Agenda

I. Quick intro: HMT-Southeast Pilot Study and webinar goals (Kelly Mahoney, Rob Cifelli)

II. HMT-SEPS Observational Data (Tim Coleman, Dan Gottas)

- GPS-Met precipitable water observations (Seth Gutman, Kirk Holub)

III. Model forecasts: ExREF (Ligia Bernadet)

IV. Questions, discussion

ExREF

Experimental Regional Ensemble Forecast System

Ligia Bernardet, Isidora Jankov, Steve Albers, Yuanfu Xie, Linda Wharton, Kirk Holub, Paula McCaslin, and and Zoltan Toth

Point of contact: ligia.bernardet@noaa.gov

NOAA/ESRL Global Systems Division

Forecast Applications Branch

July 31, 2013

Contents

1. Overview of ExREF and the meaning of EXPERIMENTAL
2. Collaborations
3. Domain, model description
4. How ExREF complements existing models
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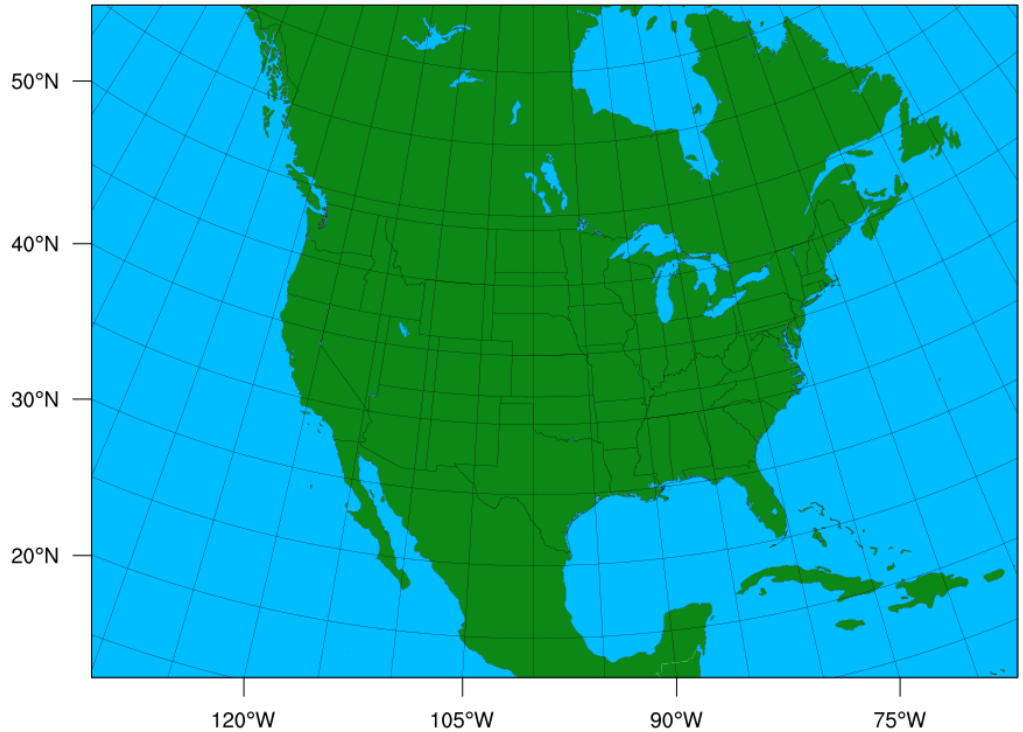
6. Distribution and fields available
7. Website
8. Verification scores
9. ExREF in the WPC Flash Flood and Intense Rainfall experiment
10. Timeliness
11. References
12. Future

Experimental Regional Ensemble Forecast

- NOAA ESRL/GSD has run an ensemble for HMT-W for various years
- Since the 2012-2013 winter, the domain became North American



Experimental

- ExREF is a community resource for development and testing of new ensemble techniques
- Configuration can change in response to partners needs
- Runs are conducted on NOAA R&D machines (non-operational)

ExREF Collaborations

NOAA ESRL Global Systems Division
Run ExREF in realtime Develop new initialization methods
NOAA Environmental Modeling Center
Use ExREF as a proving ground for SREF
Developmental Testbed Center
Conduct testing and evaluation of new ensemble techniques
NOAA Weather Prediction Center
Use ExREF as experimental guidance (Flash Flood experiment)
NOAA Hydrometeorology Testbed
Use ExREF for numerical guidance of high-precipitation events
National Weather Service WFOs
Use ExREF in AWIPS/GFE as experimental forecaster tool (CA STO now)

Current ExREF Model Description

Model	WRF ARW 3.4.1 (latest)
Members	8
Grid spacing	9 km
Vertical levels	35
Microphysics	Various
Cumulus	Kain Fritsh
PBL	YSU
Radiation	RRTM LW / Dudhia SW
Land surface model	Thermal diffusion
Forecast length	84 h
Frequency of run initialization	4 x day (00, 06, 12, 18 UTC)
Initial conditions	Various
Boundary conditions	Various

Member differentiation

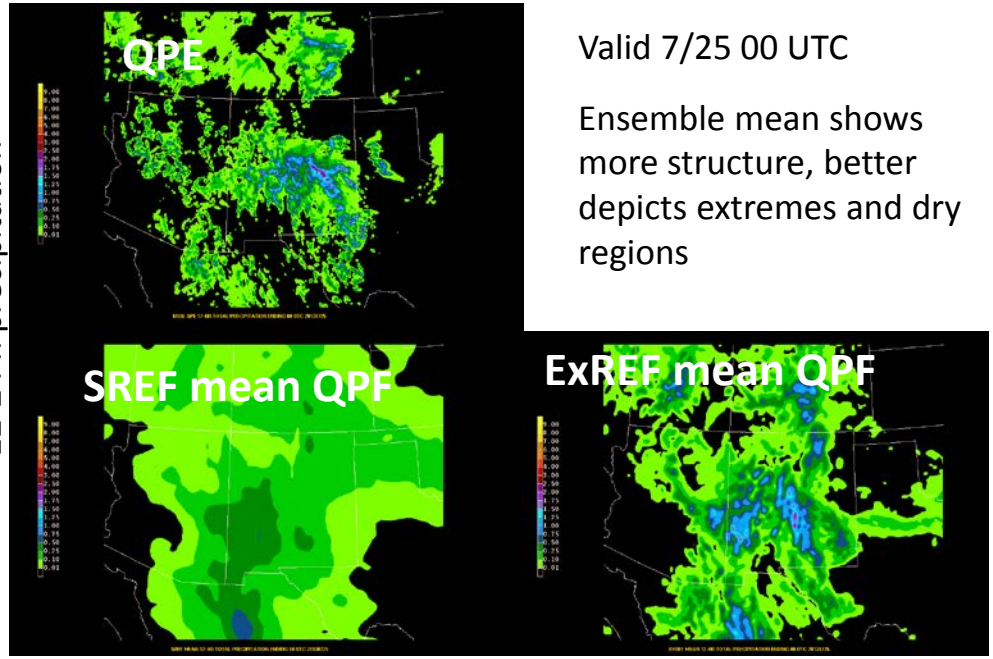
Member	Initial Conditions	Boundary Conditions	Microphysics	
m0	GFS	GFS	Thompson	
m1	**LAPS-t**	**GFS**	**Thompson**	**Control**
m2	LAPS-t	GEFS1	Ferrier	
m3	LAPS-t	GEFS2	WSM6	
m4	LAPS-t	GEFS3	Thompson	
m5	LAPS-t	GEFS4	Ferrier	
m6	LAPS-t	GEFS5	WSM6	
m7	LAPS-v	GFS	Thompson	

- Goal: representation of sources of uncertainty in NWP, both in model & IC/BC
- Members differ in initial and boundary conditions, as well as in microphysics
- Representing uncertainty well means solution enveloped by members

ExREF and SREF

	ExREF	SREF
Domain	North American (covers G212)	Twice as large (often distributed on G212)
Spacing	9 km (higher-resolution)	16 km
Members	8 ARW	21 ARW, NMM-E, NMM-B
Microphysics	Ferrier, Thompson, WSM6 (more sophisticated to represent precip)	Ferrier

