North American Mesoscale (NAM) Analysis and Forecast System Characteristics

Forecast Model Dynamics / Physics

Component		Comments/References
Infrastructure	NOAA Environental Modeling System (NEMS)	http://www.emc.ncep.noaa.gov/index.php?branch=NEMS
Dynamics	Non-Hydrostatic Multiscale Model on B-grid (NMMB)	Janjic, Z., and R.L. Gall, 2012: Scientific documentation of the NCEP nonhydrostatic multiscale model on the B grid (NMMB). Part 1 Dynamics. NCAR Technical Note NCAR/TN-489+STR Janjic, Z. I., J. P. Gerrity, Jr. and S. Nickovic, 2001: An Alternative Approach to Nonhydrostatic Modeling. *Monthly Weather Review*, Vol. **129**, 1164-1178. Janjic, Z. I., 2003: A Nonhydrostatic Model Based on a New Approach. *Meteorology and Atmospheric Physics*, **82**, 271-285. http://dx.doi.org/10.1007/s00703-001-0587-6 Janjic, Z. I.: A unified model approach from meso to global scales. Geophys. Res. Abstracts, 7, SRef{ID: 1607{7962/gra/EGU05{A{05 582, 2005. Janjic, Z. I. and Black, T: A unified model approach from meso to global scales. Geophys. Res. Abstracts, 7, SRef{ID: 1607{7962/gra/EGU2007{A{05 025, 2007. Janjic, Z., Huang, H., and Lu, S.: A unified atmospheric model suitable for studying transport of mineral aerosols from meso to global scales, IOP C. Ser. Earth Env., 7, 012011, http: 25 //iopscience.iop.org/1755-1315/7/1/012011/refs, doi:10.1088/1755-1307/7/1/012011, 2009. Janjic, Z., 2010: Recent Advances in Global Nonhydrostatic Modeling at NCEP. Invited lecture at the ECMWF Workshop on Non-hydrostatic Modeling. November 2010, 14pp. ECMWF, Shinfield Park, Reading, Berkshire RG2 9AX, U.K. Janjic, Z., Janjic, T., and Vasic, R.: A Class of conservative fourth order advection schemes and impact of enhanced formal accuracy on extended range forecasts, Mon. Weather Rev., 0, null, doi:10.1175/2010MWR3448.1, 2011. For changes with the 21 March 2017 NAM upgrade, see http://www.emc.ncep.noaa.gov/mmb/mmbpll/misc/namv4docs/NMMB_Model_Changes_8-24-2016_v3.pptx
Model Top Pressure and Vertical Characteristics	Hybrid sigma-pressure vertical coordinate 2 mb model top pressure 60 vertical layers	Figs. 1 and 2.

