WGNE 28
High Resolution Modeling

Compiled by Bill Lapenta & Gary Dietachmayer

Thanks to WGNE Members for the contributions

Observed Commonalities Across Operational Centers

Trends:

- **Operational limited area models at > 5km horizontal resolution**
- **Designed for special applications**
  - **NOAA—Severe Wx (convection, hurricanes) and aviation**
  - **Meteo France---Fog**
  - **CMA– Flooding**
  - **UKMO & JMA—Coastal phenomena**
  - **BOM—coasts and cities**
  - **ECMWF—global application**
- **Trying to simplify/unify configurations**
- **Move toward rapidly updating systems—hourly DA and forecasts**

Challenges:

- **Data Assimilation methodology and control variables**
- **Physical representations**
- **Prediction of sensible weather elements**
- **Nesting & Computational costs**
- **Verification (development & customer)**
- **High resolution ensemble systems**

An Important Pinpoint Prediction Challenge:

The 29 June 2012 Mid-Atlantic Derecho

After the storm, D.C. still scrambling

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By ANDREW RESTUCCIA and DARIUS DIXON | 7/2/12 1:44 PM EDT

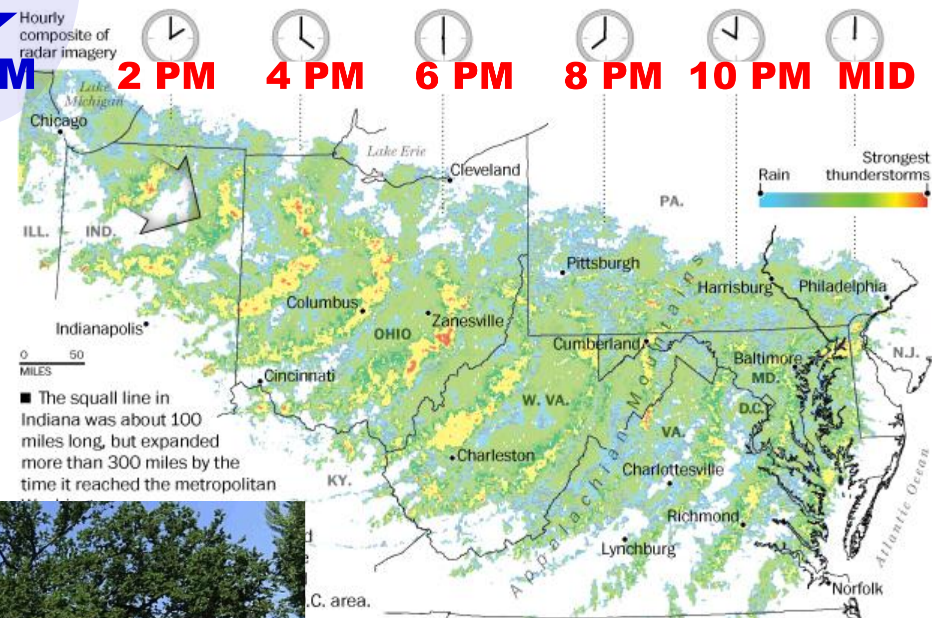
Congress closed down for the holiday week — and then the derecho turned the lights out.

On Monday, the massive weekend storm that pummeled the mid-Atlantic region had congressional and administration staffers scrambling amid power outages, fallen trees and

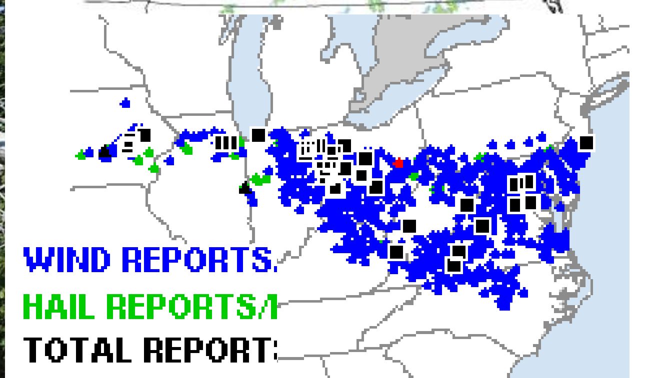
Start HRRR run

11 AM

A fast moving damaging wind event…

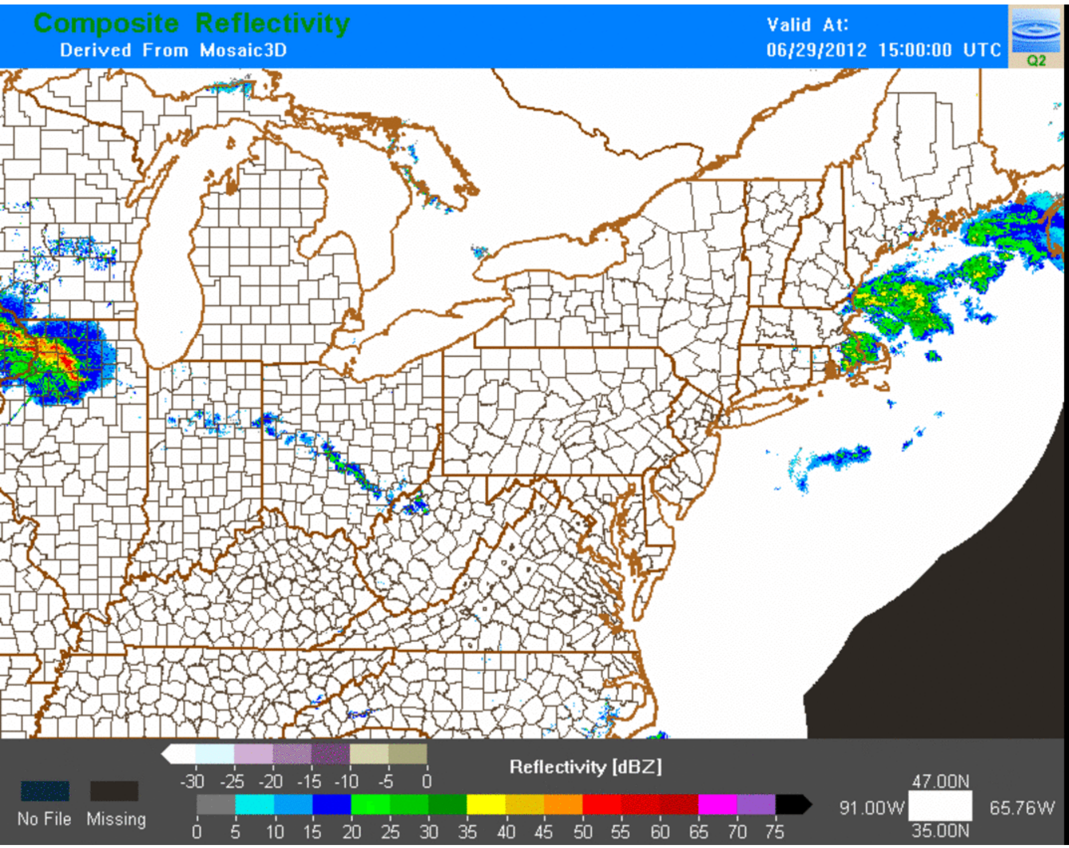


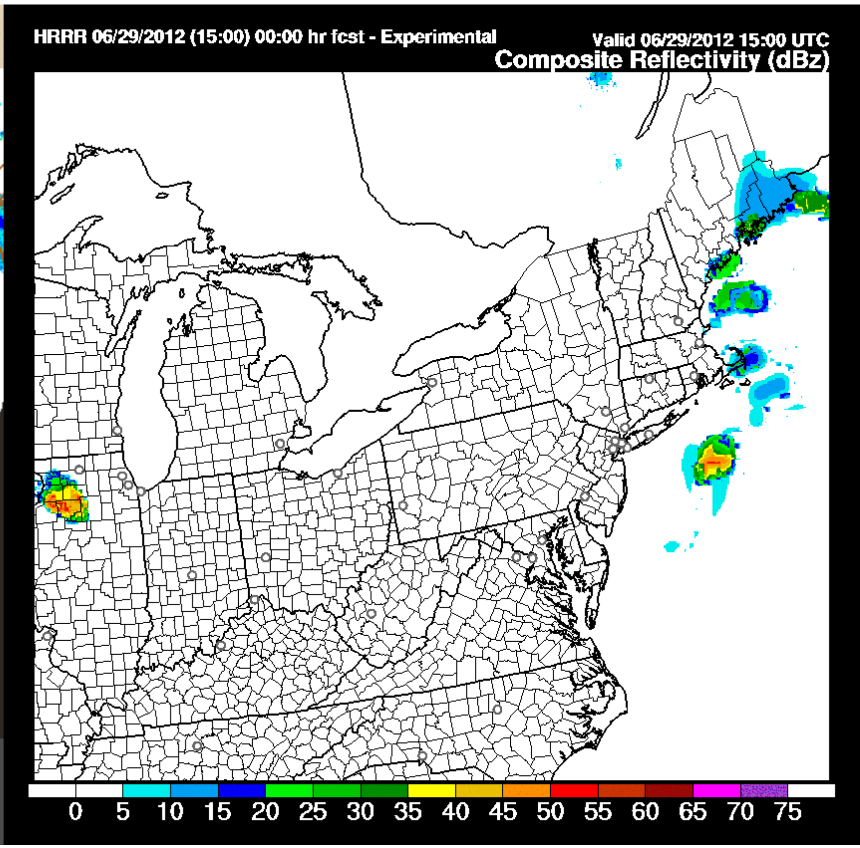
700 mile long swath of damage, 5 million without power, 22 fatalities



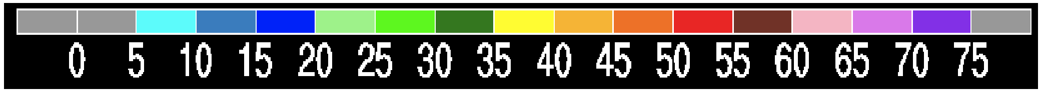
NOAA Next-Generation RAP / HRRR System
Forecast of Mid-Atlantic Derecho

Radar observed | **HRRR forecast**

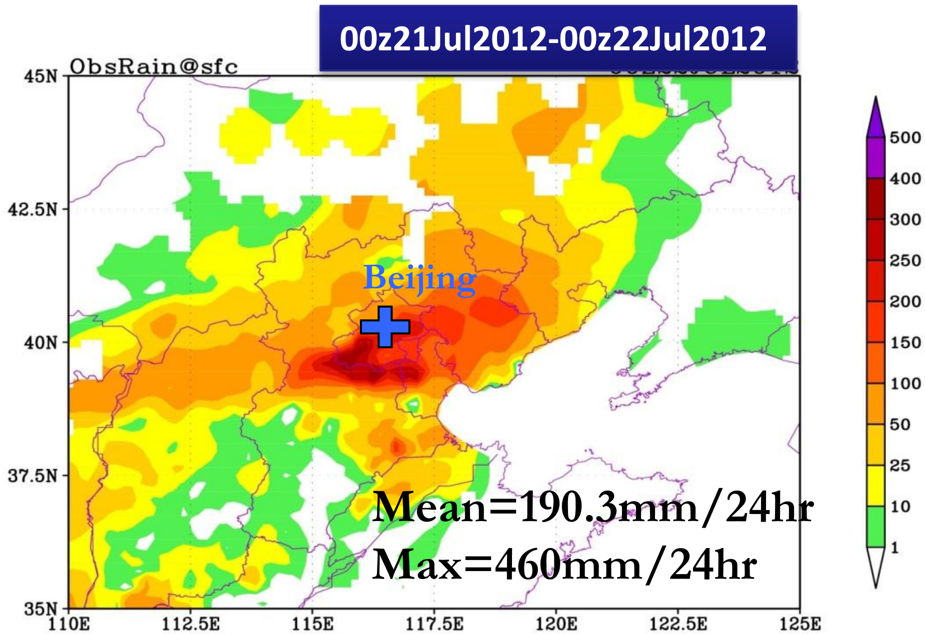


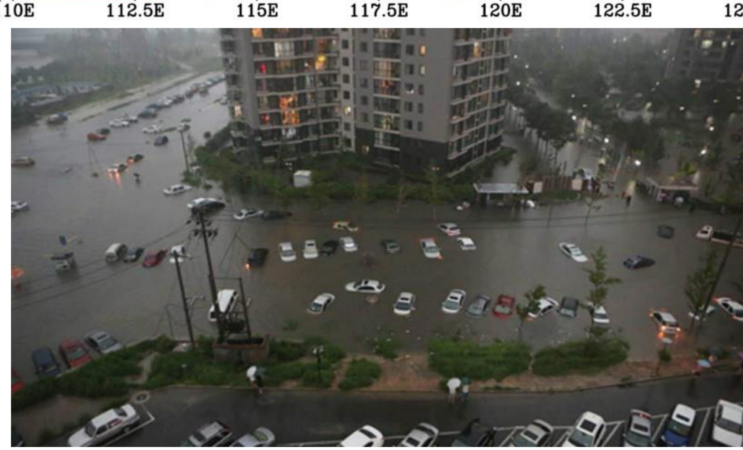


Composite Reflectivity (dBZ)



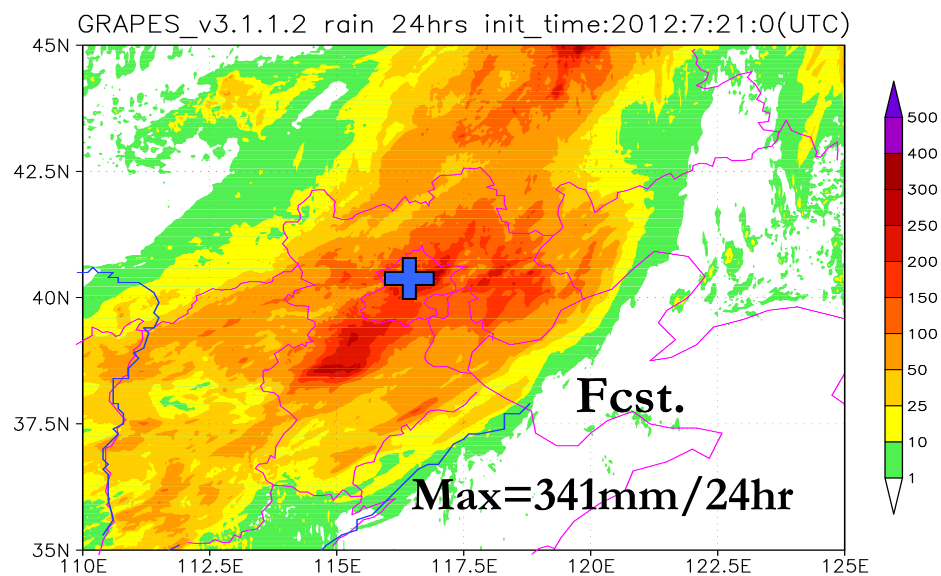
CMA: Heavy rainfall event on Jul.21/2012 Beijing





Initial: global analysis
BC: global forecast
Grid size:3km
Physics:
- microphysics: WSM6
- radiation: RRTM S&L
- pbl : MRF
- land surface : NOAH

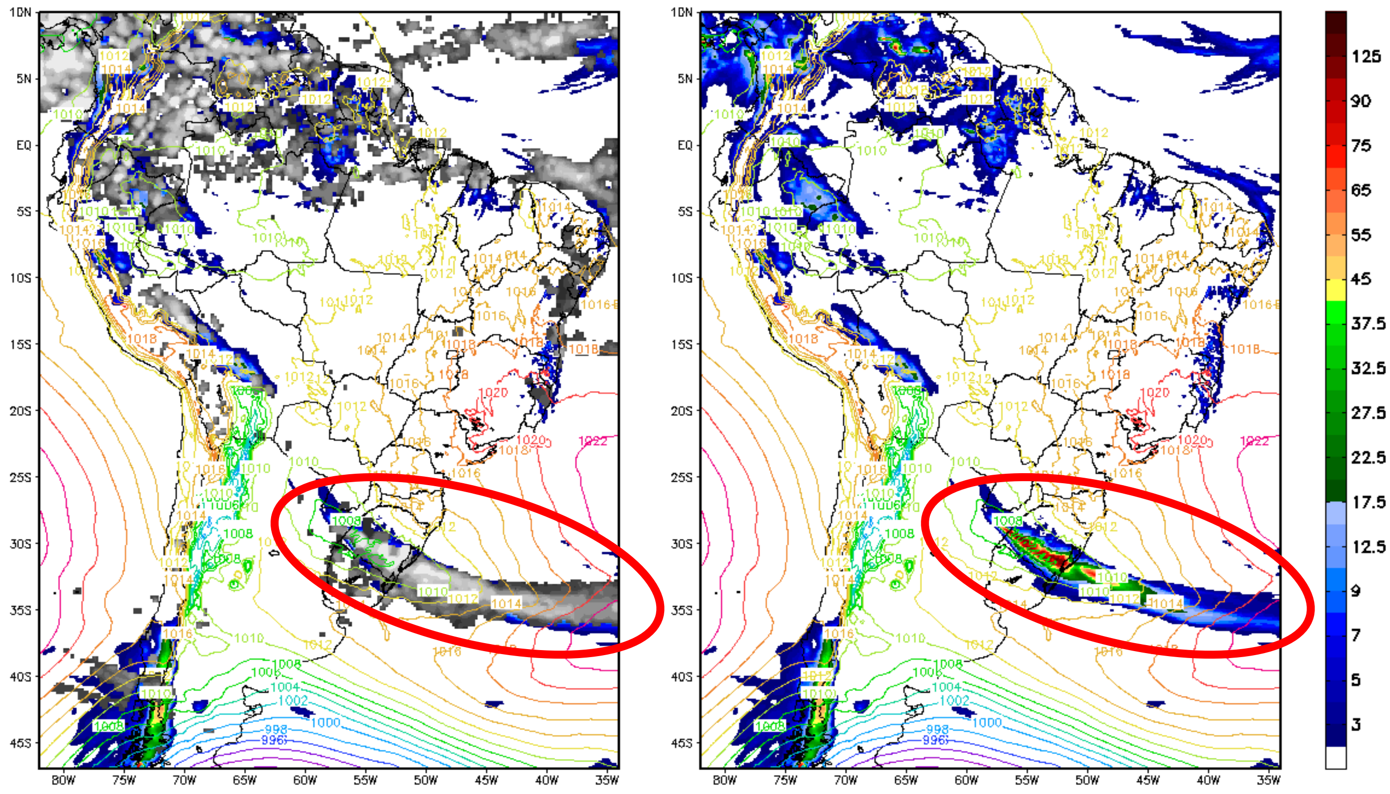
24-hour accumulated rainfall



CPTEC: BRAMS 5 km resolution (experimental, under evaluation)

- **Grid spacing: H - 5 km x 5 km, V - 50 to 800 m, model top @ 21 km**
- **Model domain: South America with 100 x 10^6 (1360 x 1489 x 55) grid points**
- **Forecast length: 5 days, currently at 00 UTC, planned to include at 12 UTC**
- **Parameterization for deep convection: Grell version 3d with lateral spreading of environmental subsidence.**

Remote Sensing Rainfall — Model Rainfall – 24 hr accum.



