THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Modelling and remote sensing of lakes Onoke and Wairarapa

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Introduction

Approaches to assess water quality

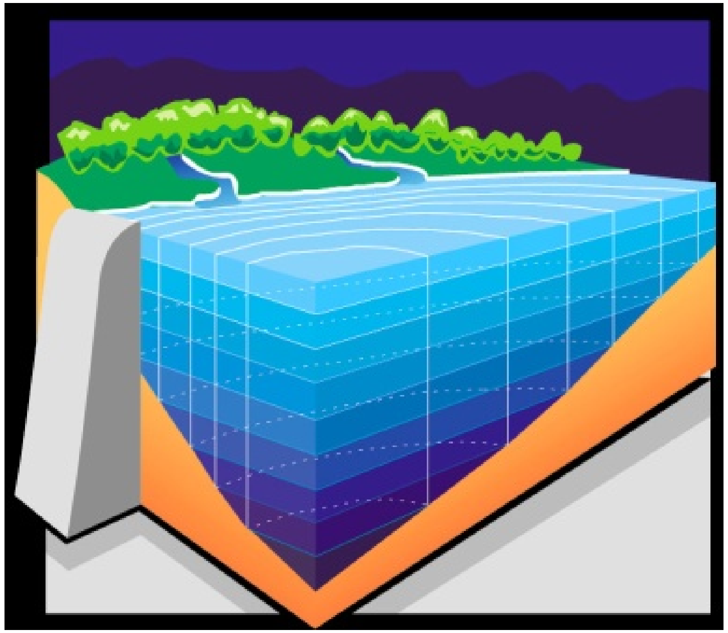
- In situ sampling, numerical modelling and remote sensing
- In situ sampling lacks the ability to effectively monitor the spatial variability
- Three-dimensional (3-D) and one-dimensional (1-D) hydrodynamic modelling of lake water quality and temperature:
  - interpolate temporal gaps in data derived from satellite and traditional monitoring
  - extend the analysis to the vertical domain
  - provide insights into the spatial variability of biogeochemical processes

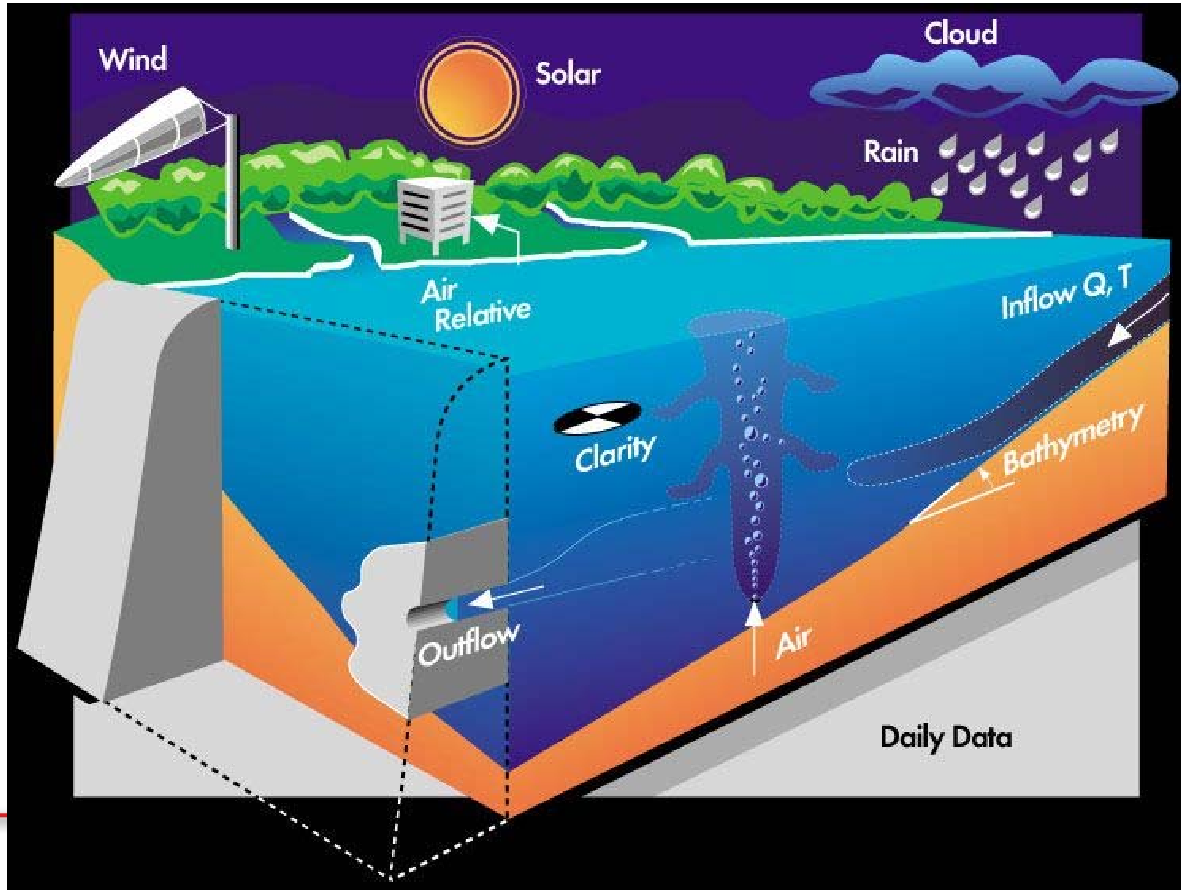
Method: 3-D Numerical Hydrodynamic Model

The Estuary and Lake Computer Model (ELCOM)

CWR Australia

Hydrodynamic and thermodynamic models in order to predict velocity, salinity and temperature in waterbodies