12-24 h precipitation

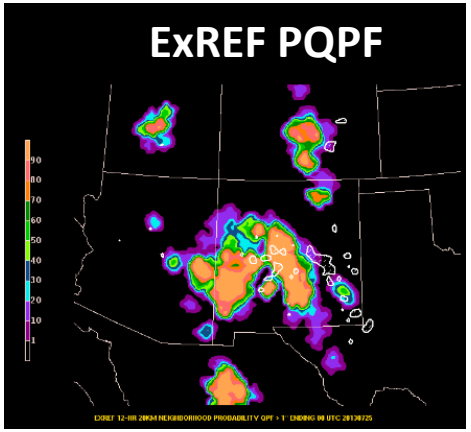


Valid 7/25 00 UTC

Ensemble mean shows more structure, better depicts extremes and dry regions

Best products from ensemble are probabilistic fields that help determine uncertainty

12-24 h PQPF 1 in



Figures courtesy F. Barthold (WPC)

ExREF m1 and NAM, RAP, HRRR

Member 1 is the control and can be used as a deterministic forecast

	ExREF m1	NAM and nest	RAP	HRRR
Domain	North American	North American/CONUS	North American	CONUS
Spacing	9 km	12 / 4 km	13 km	3 km
Dyn core	ARW	NMM-B	ARW	ARW
Microph	Thompson	Ferrier	Thompson	Thompson
Length	84 h	84 h	18 h	15 h

WPC Flash Flood Experiment

- ExREF was used to provide experimental guidance for QPF and FF
- ExREF compared to operational SREF

Very preliminary results on ExREF for QPF and FF guidance

- Was trusted and often used as a basis for the experimental forecasts
- Subjective model evaluation of QPF shows ExREF provided better guidance than SREF
- Underdispersive in the first 24 h (not evaluated for later lead times)
  - Several members starts from LAPS-t and differences from lateral boundaries and physics will have more effect later
- Forecasts are best when events are strongly forced
- Struggled with southern part of rain events

Local Analysis and Prediction System

LAPS has been developed by NOAA/ESRL/GSD

- Observation oriented analysis
- Efficient and fine resolution analysis, short latency
- Portability and ease of use
- Multiscale analysis
- Hot-start analysis
- Cloud analysis
- Good performance in verification of real time forecast

Traditional versus Variational LAPS

- LAPS-t uses Barnes analysis; LAPS-v uses variational analyses
- Those are methods to combine many observations onto a gridded analysis
- In the future, LAPS-t will be discontinued in favor of LAPS-v

More info: laps.noaa.gov

LAPS Motivation

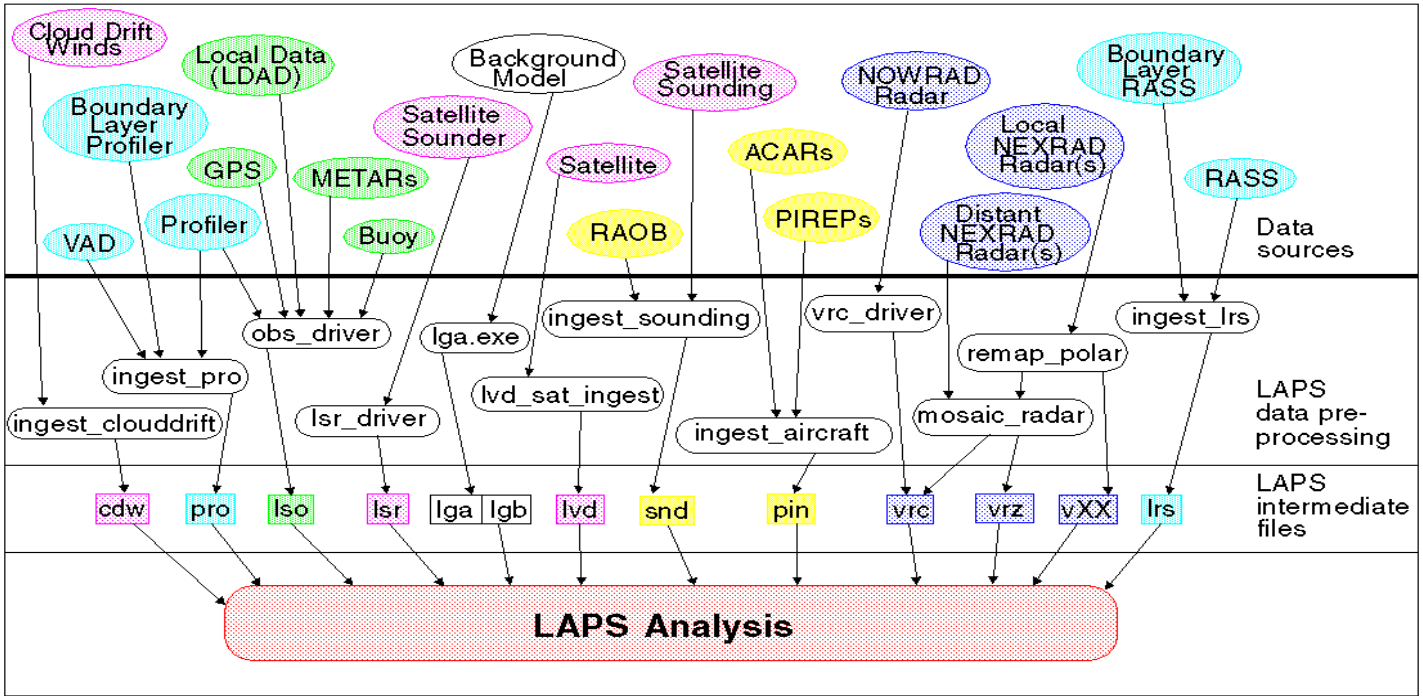
High resolution (0.5 – 20km), rapid update (10-60min), local to global

Highly portable system

Collaboration with user community - about 150 world wide

- Federal Gov't – NWS, RSA, PADS, FAA, DHS, SOS
- State Gov't – California Dept of Water Resoures
- International – Finnish Met. Inst., China Heavy Rain Inst.
- Private Sector – Toyota, WDT

Wide variety of data sources:



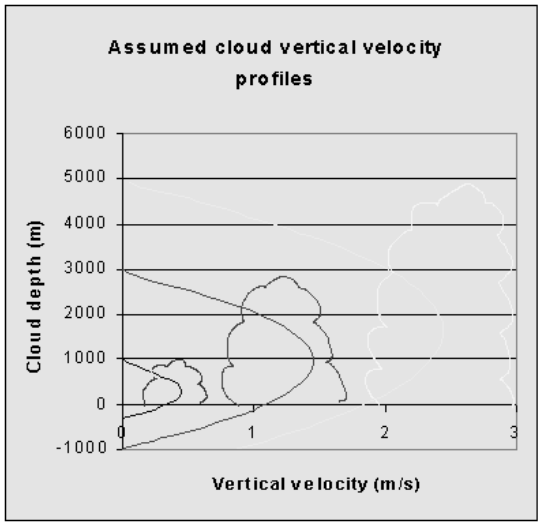
LAPS Hot Start

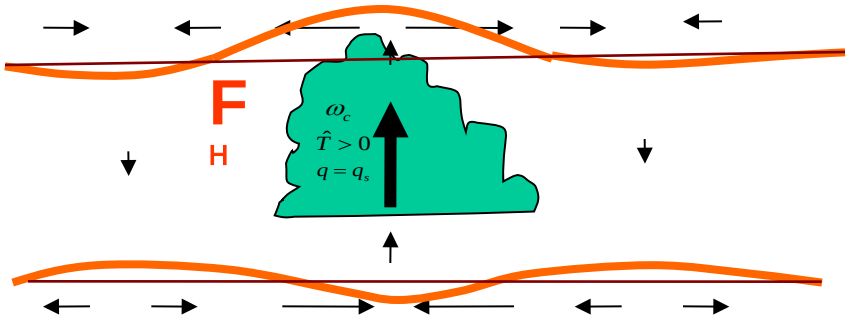
- Goal
  - Reduce model spinup time
- Method
  - Start the model file clouds and thermodynamic fields
- Process
  - Assimilate hydrometeors
  - Assure consistency with water vapor fields
  - Create balanced vertical velocity and divergence fields
  - Adjust temperature and height fields

