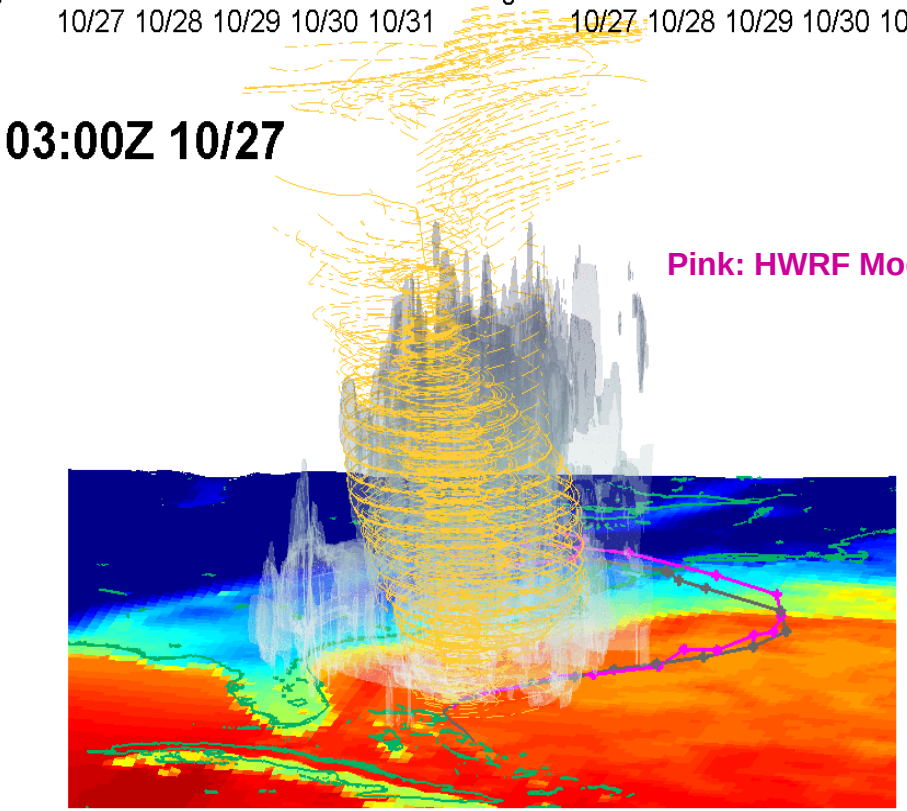
- High-Resolution (2km) near the storm
- Advanced hurricane physics
- Coupled to ocean model
- 1-way coupled to wave model (July 11, 2018)
- Custom coupler, 3-way coupling is being tested.



Three telescopic domains: 18km: 80x80°; 6km ~12x12° 2km inner-most nest 7x7°







Accurate intensity and structure forecasts from HWRF
→ Better wave and storm surge forecasts for landfalling storms

The Approach

Basic approach : coupling

This is not just a science problem

- Requirements for additional, traditionally downstream products
- '"One-way" model coupling versus downstream model:
  - Increases forcing resolution of downstream models while reducing I/O needed to force models
  - Creates a better integrated test environment for holistic evaluation of model upgrades
  - Less implementations
  - Creates environment for investigating benefits of two-way coupling. Enables two-way coupling if science proves benefit

Negative aspects of coupling:

- More complex implementations
- Less flexibility to tailor product.
- Produce "too much"

Basic approach : coupling

Many potentially coupled model components already have products in the production suite :

- Where no products exists, science suggests benefit of coupling
- For the hourly forecast range, all still TBD
- DA is also moving (internationally) to coupling
- Space weather making its way into operations
- Ecosystems (marine) being considered (not in table)

Subsystem	Year	Month	Week	Day	Hour
Land / hydro	Y	Y	Y	S	?
Ocean / coast	Y	Y	Y	S/R	?
Ice	Y	Y	S	?	?
Waves	S	Y	Y	Y	?
Aerosols	S	S	Y	Y	?
Space weather	?	?	Y	?	?

Y: present product
S: science benefit
R: unmet requirement
?: TBD

Basic approach : coupling “now”

	Influencing						
	Atmos.	Land / hydro	Ocean / coast	ice	waves	Aerosols	Space W.
Atmos.		yes	yes	yes	yes	yes	yes
Land/hydro	yes		inflow	yes	inundation		
Ocean/coast	yes	inundation		yes	WCI	climate	
Ice	yes		yes		yes		
Waves	fluxes		WCI	yes			
Aerosols	climate						yes
Space W.	yes					yes	

Green boxes:	light:	tradition 1-wy downstream coupling
	dark:	two-way coupling in selected operations.
Grey boxes:	fixed data, not dynamic coupling	
Black text:	presently in place.	
Red text:	science has shown impact	