3-D model

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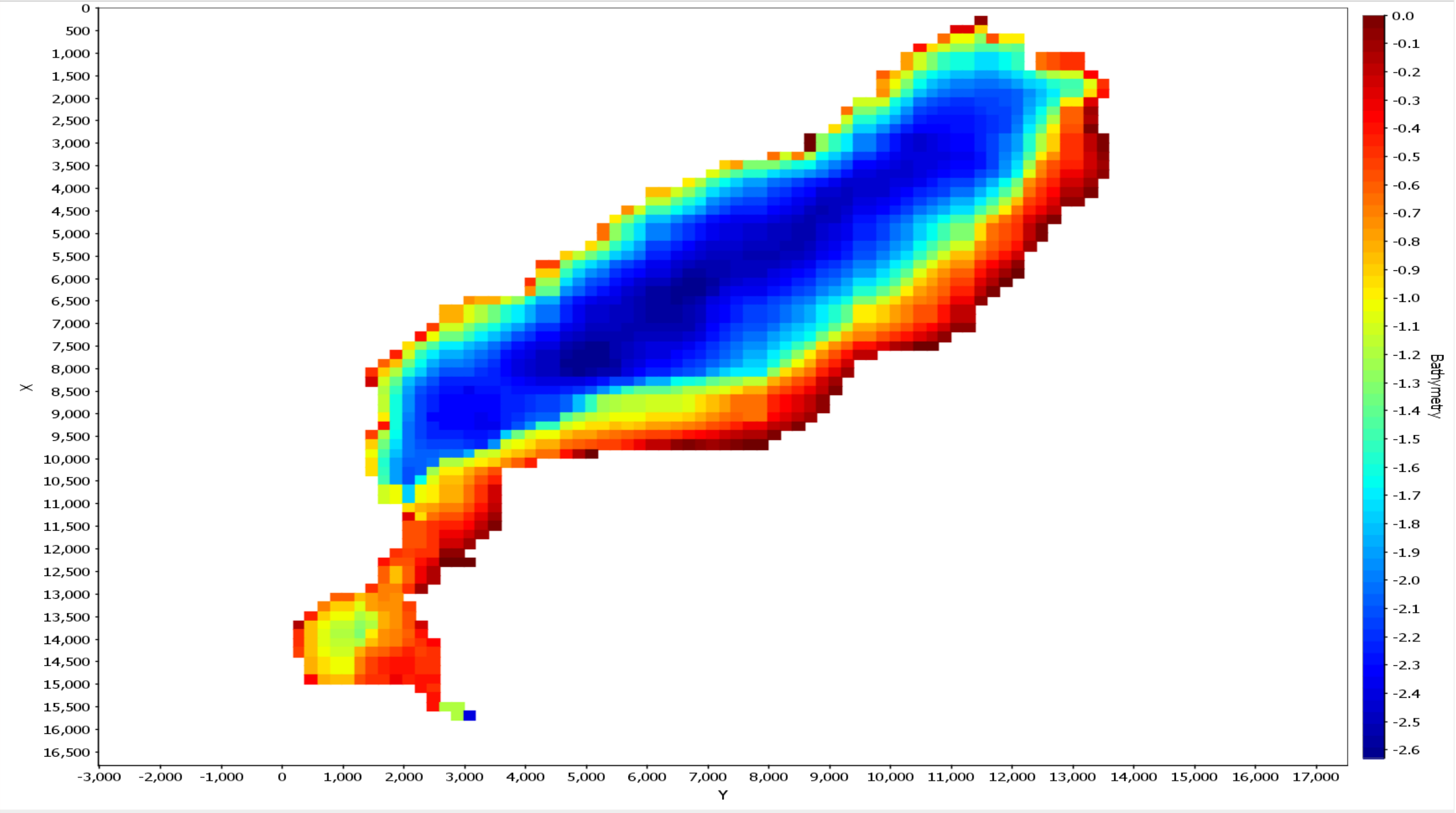

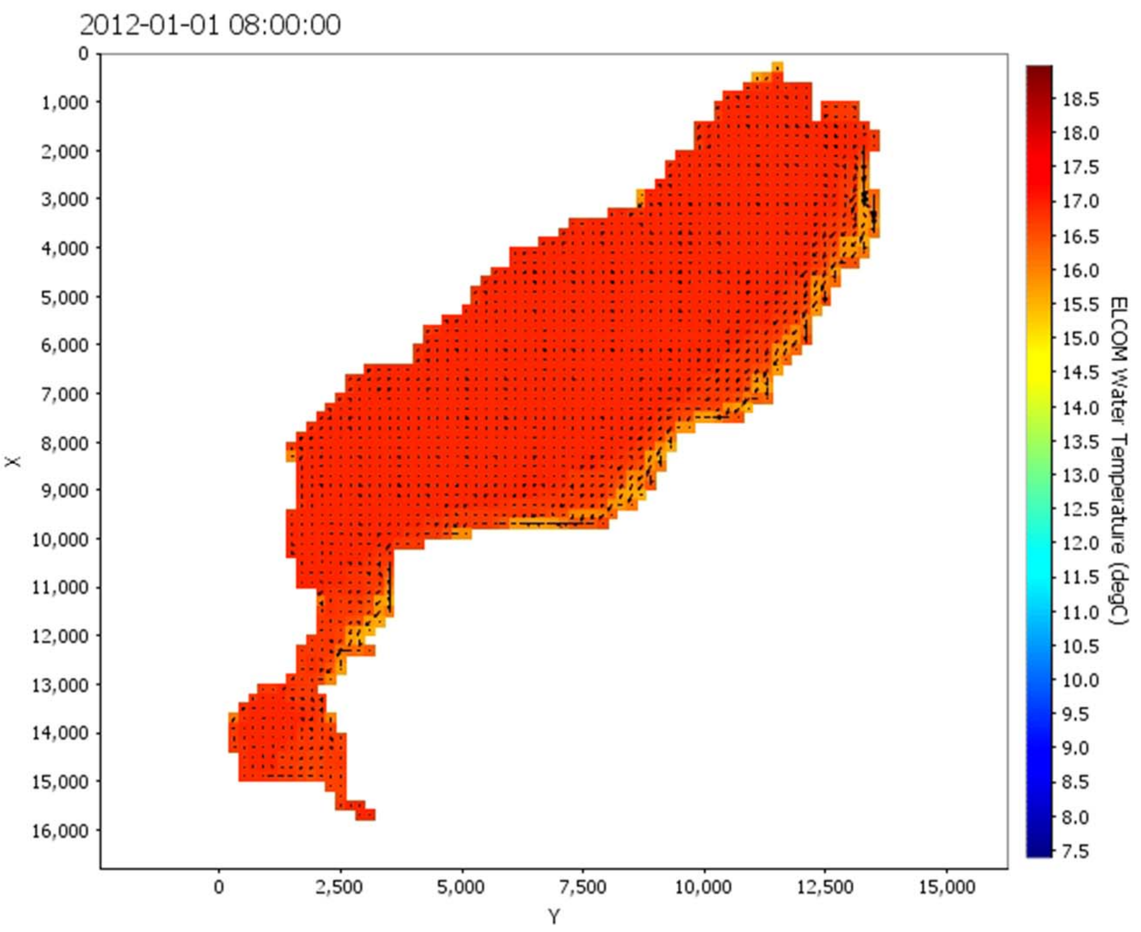
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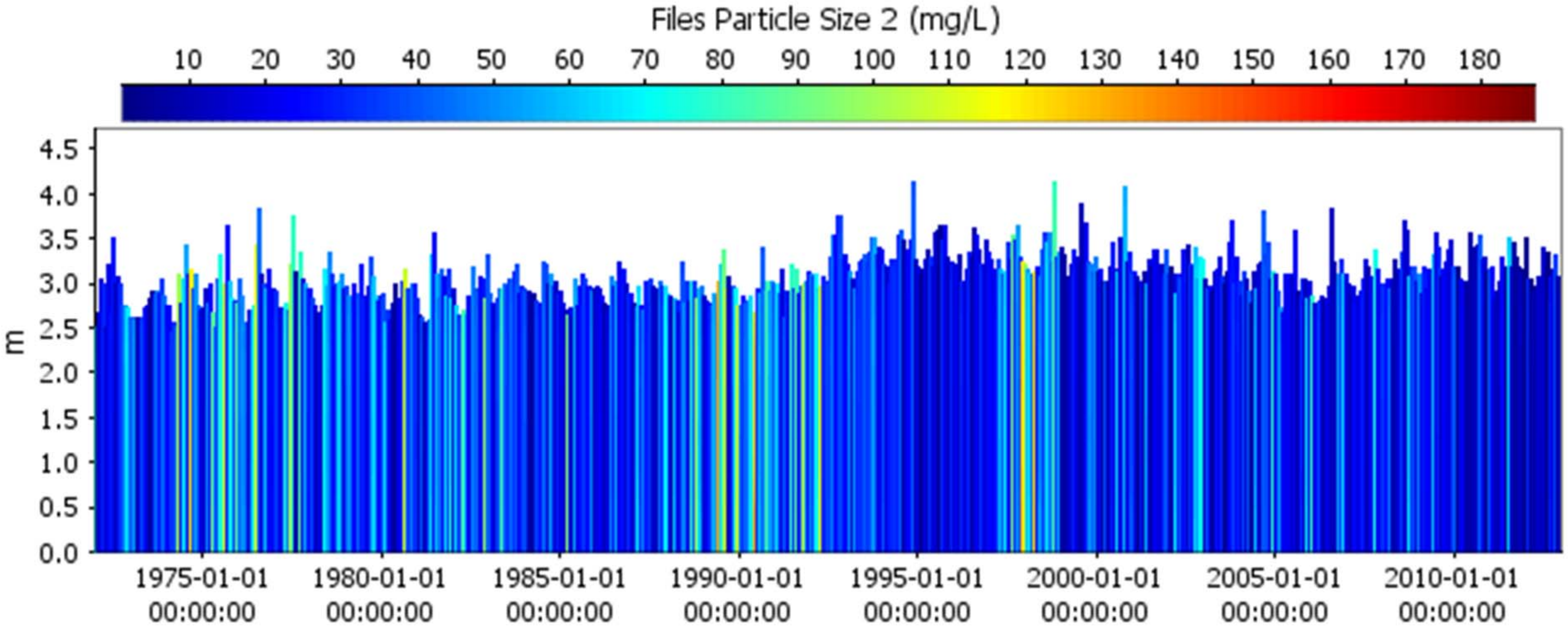
7.5
ELCOM Water Temperature (degC)

