RECENT PROGRESS in and FUTURE PLANS for NUMERICAL WEATHER PREDICTION AT NCEP

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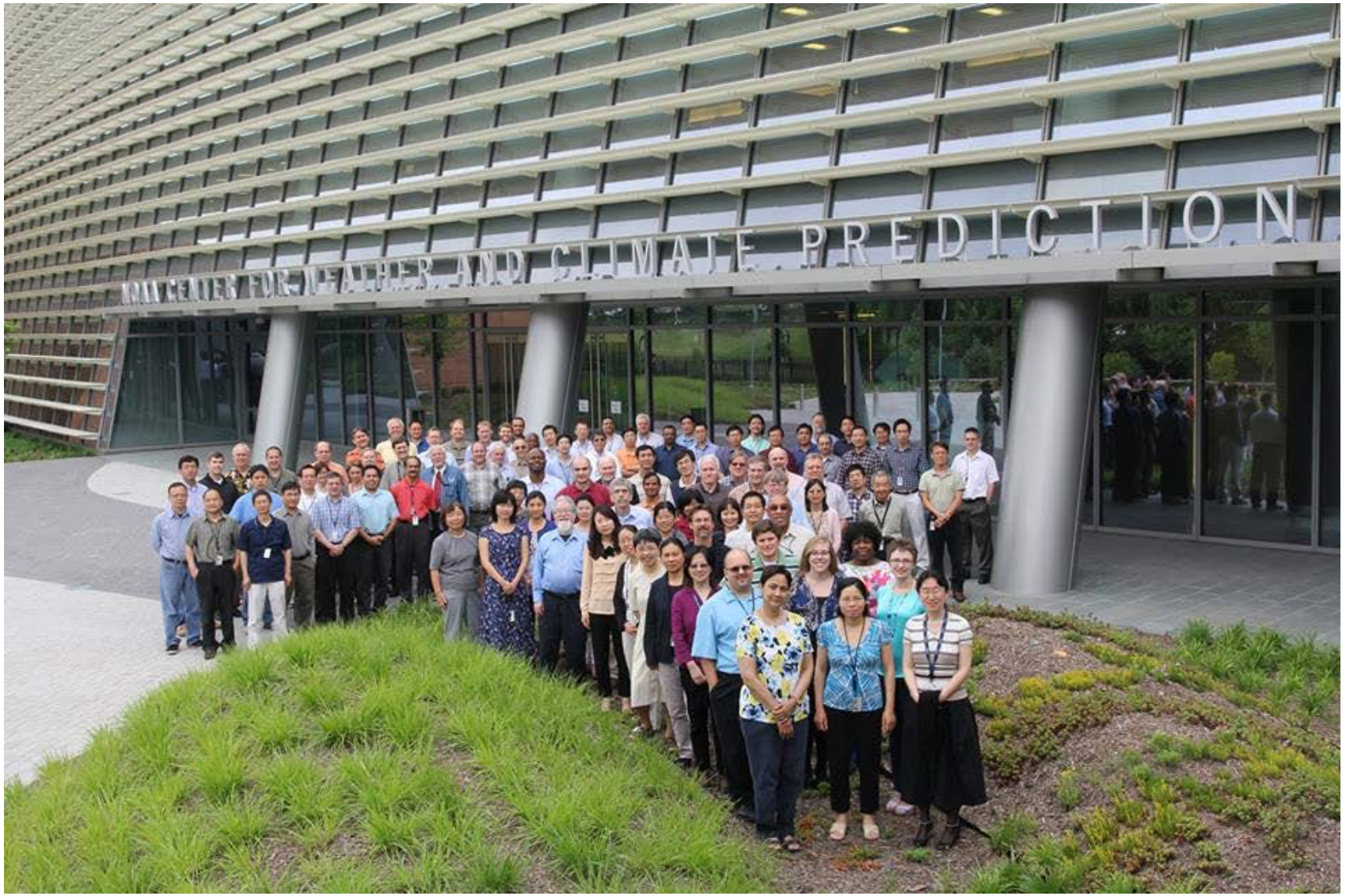
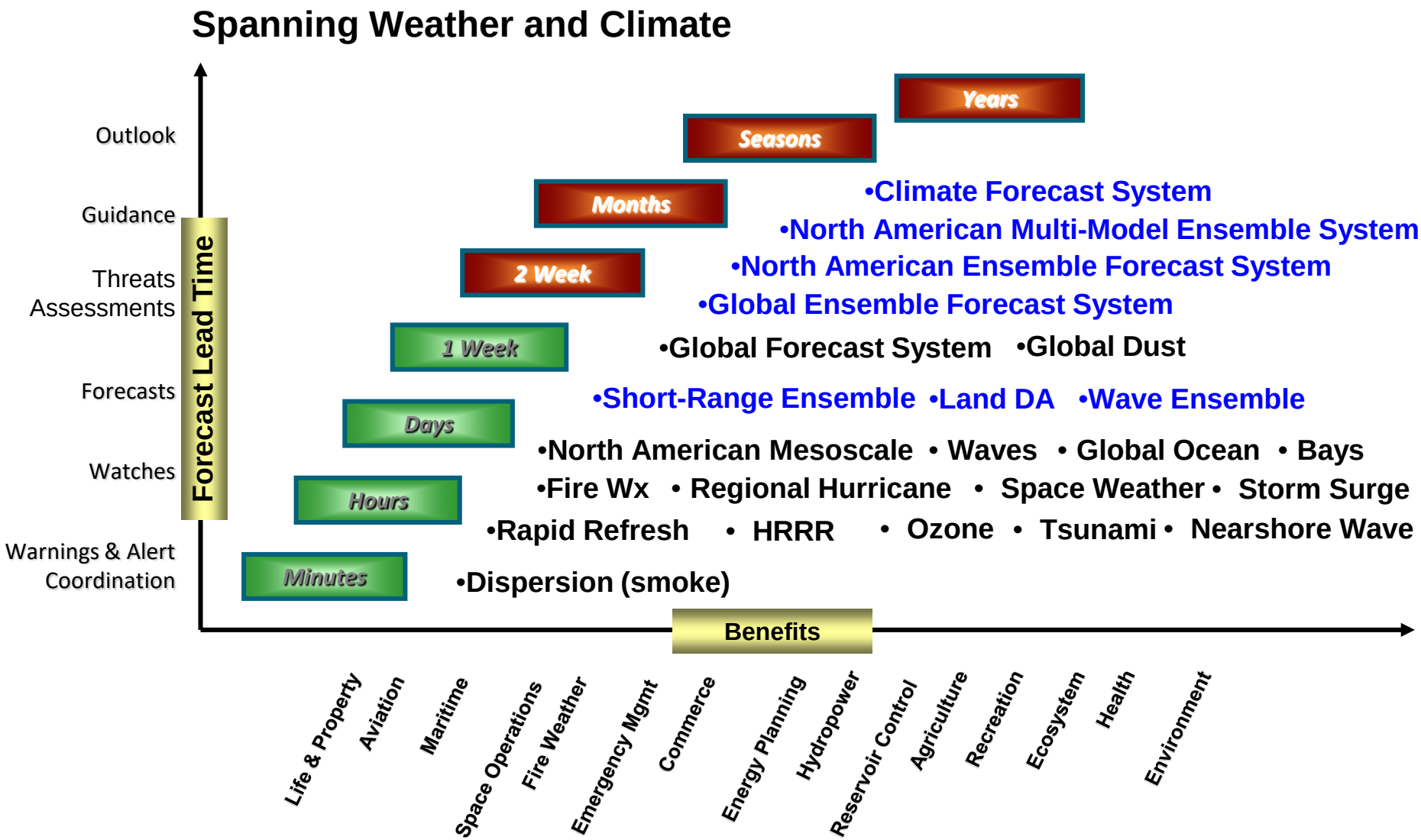
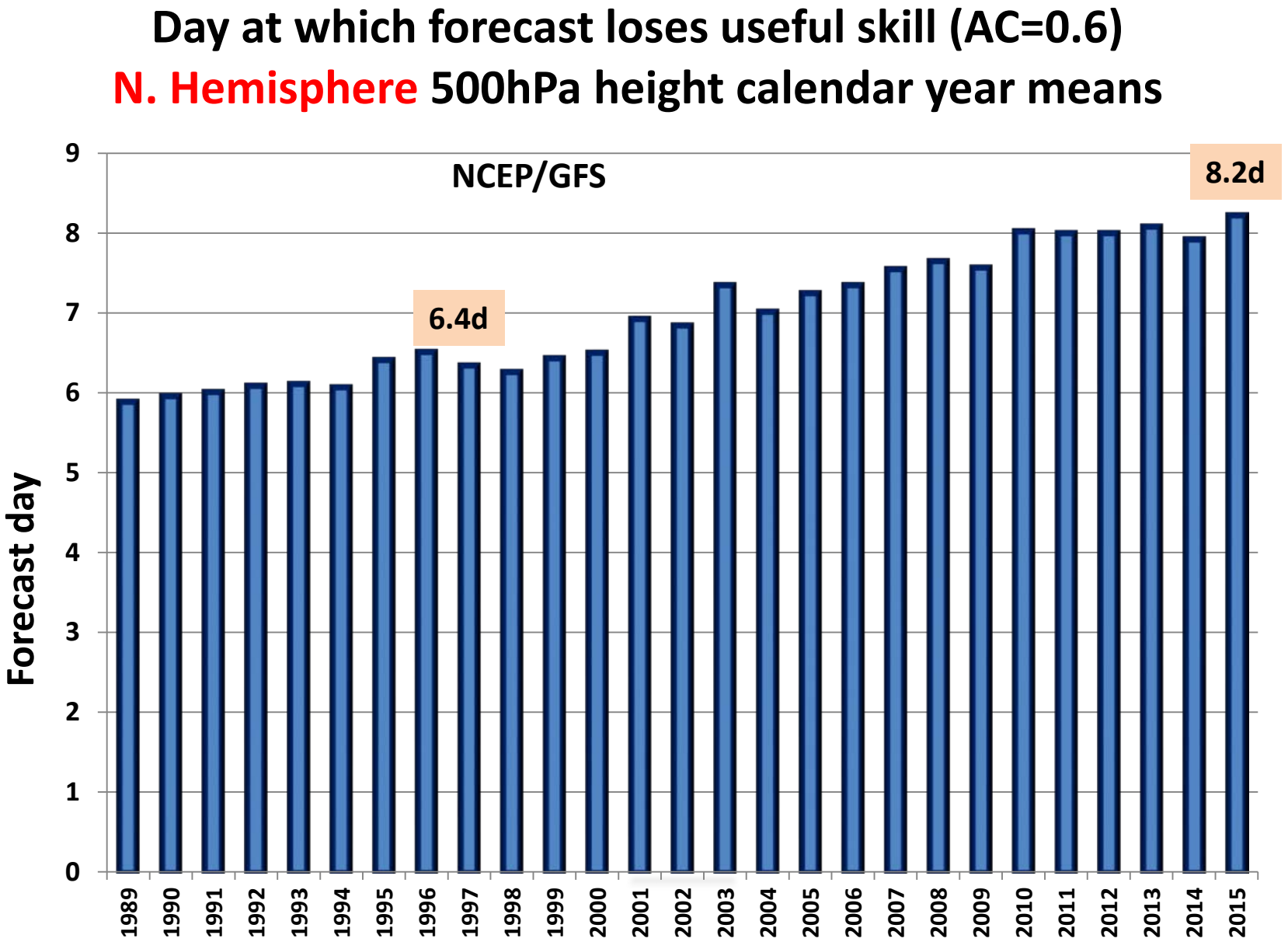
NOAA/NCEP's ENVIRONMENTAL MODELING CENTER COLLEGE PARK, MD



