A Limited Area Modeling Capability for the Finite-Volume Cubed-Sphere (FV3) Dynamical Core

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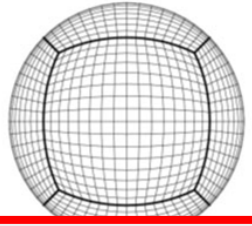
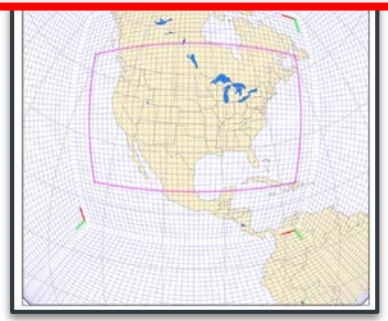
The topic of this presentation is currently under review for publication with Mon. Wea. Rev.

Motivation

- FV3 is a global model with a nest capability
- Need a limited area option for CAM applications
- *Why?*
  - *Avoids extra resources required to run a global parent*
  - *Rapid updates in DA are more feasible in LAM*
    - *Earlier data-cutoffs*
      - *12Z HRRR starts at ~12:23Z*
      - *12Z GFS starts at ~14:45Z*
- Obvious potential drawback
  - *Boundary data from an external forecast cannot be as accurate as those provided by a parent to a nest every timestep during the integration*

