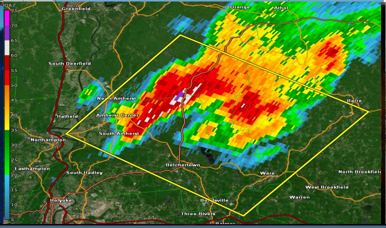


Welcome to our NWS Boston/Norton Webinar!

Weather Models 101

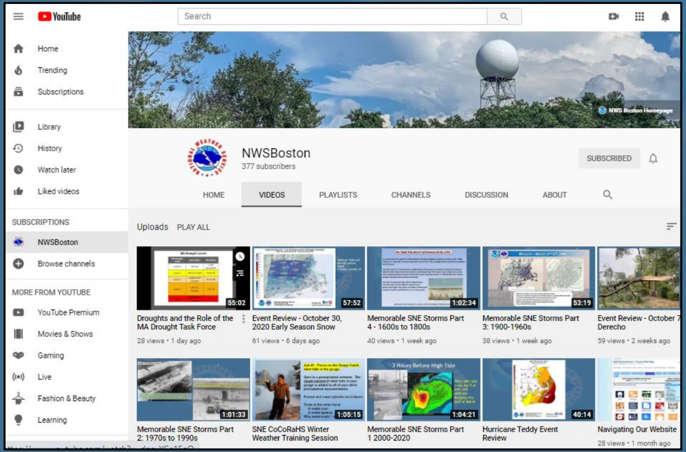





Check our Webinar page for the latest schedule!

www.weather.gov/boston/webinars



Recorded webinars are on our YouTube Channel!
YouTube.com/NWSBoston

NWS Boston/Norton -Public Webinars-

Upcoming Webinars:

Date/Time (EDT)	Topic	Registration
Thu Feb 3	**Weather Models 101**	https://bit.ly/3HB8Sp1

Join us as we talk all about weather models! We'll give you a brief history on how computers were first used to forecast the weather in the 1940s and the process evolved over the years. We'll also talk about many of the weather models used today and show you what lies ahead in the modeling world over the next several years.

Thu Feb 10	**Lake Effect and Ocean Effect Snow**	Register Here

Join us as we provide a basic overview of lake effect snow and ocean effect snow. We'll discuss the processes that lead to the development of both, which are very similar to one another, except that ocean effect snow occurs on a smaller scale. We will also review the ocean effect snow event that affected eastern Massachusetts on January 21 and 22 to help reinforce the concepts.

Tue Feb 15	**Review of the January 28-29, 2022 Blizzard**	Register Here

Join us as we take an in-depth look at the "Blizzard of 2022." We'll review some of the model data, analysis maps, and observations to show the evolution of the storm as well as the forecast and messaging challenges it presented.

Tue Mar 1	**Weather Models 202**	Register Here

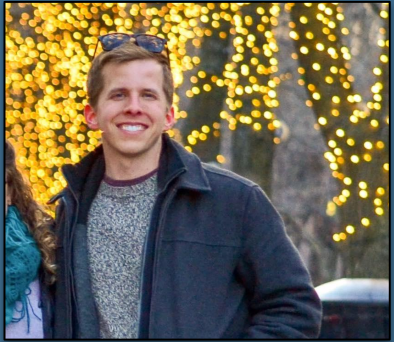
How accurate are those model snowfall forecasts? Join us for the next part in our series about weather models. In this webinar, we'll discuss how they determine precipitation type and snowfall accumulation. You'll learn the strengths and weaknesses of using the output.

Join our email list for new webinar dates!
Email Joseph.Dellicarpini@noaa.gov to be added.

Presenters

Joe Dellicarpini

Science and Operations Officer



Bryce Williams

Meteorologist

Weather Models 101

Numerical weather prediction involves the use of mathematical models of the atmosphere to predict the weather.

213,000 Trillion calculations per second!

History of Numerical Weather Prediction

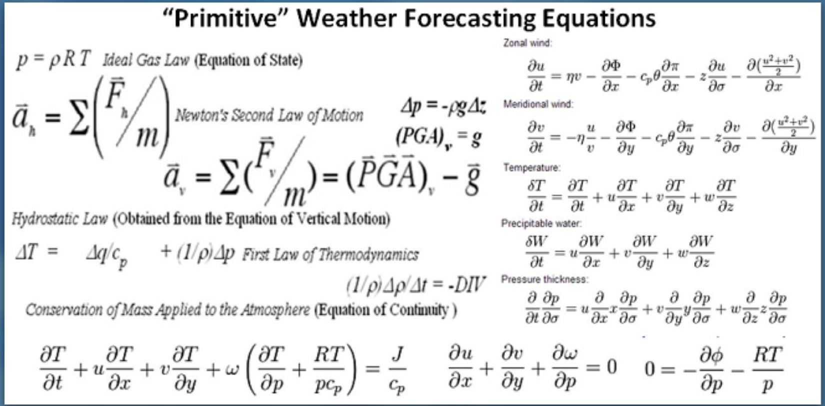
The roots of numerical weather prediction can be traced back to the work of Vilhelm Bjerknes, a Norwegian physicist who has been called the father of modern meteorology.

In 1904, he published a paper suggesting that it would be possible to forecast the weather by solving a system of nonlinear partial differential equations.

Vilhelm Bjerknes

History of Numerical Weather Prediction

A British mathematician, Lewis Fry Richardson, spent three years developing Bjerknes's techniques to solve these equations.

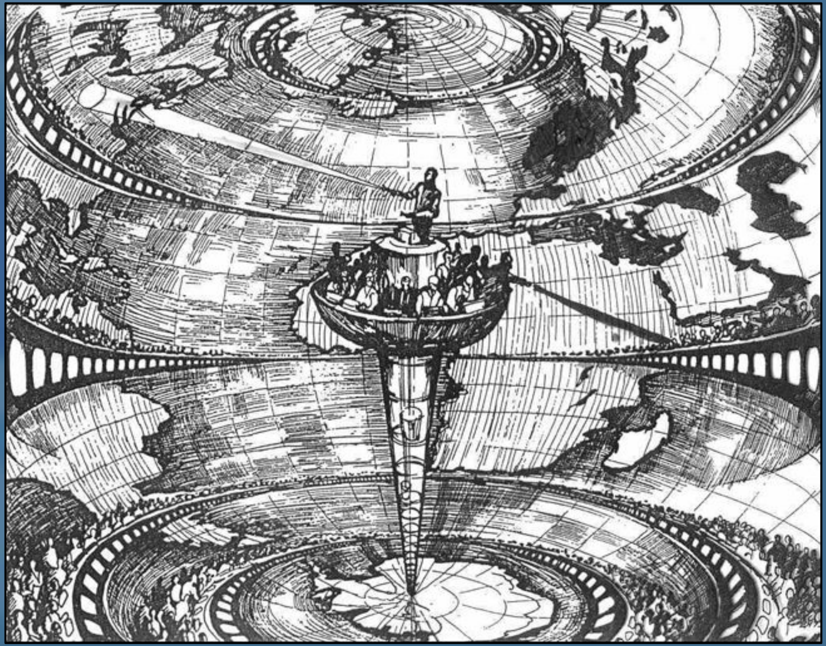


Armed with no more than a slide rule and a table of logarithms, and working among the World War I battlefields of France where he was a member of an ambulance unit, Richardson computed a prediction for the change in pressure at a single point over a six-hour period.

The calculation took him six weeks, and the prediction turned out to be completely unrealistic, but his efforts were a glimpse into the future of weather forecasting.

History of Numerical Weather Prediction

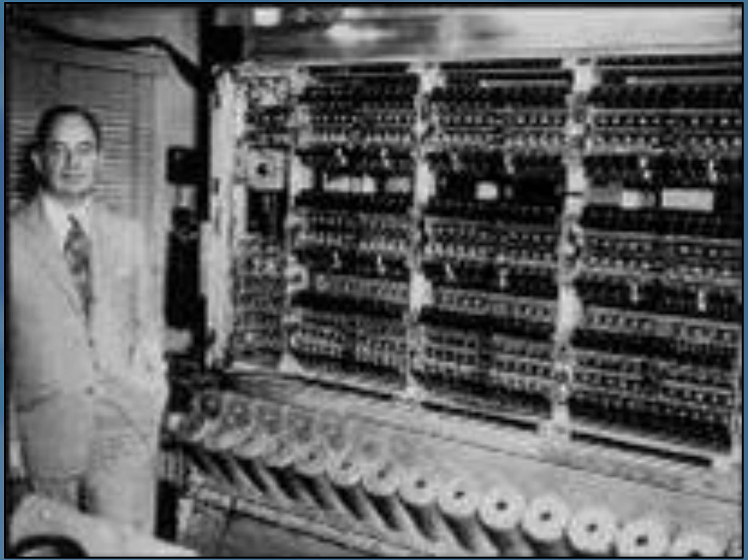
Richardson foresaw a "forecast factory," where he calculated that 64,000 human "computers," each responsible for a small part of the globe, would be needed to keep "pace with the weather" in order to predict weather conditions.



They would be housed in a circular hall like a theater, with galleries going around the room and a map painted on the walls and ceiling. A conductor located in the center of the hall would coordinate the calculations using colored lights.

History of Numerical Weather Prediction

John von Neumann, the developer of that first computer (called the ENIAC), recognized that the problem of weather forecasting was a natural for his computing machinery.



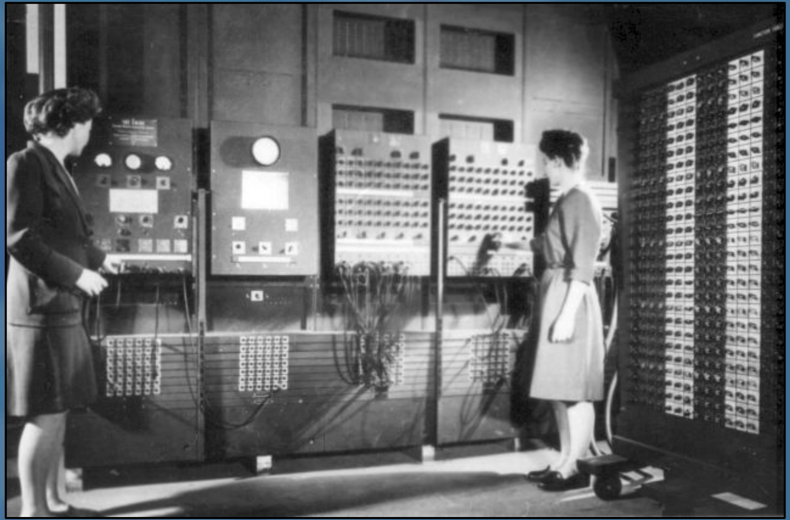
In 1948, he assembled a group of theoretical meteorologists at the Institute of Advanced Study in Princeton, New Jersey. The group was headed by Jule Charney, who had done extensive work on developing a simplified, filtered system of equations for weather forecasting. His group constructed a successful mathematical model of the atmosphere and demonstrated the feasibility of numerical weather prediction.

History of Numerical Weather Prediction

The first one-day, nonlinear weather prediction was made in April, 1950.

Its completion required the round-the-clock services of the modelers, and, because of several ENIAC breakdowns, more than 24 hours to execute.

However, this first forecast was successful in proving to the meteorological community that numerical weather prediction was feasible.