LAPS Hot Start

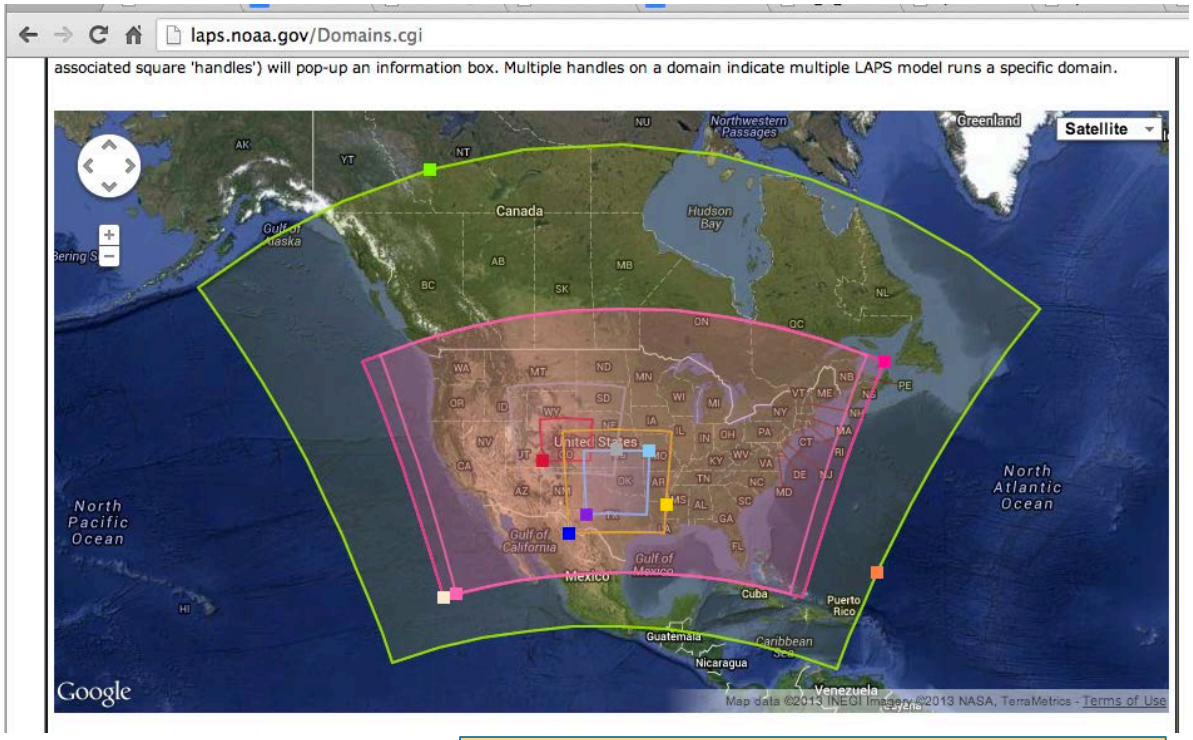
Three-Dimensional Cloud Analysis

METAR





LAPS domains and distribution

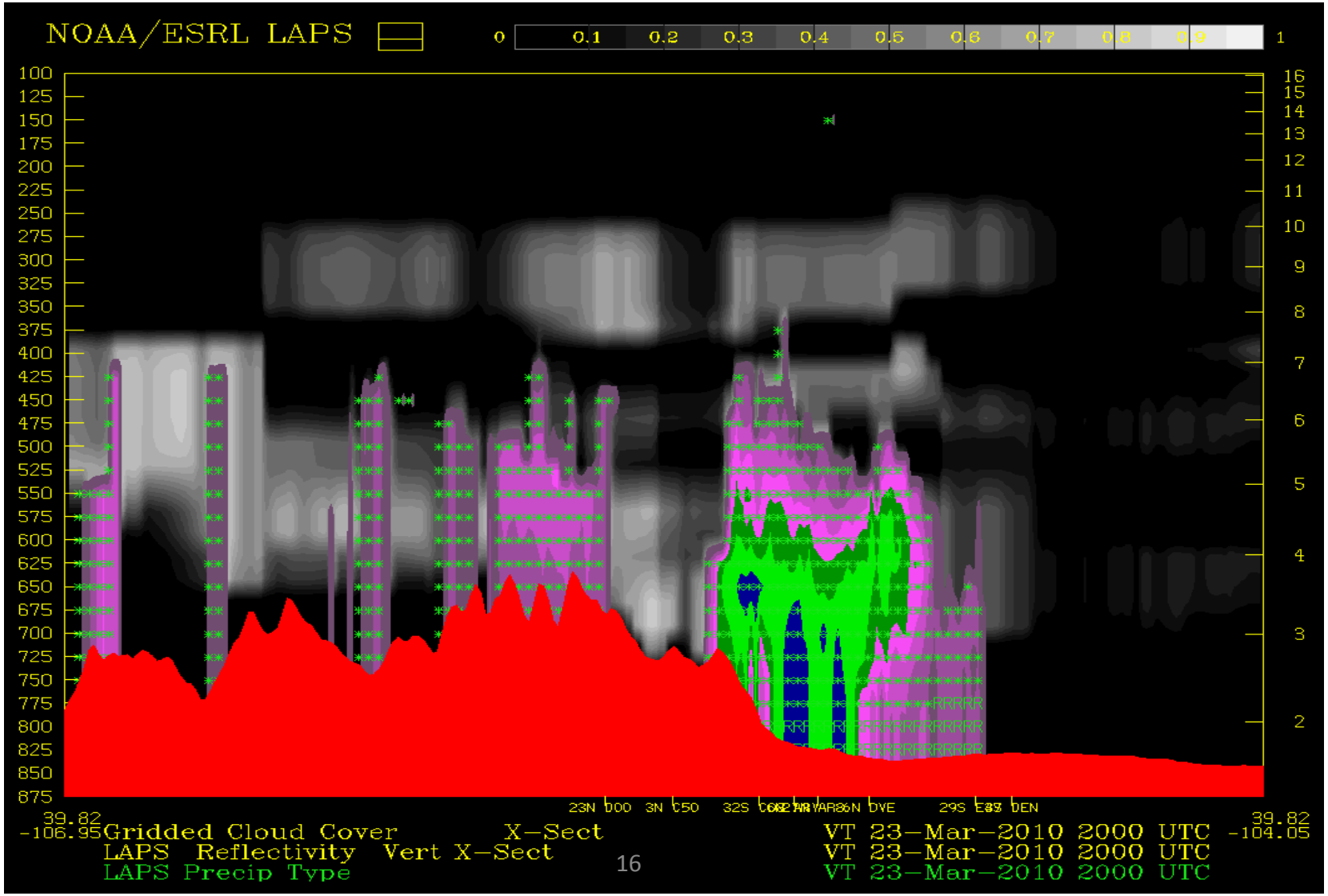


Domains of interest
laps.noaa.gov

- ExREF
  - NA LAPS-t: 9 km; hourly
  - NAV LAPS-v: 9 km; hourly
- CONUS: 3 km; 30 min
- ROC_HIRES: 1 km; 15 min over CO
- HWT
  - LAPS: 3 km; 15 min
  - VLAPS: 1 km; 15 min

Example of analyses available

Cloud, reflectivity, precipitation type 1-km, 15min update



Current ExREF distribution

- Sacramento WFO
  - Receives via LDM a geographical subset of ensemble mean over west coast
  - Used in AWIPS-I and GFE
- Weather Prediction Center
  - Receives all members and mean via ftp
  - Obtaining account on zeus for independent retrieval of data
- Other users
  - Images on web at http://laps.noaa.gov/hmt/hmt.html

ExREF Products

GRIB 2 (members and mean)

- 10-m U, V
- 2-m T, Td equivalent potential T
- CAPE, CIN
- MSLP
- Precipitable Water
- Precipitation
  - Runtotal
  - 3-h accumulations
- Snow
  - Runtotal
  - 3-h accumulations
- U, V, W, geop height, T, spec hum
  - 1000, 925, 850, 700, 500, 250