Environment Canada's
High Resolution Deterministic Prediction System

1. Multi-grid 2.5 km HRDPS

- 1 operational domain (2 x 42-h runs)
- 4 experimental domains (1 x 24 h run)

→ **Currently running**

2. National-2.5 km– STAGE 1

- single, national grid
- 2 x 48-h runs
- high-resolution surface fields (CaLDAS)
- cycling of cloud fields
- detailed microphysics (to be upgraded)
- increased vertical resolution

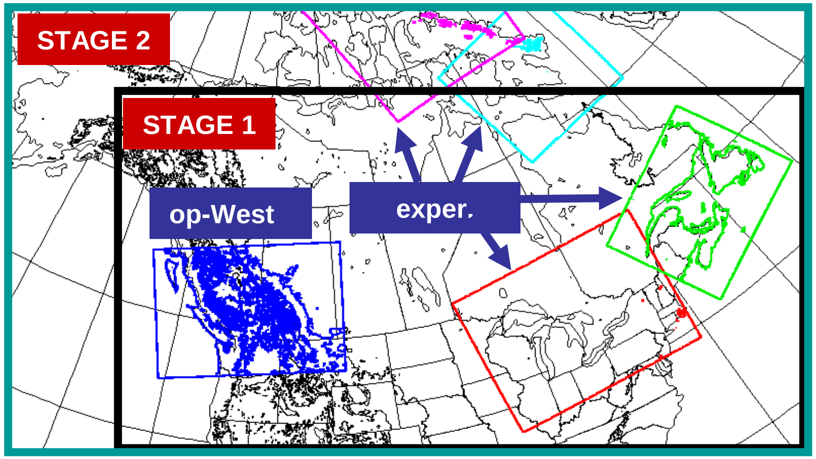
→ **2013**

3. National-2.5 km – STAGE 2

- 4 x 48-h
- upper-air data assimilation cycle (EnVar*)

→ **2015**

Simplify Grid Configurations



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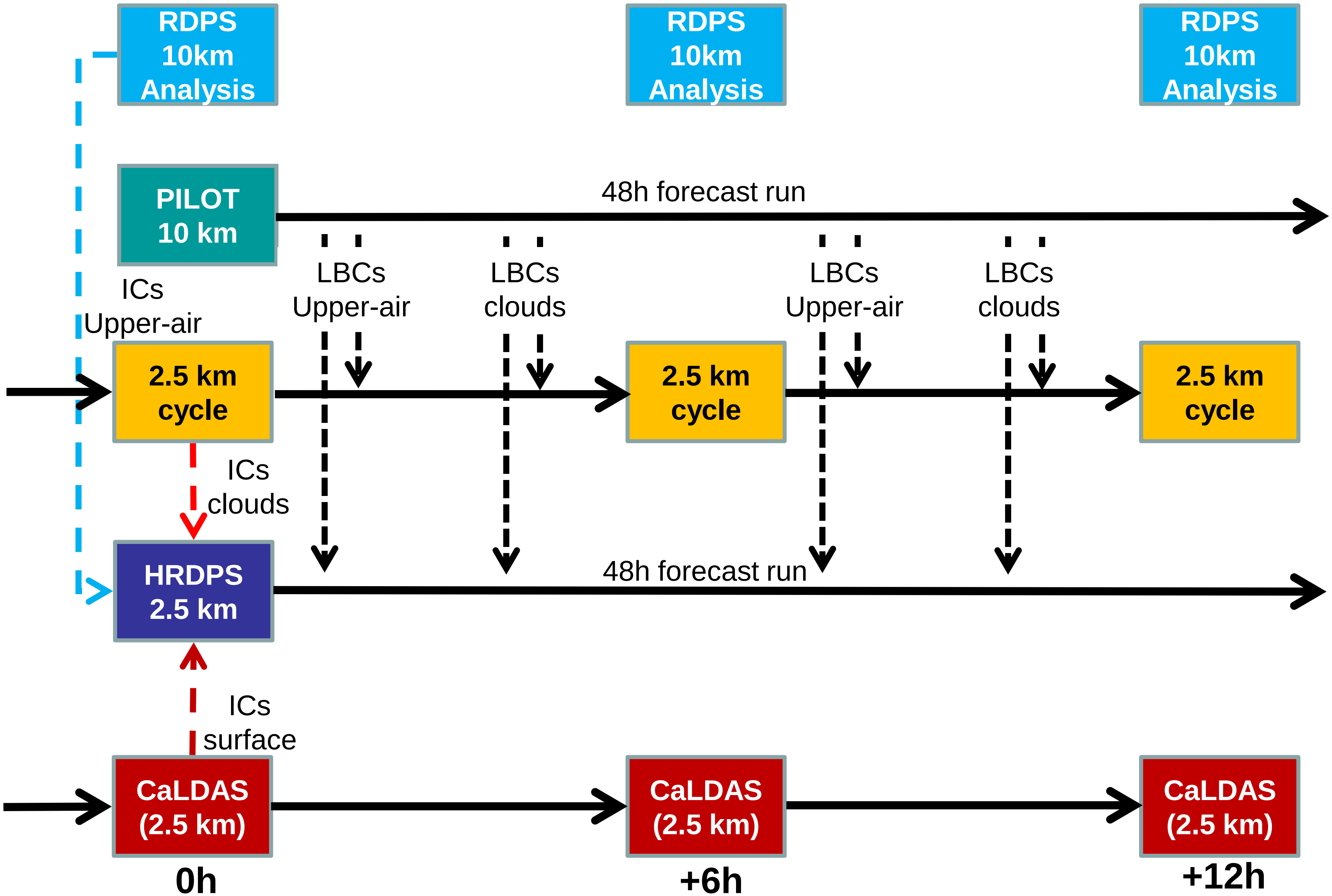
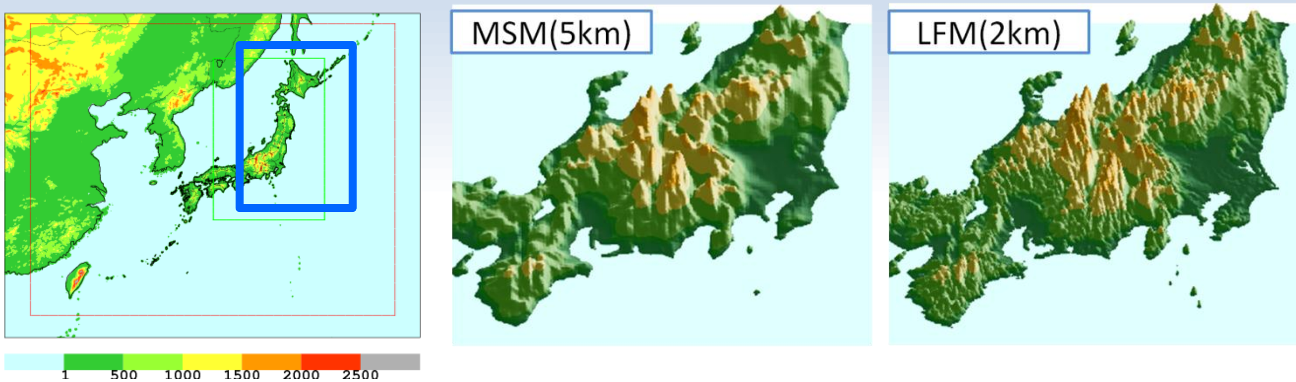
Future sequence for ICs and BCs (National-2.5 system):

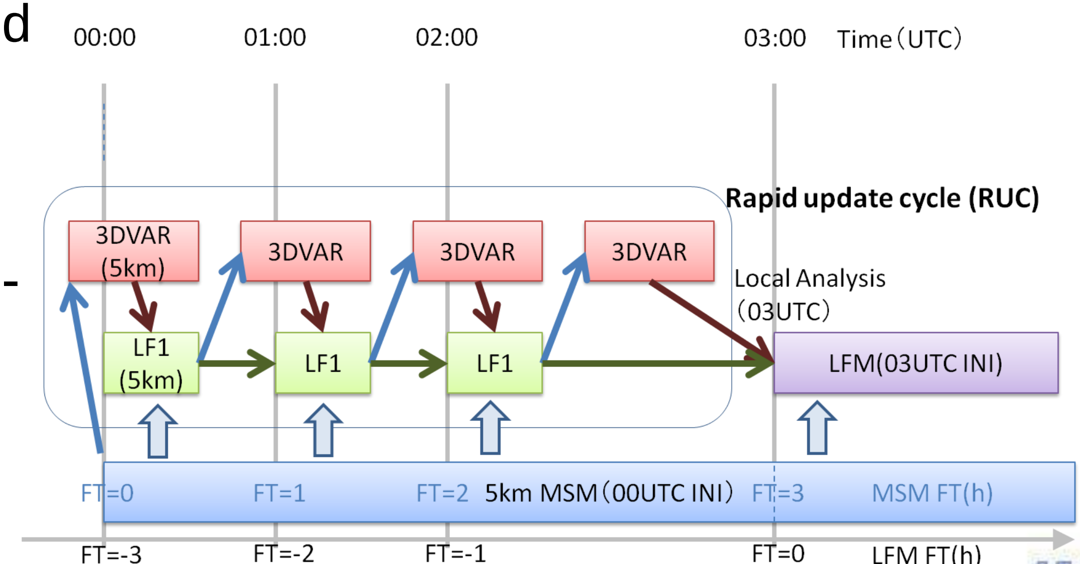


JMA: Rapidly Updating Cycle



Forecast domain of LFM (Blue) and topography of MSM and LFM

A schematic figure of the rapid update cycle (generating an analysis at 0300UTC in this case). The cycle repeats assimilation by 3DVAR and 1-hour forecasts (LF1). The cycle is executed at 5-km horizontal resolution.



Data Assimilation @ CAWCR / BoM

- **Main focus on convective scale NWP**
  - **1.5km, 3dVAR, latent heat nudging, Doppler winds**
  - **Centred on Sydney (central east coast)**
    - **population, obs coverage, high impact weather (t/storms, E.Coast Lows, fires etc.)**

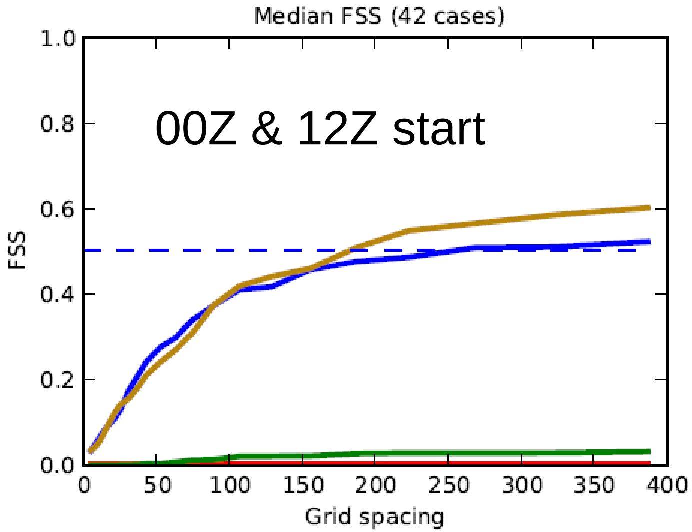
- **9 months trial, 3hourly 3dVAR**
  - **Hourly rainfall: 1.5km+3dVAR(3hour) no better than 12km+4dVAR(6hour) interpolated to 4km… if start at same time**
  - **BIG advantage from more frequent update (compare "latest run")**
  - **Model rainfall bias major source of error**
  - **Skilful length scales still ~150km or more**
  - **Latent Heat Nudging: small positive gain for a few hours**

- **Clear air winds**
  - **Model comparisons show small bias**

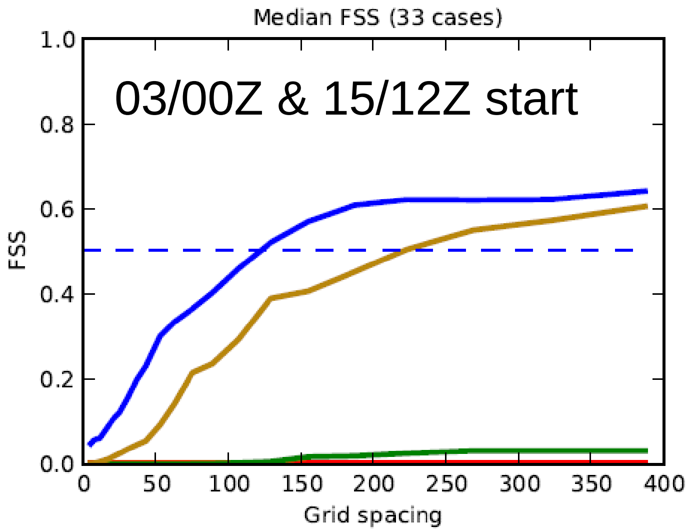
Data Assimilation @ CAWCR / BoM

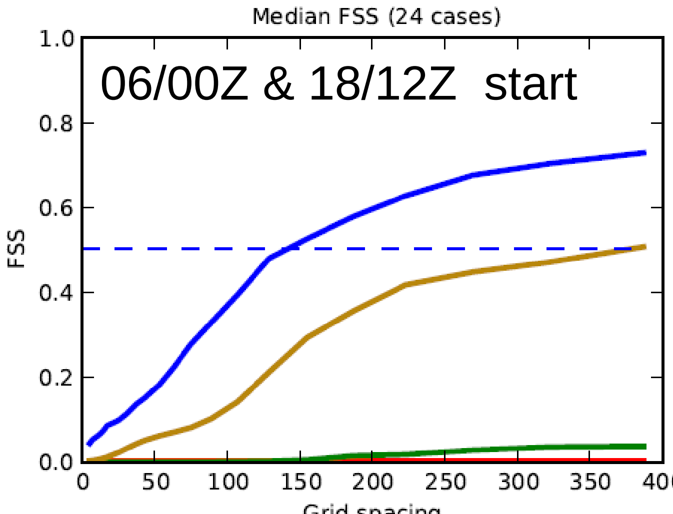
- Effect of meso DA fades by ~12hours (LBC's, predictability etc.)

FSS for 8mm/h threshold

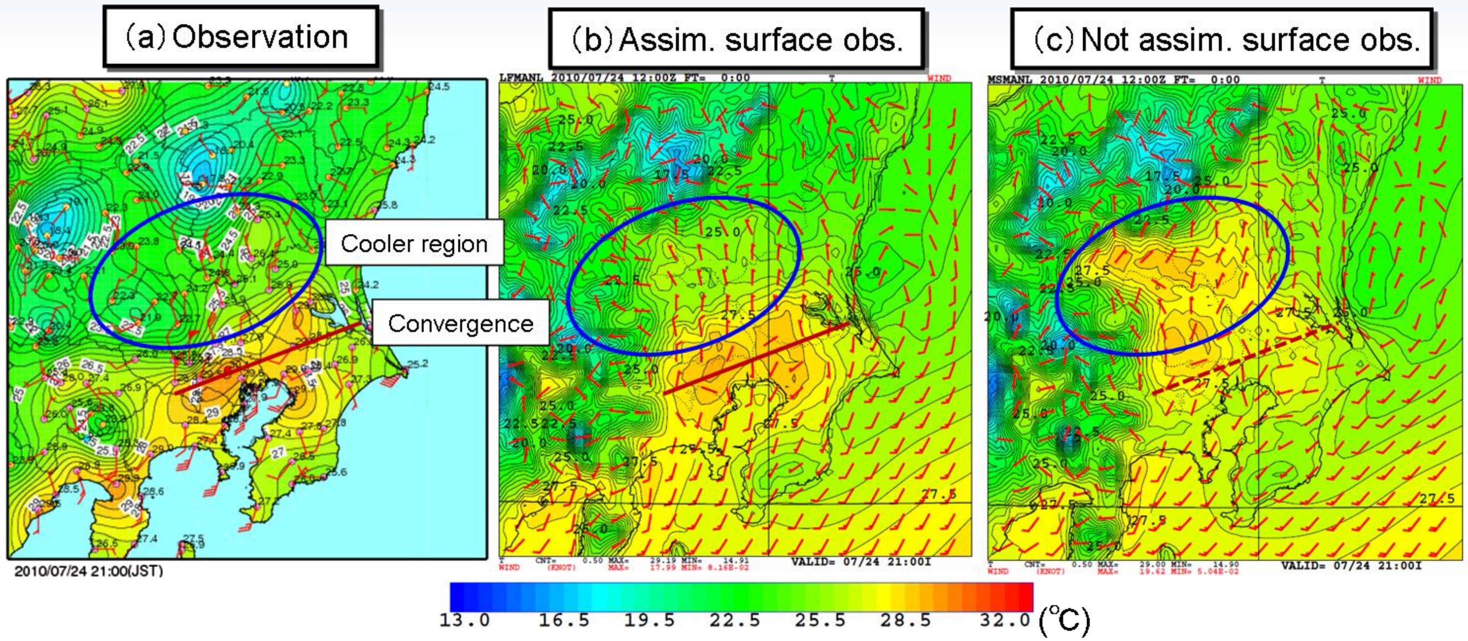


1.5km+3dVAR+LHN
ACCESS-A 12km
ACCESS-SY 0.05º (APS0)
ACCESS-SY 4km (APS1)





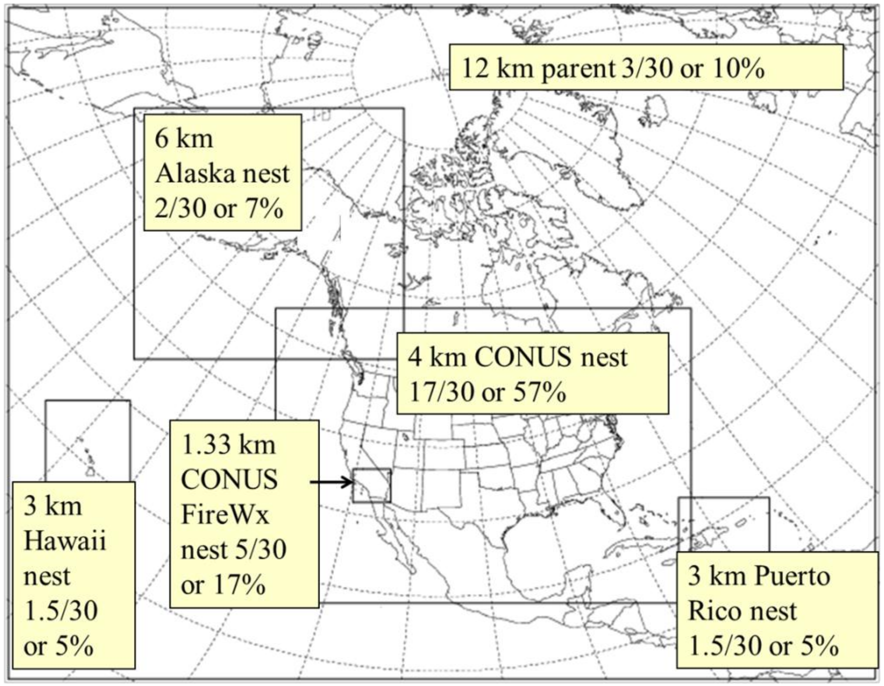
JMA: Impacts of assimilating observations near the surface



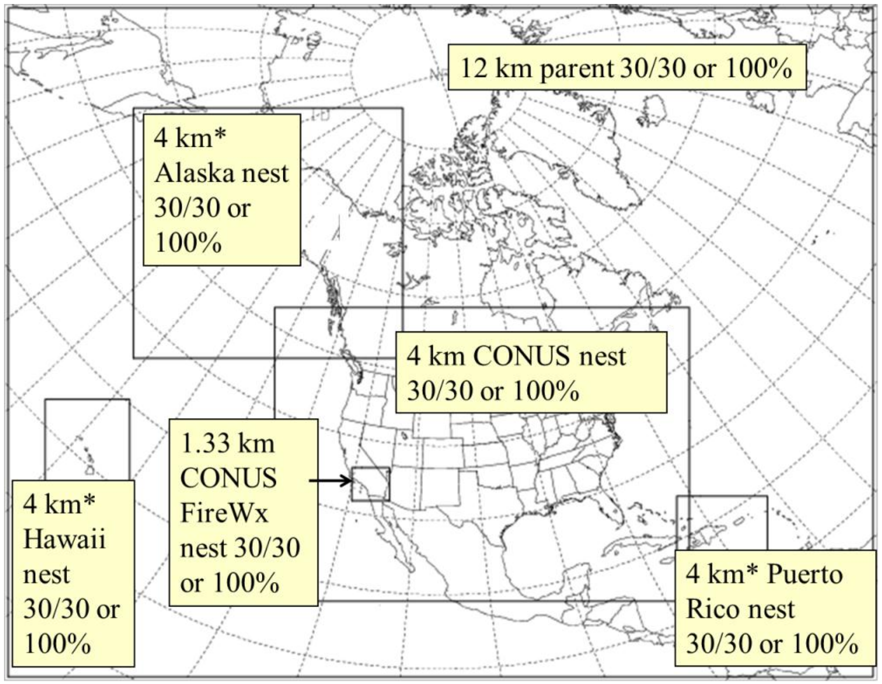
- **Typical effects of assimilating the screened level temperature and wind (Shade: 1.5 m temperature, Wind barb: 10m wind)**
- **Position of the convergence line was corrected as well as temperature distribution**

NOAA: Code Optimization for Operations

NMM-B
(30 nodes): 12 hr fcst in 1619 s

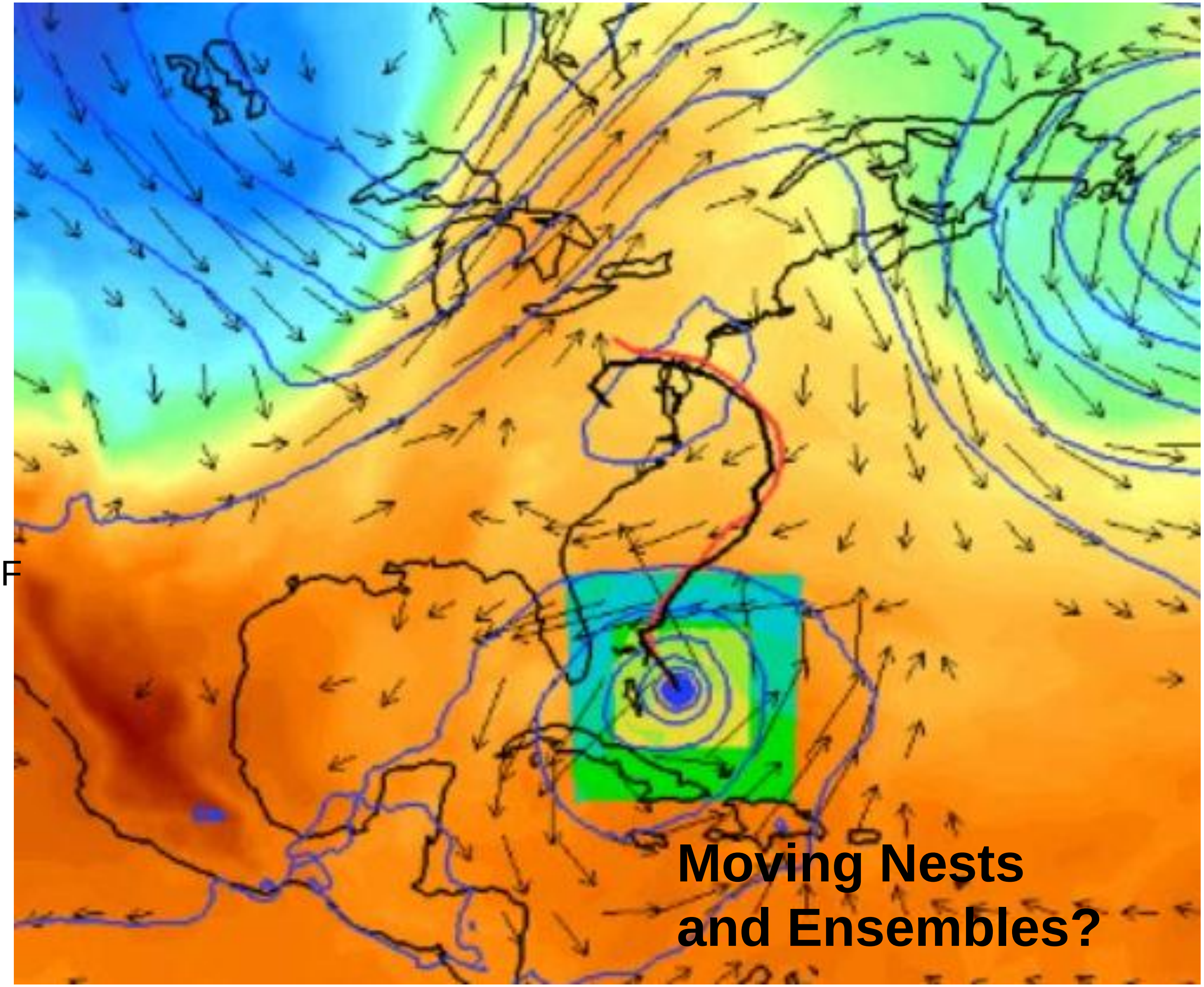


WRF-NMM
(30 nodes): 12 hr fcst in 5857 s



WRF-NMM takes 3.6 times longer to run comparable nesting with Fire Wx nest over CONUS

Obs
HWRF



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All Center Inputs Follow

Preparation of AROME future configurations

- Increase of spatial resolution planned for AROME-France NWP system : ~1.3 km and ~90 vertical levels. On-going studies to define the future vertical resolution: simulation of low level clouds (fog, stratocumulus), time-step, assimilation of satellite observations, etc.