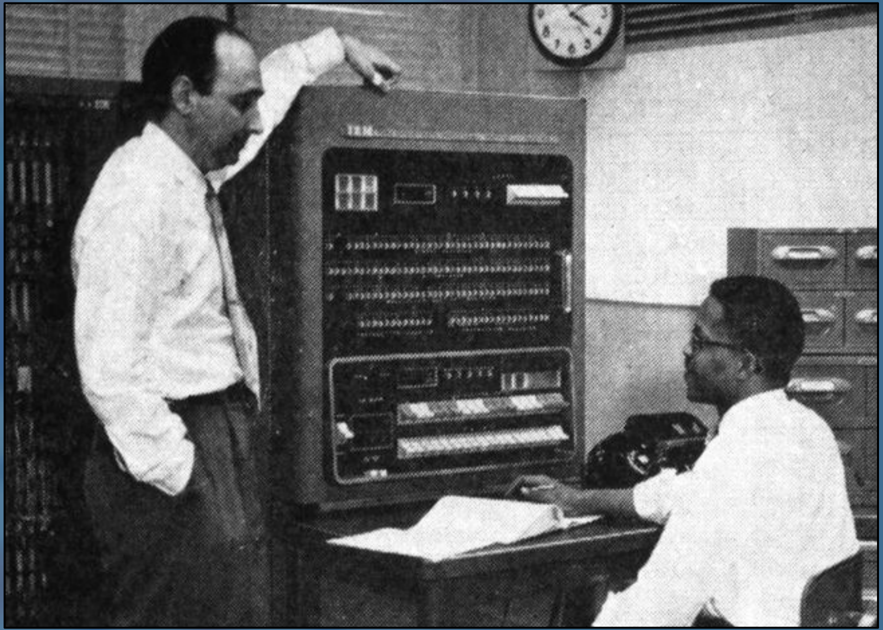


History of Numerical Weather Prediction

By 1954, both modeling capability and computer power had advanced to a point where the possibility of real-time operational numerical weather prediction was under active consideration in Europe and the United States.

On July 1, 1954, the Joint Numerical Weather Prediction Unit (JNWPU) was organized, staffed, and funded by the U.S. Weather Bureau, the U.S. Air Force, and the U.S. Navy.

This new unit was given the mission to apply emerging computer technology to the operational production of weather forecasts.

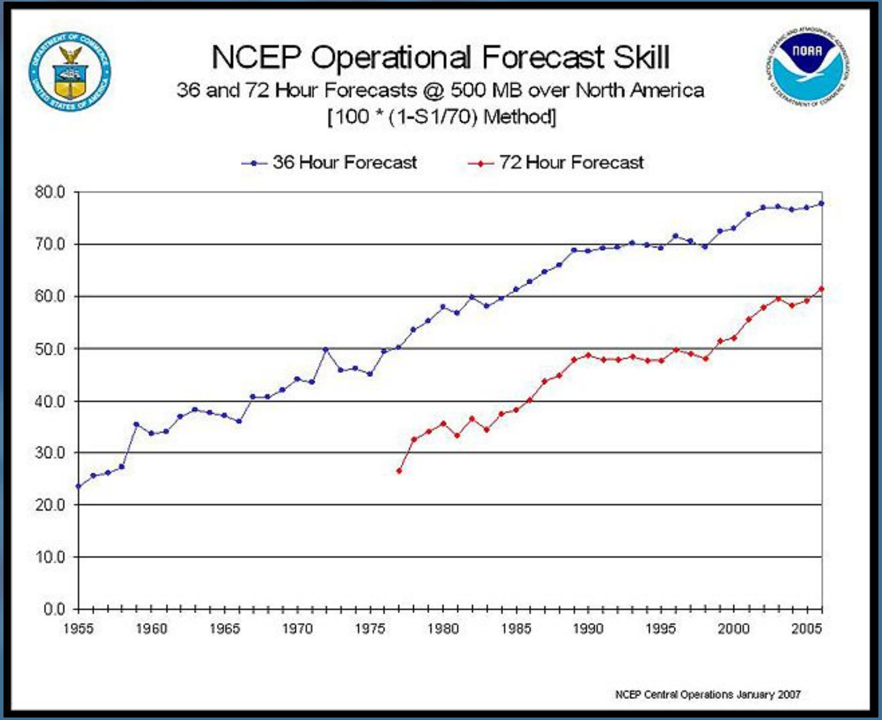


Fred Shuman (left) and Otha Fuller, circa 1955 at the IBM 701. The 701 was the first computer used by the JNWPU to produce operational numerical weather prediction.

History of Numerical Weather Prediction

A progression of more and more powerful computers procured by the National Weather Service throughout the 1960s and 1970s as well as increasing sources of data—particularly from weather satellites—allowed the expansion of both the domains and the number of models run.

Increases were also made in the number of vertical levels and the horizontal resolution of the models. A three-layer hemispheric model was introduced in 1962 and a six-layer primitive equation model appeared in 1966. Additional atmospheric layers allowed more accurate forecasts of winds and temperature, resulting in better prediction of storm motion.



What Are Weather Models?

Model Does the Math For Us

- Initial Conditions
- Runs Equations
- Graphical Output

Global models typically run 4 times a day

Models have different resolutions, initial conditions, parameterizations, and schemes that make output differ.

"Primitive" Weather Forecasting Equations

$p = \rho R T$ *Ideal Gas Law* (Equation of State)

$\vec{a}_h = \sum \left(\vec{F}_h / m \right)$ *Newton's Second Law of Motion*

$\Delta p = -\rho g \Delta z$

$(PGA)_v = g$

$\vec{a}_v = \sum (\vec{F}_v / m) = (\vec{P}\vec{G}\vec{A})_v - \vec{g}$

Hydrostatic Law (Obtained from the Equation of Vertical Motion)

$\Delta T = \Delta q / c_p + (1/\rho) \Delta p$ *First Law of Thermodynamics*

$(1/\rho) \Delta\rho / \Delta t = -DIV$

Conservation of Mass Applied to the Atmosphere (Equation of Continuity)

Zonal wind:

$$\frac{\partial u}{\partial t} = \eta v - \frac{\partial \Phi}{\partial x} - c_p \theta \frac{\partial \pi}{\partial x} - z \frac{\partial u}{\partial \sigma} - \frac{\partial (\frac{u^2+v^2}{2})}{\partial x}$$

Meridional wind:

$$\frac{\partial v}{\partial t} = -\eta \frac{u}{v} - \frac{\partial \Phi}{\partial y} - c_p \theta \frac{\partial \pi}{\partial y} - z \frac{\partial v}{\partial \sigma} - \frac{\partial (\frac{u^2+v^2}{2})}{\partial y}$$

Temperature:

$$\frac{\delta T}{\partial t} = \frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} + w \frac{\partial T}{\partial z}$$

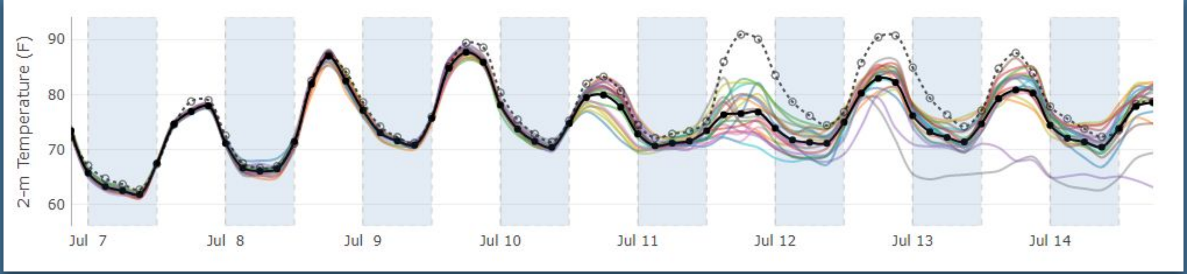
Precipitable water:

$$\frac{\delta W}{\partial t} = u \frac{\partial W}{\partial x} + v \frac{\partial W}{\partial y} + w \frac{\partial W}{\partial z}$$

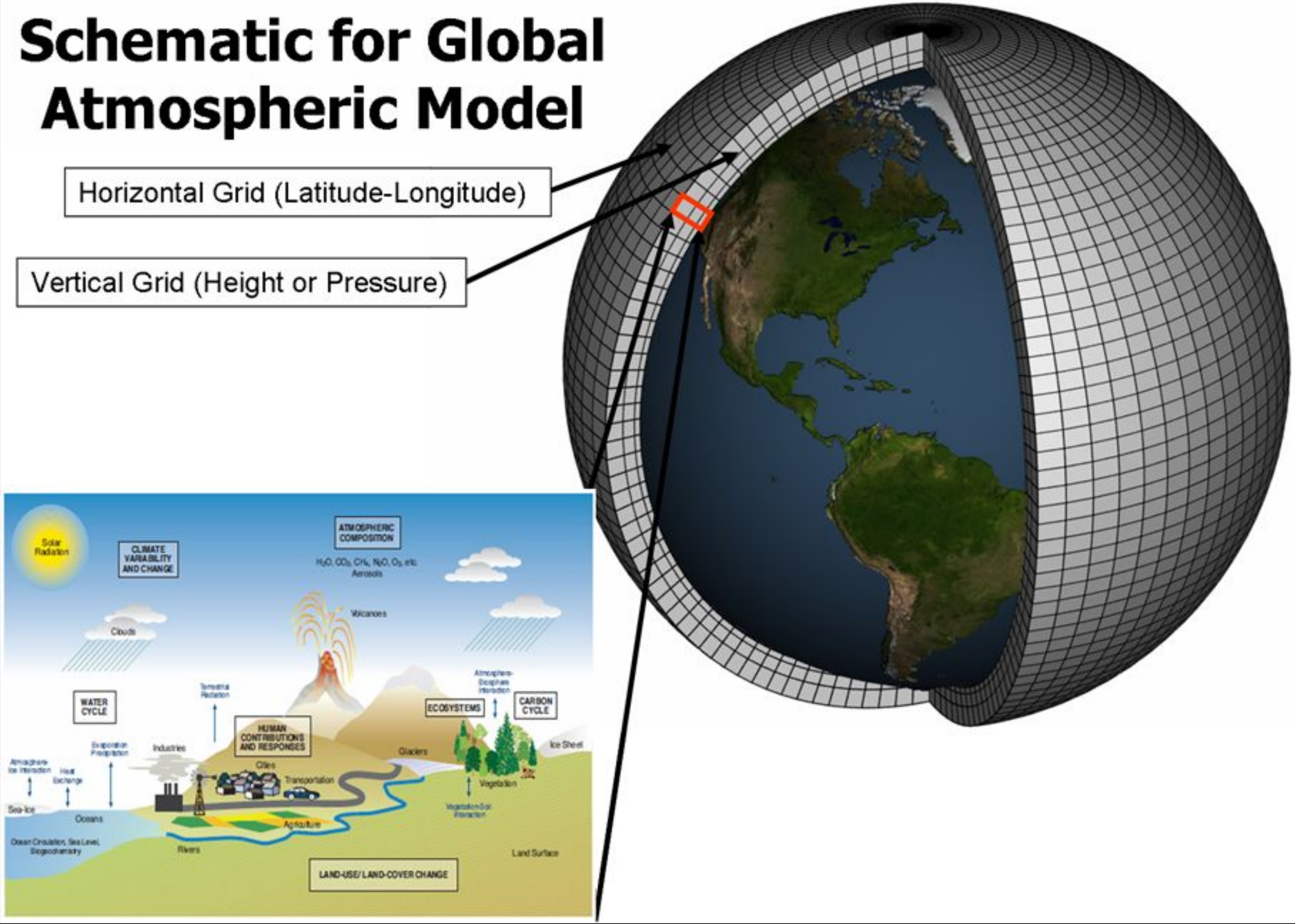
Pressure thickness:

$$\frac{\partial}{\partial t} \frac{\partial p}{\partial \sigma} = u \frac{\partial}{\partial x} x \frac{\partial p}{\partial \sigma} + v \frac{\partial}{\partial y} y \frac{\partial p}{\partial \sigma} + w \frac{\partial}{\partial z} z \frac{\partial p}{\partial \sigma}$$

$$\frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} + \omega \left(\frac{\partial T}{\partial p} + \frac{RT}{p c_p} \right) = \frac{J}{c_p} \qquad \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial \omega}{\partial p} = 0 \qquad 0 = -\frac{\partial \phi}{\partial p} - \frac{RT}{p}$$

