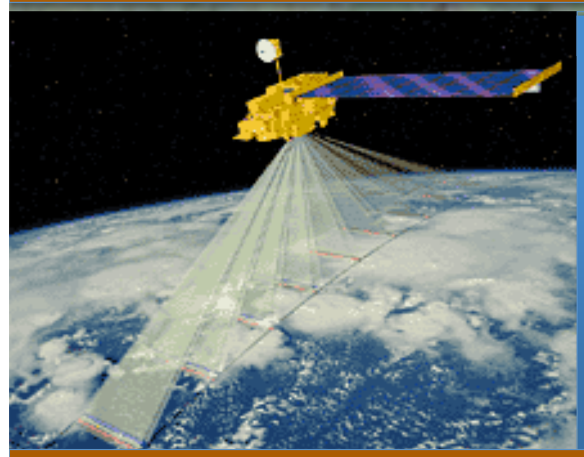
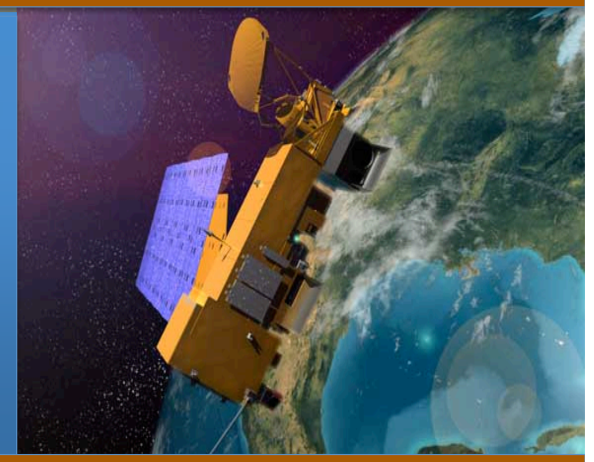


Remote Sensing of River Sediment Concentration Using MODIS Aqua 250m Land Bands



Susan Phan, Ajit Subramaniam

INTRODUCTION

With daily, near-global coverage dating back to 2002, high resolution (250m) images from the MODIS Aqua satellite have the potential to become a useful tool in studying long-term trends in the sediment load of rivers around the world. Satellite imagery's ability to capture simultaneous information over a large area every day makes it a low-cost compliment to field data. However, atmospheric interference from clouds and aerosols, land adjacency effects, and oblique sun and view angles often reduce the quality of water-leaving reflectance signal reaching the satellite sensor, resulting in very noisy data. The goal of this project is to develop universally-applicable numerical criteria to filter out flawed satellite pixels in order to construct a time series to study long-term trends in river sediment concentration.

IMPORTANCE OF RIVERS' SEDIMENT LOAD

- Hydrological: sediments stabilize the shoreline, maintain wetlands, and protect against storm surges
- Biological: components of sediment load such as silica and particulate organic matter provide nutrients for phytoplankton and other microorganisms that form the base of the food chain
- Chemical: monitoring turbidity to help track certain contaminants in the river
- Economic: estimating the rates at which dams and harbors accumulate sediment

