2009 CAPS Spring Forecast Experiment

Program Plan

April 20, 2009

Table of Content

1. Overview of New Features for 2009 Season

Major changes from 2008:

- **Add eight WRF-NMM members into the ensemble system**. Since WRF-NMM uses rotated lat-lon horizontal grid (E-grid), its computational domain does not match WRF-ARW's. As a result, three different domains are used for the 2009 season (see Figure 1). The WRF-ARW members have the same domain as in 2008, which also serves as the common verification domain for both WRF dynamical cores. The WRF-NMM domain encompasses the ARW domain, and is encompassed by an even larger outer domain in which 3DVAR radar data analysis is performed (for both WRF cores). **Add two ARPS members into the ensemble system**, one with radar data and one without, bringing the total number of storm-scale emsemble members to 20.
- **A fine-scale deterministic forecast at 1 km grid spacing**, covering the same WRF-ARW domain as the 4 km ensemble, replaces the 2 km forecast in 2008. This new forecast will be performed on ***Kraken*** at the National Institute of Computing Sciences (NICS) in the University of Tennessee, utilizing over 9600 computer cores each operation day for duration of about 7 hours.
- **WRF version 3.0.1.1** (released August 22, 2008) will be used for 2009 season. As a result, and for NMM core supporting, the ARPS-WRF interface package has been enhanced by adding two NMM-interface programs, *arps4wrf* and *nmm2arps*, and revising the existing ARW-interface programs, *arps2wrf* and *wrf2arps*.
- **Add two 12 UTC update forecasts over a smaller domain** (as part of VORTEX II project), one run is 3DVAR initialized (with radar data) and the other one is NAM 12 km initialized (without radar data). Both are 18 h forecasts ended at 0600 UTC the next day, running on ***Sooner***. Hourly precipitation and composite reflectivity forecast will be transferred to DTC in real-time for experimental demonstration of its MET verification package.
- **Two 18 UTC update forecasts on demand basis,** with the same domain and configuration, running also on Sooner.

Other changes from 2008:

- A new ARPS-WRF interface package, *arps4wrf* and *nmm2arps*, is developed in supporting WRF-NMM runs. The new interface utilizes standard WRF IO API.
- Extra 2D fields are added to the GEMPAK files, including vertical integrated graupel/hail, …
- Several 2D fields will be written out in 5 min interval inside WRF (ARW) by two ensemble members (cn and c0) and the 1 km run – for animated side by side comparison against NSSL reflectivity mosaic. The high frequency 2D dumps include composite reflectivity, reflectivity at 5 km AGL, 10 m u and v. Code changes to WRF (ARW) system are made.

- WRF-NMM is modified to include 2 m temperature and moisture in history output list (The official release only writes out the variables for MYJ LSM scheme)
- real_nmm (in WRF-NMM) is modified to take in hydrometeors variables (Qc, Qr, Qs, and Qh) that are generated from the 3DVAR output.

