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CURRICULUM VITAE

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MARK A. FRIEDL

Department of Earth and Environment, Boston University
675 Commonwealth Avenue, Boston, Massachusetts 02215
Tel: (617) 353-5745; Fax: (617) 353-8399; E-mail: Friedl@bu.edu

RESEARCH AND TEACHING INTERESTS

- Remote sensing, emphasizing ecosystem monitoring and land cover mapping
- Land surface climatology, emphasizing land surface energy and radiation balance
- Data analysis and modeling, emphasizing applied problems in physical geography

EDUCATION

- Ph.D. Department of Geography: University of California, Santa Barbara, 1993
- M.A. Department of Geography: University of California, Santa Barbara, 1988
- B.Sc. (with Honors) in Physical Geography: McGill University, 1986

PROFESSIONAL APPOINTMENTS AND EXPERIENCE

- Director, 2020 – present: Boston University Center for Remote Sensing
- Interim Chair, 2017/2018: Department of Earth & Environment, Boston University
- Chair, 2010 to 2012: Department of Earth Sciences, Boston University
- Chair, 2003 to 2009: Department of Geography & Environment, Boston University
- Co-Director, 2009 to 2015: Boston University Terrestrial Biogeosciences Program
- Professor, 2007 to present: Department of Earth & Environment, Boston University
- Associate Professor, 2000 to 2007: Department of Geography, Boston University
- Assistant Professor, 1993 to 2000: Department of Geography, Boston University
- Graduate Student Researcher, 1986-92: University of California, Santa Barbara
- Lecturer, 1989: Department of Geography, University of California, Santa Barbara
- Programmer, 1986: McGill University Advanced Cartography Laboratory
- Field Research Assistant, 1984: McGill University Sub-arctic Research Station, Schefferville, Quebec

VISITING APPOINTMENTS AND FELLOWSHIPS

- Charles Bullard Fellowship in Forest Research, 2012/2013: Harvard University
- Erasmus Mundus Visiting Scholar, 2009: University of Southampton, United Kingdom; ITC Faculty of Geoinformation Science and Earth Observation, Enscede, Netherlands; Lund University, Sweden
- Visiting Scientist, 2005/2006: Complex Systems Research Center, University of New Hampshire
- Natural Sciences and Engineering Research Council of Canada Postgraduate Scholarship
- University of California Regents Fellowship

PROFESSIONAL ACTIVITIES

- Science Teams: *Moderate Resolution Imaging Spectroradiometer Science Team* (NASA, 2004 - 2016); *Land Measurement Science Team* (NASA, 2005 - 2016); *NPOESS Preparatory Project Science Team* (NASA, 2007-2019); Suomi VIIRS Land Calibration and Validation Science Team (NOAA, 2009-2016); *Landsat 8 Science Team* (USGS, 2013-present); *Multi-Source Land Imaging Team* (NASA, 2015-present); *Land Science Data Analysis and Multi-Disciplinary Research Team* (NASA, 2021-present).
- Associate Editor, 2013-2014; Editorial Board, 2015-, *Remote Sensing of Environment*.
- Associate Editor, *Journal of Geophysical Research, Biogeosciences*, 2008-2011.
- Assigning Editor, *Ecological Applications*, 2007- 2009.
- Editorial Board, *Ecological Applications*, 2004 – 2009.
- Co-Chair: *Land Process Validation Working Group Sub-Committee on Land Cover*, Validation; *Committee on Earth Observation Satellites*, 2009-2011.
- Chair, *Oak Ridge National Lab Distributed Active Archive Center User Working Group* (2006 - 2009); member, 2004 - 2009.

AWARDS AND RECOGNITIONS

- Clarivate (ISI Web of Science Group) *Highly Cited Researcher*: 2018, 2019, 2020, 2021,2022
- William T. Pecora Team Award, Department of Interior and NASA, Terra Mission, 2019
- Leica Geosystems *Second Place Award for Best Scientific Paper in Remote Sensing* American Society for Photogrammetry and Remote Sensing, 2004
- John I Davidson President's *Second Place Award for Practical Papers*, American Society for Photogrammetry and Remote Sensing, 2008
- Leica Geosystems *First Place Award for Best Scientific Paper in Remote Sensing*, American Society for Photogrammetry and Remote Sensing, 2008

MEMBERSHIPS

- American Geophysical Union

TEACHING EXPERIENCE

University of California at Santa Barbara:

   Introduction to Air Photo Interpretation and Remote Sensing

Boston University:

   Natural Environments: The Physical Landscape
   Natural Environments: The Atmosphere
   Global Dynamics of the Earth's Atmosphere and Surface
   Micrometeorology: Energy and Mass Transfer at the Earth's Surface
   Environmental Modeling and Analysis Using GIS
   Seminar in Physical Climatology: Land Surface-Atmosphere Interactions
   Seminar in Ecological Climatology
   Multivariate Analysis: Applied Data Analysis for Environmental Science

GRADUATE STUDENT ADVISEES

(i) Graduated

Paul S. Fisher, M.A., 1995; Thesis Title: *The Utility of Derivative Spectroscopy and Linear Modeling Techniques for the Identification of Canopy Spectral Endmembers*.