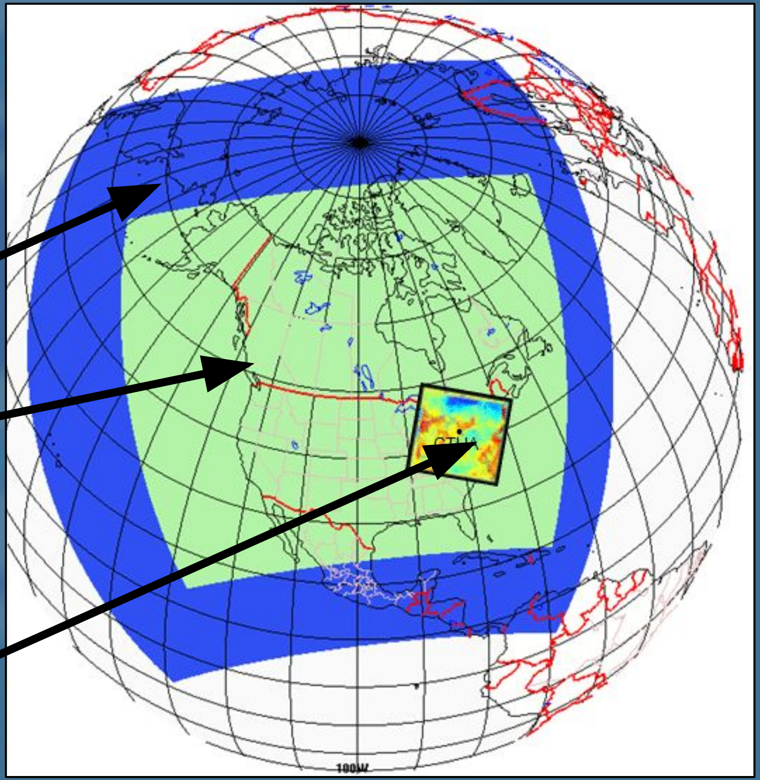


Schematic for Global Atmospheric Model



Model "Domains"

Each model is run for a specific area, in order to focus on certain weather features



Global models: entire globe or hemisphere

Regional models: smaller sections, like countries (U.S.)

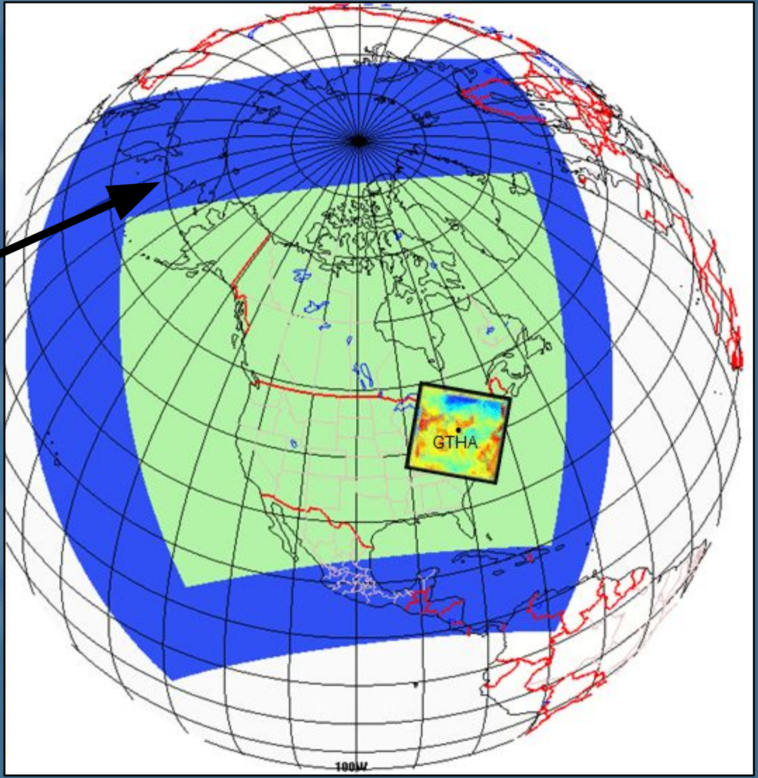
Mesoscale models: even smaller sections, like parts of the country (Northeast)

Model "Domains"

Global models:

Focus on larger scale features such as jet streams, tropical cyclones, and others that affect a large portion of the globe.

The input initializes regional models, in order to give them a "starting point" for a forecast, and also feeds climate models which provide forecasts out several weeks in time.

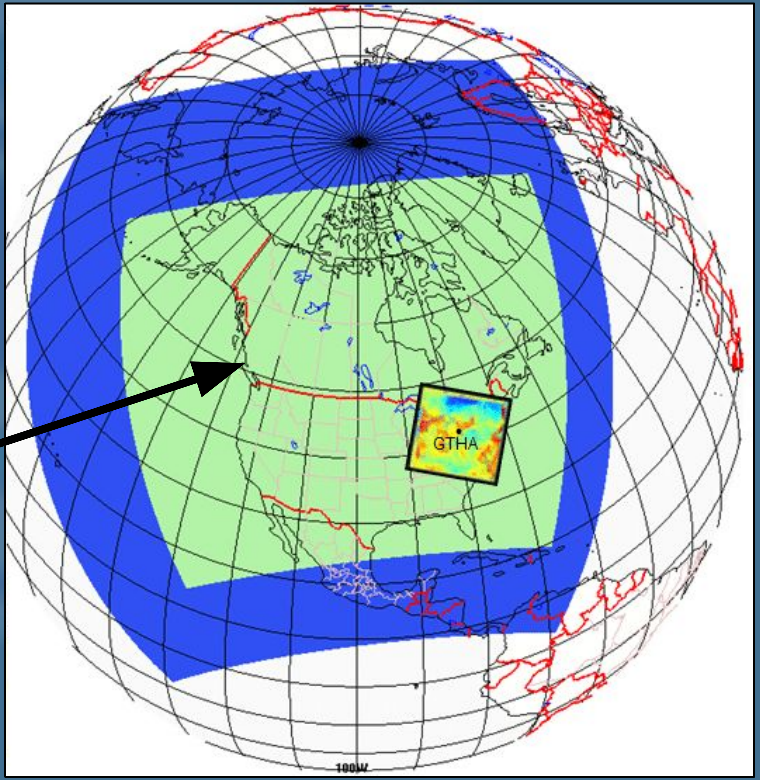


Model "Domains"

Regional models:

Able to provide more detail with larger scale systems such as winter storms, tropical cyclones, and severe weather.

The input initializes mesoscale models, in order to give them a "starting point" for a forecast.

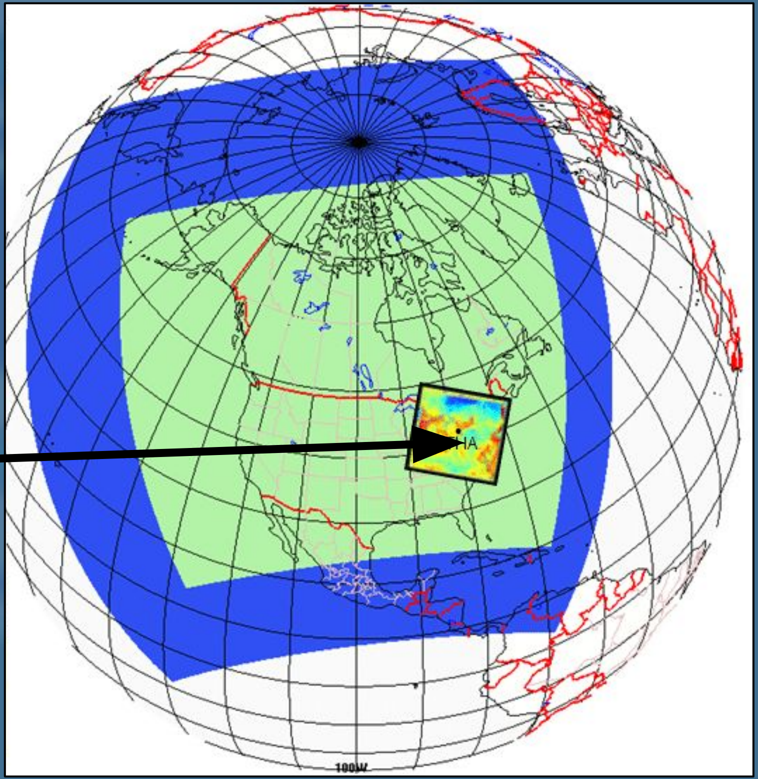


Model “Domains”

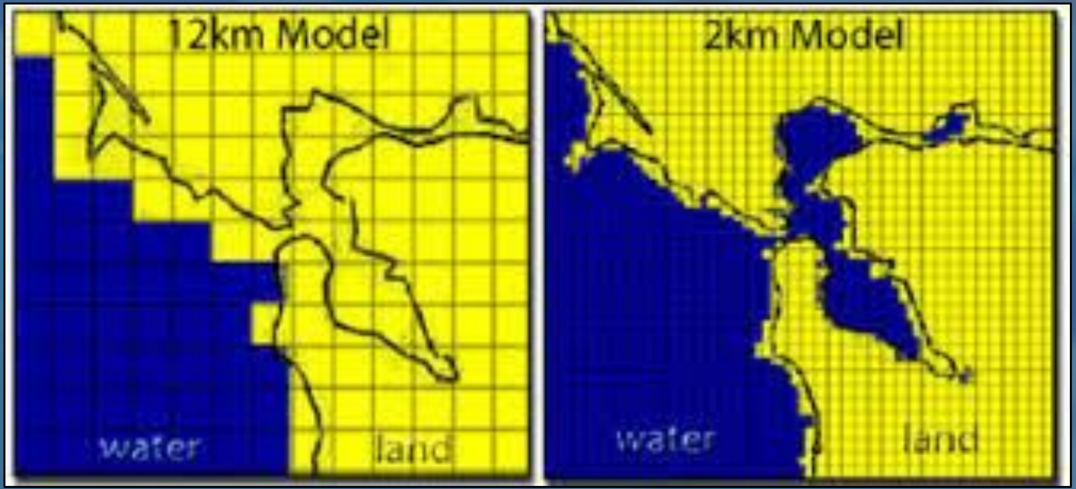
Mesoscale models:

Able to provide more detail with smaller scale systems such as rain/snow lines, supercells, and sea breezes,

They are typically run at least once per hour and can provide forecasts at very high resolution.