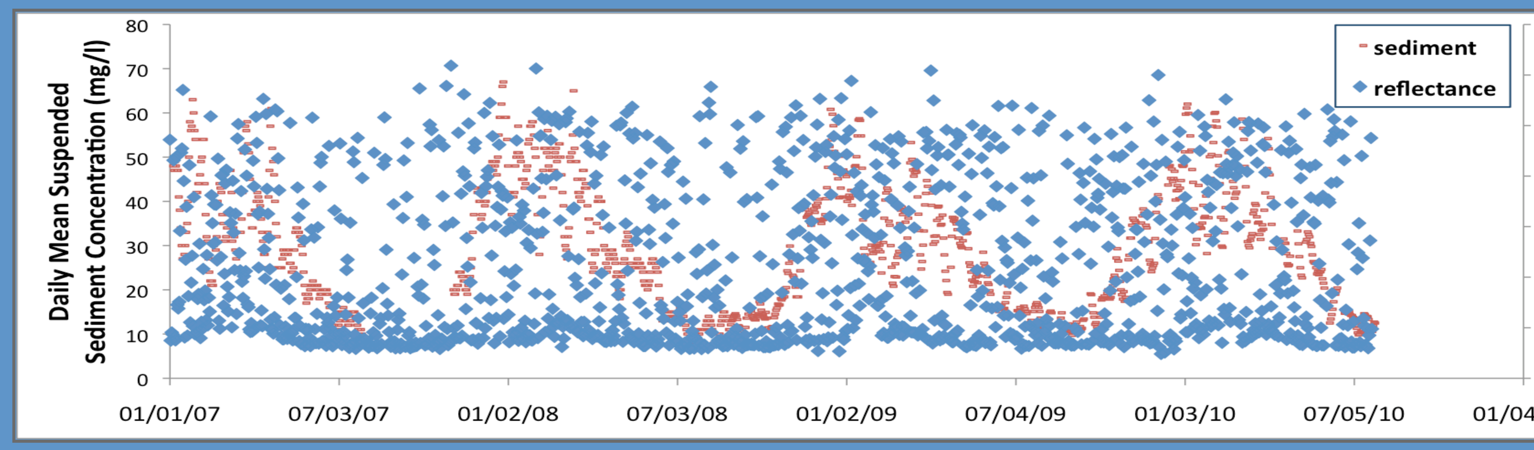


Fig. 1a: Time series of band 1 reflectance values of daily satellite images from January 2007 to July 2010 and daily mean suspended sediment concentration measured at a USGS station 2.3 miles south of Poughkeepsie, NY

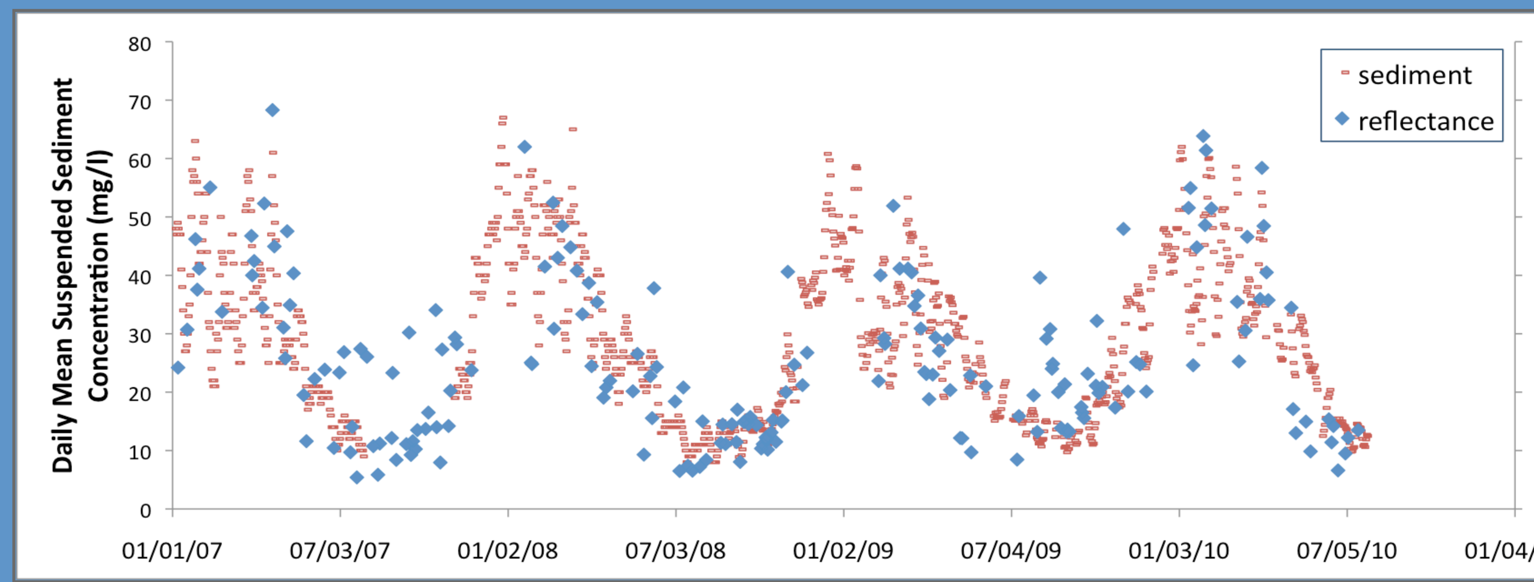


Fig. 1b: Band 1 reflectance values and sediment concentration over the same time period as above, after numerical filters have been applied to remove pixels that did not meet all the selection criteria