Nathan Morrow, M.A., 1998; Thesis Title: *Biophysical Controls on Surface Reflectance and Surface Temperature at a Tallgrass Prairie Site*.

Alexander Lotsch, M.A., 1999; *Biome-Level Classification of Land Cover at Continental Scales Using Decision Trees.*

Douglas McIver, Ph.D. 2001*; Machine Learning Tools for Large Scale Land Cover Mapping from Multitemporal Satellite Data*.

Rongqian Yang, Ph.D. 2002; *Parameterization of Spatial Heterogeneity in Vegetation for Studies of Land Surface-Atmosphere Interaction.*

Su-Yin Tan, M.A.2003: *Modeling Spatial Patterns of Vegetation Activity and Climatological Parameters in the U.S. Great Plains.*

Alexander Lotsch, Ph..D. 2004. *Spatio-Temporal Dynamics of Global Precipitation and Terrestrial Vegetation Inferred from Satellite and Climate Records*.

Alessandro Baccini, Ph.D. 2005. *Linking Plot Scale Data to Multi-Resolution Remote Sensing for Forest Structure Mapping*.

Joe Santenello, Ph.D. 2005. *Estimation of Land Surface Energy Balance and Surface Properties using Remotely Sensed Observations*.

Callan Ordoyne, M.A. 2005. *Characterizing Everglades Hydrology: Wetland Flooding Delineation Using Remotely Sensed Data.*

William Boykin-Morris, 2007. *The MODIS Crop Type Dataset (MODCTD): Global Scale Classification of Agriculture Using Data from the Moderate Resolution Imaging Spectroradiometer (MODIS).*

Manish Verma, Ph.D. 2012. *Observing and Modeling Dynamics in Terrestrial Gross Primary Productivity and Phenology from Remote Sensing: An Assessment Using In-Situ Measurements.*

Jessica Meghan Salmon, Ph.D. 2012. *Using Satellite Remote Sensing and hydrologic Modeling to Improve Understanding of Crop Management and Agricultural Water Use at Regional to Global Scales.*

Xiaomam Huang, Ph.D. 2014. *Mapping Regional Land Cover and Land Use Change Using MODIS Time Series.*

Eli Melaas, Ph.D. 2014. *Using Eddy Covariance, Remote Sensing, and In-situ Observations to Improve Models of Springtime Phenology in Temperate Deciduous Forests.*

Damien Sulla-Menashe, Ph.D. 2015. *Monitoring Forest Change in Northern Ecosystems Using Multiresolution Remote Sensing.*

Jonathan Wang, Ph.D. 2019. *Interactions Among Land Cover, Disturbance and Productivity Across Arctic-Boreal Ecosystems of Northwestern North America from Remote Sensing.*

Minkyu Moon, Ph.D., 2020. *Improved Understanding of Feedbacks Between Vegetation Phenology and the Atmosphere at Local-to-Continental Scales.*

Radost Stamirova, Ph.D., 2020. *Using Multi-Resolution Remote Sensing to Measure Ecosystem Sensitivity and Monitor Land Degradation in Response to Land Use and Climate Variability.*

Leticia Lee, Ph.D., 2022. *Phenology, Light Use Efficiency, and Productivity in Temperate Deciduous Forests.*

Adam Sibley (MA 2010), Douglas Bolton (MA, 2011), Parker Abercrombie (M.A., 2014), Mary Farina (M.A., 2014)

(ii) In progress

> Kai-Ting Hu (Ph.D.) – expected graduation, May 2023
> Tristan Green (Ph.D.) – expected graduation May 2025
> Seamore Zhu (Ph.D.) – expected graduation May 2026

BOSTON UNIVERSITY ADMINISTRATIVE RESPONSIBILITIES

- Undergraduate Advisor, Environmental Sciences: 1993-present.
- Undergraduate Advisor, Center for Energy & Environmental Science: 1993-2002
- Director of Graduate Studies, Department of Geography: 1994-1996.
- Director of Undergraduate Programs, Boston University Center for Energy and Environmental Studies: Sept. 1999-2002
- Associate Chair, Department of Geography, Boston University. 2001-2003
- Co-Director – 2009 to present: Boston University Terrestrial Biogeosciences Program.
- Board of Directors, Bahaa Hariri Institute for Computational Science and Engineering at Boston University, 2010-2014.
- Chair, Organizing Committee, Boston University Earth Systems Forum, 2010-2011.
- Member, Boston University Research Computing Governance Committee; 2011-2014
- Associate Chair, Department of Earth and Environment, 2013-2015
- Member, Vice-Chair, Chair, Boston University Committee on Academic Program Review, 2016/2017/2018/2019.