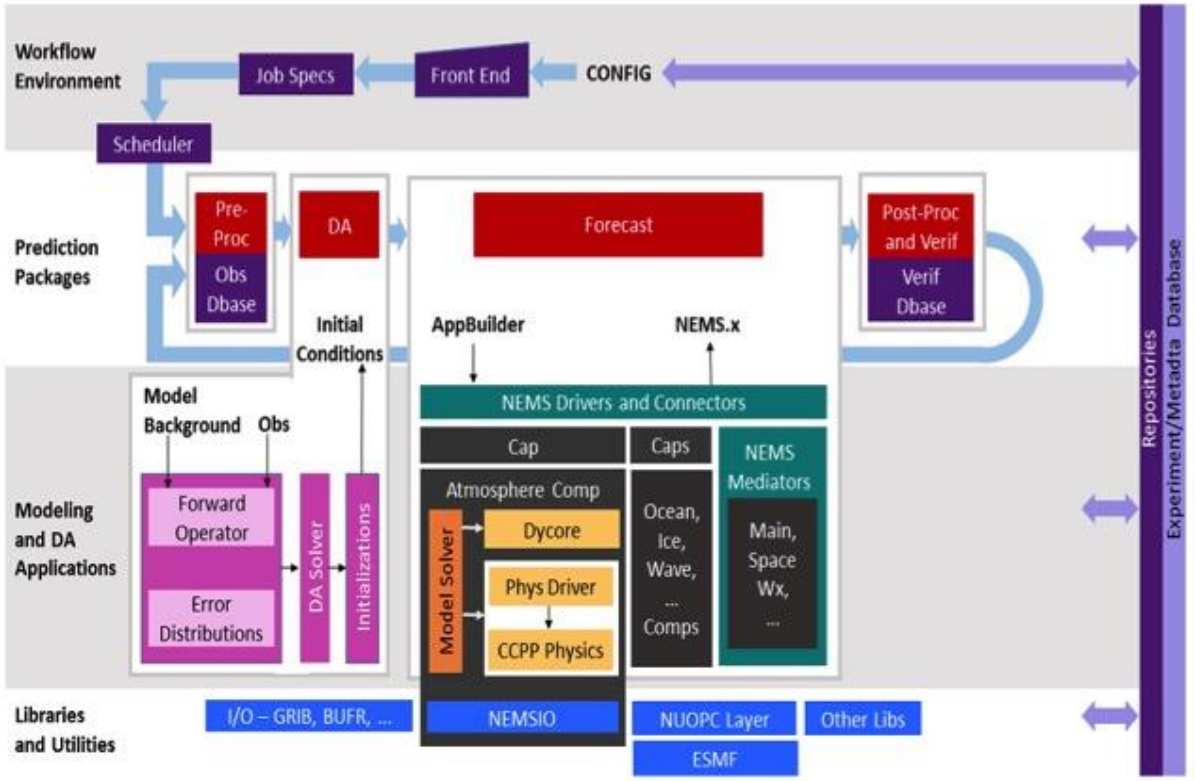
Roadmap: Architecture

ESMF: "Language"
NUOPC: "Dictionary"
NEMS: "Book"

