Modernization of NOAA's Operational Weather Modeling Suites

NATIONAL WEATHER SERVICE

December 6, 2022

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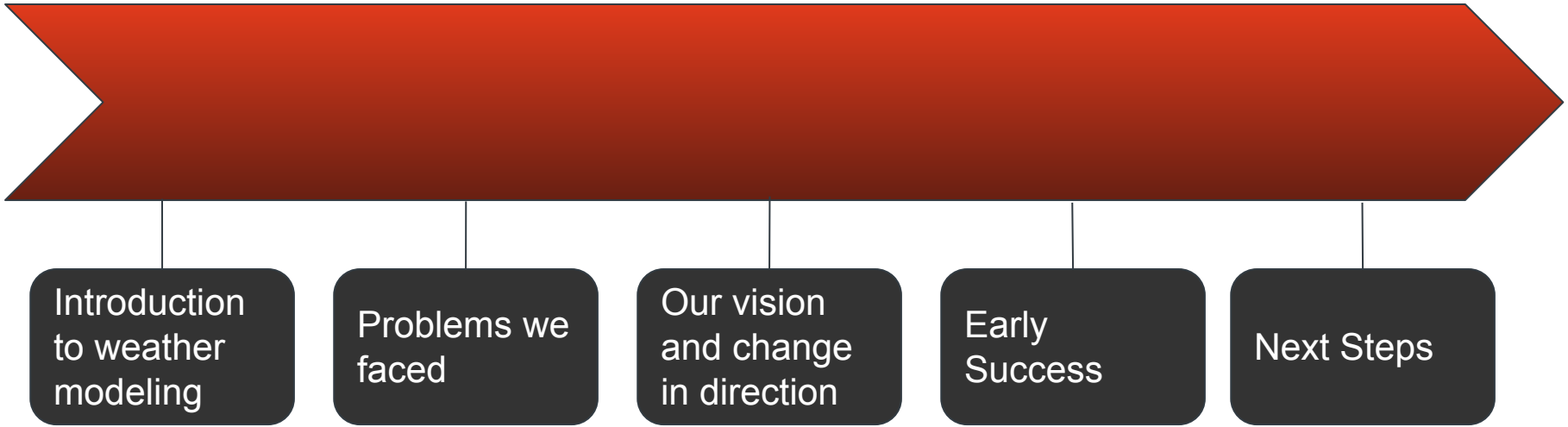
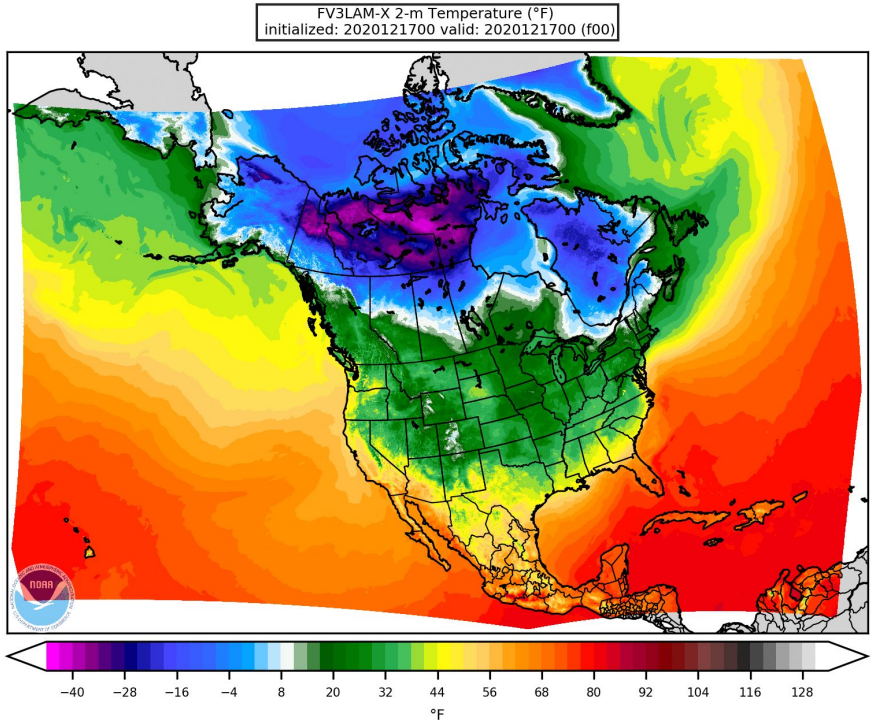
Talk Roadmap



National Weather Service (NWS)

- Part of the Federal Government's National Oceanic and Atmospheric Administration (NOAA)
- NWS mission is to build a weather ready nation by providing weather forecasts to save property and life
  - 122 Weather Forecast Offices, 13 river forecast centers, 9 national centers and other support offices
  - Partner with agencies worldwide
  - Gather and process data from around the globe