1-D model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m
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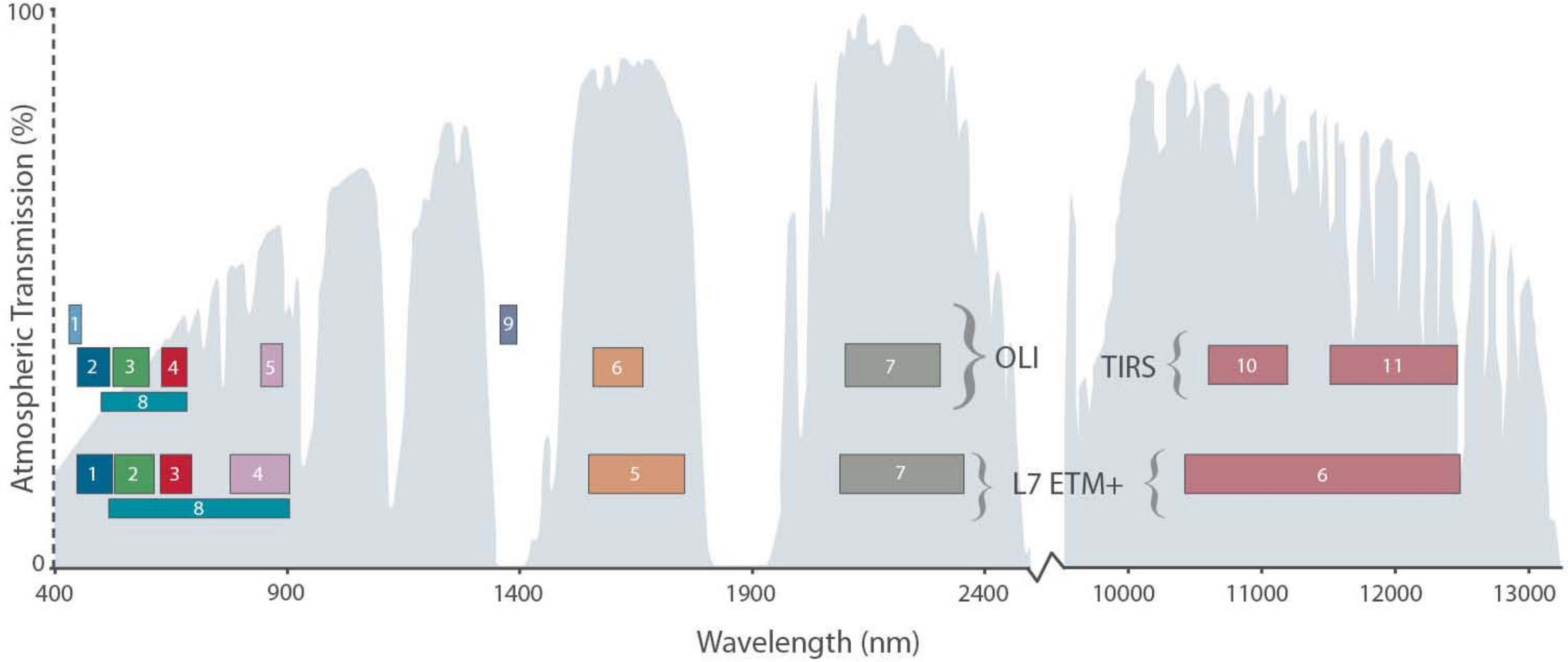
1985-01-01 00:00:00
1990-01-01 00:00:00
1995-01-01 00:00:00
2000-01-01 00:00:00
2005-01-01 00:00:00
2010-01-01 00:00:00

Modelling- future work

- Calibration/validation of 1D and 3-D models using in situ water quality data measured by the Greater Wellington Regional Council and remote sensing data

- Calibrated models will then be used to determine the likely water quality and ecological effects of specific management scenarios

