

Stephen Thomas Lancaster

Department of Geosciences
Oregon State University
104 Wilkinson Hall
Corvallis, OR 97331-5506
541-737-9258 (voice), 541-737-1200 (fax)
lancasts@geo.oregonstate.edu
<http://www.geo.oregonstate.edu/~lancasts/>

EDUCATION

Massachusetts Institute of Technology	Ph.D., Hydrology (Dept. Civil & Environmental Eng.)	1998
Harvard University	B.A., Physics major	1990

THESIS

A Nonlinear River Meandering Model and its Incorporation in a Landscape Evolution Model
Rafael L. Bras and Kelin X Whipple, co-supervisors (abstract and thesis at *http://www.geo.oregonstate.edu/~lancasts/thesis_abstract.pdf* and *[.../thesis.pdf](http://www.geo.oregonstate.edu/~lancasts/thesis.pdf)*)

PROFESSIONAL EXPERIENCE

Associate Director, Water Resources Engineering Program, Oregon State Univ.	2009-present
Associate Professor, Dept. of Geosciences, Oregon State University	2007-present
Assistant Professor, Dept. of Geosciences, Oregon State University	2001-2007
Research Associate, Dept. of Geosciences, Oregon State University	1998-2001
Research Assistant, Dept. of Civil and Environmental Engineering, MIT	1993-1998
Volunteer for Science, U.S. Geological Survey and Volunteer in the Parks, Buffalo National River	1992
Laboratory Aid, High Energy Physics Laboratory, Harvard University	1990-1991
Teaching Fellow, Physics Department, Harvard University	1990

COURSES

GEO 202 Earth Systems Science 2005–2007
Introductory course in Geosciences “core”. Revised lecture and laboratory materials in 2005. Adopted new book, lecture notes, and tests and developed some new labs in 2007. Teach in odd years.

GEO 306 Minerals, Energy, Water, and the Environment 2002
Course meeting Science and Technology requirement in the Baccalaureate Core Curriculum.

GEO 309 Environmental Justice 2004–
Developed and taught new course meeting Difference, Power, and Discrimination (DPD) requirement in the Baccalaureate Core Curriculum (first such course in Geosciences). Development funded by OSU DPD Course Development Grant. Teach every year.

GEO 322 Surface Processes 2002–
Redesigned course, including lecture and laboratory materials. Laboratory manual rewritten in 2005 with

additional TA funded in part by OSU L.L. Stewart Faculty Development Award. Teach every year.

GEO 432/532 Applied Geomorphology 2003–
Course essentially designed from scratch in 2003 and completely revised to focus on river restoration and related issues in 2005. Focuses on collection and utilization of field data in written reports. Teach every year.

GEO 582 Geomorphology of Forests and Streams 2006–
Redesigned course in 2006. Teach in even years.

GEO 699 Topics in Geomorphology 2003
Seminar course focused on modeling in geomorphology. Taught once as overload.

GRANTS

National Science Foundation, Hydrological Science, \$4.3 million (\$186K to Lancaster) 2010-2015
“Water Sustainability in the Willamette Basin,” J. McDonnell (PI), J. Bolte, B. Bond, A. Plantinga, and P. Mote (co-PIs) (S. Lancaster is Senior Personnel).

National Science Foundation, Geomorphology and Land-use Dynamics, \$27,196 2010-2011
Supplemental award for “Sediment Storage at the Transition Between Debris-Flow and Fluvial Processes,” S. Lancaster (PI).

National Science Foundation, Geomorphology and Land-use Dynamics, \$350,959 2009-2012
“Climatic and Geomorphic Triggering Mechanisms of Cascadian Periglacial Debris Flows,” A. Nolin (PI), S. Lancaster, and G. Grant (co-PIs).

USGS-IWW Small Grants Program, \$24,297 2008-2011
“The Influence of Sediment Deposition on the Emergence Success of Juvenile Salmonids,” S. Lancaster (PI) and C. May (co-PI).

National Science Foundation, Geomorphology and Land-use Dynamics, \$18,000 2007-2008
“Small Grant for Exploratory Research: Mapping the November 2006 Periglacial Debris Flows on Mount Hood and Mount Rainier,” A. Nolin (PI), and S. Lancaster (co-PI).