ESMF/NUOPC/NEMS architecture enables unified coupled modeling and DA

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

FV3, CCPP, CICE, MOM6 (HYCOM), WW3, GOCART, WRF-Hydro, JEDI, ……



Courtesy NOAA NCEP System Architecture Working Group

Roadmap Fig. 3

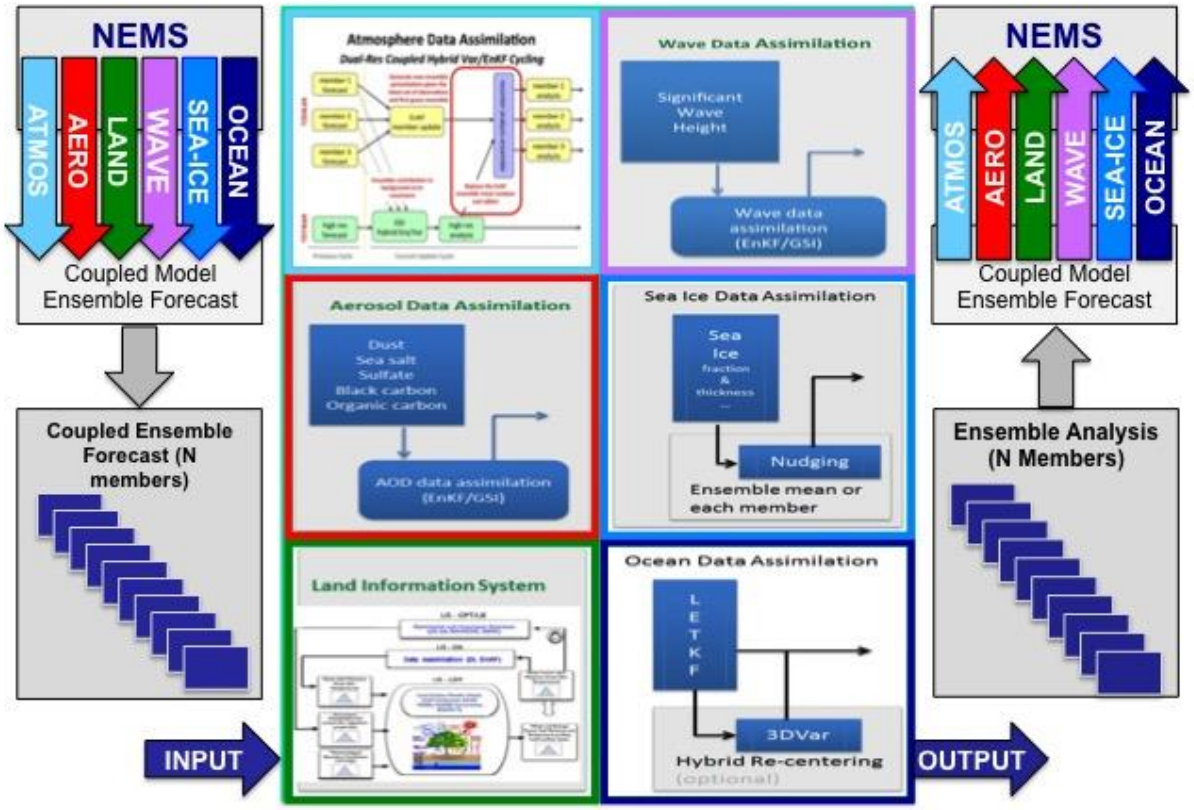
Roadmap: Fully Coupled

Moving to coupled Data Assimilation

Range of work going from weakly to strongly coupled Data Assimiliation

Commitment to go there, not mature enough for hard commitment

Joint Effort of DA Integration (JEDI)



Courtesy Suru Saha

Roadmap Fig. 4

The Progress

Team Efforts (I): Ice, Ocean, DA

The CICE consortium

- Started in October 2016
- Moving toward community modeling framework
- Icepack release this week!

Ocean modeling with ALE models

- MOM6 can be seen as a first attempt to merge existing models
- NOAA / NWS moving to MOM6 to merge MOM4 and HYCOM applications
- Can we go to a single community framework (ESPC discussions)?

Moving toward coupled Data Assimilation

- JCSDA Joint Effort for Data Assimilation Integration (JEDI), modular framework to streamline DA
- Agile code development techniques
- Marine-JEDI investments at NOAA

Team Efforts (II) : Total Water

Total coastal water prediction is identifeid as a major gap in our capabilities.

Remember Harvey ….

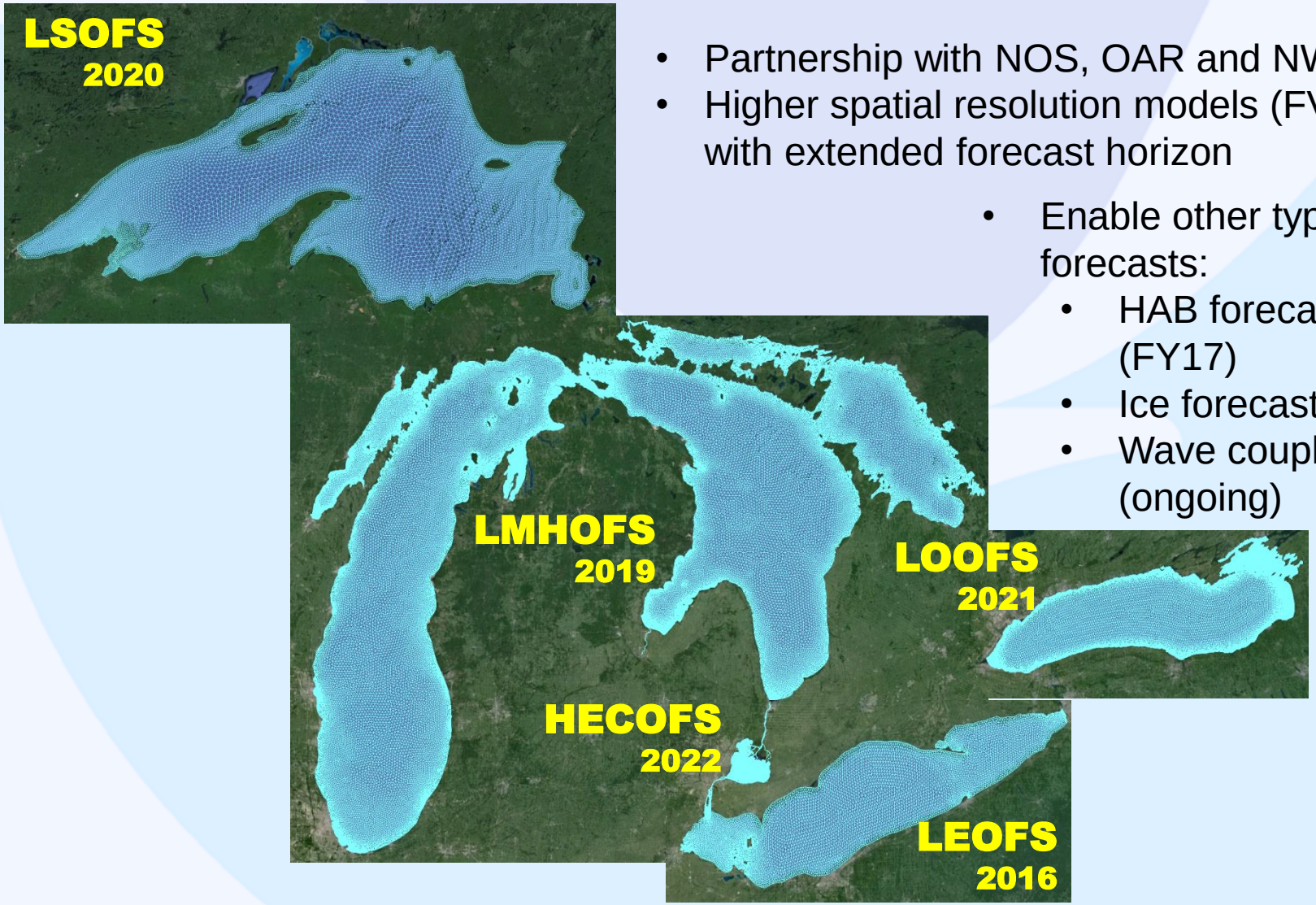
Five themes in NOAA with own programs and authorizations,

