Exploration of Multi-satellite Altimetric Data over North American Lakes

Utilizing the NASA/CNES Jason-1 and TOPEX/POSEIDON,NRL GFO, ESA ERS and ENVISAT satellite data sets.

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A. Focus on Investigating the causes of Freshwater Anomalies; Case Study of the Mackenzie River Basin

A low salinity anomaly forms in the southern Beaufort Gyre during 1996/1997, spreads westward during the fall of 1997, then dissipates in 2002. McPhee et al. [1998] measured the salinity anomaly and concluded that the main forcing was sea ice melt. Macdonald et al. [1999] used oxygen isotope data and determined that the major factor was Mackenzie River discharge. Steele et al. [2006] however concluded that river discharge was not a major source of the ocean freshwater anomaly. Can altimetric lake stage coupled with observed and model-derived river discharge aid the investigation? (Steele, Rawlings, Birkett)

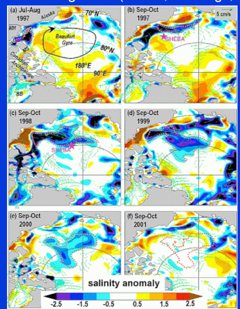


Figure 1, Tracking the SHEBA Freshwater Anomaly through the Atmosphere-Land-Ocean System Steele et al. (2006) GRL

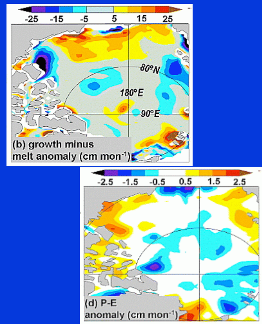
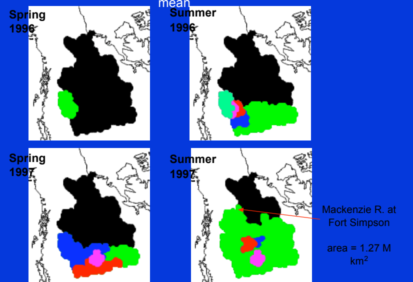
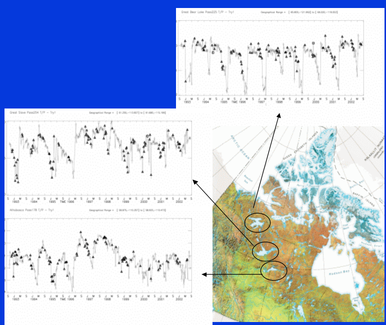


Figure 4a,d, Steele et al. (2006) GRL

Mackenzie River sub basins with anomaly > 2 standard deviations from mean

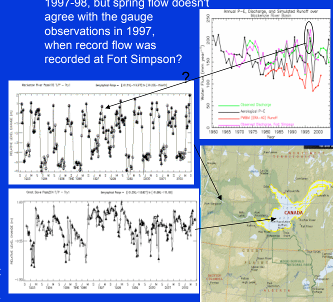


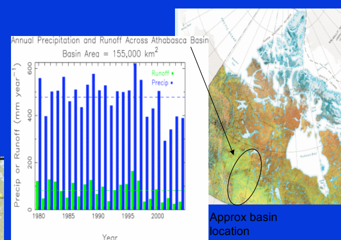
The P-E anomaly over Mackenzie Delta is ten times smaller than sea ice growth anomaly. Can we say that riverine freshwater inputs were insignificant?



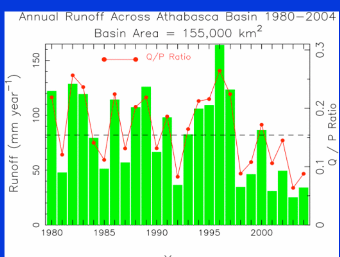
Radar data indicate that levels of lakes in the south (Athabasca and Great Slave Lake) were high in 1996-1997. Great Bear Lake in the north showed lower levels in 1996-1997 period. How did the landscape hydrology differ across the Mackenzie River and Beaufort Sea drainage basin during 1996-1997?

Why are radar returns high in winters 1996-97 and 1997-98, but spring flow doesn't agree with the gauge observations in 1997, when record flow was recorded at Fort Simpson?





Across the Athabasca basin, annual precipitation and simulated runoff in 1996 are both at their highest levels since 1980. Combined, annual runoff over two year period 1996-1997 is a maximum for the period.



Model-derived runoff was 164 mm/year in 1996, more than double the 25 year mean. Above average runoff occurred for 5 years from 1993-1997. Q/P ratio was highest in 1997. It looks like snowfall/melt forced the anomaly in 1996 and 1997?

Summary

- Aerological approach using NCEP-NCAR reanalysis atmospheric data shows highest annual P-E in 1996. Two year total 1996-1997 also a max.
- Several sub basins in the southern Mackenzie show record flow in spring and summer 1996 and 1997.
- Radar altimetry estimates of changes in lake height show high levels in 1996 and 1997. Observed discharge, simulated runoff and SWE corroborate the radar data.
- Annual discharge at downstream site of Mackenzie is POR max in 1997. Combined spring/summer are also at a maximum .Discharge in spring+summer 1997 is 126 cm of freshwater over the Beaufort Sea area.

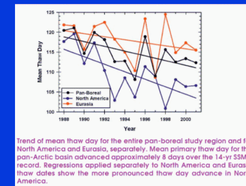
Q. How does this anomalous flux compare with the amount of water produced through sea ice melt? How does the stored volume of lake water control the flow through the Basin ?

