

Report as of FY2009 for 2008AK71B: "Study of Streamflow Response to Seasonal Snowcover Change in the Yukon River"

Publications

Project 2008AK71B has resulted in no reported publications as of FY2009.

Report Follows

12: Title: Yukon River Streamflow Response to Seasonal Snowcover Change

13. Statement of Critical State Water Problem

Arctic hydrologic system has experienced very significantly changes over past several decades due to climate variations and human impacts. For instance, recent assessments of long-term (50-60 years) hydrologic records identify significant changes in streamflow regimes over Siberia, such as increases of yearly and winter streamflow (*Lammers et al., 2001; Serreze et al, 2002; Peterson et al., 2002*), shifts of peak discharge timing associated with early snowmelt (*Yang et al., 2002, 2003*), and river-ice regime changes (*Smith, 2000*). The causes for these changes are not all clear due to insufficient investigations of arctic hydrology changes. This raises a challenging science question for the Arctic and global change research at large. It has been suggested that spring discharge increase is primarily due to an earlier snowmelt associated with climate warming during the snowmelt period (*Nijssen et al., 2001; Yang et al., 2002; Serreze et al., 2002*), and changes in winter streamflow are perhaps associated with reduction in permafrost and an increase in active layer thickness under a warming climatic condition (*Serreze et al., 2002; Yang et al., 2002; 2004a,b*).

The Yukon River is one of the largest rivers in the northern regions. It contributes 203 Km³ per year freshwater to the Bering Sea. Hydrologic conditions and its changes of the Yukon river significantly affect regional biologic and ecologic systems. Unlike other large northern rivers, Yukon River has received less research attention. The USGS (2000) produced a report to document the major hydrologic patterns with the basin. Zhang et al. (2000) found that large parts of southern Canada and Yukon Territories have experienced reduced runoff. Snowcover is one of the critical land memory processes that significantly affect atmosphere, hydrology and ecosystems in the high latitude regions. Snowcover melt and associated floods are the most important hydrologic event of the year in the northern river basins (*Kane et al. 2000*). Studies show that snowmelt has started early over the recent decades in the northern regions of Canada, Alaska and Siberia associated with warming in winter and spring seasons (*Whitfield and Cannon, 2000; Zhang et al., 2000, USGS, 2000; Yang et al., 2002*). This change in the melt pattern may indicate a hydrologic regime shift over the high latitudes (*Yang et al., 2002,2004a,b*). Due to insufficient investigation and lack of long-term records, *our current understanding of Yukon River hydrology and climate changes, particularly large-scale snowmelt processes and their interaction with climatic change and variation, is incomplete. This limits our capability of documenting past change and predict future change over this largest watershed in Alaska.*

14. Statement of Benefits

This research will apply remotely sensed long-term snowcover data in investigation of snowmelt runoff response to climate change and variation in the Yukon watershed. The methods and results of this research will be important to snowmelt model and process studies. They will improve our understanding of the spatial and temporal variability of high-latitude snowcover and its contribution to river runoff and hydrology of the arctic regions. They will also enhance our

ability of modeling cold region land memory processes and predicting future changes in water cycle over large northern regions.

The outcomes of this study will also include a comprehensive data set (including snowcover, streamflow, temperature, and precipitation) for the Yukon river basin. This dataset will support land surface model development and verifications, and is useful to ongoing international and national research programs, particularly for the GEWEX, CliC, and the SEARCH and IPY. This research will involve and train students at various levels. It will directly benefit research and education in Alaska. This project will also support the USGS programs, particularly the predictability of water cycle and its change in the northern watersheds.

15. Nature, Scope and Objective of Study

This research will use the weekly NOAA snowcover extent data to study the streamflow hydrology in the Yukon River. The focus of this research is to examine the streamflow response to snowcover extent change during the spring melt season. *The overall objective of this research is to determine the potential of using remotely sensed snowcover information to improve our capability of snowmelt runoff modeling and forecasting over large northern river basins.* The major work to be completed includes:

A. Generation and analysis of weekly snowcover extent and runoff time-series

We will calculate the basin-mean snowcover extent over the Yukon river for the entire NOAA records (1966-present) and generate a weekly basin snowcover time-series. We will use these weekly data to examine the seasonal changes of snowcover extent, such as defining the weekly snowcover climatology, determining the dates of snowcover formation/disappearance and duration of snowcover/snow-free days, and quantifying the rates of snowcover change during the accumulation and melt seasons. We will also examine snowcover extent changes and variations over time, including trend analysis, identifying extreme snowcover cases and investigating their association with climate conditions. Long-term weekly discharge time-series will be generated from the daily streamflow data collected at different locations within the watersheds and used to describe the seasonal runoff changes, including weekly runoff regime, rates of streamflow rise and peakflow during the melt period. We will also examine the spatial and temporal runoff changes including extremes and trends. In addition, precipitation and temperature records will be acquired and used to aid the investigation into the response of river hydrology to snowcover changes.

