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DRI
DROUGHT RESEARCH INITIATIVE
RÉSEAU DE RECHERCHE SUR LA SÉCHERESSE

Monitoring Groundwater Conditions from Space during Drought

by:
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(based on the PhD thesis of Sitotaw Yirdaw)

for:
DRI 5th Workshop Presentation
May 12-14, 2010

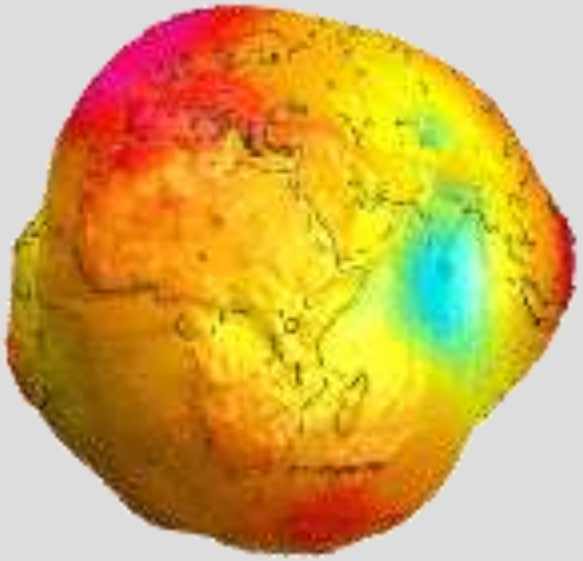
Memorial University of Newfoundland
Faculty of Engineering and Applied Science

MEMORIAL UNIVERSITY

Gravity Variability

Milligal = 10^{-5} m/s^2

source: ESA web site



source: MM Watkin, The GRACE Mission: Status and Latest Results

Gravity varies from 9.83 (poles) to 9.76 (equ)

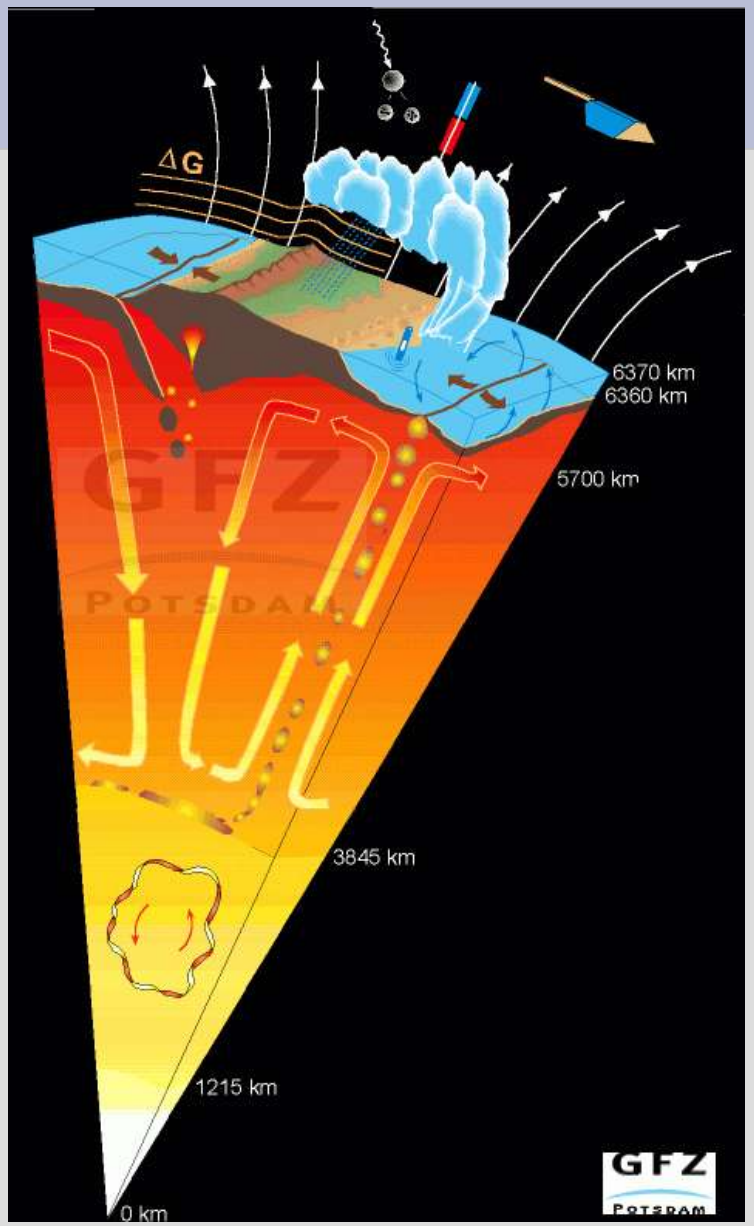
Gravitation Potential (N) given by Laplace Equation in Spherical Coordinate System

$$\nabla^2 N = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial N}{\partial r}\right) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial N}{\partial\theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 N}{\partial\phi^2} = 0$$

Solution is an orthogonal series summation for a given: lat(ϕ), lon(θ), and radius(r)

$$N(t) = a\sum_{l=0}^{l_{max}}\sum_{m=0}^{l} P_{lm}(\cos(\theta))\left[C_{lm}(t)\cos(m\phi) + S_{lm}(t)\sin(m\phi)\right]$$

Why Gravity Measurement?



Oceanography - combining gravity based sea-level geopotential with altimeter data to map ocean currents.

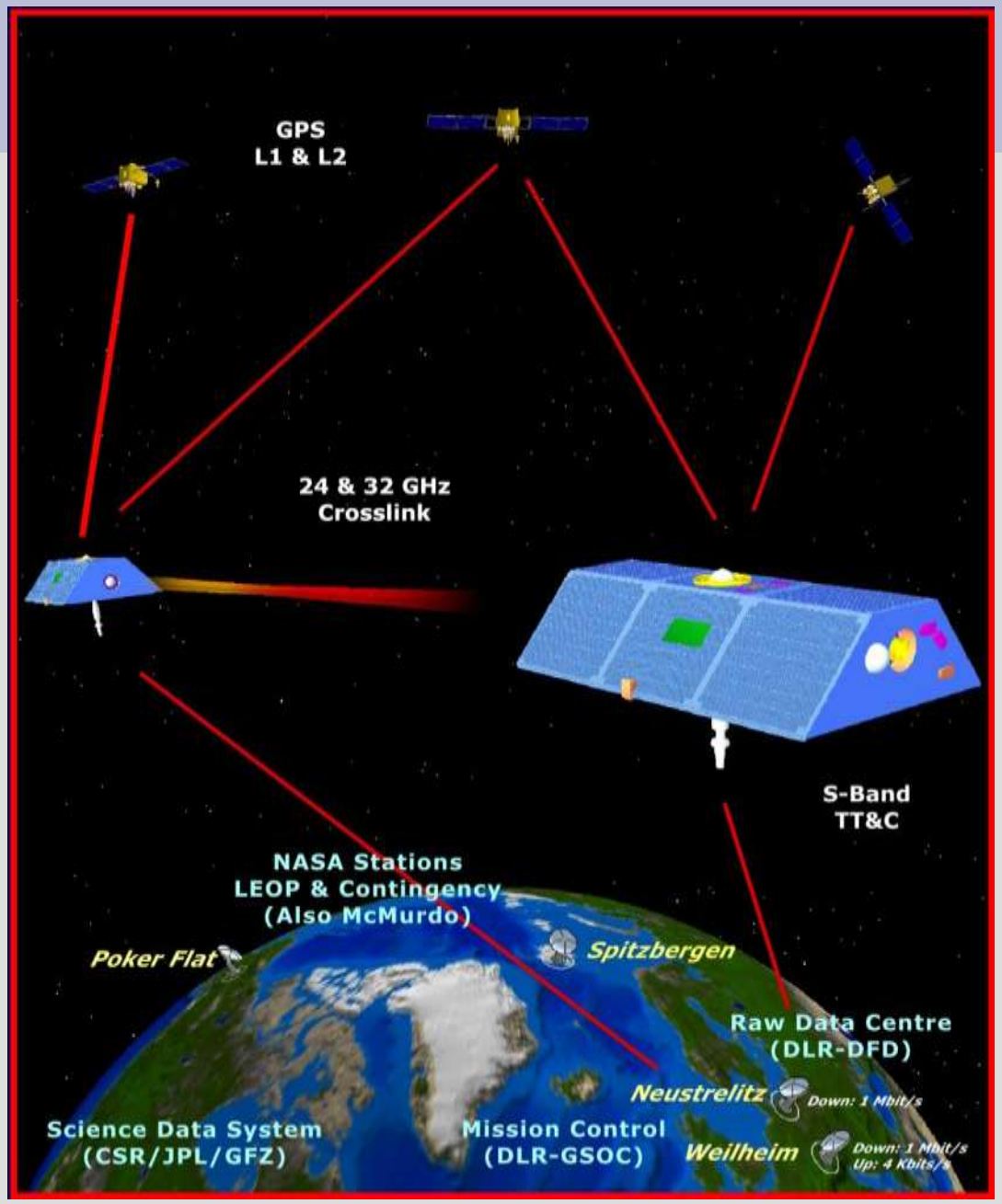
Sea-Level Rise - measure glacier mass lost from polar ice caps and non-mass related sea level rise based on ocean warming.