PUBLICATIONS (Feb 8, 2023)

ISI Web of Science:22.220 citations, h-index = 69; Google Scholar: 37,619 citations, h-index = 85.

Journal Papers:

1. Stanimirova, R., Graesser, J., Olofsson, P. and M.A. Friedl (2022). Widespread changes in 21st Century vegetation cover in Argentina, Paraguay, and Uraguay. *Remote Sensing of Environment*, 282, https://doi.org/10.1016/j.rse.2022.113277.

2. Graesser, J., R. Stanimirova, K. Tarrio, E.J. Copati, J.N. Volante, S.R. Verón, S. Banchero, H. Elena, D. de Abelleyra and **Mark A. Friedl** (2022). Temporally consistent annual

land cover from Landsat time series in the Southern Cone of South America, *Remote Sensing* 14, no. 16: 4005. https://doi.org/10.3390/rs14164005.

3. Young, A.M., **Friedl, M.A**., Novick,K., Scott, R.L., Moon, M., Frolking, S., Li, X., Carrillo, C.M. and A.D. Richardson (2022). Disentangling the relative drivers of seasonal evapotranspiration across a continental-scale aridity gradient, *Journal of Geophysical Research, Biogeosciences*, https://doi.org/10.1029/2022JG006916

4. Moon, M., Richardson, A.D., Milliman and **M.A. Friedl** (2022)*.* A high spatial resolution land surface phenology dataset for AmeriFlux and NEON sites. *Sci Data* **9,** 448. https://doi.org/10.1038/s41597-022-01570-5

5. Li, X., Melaas, E., Carrillo, C.M., Ault, T., Richardson, A.D., Lawrence, P., **Friedl, M.A**., Seyednasrollah, B., Lawrence, D.M. and A.M. Young (2022). A Comparison of Land Surface Phenology in the Northern Hemisphere Derived from Satellite Remote Sensing and the Community Land Model. *Journal of Hydrometeorol*ogy, 23, 859–873. https://doi.org/10.1175/JHM-D-21-0169.1

6. **Friedl M.A**., Woodcock C.E., Olofsson P., Zhu Z., Loveland T., Stanimirova R., Arevalo P., Bullock E., Hu K.T., Zhang Y., Turlej K., Tarrio K., McAvoy K., Gorelick N., Wang J.A., Barber C.P., and C. Souza (2022). Medium Spatial Resolution Mapping of Global Land Cover and Land Cover Change Across Multiple Decades From Landsat, *Frontiers in Remote Sensing*, 3, https://doi.org/10.3389/frsen.2022.894571.

7. Zhang Y., Woodcock, C.E., Arévalo P., Olofsson P., Tang X., Stanimirova R., Bullock E., Tarrio K.R., Zhu Z., **Friedl M.A.** (2022). A Global Analysis of the Spatial and Temporal Variability of Usable Landsat Observations at the Pixel Scale, *Frontiers in Remote Sensing,* 3, https://doi.org/10.3389/frsen.2022.894618.

8. Moon, M., Richardson, A.D., O'Keefe, J. and **M.A. Friedl** (2022). Senescence in temperate broadleaf trees exhibits species-specific dependence on photoperiod versus thermal forcing, *Agricultural and Forest Meteorology,* 322 (2022), 109026, https://doi.org/10.1016/j.agrformet.2022.109026

9. Graesser, J., Stanimirova, R. and **M.A. Friedl** (2022). Reconstruction of satellite time series with a dynamic smoother, *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 15, pp. 1803-1813, http://doi.org/10.1109/JSTARS.2022.3146081.

10. Zhang, Y., Woodcock, C.E., Chen.S., Wang, J.A., Sulla-Menashe, D., Zuo, Z., Olofsson, P. Wang, Y and **M.A. Friedl** (2022). Mapping causal agents of disturbance in boreal and Arctic ecosystems of North America using time series of Landsat data, *Remote Sensing of Environment*, 272, https://doi.org/10.1016/j.rse.2022.112935.

11. Moon, M, Richardson, A.D., and **M.A. Friedl** (2021). Multiscale assessment of land surface phenology from harmonized Landsat 8 and Sentinel-2, PlanetScope, and PhenoCam imagery , *Remote Sensing of Environment*, 266 (2021) 112716, https://doi.org/10.1016/j.rse.2021.112716.

