

Research Addendum for Peer Review

Project Manager Name: Dr. Fei Yuan

Project ID and Title: (SN-81) Improved River Quality Monitoring Using Airborne Remote Sensing

I. Abstract

This project proposes a new and innovative research methodology, airborne dynamic hyperspectral remote sensing, to improve the study and monitoring of river water quality and riparian habitat in Minnesota. Cost-effective monthly hyperspectral data will be acquired by the Civil Air Patrol (CAP) ARCHER (Airborne Real-time Cueing Hyperspectral Enhanced Reconnaissance) system for the entire Blue Earth River. Analyses of the hyperspectral data compared with the simultaneously collected pollutant data will identify specific “signatures” of pollutants that can be detected by the sensor, then, in the future, pollutant monitoring can easily, and very cost effectively, be done in all watersheds in the State using only the airborne hyperspectral sensor.

II. Background and hypothesis

Traditional river quality assessment is based on two groups of water variables – physiochemical and biological. Biological measurements include fish fauna, macrophytes, periphytic growth, and species composition of phytoplankton while physicochemical variables typically consist of chlorophyll-a, total phosphorous (TP), and Secchi depth. The operational surface water quality assessment in relatively large regions is usually based on physicochemical measurements since they are comparatively more easily measured (Koponen, S., et al, 2002), but this approach is still expensive and time consuming.

Compared to traditional methods, remote sensing, which obtains information about Earth’s surface from measurements of radiated energy by aircraft or satellite sensors, provides a more efficient way of estimating some important variables such as turbidity, and Secchi depth (Brezonik et al., 2005; Gitelson et al., 1993; Kloiber et al., 2002; Koponen et al, 2002; Menken et al., 2006). Remote sensing offers the advantages of good spatio-temporal coverage and the possibility of measuring large regions simultaneously and dynamically for consecutive years; in the meantime, it potentially reduces the need for ground sampling (Koponen et al., 2002).

In Minnesota, regional-scale remote sensing studies on water quality have focused on lakes using medium-resolution (30m) multispectral (bandwidth > 100nm) Landsat images (Kloiber et al., 2002; Brezonik et al., 2005). Although the broad spectral bands and 30-m spatial resolution of Landsat imagery can provide reliable estimates for Secchi depth, they are not suitable for measuring optical characteristics of water. A recent study by the University of Minnesota (UMN) explored water quality of 15 lakes in east-central Minnesota using hyperspectral data that has much greater spectral and spatial resolution (Menken et al., 2006). In another recent study, as a joint effort by the Minnesota Pollution Control Agency (MPCA) and the UMN, hyperspectral sensing was used to map “how tributaries can muck up the big

ivers” (Star Tribune, 2006) statically, i.e. at one point in time and in one place, rather than dynamically, i.e. over time and across space.

Thus far, no work has been done on assessing dynamic (annual and inter-annual) river quality using remote sensing. In this study, we propose to develop an effective and innovative method for both river water quality and riparian habitat assessment using airborne dynamic hyperspectral sensing in the Blue Earth River watershed. Hyperspectral sensing has superior capability to identify subtle spectral features of natural objects. It offers a continuous spectrum of the aquatic system that is acquired in water quality assessment. This superiority comes from its use of dozens to hundreds of narrow contiguous bands rather than the several broad and discrete bands typical in regular remote sensing systems (Mustard et al., 2001). Hyperspectral data is difficult to manage and interpret due to its high dimensionality and the diverse properties of materials and variations in spectral features. However, with recent improvements in computer and sensor technologies, hyperspectral sensing is now emerging as one of the most promising trends of contemporary remote sensing science (Crósta et al., 1998; Green et al., 1998; Ellis and Scott, 2004; Li et al., 2005).

In the past years, acquisition of airborne hyperspectral imagery has been limited by instrument availability and cost (Aspinall et al., 2002). Compared to other options, much more cost-effective data can be acquired now by the CAP ARCHER System, which will be the nation’s first fully operational, large-scale hyperspectral imaging system. Since August 2005, CAP strategically began placing the ARCHER systems in key locations all around the country. It had a total of 16 ARCHER systems in operation by the end of September 2006. One is located in Minnesota (<http://atg.cap.gov/>). Using the ARCHER System for hyperspectral data collection cuts the cost by a remarkable 80-90%. This makes long-term, dynamic river monitoring possible. Moreover, our proposal creates a win-win situation: such projects provide funding for training CAP pilots who are students in the aviation program at Minnesota State University; in return, CAP provides cost-effective services for our project.