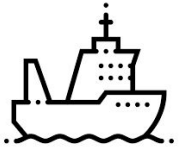
Weather Data Customers







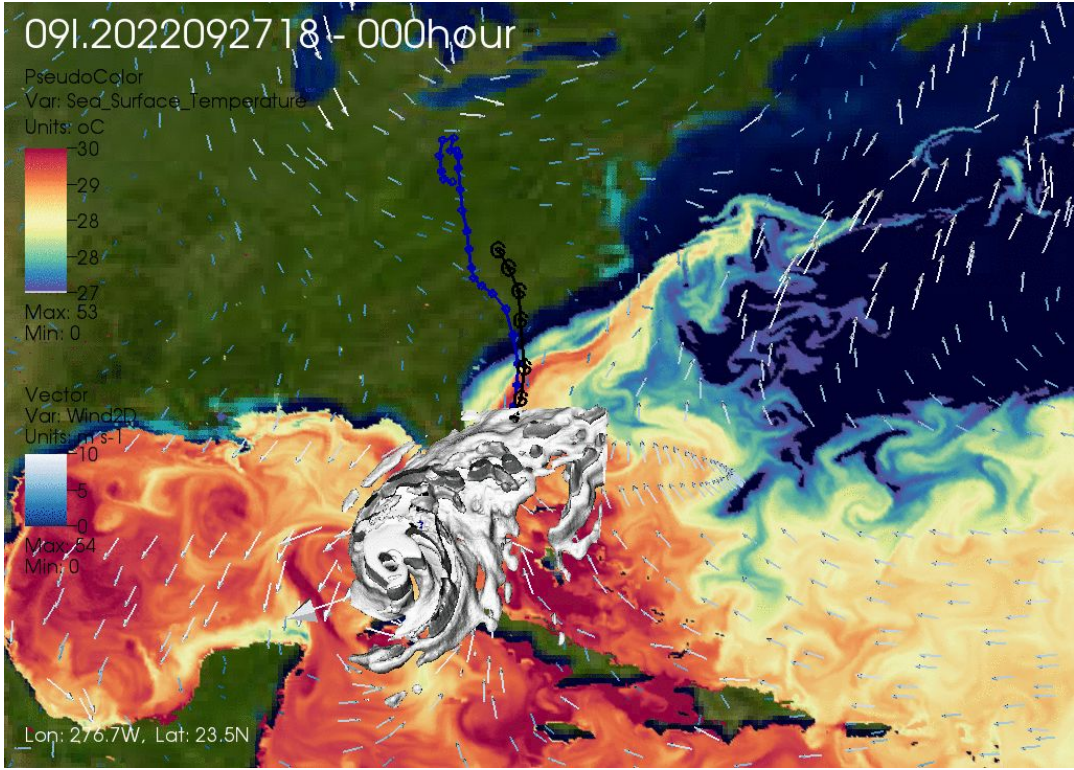



- Diverse customer sets
- Results distributed through different modalities
- Critical - failure is not an option

Weather Forecasting Infrastructure

- Global observation network
- HPC Platforms
- Data storage
- Data dissemination
- Archival



Elements of Weather Forecasting

2 TB of Global observation data pulled in daily

Daily output
Jobs: 112,000
Files: 500,000
Size: 45 TB

Public facing site sees daily download traffic of 450 TB

OBSERVATIONS

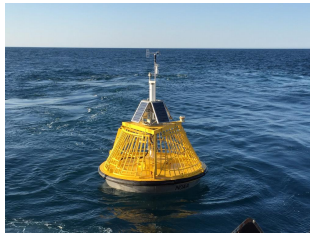
FIRST GUESS

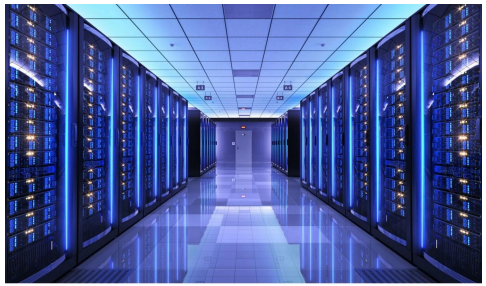
Data assimilation

INITIAL CONDITIONS

Earth System Numerical Models

Numerical Forecasts

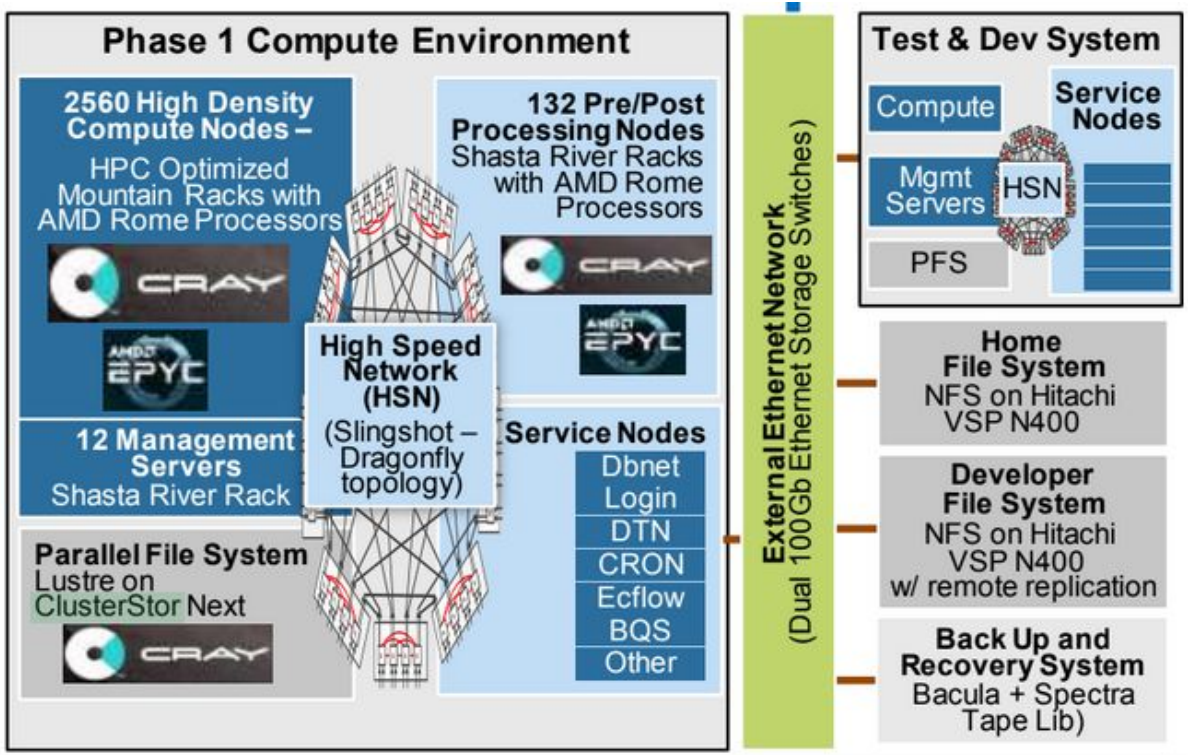




Disseminated across the world

NWS's Latest HPC for Operational Weather Prediction

- Compute nodes
  - 2,560 nodes (60 spare)
  - 327,680 cores
    - 128 cores/node
  - 1.3 PB of memory
    - 512 GB/node
- Pre/post-processing nodes
  - 132 nodes (4 spare)
  - 8,448 cores
    - 64 cores/node
  - 132 TB of memory
    - 1TB/node
- 200Gb/s Slingshot interconnect



NWS now maintains two identical HPC platforms at any given time – one operational and one back up

FCW The Business of Federal Technology

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NWS forecasting hampered after supercomputer fire

By Colleen O'Hara

OCTOBER 17, 1999

The National Weather Service's central supercomputer used to generate weather forecast models caught fire and subsequently stopped operating late last month, forcing the agency to rely on backup systems and delaying delivery of data to users. NWS' National Centers for Environmental Prediction (NCEP

The National Weather Service's central supercomputer used to generate weather forecast models caught fire and subsequently stopped operating late last month, forcing the agency to rely on backup systems and delaying delivery of data to users.