Geodesy - establishment of a vertical measurement datum.

Solid Earth Physics - combined with topography to understand internal earth processes.

Surface Fluid Motion - the short term fluctuations of gravity are related to the redistribution of near surface fluids (water & air)

GRACE Satellite System

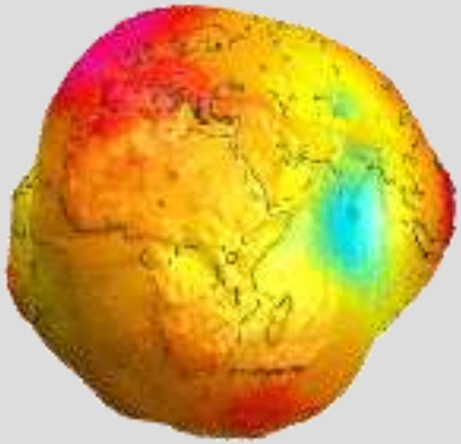


Orbit

Launched: March 17, 2002
Initial Altitude: 500 km
Current Altitude: 476 km (30 m/d)
Inclination: 89 deg
Eccentricity: ~0.001
Separation Distance: ~220 km

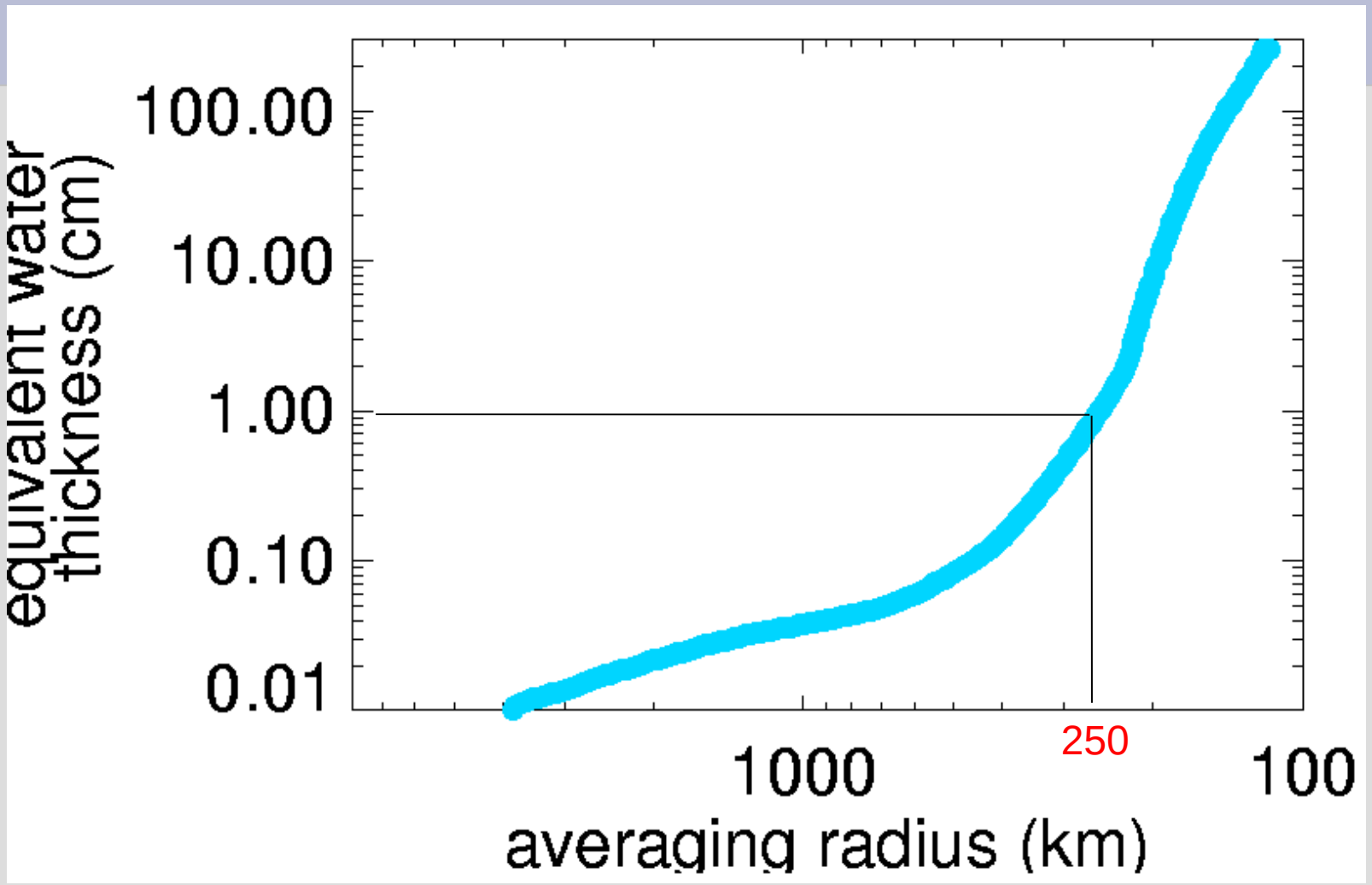
Mission Time Frame

Original Length : 5 years
Current End of Life: 2011-2015
(Depends on solar activity, etc)