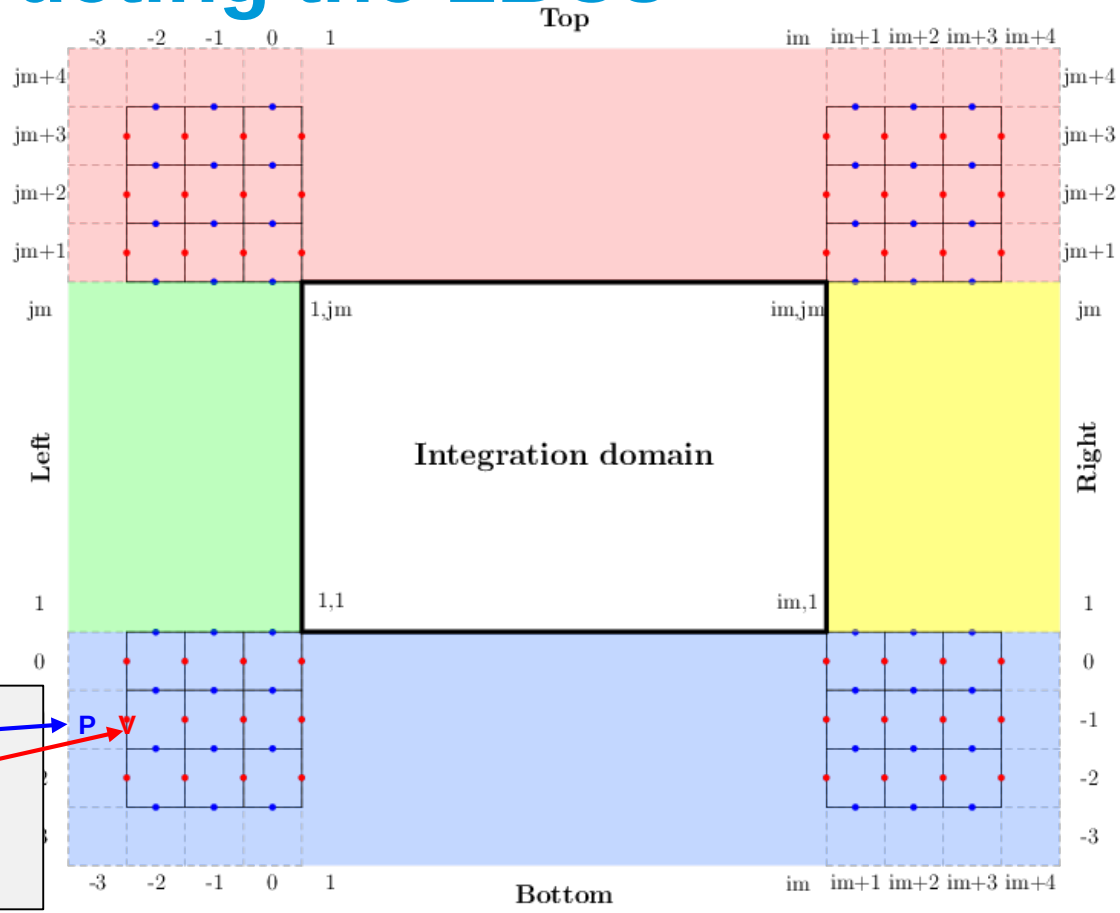


We can quantify the impact - more on this in a bit



Constructing the LBCs

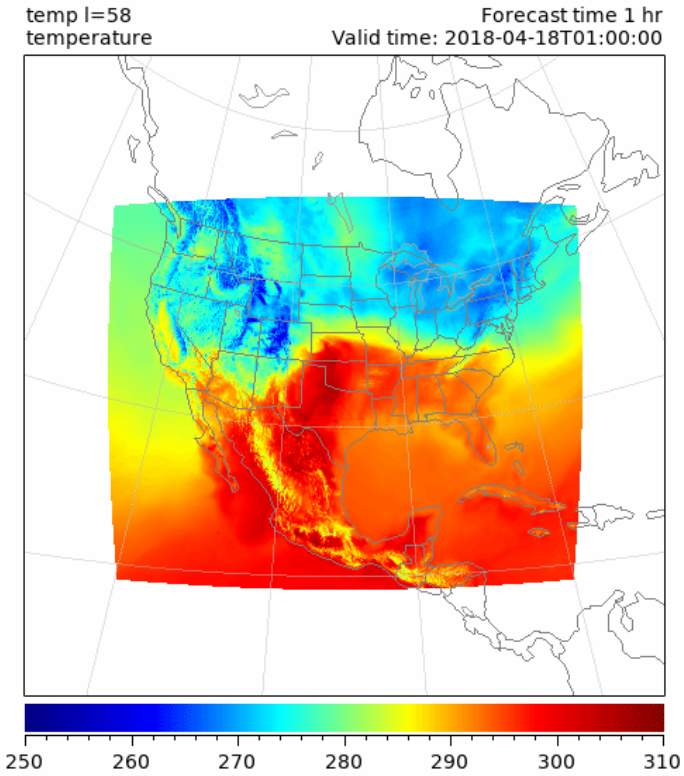
- Read the data from the external BC files
- Vertically remap scalars and wind components into the model internal structure
- The regional boundary requires fields to have 3 or 4 rows of data outside the integration domain
  - Extra rows/columns needed for the horizontal derivatives



We need 4th row
pressure
to vertically remap
wind
on the 3rd cell edge in the boundary.