National Science Foundation, Geomorphology and Land-use Dynamics, \$107,538 2007-2010
“Collaborative Research: The Role of Debris Flows in Shaping Mountainous Terrain,” S. Lancaster (with G. Tucker, U. Colorado at Boulder).

National Park Service, \$36,200 2007-2008
“Modeling a Channel Migration Corridor for the 59-mile Segment of the Missouri National Recreation River,” S. Lancaster (PI), R. Jacobson (co-PI), T. Cole, and R. Inglis.

Watershed Research Cooperative, Oregon State University, \$23,000 2007-2008
“Sediment sources and sinks observed through LiDAR in Trask River Watershed Study Area,” S. Lancaster.

National Science Foundation, Ocean Tech. & Interdisciplinary Coord., \$19,981 2007-2008
“Evaluation of Optical Fiber Distributed Temperature Sensors (DTS) as a Tool to Constrain Heat and Mass Transport Between Sediments and the Overlying Water Column,” A. Trehu (PI), R. Haggerty, S. Lancaster, and J. Selker (co-PIs).

National Council for Air and Stream Improvement, Inc., \$15,000 2006-2007
“Application of the CHILD model to determine the probability of wood and sediment delivery to a critical reach,” S. Lancaster.

Australian Research Council, AU \$1,484,016 (my share = AU \$19,000) 2006-2010

“TERRESIM: A simulation system for understanding and managing interactions between runoff, vegetation, soils and climate in a changing environment,” G. Willgoose (fellowship recipient), P. Binning, S. Lancaster, M. Kirkby, and P. Bishop (partner investigators).

National Science Foundation, Geomorphology and Land-use Dynamics, \$289,260 2006-2009
“Sediment Storage at the Transition Between Debris-Flow and Fluvial Processes,” S. Lancaster.

National Science Foundation, Hydrologic Sciences, \$80,000 2006-2009
“Heat Budget in the Hyporheic Zone of a Large, Gravel-Bed River,” S. Lancaster (PI) and R. Haggerty (co-PI).

USDI Bureau of Land Management, \$20,474 2005-2006
“Forest Management Effects on Peak Storm Flows and Consequent Effects on Stream Channel Morphology,” S. Lancaster.

Oregon Department of Environmental Quality, \$61,000 2005
“Investigation of the Temperature Impact of Hyporheic Flow,” S. Lancaster (PI) and R. Haggerty (co-PI).

OSU L.L. Stewart Faculty Development Award, \$2200 2005
“Active Learning Component for Laboratories in a Medium-Enrollment, Required Course for Geosciences Majors,” S. Lancaster.

USDA Forest Service-OSU cooperative agreement, \$499,415 2004-2009
“Geomorphic response to changing water and sediment regimes,” S. Lancaster and G. Grant (USFS).

OSU Technology Resource Fee grant, \$10,565 2004
“Enhanced Classroom for the Department of Geosciences,” S. Lancaster.

OSU Undergraduate Research Innovation Scholarship Creativity, \$1000 2003
“Mapping valley deposit surface ages with dendrochronology,” Z. Gray (S. Lancaster, advisor).

OSU Difference, Power, and Discrimination Curriculum Development Grant, \$3,000 2003
“Developing a course on environmental justice in the Department of Geosciences,” S. Lancaster.

Northwest Academic Computing Consortium, \$10,000 2003-2004
“Simulating landscape evolution in the classroom with the Channel-Hillslope Integrated Landscape Development (CHILD) model,” S. Lancaster.

Portland General Electric, \$134,000 2002-2005
“Impacts of removing Marmot Dam,” S. Lancaster.

RECENT COLLABORATORS

Linda Ashkenas (OSU), Rafael Bras (MIT), John Bolte (OSU), Nathan Casebeer (OSU), Quintijn Clevis (Shell), Sky Coyote (freelance), Roger Denlinger (USGS CVO), Arnaud Desitter (Oxford), Kevin Farthing (OSU), Walter Frueh (OSU), Nicole Gasparini (Tulane), Gordon Grant (USDA PNW), Stan Gregory (OSU), Roy Haggerty (OSU), Robert Jacobson (USGS CERC), Anne Jefferson (UNC-Charlotte), Gary Lock (Oxford), Christine May (JMU), Anne Nolin (OSU), John Selker (OSU), Anne Trehu (OSU), Gregory Tucker (CU-Boulder), Emily Underwood (OSU), Rose Wallick (OSU), Garry Willgoose (U. Newcastle).