source: MM Watkin, The GRACE Mission: Status and Latest Results

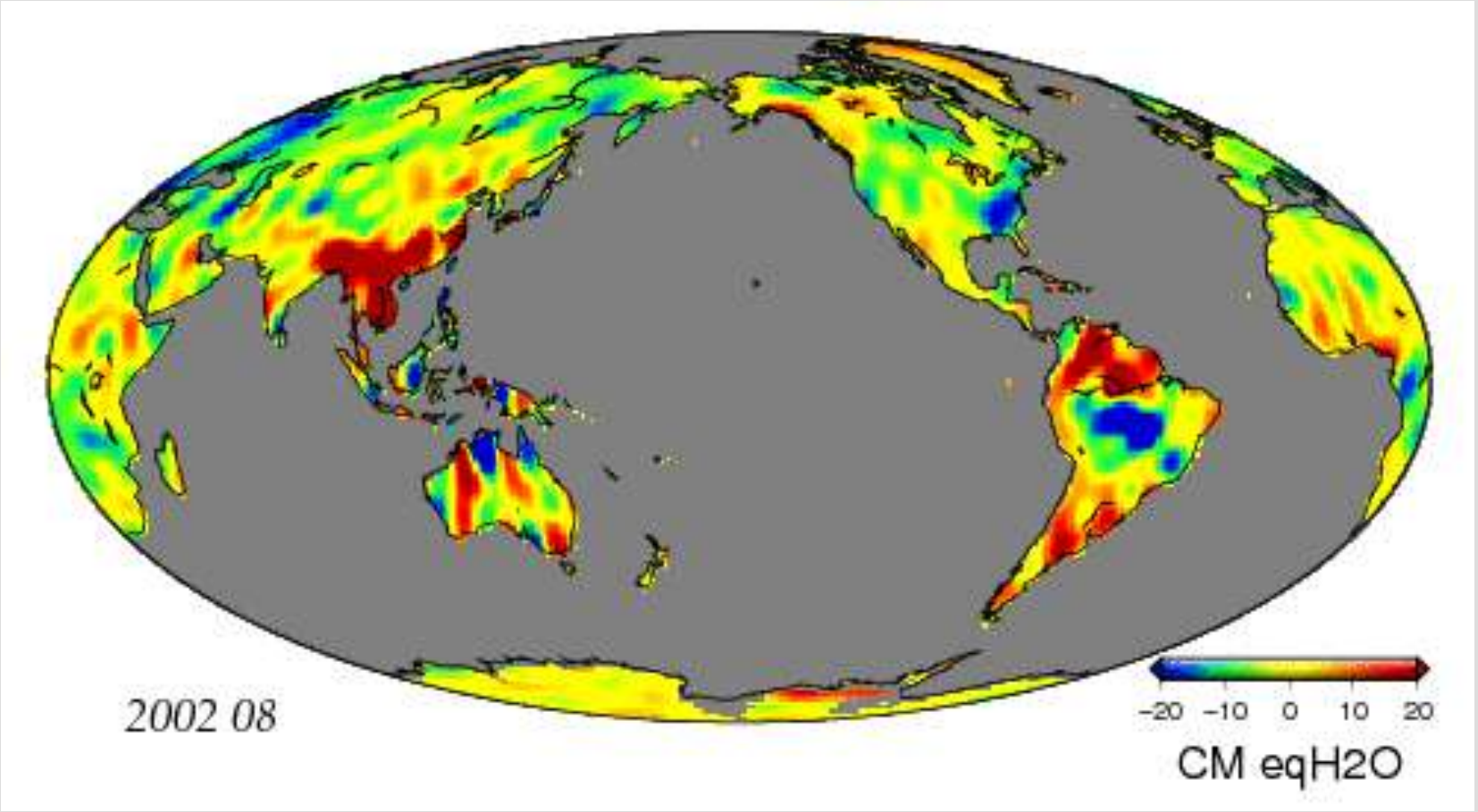
GRACE Satellite Errors



source: MM Watkin, The GRACE Mission: Status and Latest Results

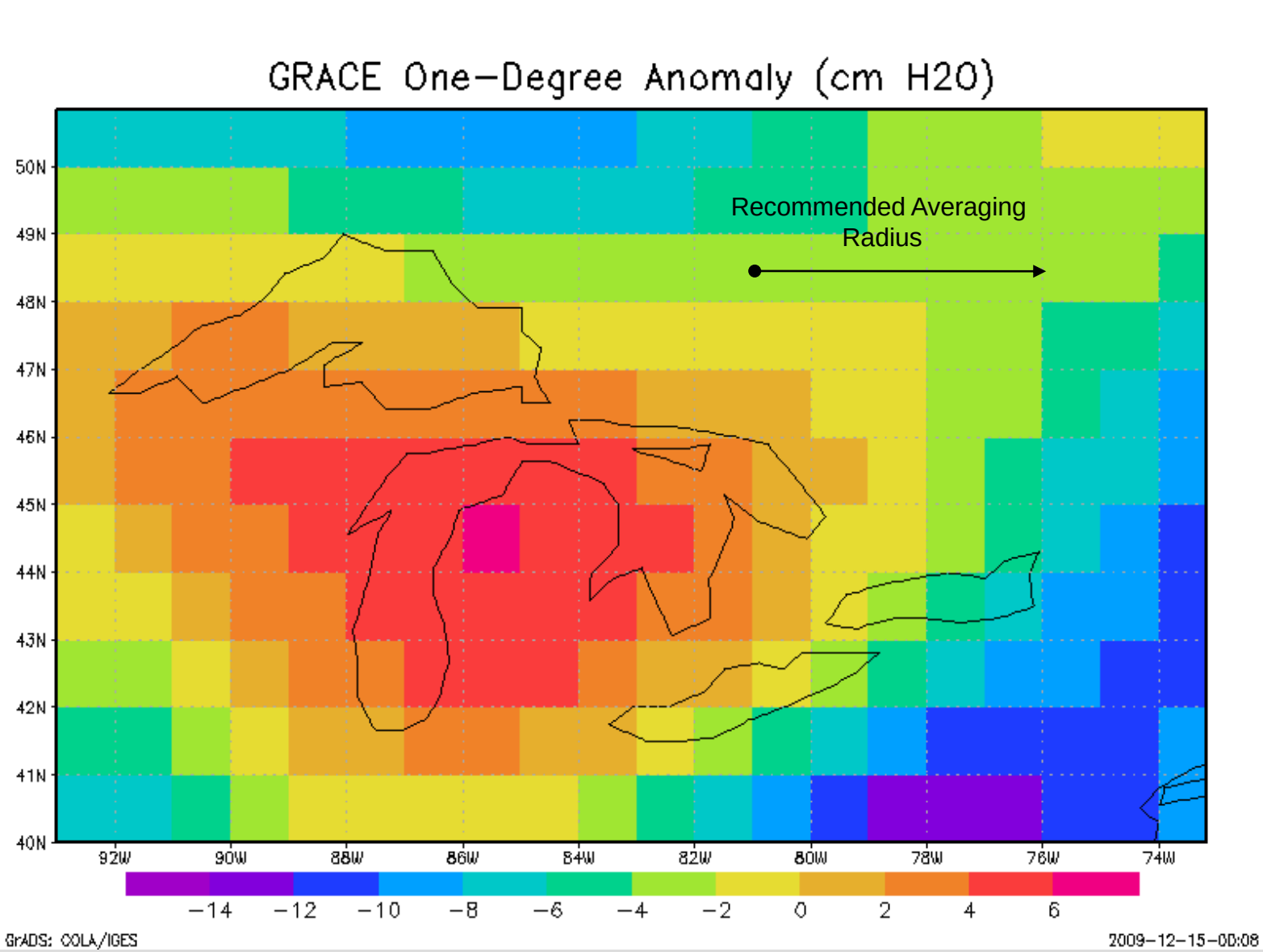
Corrections required: i) Earth Tides, ii) Ocean Tides, iii) atmospheric mass, iv) isostatic rebound, v) wind driven ocean waves.