	Bottom layer ~ 20 m	
Horizontal Resolution	12 km (parent N.American domain) 3 km CONUS nest 3 km Alaska nest 3 km Hawaii nest 3 km Puerto Rico nest Fire weather :1.5 km	Domain areal coverage : http://www.emc.ncep.noaa.gov/mmb/namgrids/namnests_domains.jpg and Fig. 3. The fire weather nest can be placed anywhere inside the CONUS or Alaska nest; it is used for fire weather forecasting during the fire season and for severe weather events during other times of the year
Boundary Conditions	Parent domain : 6-h old GFS forecast, updated every 3-h Nest domains : Every model time step from parent domain	
Horizontal diffusion	Computed on hybrid surfaces	Nonlinear Smagorinsky-type Janjic, Z.I.,1990: The step-mountain eta coordinate: Physical package. *Mon. Wea. Rev.*, **118**, 1429-1443.
Gravity wave drag (also includes mountain blocking)	Yes	Turned on for 12 km NAM parent domain only Alpert, J., 2004: Sub-grid scale mountain blocking at NCEP. Proc. 20Th Conference on Weather on Analysis and Forecasting/17th Conference on Numerical Weather Prediction, American Meteorological Society. Seattle, WA. P2.4. [Available online at https://ams.confex.com/ams/pdfpapers/71011.pdf].
Vertical diffusion	MYJ level 2.5 closure in free atmosphere	Janjic, Z. I., 2001: Nonsingular Implementation of the Mellor-Yamada Level 2.5 Scheme in the NCEP Meso model. NOAA/NWS/NCEP Office Note #437, 61 pp.
Land-surface	Noah LSM 20 MODIS-IGBP land use categories	http://www.emc.ncep.noaa.gov/annualreviews/day%201/05-EK-landsfc.pptx Ek, M. B., K. E. Mitchell, Y. Lin, E. Rogers, P. Grunmann, V. Koren, G. Gayno, and J. D. Tarpley, 2003: Implementation of Noah land surface model advances in the National Centers for Environmental Prediction operational mesoscale Eta model. *J. Geophys. Res.*, **108** (D22), 16, doi:10.1029/2002JD003296.
SST	NCEP 0.125 deg RTG_SST_HR	http://polar.ncep.noaa.gov/mmab/tpbs/operational.tpbs/RTG_SST_HR.pdf Updated once/day with new analysis at start of 00z NAM DA cycle
Snow/Sea ice	National Ice Center IMS snow cover/sea ice 577th Weather Wing (formerly AFWA) snow depth analysis	http://www.emc.ncep.noaa.gov/jcsda/ggayno/snow/snow.txt Updated once/day at the start of the 00z NAM DA cycle

Surface layer	NMM	
Boundary layer scheme	MYJ Level 2.5	Janjic, Z. I.: The Step-mountain Eta Coordinate Model: Further developments of the convection, viscous sublayer and turbulence closure schemes, Mon. Weather Rev., 122, 927– 945, 1994. Janjic, Z. I., 2001: Nonsingular implementation of the Mellor-Yamada level 2.5 scheme in the NCEP meso model. NCEP Office Note, 91 pp. [437].
Shallow Convection	BMJ	Janjic, Z. I.: The Step-mountain Eta Coordinate Model: Further developments of the convection, viscous sublayer and turbulence closure schemes, Mon. Weather Rev., 122, 927– 945, 1994. Modified in the March 2017 NAM upgrade, see http://www.emc.ncep.noaa.gov/mmb/mmbpll/misc/namv4docs/NAMv4_ScienceIT_brief_10Mar2017.final_expanded.pptx Parameterized convection only run in 12 km NAM parent domain
Deep Convection	BMJ	Janjic, Z. I.: The Step-mountain Eta Coordinate Model: Further developments of the convection, viscous sublayer and turbulence closure schemes, Mon. Weather Rev., 122, 927– 945, 1994. Modified in 21 Match 2017 NAM upgrade, see: http://www.emc.ncep.noaa.gov/mmb/mmbpll/misc/namv4docs/NAMv4_ScienceIT_brief_10Mar2017.final_expanded.pptx Parameterized convection only run in 12 km NAM parent domain
Gridscale clouds, precip microphysics	Ferrier-Aligo	Aligo, E., and coauthors : High-Resolution NMMB Simulations of the 29 June 2012 Derecho, AMS 27th WAF/23rd NWP Conference, Atlanta, GA,, viewable at https://ams.confex.com/ams/94Annual/videogateway.cgi/id/26141?recordingid=26141 Ferrier, B. S., W. Wang, and E. Colon, 2011: Evaluating cloud microphysics schemes in nested NMMB forecasts. *24th Conf. on Weather Analysis and Forecasting/20th Conf. on Numerical Weather Prediction*, Seattle, WA, Amer. Meteor. Soc. Ferrier, B. S., Y. Jin, Y. Lin, T. Black, E. Rogers, and G. DiMego, 2002: Implementation of a new grid-scale cloud and precipitation scheme in the NCEP Eta model. Preprints, *15th Conf. on Numerical Weather Prediction*, San Antonio, TX, Amer. Meteor. Soc., 280–283. Modified in 21 March 2017 NAM upgrade, see http://www.emc.ncep.noaa.gov/mmb/mmbpll/misc/namv4docs/NAMv4_ScienceIT_brief_10Mar2017.final_expanded.pptx http://www.emc.ncep.noaa.gov/mmb/mmbpll/misc/namv4docs/aligo_a