Seamless Suite of Operational Numerical Guidance Systems, Covering Different Time Scales

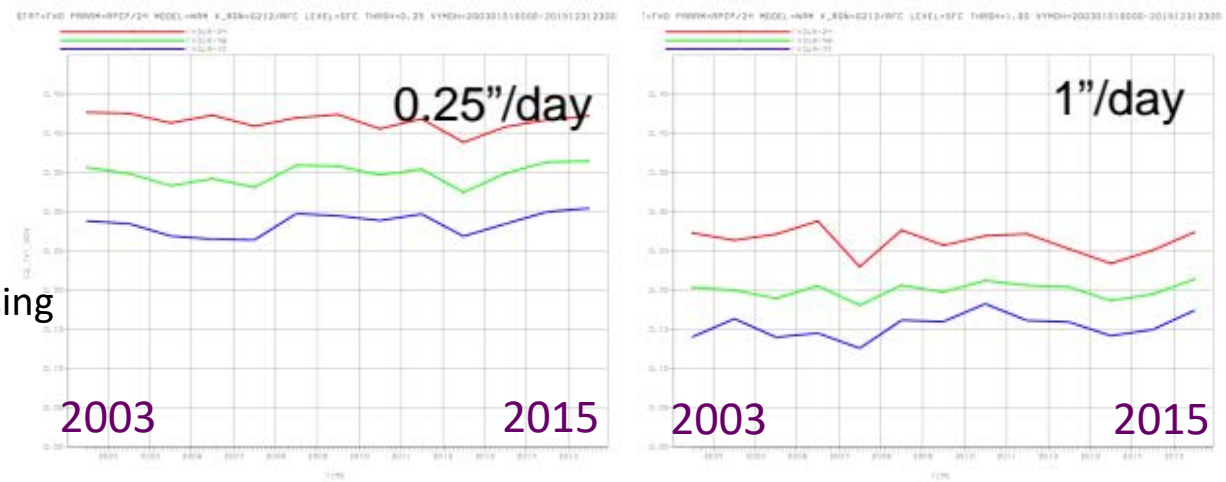


NCEP global model has gained ~2 days of predictability in 20 years



PRECIP VERIFICATION

NAM PRECIP EQUITABLE THREAT SCORES



Increasing skill

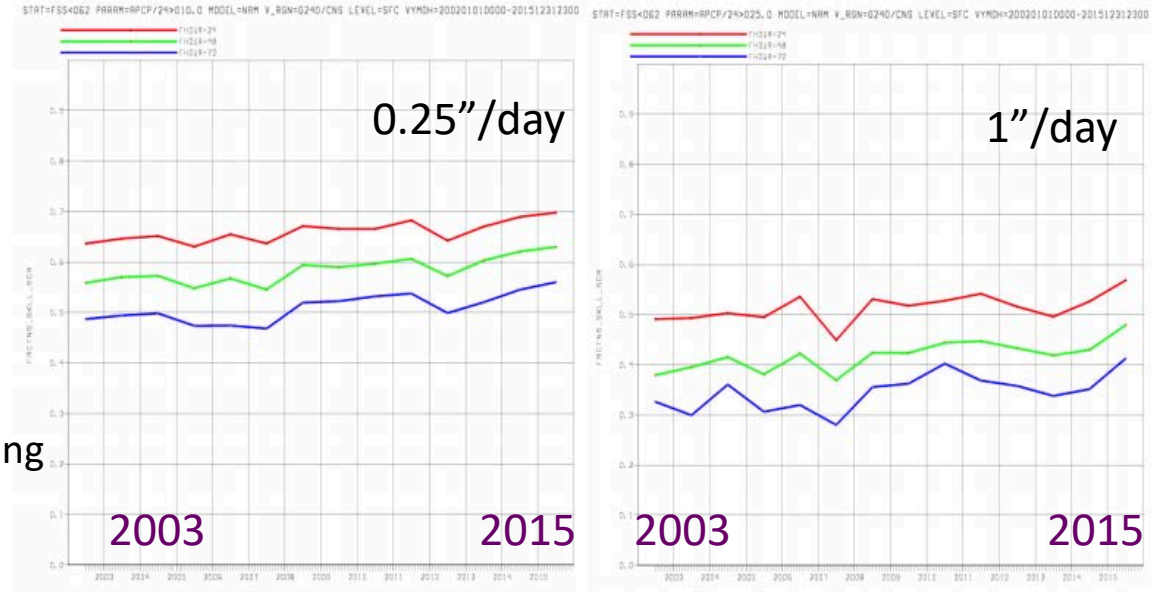
PRECIP SKILL, HOWEVER, NOT EXPERIENCING SIMILAR GAINS (lines are flat)

DAY 1

DAY 2

DAY 3

NAM PRECIP FRACTIONAL SKILL SCORES



Increasing skill

BUT VERIFICATION THAT GIVES CREDIT for BEING CLOSE DOES SHOW IMPROVEMENT (lines show modest slope)

RESOLUTION

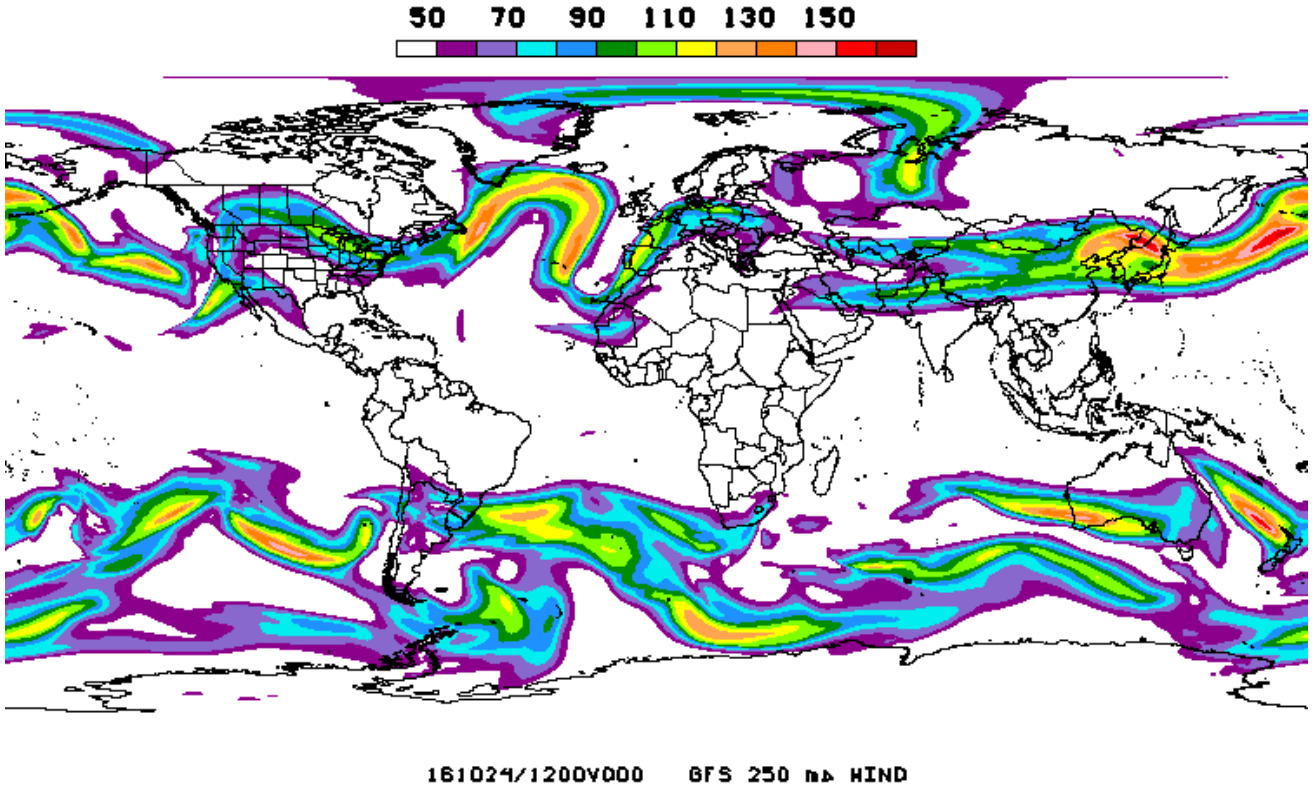
Change History of Global Foreast System (GFS) Configurations