B. FOCUS on Onset of Freeze/Thaw in Large North American Lakes

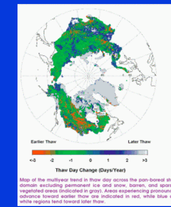
Investigations looking into the response of inland reservoirs to fluctuations in precipitation and temperature via observation of both altimetric stage and radar backscatter. The major lakes and reservoirs of Northern Canada and Alaska are the primary targets with altimetric results validated and compared to both ground-based gauge observations and findings derived from the utilization of scatterometer data such as QuickSCAT and SSM/I. (Birkett, McDonald)

1. Introduction

While investigations look into the performance of radar altimeters over inland waters in view of the quantity and quality of elevation measurements, and the potential derivation of higher level products (Q, Volume), it is interesting to explore the variation of radar backscatter, both spatially and temporally, across lake and reservoir targets. It has been previously noted that the backscatter coefficient gives a general indication of freeze/thaw episodes for lakes at high latitudes, though there are penetration and snow accumulation effects, and compared to scatterometer data, we have a paucity of observations at good temporal resolution. A synergistic combination of altimeters however provides a means of addressing the spatial and temporal resolution problem, and archival T/P and ERS datasets gives a 10-15year climatic snapshot.



Trend of mean thaw day for the entire pan-boreal study region and for North America and Eurasia, separately. Mean primary thaw day for the pan-Arctic basin advanced approximately 8 days over the 14-yr SSM/I record. Regressions applied separately to North America and Eurasia thaw dates show the more pronounced thaw day advance in North America.



Map of the multiyear trend in thaw day across the pan-boreal study domain excluding permanent ice and snow, barren, and sparsely vegetated areas (indicated in gray). Areas experiencing pronounced advance toward earlier thaw are indicated in red, while blue and white regions tend toward later thaw.

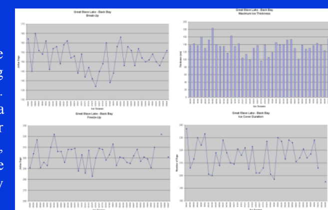
2. Freeze/Thaw Research

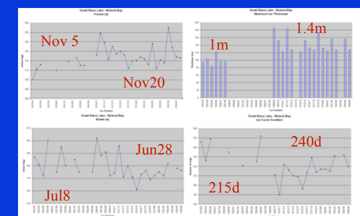
Spaceborne microwave remote sensing has been used to examine the variability in springtime thaw at terrestrial high latitudes, Findings suggest that the timing of seasonal thawing and subsequent initiation of the growing season in early spring has advanced by ~8days from 1988-2001 for the pan-Arctic Basin and Alaska (McDonald et al., Earth Interaction, 2004). With the Mackenzie Basin as a study region, can the radar altimeter datasets reveal any change in lake freeze/thaw periods over the last 15years?

3. Example from Ground-Based Gauge Records

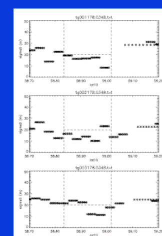
At Back Bay station there are indications of ice break-up occurring 5days earlier after the 1969-1978 period. At Mcleaod Bay indications are for a later freeze, earlier break up with shorter duration but thicker ice-cover. Clearly, sampling multiple locations across the target extent will be necessary for any altimetric interpretation.

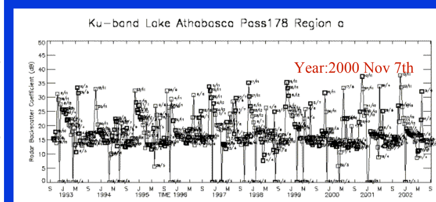
Jun 1st:149, Jul 1st: 178, Nov 1st: 305





Freeze-up and Break-up dates, and ice cover duration and thickness for the 1950's-1990's ice seasons at two gauging Stations on the Great Slave Lake, Canada.



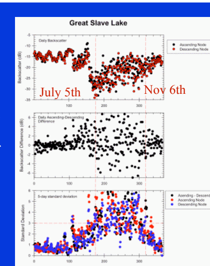


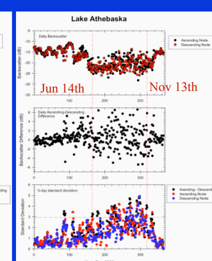
4. 1992-2002 Altimetric Indications

As an exploratory dataset, T/P GDR 10Hz sigma0 variations reveal both spatial and temporal variations across all of the basin lakes. (Far Left) for along-track Ku-band sigma0 for 3 T/P cycles across Lake Athabasca. (Left) for temporal variation across the central region of he lake. Ice-free periods are ~13dB, with peaks in November representing freeze periods, and secondary peaks in May-July during snow/ice melt.

5. Rim Cell Comparisons

Quickscat Arctic Rim Cells: Lake Athabasca (59.4N,109W) and Great Slave Lake (61.5N, 115W) shown for the Year 2000, (results courtesy of Kyle McDonald, JPL). Variation in backscattter reveal periods of freeze and thaw averaged across the cell extent.





6. Future

Focus is currently on investigating the spatial variation of altimetric radar backscatter, developing algorithms that aim to specifically identify the onset of freeze/thaw, the merger of synergistic altimetric data sets, and examining the temporal decline of backscatter in terms accumulation of snow accumulation after lake freeze, and Rim Cell results can be extended back to 1990's via SMMI.