Demonstrating the utility of the Mesoscale Model Evaluation Testbed (MMET)

17th Annual WRF Users' Workshop
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National Center for Atmospheric Research
Research Applications Laboratory and Developmental Testbed Center

DTC Developmental Testbed Center

DTC Mission

- The fundamental purpose of the DTC is to facilitate the interaction & transition of NWP technology between research & operations

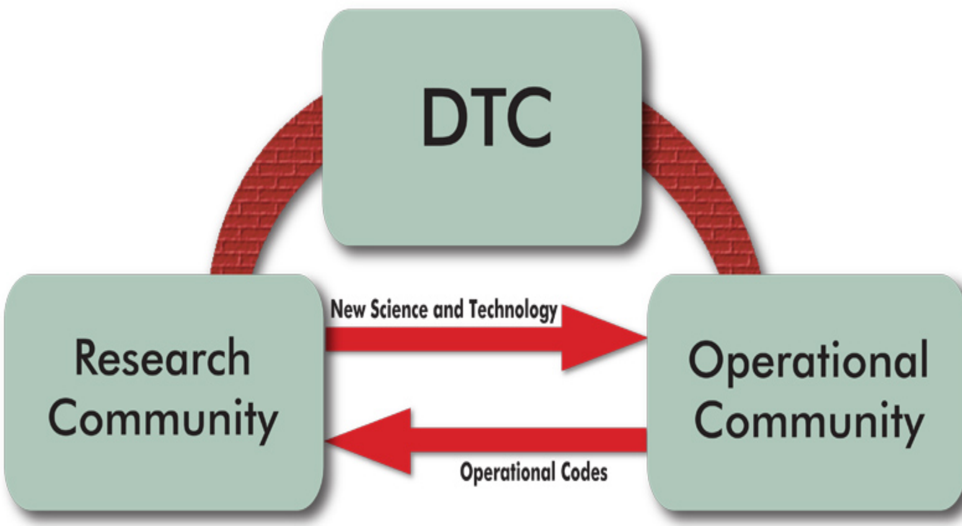
  DTC facilitates:

  - O2R transition by making the operational NWP systems available to the research community & providing community user support
  - R2O transition by performing testing & evaluation of new NWP innovations in a functionally similar operational environment over an extended period
  - Interaction between research & operational NWP communities through the organization of community workshops/meetings on important topics of interest to the NWP community & hosting a DTC Visitor Program

*DTC strives to be an **effective** and **efficient** community facility for the transition of innovations in NWP between research and operations*

Testing Protocol Motivation

- Wide range of NWP science innovations under development in the research community
- Testing protocol imperative to advance new innovations through the research to operations (R2O) process *efficiently* and *effectively*
  - Three stage process:
    1) Proving ground for research community
    2) Comprehensive T&E performed by the DTC or community member
    3) Pre-Implementation testing at Operational Centers

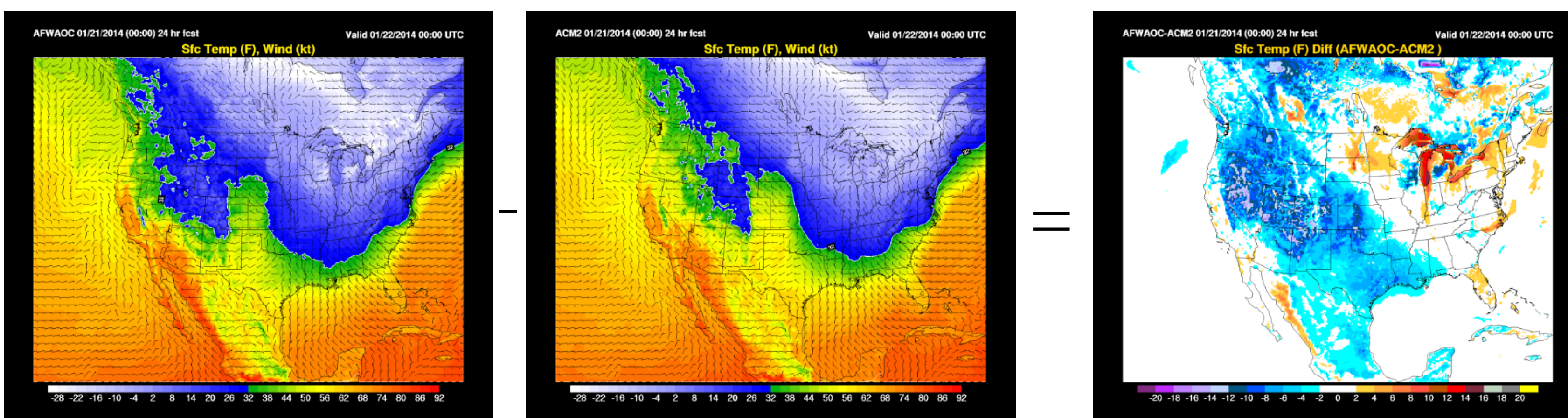


Critical to foster an environment of active development and testing with ***open communication*** *of results among the three participating partners in the process*

Testing Protocol – Stage I

Proving ground for research community

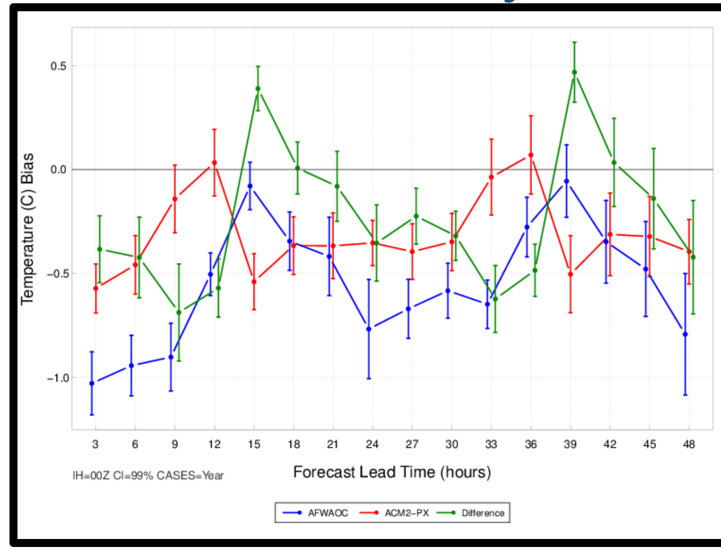
- Code development; Initial stage of testing
- Mesoscale Model Evaluation Testbed (MMET)
- Communicate results to the DTC; Nominate for Stage II testing
- Contribution of new technique into the WRF or NEMS repository encouraged
  - Work with model developers committee
  - Apply for DTC Visitor Program support (see: http://www.dtcenter.org/visitors)

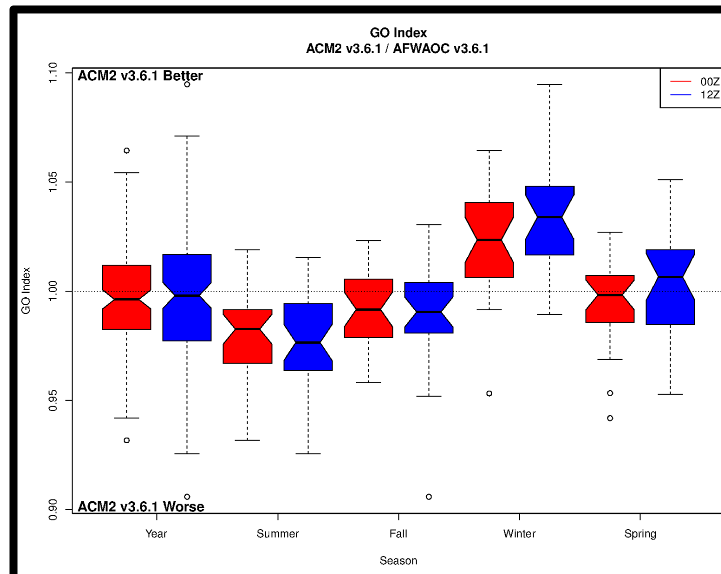


Testing Protocol – Stage II

Comprehensive T&E performed by the DTC or community

- Maintain a neutral position in order to provide a trusted, unbiased assessment
- Conduct comprehensive testing for a broad range of weather regimes
  - Run end-to-end system composed of community codes
  - Functionally similar to operational environment
- Evaluate based on extensive objective verification statistics
  - Traditional scores
  - New, relevant verification techniques (e.g., spatial methods)
  - Statistical significance assessment
- Results shared with research community and operational entities





Testing Protocol – Stage III

Pre-Implementation testing at Operational Centers

- Ultimate decision to proceed with pre-implementation testing is made by the Operational Centers and is based on a variety of factors, including:
  - Forecast performance
  - Computational requirements
- Testing specifics depend on the target production configuration, but may include:
  - Complex data assimilation testing
  - Initial condition diversity testing for ensemble members

What does MMET provide?

Initialization datasets

Pre-processing datasets

Model configurations

Post-processing scripts

Graphics of model output and scripts

Observation datasets

Verification output and scripts

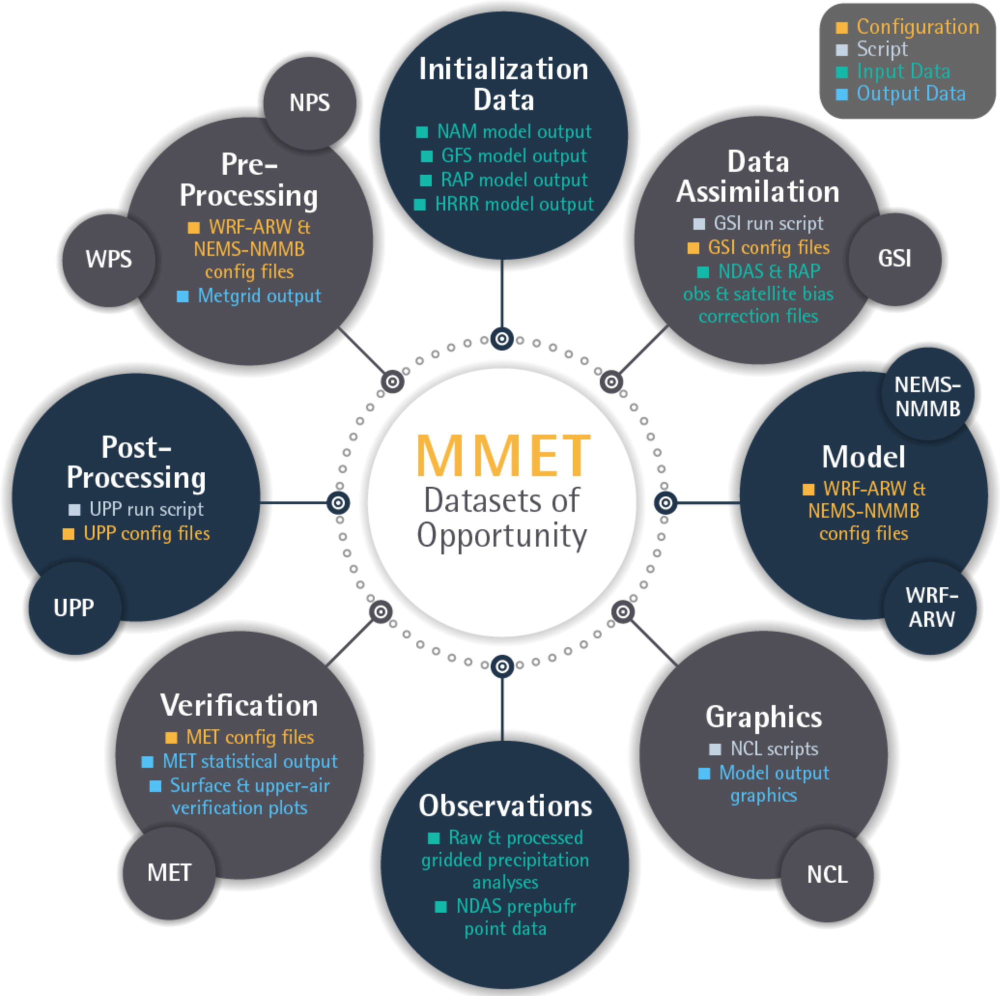
Mesoscale Model Evaluation Testbed (MMET)

Why: Assist the research community in efficiently demonstrating the merits of a new development

What: Datasets of opportunity

- Model input and observational datasets to utilize for testing and evaluation
- Common framework for testing; allow for direct comparisons
- DTC established baseline results for select operational models
- Community contributed results

Where: Hosted by the DTC; served through **R**epository for **A**rchiving, **M**anaging and **A**ccessing **D**iverse **DA**ta (RAMADDA)



http://www.dtcenter.org/eval/meso_mod/mmet/index.php

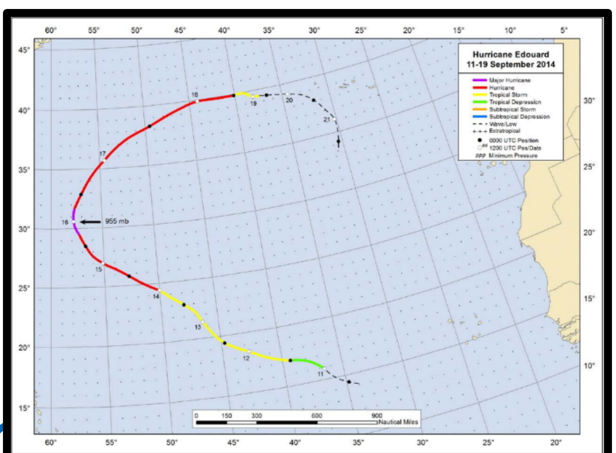
Developmental Testbed Center

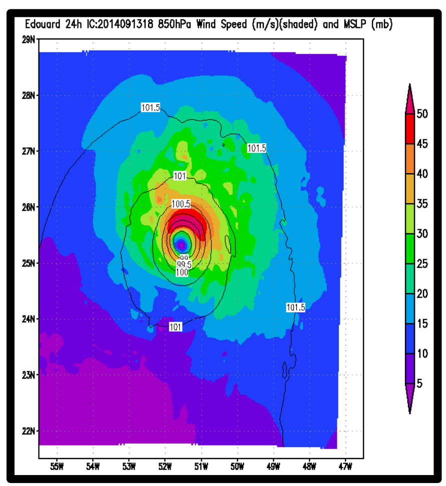
MMET – Case Inventory

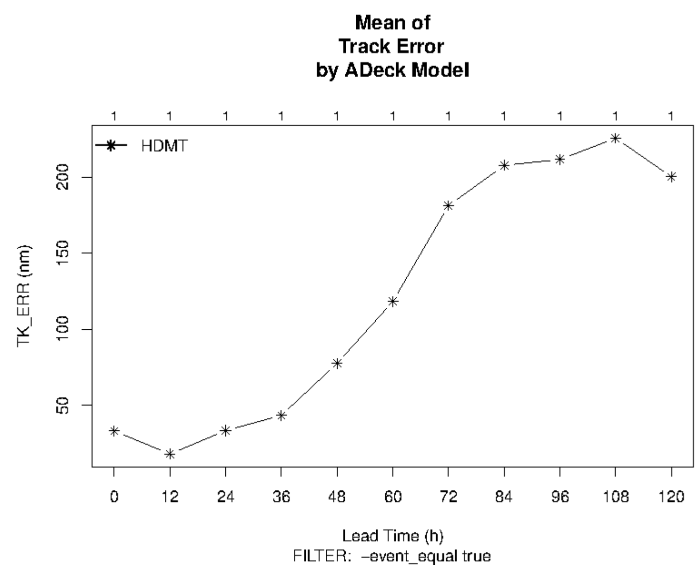
Date(s)	Meteorological Scenario
20160122-24	Major *snow storm* that impacted Mid-Atlantic region *(SBU)*
20150322	Narrow and intense band of *heavy snowfall* from northeast SD through southern MN *(SBU)*
20150125-27	Redeveloped low that intensified into strong *Nor'Easter*, bringing heavy snow and winds *(SBU)*
20150105	Clipper system over Midwest with broad band of snow but with *intense snowfall rates* *(SBU)*
20140912/15	*Hurricane Edouard* in Atlantic Ocean
20140105	*Arctic air outbreak* impacting much of the United States east of the Rockies
20130908-14	Historic Colorado *flooding* associated w/ long duration and warm rain processes
20130729	*Mesoscale convective system* (MCS) over SE Kansas
20120628	*Derecho* event that began in Iowa and traveled eastward through the Mid-Atlantic states
20120203-05	*Snow storm* over Colorado, Nebraska, etc.
20111128	*Cutoff low* over SW US
20110518-26	Extended *severe weather* outbreak covering much of the Midwest and into the eastern states
20110404	Record breaking *severe* report day
20110214-17	*Atmospheric river* impacting the West Coast *(Collaboration with HMT)*
20100428-0504	Historic Tennessee *flooding* associated w/ an atmospheric river
20091217	"*Snowpocalypse '09*"
20091007	*HIRESW* runs *underperformed* compared to coarser NAM model
20090311	*High dew point* predictions by NAM over the upper Midwest and in areas of snow
20090228	Mid-Atlantic *snow storm* -NAM high QPF shifted too far north

Tropical Cyclone Case in MMET

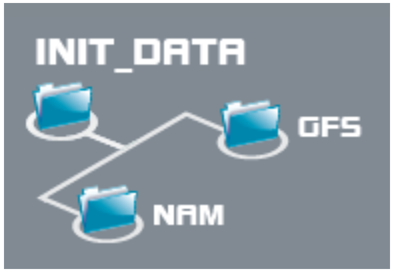
- In 2015, a hurricane case using the Hurricane WRF (HWRF) and MET for Tropical Cyclones (MET-TC) was added to the repository
- Hurricane Edouard:
  - Formed in Atlantic Ocean and became a hurricane by 12 UTC on 20140911
  - HWRF forecast track had a right bias and a low intensity bias
  - Well-sampled: Coyote Unmanned Aircraft Systems (UAS), radar, and SFMR data
  - 2014091206 & 2014091518 UTC initializations included in repository