The proposed study area is the 160km Blue Earth River, which is a major tributary of the Minnesota River and one of the most polluted rivers in south-central Minnesota. With a mean discharge of $37\text{m}^3/\text{s}$ and a maximum flood flow of $1699\text{m}^3/\text{s}$, it contributes about 55% of the sediment load carried by the Minnesota River at Mankato, MN (WRC, 2003; Thoma et al., 2005). Restoration of water quality needs proper water quality parameters. Its size and pollutant levels make it a worthy study area and it is easily accessed by the researchers and the CAP.

The specific objectives of our project include: (1)obtaining extensive spectral measurements by airborne spectrometer and ground water samples monthly from 2007-2009; (2)analyzing the relations between spectral measurements and water samples by regression; (3)creating a quantitative retrieval algorithm of water quality assessment and applying it to the images acquired by the airborne Hyperspectral camera; (4)documenting the spatio-temporal patterns of water quality along the entire length of the river for three consecutive years; (5)analyzing any correlation between riparian geography (soil type, vegetation, landforms) and river water quality within the study area; and (6)building a corresponding GIS database and a website.

If this method proves feasible, it will be easily and cost effectively applied to all of the watersheds in the State using only the airborne hyperspectral sensor.

III. Description of the methodology to be employed to carry out the proposed research.

In order to obtain valuable data on the seasonal variability of water quality, both spectral and field measurements will be collected monthly from the spring melt (May) through the first snows (November) during 2007- 2009.

Spectral data will be collected by the CAP ARCHER system, which contains an advanced hyperspectral imaging (HSI) system, a panchromatic high-resolution imaging (HRI) camera, a global positioning system (GPS) and inertial navigation system (INS). The HSI system collects hyperspectral data at 1m spatial resolution with 52 spectral bands covering visible and near infrared region (500-1100 nm). The HRI camera collects aerial photos at 3 m resolution. These remote sensing images will be copied and stored in a devoted data server in the Geography Department at MSU and processed using special remote sensing and GIS software and computers in our satellite laboratory.

On days when airborne hyperspectral imagery is flown, three separate ground crews will take water samples and gather local site data at twelve pre-determined river access points. The major field variables to be collected and measured include: total suspended solids (TSS), total suspended volatile solids (TSVS), turbidity, chlorophyll a, phaeophytin a, total phosphorus (TP), total Kjeldahl nitrogen (TKN), nitrates (NO₃), Secchi depth (SD), pH, conductivity, upwelling and downwelling irradiance as well as weather observations. These will include basic measurements of water temperature, precipitation, wind speed and direction, as well as incoming solar radiation to calibrate the hyperspectral imagery with actual ground conditions. This combination will provide a better understanding of the complete picture of the rivers and riparian corridor's environmental conditions.

Based on the remote sensing and ground sampling data, quantification of spectra with water quality parameters will be correlated. Since TSS and TSVS are the pollutants of primary concern for this river (WRC, 2000), special emphasis will be placed on analyzing the effects of TSS and TSVS on water spectral characteristics. Defining the best spectral bands for determining TSS and TSVS will provide valuable information for quantitatively estimating the sediment content of water and the contribution of soil erosion.

Once spectral bands have been established, a GIS database will be constructed that combines the hyperspectral data with riparian characteristics including soil types, landforms, and vegetation. This database will help to quantify the role of soil erosion and bank failure as contributors to TSS and TSVS and will help to define the role of each in river water quality.

In the future, spectral findings from this study can be applied to the entire 6294 km² Blue Earth River watershed, other tributaries of the Minnesota River, and eventually to the whole state of Minnesota.

IV. Description of the results and/or products (deliverables) to be produced from the proposed research

Result 1: Identify Critical Sediment and Riparian Management Areas: We will develop a Geographic Information System (GIS) integrating hyperspectral data, water quality and riparian characteristics that identify critical environmental management areas.

Result 2: Increased Knowledge of Dynamic Riverine & Riparian Systems: This study will ascertain the seasonal variability of water quality by field sampling at twelve pre-determined river access points at the same time as airborne spectral measurements are flown. Samples will then be analyzed in the laboratory or field as appropriate for: total suspended solids (TSS), total suspended volatile solids (TSVS), turbidity, chlorophyll-a, phaeophytin-a, total phosphorus (TP), total Kjeldahl nitrogen (TKN), nitrates (NO₃), pH, and conductivity. Weather and solar radiation observations will help calibrate the hyperspectral imagery. Spectral and field data will be collected monthly from May to November 2007-2009.