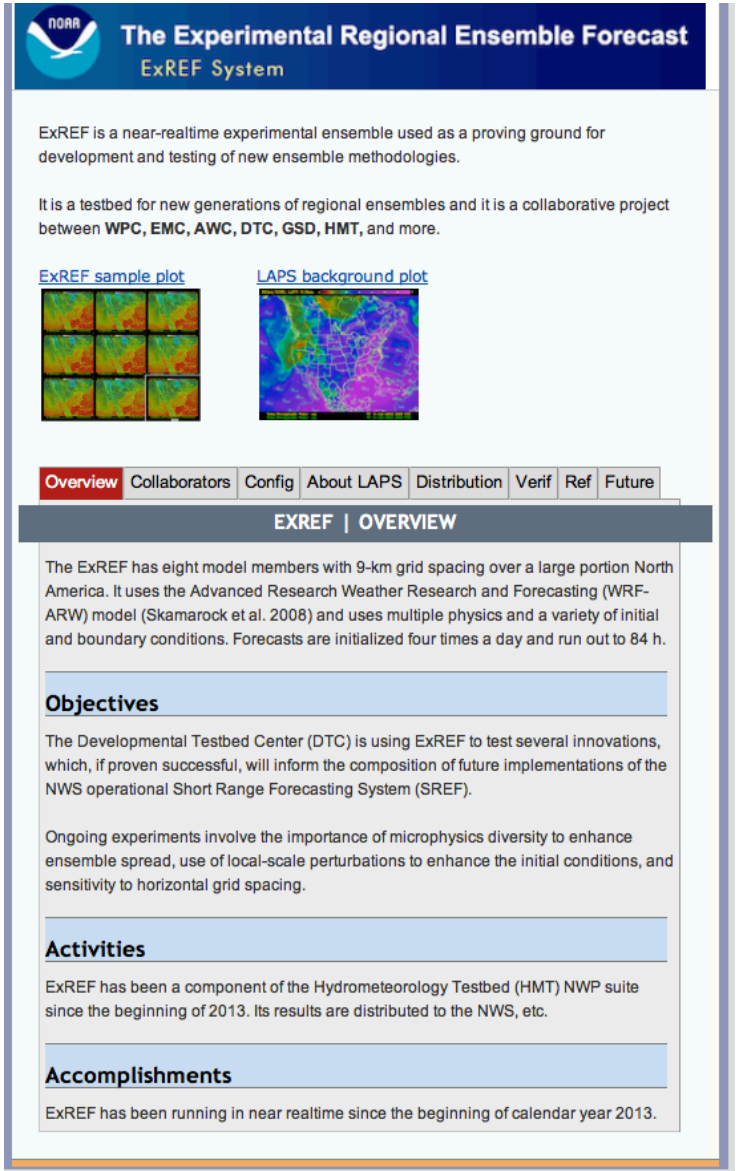
NetCDF members on Zeus

- Additional fields available

Requested fields

- Visibility (AWC and ER)
- Ceiling (AWC)
- BUFR soundings (ER)

ExREF website



The Experimental Regional Ensemble Forecast
ExREF System

ExREF is a near-realtime experimental ensemble used as a proving ground for development and testing of new ensemble methodologies.

It is a testbed for new generations of regional ensembles and it is a collaborative project between **WPC, EMC, AWC, DTC, GSD, HMT,** and more.

ExREF sample plot

LAPS background plot

Overview | Collaborators | Config | About LAPS | Distribution | Verif | Ref | Future

EXREF | OVERVIEW

The ExREF has eight model members with 9-km grid spacing over a large portion North America. It uses the Advanced Research Weather Research and Forecasting (WRF-ARW) model (Skamarock et al. 2008) and uses multiple physics and a variety of initial and boundary conditions. Forecasts are initialized four times a day and run out to 84 h.

Objectives

The Developmental Testbed Center (DTC) is using ExREF to test several innovations, which, if proven successful, will inform the composition of future implementations of the NWS operational Short Range Forecasting System (SREF).

Ongoing experiments involve the importance of microphysics diversity to enhance ensemble spread, use of local-scale perturbations to enhance the initial conditions, and sensitivity to horizontal grid spacing.

Activities

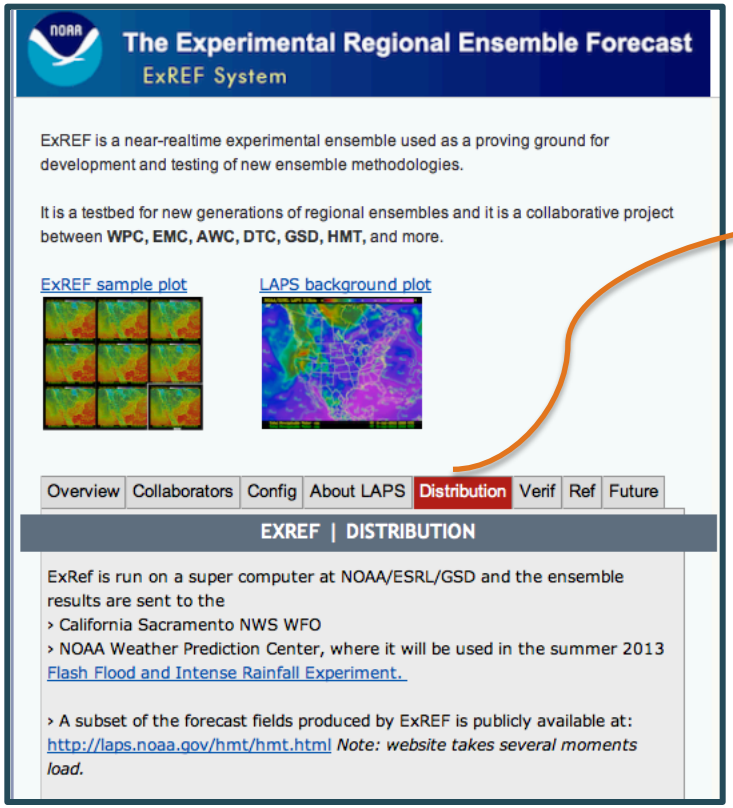
ExREF has been a component of the Hydrometeorology Testbed (HMT) NWP suite since the beginning of 2013. Its results are distributed to the NWS, etc.

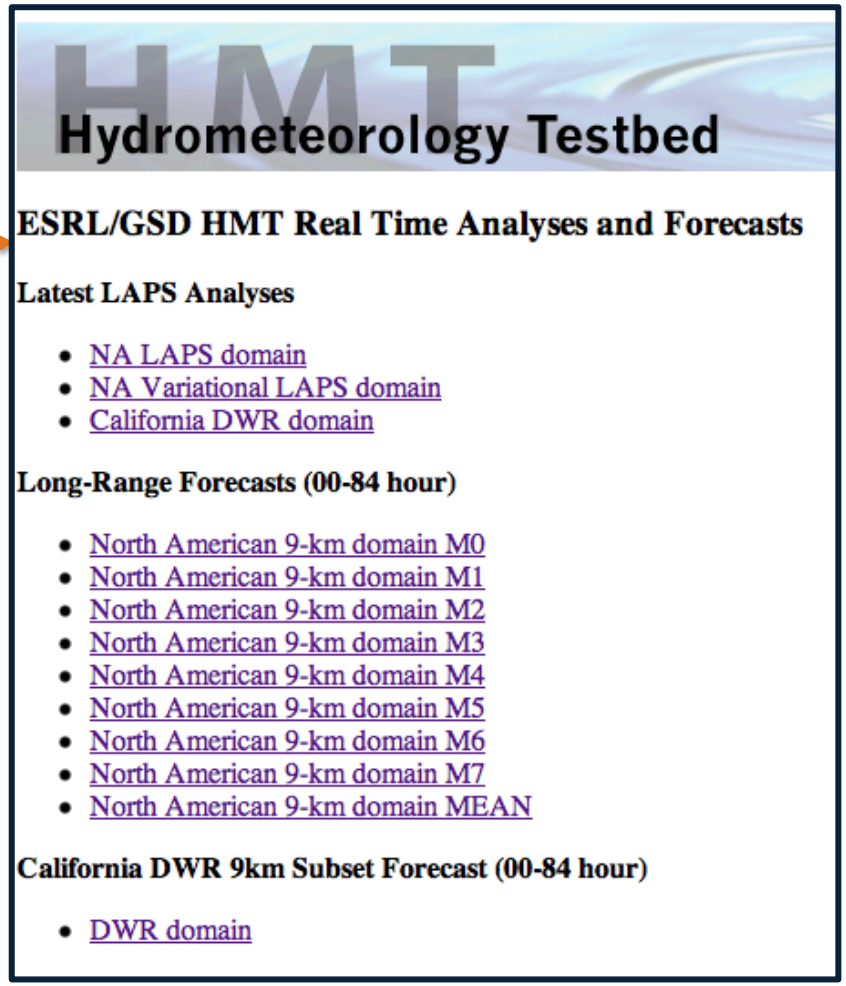
Accomplishments

ExREF has been running in near realtime since the beginning of calendar year 2013.

