A Brief Overview of NCEP SREF: *Relevance of Hydrological Application*

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<u>Acknowledgements</u>: Eric Rogers, Tom Black, Geoff Manikin, Brad Ferrier, Dusan Jovic, Matt Pyle, Hui-Ya Chuang, Henry Juang, Jongil Han, Zavisa Janjic, George Gayno, Kenneth Mitchell, NCO stuff as well as Stephen Lord and Louis Uccellini

http://www.emc.ncep.noaa.gov/mmb/SREF/SREF.html

1. How to capture uncertainties
   (ensemble system design)

2. How to convey forecast uncertainty
   (ensemble products and data)

3. Downstream applications of the SREF
   (driving other prediction systems)

(1) To Capture Uncertainty

*<u>*Atmospheric IC uncertainty</u>*:

(1) **Multi-analysis (GFS and NAM)**

(2) **Perturbed analysis: bred vector** (current), ET (ongoing/2007), and ET with DA-based rescaling (future, work with Mozheng Wei)

*<u>*Atmospheric LBC uncertainty:</u>*

(1) **different LBCs for different members simply provided by various NCEP global ensemble members**

(2) plan to work on how to better couple LBC and IC in future

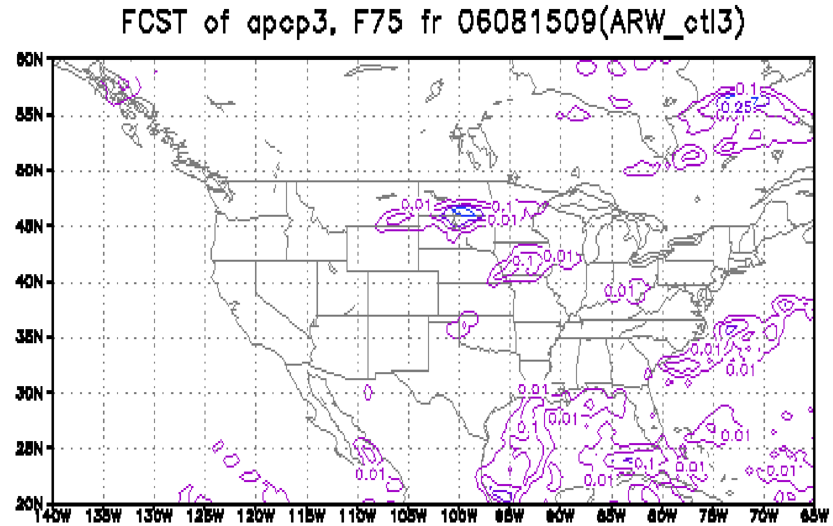
*<u>*Lower boundary/Earth surface forcing uncertainty</u>*:

(1) Land surface: **currently not perturbed** but soil moisture perturbation design is underway -- first a simple approach (Du, 2007) and then might be an ET-like approach in near future

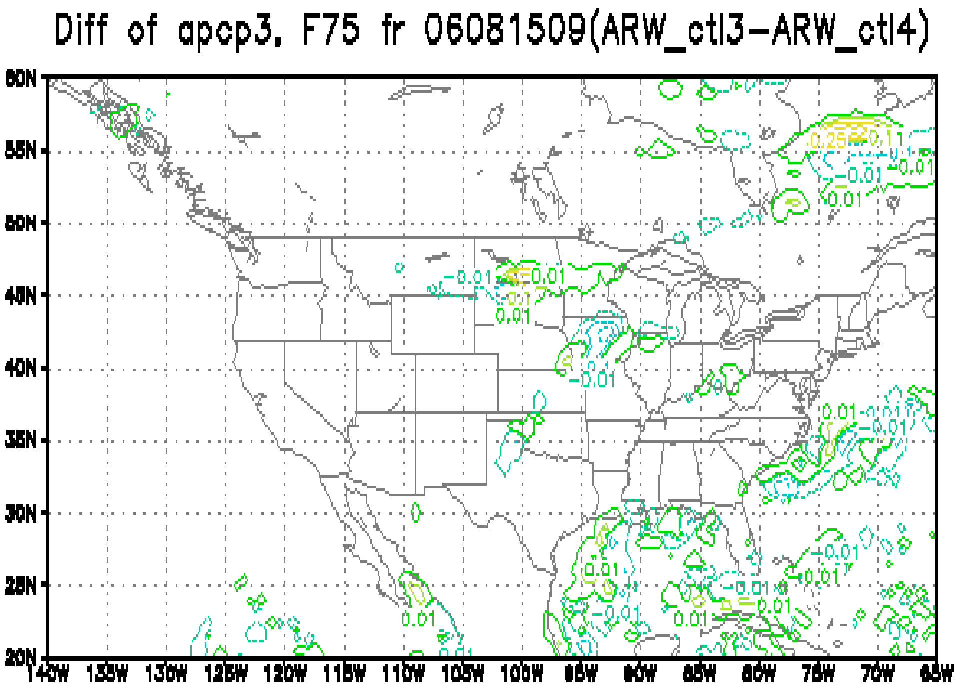
(2) Water/sea surface temperature, flux etc.: (**currently not perturbed**)

*<u>*Upper boundary uncertainty from space????</u>*

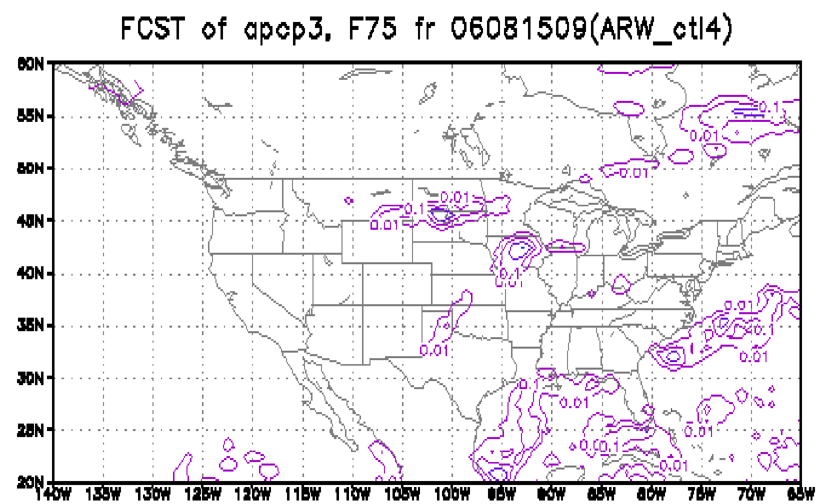
3h-apcp forecast with WRF_ARW model



with NAM soil moisture



Diff between the two forecasts (“nam” - “gfs”)

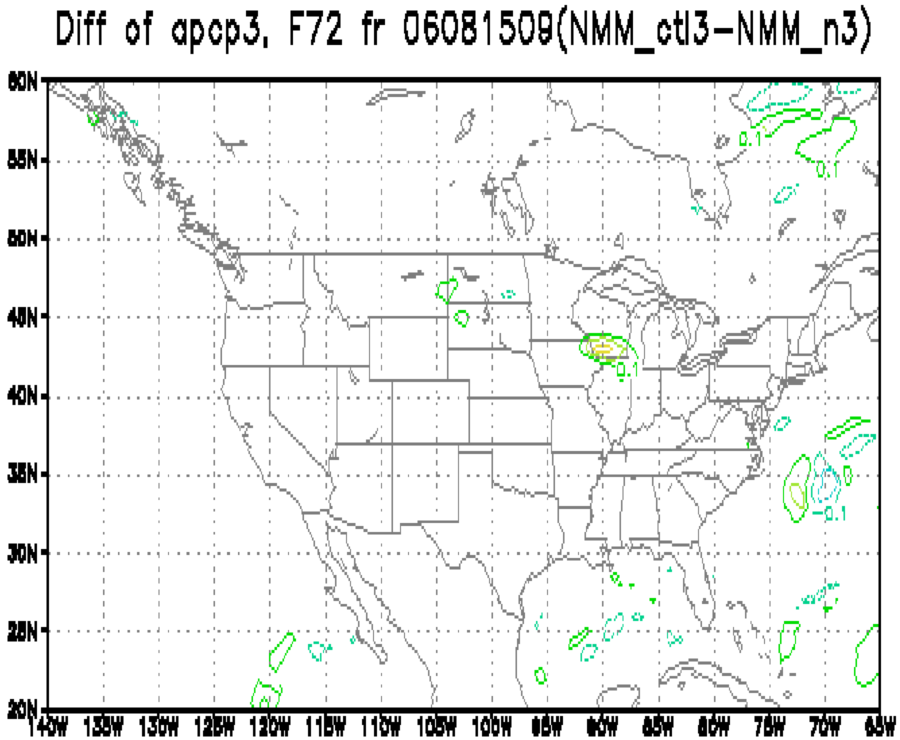


with GFS soil moisture

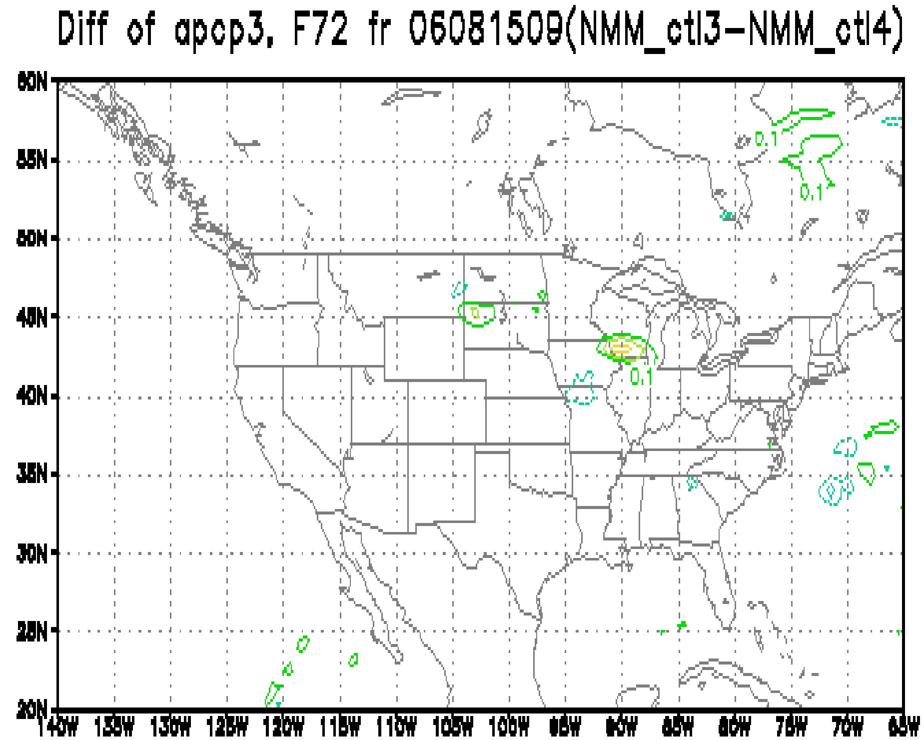
(3h-apcp, warm season case)

<u>Impact comparison between “IC diff” and “soil moisture diff” within WRF_NMM</u>

[note: (a) <0.1” contour not plotted, (b) it’s only 3h accumulation]