Result 3: Correlate Water Quality with Riparian Characteristics: Based on remote sensing and ground sampling data, spectral, water quality and riparian parameters will be correlated thus creating a model that identifies significant links between water quality and riparian environments. Results will be applicable to similar watersheds. Once the spectral model has been calibrated to water quality, riparian habitat characteristics (vegetation, soils, bank stability, etc.) will be introduced.

Deliverable products include (1) raw remote sensing images (both the hyperspectral data and high resolution visible black and white images) for two years; (2) files and maps of critical sediment and riparian management areas; (3) regression models that identify relationships between river quality and spectral data, which are applicable to future studies; (4) a digital GIS database that integrates all the data; (5) final project reports and a website for data and product distribution.

V. Timetable for completing the proposed research. (milestones and dates)

	2007						2008												2009							
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6		
Result 1	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	PR	C	C	C	C	C	C	FR	
Result 2	C	C	C	C	C	PR					C	C	C	C	C	C	C	PR					C	C	FR	
Result 3						PR	C	C	C	C	C	C	C	C	C	C	C	PR	C	C	C	C	C	C	FR	
	<ul style="list-style-type: none"> Data collection starts 7/07 and will continue through 06/09. The last melt season of data will be analyzed and repeated after the end of the grant period in late summer 09. The results will be distributed to national meetings, journal articles, as well as local communities. “C”: Continually implement; “PR”: Preliminary report; “FR”: Final report 																									

VI. Deliverable products correlated to the timetable and budget deliverables may include partial completion of major accomplishments but only if the partial product is clearly recognizable and integral to completion of the major accomplishments.

- Remote sensing images will be collected and delivered from July to November, 2007; May to November, 2008; and May to June, 2009.
- Files and maps of critical sediment and riparian management areas can be delivered by the end of the project (June 2009).
- Partial regression models that identify relationships between river quality and spectral data will be available in the spring of 2008; complete and refined models will be deliverable by June 2009.
- A digital GIS data base integrating hyperspectral data, water quality and riparian characteristics will be deliverable by June 2009.
- Final project reports and a website for data distribution will be available when the project is completed.

VII. Budget requirements to conduct the proposed research including identifying any state and non-state in-kind and/or leveraged funds provided to support the research.

TOTAL PROJECT REQUEST BUDGET TOTAL BUDGET: \$ 159,000

Staff	12% of FTE per year for each of five faculty members	\$76,649
	Six student research assistants (2 Graduate & 4 Undergraduate)	\$38,932
Vendors	CAP ARCHER System for 14 aircraft flights with hyperspectral sensor	\$11,648
Supplies	Supplies & materials for field sampling & laboratory analyses	\$23,771
Travel	Mileage, meals and lodging related to field work	\$8,000
TOTAL		\$159,000

MSU Mankato has an existing geospatial laboratory that has all the hardware, software, and service that preexist for teaching and research. To include the funds of in-kind, we estimate:

\$100,000: Existing remote sensing, GIS, GPS software and hardware at MSU

\$10,000: Existing field & laboratory equipment for water sample collection and analysis at MSU

\$16,000: Newly requested equipment funds for new hardware of field data collection at MSU

VIII. Identification and brief background (targeted resumes acceptable) of the principal investigators and cooperators who will carry out the proposed research and selected publications.

All project partners are faculty in the interdisciplinary Earth Science Program at MSU. Their expertise in remote sensing (Fei Yuan), biogeography (Forrest Wilkerson), hydrogeology (Bryce Hoppie), geomorphology (Donald Friend), and soils (Ginger Schmid) provide the multidisciplinary background necessary to complete this highly complex project.

In addition, we are in contact with following persons from various agencies on project collaboration and data sharing:

- Patrick Baskfield, Hydrologist, Minnesota Pollution Control Agency
- Bill Van Rysuyk, Hydrologist, Minnesota Department of Agriculture
- Scott Madison, Water Resources Center, MSU
- Captain, Nash Pherson, CAP, Commander, Mankato Composite Squadron
- John Salvador, National Director of Operation, CAP
- Colonel, Drew Alexa, National ARCHER program manager, CAP
- Dr. John Kershenstein, Naval Research Laboratory
- Dr. Marvin Bauer, University of Minnesota, Twin Cities

Project Manager:

Dr. Yuan is an expert in remote sensing of the environment and in GIS. Her doctorate is in remote sensing and her master's is in GIS, additionally she has several years experience applying remote sensing to environmental management issues for the Chinese national government.