B. Examination of streamflow response to snowcover extent change

Snow cover depletion is a useful indicator of snowmelt process and streamflow generation (Rango, 1997). This project will use the weekly snow data to develop snow cover depletion curves for each melt season from the maximum accumulation through complete melt. Changes in the timing and pattern of the snow cover melt are sensitive indicators to climate change at the high latitudes. This study, based on the long-term snow cover, runoff and climatic records, will investigate the spatial and temporal sensitivity of snowmelt runoff to regional climate changes and variations. We will examine the weekly correlation of streamflow with basin-mean snowcover extent and temperature and determine the consistency between snow cover and runoff changes during the snowmelt period. We will also investigate the associations between

snowcover and runoff anomalies, identify extreme snowmelt runoff cases, and examine their correspondence with snowcover and climate conditions. These analyses will define the weekly relation between snowmelt runoff and snowcover changes for the watershed.

C. Cross-validation of results

We will use microwave-derived (SMMS & SSM/I) maps of extent and SWE, ground snow survey and other field observations to calibrate/validate the results we obtain using the NOAA snowcover product at selected locations/sub-basins within the watershed. This will include cross-comparison of the timing of snowcover formation and disappearance, the rates of snowcover accumulation in fall/winter seasons and its depletion during spring and early summer seasons. Furthermore, we will compare the snowcover-runoff relation between Alaskan and Siberian rivers and explain the regional difference in sensitivity of river runoff to basin snow cover changes.

PROJECT TIMELINE

<i>Milestone</i>	<i>Definition</i>	<i>Completion</i>
1.	Complete dataset preparation and a literature review	9/2009
2.	Complete analyses of basin climatic and hydrologic changes	12/2009
3.	Complete and submit an annual progress report to USGS	2/2010
4.	Complete examination of interaction and feedback among climate-snowcover-river flow	8/2010
5.	Complete and submit a summary report to USGS	2/2011

16. Methods, procedures, and facilities

Statistical techniques will be used in this project to: 1) quantify the magnitude of changes and regime shifts in river discharge and related climatic parameters, 2) reveal major spatial and temporal variation of the climatic parameters, such as snowfall and snow cover, and, 3) examine the associations between discharge and climate parameters. Changes in discharge and climatic variables will be determined by computing trends and identifying step changes in monthly and daily time series. Statistical significance of trends will also be considered in trend discussions. The statistical associations among river flow, basin snow cover, precipitation and temperature will be evaluated by regression analyses.

We have experience working on the Serbian large rivers. We have developed useful methods and procedures to examine large-scale snow-river flow relations. We will use similar approaches for this study. Specifically, we will use daily data to generate weekly basin-mean SWE time-series for the Yukon River during 1988–2001. On the basis of these weekly records, we will examine the seasonal changes of snowcover, by defining the SWE climatology based on weekly statistics,

determining the dates of snowcover formation/ disappearance and duration of snowcover/snow-free days, and quantifying the rates of snowcover mass change during the accumulation and melt seasons. We will also derive weekly discharge time-series from the daily streamflow data collected near the basin outlet, and use the weekly data to describe the seasonal streamflow changes, including discharge regime, rates of streamflow rise, and peak flow during the melt period. We will calculate the weekly correlation of streamflow with basin SWE, and determine the consistency between SWE and streamflow changes over the seasons. Furthermore, we will identify extreme snowmelt streamflow cases and examine their correspondence with basin snowcover conditions. These analyses define the weekly relationship between snowmelt runoff and basin SWE changes for the Yukon River. In addition to streamflow and snowcover data, basin-mean weekly precipitation and temperature time series will be created from the gridded global datasets for the study period (Hulme, 1991; Jones, 1994), and used to investigate the compatibility of SWE/SCE data with climate variables and to explain the streamflow response to seasonal snowcover changes.

It is important to point out that the approach of this project is not a complete water budget calculation; rather, we focus on the major terms in basin water budget, i.e. SWE, winter precipitation, and streamflow. We relate snow cover data (SWE and SCE) with streamflow data measured near the basin outlet, since discharge represents the integrated response of basin hydrology to climate influence.

17. Related Research

Over the last few years, we have applied remote sensing snowcover data and products for snowcover and snowmelt runoff analyses over the large arctic basins. Below is a summary of our preliminary activities and results.