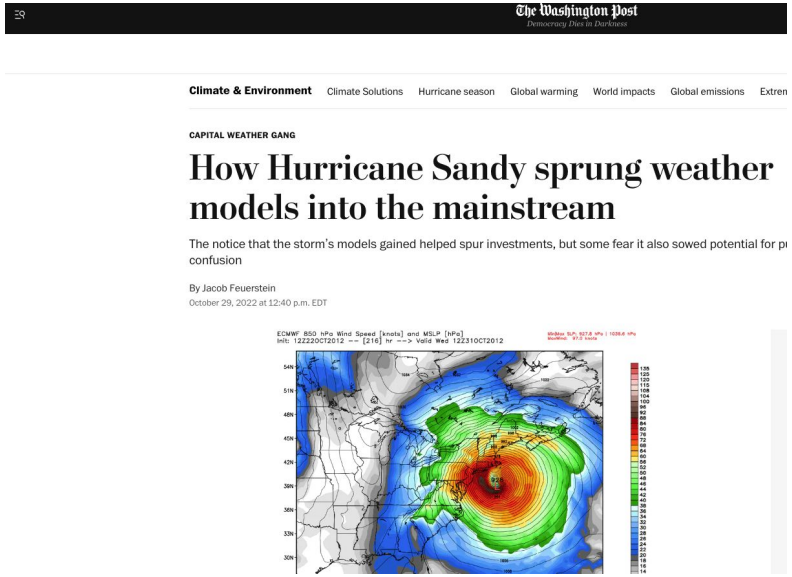
https://fcw.com/1999/10/nws-forecasting-hampered-after-supercomputer-fire/237272/

https://www.hpcwire.com/2022/06/29/noaa-launches-twin-supercomputers-tripling-operational-forecasting-capacity/

The Problem: Production Suite ‘Quilt’

"Sandy was when [models] entered mainstream popular culture," said Neil Jacobs, former acting administrator of the National Oceanic and Atmospheric Administration and chief science adviser for the agency's next generation modeling effort, in an interview.

American vs. European model forecast track for Sandy a week before landfall, compared with the actual track. (Weather.com)



The Washington Post
Democracy Dies in Darkness

Climate & Environment | Climate Solutions | Hurricane season | Global warming | World impacts | Global emissions | Extren

CAPITAL WEATHER GANG

How Hurricane Sandy sprung weather models into the mainstream

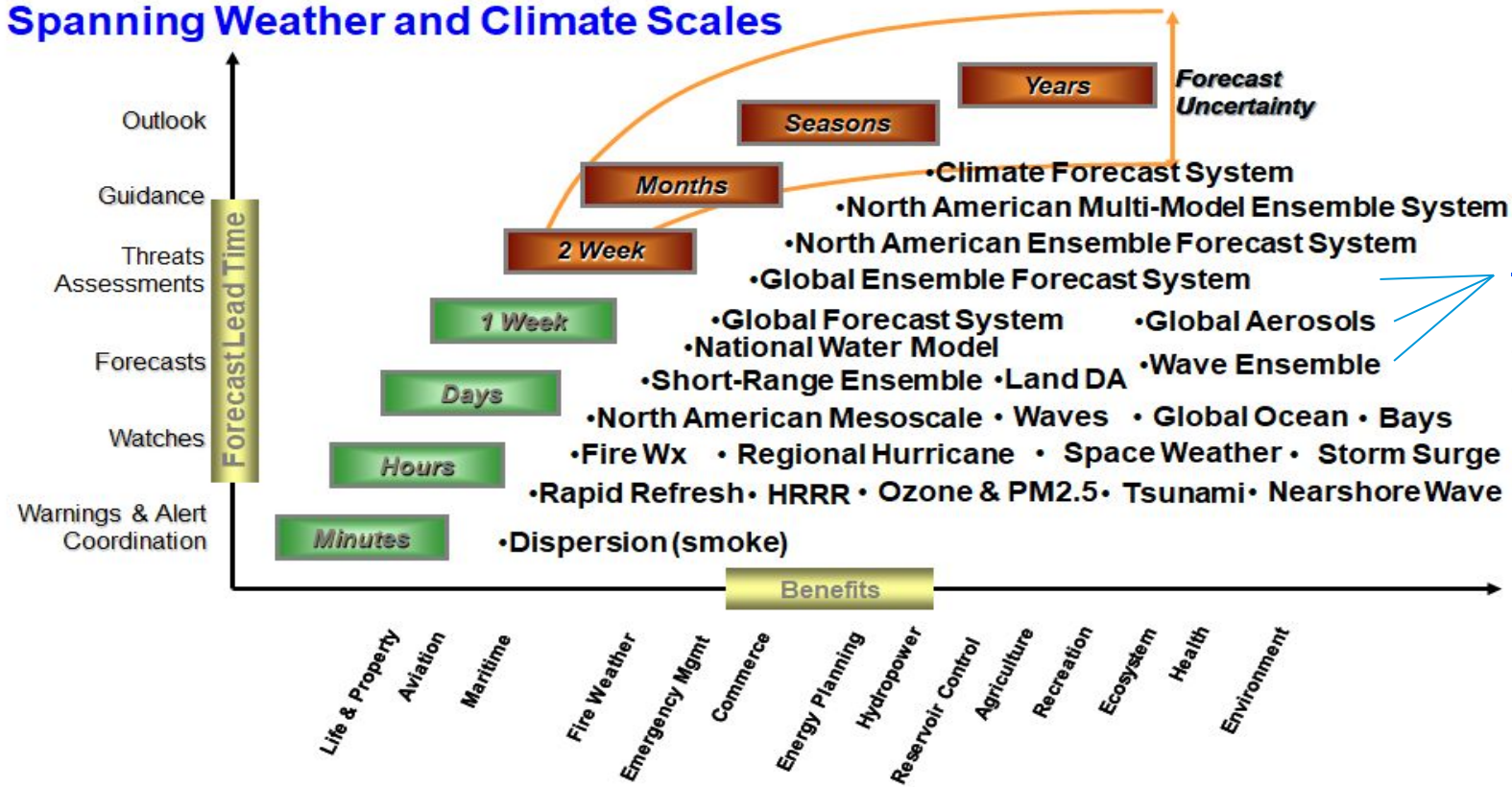
The notice that the storm's models gained helped spur investments, but some fear it also sowed potential for p confusion