Mon/Year	Levels	Truncations	Z-cor/dyncore	Major components upgrade
Aug 1980	12	R3 (375km)	Sigma Eulerian	first global spectral model, rhomboidal
Oct 1983	12	R4 (300km)	Sigma Eulerian	
Apr 1985	18	R4 (300km)	Sigma Eulerian	GFDL Physics
Aug 1987	18	T8 (150km)	Sigma Eulerian	First triangular truncation; diurnal cycle
Mar 1991	18	T12 (105km)	Sigma Eulerian	
Aug 1993	28	T12 (105km)	Sigma Eulerian	Arakawa-Schubert convection
Jun 1998	42	T1 0 (80km)	Sigma Eulerian	Prognostic ozone; SW from GFDL to NASA
Oct 1998	28	T1 0 (80km)	Sigma Eulerian	the restoration
Jan 2000	42	T1 0 (80km)	Sigma Eulerian	first on IBM
Oct 2002	64	T2 4 (55km)	Sigma Eulerian	RRTM LW;
May 2005	64	T3 2 (35km)	Sigma Eulerian	2L OSU to 4L NOAH LSM; high-res to 180hr
May 2007	64	T3 2 (35km)	Hybrid Eulerian	SSI to GSI
Jul 2010	64	T5 4 (23km)	Hybrid Eulerian	RRTM SW; New shallow cnvtion; TVD tracer
Jan 2015	64	T15 4 (13km)	Hybrid Semi-Lag	SLG; Hybrid EDMF; McICA etc
May2016	64	T15 4 (13km)	Hybrid Semi-Lag	4-D Hybrid En-Var DA

Vertical layers double every ~11 yrs; change of horizontal resolution is rapid (~30 times in 35 years); sigma-Eulerian used for 27 yrs!

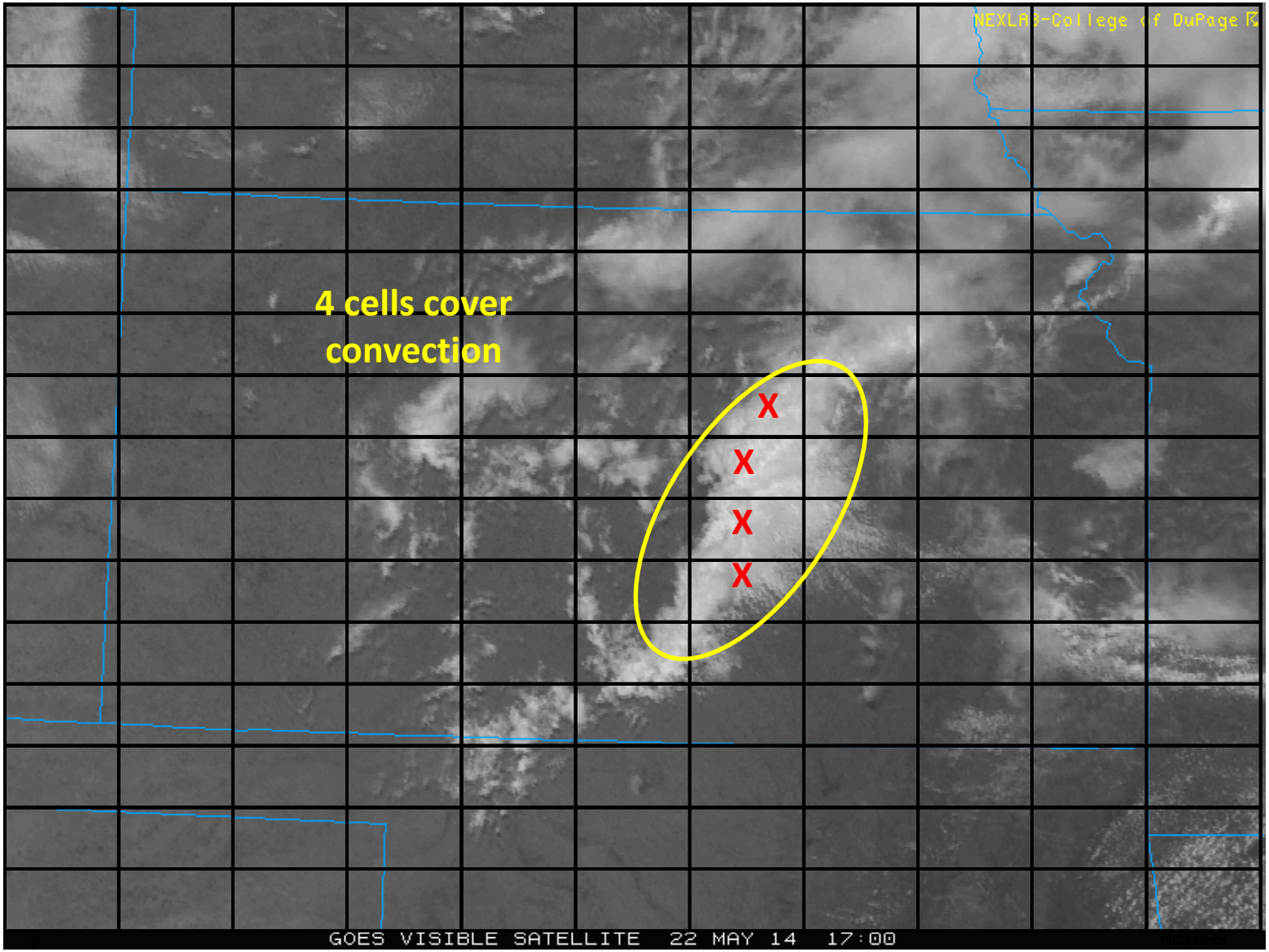
Source http://www.emc.ncep.noaa.gov/gmb/STATS/html/model_changes.html

Our GLOBAL model is now run at 13 km with hourly output out to 5 days, making detailed loops like this possible