Building first NOAA plan for total coastal water prediction.

Requirements, solutions, prioritization.

Requirement Theme	Auth. / Org/ Program	Present Geogr. Focus Area	Technical Aspects (req. / foci)		
			2D / 3D focus	Major Error Sources	Foci (other than coupling)
Tropical Storm Surge	HFIP / OWP / NHC / MDL / EMC / RFCs / COASTAL act	Atlantic Coast, Gulf of Mexico, OCONUS	2D	Atm. forcing uncertainty	Ensemble Forcing / DEM
Extratropical Storm Surge	OWP / OPC / NOS / EMC / RFCs / MDL	Continental US, AK, Puerto Rico, all US Pacific Areas of Interest	2D	Forcing (atm + waves) / bathymetry	Bathymetry (+DEM), high fidelity 2D surge model
Coastal Ocean and Lake Models (Operational Forecast Systems)	NOS	CONUS - AK - HI estuarine/ coastal (head of tide to shelf) and Great Lakes	3D	Forcing (global ocean, atm + rivers) / bathymetry	3D circulation modeling, ecosystem forecasting
Water Quality	Ecological forecasting, HABHRCA	Atlantic coast, Gulf of Mexico coast, Pacific coasts, Great Lakes	3D	3D flow details / contamination sources / biology	Coupling to 3D circulation modeling
Inland National Water Model	OWP and RFCs	CONUS, Hawaii, Alaska, Puerto Rico	2D/3D	Forcings/ bathymetry	Water mass balance modeling

Great Lakes Modeling (I)

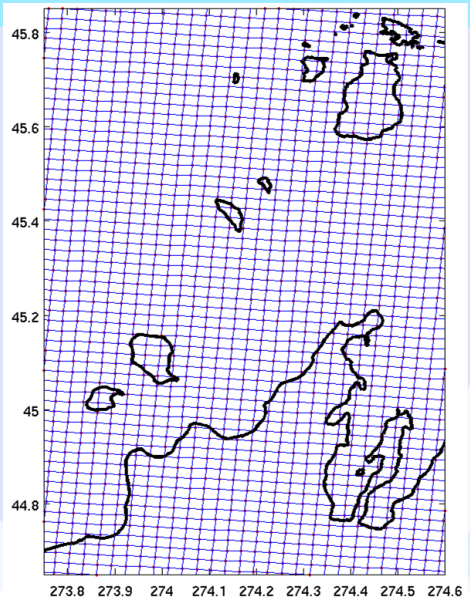


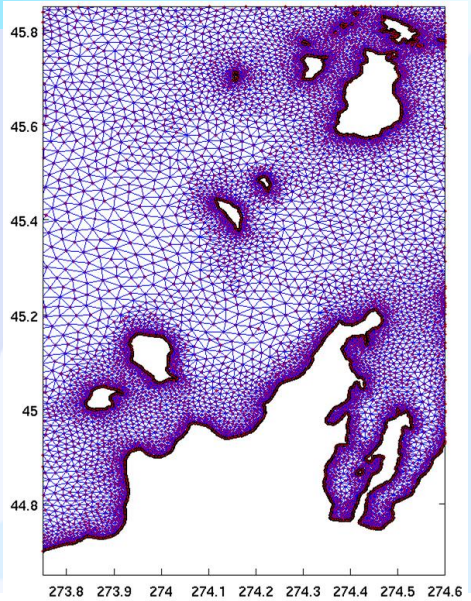
- Partnership with NOS, OAR and NWS
- Higher spatial resolution models (FVCOM) with extended forecast horizon
- Enable other types of forecasts:
  - HAB forecasting (FY17)
  - Ice forecasting (FY20)
  - Wave coupling (ongoing)

