**Mountain Terrain Atmospheric Modeling and Observations**

**(MATERHORN) Program**

**ONR FY 2011 MURI TOPIC #7: Improved Meteorological Modeling in Mountain Terrain**

**Project Website:** [www.nd.edu/~dynamics/materhorn](http://www.nd.edu/~dynamics/materhorn)

**Agency:** Office of Naval Research (Topic Chiefs: Dr. Ronald J. Ferek and CDR Daniel Eleuterio, PhD)

**Grant Number:** # N00014-11-1-0709

**Principal Investigator:**

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**MURI Team:**

Naval Post Graduate School (Joshua P. Hacker, PI)

University of California, Berkeley (Fotini Katopodes Chow, PI)

University of Utah (Eric Pardyjak, PI)

University of Virginia (Stephan F.J. de Wekker, PI)

**Partners with Alternative Funding:**

Professors Ben Balsley and Dale Lawrence, University of Colorado, Boulder (Host: Notre Dame) – Sponsor: Army Research Office to deploy Datahawk UAVs in MATERHORN-1

Dr. David Emmitt, Simpson Weather Associates (Host: Notre Dame) – Sponsor: Army Research Office to deploy TOWDL (Twin Otter Aircraft) in MATERHORN-1

Dr. Yansen Wang, Army Research Office (Host: Notre Dame) – Sponsor: Air Force Weather Agency (AFWA) to deploy Leosphere Scanning Lidar in MATERHORN-1

**Unfunded Partners Actively Participating in the Project (Collaborators):**

Professor Silvana DiSabatino, University of Selento, Italy (Host: Notre Dame)

Dr. Nick Ovenden and Prof. Julian Hunt, University College, London, U.K. (Host: Notre Dame)

Professor Julian Hunt, University of Cambridge, U.K. (Host: Notre Dame)

Professor Eliezer Kit, Tel Aviv University, Israel (Host: Notre Dame)

Dr. Andrey Grachev, CIRES, NOAA, Boulder, Colorado (Host: Notre Dame)

Professor Joachim Reuder, University of Bergen, Norway (Host: University of Utah)

Professor Chad Higgins, Oregon State University, Corvallis, Oregon (Host: University of Utah)

Dr. Stefano Serafin, University of Vienna, Austria (Hosts: University of Virginia and University of California, Berkeley)

Dr. Dorita Rostkier-Edelstein, Environmental Sciences Division, IIBR, Israel (Host: Naval Postgraduate School)

Professor Marcus Hultmark, Princeton University (Host: University of Utah)

Dr. David J. Gochis, National Center for Atmospheric Research, USA (Host: University of Virginia)