		wc_8-24-2016.pptx Aligo, E., and coauthors, 2018: Modified NAM Microphysics for Forecasts of Deep Convective Storms. Mon. Wea. Rev, 146, 4115-4153. Viewable at https://journals.ametsoc.org/doi/pdf/10.1175/MWR-D-17-0277.1 or https://www.emc.ncep.noaa.gov/users/Eric.Rogers/documents/Aligo_FAmicro_2018MWR.pdf
Shortwave Radiation	RRTM tuned for NMMB	Rogers E., and coauthors, 2014: The NCEP North American Mesoscale (NAM) Analysis and Forecast System : Near-term plans and future evolution into a high-resolution ensemble, AMS 27th WAF/23rd NWP Conference, Atlanta, GA, viewable at https://ams.confex.com/ams/94Annual/videogateway.cgi/id/26188?recordingid=26188 Mlawer, E. J., S. J. Taubman, P. D. Brown, M. J. Iacono, and S. A. Clough, 1997: Radiative transfer for inhomogeneous atmos-pheres: RRTM, a validated correlated-k model for the long-wave. *J. Geophys. Res.*, **102**, 16 663–16 682. Modifications with the 21 Match 2107 NAM upgrade described: http://www.emc.ncep.noaa.gov/mmb/mmbpll/misc/namv4docs/NAMv4_ScienceIT_brief_10Mar2017.final_expanded.pptx
Longwave Radiation	RRTM tuned for NMMB	Iacono, M. J., J. S. Delamere, E. J. Mlawer, M. W. Shephard, S. A. Clough, and W. D. Collins, 2008: Radiative forcing by long-lived greenhouse gases: Calculations with the AER radiative transfer models. *J. Geophys. Res.*, **113**, D13103, doi:10.1029/2008JD009944.
Data Assimilation (Fig. 4)		
Data Assimilation Method	Hybrid ensemble-3DVar version of NCEP Gridpoint Statistical Interpolation Analysis	http://www.dtcenter.org/com-GSI/users/index.php As of August 2014 NDAS/NAM GSI uses NCEP Global EnKF ensemble in background error covariance calculation Wu, W.-S., R. J. Purser, and D. F. Parrish, 2002: Three-dimensional variational analysis with spatially inhomogeneous covariances. *Mon. Wea. Rev.*, **130**, 2905–2916. Wang, X., 2010: Incorporating ensemble covariance in the gridpoint statistical interpolation variational minimization: A mathematical framework. *Mon. Wea. Rev.*, 138, 2990–2995.