By Jacob Feuerstein
October 29, 2022 at 12:40 p.m. EDT

https://www.washingtonpost.com/climate-environment/2022/10/29/superstorm-sandy-models-american-european/

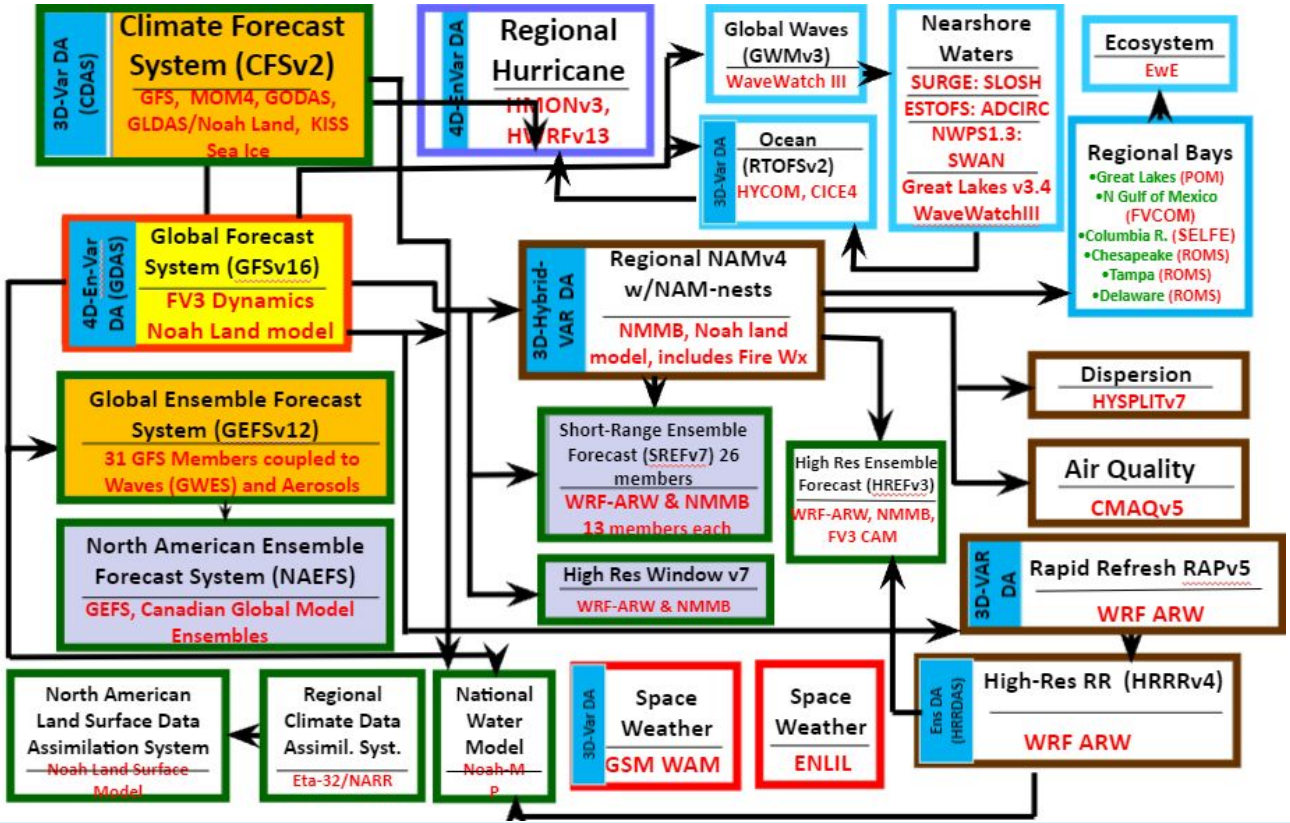
"Sandy was a big eye-opener to Congress about what needed to be funded," Jacobs said. He noted that Sandy was a motivation for the Next Generation Global Prediction System, the Weather Service's current effort to increase the accuracy of forecasts out to 30 days.

Suite of Operational Numerical Guidance Systems



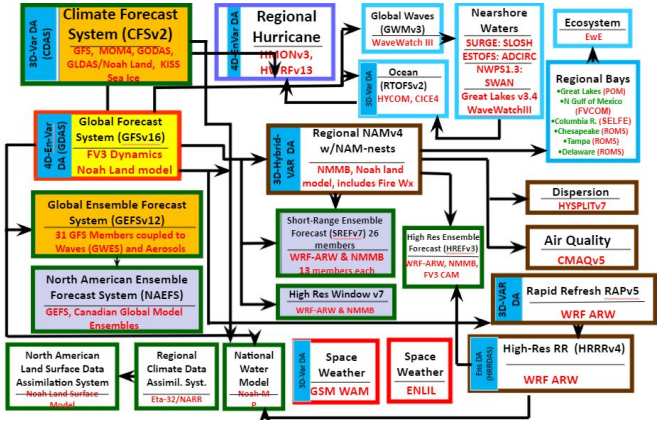
GEFS now includes wave and aerosol components

The NCEP Production Suite 'Quilt'