**List of Accomplishments:**

* The first investigator (kick off) meeting was held on September 8, 2011, at University of Utah. A field trip was organized to visit the Granite Mountain Test Bed. More than 40 participants joined the meeting (<http://www3.nd.edu/~dynamics/materhorn/kickoffmeeting.html>).
* The second investigator meeting was held at University of Utah on 17th August 2012, with 35 participants (<http://www3.nd.edu/~dynamics/materhorn/investigator_presentations.html>).
* The MATERHORN-1 Experiment was successfully conducted during September 25 to October 25, 2012. It dealt with thermally driven flows in mountain terrain in the presence of weak synoptic wind. This included the participation of more than 30 field personnel in instrument deployment and data acquisition. A host of equipment was deployed, including airborne assets such as the Navy Twin Otter (TOWDL) and University of Colorado Data Hawk UAVs.
* Conducted WRF real-time forecasting support during the Fall 2012 MATERHORN field experiment.
* All the MATERHORN-1 data were pre-processed and Quality Controlled, and a new server system was set up at Notre Dame for the investigators to download data (materhorn.ce.nd.edu).
* Immersed boundary method in WRF applied to GMAST terrain was investigated, and resolution and slope criteria to minimize numerical errors due to terrain following coordinate transformation were developed.
* A new drag law (logarithmic) as the bottom boundary condition for the immersed boundary method in WRF was developed and tested.
* Large-eddy simulation of intermittent turbulence generation under quiescent conditions in Owens Valley using 50 m gri spacing was conducted.
* All preparations are underway for the MATERHORN-2 Experiment during May 1-30, 2013, which will deal with the synoptic flow influence on mountain terrain flows.
* Two autumns of operational runs by the NCAR 4DWX, performed with 9-member land-surface ensembles of three events, including two from the MATERHORN-X Fall period, were analyzed. They illustrate that the existing thermal conductivity parameterization in the WRF is inadequate at low soil moisture and that substantial forecast improvements can be obtained using an alternative parameterization for low soil moisture. It also shows that the lack of comprehensive and reliable soil-moisture observations on scales consistent with the local topography continue to remain an Achilles heel.
* Ensemble sensitivity runs were completed for Salt Lake City airport and Rocky Mountain wind storm. Localization theory was derived, and localization factors computed.
* Initial WRF simulations on the interactions of mountain and valley flows were completed at Notre Dame, which helped placing instrumentations for the two MATERHORN experiments. University of Utah is working on high-resolution WRF analysis and data assimilation for MATERHORN Fall 2012 IOPs.
* Laboratory experiments on slope flows are completed; a criterion for flow separation on mountains was derived. New physics delineated in these experiments will be checked in the MATERHORN-2 Experiment.
* Data from a number of previous field studies were analyzed to educe new information on mountain terrain flows. These included the Vertical Transport and Mixing Experiment (VTMX) in Salt Lake City, Ballast Experiment in France, Meteo-diffusion experiment in Italy, and the Hermosa Park Experiment and TRANSFLEX experiment in Phoenix, Arizona. Most of this initial work has been published or is under consideration for publication.
* The engineering and development of a sensor system, simultaneously employing 3 frequencies (470 MHz, 915 MHz, and 2.4 GHz) and deploying the system with an automated data collection feature at Dugway, were completed.  A potential approach for soil moisture estimation using a unique form of calibration based on topology knowledge was proposed (an invention - has not yet been disclosed). Mathematical models to evaluate this approach are being developed.
* An unmanned aerial vehicle carrying turbulence probes was developed for measurements of atmospheric flow from meso- to Kolmogorov scales. All signal processing devices as well as algorithms were designed and developed for data processing.
* Developed new methods to improve retrieval of surface layer winds from airborne Doppler lidar (for Navy Twin Otter data).
* Developed new methods to determine stationarity in turbulence time series and evaluate Monin-Obukhov similarity theory in complex terrain. Analysis was conducted on PBL heights during MATERHORN-1 from 4DWX model output.

**Organization of Meetings/Special Sessions:**

A special AGU Session on Complex Terrain flows was organized by Stephan De Wekker (University of Virginia) and Fotini Chow (UC Berkeley), 2011 Fall Meeting.

Facilitated a special session on “Atmospheric Observations in Mountainous Terrain” at the [92nd American Meteorological Society Annual Meeting, January 22-26, 2012)](http://ams.confex.com/ams/92Annual/oasys.epl).

## Organization of special session on “Atmospheric boundary layers in complex terrain and over ice, snow and vegetated surfaces” at the Davos Atmosphere and Cryosphere Assembly (DACA), 8-12 July 2013 by Stephan DeWekker.

**Journal Publications:**

***Published or In Press* (6 in total)**

Dallman, A., DiSabatino, S. and Fernando, H.J.S., Flow and Turbulence in an Industrial/Suburban Roughness Canopy, *Journal of Environmental Fluid Mechanics*, Accepted for publication, 2013.

De Wekker, S.F.J., K.S. Godwin, G. D. Emmitt, and S. Greco, Airborne Doppler lidar measurements of valley flows in complex coastal terrain. *J. Appl. Meteor. Climatol.,* 51, 1558–1574*.*. doi: <http://dx.doi.org/10.1175/JAMC-D-10-05034.1>, 2012.