Global Coverage of GRACE Satellite on Monthly Time Scale

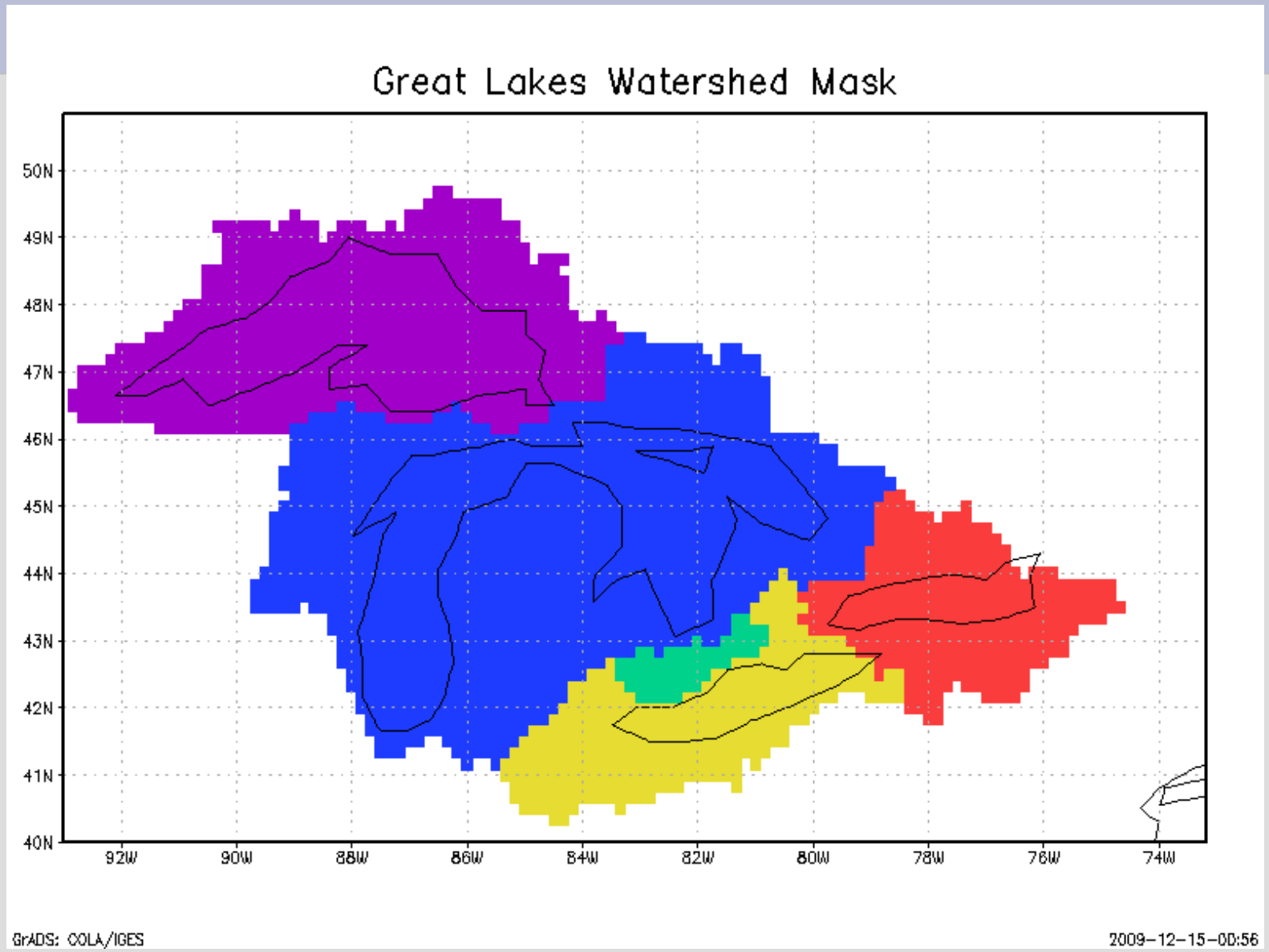


source: http://grace.jpl.nasa.gov/data/mass/

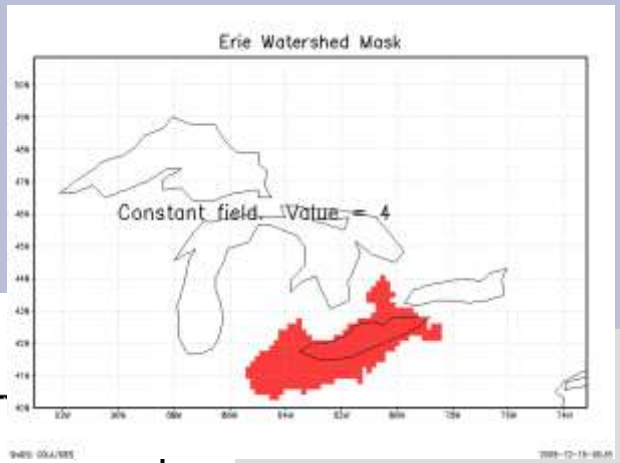
GRACE Evaluation of Great Lakes Storage

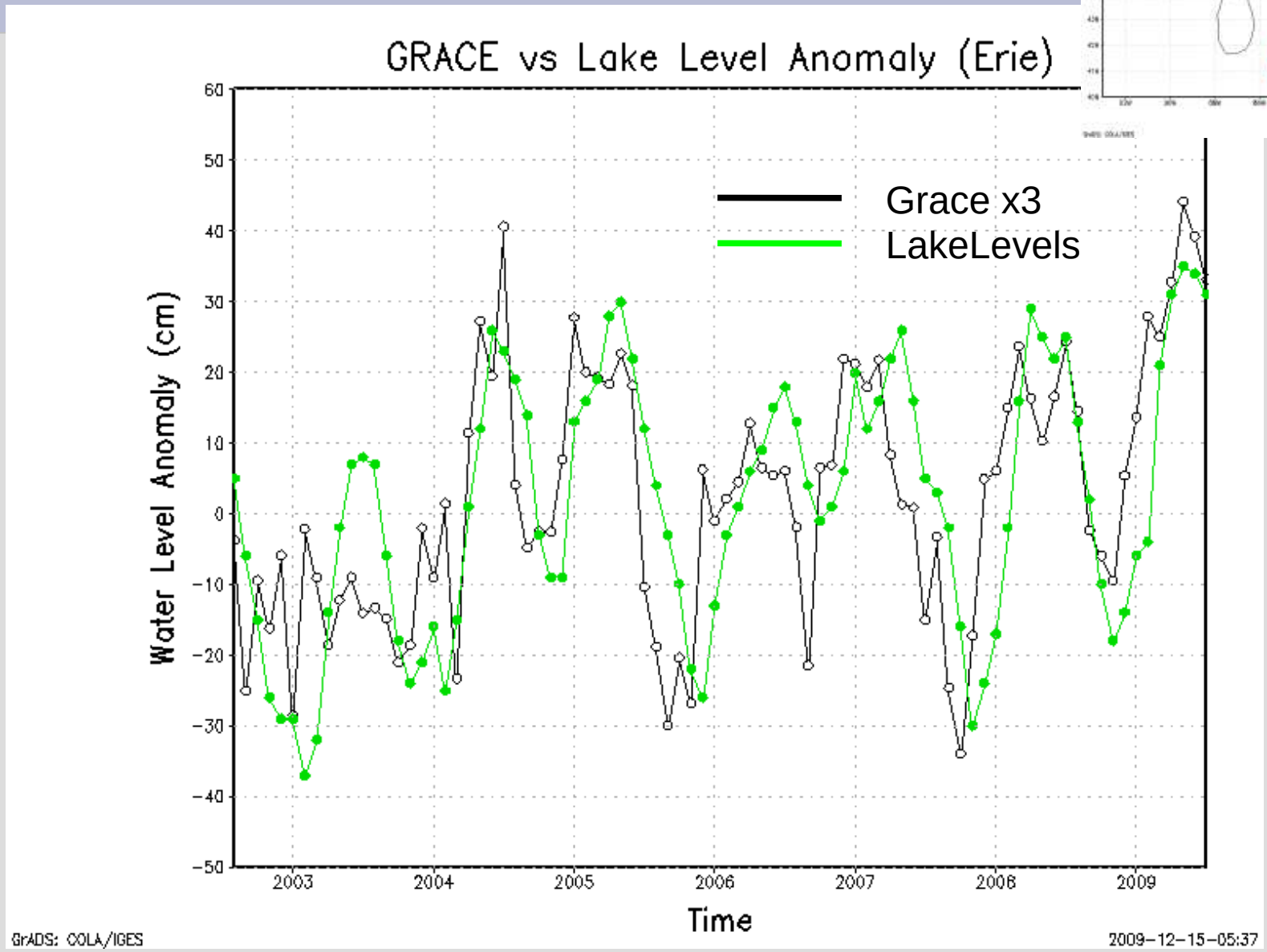


Averaging Mask for Great Lakes

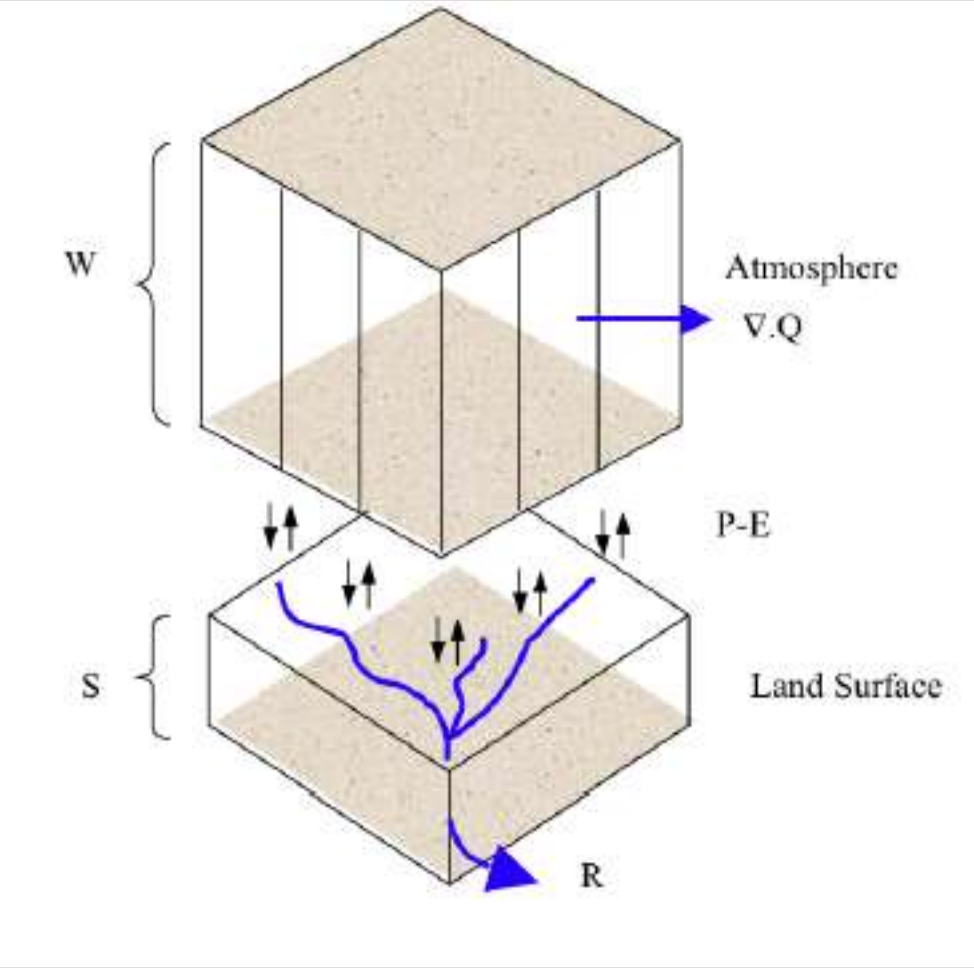


GRACE Comparison to Lake Erie Levels