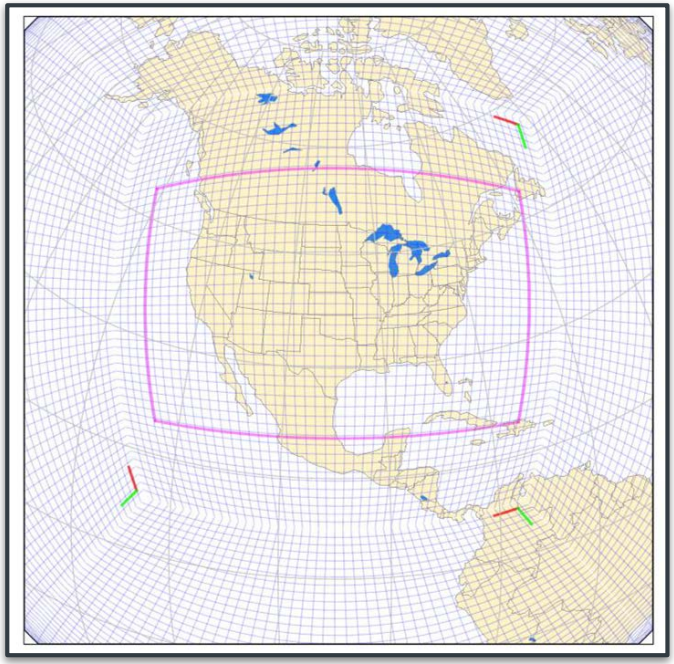
Forecast Example

84-hr forecast from 00Z 18 April 2018 using operational GFS BCs on a ~3 km grid



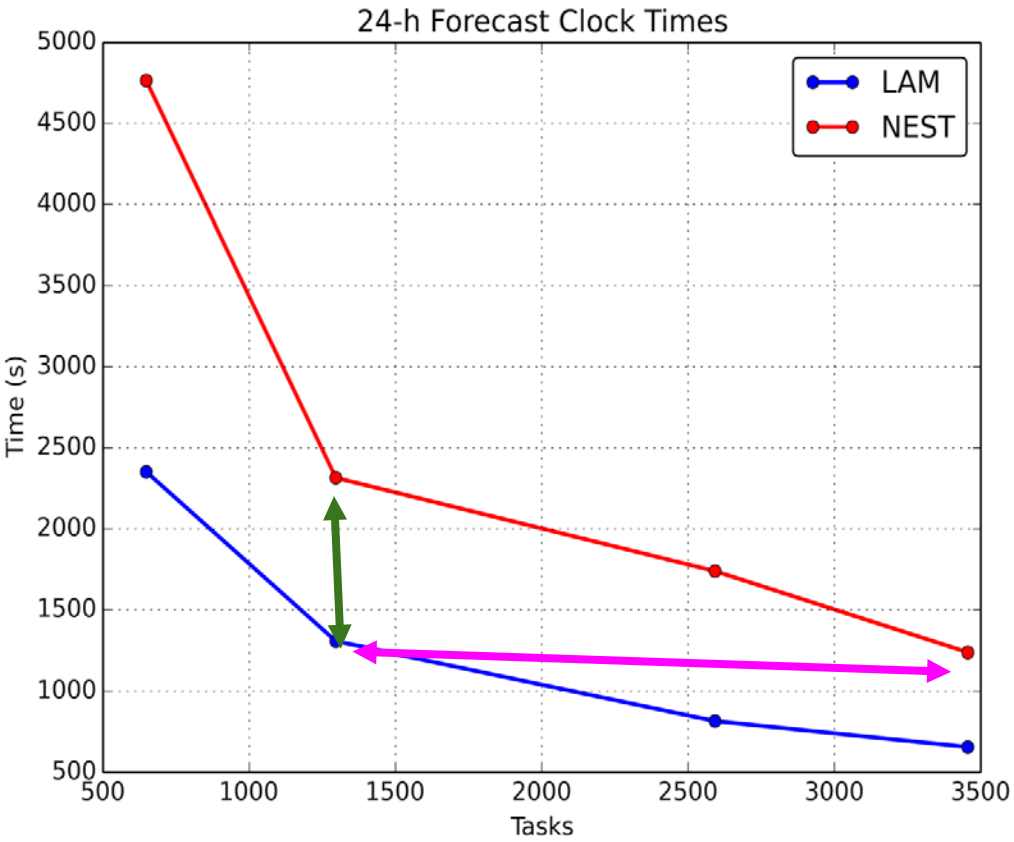
LAM vs Nest

- LAM and Nest Configured identically
  - Same ICs, physics, domain
- Domain specification
  - Process to specify a LAM domain OR a nest domain is effectively identical
    - Begin with C768 global grid
    - Apply stretch factor of 1.5 for the global parent
      - Produces a grid spacing of ~9 km on the cube face where the NEST/LAM is placed
    - Apply refinement ratio of 3 to generate the NEST/LAM grid
- Only difference is LAM vs Nest configuration
  - The nest *does* have two-way feedback included (Harris and Lin 2013)