Fernando, H.J.S., Verhoef, B., Di Sabatino, S., Leo, L. and Park, S. The Phoenix Evening Transition Flow Experiment (TRANSFLEX), *Boundary Layer Meteorology*, DOI 10.1007/s10546-012-9795-5, 2013.

Godwin, K.S., S.F.J. De Wekker, and G. D. Emmitt, 2012: Retrieving winds in the surface layer over land using an Airborne Doppler lidar. *J. Atm. Ocean. Tech*. **29**, 487–499. doi: <http://dx.doi.org/10.1175/JTECH-D-11-00139.1>.

Lozovatsky, I. and Fernando, H.J.S. “Mixing Efficiency in Natural Flows,” *Philosophical Transactions, Proceedings of the Royal Society (Lond) A*, 371: 20120213, 2012.

Nadeau, D.F., Pardyjak, E.R., Higgins, and H., Parlange, M.B., Similarity scaling over a steep alpine slope, *Boundary-Layer Meteor.* DOI 10.1007/s10546-012-9787-5*,* 2012.

***Submitted*  (9 in total)**

Garai, A., J. Kleissl, E. Pardyjak, M. Lothon, and G.-J. Steeneveld, Surface temperature and surface layer turbulence in a convective boundary layer, under revision *Boundary-Layer Meteor.*, November 2012.

Leo, L., Fernando, H.J.S and Di Sabatino, S., Flow in Complex Terrain with Coastal and Urban Influence, *Journal of Applied Meteorology and Climatology*, Submitted after revisions.

Monti, P., Fernando, H.J.S and Princevac, M., Turbulence in Katabatic Currents: Waves and Small-Scale Processes, *Journal of Environmental Fluid Mechanics,* Submitted for publication.

Pu, Z. and H. Zhang, 2012: Assimilation of near surface observations over complex terrain: EnKF versus 3DVAR. *Q. J. Roy. Meteorol. Soc.* (Under Revision).

Pu, Z., H. Zhang, and J. A. Anderson, 2012: Ensemble Kalman filter assimilation of near-surface observations over complex terrain: Comparison with 3DVAR for short-range forecasts. *Journal Title*? (Conditionally accepted).

Whiteman, C. D., R. Garibotti, and J. Whiteman, 2012: Rime mushrooms on mountains: Their causes and impacts on mountaineering. Bull. Amer. Meteor Soc., In-press.

Zhang, H., Z. Pu and X. Zhang, 2012: Examination of flow-dependent errors in near-surface temperature and wind from WRF numerical simulations over complex terrain. *Wea. Forecasting.* (Submitted).

Zhang, H., Z. Pu and X. Zhang, 2012: Examination of errors in near-surface temperature and wind from WRF numerical simulations in regions of complex terrain. *Wea. Forecasting.* (Conditionally accepted).

Zhou, B. and F.K. Chow. 2013. Nighttime turbulent events in a steep valley: a nested large-eddy simulation study, *Journal of the Atmospheric Scienc*es, submitted.

**Invited Conference Presentations: (3 in total)**

Fernando, H.J.S. “Air Quality at Different Spatial Scales: Panel Discussion,” Invited Speaker, 5th Annual CENSAM (Center for Environmental Sensing and Modeling) Workshop, MIT-Singapore Alliance, Jan 12-13, 2012.

Fernando, H.J.S., “Mixing in Stratified Shear Layers, including the Effects of Topography,” Invited Speaker, Workshop on Physical Processes in the Bay of Bengal and Monsoon ISO. 5-7 March, Indian Institute of Sciences, Bangalore, 2012.

Fernando, H.J.S., Pardyjak, E., Zajic, D., De Wekker, S.J.F., and Pace, J., The Mountain Terrain Atmospheric Modeling and Observations (MATERHORN) Program: The First Field Experiment (MATERHORN-X1), Invited Paper, *American Geophysical Union*, Fall Meeting, Abstract # A12D-01, 2012.