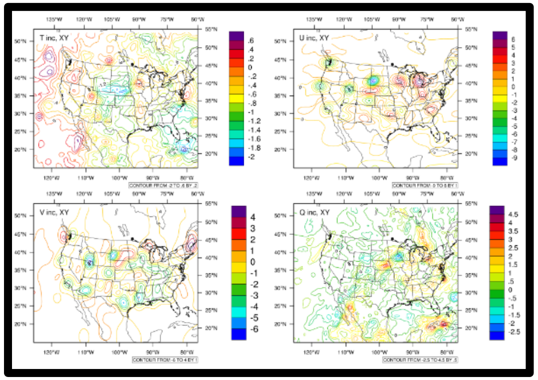


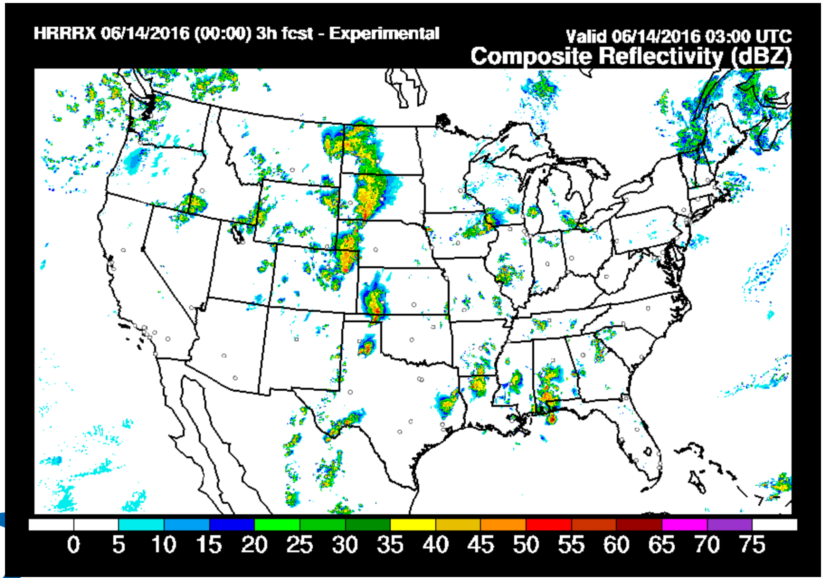


Initialization Datasets

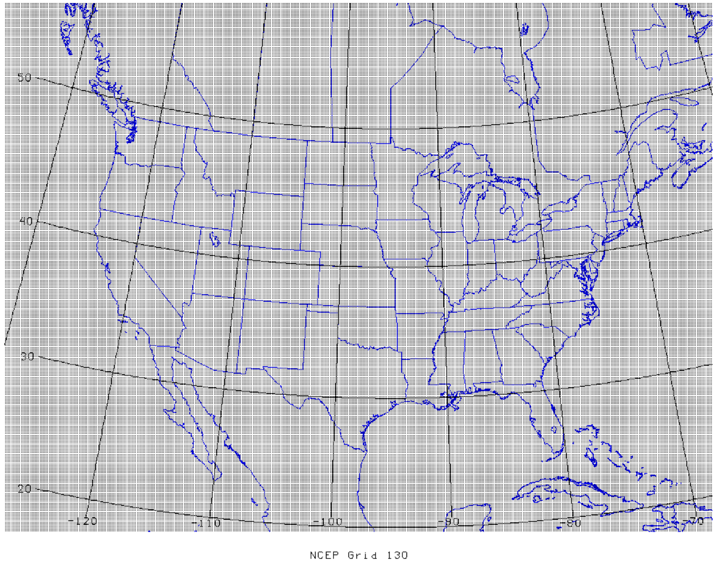


- 13-km RAP data on CONUS domain
- 3-km HRRR data on CONUS domain
- NAM on NCEP Grid 221 (~32-km N. American domain)
- GFS on 0.25° and 0.5° grid
- Necessary files for running GSI

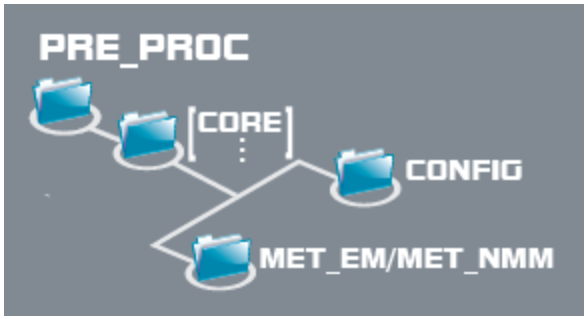




NCEP Grid 130



Pre-processing



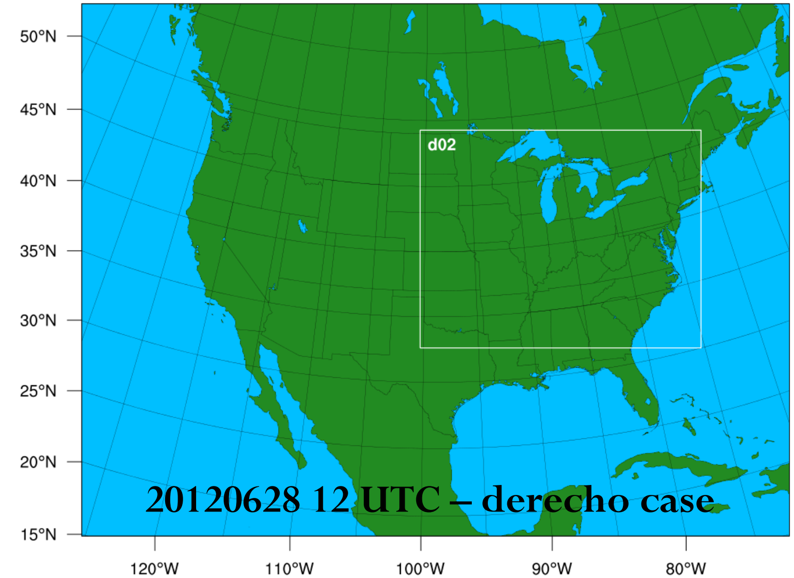
- namelist.wps and namelist.nps
- met_em* files and met_nmb* files

```
&share
 wrf_core = 'ARW',
 max_dom = 2,
 start_date = '2009-12-17_12:00:00', '2009-12-17_12:00:00',
 end_date   = '2009-12-21_00:00:00', '2009-12-21_00:00:00',
 interval_seconds = 10800,
 io_form_geogrid = 2,
/

&geogrid
 parent_id         = 1, 1,
 parent_grid_ratio = 1, 4,
 i_parent_start    = 1, 242,
 j_parent_start    = 1, 135,
 e_we             = 505, 805,
 e_sn             = 380, 629,
 geog_data_res = '2m', '30s',
 dx = 12000,
 dy = 12000,
 map_proj =  'lambert',
 ref_lat   = 38.60,
 ref_lon   = -98.90,
 truelat1  = 38.60,
 truelat2  = 38.60,
 stand_lon = -98.90,
 geog_data_path = '/path/to/geog',
 opt_geogrid_tbl_path = '/path/to/geogrid',
/

&ungrib
 out_format = 'WPS',
 prefix = 'NAM',
/

&metgrid
 constants_name='',
 fg_name = 'NAM',
 io_form_metgrid = 2,
 opt_metgrid_tbl_path = '/path/to/metgrid',
/
```

Model

- Domain: 12-km CONUS grid with 3-km nest over area of interest
- namelist.input and configure_file

Model domain

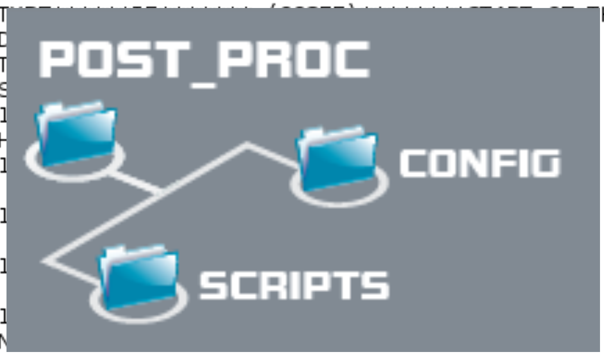


Physics Suite	WRF-ARW RAP/HRRR OC	WRF-ARW Air Force OC	NEMS-NMMB NAM OC
Microphysics	Thompson	WRF Single-Moment 5	Ferrier-Hires
Radiation (LW/SW)	RRTMG/RRTMG	RRTM/Dudhia	GFDL/GFDL
Surface Layer	MYNN	Monin-Obukhov similarity theory	Mellor-Yamada-Janjic
LSM	RUC	Noah	Noah
PBL	MYNN 2.5	Yonsei University	Mellor-Yamada-Janjic
Convection	Grell-Freitas (RAP)	Kain-Fritsch	Betts-Miller-Janjic

For more information on the Unified Post Processor (UPP): http://www.dtcenter.org/upp/users/

Post-processing

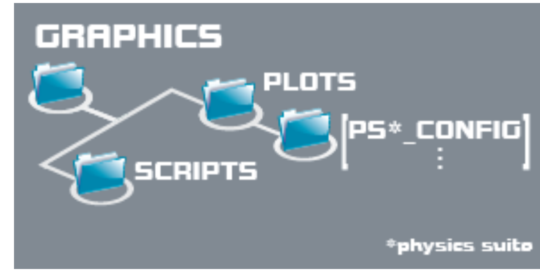
- run_unipost script
- wrf_cntrl.parm and nmb_cntrl.parm



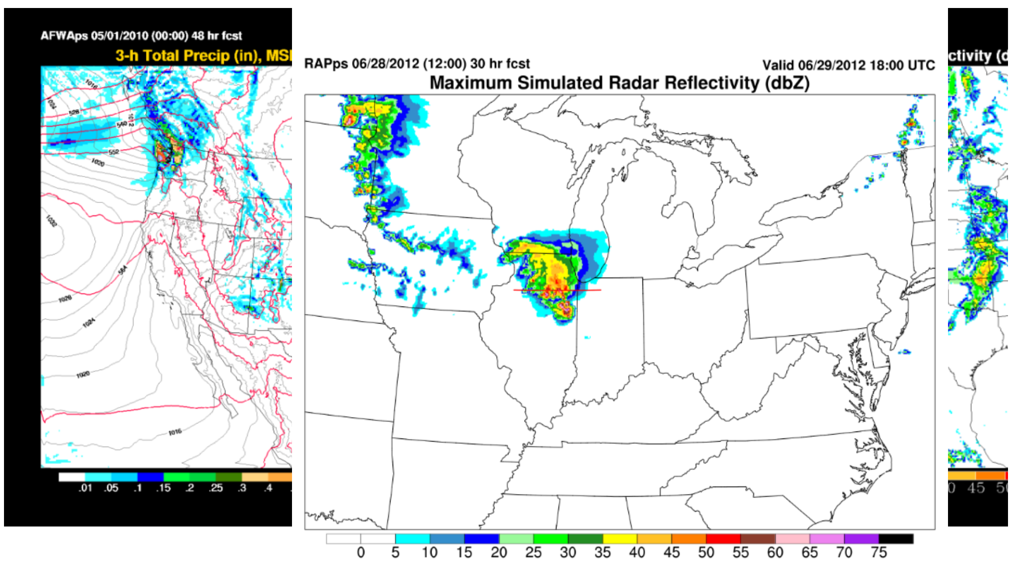

```
  KGT                                                  HIS OUTP
  IMD
  DAT
 (PRESS
 L=(111                                           11111 1
 (HEIGH
 L=(111                                           11111 1
 (TEMP
 L=(111                                           11111 1
 (DWPT
 L=(111                                           11111 1
 (SPEC
 L=(111                                           11111 1
 (U WIN
 L=(11111 11111 11111 11111 11111 11111 11111 11111 11111 1
 (V WIND ON MDL SFCS   ) SCAL=( 4.0)
 L=(11111 11111 11111 11111 11111 11111 11111 11111 11111 1
 (OMEGA ON MDL SFCS    ) SCAL=( 5.0)
 L=(11111 11111 11111 11111 11111 11111 11111 11111 11111 1
 (CLD WTR ON MDL SFCS ) SCAL=( 3.0)
 L=(11111 11111 11111 11111 11111 11111 11111 11111 11111 1
 (CLD ICE ON MDL SFCS ) SCAL=( 3.0)
 L=(11111 11111 11111 11111 11111 11111 11111 11111 11111 1
 (RAIN ON MDL SFCS     ) SCAL=( 3.0)
 L=(11111 11111 11111 11111 11111 11111 11111 11111 11111 1
 (SNOW ON MDL SFCS     ) SCAL=( 3.0)
 L=(11111 11111 11111 11111 11111 11111 11111 11111 11111 1
 (RADAR ECHO TOP       ) SCAL=( 4.0)
 L=(10000 00000 00000 00000 00000 00000 00000 00000 00000 0
 (RADAR REFL AGL       ) SCAL=( 4.0)
 L=(11000 00000 00000 00000 00000 00000 00000 00000 00000 0
***DONE WITH THIS GRID***
```

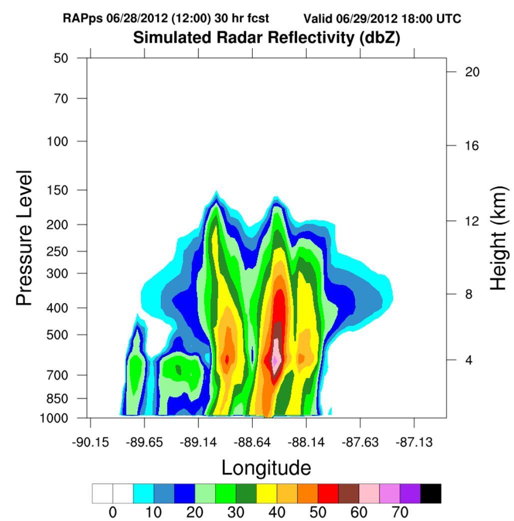
```
...
...
...
# Begin looping through domains list
# ie. for domain in d01 d02 d03
for domain in ${domain_list}
do

# Create model file name (inFileName)
dom_id=`echo "${domain}" | cut -d 'd' -f 2`
if [[ ${dyncore} == "ARW" || ${dyncore} == "NMM" ]]; then
   inFileName=${modelDataPath}/wrfout_d${dom_id}_${YY}-${MM}-${DD}_${HH}:00:00
elif [ ${dyncore} == "NMB" ]; then
   inFileName=${modelDataPath}/nmmb_hst_${dom_id}_nio_00${fhr}h_00m_00.00s
fi

# Check if that file exists
if [[ ! -e ${inFileName} ]]; then
  echo "ERROR: Can't find 'inFileName': ${inFileName}. Directory or file does not exist.  Exiting..."
  echo "ERROR: Check if 'modelDataPath': ${modelDataPath} exists."
  if [[ ${dyncore} == "ARW" || ${dyncore} == "NMM" ]]; then
     echo "ERROR: Check if file: 'wrfout_d${dom_id}_${YY}-${MM}-${DD}_${HH}:00:00' exists in modelDataPath."
  elif [ ${dyncore} == "NMB" ]; then
     echo "ERROR: Check if file: 'nmmb_hst_${dom_id}_nio_00${fhr}h_00m_00.00s' exists in modelDataPath."
  fi
  exit 1
fi

# Create itag based on user provided info.
# Output format now set by user so if-block below uses this
# to generate the correct itag.

if [[ ${outFormat} == "grib" ]]; then

cat > itag <<EOF
${inFileName}
${inFormat}
${YY}-${MM}-${DD}_${HH}:00:00
${tag}
EOF

elif [[ ${outFormat} == "grib2" ]]; then

cat > itag <<EOF
${inFileName}
${inFormat}
${outFormat}
${YY}-${MM}-${DD}_${HH}:00:00
${tag}
EOF

else
echo "ERROR: output format 'outFormat=${outFormat}' not supported, must choose 'grib' or 'grib2'. Exiting..."
exit 1
fi

#-------------------------------------------------------------------------
#   Run unipost.
#-------------------------------------------------------------------------
rm fort.*

ln -sf ${paramFile} fort.14

#-------------------------------------------------------------------------
# There are two environment variables tmmark and COMSP
# RUN the unipost.exe executable.
#-------------------------------------------------------------------------

${RUN_COMMAND} > unipost_${domain}.${fhr}.out 2>&1
...
...
...
```

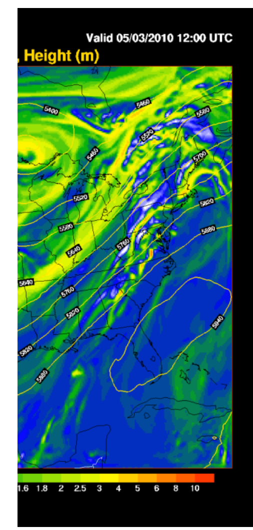
Graphics



- NCL scripts and plots for a number of variables:
  - Surface and upper air fields (e.g., temperature, wind, and moisture fields)
  - Accumulated precipitation, composite reflectivity, CAPE, vorticity, PBL heights, IVT, etc.

