

# Importing satellite imagery into R from NASA and the U.S. Geological Survey

Matt Moores



Warwick R Users' Group  
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# Outline

- 1 Introduction
- 2 Case Studies
  - Chlorophyll-*a* (MODIS)
  - Land Use Classification
  - Vegetation Index (Landsat 8)

# Satellite Remote Sensing

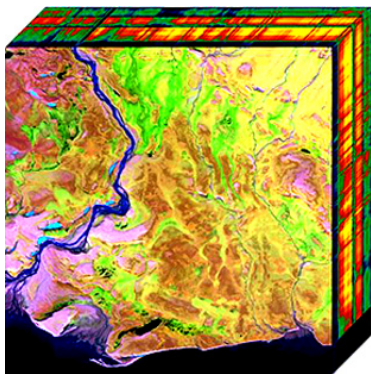
Many applications:

- Environmental monitoring
  - Land use (plant biomass)
  - Water quality (chlorophyll *a*)
  - Total column ozone
- Agriculture
- Economic development

Much of this data is available in the public domain

- First Landsat satellite launched in 1972
- Landsat 8 launched in February 2013
- Landsat 5 decommissioned in June 2013

# Multivariate Spatial Observations



Satellite	Pixel Width	Spectral Bands
Landsat 8	30m	9+2
MODIS Aqua/Terra	500m	36
EO-1 Hyperion	30m	220
ESA Sentinel	10m	12

# R Packages

`raster` : read GeoTIFF and other file formats

`rasterVis` : plotting spatial objects (lattice graphics)

`sp` : S4 classes `SpatialPoints`, etc.

`rgdal` : transform between coordinate systems  
(R interface to GDAL & PROJ.4)

`RStoolbox` : read meta-data for Landsat

`MODIS` : download and process MODIS images

`maps` : vector shapefiles

`mapdata` : larger and/or higher-resolution shapefiles

`ggmap` : access to Google Maps, OpenStreetMap, etc.

# Statistical Modelling

**INLA** : Gaussian Markov random fields (MRF)

<http://r-inla.org>

**bayesImageS** : pixel classification using discrete MRF  
(Ising/Potts)

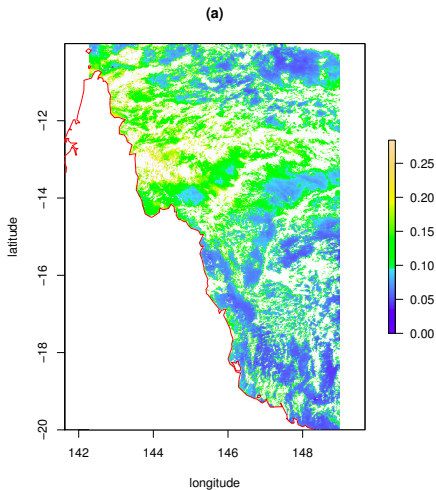
<https://CRAN.R-project.org/package=bayesImageS>

**PySSM** : dynamic state space models

<https://bitbucket.org/christophermarkstrickland/pyssm>

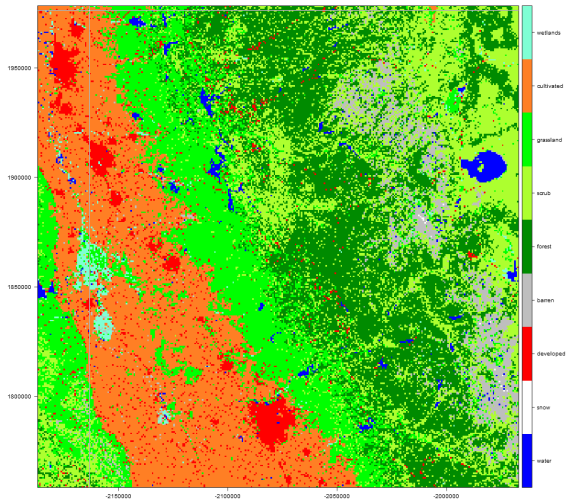
# MODIS Ocean Colour

Concentration of chlorophyll *a* (mg/m<sup>3</sup>):



# Land Use Classification

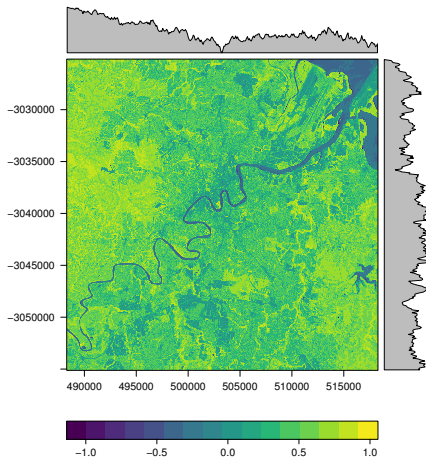
National Land Cover Database (NLCD):





# Landsat 8 Surface Reflectance

Normalised difference vegetation index (NDVI):



# For Further Reading I



M. Moores, A. N. Pettitt & K. Mengersen

Scalable Bayesian inference for the inverse temperature of a hidden Potts model.

*arXiv:1503.08066 [stat.CO]*, 2015.



M. Moores, C. C. Drovandi, K. Mengersen & C. P. Robert

Pre-processing for approximate Bayesian computation in image analysis.

*Statistics & Computing* **25**(1): 23–33, 2015.



M. Falk, C. Alston, C. McGrory, S. Clifford, E. Heron, D. Leonte, M. Moores, C. Walsh, A.N. Pettitt & K. Mengersen

Recent Bayesian approaches for spatial analysis of 2-D images with application to environmental modelling.

*Envir. Ecol. Stat.* **22**(3): 571–600, 2015.



M. Moores & K. Mengersen

Bayesian approaches to spatial inference: modelling and computational challenges and solutions.

In *Proc. 33<sup>rd</sup> Int. Wkshp MaxEnt*, AIP Conf. Proc. 1636: 112–117, 2014.

## For Further Reading II



H. Rue, S. Martino & N. Chopin

Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations.

*J. R. Stat. Soc. Ser. B* **71**(2): 319–392, 2009.



C. M. Strickland, R. Burdett, K. Mengersen & R. Denham

PySSM: A Python Module for Bayesian Inference of Linear Gaussian State Space Models.

*J. Stat. Soft* **57**(6), 2014.



United States Geological Survey (USGS)

Landsat 8 Data Users Handbook.

Technical Report LSDS-1574, Version 2.0.



Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K.

Completion of the 2011 National Land Cover Database for the conterminous United States – Representing a decade of land cover change information.

*Photogramm. Eng. Remote Sens.* **81**(5): 345–354, 2015.