Toward a Coupled Modeling System to Improve Lake-Effect Prediction

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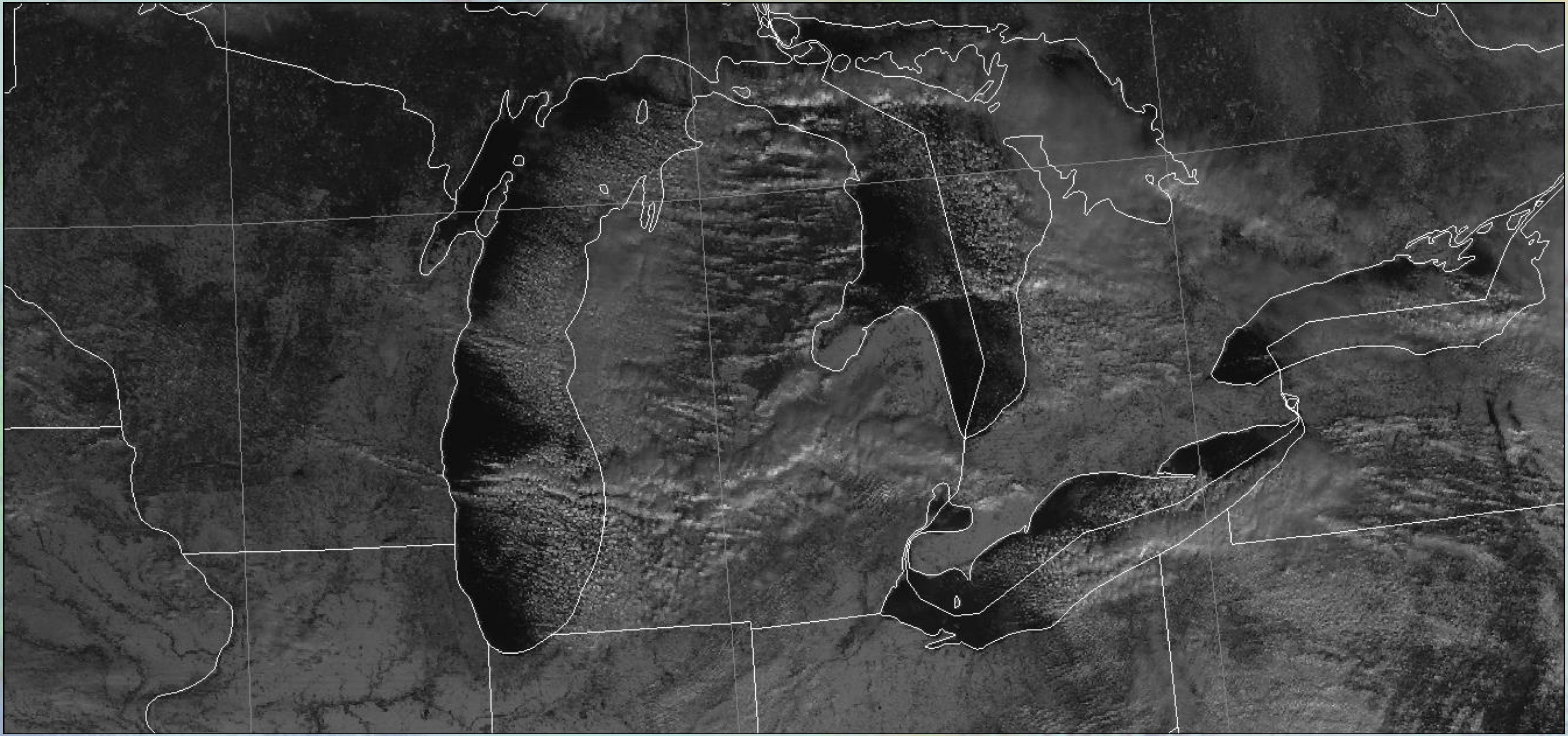
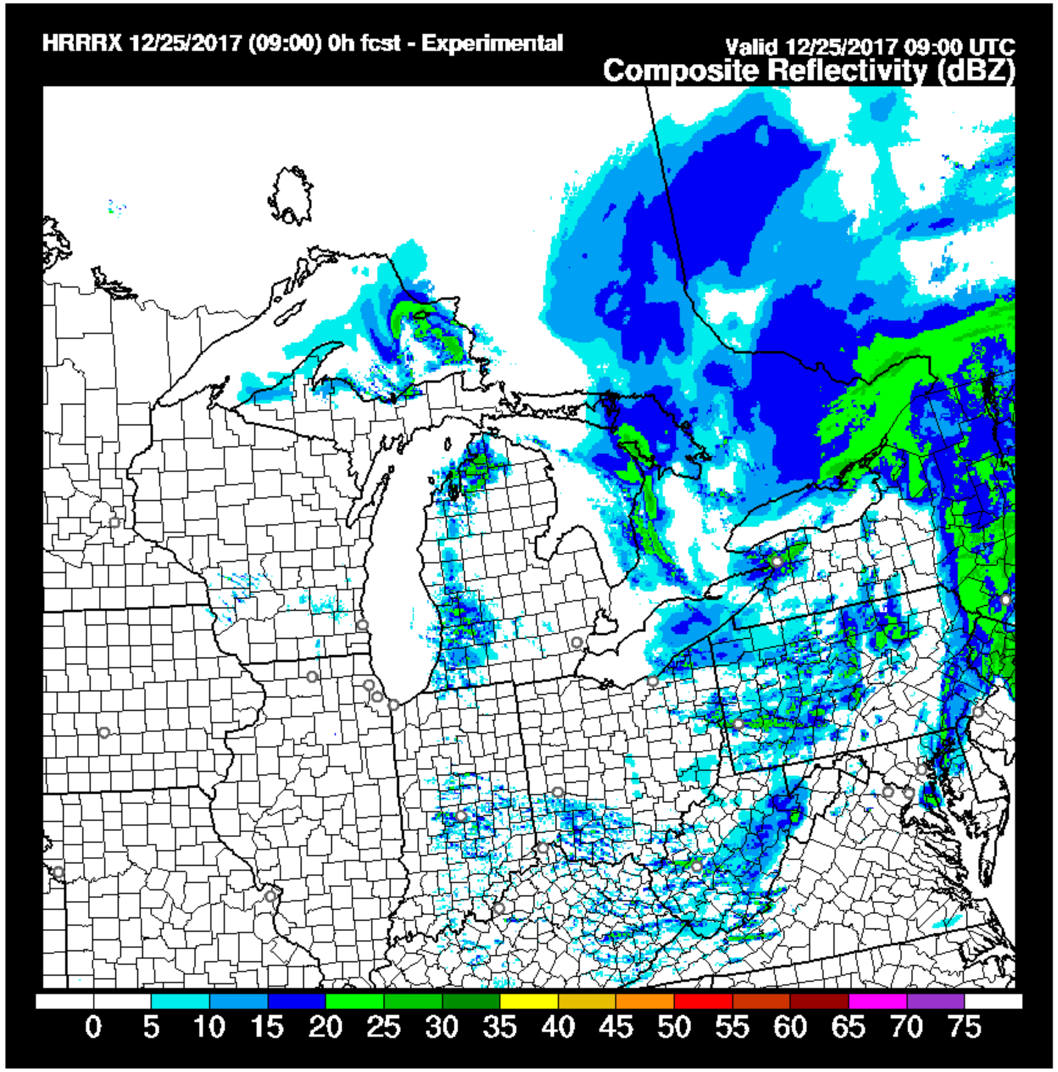
Inspiration from Above – GOES16 Band 2



Current State of Lake-Effect Forecasting

- General forecast can be based on prox
  bulk kinematics and thermodynamics
- Much greater Reliance on Convective
  Allowing Models – especially in first d
  forecast adjustments
  - HRRR (HRRR-TL, HRRRE)– ESRL/GSD
    - 3 km Δx – C grid (Effective resolution ~ 20
  - NAMnest – NCEP/EMC
    - 3 km Δx – B grid (Effective resolution ~ 30
  - HREF – NCEP/EMC
    - 4km Δx – mixed core (ARW/NMB)
  - HRDPS – CMC
    - 2.5 km Δx – C grid (Effective resolution ~ 1



HRRRv3

- High resolution subset of the Rapid Refresh Model (RAP) developed at NOAA/OAR/ESRL/GSD and run on WCOSS
- Hourly cycles with simulation lengths of 18 hours
  - Starting with HRRRv3 (June 2018) – 4 cycles to 36 hours (00z,06z,12z,18z)
- WRF v3.8.1+ – ARW dynamical Core
  - MYNN PBL (w/EDMF)
  - Thompson Aerosol-aware Microphysics
  - RUC LSM
  - no CU scheme (Grell-Freitas scale aware used in RAP)
  - Hybrid vertical coordinate

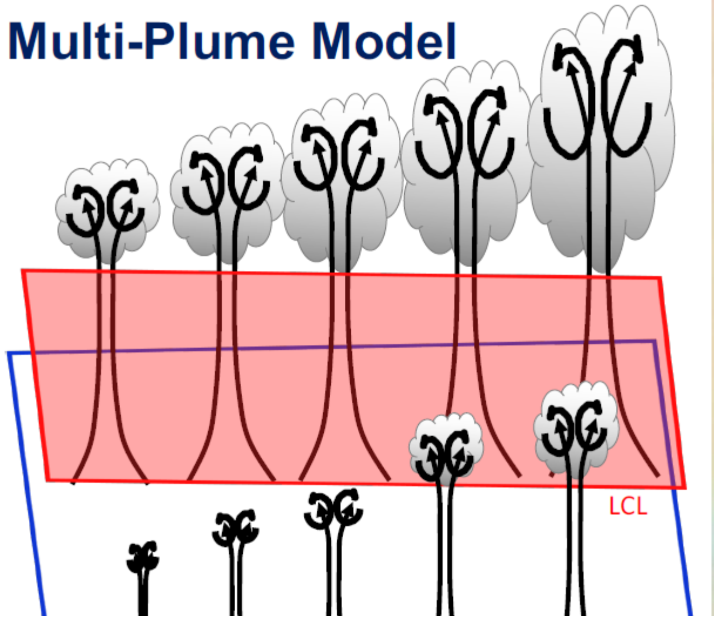
HRRRv3 MYNN

- EDMF – Eddy Diffusivity Mass Flux
- Mass Flux is governed by trackable coherent plumes within each grid cell
- Meant to provide greater coherency with grid scale hand off and interactions with other parameterizations (e.g. microphysics, cumulus, radiation)

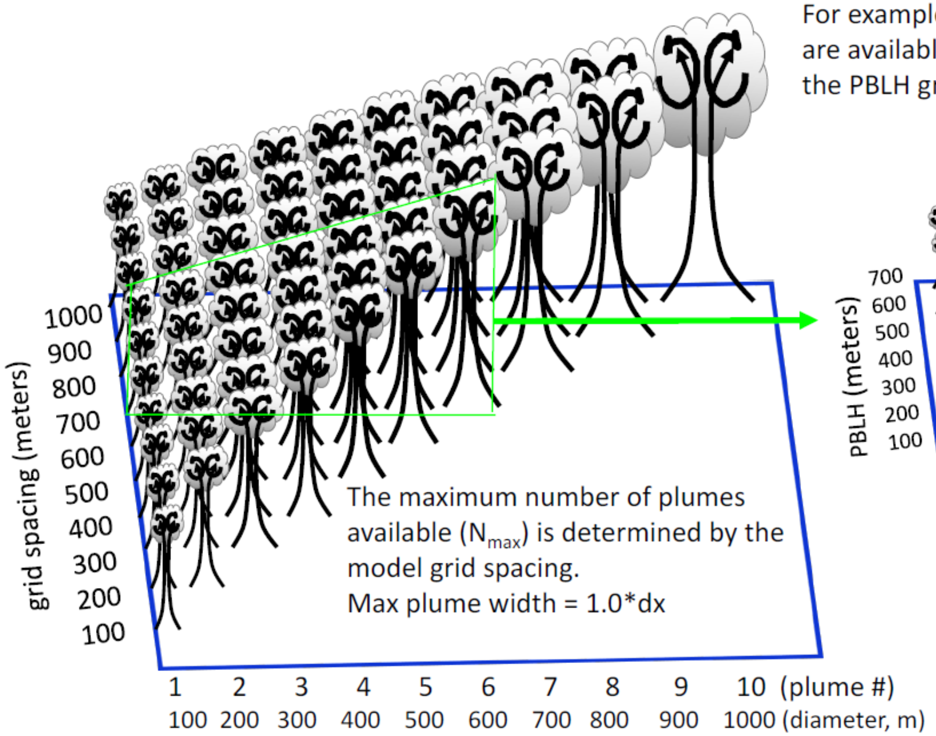
MYNN-EDMF: Dynamic Multi-Plume Model

An attempt to explicitly model plumes of various sizes that are likely to exist in a given atmospheric state, following **Neggers (2015, JAMES)** and **Suselj et al. (2013, JAS)**.

- Total maximum number of plumes possible in a single column: 10.
- Diameters (ℓ): 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 m.
- Lateral entrainment varies for each plume $\propto (w\ell)^{-1}$.
- Plumes condense only if they surpass the lifting condensation level (LCL).



Dynamic Multi-Plume (DMP)



The number of plumes (N) is further limited by the **PBLH.** For example, at dx = 700 meters, a maximum of 7 plumes are available, but the number od plumes used will grow as the PBLH grows:

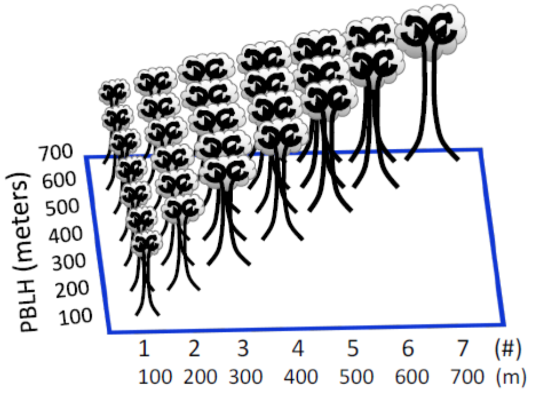


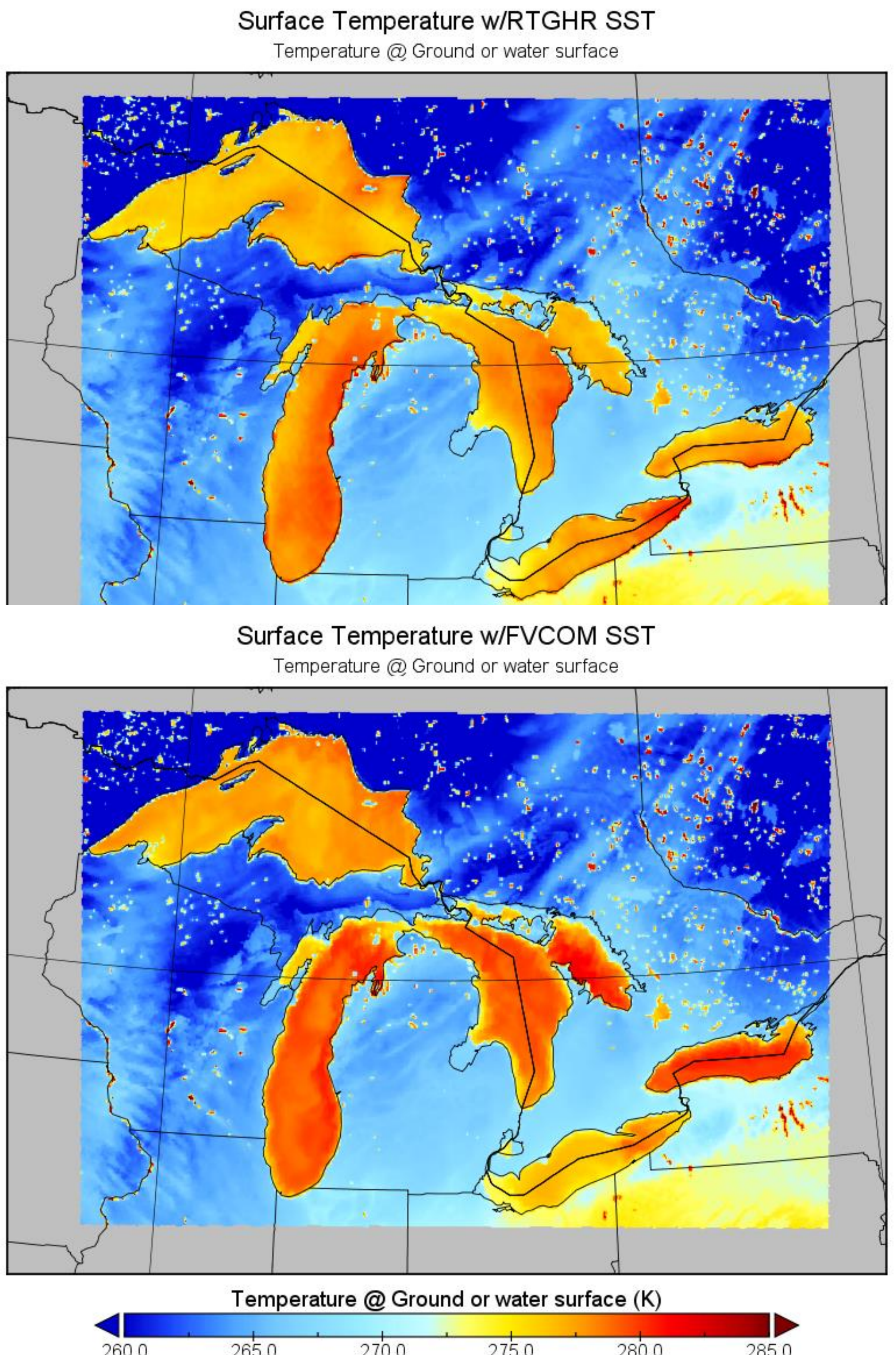
TABLE 2. The position of the scale break in the cloud size densities of the BOMEX, SCMS, and ARM case.

Case	Scale break size (m)
BOMEX	700
SCMS	1050
ARM 1500–1600 UTC	400
ARM 1600–1700 UTC	700
ARM 1700–1800 UTC	1000
ARM 1800–1900 UTC	1100
ARM 1900–2000 UTC	1250

Taken from Neggers et al. 2003, JAS

Opportunities for Improvement

- Operational modeling system resolution increases are not expected
    - HR ensembles are emerging
- Given prediction of lake-effect is sensitive to lower boundary prescription, improvements can be made in the quality of SST data.
- Observed SST datasets are based upon satellite retrievals.
    - Data quality depends upon clear sky views, which are very limited during lake-effect season.
    - SST data can become unrepresentative and may not contain spatio-temporal integrity due to varying age of quality retrievals.
- Dynamically produced SST data provides physically consistent SST distribution.
    - Lake-effect bands are commonly governed by differential stability gradients governed by the spatial variability of SST.

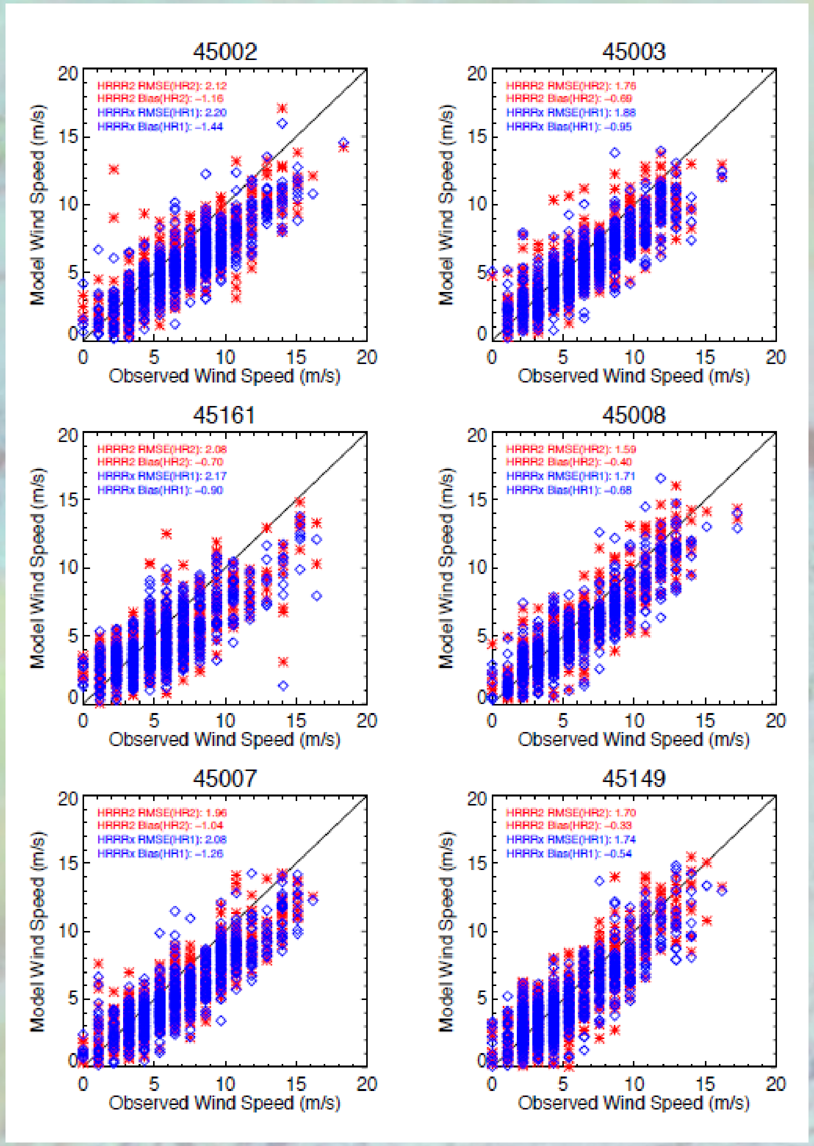


NOAA Collaborative Project

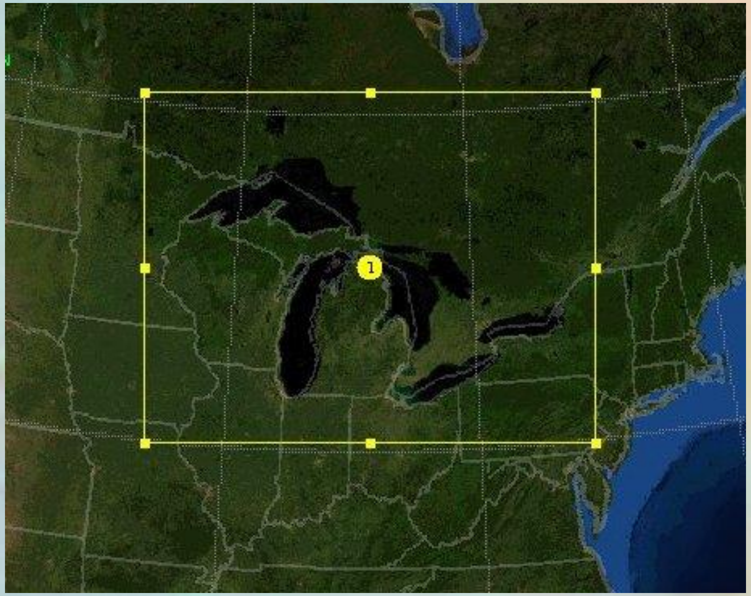
- Improving Lake-Effect Snow and Ice Forecasts
  - Funded via the Office of Water and Air Quality
- Principle Investigators
  - NOAA/OAR/GLERL & CIGLR
    - Philip Chu, Eric Anderson, Ayumi Fujisaki-Manome
  - NOAA/OAR/ESRL/GSD
    - Stan Benjamin
  - NOAA/NWS DTX
    - Greg Mann
- Contributing Scientists
  - Lindsey Fitzpatrick, CIGLR
  - Curtis Alexander and Joe Olson, ESRL/GSD
  - Kyle Klein, UM/CLASP