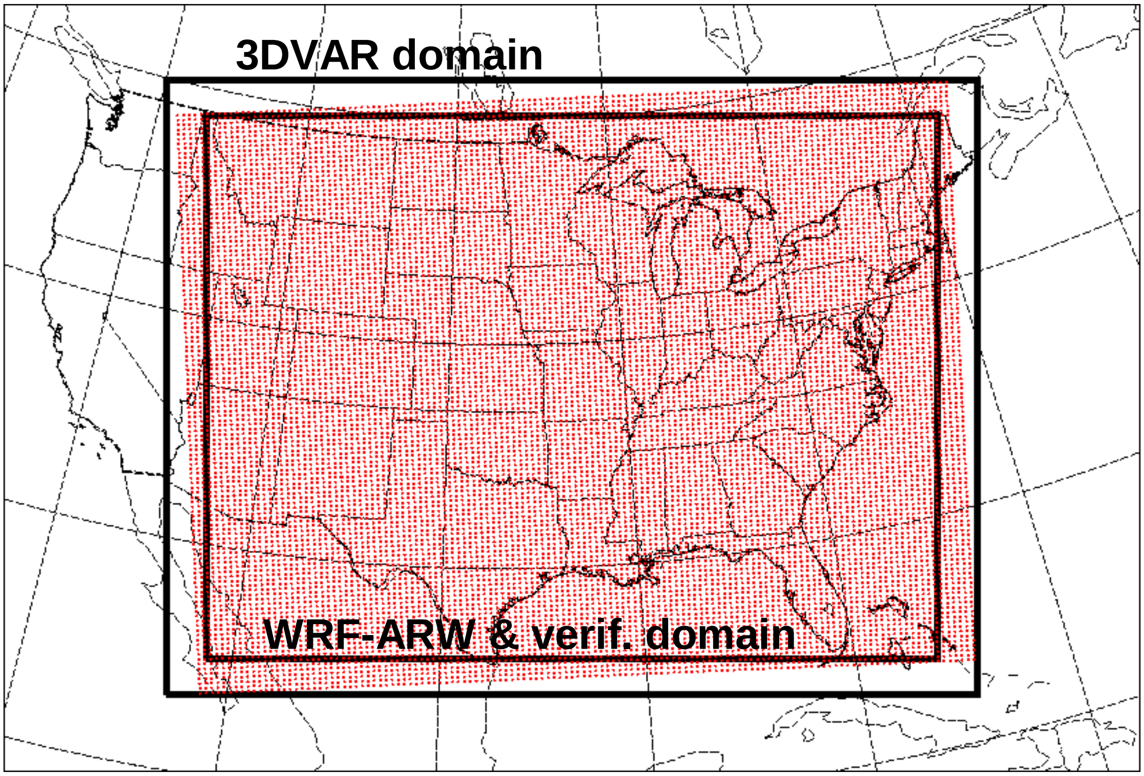

*Figure 1. Computational domains for the 2009 Season. The outer thick rectangular box represents the domain for performing 3DVAR (**Grid 1** – 1000×760). The red dot area represents the WRF-NMM domain (**Grid 2** – 650×979). The inner thick box is the domain for WRF-ARW and ARPS and also for common verification (**Grid3** - 900×672).*

2. Program Duration

From **20 April 2009** though **5 June 2009**

The 2009 SPC/NSSL HWT Spring Experiment, a joint effort among NOAA Storm Prediction Center (SPC) and National Severe Storm Laboratory (NSSL) and the Center for Analysis and Prediction of Storms (CAPS) at University of Oklahoma, will officially start on 4 May and end on 5 June, with four days a week (Monday through Thursday). CAPS 2009 Spring Program will begin regular forecast production two weeks earlier on 20 April, and will remain five days a week (running forecasts on the night of Sunday through Thursday) with possible weekend runs upon SPC request according to weather circumstance.

Related program

VORTEX-II:

CASA:

3. Forecast System Configuration

Both WRF solvers, ARW and NMM, will be used in 2009 Spring Experiment. All forecasts use **51** vertical levels, though horizontal grids are different between ARW and NMM. WRF code (both cores) was modified by CAPS to allow initial hydrometeor fields generated from 3DVAR/ARPS Cloud analysis of WRS-88D radar reflectivity to pass into WRF initial condition, and (for ARW) to write out reflectivity field every 5 min. ARPS members have the same horizontal grid as WRF-ARW, while its vertical grid is different with 43 vertical levels.

Storm-scale ensemble forecast:

All experimental forecasts will be generated with both dynamical cores (solvers) of the Weather Research and Forecast (WRF) modeling system (**Version 3.0.1.1)**, the Advanced Research WRF (ARW) core and the operational NMM core**.** As in 2008 season, the 00Z NAM analyses available on the 12 km grid (218) will be used for initialization of control (non-perturbed) members and as first guess for initialization of perturbed members with the initial condition perturbations coming directly from the NCEP Short-Range Ensemble Forecast (SREF). WSR-88D data will be analyzed using ARPS 3DVAR and cloud analysis system, over **Grid 1**, for all members except two (one from each core). Forecast output at hourly intervals (higher time frequency output for a limited selection of 2D fields) will be archived at the PCS mass storage (FAR).

The *daily* ensemble forecast configuration includes the following, all of which will be run on ***Bigben***, a Cray XT3 system and one of NSF TeraGrid resources at Pittsburgh Supercomputing Center (PSC), except the two ARPS members which will be run on Kraken at NICS:

- ARW: A daily 30-hour, 10-member ensemble at 4 km grid spacing over **Grid 3** initialized at 00 UTC. Model execution will begin around 0230 UTC (9:30pm CDT) and finish in about 10 hours, using about 800 CPUs, with results being processed as they become available. **Table 1** lists the configuration and physics options for each ARW member.