Data Assimilation / Spin-up	Partial cycling NAM Data Assimilation (DA) 6-h spin-up from Global Data Assimilation System (GDAS) atmospheric states and NAM DA soil states	See Fig. 4 and schematic comparing NDAS vs GDAS at http://www.emc.ncep.noaa.gov/mmb/mmbpll/misc/NDAS_vs_GDAS.pdf Partial cycling: Rogers, E., and Coauthors, 2009: The NCEP North American Mesoscale modeling system: Recent changes and future plans. Preprints, *23rd Conf. on Weather Analysis and Forecasting/19th Conf. on Numerical Weather Prediction*, Omaha, NE, Amer. Meteor. Soc., 2A.4. [Available online at http://ams.confex.com/ams/pdfpapers/154114.pdf]. 6-h spin-up consists of hourly GSI analyses and 1-h NMMB forecasts for the 12 km NAM parent and 3 km CONUS/Alaska nests with assimilation of radar/lightning data. NAM DA 1-h forecast va;id at 00/06/12/18z used as first guess for 12 km parent and CONUS/Alaska nests analyses, non-cycled nests (Hawaii, Puertto Rico/Fire Weather) use 12 km parent for on-time analysis first guess All NAM forecasts (during data assimilation and 84-h forecast) are initialized with a diabatic digital filter
Data cutoff time	NAM analysis : T+70 min NAM DA cycle TM06 : T-150 min TM05 & TM04 : T-120 min TM03 : T-90 min TM02 : T-27 min TM01 : T+18 min	T = NAM forecast cycle time (00/06/12/18z) TMXX = NAM data assimilation analysis rtims; for example, “TM06” for the 12z NAM is valid at 06z.
Conventional observations assimilated	- Rawinsondes - Aircraft winds, temperature, moisture - Surface pressure. Wind. /temperature, moisture (including selected mesonets) - VAD wind profiles - Wind profilers - WSR-88D Doppler radial velocities - Radar reflectivity (used to computer temperature tendencies in daibatic digital filter)	Details on radar/lightning data assimilation are at : http://www.emc.ncep.noaa.gov/mmb/mmbpll/misc/namv4docs/radar_lightningDA_namv4.ppt
Satellite observations assimilated	- Cloud-drift winds from GOES and polar orbiting satellites - Radiances assimilated (using the Community Rapid Radiative Transfer Model) from GOES and polar orbiting satellites - GPS IPW data - Lightning data	
Precipitation assimilated	- Merged Hourly Stage II/IV precipitation; drives	http://www.emc.ncep.noaa.gov/mmb/ylin/docs/precip_assim.pdf

	NOAH land-surface physics during NAM DA cycle	

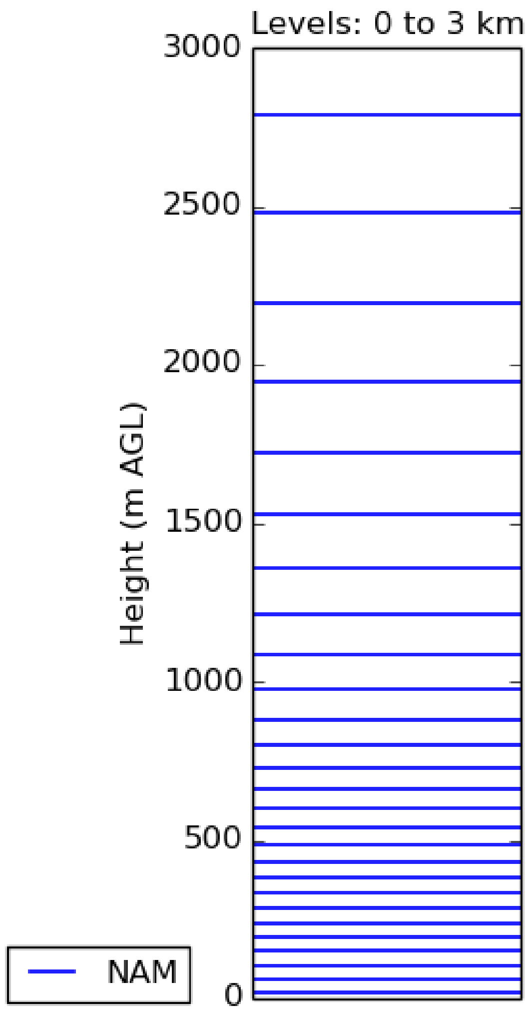

Fig. 1 NAM vertical levels from 0 m to 3 km AGL.