HRRR - Near Surface Wind Treatment

- Low wind bias over water evident in HRRRv2
- Initial tests for developmental HRRRv3 used and early introduction of COARE3.5 into WRF with detrimental results – so reverted to COARE3 with a couple of small modifications
  - COARE3.5 currently being reconfigured for use within MYNN PBL code for HRRRv4 testing
- Identified a mismatch in the post production of the 10 m wind from the native hybrid vertical grid which improved results – but a slight negative bias remains



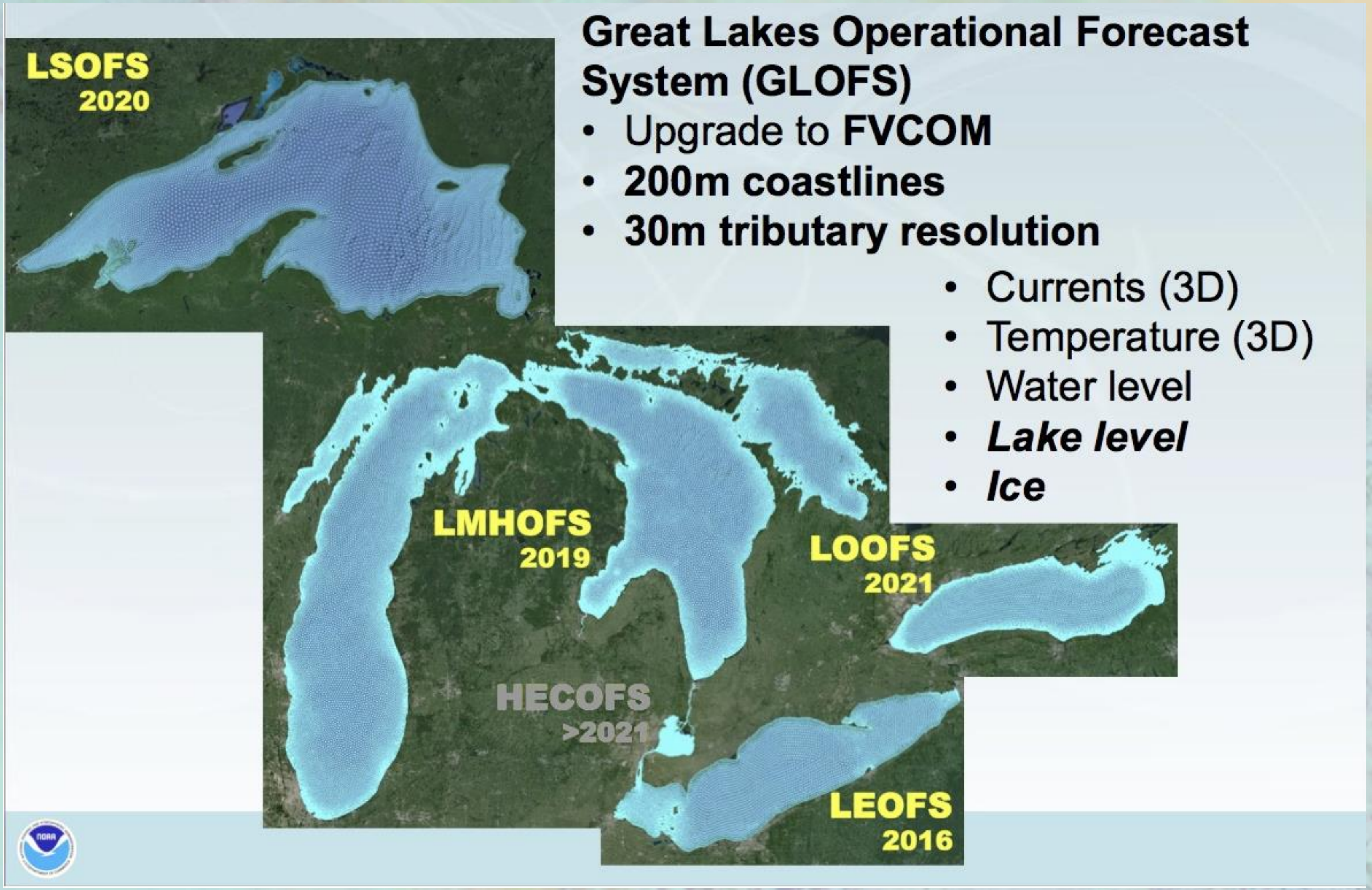
HRRR-like Experiments



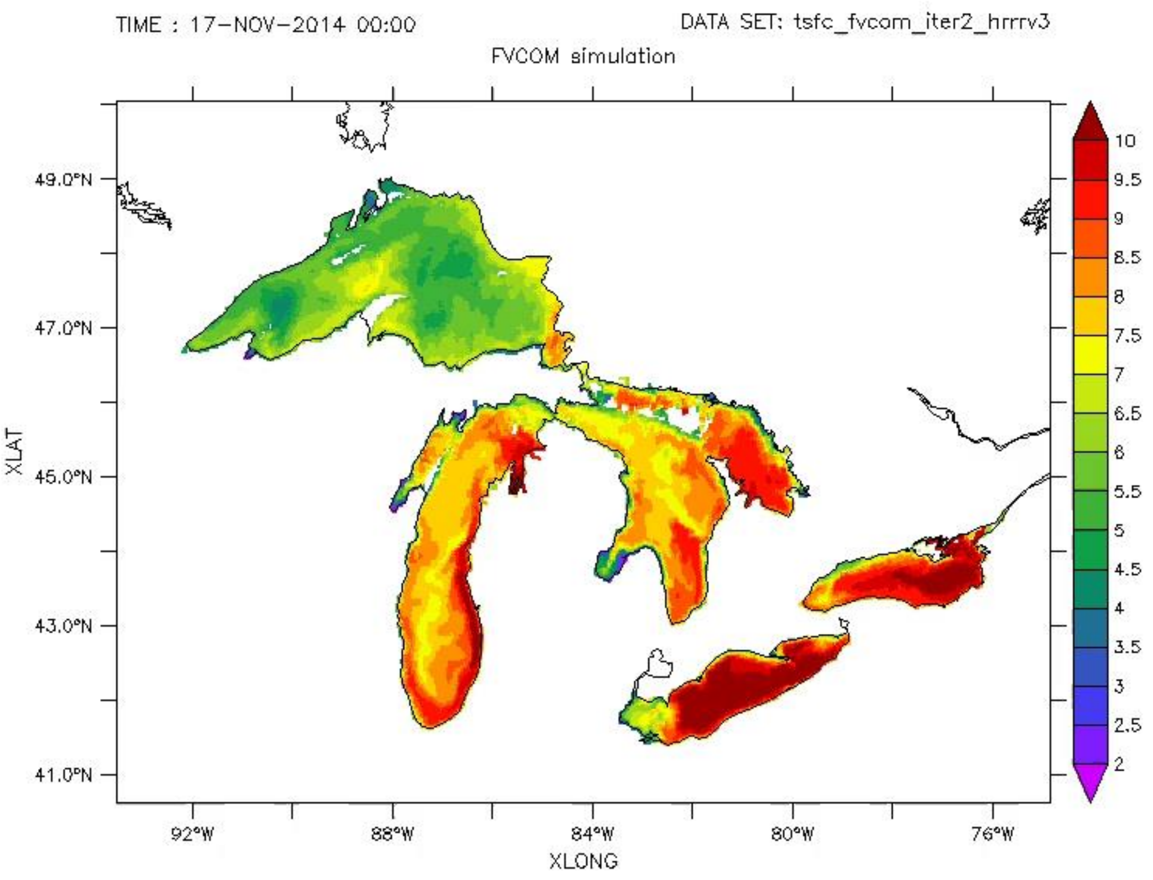
- Mimic HRRR configuration on a regional domain
    - Test HRRRv2 and HRRRv3 physics
    - Test and Evaluate developmental HRRRv4 physics
- IC/BC RAP native hourly analyses
- Surface Boundary Condition
    - RTG High Resolution SST (1/12 degree) - Control
    - Great Lakes Hydrodynamic model output FVCOM
        - Static SST and Ice Coverage from hour 0
        - Dynamic SST and Ice Coverage forced by HRRR-like simulations
            - Iterative Loose Coupling via surface boundary conditions

FVCOM – Hydrodynamic Model

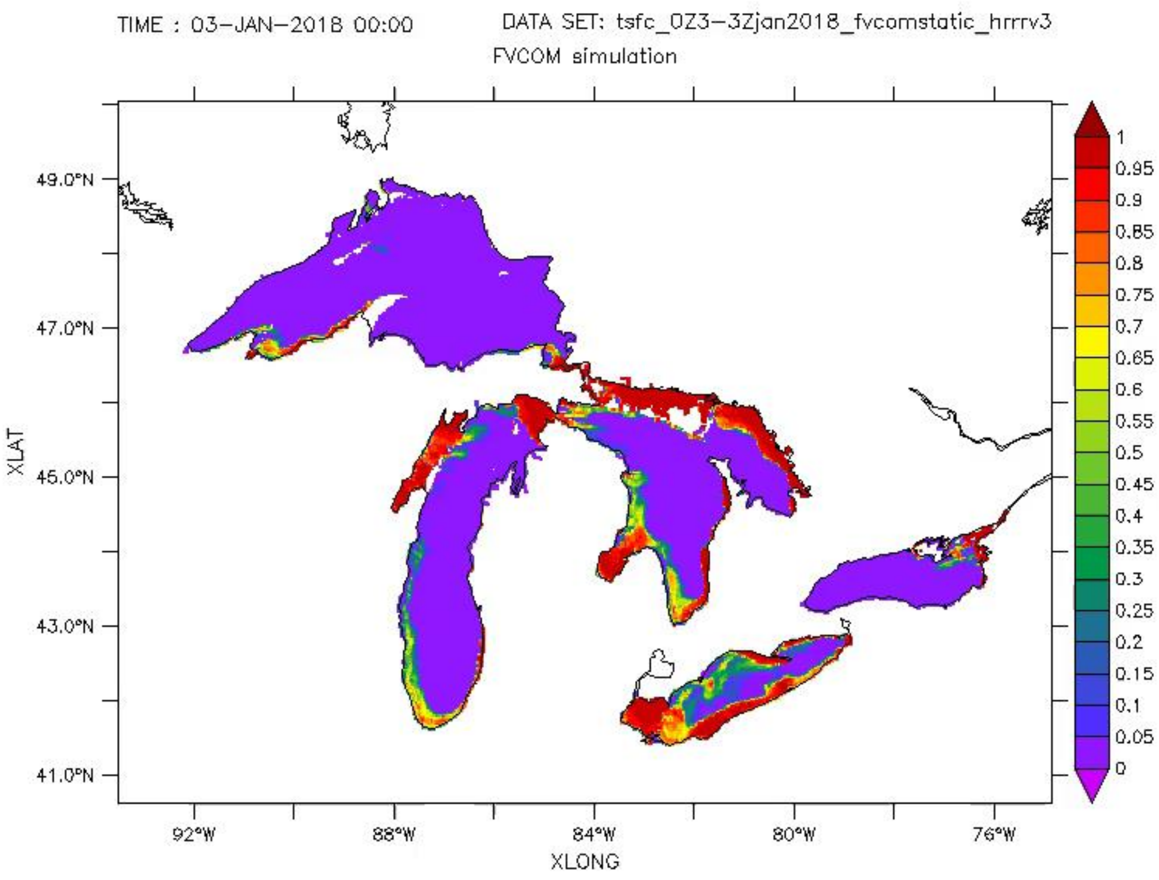
- Finite Volume
- Triangular Irregular Grid
- Development and testing at GLERL
- Operational transition to WCOSS by NOAA/NOS/CSDL



FVCOM Examples



FVCOM simulated skin temperature, 17–19 Nov 2014

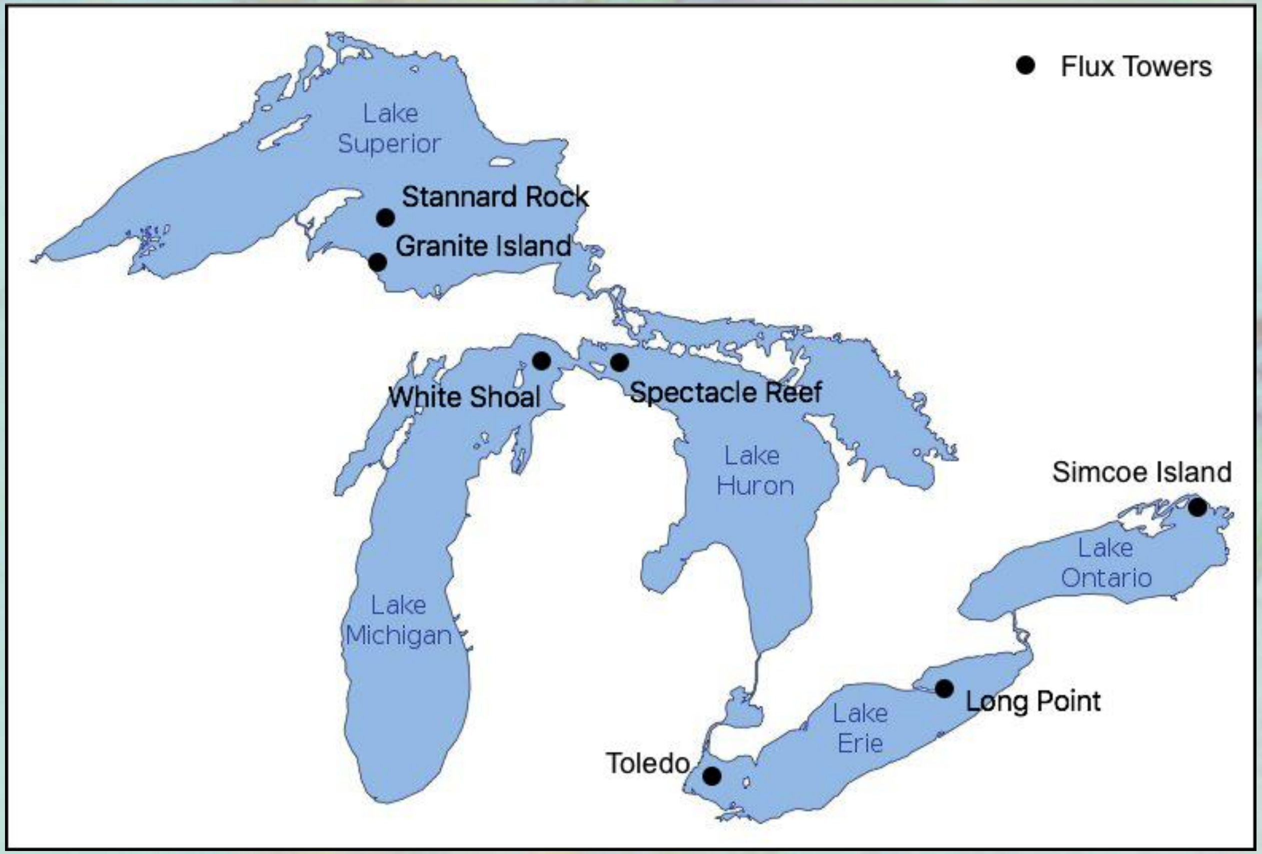


FVCOM simulated ice concentration, 3–6 Jan 2018

Evaluating Heat Flux

Great Lakes Evaporation Network (GLEN)

White Shoal Lighthouse
(Credit: Dick Moehl)

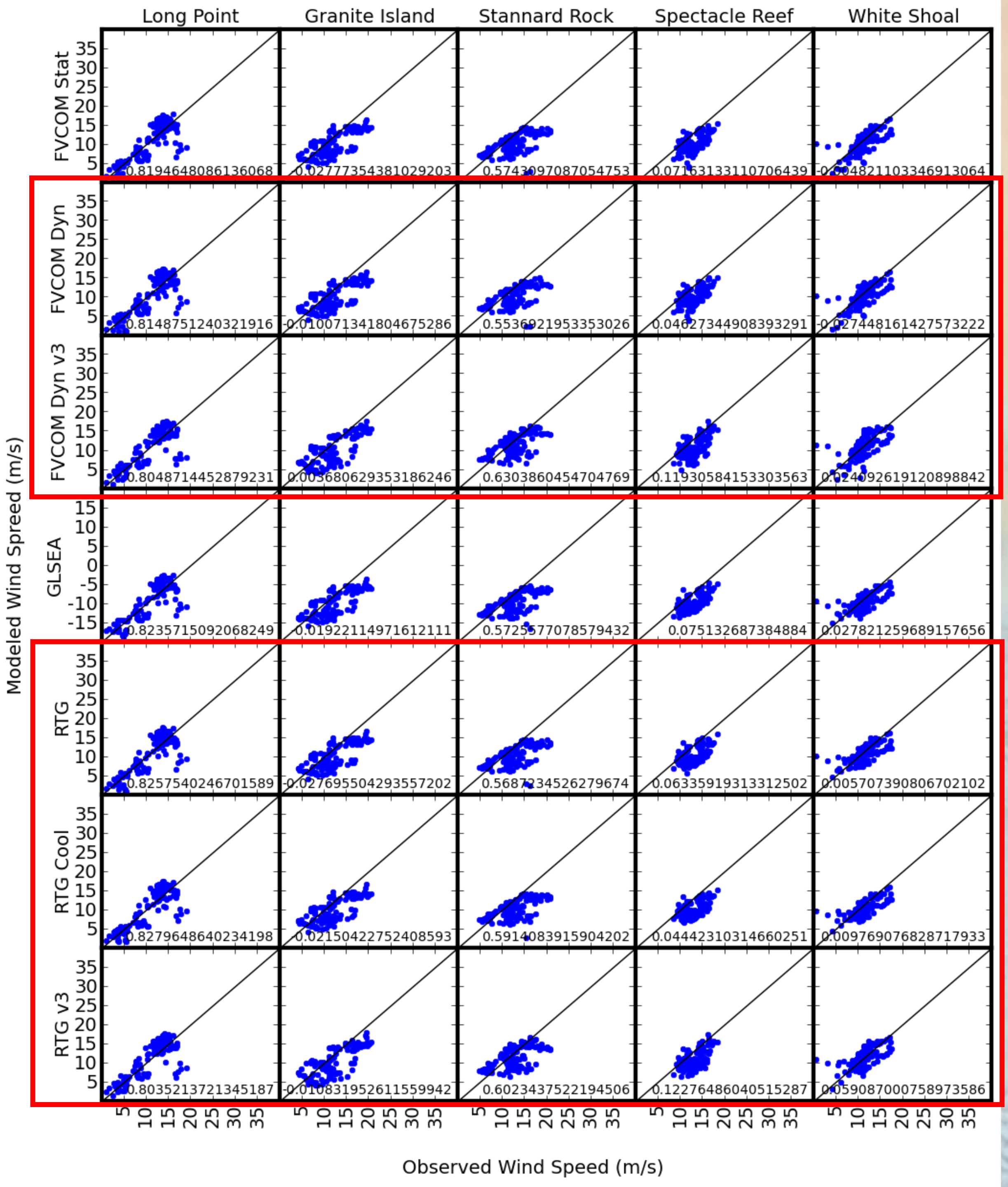


Credit: Lindsay Fitzpatrick(CIGLR) adapted from the GLEN website

Sonic anemometer and gas analyzer at Toledo site (Credit: L. Fitzpatrick)

HRRR physics test

- Test using HRRRv2 and new HRRRv3 physics code and configuration
- Results from November 2014 Lake-Effect event shown
  - In addition to conventional data, flux tower measurements are also used to assess quality
- Experiments using several different SST sources for surface boundary conditions
- Slight improvements in Wind Speed using HRRRv3 package