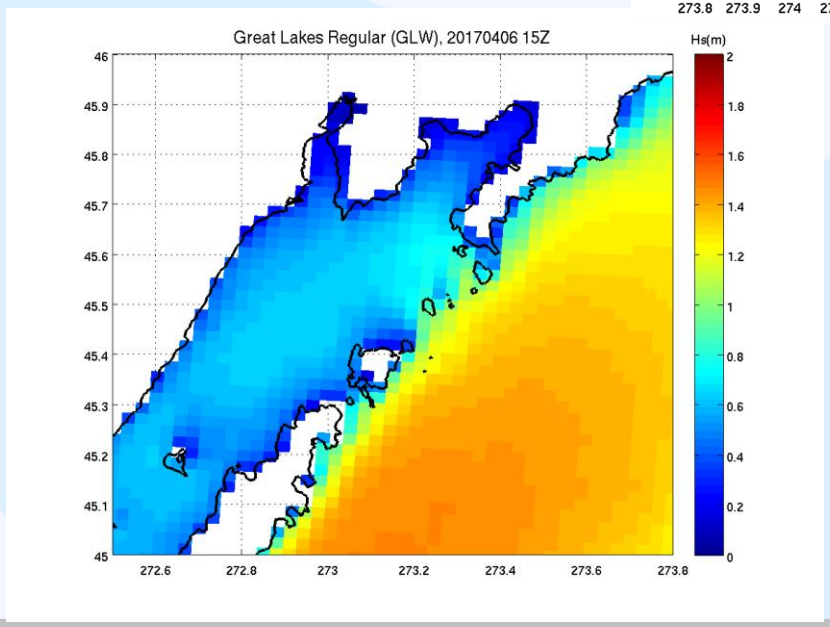
Great Lakes Modeling (II)

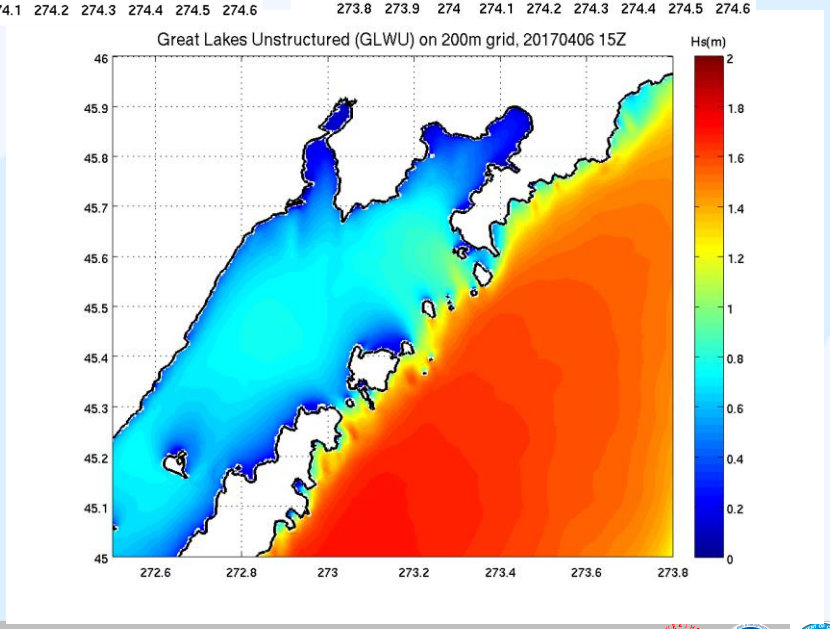
Unstructured grid Wave model in ops.

