# SRTM Water Elevations and their Implications for Ground Water Flow Predictions

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## Introduction

In humid climates surface water and ground water are closely connected. Surface water heads (stage) provide information about ground water heads, which in turn can be used to predict ground water flow. In this project we evaluate the potential for using radar-derived elevations to constrain ground water flow models. We investigate how error in elevation measurements propagate through ground water predictions by numerical ground water flow models. Radar backscatter information is used to help classify error in terms of surface water type (open water, peatland, wetland).

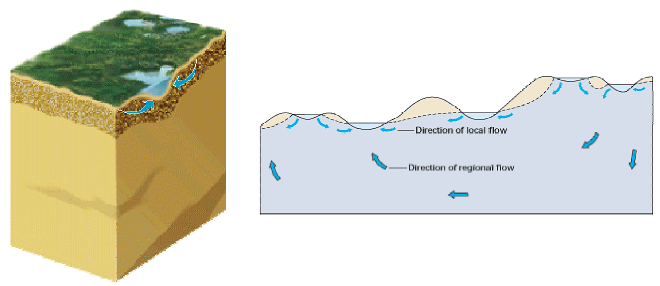
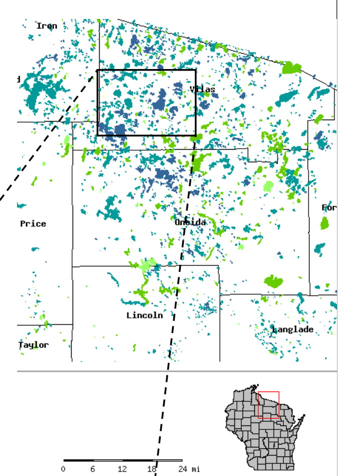


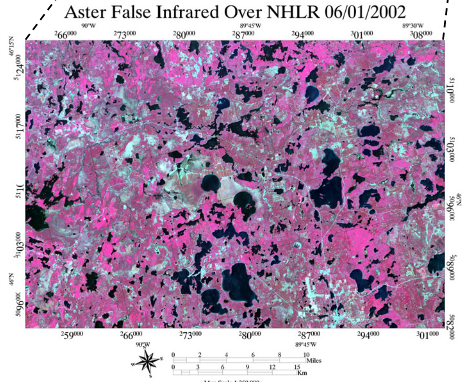

Figure from Winter et al., Ground Water and Surface Water A Single Resource, USGS Circular 1139, 1998

## Study Site

The study site is the **Northern Highlands Lakes Region (NHLR) of Wisconsin**. This region is defined by an approximately 70 by 70 km lobe of Pleistocene aged glacial outwash that is densely populated by kettle lakes and wetlands. In lowlands, lakes and streams are highly inter-connected to form "flowages". There are 7500 connected water bodies across the NHLR. Wetlands in this area are dominated by peatlands, which may be isolated (usually formed in kettles) or adjacent to streams or lakes. Wetlands in the NHLR may be roughly classified as forested, shrubby, or grassy. Some peatlands are quite expansive, covering more than 40 km².



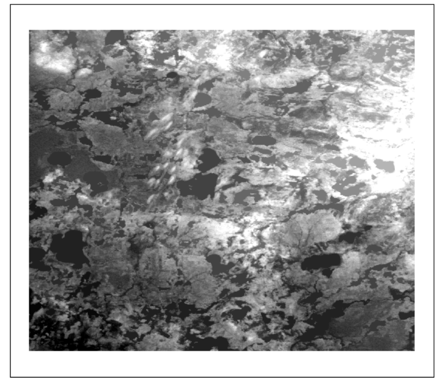

Aster False Infrared Over NHLR 06/01/2002



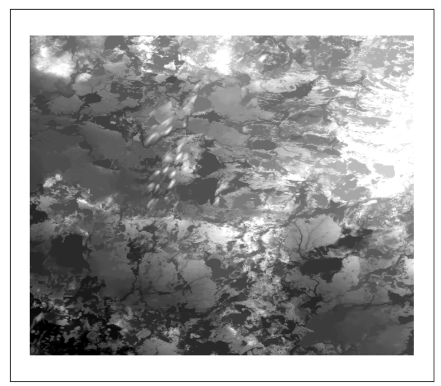
## Data Sets

We compare elevation data from SRTM Seamless DEM to the National Elevation Dataset Seamless DEM, with respect to the 1992 National Land Cover Dataset. The purpose is to see how errors in SRTM are distributed among various land cover types in this variable terrain.