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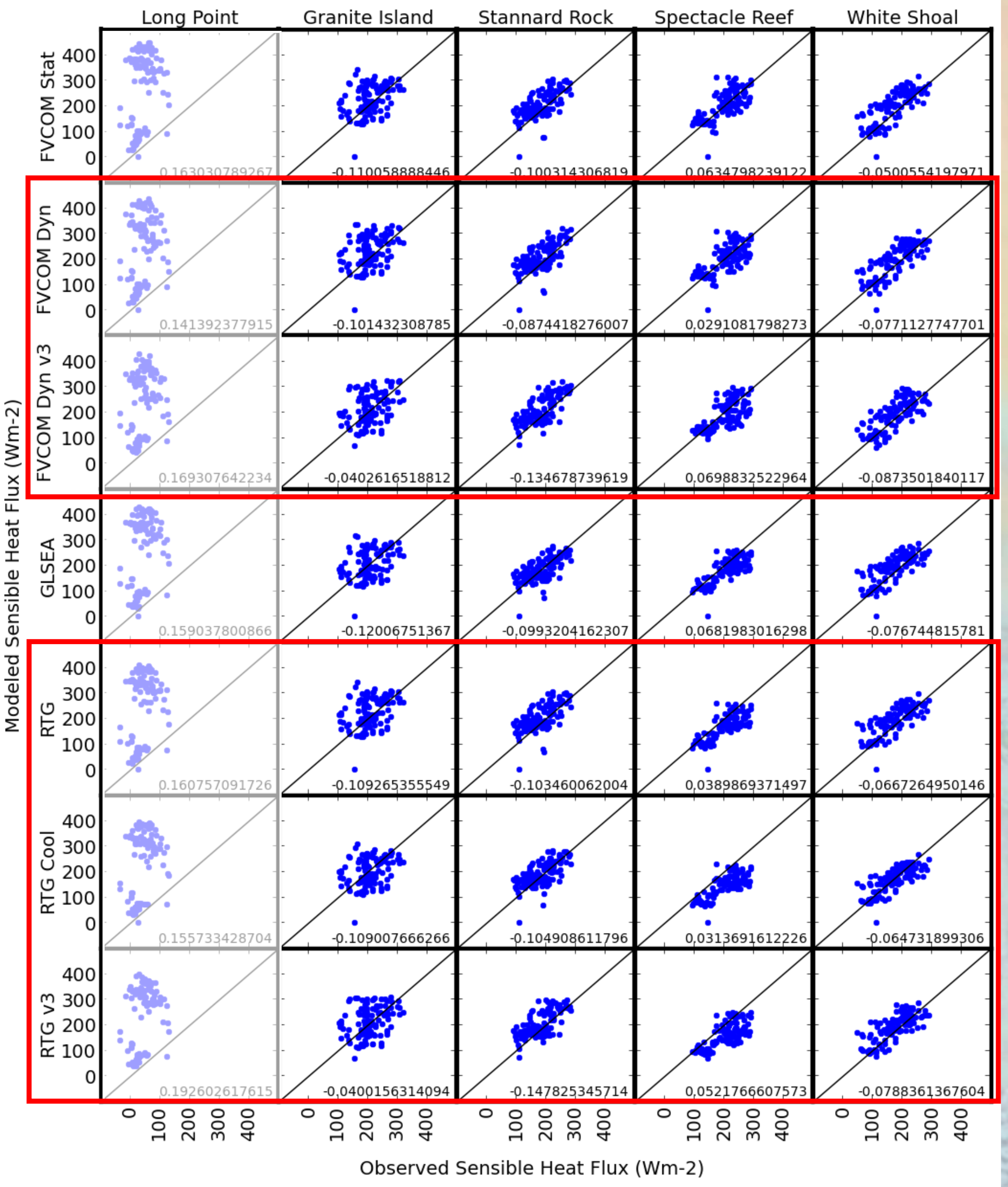
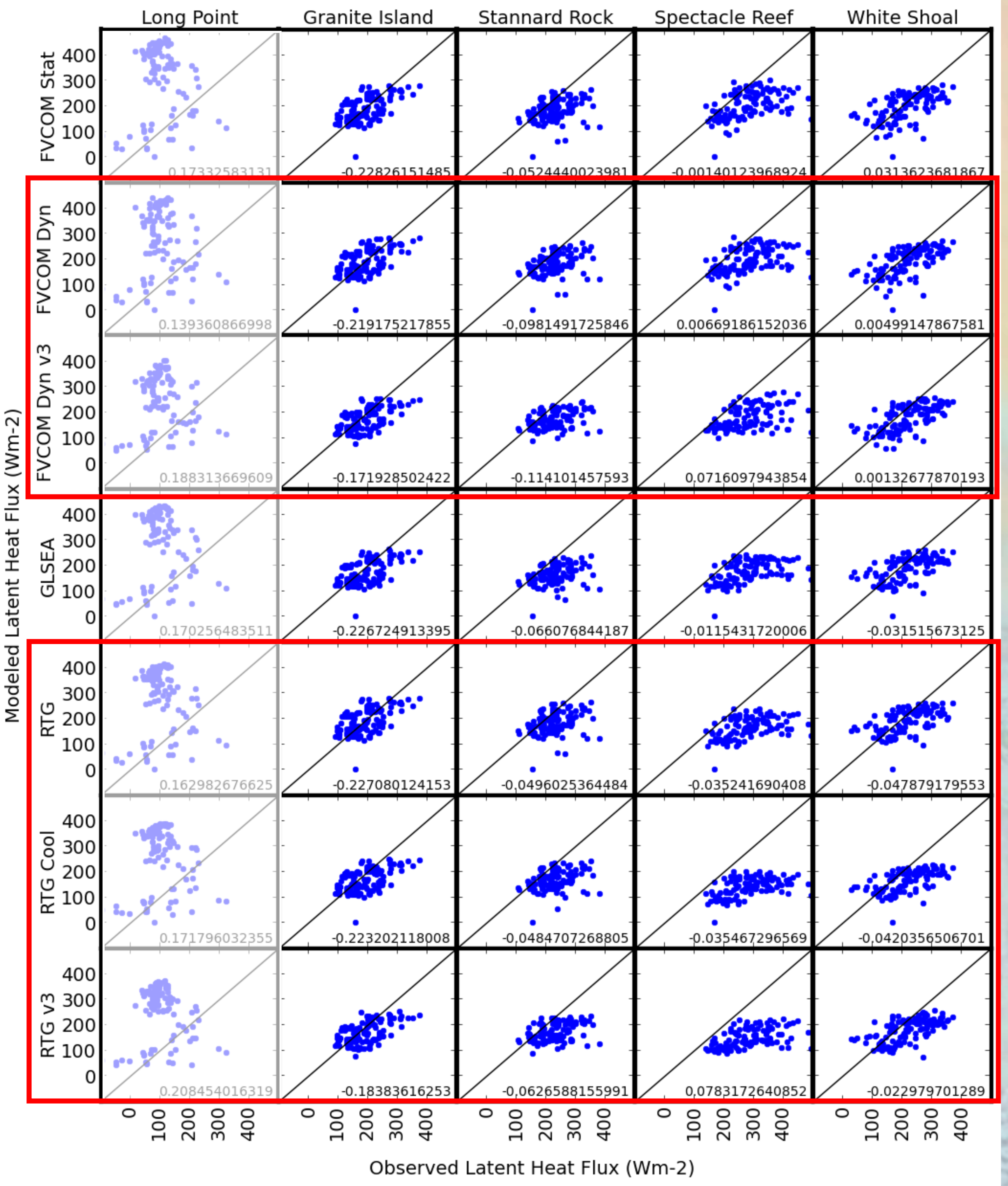


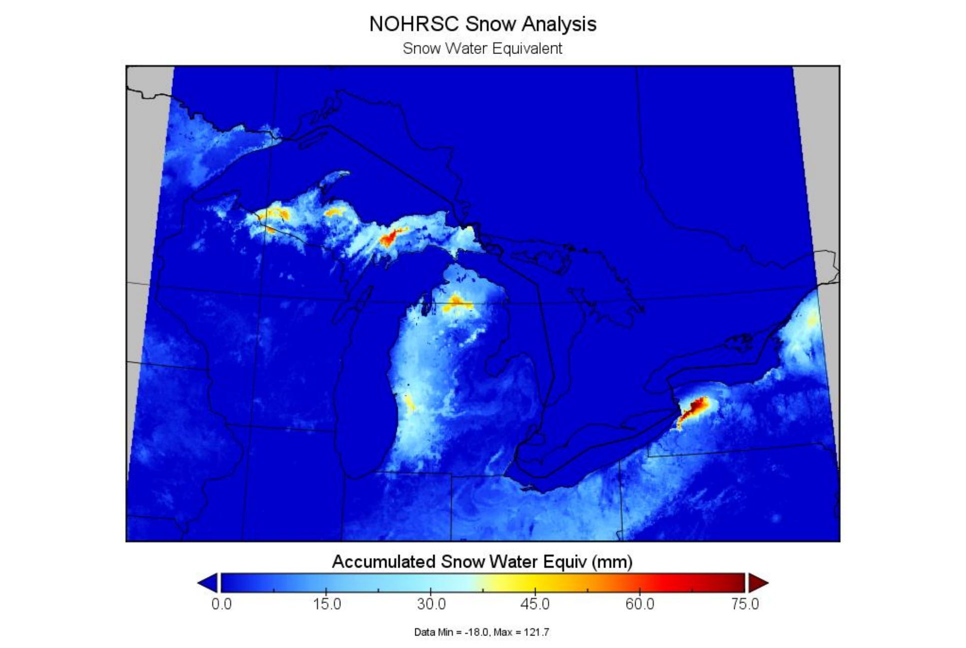
HRRR physics test

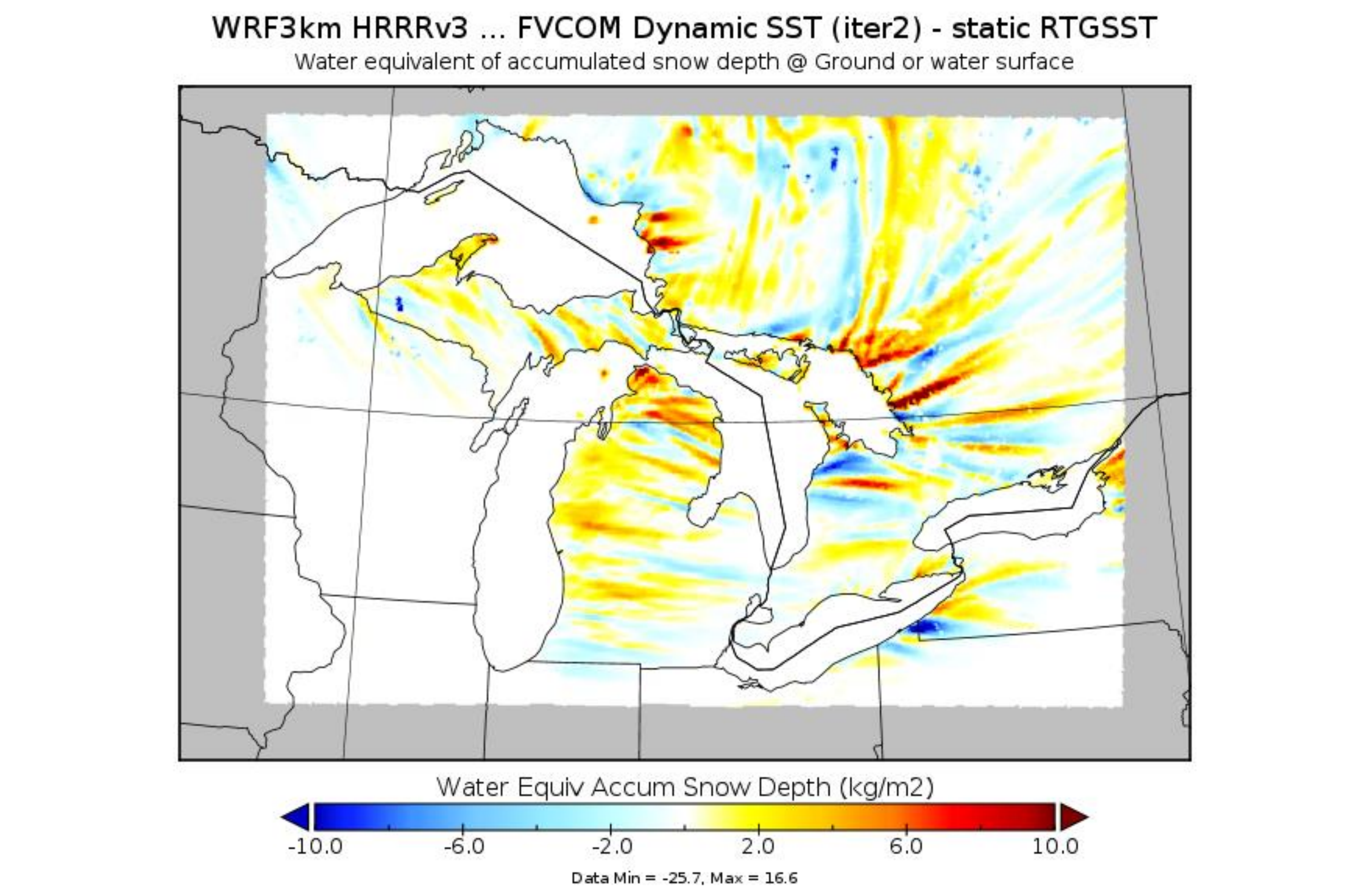
- Test using HRRRv2 and new HRRRv3 physics code and configuration
- Results from November 2014 Lake-Effect event shown
  - In addition to conventional data, flux tower measurements are also used to assess quality
- Experiments using several different SST sources for surface boundary conditions
- Still problems with Latent Heat Flux
  - Potential key finding – could be source of observed reduced precipitation coverage
  - Evaluating extended event from Dec 2016 to tease out the systematics



WRF3km – "Coupled" vs Control Static SST

- Significant alteration to snowfall distribution with improvements in the right locations

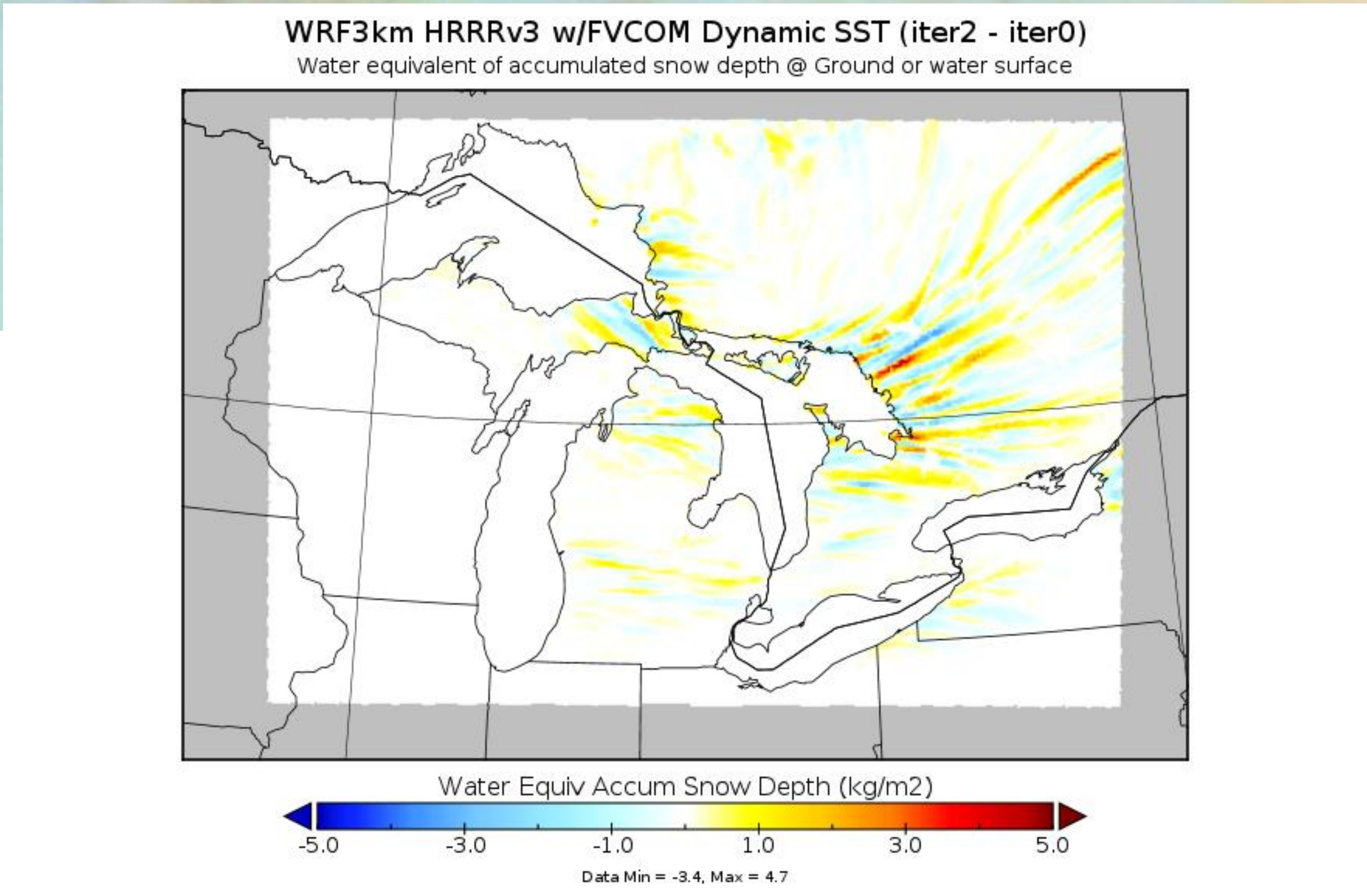


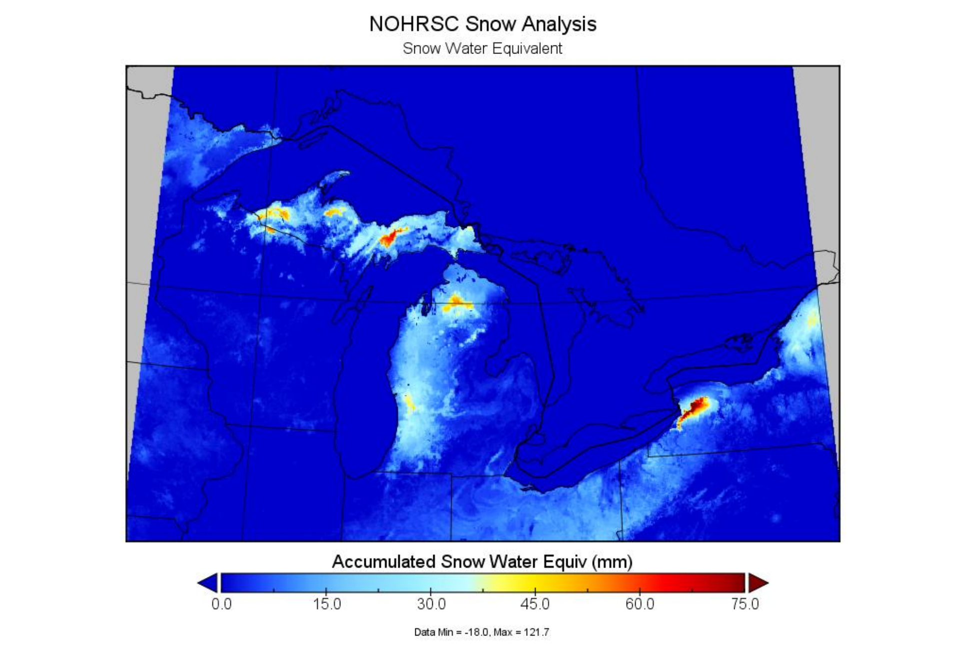


2014 Nov 17-19

WRF3km “Coupled” Solution Convergence

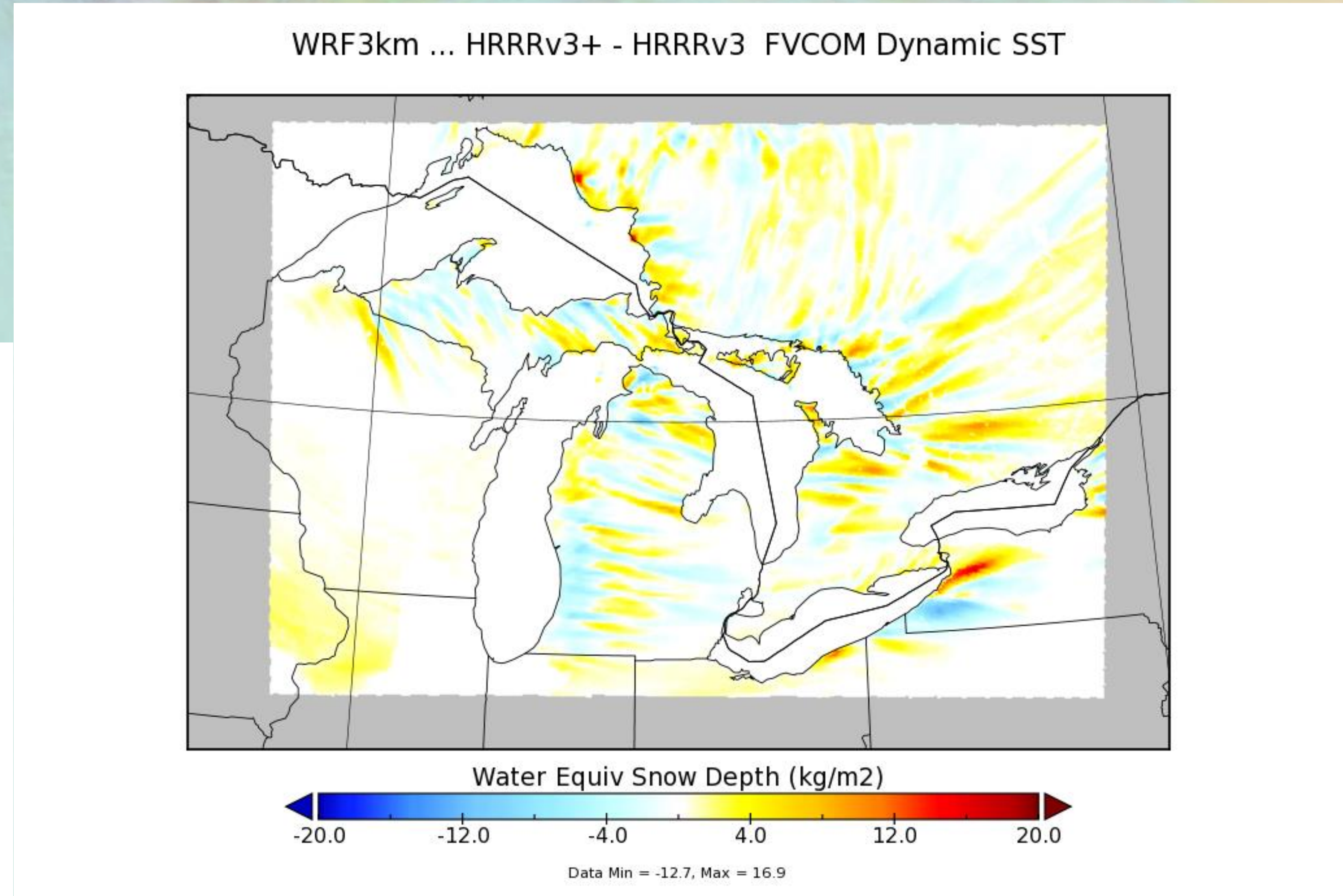
- Minor adjustments in regions where greatest changes to SST spatial distribution