- One control 4 km forecast uses ARPS 3DVAR and cloud analysis (with radar data – both radial wind and reflectivity) with NAM 00 UTC 12-km grid analysis as the background and the 00 UTC NAM forecasts as boundary conditions. The radar analysis is performed over a larger Grid 1, and is trimmed to fit the ARW forecast grid (Grid 3).
    - Another 4 km member is the same as the 4 km control except for using as IC the 12 km NAM 00 UTC analyses directly (no-radar)
    - Eight members with IC perturbations as well as physics variations. The IC/BC perturbations will be derived from the evolved (through 3 hours) bred perturbations of the 21 UTC SREF, and we will use SREF's WRF-ARW, WRF-NMM, RSM, ETA-BMJ and ETA-KF positive and negative pairs. The IC perturbations are extracted from the IC-perturbation members of SREF, and added to the IC of control member. The BCs will come directly from the forecasts of corresponding SREF (perturbed) members. They represent the direct nesting of storm-scale ensemble forecasts within the SREF, with enhanced resolution for the IC. For most members physics options are the same as in 2008, except RUC LSM is used for two members (due to WRFV3's better support of RUC LSM scheme) – arw_n2 and arw_p4. By doing so, one member (arw_n2) has the same physics configuration as the planned 3 km HRRR (High Resolution Rapid Refresh) at NOAA/ESRL/GSD
- <u>NMM:</u> A daily 30 h, 8-member NMM at about 4 km grid spacing over **Grid 2**, initialized at 00 UTC. **Table 2** lists the configuration and physics options for each NMM member.
    - One control 4 km forecast uses ARPS 3DVAR and cloud analysis (with radar data – both radial wind and reflectivity) with NAM 00 UTC 12-km grid analysis as the background and the 00 UTC NAM forecasts as boundary conditions. The radar analysis is performed over a larger Grid 1 (only need down once for both cores), and is interpolated using arps4wrf to the NMM forecast grid (Grid 2). The physics options for this control member are the same as NCEP operational forecasts (NAM and NMM 4km) – they are different from ARW's.
    - Another 4 km member is the same as the 4 km control except for using as IC the 12 km NAM 00 UTC analyses directly (no-radar)
    - Six members with IC perturbations as well as physics variations. The IC/BC perturbations are constructed similarly as ARW members.
- <u>ARPS:</u> A daily 30 h, 2-member ARPS forecasts at 4km grid spacing over **Grid 3**, initialized at 00 UTC. (**Table 3**)
    - One control member (arps_cn) using ARPS 3DVAR and cloud analysis (with radar data – both radial wind and reflectivity) with NAM 00 UTC 12-km grid analysis as the background and the 00 UTC NAM forecasts as boundary conditions. The radar analysis is performed in **Grid 3** with ARPS vertical grid configuration of 43 stretching levels.
    - Another member (arps_c0) doesn't perform radar analysis, directly using as IC the 12 km NAM 00 UTC analyses.

- Lin microphysics scheme is used for both ARPS members. Other physics options (radiation, PBL, turbulence) used are those from ARPS physics package (not the same as either WRF cores). See Table 3.

Table 1. Configurations for each individual member with ARW core. NAMa and NAMf refer to 12 km NAM analysis and forecast, respectively. ARPSa refers to ARPS 3DVAR and cloud analysis