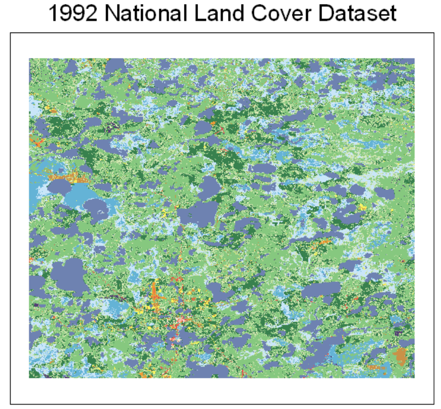
SRTM DEM

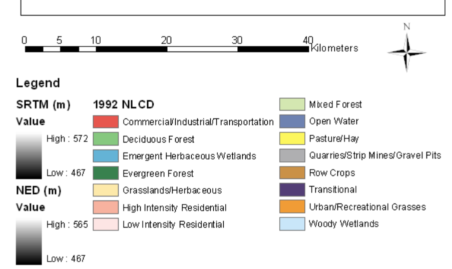


National Elevation Dataset DEM



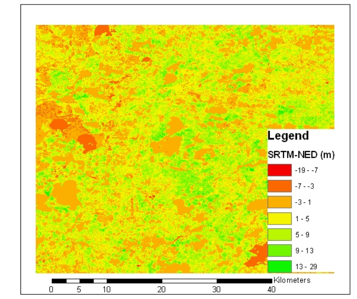
1992 National Land Cover Dataset



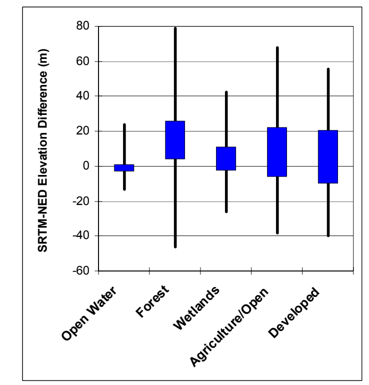



## Error Analysis

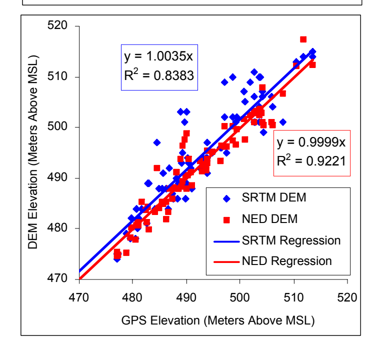
We subtracted NED elevations from SRTM elevations in the scenes shown at left. The results are shown at right, classed in 1 standard deviation increments of meters in elevation. Note that lakes and wetlands appear to be underestimated by SRTM with respect to the NED.




The plot at right shows the difference between SRTM and NED elevations (SRTM-NED) classed by land cover type. The blue bars represent a one standard deviation spread about the mean, black lines represent the range of results. Open water elevations show the best agreement between DEMs. Wetlands and forests show a wider range of disagreement between DEMs.

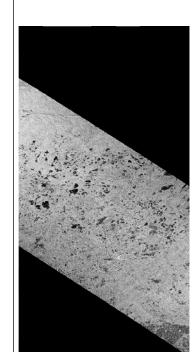



During the Summer of 2003 we surveyed 86 lakes in the NHLR using a high resolution GPS device (TOPCON Hiper GGD system) that has 1 cm vertical accuracy. The USGS NED DEM product compared somewhat better to GPS lake elevations than SRTM, with a 95% confidence error of 5.3 m, versus 6.6 m for the SRTM DEM.