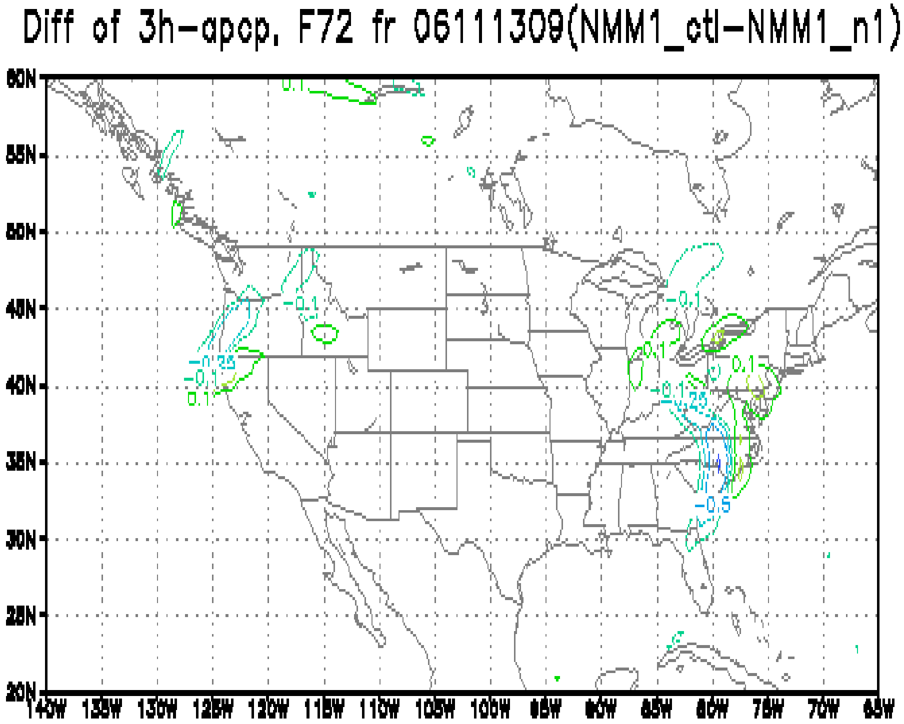
Difference caused by different ICs



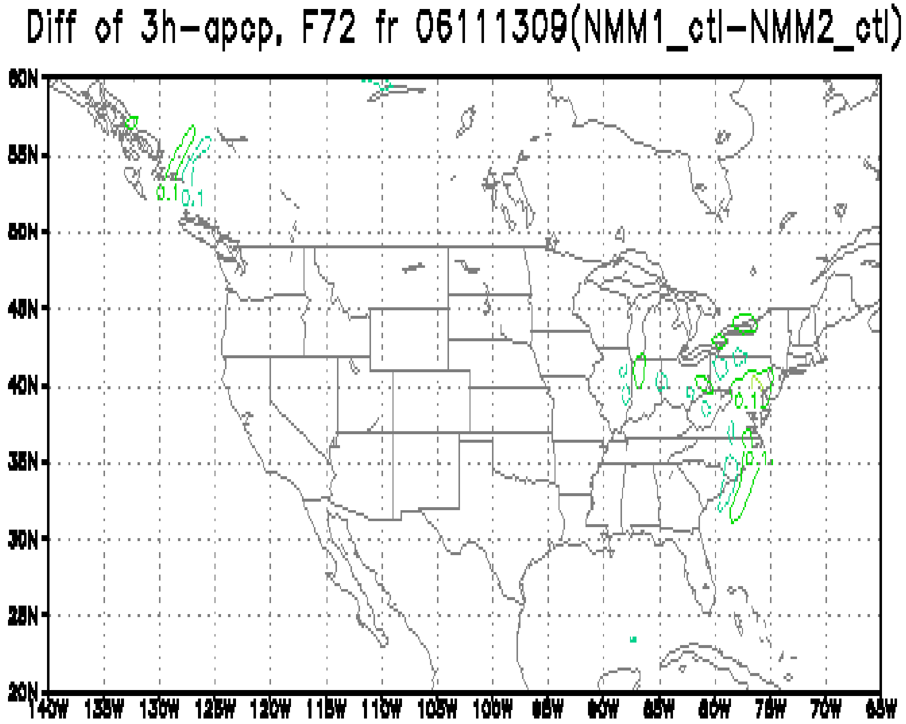
Difference caused by different soil moisture

Impact from diff soil moisture is comparable to that from diff ICs within NMM!

Sensitivity of 3h-apcp forecasts (cold season case)

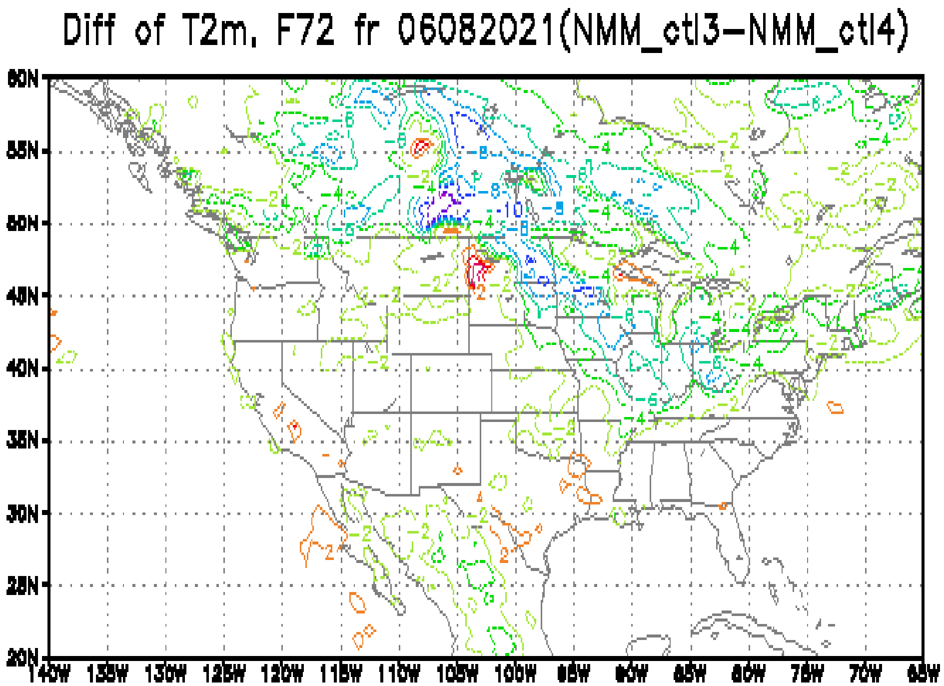


To atmospheric ICs

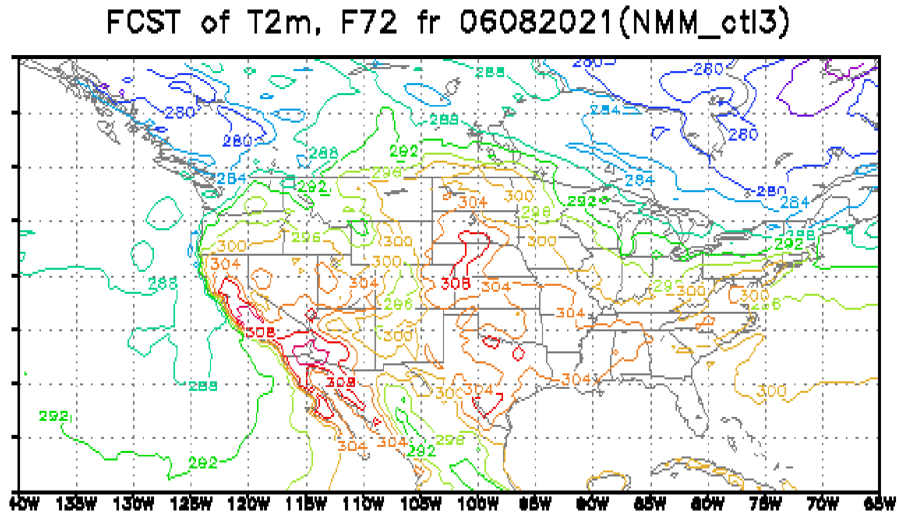


To soil moisture initial states

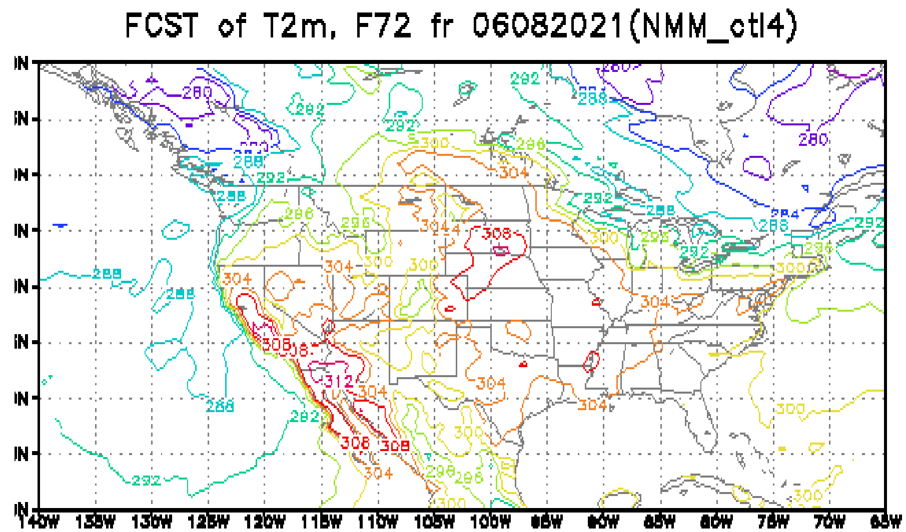
Within WRF_NMM model:
Impact on T2m is significant!



T2m diff (namSM – gfsSM, NMM)

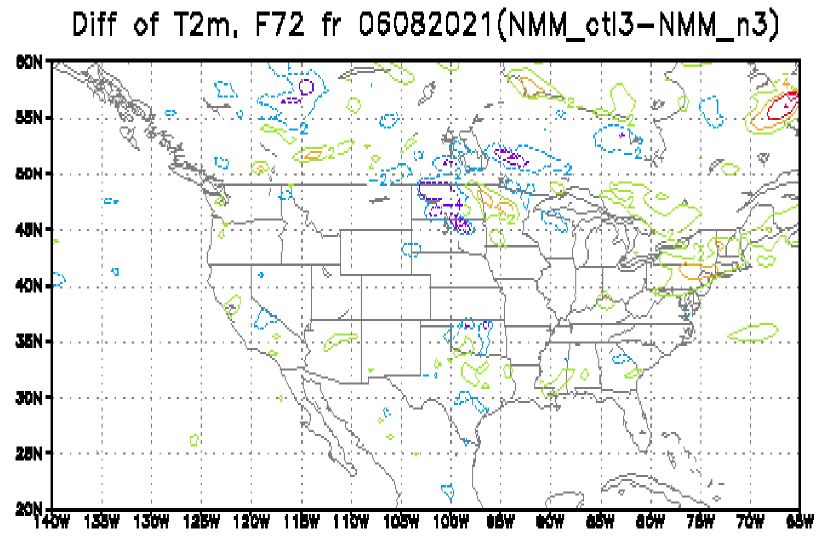


With nam soil moisture (NMM)

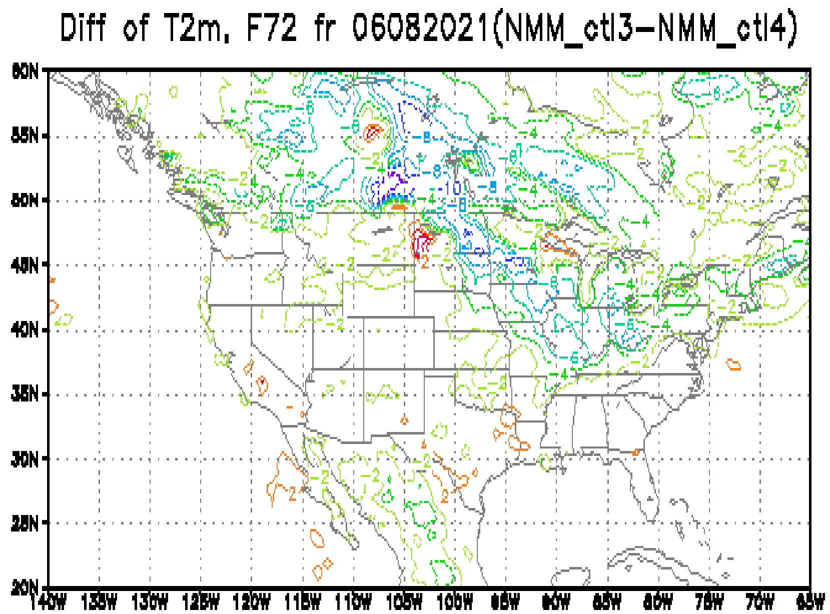


With gfs soil moisture (NMM)

