The NCEP experience in Earth System Modeling

NWS changing the way it is doing business.

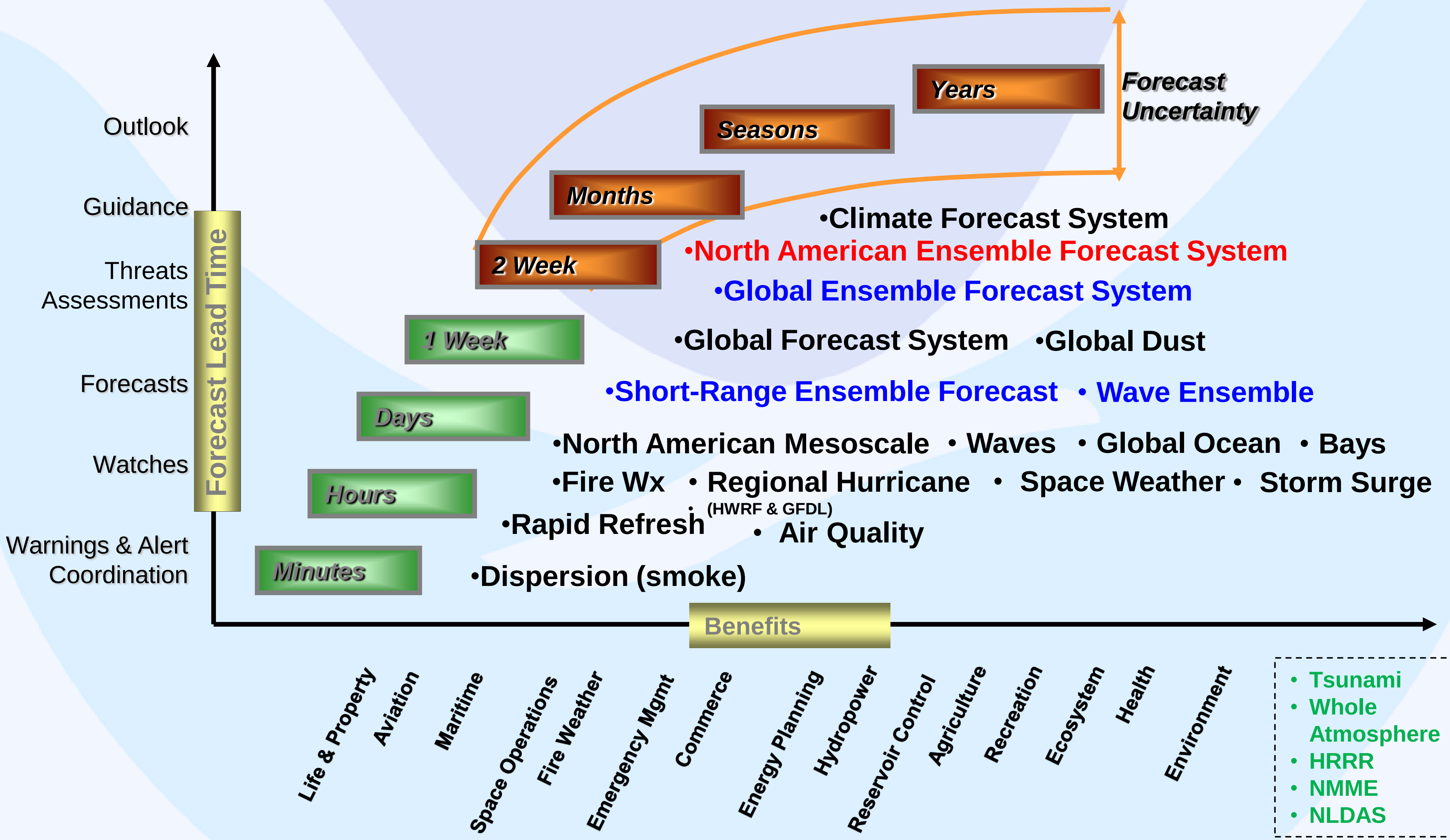
Hendrik L. Tolman
Senior Advisor for Advanced Modeling Systems
Office of Science and Technology Integration, NWS / NOAA

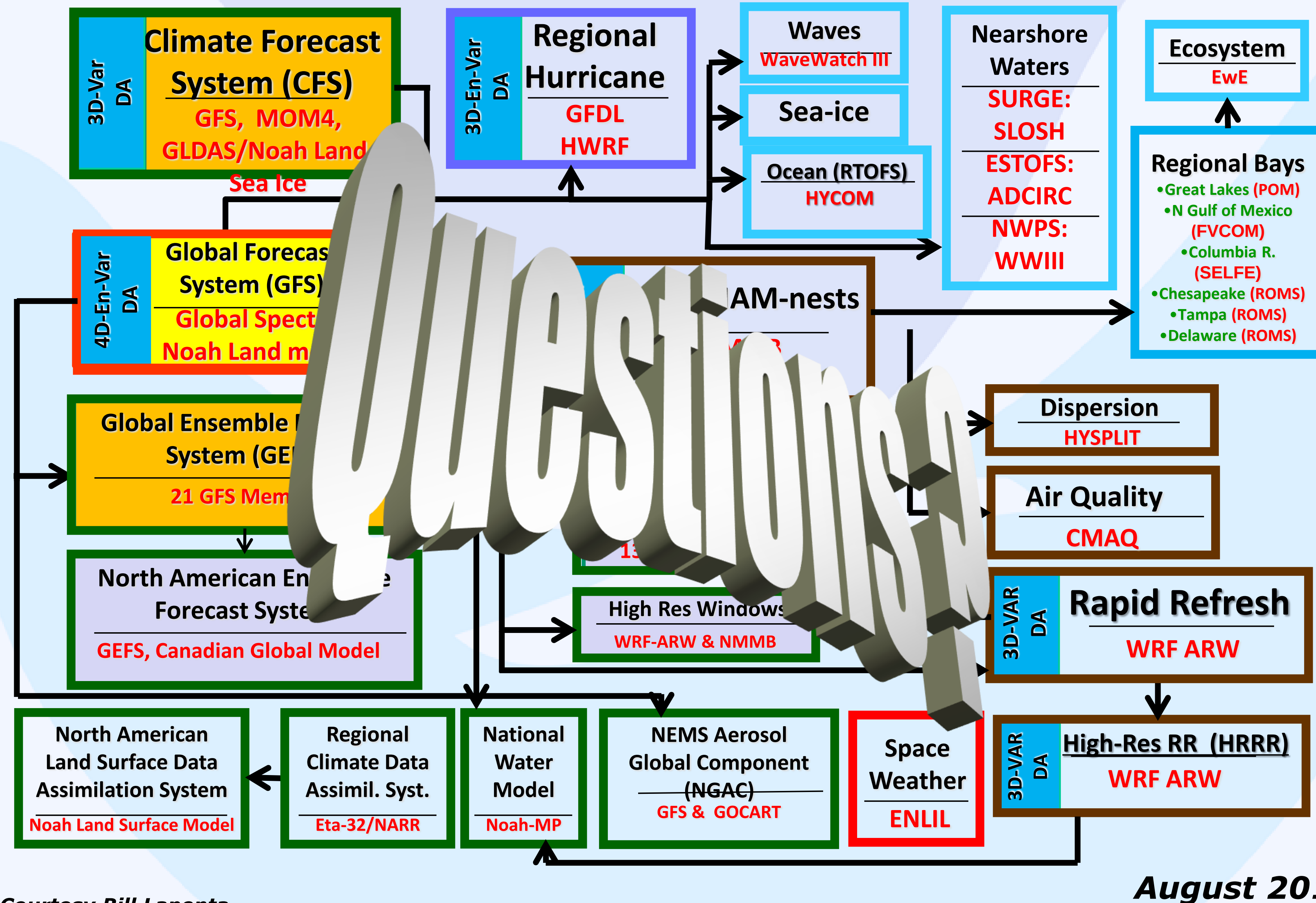
Hendrik.Tolman@NOAA.gov

The Big Picture

The presentation in two slides …..

