Estimating Evapotranspiration at the Regional Scale: a Remote Sensing Analysis of Improvements and Possibilities Afforded by Landsat 8

A.V. Johnson, P. C. Stoy, E. Harris, S. A. Ewing, W. A. Sigler

Dept. of Land Resources and Environmental Sciences, Montana State University, Bozeman, MT

2012-13 Institute on Ecosystems Graduate Fellow

Contact: Johnson.aiden@ymail.com

Introduction

Accurate measurements or estimates of evapotranspiration (ET) are critical for water resource management, especially in areas of water limitation. ET is controlled by several factors that include leaf and canopy conductance to water, plant and surface available water, and available energy. These controls are dynamic across space and time, and integrating plot-scale measurements from eddy covariance or similar measurement systems across landscapes in a cogent way is not a trivial task. Remotely sensed data provides the spatial extent with which to bridge spot measurements to the regional scale of interest. Here we compare estimates of ET factors generated from Landsat ETM and Landsat 8 over a region dominated by dryland wheat production in the Judith River Watershed of central Montana.

Motivation

In an era of increased anthropogenic demand for water, we must manage resources in the most efficient manner. Efficient management requires improved understanding of the observed changes in global hydrologic cycle at the regional scale. Quantifying ET through an energy balance approach using Landsat satellite data provides the regional scale information which is actionable for resource managers and informative to scientists.

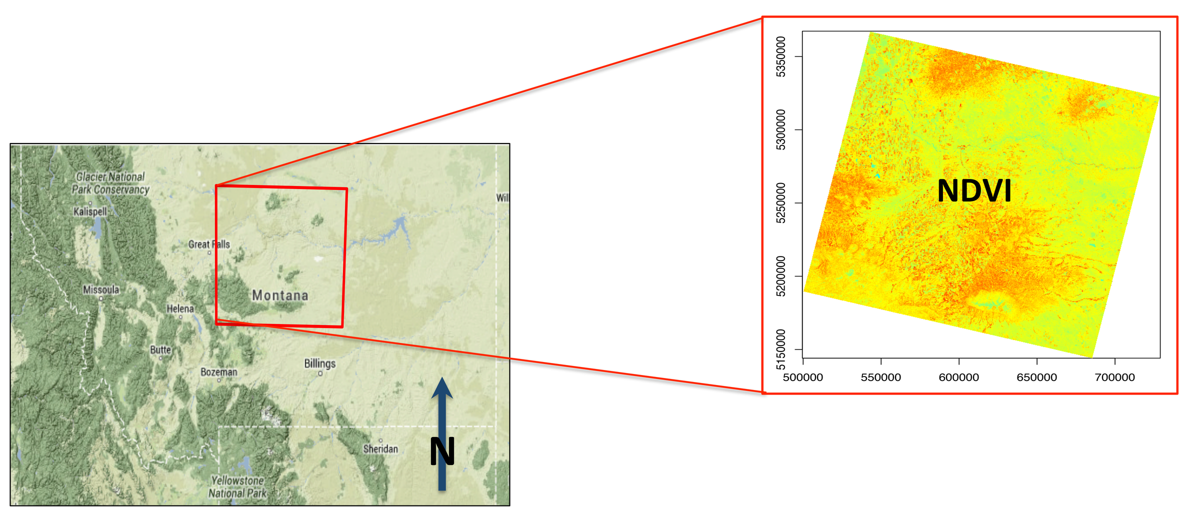


Figure 1. Outline of Landsat scene that makes up study region within Montana

Methods

The location of our study is in central Montana in Judith River Watershed, figure 1. is the location of our study site within the state. The regional extent is 185Km x 176 Km, defined by a single Landsat scene. In order to compare the improvements of the latest Landsat 8 satellite on the previous Landsat ETM data, we downloaded three scenes from each satellite. The data are then preprocessed to apply radiometric and atmospheric corrections. Data derivatives to inform ET factors are then developed from the preprocessed satellite data, figure 2 below shows the steps required. Ultimately, we are working towards a parsimonious method for ET estimation from Landsat data.