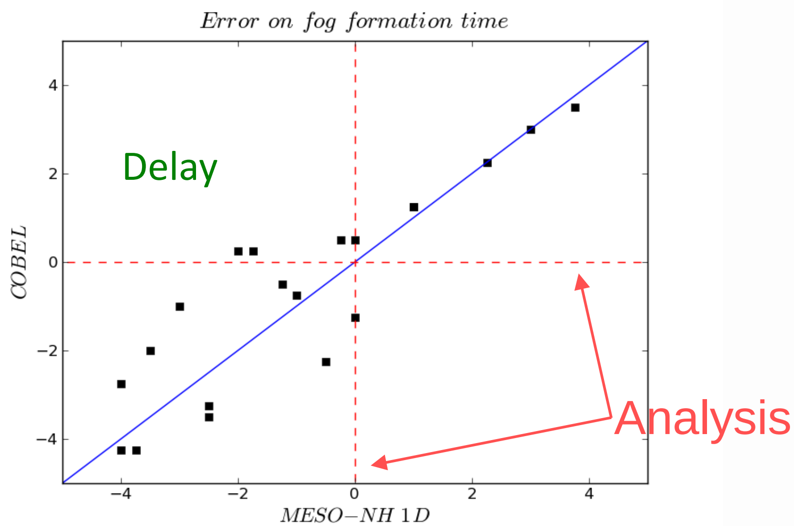
- Development of a nowcasting system based on AROME NWP model at 2.5km with hourly assimilations and short range forecasts (few hours)

- Evaluation of AROME-500m over dedicated areas (airports, mountains, ...) : case studies of heavy precipitation and mountains waves, wake vortex dissipation over airport (SESAR European project), research on thermals parameterization in the grey-zone of turbulence

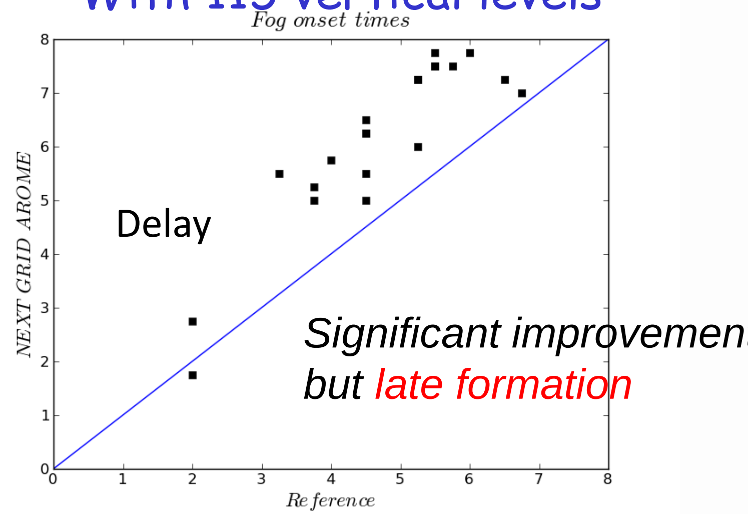
Vertical resolution (fog forecasting)

COBEL (Bergot et al., 2005): 1D oper model for FOG forecast on airports.
<u>Characteristics</u>: - Very high vertical resolution (1st level : 25cm)
- Local assimilation scheme
- Physics adapted to fogs (but warm 1-moment microphysics)

Evaluation of AROME/Méso-NH 1D on radiative fogs on CDG airport for 2 winters :



With 115 vertical levels

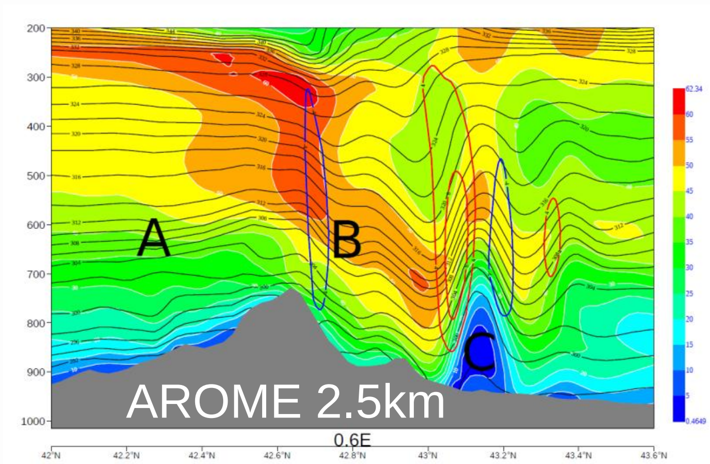


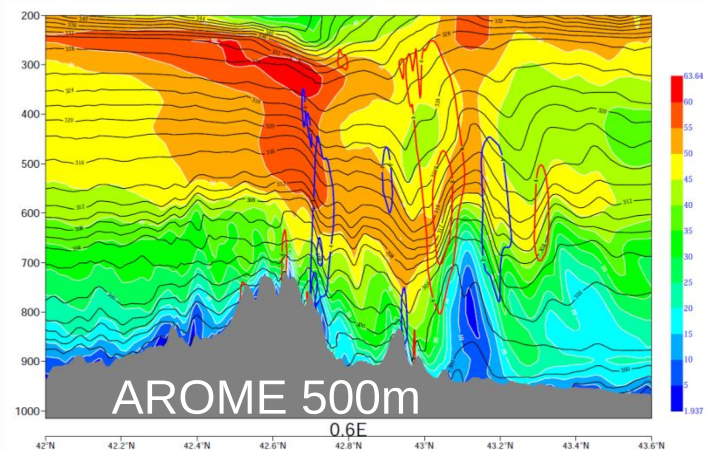
REFERENCE = COBEL GRID

⇒ Same vertical resolution (COBEL grid) and same surface scheme (7 vertical levels) are the the two most important ingredients to include in AROME/Méso-NH 1D to have a comparable fog forecasting skill than COBEL model.

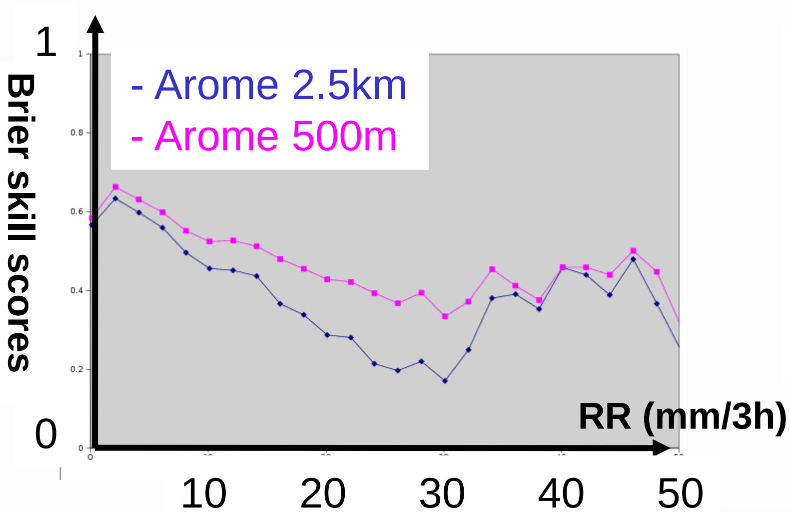
AROME 500m configuration

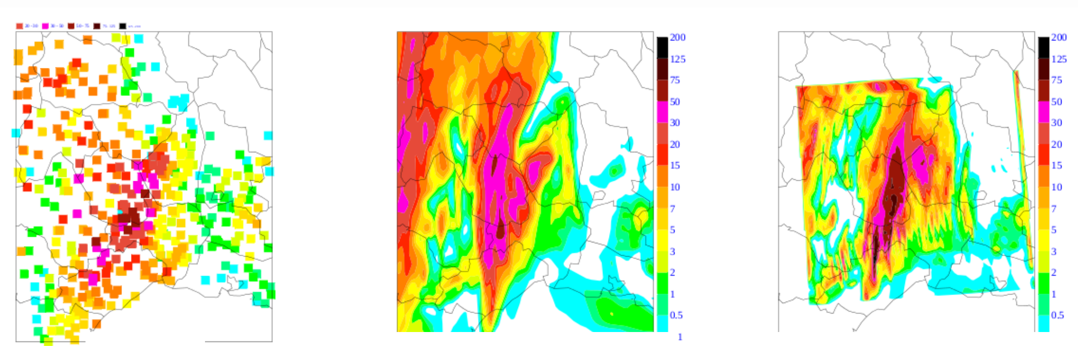
Cross section over the Pyrenees for the Xynthia storm case.
Small scales Trapped Lee waves well captured at 500m res.





Heavy precipitations cases over south-east of France, 2-8 November 2011



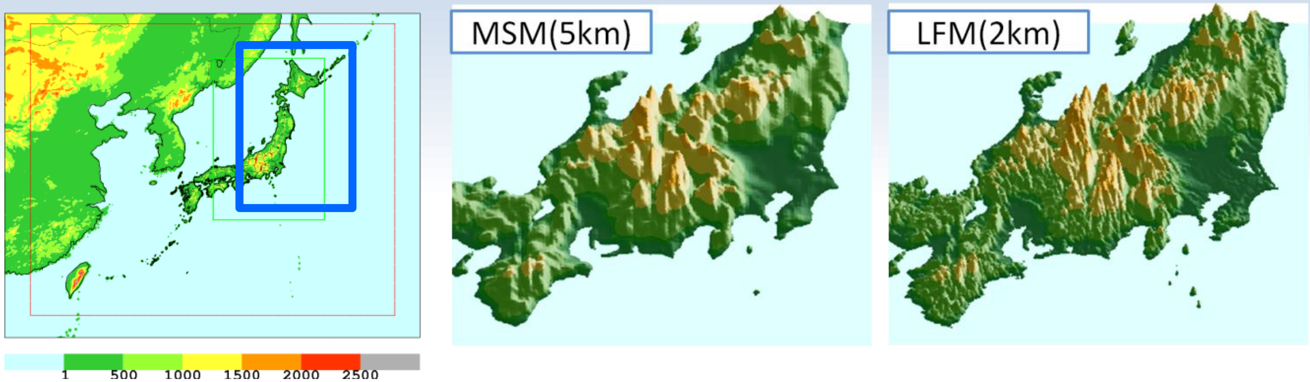


3/11/2012 18-21h RR

An operational high resolution regional NWP system at JMA

Comparison between the specification of LFM and MSM

	Local Forecast Model (LFM)	Meso-Scale Model (MSM)
Horizontal Resolution	**2km** (551 x 801)	5km (721 x 577)
Vertical Layers	60 Layers up to 20km	50 Layers up to 22km
Integration Time Step	8 seconds	20 seconds
Initial Condition	Local Analysis (LA) JNoVA 3D-Var	Meso-Scale Analysis (MA) JNoVA 4D-Var
Boundary Condition	MSM	GSM
Forecast hours	9 hours	33/15 hours
Cloud Physics	Mixing ratio of cloud, rain, cloud ice, snow and graupel (Qc, Qr, Qi, Qs, Qg)	Qc, Qr, Qi, Qs, Qg and Number density of cloud ice
Cumulus convective parameterization	**Not used**	Kein-Fritsch scheme



Forecast domain of LFM (Blue) and topography of MSM and LFM

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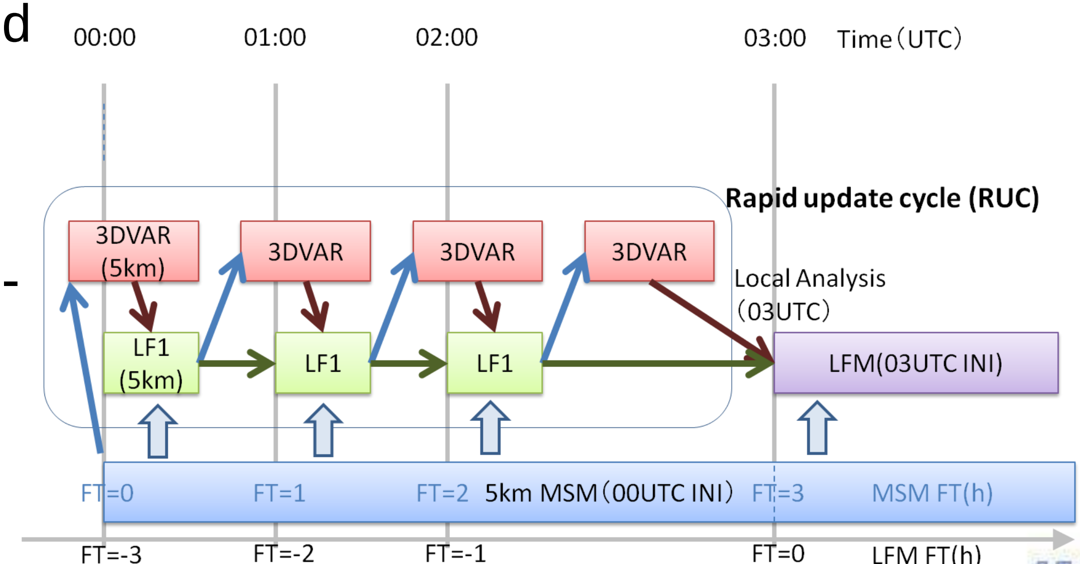
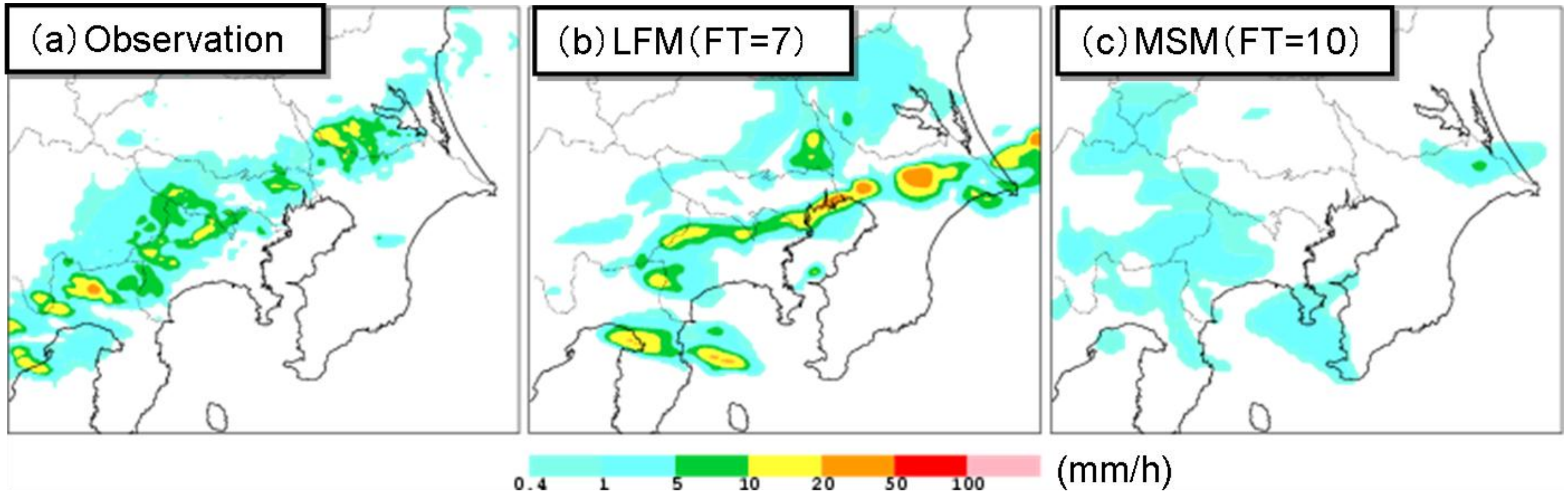
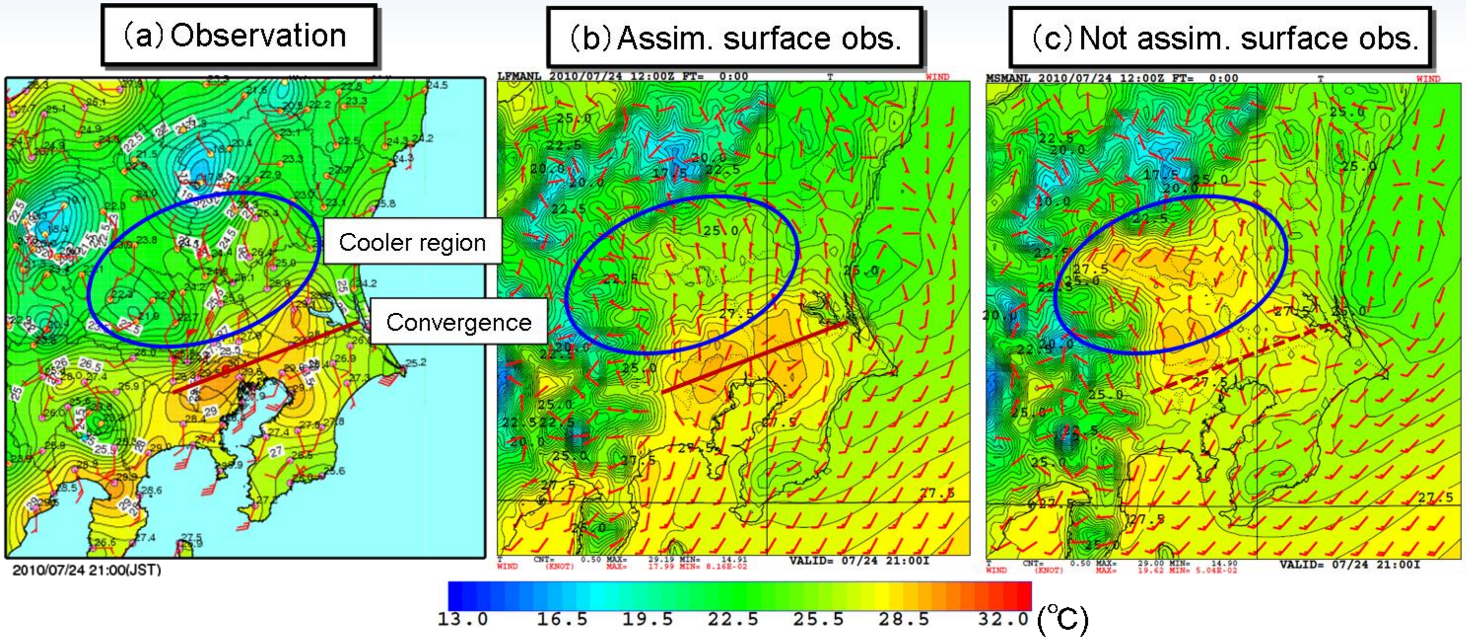


The ability of LFM to predict smaller scale phenomena



Example of 1 hour accumulated precipitation in which LFM predicted smaller scale convective cells than MSM .