**Conference Papers: (4 in total)**

Fernando, H.J.S. The Mountain Terrain Atmospheric Modeling and Observations (MATERHORN) Program: An Overview, Extended Abstract, American Meteorological Society 92nd Annual Meeting, New Orleans, Paper 11.12, 2012.

Fernando, H.J.S., Leo, S.L., DiSabatino, S., Dallman, A. “Evening Transition in Inland and Coastal Mountainous Terrain,” AMS 91st Annual Meeting, 23-27 January, Seattle, WA, paper 4.5, January 2011.

Monti, P., Fernando, H.J.S. and Princevac, M., “Waves and Turbulence Contributions to Stratified Turbulence in Katabatic Flows,” Proceedings, 7th International Symposium of Stratified Flows, (Ed. A. Cenedese), 22-26 August, 2011.

Simon, J.S., K.A. Lundquist, and F.K. Chow. 2012. Application of the immersed boundary
method to simulations of flow over steep, mountainous terrain. Paper 45. 15th Conference on Mountain Meteorology, American Meteorological Society, 9 pages.

**Conference Presentations: (44 in total)**

Dallman, A., DiSabatino, S., Leo, L.S. and Fernando, H.J.S., “Flow Characteristics in an Urban Area Located in Complex Terrain,” American Meteorological Society 92nd Annual Meeting, New Orleans, Paper 11.4, 2012.

De Wekker, S.F.J., 2012: Convective Boundary Layer Heights in Mountainous Terrain. New Insights From Observations in the Appalachian Mountains. 17th AMS Conference on Air Pollution Meteorology with the A&WMA, New Orleans, LA, 22-26 January 2012.

De Wekker, S.F.J., J. Doyle, Q. Jiang, K. Godwin, E. Erfani, G. D. Emmitt, 2011: Investigation of multi-scale flow interaction in the Salinas Valley using a combination of airborne Doppler lidar data and a mesoscale numerical model. AGU Fall meeting, San Francisco, CA, 5–9 December 2011.

De Wekker, S.F.J., G.D. Emmitt, S. Greco. K. Godwin, R. Foster, S. Pal, and H.J.S. Fernando, 2013: Wind and turbulence structure in the boundary layer around an isolated mountain: airborne measurements during the MATERHORN field study, Davos Atmosphere and Cryosphere Assembly (DACA), 8-12 July 2013.

De Wekker, S.F.J., J. Knievel, Y. Liu, G.D. Emmitt, S. Pal, B. Balsley, D. Lawrence, S. Hoch, C. Hocut , Y. Wang, and H.J.S. Fernando, 2013: Multi-scale flows and boundary layer structure during the morning transition period: a case study from the MATERHORN field study, Davos Atmosphere and Cryosphere Assembly (DACA), 8-12 July 2013.

DiSabatino, S., Leo, L., Liberzon, D., Retallack, C., Coppersmith, R.S., Sentic, S., Huq, P., Hocut, C., Fernando, S. and Fernando, H.J.S., Evening Transition of Atmospheric Boundary Layer (ABL) in Heterogeneous Flat Terrain,” American Meteorological Society 92nd Annual Meeting, New Orleans, 2012.

Dunn, P.F., Brownell, G.A., Strebinger, R.B. and Harper, A.G., Fog Sampling Using an Unmanned Air Vehicle" submitted for the 2013 European Aerosol Conference, Prague, Czech Republic, 1st-6th September 2013.

Farley-Chrust, M. , C. D. Whiteman and S. W. Hoch: Observations of Wind Jets at the Exit of Weber Canyon, Utah. 15th Conference on Mountain Meteorology, Steamboat Springs, CO, 20-24 August 2012.

Fernando, H.J.S. and Lozovatsky, I., Mixing Efficiency in Natural Flows, *Ocean Sciences Meeting*, TOS/AGU/ASLO Proc., 110, 2012.

Hocut, C., Liberzon, D. and Fernando, H.J.S., “Thermally Driven Upslope Flow in Mountain Terrain,” American Meteorological Society 92nd Annual Meeting, New Orleans, Paper 11.3, 2012.