A: Application of snowcover extent data

Remote sensing data/products have been very useful to cold region climate and hydrology investigations. For instance, the NOAA weekly maps (since June 1999, daily) based on visible data, despite some limitations, are quite reliable at many times and in many regions, and have shown to be important for polar regions climate, snow/ice and hydrology studies (*Steffen et al., 1993*). The establishment of the weekly snow cover dataset over the Northern Hemisphere permits quantitative assessments of changes and variations in regional snow cover extent (*Robinson et al., 1990*). These maps extend back to late 1966, and have recently had several inconsistencies rectified. They may be viewed at <http://climate.rutgers.edu/snowcover>. The NOAA snow cover maps are also useful for developing snowcover depletion curves and for generating the input snowcover data necessary to run the hydrologic and snowmelt runoff models (*Rango et al., 1997*).

We recently applied the weekly snowcover data in large Siberian watersheds (Lena, Yenisei and Ob rivers) and identified a close association of the runoff to snowcover extent changes during the spring melt period (*Yang et al., 2002*). Our initial analyses of snowcover and streamflow data in Alaska also show a strong correlation of monthly runoff with snowcover extent during early summer season (*Zhao, 2004*). These encouraging results clearly indicate the potential of using the weekly snowcover information to improve snowmelt runoff modeling and prediction in the

high latitude regions. This proposed research will continue our effort in the Yukon River with a focus on analyzing sub-basin snowmelt processes.

B: Application of SSM/I SWE data

Snow water equivalent (SWE) derived from passive microwave satellite data (SMMR and SSM/I) for the Northern Hemisphere have been produced at the NSIDC (*Armstrong and Brodzik, 2002*) using a modified version of the *Chang et al. (1987)* algorithm. Regional maps and products have also been developed in Canada from the SMMR and SSM/I data, and used for analyses of snowcover variations over space and time (*Walker and Goodison, 1993*). These data have been used for climate and hydrology analyses, including arctic active layer depth simulation (*Oelke et al. 2003*), arctic hydrologic model (*Su et al. 2005*). *Armstrong et al. (2005)* recently developed SWE data and climatology for the arctic watersheds.

Our initial analyses explored the compatibility between winter snowfall and snowcover data. Comparisons of Yukon basin winter snowfall and SWE accumulation show basin that maximum SWE is generally less than winter snowfall accumulation in most winter during 1988-2001, except for a few years when SWE was greater than total snowfall. It is expect to see the max SWE usually being less than winter snowfall due to snow sublimation. The comparisons also show greater inter-annual variations in snowfall relative to the basin SWE, i.e. higher and lower snowfall winters associated with similar SWE amounts. The differences between the total snowfall and maximum SWE are smaller in lower snowfall winters. These results indicate a discrepancy between the basin SWE and snowfall data. The possible causes may include, at least, biases in Arctic snowfall observations (*Yang et al., 2005*) and the uncertainty in remote sensing snowcover algorithm (*Armstrong and Brodzik, 2002; Walker and Goodison, 1993*). Nevertheless, it is important to identify this inconsistency, as it clearly illustrates the difficulties of accurately determining the major water budget fluxes in the large Arctic watersheds. In this project, we will use bias corrected daily precipitation data (*Yang et al., 2005*) to compare with SSM/I and *in-situ* snowcover data over the Yukon basin and its sub-basins.

18. Training potential

This project has significant training potential. The funds required will be used mainly to support graduate student(s). This project will train graduate and undergraduate students at UAF. It will directly involve 1 graduate and 2 (part-time) undergraduate students for dataset development and analyses. This project will also make efforts to increase the participation of Alaskan Natives in undergraduate and graduate studies, and to integrate this proposed research into the existing UAF Alaska Native Science & Engineering education infrastructure.

19. Investigators Qualifications (CV):

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PROFESSIONAL PREPARATION

- McMaster University, Hamilton, Ontario, Canada, Cold Region Hydrology, Postdoctoral Research Associate, April 1995 - March 1998
- Canadian Meteorological Service, Downsview, Ontario, Canada, Snow Hydrology and Climate, Post Doctoral Fellow, February 1992 - March 1995
- Chinese Academy of Sciences, Lanzhou, China, Hydrology, Ph.D., 1988
- Hohai University, Nanjing, China, Hydrometeorology, M.Sc., 1984
- Xinjiang University, Urumqi, China, Hydrology, B.Sc., 1981

APPOINTMENTS

- July 2006 - present, Associate Professor, CEE Dept. and Water and Environmental Research Center, Inst. of Northern Engineering, UAF.
- July 2005 – June 2006, Research Professor, Water and Environmental Research Center, Inst. of Northern Engineering, UAF.
- June 2002 – June 2005, Associate Professor, Water and Environmental Research Center, Inst. of Northern Engineering, University of Alaska Fairbanks.
- July 1999 – May 2002, Assistant Professor, Water and Environmental Research Center, Inst. of Northern Engineering, University of Alaska Fairbanks.
- April 1998 - June 1999, Research Scientist, Inst. for Global Change Research/Frontier Research System for Global Change, Tokyo, Japan.
- September 1989 - January 1992, Research Associate, Lanzhou Inst. of Glaciology and Geocryology, Chinese Academy of Sciences, Lanzhou, China.
- January 1989 - August 1989, Visiting Scientist, Centre for Remote Sensing and Environmental Optics, University of California, Santa Barbara.