Impacts of assimilating observations near the surface



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High Resolution Modeling Activities in CMA Based on GRAPES_Meso

Upgrade activities

•Vertical coordinate from terrain-following Z to hybrid coordinate (Schar, 2002)

•Inclusion of thermal expansion effect in continuity equation

•Improve the interpolation accuracy in physics-dynamics interface

•Refinement of 2-moment microphysics scheme

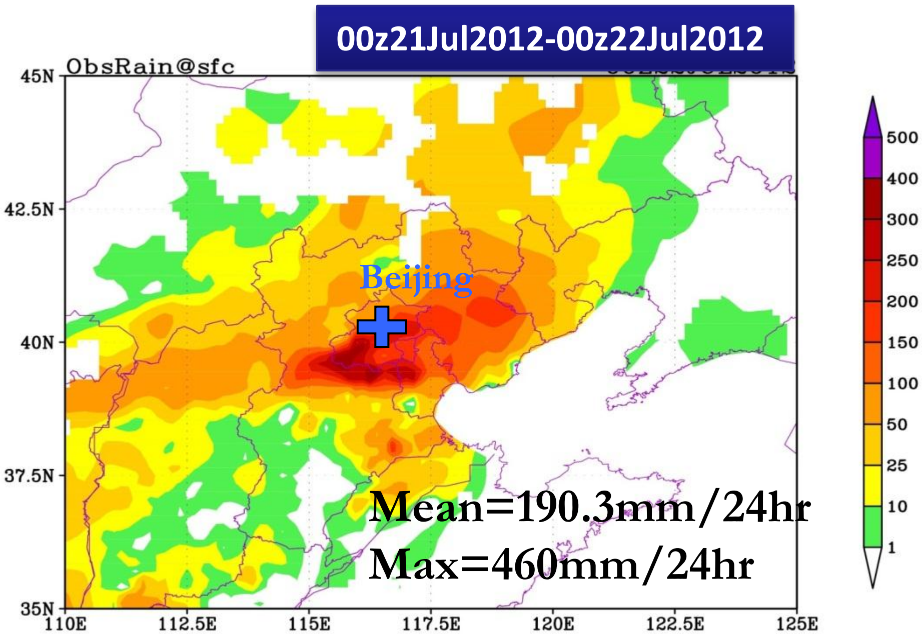
•Some bug fix in land surface scheme

•Refinement of back ground error covariance in 3DVAR

Current status

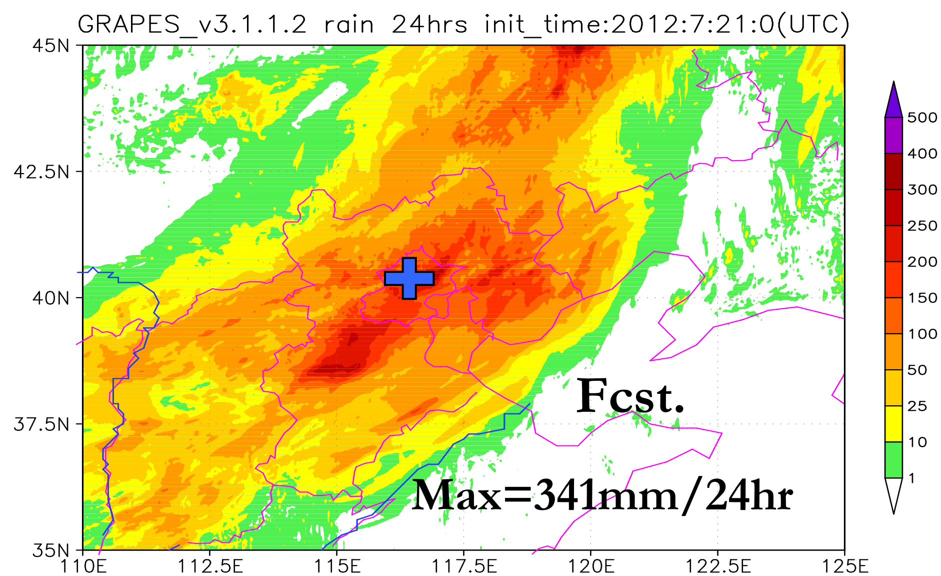
- Test run in Center for Numerical Prediction/CMA and Guangzhou Meteorological Bureau

Heavy rainfall event on Jul.21/2012 Beijing

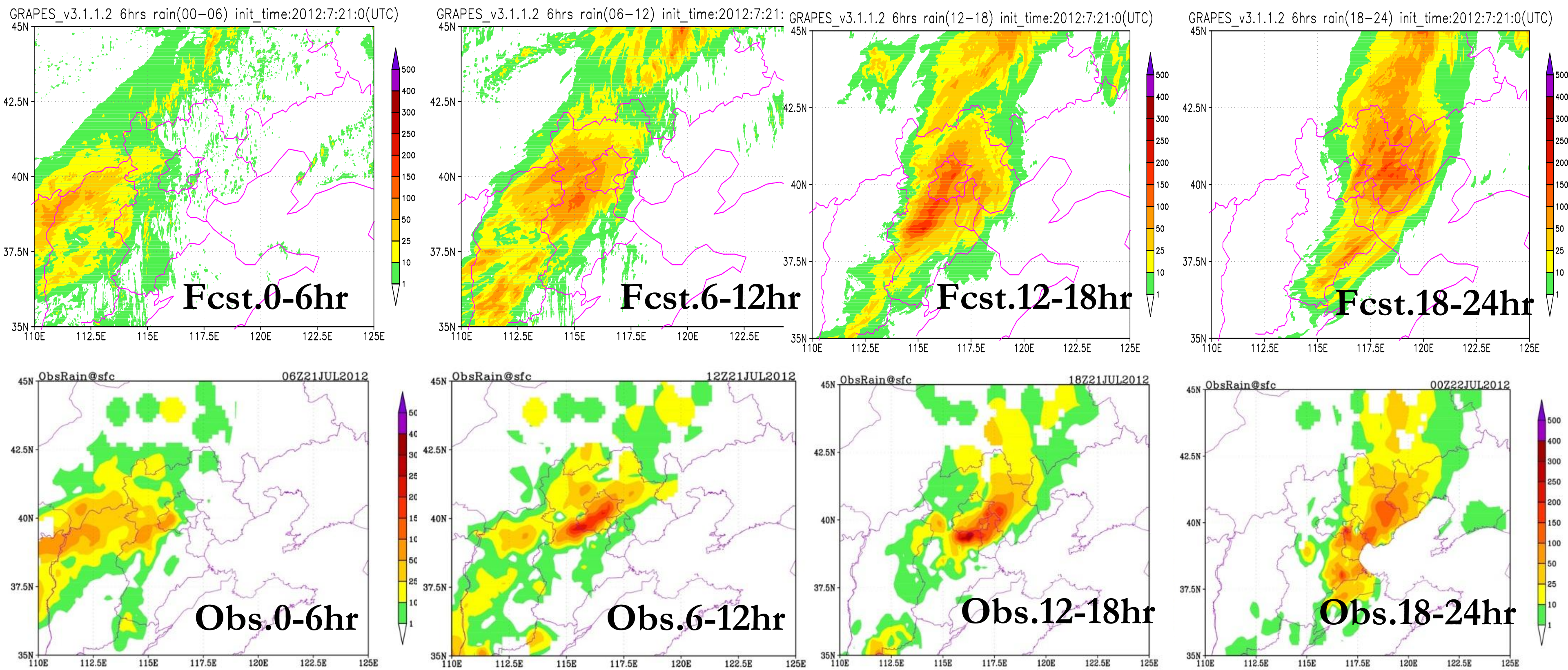


Initial: global analysis
BC: global forecast
Grid size:3km
Physics:
- **microphysics: WSM6**
- **radiation: RRTM S&L**
- **pbl : MRF**
- **land surface : NOAH**

24-hour accumulated rainfall

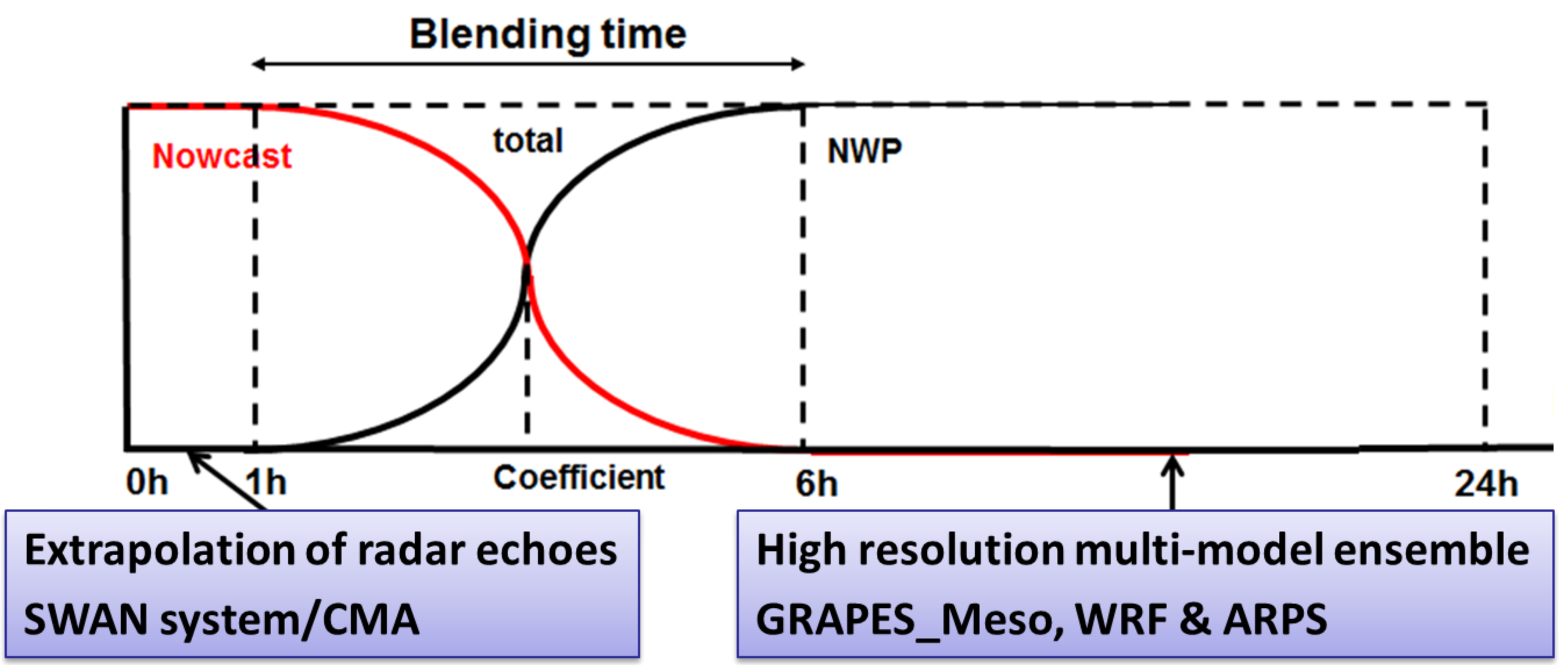


Comparison of precipitation every 6-hour between Obs. & Fcst.



Plan in next two years

- Implement a very-short term forecast system with 3km resolution based on multi-model ensemble including GRAPES_Meso, WRF and ARPS (collaborate with Nanjing University)
- Data assimilation: hybrid DA (3DVAR+EnKF) (collaborate with Ming Xue, Oklahoma Univ.)



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- 1 operational domain (2 x 42-h runs)
- 4 experimental domains (1 x 24 h run)

→ **Currently running**

2. National-2.5 km– STAGE 1

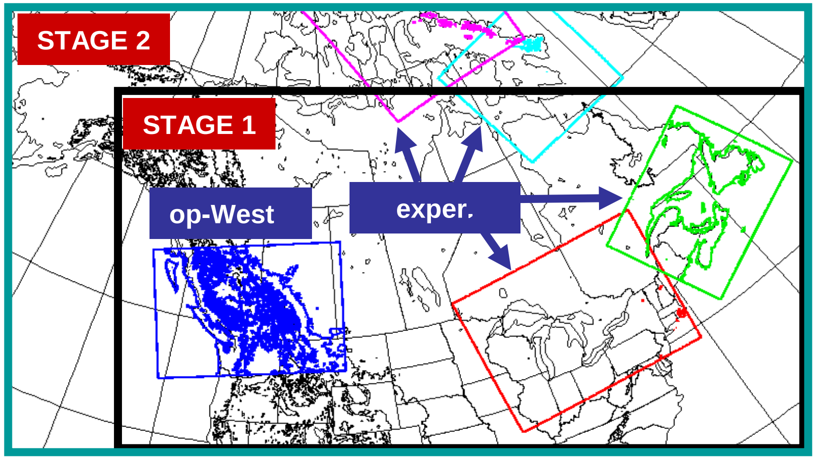
- single, national grid
- 2 x 48-h runs
- high-resolution surface fields (CaLDAS)
- cycling of cloud fields
- detailed microphysics (to be upgraded)
- increased vertical resolution

→ **2013**

3. National-2.5 km – STAGE 2

- 4 x 48-h
- upper-air data assimilation cycle (EnVar*)

→ **2015**



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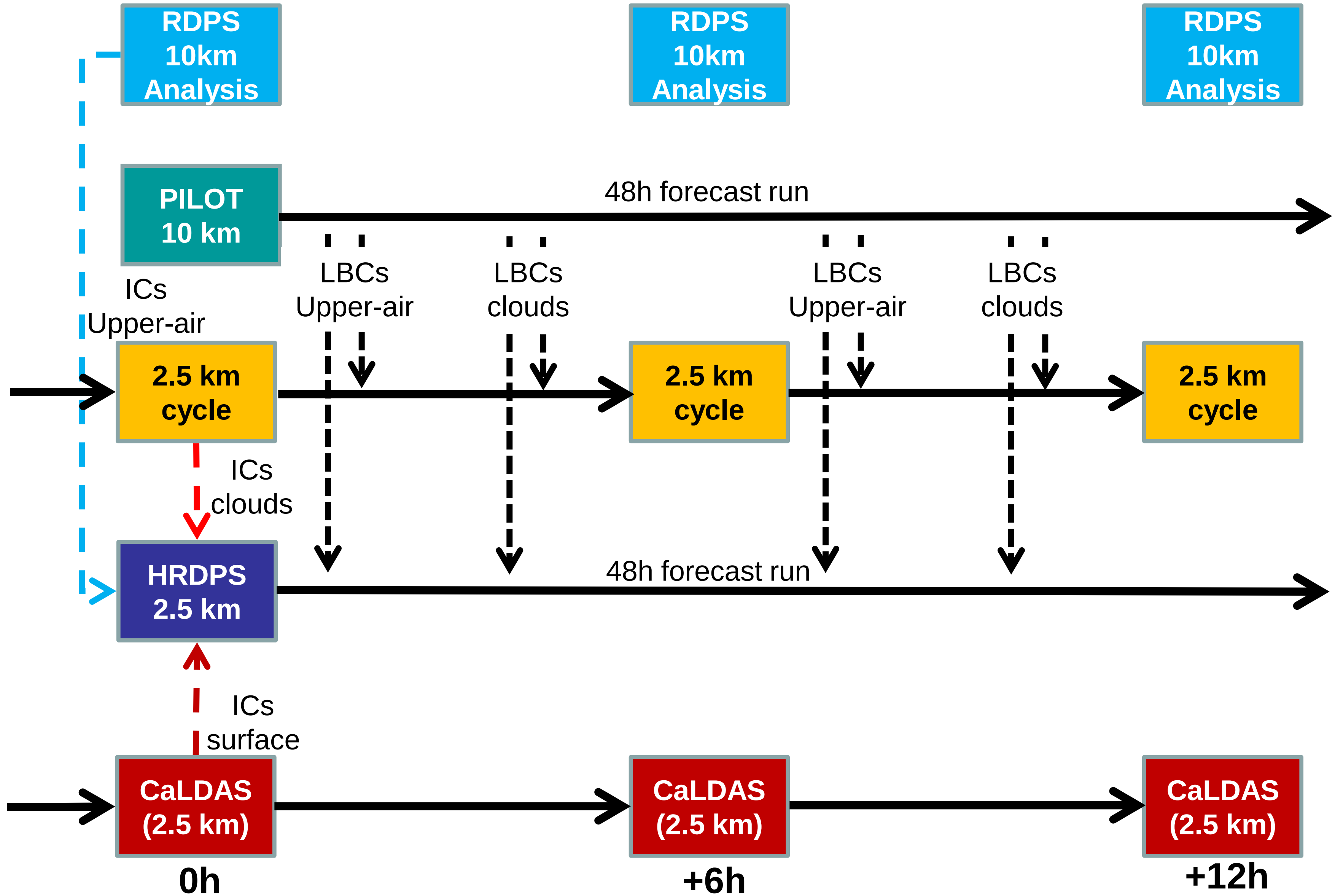
Future sequence for ICs and BCs (National-2.5 system):



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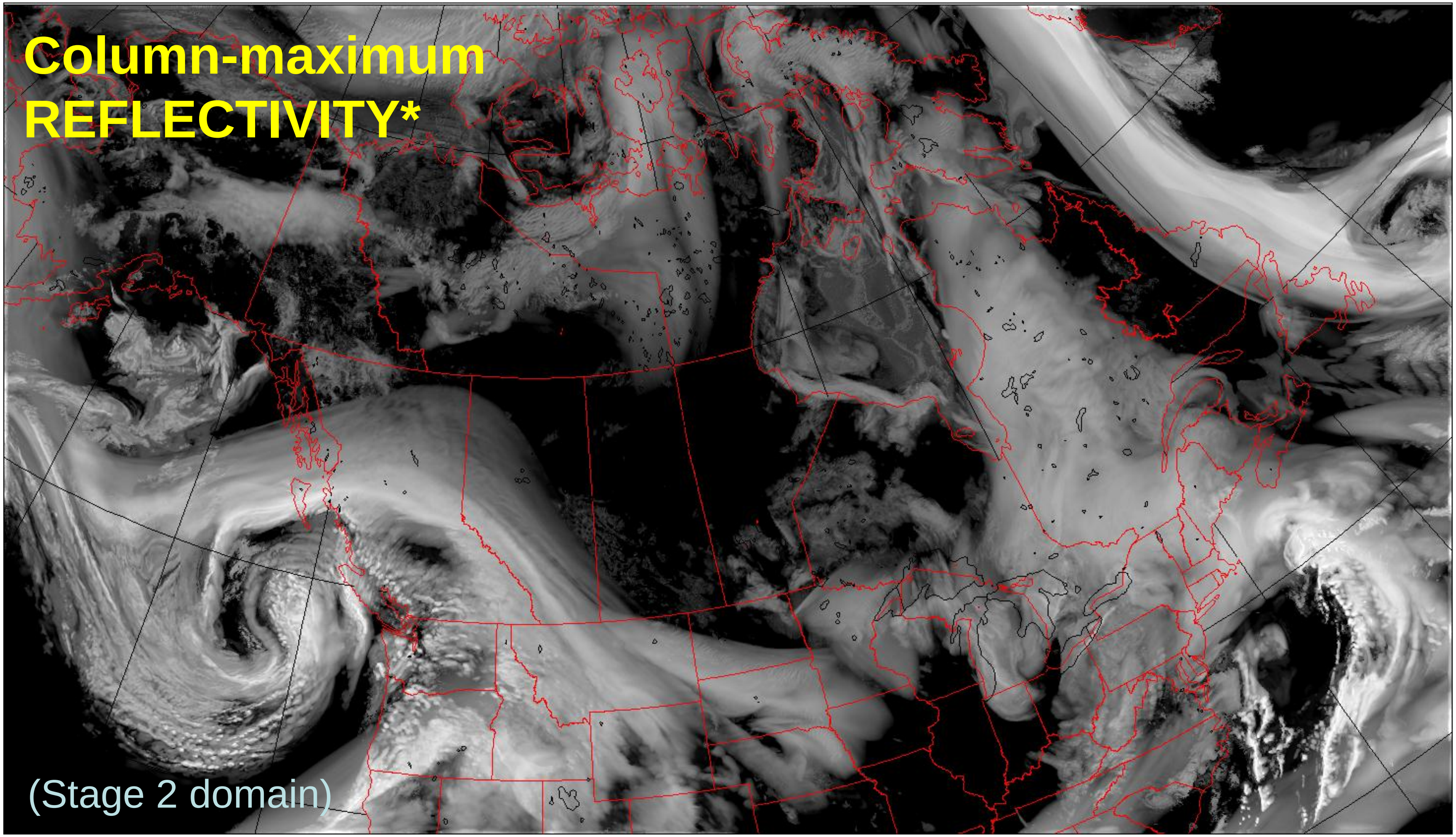
Simulation with prototype of National-2.5 Stage-1:



* Computed from hydrometeor fields from 2-moment microphysics scheme

ECMWF High-resolution modelling developments (inputs: Nils Wedi, Mats Hamrud, George Mozdzynski, Jean Bidlot, Geir Austad, Sinisa Curic)

Current and planned resolutions:

IFS model resolution	Envisaged Operational Implementation	Grid point spacing (km)	Time-step (seconds)	Estimated number of cores[1]
T1279 H[2]	2010 (L91) 2013 (L137)	16	600	1100 1600
T2047 H	2014-2015	10	450	6K
T3999 NH[3]	*2020-2021*	*5*	*240*	*80K*
T7999 NH	*2025-2026*	*2.5*	*30-120*	*1-4M*

1 - a gross estimate for the number of 'Power7' equivalent cores needed to achieve a 10 day model forecast in under 1 hour (~240 FD/D), system size would normally be 10 times this number.