STUDENTS

Likun Chen, M.S., Geography 2010-present
John Zunka, M.S., Geology 2008-present
J. Rose Wallick, Ph.D., Geology 2007-present

W. Terry Frueh, Ph.D., Water Resources Engineering	2007-present
Graysen Squeochs, M.S., Water Resources Science (with R. Haggerty)	2006-present
Emily Underwood, M.S., Geology	2005-2007
Kevin Farthing, M.S., Environmental Engineering	2005-2006
Colin MacLaren, M.S., Geography	2004-present
Anne Jefferson, Ph.D., Geology (with G. Grant, USFS)	2002-2006
Nathan Casebeer, M.S., Geology	2002-2004
J. Rose Wallick, M.S., Geology and Bioengineering	2001-2004

RECENT INVITED PRESENTATIONS AND WORKSHOPS

Special session on debris flows, Geological Society of America Annual Meeting, Denver, November, 2010.

Seminar series, USGS Oregon Water Science Center, Portland, November, 2009.

Seminar series, USGS Oregon Water Science Center, Portland, November, 2008.

Special seminar, School of Engineering, U. Newcastle, Australia, October, 2008.

Applied Math Seminar, OSU, November, 2007.

Meeting on thermal pollution credit trading sponsored by the Willamette Partnership, OSU, June, 2006.

PROFESSIONAL ORGANIZATIONS

American Geophysical Union	1993-present
Geological Society of America	2009-present
Society for the Advancement of Chicanos and Native Americans in Science	2003-2004
American Indian Science and Engineering Society	1993-1994

SYNERGISTIC ACTIVITIES

Associate Editor, Journal of Geophysical Research - Earth Surface 2009-present
Assign reviewers and make recommendations for papers, particularly those addressing debris flows and landscape evolution.

Core Member, Terrestrial Working Group(TWG), CSDMS 2007-present
Attended both annual meetings and led breakout sessions for the Community Surface Dynamics Modeling System (CSDMS) TWG. Worked with TWG leader, Greg Tucker, to devise annual meeting strategies. Helped write and edit TWG's annual report.

Temperature Total Maximum Daily Load, Willamette River, Oregon 2005-present
Made several presentations to and met with Oregon Dept. Environmental Quality, municipal clean water agencies, and other stakeholders regarding formulation of new rules for stream temperature regulation of the Willamette River, Oregon, and development of a scheme for trading pollution and restoration credits.

Developer, Channel-Hillslope Integrated Landscape Development (CHILD) Model 1996-present
One of the original group of four scientists (others, R.L. Bras, N.M. Gasparini, G.E. Tucker) that designed and programmed this modeling "toolbox" for landscape evolution at MIT and, subsequently, elsewhere.

Designed and implemented algorithms for meandering over geologic time, movement of points with dynamic remeshing, debris-flow runout, and incorporation of vegetation, among others. Recently directed the development of a graphical user interface that will allow classroom use of the CHILD model.

Coastal Landscape Analysis and Modeling Study (CLAMS) 1998-present

Participate as a “PI” in this project uniting foresters, ecologists, economists, sociologists, and geomorphologists and funded by the Oregon Department of Forestry and the U.S. Forest Service’s Northwest Forest Plan. Adapted CHILD model to problems of forest-geomorphology interactions influencing aquatic habitat. Make presentations to and attend meetings with participants from federal and state agencies, local watershed councils, forest industry, and non-governmental organizations.

Difference, Power and Discrimination (DPD) Program, OSU 2001-present

Attended two workshop series for pedagogical development and incorporation of curricular materials for teaching issues of difference, power, and discrimination in the classroom. Awarded a DPD Curriculum Development Grant for the development of a “DPD” course on environmental justice in the Department of Geosciences. Developed course, GEO 309 Environmental Justice, which meets the DPD requirement in OSU’s Baccalaureate Core Curriculum.

Faculty Advisor, American Indian Science and Engineering Society, OSU Chapter 2002-2008

Attend weekly meetings. Supervise and assist activities including retreats, pow-wows, and regional and national meetings.