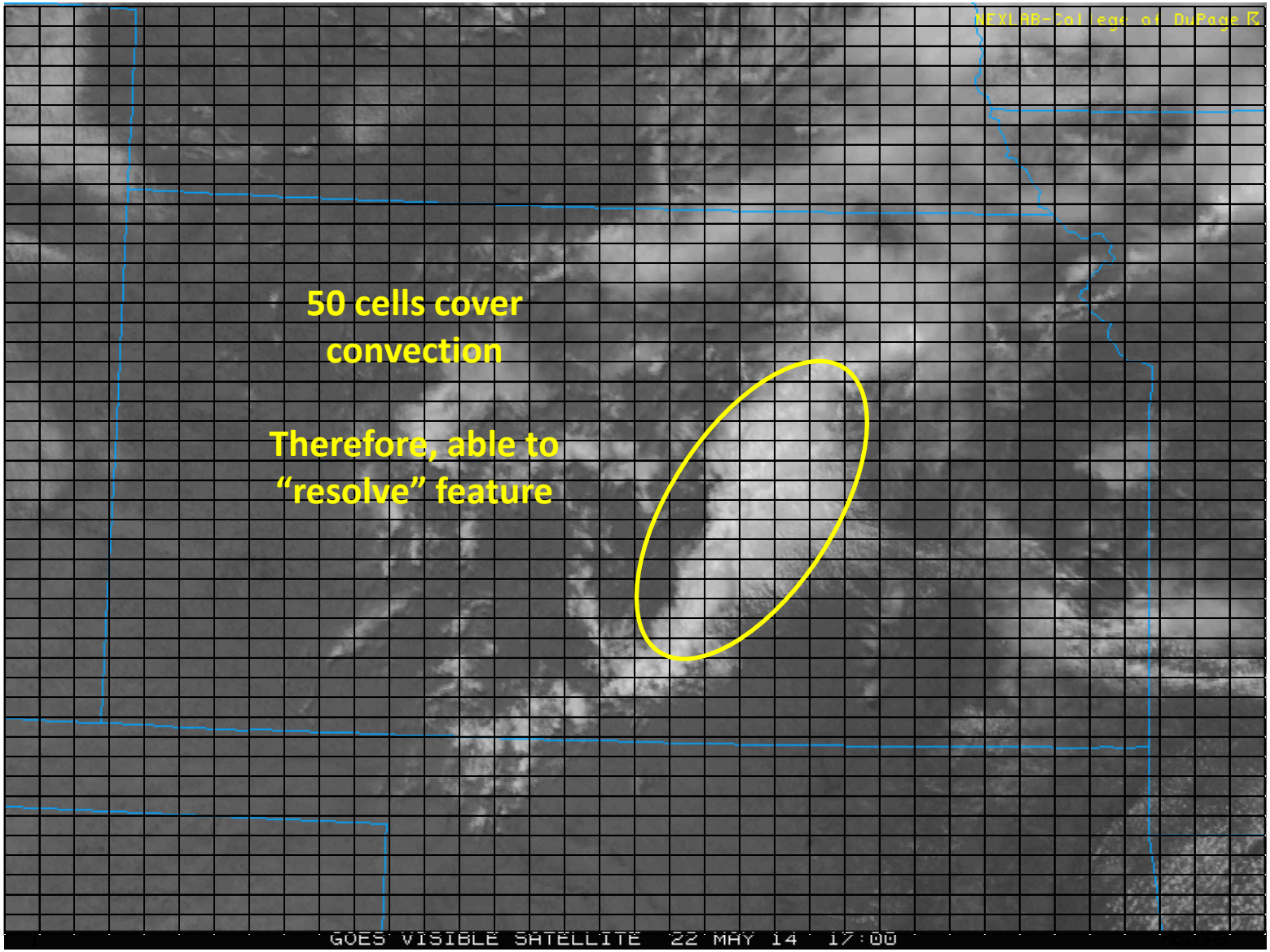


HOURLY LOOP of GFS 250mb WINDS

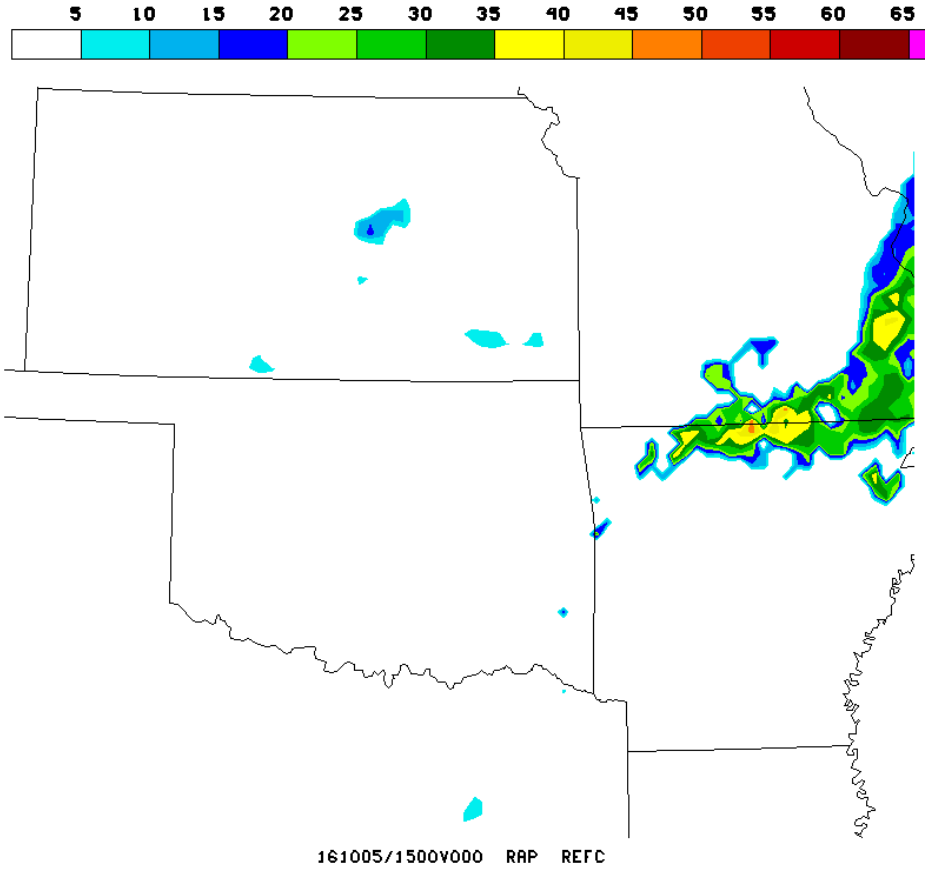
Importance of Model Resolution
Example--Low (Coarse) Resolution



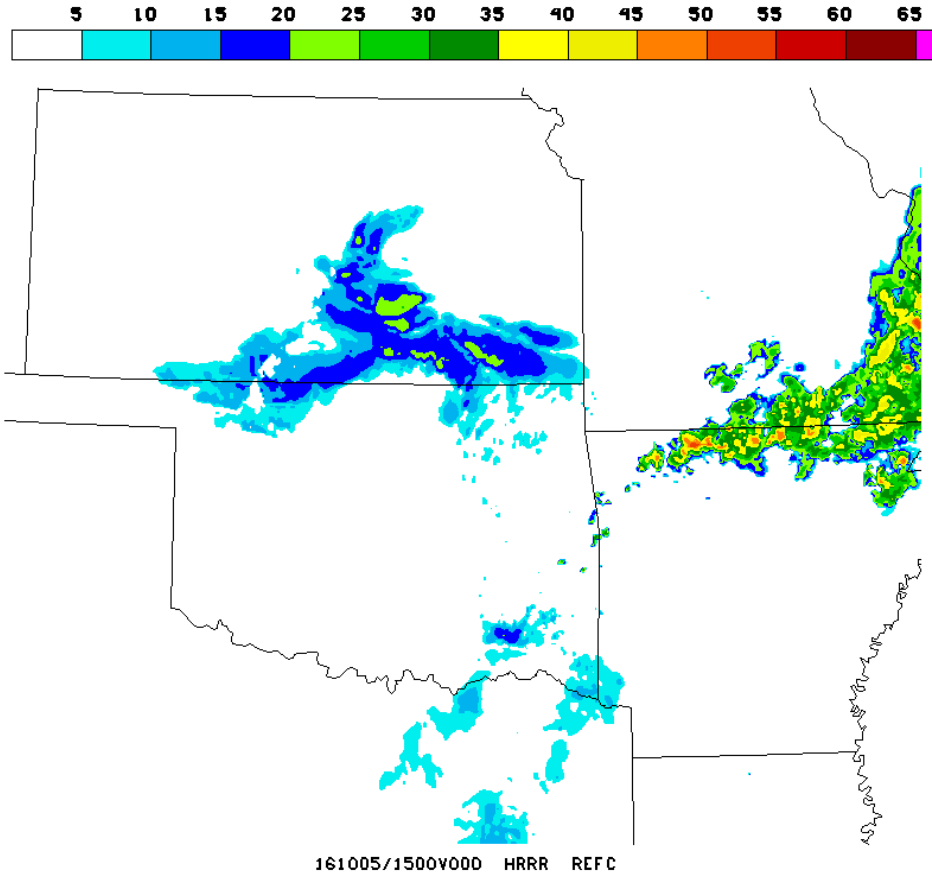
Increasing (high) Grid Resolution



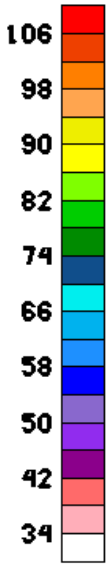
RAP-13 km



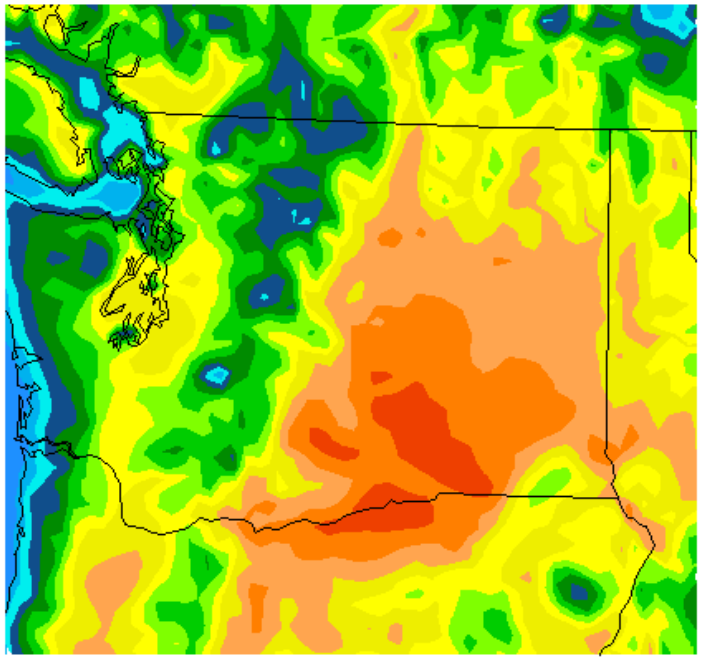
HRRR-3 km



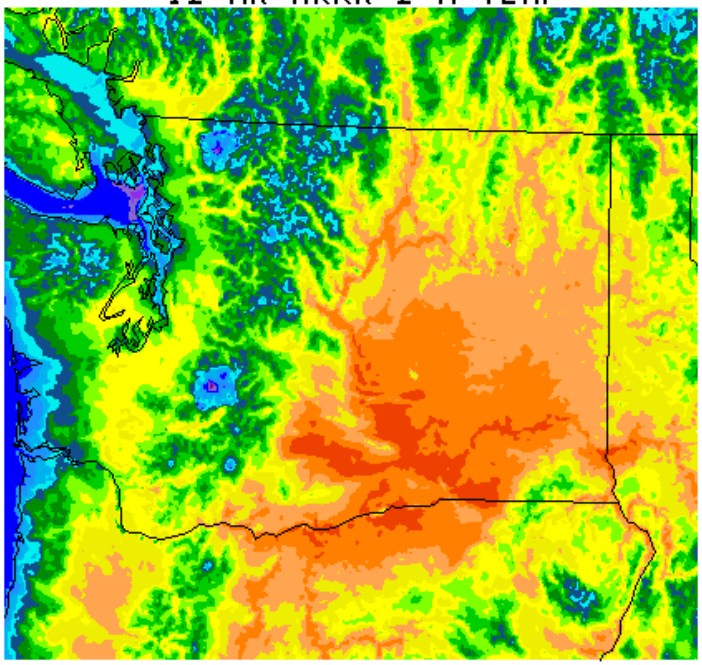
Simulated Composite Reflectivity Forecasts for same event