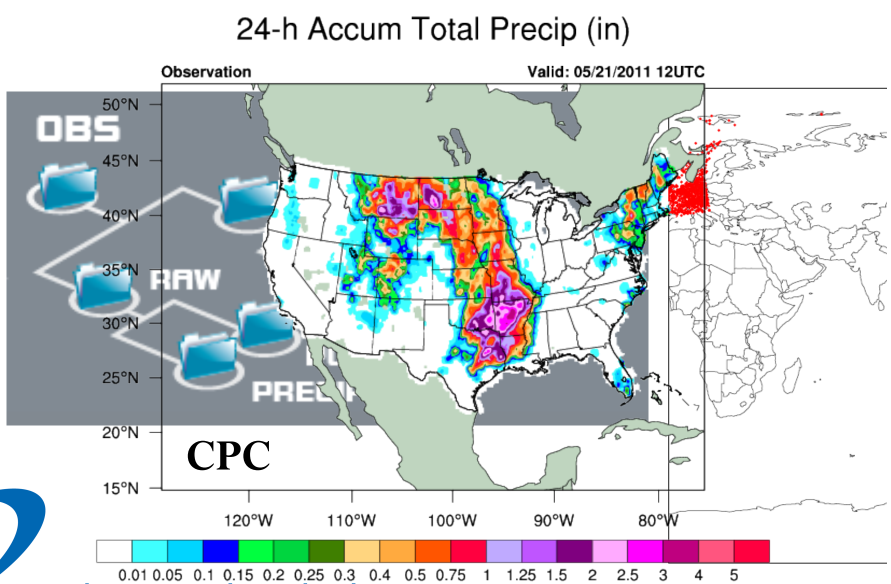


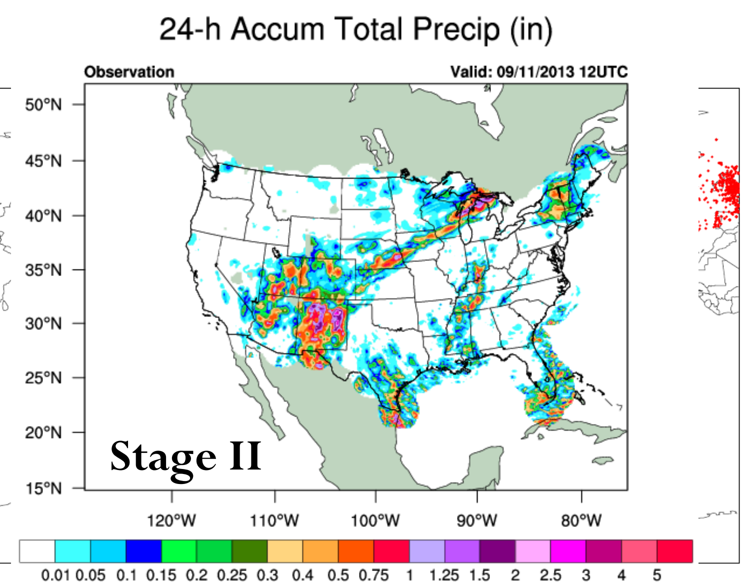




Observation Datasets

- Raw and processed for point observations (METAR, RAOB, etc.)
  - North American Data Assimilation System (NDAS)
  - Rapid Refresh (RAP) prepbufr
- Raw and processed gridded observations (3- and 24-h accumulations, comp. reflectivty)
  - Stage II and Stage IV (currently only available for the 20110213-16 atmospheric river case)
  - Climate Prediction Center Unified Gauge-Based Analysis (CPC)
  - Multi-Radar/Multi-Sensor system (MRMS)
- NCL scripts and plots for accumulated observed precipitation





Verification
Why / how should you verify?

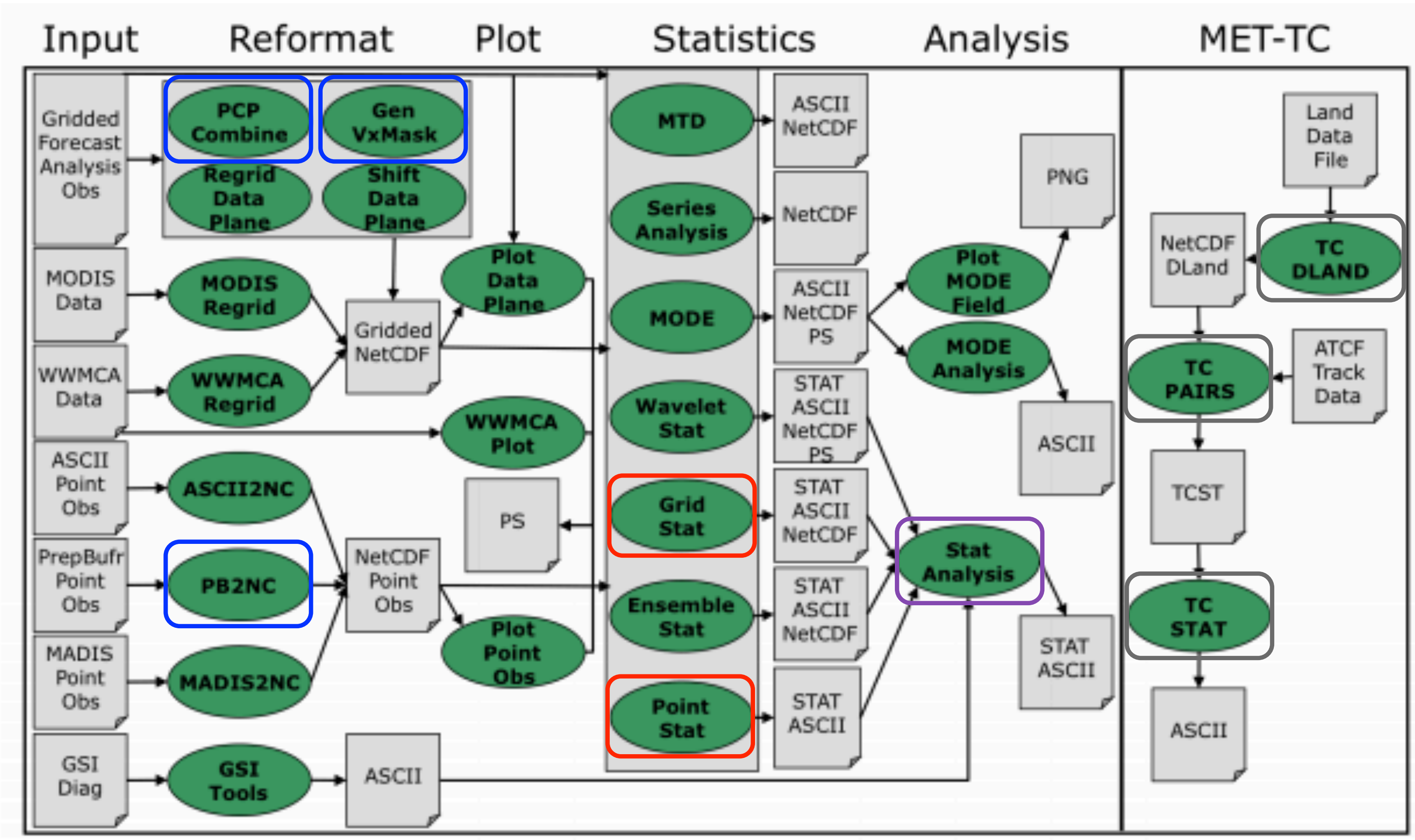
Adapted from presentations by MET team, including Tara Jensen, Tressa Fowler, John Halley Gotway, and Kathryn Newman!

- Why verify your forecasts??
  - Identify forecast strengths and weaknesses; use information to improve model
  - Help users and model developers interpret forecasts
  - Assist operational forecasters in understanding model biases and applying knowledge to forecasts
  - Monitor performance of model and/or configuration
  - Use information for enhanced decision making (e.g., emergency managers, wind energy)
  - Provides a standardized evaluation platform for cross-institution comparisons
- MET is freely available community code supported by the DTC **(must register to download)**
  - State-of-the-art suite of verification tools
  - Approximately 3000 registered users spanning ~120 countries
  - Users from universities, government, private companies, and non-profits
- MET provides a number of tools for evaluating model performance:
  - Full suite of standard statistics with non-traditional statistics regularly added
  - Neighborhood and object-based methods
  - Scale decompositions
  - Tropical cyclone verification

Verification
MET capabilities

MET has a number of tools for:

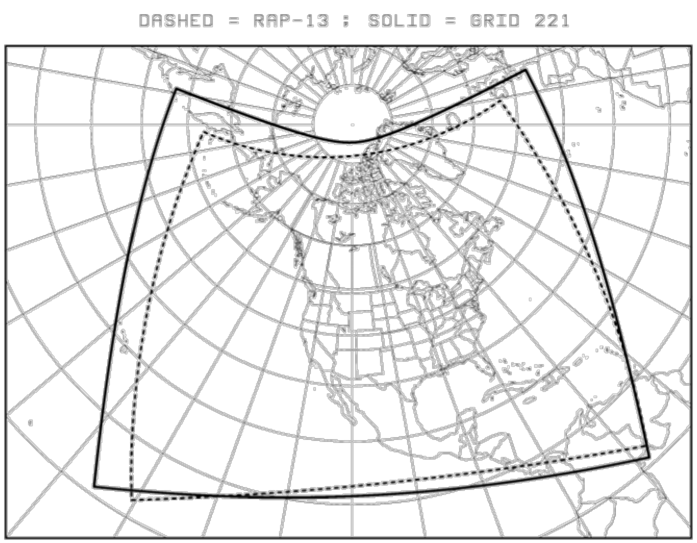
- reformatting
- plotting
- calculating statistics
- statistical analysis
- tropical cyclone verification



Verification

MET re-gridding

Basic capability for automated regridding



<u>Interpolation options:</u>

- Unweighted mean
- Distance-weighted mean
- Min, max, median
- Least squares
- Bilinear
- Budget

<u>Regridding options:</u>

- To forecast grid
- To observation grid
- To pre-defined grid (e.g. NCEP Grid193, user generated)
- To a grid specification (similar concept to UPP *copygb*)

ALSO: Stand-alone tool available for regridding outside statistical tools

Verification
MET data formats & tools

MET components highly-configurable:
- Verify over specified fields and/or levels
- Apply thresholds
- Apply various interpolation methods
- Verify over user-specified regions

Data	MET Tool
Gridded Forecasts Gridded Observations *(Grib1 / Grid2 / NetCDF with grid specifications included; next release to include reading GSI diagnostic file)*	Grid Stat (traditional or neighborhood) Ensemble Stat Wavelet Stat MODE / MODE-TD Series Analysis
Gridded Forecasts Point Observations *(ASCII / PrepBufr / MADIS / littleR)*	Point Stat Ensemble Stat Series Analysis
Point Forecasts Point Observations *(ATCF file format)*	TC Pairs TC Stat

Verification
MET basics for MMET

- **Point-stat (grid-to-point verification)**
  - Input files:
    - Gridded forecast file (e.g., Grib1, Grib2, NetCDF)
    - Point observation file in NetCDF format (e.g., output of PB2NC, MADIS2NC, or ASCII2NC)
    - Configuration file
  - Output files:
    - ASCII statistics file(s) containing all of requested line types
  - Basic usage command:

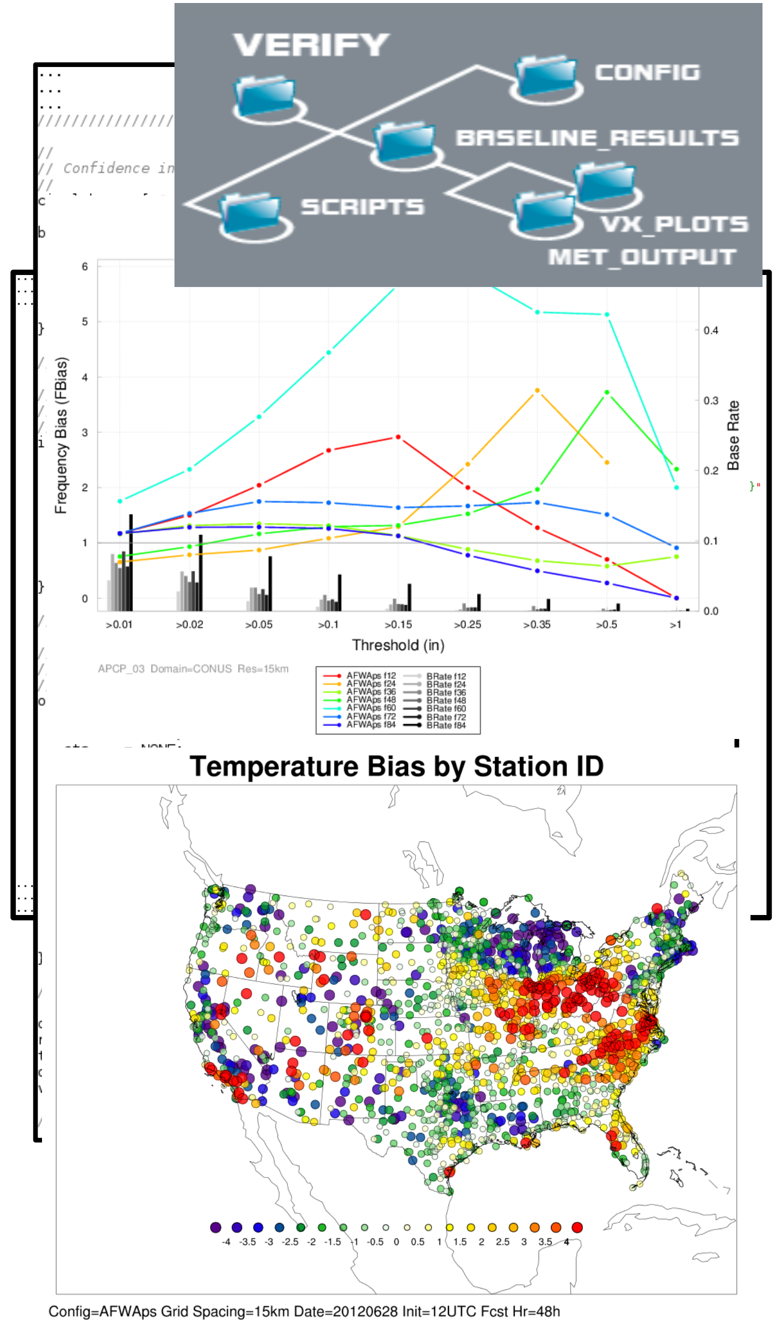
```
met-5.1/bin/point_stat \
  wrfprs_d01_03.tm00 \
  prepbufr.ndas.20110405.t03z.tm09.nc \
  PointStatConfig_ADPSFC \
  -outdir . \
  -log point_stat_ADPSFC.log \
  -v 2
```

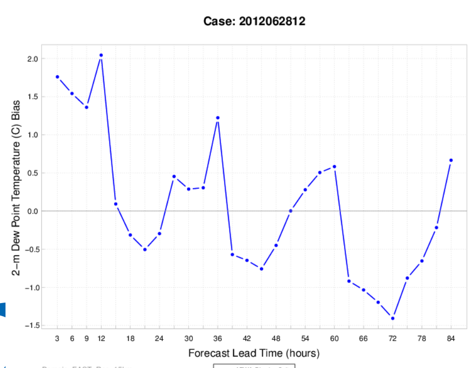
- **Grid-stat (grid-to-grid verification)**
  - Input files:
    - Gridded forecast file (Grib1, Grib2, NetCDF)
    - Gridded observation file (Grib1, Grib2, NetCDF)
    - Configuration file
  - Output files:
    - ASCII statistics file(s) containing all of requested line types
    - Optional NetCDF file with matched pairs
  - Basic usage command:

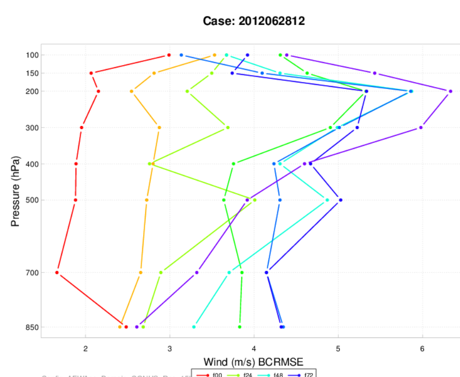
```
met-5.1/bin/grid_stat \
  wrfpcp_d01_03_03.nc \
  ST2ml.2011040503.grb \
  GridStatConfig_03h \
  -outdir . \
  -log grid_stat_03h.log \
  -v 2
```

Verification

- Scripts to run MET (grid-to-point and grid-to-grid vx)
- MET configuration files
- Baseline results
  - Objective verification:
    - Surface and upper air [(BC)RMSE, bias] – temperature, dew point temperature, wind speed
    - Precipitation [Gilbert skill score, frequency bias] – 3- and 24-h accumulations
    - Radar reflectivity [Fractions Skill Score]
    - Over CONUS and 14 sub-regions to *identify spatial differences* and *perform focused impact studies*