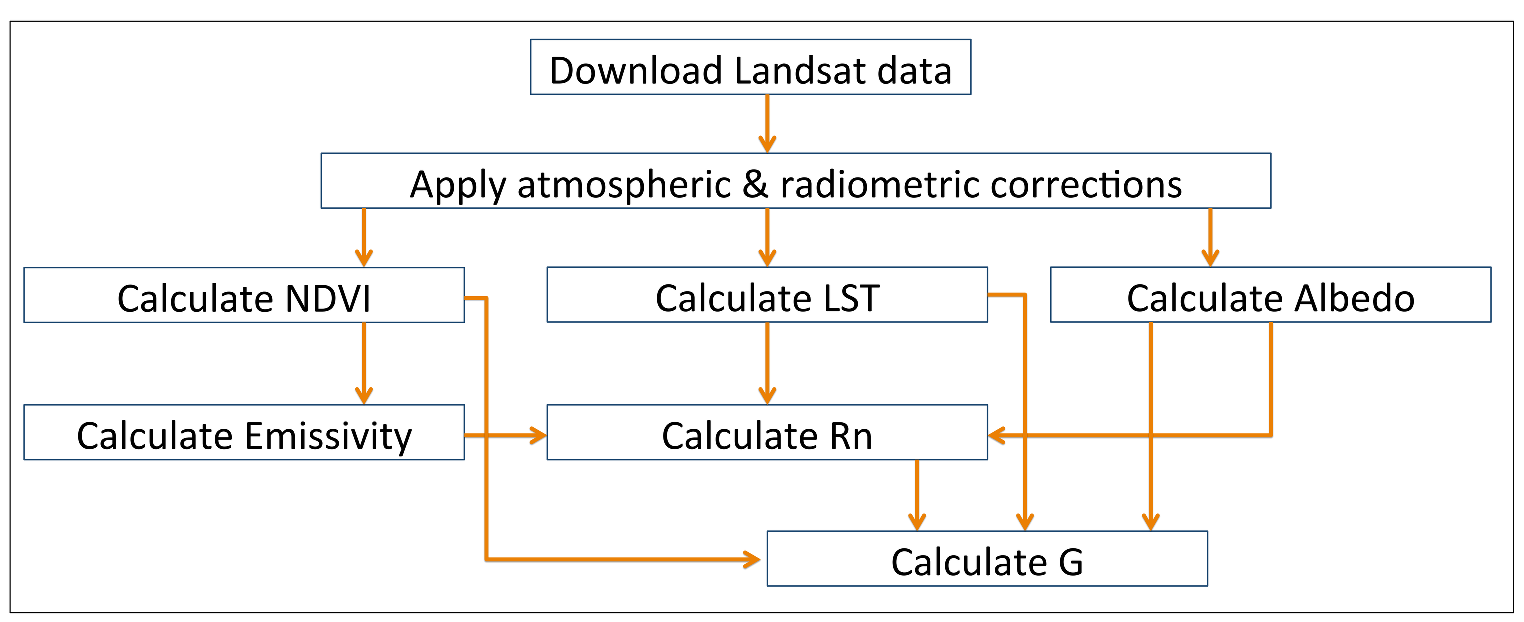