AWARDS AND HONORS

L.L. Stewart Faculty Development Award, OSU (\$2200 for lab manual development)	2005
GE Fund Junior Faculty Coupon (\$15,000 start-up funds upon faculty appointment)	1998
American Geophysical Union Outstanding Student Paper Award, Hydrology section	1996
National Science Foundation Minority Graduate Research Honorable Mention	1993
MIT Minority Graduate Fellowship	1992-93
Parsons Fellowship, MIT	1992-93
Graduated <i>Cum Laude</i> in General Studies, Harvard University	1990
Harvard College Scholarship for academic achievement of high distinction	1988-89
National Merit Scholarship	1985-86

PUBLICATIONS (PEER-REVIEWED)

Tucker, G.E., S.W. McCoy, A.C. Whittaker, G.P. Roberts, S.T. Lancaster, and R. Phillips, 2011. Geomorphic significance of post-glacial bedrock scarps on normal-fault footwalls, *Journal of Geophysical Research*, in press.

Lancaster, S.T., E.F. Underwood, and W.T. Frueh, 2010. Sediment reservoirs at mountain stream confluences: Dynamics and effects of tributaries dominated by debris flow and fluvial processes, *Geological Society of America Bulletin*, 122(11/12), 1775–1786, doi: 10.1130/B30175.1. (<http://bulletin.geoscienceworld.org/cgi/content/full/122/11-12/1775?ijkey=rIbtPzz2RZmak&keytype=ref&siteid=gsabull>)

Jefferson, A., G.E. Grant, S.L. Lewis, and S.T. Lancaster, 2010. Coevolution of hydrology and topography on a basalt landscape in the Oregon Cascade Range, USA. *Earth Surface Processes and Landforms*, 35, 803-816, doi:10.1002/esp.1976 . (<http://www.geo.oregonstate.edu/~lancasts/>)

Jefferson_EtAl_ESPL_online_2010.pdf)

- Lancaster, S.T., 2008. Evolution of sediment accommodation space in steady-state bedrock-incising valleys subject to episodic aggradation. *Journal of Geophysical Research*, 113, F04002, doi:10.1029/2007JF000938. (http://www.geo.oregonstate.edu/~lancasts/Lancaster_2007JF000938_JGR_2008.pdf)
- Lancaster, S.T., and N.E. Casebeer, 2007. Sediment storage and evacuation in headwater valleys at the transition between debris-flow and fluvial processes. *Geology*, 35(11), 1027-1030, doi:10.1130/G239365A.1. (http://www.geo.oregonstate.edu/~lancasts/Lancaster_Geology_2007.pdf, http://www.geo.oregonstate.edu/~lancasts/Lancaster_Geology_2007_Supplementary_Material.pdf)
- Wallick, J.R., G.E. Grant, S.T. Lancaster, J.P. Bolte, and R.P. Denlinger, 2007. Patterns and controls on historical change in a large river, Willamette River, Oregon, USA, in *Large Rivers: Geomorphology and Management*, edited by A. Gupta, John Wiley & Sons, Ltd., Hoboken. (http://www.geo.oregonstate.edu/~lancasts/Wallick_etal_Willamette_Large_Rivers.pdf)
- Clevis, Q., G. Tucker, G. Lock, S. Lancaster, N. Gasparini, A. Desitter, and R. Bras, 2006. Geoarchaeological simulation of meandering river deposits and settlement distributions: A three-dimensional approach. *Geoarchaeology: An International Journal*, 21(8), 843-874, doi:10.1002/gea.20142. (http://www.geo.oregonstate.edu/~lancasts/Clevis_EtAl_Geoarch_21_2006.pdf)
- Lancaster, S.T., and G.E. Grant, 2006. Debris dams and the relief of headwater streams, *Geomorphology*, 82, 84-97, doi:10.1016/j.geomorph.2005.08.020. (special issue: The Hydrology and Geomorphology of Bedrock Rivers, edited by P.A. Carling) (http://www.geo.oregonstate.edu/~lancasts/Lancaster_Grant_debris_dams_Geomorphology_82_2006.pdf) INVITED.
- Wallick, J.R., S.T. Lancaster, and J.P. Bolte, 2006. Determination of bank erodibility for natural and anthropogenic bank materials using a model of lateral migration and observed erosion along the Willamette River, Oregon, USA, *River Research and Applications*, 22(6), 631-649, doi:10.1002/rra.925. (http://www.geo.oregonstate.edu/~lancasts/Wallick_EtAl_Bank_Erodibility_RRA_22_2006.pdf)
- Clevis, Q., G.E. Tucker, S.T. Lancaster, A. Desitter, N. Gasparini, and G. Lock, 2006. A simple algorithm for the mapping of TIN data onto a static grid; applied to the stratigraphic simulation of river meandering deposits, *Computers and Geosciences*, 32(6), 749-766, doi:10.1016/j.cageo.2005.05.012. (http://www.geo.oregonstate.edu/~lancasts/Clevis_EtAl_CompGeosci_32_2006.pdf)
- Lancaster, S.T., S.K. Hayes, and G.E. Grant, 2003. Effects of wood on debris flow runout in small mountain watersheds, *Water Resources Research*, 39(6), 1168, doi:10.1029/2001WR001227. (http://www.geo.oregonstate.edu/~lancasts/2001WR001227_lancaster_effwooddf.pdf)
- Lancaster, S.T., and G.E. Grant, 2003. You want me to predict what? in *Prediction in Geomorphology*, edited by P.R. Wilcock and R.M. Iverson, pp. 41-50 (DOI: 10.1029/135GM04), American Geophysical Union, Washington. (http://www.geo.oregonstate.edu/~lancasts/CH4_Layout.pdf)
- Lancaster, S.T., and R.L. Bras, 2002. A simple model of river meandering and its comparison to natural channels, *Hydrological Processes*, 16(1), 1-26. (http://www.geo.oregonstate.edu/~lancasts/LancasterBras2002_fmtd.pdf)
- Tucker, G.E., S.T. Lancaster, N.M. Gasparini, and R.L. Bras, 2001b. The channel-hillslope integrated landscape development (CHILD) model, *Landscape Erosion and Evolution Modeling*, ed. by R.S. Harmon and W.W. Doe, III, pp. 349-388, Kluwer Academic/Plenum Publishers, New York. (<http://www.colorado.edu/geolsci/gtucker/preprints/child01nofigs.doc> and <http://www.colorado.edu/geolsci/gtucker/preprints/child01caps+figs.pdf>)