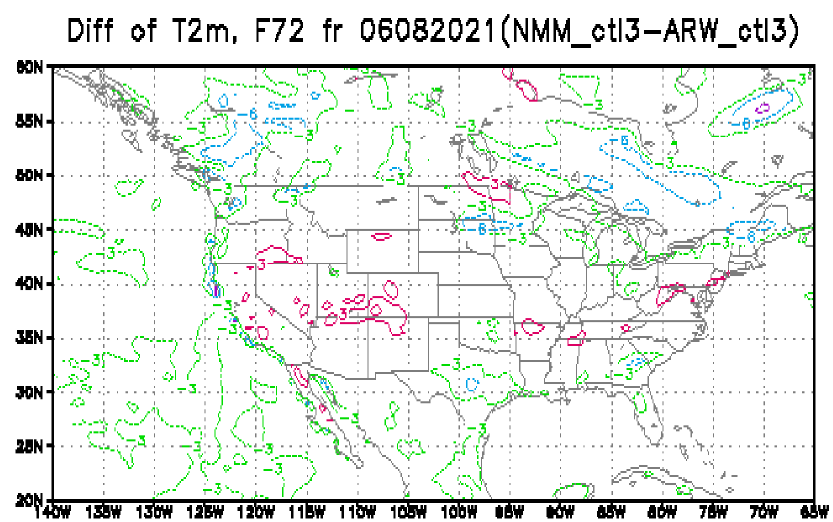
T2m -- impact comparison (NMM):
Soil moisture impact on T2m is bigger
Than that of IC and of model difference!



different IC (NMM; namSM)



Diff soil moisture (nam – gfs; NMM)



different models (nmm vs. arw; namSM)

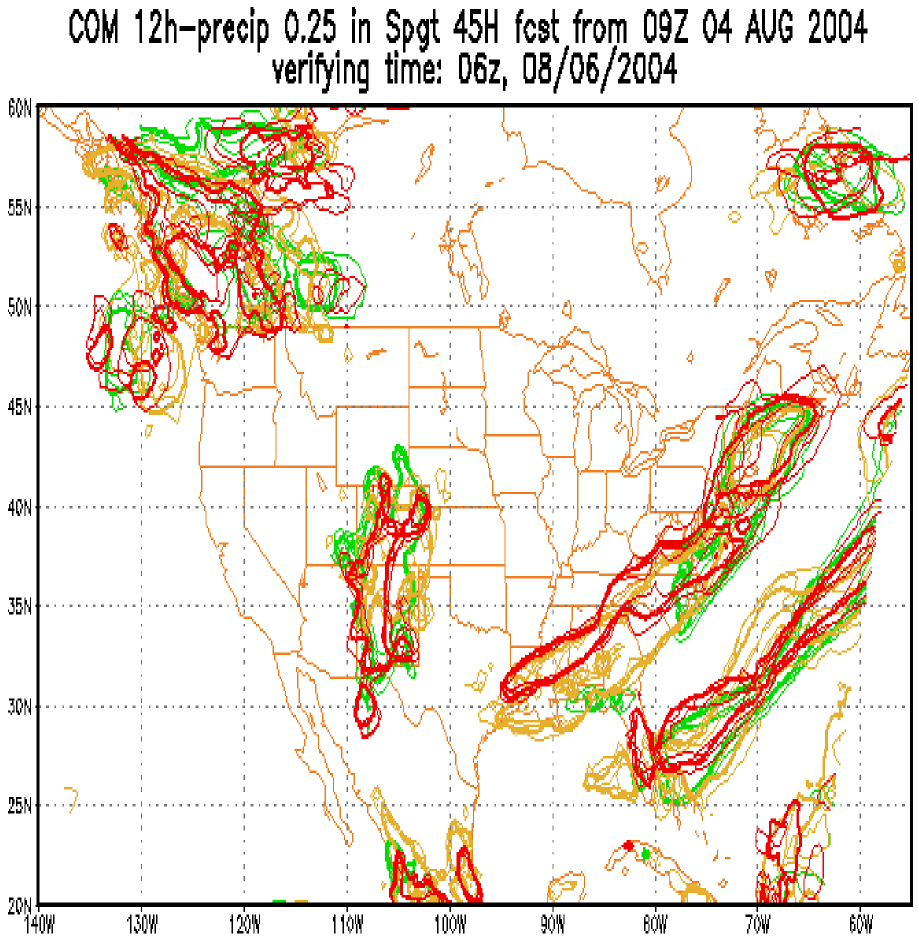
*<u>*Model uncertainty (both dynamics and physics):*</u>

(1) multi-model: **Eta, RSM, WRF-NMM, WRF-ARW (current),** plan to replace Eta and RSM members with all WRF members in 2008 (<u>issue: how important will the diversity of model dynamics be?)</u> *(disadvantage: difficult to maintain; different model has different bias)*

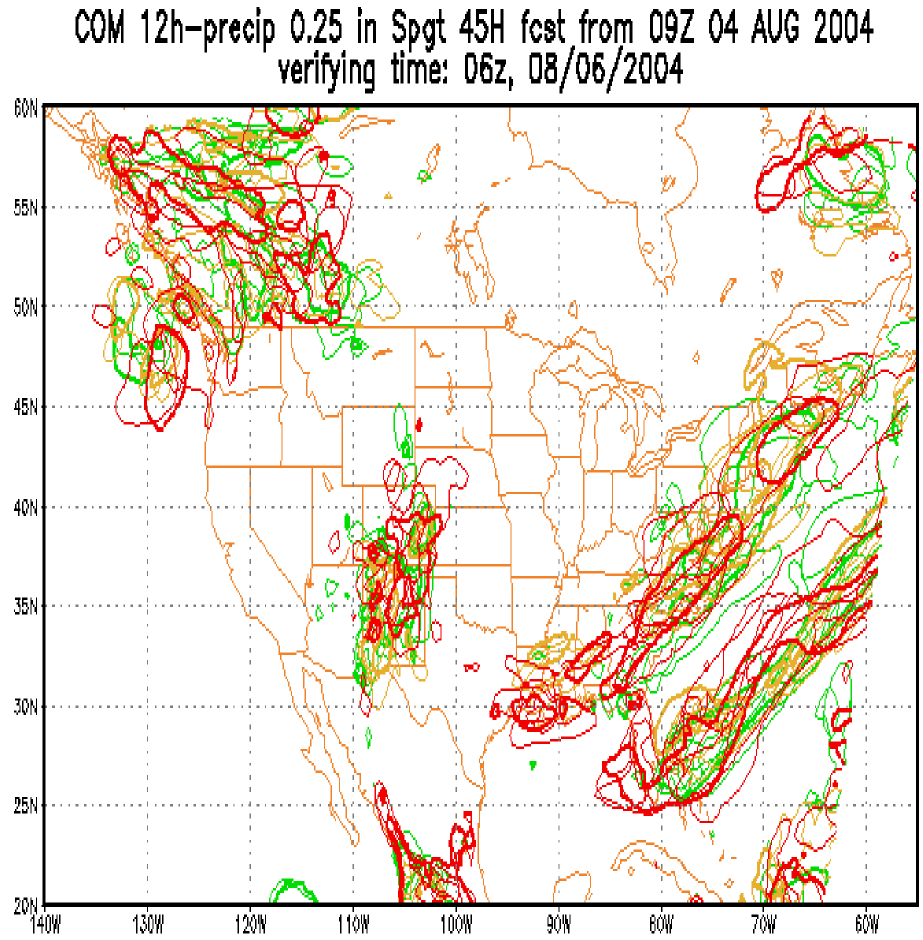
(2) multi-physics: **GFS, Eta, MM5, BMJ/SAT, KF/DET, SAS/RAS (current)**, diversity in LSM, cloud, PBL, radiation as well as WRF-GFS, WRF-RUC in near future [*disadvantage: don't produce enough spread in larger scale (Du) and cannot maintain extra spread after a certain time length (according to Peter H.*)]

(3) stochastic physics: currently an ongoing research on NCEP global ensemble (Dingchen Hou) and could be adopted to SREF once it's ready. (<u>issue: can stochastic physics alone perform as well as or exceed what multi-model and multi-physics ensemble can currently provide in a consistent manner?)</u>

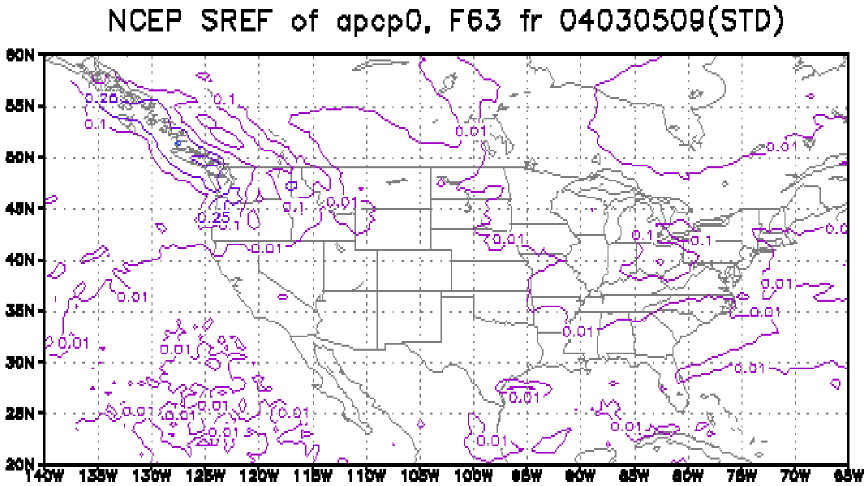
Before introducing "physics diversity"



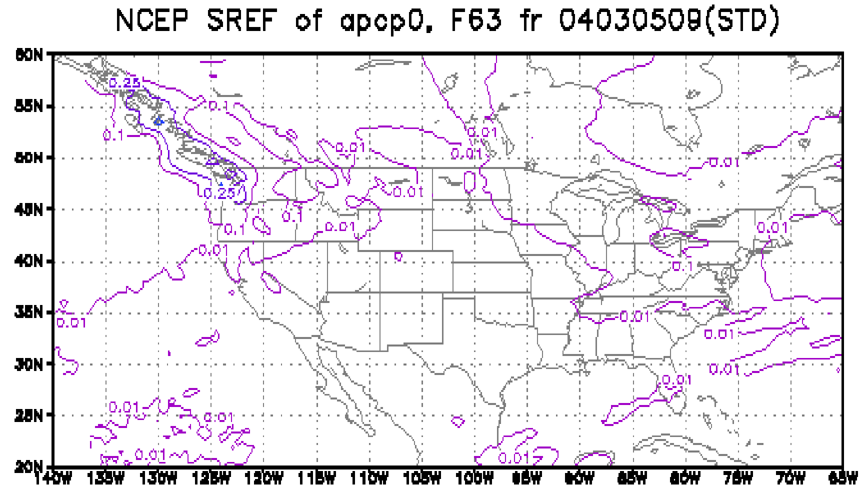
After introducing "physics diversity"