Remote sensing data



United States Geological Survey (USGS) on demand atmospherically corrected Landsat imagery ordered from http://espa.cr.usgs.gov/index/, including 91 images

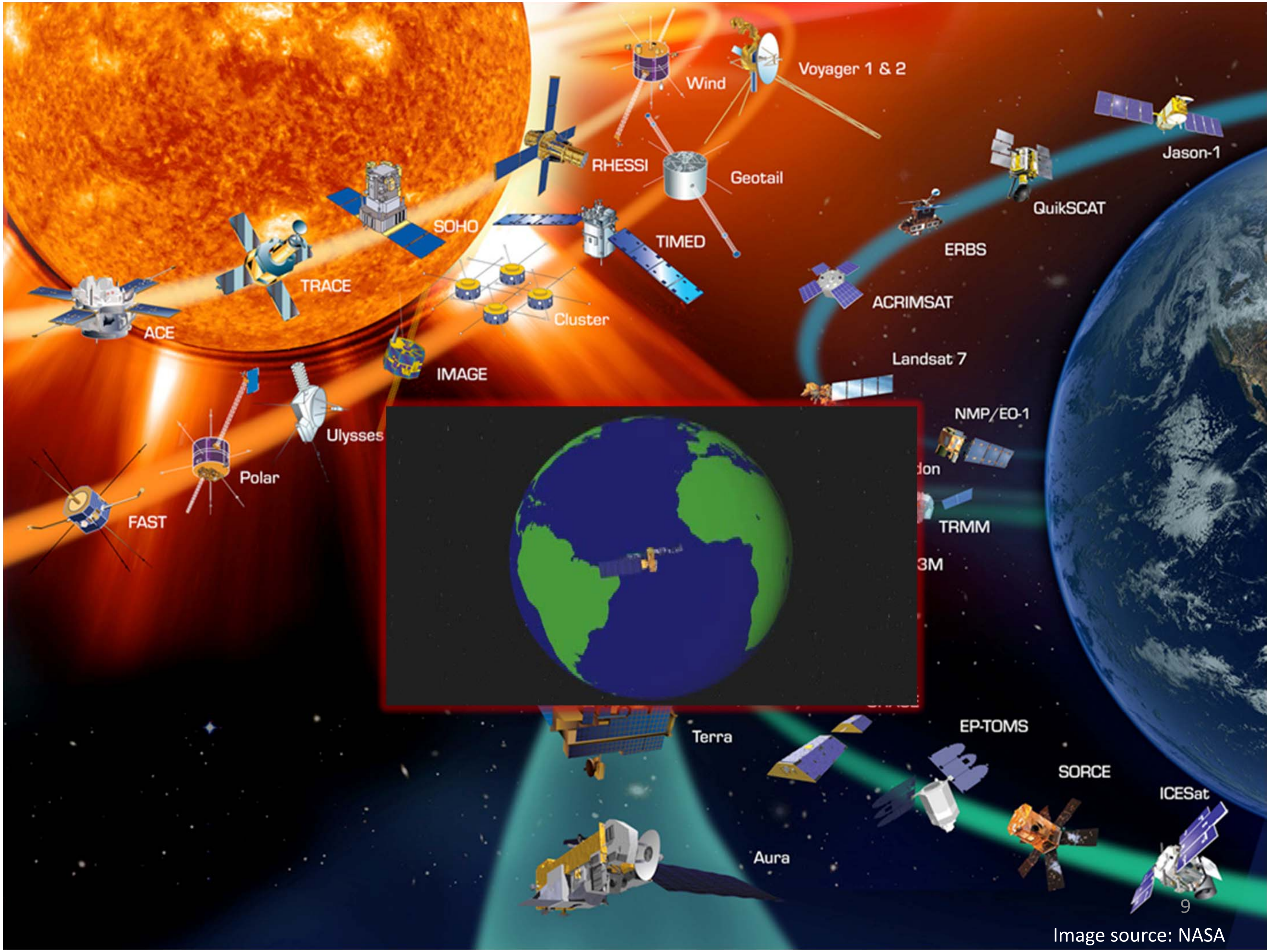


Image source: NASA

Remote sensing semi-analytical model

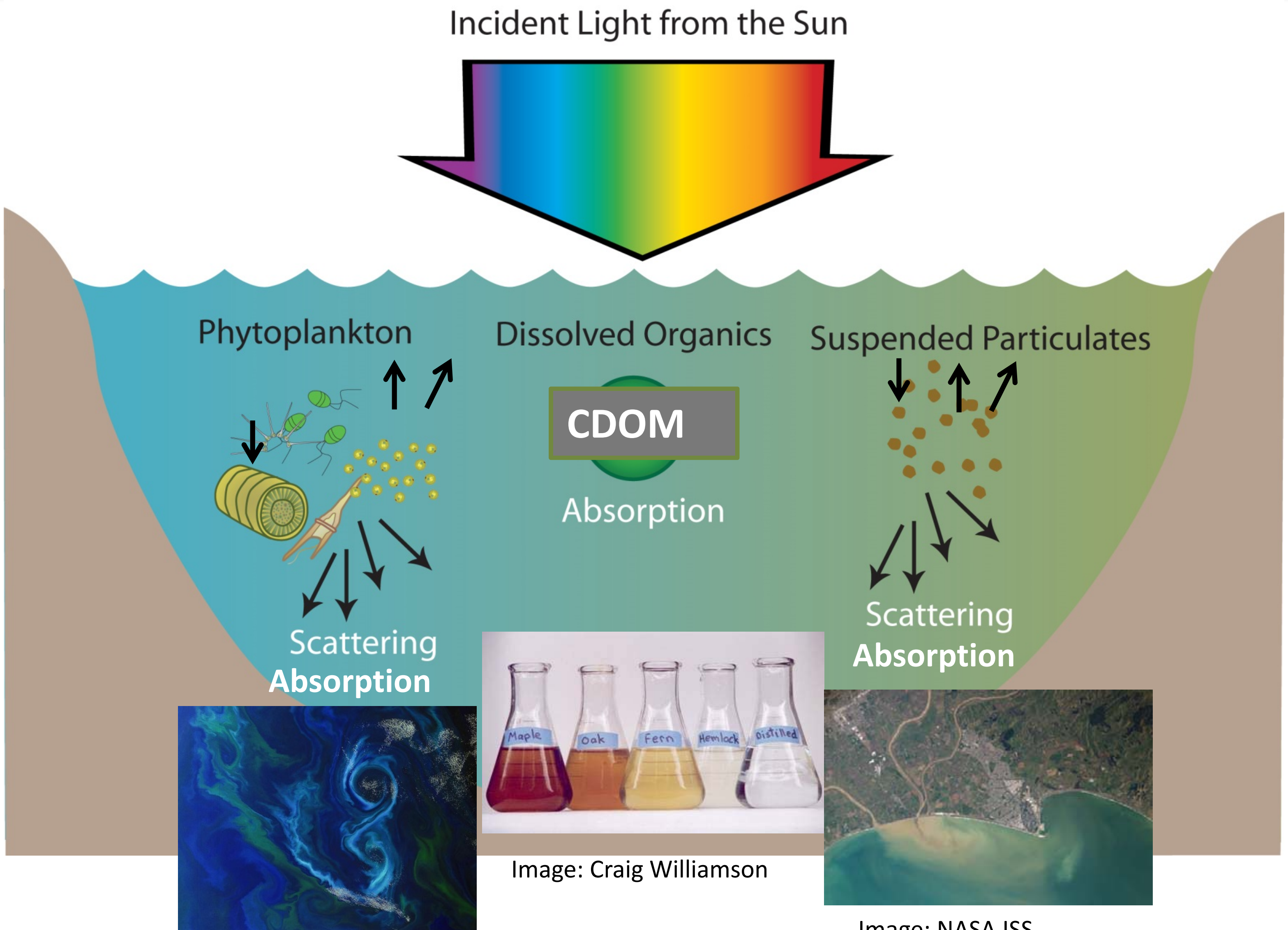