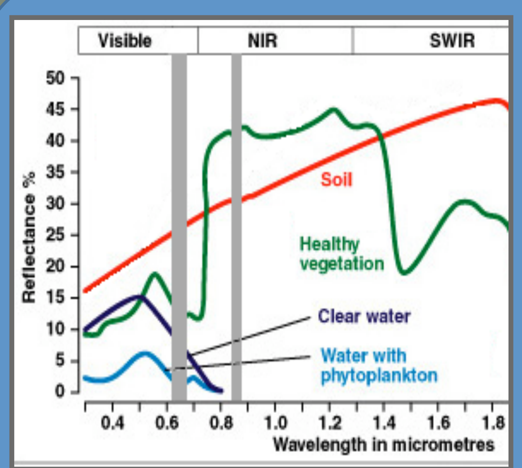


Fig. 2: Reflectance spectra of different surfaces (RSAC)

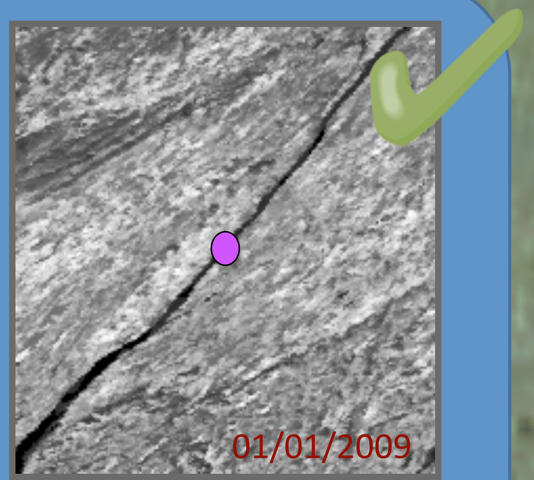


Fig. 4a: Clear view of the Hudson at Poughkeepsie

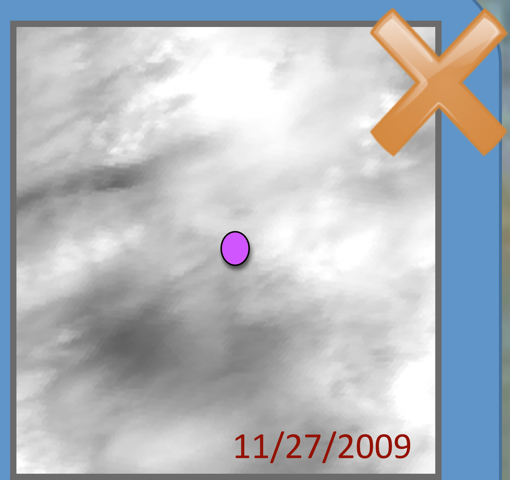


Fig. 4c: Area completely obscured by clouds

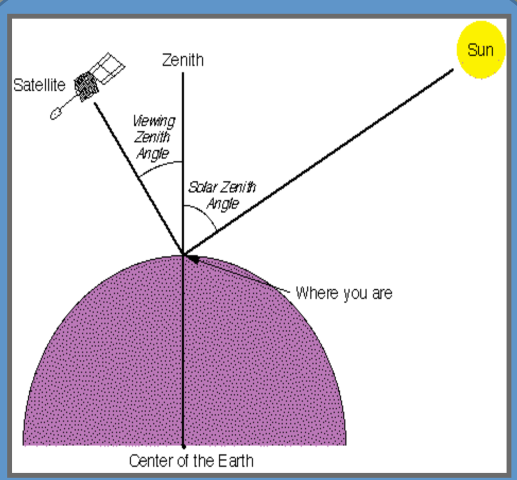


Fig. 3: Solar zenith and satellite zenith angles (NASA)