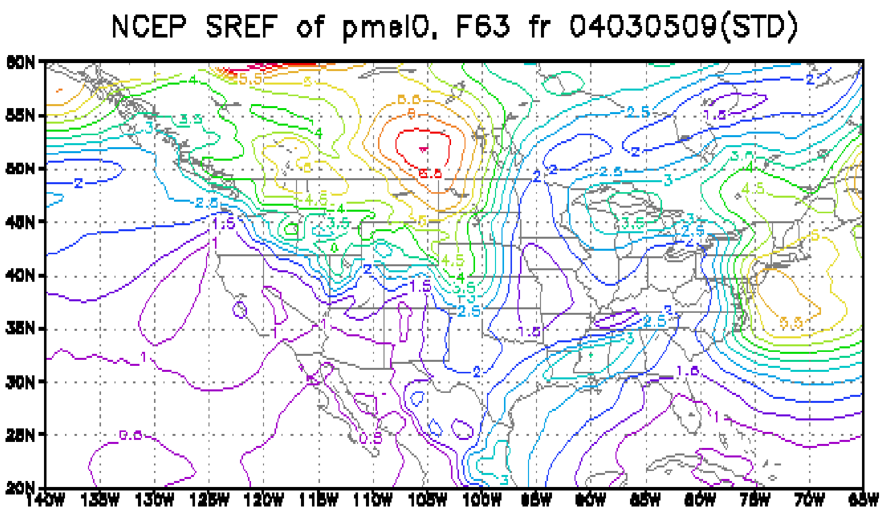
Cold season case 1(09z, March 5, 2004): ens spread comparison at 63h fcst: similar



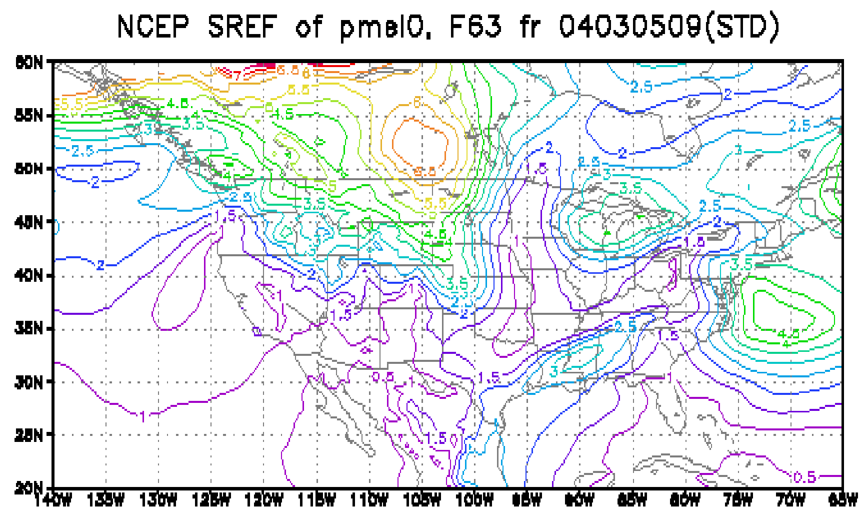
OPS/12h-apcp



PAR/12h-apcp



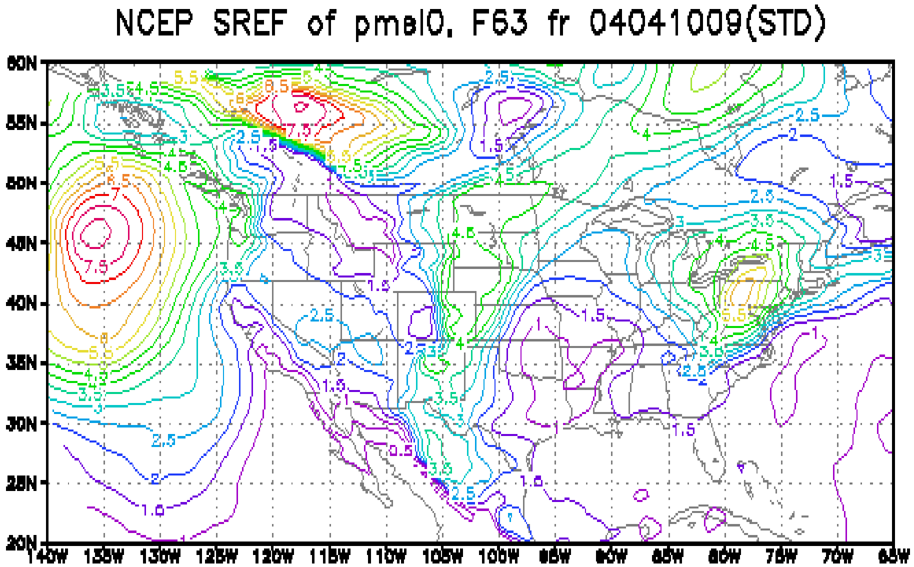
OPS/SLP



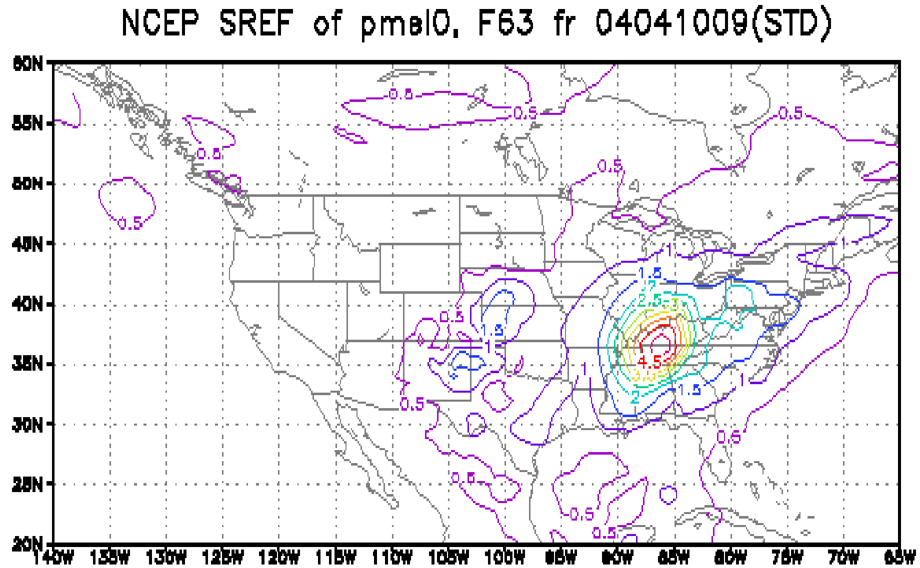
PAR/SLP

<u>Sensitivity Experiment on IC vs Physics (Experiment I)</u>

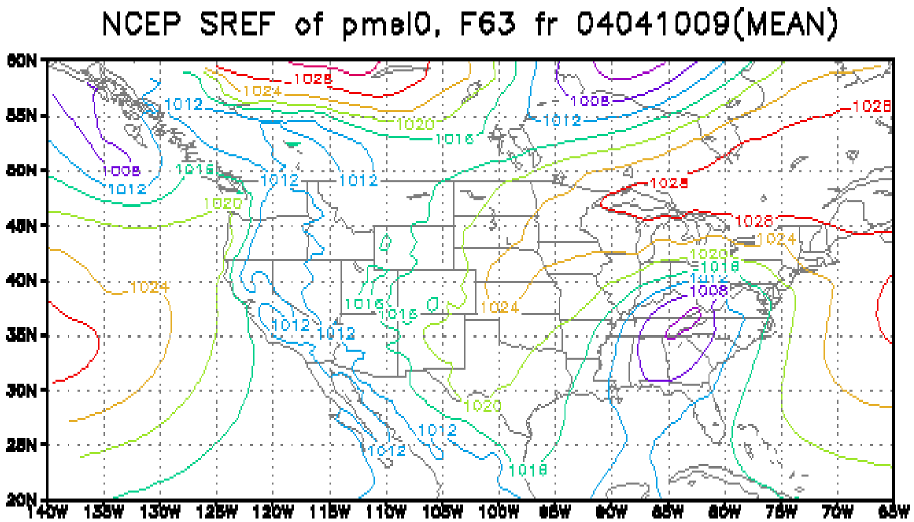
IC-ensemble	**PHY-ensemble**
Eta_BMJ_ctl	Eta_BMJ_ctl
Eta_BMJ_n1	Eta_KFc_ctl
Eta_BMJ_p1	Eta_SAT_ctl
Eta_BMJ_n2	Eta_DET_ctl
Eta_BMJ_p2	Eta_CON_ctl
Eta_BMJ_n3	Eta_Fer_ctl
Eta_BMJ_p3	Eta_RAS_ctl



IC-ensemble spread (SLP at 63h)

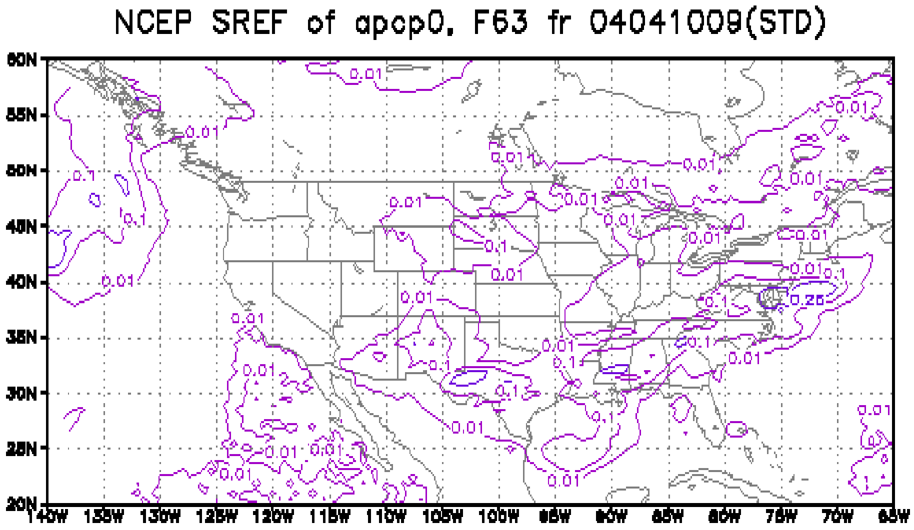


PHY-ensemble spread (SLP at 63h)

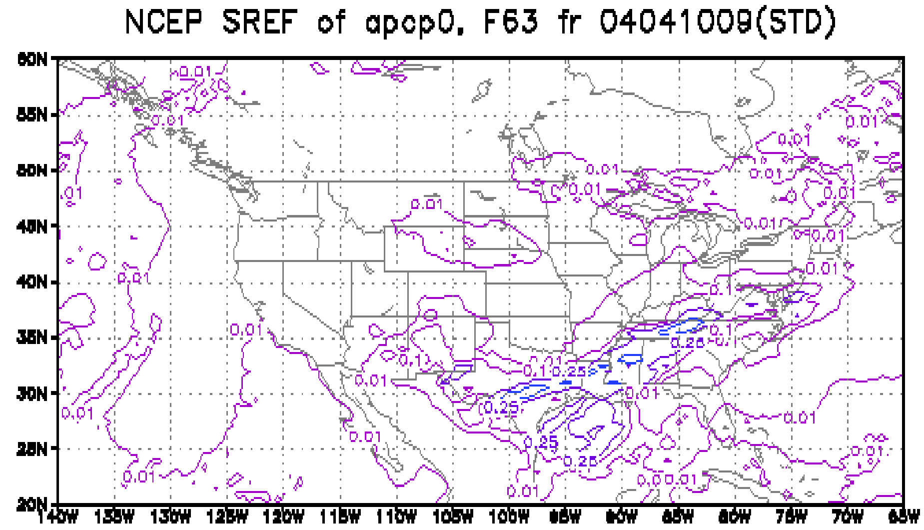


PHY-ensemble mean 63h fcst (SLP)