Seamless Suite, spanning weather and climate





Courtesy Bill Lapenta

The Big Picture II

Operations and strategy rather than science

Outline

This will be a strategic presentation, without any slides with model results!

We are working toward a detailed strategic plan (Full draft Dec 2016), this is a preview subject to changes!

A little more about the present suite

- NWS reorganization
- Emerging requirement

Outline – cont'ed

External reviews

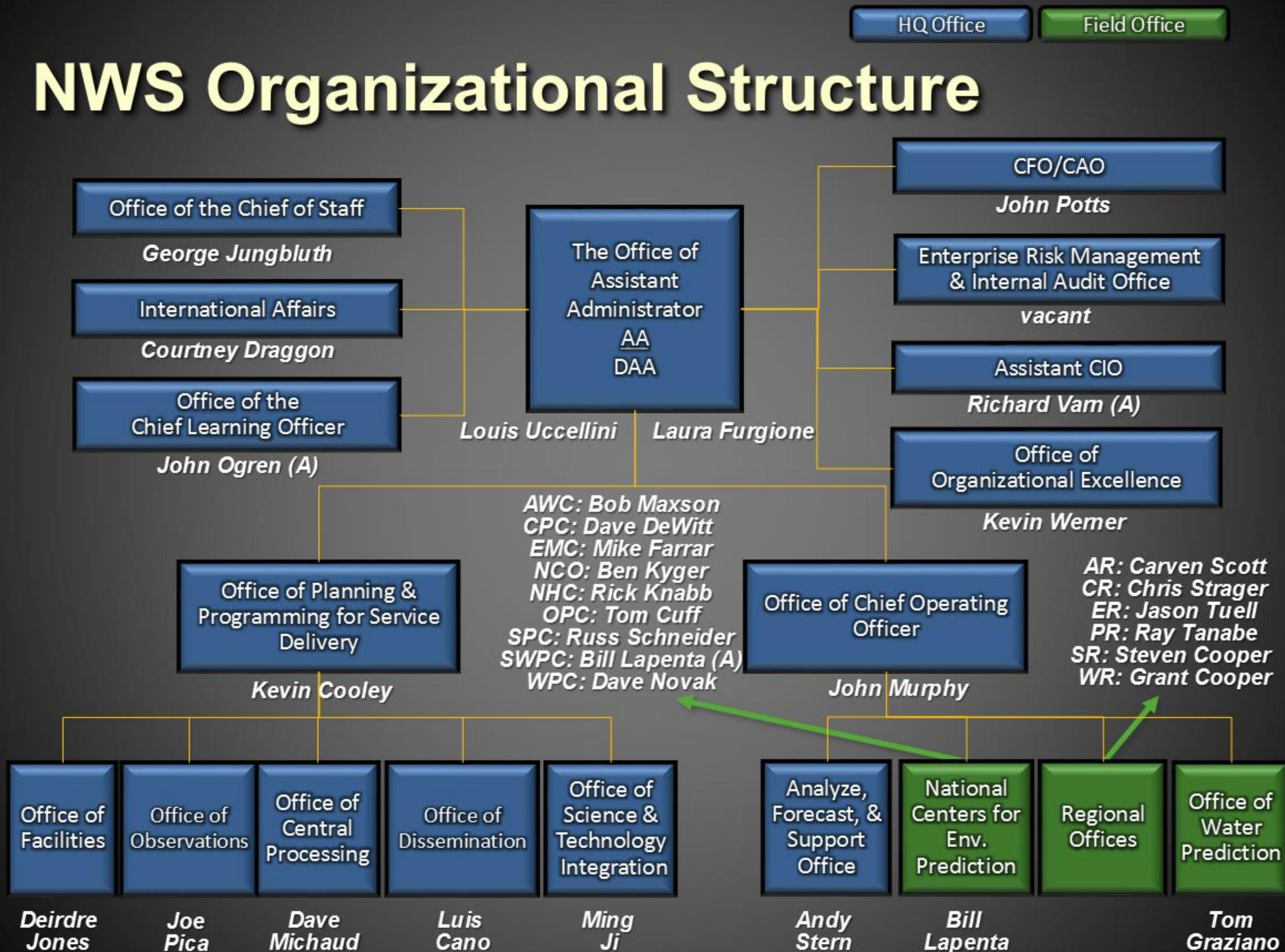
Where to go with the NCEP Production Suite

- Layout of products
- Mapping present models
- Coupling
- Can we afford this
- Architecture considerations
- Implementation process
- Community Modeling

Final thoughts (from operations …)

A little more about the present state ….

NWS Organizational Structure



Emerging requirements

- Weather Ready Nation.
  - Products.
  - Social science.
- High impact events.
- Weather to climate—seamless suite of guidance and products.
  - Week 3-4.
  - Systematic reforecast need.
    - Forecast uncertainty.
    - Calibration of outlook products.
    - Integrated Decision Support Services (IDSS)
- Range of products beyond weather:
  - Land, ice, ocean, waves, aerosols, (ecosystems, space weather).
  - Water cycle, Office of Water Prediction (OWP) (initially stood up as National Water Center (NWC))

External Reviews

External Reviews

Annual review of UCAR Community Advisory Committee for NCEP (UCAN)

- 2009 Deep dive
- Annual updates
- 2015: review NCEP Production Suite instead of new deep dive.
  - UCACN Model Advisory Committee (UMAC)
  - December 2015 final report

Frederick Carr (co-chair)	Tom Hamill
Richard Rood (co-chair)	Anke Kamrath
Alan Blumberg	Jim Kinter
Chris Bretherton	Ben Kirtman
Andy Brown	Cliff Mass
Eric Chassignet	Peter Neilley
Brian Colle	Christa Peters-Lidard
James Doyle	

UMAC main recommendations

- Reduce the complexity of the NCEP Production Suite.
- The NOAA environmental modeling community requires a rational, evidence-driven approach towards decision-making and modeling system development.
- A unified, collaborative strategy for model development across NOAA is needed.
- Essential to effective planning and execution is the creation of a Chief Scientist position for Numerical Environmental and Weather Prediction (NEWP). NOAA needs to better leverage the capabilities of the external community
- NOAA must continue to enhance High Performance Computing (HPC) capabilities
- NOAA must develop a comprehensive and detailed vision document and strategic plan that maps out future development of national environmental prediction capabilities.
- Execute strategic and implementation plans based on stakeholder requirements.

https://www.earthsystemcog.org/projects/umac_model_advisory

Basic issues / UMAC

The findings of the UMAC pointed NCEP to the following observation:

The production suite has evolved as a set of solutions for (ill-defined) requirements, instead of a set of products serving well defined requirements.

Basic issues / UMAC

Moving away from implementing solutions:

- Need better NWS requirements process
- Map requirements to products (not models)
- Target model development to better serve requirements
  - Community involvement from start
- Business case is integral part of decisions:
  - Unified model with concentrated effort, versus
  - models tailored to selected requirements

Additional considerations

- Coupled modeling needs to be considered in this context
- Focus on predictability and outlook products requires systematic ensemble / reanalysis (retrospective) / reforecast approach
- Data assimilation

Where to go with the NCEP Production Suite

Basic approach : atmosphere

Start with weather side:

- We are NWS !

