The value of very high resolution weather forecasts? Experiences from The Jefferson Project at Lake George

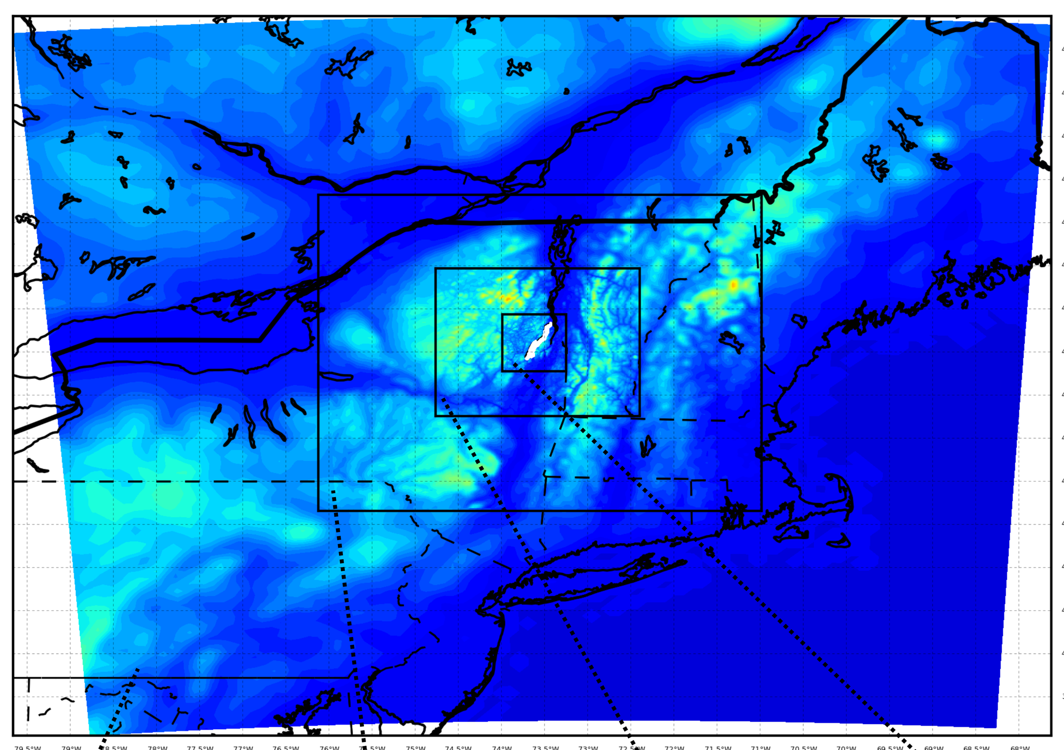
Campbell D. Watson*, James P. Cipriani, Mukul Tewari, Anthony P. Praino, Lloyd A. Treinish, Michael Henderson, Harry R. Kolar
IBM T. J. Watson Research Center, Yorktown Heights, NY *campbell.watson@weather.com

The Jefferson Project at Lake George

The Jefferson Project is a research endeavor at Lake George, NY by IBM Research, Rensselaer Polytechnic Institute (RPI) and The FUND for Lake George. Lake George is a dimictic, oligotrophic lake and The Jefferson Project is working to understand, predict and enable a healthy Lake George ecosystem.

An modeling system is being developed to provide data on the physical, chemical and biological parameters that drive ecosystem function. This includes a weather model that drives simulations of the watershed hydrology and lake circulation (and eventually the food web dynamics).

Weather Modeling: How high is too high?



d01 – 9km | d02 – 3km | d03 – 1km | d04 – 0.33km

- WRF-ARW Core V3.6.1
- Daily 36-hr forecasts at 00Z (May 21 2016 – present)
- Assimilation of local and regional weather obs using WRF 3DVar
- 39 vertical levels (11 below 1 km)
- Thompson double-moment microphysics
- MYNN surface and boundary layer / RRTMG radiation / Noah LSM

Towards this end, we consider two questions:

1) *Does model resolution impact simulated wind stress at the lake surface?*
2) *What is the impact on precipitation within the watershed?*

For wind stress, we find the lake-wide average converges at higher resolution despite more extreme values emerging. Do these regions of higher/lower wind stress have a material effect on lake circulation?