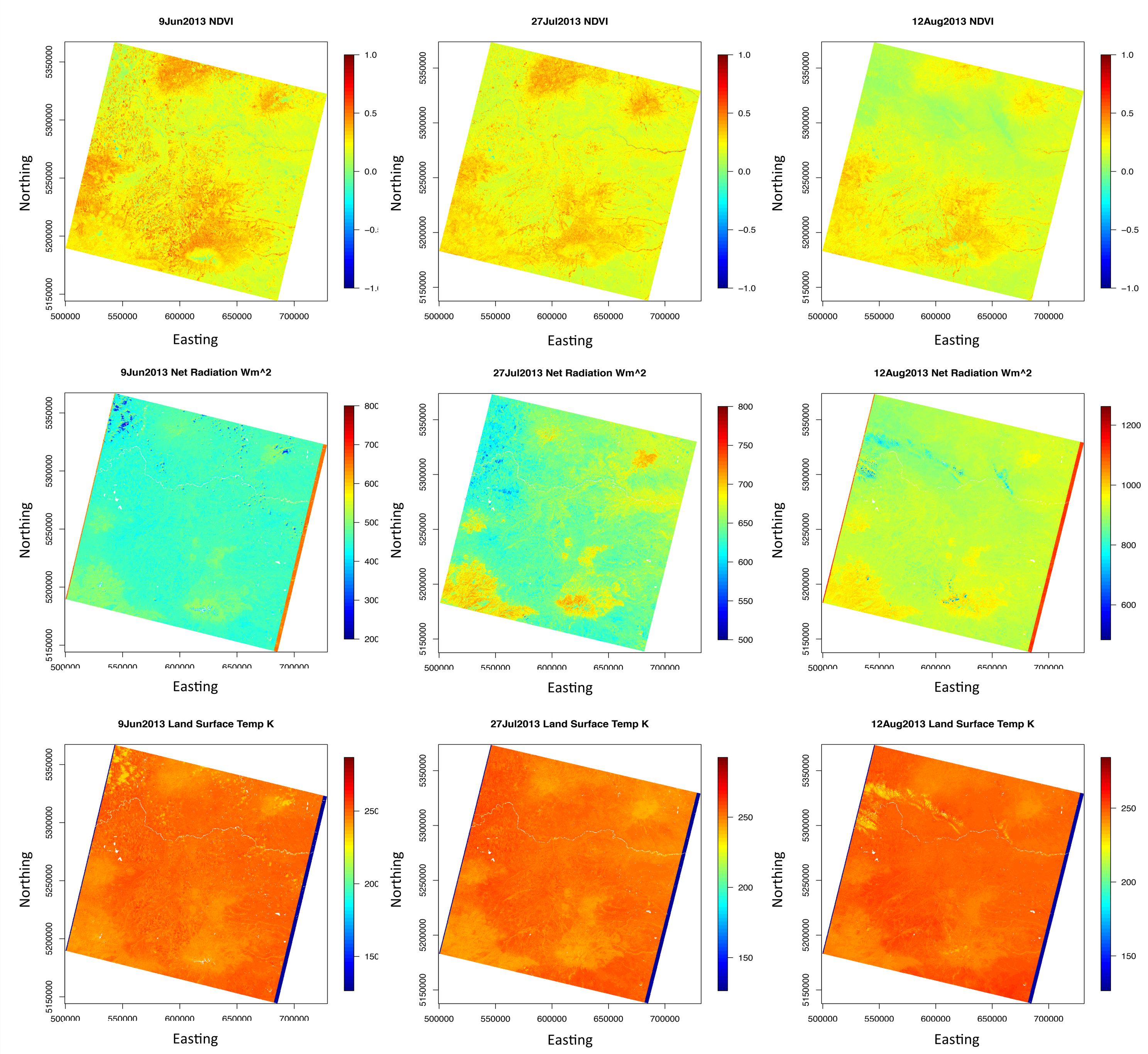