Starting with products:

- What forecast time ranges
- which reasonably imply
  - Run cadences
  - Update cycle.
- Not so clear:
  - Resolutions
  - Data Assimilation
  - Reforecast / reanalysis / retrospectives
- Need to map requirements to forecast ranges

Possible Approach			
Range	Target	Cadence	Means
year	Seasonal	?	9-15mo
month	S2S	6-24h	35-45d
week	Actionable weather	6h	3-16d
day	Convection resolving	1h	18-36h
hour	Warn On Forecast *	5-15 ‘	3-6h
now	Analyses **	?	now

* FACETs

** Separating from DA for models

Tentatively vetted at the Dec. 2015 NCEP Production Suite Review

Models: atmosphere

Range	Year	Month	Week	Day	Hour	Now
Target	Seasonal outlook	S2S outlook	Actionable weather	Convection resolving	Warn On Forecast	Analyses / nowcast
Present models	CFS	CFS (GEFS extension)	GFS, GEFS, NAM, SREF, RAP, hurricane	HRRR, NAM nest, HiresW		RTMA, URMA, blend
Cadence	? (is 6h)	24h (is 6h)	6h	1h	5-15'	?
Range	9-15mo global	35-45d global	3-16d global (?)	18-36h regional (?)	3-6h ? regional	0 regional (?)
Updates	4y	2y	1y	1y	1y	6 mo
Reanal.	1979-now	20-25y	3y	?	?	
Where	?	WCOSS	WCOSS	WCOSS	?	WCOSS

- Ensemble based DA for all ranges (day and hour TBD), except possibly for the now range
- All global applications from single unified modeling system.
- Global / regional unification ?

- Present NPS elements not fitting in this layout:
  - Space weather (WAM-IPE / Geospace).
  - Hurricane models (GFDL / HWRF).

Year:

Tentative layout:

- 50km resolution, 9-15 month forecasts, full ensemble, updating weekly. Assuming DA mostly from week range, coupled

Present status:

- Corresponds to present CFS, but will only include longest runs

Key science questions

- Predictability; what to focus on for products
- Advanced coupling
- Physics suitable for severe weather outlook

Implementation issues:

- Dropping 45 day runs of present CFS requires “month” solution to be in place, otherwise “trivial”.

Month:

Tentative layout:

- Extend present weather scale ensembles out to week 3-4.
- 35km resolution (constant for forecast), coupling (ocean, ice, ?), increased ensemble size, DA from week range ?

Present status:

- Extend range of GEFS without stepping down resolution
- Could be uncoupled baseline IOC, but coupling preferred

Key science questions:

- Predictability, target products
- Need / payback for coupling
- Physics improvements (severe weather outlook)

Implementation issues:

- Slot can be filled by natural extension of GEFS

Week:

Tentative layout:

- Global 10-13km resolution full ensemble (21-26 members?), 5-7 day forecast at 6h cadence.
- Focal point for global DA.
- At least 1-way coupling for other component products

Present status:

- GFS, GEFS, NAM, SREF, RAP, hurricane all have element to be merged in this (single) product
- Wave, ocean, ice, aerosol all have “downstream” products in this range

Week (cont'ed):

Key science questions:

- Develop suitable single-core ensembles at this scale
- Develop scale aware and stochastic "unified" physics
- DA development, in general,
  - higher cadence for DA to support full suite?
- How and where to merge space weather and hurricanes
- Move this eventually into "grey zone" resolutions?

Implementation issues:

- Consolidating of models in a single set of products will be tricky
  - Products for users (availability, quality)
  - Transition downstream dependencies (regional models)
  - Develop incremental plan
- Larger relative resources needed compared to longer forecast ranges (due to regional → global ensembles)

Day:

Tentative layout:

- 3km resolution full regional (US+) ensemble
  - Hourly cycling model for short term forecast (18h, ensemble version of HRRR)
  - 2x or 4x per day, extend the forecast to 30h (for FAA, small craft advisory and other requirements)
  - 2x or 4x per day, extend the forecast to 60h to cover present NAM (nest) product usages.

Present status:

- Presently, the HRRR with hourly cadence, NAM nest and HighRes Window with 6 and 12h cadences and longer forecast ranges.
- No ensemble yet
- DA less mature (expensive) than for global models

Day (cont'ed):

Key science questions:

- Development of suitable ensemble
  - Single core, stochastic scale-aware physics
- DA development to bring up to par with global models
  - General approach
  - Hybrid ensemble based DA development
    - Ensemble size?

Implementation issues:

- Resources
  - At least 20x of HRRR, even without much more expensive DA
- Core unification
  - Presently simplifying to WRF-ARW and NMMB only approach
  - How to go to single core AND NGGPS
    - Need focus on model agnostic short-term development!

Hour:

Tentative layout:

- 1km resolution, 5-15 min cadence short forecast (3-6h ?) for same domain as "day" range products, with DA and ensemble approach

Present status:

- N/A

Key science questions:

- All of "day" range and then some, focusing on general DA and ensemble design
- Cost: on-demand and local as with hurricanes?

Implementation issues:

- Too expensive for tentative layout
- Will need some serious work on designing a manageable system
- Decision point around 2020, implementation 2016?

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 products
- Produce “too much” compared to tailored products (forecast range, cadence)

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-way 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	

Basic approach : DA

Unifying on GSI and ensemble hybrid 4DVAR.

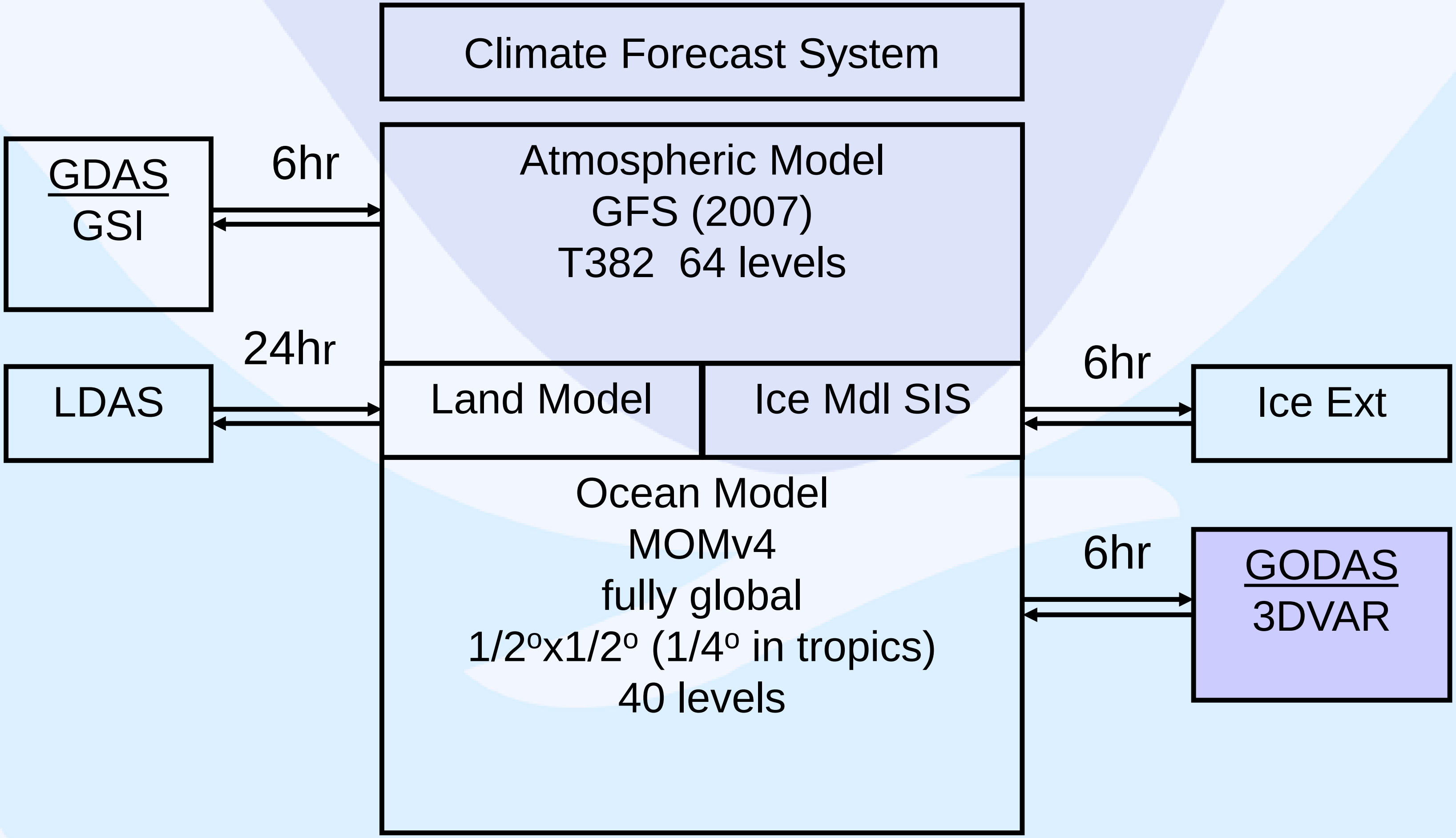
Global focus:

- Is a single DA system for all global models feasible?
  - Freeze or update DA for climate applications
- Where do we go with coupling
- Issues:
  - Scaling of GSI
  - Resolution of underlying ensemble

Regional focus:

- We do want to unify, but how feasible is this?
- Great progress with convection resolving, but
- not yet at the science level achieved at global scales
  - Ensemble based convection resolving DA ….
  - Hourly WoF, many efforts, no real link to production suite yet

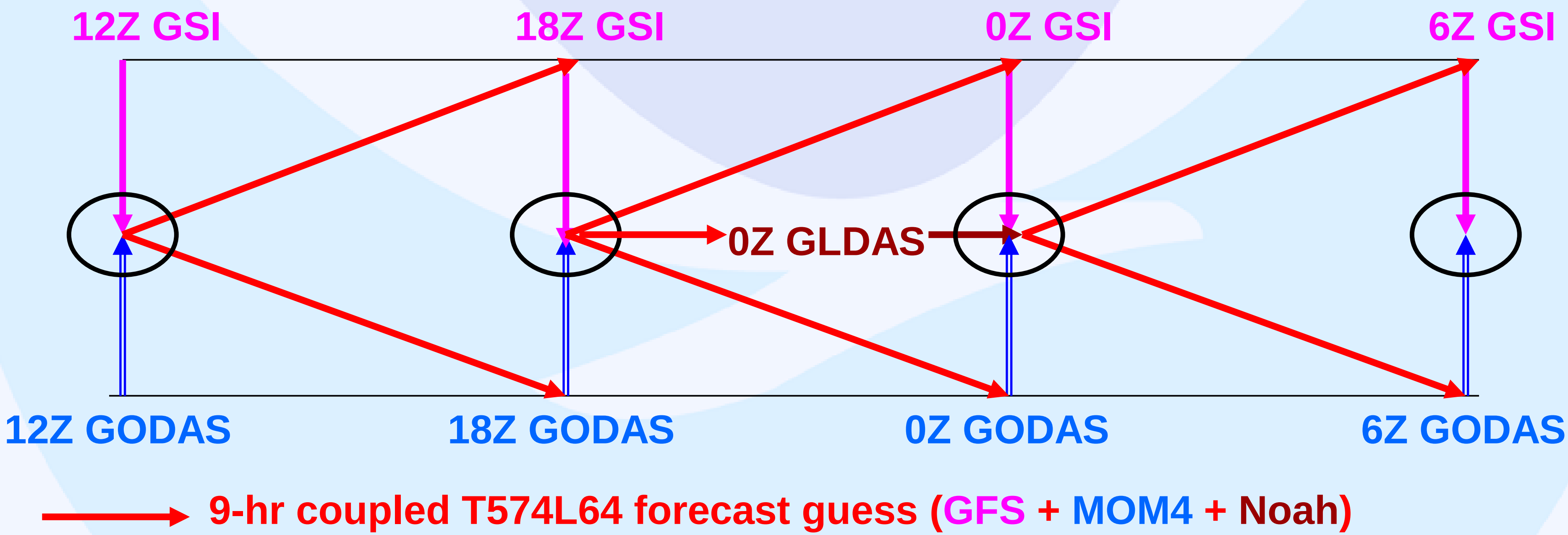
CFS at NCEP (RR – v2)



http://cfs.ncep.noaa.gov/cfsr

Data Assimilation (CDASv2)

CFSv2 is the dynamical model used in the CFS Reanalysis
The CFSR is an ocean, land, atmosphere, and sea-ice analysis, which covers the period from 1979 to present.



GSI is the atmospheric component
GODAS is the ocean component (includes sea ice)
GLDAS is the land component

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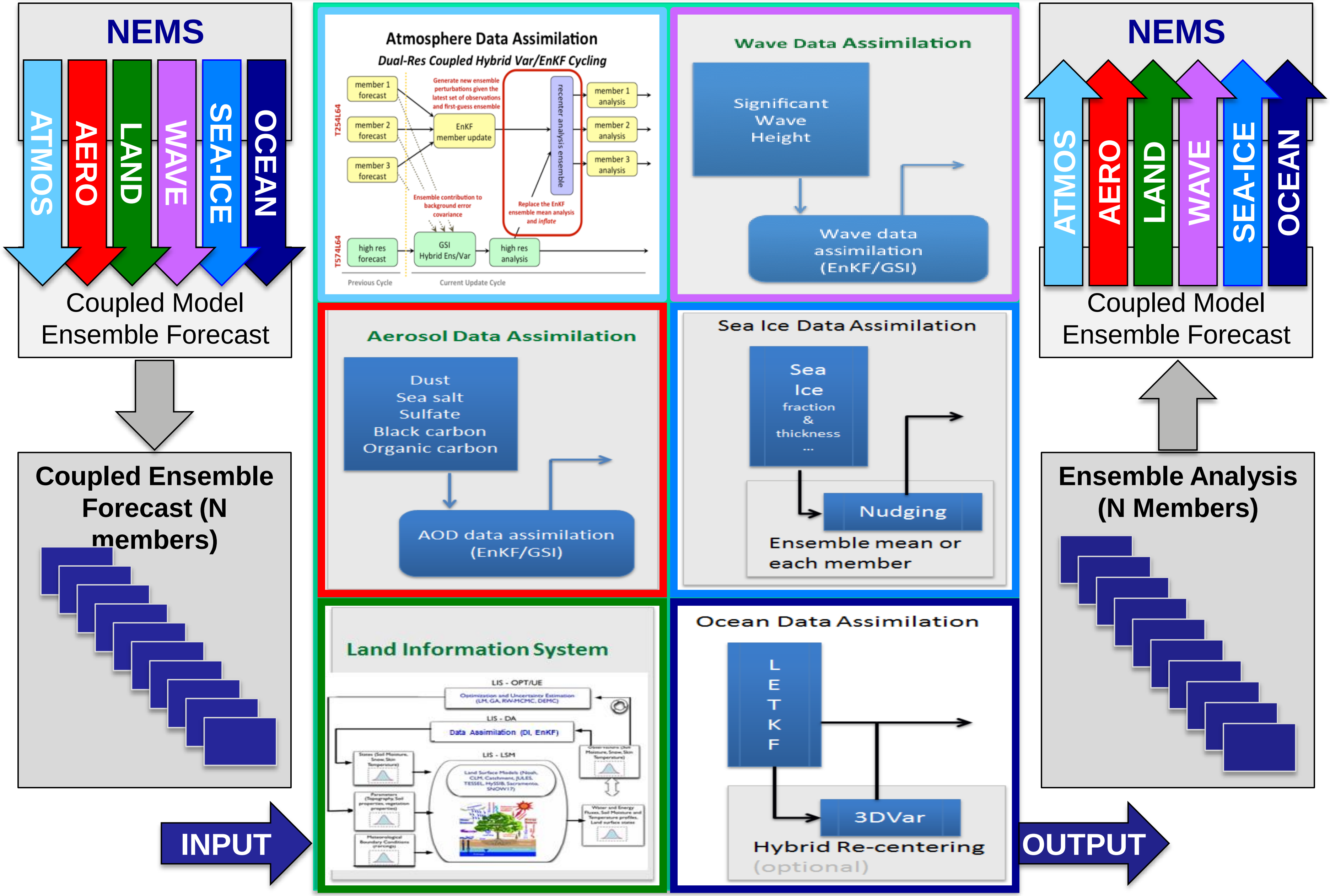
COUPLED DA PROOF OF CONCEPT