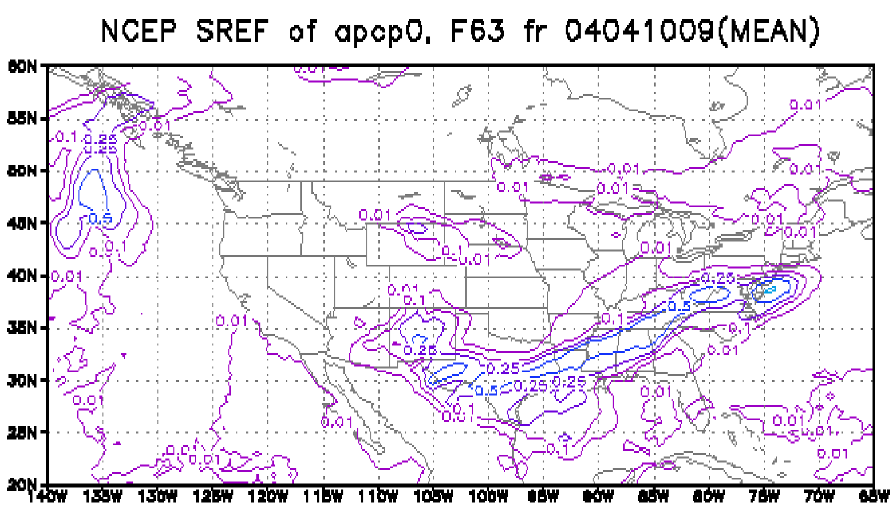
More sensitive to IC pert than PHY
Diversity in general except for the
Cyclone region where is more convective



IC-ensemble spread (12h-apcp at 63h)

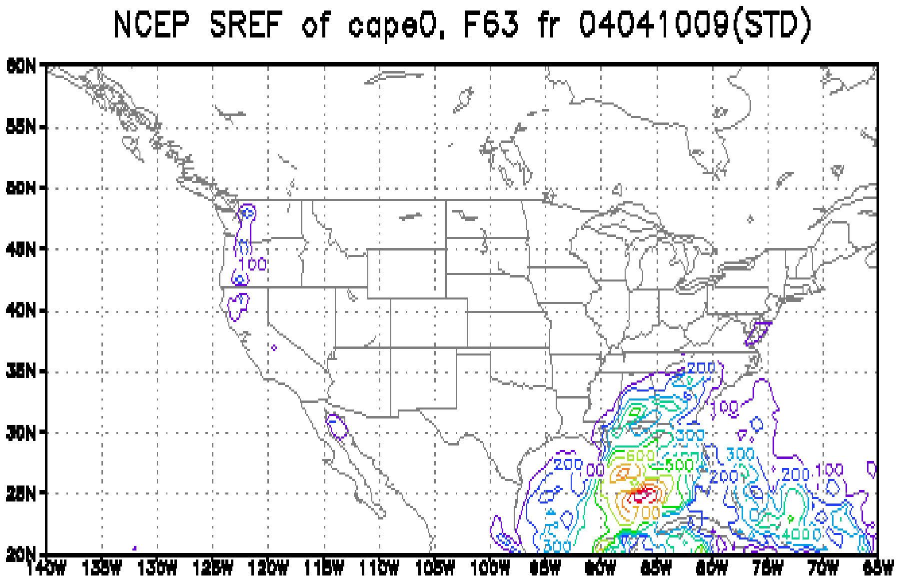


PHY-ensemble spread (12h-apcp at 63h)

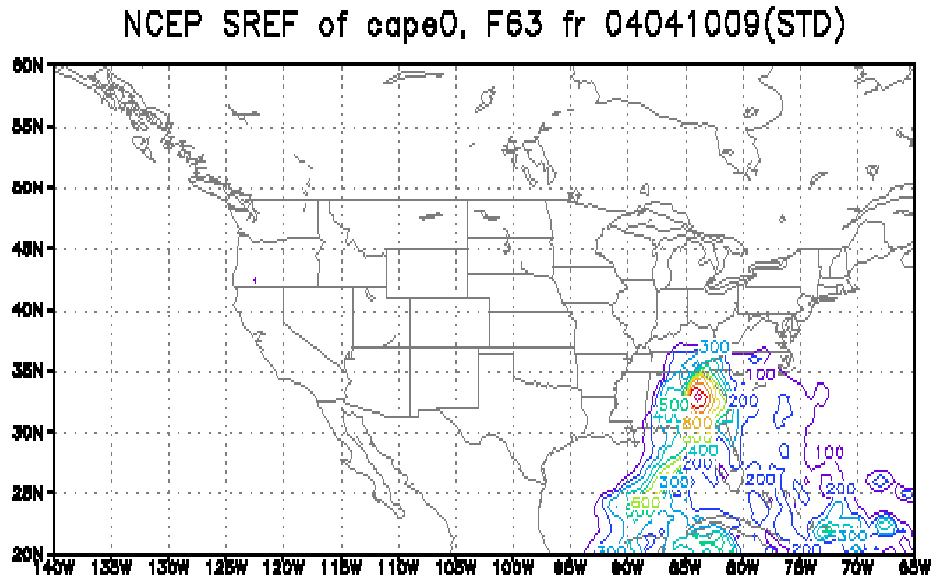


PHY-ensemble mean 63h fcst (12h-apcp)

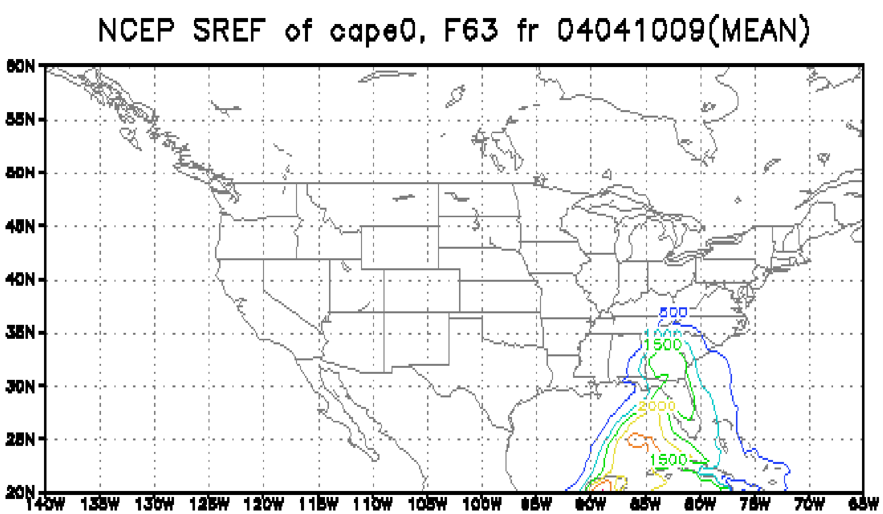
Similar sensitivity to both IC pert and to PHY Diversity for precip in general. PHY diversity enhances sensitivity in Convective areas.



IC-ensemble spread (CAPE at 63h)



PHY-ensemble spread (CAPE at 63h)



PHY-ensemble mean 63h fcst (CAPE)

Equally sensitive to IC pert and PHY Diversity for CAPE (focusing different Sub-regions though)

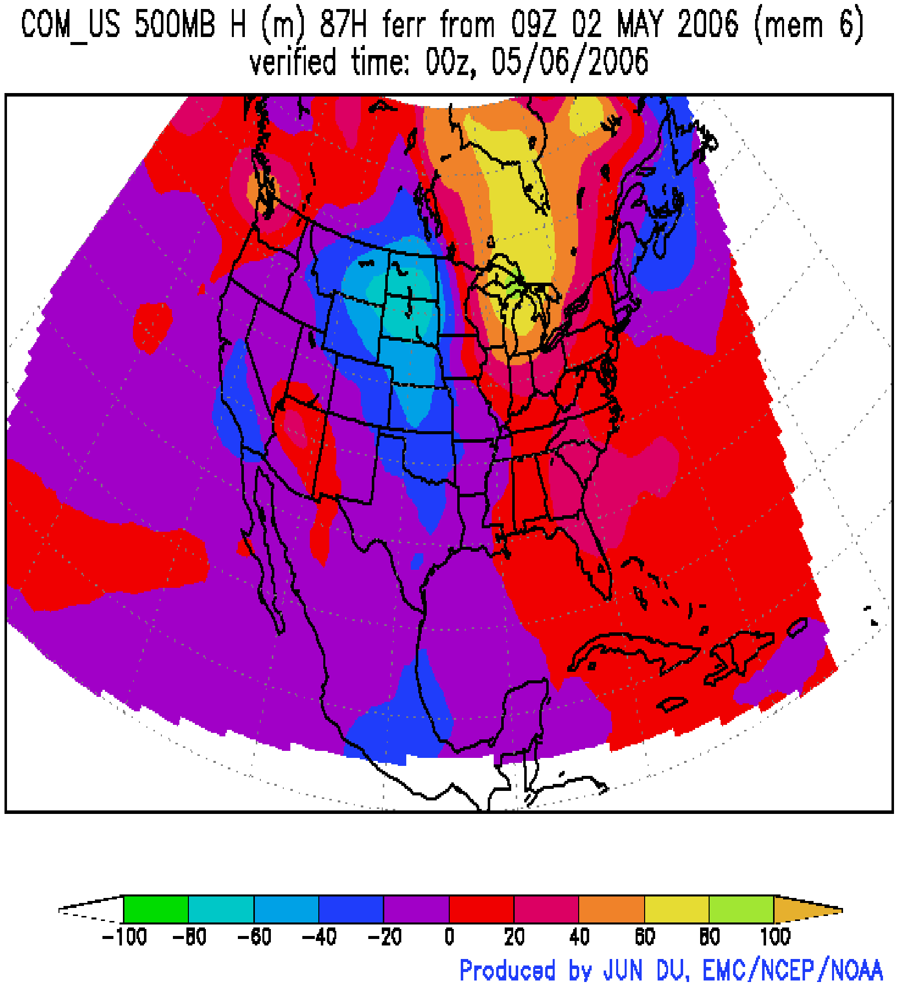
Besides dealing with the uncertainties in initial state, external forcing, governing laws and numerical methods as discussed above

<u>Residual Part (either uncounted or over estimated uncertainties)</u>: post processing to calibrate ensemble system to have a reliable probabilistic forecast. **Currently, work is going on only for the 1st-moment (statistical decaying average by Cui and dynamical/flow-dependent dual-resolution approach by Du (2007).**