As project director she is responsible for overall coordination of data gathering and analyses. She will personally coordinate the remote sensing data collection and analyses, perform all needed analyses correlating field, water and remotely sensed data and will then develop a GIS to further analyze and display all data and results. Other team members will collect data and samples in the field and perform laboratory analyses.

FEI YUAN

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Education

2004: Ph.D., Remote Sensing, University of Minnesota
2003: MGIS (Master of Geographic Information Systems), University of Minnesota
1994: B.S., Geography, East China Normal University, Shanghai, China

Experience

2005/08 – Present: Assistant Professor, Geography, Minnesota State University, Mankato
2004/08 – 2005/05: GIS Coordinator, Geography, Miami University, Oxford, OH
2000/01 – 2004/07: Research Assistant, Remote Sensing & GIS Lab, U. of Minn., Twin Cities
1999/08 – 1999/12: Research Assistant, University of Arizona, Tucson
1994/07 – 1999/07: Remote Sensing Specialist, National Satellite Meteorological Center, China

Selected Journal Publications

Yuan, F. (In Review). Land cover change and environmental impact analysis in the Greater Mankato Area of Minnesota using remote sensing and GIS Modeling. *International Journal of Remote Sensing*.

- Wu, C.S. and Yuan, F. 2007. Seasonal sensitivity analysis of impervious surface estimation with satellite imagery. *Photogrammetric Engineering and Remote Sensing*. Accepted. In Press.
- Yuan, F. and Bauer, M.E. 2007. Comparison of impervious surface area and Normalized Difference Vegetation Index as indicators of surface Urban Heat Island effects in Landsat Imagery. *Remote Sensing of Environment*. 106(2): 375–386
- Roy, S.S. and Yuan, F. 2007. Patterns and variability of summer NDVI in response to climate variables at the local level in Minnesota. *GIScience and Remote Sensing*. 44(2): 1–16.
- Yuan, F., Sawaya, K.E., Loeffelholz, B.C., and Bauer, M.E. 2005. Land cover mapping and change analysis in the Twin Cities Metropolitan Area with Landsat remote sensing. *Remote Sensing of Environment*, 98(2-3): 317-328.
- Yuan, F., Bauer, M.E., Heinert, N. and Holden, G. 2005. Multi-level land cover mapping of the Twin Cities (Minnesota) Metropolitan Area with multi-seasonal Landsat TM/ETM+ data. *Geocarto International*, 20(2): 5-14.

Grants

- 2007: (Pending) MSU Technology Fee Grant – “Using New Remote Sensing Technologies to Enhance Student Learning in a Multi-Curricular Context”, \$18,268
- 2006: MSU Research Reassignment Grant – “Follow-up Research of Environmental Impacts Analysis in the Greater Mankato”, 1 course release
- 2006: MSU Faculty Improvement Grant – “Hyperspectral Remote Sensing Training”, \$900
- 2005: MSU Faculty Research Grant – “Environmental Change and Effects Analysis in the Greater Mankato Area using Remote Sensing and GIS Modeling”, \$4,115

Service

- 2006/01 – Present: *Minnesota GIS/LIS Consortium Board*, Higher Education
- 2006: Organizer and instructor, *Minnesota GIS/LIS Consortium Spring Workshop* – “Overview of ArcGIS 9.0”, Mankato, June, 9th, 2006
- 2006: Instructor, *Minnesota GIS/LIS Annual Conference Workshop* – “Advanced Remote Sensing for Image Processing and Analysis”. Oct. 4th, 2006
- 2006: College of Social and Behavioral Sciences Technology & Equipment Committee, MSU
- 2005: College of Social and Behavioral Sciences Teaching & Learning Committee, MSU

Manuscripts Reviewing

- Remote Sensing of Environment,
- Photogrammetric Engineering & Remote Sensing
- Remote Sensing of Impervious, Weng, Q.H. (Eds.)

