Verification and Evaluation of Environmental Prediction Systems at the NOAA Environmental Modeling Center

NATIONAL WEATHER SERVICE

NOVEMBER 17, 2020

Presenter: Jason Levit, Branch Chief
Environmental Modeling Center/Verification, Post-Processing, Product Generation

Acknowledgements

EMC Acknowledgements: Alicia Bentley, Partha Bhattacharjee, Logan Dawson, Christopher MacIntosh, Geoff Manikin, Phillipe Papin (now at NHC), Jiayi Peng, Mallory Row, Perry Shafran, Shannon Shields, Deanna Spindler, Todd Spindler, BinBin Zhou

External Acknowledgements: Tara Jensen and the entire METplus team

National Weather Service (NWS) Vision and Mission

Vision

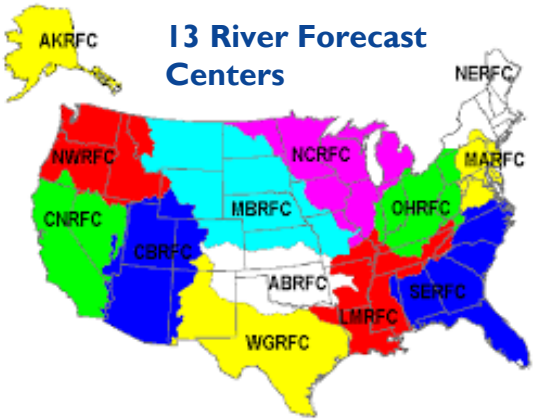
Build a Weather-Ready Nation where Society is prepared for & responds to Weather-Dependent Events

Mission

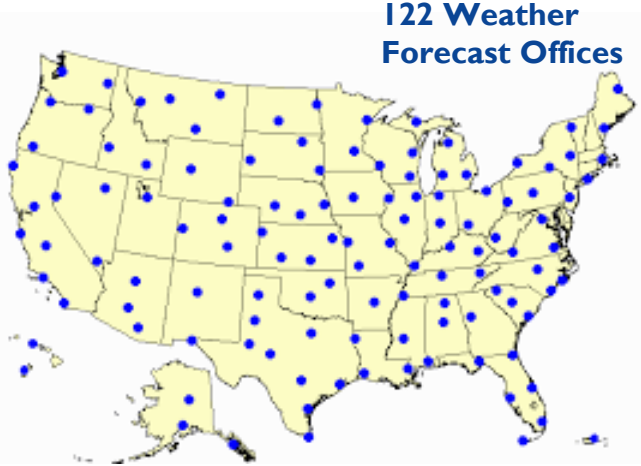
The National Weather Service (NWS) provides weather, water, & climate forecasts & warnings for the United States, its territories, adjacent waters & ocean areas, for the protection of life & property & the enhancement of the national economy. NWS data & products form a national information database & infrastructure which can be used by other governmental agencies, the private sector, the public, & the global community.

Connecting the NWS Organization to Deliver Accurate & Consistent Products and Services

13 River Forecast Centers



122 Weather Forecast Offices

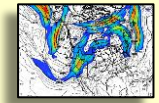


9 National Centers

490 FTE
237 Contractors
40+ Visiting Scientists
6 NOAA Corps Officers
$137M Budget


Aviation Weather Center Kansas City, MO


Climate Prediction Center College Park, MD


Environmental Modeling Center College Park, MD


National Hurricane Center Miami, FL


NCEP Central Operations College Park, MD (Supercomputers in Reston & Orlando)


Ocean Prediction Center College Park, MD

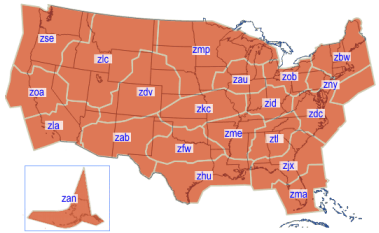

Space Weather Prediction Center Boulder, CO


Storm Prediction Center Norman, OK

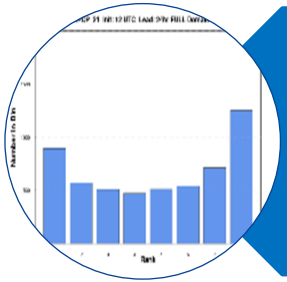

Weather Prediction Center College Park, MD

National Water Center

21 Central Weather Service Units

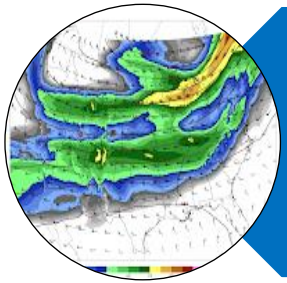


EMC's Verification, Post-Processing, and Product Generation Branch



Verification and Validation

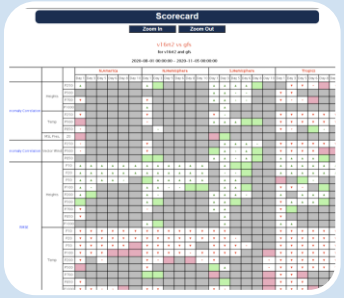
- Independent model evaluations
- Supports EMC modeling groups
- Model Evaluation Group (MEG)
- Real-time verification
- Model diagnostics and systematic error investigation
- Outreach to NWS forecast offices



Post-Processing and Products

- Unified Post Processor development
- Manages model output and products
- WAFS international aviation products
- Develops post-processing algorithms
- Ensemble product development