member	IC	BC	Radar data	mp_phy	sw-phy	sf_phy	pbl_phy
arw_cn	00Z ARPSa	00Z NAMf	yes	Thompson	Goddard	Noah	MYJ
arw_c0	00Z NAMa	00Z NAMf	no	Thompson	Goddard	Noah	MYJ
arw_n1	arw_cn – em_pert	21Z SREF em-n1	yes	Ferrier	Goddard	Noah	YSU
arw_p1	arw_cn + em_pert	21Z SREF em-p1	yes	WSM 6-class	Dudhia	Noah	MYJ
arw_n2	arw_cn – nmm_pert	21Z SREF nmm-n1	yes	Thompson	Dudhia	RUC	MYJ
arw_p2	arw_cn + nmm_pert	21Z SREF nmm-p1	yes	WSM 6-class	Dudhia	Noah	YSU
arw_n3	arw_cn – etaKF_pert	21Z SREF etaKF-n1	yes	Thompson	Dudhia	Noah	YSU
arw_p3	arw_cn + etaKF_pert	21Z SREF etaKF-p1	yes	Ferrier	Dudhia	Noah	MYJ
arw_n4	arw_cn – etaBMJ_pert	21Z SREF etaBMJ-n1	yes	WSM 6-class	Goddard	Noah	MYJ
arw_p4	arw_cn + etaBMJ_pert	21Z SREF etaBMJ-p1	yes	Thompson	Goddard	RUC	YSU

* For all members: ra_lw_physics= RRTM; cu_physics= NONE

Table 2. Configurations for each individual member with NMM core

member	IC	BC	Radar data	mp_phy	lw_phy	sw-phy	sf_phy	pbl_phy
nmm_cn	00Z ARPSa	00Z NAMf	yes	Ferrier	GFDL	GFDL	Noah	MYJ
nmm_c0	00Z NAMa	00Z NAMf	no	Ferrier	GFDL	GFDL	Noah	MYJ

nmm_n1	nmm_cn – em_pert	21Z SREF em-n1	yes	Thompson	RRTM	Dudhia	Noah	MYJ
nmm_p1	nmm_cn + em_pert	21Z SREF em-p1	yes	WSM 6-class	GFDL	GFDL	RUC	MYJ
nmm_n2	nmm_cn – nmm_pert	21Z SREF nmm-n1	yes	Ferrier	RRTM	Dudhia	Noah	YSU
nmm_p2	nmm_cn + nmm_pert	21Z SREF nmm-p1	yes	Thompson	GFDL	GFDL	RUC	YSU
nmm_n3	nmm_cn – etaKF_pert	21Z SREF etaKF-n1	yes	WSM 6-class	RRTM	Dudhia	Noah	YSU
nmm_p3	nmm_cn + etaKF_pert	21Z SREF etaKF-p1	yes	Thompson	RRTM	Dudhia	RUC	MYJ
nmm_n4	nmm_cn – etaBMJ_pert	21Z SREF etaBMJ-n1	yes	WSM 6-class	RRTM	Dudhia	RUC	MYJ
nmm_p4	nmm_cn + etaBMJ_pert	21Z SREF etaBMJ-p1	yes	Ferrier	RRTM	Dudhia	RUC	YSU

* For all members: cu_physics= NONE

**** The two grayed out rows are not included in final real-time forecast system, leaving total eight NMM contributing members, reflecting the computing resource limitation at PSC.**

Table 3. Configurations for each individual member with ARPS

member	IC	BC	Radar data	Microphy.	radiation	sf_phy
arps_cn	00Z ARPSa	00Z NAMf	yes	Lin	Chou/Suarez	Force-restore
arps_c0	00Z NAMa	00Z NAMf	no	Lin	Chou/Suarez	Force-restore

* For all members: no cumulus parameterization

<u>High-resolution (1 km) deterministic forecast:</u>

One 1 km grid spacing forecast over the same ARW domain as the 4 km ensemble (**Grid 3**) will be produced using the same physics configuration as the control member *arw_cn*. The forecast will be initialized from 00 UTC and last 30 h. The ARPS 3DVAR and cloud analysis will be performed separately at the 1 km grid with available radar data (radar radial velocity and reflectivity). NAM 00 UTC analysis will be used as the background and its forecasts will be used to provide the LBC.

The 1 km forecast will be run on ***Kraken***, a Cray XT5 supercomputing system that has over 66000 2.3 GHz AMD Opteron cores, at the National Institute of Computing Sciences (NICS). It will use 9600 CPU cores on ***Kraken*** and will take 7-8 h to run.

<u>1200 UTC and 1800 UTC update forecasts:</u>

Two update forecasts initiated at 1200 UTC will be generated over a smaller domain (Figure 2), one 3DVAR initialized (with radar data analysis) and another one NAM 12 km initialized (without radar data). WRF-ARW model will be used to generate the two 18 h forecasts ending at 0600 UTC the next day. The physics options will be the same as ARW control member, *arw_cn* (see Table 1). These two forecasts will be performed locally on OSCER's ***Sooner*** system. The first 5 h hourly accumulated precipitation and composite reflectivity data will be transferred to DTC in real-time for experimental verification demonstration.