http://esrl.noaa.gov/exref/

Images on web





These images take a while to load

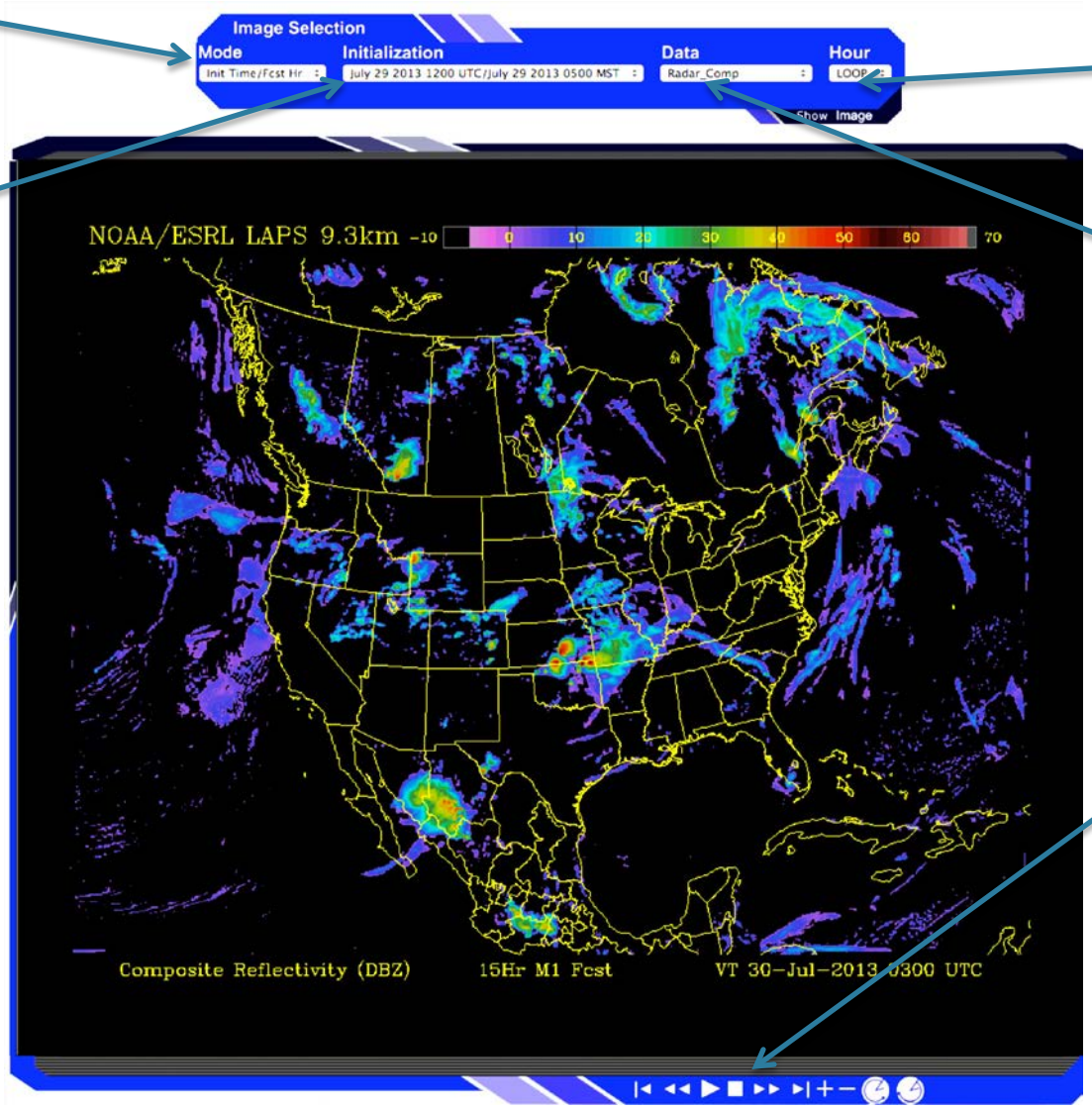
Image display

Leave as "Init Time"

Leave as "Loop"

Choose model initialization date

Choose variable



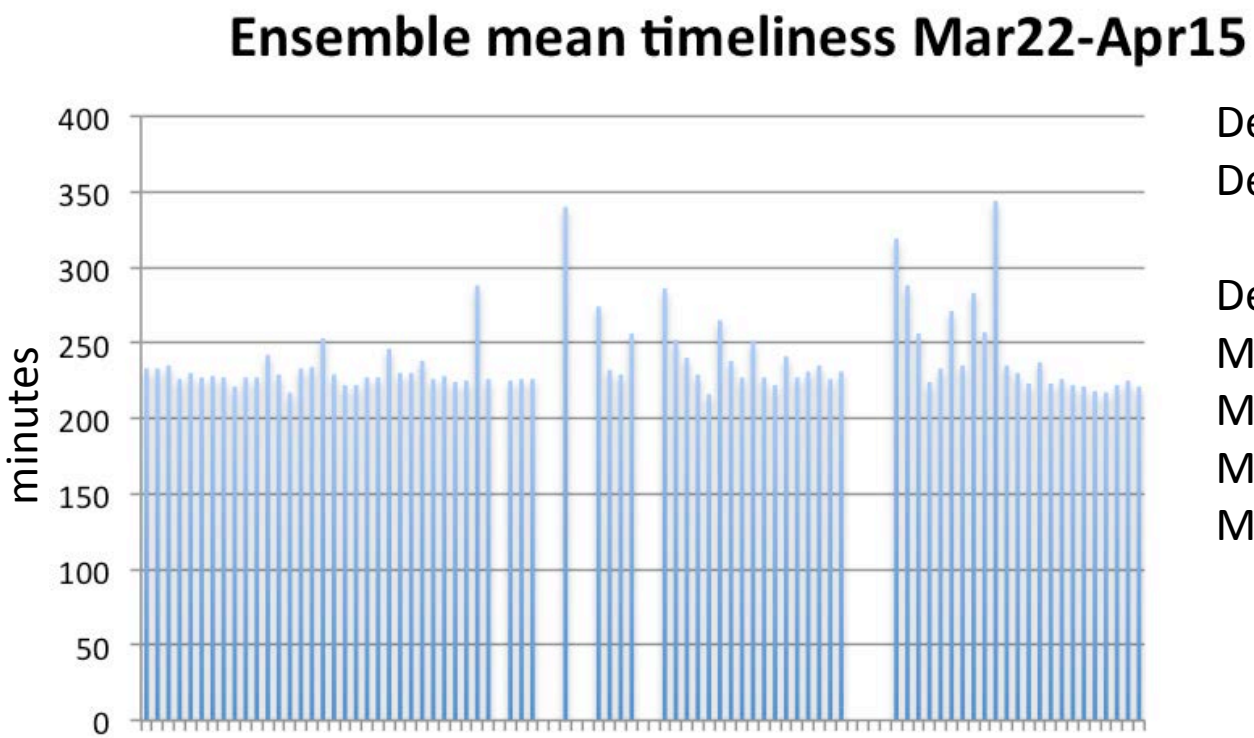
Animation controls

- To beginning
- Back one
- Loop
- Stop
- Forward one
- To end

Variables available on website

	0, 1, 3, 4, 6, 7	2,5 (Ferrier)	Mean
11 micron	✓	✓	✓
CAPE	✓	✓	✓
Cloud	✓	✓	
Fire danger	✓	✓	
IWV	✓	✓	✓
LiftedIndex_SfcDewPt	✓	✓	✓
Moist_flux	✓	✓	✓
Precip			✓
Radar_850	✓		✓
Radar_Comp	✓		✓
Radar_Sfc	✓		✓
Sfc_RelHum	✓	✓	✓
Snow	✓	✓	✓
Solar	✓	✓	✓
SfcTempWind	✓	✓	✓