Professional Affiliations

- American Society for Photogrammetry & Remote Sensing (ASPRS)
 Association of American Geographers (AAG)

FORREST D. WILKERSON

Biogeographer

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Education: 2004 Ph.D. Texas State University. *Environmental Geography*
1994 M.A. University of California, Davis. *Geography*
1990 B.A. California State University, Sacramento. *Geography*

Related Research Experience:

Revegetation Survey, Bass Lake, MN
Invasion of *Juniperus virginiana* at the Nye Center, Le Sueur County, MN
Global Observation Research Initiative in Alpine Environments, Inyo County, CA
Ice Jam Impacts on *Pinus ponderosa*, Middle Fork of the Salmon River, Idaho
Spatial and Temporal Hazards of Debris Flows, Glacier National Park, Montana

Representative Publications:

Wilkerson, Forrest D., and Ginger L. Schmid. 2003. Debris flows in Glacier National Park: Geomorphology and hazards. *Geomorphology* Vol. 55, no. 1-4: 317-328.
Wilkerson, Forrest D., Ginger L. Schmid, and David R. Butler. 2002. Lichenometric dating of hazardous debris flows, Glacier National Park, Montana. Graham A. Tobin, Burrell E. Montz, and F. Andrew Schoolmaster, eds. *Papers and Proceedings of the Applied Geography Conference*, Binghamton, NY, Vol. 25: 76-84.
Butler, David R., and Forrest D. Wilkerson. 2001. Hazardous ice jams in northwestern Montana: Their prediction and effects on the landscape. Graham A. Tobin, Burrell E. Montz, and F. Andrew Schoolmaster, eds. *Papers and Proceedings of the Applied Geography Conference*, Fort Worth, TX, Vol. 24: 57-64.
Wilkerson, Forrest D. 1995. Rates of frost heave and surface rotation of periglacial frost boils in the White Mountains, California. *Physical Geography* 16, no. 6: 487- 502.

Representative Professional Presentations:

Otto, Chad, Forrest Wilkerson, and Ginger Schmid. 2006. *A Floristic Resurvey of Bass Lake: A Successional Study Eighty-One Years After Catastrophic Drainage*. Association of American Geographers West Lakes Division.
Wilkerson, Forrest D., Komal Patel, Trisha T. Jackson, and Ginger L. Schmid. 2004. *Volumetric measurements of erosion in the Canyon Lake Spillway, south-central Texas*. Association of American Geographers (AAG) Abstracts. 100th Annual Meeting, Philadelphia. P. 467-68.
Wilkerson, Forrest D., Ginger L. Schmid, and David R. Butler. 2002. *Lichenometric dating of hazardous debris flows, Glacier National Park, Montana*. Applied Geography Conference. Binghamton, NY. p. 425.
Schmid, Ginger L., and Forrest D. Wilkerson. 2002. *Effect of tree invasion on alpine tundra soils, Glacier National Park, Montana*. Association of American Geographers Abstracts. 98th Annual Meeting, Los Angeles. p. 553.
Schmid, Ginger L., and Forrest D. Wilkerson. 1999. *Ice jam hazards on the Middle Fork of the Salmon River, Idaho*. Southwest Division of the AAG Abstracts. San Marcos, Texas. p. 23.

BRYCE HOPPIE
Hydrogeologist

Education

Ph. D., Earth Sciences, University of California, Santa Cruz, California; August, 1996.
B.S., Geological Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota; December, 1986.

Employment

1996 - Present Assistant/Associate Professor of Geology, Minnesota State University, Mankato
2003 - 2004 Lecturer and Research Associate, University of California, Santa Cruz
1991 - 1996 Teaching and Graduate Research Assistant, University of California, Santa Cruz
1986 - 1991 Geological Engineer, Shell Western E&P Inc., Bakersfield, California

Recent Teaching and Research Support History

2007: (Pending) Fecal Indicator Bacteria Fate and Transport in Shallow Lakes of the Southeastern Prairie Pothole Region. USDA NRI. \$350,000.
2005: Pre-Historical Environmental Changes in the Minnesota Prairie – Forest Ecotone Deduced From The Paleolimnology of High Island Lake, Sibley County, Minnesota: MSU Mankato Faculty Research Grant program. \$3600.
2004: Rock Preparation and Imaging Laboratory Phases I & II: Institutional Development Fund, Minnesota State University. \$27,000.
2001: Improved Regional Water Quality Assessment Using Thematic Mapper: Minnesota State University Faculty Research Grant program: \$2,400.