Upon request from SPC, two more update forecasts initialized at 18 UTC will be generated using the same configuration as the 12 UTC forecasts, and will also be run on Sooner.

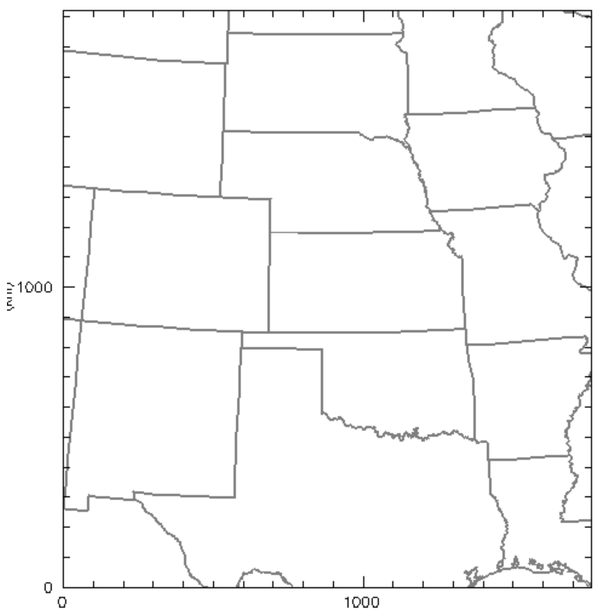

Figure 2. Model domain used for the 12 UTC and 18 UTC update forecasts, with 440×480 horizontal grid points at 4 km grid spacing.

4. Logistics

- 80 PSC ***Bigben*** computing cores will be used by each member, and all ensemble members will be run in parallel in 10 by 8 decomposition. 8-10 hours will be needed. An additional 20 cores will be used for post-processing, running side by side, processing model output when they are produced. (Total **1000 *Bigben*** nodes). Two ARPS members are run on Kraken, using 320 cores for each member in regular job queues (total 640 cores), ARPS forecasts require under 4.5 h to complete.

- The ensemble forecasts will be output every hour, and converted to ARPS grid in HDF4 format in high compression (on Grid 3). Hourly gridded output, in both WRF and ARPS grids, will be archived at PSC in FAR mass storage for the 4 km ensemble runs and at NICS in HPSS storage for the 1 km single runs. Data volume will be close to **1TB** per day on ***Bigben*** and **1.3 TB** per day on ***Kraken*** (1TB WRF raw data; 225 ARPS grid data; 62GB 2D data).

- 2D fields and ensemble products will be extracted/generated and written in the ARPS arbitrary 2D/3D array format for plotting by ARPSPLT and for post-analyses. This task will mostly be performed on ***Sooner***.

- NAM 00 UTC analysis and forecasts (first 30 h) on 218 grid will be downloaded from NCEP ftp server, in tiles. Tiles sufficient to cover CONUS and surrounding areas will be archived by CAPS for later use.

- Eight SREF 21 UTC forecast members (first 33 h) on 212 grid will be made available by NCEP on NCEP ftp server - 2 each from WRF-NMM , WRF-ARW, ETA-KF, and ETA-BMJ, respectively, will be used for the construction of IC/BC for the 4 km perturbed members

- Hourly products and fields for the 1 km grid and for the ensemble will be created and written in GEMPAK format that can be readily ingested into N-AWIPS at SPC.

- Near-real time verification products, for 1 km, 4 km control and for ensemble members will be produced and displayed on CAPS website, including various skill scores for both deterministic and probabilistic forecasts. Verification production is automated for 2009 season.

- CASA: CAPS will be running parallel forecast experiment for CASA, using ARPS model, on OSCER Sooner, using about 800 CPU cores. It will consist of 6 hour forecasts at 1 km horizontal resolution, with and without WSR88D and/or CASA radar data (NETRAD). The goal is to evaluate/demonstrate the value of CASA IP1 radars. ARPS 3DVAR and ARPS will be used, with 40-minute long assimilation window with 10-minute assimilation cycles and IAU (incremental analysis update). [text need update!!!]