ExREF Timeliness



Delivered 80 out of 90 forecasts
Delivery rate of 89%

Delivery timing stats in minutes
Mean: 239 minutes
Mode: 227
Max: 344
Min: 216

Primary issue is zeus unavailability
Zeus is not an operational machine; it is a R&D machine with downtimes
We cannot change zeus; we are improving all other aspects of reliability

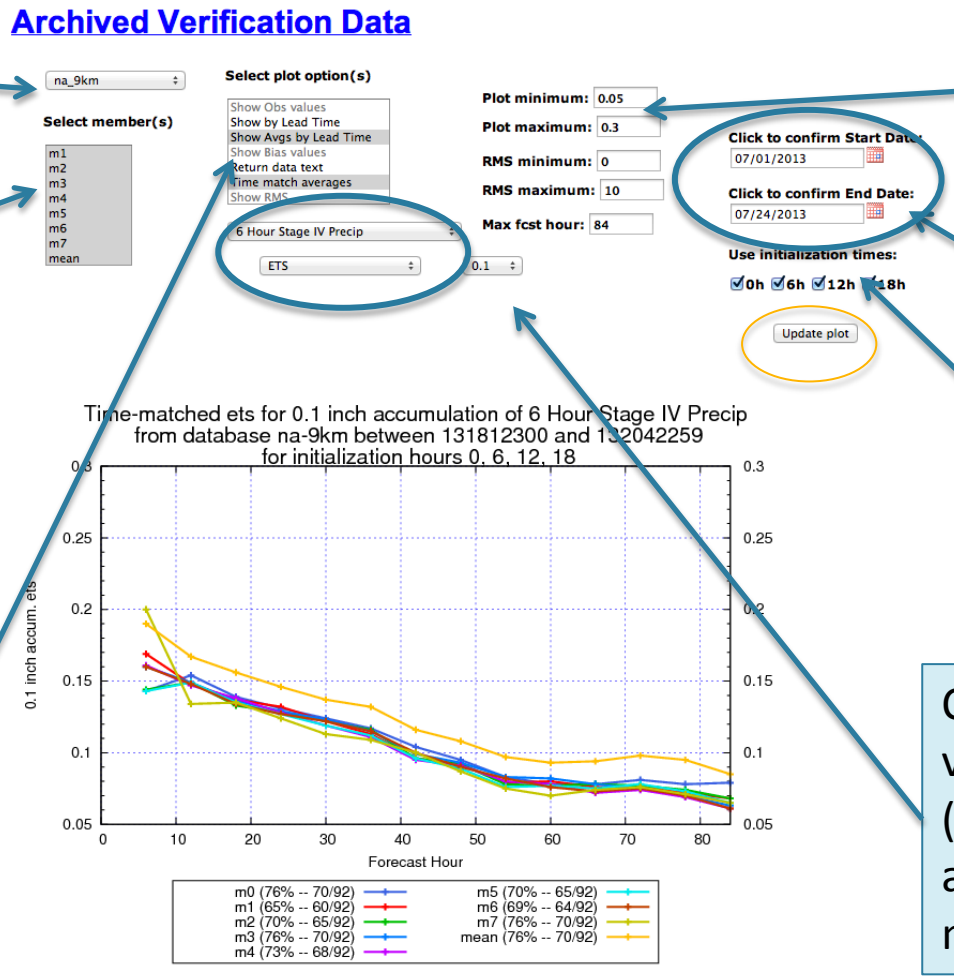
Verification database

http://laps.noaa.gov/verification/arc/

Choose "na_9km"

Choose members/ mean

Choose plot options
- Avs by lead time
- Time matches (homogeneous sample)
- Return data text (to download data)