RESEARCH INTERESTS

Cold Region Hydro-climatology, Snow Hydrology, Climate and Climate Change, and Applications of Remote Sensing Data/Products in the high latitude regions.

SELECTED PUBLICATIONS

- Woo, M-K., D. Kane, S. Carey, **D. Yang**, 2008: Progress in permafrost hydrology in the new millennium, *Permafrost and Periglacial Processes*, Volume 19 Issue 2, 237-254.
- Majhi, I., and **D. Yang**, 2008: Streamflow characteristics and changes in Kolyma basin in Siberia, *Journal of Hydrometeorology*, Vol. 9, 267-279.
- Yang, D.**, Y. Zhao, R. Armstrong, D. Robinson, and M.-J. Brodzik, 2007: Streamflow response to seasonal snow cover mass changes over large Siberian watersheds, *J. Geophys. Res.*, 112, F02S22, doi:10.1029/2006JF000518.

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- Berezovskaya, S., **D. Yang**, and D. Kane, 2004: Compatibility analysis of precipitation and runoff trends over the large Siberian watersheds, *Geophysical Research Letters*, Vol. 31, L21502, doi:10.1029/2004GL021277.
- Yang, D.**, B. Ye, A. Shiklomanov, 2004: Streamflow characteristics and changes over the Ob river watershed in Siberia. *J. of Hydrometeorology* 5(4), 69-84.
- Yang, D.**, B. Ye, and D. Kane, 2004: Streamflow changes over Siberian Yenisei river basin. *J. of Hydrology*, 296(1-4), 59-80.
- Kane, D., J. McNamara, **D. Yang**, P. Olsson, and R. Gieck, 2003: An Extreme Rainfall/Runoff Event in Arctic Alaska, *J. of Hydrometeorology*, 4(6), 1220–1228.
- Sugiura, K., **D. Yang**, and T. Ohata, 2003: Systematic error aspects of gauge-measured solid precipitation in the Arctic, Barrow, Alaska, *Geophysical Research Letters*, 3(4), 1192, doi: 10.1029/2002GL015547.
- Yang, D.**, D. Robinson, Y. Zhao, T. Estilow, and B. Ye, 2003: Streamflow response to seasonal snowcover extent changes in large Siberian watersheds. *J. of Geophysical Research-Atmospheres*, 108(D18), 4578, doi: 10.1029/2002JD003149.
- Yang, D.**, B.E. Goodison, J.R. Metcalfe, P.Y.T. Louie, E. Elomaa, C.L. Hanson, V.S. Golubev, Th. Gunther, J. Fullwood, R. Johnson, J. Milkovic, M. Lapin, 2001: Compatibility evaluation of national precipitation gauge measurements. *J. of Geophysical Research-Atmospheres*, 106(D2), 1481-1492.
- Yang, D.**, D.L. Kane, L.D. Hinzman, B.E. Goodison, J.R. Metcalfe, P.Y.T. Louie, G.H. Leavesley, D.G. Emerson, C.L. Hanson, 2000: An evaluation of the Wyoming gauge system for snowfall measurement. *Water Resources Research*, 2665-2678.
- Yang, D.**, 1999: An improved precipitation climatology for the Arctic Ocean. *Geophysical Research Letters*, Vol.26, No.11, 1625-1628.

SYNERGISTIC ACTIVITY

- Member, Science Team of the NASA Cold Land Process Pathfinder Mission (2004-present)
- Member, Northern Research Basin (NRB) Committee on Prediction in Undergauged Basins (PUB) (2004-present)
- Development of bias-corrected precipitation dataset and climatology for the Arctic
- Investigation of hydrologic response of large arctic rivers to climate change and variation
- Synthesis of water balance data from northern experimental watersheds
- Application of remote sensing snowcover data and products for Arctic hydrology research

COLLABORATORS

Barry Goodison, Canadian Meteorological Service, Downsview, Ontario, Canada

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Douglas Kane, Larry Hinzman, and Svetlana Berezovskaya, Water and Environmental Research Center, University of Alaska Fairbanks, AK

Tetsuo Ohata, Hokkaido University, Sapporo, Japan

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- Armstrong, R.L., M.J. Brodzik, K. Knowles, & M. Savoie. 2005. *Global monthly EASE-Grid snow water equivalent climatology*. Boulder, CO: National Snow and Ice Data Center. Digital media.
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- Serreze, M.C., D. H. Bromwich, M.P. Clark, A.J. Etringer, T. Zhang, and R. B. Lammers, 2002: The large scale-hydro-climatology of the terrestrial arctic drainage system. *J. of Geophys. Res.*, 107, doi:10.1029/2001JD000919.
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