Model Resolution



- Higher resolution = greater precision (more grid boxes over a given area)
- A higher resolution model has a smaller grid size and can forecast smaller-scale features better than a lower resolution model
- A 12km model (NAM) is lower resolution than a 2 or 3 km model (HRRR)

Model Output

- **Maps**

- **MOS (Model Output Statistics)**
  - Developed by the NWS in 1965 and forecasts first issued from it in 1968.
  - Given its long history and continuous improvement, it is still one of the most valuable forecast tools
  - Consistently performs better than “raw” model guidance

MAV TEXT BULLETIN

KPVD GFS MOS GUIDANCE 1/04/2022 0600 UTC

DT	/JAN 4				/JAN 5								/JAN 6							/	
HR	12	15	18	21	00	03	06	09	12	15	18	21	00	03	06	09	12	15	18	00	06
X/N					32				25				50				35			40	
TMP	16	24	31	30	27	26	27	29	32	44	46	46	45	45	44	40	36	36	39	33	28
DPT	1	-1	1	6	13	16	19	23	28	37	40	40	39	37	34	30	26	20	18	20	20
CLD	CL	CL	CL	FW	CL	CL	SC	OV	OV	OV	OV	OV	OV	OV	BK	CL	FW	FW	SC	OV	OV
WDR	33	33	25	21	21	21	21	20	20	18	18	18	21	23	23	25	27	29	28	23	05
WSP	06	06	05	07	04	04	04	06	07	10	14	14	12	09	08	10	10	12	08	03	03
P06			0		0		0		0		39		94		17		1		6	7	7
P12					0				0				94				18			8	
Q06			0		0		0		0		0		3		0		0		0	0	0
Q12					0				0				3				0			0	
T06			0/ 1		0/ 0		0/ 0		0/ 3		0/ 3		3/10		0/13		0/12		0/ 6		0/ 0
T12							0/ 0				0/ 4				3/19				0/12		1/ 4
POZ	1	1	0	1	2	0	1	1	4	4	1	0	1	0	0	0	0	0	0	1	0
POS	96	99	100	99	93	97	69	57	37	14	1	0	0	9	17	27	56	84	78	85	79
TYP	S	S	S	S	S	S	S	S	R	R	R	R	R	R	R	R	S	S	S	S	S
SNW									0								0				
CIG	8	8	8	8	8	8	8	8	6	5	4	3	3	8	8	8	8	8	8	8	7
VIS	7	7	7	7	7	7	7	7	7	7	5	2	5	7	7	7	7	7	7	7	7
OBV	N	N	N	N	N	N	N	N	N	N	HZ	FG	BR	N	N	N	N	N	N	N	N

MET TEXT BULLETIN

KPVD NAM MOS GUIDANCE 1/04/2022 1200 UTC

DT	/JAN 4		/JAN 5								/JAN 6								/JAN 7		
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N/X							25				54				35				44		28
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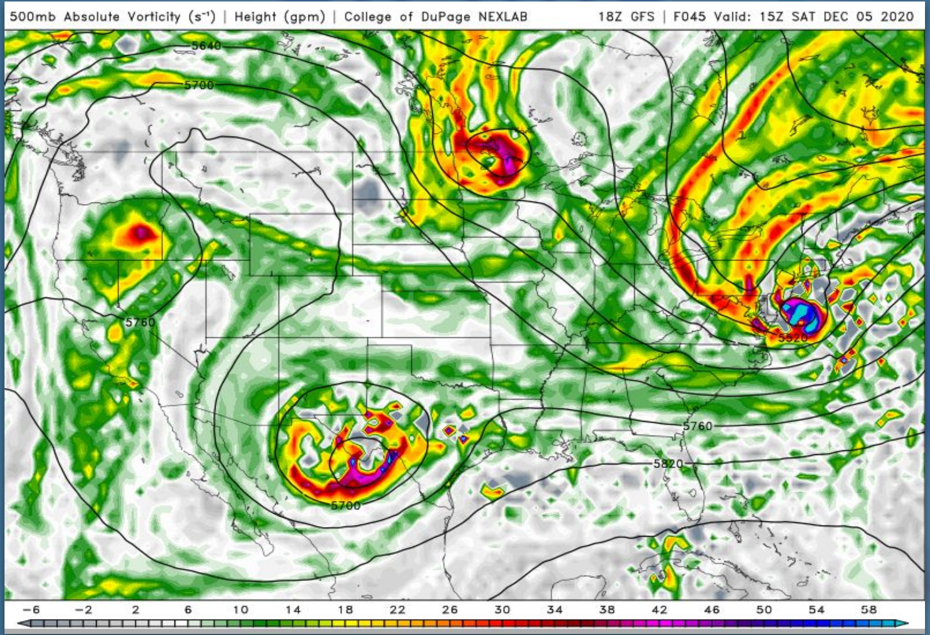
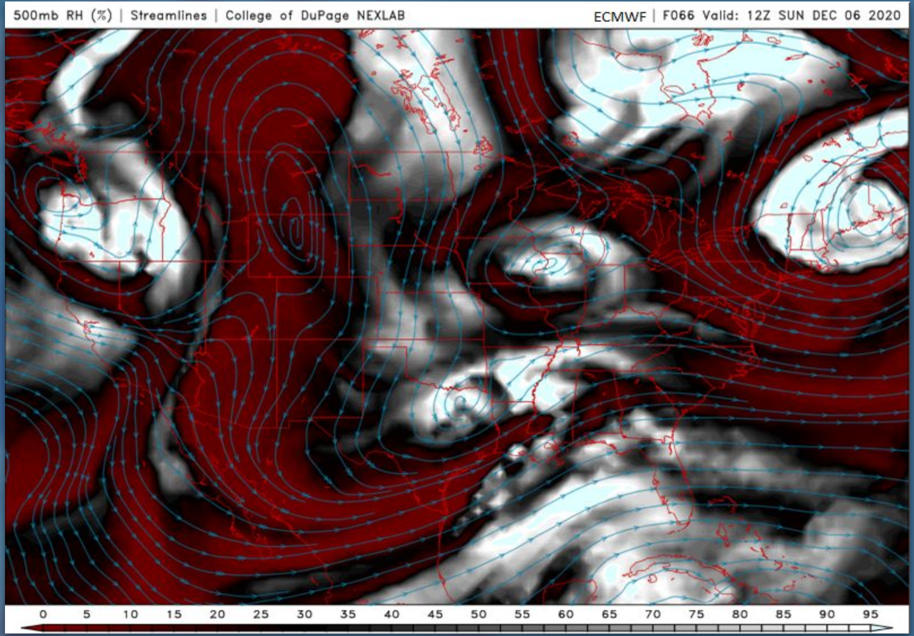
CLD	CL	FW	CL	CL	CL	OV	OV	OV	OV	OV	OV	OV	OV	CL	SC	FW	SC	SC	BK	OV	OV
WDR	25	20	20	21	20	20	20	19	17	18	20	23	25	25	26	28	27	27	27	35	03
WSP	05	05	04	03	05	05	07	09	16	16	11	09	09	09	09	12	10	08	04	02	08
P06			0		0		0		31		83		17		6		8		10	10	22
P12							1				83				17				10		22
Q06			0		0		0		0		2		0		0		0		0	0	0
Q12							0				2				0				0		0
T06			0/ 0		0/ 0		0/ 0		0/ 1		1/ 6		0/ 6		0/ 8		0/ 2		0/ 0		0/ 1
T12					0/ 0				0/ 1				1/14				0/ 8			0/ 7	
POZ	1	0	3	6	8	2	6	3	2	0	1	0	0	0	0	0	1	0	2	0	1
POS	99	100	97	84	58	40	21	8	1	2	0	6	9	36	52	82	91	79	89	74	77
TYP	S	S	S	S	S	R	R	R	R	R	R	R	R	R	S	S	S	S	S	S	S
SNW							0								0						1
CIG	8	8	8	8	8	5	5	5	4	3	3	6	8	8	8	8	8	8	8	8	6
VIS	7	7	7	7	7	7	7	7	5	4	4	7	7	7	7	7	7	7	7	7	7
OBV	N	N	N	N	N	N	N	N	N	BR	BR	N	N	N	N	N	N	N	N	N	N

Global Models - GFS and ECMWF

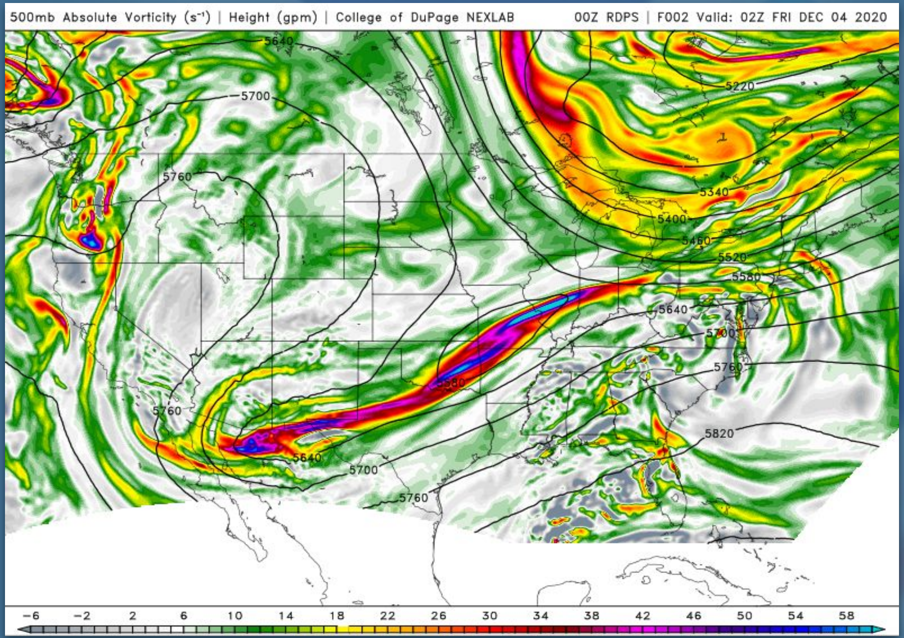


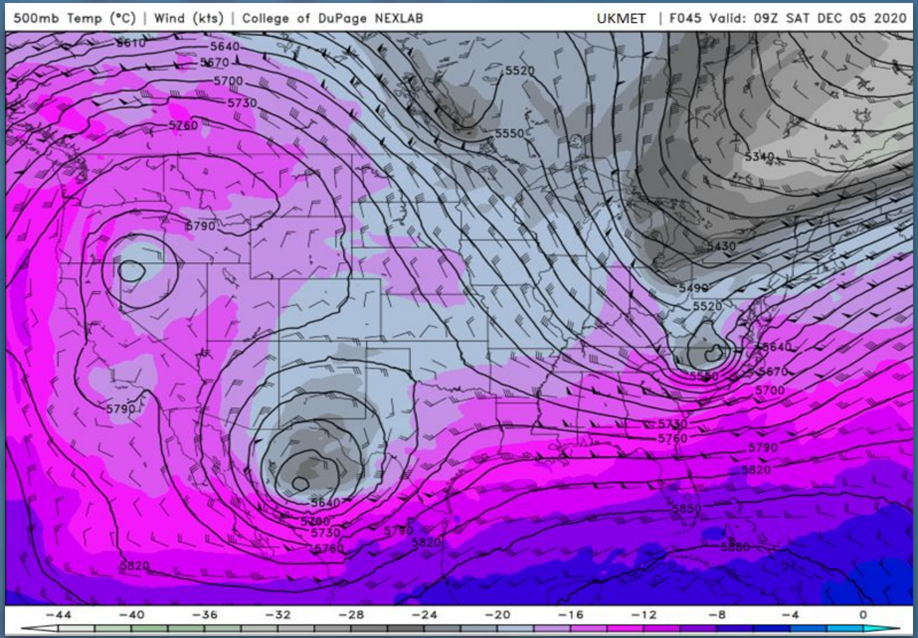


- Forecasts 384 Hours (16 Days)
- Resolution: 13 km (8 miles) horizontal, 64 vertical levels
- Country/Organization: U.S. NOAA, NCEP

- Forecasts 240 Hours (10 days)
- Resolution: 9 km horizontal (5.5 miles), 91 vertical levels
- Country/Organization: European Centre for Medium-Range Weather Forecasting