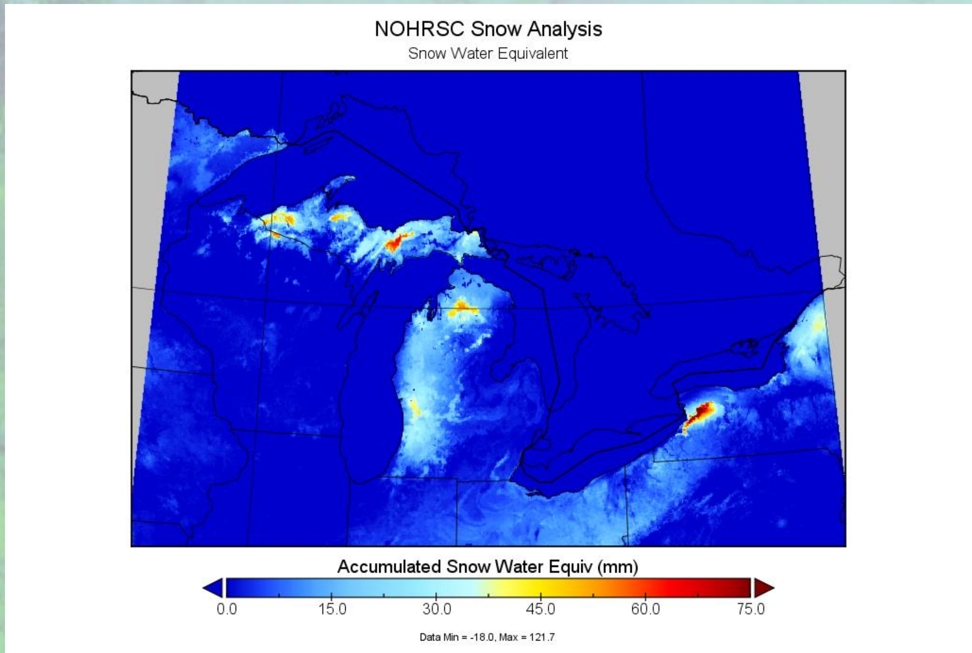




Influence of Updated Physics -> HRRRv3+

- Further significant improvement to snowfall distribution



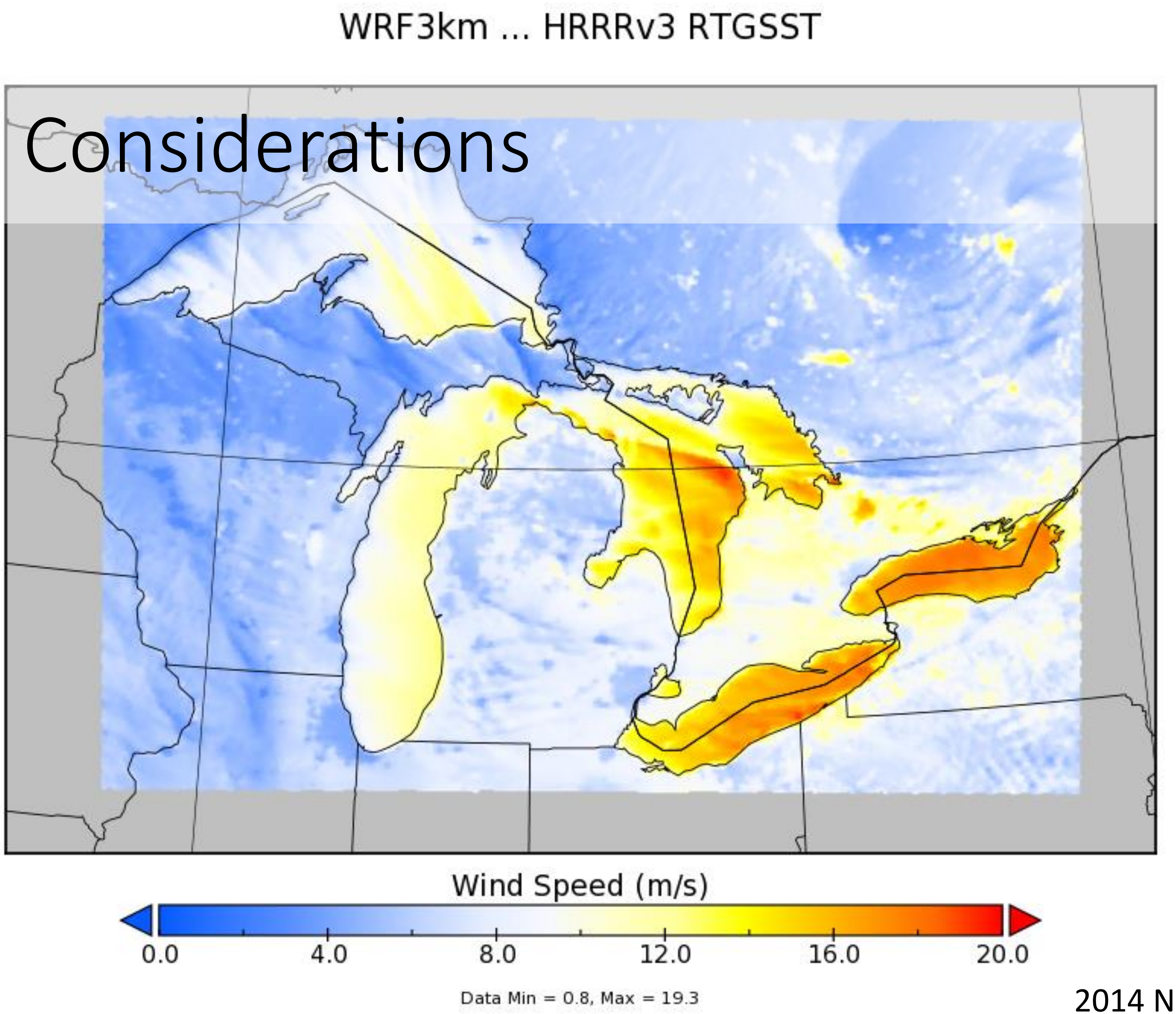


2014 Nov 17-19

Resolution Considerations

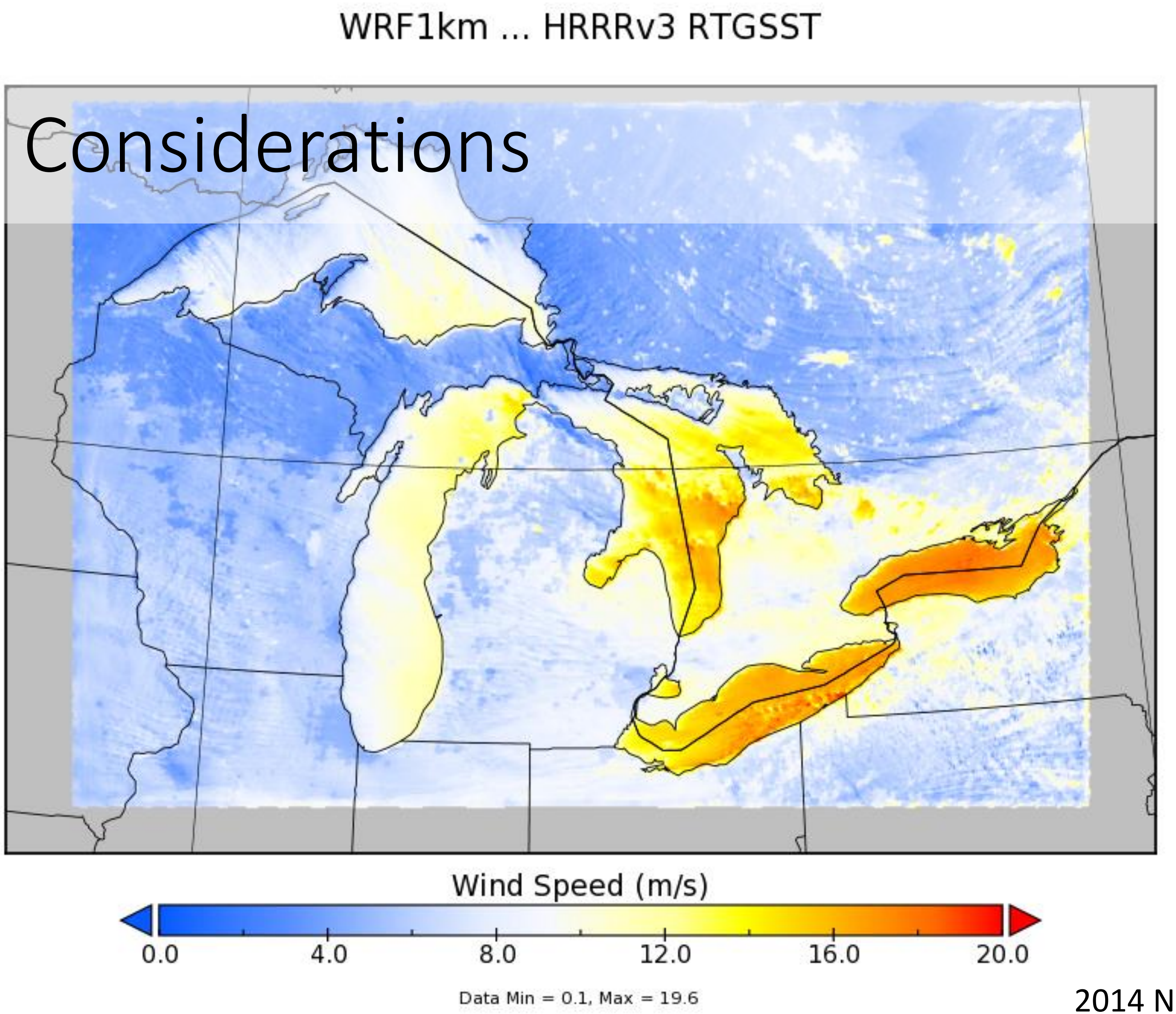
- Scales of motion are coupled in space and time and need to be considered
- NWP spatial resolution is at a practical minimum 7 delta grid spacing with an intrinsic time scale (Orlanski 1975)
  - 12 km grid -> 80+ km feature
    - 3+ hour time evolution
  - 3 km grid -> 20+ km feature
    - 1+ hour evolution
  - 1 km grid -> 7+ km feature
    - 10+ minute evolution

Resolution Considerations



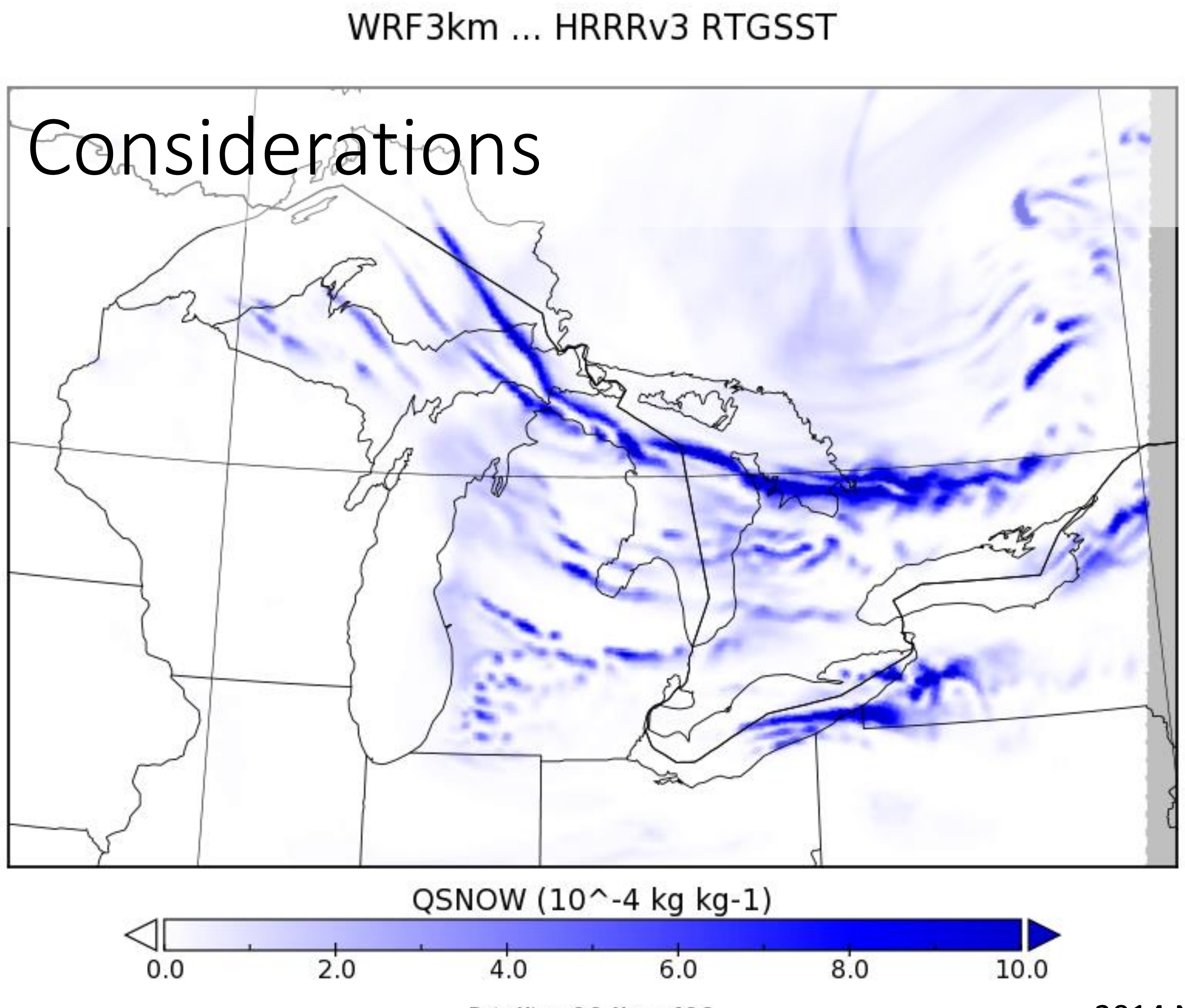
2014 Nov 18 20z

Resolution Considerations



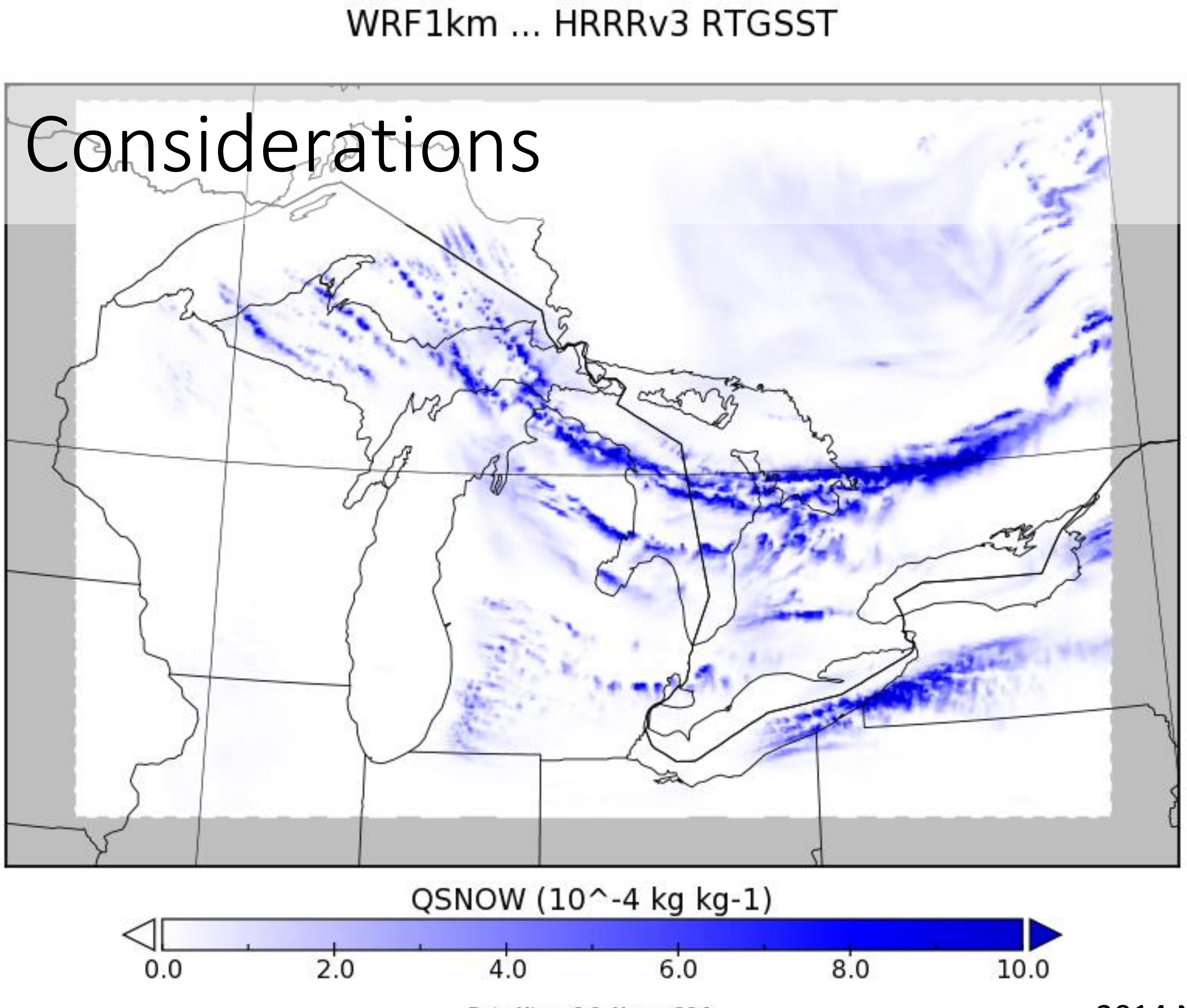
2014 Nov 18 20z

Resolution Considerations



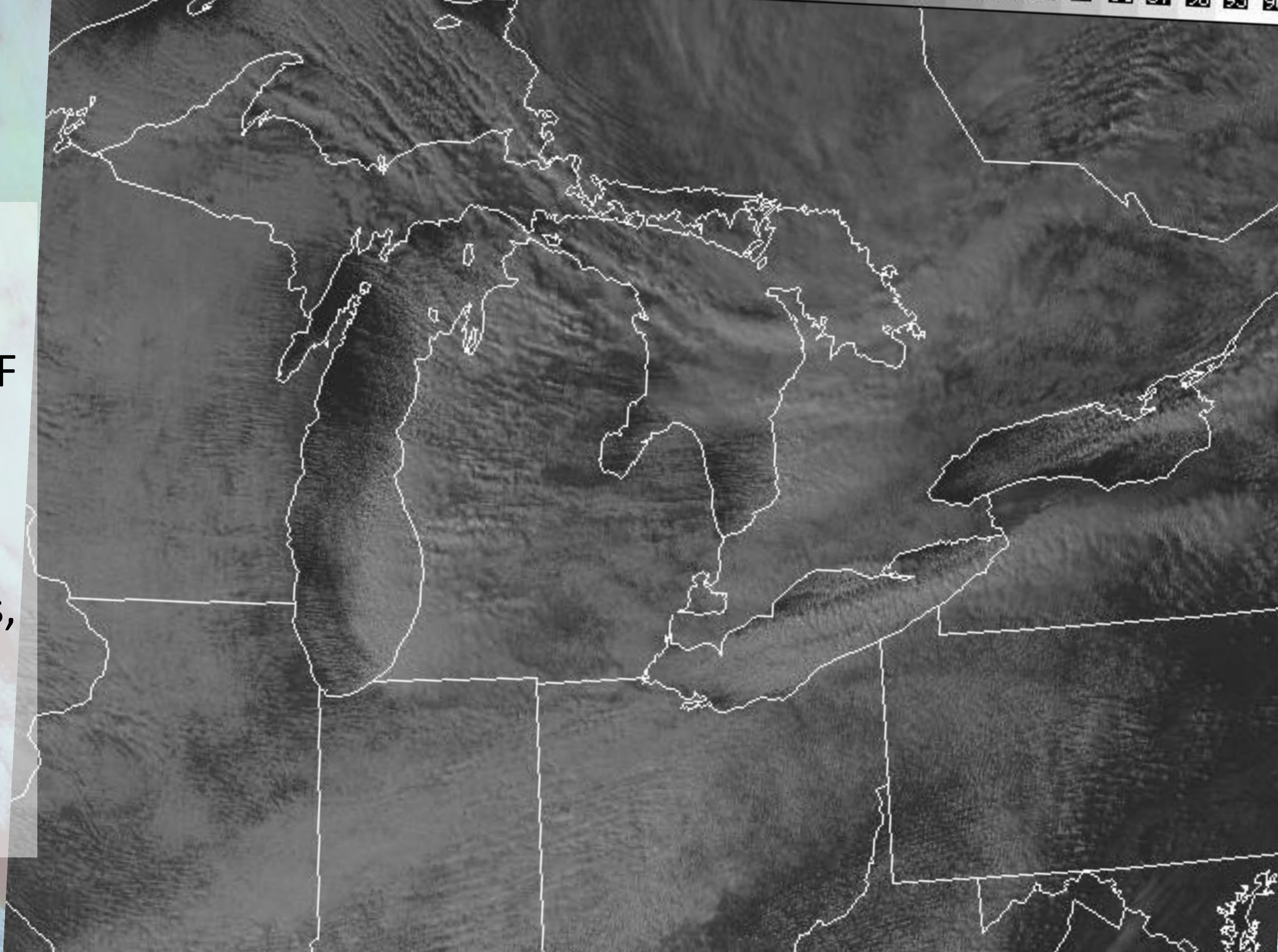
2014 Nov 18 20z

Resolution Considerations



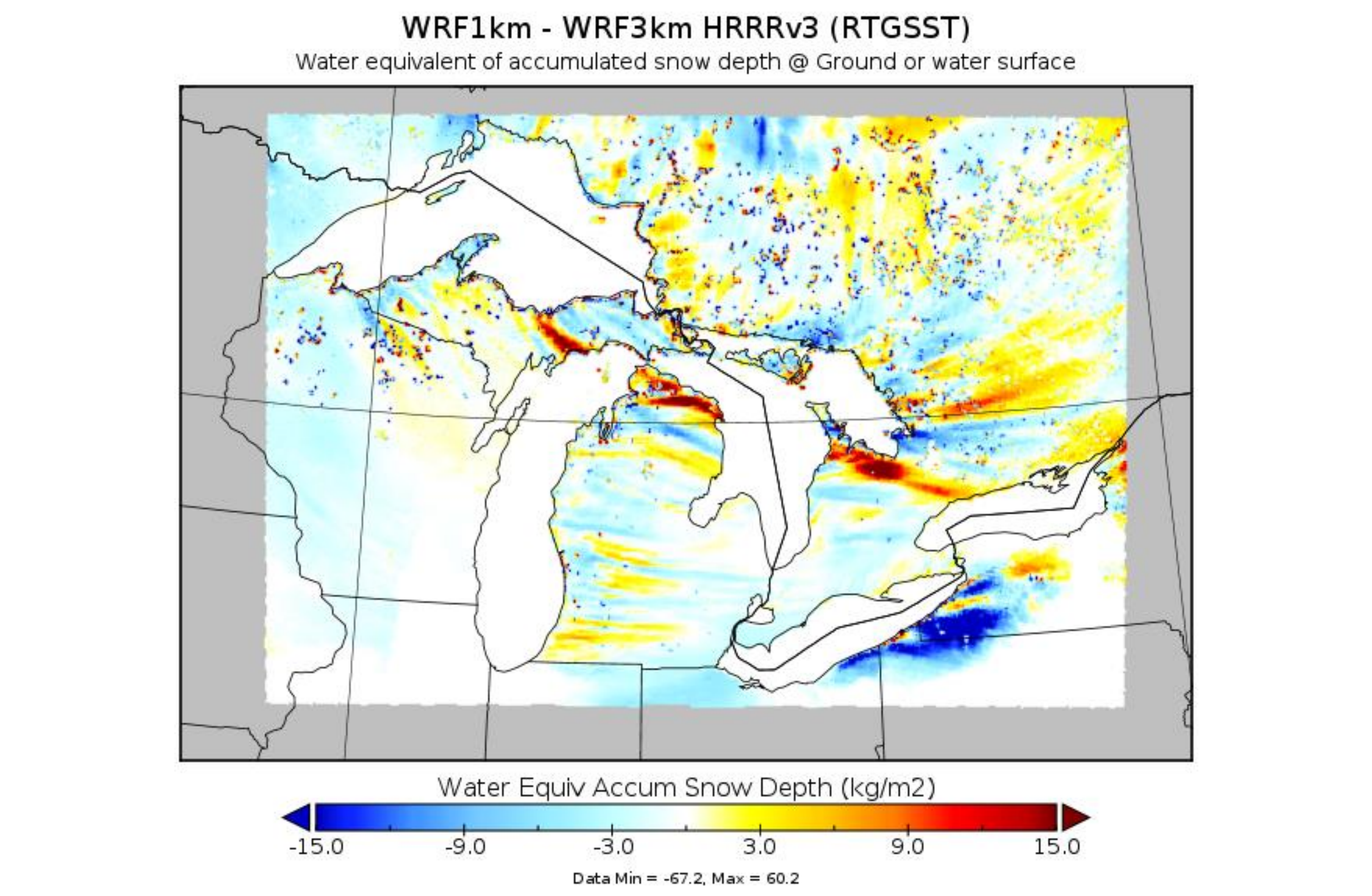
2014 Nov 18 20z

Under most circumstances, native HRRR, NAMnest, and HREF resolutions are insufficient in representing LES band structures, lake scale dynamics, and the net character of the lake aggregate disturbance