Figure 2. Flow chart of Landsat data processing

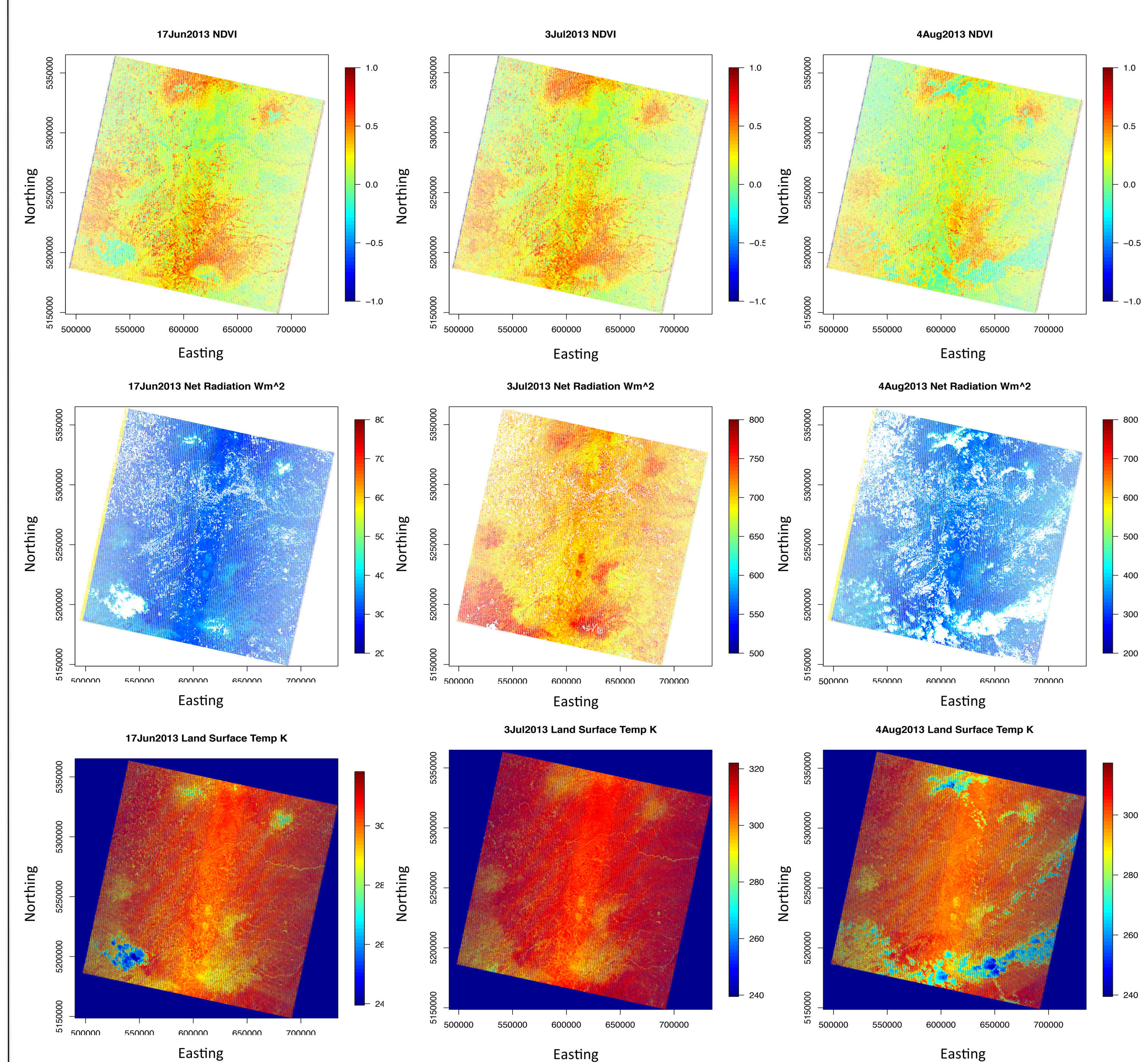
Data Descriptions

NDVI = Normalized Difference Vegetation Index (-1:1)
Emissivity = ability of a surface to emit energy by radiation
LST = land surface temperature (degrees Kelvin)
Albedo = proportion of incident radiation reflected by a surface (0-1)
Rn = Net radiation (Watts per meter squared)

Landsat 8 summer 2013 data



Landsat ETM summer 2013 data



Acknowledgements

This material is based on work supported by the National Science Foundation under Grant EPS-1101342. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Evapotranspiration (ET); An Energy balance Approach

$$Rn = LE + H + G$$

Rn = Total Incoming Radiation
LE = Latent Heat (ET)
H = Sensible Heat
G = Soil Heat Flux

ET can be quantified as a the latent heat of vaporization (LE); the amount of energy required to convert a given quantity of water to a gas. Therefore using an energy balance approach we can estimate ET .