12-HR RAP 2-M TEMP



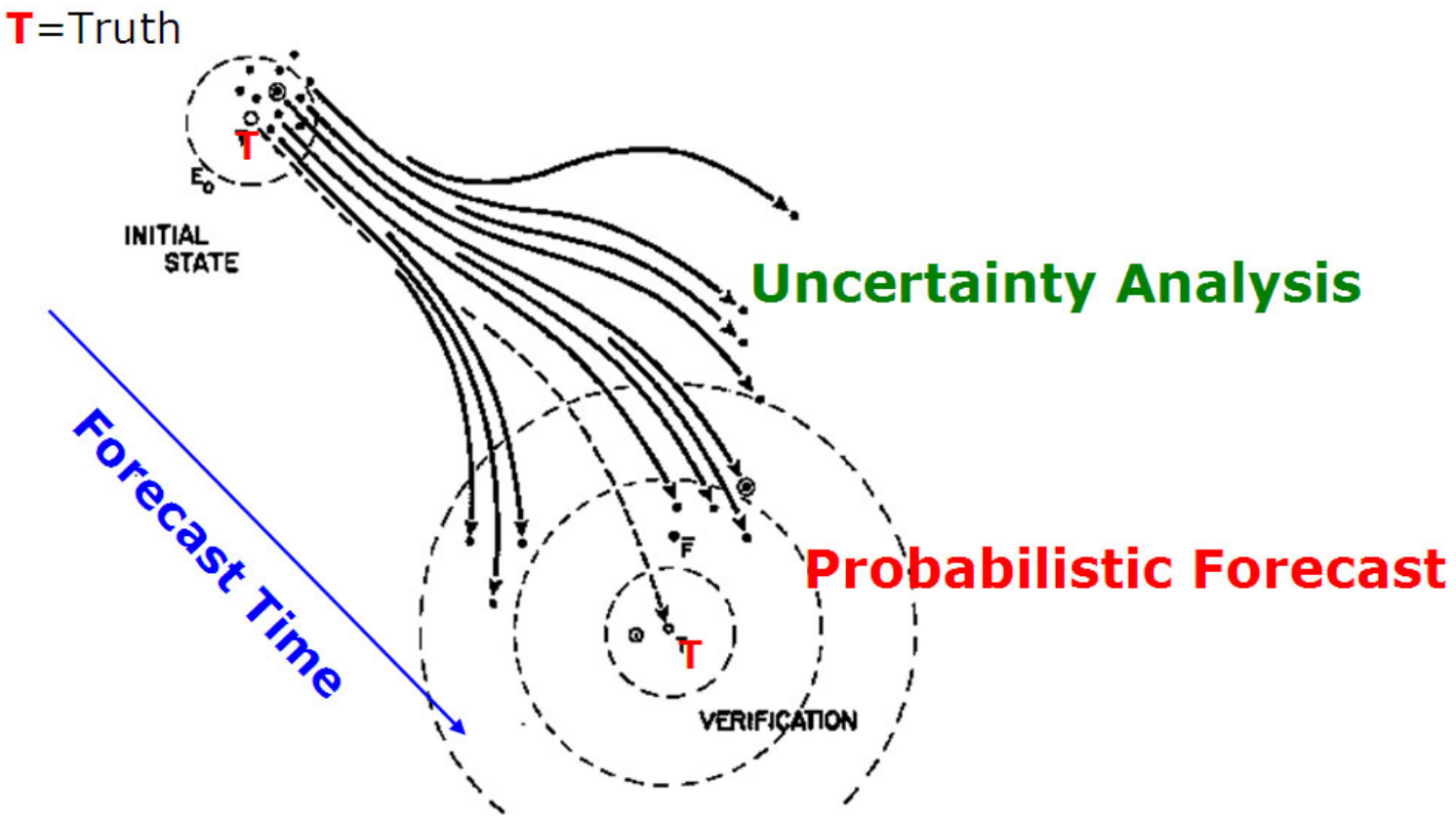
12-HR HRRR 2-M TEMP



13 KM

3 KM

ENSEMBLES


T=Truth
T
E_0
INITIAL STATE
Uncertainty Analysis
Forecast Time
F
T
VERIFICATION
Probabilistic Forecast

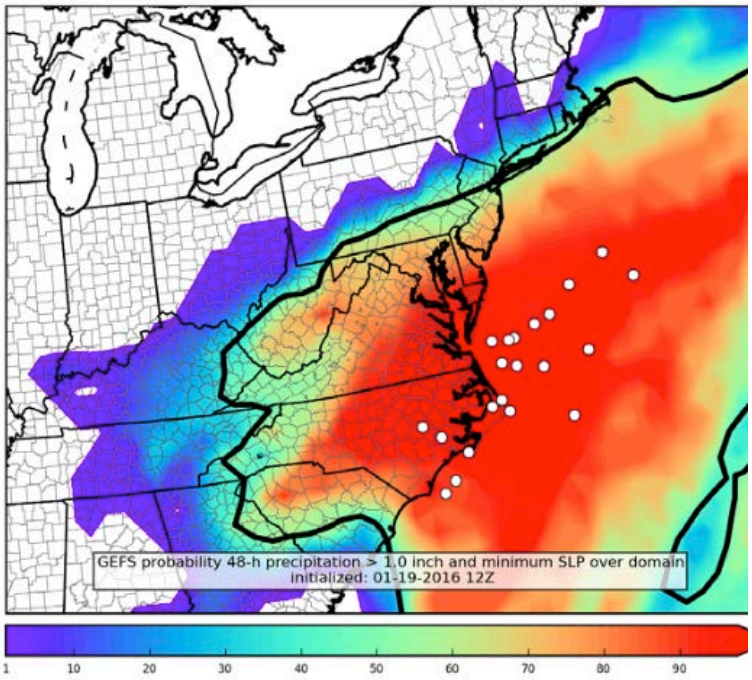
Ensemble Prediction

NMC 1992:

- **First operational global ensemble forecast system (GEFS)**
- **Global spectral, 3 members, ~210km / 18 layers to 240 hours**

NCEP: 2016:

- **GEFS now 21 members, ~33 km (55 km after day 8) / 64 layers out to 384 hr**
- **Short range Ensemble Forecast (SREF) system**
  - **26 members @ 16 km / 40 layers, North America out to 87 hours**



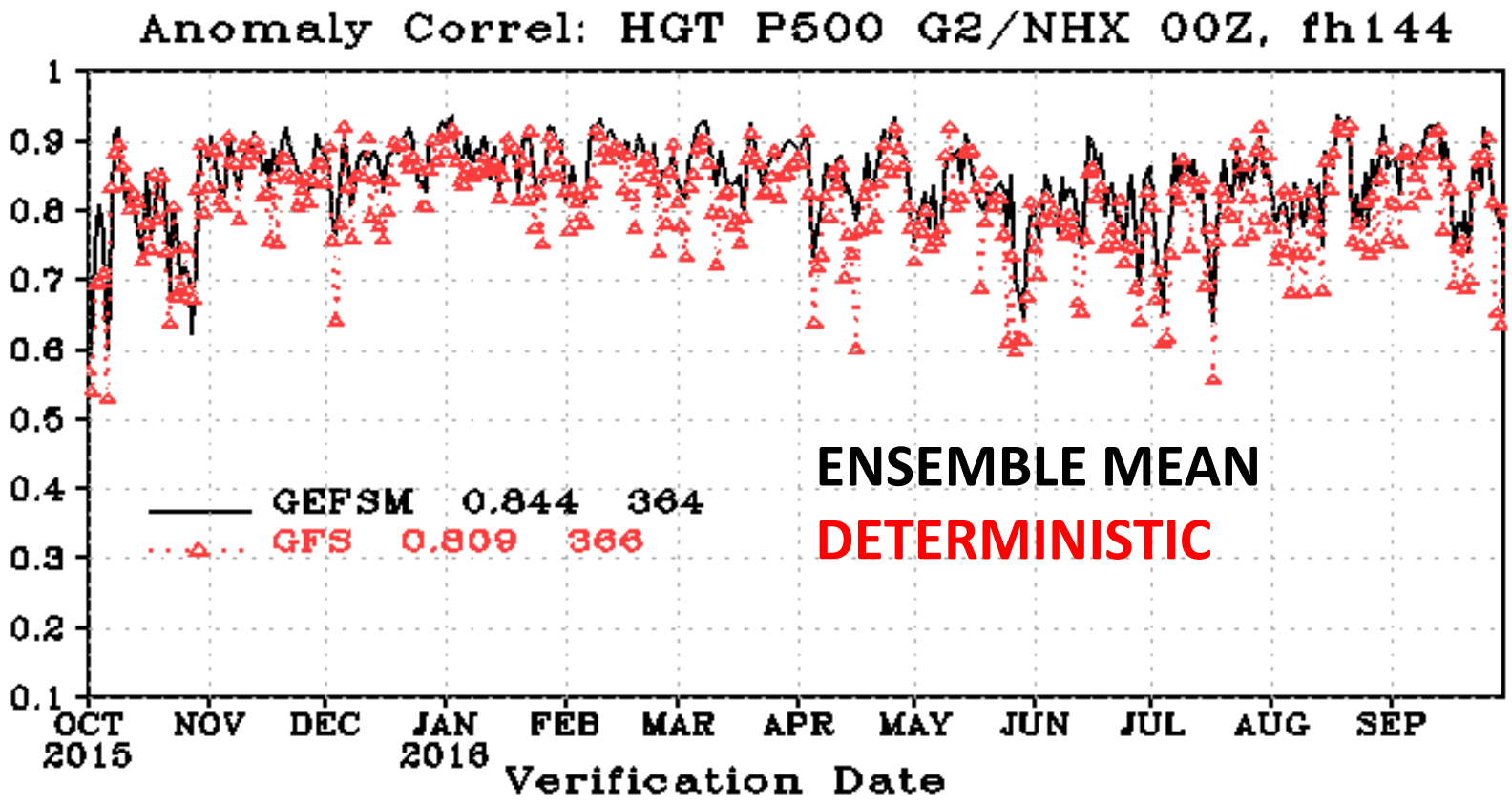
GEFS 5 day forecast for Blizzard of 2016