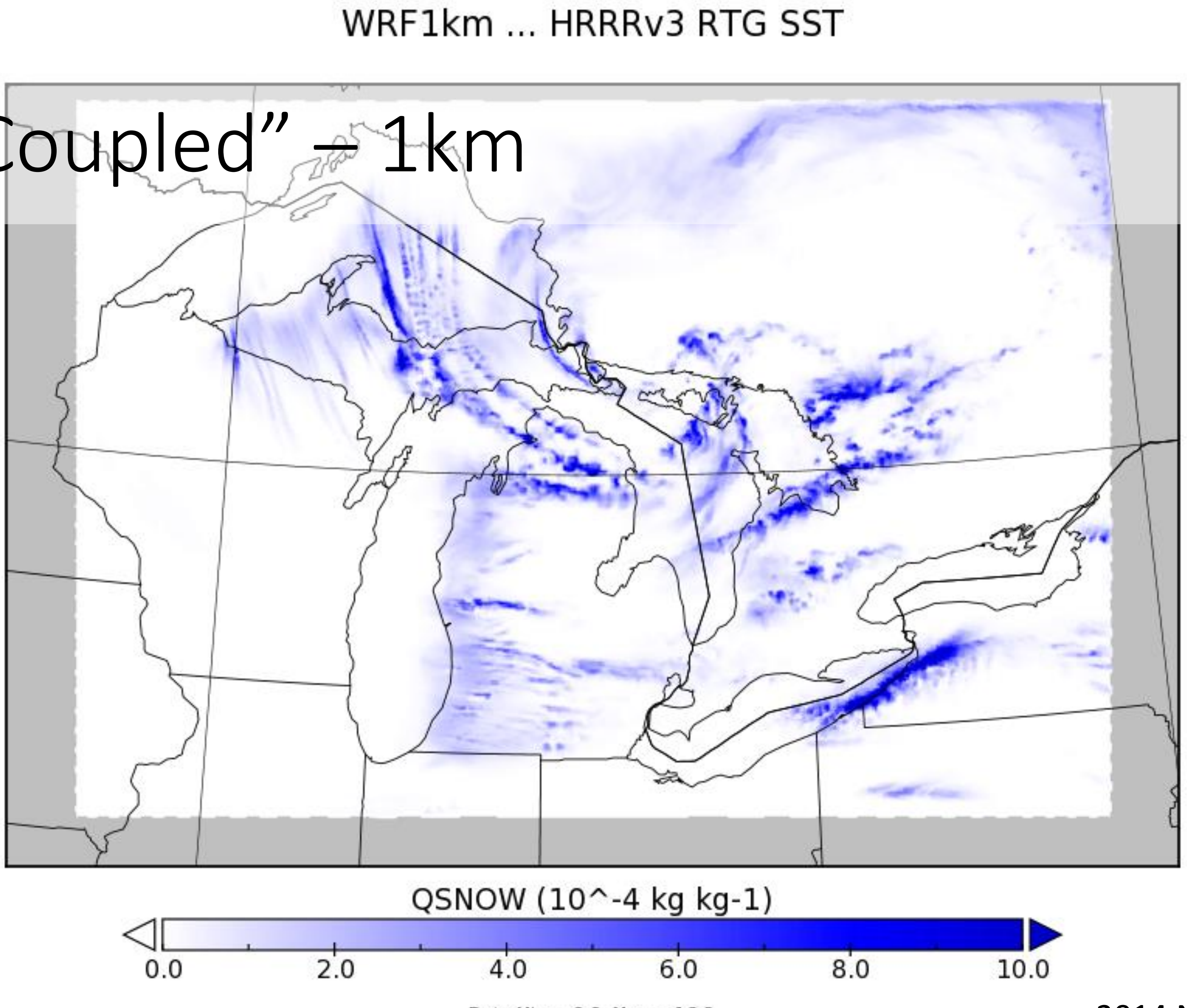
Resolution Impact

- Substantial differences in spatial distribution simply due to changes in resolution
- Meaningful shift of the main convective band structure into Buffalo
- Additional 1km test using HRRRv3+ physics with FVCOM dynamic SST is ongoing



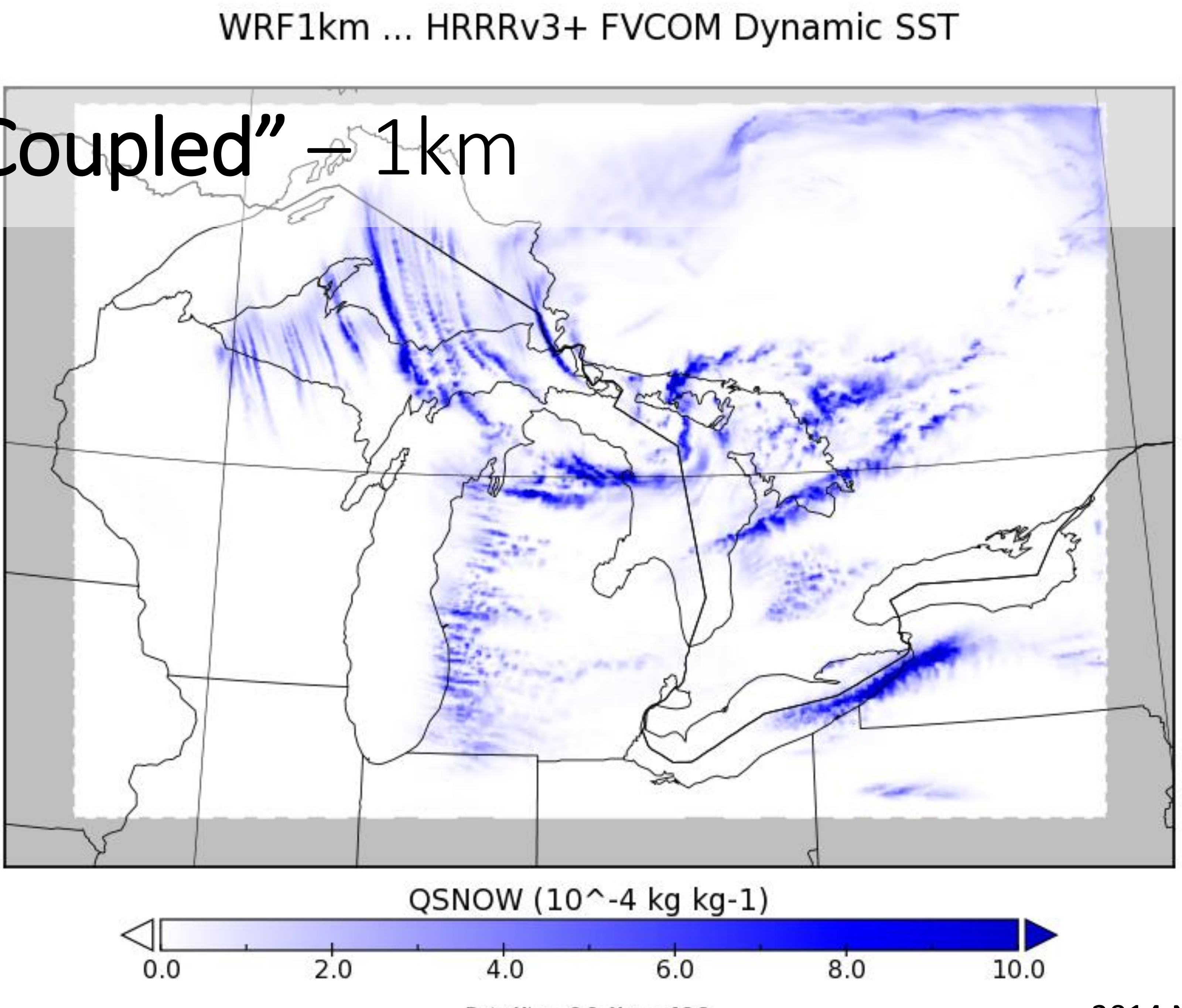
2014 Nov 17-19

Static vs "Coupled" – 1km



2014 Nov 18 08z

Static vs "Coupled" – 1km



2014 Nov 18 08z

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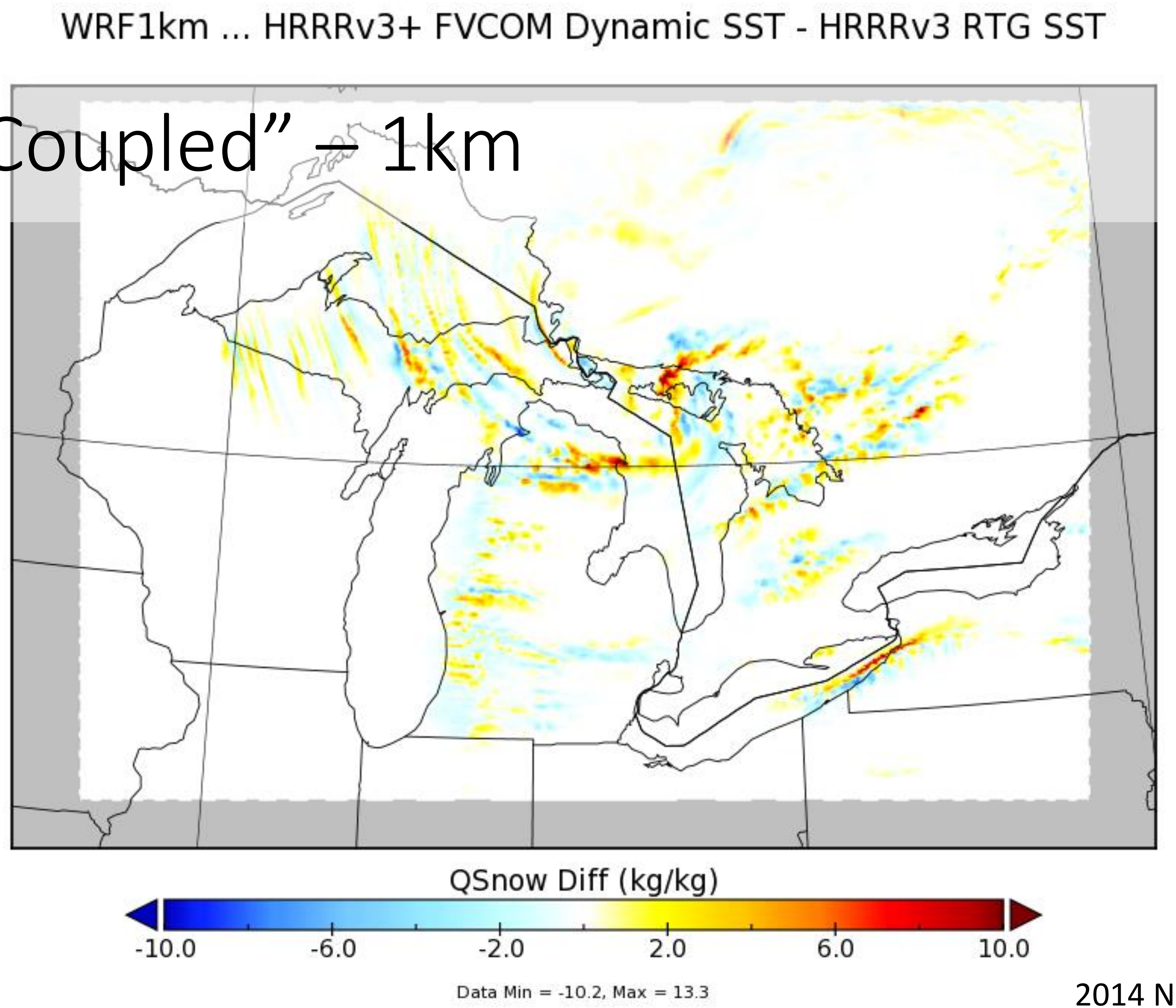
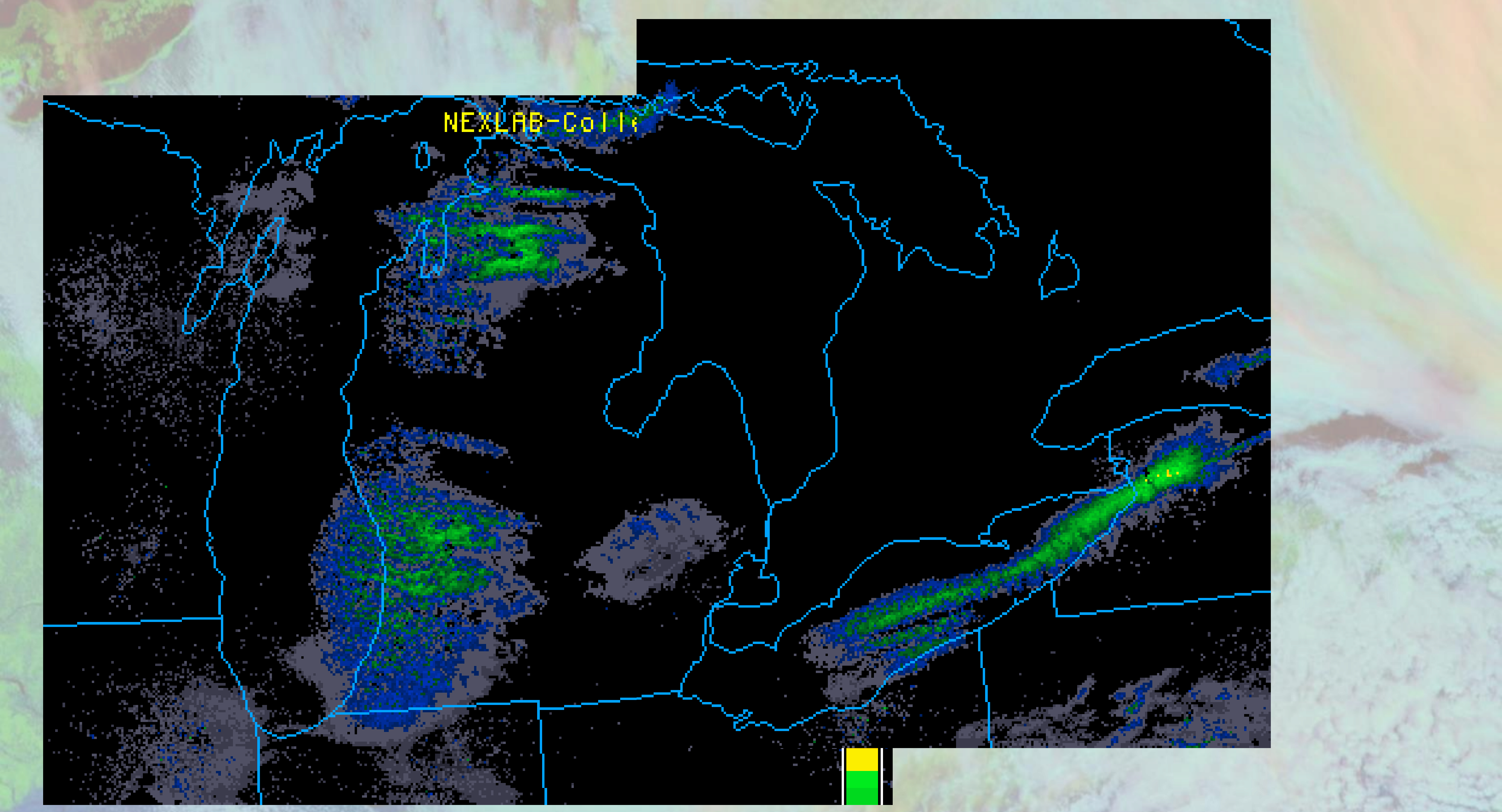
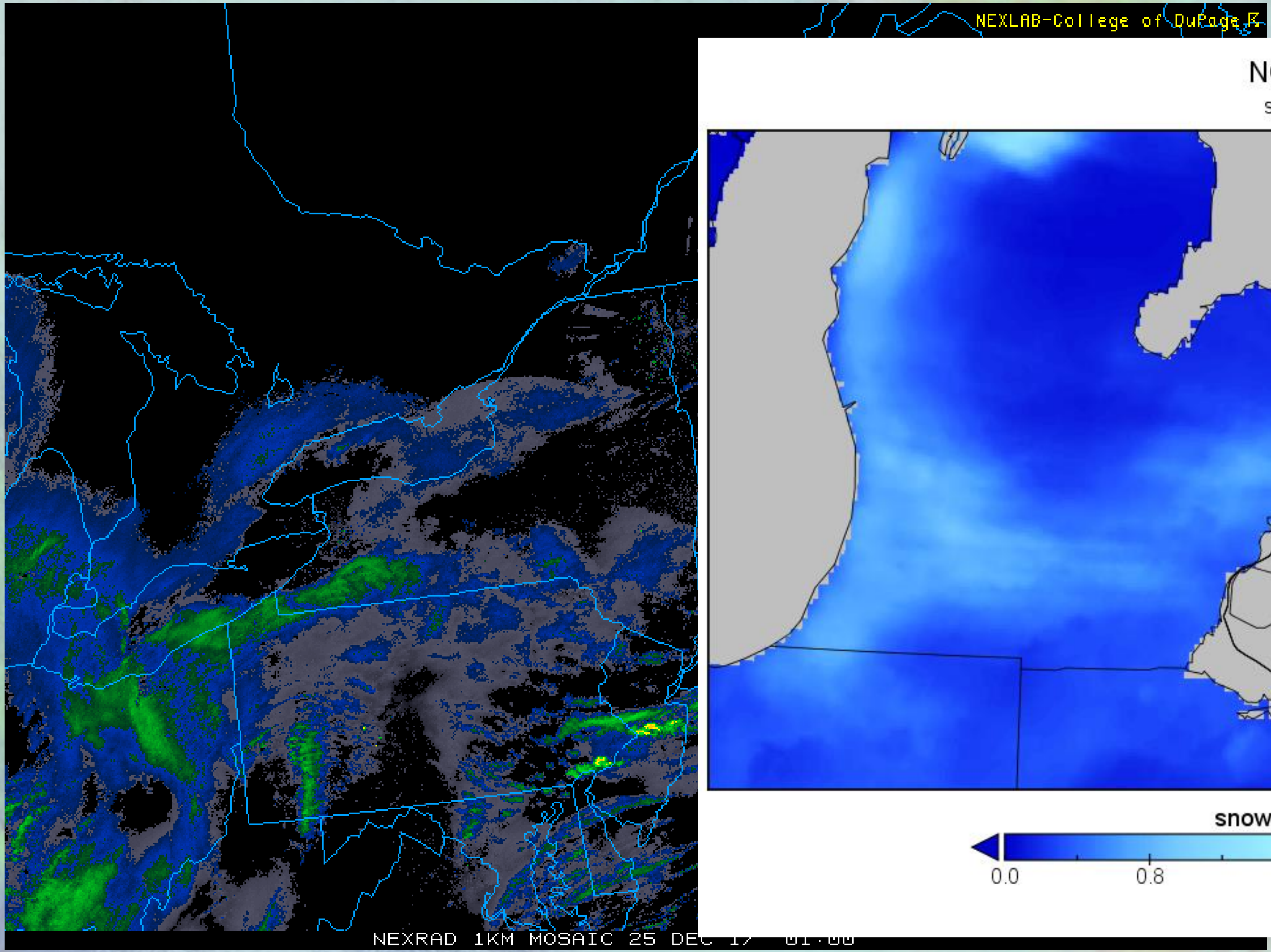