Hocut, C., Liberzon, D. and Fernando, H.J.S., “Thermally Driven Upslope Flow Separation in Steep Mountainous Terrain,” 15th AMS Conference on Mountain Meteorology, 20-24, August, 2012.

Hocut, C., Dimitrova, R., Silver, Z., Di Sabatino, S., Leo, L., Hoch, S., Wang, Y., Pardyjak, E. and Fernando, H.J.S., Slope-Valley Flow Interactions in Materhorn-1, Davos Atmosphere and Cryosphere Assembly (DACA), 8-12 July 2013.

Jeffrey D. Massey, University of Utah, Salt Lake City, UT; and W. J. Steenburgh, J. C. Knievel, M. E. Jeglum, and S. W. Hoch: Observations and Modeling of Thermally Driven Flows over the Great Salt Lake Desert. 15th Conference on Mountain Meteorology, Steamboat Springs, CO, 20-24 August 2012

Jeglum M. E, S. W. Hoch, C. D. Whiteman, and J. D. Massey: Land-Surface Contrasts and Thermally Driven Flows at Dugway Proving Ground, Utah. 15th Conference on Mountain Meteorology, Steamboat Springs, CO, 20-24 August 2012

Liberzon, D, Hocut, C. and Fernando, H.J.S., Thermally Driven Upslope Flow in Mountainous Terrain, *Bull. Am. Phys. Soc.,* **56(18)**, 216, 2011.

Leo, L., DiSabatino, S, and Fernando, H.J.S., “Flow in Complex Terrain with Coastal and Urban Influence, American Meteorological Society 92nd Annual Meeting,” New Orleans, Paper 11.1, 2012.

Leo, L., Di Sabatino, S., Grachev, A.A., Hocut, C., Fernando, H.J.S., Pardyjak, E., Jensen, D., Hoch, S., and Whiteman, D., Spatial and Temporal Evolution of katabatic flows in MATERHORN 1, Davos Atmosphere and Cryosphere Assembly (DACA), 8-12 July 2013.

Lozovatsky, I. and Fernando, H.J.S., Mixing Efficiency in Natural Flows, 3rd International Conference 'Turbulent Mixing and Beyond', Trieste, Italy, 21 July - 28 August, 2011.

Massey, J. D., W. J. Steenburgh, J. C. Kneivel, M. E. Jeglum, and S. W. Hoch, 2012: Observations and modeling of thermally driven flows over the Great Salt Lake Desert.  15th Conference on Mountain Meteorology, American Meteorological Society, 20-24 Aug 2012.

Massey, J. D., W. J. Steenburgh, et al., 2012: Observations and Modeling of Thermally Driven Flows over the Great Salt Lake Desert. 15th Conference on Mountain Meteorology, American Meteorological Society, Steamboat Springs, CO.

Oldroyd, H.J., E. Pardyjak, M. Calaf, D.F. Nadeau, M. Hultmark, and M.B. Parlange, Steep slope flow observations during the morning transition in a narrow alpine valley. Abstract A13C-0243, presented at 2012 Fall Meeting, AGU, San Francisco, Calif., 3-7 Dec.

Pardyjak, E.R., D. Nadeau, C. Higgins, H. Huwald, and M. B. Parlange, 2012. Developing an improved understanding of steep slope evening transition processes. 92nd American Meteorological Society Annual Meeting, January 22-26, 2012, New Orleans, 11.6.

Pardyjak, E.R., D. Alexander, M. Lothon, F. Lohou, S. Derrien; J. Reuder, D. Legain, O. Traulle, H. Pietersen, O. Decoster, G. Canut, C. Darbieu, A. Garai, E. Pique, 2011: First results from the surface heterogeneity focus area of the Boundary Layer Late Afternoon and Sunset Turbulence (BLLAST) Experiment, Abstract A41A-0034, presented at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-9 Dec.