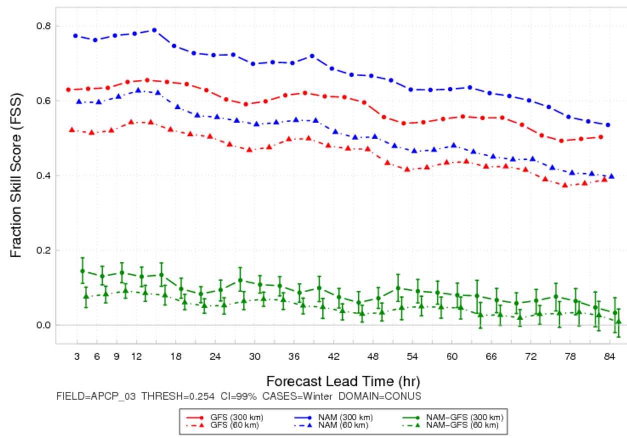


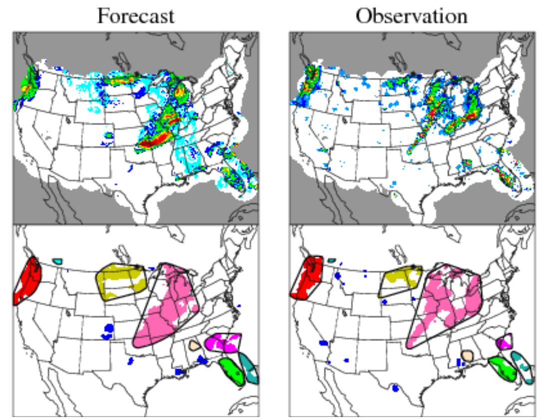


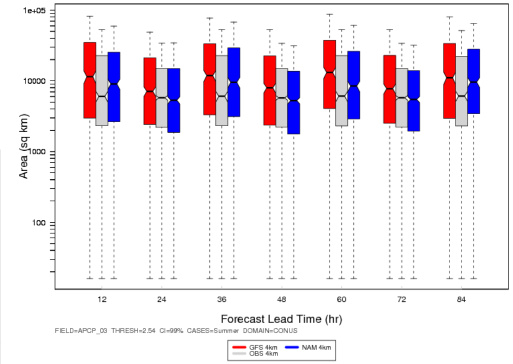
Verification
Beyond the basics in MET

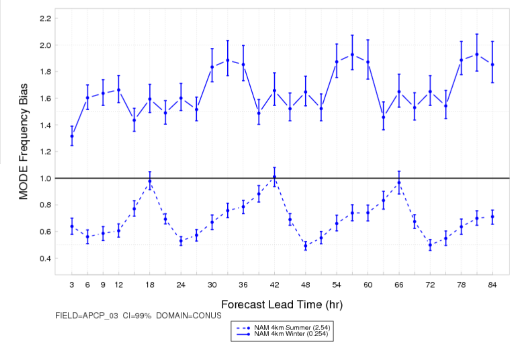
Object-based Methods

Neighborhood Methods

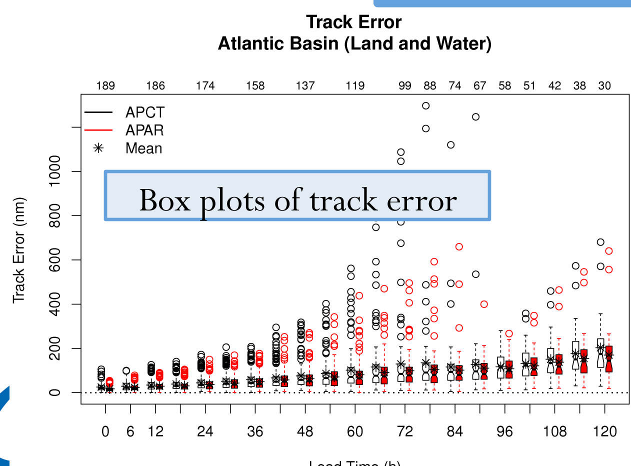


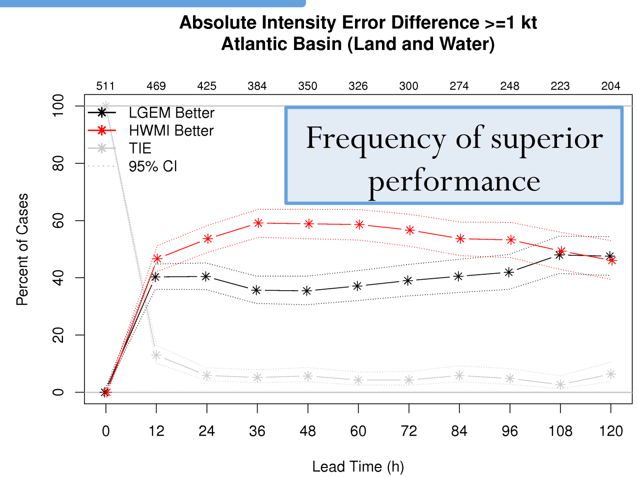




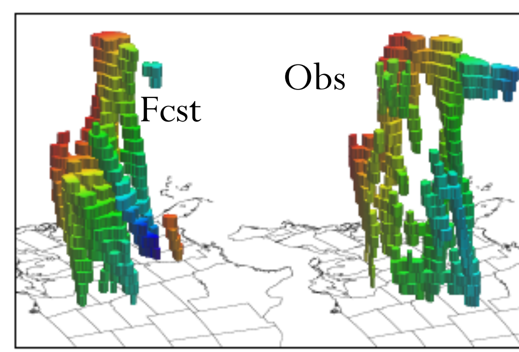


Tropical Cyclone Verification



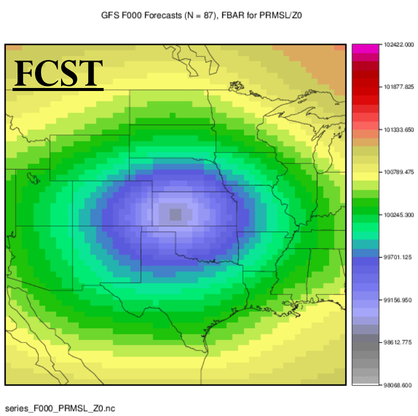


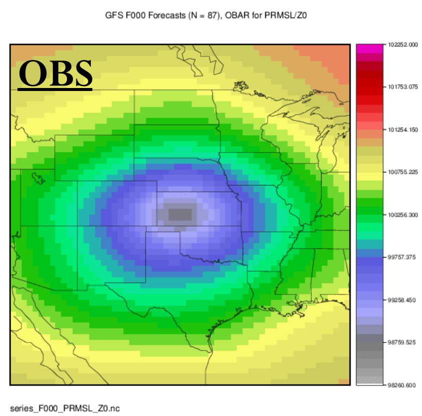
MODE-Time Domain

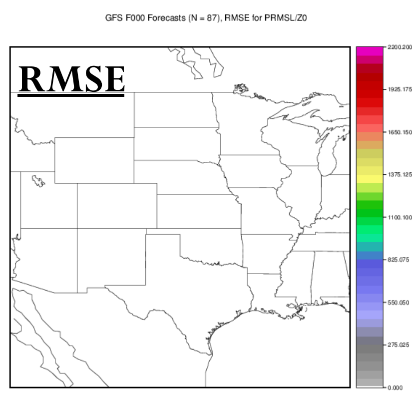


Verification
Beyond the basics in MET

Feature centric evaluation using Series Analysis

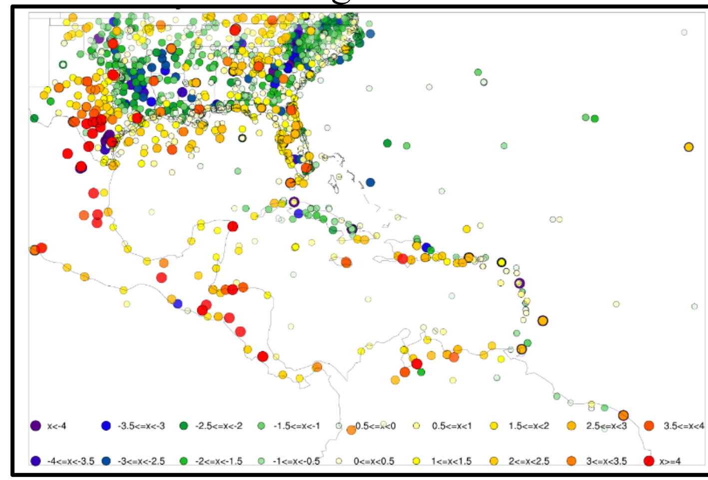




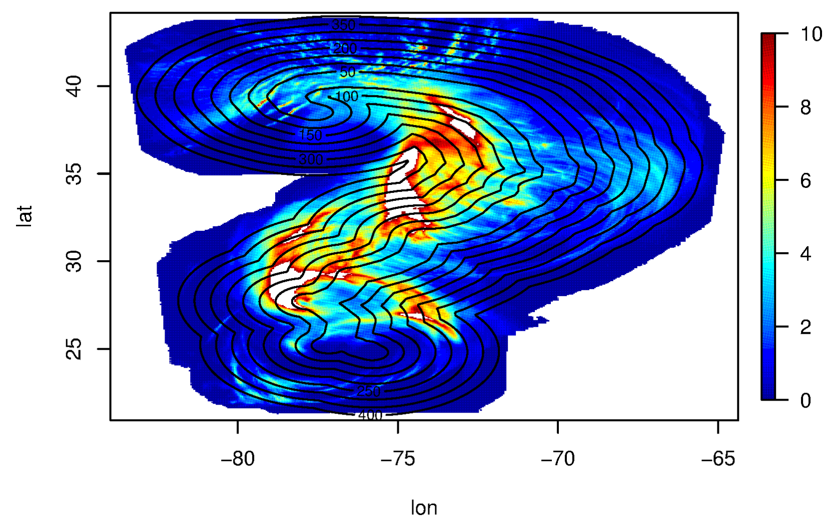


Ensemble Verification
- Ensemble means
- Probability fields
- Rank histograms
- Spread-skill calculation
- Brier score
- Reliability diagrams
- Receiver Operating Characteristic Diagram + Area Under the Curve

Temperature Innovations from GSI Diagnostics File



Storm-following masking w/ range rings



Verification

METv5.2 – Upcoming Advances

Summer of 2016!

<u>New features being added to METv5.2 (Summer 2016):</u>

- Enhanced handling of Grib1 and Grib2 files including determining the Grib Table automatically, reading UK Met Office and ECMWF tables, and reading the extended PDS information for ensemble meta-data
- Area and cosine latitude weighing of continuous scores – important for global grids
- "Feature-centric" verification (on previous slide)
- Enhanced handling of missing point observations – the user may now specify what percentage of observations must be present to compute a value over a given time window

<u>New features being added to METv6.0 (Fall/Winter 2016):</u>

- Support for NetCDF4
- Support for NCEP climatology methods
- Forecast consistency measures
- New spatial methods based on distance maps

Verification
Helpful MET resources

MET website: http://www.dtcenter.org/met/users/

- Download code (current version 5.1)
- Documentation: user's guide and tutorial presentations
- Online practical tutorials
- Related links for verification resources
- Questions regarding MET?

  met_help@ucar.edu

MET
Model Evaluation Tools

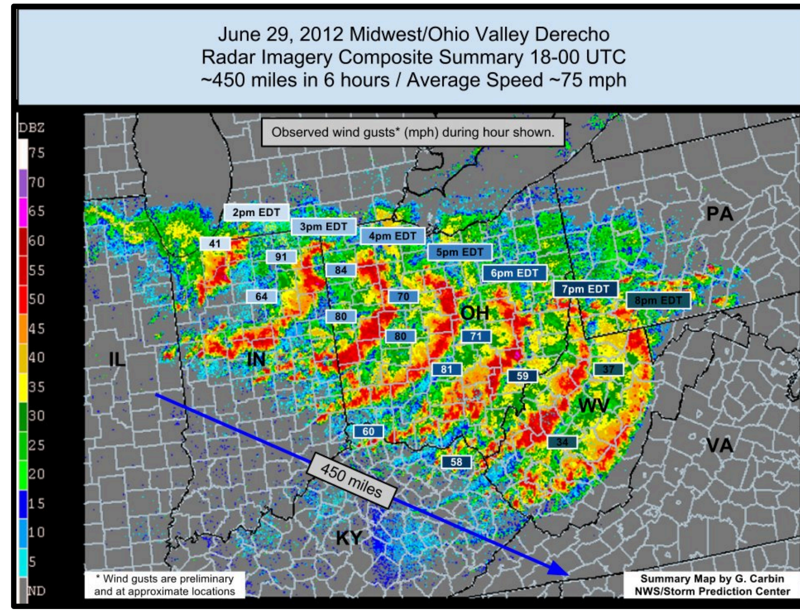
28 June 2012 Case

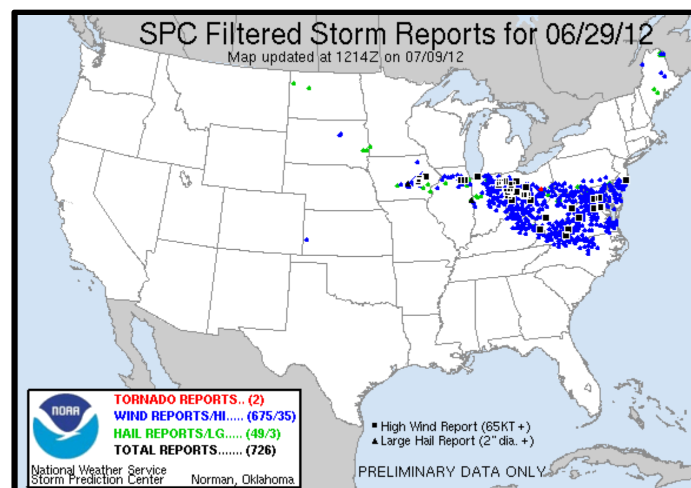
Initialized 28 June 2012 at 12 UTC

RAP Operational Configuration w/ WRF-ARW (RAP OC)
NAM Operational Configuration w/ NEMS-NMMB (NAM OC)

Event Background

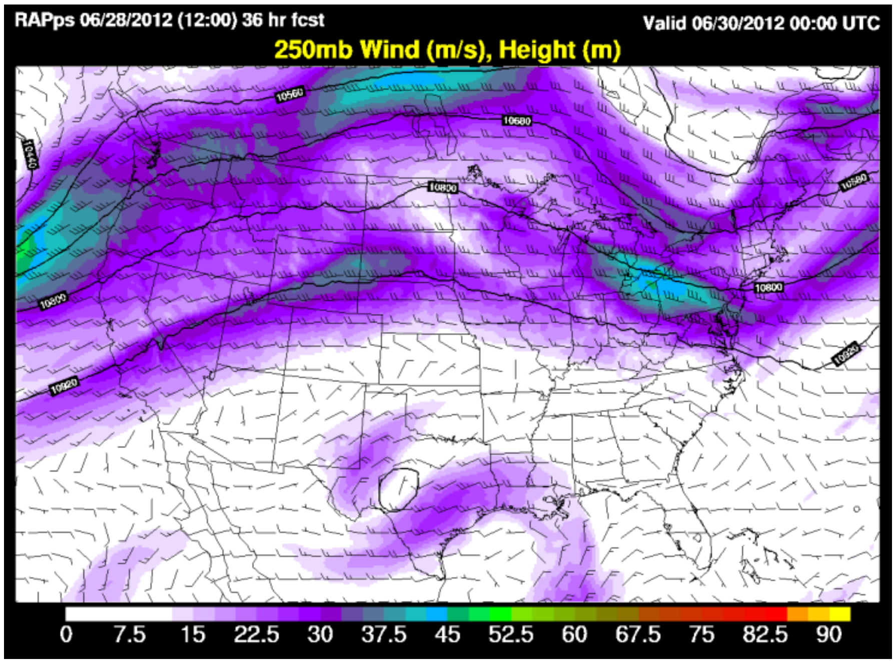
- Progressive derecho originated in Midwest, moved ESE across the Ohio Valley into the Mid-Atlantic
  - Traversed over 700 miles over 10 states
  - 13 deaths directly associated with storm
  - 4 million lost power
- Operational forecast guidance:
  - Global Forecast System (GFS) and NAM did not provide much forecast assistance more than 24 hours out from the event
  - High-Resolution Rapid Refresh (HRRR) model forecast an MCS to move through impacted area on morning of 29 June 2012 → *however, previous performance by HRRR did not allow for much confidence in forecast*
- Case evaluation:
  - Objective verification
  - Subjective assessment of performance
  - Grid-spacing impact → *does higher resolution improve forecast?*



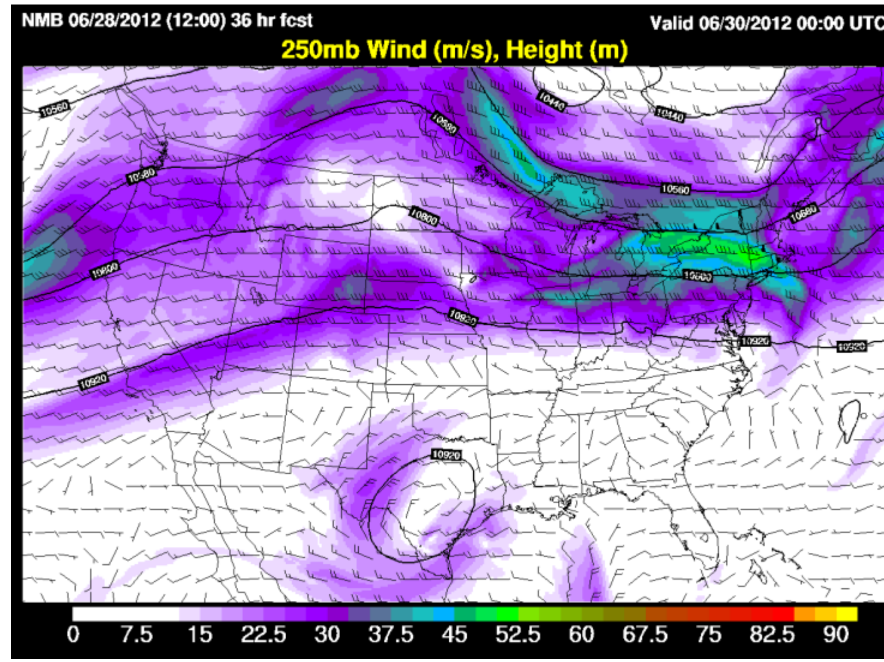


250mb Winds
Absolute Vorticity
36-h forecast

RAP OC



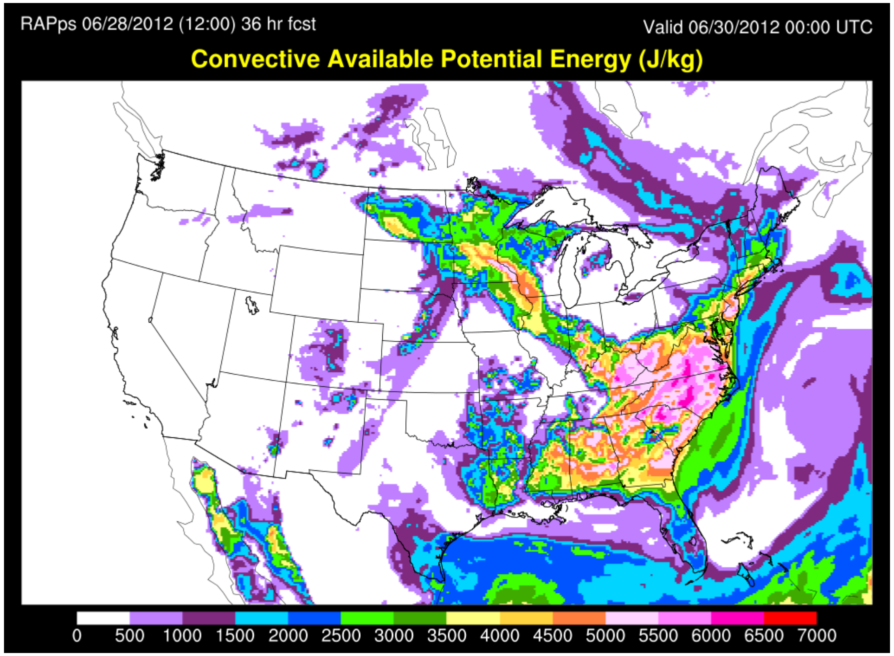
NAM OC

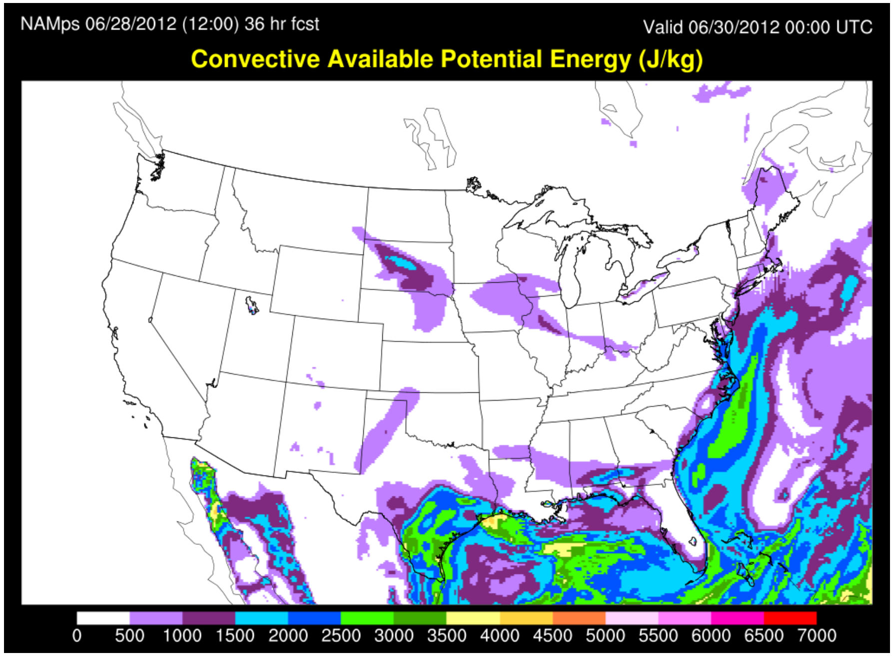


- Large-scale pattern characterized by high pressure in mid-levels over the southeast and near-zonal flow over the Midwest
- Core of the jet stream moving across Midwest/Appalachian regions