Image: Craig Williamson

Image: NASA ISS

Image: NASA

Remote sensing results

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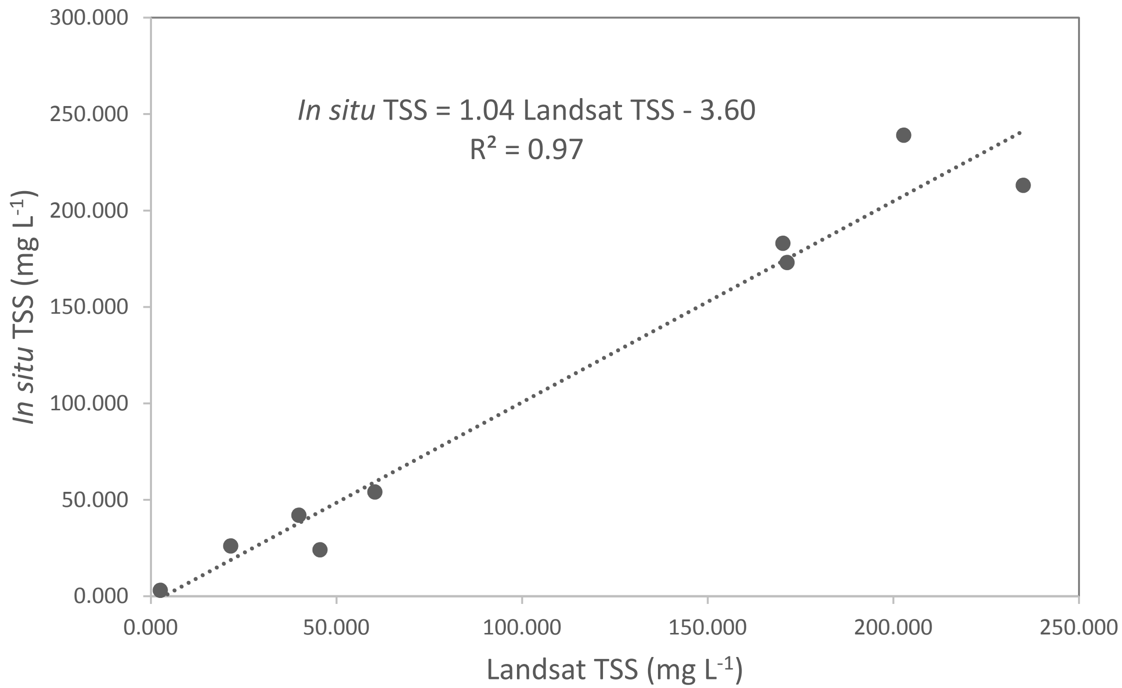


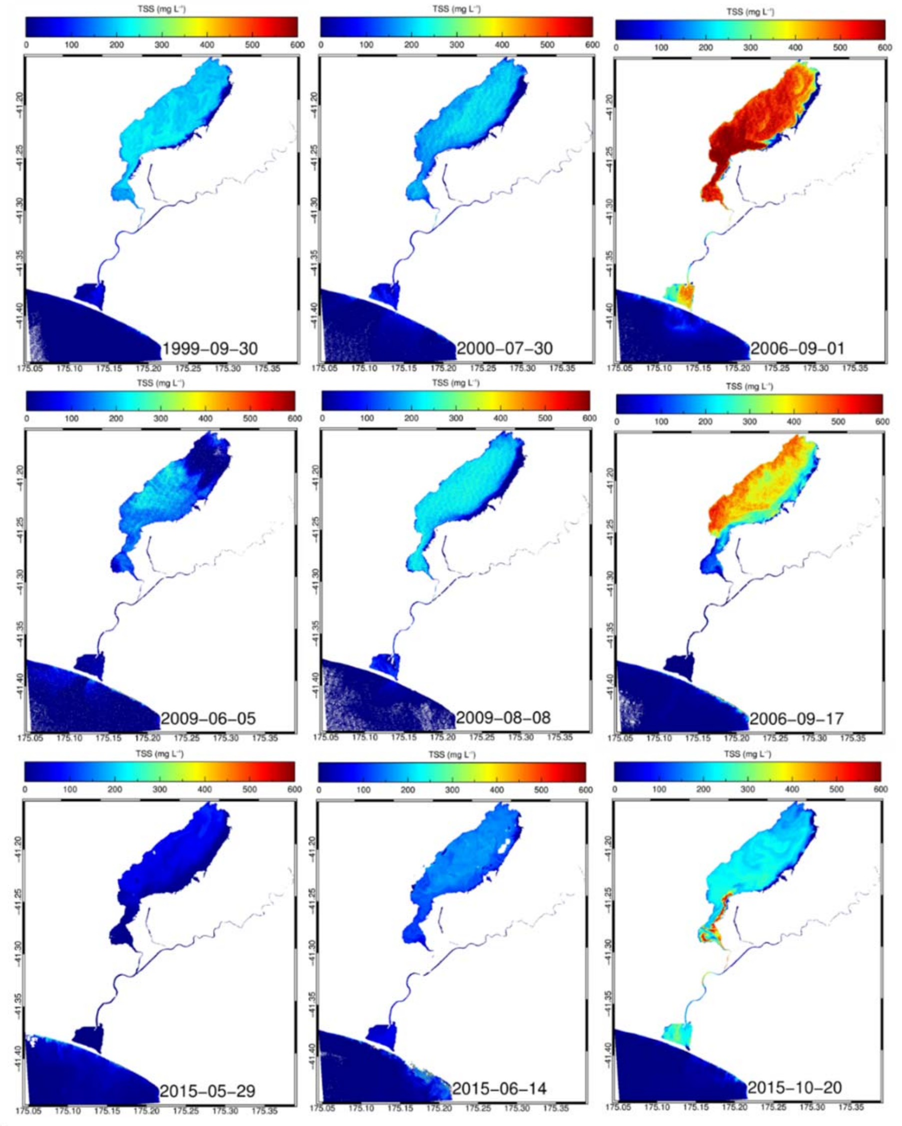
Comparison of *in situ* TSS to Landsat estimated TSS (mg L^{-1}) using a semi-analytical relationship