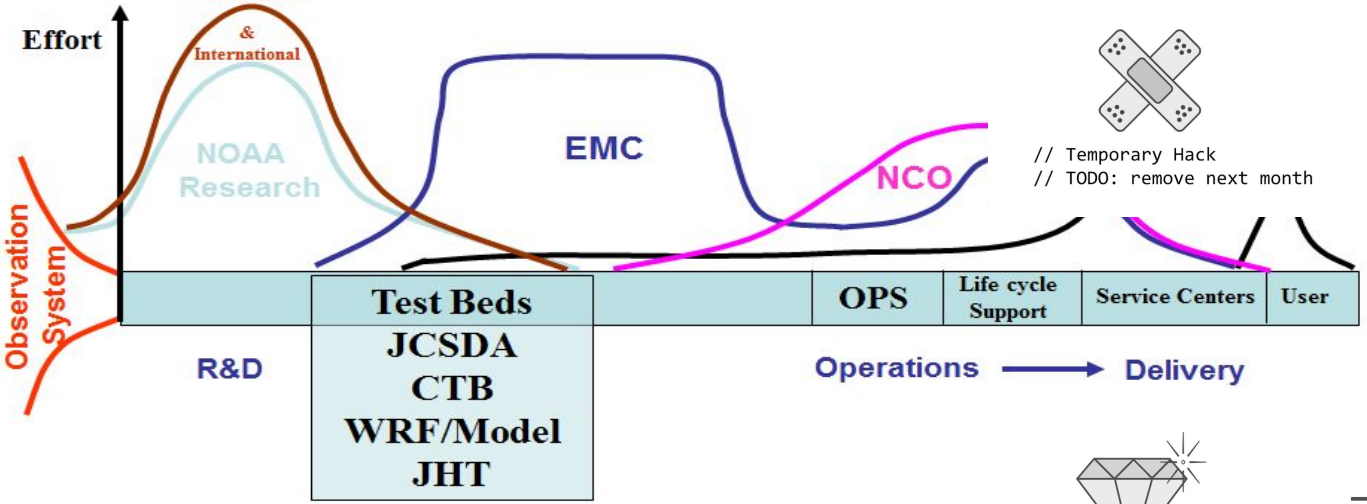


The Problem

- Fractured model development
  - Software infrastructure repeated
  - Limited resources spread too thin
- In-house development
  - Run on NOAA HPC platforms only
  - No easy access to codes for external partners
- Legacy models, cannot keep up
- Too many similar models
- Models not keeping up with new science
- Innovate or perish



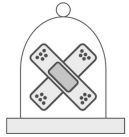
The “Valley of death”



Strategy

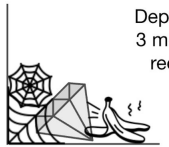

```
// Temporary Hack
// TODO: remove next month
```

Result



Still in use everywhere 10 years later, nobody can change it now.

Well-thought permanent solution



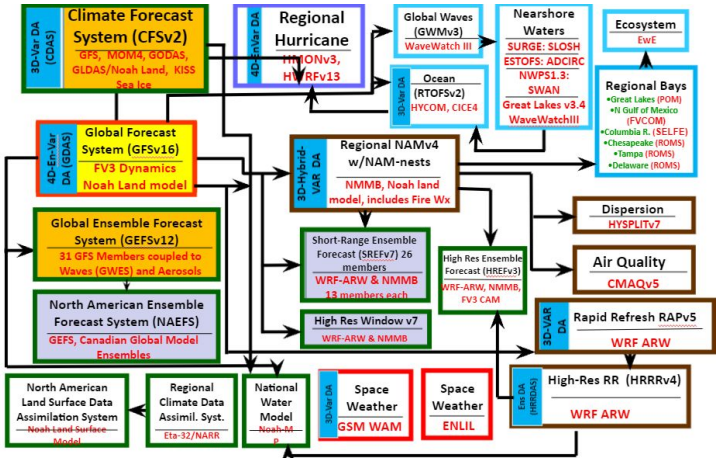
Deprecated after 3 months due to requirements change

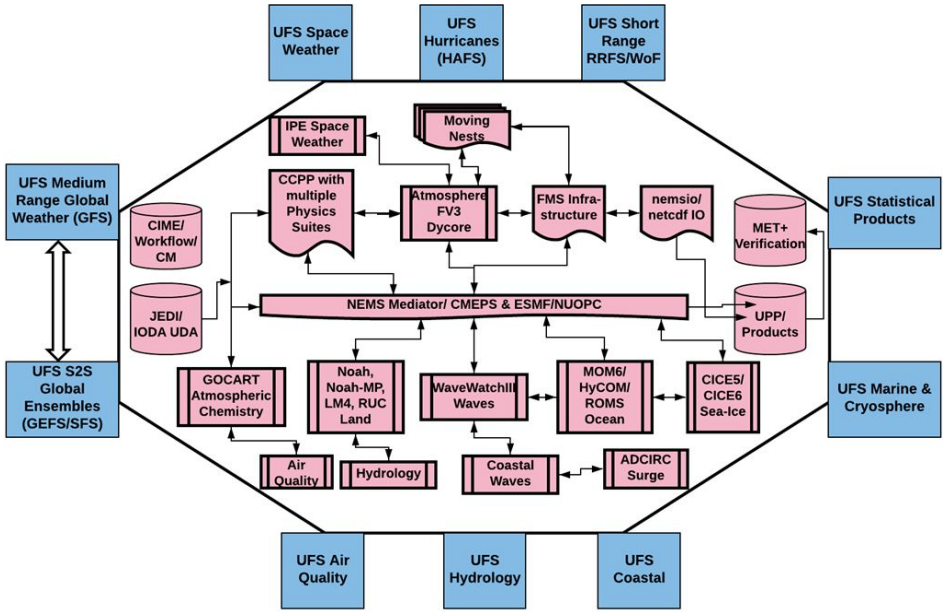
The Vision: Unified Model, Unified Community

NOAA's Modernization Plan - Model

- Develop a new modeling system that
  - Unifies across different scales
  - Uses shared common infrastructure
  - Couples across different components (atmosphere, ocean, waves, ice)
- Remove legacy models from operations
- Grow the pool of development partners

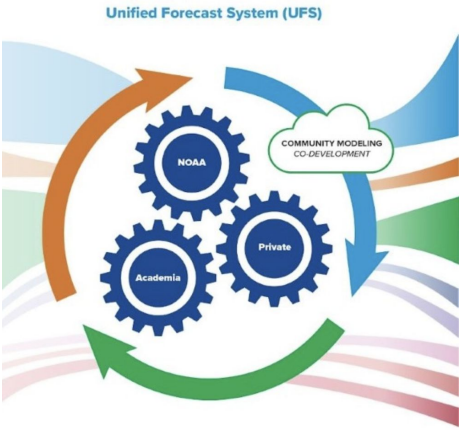
Goal: Simplifying the NCEP Production Suite