1. Waves in ops., hourly update — 2017
2. Couple to ice and circulation — Incr.
3. Couple to RRFS — 2022 +



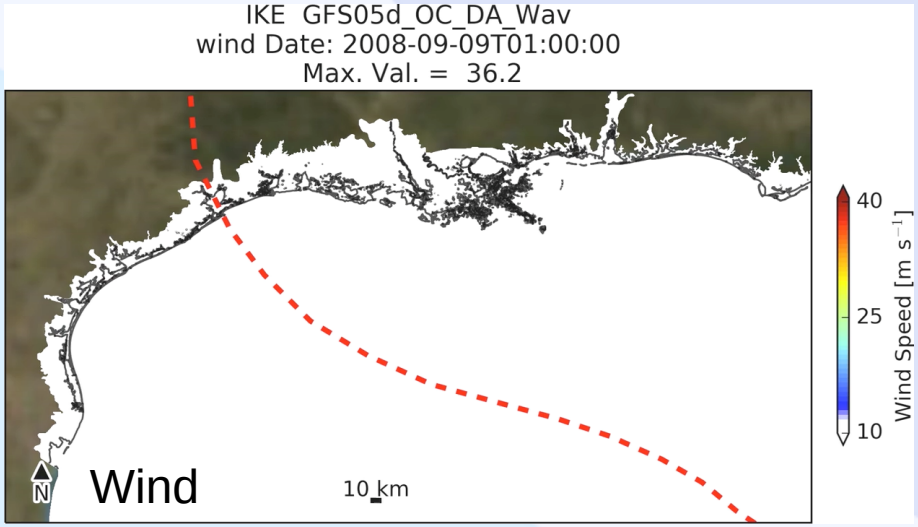


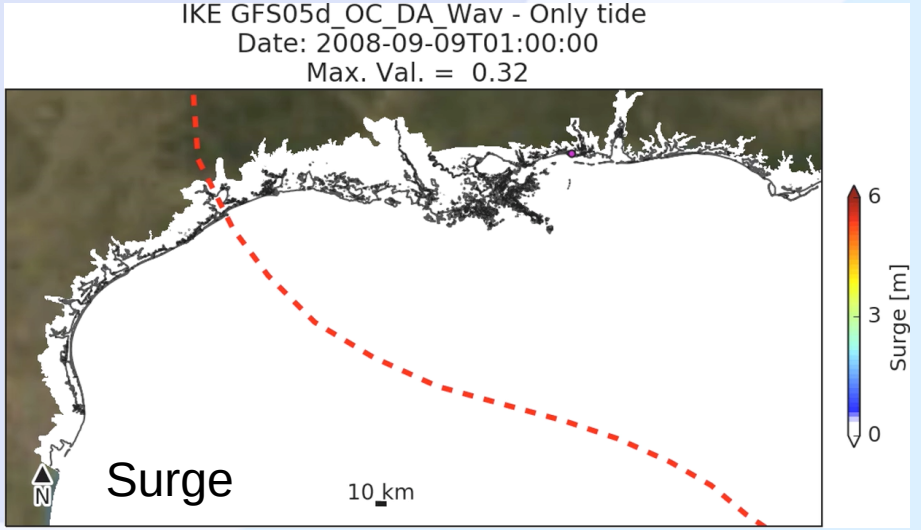


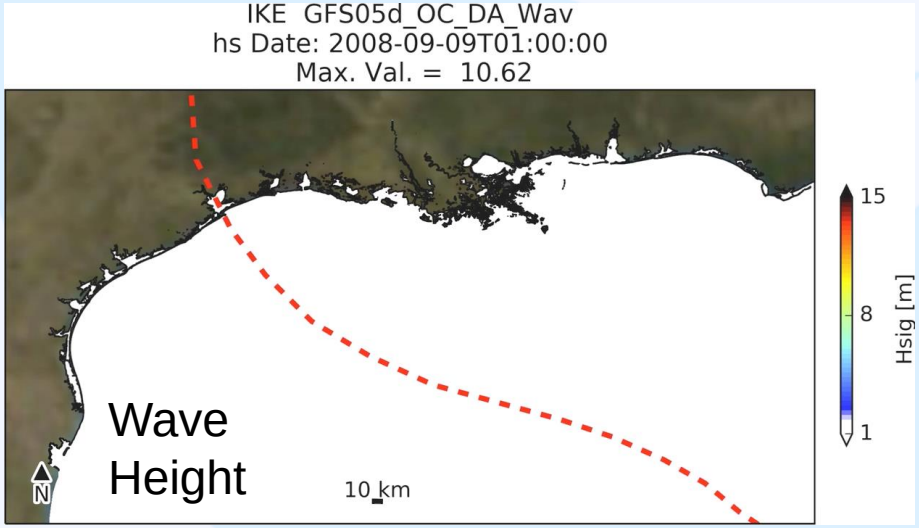


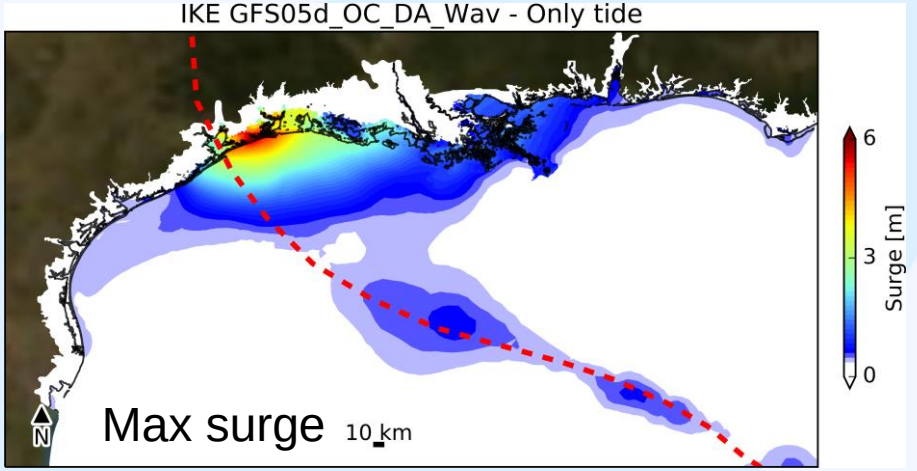
COASTAL Act

Preliminary findings