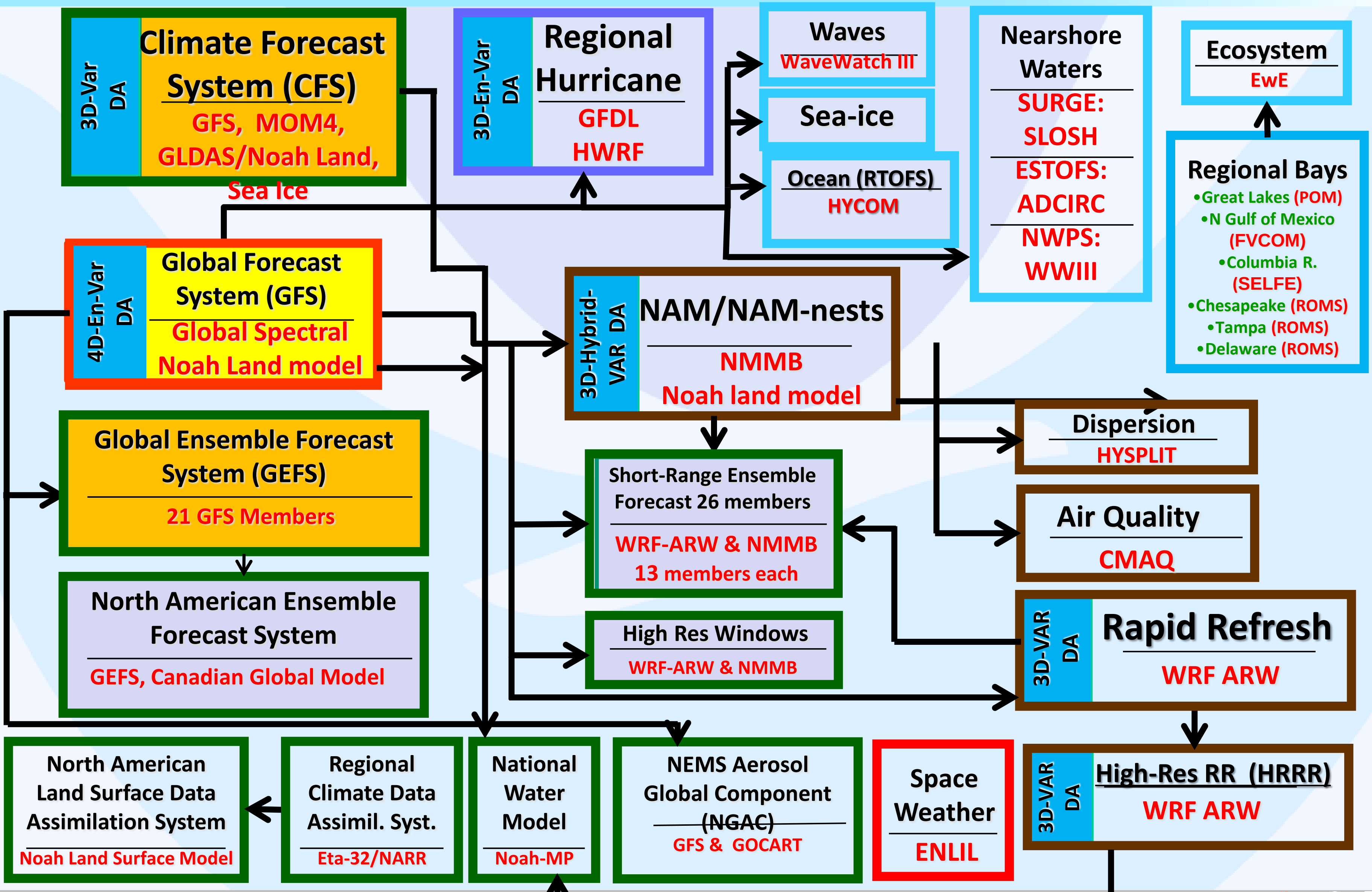
We are building a prototype stronger coupled DA system

- Atmosphere: Hybrid 4D-EnVAR approach using a 80-member coupled forecast and analysis ensemble, with Semi-lagrangian dynamics, and 128 levels in the vertical hybrid sigma/pressure coordinates.
- Ocean/Sea ice: GFDL MOM5.1/MOM6-SIS and/or HYCOM-CICE for the ocean and sea-ice coupling, using the NEMS coupler.
- Aerosols: Inline GOCART for aerosol coupling.
- Waves: Inline WAVEWATCH III for wave coupling.
- Land: Inline Noah Land Model for land coupling.