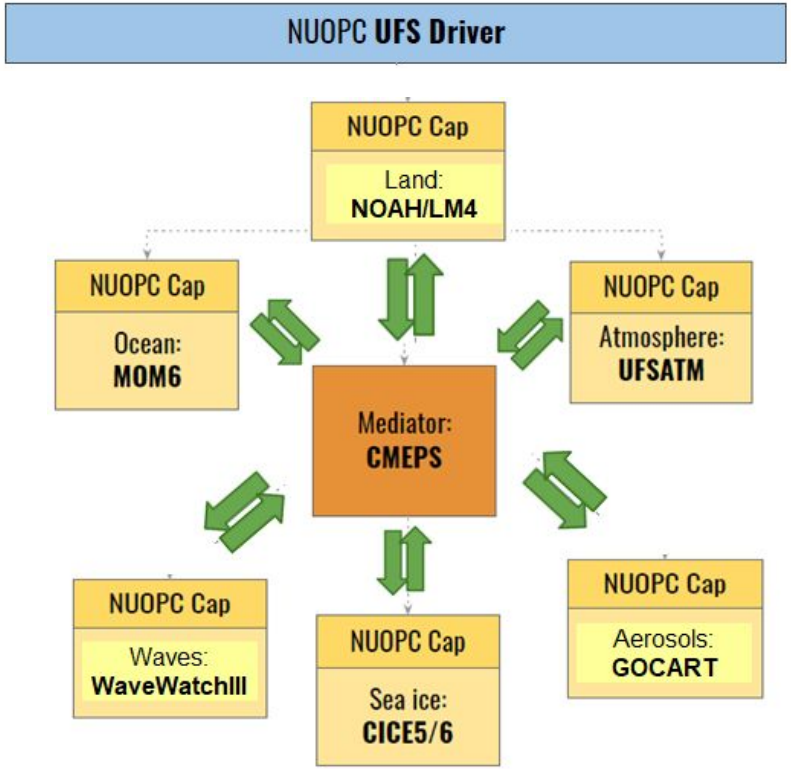
NOAA's Modernization Plan – Community

- Change paradigm of model development
  - In-house to community
  - Modernize the process
    - Documentation and testing from start
    - CI/CD
    - Modular development
    - Portability
- Reduce time from innovation to operations
- Build and nurture a community



Goal: Design Forecast System Around Community Development Needs

- Multiple components
- Each its own community
- Built a coalition of the willing
- Minimize disruption
- Separation of concerns



Our Challenge

- Cultural
  - Ambivalence on community development
  - Scientists, not software engineers
  - Resistance to new approaches
- Technical
  - Components distributed across different agencies
  - Large codes that few understand end to end
  - Need to bridge software and science
- Scientific
  - No correct answer
  - Non-linear feedback loop between components

Approach and Observations

Our Approach

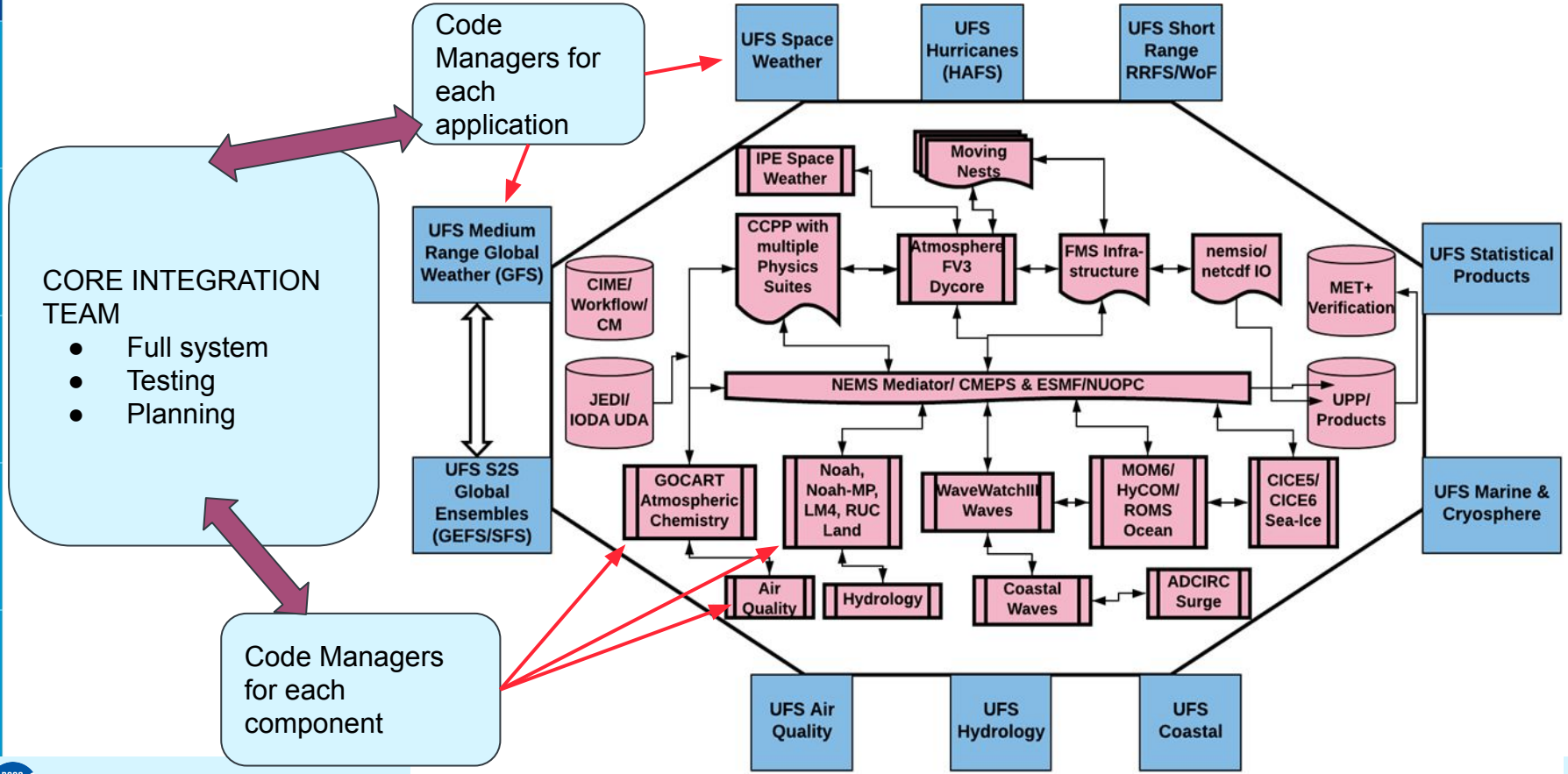
First, a unified development community

Transition core models into operations

Unify operations and development environments

Create a true DEVOPS culture

Observation: Communication is Key!