Probability of Storm Total of 1” of liquid is shaded, 1” mean is black contour

Dots are predictions for center of storm

NH DAY 6 ANOMALY CORRELATION of SYNOPTIC PATTERN

values closer to 1 are better



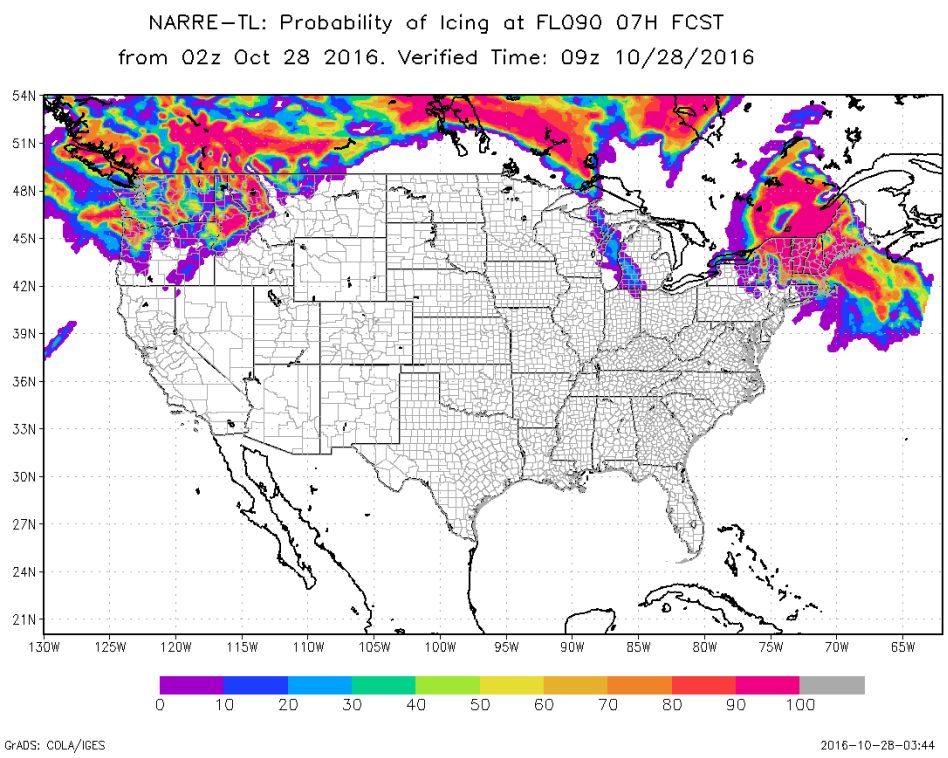
The NOAA Operational Modeling Strategy…High Level Perspective

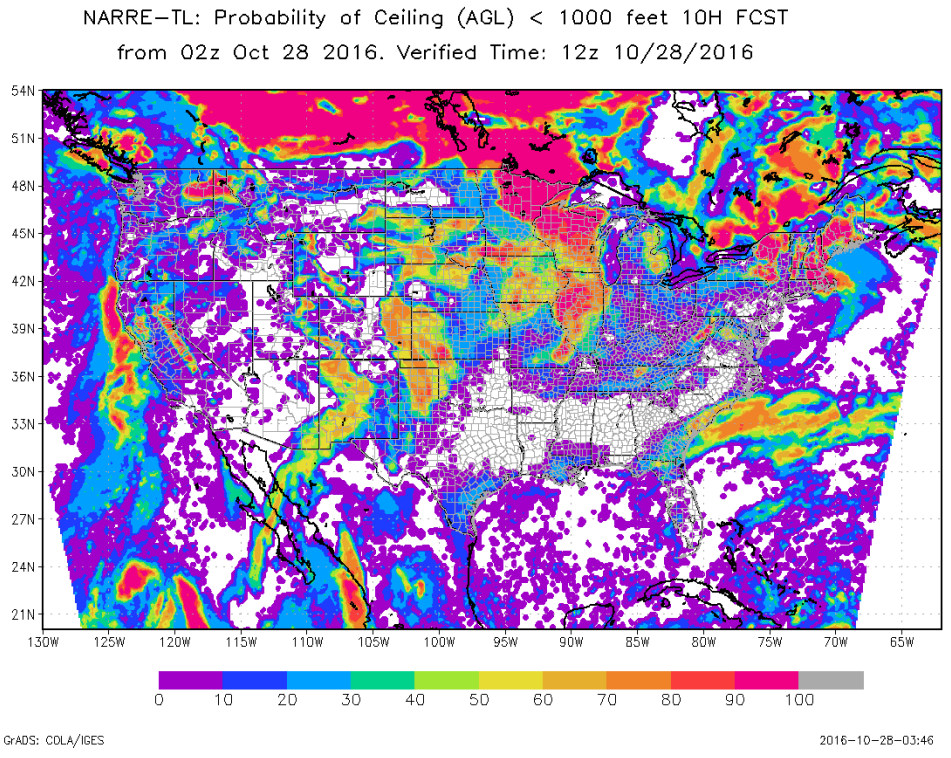
- **Moving away from the "model of the day"**
  - Ensemble-based numerical guidance
  - Ensemble system only as good as the modeling system it is built from

- **Priorities for end-to-end model development:**
  1. Data assimilation (methodology and observations)
  2. Resolution—horizontal and vertical
  3. Physics
     - Clouds, microphysics, radiation, land, ocean, ice, aerosols….includes coupling
  4. Post processing techniques
  5. Dynamic core

TIME-LAGGED ENSEMBLES

NARRE-TL: NORTH- AMERICAN RAPID REFRESH ENSEMBLE – TIME-LAGGED





Means and probabilities for icing, turbulence, ceiling, visibility, fog, more

http://www.emc.ncep.noaa.gov/mmb/SREF_avia/FCST/NARRE/web_site/html/cat.html

GOING FORWARD

External Review Committee for NCEP Modeling Suite

First	Last	Affiliation
Christa	Peters-Lidard	NASA/GSFC
Alan	Blumberg	UCACN; Stevens Tech
Andy	Brown	Met Office
Cliff	Mass	U Washington
Ricky	Rood	U Michigan
Tom	Hamill	NOAA/ESRL
Chris	Bretherton	U Washington
Brian	Colle	Stony Brook
Jim	Doyle	NRL, Monterey
Ben	Kirtman	U Miami
Anke	Kamrath	NCAR
Eric	Chassignet	FSU, Director, COAPS
Peter	Neilley	UCACN; Weather Company
Fred	Carr	UCACN; U Oklahoma
Jim	Kinter	UCACN; COLA/GMU
Bill	Kuo	UCACN; DTC; NCAR
Gilbert	Brunet	UCACN; Met Office
Tsengdar	Lee	UCACN; NASA HQ

- Meeting 4-7 August 2015 in College Park
- 90 Participants across the community
- Preliminary findings and recommendations briefed to NOAA leadership
- Report published December 2015:

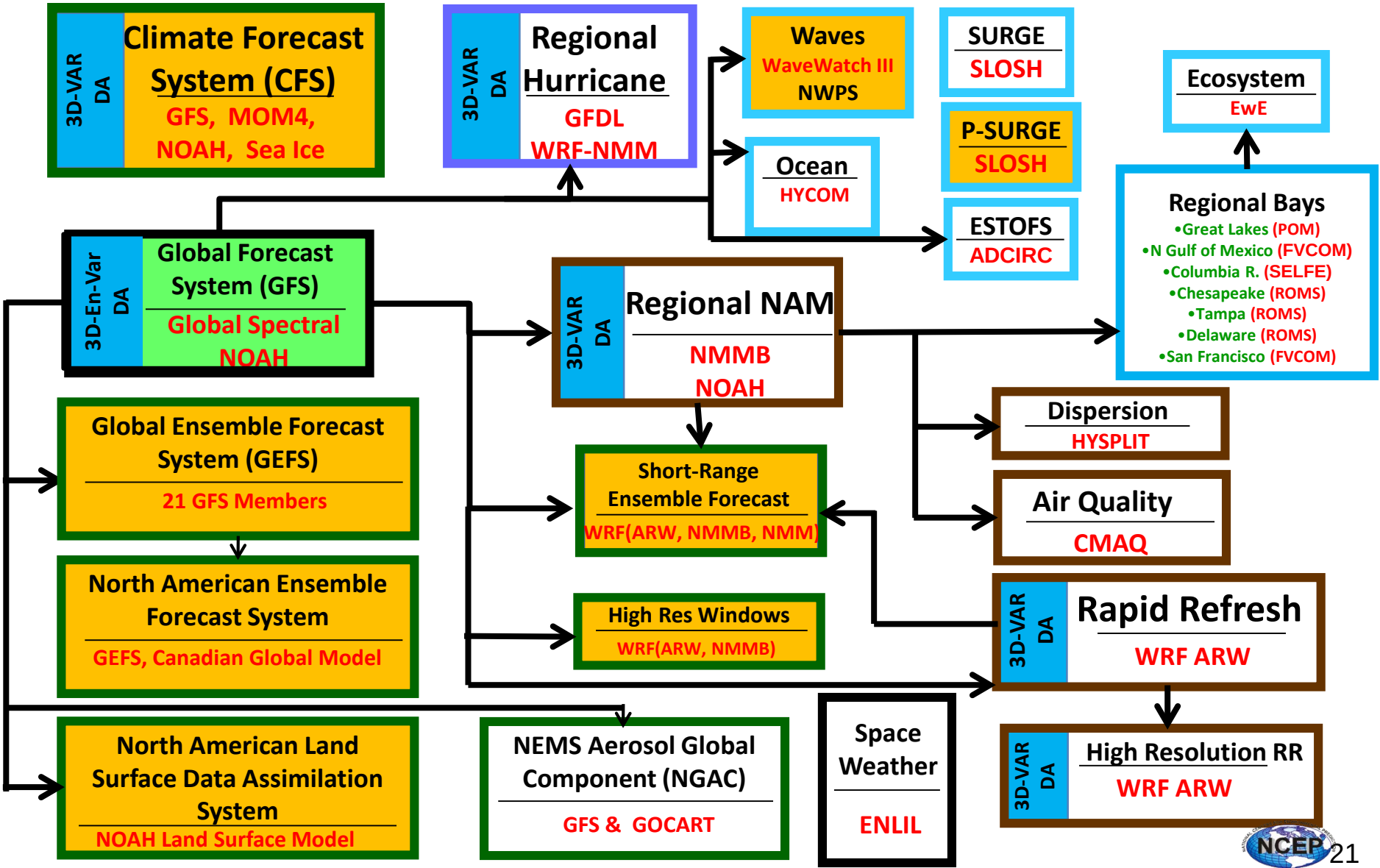
http://www.ncep.noaa.gov/director/ucar_reports/ucacn_20151207/UMAC_Final_Report_20151207-v14.pdf

UMAC Overarching Recommendations

* UCACN Model Advisory Committee

- **Reduce complexity of the NCEP Production Suite.**
- **A unified, collaborative strategy for model development across NOAA is needed.**
- **Leverage the capabilities of the external community .**
- **Continue to enhance High Performance Computing capabilities.**
- **Execute strategic and implementation plans based on stakeholder requirements.**

Complexity???
What Complexity?



Basic issues / UMAC

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

* UCACN Model Advisory Committee

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 Approach

- 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**

How do we define requirements for atmospheric models?

FORECAST RANGE is **THE** THING!

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, hurricane	HRRR, RAP NAM nest, HiresW		RTMA, URMA, blend
Cadence	6h	6h	6h	1h		1h
Proposed Cadence	?	24h	6h	1h	5-15'	?
Range	9-15mo globl	35-45d global	3-16d global (?)	18-36h regional (?)	3-6h ? regional	0 regional (?)
Updates	4y	2y	1y	1y	1y	6 mo

What's not so clear?
- Resolutions
- Data Assmilation

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

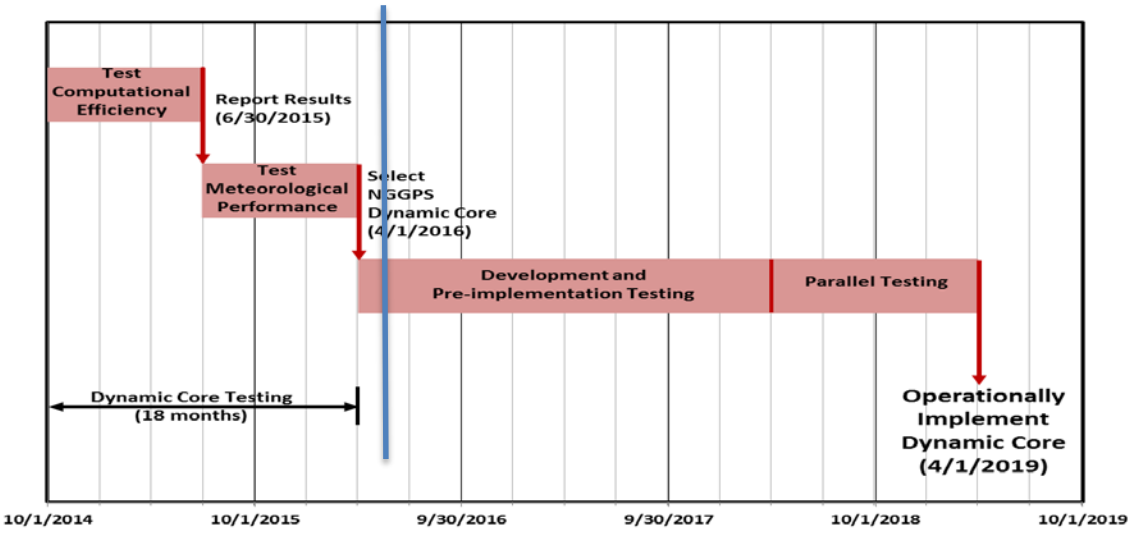
One Way to Simplify Production Suite:

Move towards a unified modeling system

Starts with Next-Generation Global Prediction System (NGGPS)

NGGPS dycore Selection

- **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.
- Final contestants
  - ~~GSM-NH (EMC)~~
  - MPAS (NCAR)
  - FV3 (GFDL)
  - ~~NIM (ESRL)~~
  - ~~NEPTUNE (NRL)~~
  - ~~NMMB-UJ (EMC)~~



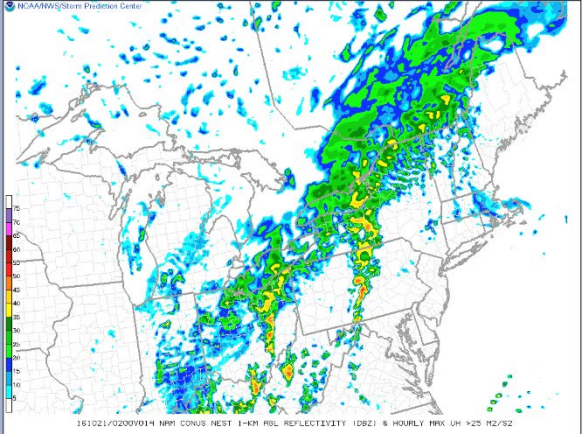
FV3

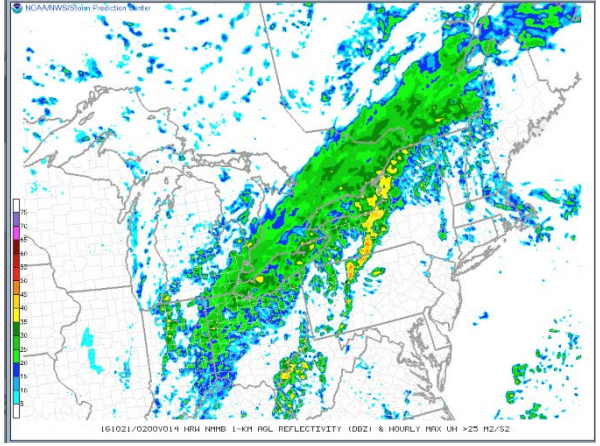
- Plan to move all NCEP weather models to FV3: 5-10 years??