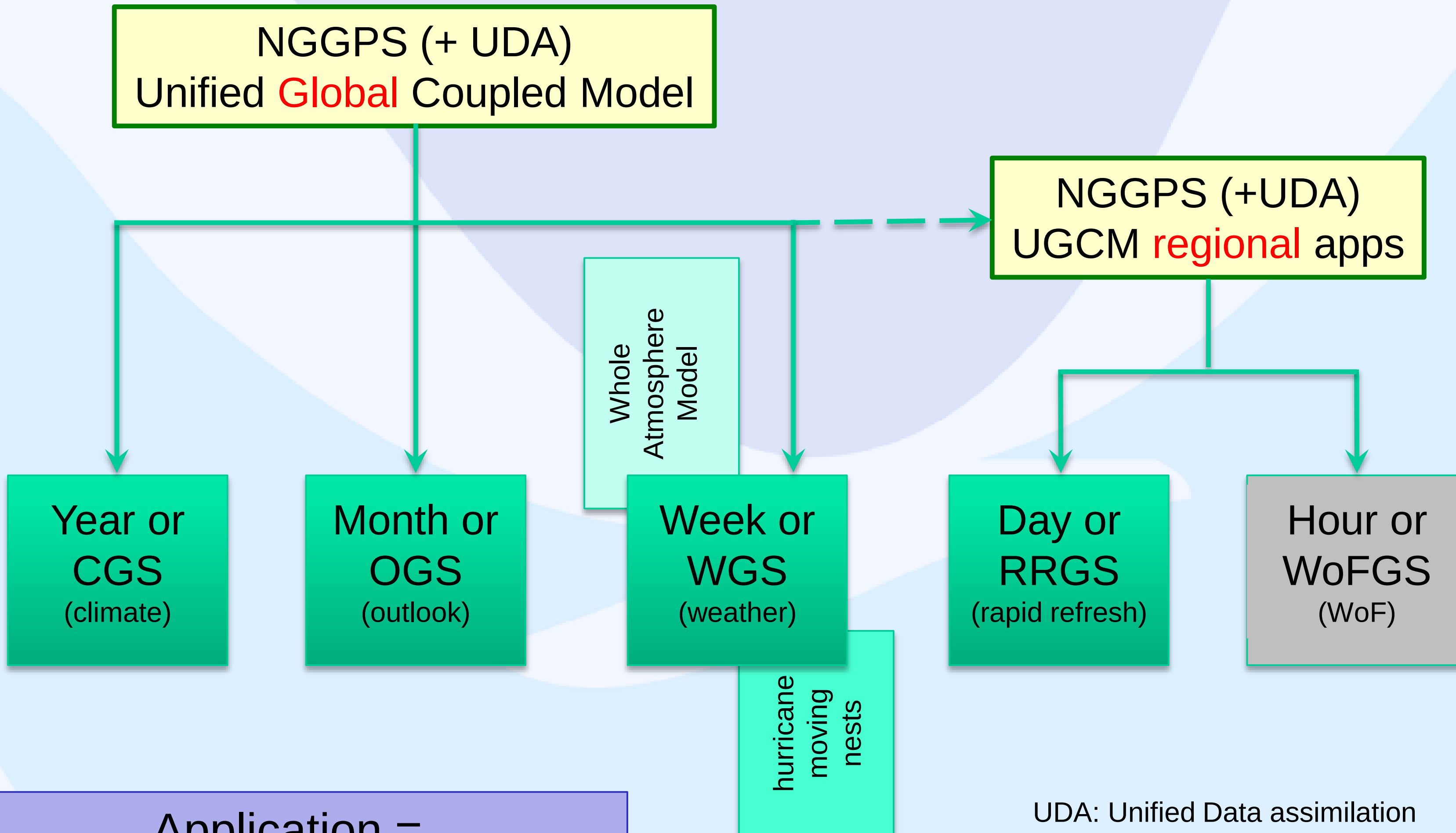
NCEP Coupled Hybrid Data Assimilation and Forecast System



What we have .....


3D-Var DA
Climate Forecast System (CFS)
GFS, MOM4, GLDAS/Noah Land, Sea Ice
3D-En-Var DA
Regional Hurricane
GFDL
HWRF
Waves
WaveWatch III
Sea-ice
Ocean (RTOFS)
HYCOM
Nearshore Waters
SURGE:
SLOSH
ESTOFS:
ADCIRC
NWPS:
WWIII
Ecosystem
EwE
Regional Bays
•Great Lakes (POM)
•N Gulf of Mexico (FVCOM)
•Columbia R. (SELFE)
•Chesapeake (ROMS)
•Tampa (ROMS)
•Delaware (ROMS)
4D-En-Var DA
Global Forecast System (GFS)
Global Spectral
Noah Land model
3D-Hybrid-VAR DA
NAM/NAM-nests
NMMB
Noah land model
Dispersion
HYSPLIT
Air Quality
CMAQ
Global Ensemble Forecast System (GEFS)
21 GFS Members
Short-Range Ensemble Forecast 26 members
WRF-ARW & NMMB
13 members each
North American Ensemble Forecast System
GEFS, Canadian Global Model
High Res Windows
WRF-ARW & NMMB
3D-VAR DA
Rapid Refresh
WRF ARW
North American Land Surface Data Assimilation System
Noah Land Surface Model
Regional Climate Data Assimil. Syst.
Eta-32/NARR
National Water Model
Noah-MP
NEMS Aerosol Global Component (NGAC)
GFS & GOCART
Space Weather
ENLIL
3D-VAR DA
High-Res RR (HRRR)
WRF ARW

What we want ….



Application =
Coupled Ensemble
+ Reanalysis + Reforecast

UDA: Unified Data assimilation
CGS: Climate Guidance System
OGS: Outlook Guidance System
WGS: Weather Guidance System
RRGS: Rapid Refresh Guidance System
WoFGS; WoF Guidance System

Can we afford this ?

Factors driving costs

Start from existing models, compute impact of X factor increase in relevant model features.

Factor impacting costs	Scaling	Comments
Horizontal resolution	X^2 –X^3	Quadratic in number of grid points + up to linear in associated time step (CFL criterion)
Vertical resolution (including extent)	X^1 –X^2	Linear in number of grids points, + up to linear in associated time step (CFL criterion)
Cadence (runs per day)	X	
Forecast range	X	
Ensemble size	X	
Physics / numerics	TBD	Unknown, potentially important.
Output rate	TBD	Ignored here, but can be potentially important, needs to be considered in computer design.

Estimating element costs

	resolution	levels	length	cadence	members	phys / num	coupling	DA	cost
	km	-	h	per day	-	X	X	X	Pflops
Year ("CFS")	100	64	6480	4	1				0.009
low	50	128	6480	0.14	28	1.3	1.1	1	0.126
med	50	128	8640	0.14	28	1.5	1.1	1	0.194
high	50	128	10800	0.14	56	1.7	1.1	1	0.550
high (res)	35	128	10800	0.14	56	1.7	1.1	1	1.604
Month ("GEFS")	35	64	277	4	21				0.020
wave ensemble	55	1440	240	4	21				0.006
low	35	64	840	4	21	1.3	1.5	1	0.119
med	35	90	960	4	31	1.5	1.5	1	0.326
high	35	128	1080	4	41	1.7	1.5	1	0.782
high (res)	18	128	1080	4	21	1.7	1.5	1	2.944
Week ("GFS")	13	64	256	4	1				0.028
SREF	16	40	84	4	26				0.029
RAP	13	50	18	4	1				0.004
wave multi_1/2	54-18-7	1440	180	4	1				0.005
RTOFS Global	13	64	192	1	1				0.003
low	11	128	144	4	15	1.3	1.3	2	2.644
med	11	128	168	4	21	1.5	1.3	2	4.982
high	11	128	192	4	26	1.7	1.3	2	7.990
high (res)	9	128	192	4	31	1.7	1.3	2	17.393
Day ("HRRR")	3	64	15	24	1				0.025
NAM parent and nest	4	60	60	4					0.014
HiResWin	3	45	48	2					0.010
low	3	64	18	24	21	1	1.3	3	5.063
med	3	90	21	24	26	1	1.3	3	9.173
high	3	128	24	24	31	1	1.3	3	16.160
high (res)	2	128	24	24	31	1	1.3	3	54.541
Hour (WoF from HRRR)	data taken directly from previous "day" block								
low	1	64	4	96	26	1	1	3	56.300
med	1	90	3	144	26	1	1	3	89.068
high	1	128	2	288	26	1	1	3	168.900
high (res)	0.5	128	2	288	26	1	1	3	1351.200

Resulting compute needs (ops)

Cost in PFlop

	year	month	week	day	hour	total
low	0.32	0.30	6.6	12.7	141	161
med	0.49	0.81	12.5	22.9	223	259
high	1.38	1.95	20.0	40.4	422	486
high-2	4.01	7.36	43.5	136.4	3378	3569

Overall costs per element uncertain, but clearly different with respect to NPS element:

- Hour / WoF very expensive
- Other elements feasible in next 5-10 years at "med" level

Moving from equal split between global (year-week) and meso (day-hour) modeling to compute focus on meso.