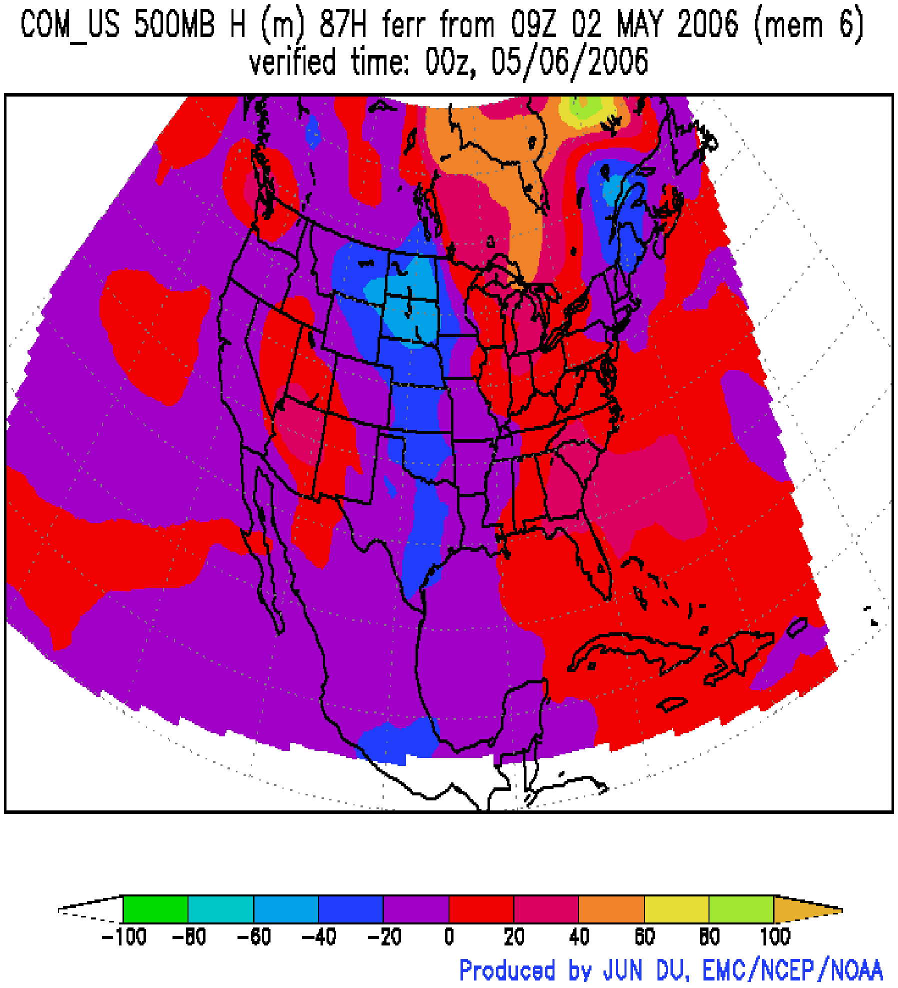
BMA-type approach is planned to be tested in future for the 2nd- and higher moments (Toth); Huiling Yuan of GSD (former FSL) is also working on a bias correction method for the SREF.

Post-processing with Hybrid-Ensembling appraoch (Du, 2004): fcst error of 21-mem ens mean of 500mb H at 3.5 days

Raw SREF fcst error



Hybrid SREF fcst error



Bias correction of PQPF Over the central U.S., day 3

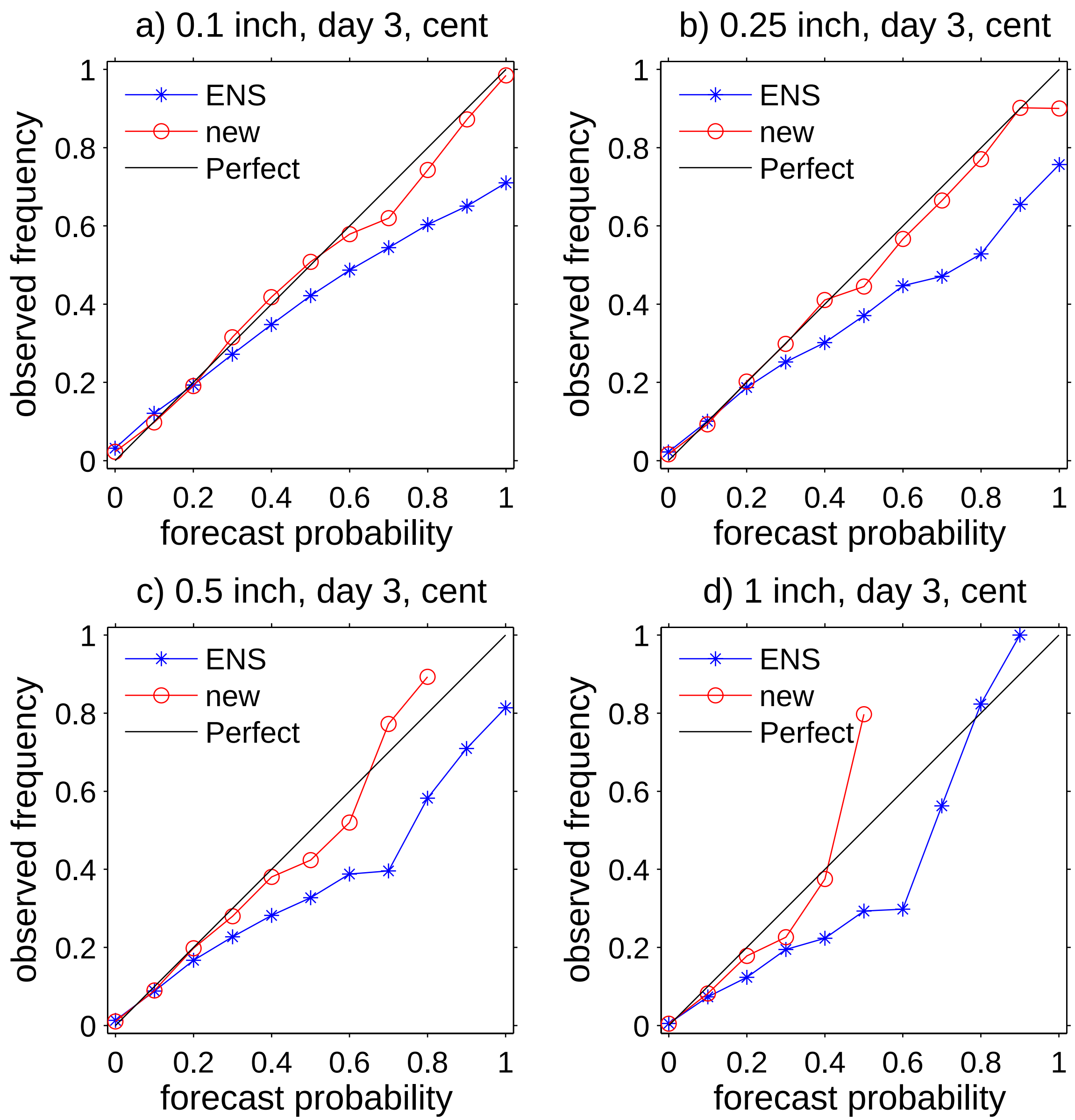
Reliability Diagrams

Cross validation

blue: old, red: new

2006 April-Sept.

Thresholds: 0.1, 0.25, 0.5, 1 inch /24 h



Reliability improved

Lack high probabilities for higher thresholds

(Huiling Yuan/GSD, 2006)

SREF Configuration

- 21 members (**5 Eta_bmj, 5 Eta_kf, 5 RSM, 3 WRF_nmm, 3 WRF_arw** → about 10 WRF_nmm & 10 WRF_arw in 2008)
- **32-45km** → 32km for all members (2007) → 20-25km (2009)
- Four cycles per day (**03,09,15,21z**) → 00,06,12,18z in future
- **3hrly output to 87hr each cycle** (possibly hourly output in future)
- Three output domains: **CONUS, Alaska and Pacific/Hawaii**

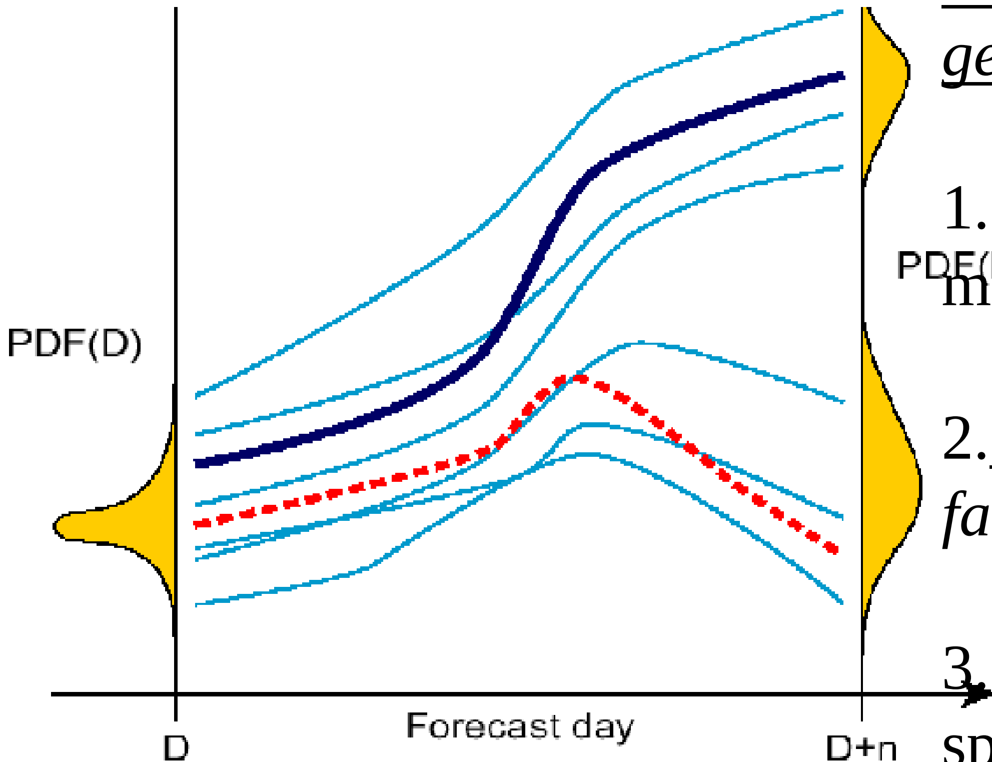
(2) To Convey Uncertainty

Ensemble Product type in general:

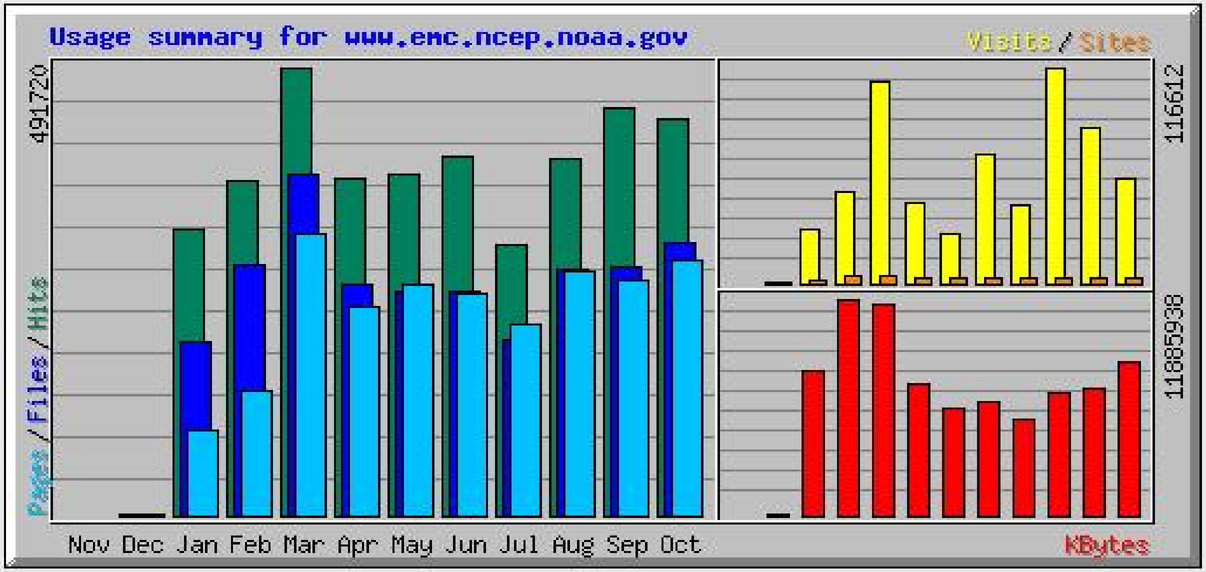
1. single outcome: mean, median, mode, extremes

2. uncertainty: spread, *confidence factor*

3. distribution: probability, spaghetti, meteogram, postage stamps, *clustering*



Schematic of Stochastic Prediction: The initial probability PDF(D) represents the initial uncertainties. From the best estimate of the initial state a single deterministic forecast (blue solid curve) is performed. This single deterministic forecast fails to predict correctly the future state (red dotted curve). An ensemble of perturbed forecasts (thin blue solid curves) starting from perturbed initial conditions designed to sample the initial un- certainties can be used to estimate the probability PDF(D+n) at future time, D+n.