Verification, Validation, and Evaluation Efforts at EMC



Performance

- Monitor real-time model performance
- Report statistics to Congress and HQ

Evaluation

- Evaluate both parallel and real-time models
- Contribute to evaluation reports

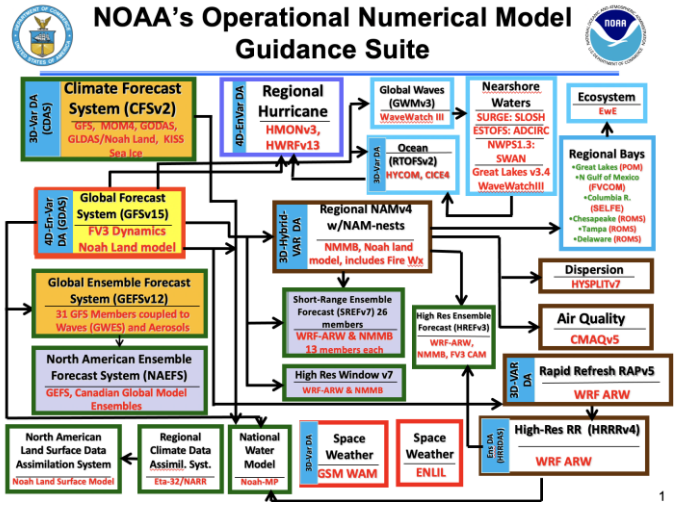
Research

- Develop new metrics and indexes
- Create new metrics software and technology with METplus

Community

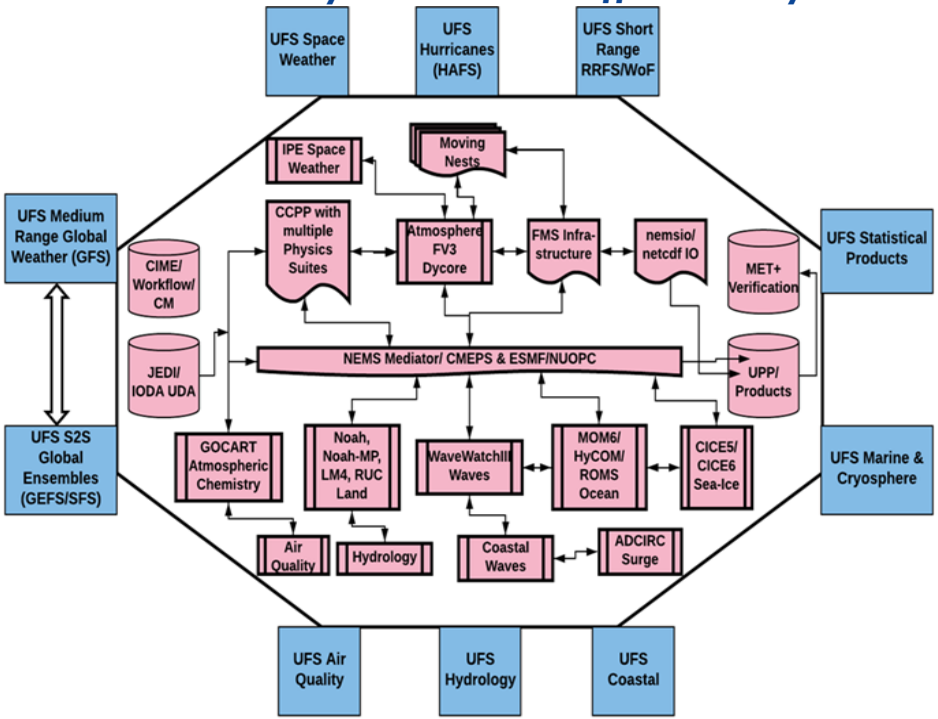
- Support the Unified Forecast System community
- Involve partners and stakeholders in evaluations

Unified Forecast System Strategic Vision



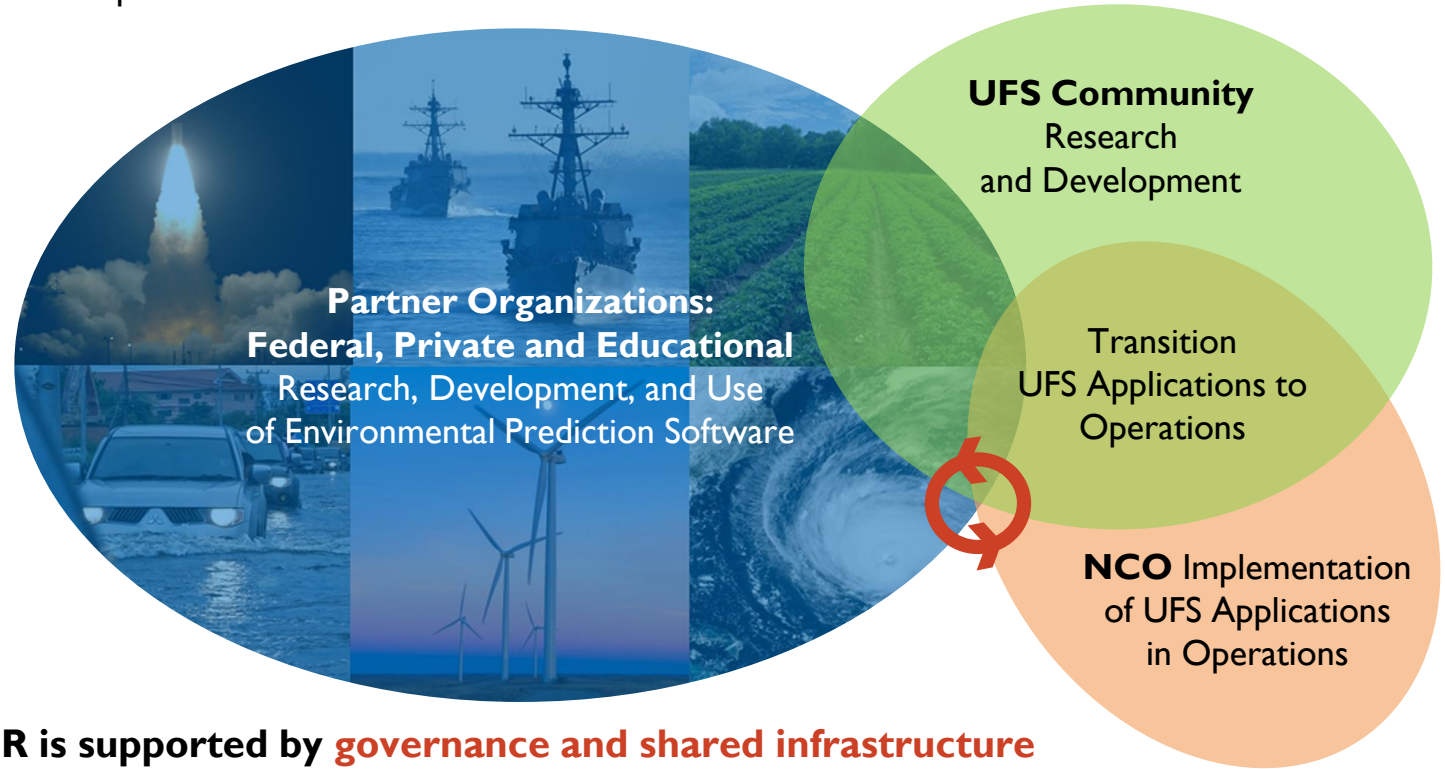
Starting from the quilt of models and products created by implementing solutions rather than addressing requirements ….