Recent Publications, Abstracts, and Presentations

Vorlicek, T., Swart, D., and Hoppie, B. (2006) Abnormal hydrogeochemistry within the Prairie du Chien confined bedrock aquifer, southeastern Minnesota, USA: 231st ACS National Meeting, Atlanta, GA, vol. 46, no. 1, p. 189-192.
Hoppie, B., Vorlicek, T., and Swart, D. (2005) Rapid recharge of a deeply buried carbonate aquifer, Rice County, Minnesota. GSA Abstracts with Programs, vol. 37, no. 7, pp. 32.
Schimek, M., and Hoppie, B. (2005) Seasonal dynamics of a high arctic lake, Lake Linne, Spitsbergen Island, Svalbard. Abstracts with Programs, GSA (NE Section), March, 2005.
Hoppie, B. W., and Roost, B. (2004) Enhanced Thematic Mapper Plus Analyses of Chlorophyll-a Concentration and Distribution in Small Kettle Lakes, Southern Minnesota. Eos, Transactions of the American Geophysical Union, 85(47) H11F-0365.
Hoppie, B. W. and Garrison, R. E. (2002) Post-rifting stratigraphic development in a transform margin basin: The Miocene Cuyama Basin, California. Jour. Sed. Pet., V. 72, p. 268-287.
Hoppie, B. W. and Garrison, R. E. (2001) Miocene Phosphate Accumulation in the Cuyama Basin, Southern California. Marine Geology, Vol. 177, p. 353-380.
Green, M. B., and Hoppie, B. W. (2000) Hydrologic properties of lake bottom sediments, Mills Lake, Blue Earth County, Minnesota. Geological Society of America, Abstracts with Programs, vol. 32, no. 7, pp. 271.
Fisher, A. T., Von Herzen, R., Blum, P., Hoppie, B., and Wang, K., (1999) Evidence may indicate recent warming of shallow slope bottom water off New Jersey shore: Eos, Transactions of the American Geophysical Union, Vol. 80, No. 15, p. 165, 172-173.

Ginger Lee Schmid
Soils Geographer

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Education

Ph.D. 2004 *Environmental Geography*, Texas State University
M.S. 1989 *Soil Science*, Montana State University
B.S. 1985 *Earth Sciences* (with honors), Montana State University

Relevant Research Experience

Global Observation Research Initiative in Alpine Environments, Inyo County, CA
Soils and Environmental Change at Alpine Treeline, Glacier National Park, MT
Fluvial Instability, Soil Stratigraphy, and Tectonics, Napa County, CA
Fire and Soil Erosion, Yellowstone National Park
Soil Erosion and Surface Disturbance, Gallatin National Forest, MT

Relevant Publications and Professional Presentations

- Wilkerson, Forrest, Ginger Schmid, and Jeff Cook. 2006. Geomorphic Monitoring of Periglacial Activity near White Mountain Research Station GLORIA Sites. Invited presentation, GLORIA Planning Workshop, White Mountain Research Station, Bishop CA
- Wilkerson, Forrest D., and Ginger L. Schmid. 2003. Debris flows in Glacier National Park: Geomorphology and hazards. *Geomorphology* Vol. 55, no. 1-4: 317-328.
- Schmid, Ginger L., and Forrest D. Wilkerson. 2002. Effect of tree invasion on alpine tundra soils, Glacier National Park, Montana. Association of American Geographers Abstracts. 98th Annual Meeting, Los Angeles. p. 553.
- Wilkerson, Forrest D., Ginger L. Schmid, and David R. Butler. 2002. Lichenometric dating of hazardous debris flows, Glacier National Park, Montana. Graham A. Tobin, Burrell E. Montz, and F. Andrew Schoolmaster, eds. Papers and Proceedings of the Applied Geography Conference, Binghamton, NY, Vol. 25: 76-84.
- Schmid, Ginger L., and Forrest D. Wilkerson. 1997. Soils in active periglacial patterned ground, White Mountains, California. Poster. Association of American Geographers Abstracts. 93rd Annual Meeting, Ft. Worth. p. 234.
- Schmid, Ginger L. 1993. Endangered aquatic habitat versus vineyard productivity: Is there a compromise? Association of American Geographers Abstracts. 89th Annual Meeting, Atlanta. p. 212.
- Schmid, Ginger L. 1992. Soil erosion and channel hydrology in a coastal California watershed. Association of American Geographers Abstracts. 88th Annual Meeting, San Diego. p. 215.
- Hansen-Bristow, Katherine, Clifford Montagne, and Ginger Schmid. 1990. Geology, geomorphology, and soils within whitebark pine ecosystems. In Proceedings-Symposium on whitebark pine ecosystems: Ecology and management of a high-mountain resource. 62-71. USDA Forest Service. General Technical Report INT-270.