Convective Available Potential Energy
36-h forecast

RAP OC **NAM OC**



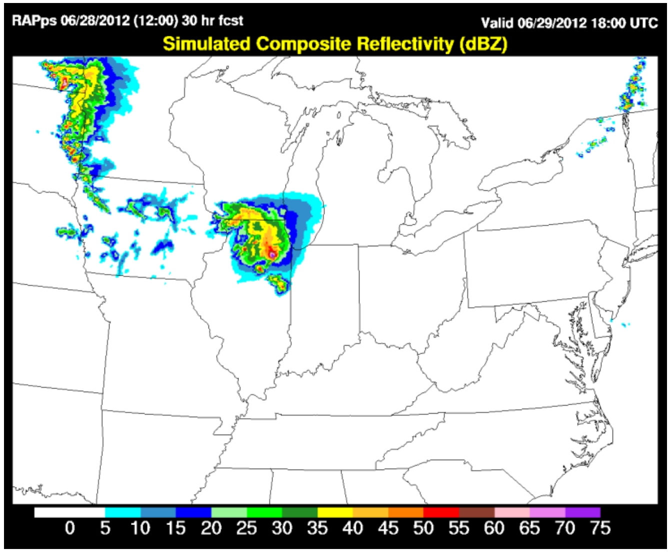


- CAPE axis aligns with elongated mid-level ridge in the RAP OC
- The RAP OC has CAPE values indicative of a potential high-impact event with maximum values >5000 J/kg
- The NAM OC has higher CAPE values at the earlier forecast hours, but low values at the time of the actual event

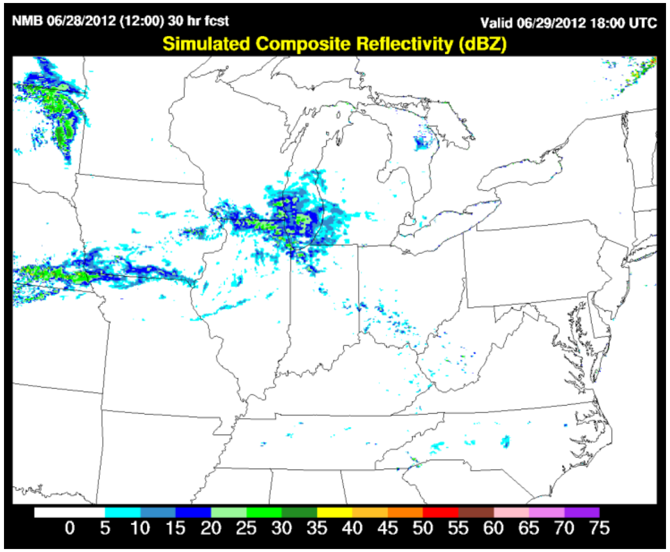
Composite Reflectivity – 3 km nest

30-h forecast, valid at 18 UTC 29 June 2012

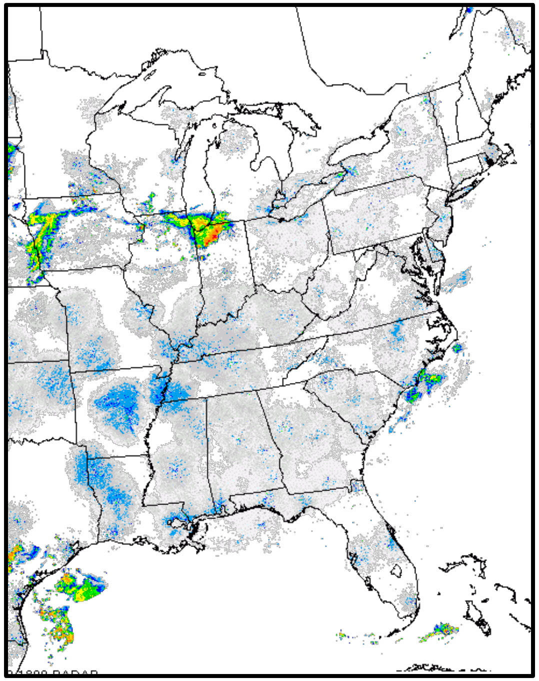
RAP OC



NAM OC



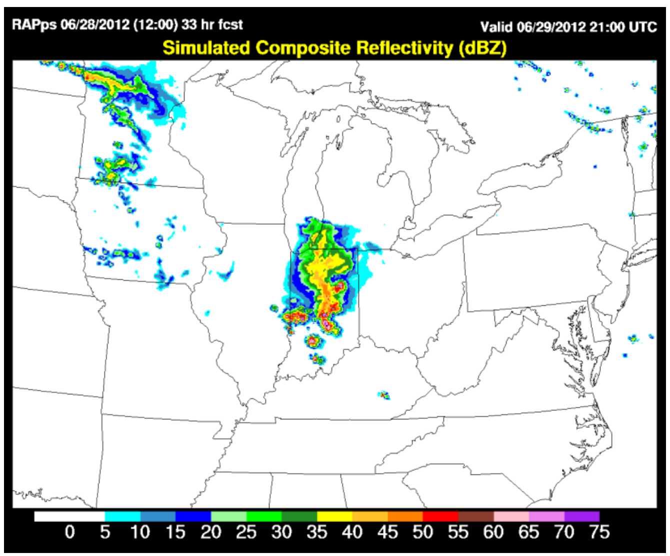
Observation



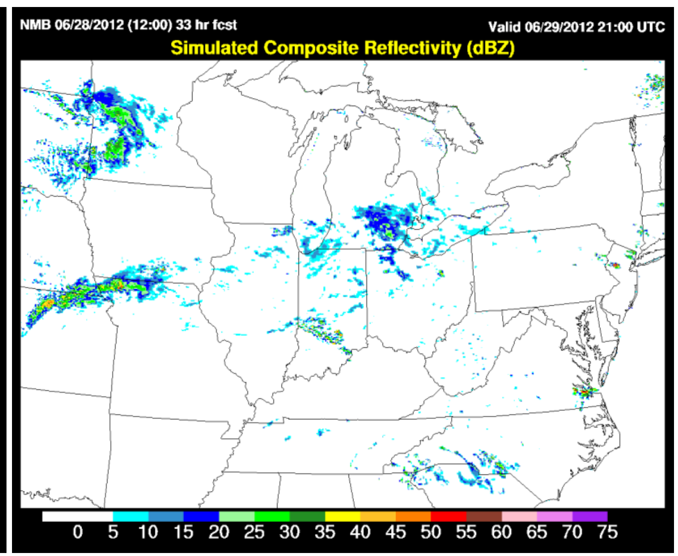
Composite Reflectivity – 3 km nest

33-h forecast valid at 21 UTC 29 June 2012

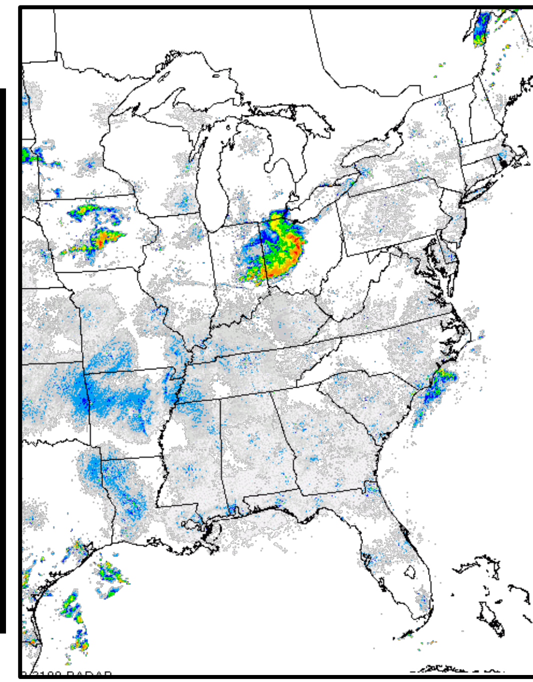
RAP OC



NAM OC

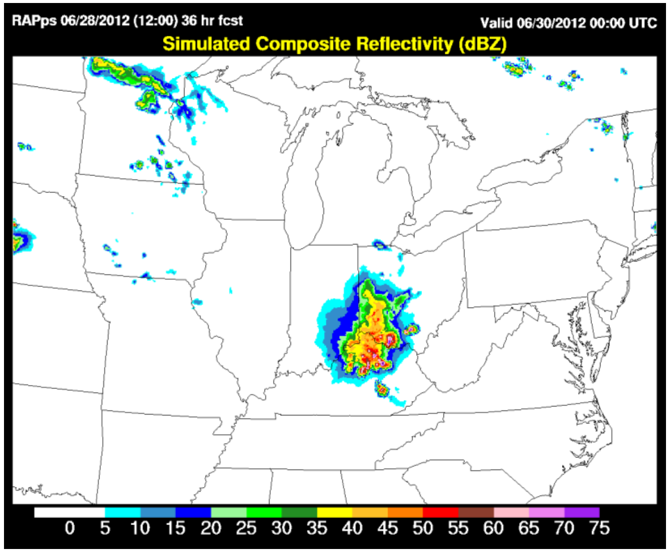


Observation

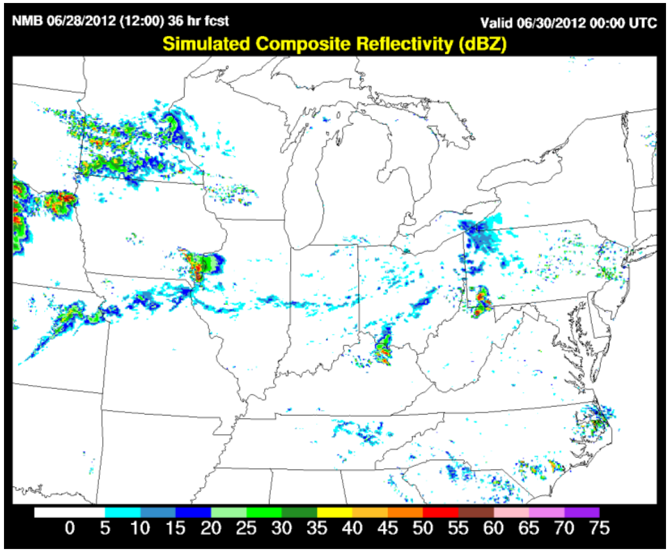


Composite Reflectivity – 3 km nest
36-h forecast, valid at 00 UTC 30 June 2012

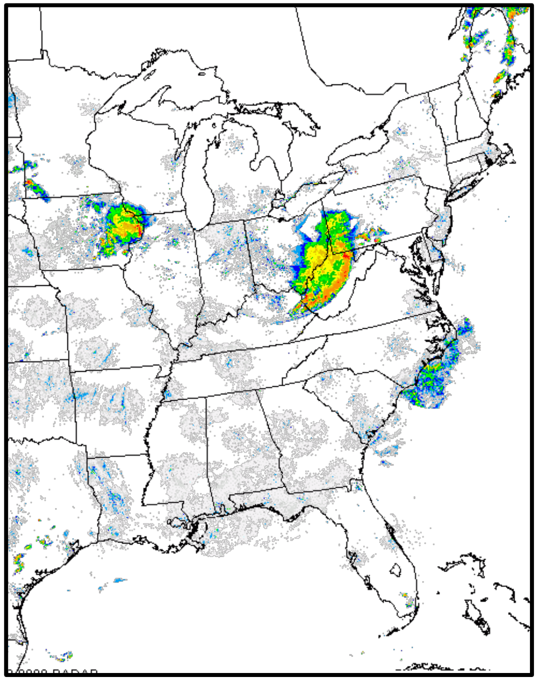
RAP OC



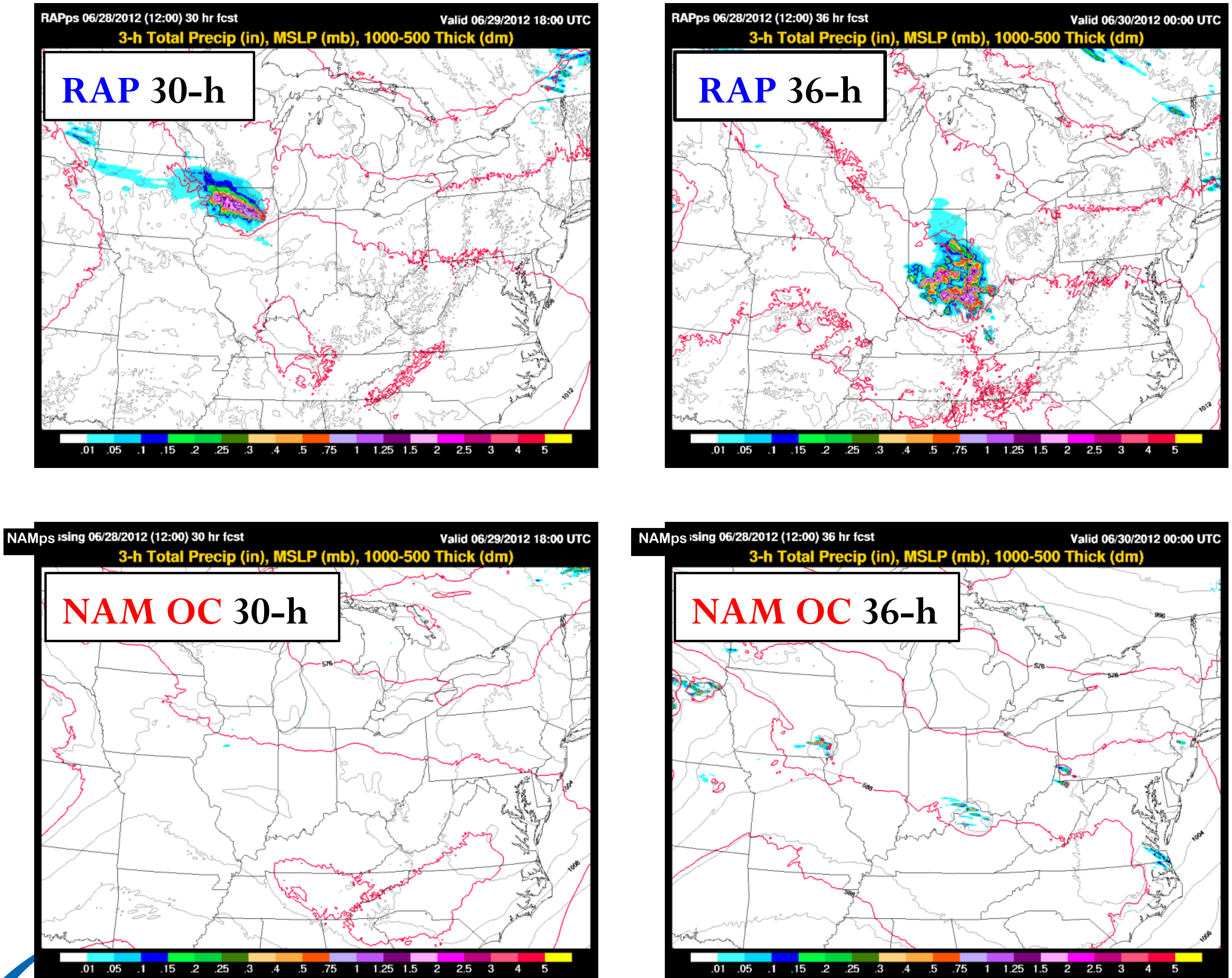
NAM OC



Observation

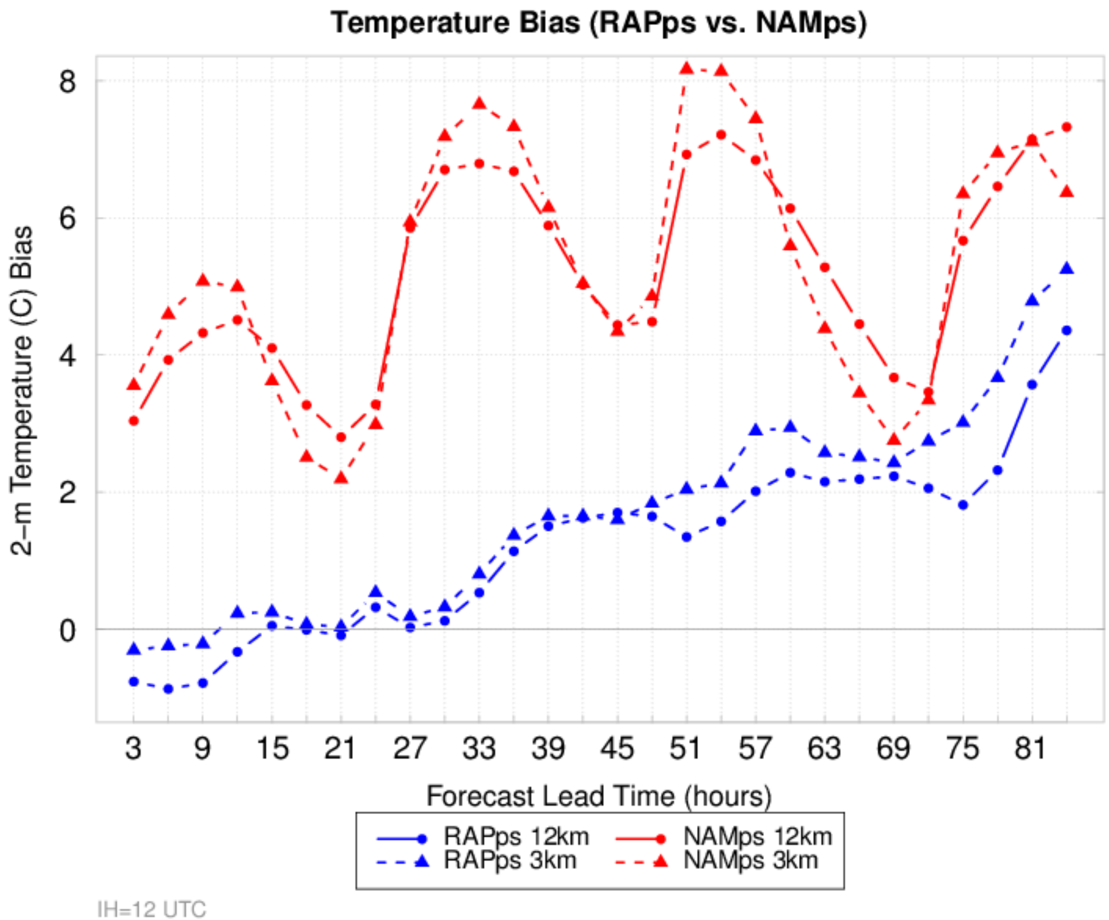


3-h Accumulated Precipitation – 3 km nest

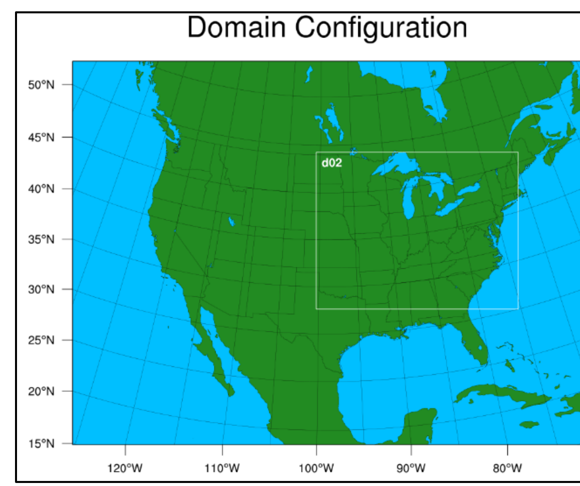


- RAP OC produces a fair amount of precipitation associated with the event while NAM OC does not for the 3 km domain