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



Community-Based Development

The Unified Forecast System (UFS) is a comprehensive, **community-based** Earth modeling system, designed as both a research tool and as the basis for NOAA's operational forecasts.



R2O2R is supported by governance and shared infrastructure

Migration to the Unified Forecast System

NPS Modeling System	Current Version	Q1 FY 20	Q2 FY 20	Q3 FY 20	Q4 FY 20	Q1 FY 21	Q2 FY 21	Q3FY 21 - Q2FY22 MORATORIUM	Q3 FY 22	Q4 FY 22	Q1 FY 23	Q2 FY 23	Q3 FY 23	Q4 FY 23	Q1 FY 24	Q2 FY 24	Q3 FY 24	Q4 FY 24	UFS Application
Global Weather & Global Analysis	GFS/ GDASv15						GFSv16									GFSv17/ GEFSv13			UFS Medium Range & Sub-Seasonal
Global Waves	GWMv3																		
Global Weather Ensembles	GEFSv11				GEFSv12														
Global Wave Ensembles	GWESv3																		
Global Aerosols	NGAC v2																		
Short-Range Regional Ensembles	SREFv7																		
Global Ocean & Sea-Ice	RTOFSv1.2					RTOFSv2					RTOFSv3								UFS Marine & Cryosphere
Global Ocean Analysis	GODASv2										GODASv3								
Seasonal Climate	CDAS/ CFSv2																	SFSv1	UFS Seasonal
Regional Hurricane 1	HWRFv12			HWRFv13					HAFSv1				HAFSv2				HAFSv3		UFS Hurricane
Regional Hurricane 2	HMONv2			HMONv3															
Regional High Resolution CAM 1	HiRes Window v7											RRFSv1				RRFSv2			UFS Short-Range Regional HiRes CAM & Regional Air Quality
Regional High Resolution CAM 2	NAM nests/ Fire Wxv4																		
Regional High Resolution CAM 3	RAPv4/ HRRRv3			RAPv5/ HRRRv4															
Regional HiRes CAM Ensemble	HREFv2					HREFv3													
Regional Mesoscale Weather	NAMv4																		
Regional Air Quality	CMAQv5								CMAQv6										
Regional Surface Weather Analysis	RTMA/ URMA v2.7			RTMA/ URMA v2.8									3DRTMA /URMAv 3						
Atmospheric Transport & Dispersion	HySPLITv7								HySPLIT v8								HySPLIT v9		UFS Air Quality & Dispersion
Coastal & Regional Waves	NWPSv1.2					NWPS v1.3			NWPS v1.4						RWPSv1				UFS Coastal
Great Lakes	GLWUv3.4								GLWUv4								GLWUv5		UFS Lakes
Regional Hydrology	NWMv2					NWMv3							NWMv4						UFS Hydrology
Space Weather 1	WAM/IPEv1																	WAMv2	UFS Space Weather
Space Weather 2	ENLILv1																		

EMC's Model Evaluation Group (MEG)

Evaluate EMC Model Suite

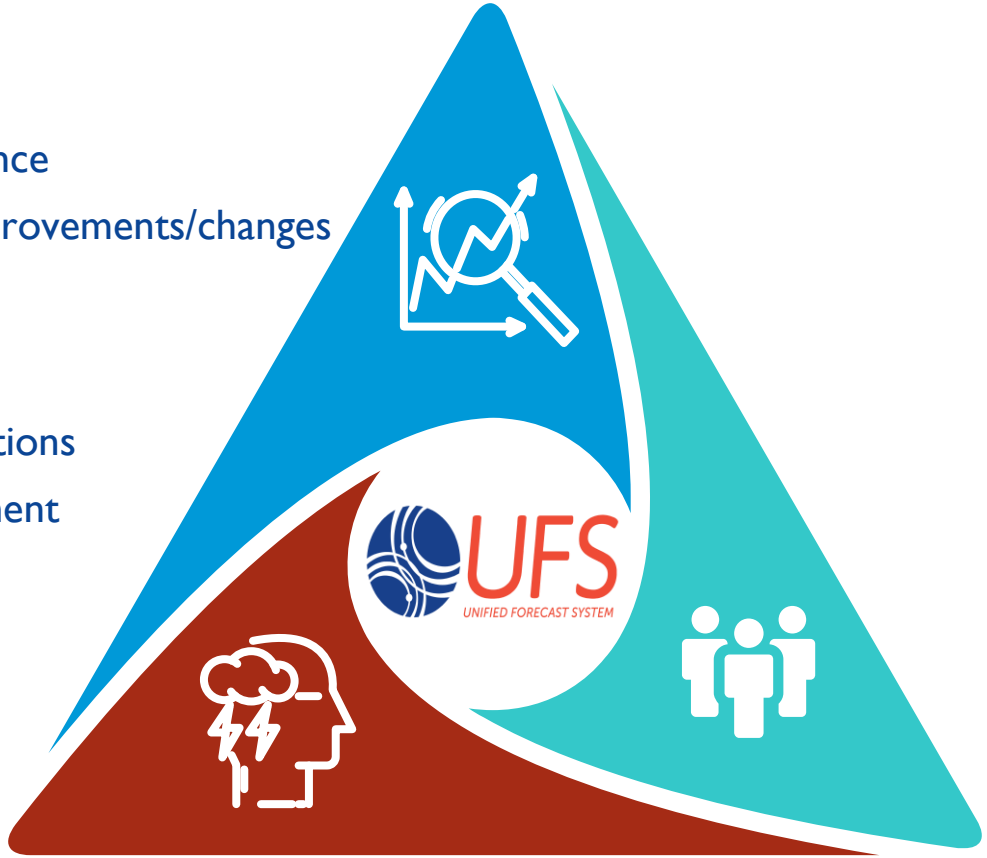
- Continuously evaluate model performance
- Diagnose errors and suggest model improvements/changes