r^2 of 0.97,

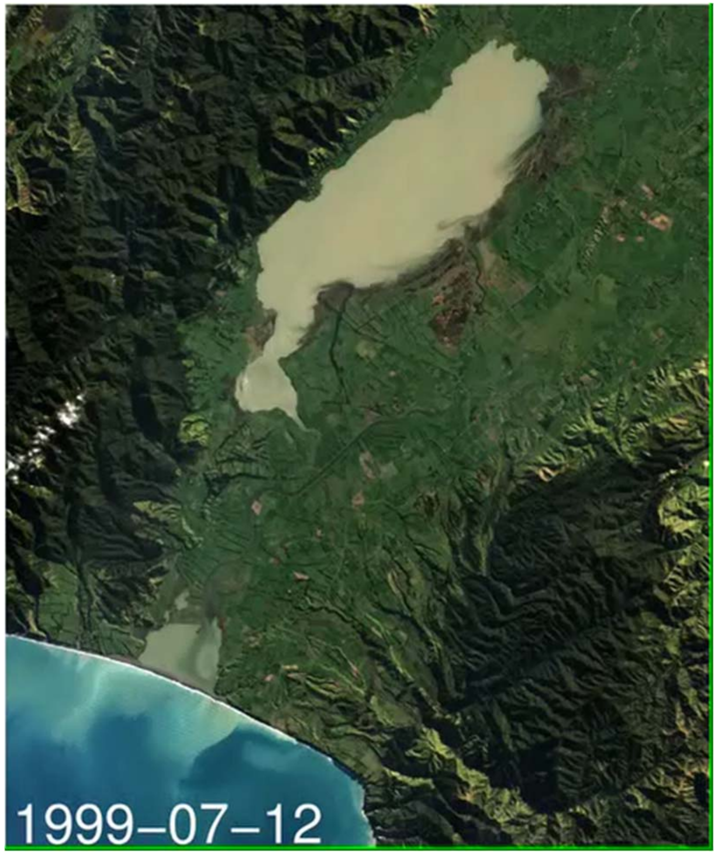
RMSE 16.62 mg L^{-1}

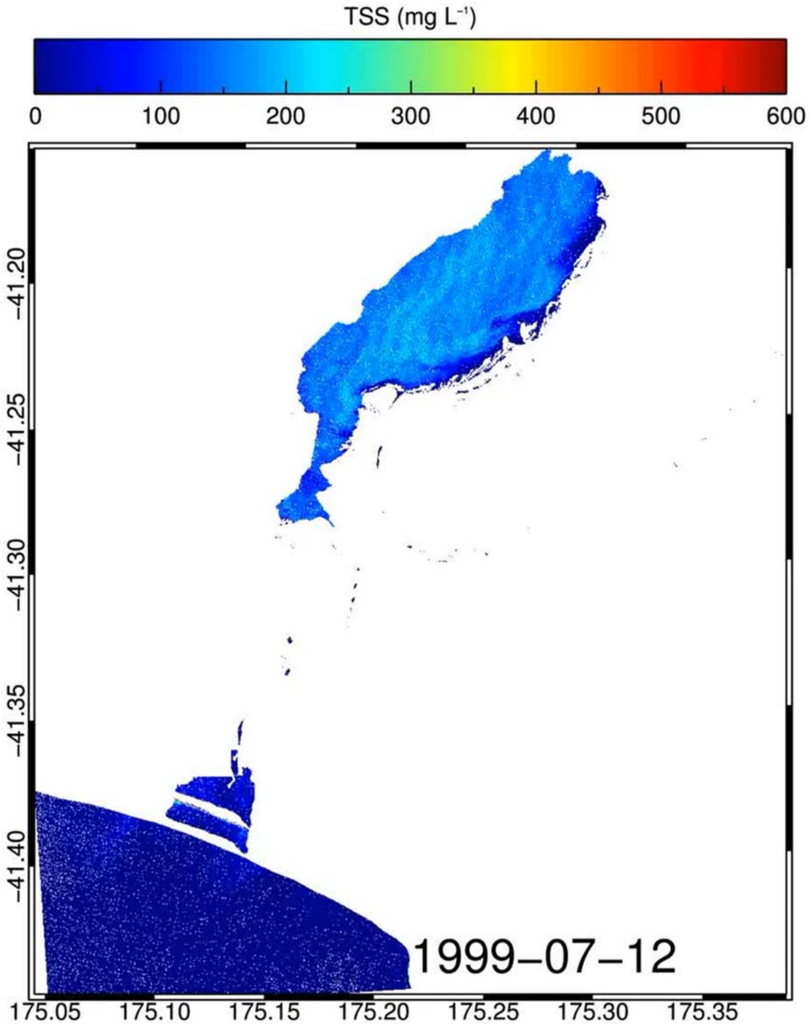
32% RMSE over a range of *in situ* TSS from 3 - 239 mg L^{-1}.