Percentage of NPS without hour element

	year	month	week	day
low	1.6%	1.5%	33.2%	63.7%
med	1.3%	2.2%	34.0%	62.5%
high	2.2%	3.1%	31.4%	63.4%
high-2	2.1%	3.8%	22.7%	71.3%

Compute needs beyond operations

More elements that operational machine only

- Backup machine of same size
- T2O needs for NCEP and partners to fully support ops
- R&D needs "higher up in the funnel" (tentative)
    - ➤ Outside NPS represents balanced one-NOAA HPC approach
- Separate resources for Reforecast / Reanalysis (RR)

PFlop with hour element, feasible ?

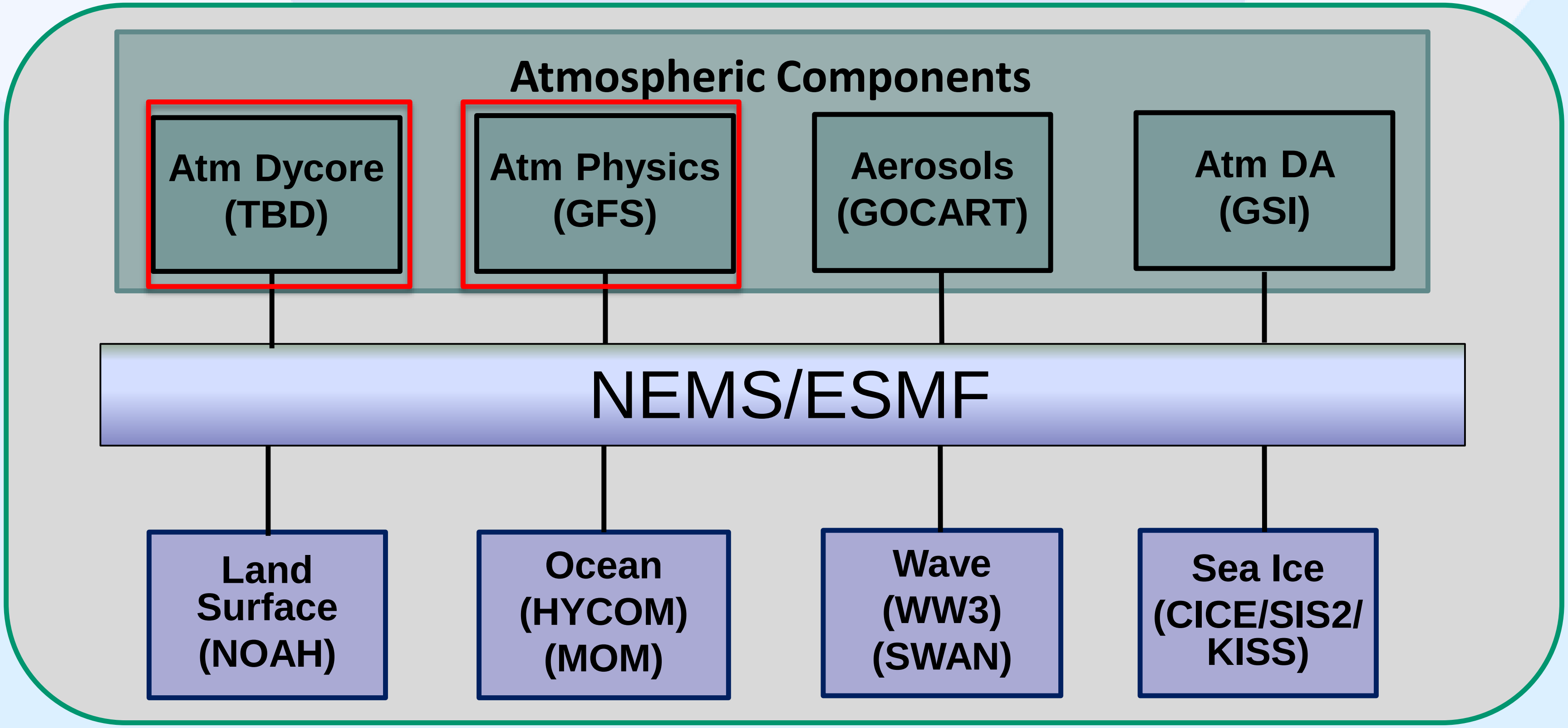
	ops	backup	T2O	R&D	RR	total
low	161	161	321	1071	120	1834
med	259	259	519	1729	195	2961
high	486	486	972	3240	364	5548
high-2	3569	3569	7138	23795	2677	40748

PFlop without hour element, feasible !

	ops	backup	T2O	R&D	RR	total
low	20	20	40	133	15	227
med	37	37	73	245	28	419
high	64	64	127	425	48	727
high-2	191	191	382	1275	143	2183

Architecture

NGGPS/UGCM and NEMS / ESMF



Modular modeling, using ESMF to modularize elements in fully coupled unified global model

(+ *NWM*, *ionosphere* , *ecosystems* , ……)

NGGPS physics

Scale aware
Stochastic
“Unified”

Atmosphere Model including Dynamics

Dynamical equations, advection, horizontal mixing, diffusion.

standard interface for model physics

Δt, u, v, w, T, θ, p, z, q_x, c_x, a_x
destaggered

Tendencies
and Updates

Initialize
Physics
Tables and
Databases

Init Mode

Atmospheric Physics Driver

(init, run, finalize modes)

Modified Kalnay Rules Layer

- Radiation
- Deep and Shallow Cumulus
- Surface Layer
- PBL and Vertical Mixing
- Micro-physics

Finalize Mode.

Output
Diagnostics

- fields
- rates
- budgets
- others

NUOPC Physics Driver Schematic
Extend to coupling!

DTC support as CCPP

NGGPS

(Next Generation Global Prediction System)

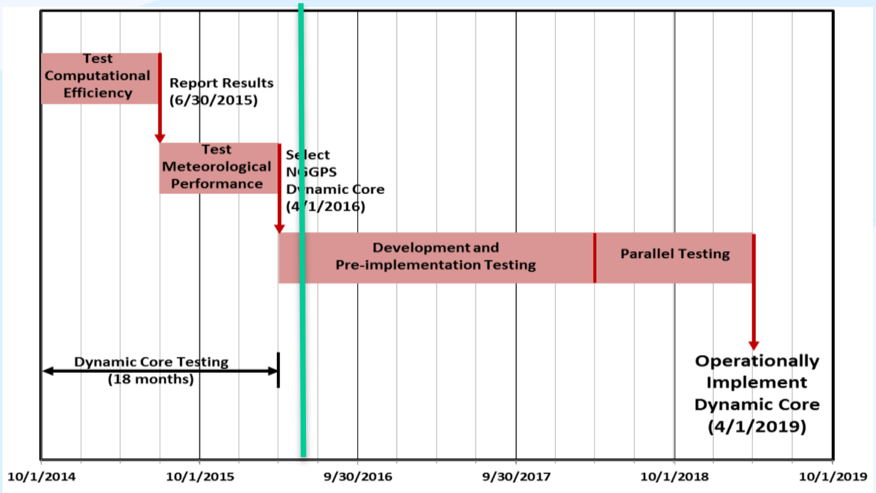
NWS R2O funding and NGGPS projects.

- For first time NWS is funding agency.
  - Fund gaps in operations.
  - Project based funding for strategic development.
    - Within US government.
    - Academia, with NWS partners / champions.
  - Test beds for R2O.