Field Evaluation Coordination

- Coordinate all NWS model field evaluations
- Ensures transparency and field involvement

Develop Techniques

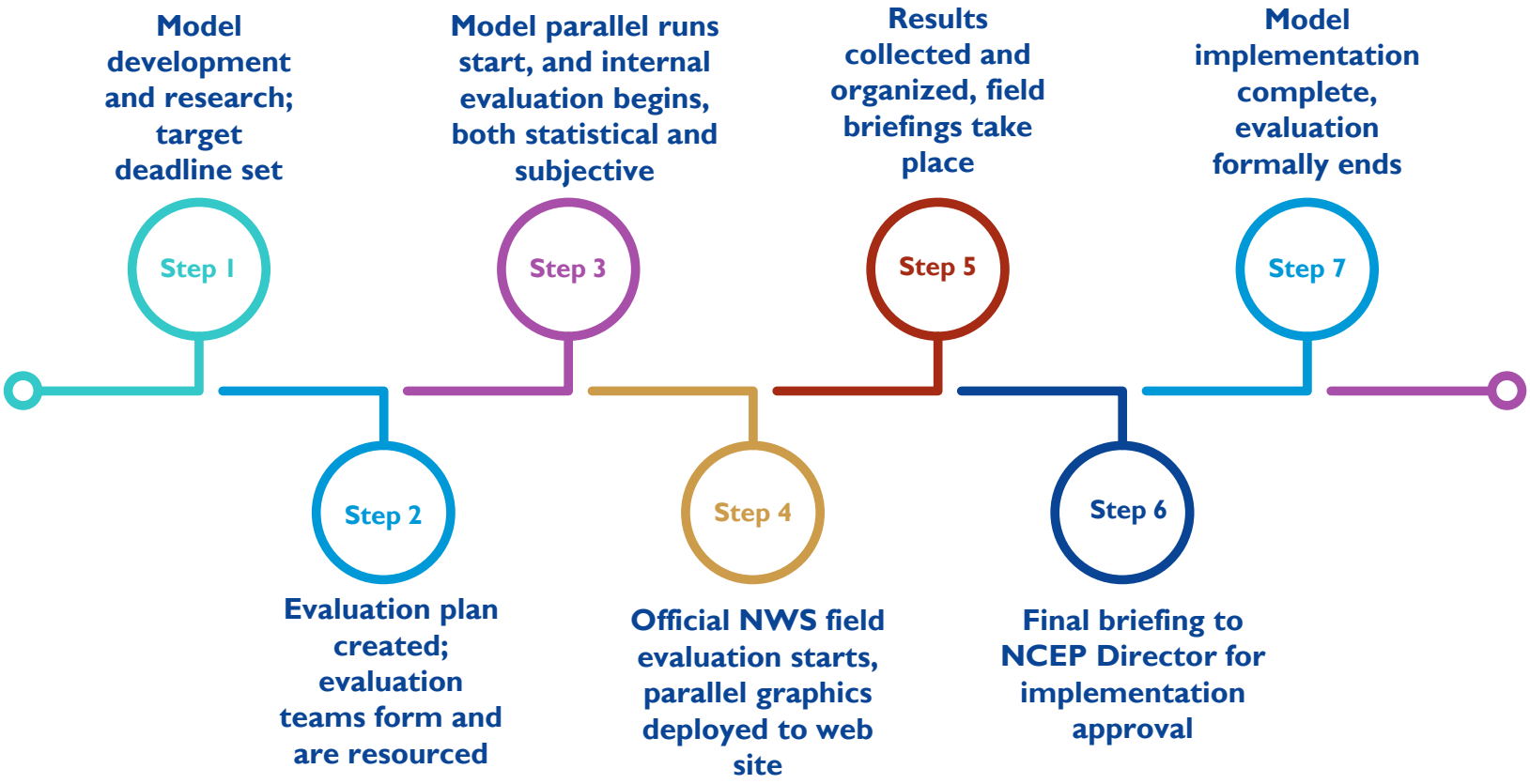
- Create new verification techniques
- Develop web pages and graphics



2020-21 EMC Model Implementation Timeline

Model version #	Implementation Date
HMON v3 - Hurricane	JUN 2020, implemented
RTMA/URMA v2.8 – Real-time Mesoscale Analysis	JUL 2020, implemented
HWRF v13 - Hurricane	AUG 2020, implemented
GEFS v12 (unified with NGAC & GWES) – Global Ensemble	SEP 2020, implemented
NWPS v1.3 - Waves	DEC 2020, planned
RTOFS Global v2 - Oceans	DEC 2020, planned
RAP/HRRR v5/v4 – High Resolution Storm-Scale	DEC 2020, planned
HREF v3 – High Resolution Storm-Scale Ensemble	FEB 2021, planned
GFS/GDAS v16 (unified with GWM) – Global Model	FEB 2021, planned

EMC Model Evaluation Methodology



GEFSv12 Upgrade – Implemented 23 Sept 2020

	GEFSv11	GEFSv12
Model	GSM (hydrostatic)	FV3 (non-hydrostatic)
Resolution	~33km, 0-8 days ~50km, 8-16 days	~25km
Forecast days	16 days	16 days (06Z, 12Z and 18Z) 35 days (00Z)
Ensemble size	21 members	31 members
IC uncertainty	EnKF TC perturbed after relocation	EnKF No TC vortex relocation
Model uncertainty	STTP	Stochastic physics (SPPT + SKEB)
Microphysics	Zhao-Carr	GFDL
Ocean forcing	Persistent + relaxation SST	NSST and 2-tiered SST

Global wave ensemble & global aerosol model were also wrapped into GEFSv12 upgrade.