Global Models - Canadian and UKMET

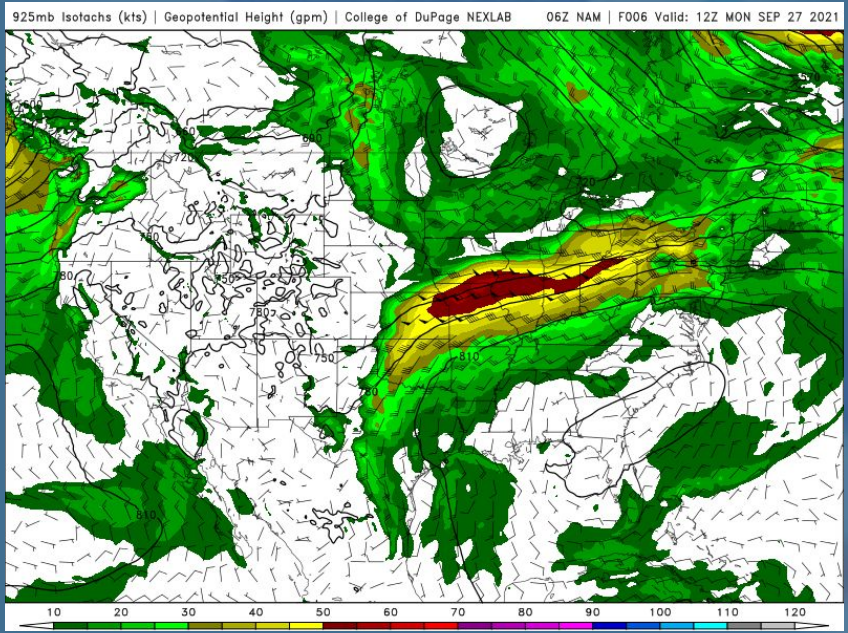


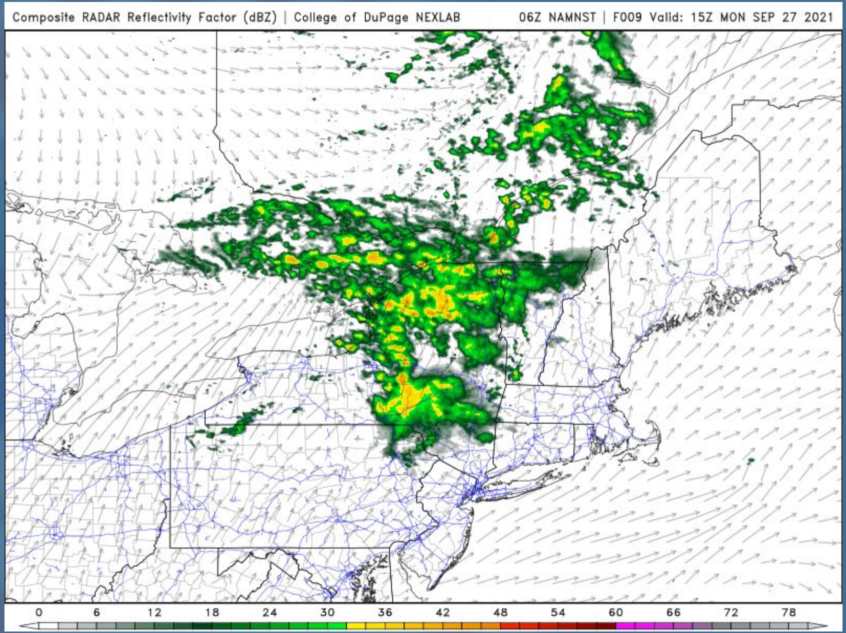


- Forecasts 240 Hours (10 days)
- Resolution: 15 km horizontal (9 miles), 84 vertical levels
- Country/Organization: Environment and Climate Change Canada

- Forecasts 144 Hours (6 days)
- Resolution: 10 km horizontal (6 miles), 70 vertical levels
- Country/Organization: United Kingdom Meteorological Agency

Other Models - NAM and 3km NAM

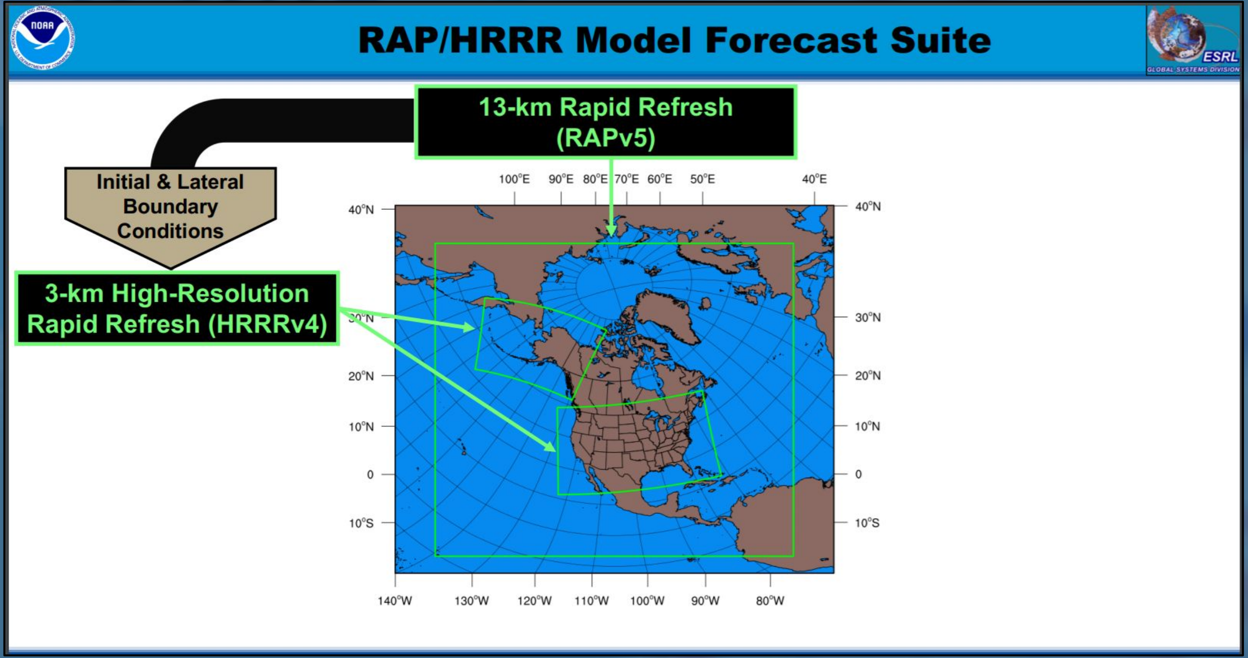




- Forecasts 84 hours (3.5 days)
- Resolution: 12 km horizontal (7.5 miles), 60 vertical levels
- Country/Organization: U.S. NOAA, NCEP

- Forecasts 60 hours (2.5 days)
- Resolution: 3 km horizontal (2 miles), 70 vertical levels
- Country/Organization: U.S. NOAA, NCEP

Other Models - RAP and HRRR

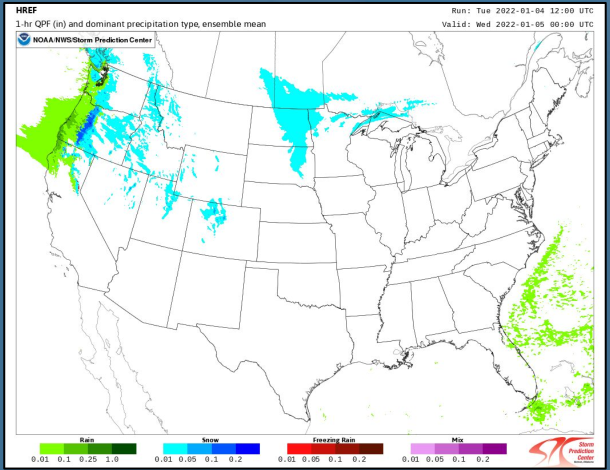


- Forecasts 36 hours
- Resolution: 13 km horizontal (8 miles), 50 vertical levels
- Country/Organization: U.S. NOAA, NCEP

- Forecasts 36 hours
- Resolution: 3 km horizontal (2 miles), 50 vertical levels
- Country/Organization: U.S. NOAA, NCEP

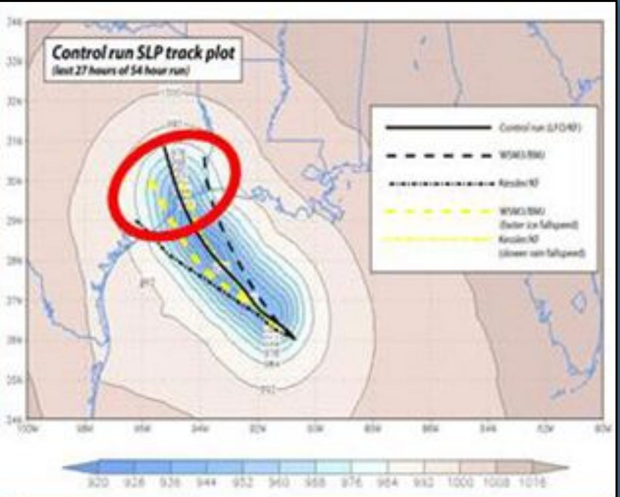
Ensembles

Ensemble Forecast Systems (EFS) use initial condition sensitivity, model estimates and errors, or both, to tease out potential forecast outcomes.



WFO BOX Table Jan 4, 2022 00Z Run

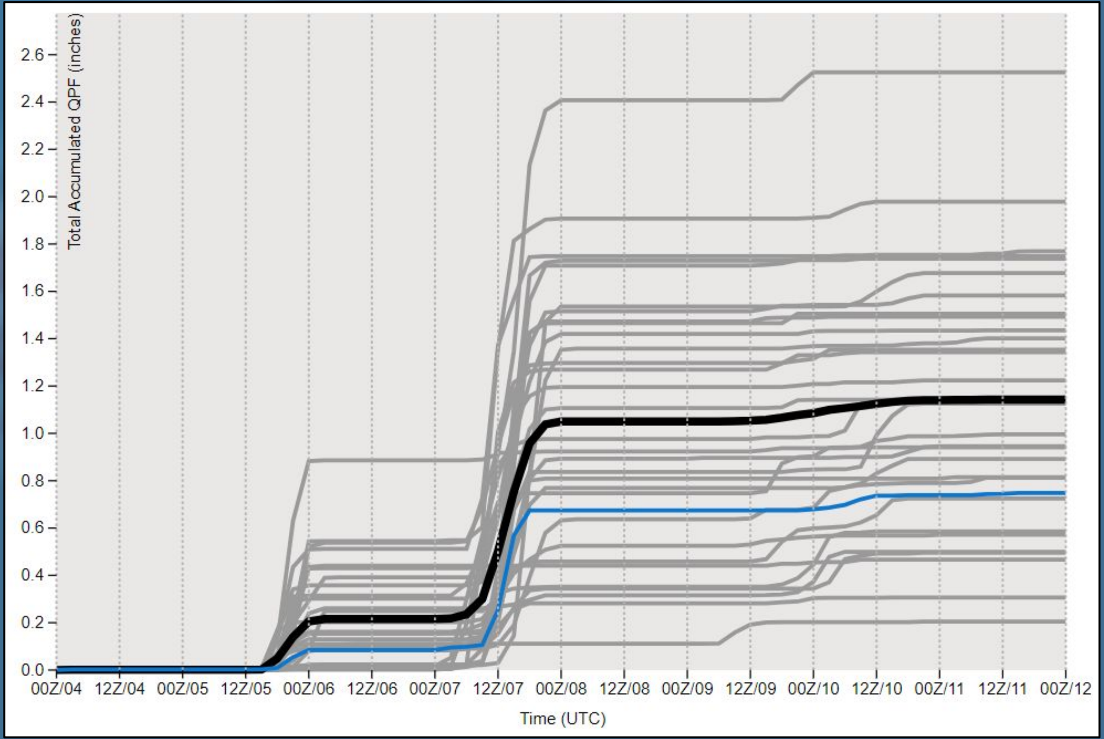
			Z	T	U	V	WSP	SLP	Q	PW	IVT
0	Tue 4th	00Z	-2.1	1.6	-3.4	-3.0	2.9	-1.9	3.0	2.7	3.8
6		06Z	-1.2	1.5	-1.3	-3.0	2.6	-1.0	-1.1	-1.1	0.5
12		12Z	1.0	-1.4	1.1	-1.9	1.2	1.1	-1.1	-1.1	0.0
18		18Z	1.1	-1.6	1.4	-1.6	1.2	1.1	-1.2	-1.1	0.3
24	Wed 5th	00Z	1.2	-2.1	1.6	1.1	1.4	1.2	-1.1	-1.1	0.6
30		06Z	1.2	-2.2	1.4	2.5	1.7	1.2	-1.0	-0.9	0.5
36		12Z	1.0	-2.1	1.4	2.8	2.4	0.9	1.1	-0.4	0.6
42		18Z	-1.0	-2.0	1.4	2.9	2.3	-1.3	1.8	1.1	2.0
48	Thu 6th	00Z	-1.4	2.0	1.6	2.7	2.6	-1.7	2.5	1.8	3.2
54		06Z	-1.5	1.8	2.2	2.7	2.5	-1.5	1.7	1.7	2.6
60		12Z	-1.1	1.3	2.2	1.9	2.4	-1.2	1.1	-0.8	0.6
66		18Z	-1.1	-0.7	2.0	1.2	1.9	-0.7	1.1	-0.7	0.1
72	Fri 7th	00Z	-1.0	-0.7	1.5	1.7	1.6	-0.6	0.8	-0.4	0.2
78		06Z	-1.3	0.8	1.4	2.1	1.7	-1.3	0.9	0.6	1.0
84		12Z	-1.8	1.5	-1.5	2.3	1.6	-1.7	1.5	1.3	1.9
90		18Z	-2.0	1.8	-2.0	2.1	2.0	-2.0	-0.9	-0.9	0.9