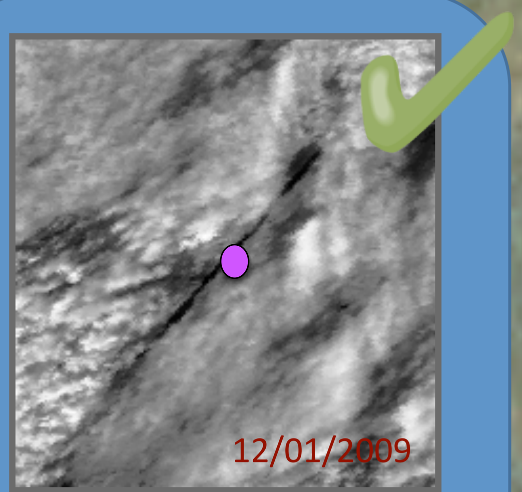


Fig. 4b: Clouds over region, but clear over site

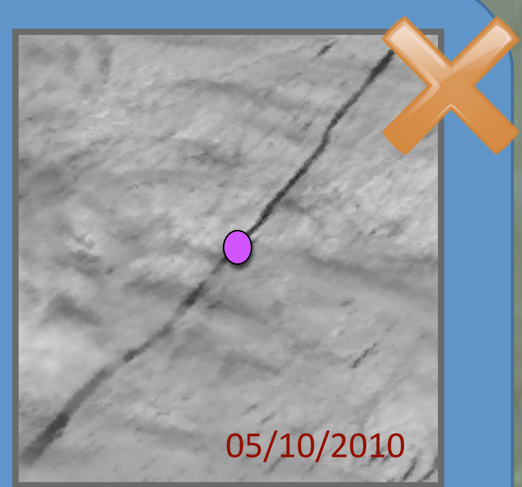


Fig. 4d: Thin wispy clouds over site

PIXEL SELECTION CRITERIA

- 0 < Band 2 (841-876 nm) Reflectance < 1% --- We observed that river pixels with Band 2 values greater than 1% are almost always cloudy pixels or otherwise contaminated by signal from land
- Satellite zenith angle (view angle) < 45° --- At high view angles, off-nadir pixel geometry is distorted and light signal has to travel longer distances through the atmosphere before reaching the satellite
- Solar zenith angle < 65° --- Oblique sun angles reduce solar irradiance on the Earth's surface, reducing the amount of light scattered back to the satellite
- Adjacent pixels in cluster have correlation > 0.9 --- This filter avoids using land-contaminated pixels: important in a narrow river like the Hudson
- More than 50% of pixels in cluster pass the above 4 tests --- This filter avoids high variability from subpixel contamination due to clouds, land, etc.

REMOTE SENSING SEDIMENT: HOW IT WORKS

- The MODIS Aqua sensor captures images at 250m resolution for two spectral bands, which are highlighted in gray in Fig. 1: Band 1 (red) at 620-670 nm, and Band 2 (near-infrared) at 841-876 nm.

- In the red and near-infrared range, pure water is highly absorbing and less reflective, while sediment particles scatter light and are much more reflective (Fig. 2), so we expect the reflectance signal in these bands to contain information about the amount of sediment in the water column.

- Sources of noise in satellite data: atmospheric interference - over 90% of the signal that the satellite receives come from the atmosphere and not from water at the surface; land adjacency effect – near-shore river pixels are often contaminated by signal from ground and vegetation on the banks; oblique satellite zenith angles and solar zenith angles distort pixel geometry and reduce the amount of light reaching the sensor (Fig. 3).

- Due to all this noise, plotting Band 1 reflectance values of a specific river location of all daily satellite images over 4 years yields no coherent trend (Fig. 1a). In this project, numerical selection criteria were developed to discard noisy pixels from the time series (Fig. 1b). For example, a pixel with Band 2 reflectance greater than 1% was filtered out for clouds: the pixel of interest in Fig. 4a and 4b passed this "cloud threshold," while the pixel in Fig. 4c and 4d did not.