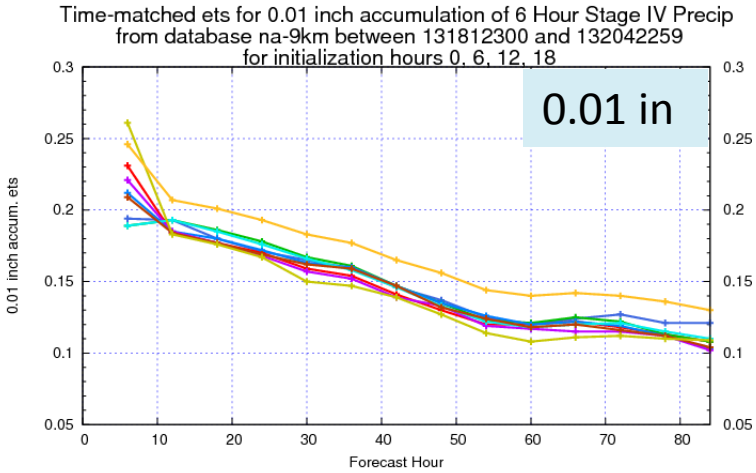
Choose axis max/min

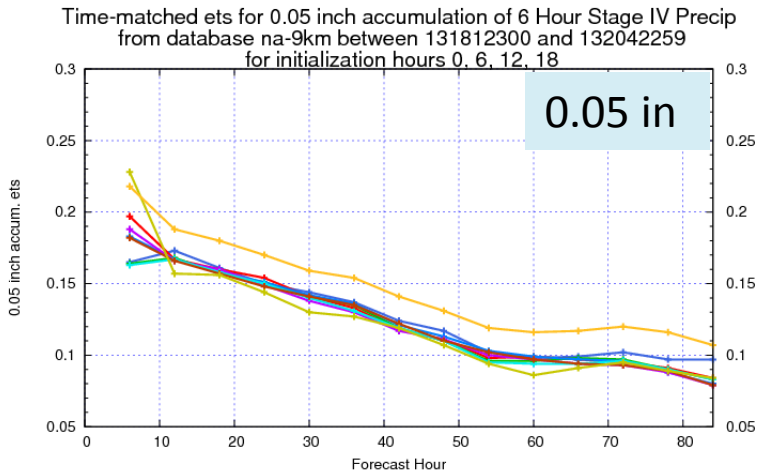
Choose period

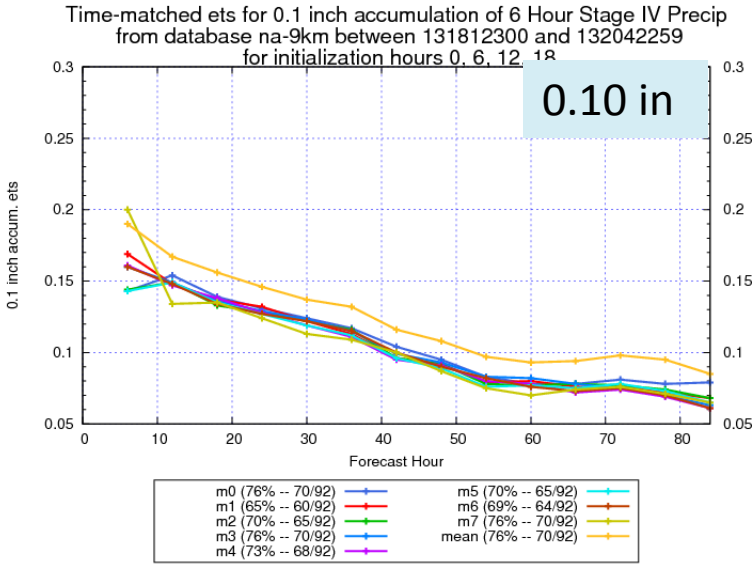
Choose init time

Choose variable to verify (threshold, if applicable), and metric

6-h QPF ETS July 1-24







ETS is higher

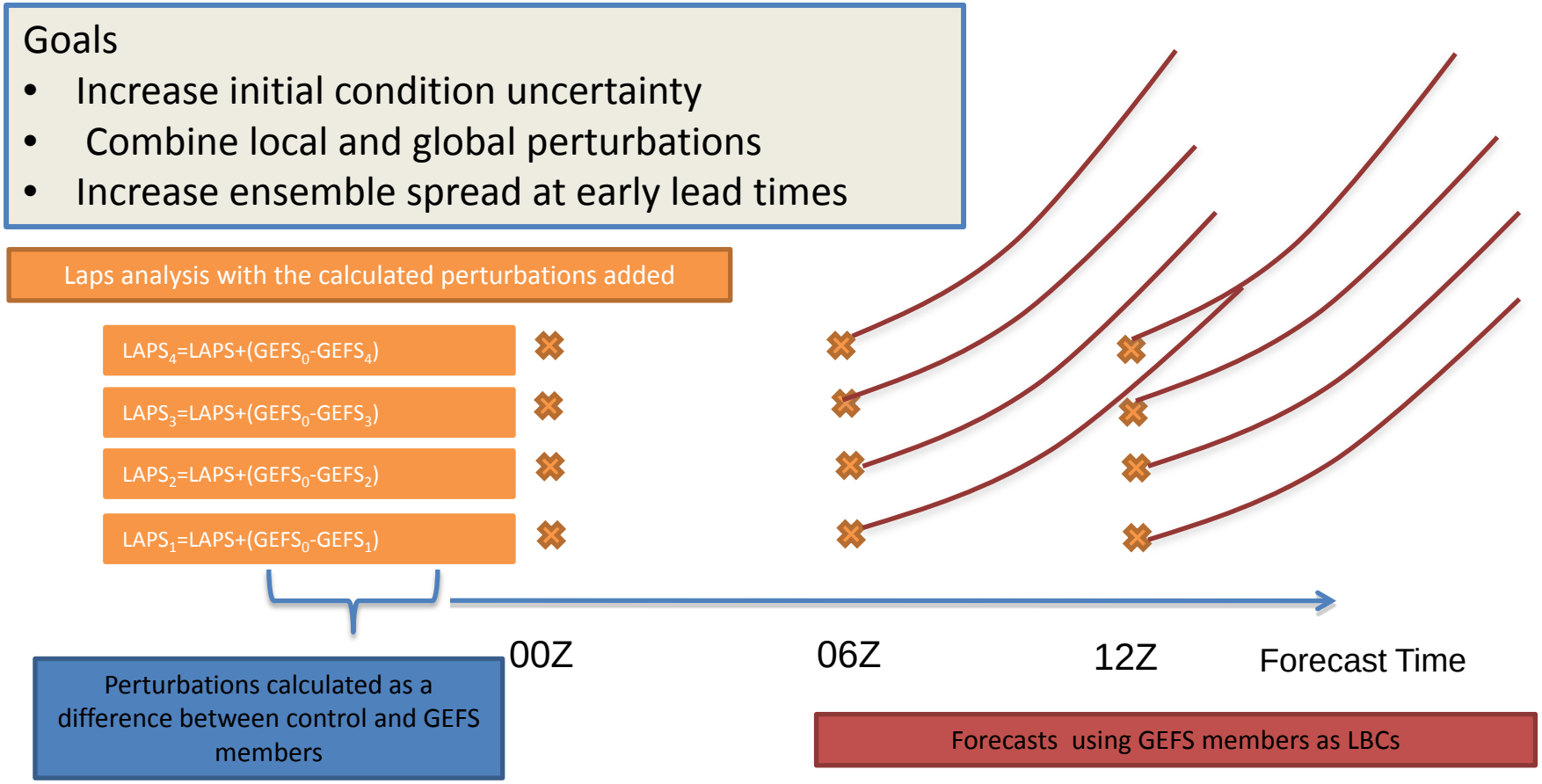
- at early lead times
- for lower thresholds

Member 7, LAPS-v, best at 6h

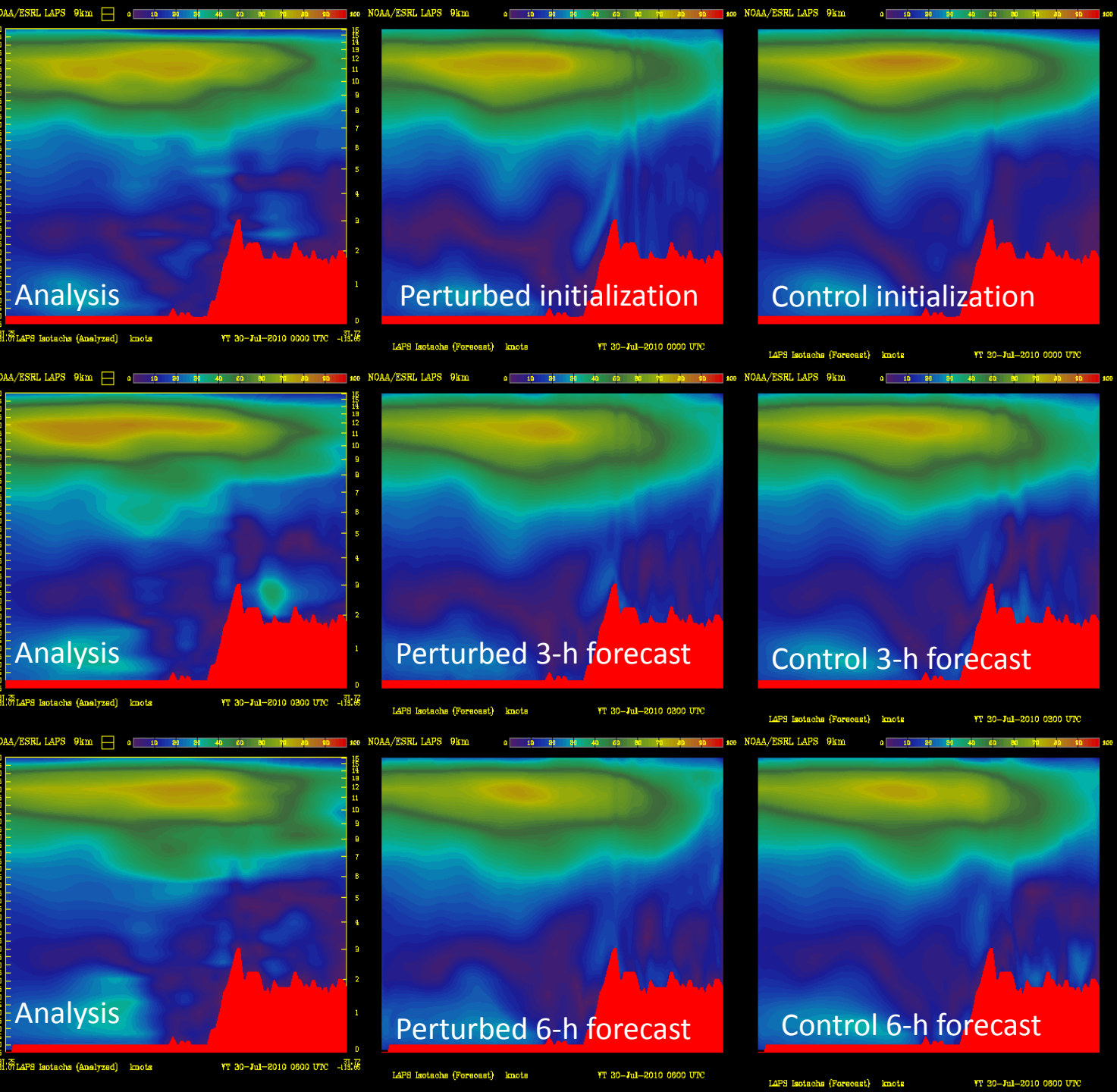
Ensemble mean distinctly higher

Under development: Initial Condition Perturbations

Goals
- Increase initial condition uncertainty
- Combine local and global perturbations
- Increase ensemble spread at early lead times



Similar work in dynamic downscaling of perturbations is being conducted at
- Austrian meteorological bureau
- University of Oklahoma