GRACE Water Balance Comparison



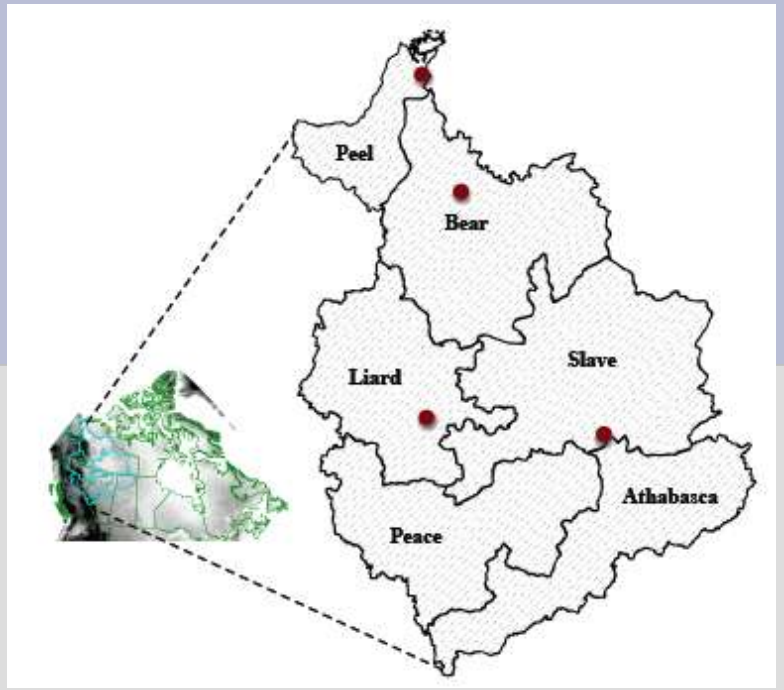
Atmospheric-Land Surface Water Balance

$$-\left(\frac{\partial W}{\partial t}+\nabla\cdot Q\right)=\left(\frac{\partial S}{\partial t}+R\right)=(P-E)$$

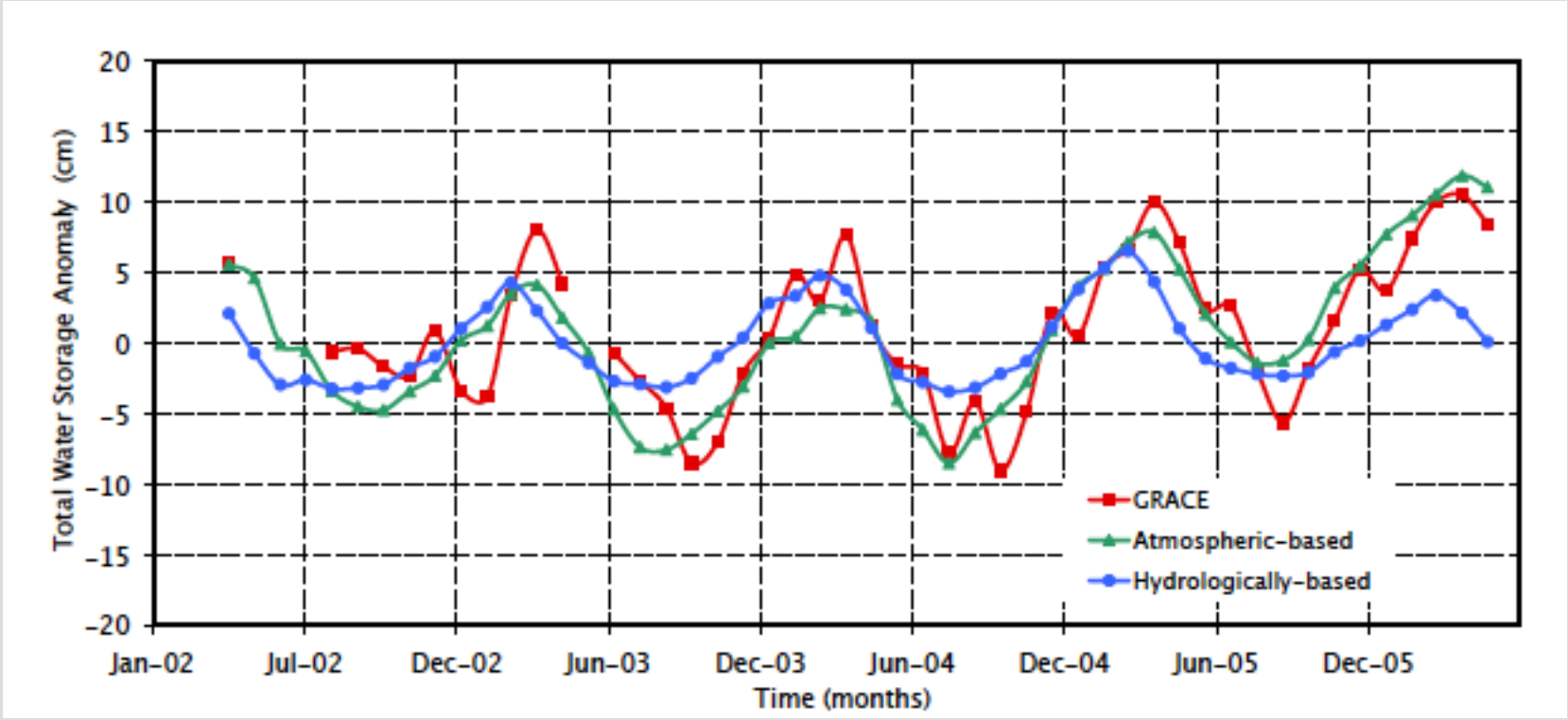
Given a starting storage (S_{n-1}) as the mean storage, we can determine GRACE equivalent measurement