Accuracy of ET Attributes

We evaluated the uncertainties associated with generating albedo from Landsat ETM data. There are two primary sources of uncertainty in the albedo product generated from Landsat: uncertainty associated with coefficients assigned to Landsat bands for generating albedo; uncertainty in the raw digital remote sensing values. We employed a Monte Carlo method of random parameter generation and implementation of these coefficients to characterize changes to and uncertainty in Landsat albedo. The motivation for the uncertainty analysis is to accurately quantify significant changes to land surface properties over time accurately. Results presented in figure 3 below indicate that the overall variability in the albedo layer is not strongly impacted by the coefficients applied to the Landsat data bands, and is more affected by the variance within the Landsat data themselves. Specifically in bands 4 and 5 which are predominantly used to develop the NDVI and quantify vegetative cover.

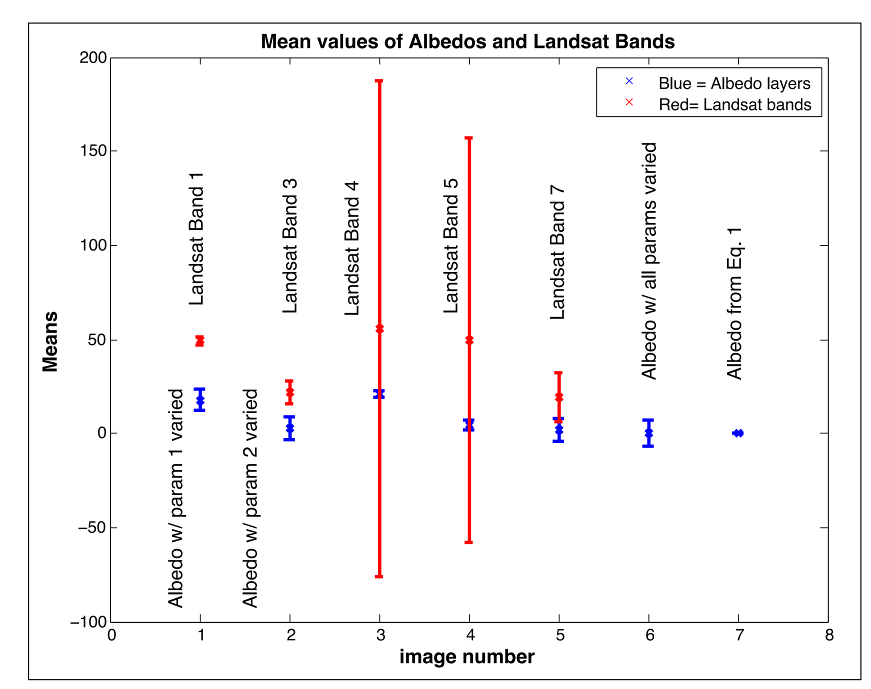


Figure 3. Mean and variances of Landsat bands and albedos generated with varying parameters.

Discussion and future work

Remote sensing-based observations of ET will be used to improve understanding of the role of surface-atmosphere water flux in local, regional and global water cycling. We have found increased radiometric accuracy of Landsat 8 remote sensing data improves our remotely sensed ET observations. The utility of a Landsat derived ET product is immense and will inform resource management decisions in part mitigating the increased resource demands. Research in resource management efficiency is necessary in an era of climate change and unparalleled anthropogenic resource demands.
Future analysis will include an additional Monte Carlo uncertainty analysis of Landsat 8 data. Methods for estimating soil heat flux (G) has successfully been applied, but latent and sensible heat flux are remaining challenges. Applying adjustments from in situ Eddy Covariance data to improve estimates and scale down is also of interest.