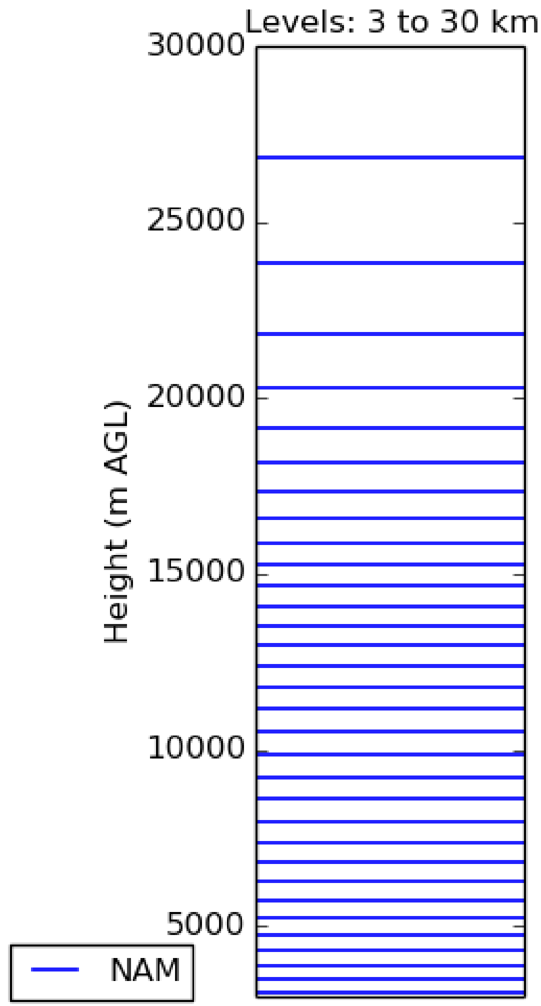

Fig. 2 NAM vertical levels from 3 km AGL to 30 km AGL.