$$S_n = S_{n-1} + \left(\frac{\Delta S}{\Delta t}\right)_n$$

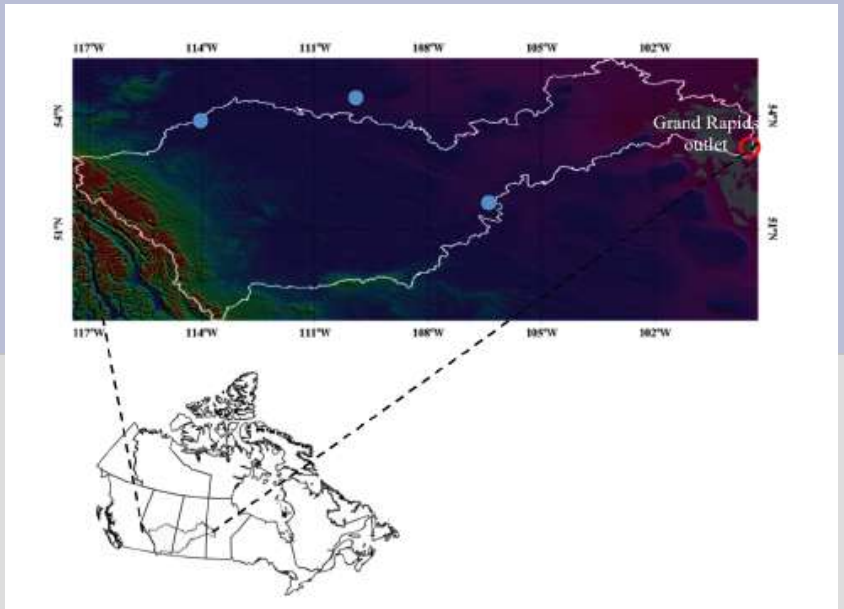
GRACE Water Balance Comparison
Mackenzie River Basin