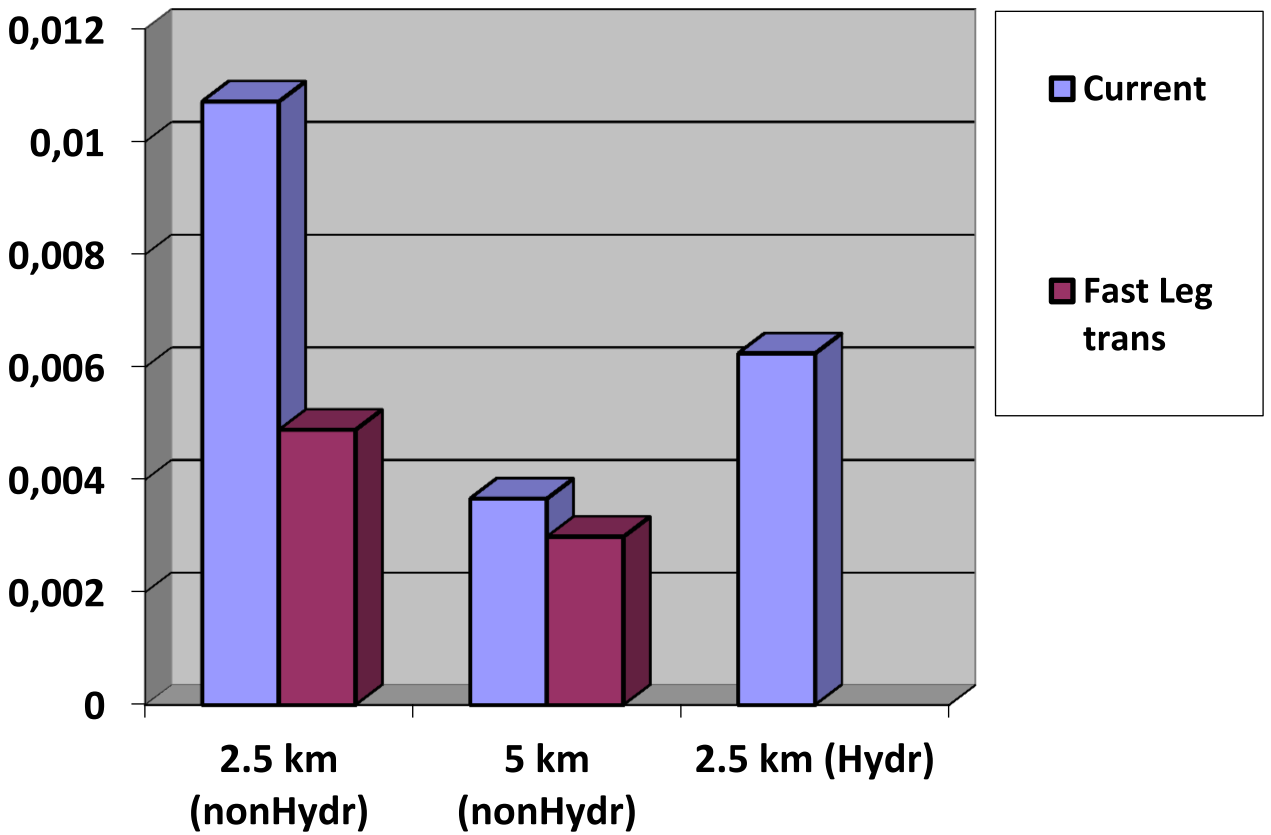
2 – Hydrostatic Dynamics

3 – Non-Hydrostatic Dynamics

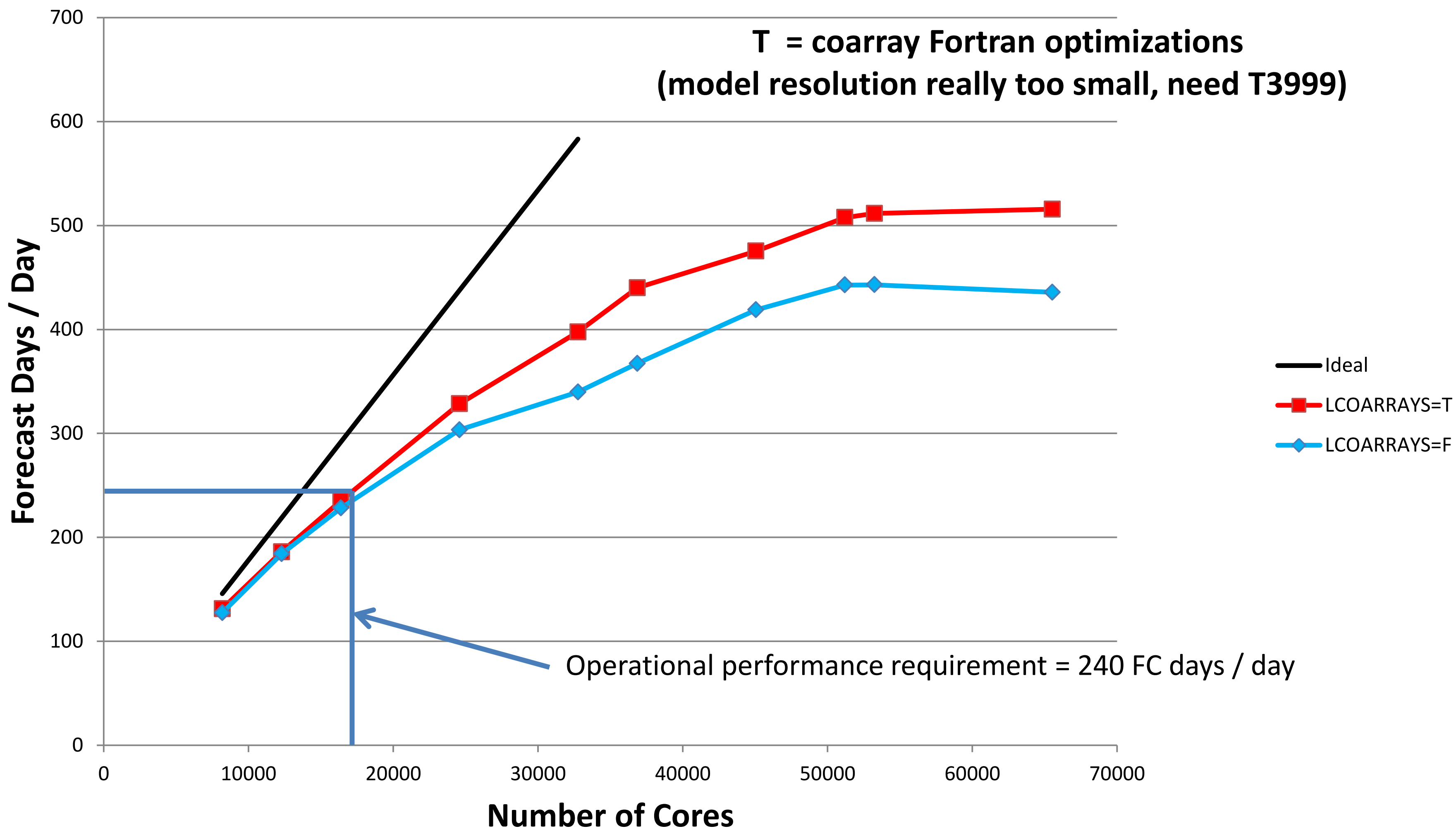
More speculative: extrapolated capability more than firm plans

(Wall-clock comp cost)*$(N_{ref}/N)^2$ in ms

for spectral transforms, 1h simulation
N truncation limit



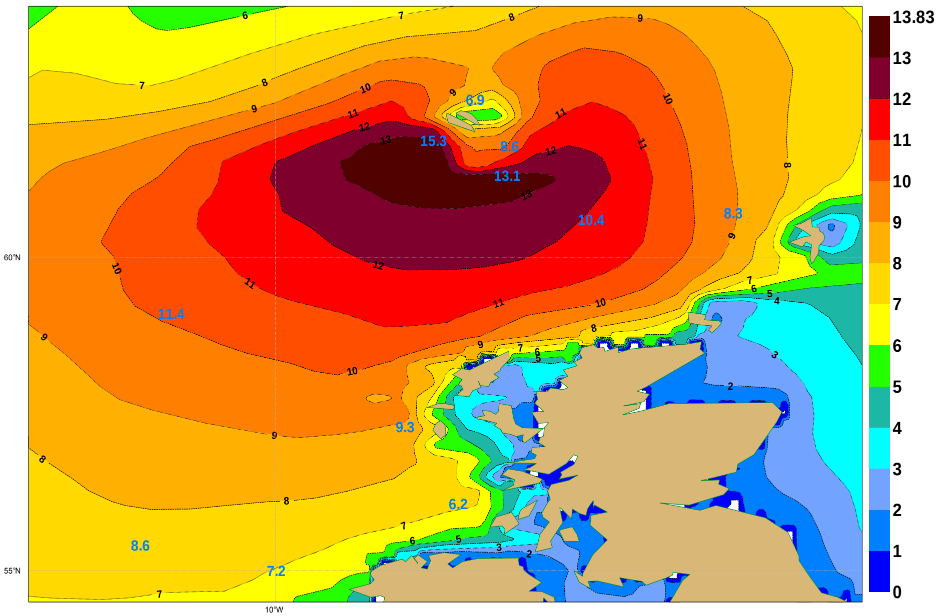
T2047L137 model performance on HECToR (CRAY XE6)
RAPS12 IFS (CY37R3), cce=8.0.6 -hflex_mp=intolerant

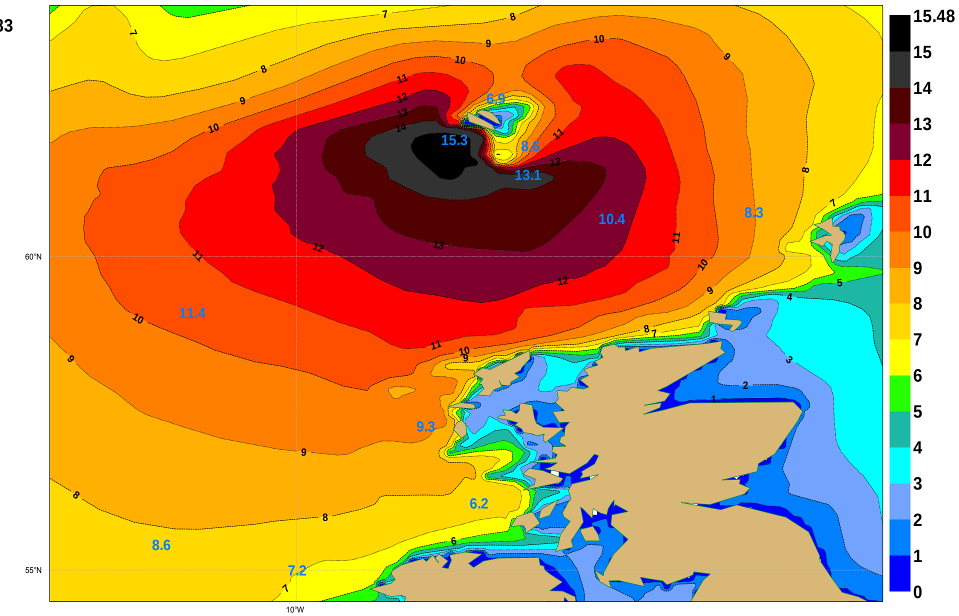


Going higher resolution: T_L3999 (5 km) wave fc (+24h)

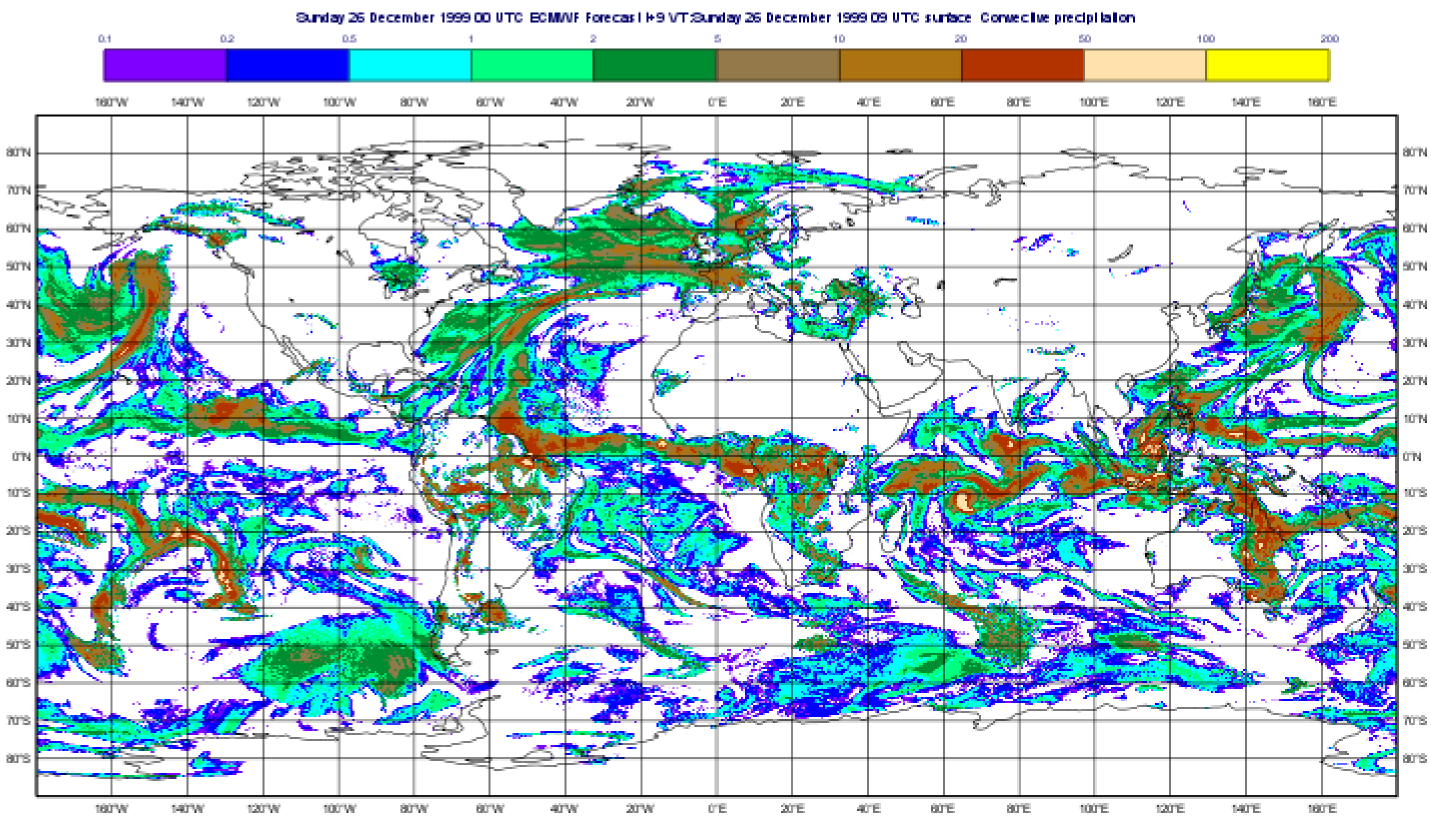
24-hour forecast for significant wave height (colour shadings in metres) for 00 UTC on 25 November 2011:

- T1279 model coupled to a 0.25° global wave model (operational configuration, left)
- T3999 model coupled to a 0.1° global wave model.

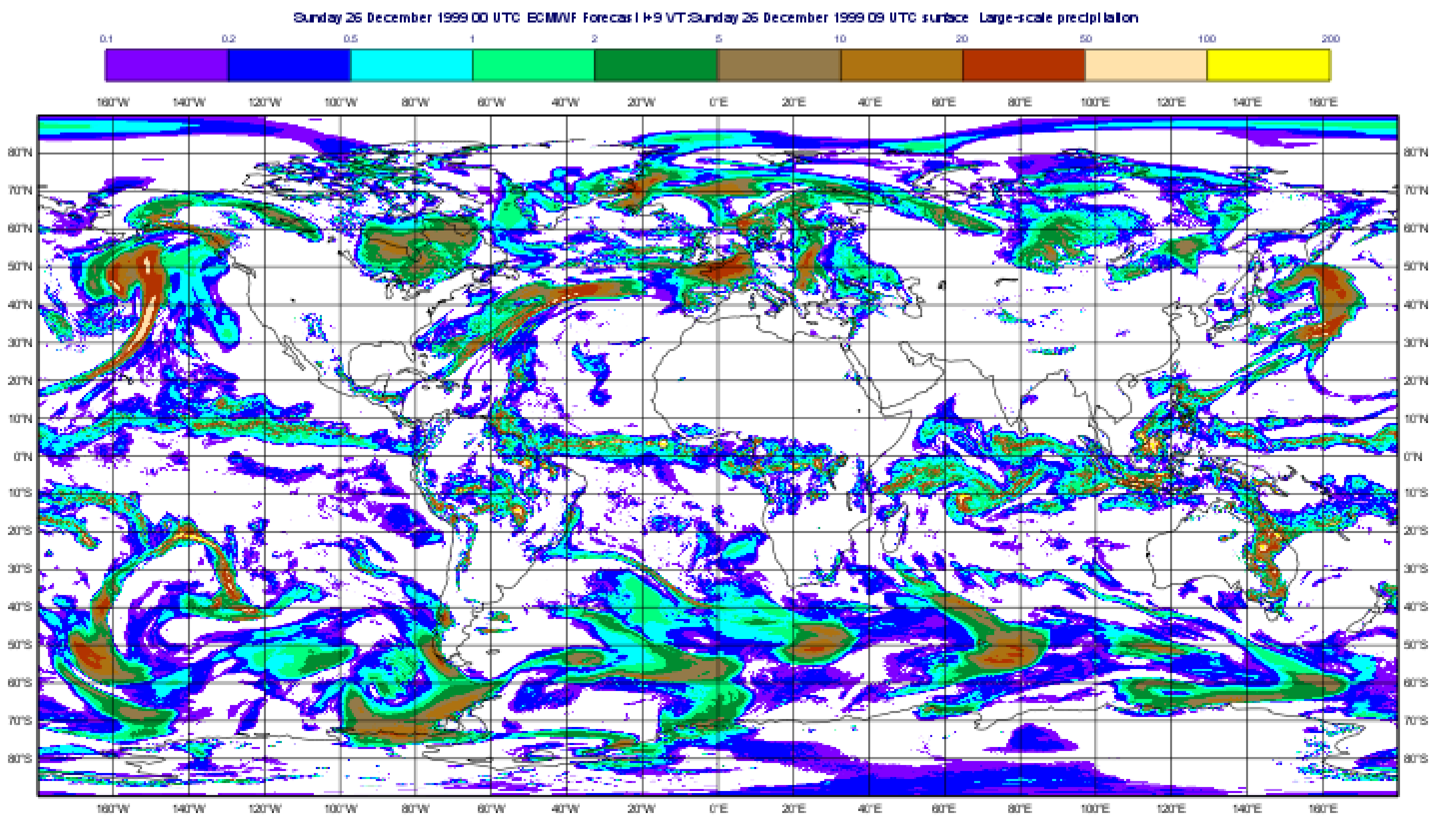




T1279 convective precipitation



T7999 large-scale precipitation
(ran without deep convection parametrization)

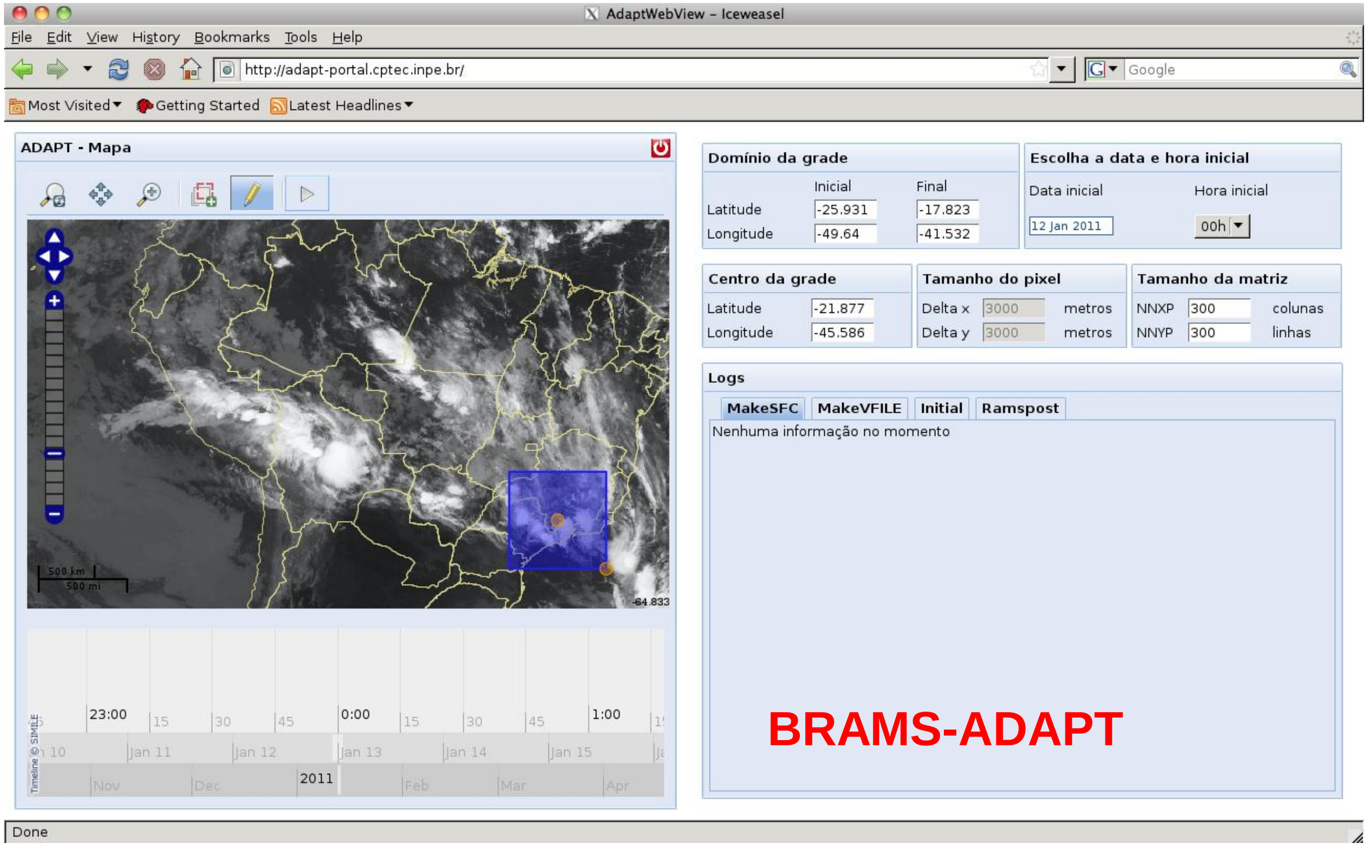


Summary

- Fast Legendre transform is effective.
- Enabled 10-day forecasts at T3999 (~5km)
- Enabled 1st global, convection-permitting, non-hydrostatic IFS forecasts at T7999 (~2.5km)
  - Spectral technique still viable
- Future work:
  - Towards a cheaper non-hydrostatic option
  - Towards a more flexible software infrastructure
  - Vertical discretization aspects and stability
  - Is it technically possible to create a Reduced Gaussian Grid at T20000 (~1km) ?
  - Learn from the Gung-Ho project