Summary by Month

Month	Daily Avg				Monthly Totals					
	Hits	Files	Pages	Visits	Sites	KBytes	Visits	Pages	Files	Hits
Oct 2006	15016	10315	9624	1949	3467	8382703	56538	279108	299145	435476
Sep 2006	14867	9045	8620	2789	2903	7026105	83692	258626	271375	446034
Aug 2006	12631	8705	8643	3761	2902	6727309	116612	267938	269864	391590
Jul 2006	9548	6208	6792	1344	3091	5280824	41678	210565	192462	296014
Jun 2006	13131	8221	8138	2324	3250	6206747	69740	244149	246654	393938
May 2006	12043	7926	8129	866	3158	5913219	26875	252015	245730	373343
Apr 2006	12343	8466	7599	1454	3257	7255029	43639	227980	254003	370297
Mar 2006	15861	12069	9995	3514	4022	11553060	108956	309854	374142	491720
Feb 2006	13077	9802	4873	1768	3585	11885938	49504	136467	274460	366166
Jan 2006	10149	6132	3016	924	2270	7930670	28664	93513	190095	314647
Dec 2005	2	1	2	2	2	5	2	2	1	2
Totals						**78161609**	**625900**	**2280217**	**2617931**	**3879227**

SREF Product list (GRIB-ext)

Mean&spread(11)

T (2m, 850,700mb)
T-H-index(2m)
SLP
W(10m,850,250mb)
RH(850,700mb)
Thickness(1000-850mb
850-700mb
1000-500mb)
Hgt(500mb, 250mb)
APCP(3,6,12,24hr)
Dominant precp(3hr)
Snowfall(3,6,12,24hr)
Instability (CAPE,LI,IN)

Probability(15)

T2m>(75,80,85,90,100F)
T-H-Index>(70,75,80,85,90F)
Td2m>(50,60,70,80,90F)
W10m>(15,20,25,34,50 kn)
CAPE>(500,1000,2000,3000,4000J/kg)
LI < (0,-4,-8 K)
3hr-apcp > (0.1,0.25,0.5,1.0, 2.0in)
6hr-apcp > (0.1,0.25,0.5,1.0, 2.0in)
12hr-apcp > (0.1,0.25,0.5,1.0, 2.0in)
24hr-apcp > (0.1,0.25,0.5,1.0, 2.0in)
Precip types (rain, frozen-rain, snow)
3hr-snowfall > (1,2.5,5,10,20 in)
6hr-snowfall > (1,2.5,5,10,20 in)
12hr-snowfall > (1,2.5,5,10,20 in
24hr-snowfall > (1,2.5,5,10,20 in)

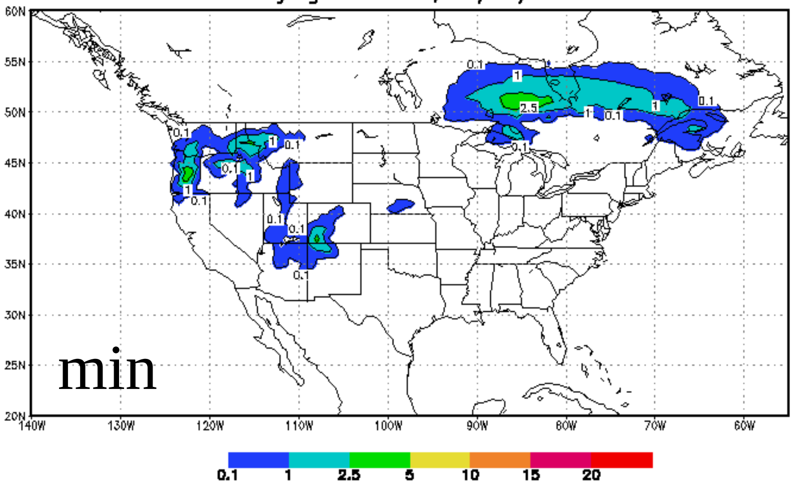
Spaghetti(12)

Surface pressure=(976,984,…..1008,1016mb)
T2m=(-35,-30,..-5,0, 5,…30,35C)
500mb-hgt=(5220,5280,….5820,5880m)
T850mb=(-15,-10,-5,0,5,10,15C)
1000-850mb thickness=(1240,1280,…1360m)
850-700mb thickness=(1480,1500,…1560m)
1000-500mb thickness=(5160,5280,…5640m)
CAPE=(500,1000,2000,3000,4000 J/kg)
3hr-apcp=(0.1,0.25,0.5,1.2 in)
6hr-apcp=(0.1,0.25,0.5,1.2 in)
12hr-apcp=(0.1,0.25,0.5,1.2 in)
24hr-apcp=(0.1,0.25,0.5,1.2 in)

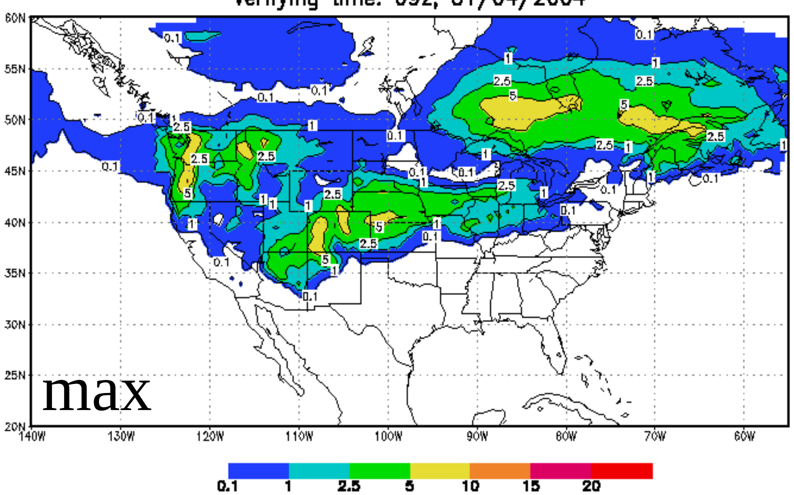
■ SREF Aviation product List (Binbin)

Variables (14)	Products	Levels/Regions	Algorithms
Icing	Prob of occurrence	FL240,180,150,120 090,060,030,FL000	T-RH-Vertical drift
Clear air turbulence (CAT)	Prob of occ (LGT,MDT,SVR)	FL420,390,360,330 300,270,240,FL210	Ellrod 1992
Cloud	Mean/spread Prob of ovc,sct,bkn,clr	Ceiling, cloud base	Model-output
Visibility	Mean/spread	Surface	Stoelinga 1999
Ceiling	Mean/spread	Ceiling, cloud base	Conditional
Flight-Restriction	Prob of LIFR,IFR,MVFR,VFR	Vis and/or Ceiling	Visibility-ceiling
Jet-stream	Prob of >60,80,100 kt	4500, 18000, 34000 ft.	Model-output
10m-wind speed	Mean/spread Prob of >10,20,30 kt	10m	Model-output
Convective cloud	Mean/spread/directions		Grid convective cloud
Low level wind shear (LLWS)	Mean/spread Prob of severe (20 kt/2000 ft)		Wind vector difference
Tropopause	Mean/spread		Model-output
Freezing-level	Mean/spread	Sfc, 4000, 8000, 12000, 16000	Model-output
Fog	Prob of occurrence	Surface	Cloud base/top threshold
Mountain obscuration to be added	Prob of occurrence	Mountains	RH ≥ 80%, 90% Cloud water/ice/snow

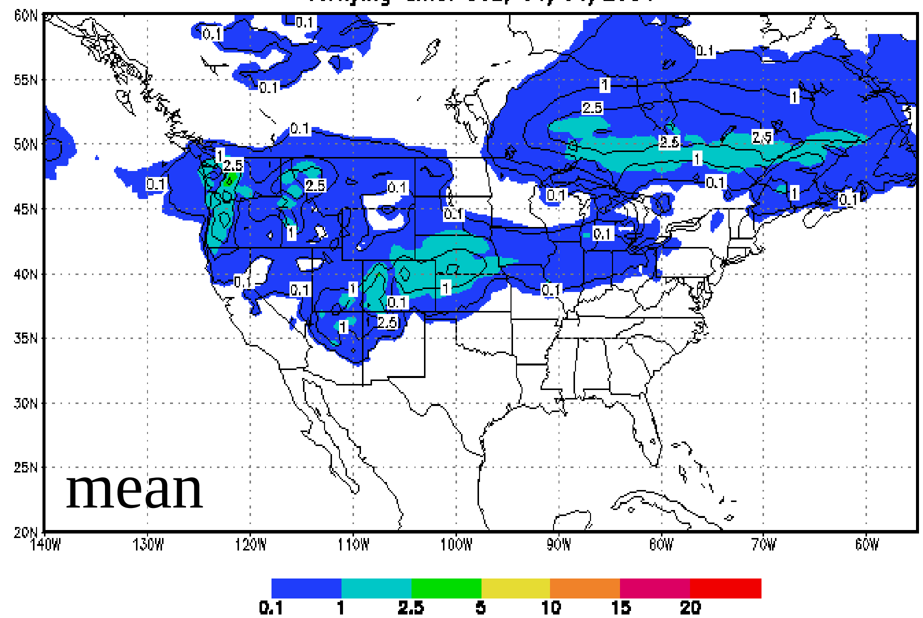
COM minimum 24h-snowfall (in) 48H fcst from 09Z 02 JAN 2004
verifying time: 09z, 01/04/2004