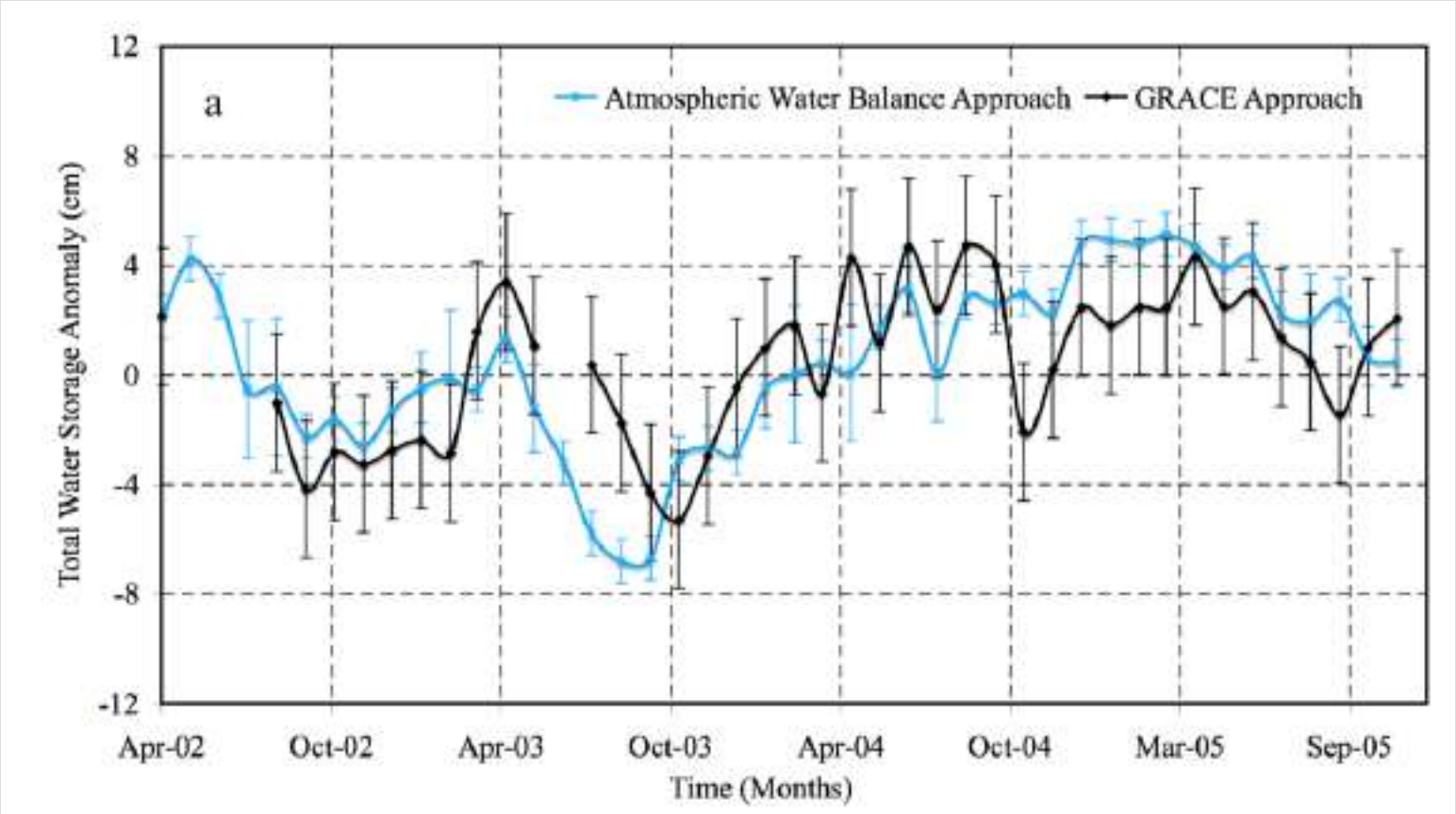


Correlation for G vs. A = 0.86

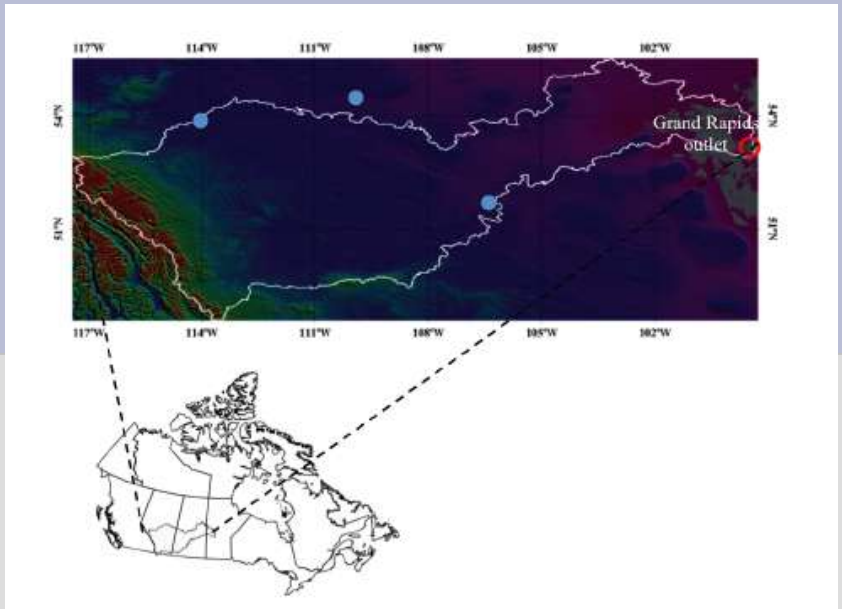


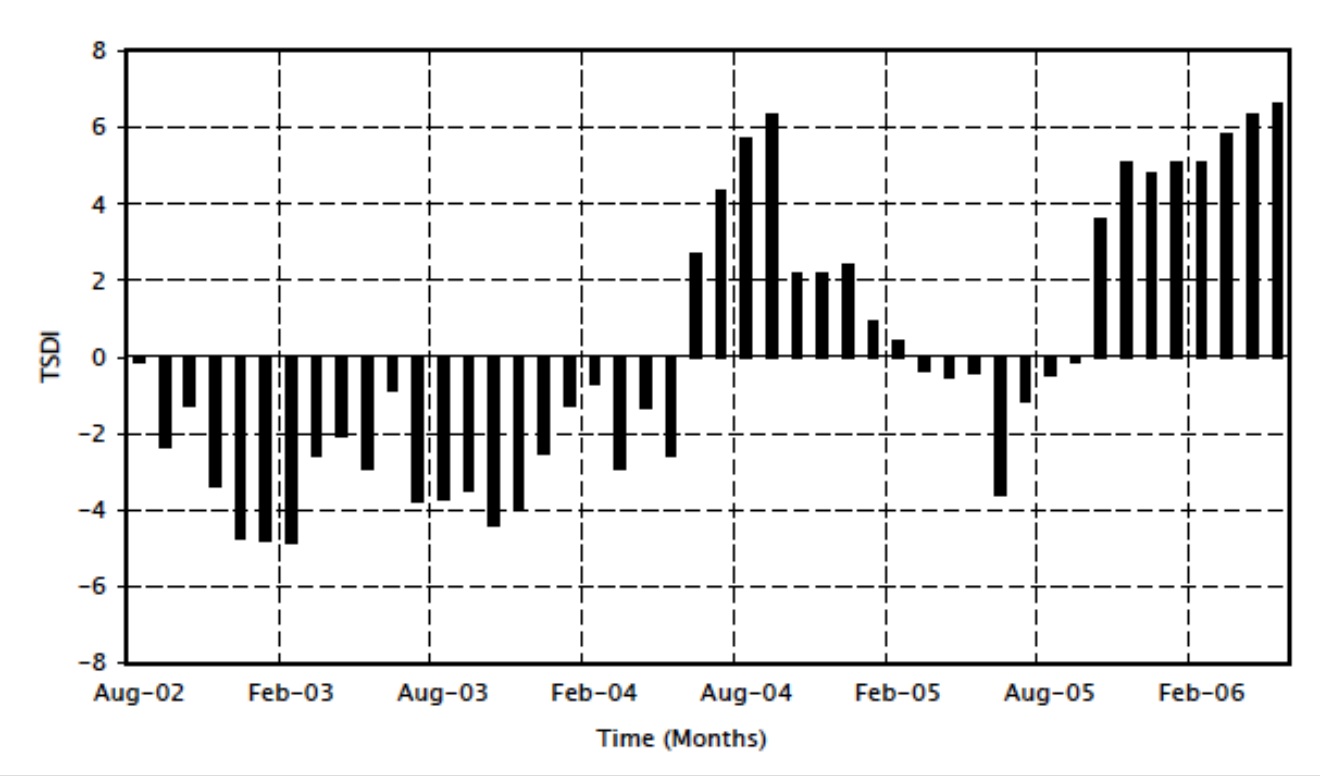
GRACE Water Balance Comparison
Saskatchewan River Basin