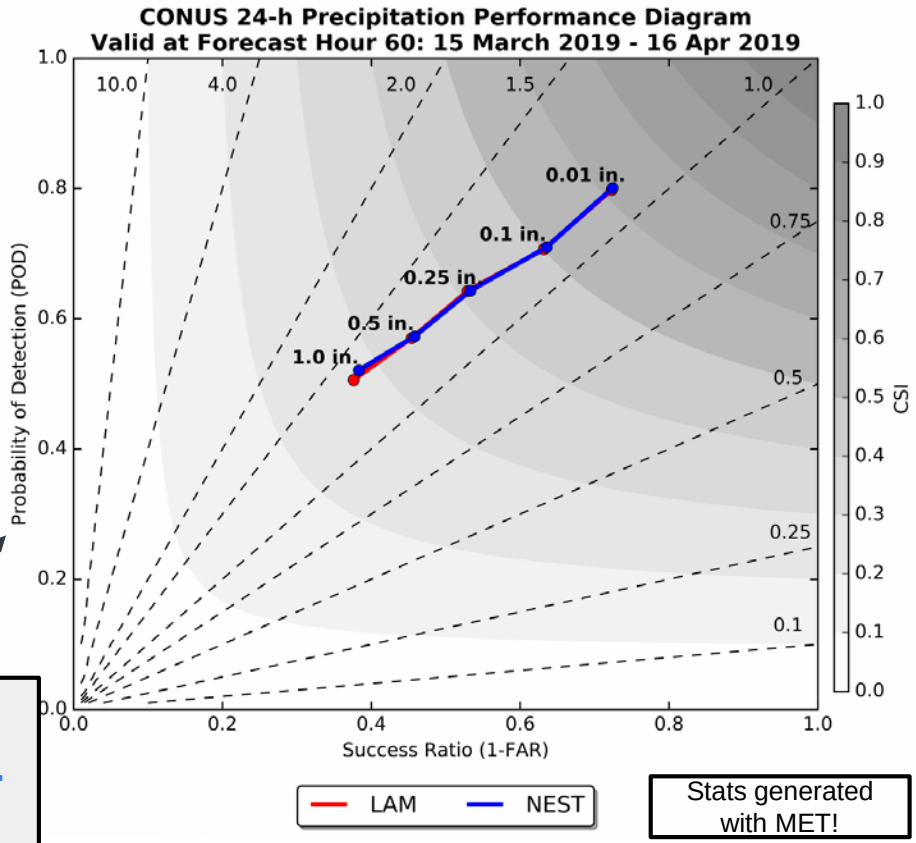
Computational Performance

- LAM vs NEST at 3 km over CONUS
- 24-h forecasts
  - No model history writes to eliminate any overhead associated with I/O
  - 20 MPI tasks each w/ 2 threads per node
- **LAM completes in ~half the time of the NEST for a given number of tasks**
- **LAM uses less than half the tasks that the NEST needs for completing in a given amount of time**
- LAM is considerably more efficient
  - No need to integrate a global model or handle two-way feedback
  - Eliminates parent's generation of the nest's LBCs every parent timestep and the exchange of those values



Forecast Performance

- GFS ICs
- 3-hrly LBC updates for LAM
  - GFS for LBCs
- 15 March - 16 April 2019
- Daily 00 UTC initializations
- Forecasts to 60-h
- Total of 29 cases
  - Machine outages + maintenance
- Precip and upper air stats



Stats generated with MET!

Performance diagram: 24-h precipitation accumulation intervals out to 60 h (vs. CCPA). LAM and NEST are overall very similar.

Forecast Performance

- Negative height and temperature bias appears in LAM by F24
- BC RMSE diffs not statistically significant until ~F48 in eight

▲	LAM is better than NEST at the 99% significance level
	LAM is better than NEST at the 95% significance level
	Difference between LAM and NEST is not statistically significant
	LAM is worse than NEST at the 95% significance level
▼	LAM is worse than NEST at the 99% significance level
	Null or Missing Data
	Statistic for symbols: DIFF_SIG , Statistic for values: DIFF