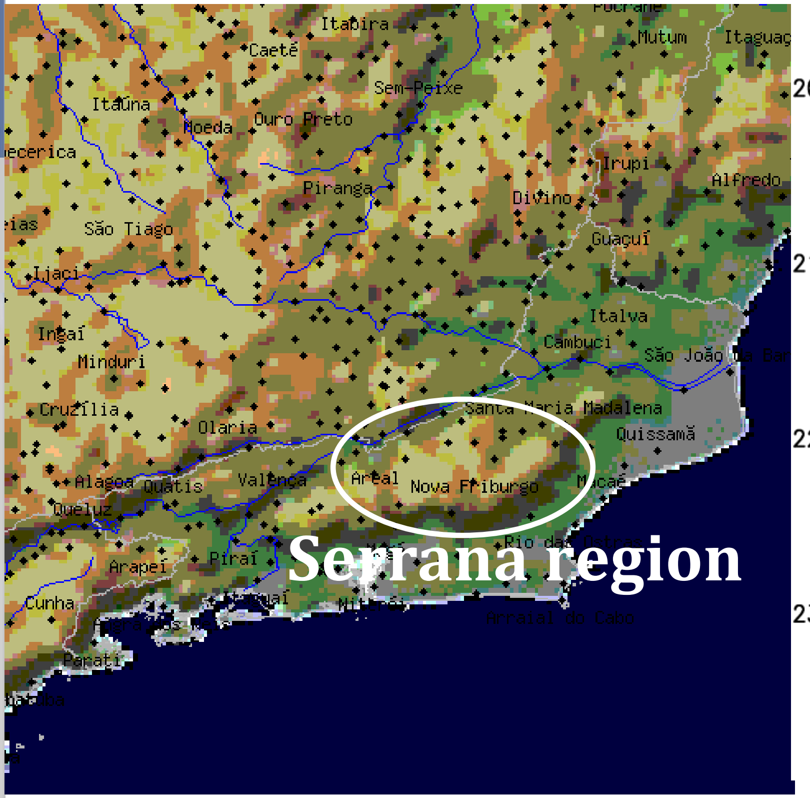
Emergency system for severe storms

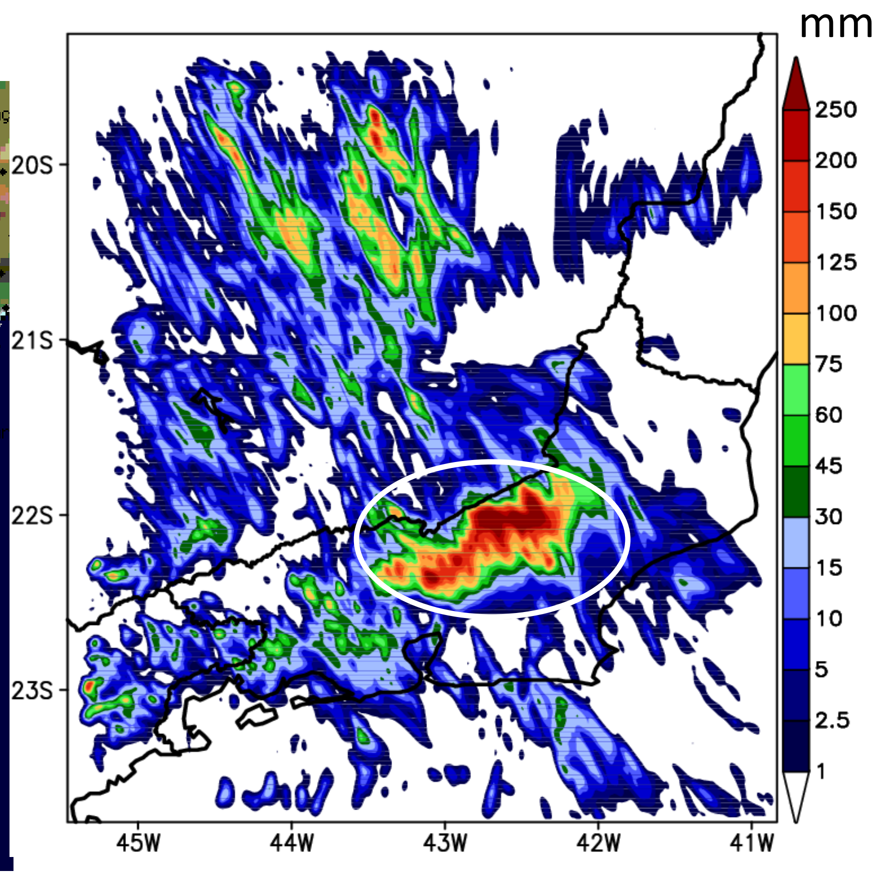
- System remains in stand-by but ready to be executed at any time and limited area over South America.
- Applies BRAMS non-hydrostatic mesoscale model with 1 km resolution over 500 x 500 km^2 producing 36 hours forecast.
- With 600 processors on CRAY XE6, the run takes ~ 1 h.



BRAMS-ADAPT

24 h Accumulated rainfall - 12/jan/2011
BRAMS with 1 km resolution

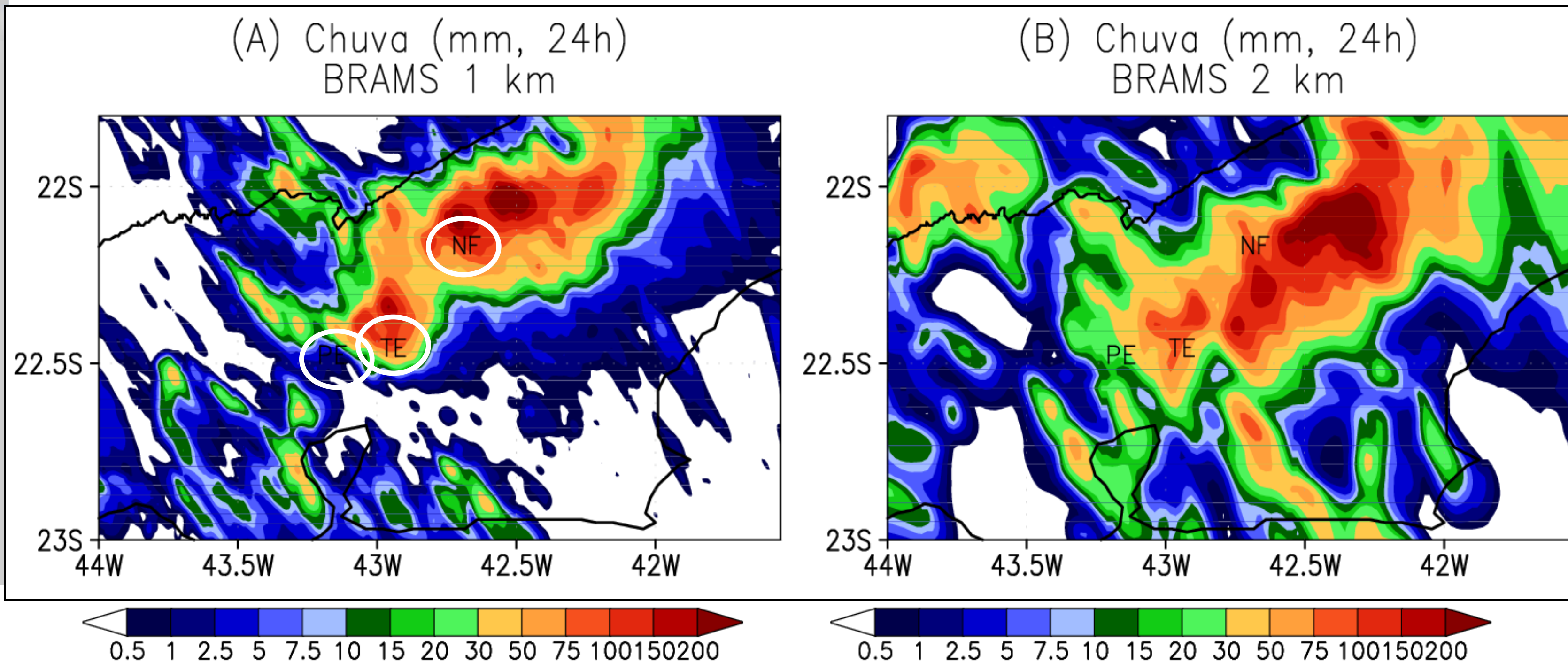




BRAMS 1 km : NX, NY = 500, 500

Model comparison with observation:
Distribuição Espacial e Quantitativa da Chuva

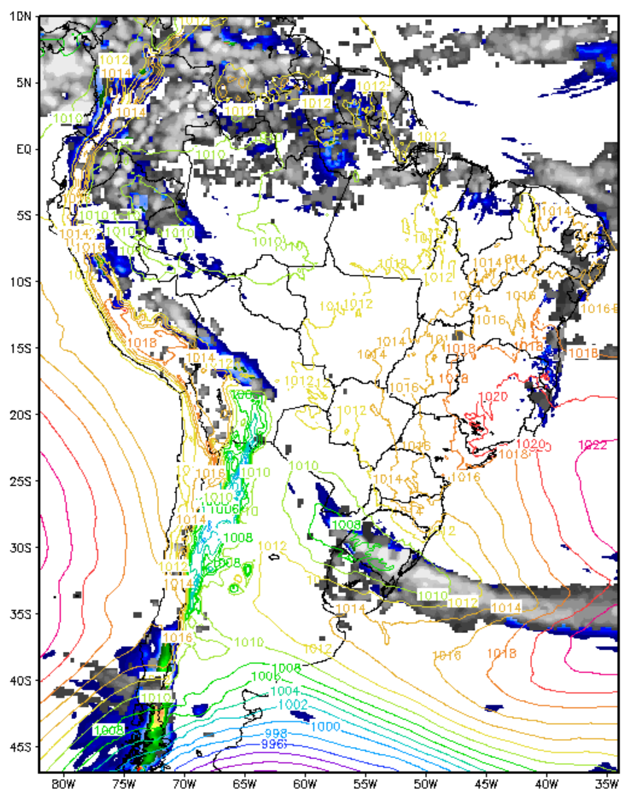
Cidade/Região	Observation 24h, mm	BRAMS 1 km (24h, mm)
Nova Friburgo (NF)	163	100 – 200
Teresopolis (TE)	79	30 - 100
Petropolis (PE)	8	1 - 15



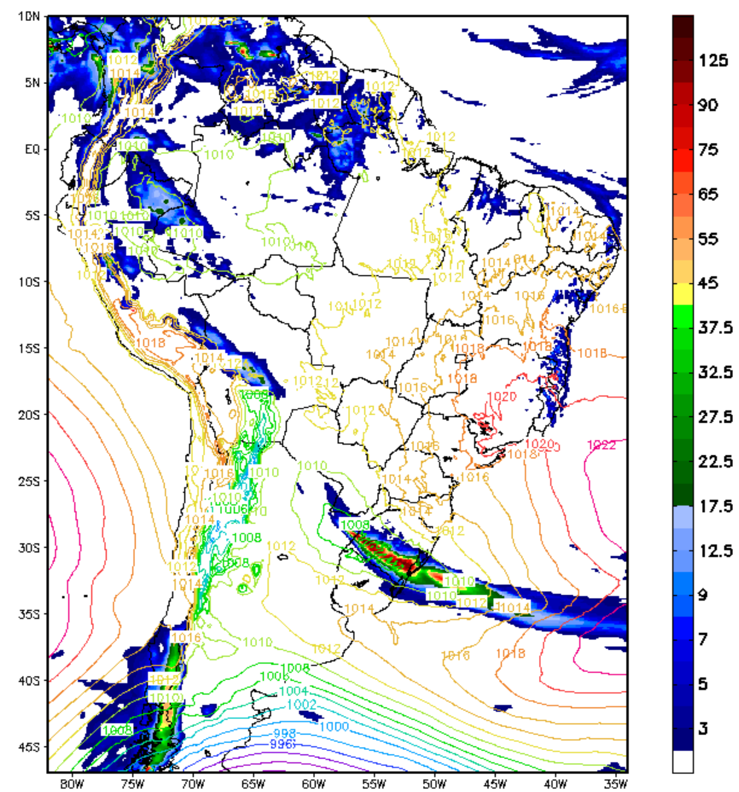
BRAMS 5 km resolution (experimental, under evaluation)

- Grid spacing: H - 5 km x 5 km, V - 50 to 800 m, model top @ 21 km
- Model domain: South America with 100 x 10^6 (1360 x 1489 x 55) grid points
- Forecast length: 5 days, currently at 00 UTC, planned to include at 12 UTC
- Parameterization for deep convection: Grell version 3d with lateral spreading of environmental subsidence.

Remote Sensing Rainfall

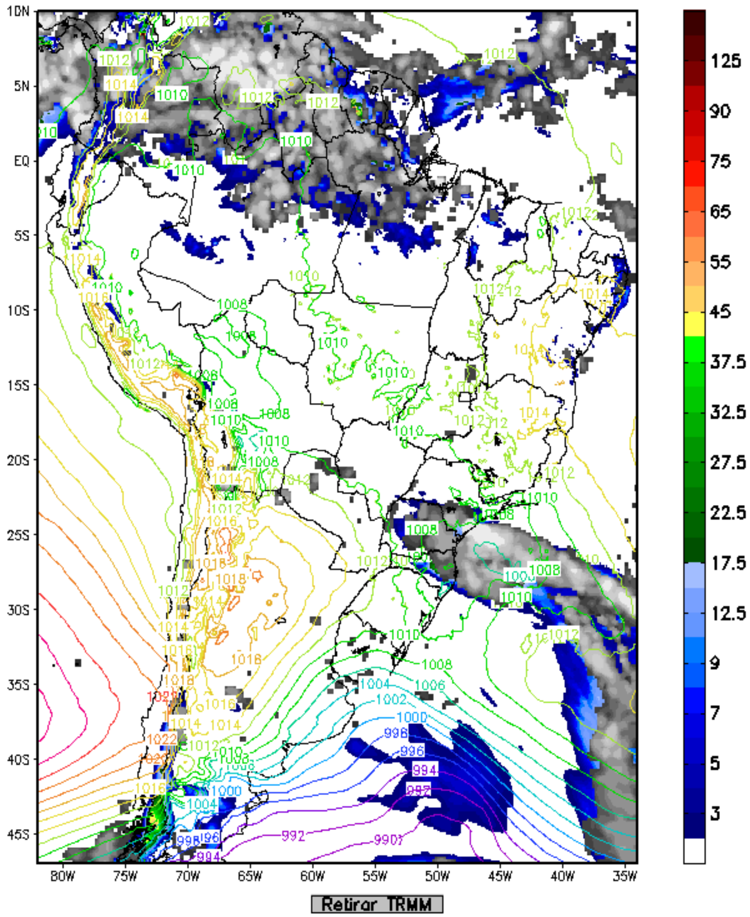


Model Rainfall – 24 hr accum.



BRAMS 5 km resolution (experimental, under evaluation)

BRAMS 05 Km
Análise Inicializada em: 11/7/2012, 00 UTC (Quarta-feira) Válida para: 12/7/2012, 12 UTC (Quinta-feira)
Variável: Precipitação Acumulada em 24h/Pressão ao nível médio do mar
CPTEC/INPE



BRAMS 05 Km
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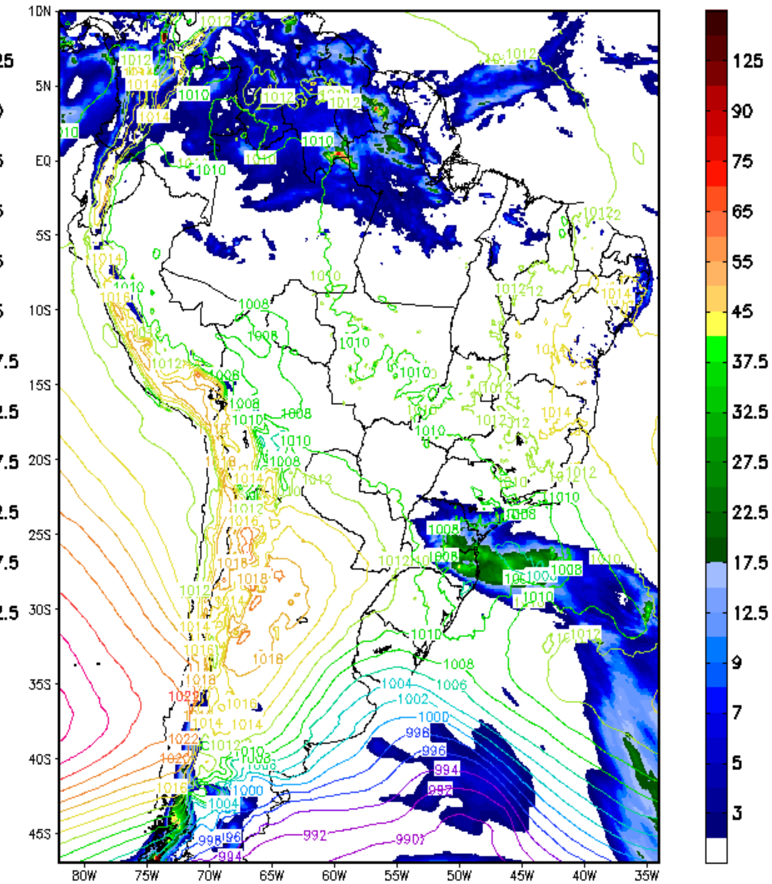
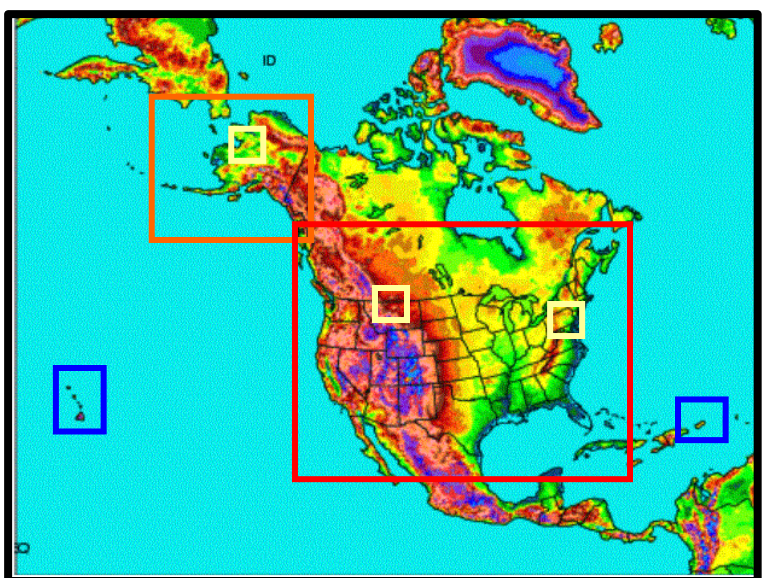


Operational Mesoscale Modeling for CONUS:

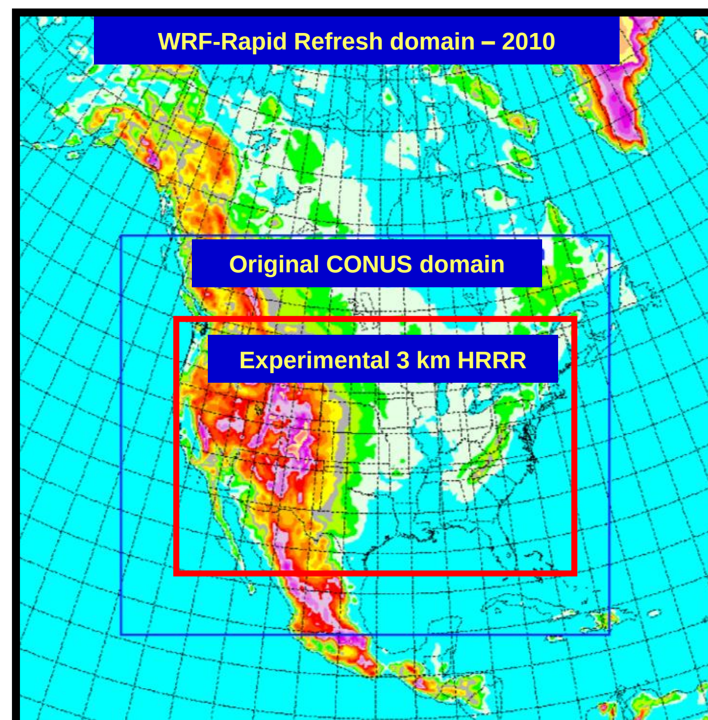
North America Model (NAM)

- *Implemented 18 October 2011*
- **NEMS based NMM**
- **Outer grid at 12 km to 84hr**
- **Multiple Nests Run to ~48hr**
  - **4 km CONUS nest**
  - **6 km Alaska nest**
  - **3 km HI & PR nests**
  - **1.3km DHS/FireWeather/IMET**



Rapid Refresh (RAP)

- *Implemented 1 May 2012*
- **WRF-based ARW**
- **Use of GSI analysis**
- **Expanded 13 km Domain to include Alaska**
- **Experimental 3 km HRRR**



An Important Pinpoint Prediction Challenge:
The 29 June 2012 Mid-Atlantic Derecho

After the storm, D.C. still scrambling

10 Like 7 Tweet 7 Share 3 Short URL Email Print

POLICE LINE DO NOT CROSS

By ANDREW RESTUCCIA and DARIUS DIXON | 7/2/12 1:44 PM EDT

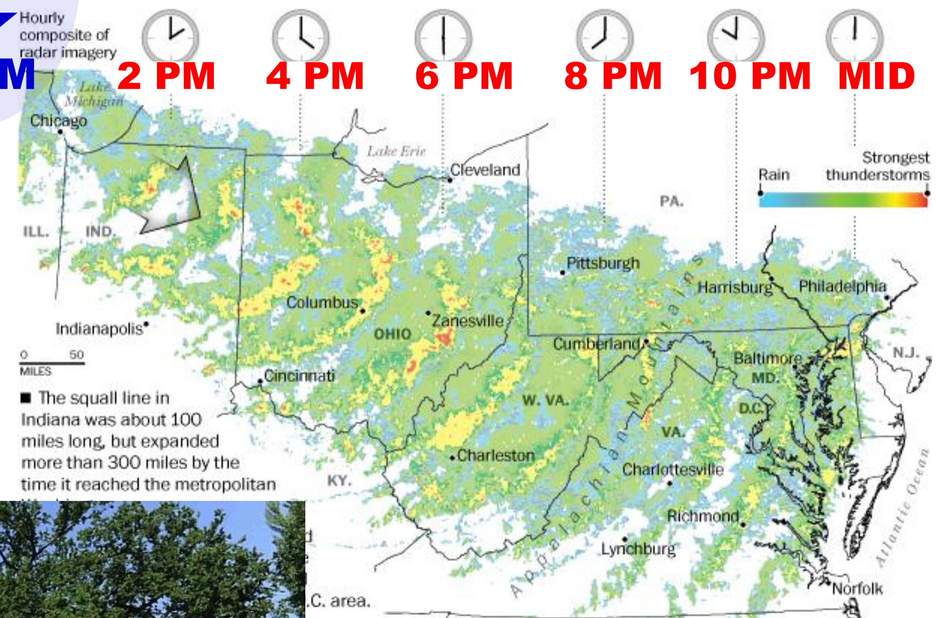
Congress closed down for the holiday week — and then the derecho turned the lights out.

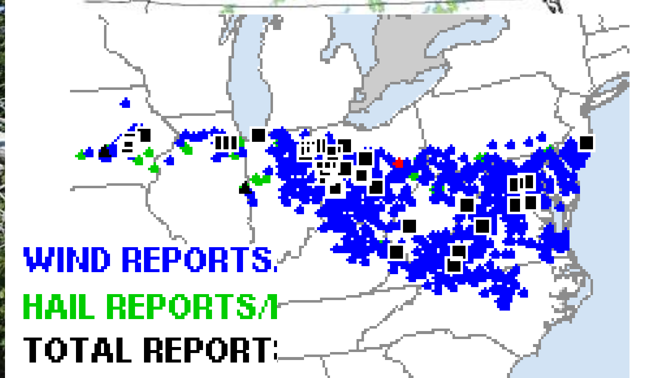
On Monday, the massive weekend storm that pummeled the mid-Atlantic region had congressional and administration staffers scrambling amid power outages, fallen trees and

Start HRRR run

11 AM

A fast moving damaging wind event…

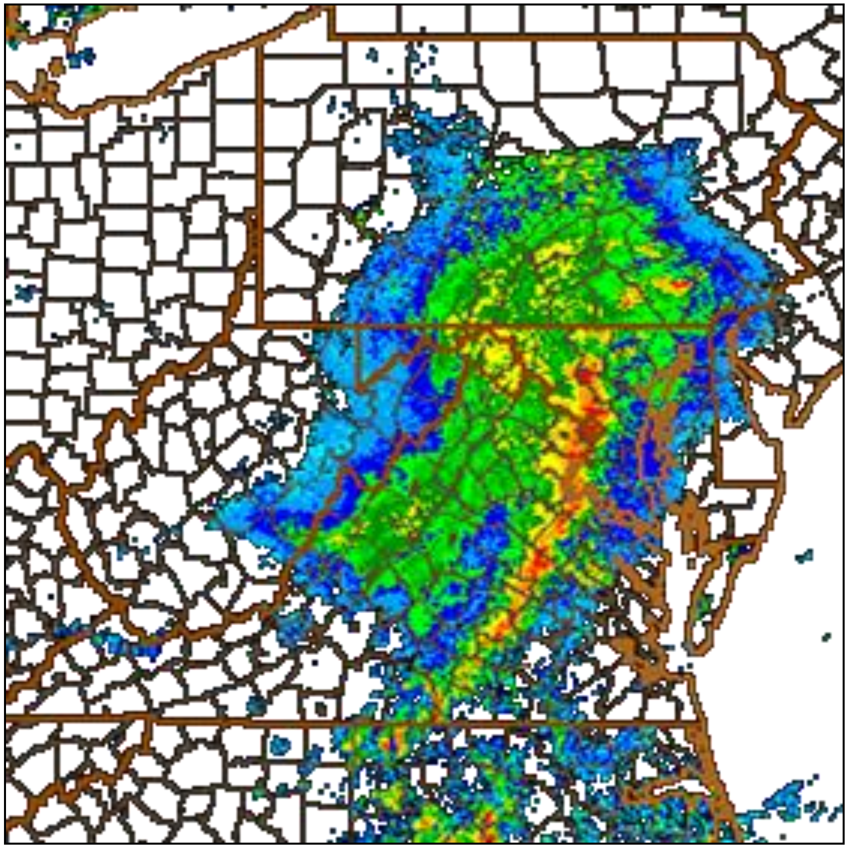




700 mile long swath of damage, 5 million without power, 22 fatalities

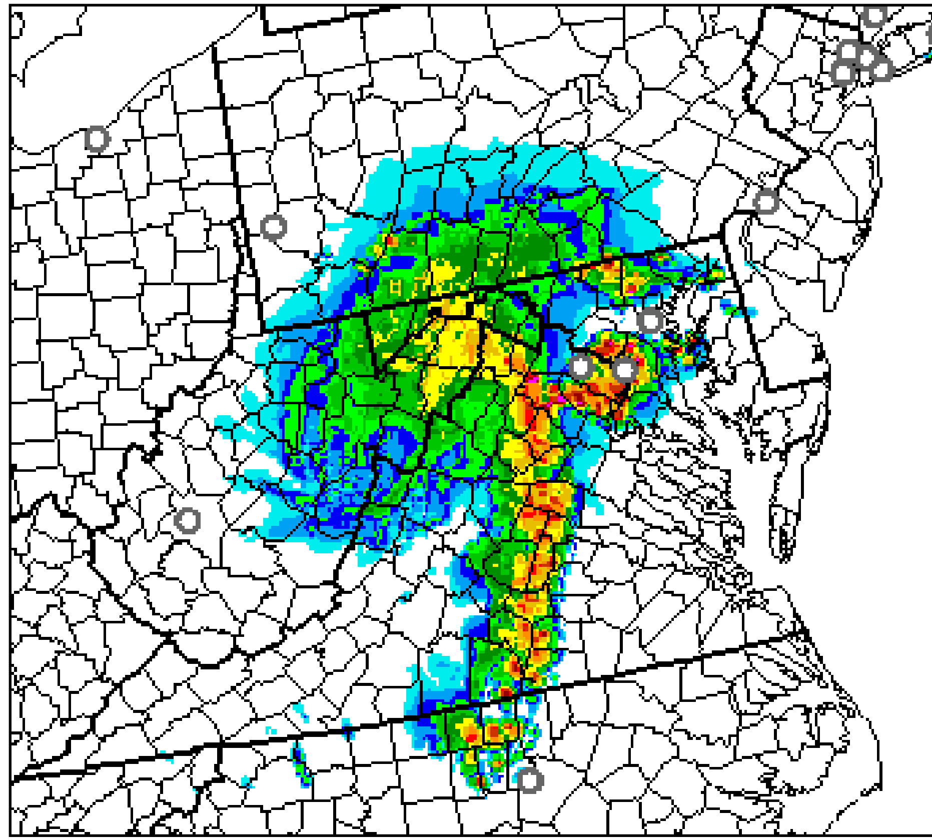
NOAA Next-Generation RAP / HRRR System
Forecast of Mid-Atlantic Derecho

Radar observed



Composite Reflectivity (dBZ)

HRRR 12-h forecast



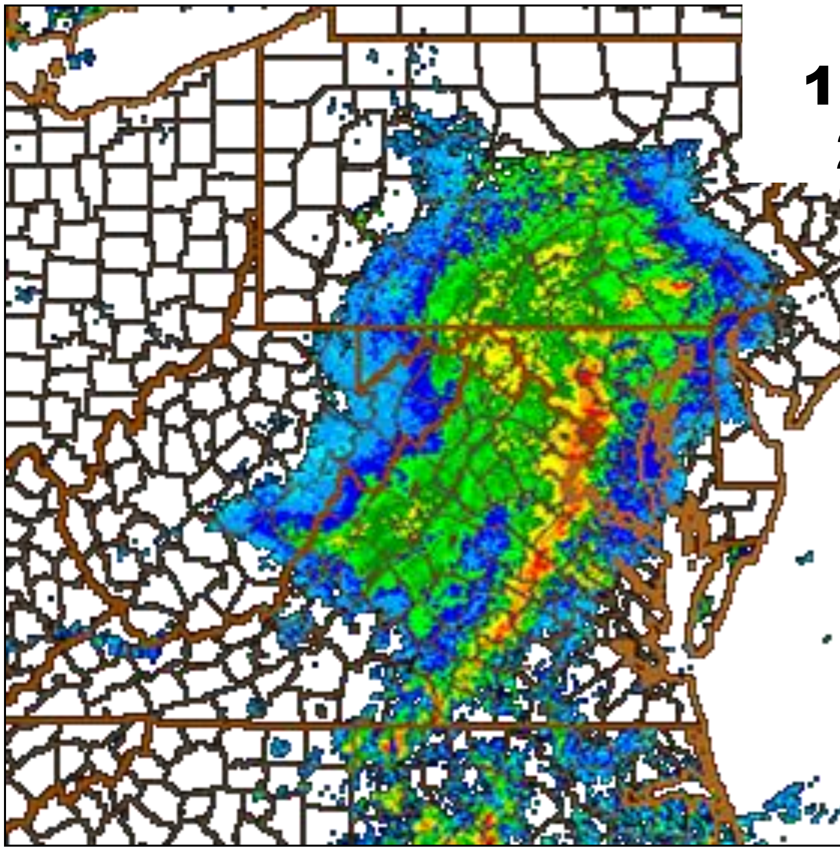
Valid 11PM EDT
29 June 2012

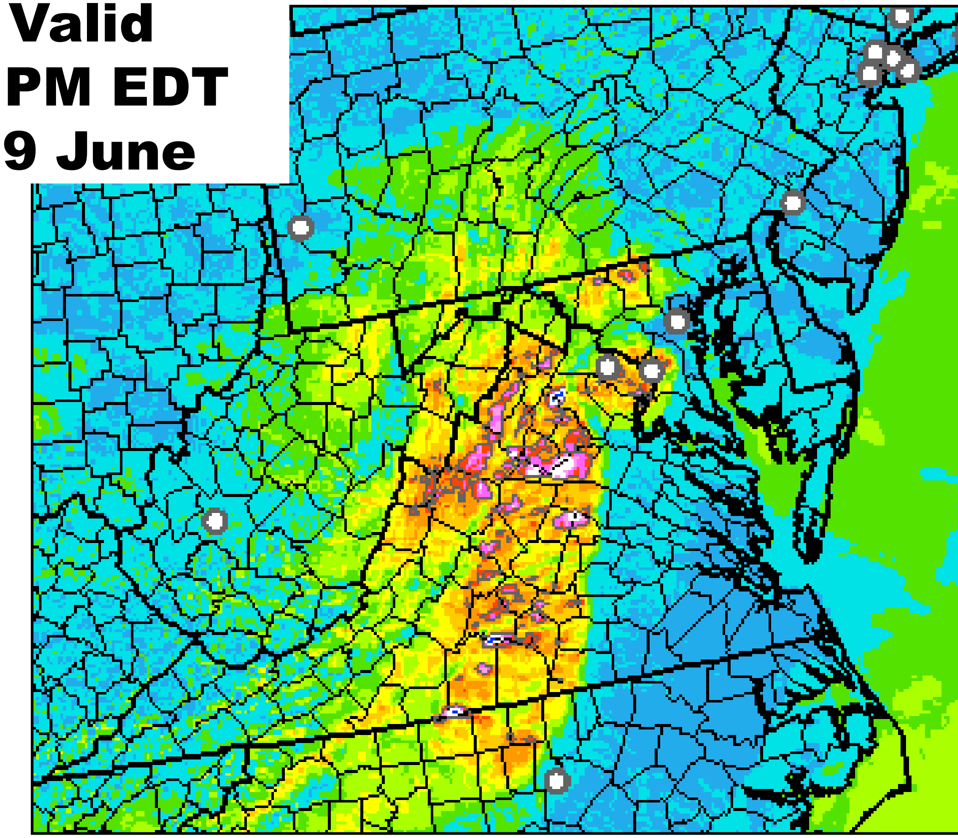
NOAA Next-Generation RAP / HRRR System
Forecast of Mid-Atlantic Derecho

Radar observed

HRRR 12-h forecast

Valid 11PM EDT 29 June



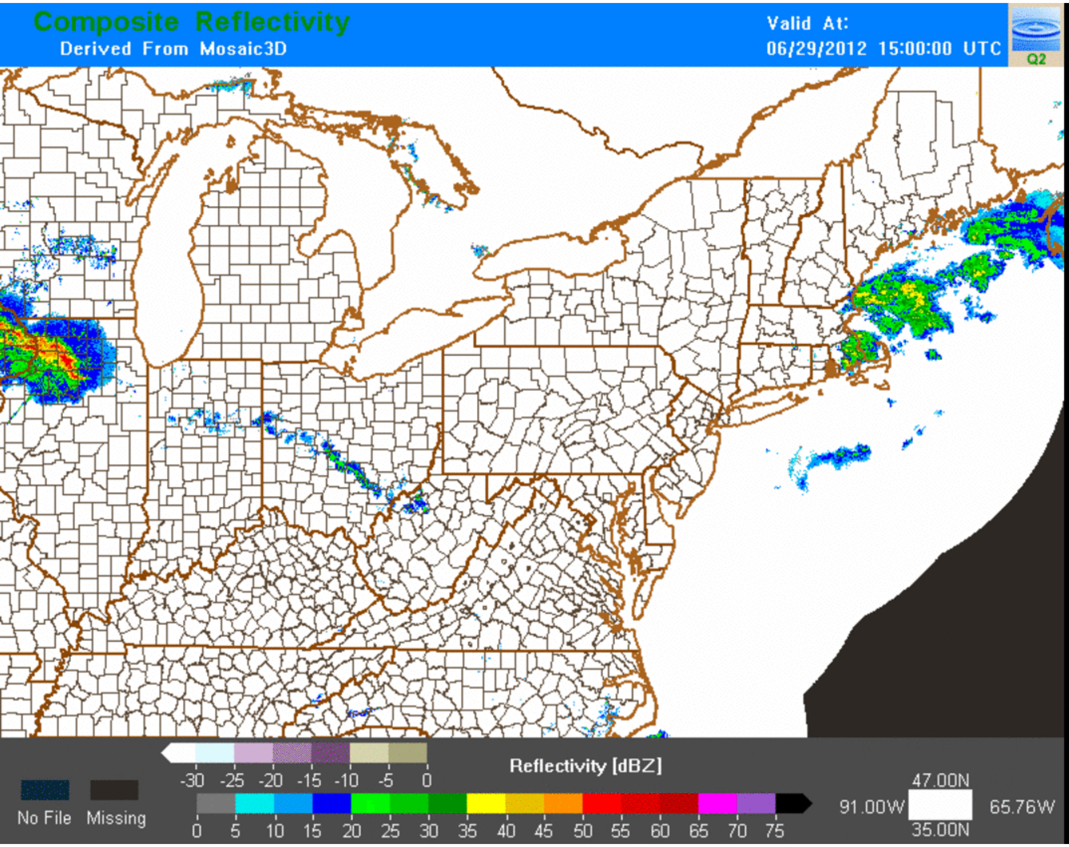


Composite Reflectivity (dBZ)

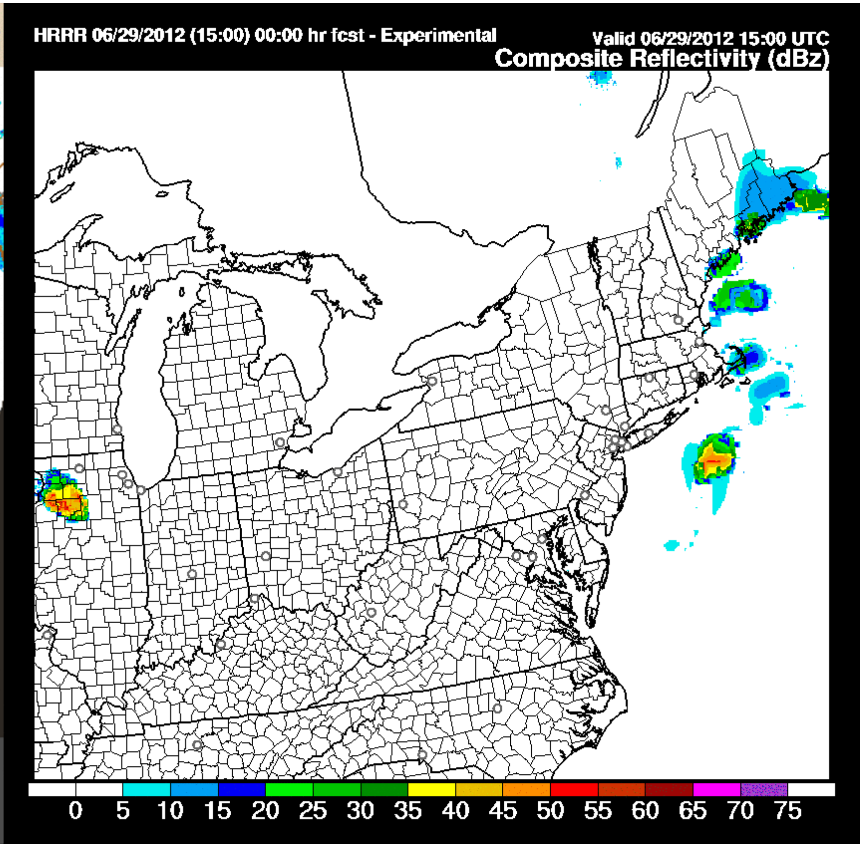
Maximum 10m wind speed during previous (kts)