Ensembles

Each member of the ensemble has a unique representation in the range or “envelope” of outcomes.

Ensembles are especially useful in forecasting the probability of high-impact events, and clustering of members around two or more forecast outcomes.

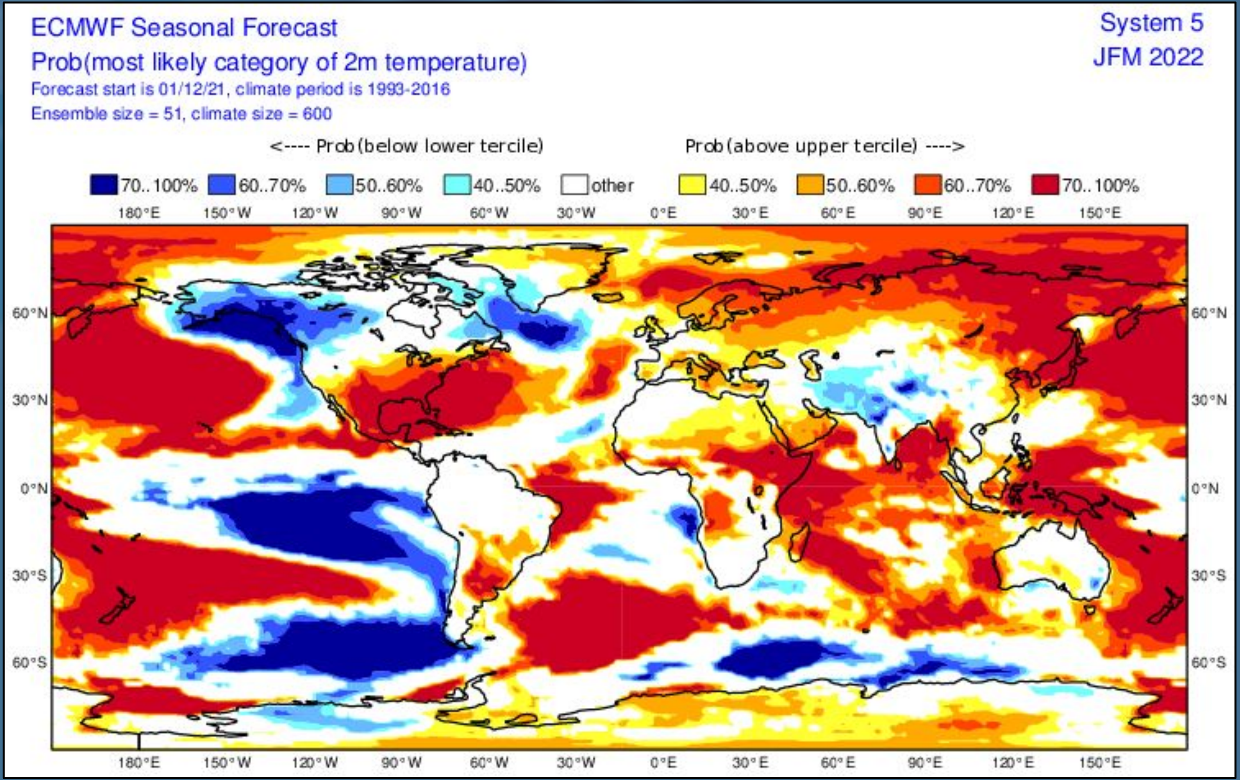


Global Ensembles

GFS: 31 members

ECMWF: 50 members

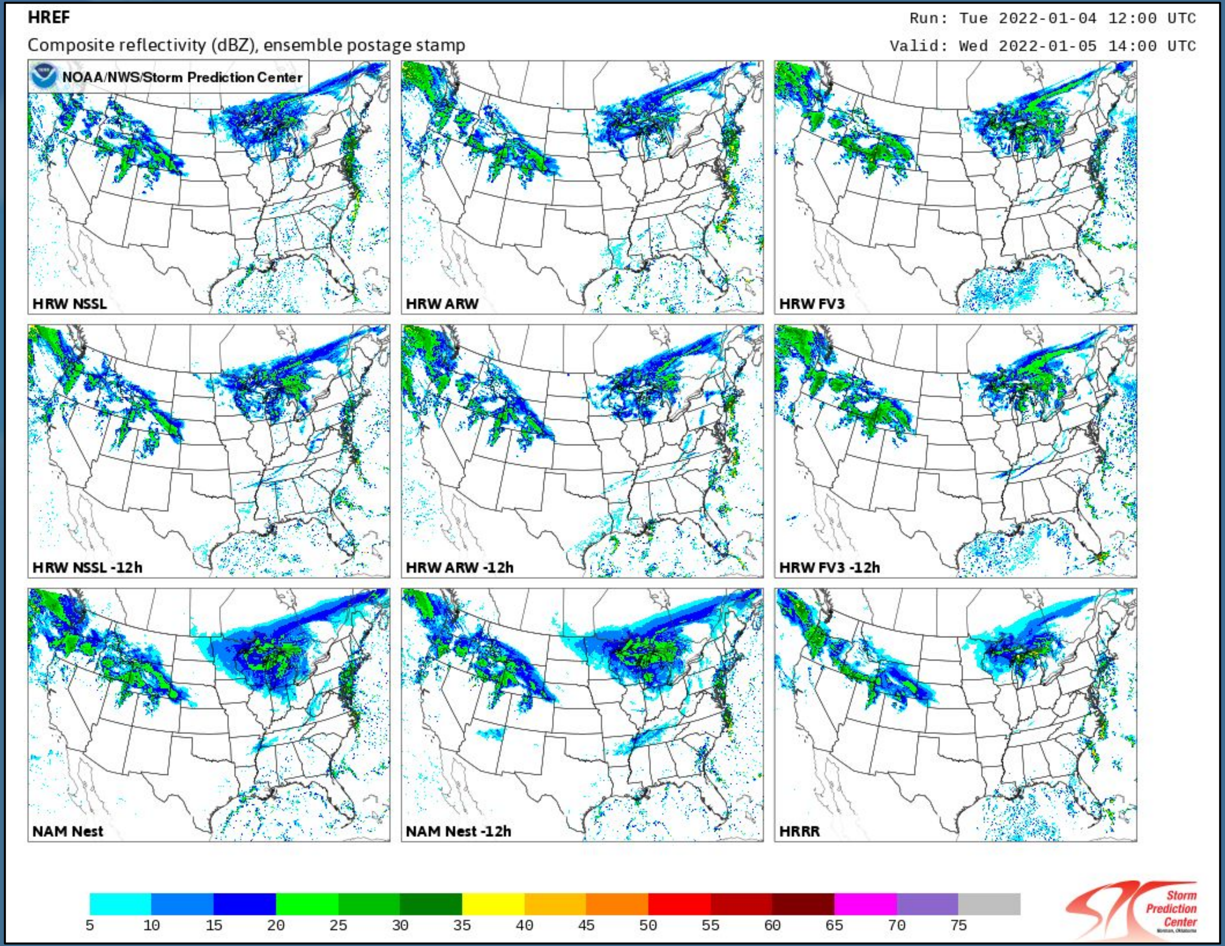
Canadian: 20 members



High Resolution Ensembles

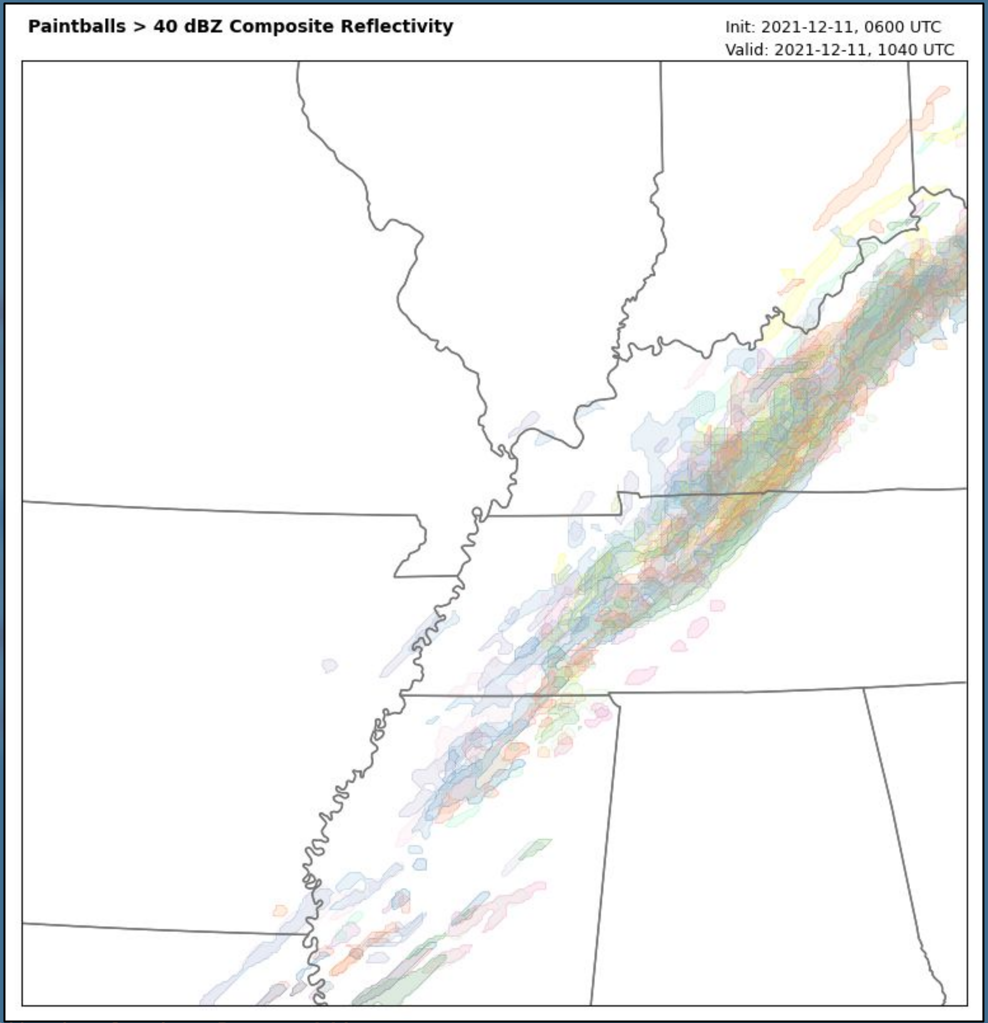
SREF: 26 members

HREF: 10 members



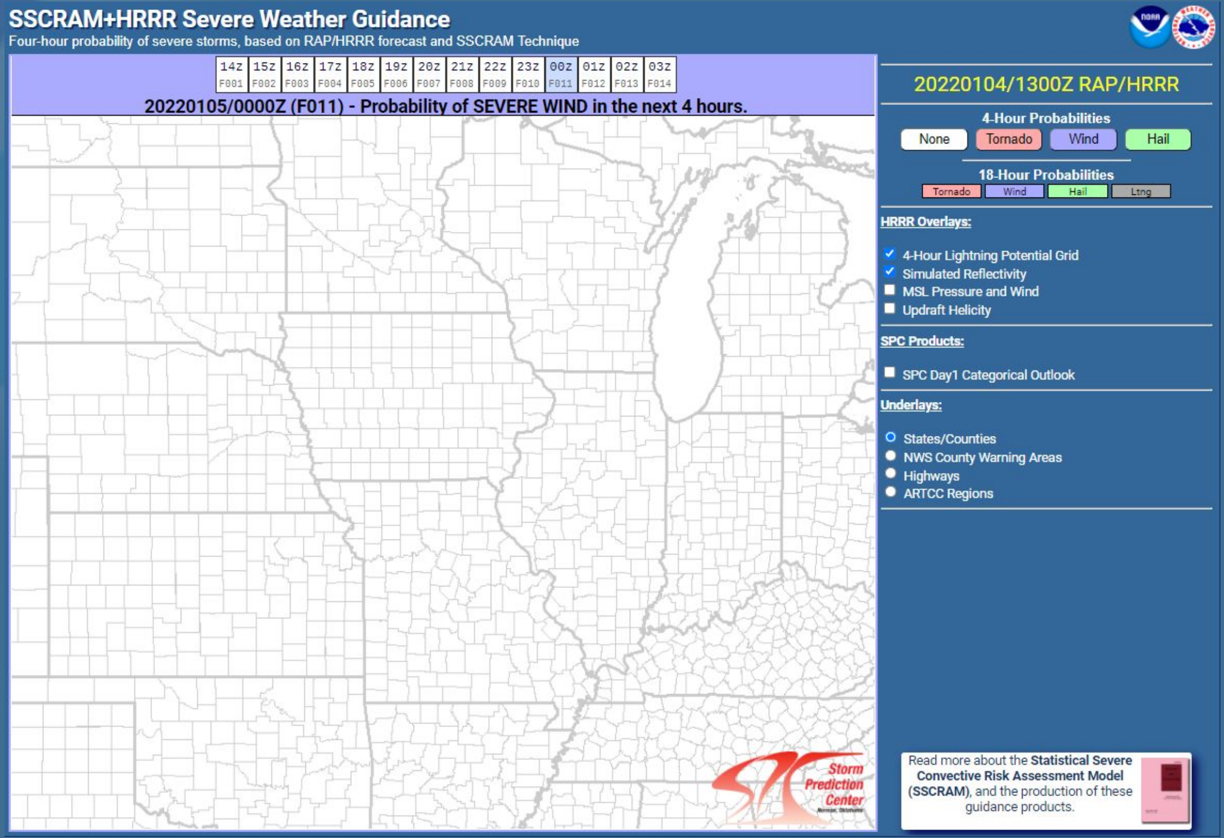
Warn On Forecast System

Uses output from high-resolution ensembles and models to provide severe weather guidance in real time



SSCRAM
Statistical Severe Convective Risk Assessment Model