Landsat estimated total suspended solids



Landsat estimated total suspended solids





Acknowledgements

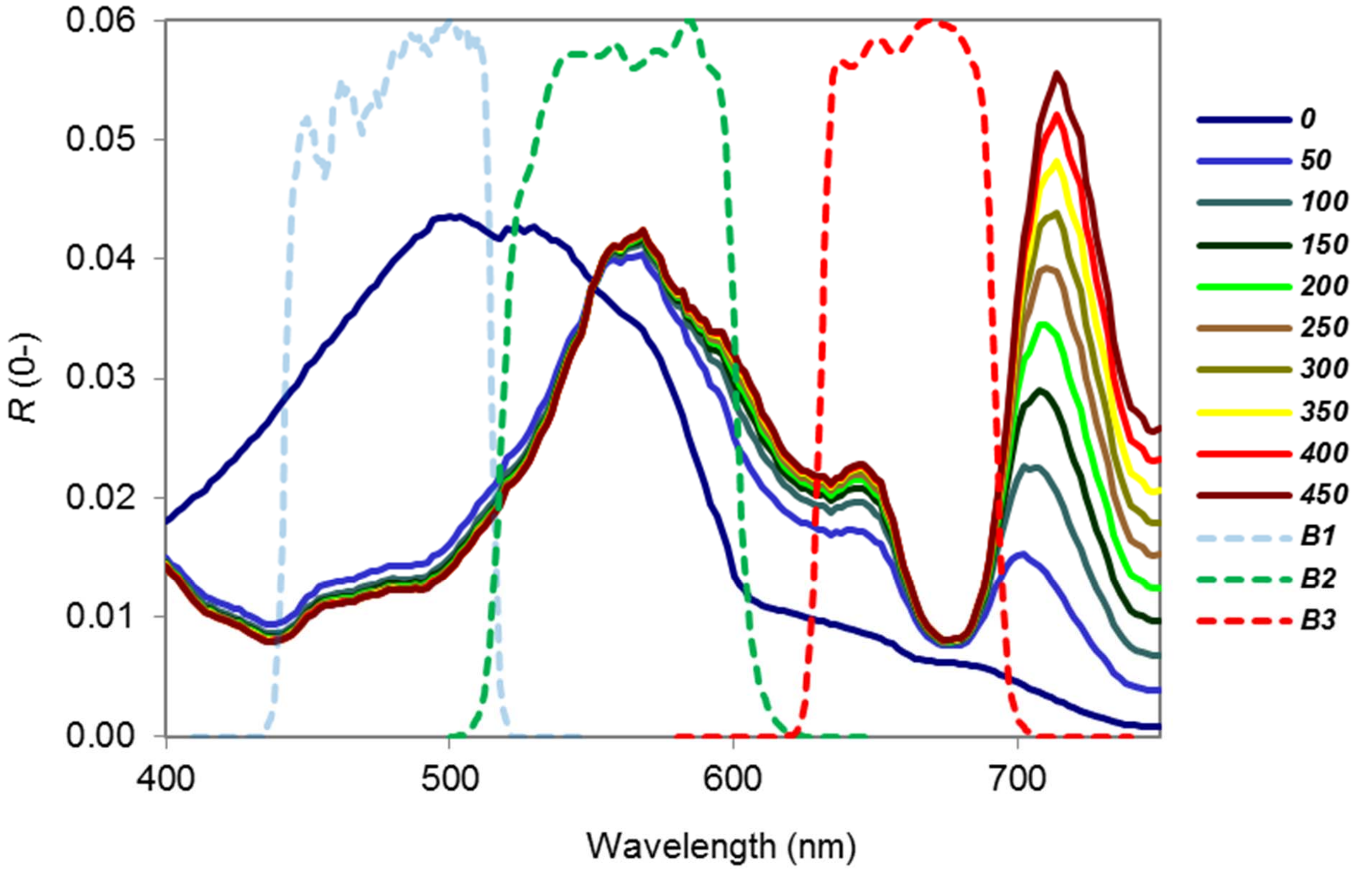
- Greater Wellington Regional Council staff
- Ruamāhanga Whaitua Committee
- Chris McBride (UOW)