Rigorous Testing Infrastructure

- Automated testing across key platforms for each commit
  - Over 600 tests in different configurations
- Docker container for UFS stack on AWS

Common Infrastructure Stack

SPACK-STACK

- Automated build
- 140+ packages
- Total build time ~ 1 hr
- Reproducible, stable builds
- Support for multiple environments
- 40+ contributors
- Joint collaboration (NOAA, JCSDA)
- Container support
- Builds on MacOS, AWS, several on-prem HPCs

https://github.com/noaa-emc/spack-stack

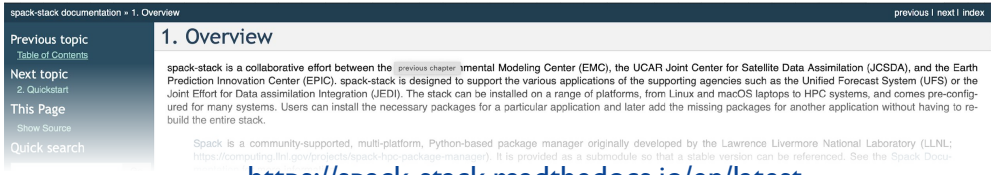
Spack package manager (LLNL)

Spack

ufs-weather-model
soca
jedi-mpas
jedi-um
gfs-wafs
ufs-srw-app
ufs-utils
gldas
jedi-tools
global-workflow
jedi-ufs
jedi-ewok
nceplibs
ufswm-python
gsi
gw-python
jedi-fv3
upp
ww3

One stack to build them all

Ensures the same environment across different HPC platforms

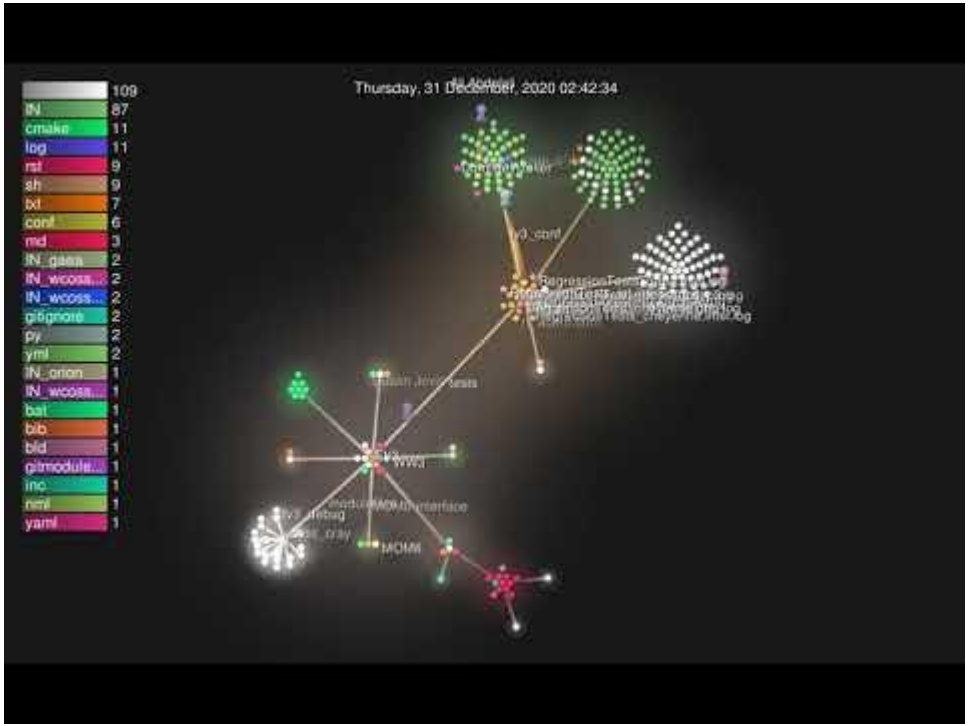


https://spack-stack.readthedocs.io/en/latest

Observation: Explosive Growth in Development

Since starting the open repository (4 years)

- 10 new component systems added
- 613 issues competed
- 314 enhancements
- 175 development forks
- 66 contributors



Early Successes and Testimonials

Initial Success – File compression in operations

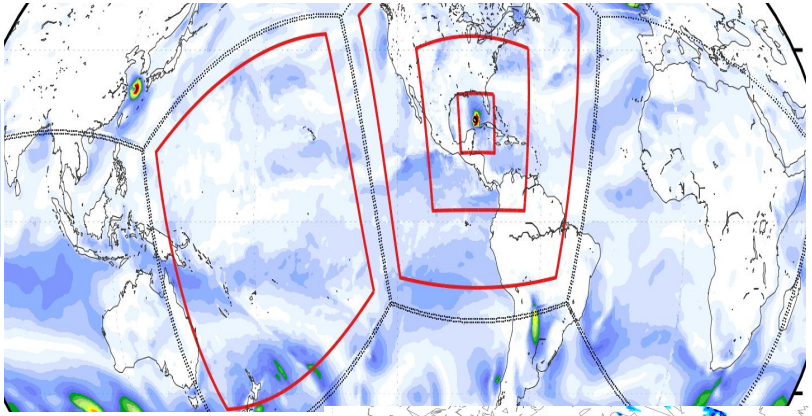
C768L127 fcst output	Nemsio No compression	Netcdf No compression	Netcdf Lossless (deflate=1,nbit=0)	Netcdf Lossy (deflate =1, nbit=20)	Netcdf Lossy(deflate=1,nbit=14)	Netcdf Lossy (deflate=1, nbits=14),parallel writing, default decomposition chunksize	Netcdf Lossy (deflate=1, nbits=14),parallel writing Layer chunkcsize
A 3D file size (total fcst)	33.6GB (7TB)	33.6GB (7TB)	23.6GB (5TB)	13.5GB (2.8TB)	6.3GB (1.3TB)	6.3GB (1.3TB)	6.3GB (1.3TB)
Write Time	79s	300s	960s	680s	400s	43s	34s