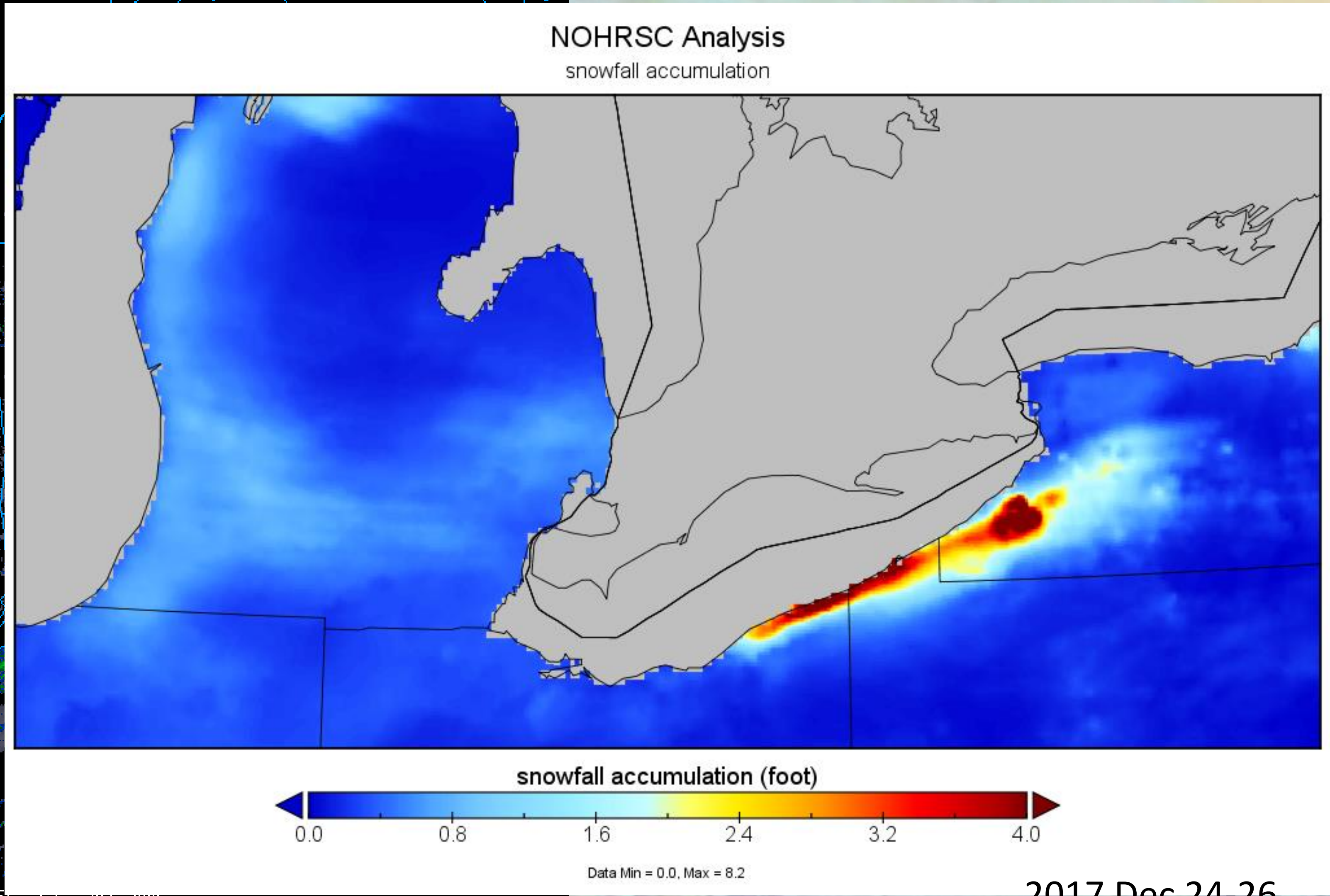
2014 Nov 18 08z



2014 Nov 18 08z

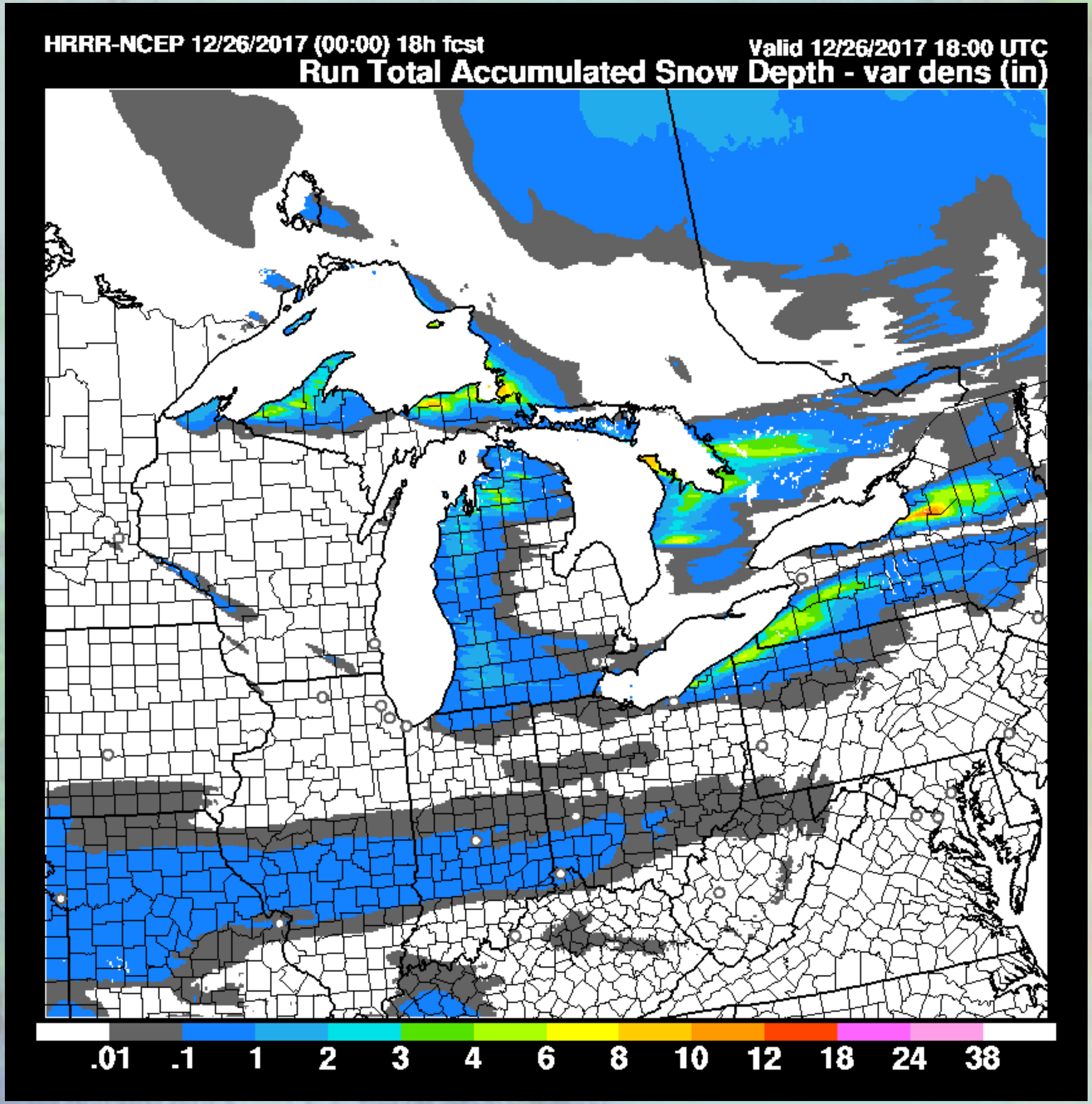
Christmas and Boxing Day Event – Erie PA

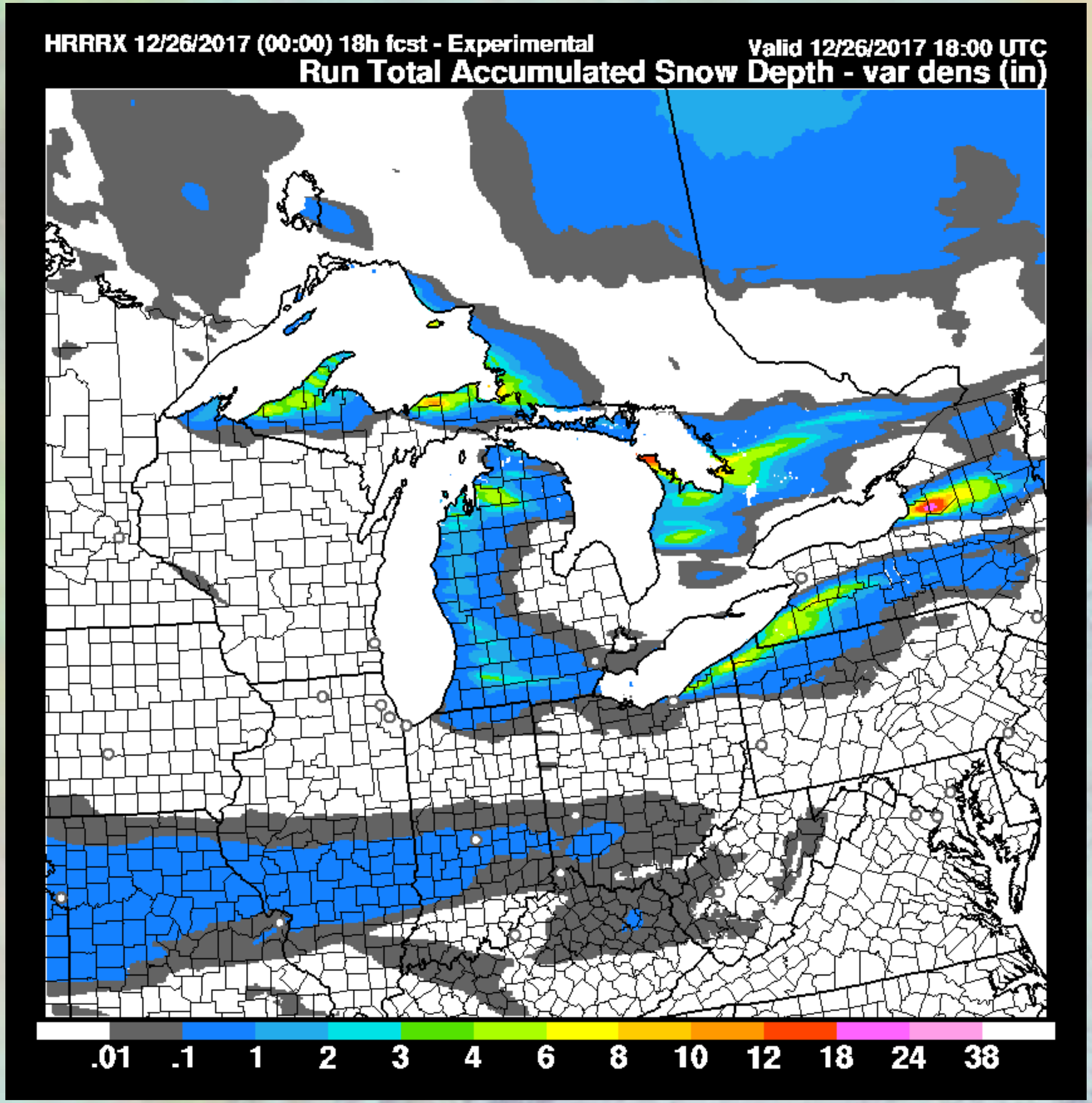




2017 Dec 24-26

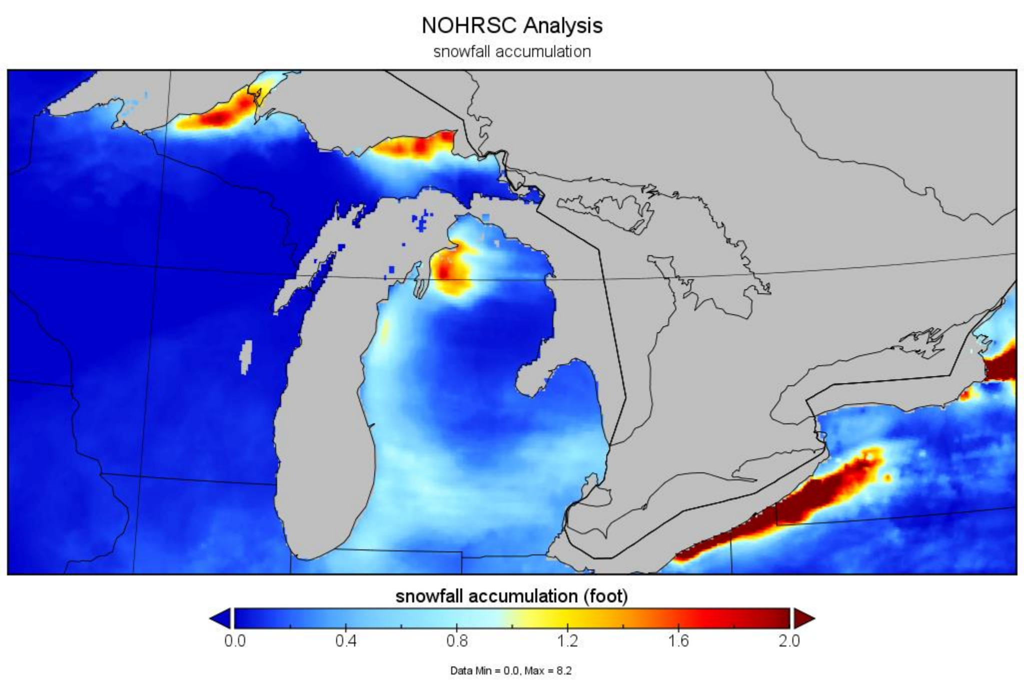
HRRR

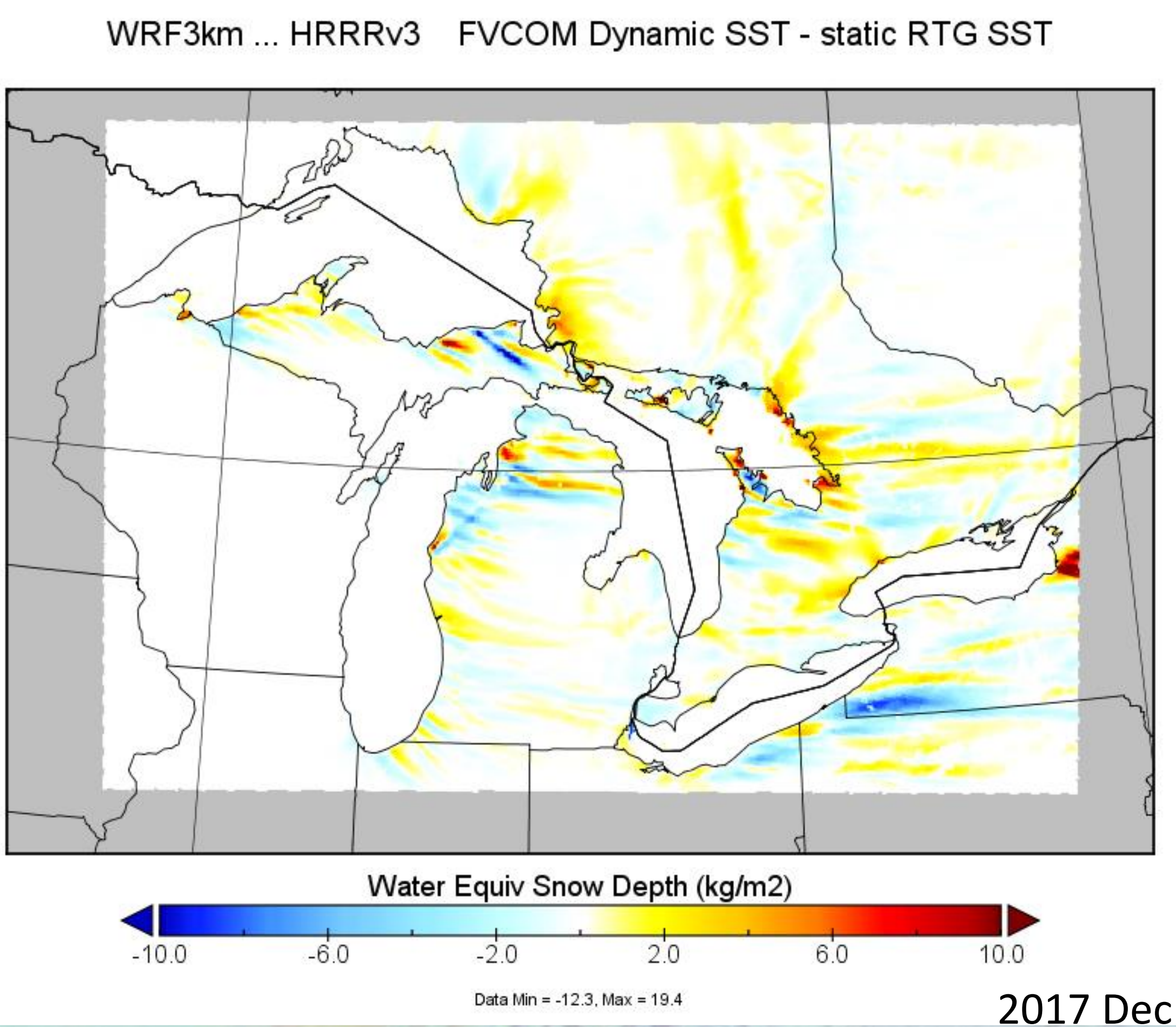

HRRR-NCEP 12/26/2017 (00:00) 18h fcst
Valid 12/26/2017 18:00 UTC
Run Total Accumulated Snow Depth - var dens (in)
.01 .1 1 2 3 4 6 8 10 12 18 24 38


HRRRX 12/26/2017 (00:00) 18h fcst - Experimental
Valid 12/26/2017 18:00 UTC
Run Total Accumulated Snow Depth - var dens (in)
.01 .1 1 2 3 4 6 8 10 12 18 24 38

WRF3km – "Coupled" vs Control Static SST

- Some improvement to snowfall distribution
  - esp. downstream of Ontario
  - Erie band has minor shift toward the coast

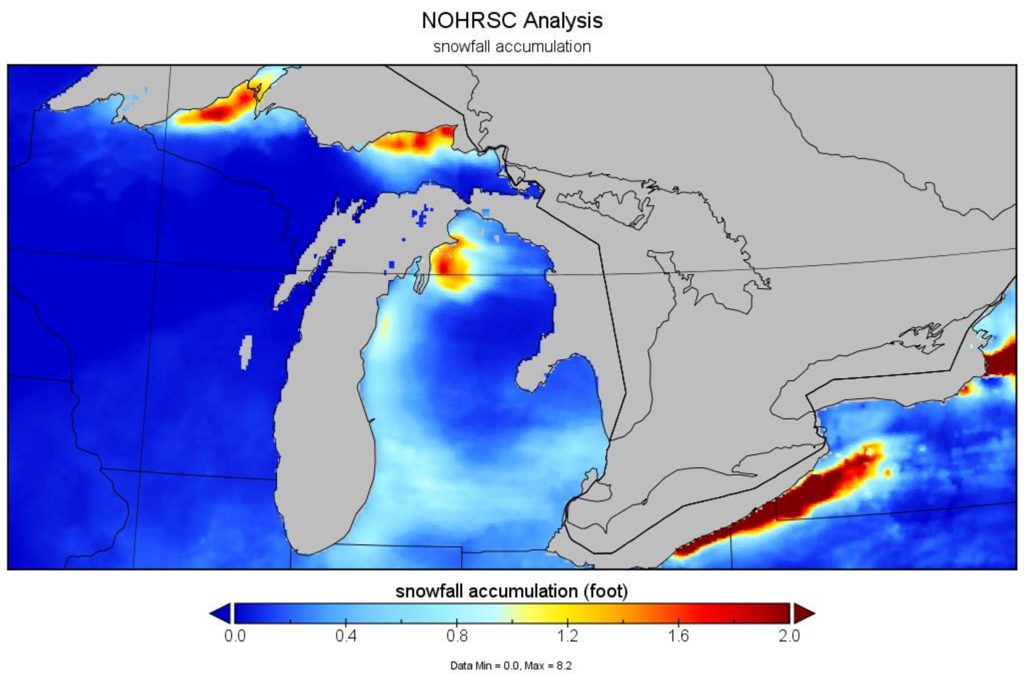


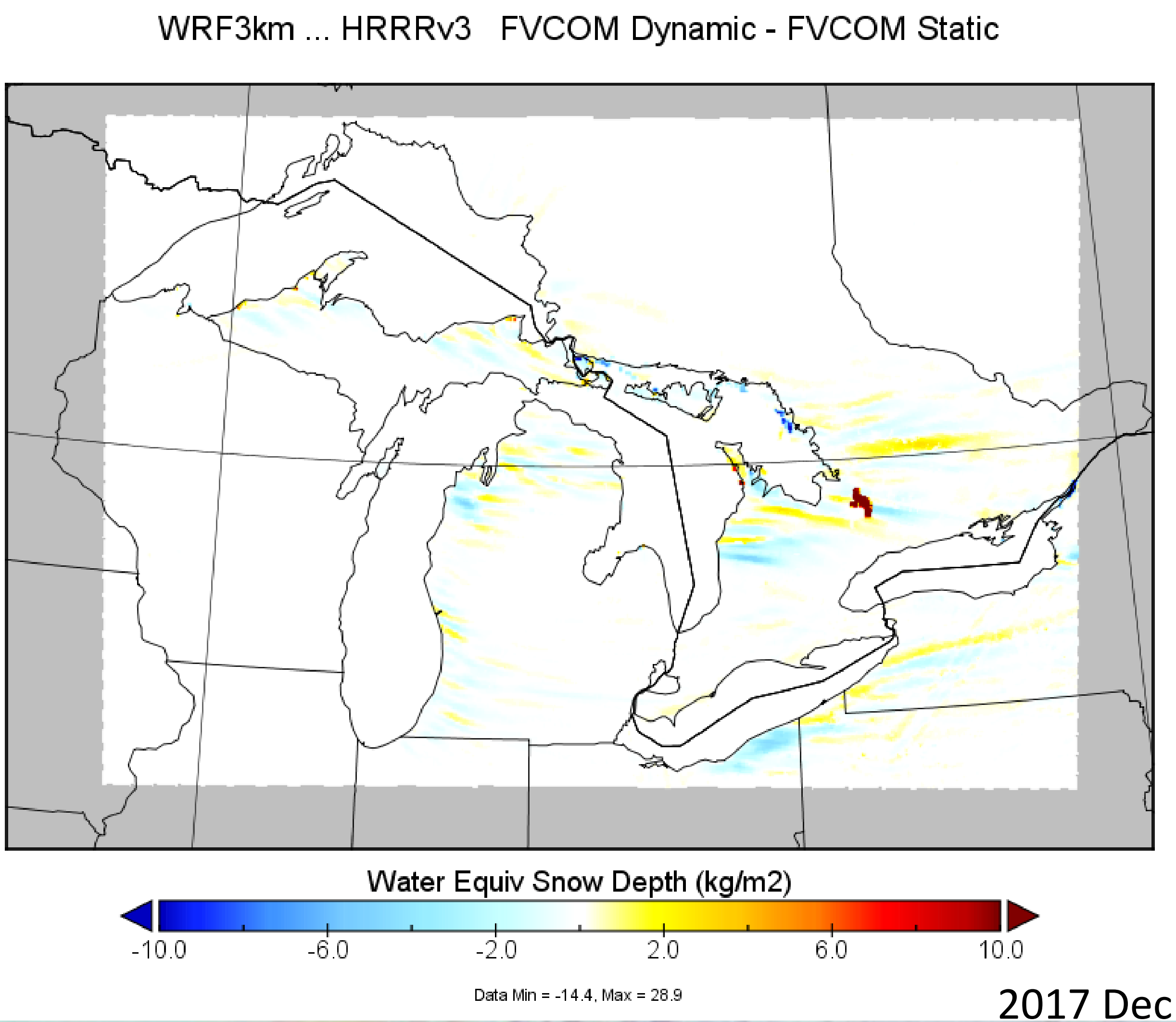


2017 Dec 24-26

WRF3km – "Coupled" vs FVCOM Static SST

- Changing SST influences
  - Ontario band diffs due to SST source (FVCOM v RTG)
  - minor shift of Erie Band toward the coast