- LEAD: on-demand, 15-18 UTC initiation ???

- VORTEX-II: two 12 UTC update forecast, and two demand-base 18 UTC update forecast

5. Forecast Product Generation and Delivery to the SPC

<u>Products that will be available to SPC in GEMPAK:</u>

Table 4 lists the 2D fields (55 fields) that will be produced and made available to SPC in GEMPAK format. Shaded items are new for 2009.

Table 4. 2D fields for SPC

Field	GEMPAK name	Unit	Type	Level
Surface pressure	PRES	hPa	Surface/single layer	0
Sea level pressure	PMSL	hPa	Surface/single layer	0
1-h precipitation	P01M	mm	Surface/single layer	0
Precipitable water	PWAT	mm	Surface/single layer	0
2 m temperature	TMPF	F	Surface/single layer	0
2 m dew point	DWPF	F	Surface/single layer	0
2 m mixing ratio	MIXR	g/kg	Surface/single layer	0
10 m U	UREL	m/s	Surface/single layer	0
10 m V	VREL	m/s	Surface/single layer	0
Surface geo-height	HGHT	m	Surface/single layer	0
1 km AGL reflectivity	REFL1KM	dBZ	Surface/single layer	0
4 km AGL reflectivity	REFL4KM	dBZ	Surface/single layer	0
Composite reflectivity	REFLCMP	dBZ	Surface/single layer	0
Surface-based CAPE	CAPE	J/kg	Surface/single layer	0
Moist unstable CAPE	MUCAPE	J/kg	Surface/single layer	0
Surface-based CIN	CINS	J/kg	Surface/single layer	0
Moist unstable CIN	MUCINS	J/kg	Surface/single layer	0

Surface-based LCL	HLCL	m	Surface/single layer	0
0-1 km AGL SRH	SRH01	m^2/s^2	Surface/single layer	0
0-3 km AGL SRH	SRH03	m^2/s^2	Surface/single layer	0
Updraft helicity	VHEL	m^2/s^2	Surface/single layer	0
3-6 km max W	VVELMAX	m/s	Surface/single layer	0
0-1 km AGL wind shear	SHR01	1/s	Surface/single layer	0
0-6 km AGL wind shera	SHR06	1/s	Surface/single layer	0
Vertical-integrated Qg	COLQG	kg/ m^2	Surface/single layer	0
Geopotential height 850	HGHT	m	pressure	850 hPa
Geopotential height 700	HGHT	m	pressure	700 hPa
Geopotential height 600	HGHT	m	pressure	600 hPa
Geopotential height 500	HGHT	m	pressure	500 hPa
Geopotential height 250	HGHT	m	pressure	250 hPa
850 hPa U	UREL	m/s	pressure	850 hPa
700 hPa U	UREL	m/s	pressure	700 hPa
600 hPa U	UREL	m/s	pressure	600 hPa
500 hPa U	UREL	m/s	pressure	500 hPa
250 hPa U	UREL	m/s	pressure	250 hPa
850 hPa V	VREL	m/s	pressure	850 hPa
700 hPa V	VREL	m/s	pressure	700 hPa
600 hPa V	VREL	m/s	pressure	600 hPa
500 hPa V	VREL	m/s	pressure	500 hPa
250 hPa V	VREL	m/s	pressure	250 hPa
850 hPa W	VVEL	m/s	pressure	850 hPa
700 hPa W	VVEL	m/s	pressure	700 hPa

600 hPa W	VVEL	m/s	pressure	600 hPa
500 hPa W	VVEL	m/s	pressure	500 hPa
250 hPa W	VVEL	m/s	pressure	250 hPa
850 hPa T	TMPC	C	pressure	850 hPa
700 hPa T	TMPC	C	pressure	700 hPa
600 hPa T	TMPC	C	pressure	600 hPa
500 hPa T	TMPC	C	pressure	500 hPa
250 hPa T	TMPC	C	pressure	250 hPa
850 hPa mixing ratio	MIXR	g/kg	pressure	850 hPa
700 hPa mixing ratio	MIXR	g/kg	pressure	700 hPa
600 hPa mixing ratio	MIXR	g/kg	pressure	600 hPa
500 hPa mixing ratio	MIXR	g/kg	pressure	500 hPa
250 hPa mixing ratio	MIXR	g/kg	pressure	250 hPa