For precipitation, the long-term average is similar across model resolutions although larger maximums emerge at Δ0.33 km. Whether this difference is important probably depends on user need (e.g., long-term hydrology studies vs. flash flood prediction).

Effect of resolution on lake wind stress

Surface winds drive lake circulation by applying stress at the surface. Surface winds are strongly controlled by topography, which is more realistically resolved at higher resolution.

Following Xiao et al (2013), we compute the wind stress, τ, as follows:

$$\tau = \rho_a C_D u^2$$

$$C_{D10N} = k^2/[\ln(z/z_0)]^2$$

Units: $\mathrm{kg\,m^{-1}\,s^{-2}}$ or $\mathrm{N\,m^{-2}}$

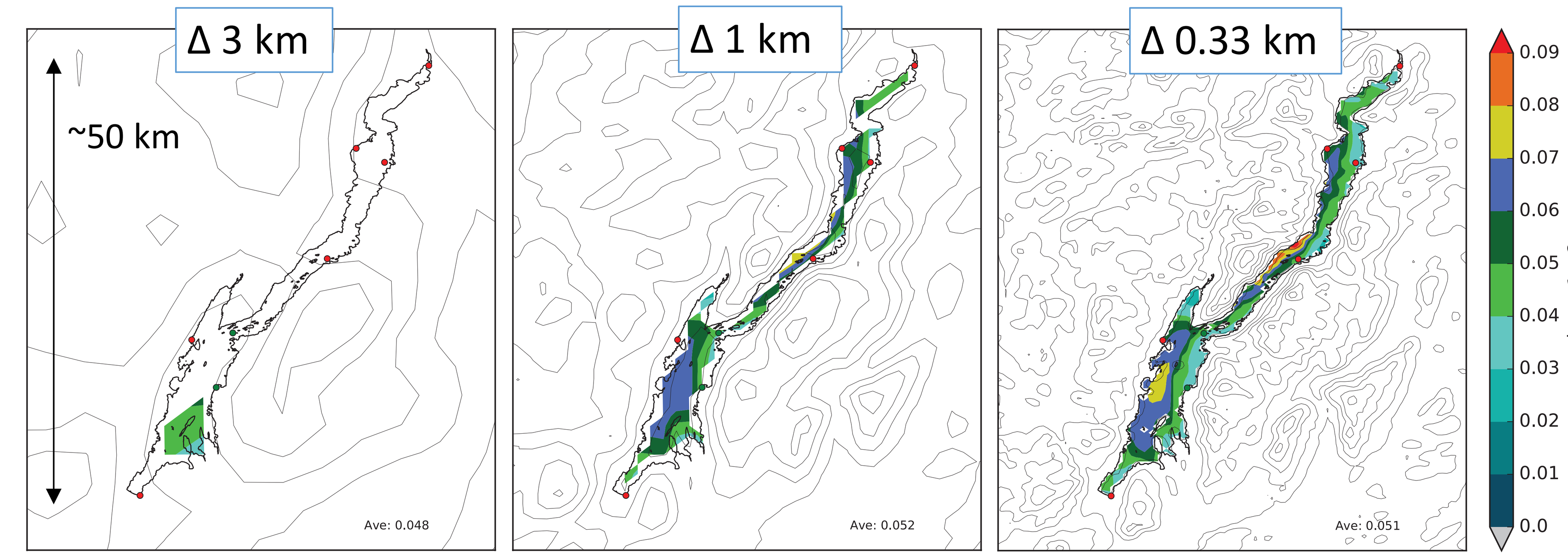
ρ_a is air density
C_{D10N} is the drag coefficient
u is wind speed
k is von Karmen constant
z is height above ground
z_0 is surface roughness

Over 7.5 months, the average wind stress on the lake converges as model resolution increases. However, variation in wind stress increases at higher resolution (i.e., higher highs, lower lows). Are these differences important?

Next step: quantify the importance of these differences by using a lake circulation model.