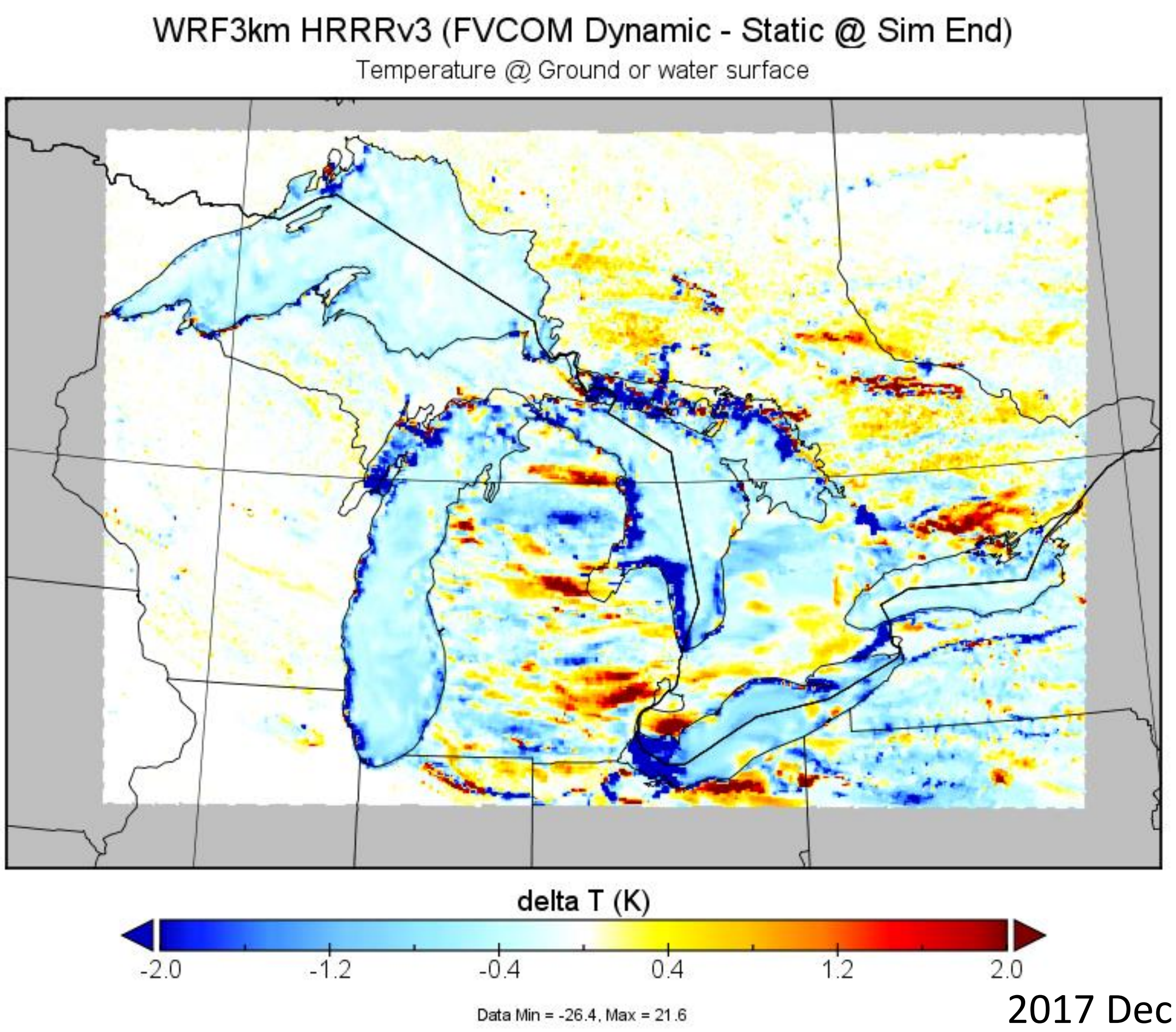




2017 Dec 24-26

Dynamic SST vs Static SST

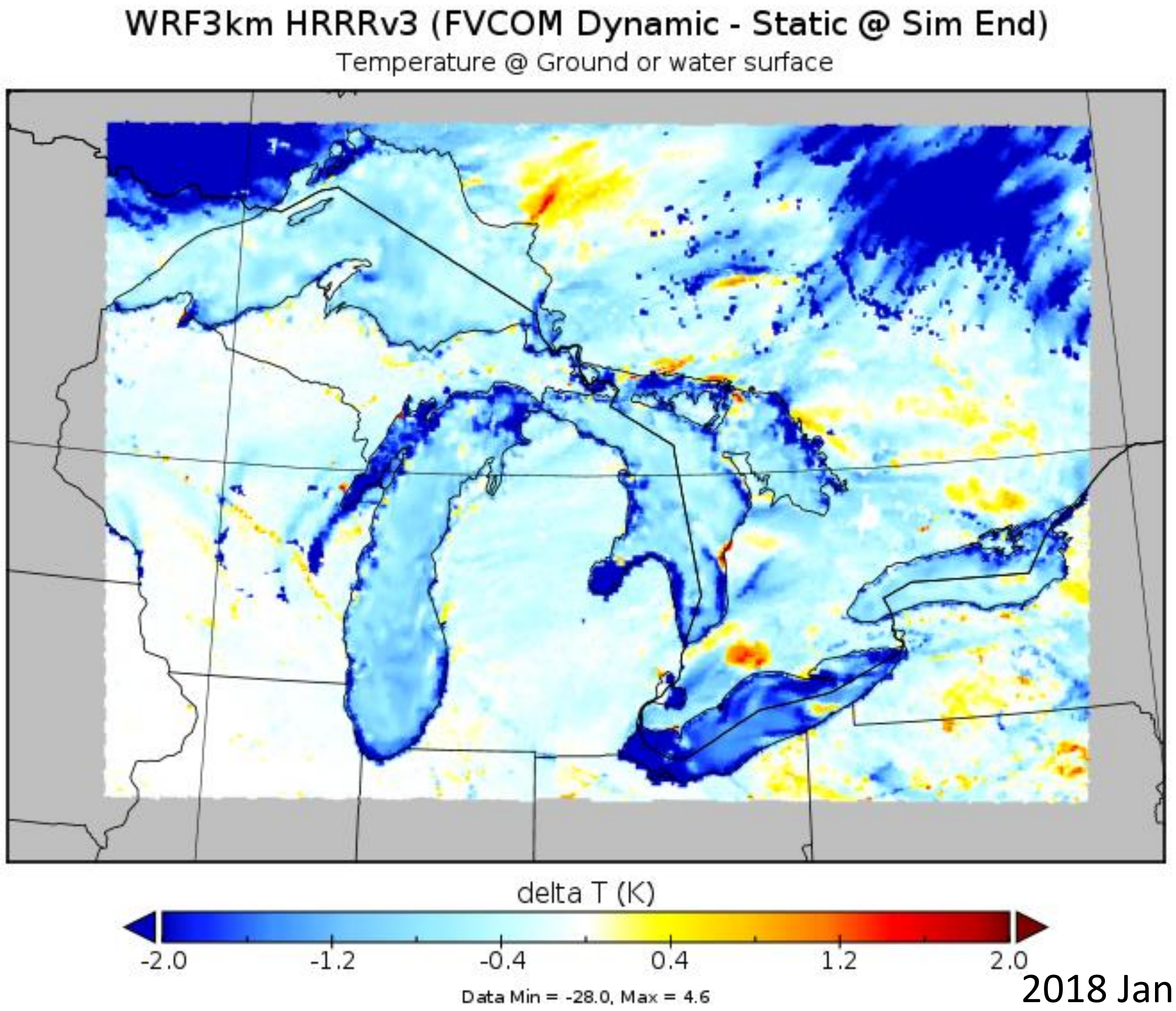
- Alterations to SST distribution, including the formation of ice cover along periphery of Michigan and Huron. Substantial increase in ice on West Lake Erie
  - (seen as a dramatic drop in skin temp)



2017 Dec 24-26

Dynamic SST vs Static SST - Rapid Ice Formation

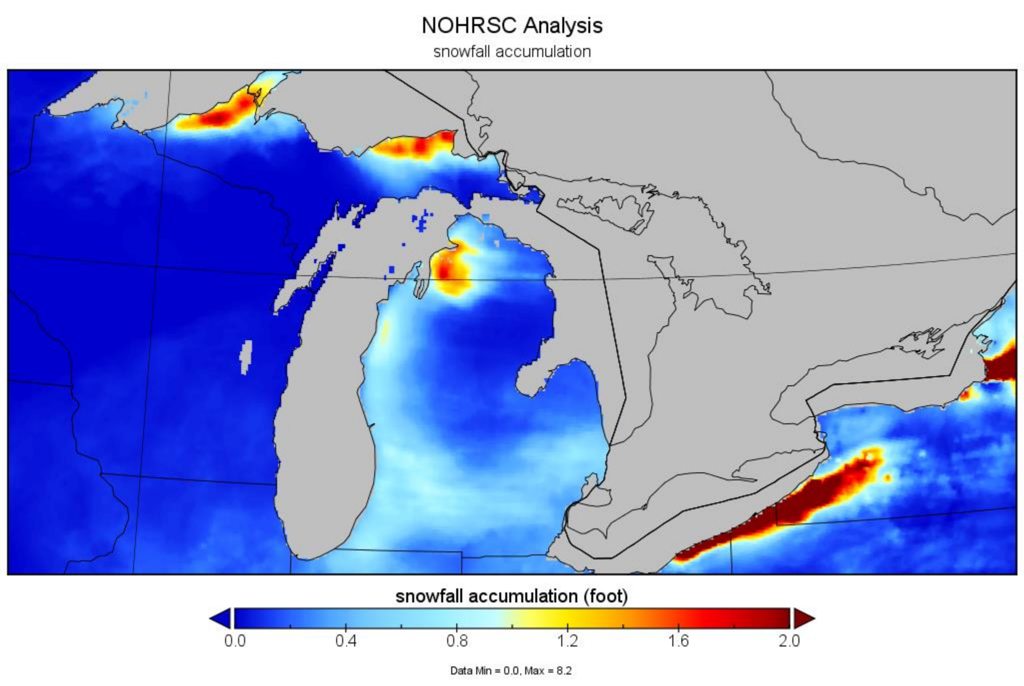
- Alterations to SST distribution, including the formation of ice cover over Saginaw Bay and West Lake Erie (seen as a dramatic drop in skin temp)

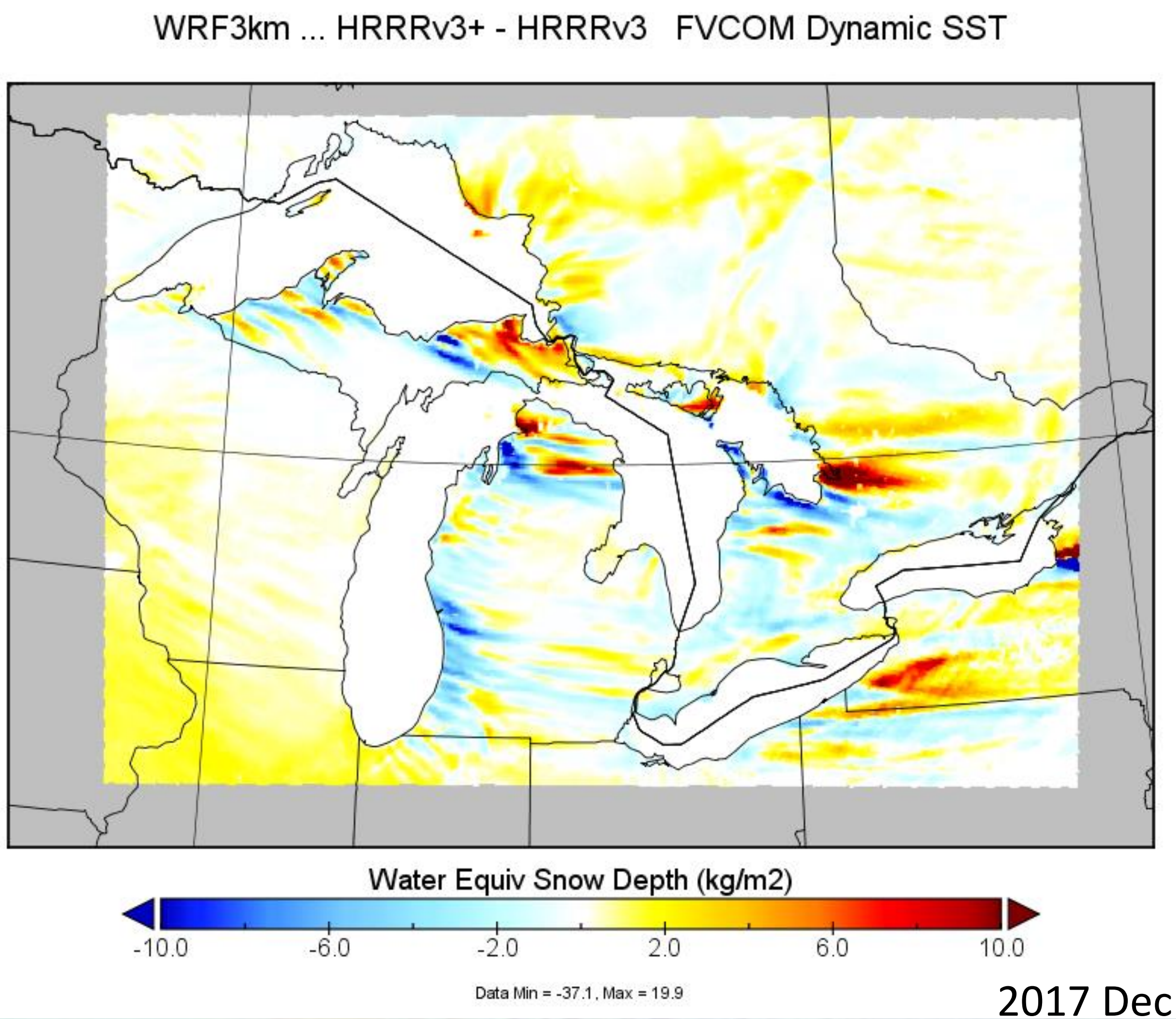


2018 Jan 3-6

Influence of Updated Physics -> HRRRv3+

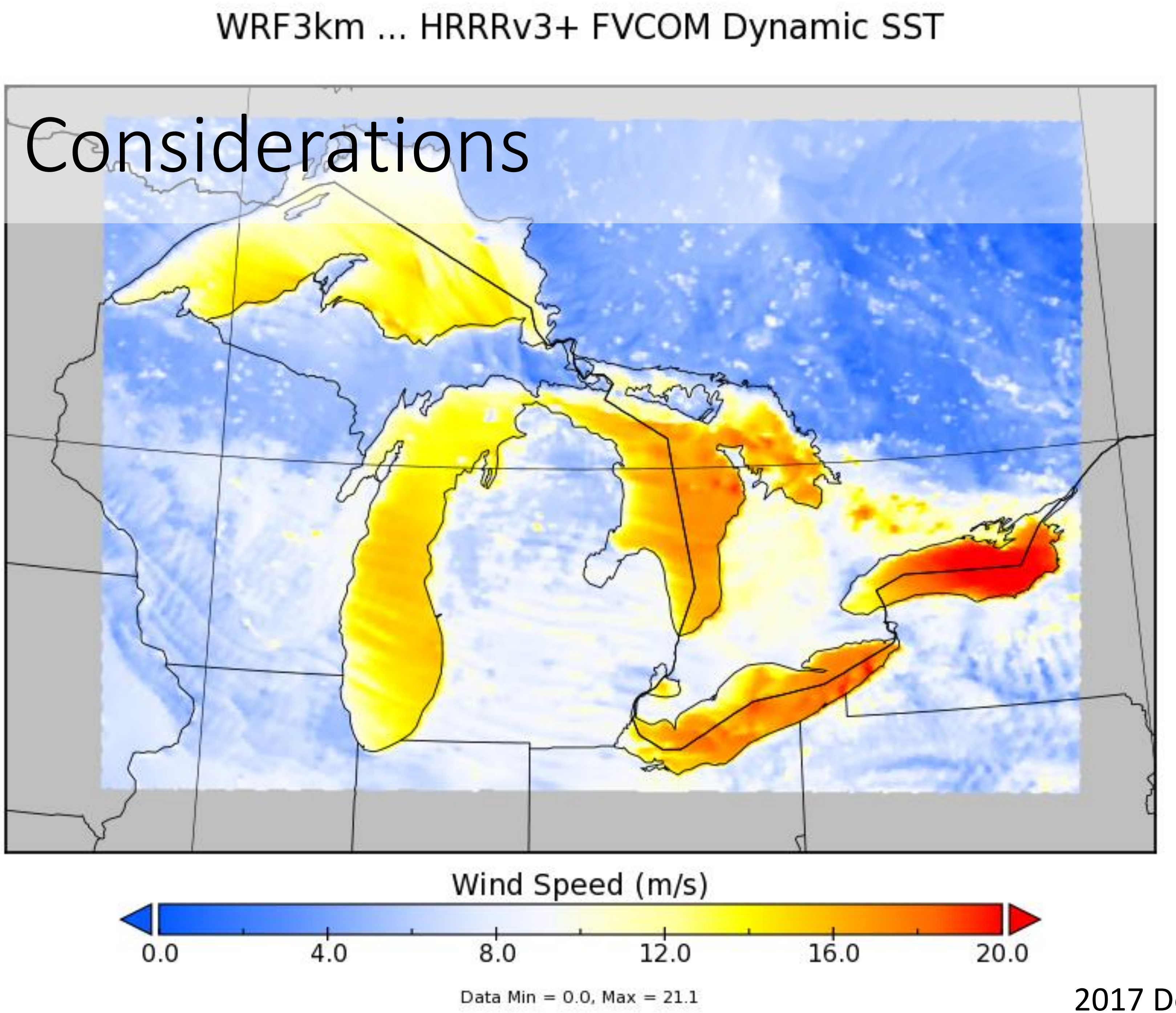
- Qualitative improvements – additional quantitative analysis ongoing
  - Erie band has further minor shift toward the coast