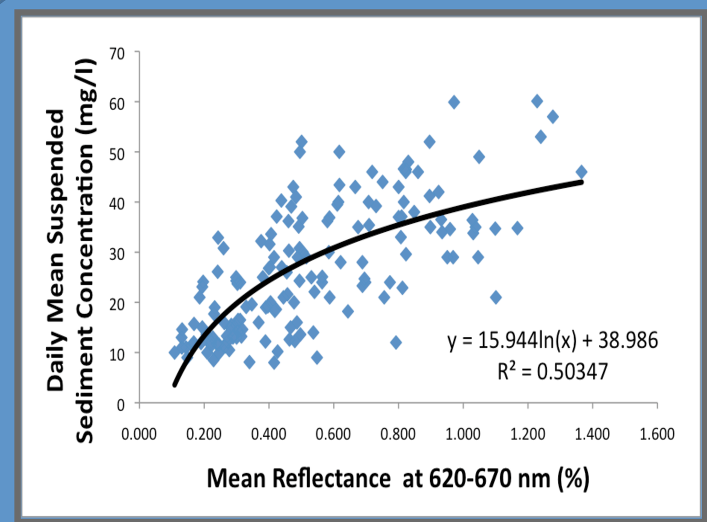


Fig. 5a: Daily mean sediment concentration measured in-situ vs. mean band 1 reflectance of cluster of pixels corresponding to sampling site: 2007-2009

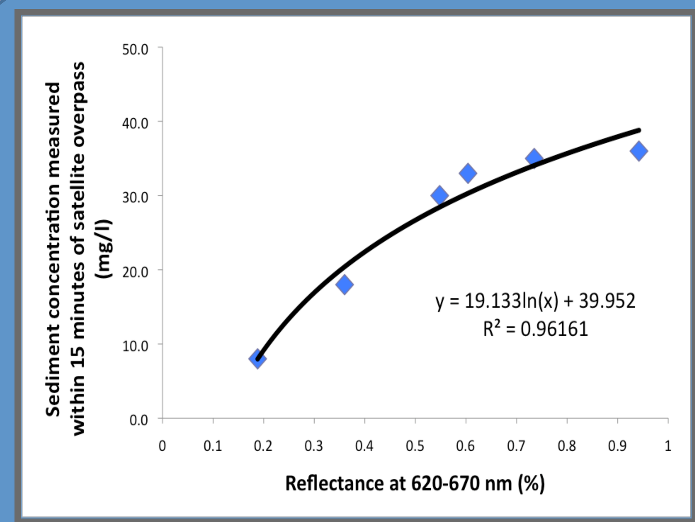


Fig. 5b: Sediment concentration measured within 15 minutes of satellite overpass vs. band 1 reflectance of pixel corresponding to sampling site: Mar – July 2010

FUTURE DIRECTION

- Test selection criteria in other locations on the Hudson as well as other rivers around the world.
- Construct time series at these locations

REFERENCES

Doxaran, D., J. Froidefond, P. Castaing, and M. Babin (2009). Dynamics of the turbidity maximum zone in a macrotidal estuary (the Gironde, France): Observations from field and MODIS satellite data. Estuarine, Coastal and Shelf Science **81** 321-332.

Martinez, J.M., J.L. Guyot, N. Filizola, and F. Sondag (2009). Increase in suspended sediment discharge of the Amazon River assessed by monitoring network and satellite data. Catena **79** 257-264.

Miller, R.A. and B.A. McKee (2004). Using MODIS Terra 250 imagery to map concentrations of total suspended matter in coastal waters. Remote Sensing of Environment **93** 259-266.

Seelye, M. An Introduction to Ocean Remote Sensing. Cambridge University Press: Cambridge, 2004.

Wang, M. (2006). Effects of ocean surface reflectance variation with solar elevation on normalized water-leaving radiance. Applied Optics. **45** (17) 4122-4129.