East 2-m Temperature Bias Time Series (03 – 84 h)



- The RAP OC has low temperature biases at the start of the forecast, up until the time of the event where biases increase with lead time
- NAM OC has a large warm bias at all forecast lead times with a large diurnal signal



Point Verification

2-m Temperature Bias (84-h forecast)

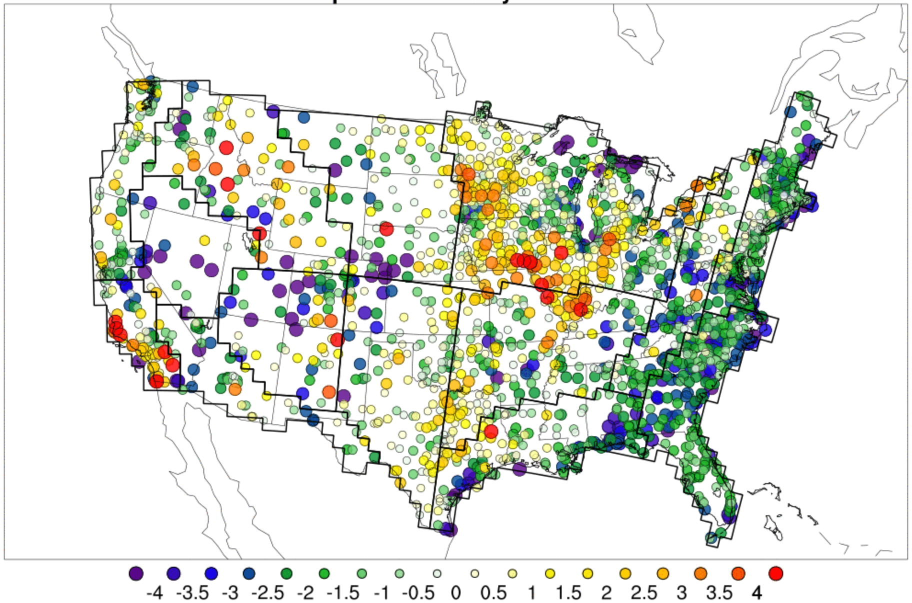
Fcst Hr: 03

Valid: 15 UTC

RAP OC

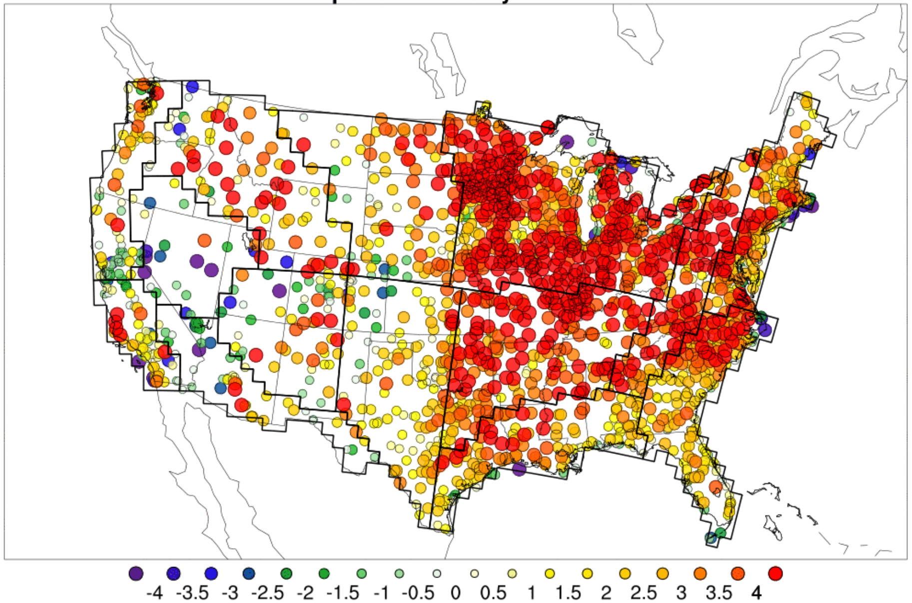
NAM OC

Temperature Bias by Station ID



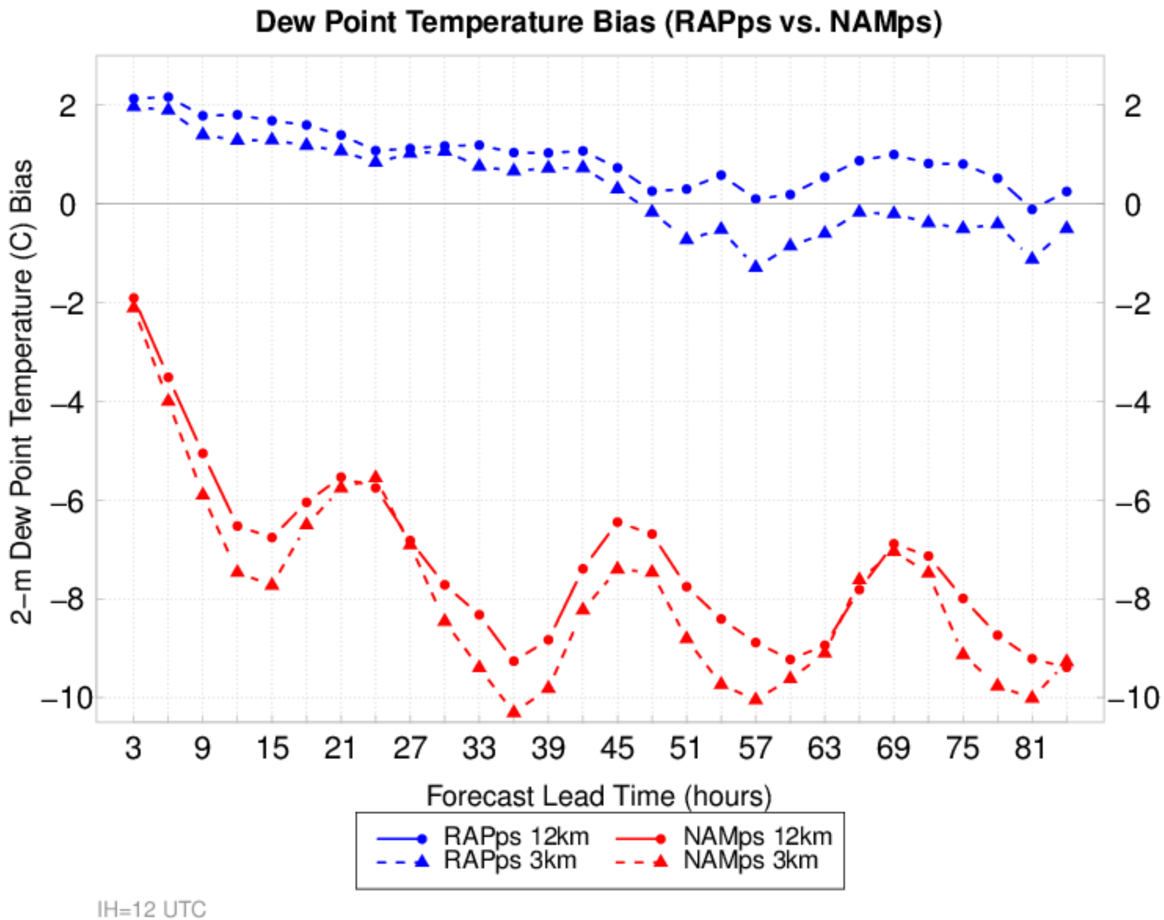
Config=RAPps Grid Spacing=12km Date=20120628 Init=12UTC Fcst Hr=03h

Temperature Bias by Station ID



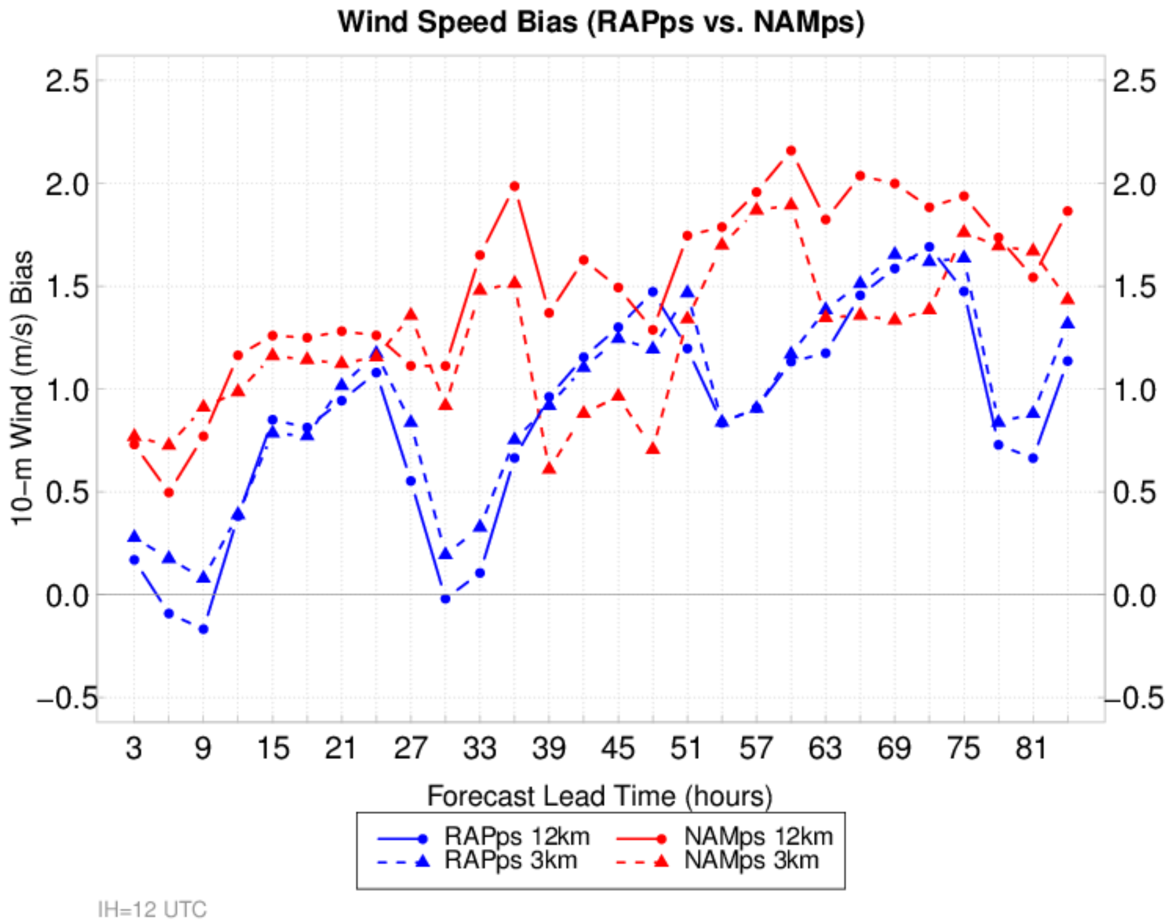
Config=NAMps Grid Spacing=12km Date=20120628 Init=12UTC Fcst Hr=03h

East 2-m Dew Point Temperature Bias Time Series (03 – 84 h)



- The RAP OC has a moist bias at the beginning of the forecast period, decreasing with forecast lead time
- NAM OC has a large dry bias, becoming more dry with forecast lead time with large amplitude diurnal signal

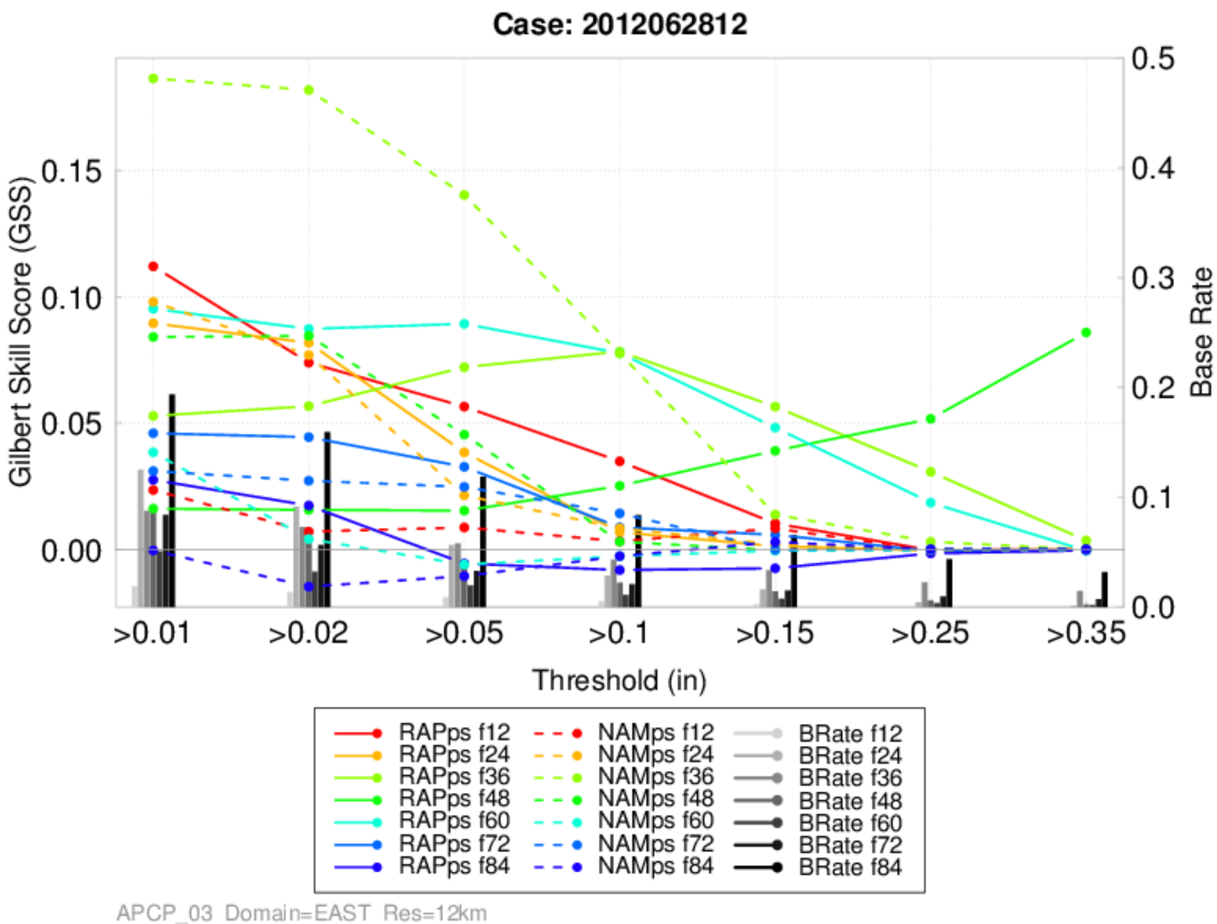
East 10-m Wind Speed Bias Time Series (03 – 84 h)



- Both RAP OC and NAM OC have high wind speed biases; RAP OC shows a large spike in speed bias during the time of the event
- RAP OC has lower median biases than NAM OC at nearly all forecast lead times

East 3-h Precipitation Verification

Gilbert Skill Score (GSS) by threshold



- Description:
  - RAP OC solid
  - NAM OC dashed
  - Cooler colors with increasing forecast lead time
  - Base rate = relative frequency of occurrence of the event
- Both configurations show a general decrease in skill and base rate with increasing threshold

Example of Community Use

Derecho Event (28 June 2012) – ***Liantang Deng***

MMET – Community Use
User Cases – Liantang Deng

Case Details: 29 June 2012 **Derecho over Midwest and Mid-Atlantic States**

Collaboration w/ CMA to diagnose potential model biases in Global/Regional Assimilation Prediction System (GRAPES) using well-studied case in MMET