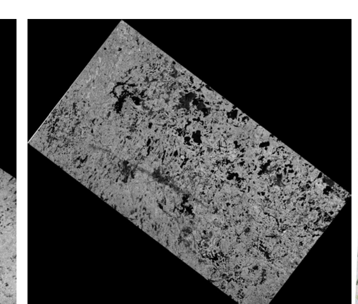



## Additional Radar Data

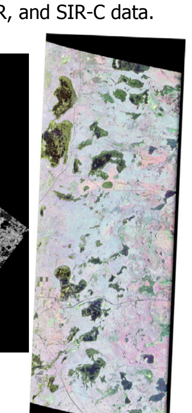
We are reviewing additional radar data to determine how wetland errors are distributed among different wetland types, i.e. forested, sedge lands, peat lands. Available for this area are SRTM C-band, AIRSAR, and SIR-C data.



SRTM C-band
HH polarization
February 2000



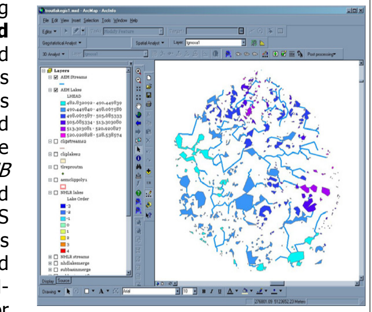
SIR-C L-band
HH polarization
April 1994



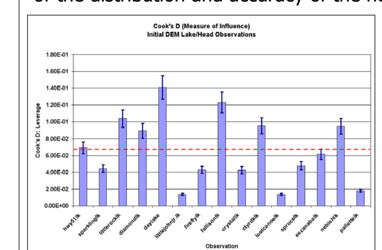
AIRSAR
HH (R), VV(G), HV(B)
March 2002

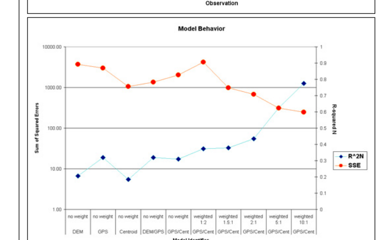
## Interpretation

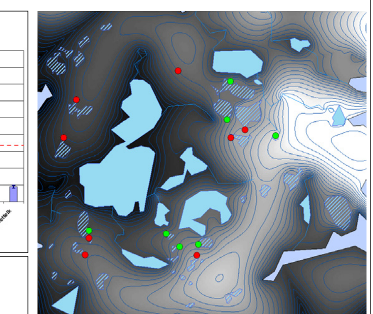
We model ground-water flow using the **Analytic Element Method** (AEM). AEM models are constructed by superimposing analytic equations that represent hydrologic features such that ground-water flow or head can be calculated at any point in the domain at machine precision. *UB Groundwater Group* implemented AEM modeling in a ArcGIS environment (right). These tools allow us to rapidly calibrate ground water flow models to SRTM-measured heads and derive error statistics from the results.



Below are modeling results that examine the propagation of error from elevation measurements through the prediction of a ground water potential (head) surface and estimation of hydraulic conductivity. Head observations, coincident with GPS points, are used for calibration targets, with the regional hydraulic conductivity as the calibrated parameter. The final result is a function of the distribution and accuracy of the head measurements.



| Method | K (m/day) | Sum of Squared Error |
|---|---|---|
| DEM | 7.57 | 6.70 |
| GPS | 11.80 | 19.02 |
| Centroid | 13.19 | 5.51 |

## Conclusions

- ✓ SRTM water elevations are useful inputs for regional flow models in shallow aquifer systems.
- ✓ Elevation error from SRTM can influence parameter estimation and head predictions from these models.
- ✓ Radar backscatter is useful for classifying the surface water type and, therefore, constraining head error.
- ✓ This work is preliminary, simulation and remote sensing efforts are ongoing.

## References

Fredrick, K., S. Mattot, M.W. Becker, Calibration of the Geometry of Hydraulic Conductivity Zones in Groundwater Flow Models, Eos Trans. AGU, 85(47), Fall Meet. Suppl., Abstract H11C-0318, 2005.

Haitjema, H.M., *Analytic element modeling of ground water flow*, 394 pp., Academic Press, 1995.

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