USGS science for a changing world

global lake ecological observatory network GLEON

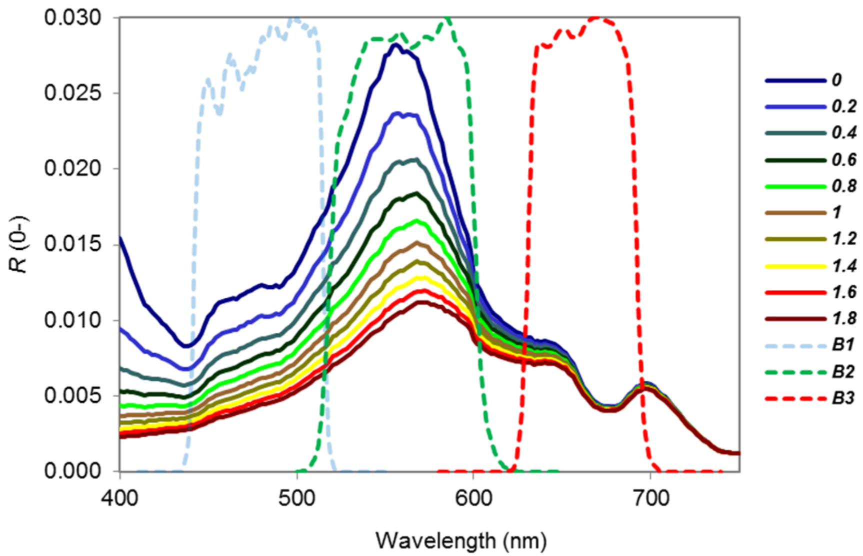
NASA

Ministry of Business, Innovation & Employment

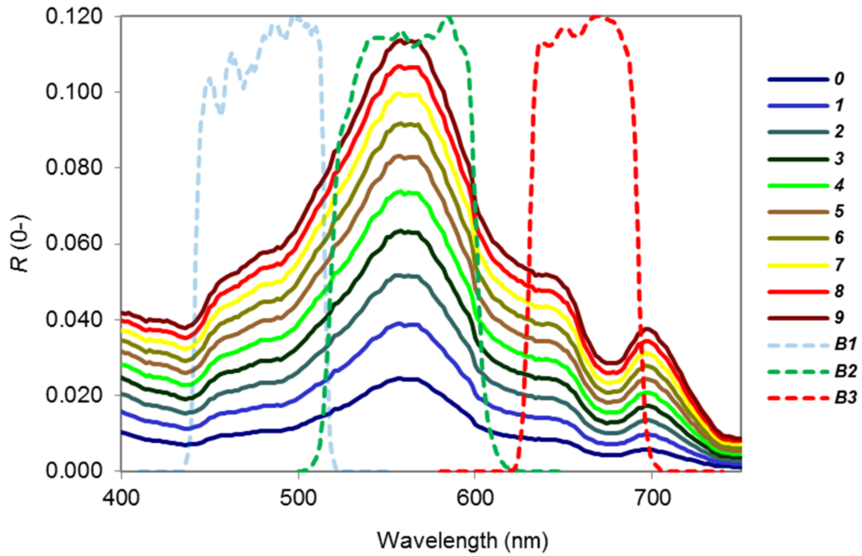


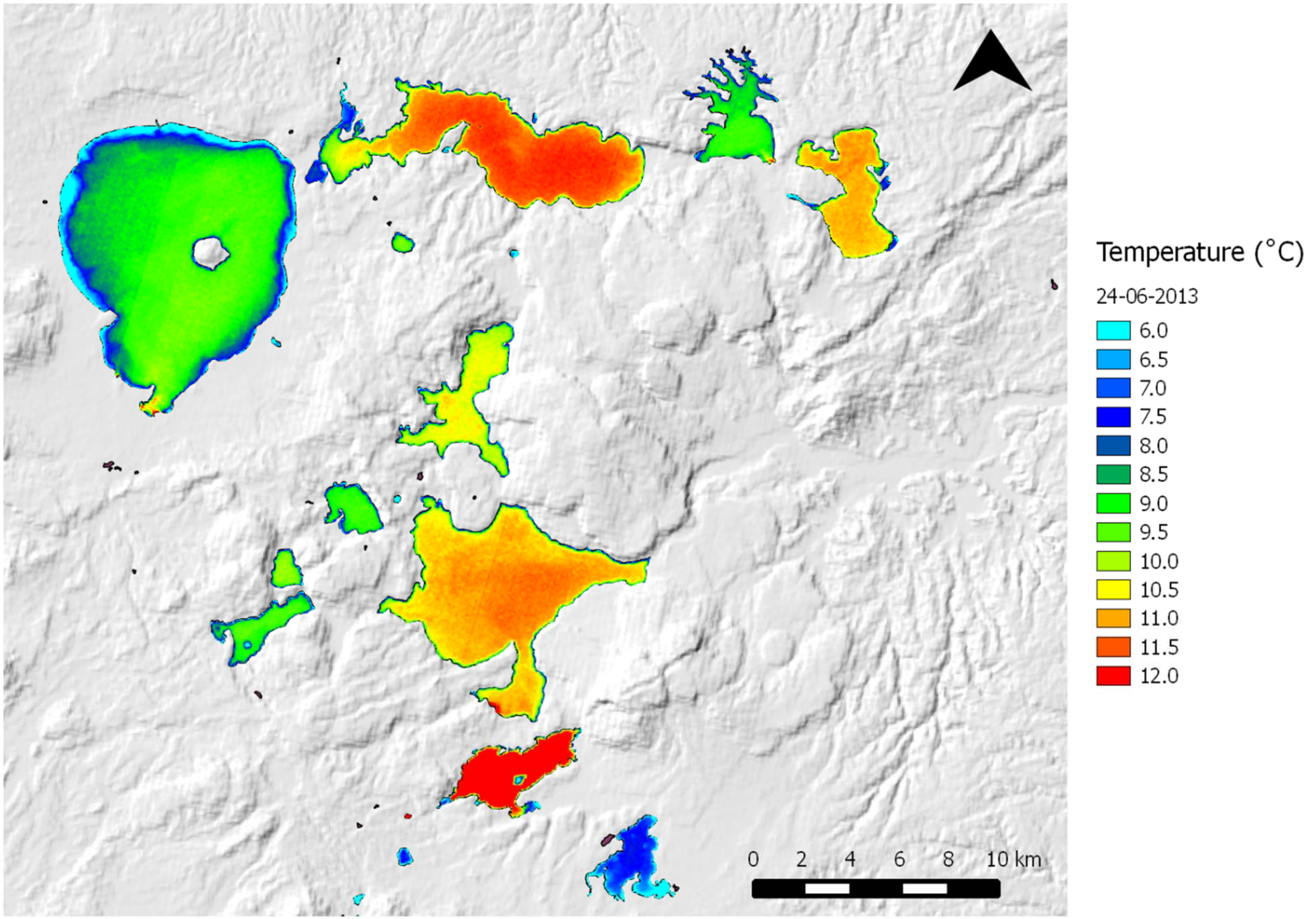
Modelled subsurface reflectance (*R*(0-)) for varying chlorophyll *a* concentrations ranging from 0 to 450 µg L^{-1} with fixed CDOM absorption of 0.16 m^{-1} and tripton concentration of 0.5 mg L^{-1}. The relative spectral response of Landsat bands B1, B2 and B3 is overlaid.

CDOM



TSS – non-living




Temperature (°C)
24-06-2013
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6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
0 2 4 6 8 10 km

Equations RS

$$r_{rs}(\lambda) = g_0 u(\lambda) + g_1[u(\lambda)]^2$$

$$u(\lambda) = \frac{b_b(\lambda)}{a(\lambda) + b_b(\lambda)}$$

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-
- and go and g1 are empirical constants that depend on the anisotropy of the downwelling light field and scattering processes within the water. The constant go is equivalent to f/Q where f represents geometrical light factors and Q represents the light distribution factor, which is defined as upwelling subsurface irradiance/upwelling subsurface radiance) (Maritorena et al. 2002). It has been suggested that go and g1 should be considered as variables in optically complex inland waters (Aurin and Dierssen 2012; Li et al. 2013) therefore we used fitted values for go and g1 of 0.103 and 0.009 respectively, which were derived previously for Lake Ellesmere (Allan, 2014).

- The absorption and backscattering coefficients are comprised of individual optically active constituents:

- bb(λ) = bbw(λ) + BbTSS b*TSS(λ) CTSS
- a(λ) = aw(λ) + Cφ a*φ(λ) + aCDOMD(λ)
- aCDOMD(λ) = aCDOMD(λ440) exp[-S (λ - λ440)]
- where:
- bbw(λ) = backscattering coefficient of water
- BpTSS = backscattering ratio from TSS
- b*TSS(λ) = specific scattering coefficient of TSS
- CTSS = concentration of TSS
- b*φ(λ) = specific scattering coefficient of phytoplankton
- aw(λ) = absorption coefficient of pure water
- Cφ = concentration of chl a
- a*φ(λ) = specific absorption coefficient of phytoplankton
- aCDOMD(λ) = absorption coefficient for coloured dissolved organic matter (CDOM)
- S = spectral slope coefficient
- Values of aw(λ) and bbw(λ) were prescribed from the literature (Morel 1974; Pope and Fry 1997). The backscattering ratio of TSS, BpTSS , was set to 0.019 (Petzold 1972). The specific scattering coefficient of TSS at the Landsat b3 wavelength was estimated using a power function (Morel and Prieur 1977) where the value b*TSS (555) was set to 0.6 m2 g-1. The hyperbolic exponent n was set to 0.63, equating to a value measured in Lake Taupo, New Zealand (Belzile et al. 2004). The a*φ(662) was 0.0136 m2 mg-1 , equal to the average value measured in eight Dutch lakes (Dekker et al., 2002). The bio-optical simulations were run by varying TSS concentration from 0.1 to 417.6 mg L-1 in increments of 0.5 mg L-1 while aCDOMD(440) was fixed at 0.042 m-1, which is average in situ of measurement in Lakes Wairarapa and Onoke, with chl a (µg L-1) taken to increase with TSS (chl a= TSS/6) ranging from 0.017 to 67.6 µg L-1 (encompassing a similar range to that measured in situ in Lakes Onoke and Wairarapa).