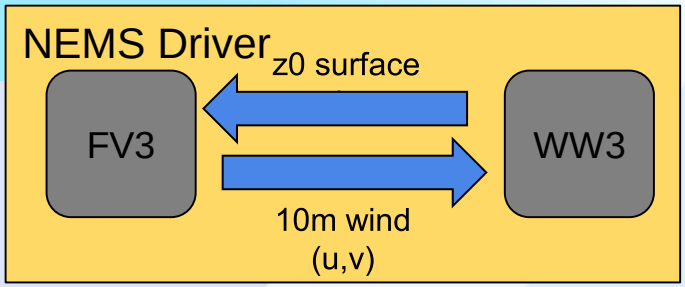




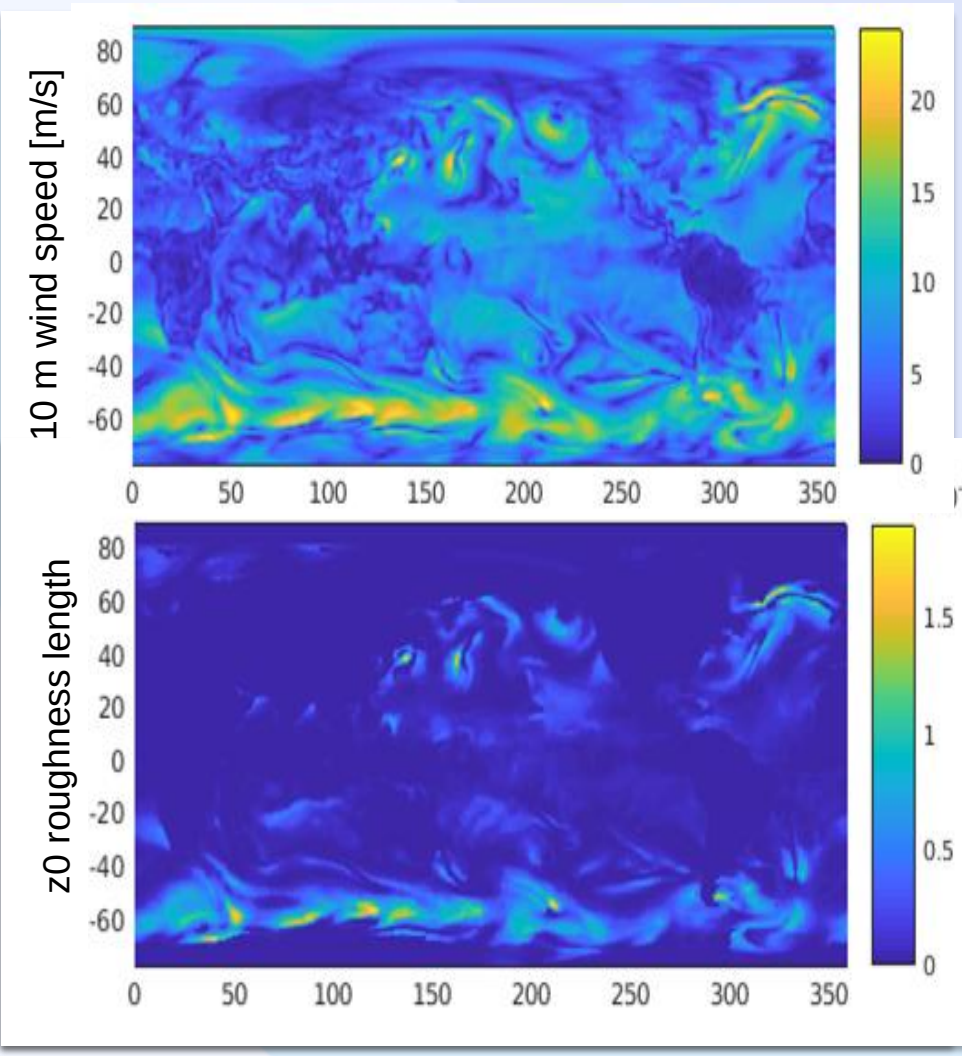


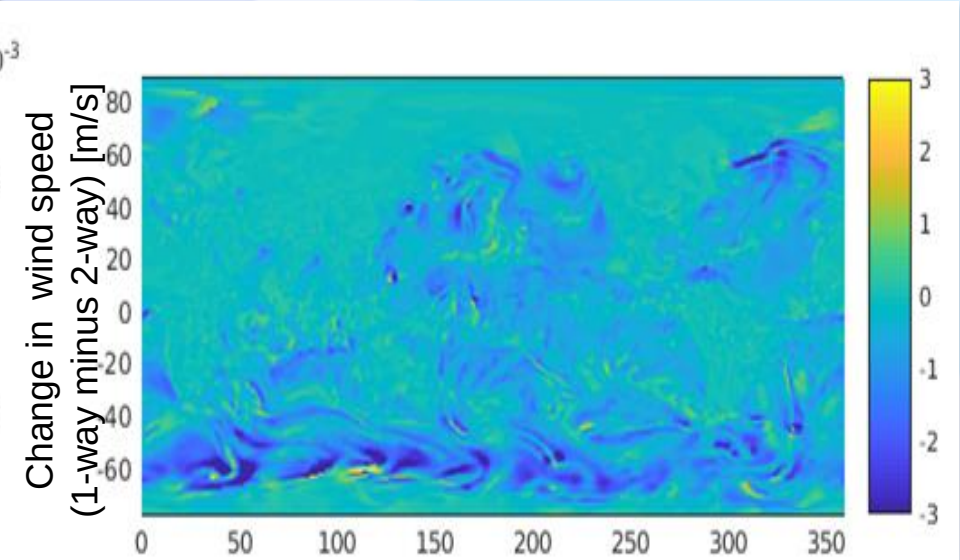
Credit: S. Moghimi, A. Abdolali and Z. Ma

Atm. – wave coupling



Will be used in next implementations to move global wave model and global wave ensembles into GFS and GEFS (at least 1-way coupling).