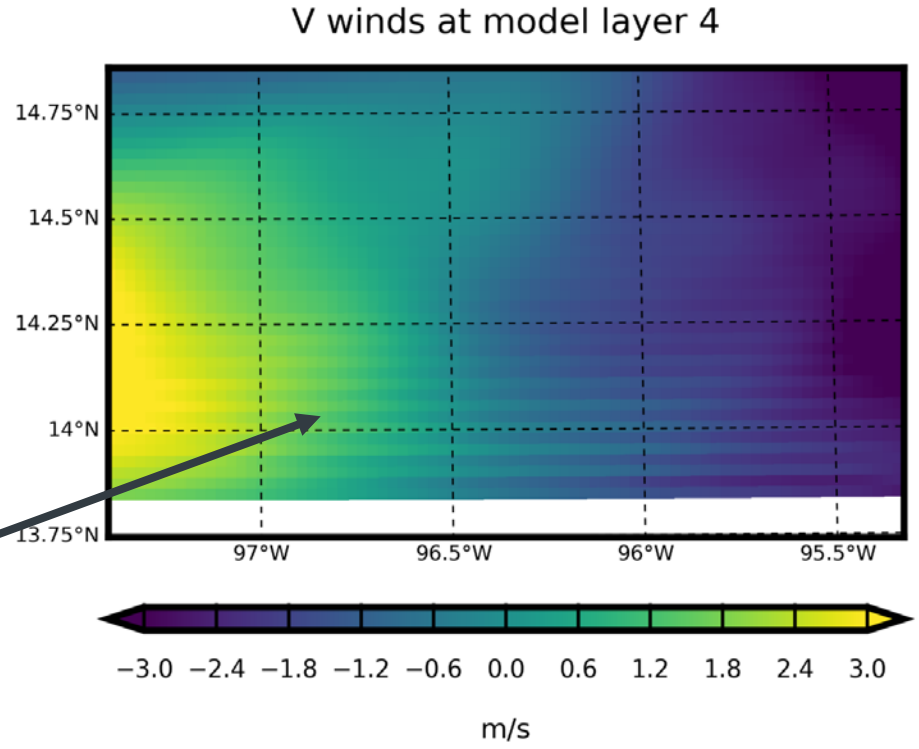
			CONUS					
			F00	F12	F24	F36	F48	F60
Bias	Geopotential Height	250 hPa	0.003	-0.256	▼ -1.112	▼ -1.204	▼ -2.205	▼ -3.273
		500 hPa	-0.002	-0.190	▼ -0.712	-0.426	▼ -1.083	▼ -1.679
		850 hPa	-0.001	-0.085	▼ -0.536	-0.234	▼ -0.937	▼ -1.517
	Temperature	250 hPa	0.000	-0.006	▼ -0.030	▲ -0.060	▼ -0.105	▲ -0.166
		500 hPa	0.000	-0.011	▼ -0.021	-0.019	▼ -0.029	-0.025
		850 hPa	0.000	-0.008	-0.010	-0.002	0.003	0.007
	Specific Humidity	300 hPa	0.000	0.000	0.002	0.000	-0.002	-0.001
		500 hPa	▼ 0.000	0.001	0.000	-0.006	0.004	0.006
		850 hPa	0.000	0.003	-0.007	0.017	-0.001	0.013
BC RMSE	Geopotential Height	250 hPa	-0.002	-0.025	0.110	0.130	-0.028	-0.050
		500 hPa	-0.003	-0.066	0.036	0.130	0.354	0.583
		850 hPa	-0.005	-0.095	-0.012	0.022	▼ 0.515	0.395
	Temperature	250 hPa	0.000	0.002	-0.002	-0.006	0.010	0.034
		500 hPa	0.000	0.004	0.006	0.011	0.003	-0.004
		850 hPa	0.000	0.004	0.002	0.003	-0.010	-0.001
	Specific Humidity	300 hPa	0.000	0.000	0.000	0.000	0.000	0.001
		500 hPa	0.000	-0.007	-0.001	0.003	0.007	0.008
		850 hPa	0.000	-0.012	0.013	0.022	0.012	0.004

Scorecard generated with MET!

Improvements to the LBC Treatments

Initial version features no special blending treatments - conditions are prescribed at the edges

- **3-km grid showing *v*-wind near-boundary wave at model layer 4, ~267 Pa**
- **About 1 ms^{-1} and with a 2Δx appearance**
- **The wave dissipates ~40 km into the domain**



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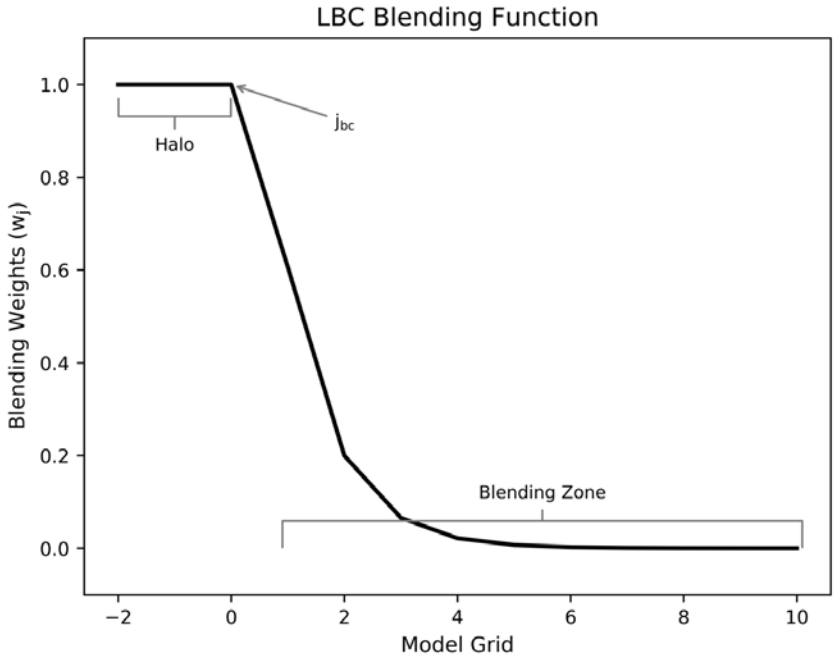
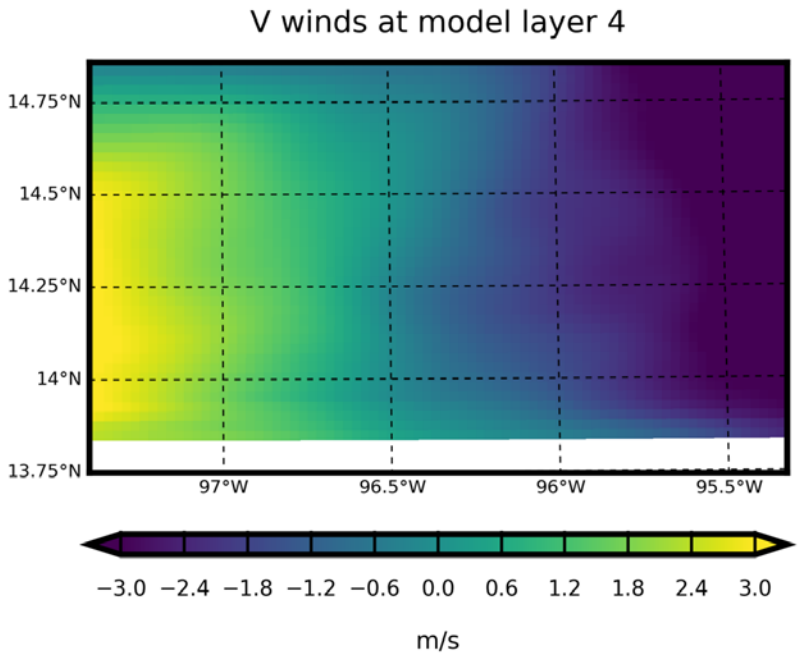