- Transition to NetCdF+compression+Parallel I/O
- Testing, release and deployment in operations in under two months

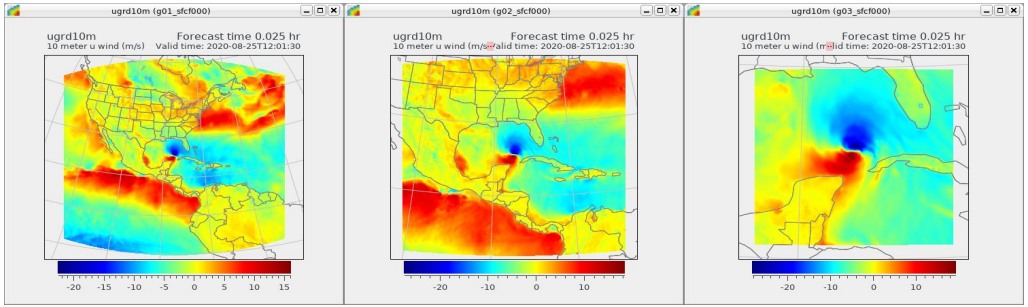
Initial Success - Moving Nests

- 4 Organizations
- 2 HPC platforms for testing
- Integrated into main repository in weeks

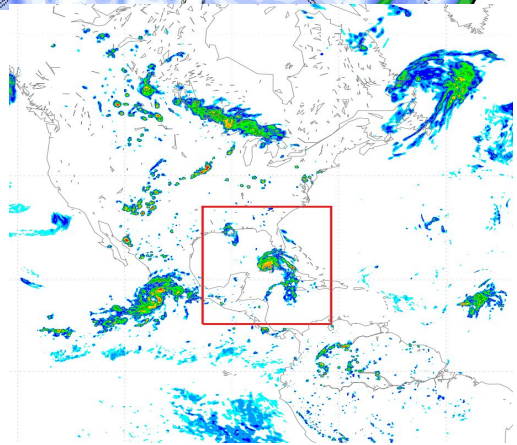
GFDL – Telescopic Nests



EMC & NCAR – Asynchronous I/O



AOML – Moving Nests



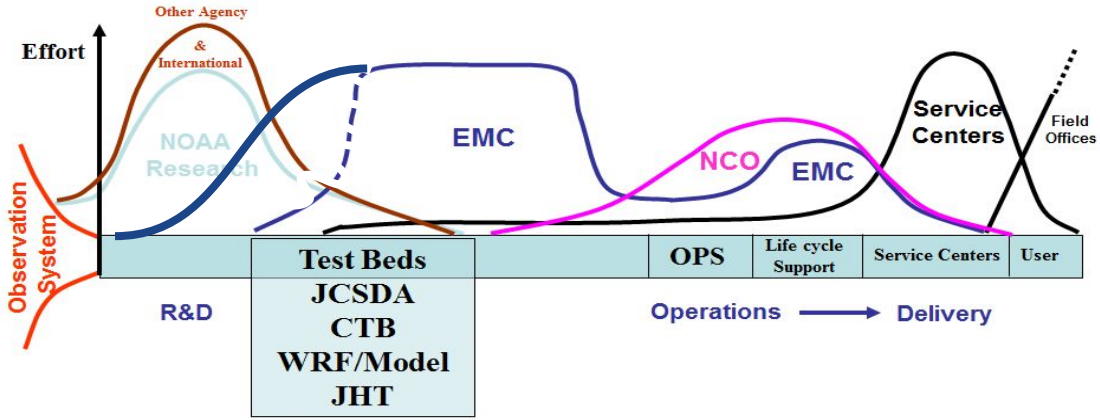
Testimonials

Started with a handful of systems (~3) on GitHub, now almost all our packages (> 50) are in open development environments

NOAA Leadership has endorsed open community development, providing funding for dedicated code managers

Changed the paradigm of model development – "valley of death" problem

Operations keen to adopt Spack-Stack to equate dev and ops environments



Next Steps

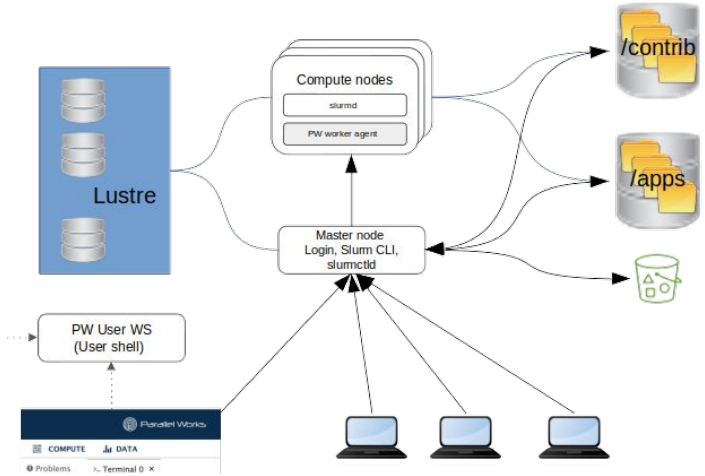
Is the Future Cloudy?

Pilot project to show
- Can our system be ported to the cloud ?
- Can we do real time forecasting ?
- Primarily run on AWS, but is cloud agnostic

Instances
- C5n18xlarge – For compute
  - 3.5GHz chips, 36 cpus, 192GB memory
  - 100 Gbps network
- R524xlarge – Pre processing and graphics
  - 3.1GHz chips, 48 cpus, 768 GB memory
  - 25 Gbps network

File Systems
- AWS FSX – fast interconnect for compute
- AWS EFS – persistent storage for libraries, data
- AWS S3 – long term storage of output

On performance cloud resources comparable to on prem systems for weather simulations. A viable resource.



System	Number of instances or nodes	Wall time for FFAIR 60hr forecast (hrs)
AWS	80 (c5n.18xlarge)	3.96
NOAA HPC System (Hera)	80	4.68

In Conclusion

- Transitioned to an open development environment
  - Partnerships with multiple institutions
  - Faster developments
  - New infrastructure
  - Biggest challenge cultural, not technical
  - Including operations work in progress

- Would like to learn
  - Can we be more efficient?
  - What new technologies can we use ?
  - How can DEVOPS be deployed when
    - Safety of life is a big concern
    - Need long experiments to show success of models
    - Many downstream dependencies