Similarly, uses output from HRRR to provide severe weather guidance in real time



National Blend *of* Models

A nationally consistent and skillful suite of calibrated forecast guidance based on a blend of both National Weather Service and external numerical weather prediction model data and post-processed model guidance.

A highly accurate, skillful and consistent starting point for the gridded forecast.

Probabilistic and bias-corrected weather elements across several service areas.

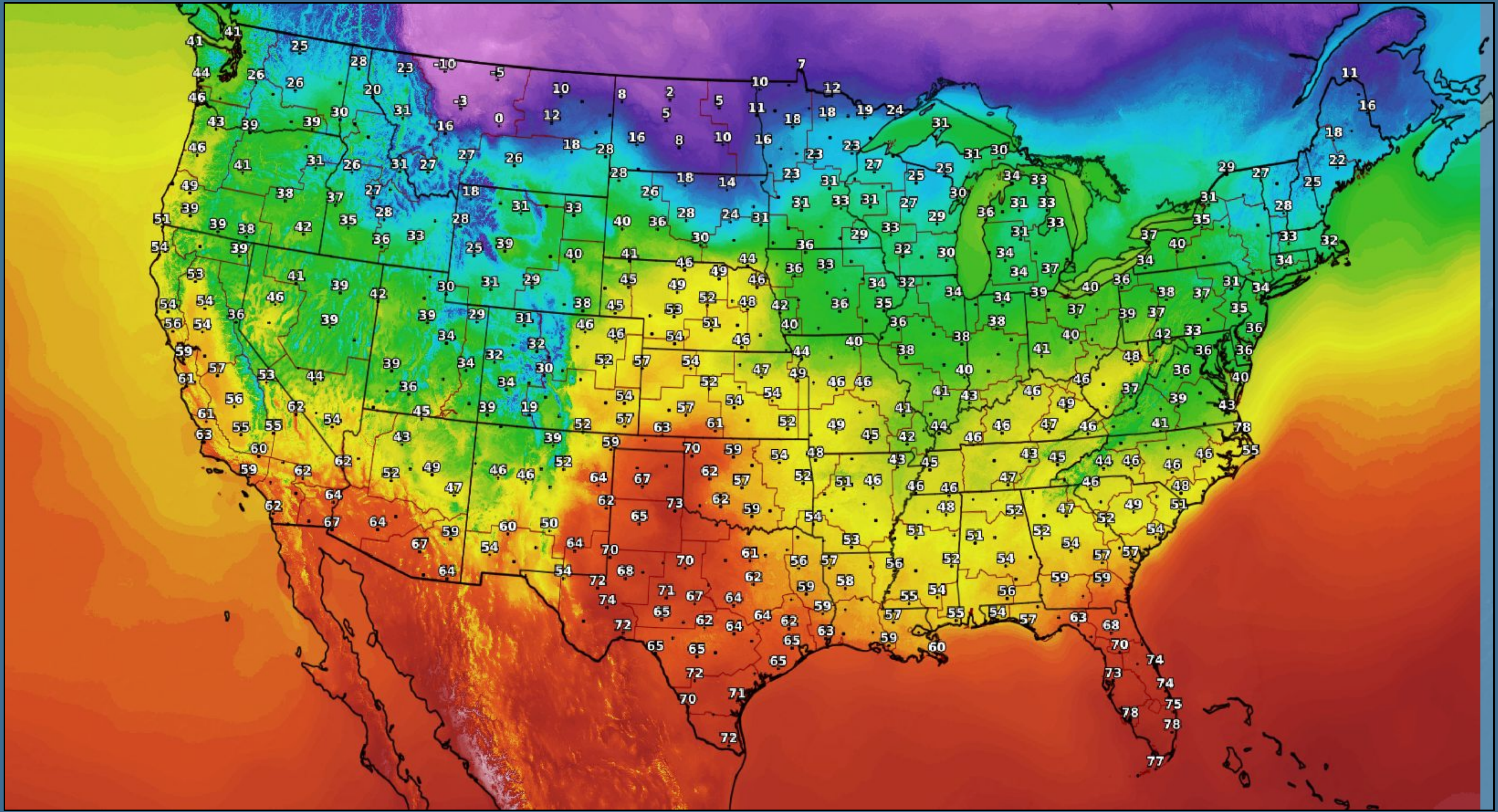
Providing forecasters with a suite of information to use for their forecasts.

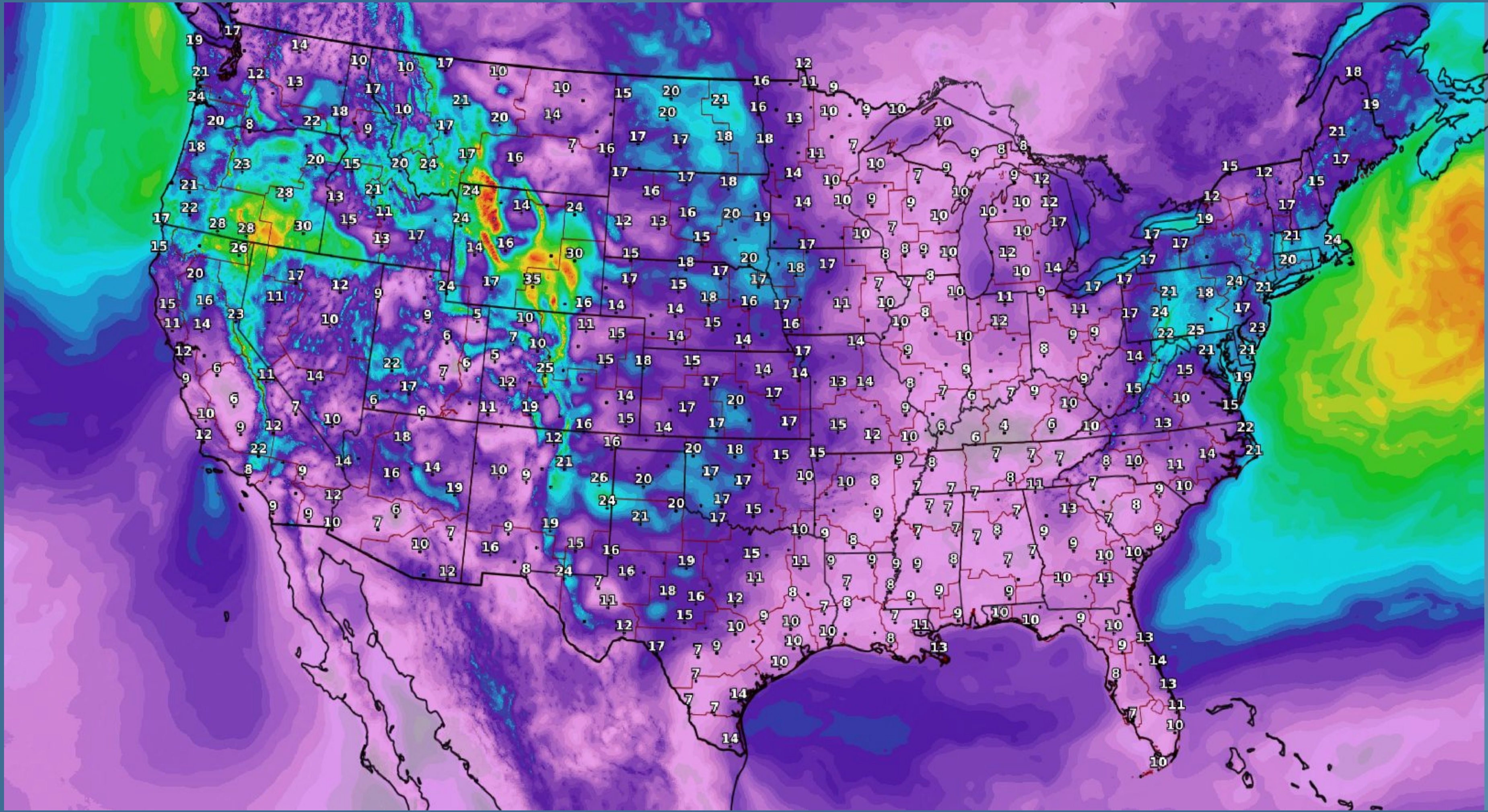
An important part of the efforts to evolve NWS capabilities to achieve a Weather-Ready Nation.