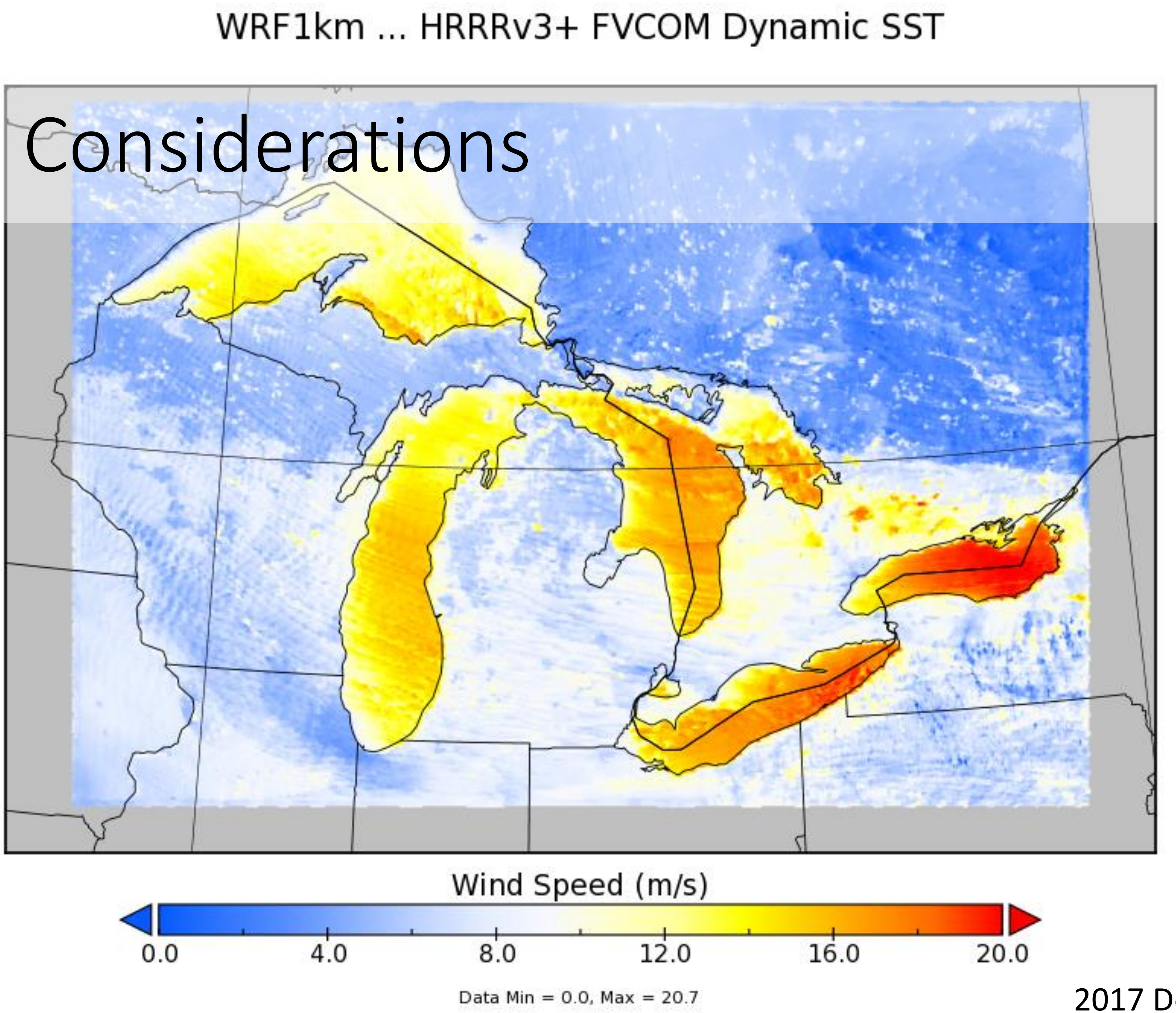
2017 Dec 24-26

Resolution Considerations



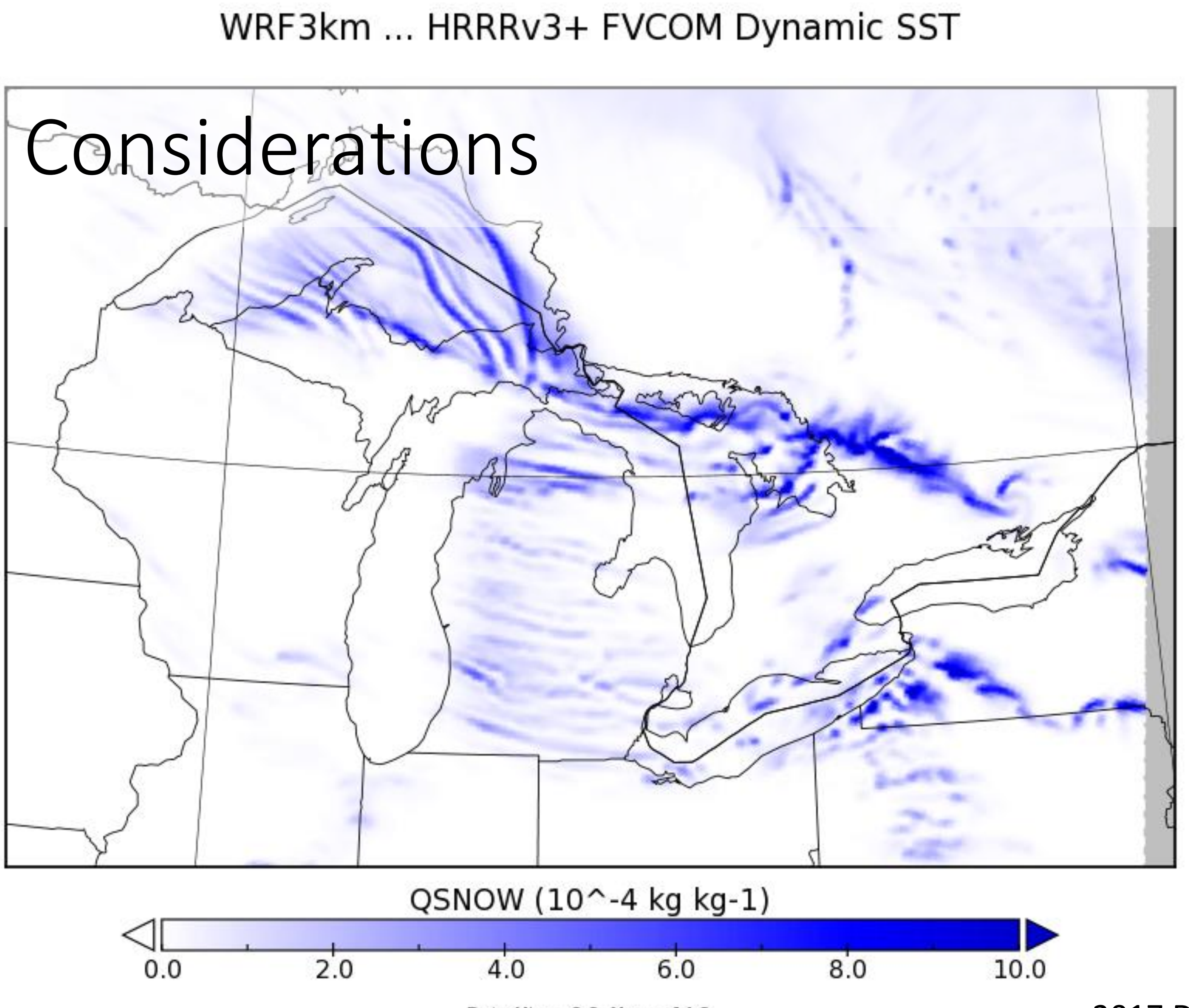
2017 Dec 25 21z

Resolution Considerations



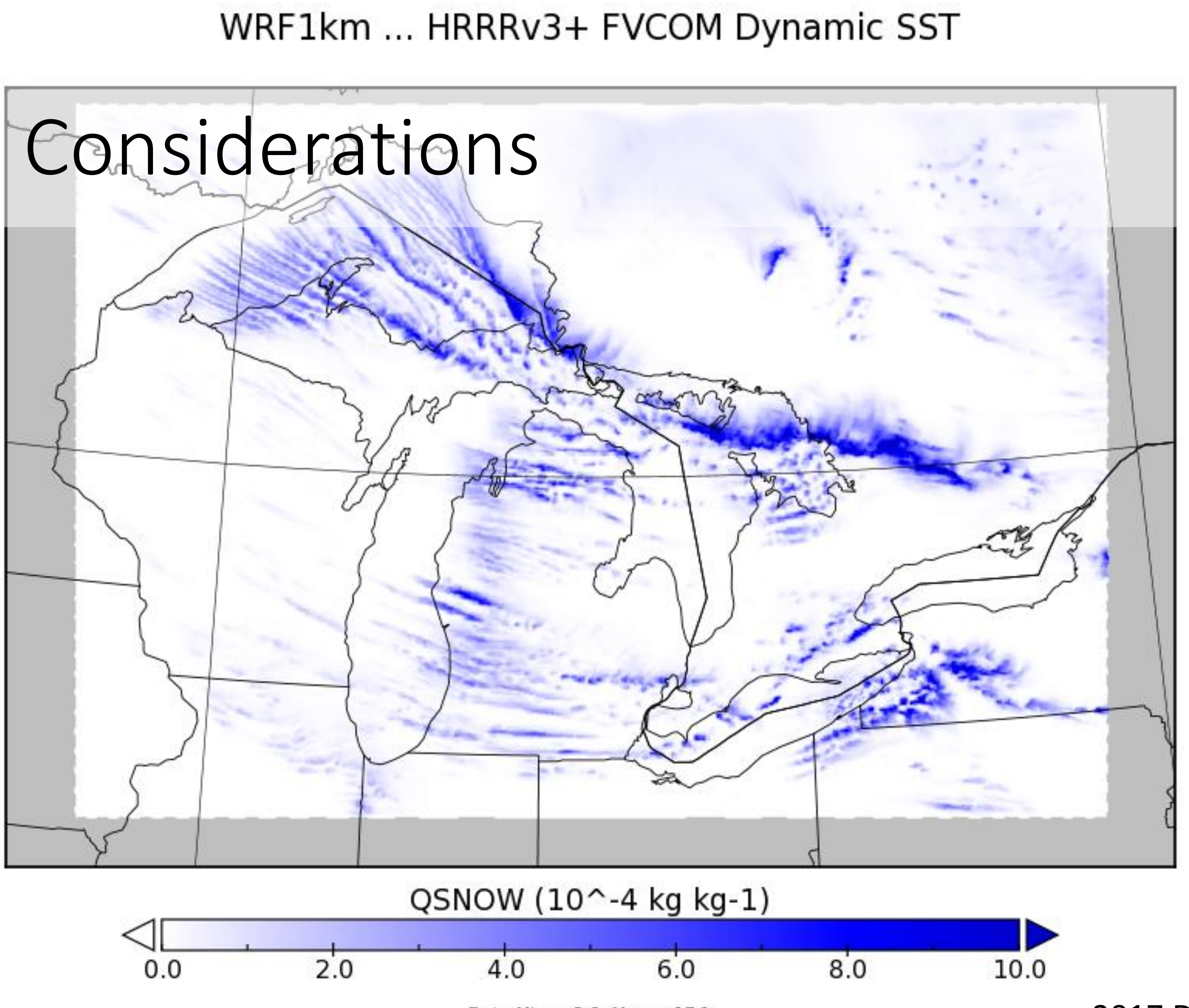
2017 Dec 25 21z

Resolution Considerations



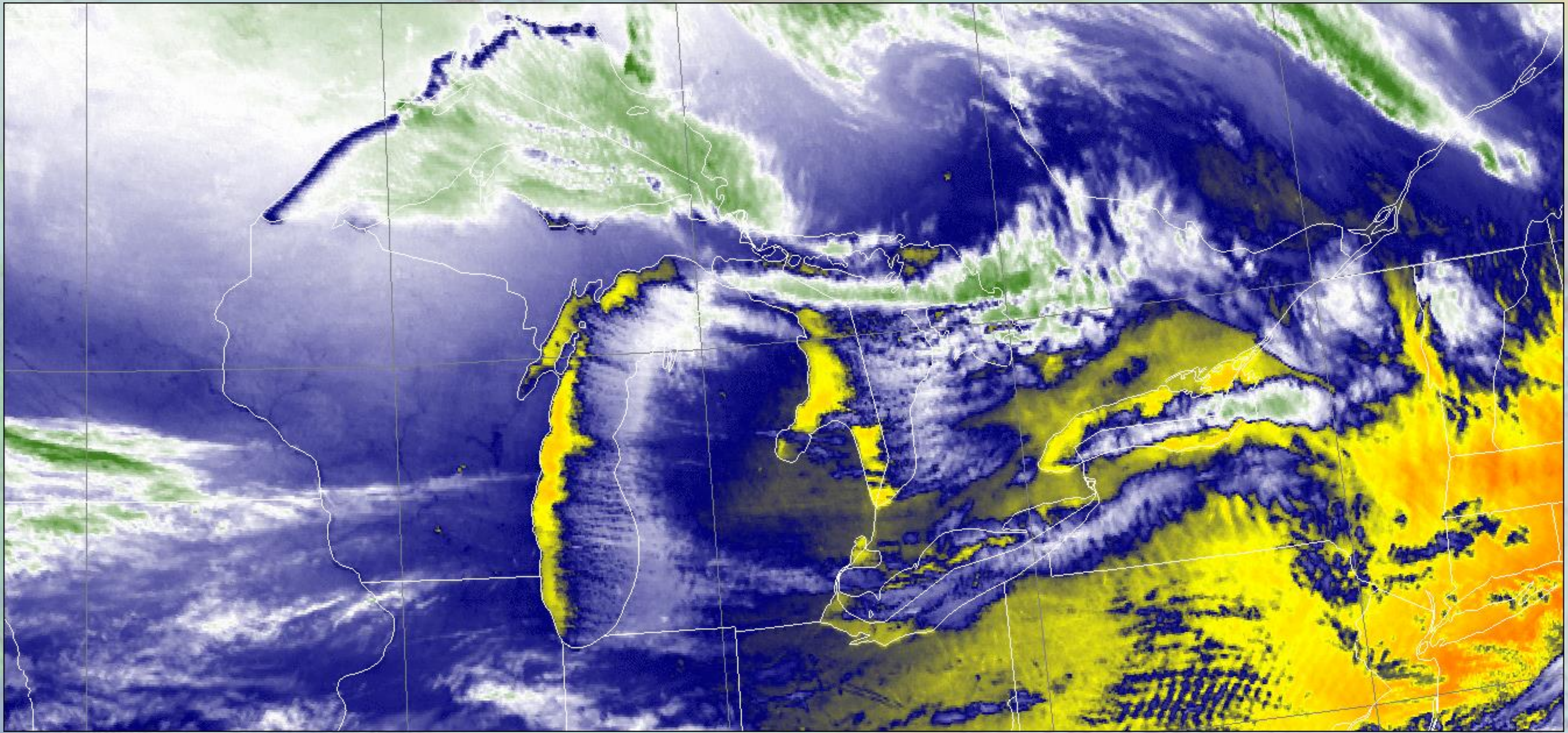
2017 Dec 25 21z

Resolution Considerations



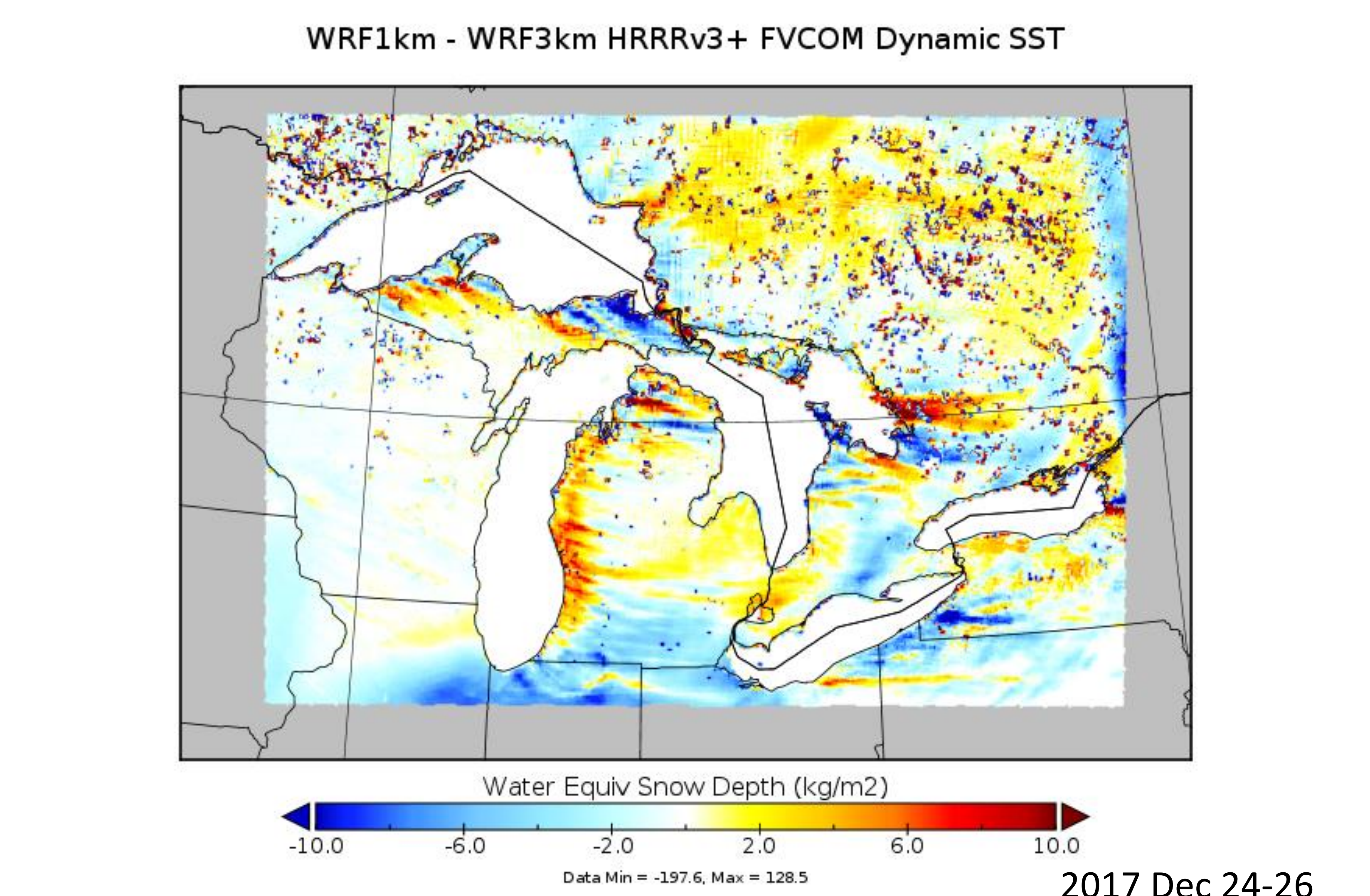
2017 Dec 25 21z

Low Level WV – GOES16 Band 10 (7.3um)



Resolution Impact

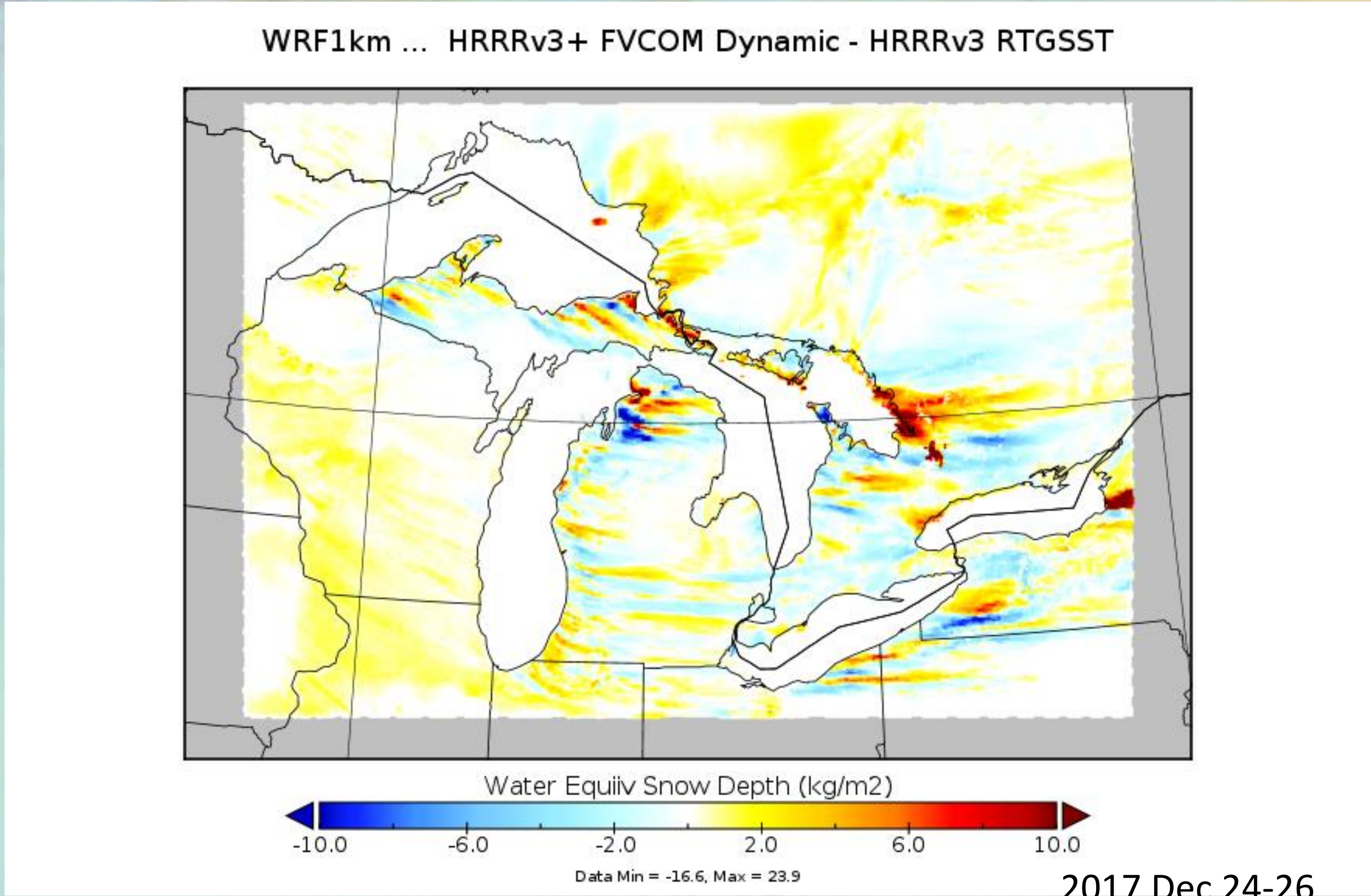
- Substantial differences in spatial distribution simply due to changes in resolution
- Greatest gains in the representation of the multiple wind parallel bands
- No real gains in relationship to Lake Erie dominant band



2017 Dec 24-26

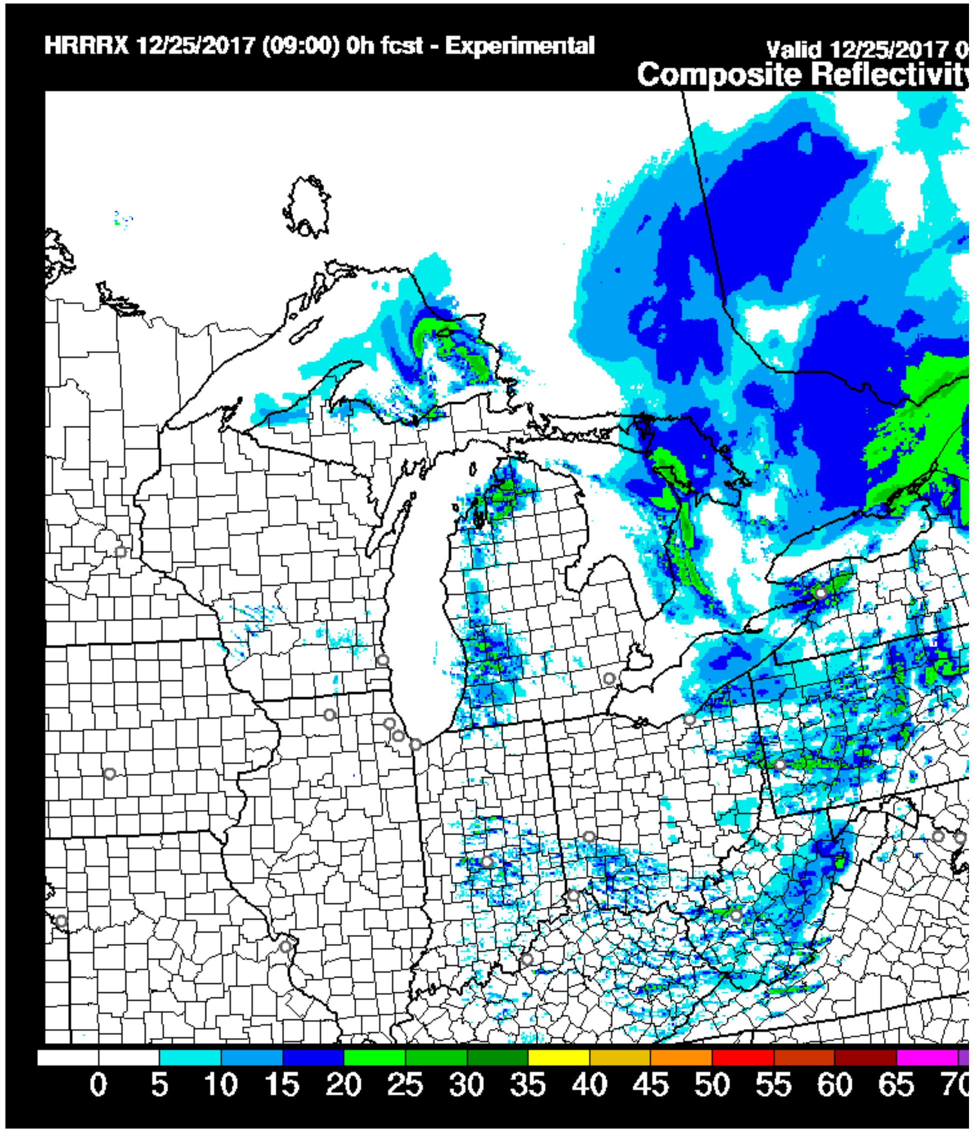
WRF1km … Influence of Updated Physics and Dynamic SST

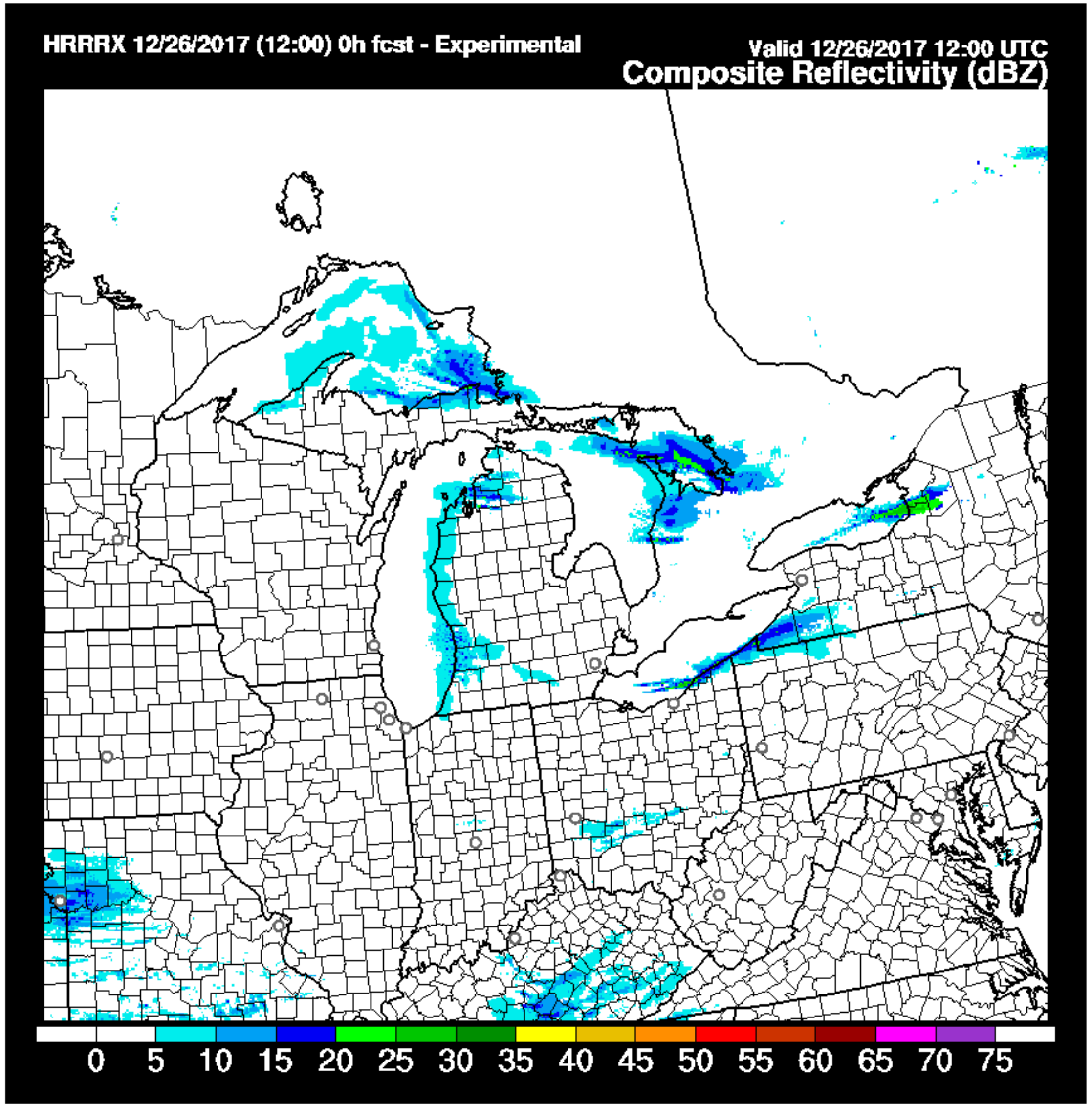
- Qualitative improvements using FVCOM dynamic SSTs over the static RTGSST
- Greatest gains in band positioning over N. Michigan and the Tughill
- Minor gains in relationship to Lake Erie dominant band



2017 Dec 24-26

Final Operational Comment: HRRR Spin-up issues





Testbed Activities

- Test operational application of “coupled” HRRRv4-FVCOM system for 2018-2019 lake-effect season (November-March)
  - Additional HRRRv4 physics improvements will also be informed through testing this summer (ESRL)
  - Expansion of FVCOM to all Great Lakes basins for the test (GLERL)
- NOAA/NWS/NCEP/WPC Winter Weather Experiment will facilitate testing the operational application and utility of the new dataset
  - Great Lakes WFOs will participate remotely to assist
  - Subjective evaluation by experiment participants
  - Objective validation for available datasets throughout the season
    - Including object based verification
- Testbed results will inform NOAA R2O Transition plans

Questions?

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