Name convention:

SPC file name *CAPS web name*

ARW members:

ssef_s4cn_arw_2009042000 SPC4-EF CN WRFARW Fcst

ssef_s4c0_arw_2009042000 SPC4-EF C0 WRFARW Fcst

ssef_s4n1_arw_2009042000 SPC4-EF N1 WRFARW Fcst

ssef_s4p1_arw_2009042000 SPC4-EF P1 WRFARW Fcst

ssef_s4n2_arw_2009042000 SPC4-EF N2 WRFARW Fcst

ssef_s4p2_arw_2009042000 SPC4-EF P2 WRFARW Fcst

ssef_s4n3_arw_2009042000 SPC4-EF N3 WRFARW Fcst

ssef_s4p3_arw_2009042000 SPC4-EF P3 WRFARW Fcst

ssef_s4n4_arw_2009042000 SPC4-EF N4 WRFARW Fcst

ssef_s4p4_arw_2009042000	SPC4-EF P4 WRFARW Fcst

NMM members:

ssef_s4cn_nmm_2009042000	SPC4-EF CN WRFNMM Fcst	
ssef_s4c0_nmm_2009042000	SPC4-EF C0 WRFNMM Fcst	
ssef_s4n1_nmm_2009042000	SPC4-EF N1 WRFNMM Fcst	**Drop out!**
ssef_s4p1_nmm_2009042000	SPC4-EF P1 WRFNMM Fcst	
ssef_s4n2nmm_2009042000	SPC4-EF N2 WRFNMM Fcst	
ssef_s4p2_nmm_2009042000	SPC4-EF P2 WRFNMM Fcst	
ssef_s4n3_nmm_2009042000	SPC4-EF N3 WRFNMM Fcst	
ssef_s4p3_nmm_2009042000	SPC4-EF P3 WRFNMM Fcst	**Drop out!**
ssef_s4n4_nmm_2009042000	SPC4-EF N4 WRFNMM Fcst	
ssef_s4p4_nmm_2009042000	SPC4-EF P4 WRFNMM Fcst	

1-km run:

ssef_spc1_2009042000	SPC1 WRF Fcst

Possible ARPS members:

ssef_arps_cn_2009042000	SPC4-EF CN ARPS Fcst
ssef_arps_c0_2009042000	SPC4-EF C0 ARPS Fcst

<u>Other ensemble products that will be on CAPS web page:</u>
In addition to ARPS routine hourly forecast graphics from individual members, the following ensemble forecast products will be automatically created in real-time on an *hourly basis*.

- Ensemble mean (in the form of Probability Matching - PM) and spread

- Spaghetti plots of selected quantities
- Probability
- Individual ensemble member “postage stamp” charts

6. Task List

To-do-list and Timeline:

- Basic configuration (domain, etc.) (Fanyou) - Done

- ARPS-WRF interface enhancement. Both arps4wrf and nmm2arps have been tested well on MPI. Some refining is needed for arps4wrf A separate program to trim the Grid 1 to get Grid 3 is under development (Yunheng, Fanyou) - Done

- WRF 5min 2D write out. Mostly use the same modification for ARW as v2.2 in 2008; implement for NMM is more complicated (Yunheng) - Done for ARW

- real_nmm.exe and real.exe modification to allow hydrometeor variables to be read and interpolated (Yunheng, Fanyou): - Done

- Full NMM testing (Fanyou, Kevin) - Done on Kraken, and **Done**

- Pre- and post- component setup and testing on Bigben (Kevin) – **working on**

- Decide final ensemble configuration on physics (Ming, Fanyou, SPC, NCAR). This involves the final set of namelist.input files for both ARW and NMM - **Done**

- Full ensemble system testing on Bigben (Kevin, Fanyou) – **Done**

- Full 1km system testing on Kraken (Kevin) – **Done**

- Ensemble-products (Fanyou, Kevin) – mid April

- Full system case study (Kevin, Fanyou, Yunheng) – Before 20 April

- Supplemental computer time request proposal to TeraGrid for Kraken and Bigben (Fanyou, Ming) – Done, Funded!

- Test on additional random perturbation and soil moisture perturbation (Xuguang, Fanyou, Zejun) – parallel and/or post season, Working on