Tucker, G.E., S.T. Lancaster, N.M. Gasparini, R.L. Bras, and S.M. Rybarczyk, 2001a. An object-oriented framework for hydrologic and geomorphic modeling using triangulated irregular networks, *Computers and Geosciences*, 27(8), 959-973. (http://www.geo.oregonstate.edu/~lancasts/Tucker_EtAl_CompGeosci_27_2001.pdf)

Lancaster, S.T., S.K. Hayes, and G.E. Grant, 2001. Modeling sediment and wood storage and dynamics in small mountainous watersheds, *Geomorphic Processes and Riverine Habitat*, ed. by J.M. Dorava, D.R. Montgomery, B.B. Palcsak, and F.A. Fitzpatrick, pp. 85-102, American Geophysical Union, Washington. (http://www.geo.oregonstate.edu/~lancasts/SedWoodDynStor_fin.pdf)

REPORTS (NOT PEER-REVIEWED)

Lancaster, S.T., R.B. Jacobson, and S. Coyote, 2009. *Modeling a Channel Migration Corridor for the 59-Mile Segment of the Missouri National Recreation River*, Final Report to National Park Service, Oregon State University, Corvallis, 103 pp.

Lancaster, S., R. Haggerty, S. Gregory, K.T. Farthing, and S. Biorn-Hansen, 2005. *Investigation of the Temperature Impact of Hyporheic Flow: Using Groundwater and Heat Flow Modeling and GIS Analyses to Evaluate Temperature Mitigation Strategies on the Willamette River, Oregon*, Final Report to Oregon Dept. Environmental Quality, Oregon State University, Corvallis, 104 pp. (http://www.geo.oregonstate.edu/~lancasts/Lancaster_et_al_Hyporheic_Report_for_DEQ_Final.pdf)

Tucker, G.E., N.M. Gasparini, R.L. Bras, and S.T. Lancaster, 1999. *A 3D Computer Simulation Model of Drainage Basin and Floodplain Evolution: Theory and Applications*, Technical Report for U.S. Army Construction Engineering Research Laboratories. (<http://platte.mit.edu/~child/Lit/report99.html>)

Tucker, G., N. Gasparini, S. Lancaster, and R. Bras, 1997. *An Integrated Hillslope and Channel Evolution Model as an Investigative and Prediction Tool*. Year 2 annual report, DACA88-95-R-0020. Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, Mass., irregular pagination.