Strengths of GEFSv12

EMC and NWS Regions/Centers evaluated 2.5 years of retrospective forecasts using objective verification statistics and subjective evaluation of 45 cases

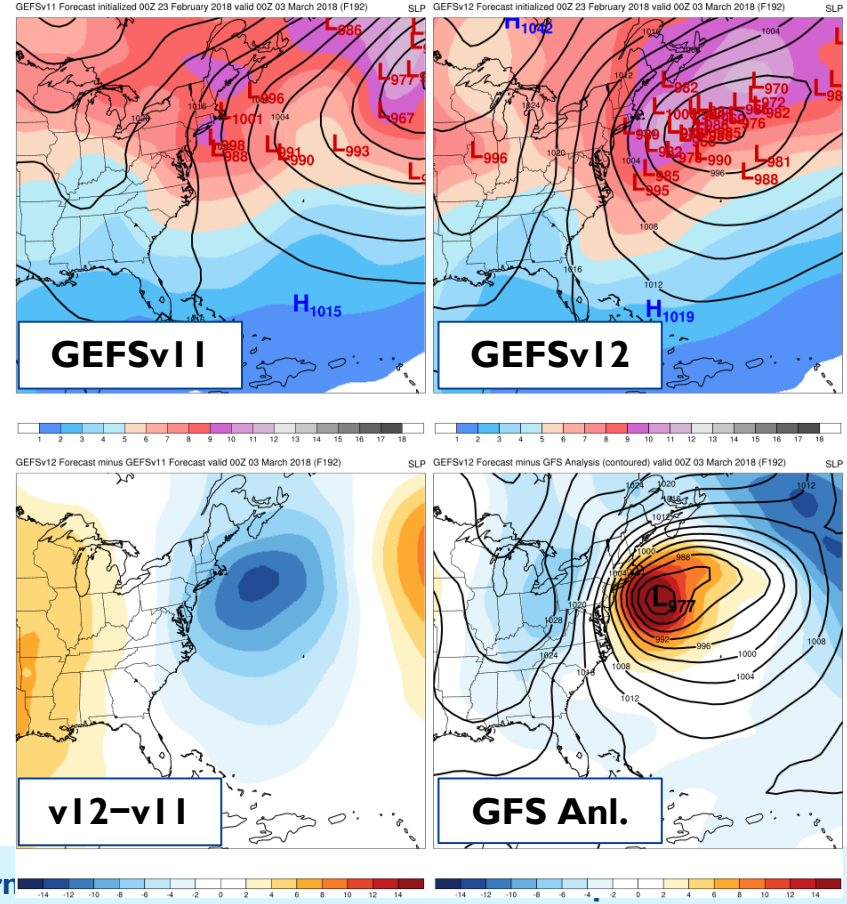
1) Higher 500-hPa AC scores and improved synoptic predictability
2) Increased ensemble spread (improved ensemble dispersion)
3) Improved TC tracks, spread, and location of precip maxima
4) Better handling of deepening extratropical cyclones
5) More reliable precipitation forecasts
6) Improved representation of weather events near topography
7) Mitigation of exaggerated offshore QPF maxima

GEFSv12 Strength: Improved Synoptic Predictability

- GEFSv12 had higher 500-hPa AC scores throughout the entire retrospective period

192-h Forecast Comparison: Mid-Atlantic Windstorm (00Z 3/3/2018)

- GEFSv12 members correctly positioned the extratropical cyclone closer to the East Coast than GEFSv11 members
- Due to better handling of upper-level cutoff low in the long range



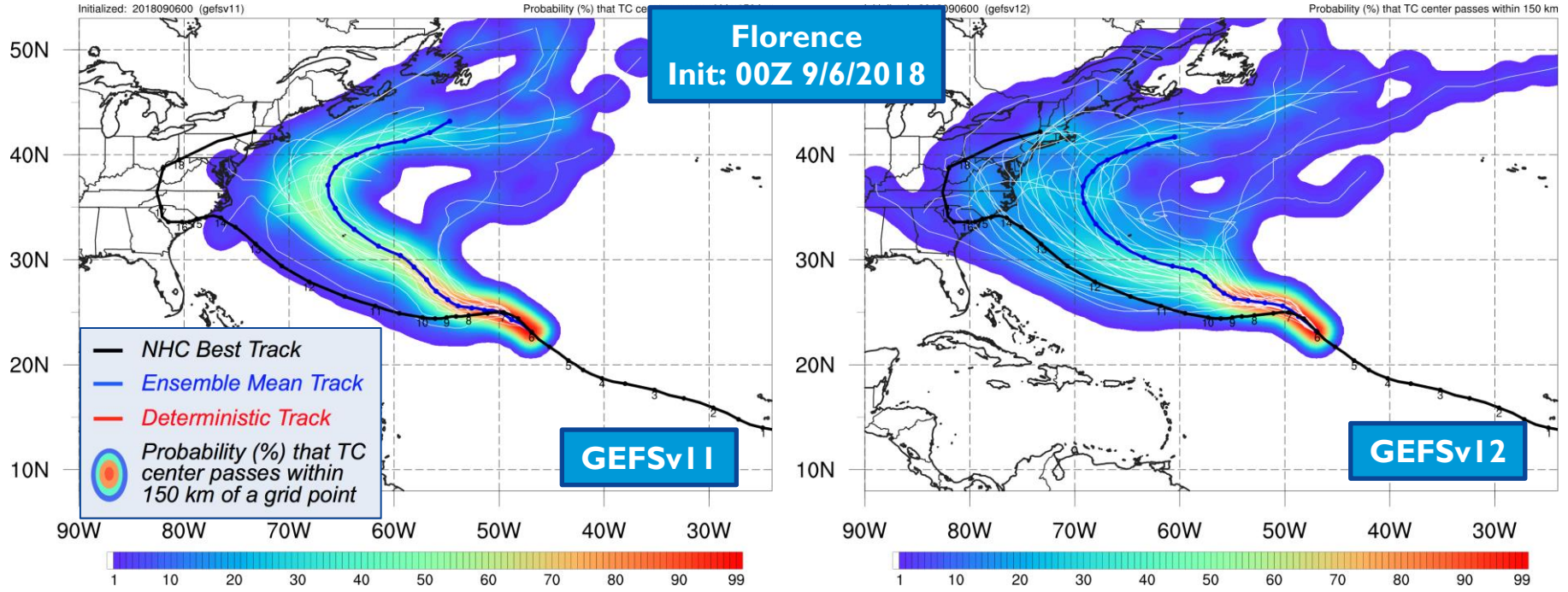
GEFSv12 Strength: Increased Spread

	Mean Rating (−3 to +3)	% of Cases Rated as Good or Better than v11	% of Cases Rated Worse than v11
Day 10	0.18	**82**	18
Day 9	0.14	**74**	26
Day 8	0.23	**70**	30
Day 7	0.32	**70**	30
Day 6	0.23	**74**	26
Day 5	0.30	**74**	26
Day 4	0.44	**74**	26
Day 3	0.53	**82**	18
Day 2	0.58	**84**	16
Day 1	0.44	**95**	5