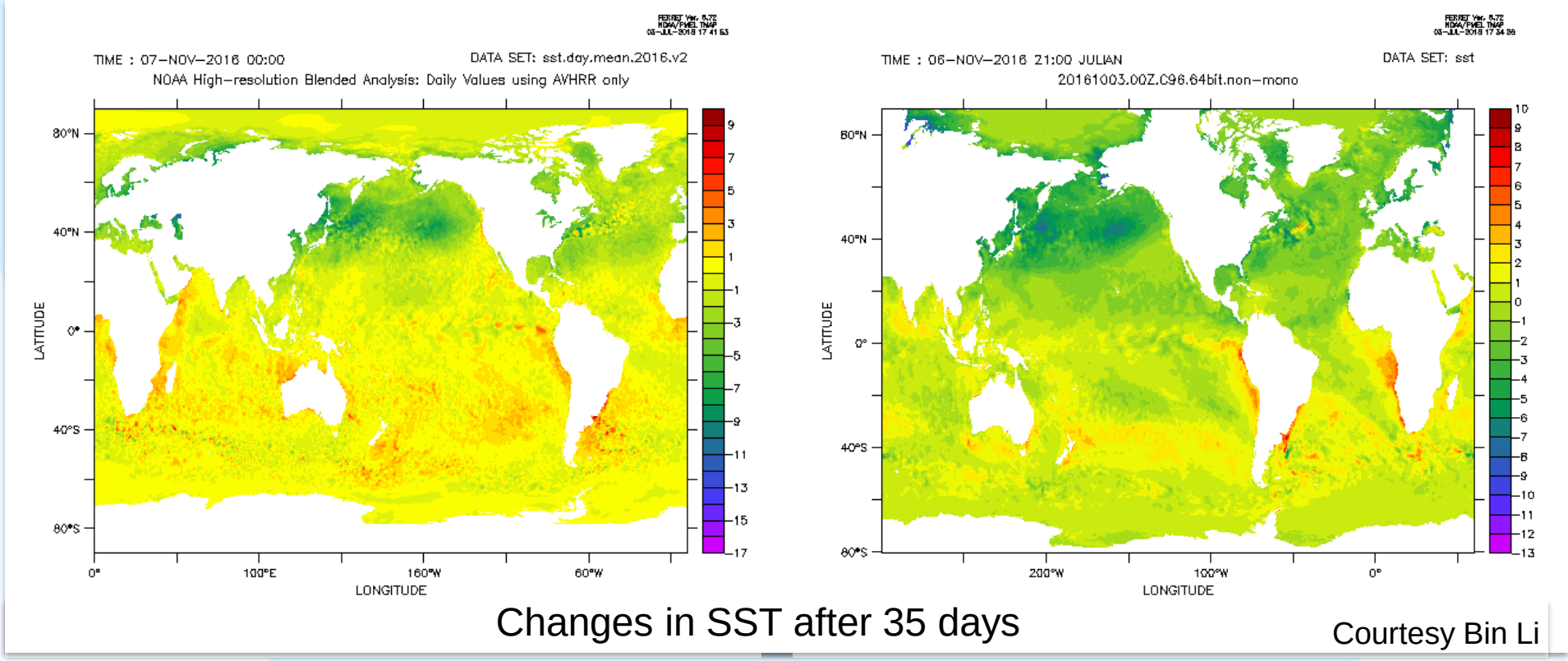




Courtesy Jessica Meixner

Atm. – ocean – ice coupling

- Air-sea fluxes are computed in FV3
- Regridding from FV3 to MOM6 is done in coupler
- SST from MOM6 is used in FV3
- Sea ice fields are received by FV3, but are not used in FV3 yet



Changes in SST after 35 days

Courtesy Bin Li