SELECTED ABSTRACTS

Nolin, A.W., G.E. Grant, and S.T. Lancaster, 2010. Melting mountains: LiDAR mapping and characterization of the periglacial debris flows on Mt. Rainier, Washington and Mt. Hood, Oregon, *GSA Abstracts with Programs*, 42(5), 37 (Paper No. 7-4). *INVITED*.

Lancaster, S.T., G.E. Grant, G.E. Tucker, W.T. Frueh, S.W. McCoy, and A.C. Whittaker, Episodicity and geologic timescales: Implications of debris flows for landscape evolution, *GSA Abstracts with Programs*, 42(5), 385 (Paper No. 156-8). *INVITED*.

Frueh, W.T., and S.T. Lancaster, 2010. Quantifying charcoal budgets in steepland watersheds: Field measurements and modeling of coupled sediment-charcoal transport and storage in the Oregon Coast Range, *GSA Abstracts with Programs*, 42(5), 159 (Paper No. 62-10).

McCoy, S., G. Tucker, A. Whittaker, S. Lancaster, G. Roberts, and P. Cowie, 2010. Debris flows and landscape evolution: Insight from topographic analysis, millennial erosion rates and grain-scale flow mechanics, *Geophysical Research Abstracts*, 12, EGU2010.

Lancaster, S.T., E.F. Underwood, and W.T. Frueh, 2009. Sediment reservoirs at mountain stream confluences: Dynamics and effects of tributaries dominated by debris flow and fluvial processes, *Eos Trans. AGU*, 90(52), Fall Meet. Suppl., Abstract EP53E-08.

Zunka, J.P., D. Tullos, and S. Lancaster, 2009. Effects of small sediment barrier removal on geomorphic complexity and habitat diversity, *Eos Trans. AGU*, 90(52), Fall Meet. Suppl., Abstract H51G-0853.

- Grant, G., A.W. Nolin, E. Copeland, J. Ellinger, L. Parker, S.T. Lancaster, P.M. Kennard, I. Delaney, and E. Tainer, 2009. From atmospheric rivers to rivers of debris: Coupling extreme precipitation events, glacial retreat, debris flows, and channel changes on Mount Rainier, Washington, *GSA Abstracts with Programs*, 41(7), 40 (Paper No. 8-2).
- McCoy, S.W., G.E. Tucker, A.C. Whittaker, and S.T. Lancaster, 2009. Can snow avalanches carve steepland channels? Evidence from channel morphology, deposit stratigraphy and discrete element modeling, *GSA Abstracts with Programs*, 41(7), 716 (Paper No. 280-6).
- May, C.L., T.E. Lisle, B. Pryor, and S.T. Lancaster, 2009. Spatial patterns of sediment deposition and the effects on salmonid survival, *GSA Abstracts with Programs*, 41(7), 573 (Paper No. 225-2).
- Squeochs, G., S.T. Lancaster, R. Haggerty, A.M. Trehu, and J. Selker, 2008. Distributed Temperature Sensing (DTS) using optical fiber probes to constrain heat and fluid transport in the subsurface, *Eos Trans. AGU*, 89(23), Jt. Assem. Suppl., Abstract NS24A-05.
- Lancaster, S.T., and G.E. Grant, 2005. Coalescing debris-fill complexes in headwater valleys of the Oregon Coast Range, *Eos Trans. AGU*, 86(47), Fall Meet. Suppl., Abstract H51H-01.
- Lancaster, S.T., and G.E. Grant, 2004. Debris dams, sediment impoundment, and the relief of headwater streams, *Eos Trans. AGU*, 85(47), Fall Meet. Suppl., Abstract H41G-02.
- Lancaster, S.T., S.K. Hayes, and G.E. Grant, 2000. Sediment and wood storage and dynamics in small mountainous watersheds, *EOS, Trans. AGU*, 82(20), suppl., p. S189. (INVITED)
- Lancaster, S.T., R.L. Bras, and K.X Whipple, 1996. Simulation of river meandering over long distances and times: A physically based model, *EOS, Trans. AGU*, 77(17), suppl., p. S124.

Last updated: February 24, 2011