GEFSv12 NWS SOO Team Ratings for Spread Amount

- Mean rating shows more perceived spread in GEFSv12 at all forecast ranges, including at short ranges

GEFSv12 Strength: Increased Spread, Including w/ TC Tracks



- GEFSv11 indicated a high probability of Florence recurving off the East Coast, whereas Best Track is well within the GEFSv12 envelope of possibility

Concerns with GEFSv12

1) Progressiveness of upper-level troughs
2) Right of track bias for tropical cyclones
3) Low QPF bias
4) Spread is occasionally too large
5) Issues with West Coast performance
6) Handling of Arctic air
7) Reduced instability (lower CAPE magnitudes)

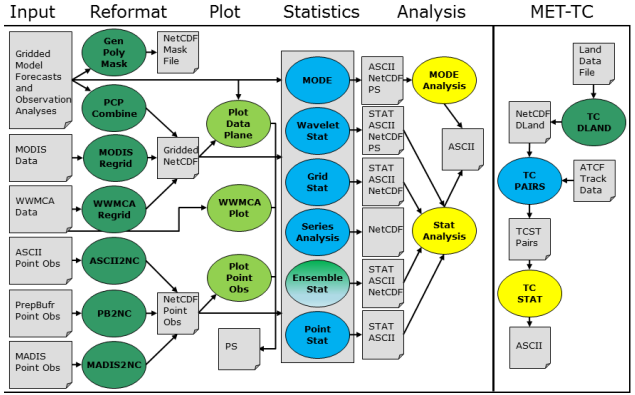
EMC Model Evaluation Group (MEG)

- Tasked with providing independent evaluation of EMC models and engaging NWS Regions, Centers, and other stakeholders in the evaluation process
- Organized and led official evaluations for:
  - **Global Ensemble Forecast System (GEFSv12)**
    www.emc.ncep.noaa.gov/users/meg/gefsv12
  - **Global Forecast System (GFSv16)**
    www.emc.ncep.noaa.gov/users/meg/gfsv16
  - **Rapid Refresh (RAPv5) and High-Resolution Rapid Refresh (HRRRv4)**
    www.emc.ncep.noaa.gov/users/meg/rapv5_hrrrv4
  - **High Resolution Ensemble Forecast (HREFv3)**
    www.emc.ncep.noaa.gov/users/meg/hrefv3

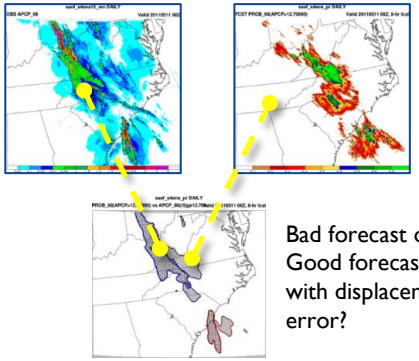
MET
Model Evaluation Tools

A verification toolkit designed for flexible yet systematic evaluation
(supported to the community via the DTC)

- **Originally developed to replicate the EMC mesoscale verification system**
- **Over 85 traditional statistics** using both point and gridded datasets
- 15 interpolation methods
- Computation of confidence intervals
- Able to read in GRIB1, GRIB2 and CF-compliant NetCDF
- Applied to many spatial and temporal scales
- 3500+ users, both US & Int'l



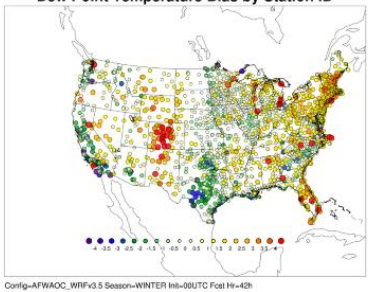
Object Based and Spatial Methods



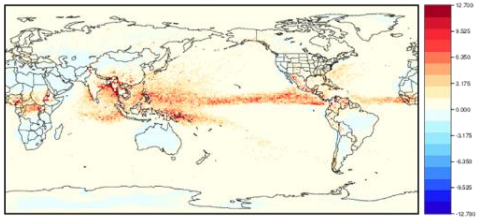
Bad forecast or Good forecast with displacement error?

Geographical Representation of Errors

Dew Point Temperature Bias by Station ID



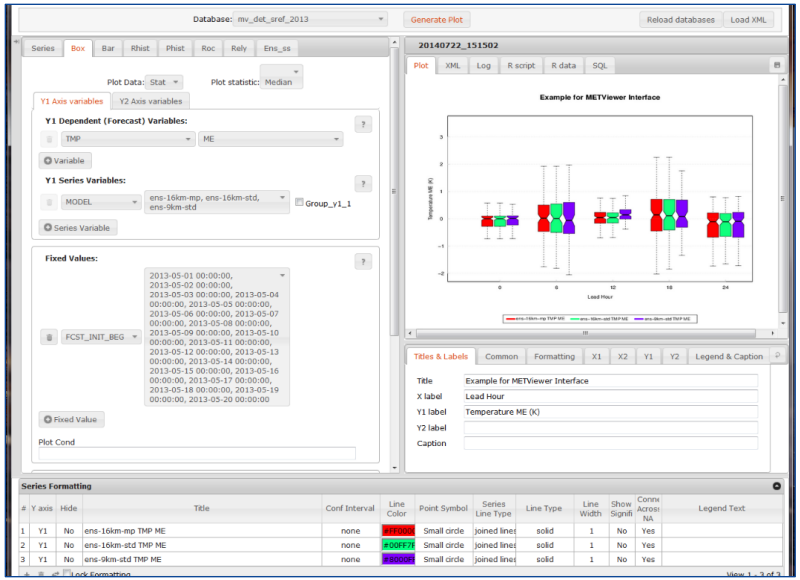
90th Percentile of difference between two models