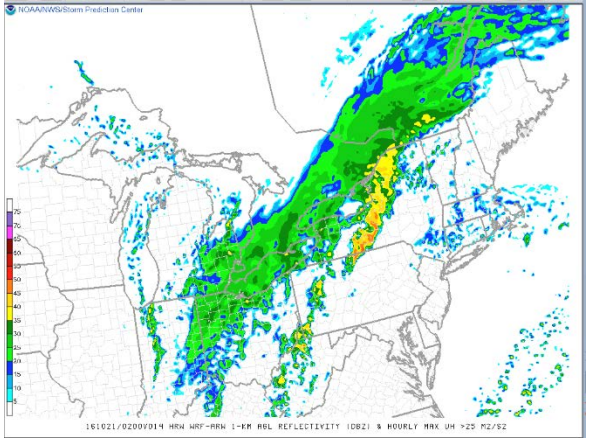
- Will allow NCEP to focus development effort on a single system

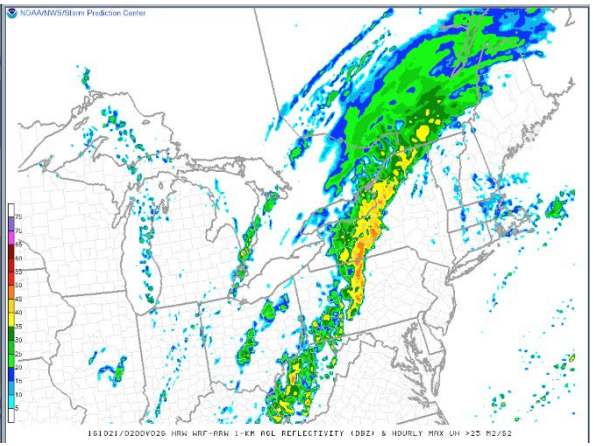
Another Way to Reduce Production Suite Complexity

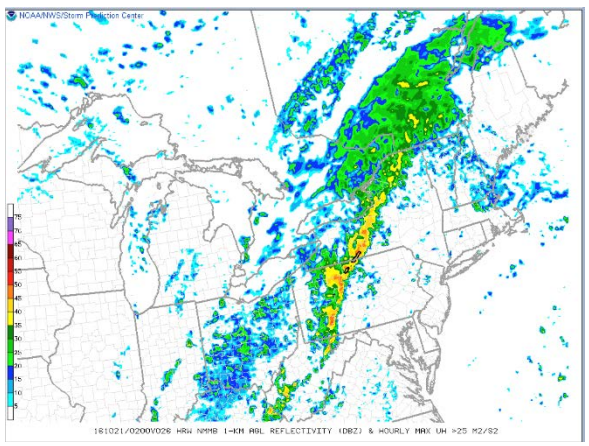
ENSEMBLES!

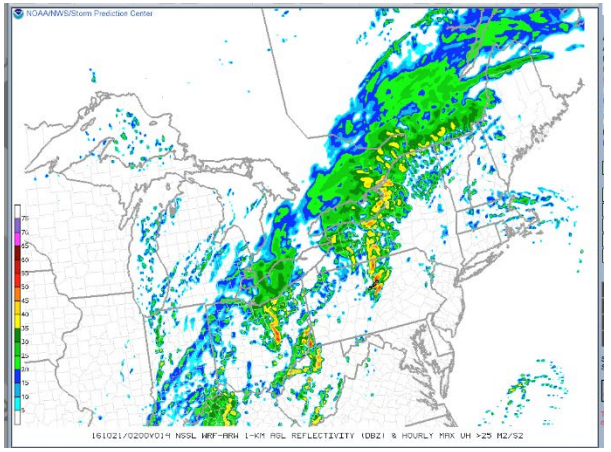






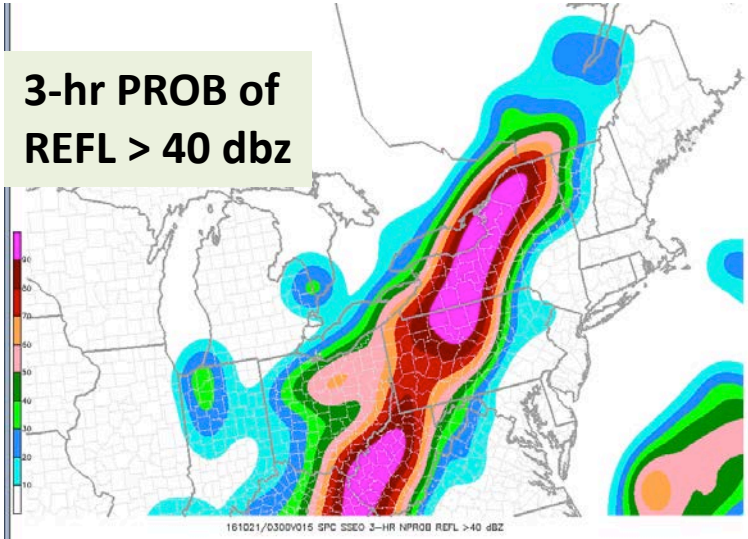


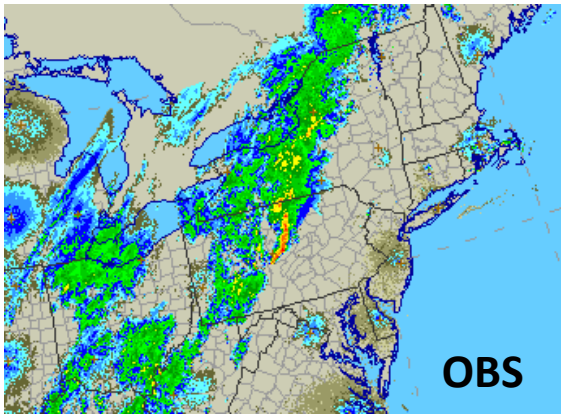




Combine these deterministic hi-res forecasts Into ensemble products

3-hr PROB of REFL > 40 dbz



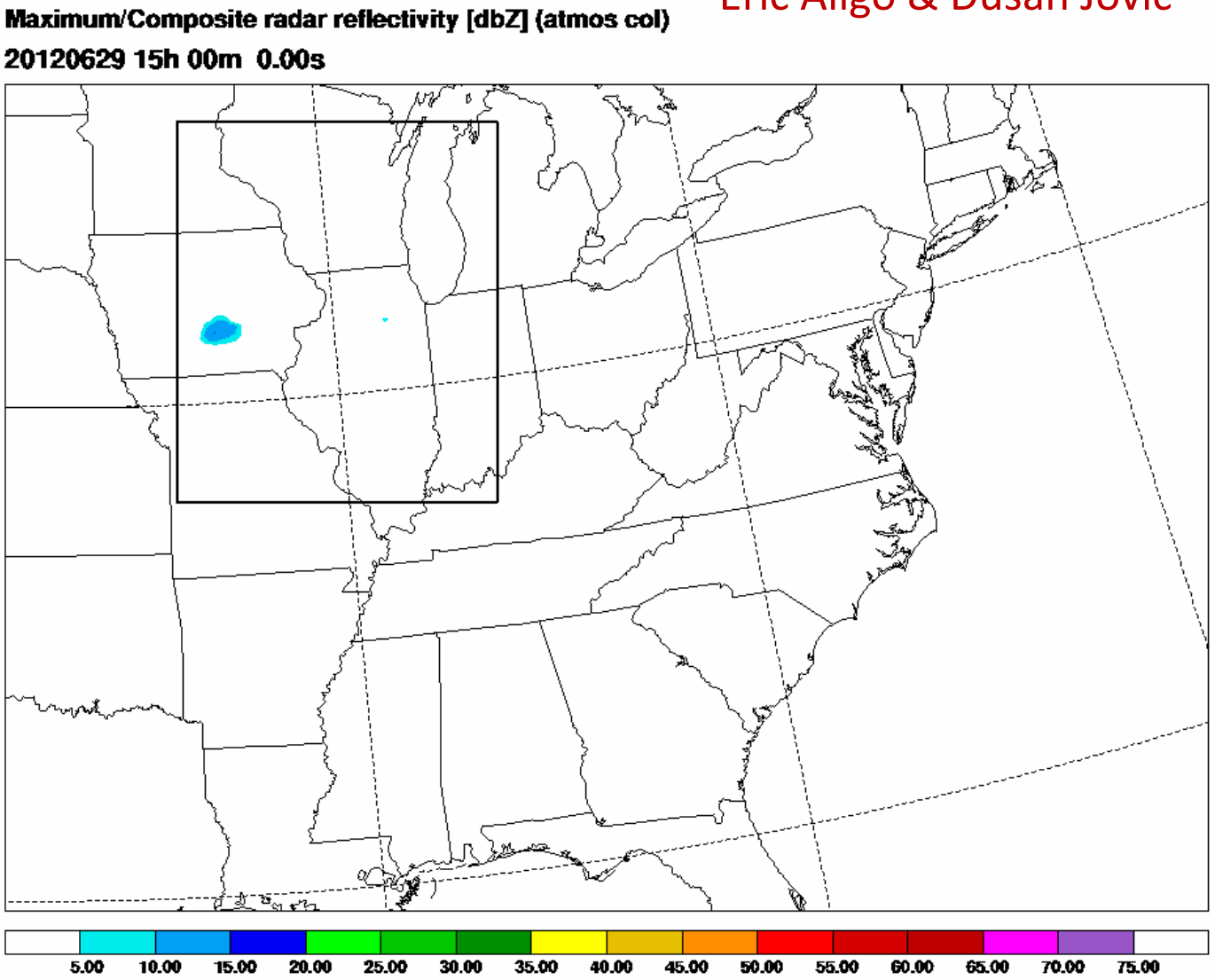


1.33 km Moving nest

Courtesy Brad Ferrier, Eric Aligo & Dusan Jovic

Ultimately, high resolution and ensembles will both play major role in advances in NWP

Having the ability to run fixed and relocatable hi-res nests, eventually in an ensemble framework, will likely play a big role



EMC Model Evaluation Group (MEG)

Goal: Enhance communication between EMC and its customers!

- Weekly webinars covering upcoming model plans, case studies, statistical model performance, parallel evaluations, and other issues

Weekly webinars Thursday at 11:30 EDT – open to all model customers
contact geoffrey.manikin@noaa.gov for more info

THANK YOU!