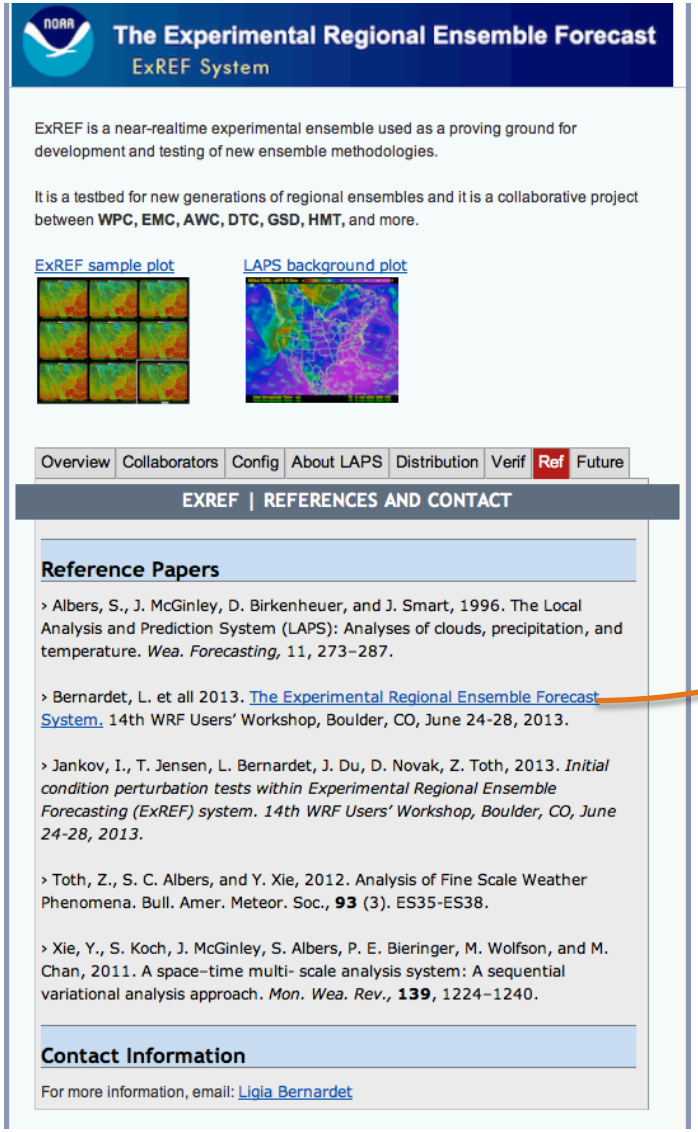


Previous work done at GSD for HMT-West in 2010, using a similar technique

Wind Speed Forecast initialized July 30 2010 00UTC

Note presence of more small scale features in initial model fields

References



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ExREF sample plot

LAPS background plot

Overview | Collaborators | Config | About LAPS | Distribution | Verif | Ref | Future

EXREF | REFERENCES AND CONTACT

Reference Papers

› Albers, S., J. McGinley, D. Birkenheuer, and J. Smart, 1996. The Local Analysis and Prediction System (LAPS): Analyses of clouds, precipitation, and temperature. *Wea. Forecasting,* 11, 273–287.

› Bernardet, L. et all 2013. The Experimental Regional Ensemble Forecast System. 14th WRF Users' Workshop, Boulder, CO, June 24-28, 2013.

› Jankov, I., T. Jensen, L. Bernardet, J. Du, D. Novak, Z. Toth, 2013. *Initial condition perturbation tests within Experimental Regional Ensemble Forecasting (ExREF) system. 14th WRF Users' Workshop, Boulder, CO, June 24-28, 2013.*

› Toth, Z., S. C. Albers, and Y. Xie, 2012. Analysis of Fine Scale Weather Phenomena. Bull. Amer. Meteor. Soc., **93** (3). ES35-ES38.

› Xie, Y., S. Koch, J. McGinley, S. Albers, P. E. Bieringer, M. Wolfson, and M. Chan, 2011. A space–time multi- scale analysis system: A sequential variational analysis approach. *Mon. Wea. Rev.,* **139**, 1224–1240.

Contact Information

For more information, email: Ligia Bernardet

Bernardet, L., S. Albers, L. Wharton, I. Jankov, D. Reynolds, K. Mahoney, E. Sukovich, W. Hogsett, D. Novak, and J. Du, 2013. The Experimental Regional Ensemble Forecast (ExREF) System.

14th WRF Users' Workshop, Boulder, CO, June 24-27. Available from http://www.mmm.ucar.edu/wrf/users/workshops/WS2013/extended_abstracts/p49.pdf.

The Experimental Regional Ensemble Forecast (ExREF) System

Ligia Bernardet[1*], S. Albers[1b], L. Wharton[1*], I. Jankov[1b], D. Reynolds[2], K. Mahoney[2*], E. Sukovich[2*], W. Hogsett[3], D. Novak[3], and J. Du[4]

[1]NOAA ESRL – Global Systems Division, Boulder, CO
[b]NOAA ESRL – Physical Sciences Division, Boulder, CO
[3] NOAA NCEP – Weather Prediction Center, Silver Springs, MD
[4] NOAA NCEP – Environmental Prediction Center, Silver Springs, MD
[*]Cooperative Institute for Research in the Environmental Sciences – Univ. of Colorado, Boulder, CO
[*]Cooperative Institute for Research in the Atmosphere – Colorado State University, Fort Collins, CO

1. Introduction

The Experimental Regional Ensemble Forecast (ExREF) system is a tool for the development of Numerical Weather Prediction (NWP) methodologies. ExREF is run in near-realtime by the Global Systems Division (GSD) of the National Oceanic and Administration (NOAA) Earth System Research Laboratory (ESRL), and its products are made available through a website, an ftp site, and via the Unidata Local Data Manager (LDM).

ExREF has been a component of the Hydrometeorology Testbed (HMT) NWP suite since the beginning of 2013. Its results are distributed to the National Weather Service Weather Forecast Office and the River Forecast Center in Sacramento, California, where they are ingested in the Advanced Weather Interactive Processing System (AWIPS) to provide guidance on the forecasting of extreme precipitation events. ExREF is also being supplied to the National Weather Service (NWS) Weather Prediction Center (WPC) where it will be tested in the upcoming Flash Flood and Intense Rainfall Experiment in July 2013. Finally, ExREF is being used as a proving ground for new methodologies in ensemble forecasting.

The Developmental Testbed Center (DTC) is using ExREF to test several innovations, which, if proven successful, will inform the composition of future implementations of the NWS operational Short Range Forecasting System (SREF). One innovation is an alternative initialization technique that uses dynamic downscaling of perturbations, as discussed in a companion poster by Jankov et al. (2013). Another is the use of multiple microphysical parameterizations as a way to generate ensemble diversity. And finally, ExREF will serve as a demonstration of the capabilities of a 9-km horizontal grid spacing ensemble, which SREF (currently run with 16-km grid spacing) will achieve in a few years, pending computational capability upgrades.

2. ExREF Overview

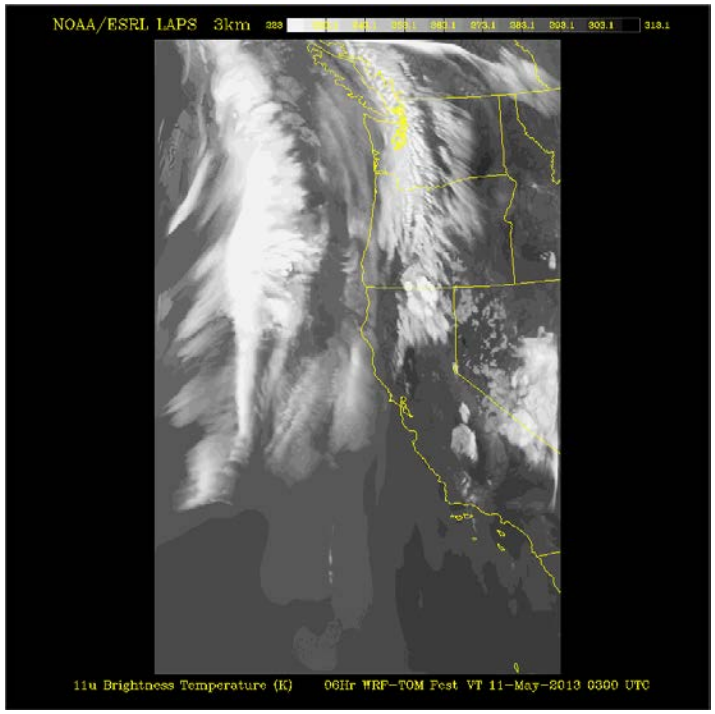
The ExREF has eight members with 9-km grid spacing over a large portion North America

Figure 1. ExREF domain.

Corresponding author address: ligia.bernardet@noaa.gov

Preliminary work towards the High-Impact Relocatable Ensemble HIRES

- Next year, GSD is planning to run a relocatable 3-km ensemble
- Relocation on the fly as meteorology dictates
- Prototype: one 3-km member over the HMT-W in winter



Configuration

3-km grid spacing; 532x832 pts
Run hourly
Forecast length: 12 h
IC: LAPS using NAM as background
BC: NAM