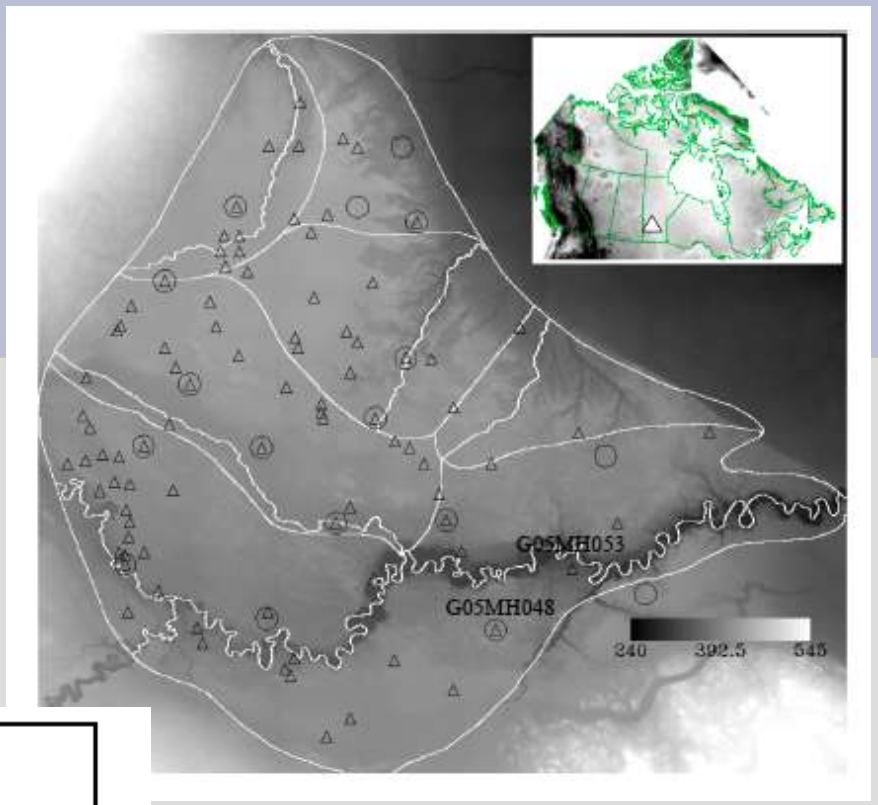
GRACE Application
Drought Monitoring

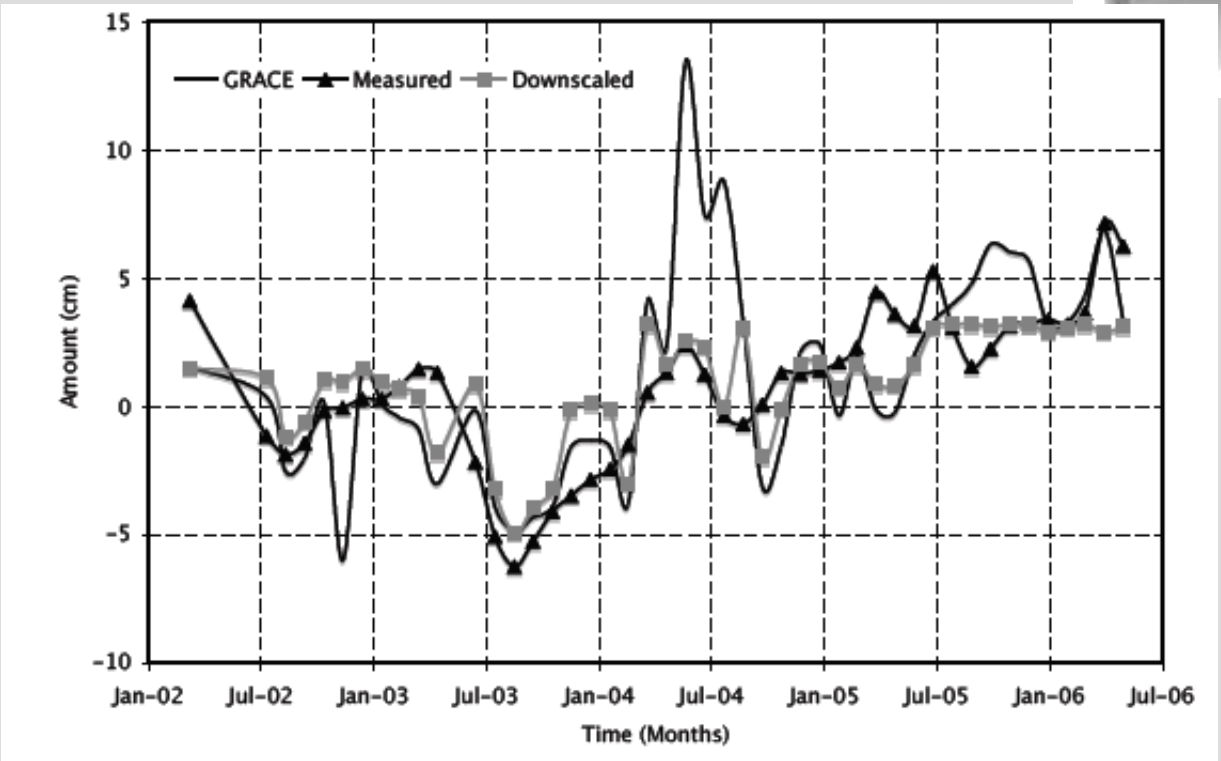




TSDI - total storage deficit index

GRACE Application
Assiniboine Delta Aquifer
Well Comparison

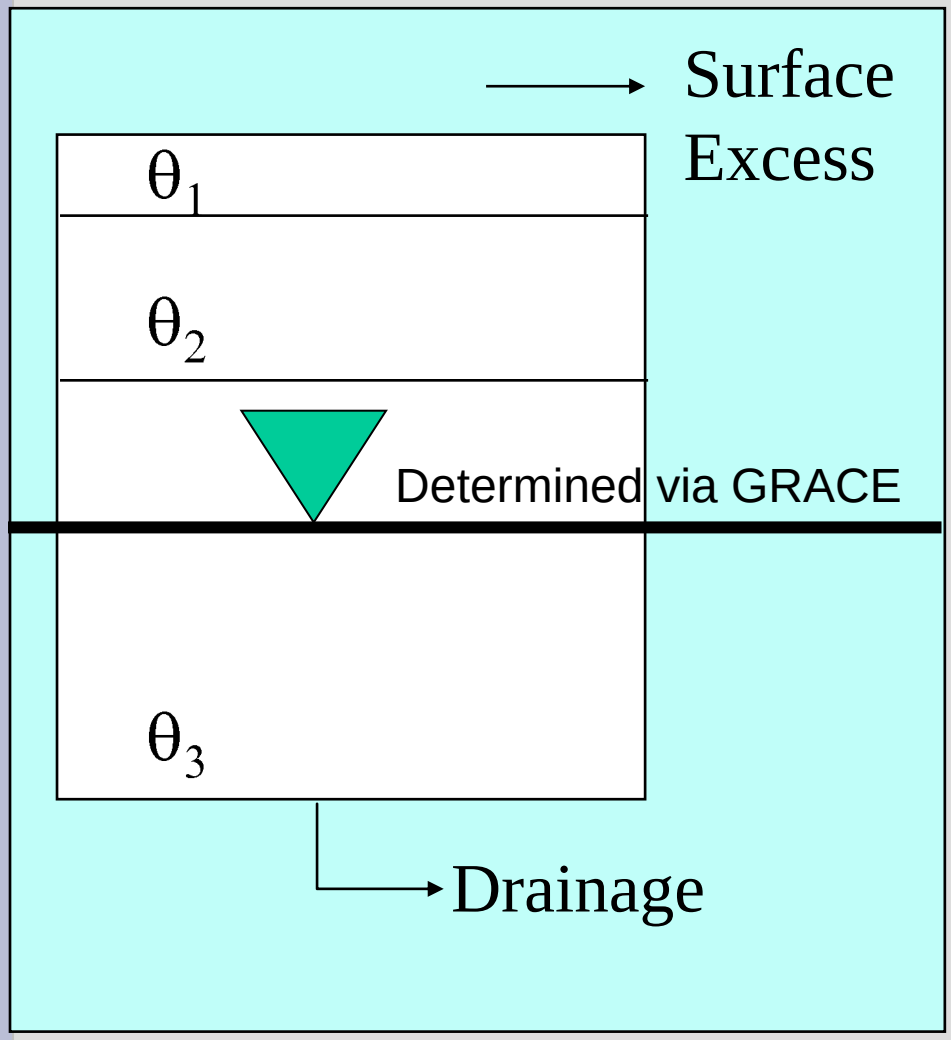


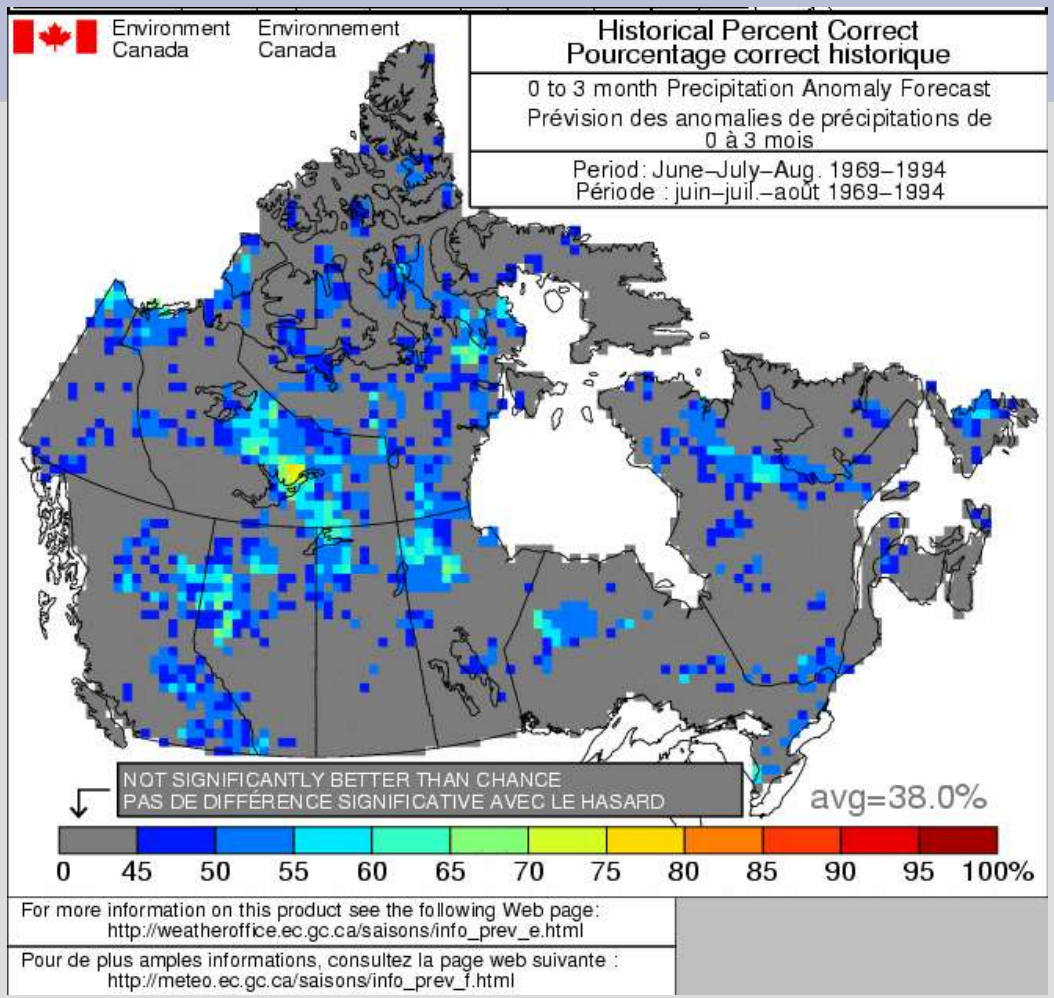


Downscaling GRACE data to fit well observations.

Useful for aquifer model studies.

GRACE Application (Future Work)
Seasonal Forecasting





Does storage initialization improve seasonal forecasts?

Test with 7 years of GRACE data