Pu, Z. and H. Zhang: On the assimilation of surface observations over complex terrain: EnKF vs. 3DVAR. *AGU Fall Meeting*. December 5-9, 2011. San Francisco, CA.

Pu,Z. and H. Zhang, 2012: Evaluation of the Diurnal Variation of near-Surface Temperature and Winds From WRF Numerical Simulations Over Complex Terrain and the Impact on Assimilation of Surface Observations, *17th Conference on Air Pollution* *Meteorology with the A&WMA,* January 22-27, 2012, New Orleans, LA

Pu, Z. and H. Zhang, 2012: Examination of Flow-Dependent Errors in Near-Surface Temperature and Wind from WRF Numerical Simulations over Complex Terrain. 3rd WRF Users Workshop, June 26-29. 2012.

Pu, Z., H. Zhang and X. Zhang, 2012: Data assimilation over complex terrain. Materhorn Annual Review Meeting, Salt Lake City, UT, August 17, 2012.

Pu, Z., H. Zhang and X. Zhang, 2012: The impact of surface data assimilation on the predictability of atmospheric boundary layer and near surface conditions over complex terrain. AMS 15th Conference on Mountain Meteorology, Steamboat, CO, August 20-24, 2012

Pu, Z., H. Zhang and X. Zhang, 2013: Evaluation of high-resolution surface analyses and forecasts with ensemble data assimilation in regions of complex terrain. 17th Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface. 93rd AMS annual meeting. Austin, TX. January 05-10, 2013

Retallack, C., Fernando, H.J.S and Hunt, J.C.R., “Turbulent stratified flows over orography with large scale forcing-concepts and idealized models,” 15th AMS Conference on Mountain Meteorology, 20-24, August, 2012.

Retallack, C., H. Fernando, E. Pardyjak, S.F.J. De Wekker, J.C Pace, 2011: The MATERHORN Experiment. AGU Fall meeting, San Francisco, 5–9 December 2011.

Simon, J.S., Lundquist, K.A., and F.K. Chow. 2012. Application of the immersed boundary method to simulations of flow over steep, mountainous terrain. *15th Conference on Mountain Meteorology,* Steamboat Springs, Colorado, August 20-24, 2012.

Simon, J., Lundquist, K.A. and F.K. Chow. 2012. Addressing the “terra incognita” - appropriate
representation of terrain from mesoscale to microscale. Abstract A13C-0242 presented at
2012 AGU Fall Meeting, San Francisco, California, 3-7 December. [poster]

Vecenaj, Z., S. F.J. De Wekker, 2013: Determination and characteristics of nonstationarity in the surface layer during the T-REX experiment. Davos Atmosphere and Cryosphere Assembly (DACA), 8-12 July 2013.

Večenaj, Ž., and S.F.J. De Wekker,2012: Nonstationarity in the surface layer over complex terrain during T-REX. 15th AMS Conference on Mountain Meteorology, Steamboat Springs, CO, 20-24 August 2012.

Večenaj, Ž., and S.F.J. De Wekker,2012: Exploring Monin-Obukhov similarity in the surface layer over complex terrain during T-REX. 15th AMS Conference on Mountain Meteorology, Steamboat Springs, CO, 20-24 August 2012.

Večenaj, Ž., and S.F.J. De Wekker, 2012: Averaging Time Scale for Daytime Turbulent Flux Measurements in a Wide and Steep Valley. 17th AMS Conference on Air Pollution Meteorology with the A&WMA, New Orleans, LA, 22-26 January 2012.

Whiteman, C. D. and S. W. Hoch, M. Jeglum and L. Campbell: MATERHORN-X Field Studies. MATERHORN Kick-off Meeting, Salt Lake City, UT., 8 Sept. 2011.

Zajic, D., J. C. Pace, C. D. Whiteman, and S. Hoch, 2011: The Granite Mountain Atmospheric Sciences Testbed (GMAST): A Facility for Long Term Complex Terrain Airflow Studies. AGU Fall Meeting, 5-9 December 2011, San Francisco, CA.