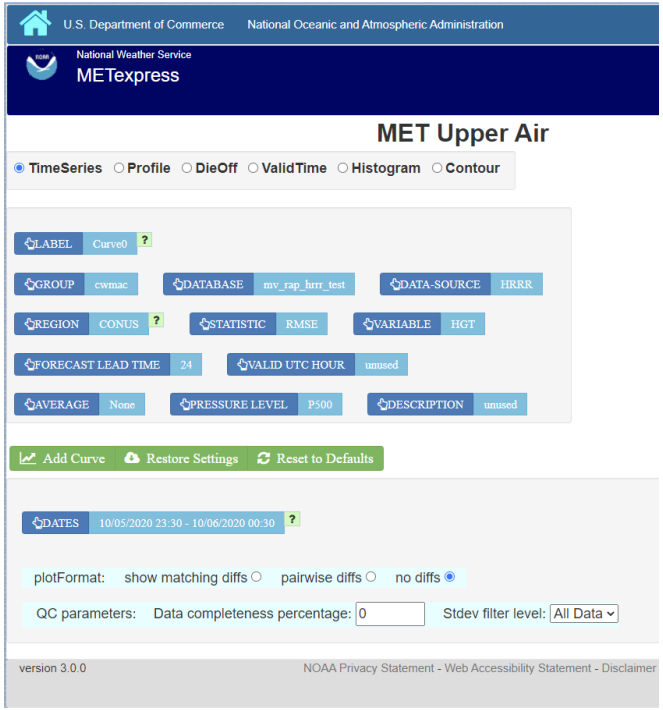


METViewer and METExpress on AWS

NOAA Environmental Modeling Center's first Cloud-based project

- MET: Model Evaluation Tools, used for model verification
- METViewer and METExpress: Web-based UI for verification graphic plotting
- Collaboration with the Meteorological Development Laboratory





2021 UFS Metrics Workshop: Feb 22-24, 2021

- Community-based workshop to investigate common metrics for the Unified Forecast System
- UFS community will develop community-vetted and peer-reviewed metrics to be used by application developers
- Pre-workshop surveys will assist in focusing on priorities and discussion topics
- Uses ideas developed in the 2018 Metrics Workshop as a baseline

2021 DTC UFS EVALUATION METRICS WORKSHOP

FEB 22 - 24 2021

The Developmental Testbed Center (DTC), in collaboration with the National Oceanic and Atmospheric Administration (NOAA) and the Unified Forecast System's Verification and Validation Cross-Cutting Team (UFS-V&V), will be holding a three day workshop to identify key verification and validation metrics for UFS applications. **The workshop will be held remotely February 22-24, 2021.**

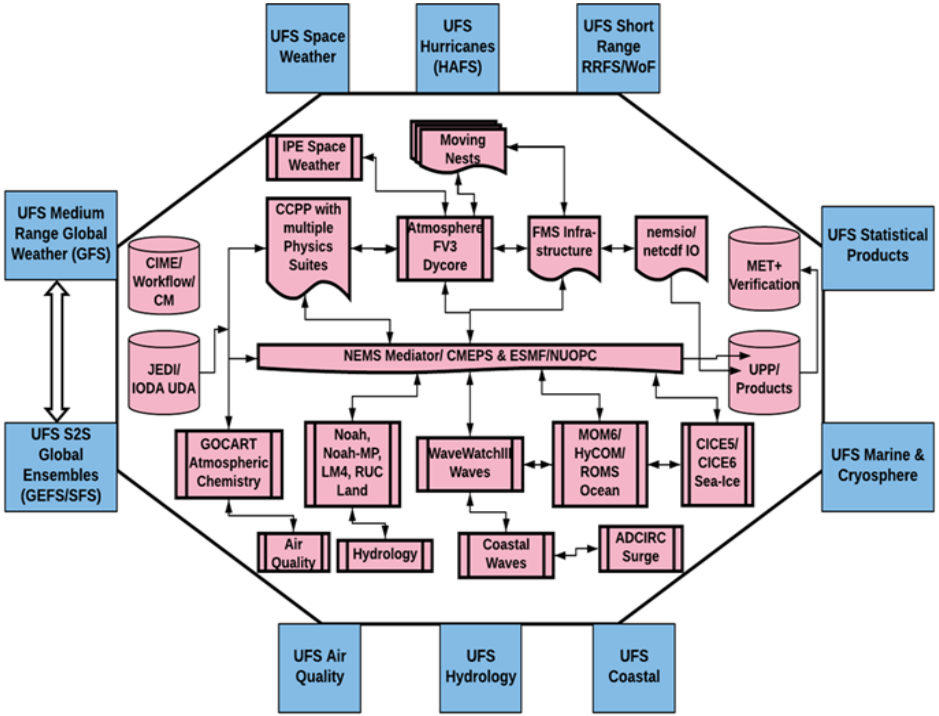
The **goal** of this workshop is to **identify and prioritize key metrics** to apply in evaluating UFS research products that will **help guide** their **transition from research-to-operations**. Since all UFS evaluation decisions affect a diverse set of users, workshop organizers welcome members from government, academic, and private sector organizations to participate in the workshop. In preparation for the Workshop, a series of pre-Workshop surveys will be distributed to interested parties. Sign-up now to participate and receive updates as the planning process evolves.