Xiao, W., Liu, S., Wang, W., Yang, D., Xu, J.,Cao, C., Li, H and Lee, X. 2013. Transfer Coefficients of Momentum, Heat and Water Vapour in the Atmospheric Surface Layer of a Large Freshwater Lake. *Boundary-Layer Meteorol. 148: 479-494*

May 21 – Dec 31 2016: The average wind stress ($\mathrm{N\,m^{-2}}$) on Lake George



12 cells | 119 cells | 1042 cells

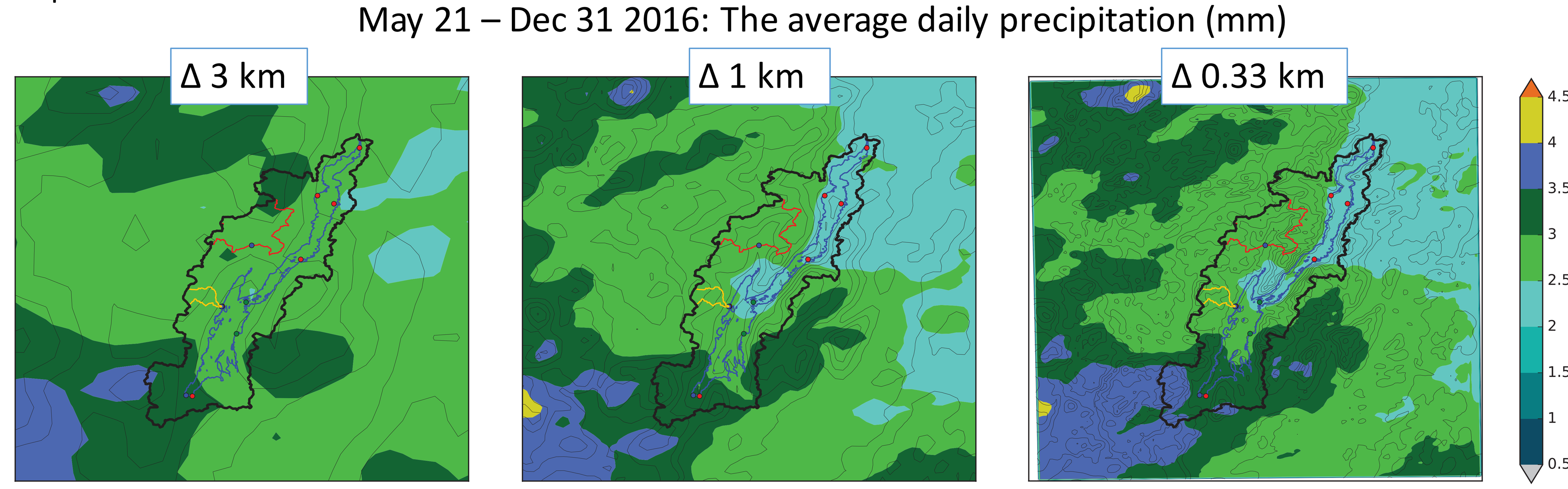
Number of grid cells over Lake George at each resolution

Wind Stress ($\mathrm{N\,m^{-2}}$)	3 km (d02)	1 km (d03)	0.33 km (d04)
Average	0.048	0.052	0.051
Average Minimum	0.017	0.005	0.002
Average Maximum	0.091	0.152	0.195

Effect of resolution on precipitation

The watershed hydrology is driven by precipitation. Accurately simulating the amount and location of precipitation *inside each watershed* is crucial to understanding the physical system. The difference in average daily precipitation across domain resolutions for each (sub)watershed never exceeds 10%. However, like with wind stress, variations increase at higher resolution (e.g., differences in maximum precipitation are larger). Are these differences important?

May 21 – Dec 31 2016: The average daily precipitation (mm)



Terrain height at 100 m intervals (as resolved by the model) shown by black contours; thick black line shows the extent of the Lake George watershed; red and orange lines show Northwest Bay and Finkle Brook subwatersheds, respectively; blue line shows the lake.

Next step: identify precipitation events where differences in maximum precipitation are largest across domains and quantify the impact on surface hydrology using a land surface model and runoff model.

Full Watershed (black line)

Daily Precip (mm)	3 km (d02)	1 km (d03)	0.33 km (d04)
Average	2.86	2.72	2.81
Average Maximum	5.97	6.75	7.66

Northwest Bay Brook (red line)

Daily Precip (mm)	3 km (d02)	1 km (d03)	0.33 km (d04)
Average	2.93	2.73	2.76
Average Maximum	3.69	4.13	4.35

Finkle Brook (orange line)

Daily Precip (mm)	3 km (d02)	1 km (d03)	0.33 km (d04)
Average	2.83	2.66	2.85
Average Maximum	2.83	3.18	3.55