Zajic, D., J. C. Pace, C. D. Whiteman, and S. W. Hoch, 2012: An Overview of the Granite Mountain Atmospheric Sciences Testbed (GMAST). 17th Conference on Air Pollution Meteorology with the A&WMA, January 2012, New Orleans, LA.

Zhang, H., C. W. Pace and Z. Pu, 2011: Evaluation of the Diurnal Variation of near-Surface Temperature and Winds From WRF Numerical Simulations Over Complex Terrain, *AGU Fall Meeting*. December 5-9, 2011. San Francisco, CA.

Zhang, H. and Z. Pu, 2012: Examination of flow-dependent errors in near-surface temperature and winds from WRF numerical simulations over complex terrain. AMS 15th Conference on Mountain Meteorology, Steamboat, CO, August 20-24, 2012

Zhou, B. and F.K. Chow. 2012. Nighttime Cold-Air Intrusions and Transient Warming in a Steep Valley: A Nested Large-eddy Simulation Study. Paper 3.2. 15th Conference on Mountain Meteorology, American Meteorological Society.

**Awards: (5 in total)**

Ann Dallman – *Second place for the Best Student Oral Presentation*, 92nd Annual Meeting of the American Meteorological Society, 17th Conference on Air Pollution Meteorology, Jan 22-26, New Orleans.

Christopher Hocut, *Best Overall Presentatio*n, 92nd Annual Meeting of the American Meteorological Society, 17th Conference on Air Pollution Meteorology, Jan 22-26, New Orleans.

Jeff Massey, 3rd place, Best Student Poster, 15th Conference on Mountain Meteorology.

David Whiteman, American Meteorological Society. Mountain Meteorology Award 2012.

Bowen Zhou - 3rd place - best oral presentation at 15th AMS Mountain Meteorology Conference.

**Recognitions:**

H.J.S. Fernando was elected as Fellow, American Association for the Advancement of Science (AAAS), 2012.

**Number of Post Docs: (8 total)**

Dan Liberzon 2011 June -2012 July University of Notre Dame
Laura Leo 2011 August - continuing University of Notre Dame

Charles Retallack 2011 June -2012 October University of Notre Dame

Zeljko Vecenai March-September 2012) University of Virginia

Sandip Pal February 2013 – present) University of Virginia

Jared Lee Part time Naval Postgraduate School

Walter Kolczynski Part time, FY13 Naval Postgraduate School

Vigneshwaran Kulandaivelu University of Utah

**Number of Graduate Students: (14 PhD Students and 2 MS Students)**

Jordan Bryant MS University of Notre Dame Esteemed Fellow

Patrick Conry PhD University of Notre Dame

Zi Lin MS University of Notre Dame

Kelly McEnerney PhD University of Notre Dame

Zachariah Silver PhD University of Notre Dame

Michael Thompson PhD University of Notre Dame

Ehsan Erfani PhD University of Virginia January-April 2012

Maj. Paul Homan PhD Naval Postgraduate School

Capt. Sean Wile PhD Naval Postgraduate School

Jason Simon PhD University of California, Berkeley

Estel Blay Carreras PhD University of Utah visiting student

Matthew Jeglum PhD University of Utah

Derek Jensen PhD University of Utah

Jeff Massey PhD University of Utah

Hailing Zhang PhD University of Utah partial support

Xuebo Zhang PhD University of Utah partial support

**Number of Undergraduate Students (12 in total)**

Jordan Bryant University of Notre Dame current

Andrew Harper University of Notre Dame current

Mike Higginson University of Notre Dame

Kristin Stryker University of Notre Dame

Capt. Samuel White University of Notre Dame current

Patrick Conry University of Notre Dame 06/11 to 01/13

Rich Strebinger University of Notre Dame 2012

Greg Brownell University of Notre Dame 2012

Sahan Fernando University of Notre Dame summer 2012

Kevin Peters University of Notre Dame 2012

Nipun Gunawardena University of Utah

Christan Holbert University of Utah