ABOUT

Pre-Workshop Survey 1

Sign-Up For Updates

Metrics Workshop: Surveys and Organization

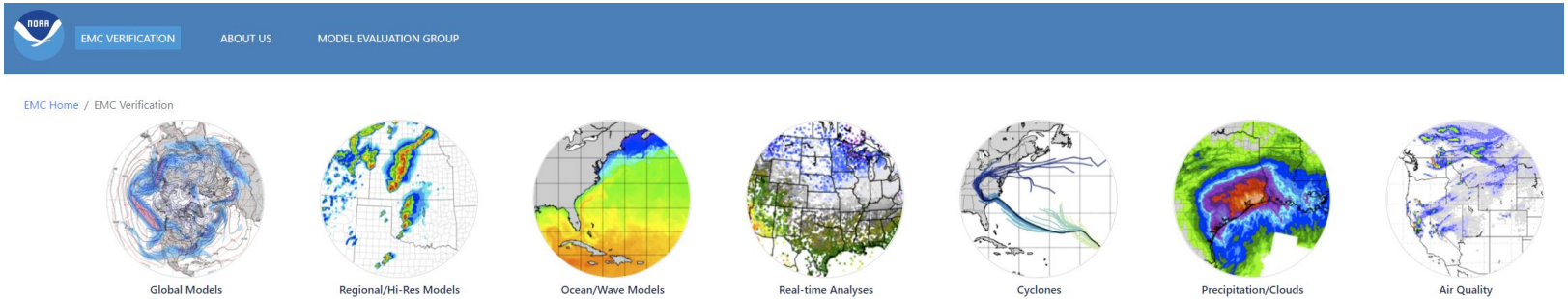


- Prior to workshop: community surveys
- Round 1: Priority variables (temperature, etc.)
- Round 2: Metrics
- Round 3: ?
- Idea is to obtain info upfront before workshop
- Round 1 is complete

- Forecast Field
- Application (RRFS, GFS, etc.)
- Vertical Attribute (pressure, etc.)
- Temporal Attribute (instant, 3-hr, etc)
- Validation Source
- Priority
- Maturity
- Deterministic Methodology
- Deterministic Scores (ACC, RMSE, etc.)
- Deterministic Stratifications (f00 – f240)
- Ensemble Methodology
- Ensemble Scores (spread-skill, etc.)
- Ensemble Stratifications

New web sites and internal verification system

- Moving from in-house custom software to community-based METplus
  - Will produce real-time graphics and stats for web sites
  - Allows us to share and use community code
  - Will follow UFS standards and priority metrics from Metrics Workshop
- New EMC verification web sites: https://www.emc.ncep.noaa.gov/users/verification/
  - Re-organization and new graphics
  - Organized by application
  - Much more to build out in coming months and years



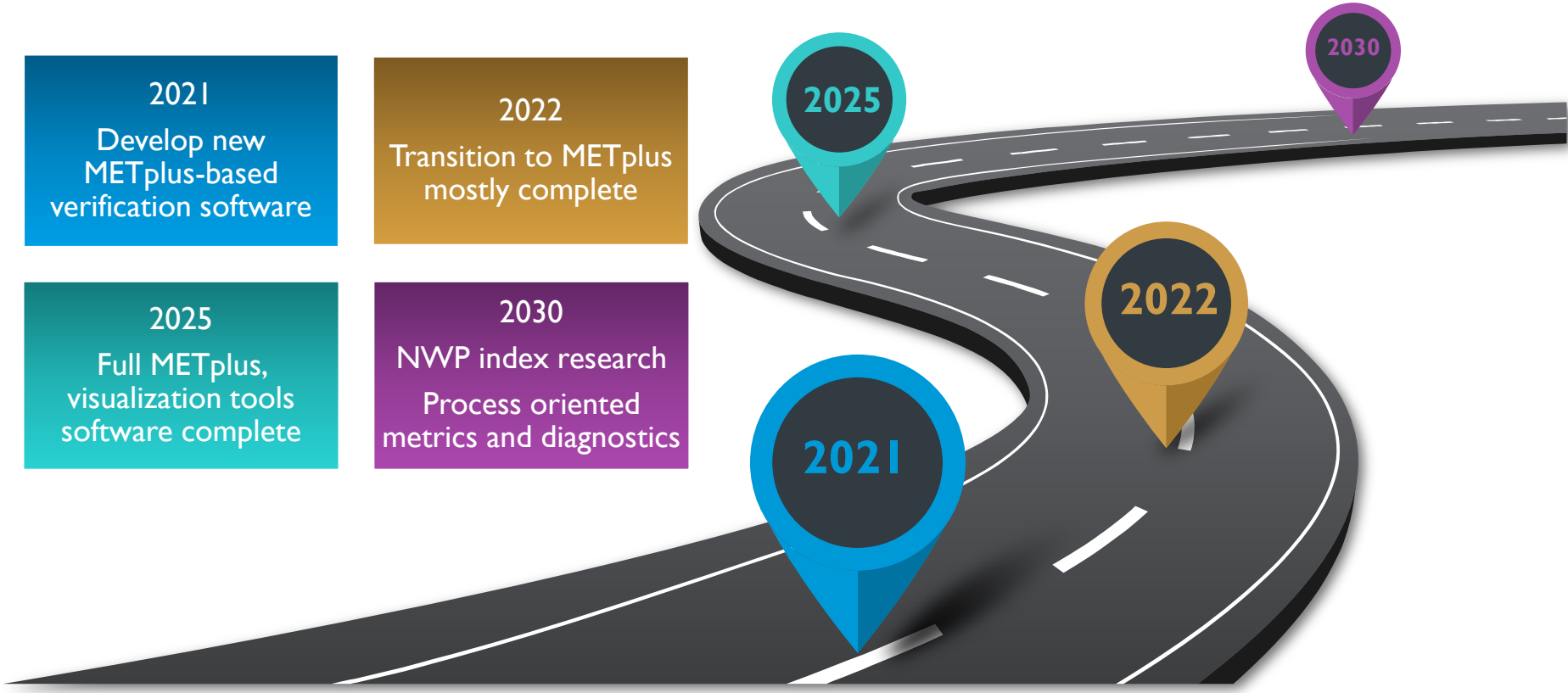
Verification Development: Future Plans

2021
Develop new METplus-based verification software

2022
Transition to METplus mostly complete

2025
Full METplus, visualization tools software complete

2030
NWP index research
Process oriented metrics and diagnostics



Thanks for listening!

Questions?