NOAA Next-Generation RAP / HRRR System
Forecast of Mid-Atlantic Derecho

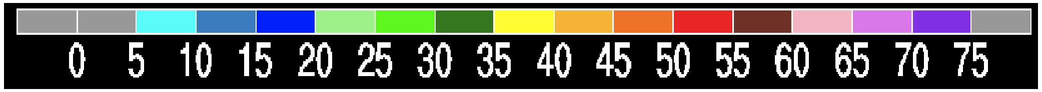
Radar observed



HRRR forecast



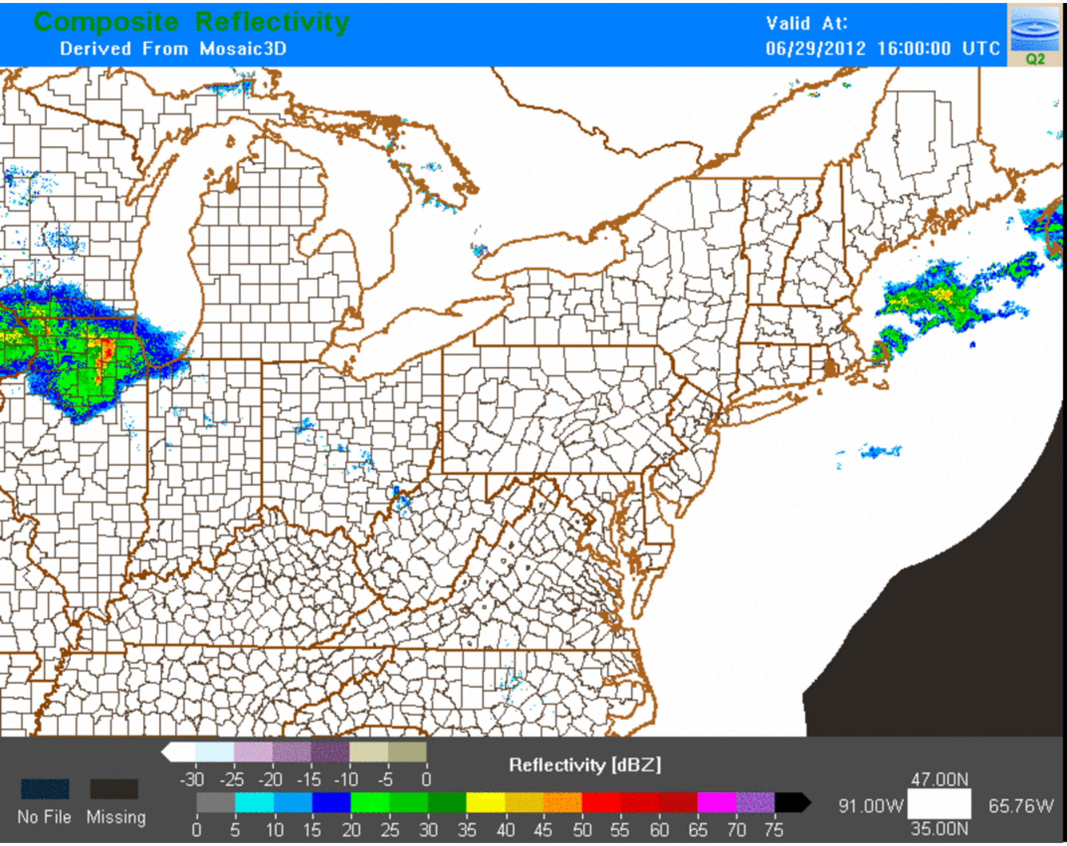
Composite Reflectivity (dBZ)

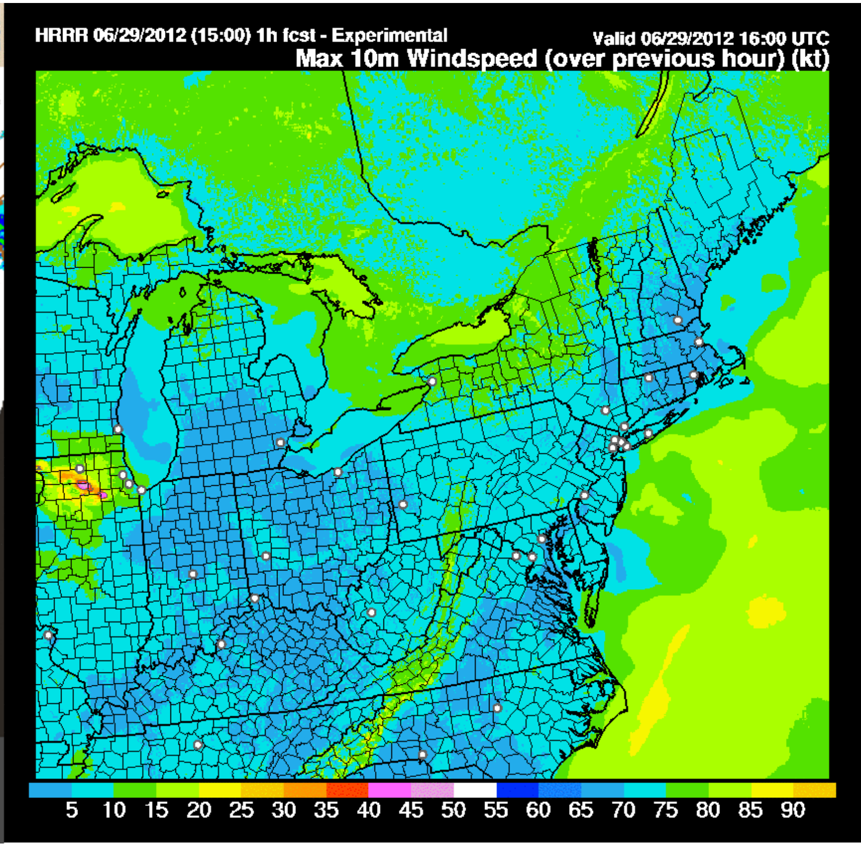


NOAA Next-Generation RAP / HRRR System
Forecast of Mid-Atlantic Derecho

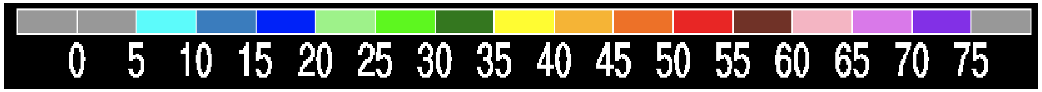
Radar observed

HRRR forecast



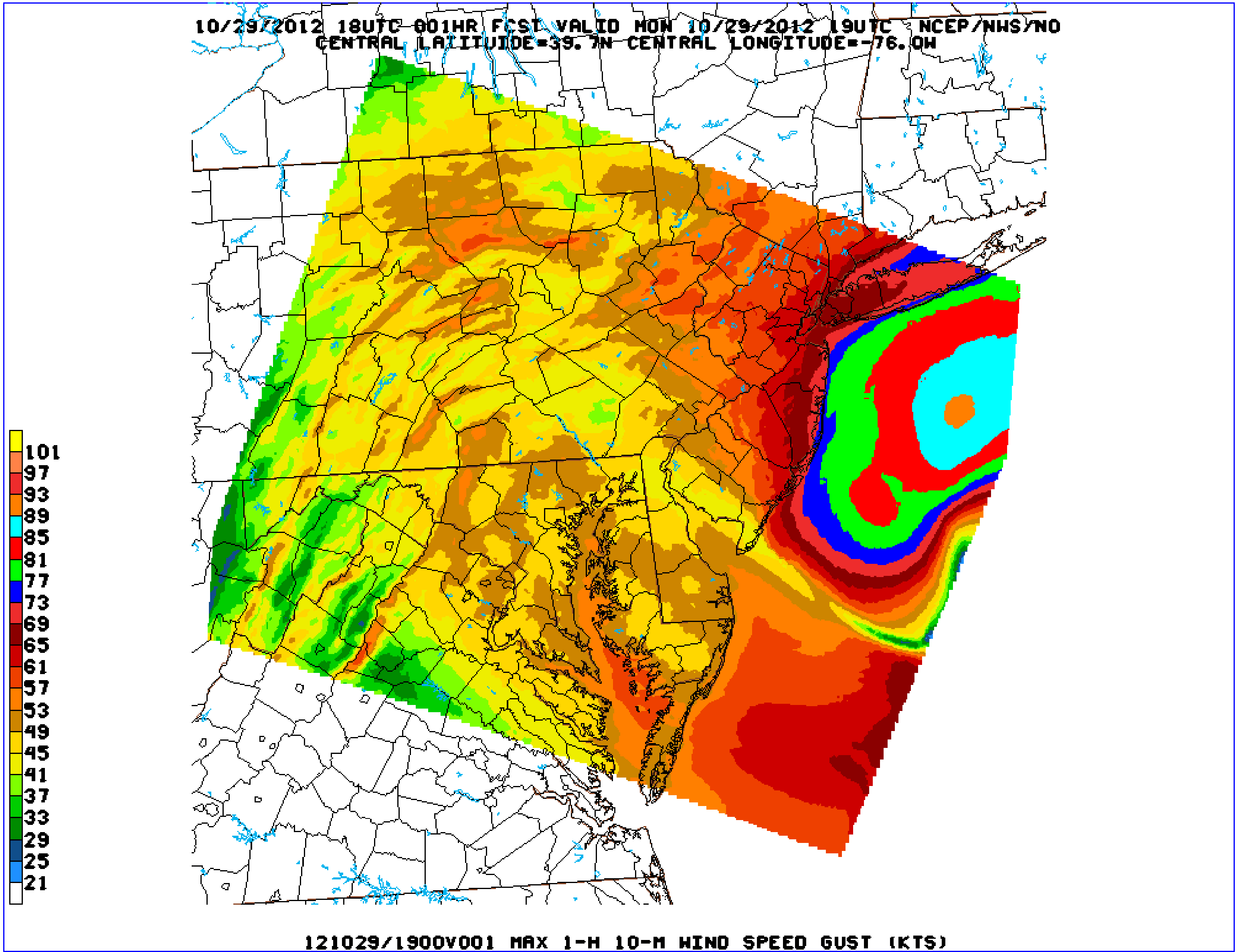


Composite Reflectivity (dBZ)



Maximum 10m wind speed during previous (kts)

NAM 1.33 km nest from 18z 10/29/12
1-h Maximum Wind Speed Gust (kt)



Data Assimilation @ CAWCR / BoM

- Main focus on convective scale NWP
  - 1.5km, 3dVAR, latent heat nudging, Doppler winds
  - Centred on Sydney (central east coast)
    - population, obs coverage, high impact weather (t/storms, E.Coast Lows, fires etc.)

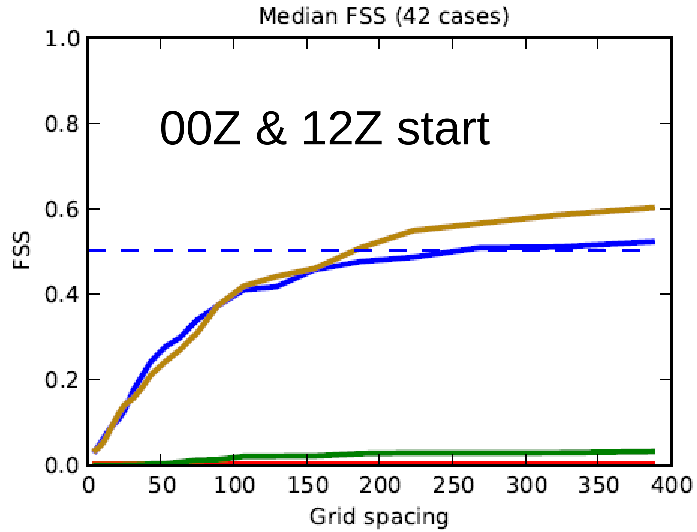
- 9 months trial, 3hourly 3dVAR
  - Hourly rainfall: 1.5km+3dVAR(3hour) no better than 12km+4dVAR(6hour) interpolated to 4km… if start at same time
  - BIG advantage from more frequent update (compare “latest run”)

Where to?

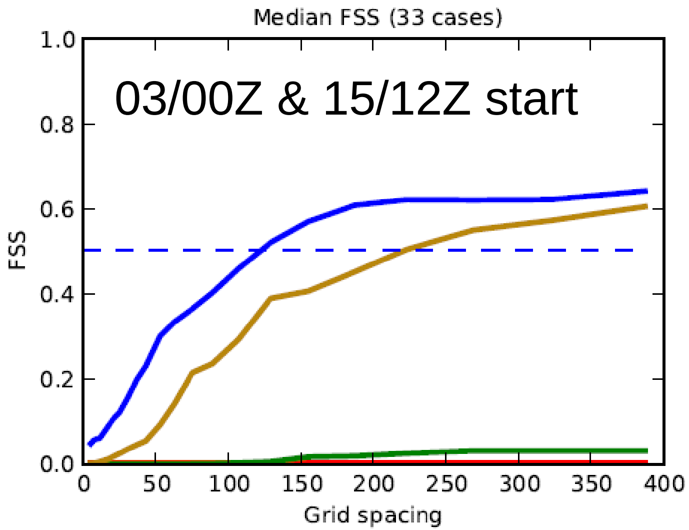
- Hourly DA
  - High resolution AMV's
  - Remove large scale from bkg. error covariance estimation
  - MTSAT cloud top info
  - Explore possibility of using some satellite radiances
    - ~1/3 domain is ocean
  - Doppler winds (rain & clear)
- May also explore

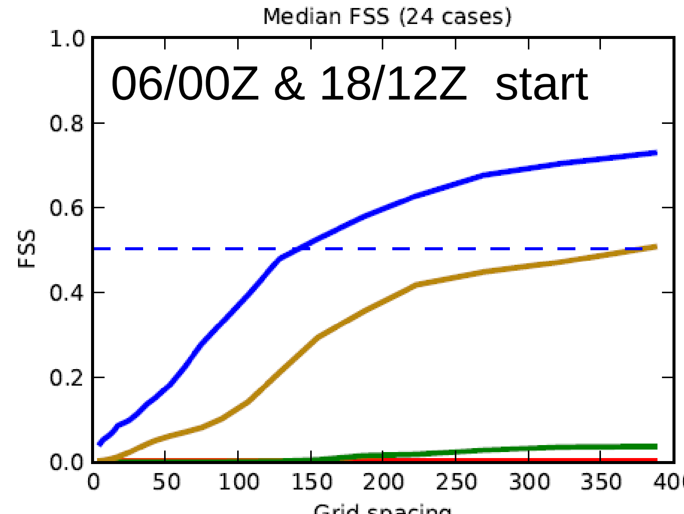
- Effect of meso DA fades by ~12hours (LBC’s, predictability etc.)

FSS for 8mm/h threshold



1.5km+3dVAR+LHN
ACCESS-A 12km
ACCESS-SY 0.05º (APS0)
ACCESS-SY 4km (APS1)

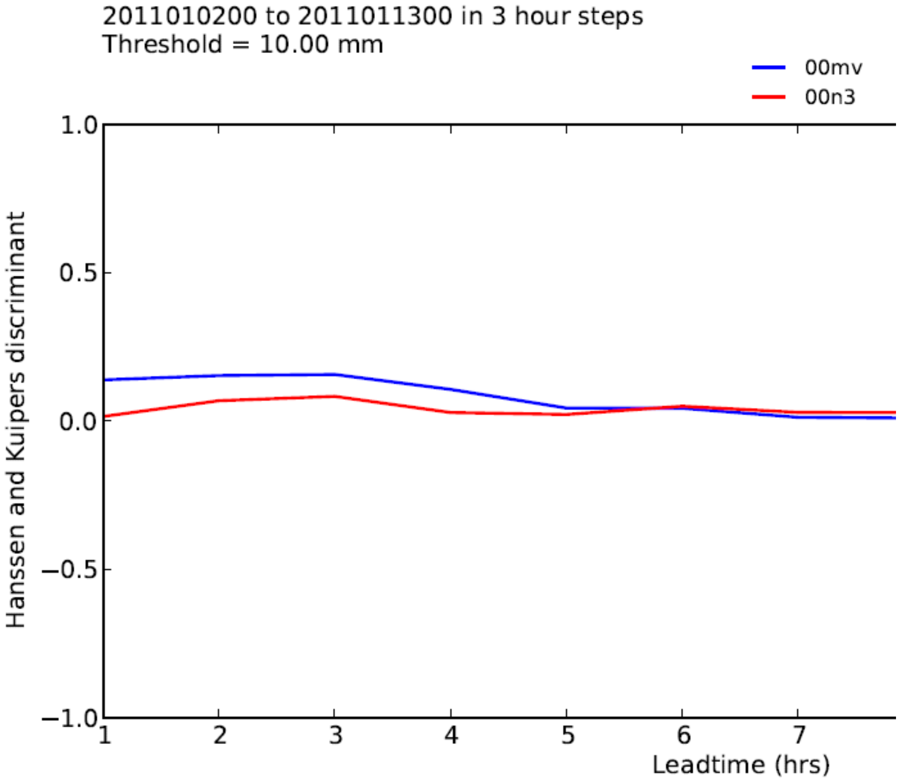


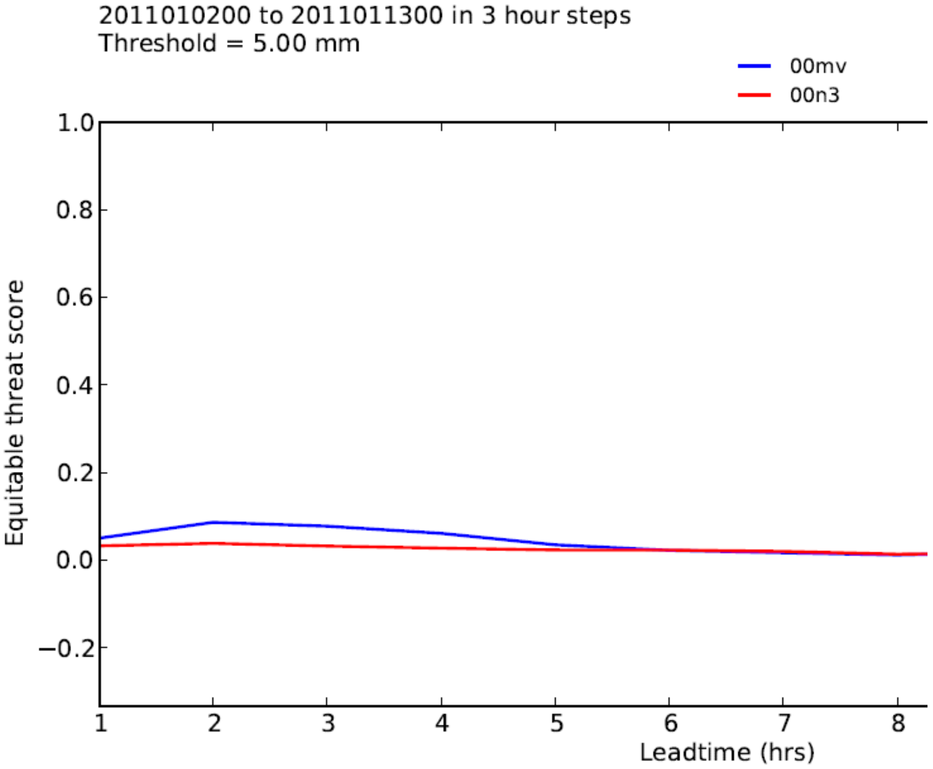


Value-added by Latent Heat Nudging over 3dVAR

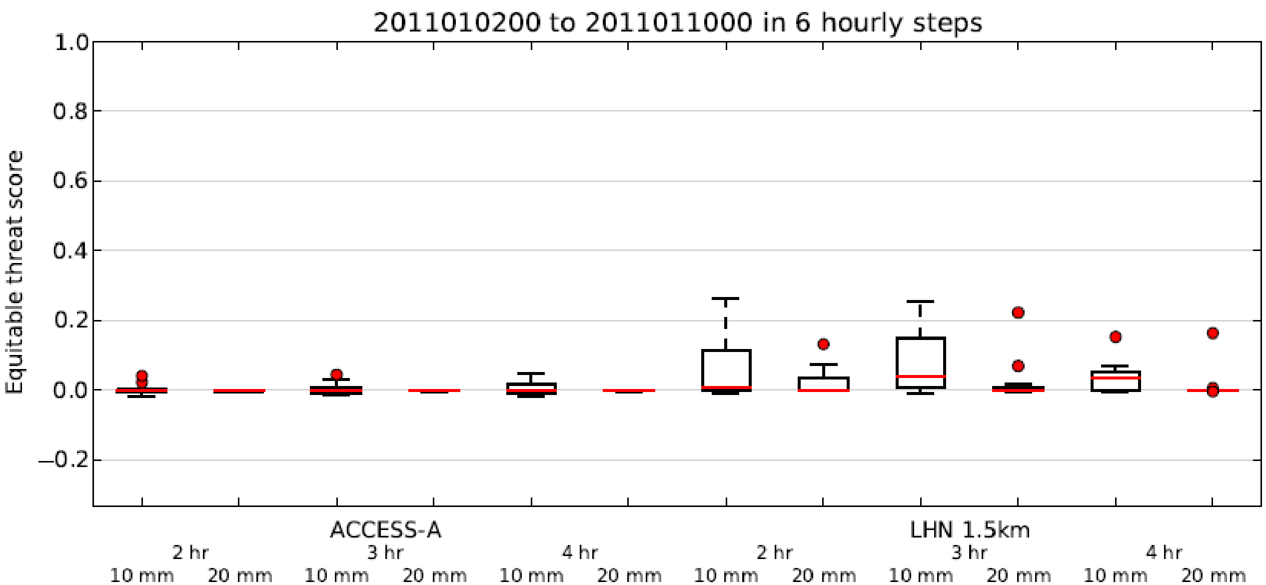
Latent Heat Nudging + 3dVAR

3dVAR only





APS0 & SREP



Hourly Precip &

Model native grid