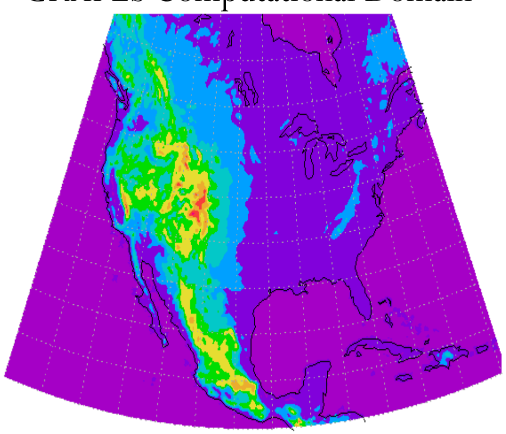
Forecasts: All simulations @ 12-km grid length

1. WRF v3.7.1 ARW baseline (MMET Baseline Configuration w/ *NAM initial conditions*)
2. GRAPES model configuration w/ *GFS initial conditions*
3. WRF v3.7.1 ARW namelist w/ *GRAPES-like physics suite and NAM initial conditions*

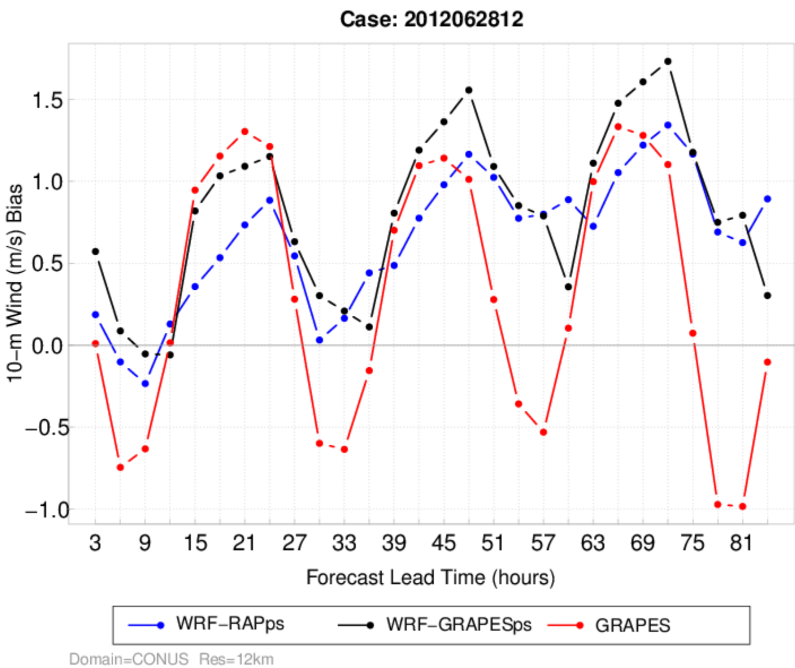
Model Initialization: 12 UTC 28 June 2012, utilized IC/BC files from DTC

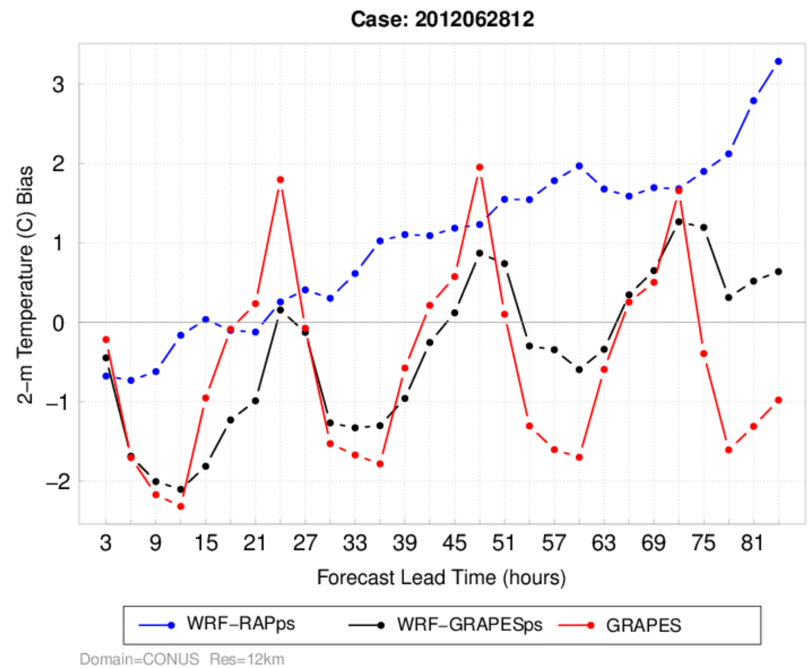
Physics Suites	WRF-RAPps	WRF-GRAPES	GRAPES
Microphysics	Thompson	WSM6	WSM6
Cumulus	Grell-Freitas	Kfeta	Kfeta
LW	RRTMG	RRTM	RRTM
SW	RRTMG	Dudhia	Dudhia
PBL	MYNN2.5	MRF	MRF
Land Surface	RUC	NOAH	NOAH

GRAPES Computational Domain



MMET – Community Use
User Cases – Liantang Deng





<u>Case Summary</u>

- Both WRF and GRAPES model runs had trouble with convective initiation
    - Try running GRAPES at higher resolution with boundary conditions from 12-km run?
- Obvious sensitivity to initial conditions (GFS vs. NAM) in statistical results
- Successful collaboration that helped determine model biases in both WRF and GRAPES models
- Added I/O interface to UPP for GRAPES model

Facilitating R2O using MMET

Stage 1: Initial testing utilizing MMET

Stage 2: Extended testing at the DTC

Stage 3: Pre-implementation testing by Operational Centers

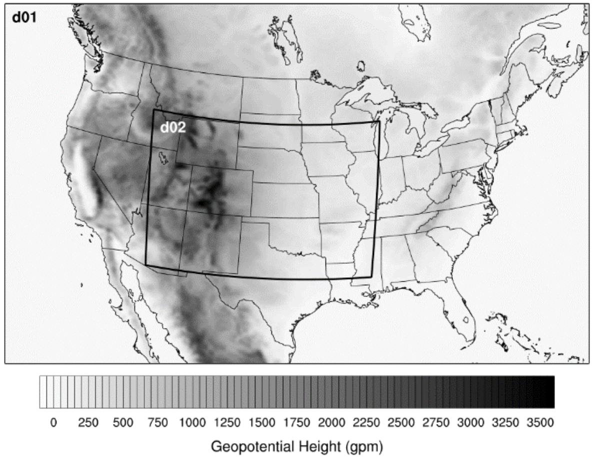
Wolff, J. K., M. Harrold, T. Hertneky, E. Aligo, J. Carley, B. Ferrier, G. DiMego, L. Nance, Y.-H. Kuo, 2016**: Mesoscale Model Evaluation Testbed (MMET): A resource for transitioning NWP innovations from research to operations (R2O).** *Bull. Am. Met. Soc.*

DOI: http://dx.doi.org/10.1175/BAMS-D-15-00001.1

Stage I: Utilizing MMET in R2O transition

- Identify persistent operational model shortfalls
  - Surface daytime temperature biases: Warm in summer; cold in winter
- Identify new approaches that may help alleviate the problem
  - Thompson MP recently ported to NEMS/NMMB code base; directly coupled with RRTMG radiation
- Perform case study testing to investigate the impacts

Model domain



	Current NAM Op Configuration	Replacement Configuration
Microphysics	Ferrier-Aligo	Thompson
Radiation SW and LW	RRTM	RRTM
Surface Layer	MYJ	MYJ
Land-Surface Model	Noah	Noah
Planetary Boundary Layer	MYJ	MYJ
Convection	BMJ (parent only)	BMJ (parent only)

Thompson coupling with RRTMG

- In general, constant-coupled shows more reflective (higher albedo) clouds, leading to less shortwave reaching ground

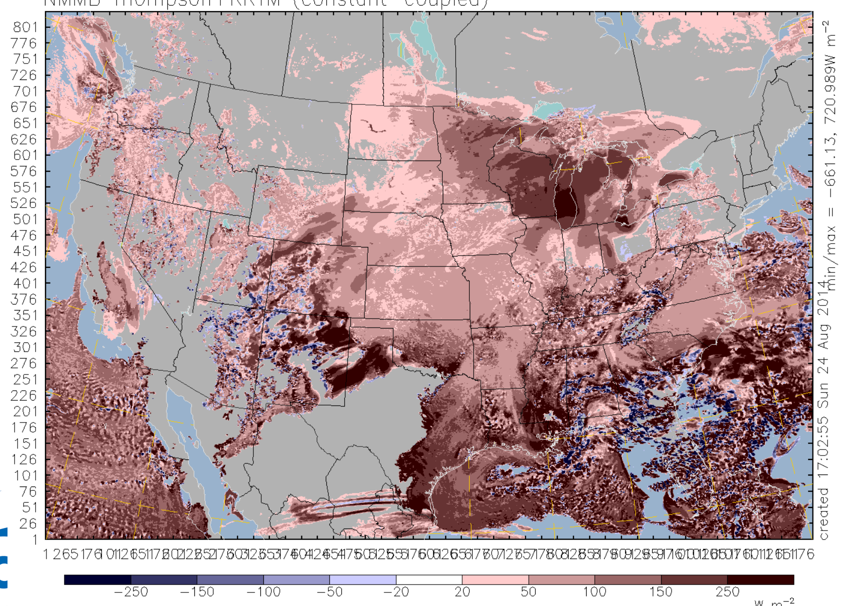
RSWTOA
upward shortwave
top-of-atmos

RSWIN
downward shortwave
reaching ground

Difference RSWTOA constant-coupled

18-hour forecast valid 18:00 UTC 31 Jan 2011 initial time: 00z 31Jan

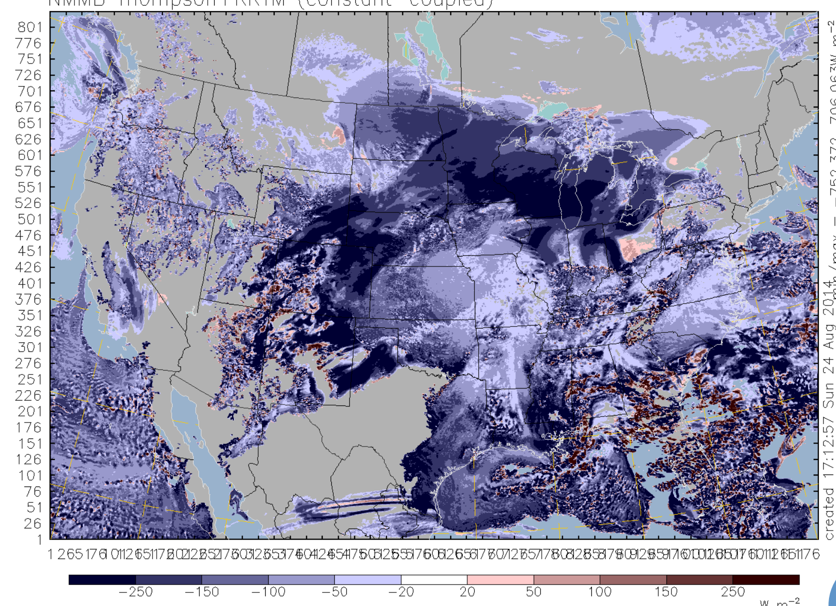
NMMB Thompson+RRTM (constant−coupled)



Difference RSWIN constant-coupled

18-hour forecast valid 18:00 UTC 31 Jan 2011 initial time: 00z 31Jan

NMMB Thompson+RRTM (constant−coupled)



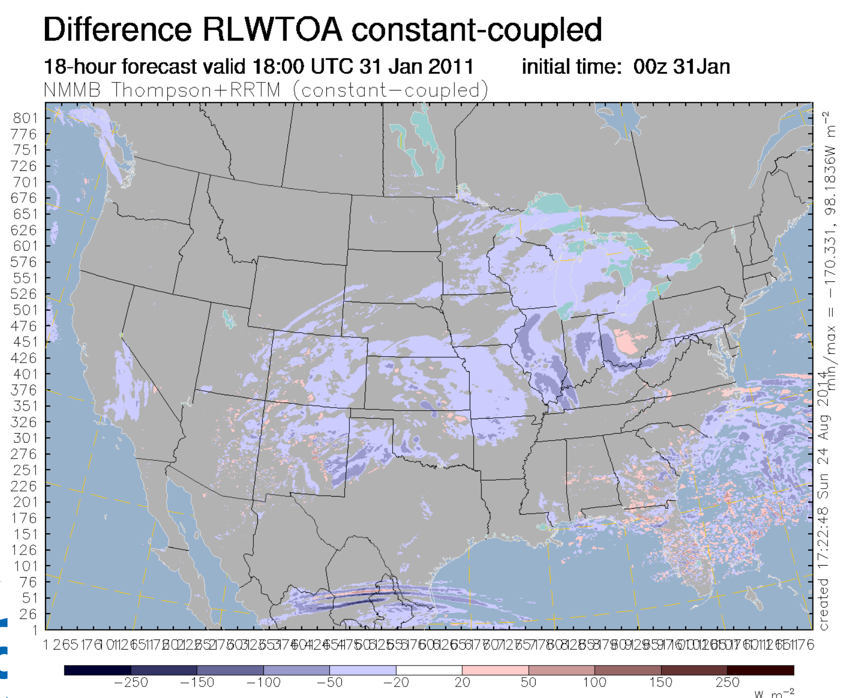
Courtesy: Greg Thompson

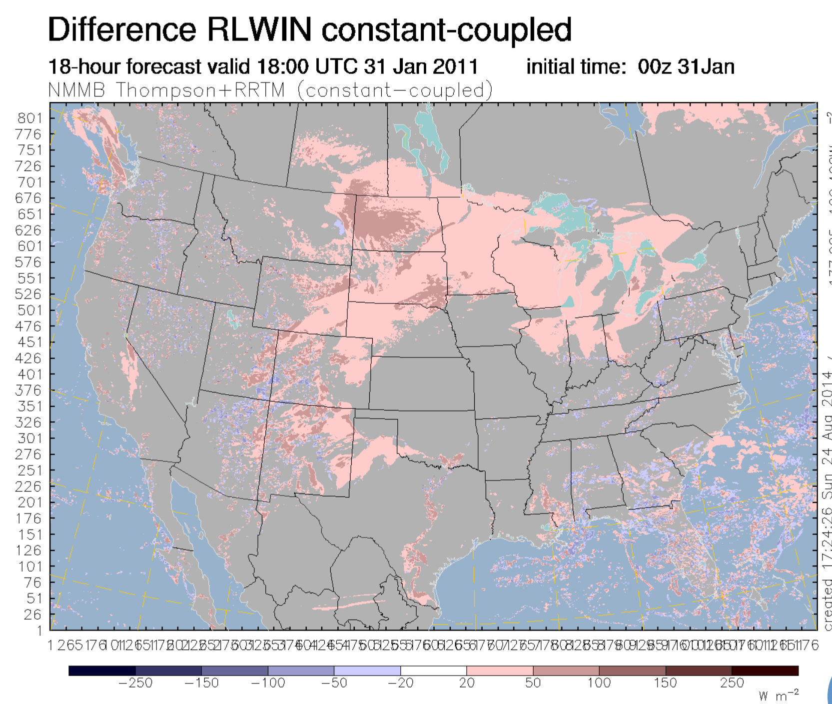
Thompson coupling with RRTMG

- Top of clouds have lower outgoing radiation in constant because of smaller ice particles