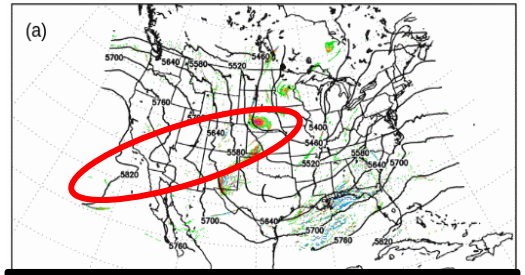
- Blending requires pre-processed LBCs to extend into the integration domain
- During the forecast, the prescribed LBCs and model integration values are blended to produce the final values for each timestep
- An exponential drop off of weights applied to the external values effectively removes the noise

DA and the Lateral Boundaries

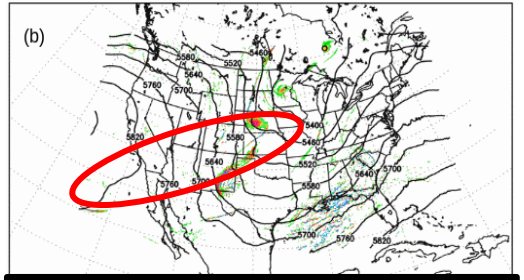
- Imbalance can arise from integrating a forecast following the data assimilation step IF the LBCs are not updated to be consistent with the new analysis state
- Address by extending the data assimilation step into the halo/LBCs

Model writes fields into restart files ***with the boundary***:

DA updates the entire domain ***including the boundary***:



NO LBC Update + DA

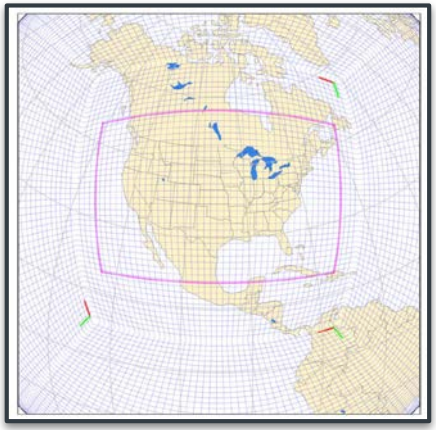


WITH LBC Update + DA

2-h forecast of 500-hPa geopotential heights

Closing

- The LAM is more efficient than the NEST
- The LAM shows some degradation at times > F24
  - Negative bias in temperature and height
  - Moving from 3-hr LBC updates to 1-hr may help
  - Test with LBC blending
  - Domain size
- LAM capability is in UFS SRW App
  - Release ~Nov. 2, 2020
- Will support multiple sources for ICs and LBCs
  - GFS, NAM, RAP, HRRR [GRIB2]



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