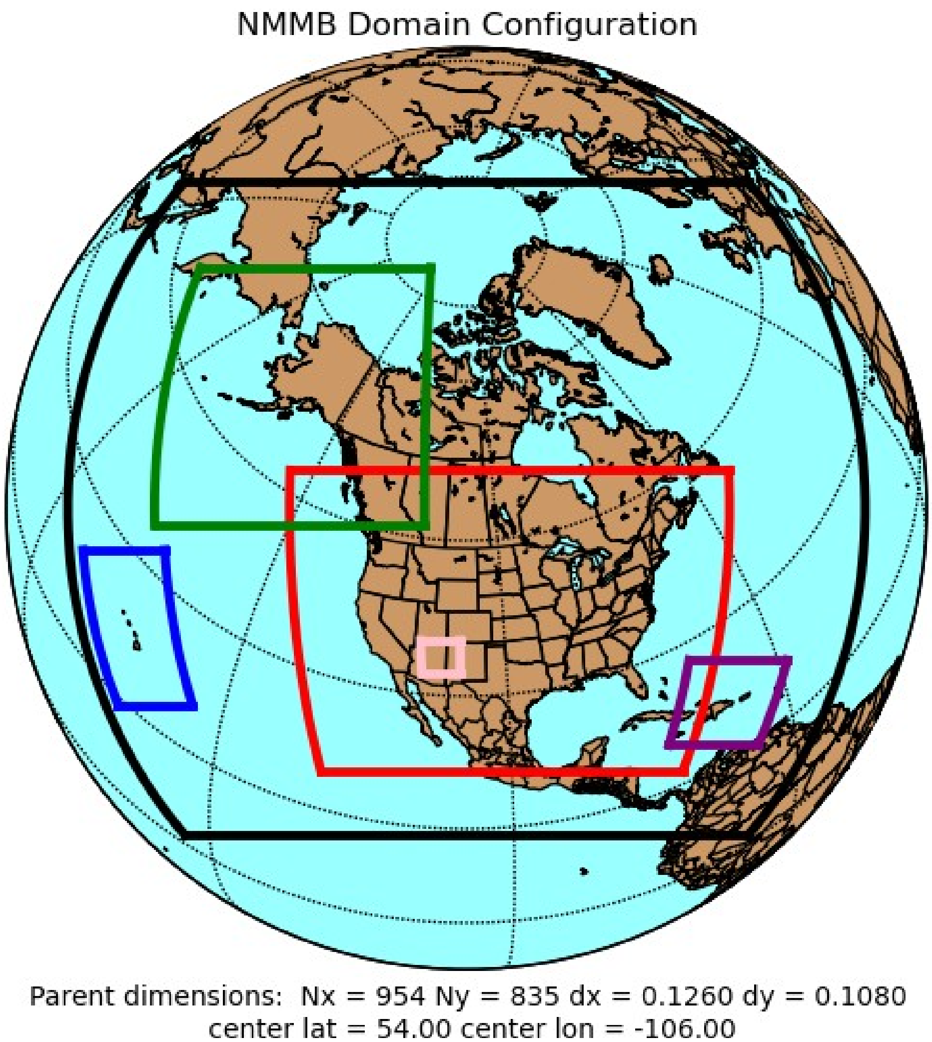

Fig. 3. NAM Parent 12 km (black), 3 km Alaska nest (green), 3 km CONUS nest (red), 3 km Hawaii nest (blue), 3 km Puerto Rico nest (Purple), and on-demand 1.5 km Fire WX nest computational domains.

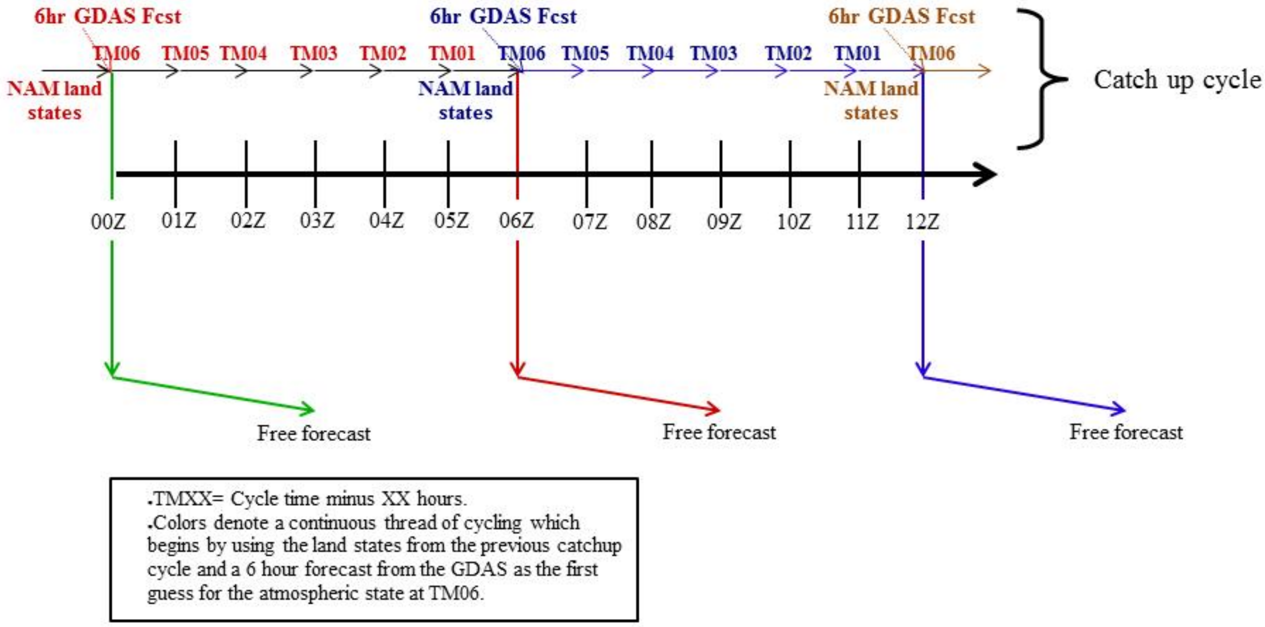

Fig. 4. NAM data assimilation (DA) cycling diagram. Each forecast cycle begins with a 6 hour analysis-forecast window during which analyses are conducted at one hour intervals (TM06, TM05, etc.). TM00 refers to the forecast initialization time (e.g. 00, 06, 12, or 18 UTC). At TM06 the first guess for the atmosphere is a 6 hour forecast from the GDAS. The land states are, however, still cycled from the previous NAM DA cycle. The 12 km NAM parent and 3 km CONUS/Alaska nests are run during the 6-h NAM DA cycle, the non-cycled nests (Hawaii, Puerto Rico, Fire Weather) and initialized using the TM00 first guess from the 12 km parent domain.