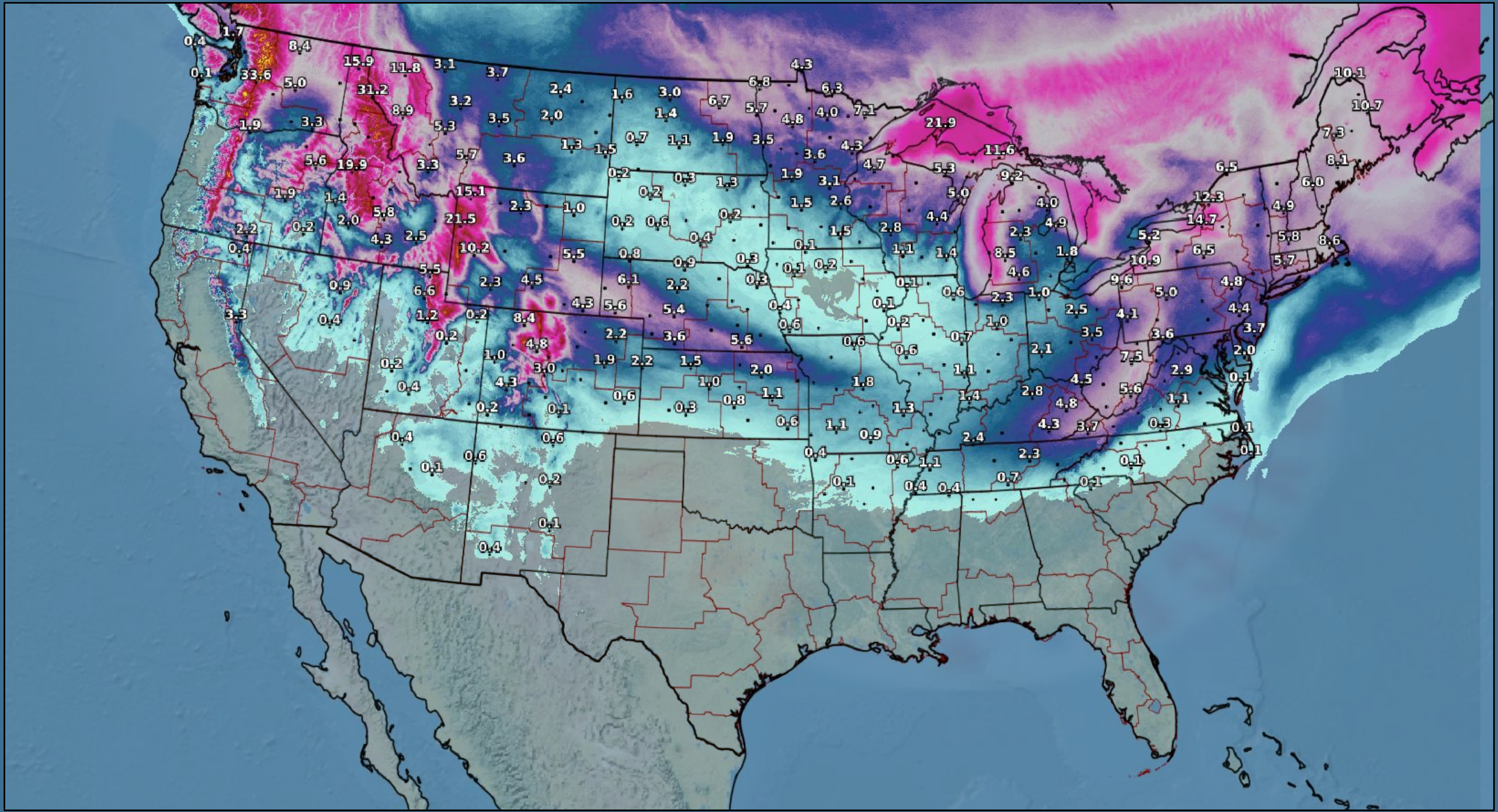
NBM Inputs

- WRF MEM2
- WRF ARW
- RAP
- RAPX
- HRRR
- HRRRX
- GFS GMOS
- NAM GMOS
- EKDMOS/BMOS
- GLMP
- WW3D (0.5)
- WW3E (0.5)
- WW3D-Regional
- GLW
- HWRF
- HMON
- wTCM
- GEFS
- GFS
- NAM-Parent
- SREF
- NAM-Nest
- NEMS NMMB
- WRF ARW
- CMC GDPS
- CMC RDPS
- CMC REPS
- CMC GEPS
- ECMWFD
- ECMWFE
- NAVGEMD
- NAVGEME
- FNMOC
- ACCESS-G

- NOAA
- Canadian Meteorological Centre
- European Centre for Medium-Range Weather Forecasts
- U.S. Navy Fleet Numerical Meteorology and Oceanography Center
- Australia Bureau of Meteorology







National Weather Service - Boston, MA

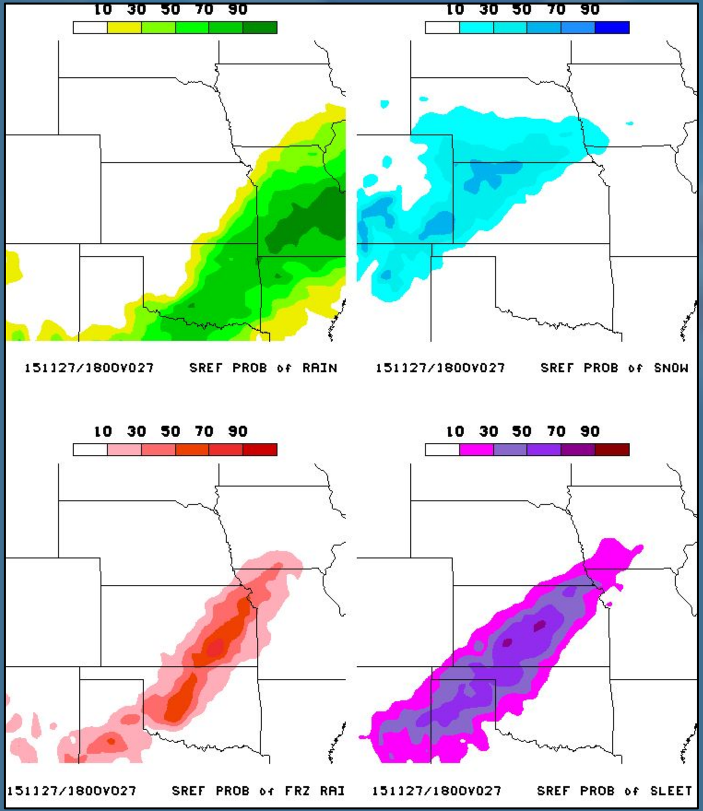
The Future of Modeling: Unified Forecast System

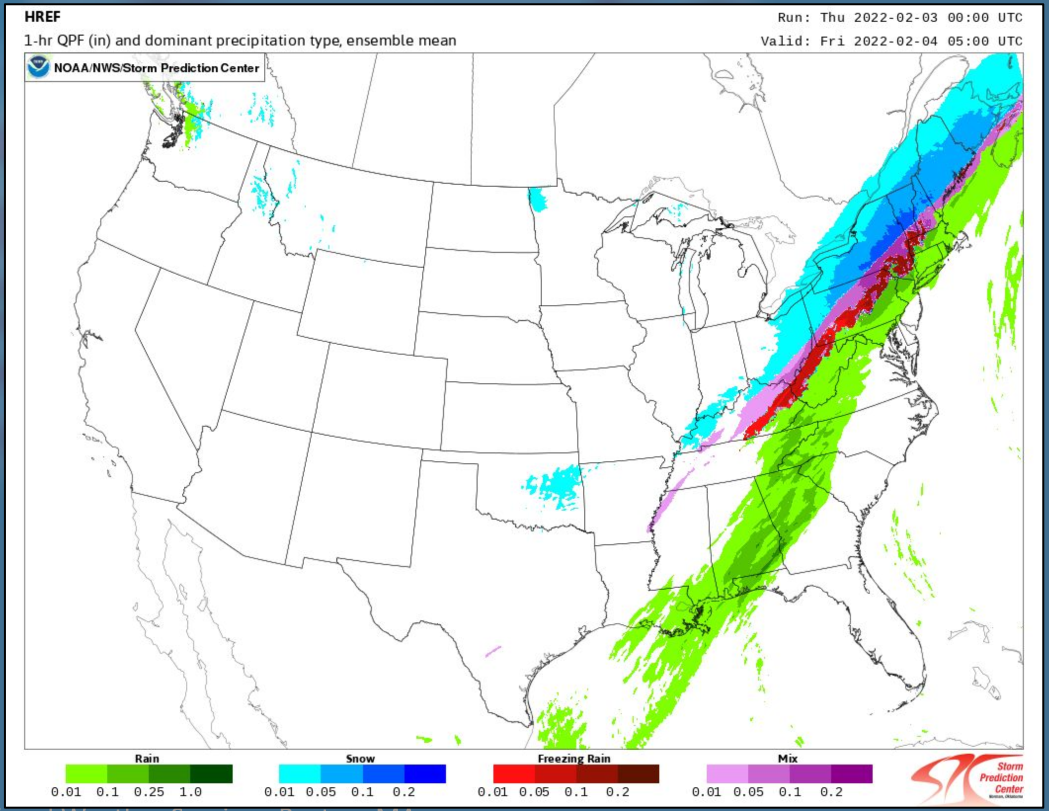
NPS Modeling System	Current Version	Q3 FY 20	Q4 FY 20	Q1 FY 21	Q2 FY 21	Q3 FY 21	Q4FY21-Q3FY22 Moratorium	Q4 FY 22	Q1 FY 23	Q2 FY 23	Q3 FY 23	Q4 FY 23	Q1 FY 24	Q2 FY 24	Q3 FY 24	Q4 FY 24	Q1 FY 25	Q2 FY25	Q3 FY25	UFS Application
Global Weather & Global Analysis	GFS/ GDASv15				GFSv16	GFSv16.1									GFSv17/ GEFSv13					UFS Medium-Range (Weather, Marine, Cryosphere)
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 Subseasonal
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					HIRESWv8						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/URMAv2.8										3DRTMA/ URMA v3				3DRTMA/ URMA v4			UFS Analysis
Atmospheric Transport & Dispersion	HySPLITv7							HySPLIT v8						HySPLIT v9						UFS Air Quality & Dispersion
Coastal & Regional Waves	NWPSv1.2				NWPSv1.3					NWPSv1.4						RWPSv1				UFS Coastal
Great Lakes	GLWUv3.4							GLWUv4								GLWUv5				UFS Lakes
Regional Hydrology	NWMv2				NWMv2.1						NWMv3									UFS Hydrology
Space Weather 1	WAM/IPEv1					WAM/IPEv1												WAM/IPEv2		UFS Space Weather
Space Weather 2	ENLILv1																			

Join Us For "Weather Models 202"

Precipitation Type and Snowfall

Tuesday, March 1





Questions?

Matthew.Belk@noaa.gov