RLWTOA
upward longwave
top-of-atmos

RLWIN
downward longwave
reaching ground

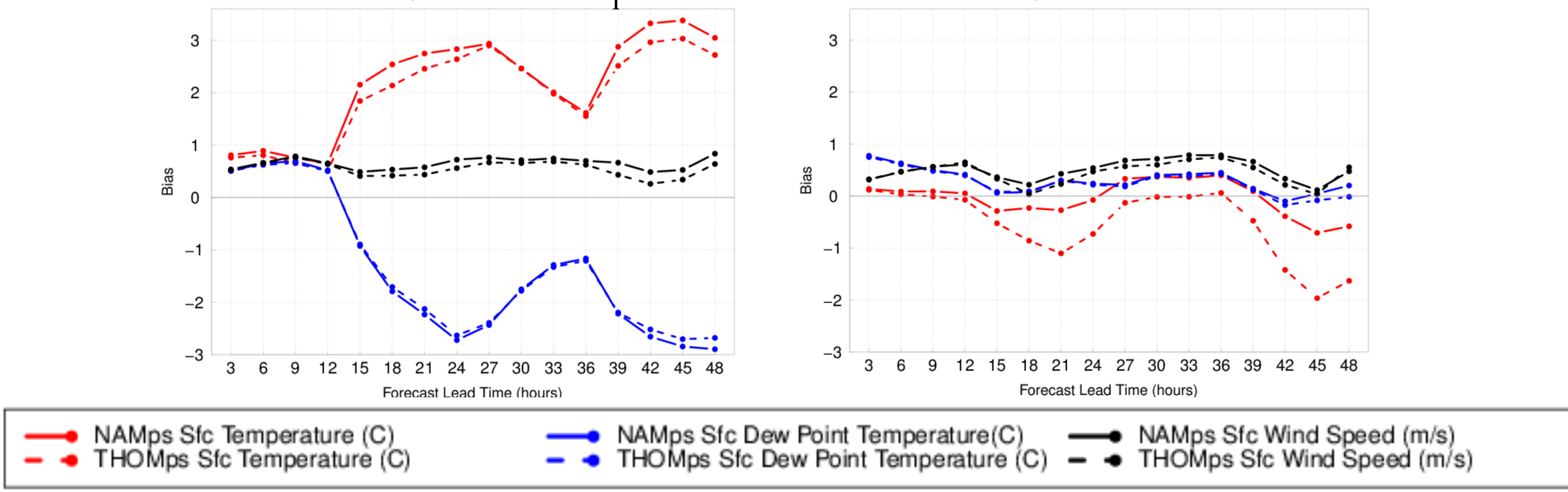




Results using MMET cases

Summer case: 00 UTC 11 Sep 2013

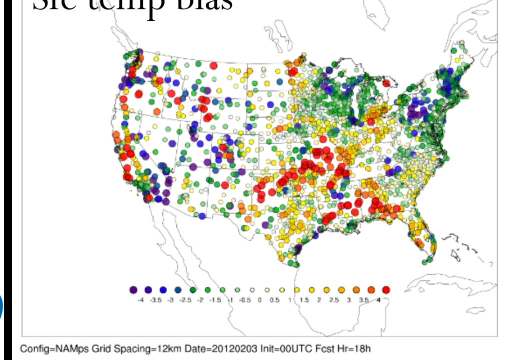
Winter case: 00 UTC 03 Feb 2012



Winter case: 00 UTC 03 Feb 2012 Fhr=18

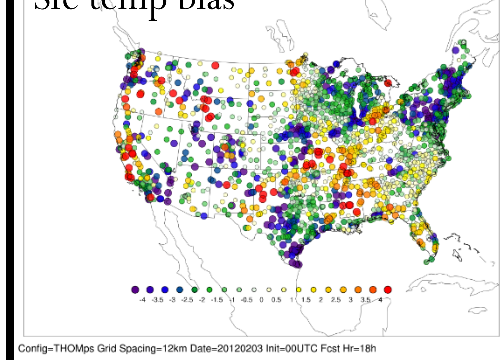
NAMps

Sfc temp bias



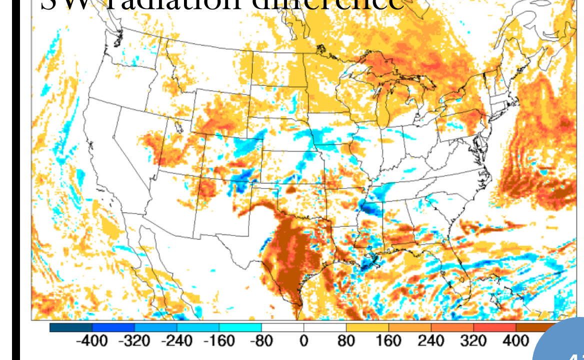
THOMps

Sfc temp bias



NAMps-THOMps

SW radiation difference

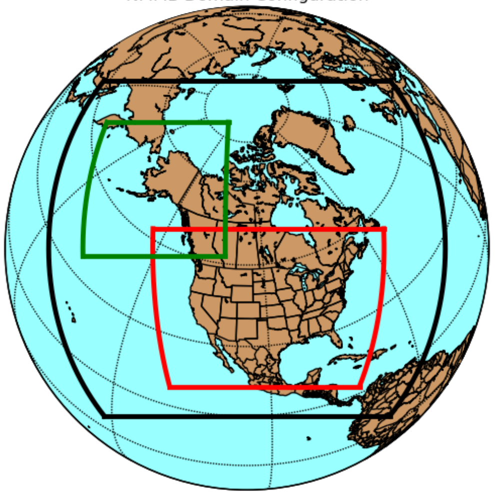


Stage II: DTC extended T&E

NEMS/NMMB inter-comparison

- **End-to-end system:** NPS, NMMB, UPP, and MET
- **Test period:** : One month per season, w/ 48-h forecasts initialized every 36 h
- **Domain:** 12-km North American grid w/ 3-km CONUS and AK nests; 60 vertical levels and model top of 10 hPa
- **Evaluation:** Performance assessment of the Ferrier-Aligo and Thompson microphysics schemes
  - Surface and upper air [BCRMSE, bias]
    - Temperature, dew point, wind speed
  - Precipitation [Gilbert skill score (GSS), frequency bias]
    - 3- and 24-h accumulations, composite reflectivity
  - Statistical Assessment
    - Confidence Intervals (CI) at the 99% level
    - Pair-wise difference methodology
    - Statistical significance (SS) and practical significance (PS)
  - Verification by observation station
    - Temperature, dew point temperature, and wind speed bias
  - Accumulated stats over domain
    - Base rate, GSS, frequency bias
  - Accumulated model output over domain
    - PBL height, SW/LW radiation, sensible/latent heat flux

Fall	**12 Oct – 15 Nov 2013**
Winter	**16 Jan – 19 Feb 2014**
Spring	**16 Apr – 17 May 2014**
Summer	**6 Jul – 9 Aug 2014**

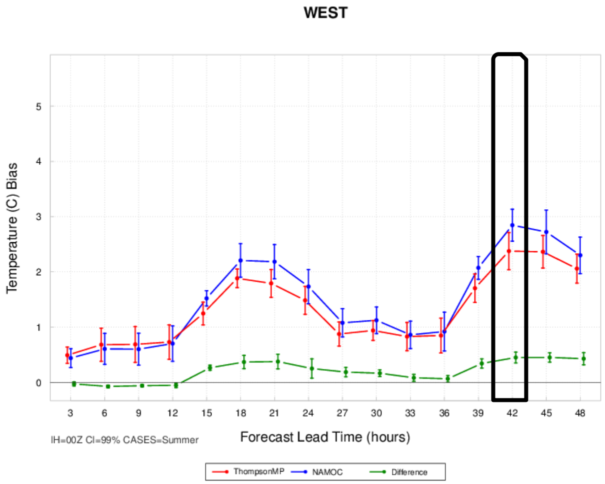


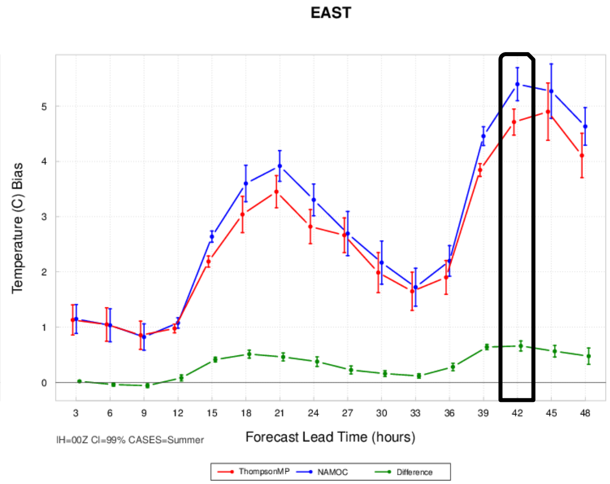
http://www.dtcenter.org/eval/meso_mod/nmmb_test/nems_v0.9/

2-m temperature bias

00 UTC initializations - fcst hr 42

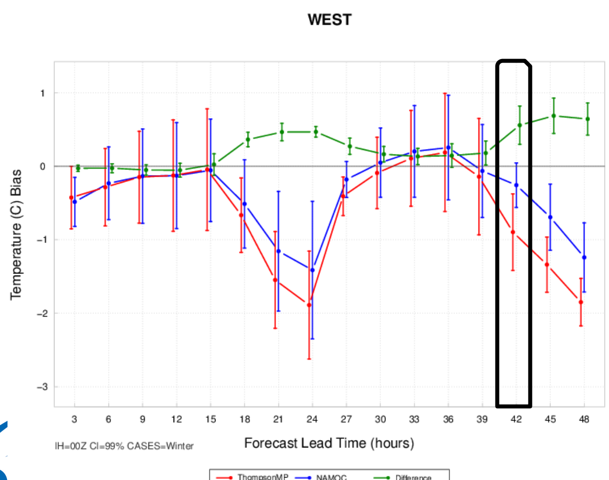
Summer

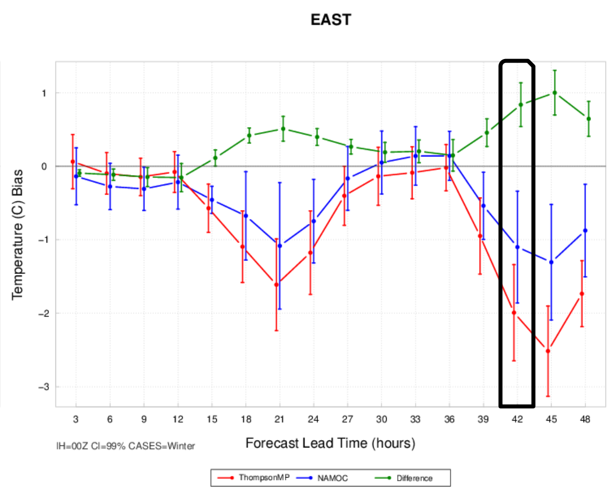




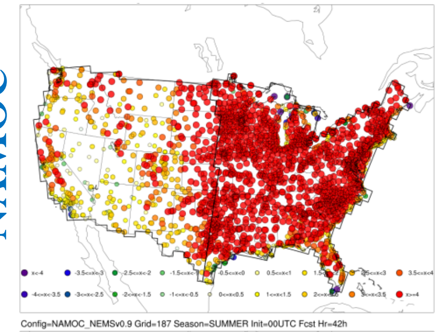
NAMOC ThompsonMP Difference

Winter

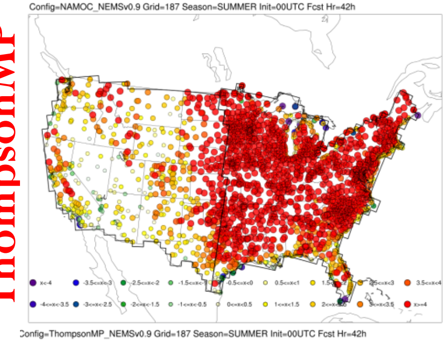




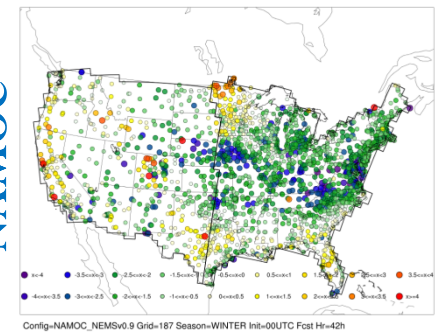
NAMOC



ThompsonMP



NAMOC



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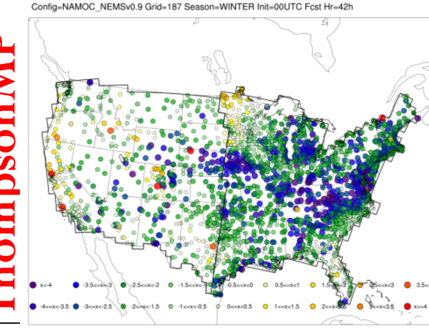
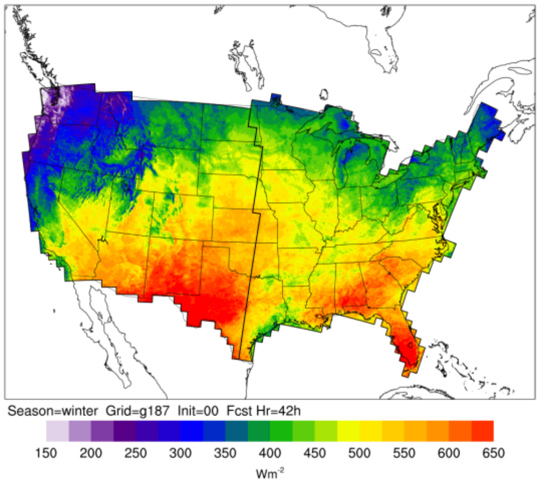


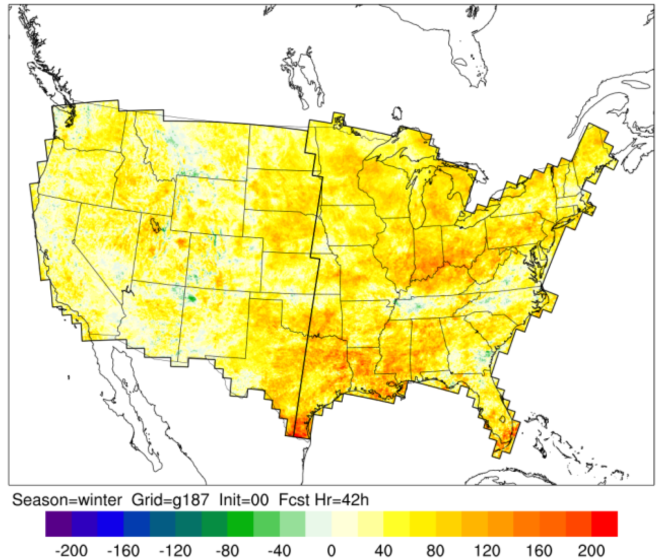
Downward SW radiation

00 UTC initializations – fcst hr 42; Winter

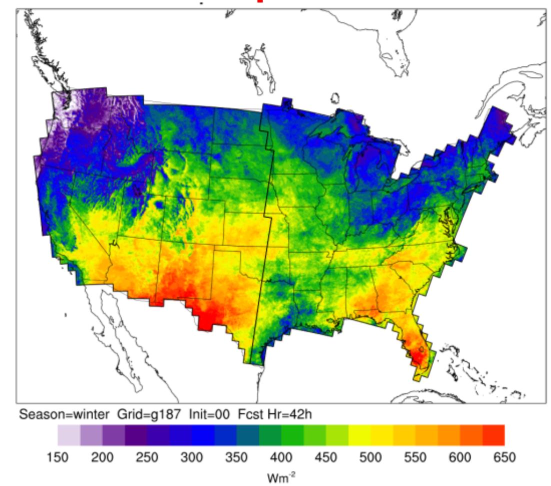
NAMOC



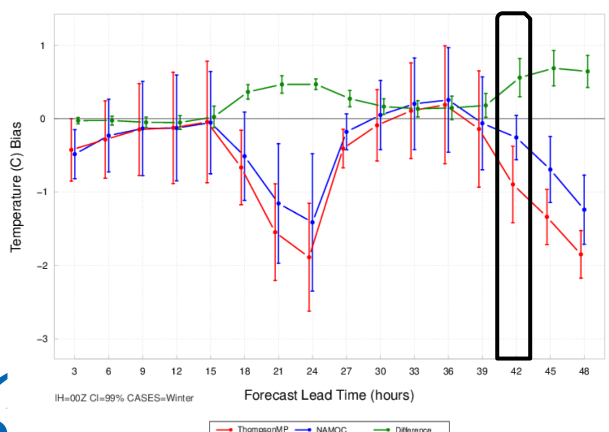
Mean Differences for DSWRF (NAMOC-ThompsonMP)



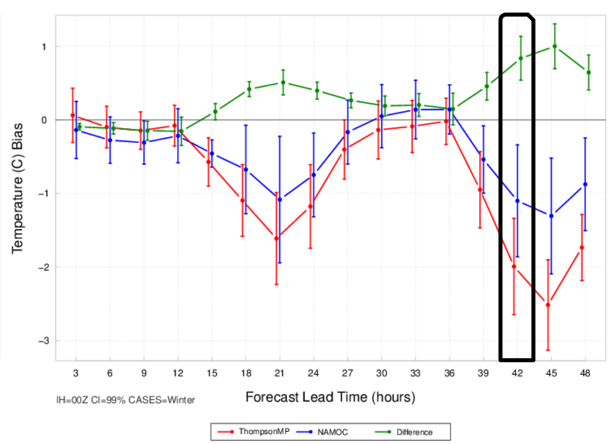
ThompsonMP



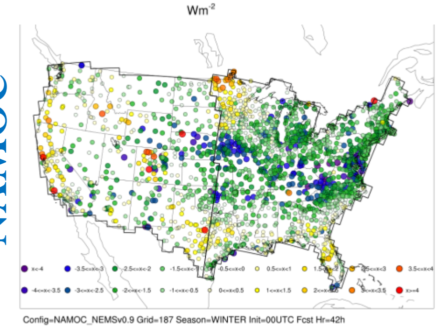
WEST



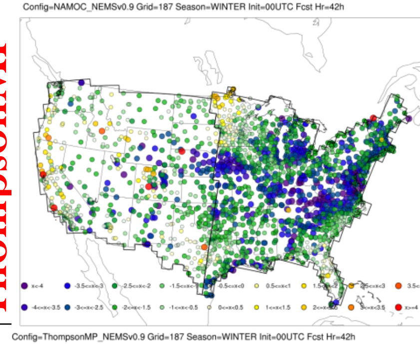
EAST



NAMOC



ThompsonMP



Stage III: Operational impact

- Results were shared with developers
  - NAMOC had higher radiative values than ThompsonMP
    - Except for downward longwave flux → likely influenced by expansive winter cloudiness and coupling between microphysics and radiation
  - Correspond with regional point verification
    - Thompson generally colder than NAMOC
- Based on results from DTC extended T&E and parallel runs conducted by EMC:
  - Removed the lower limit for cloud droplet effective radius in RRTMG with the Ferrier-Aligo microphysics scheme
  - Implementing a partial cloudiness scheme to better represent subgrid scale clouds
- Both modifications are expected to improve surface shortwave radiation fluxes and improve surface temperature forecasts

NAM parallel change log:

2015/07/30/18	Ferrier, H-M. Lin	• Changes to the radiation / microphysics: 1. The cloud droplet effective radius is calculated assuming a monodisperse droplet distribution. It is also not allowed to be less than minimum a value of 5 microns, which is reached when cloud water contents are less than 0.1045 g m^-3. The droplet effective radius is no longer forced to be between 10 and 15 microns. The change is anticipated to reduce incoming surface shortwave fluxes under liquid clouds and reduce daytime 2 m warm biases. 2. The assumed cloud droplet number concentration within radiation is no longer assumed to vary with temperature. Instead it is assumed to be a fixed value of 200 cm^-3, the same as what is assumed in the FA microphysics.

Helpful links

MMET Online Links

MMET Website

- http://www.dtcenter.org/eval/meso_mod/mmet/index.php

R2O Testing Protocol Document

- http://www.dtcenter.org/eval/meso_mod/mmet/testing_protocol.pdf

Nomination form for new innovations

- http://www.dtcenter.org/eval/meso_mod/mmet/candidates/form_submission.php

Submission form for additional cases to be included in MMET

- http://www.dtcenter.org/eval/meso_mod/mmet/cases/form_submission.php

RAMADDA Data Repository

- http://www.dtcenter.org/repository

Community Code Links

Weather Research and Forecasting Model (WRF)

- http://www.wrf-model.org/index.php

NOAA Earth Modeling System (NEMS)

- http://www.dtcenter.org/nems-nmmb/users/

Unified Post Processor (UPP)

- http://www.dtcenter.org/upp/users/

Model Evaluation Tools (MET)

- http://www.dtcenter.org/met/users/

Gridpoint Statistical Interpolation (GSI)

- http://www.dtcenter.org/com-GSI/users/

Questions?

Thank You!

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