- Key element: Next Generation Global Prediction System.
  - Next generation Dycore Selection.
  - Unified physics interface, focus on physics.
  - 11 more NGGPS teams ….
  - Model Coupling
    - Started with Climate Forecast System
    - Arctic modeling

NGGPS dycore

- Selecting a new dynamic core for global model to serve the NWS for the coming decades.
  - Architecture suitable for future compute environments.
  - Non-hydrostatic to allow for future convection-resolving global models.
- 18 month process to down-select candidate cores.
- 5 year plan to replace operations.
- Core → NEMS → applications.
  - ~~GSM-NH (EMC)~~
  - MPAS (NCAR)
  - FV3 (GFDL)
  - ~~NIM (ESRL)~~
  - ~~NEPTUNE (NRL)~~
  - ~~NMMB-UJ (EMC)~~



Implementation

The old (present) process

EXP	Description	Comments	Platform/# of cases
Pre-Baseline Experiments			
TDRP	FY12 HWRF + One-Way Hybrid GSI	Run in real-time [illegible] 2012 [illegible]urricane season (Stream 2.0 Demo). Also included real-time TDR data for 19 cases.	CCS, All 2012 ATL and EP 821 cases
HDFL	FY12 HWRF + Flux truncation into POM	DTC performed these tests to evalu[illegible] of 25% reduction of heat, momentu[illegible] radiative fluxes in the operational couple[illegible]-POM	Jet, All 2012 ATL and EP 821 cases
P160	FY12 HWRF + Initialization Chang[illegible]	Improved size correction, m[illegible]tions to filter domain and use GFS v[illegible]x [illegible] initial storm intensity less than 16 m[illegible]	[illegible]t, All 2012 ATL and EP [illegible]1 cases
HNPI	FY12 HWRF + [illegible] nest-parent interpolations	Revised nest-parent [illegible]olations and improved treatment of vari[illegible] nest boundaries	J[illegible] All 2012 ATL and EP a[illegible]6 others from 2010 - 11 [illegible]38 cases
HNTT	HNPI+ New [illegible]st movement algor[illegible]	Improve[illegible] tracking based on [illegible] MSLP and T[illegible]'s tra[illegible]er. Choice of [illegible]8 [illegible] th[illegible] had diff[illegible] tracking the nest p[illegible]	J[illegible] Selected storms 168 cases
HHPC	FY12 HWRF + [illegible] Frequency P[illegible]sics Calls	[illegible]creased Physics calling fre[illegible] from 180 sec. to [illegible] sec. Third nest s[illegible]e incr[illegible]sed by about 20% from [illegible].5x5 to 7x6.5	Jet, A few selected storms from 2012; 100 cases
Baseline Experiment			
H130	All modifications from pre-baseline experiments	2013 HWRF b[illegible]eline is based on positive outcome from the pre-baseline experiments described above. Run on three different platforms.	Jet/Zeus/WCOSS, All 2010-2011-2012 ATL and EP 1870 cases each
Physics Upgrades			
H131 (Final)	H130 + PBL changes	HWR[illegible] (GFS based scheme) is up[illegible] to include [illegible] critical Richardso[illegible]er for improved [illegible]ent of PBL height[illegible] weather conditions.	Jet/Zeus/WCOSS, All 2011-2012 and August - October 2010 ATL and EP 1870 cases

Systematic Testing

EMC Change Control Board
- Scientific Integrity
- Product Quality
- EMC Mgmt Approval

- Generate RFC's
- Submit RFC's to NCO

Implementation Phase
- SPA's build NCO parallel from RFC's
- 30-day NCO parallel
  - Test code stability
  - Test dataflow
  - Products to NCEP Centers and EMC code developers
- NCEP Centers
  - Evaluate impact
  - Assessments to NCEP OD

- 30-day NCO parallel stable
- NCEP centers approve

- Briefing to NCEP Director for final approval

Implementation

Stakeholder input

Requirements definition

- Identified as a weakness by NCEP stakeholders and UMAC
- incomplete requirements may create false expectations
- NWS needs an improved process—is portfolio management the answer?

Stakeholders--- need earlier access to information

- What changes are being made?
- What's the rational?
- What characteristics of the tool will change?
- Stakeholder calibration methods need time and access to pre-implementation data in order to adapt (i.e., GEFS FY15 Upgrade)
- 30-day NCO parallel insufficient for customer assessment

IMPROVE COMMUNICATION BETWEEN MODEL DEVELOPERS AND STAKEHOLDERS

Process suggested recently to AA

<u>Start of Development Cycle</u>

- Conduct a workshop (modelers, field, academia, customers)
- Prioritize features to be improved
- How do you propose to improve them?
- How much will it cost (time=$, HPC)
- How will data be disseminated?
- Develop detailed test plan
- Create end-to-end charter
- Get appropriate approval to proceed

Phase 1 of test plan (2-4 months)

Assessment of Phase 1 results (2 weeks)
Invite SOO's to participate

MEG !?

Phase 2 of test plan (2-4 months)

Assessment of Phase 2 results (2 weeks)
Invite SOO's to participate

MEG !?

Test

Assess

Final Approval

NCO Testing & Implementation

Community Approach

Public-private partnership

The US is unique in that weather forecasting is treated as a public-private partnership with close interactions between

- National Weather Service.
- Other government entities.
  - In NOAA, NASA, DoD, ….
- Commercial weather companies.
- Including and integrated in the media.

- 2003 report from Committee on Partnerships in Weather and Climate Services, Committee on Geophysical and Environmental Data, National Research Council:
  - Fair Weather: Effective Partnerships in Weather and Climate Services.

Google: Fair weather report

Fair Weather report

Impact on operations:

- From Fair Weather report and last NCEP strategic plan:
  - Emphasis on timeliness and reliability.
  - Accuracy only at the third place.

- NOAA / NWS / NCEP does this better than any other organization in the world.
  - 99.9% on time delivery of products.
  - Products go to the public as soon as we produce them.

  - Example HRRR transition from ESRL to NCEP.
    - Immediate 99.9% reliability.
    - 45 min faster delivery of products.

Business model

Traditionally two types of implementations:

- Forklift upgrades (brand new model) :
  - Historically 5+ year process with need for maintaining old and new models side-by-side.
    - Examples: first WW3 model, GFDL-HWRF transition, ….
- Incremental improvement of existing systems:
  - Typically one significant upgrade per year (target).
  - Can be done with existing support for model, no second effort needed.
  - Up to order of magnitude cheaper than forklift upgrade.

- For price of forklift upgrade we can do 5 to 10 incremental upgrades
  - More efficient for majority of upgrades!

New business model

Moving to community modeling:

- Operations and research work on the same codes:
  - Open-source style environment, but …
  - operations needs to retain some control over codes to assure continued robustness and reliability of codes.
  - R2O and O2R are tightly joined in this concept, focus of NCEP of making ALL operational codes available with the proper support to make community modeling possible.
  - Concept proven within NWS particularly with the CRTM, WAVEWATCH III and HWRF.
    - WRF, GSI, GOCART, Noah, MOM, HYCOM, …….
  - Large part of our codes are community codes, but needs work for flagship models (NEMS, GFS, NMMB).

New business model

This does not mean we will take any community model …

- Small number of models for each application, with a well defined business model, strategic plan:
  - NMMB and WRF-ARW,
  - WAVEWATCH III and SWAN,
  - MOM and HYCOM, ….
  - Similar approach at NOS for coastal ocean models.

- Focus first on incremental upgrades with the community of accepted operational community models.
- Strategic planning essential for address if and when community models need to be added, replaced or retired.
  - This will still be a much more expensive business model and therefore needs to be addressed carefully and strategically.

Final thoughts

(from operations …)

Operations vs. research

NWS mission, saving life and property:

- The right answer for the wrong reason does save life and property, but
- Any answer for the right reason is required for real progress.
- Better than doing “nothing” (persistence) helps my mission
  - Don’t let perfect stop good enough.
- There is a business model associated with this:
  - Is the improvement worth the cost.
- WRN: Hurricanes, severe weather, rip currents, ….

Another look at coupling / complexity:

- Signal versus noise, application dependent.

Thank You!