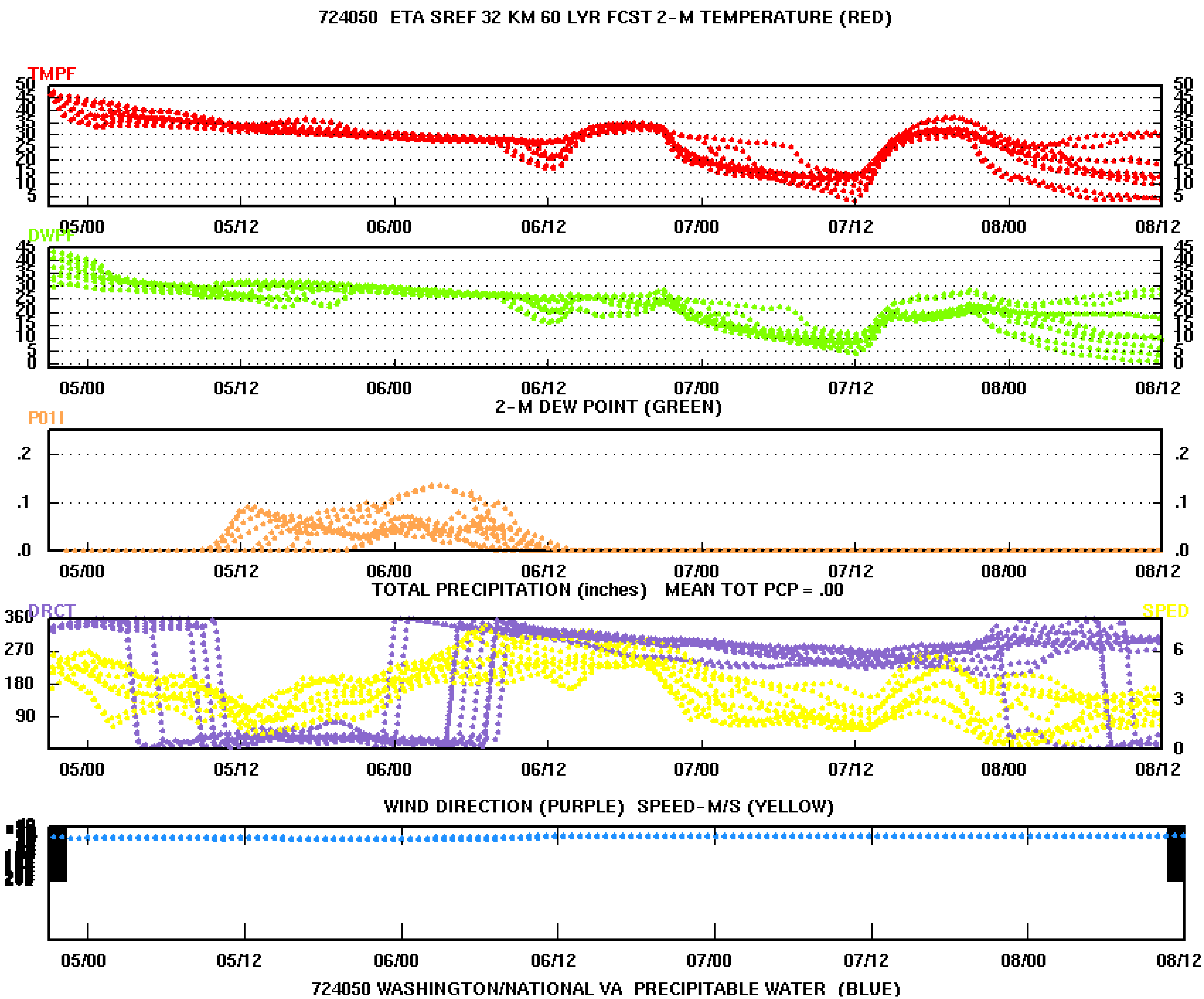


COM maximum 24h-snowfall (in) 48H fcst from 09Z 02 JAN 2004
verifying time: 09z, 01/04/2004

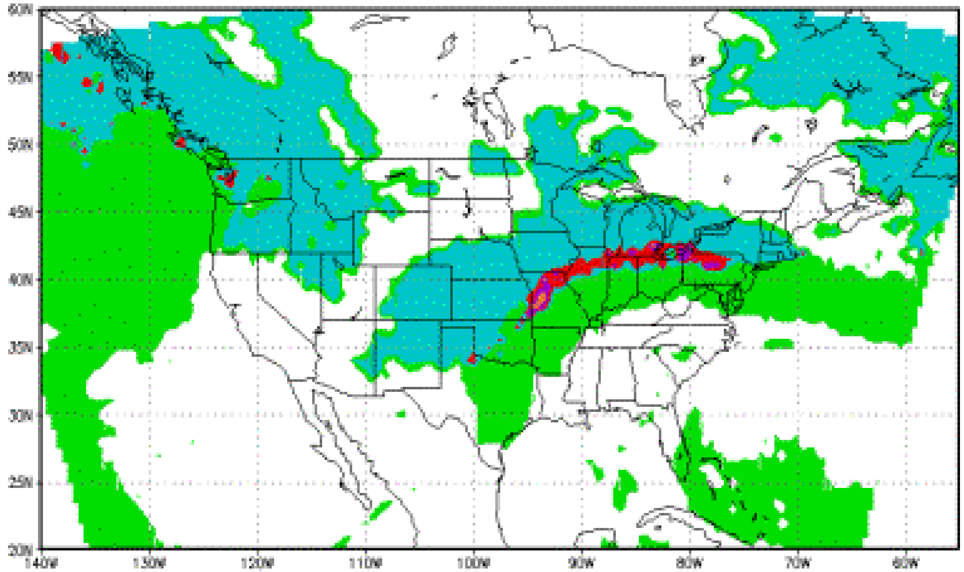


COM 24h-snowfall (in) 48H fcst from 09Z 02 JAN 2004
mean is in contour and color represents spread in inches
verifying time: 09z, 01/04/2004




724050 ETA SREF 32 KM 60 LYR FCST 2-M TEMPERATURE (RED)
TMPF
DWPF
2-M DEW POINT (GREEN)
P01I
TOTAL PRECIPITATION (inches) MEAN TOT PCP = .00
DRCT
SPED
WIND DIRECTION (PURPLE) SPEED-M/S (YELLOW)
05/00
05/12
06/00
06/12
07/00
07/12
08/00
08/12
724050 WASHINGTON/NATIONAL VA PRECIPITABLE WATER (BLUE)

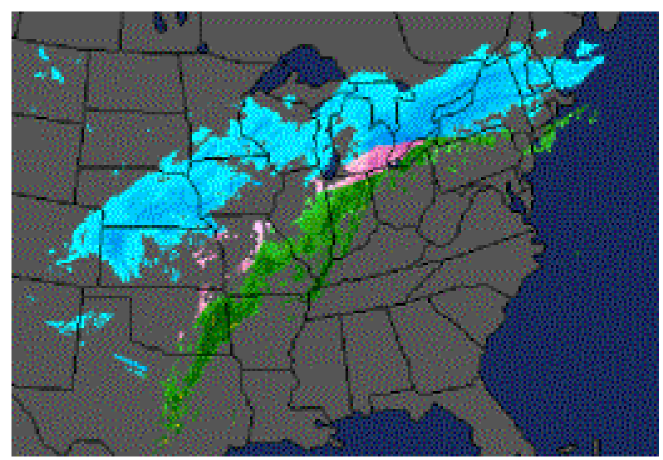
Ensemble Performance January 31, 2002



Dominant precipitation type 27 hour forecast valid 12Z January 31

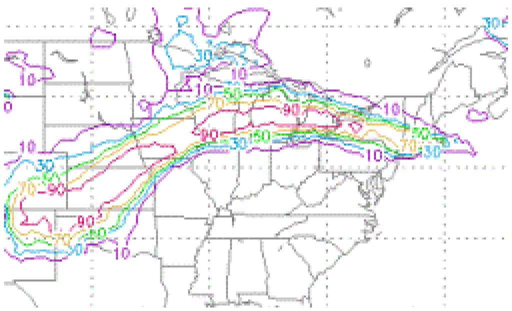
(mode)

9AM Radar January 31

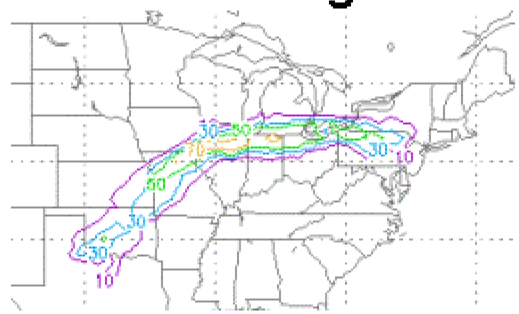


Ensemble Performance January 31, 2002

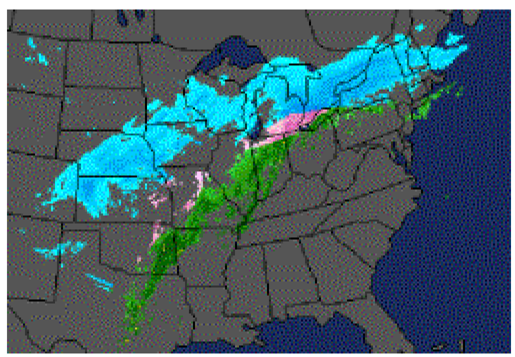
Prob Snow



Prob Freezing Rain



27 hour forecasts valid 12Z January 31



9AM Radar
Jan. 31, 2002

SREF

Grib Mean/Spread Products

Mean and spread Parameters	*Units*	*Level*	*(*= not in Spread files)*
2m Temperature	**[K]**	**Sfc**	
10m U, Vwind	**[m/s]**	**10 m**	
Total precipitation(3,6,12,24hr)	**[kg/m2]**	**Sfc**	
Convective Avail. Pot. Energy	**[J/kg]**		
Convective inhibition (CIN)	**[J/kg]**		
Storm RElative Helicity (SREH)	**[m2/s2]**	**0-3000 m**	
Lifted Index	**[K]**	**0-30 mb abv grnd**	
Sea Level Pressure	**[Pa]**	**Sfc**	
Pressure	**[Pa]**	**1000-50 mb (every 50 mb) ?**	
Categorical rain *	***[y/n]***	***Sfc***	
Dominant precip type (over 3hr)*	***[1-7]***	***Sfc***	
12hrly Large scale Snow Fall*	***[kg/m2]***	***Sfc***	
12hrly Snow Depth*	***[kg/m2]***	***Sfc***	
12hrly Accumulated Snow Fall	**[kg/m2]**	**Sfc**	
Absolute vorticity*	***[/s]***	***1000-50 mb (every 50 mb)?***	
Geopotential height	**[gpm]**	**1000-50 mb (every 50 mb)?**	
Relative humidity	**[%]**	**1000-50 mb (every 50mb)?**	
U, V- wind	**[m/s]**	**1000-50 mb (every 50 mb)**	
Temperature	**[K]**	**1000-50 mb (every 50 mb)?**	
Thickness	**[gpm]**	**1000-850, 1000-500, 850-700mb**	
Total preciptable water			

SREF
probabilistic products

Probabilistic Parameters	*Units*	*Threshold*
Convective Avail. Pot. Energy	**[J/kg]**	**≥ 500, 1000, 2000, 3000, 4000**
Convective Inhibition (CIN)	**[J/kg]**	**≤ -50, -100, -200, -300, -400**
Storm Relative Helicity (SREH)	**[m2/s2]**	**≥ 100, 150, 200, 250, 300**
Lifted Index	**[K]**	**≤ 0, -2, -4, -6, -8**
Precipitation (3, 6, 12, 24 hr)	**[Inches]**	**≥ 0.1, 0.25,0.5, 1.0, 2.0**
12hrly Accumulated Snow Fall	**[Inches]**	**≥ 1, 2.5, 5, 10, 20**
Prob precip type is rain	**[%]**	
Prob precip type is freezing rain	**[%]**	
Prob precip type is snow or sleet	**[%]**	

SREF Variables at AWIPS/2007

Means/Spreads

- Heights at 1000, 850, 700, 500, 250 mb
- U+V at 1000, 850, 700, 500, 250 mb & 10 m
- Temperature 850, 700, 500 mb & 2 m
- Dew Point (RH) 850, 700, 500 mb & 2 m
- QPF at 3, 6, 12 and 24 hour totals
- 12-hr Snowfall
- Sea Level Pressure
- Precipitable Water

Probabilistic Fields

- 3-hr/6-hr QPF GE .01”, .25”, .50”, 1.0”
- 12-hr/24-hr QPF GE 01”, .25”, .50”, 1.0”, 2.0”
- 12-hr Snowfall GE 1”, 4”, 8”, 12” (have 2.5, 5, 10, 20”)
- Temperature at 2 m & 850 mb LE 0^oC
- 10 m Wind GE 25 kt, 34 kt, 50 kt
- CAPE GE 500, 1000, 2000, 3000, 4000
- Lifted Index LE 0, -4, -8
- Surface Visibility LE 1 mi, 3 mi
- Cloud Ceiling LE 500 ft, 1000 ft, 3000 ft
- Probability of precipitation types (have rain, frozen, & freezing)
- 6-hr/12-hr/24-hr QPF Best Category

3. Downstream Applications of SREF

- DTRA dispersion model (HPAC/SCIPUFF, Jeff McQueen, Patrick Hayes, Steve Hanna and PSU/David Stauffer)
- SREF drives Air Quality Forecast system (research, a student of Prof. Eugenia Kalnay from UMD, Ms. Debra Baker, is working with us now)
- Hydrology in future (this workshop)?