DONALD FRIEND

Geomorphologist

Dr. Friend is Professor and Chair of the Department of Geography, as well as Director of Earth Science Programs, at Minnesota State University (MSU). He serves on the Association of American Geographers (AAG) governing body, the AAG Council, and is the US Representative to the International Geographical Union Commission on Mountain Systems. He is past Chair and Founder of the Mountain Geography Specialty Group of the AAG. He is a member of the Editorial Board of the Journal of Mountain Science published by the Chinese Academy of Sciences and serves as North American Regional Editor for Geographische Rundschau – International Edition published by Westermann. He sits on the advisory boards of The Mountain Studies Institute and McGraw-Hill Publishers. His training has great breadth with specialization in mountain and desert environments. His research and teaching interests focus on physical geography, especially earth surface and atmospheric processes, their interaction and human impacts in mountains. He is also keenly interested in geographic, environmental and international education. Honors he has received include: a Fulbright Senior Scholarship to Germany; the "J. Warren Nystrom" Award from the AAG for the most outstanding research based upon a dissertation in Geography; being named a "Teaching Scholar Fellow" at MSU; membership in Gamma Theta Upsilon, the International Geographical Honor Society; outstanding teaching and advising awards at MSU; the annual "Frontier Forum" distinguished lectureship at MSU; listing in Who's Who in America, Who's Who in the World and Who's Who in Science and Engineering; and he has been an invited speaker on many occasions, most recently to the University at Cologne, Germany where he discussed the development of desert slopes.

EDUCATION

Ph.D., Geography, Arizona State University, 1997.

Association of American Geographers 'Nystrom' Award for the Most Outstanding Dissertation Research.

Dissertation: "Evolution of Desert Colluvial Boulder Fields, Eastern California."

M.A., Geography, University of Colorado at Boulder, 1988.

Thesis: "Glacial Outburst Floods of the Kennicott Glacier, Alaska: An Empirical Test."

B.S., Conservation of Natural Resources, University of California at Berkeley, 1984.

PUBLICATIONS (selected)

(* Refereed)

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| In Press | * | Brenning, A., M. Grasser and D. A. Friend. "Statistical Estimation and Generalized Additive Modeling of Rock Glacier Distribution in the San Juan Mountains, Colorado, USA." <u>Journal of Geophysical Research</u> . <i>Impact Factor 2.784 in 2005</i> . |
| In Press | * | Fickert, Thomas, Donald Friend, Friederike Grüniger, Bruce Molnia & Michael Richter. "Did Debris Covered Glaciers Serve as Pleistocene Refugia for Plants? A New Hypothesis Derived from Observations of Recent Plant Growth on Glacier Surfaces?" <u>Arctic, Antarctic and Alpine Research</u> . <i>Impact Factor 1.089 in 2004</i> . |
| 2005 | * | Friend, Donald A., "Surface Macrofabric of Boulder Dominated Desert Mountain Slopes, California, USA." <u>Journal of Mountain Science</u> , v.2(3):181-192.

Friend, Donald A., "Rock Glaciers and Climate Change: Some of the Effects of Higher Atmospheric Temperature in Mountains." <u>The Funnel: News Magazine of the German-American Fulbright Commission</u> , v.41(2):26. |
| 2004 | | Friend, Donald A., "Foreword: An Environmental and Geographic Perspective." In: Bishop, Michael P., and John F. Shroder, Jr., editors, <u>Geographic Information Science and Mountain Geomorphology</u> . Springer-Praxis, Berlin, Heidelberg, New York. Pp. xxiii-xxiv. ISBN: 3-540-42640-X |
| 2003 | * | Friend, D. A. and Williams M.W. "Water Quality as an input to Development Policy." In: Taylor, Leslie and Anne Ryall, editors, <u>Sustainable Mountain Communities: Environmental Sustainability for Mountain Areas Impacted by Tourism and Amenity Migration</u> , The Banff Centre, Canada. pp. 93-97. ISBN 1-984773-07-1. |

References

- Aspinall, R.J., Marcus, W.A., and Boardman, J.W., 2002. Considerations in collecting, processing, and analyzing high spatial resolution hyperspectral data for environmental investigations. *Journal of Geographic System*, 4:15-29
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