12. Young, A.M., **Friedl, M.A**., Seyednasrollah, B., Beamesderfer, E., Carrillo, C.M., Li, X., Moon, M., Arain, M.A., Baldocchi, D.D., Blanken, P.D., Bohrer, G., Burns, S.P., Chu, H., Desai, A.R., Griffis, T.J., Hollinger, D.Y., Litvak, M.E., Novick, K., Scott, R.L.,

Suyker, A.E., Verfaillie, J., Wood, J.D. and A.D. Richardson (2021), Seasonality in aerodynamic resistance across a range of North American ecosystems, *Agricultural and Forest Meteorology*, Volume 310, https://doi.org/10.1016/j.agrformet.2021.108613.

13. Wang, J.A., Baccini, A, Farina, M., J.T. Randerson and **M.A. Friedl** (2021). Disturbance suppresses the aboveground carbon sink in North American boreal forests. *Nature Climate Change*, https://doi.org/10.1038/s41558-021-01027-4.

14. Moon, M., Seyednasrollah, B., Richardson, A.D. and **M.A. Friedl** (2021). Using time series of MODIS land surface phenology to model temperature and photoperiod controls on spring greenup in North American deciduous forests, *Remote Sensing of Environment*, 260 (2021), https://doi.org/10.1016/j.rse.2021.112466.

15. Hu, Q., Yin, H., **Friedl, M.A**., You, L., Li, Z., Tang, H. and W. Wu (2021). Integrating coarse-resolution images and agricultural statistics to generate sub-pixel crop type maps and reconciled area estimates. *Remote Sensing of Environment*, https://doi.org/10.1016/j.rse.2021.112365.

16. Elmes, A., Alemohammad, H., Avery, R., Caylor, K., Eastman, R.J., Fishgold, L., **Friedl, M.A.,** Jain, M., Kohli, D., Bayas, J.C.L., Lunga, D., McCarty, J.L., Pontius, R.G., Reinman, A.B., Rogan, J., Song, L., Stoynova, H., Ye, S., Yi, Z.F. and L. Estes (2020), Accounting for training data errors in machine learning applied to Earth observations, *Remote Sensing*, 12(6), 1034: https://doi.org/10.3390/rs12061034.

17. Seyednasrollah, B., Young, A.M., Li, X., Milliman, T., Ault, T., Frolking, S., **Friedl, M**., and A.D. Richardson, Sensitivity of deciduous forest phenology to environmental drivers for climate change impacts across North America (2020), *Geophysical Research Letters*, *47*, e2019GL086788. https://doi.org/10.1029/2019GL086788.

18. Bolton, D, K., Gray, J.M, Melaas, E.K., Moon, M., Eklundh, L. and **M.A. Friedl** (2020). Continental-scale land surface phenology from harmonized Landsat 8 and Sentinel-2 imagery, *Remote Sensing of Environment*, 240, https://doi.org/10.1016/j.rse.2020.111685.

19. Moon, M., Li, D., Liao, W., Rigden, A.J. and **M.A. Friedl** (2020). Modification of Surface Energy Balance During Springtime: The Relative Importance of Biophysical and Meteorological Changes, *Agricultural and Forest Meteorology*, 284, 107905; https://doi.org/10.1016/j.agrformet.2020.107905

20. Stanimirova, R., Arevalo, P., Kaufmann, R.K., Maus, V., Lesiv, M., Havlik, P. and **M.A. Friedl** (2019). Sensitivity of global pasturelands to climate variation, *Earth's Future*, 7, https://doi.org/10.1029/2019EF001316.

21. Wang, J.A. and **M.A. Friedl** (2019). The role of land cover change in Arctic-Boreal greening and browning trends. *Environmental Research Letters*, 14 125007, https://doi.org/10.1088/1748-9326/ab5429.

22. Seyednasrollah, B., A.M. Young, K. Hufkens, T. Milliman, **M.A. Friedl**, S. Frolking and A.D. Richardson (2019). Tracking vegetation phenology across diverse biomes using Version 2.0 of the PhenoCam dataset, *Scientific Data*, 6, 222 doi:10.1038/s41597-019-0229-9.

23. Wang, J.A., Sulla-Menashe, D., Woodcock, C.E., Sonnentag, O., Keeling, R.F. and **M.A. Friedl** (2019). Extensive land cover change across Arctic–Boreal Northwestern North America from disturbance and climate forcing, *Global Change Biology*, 2019; 00:1–16. https://doi.org/10.1111/gcb.14804.

24. Stanimirova, R., Cai, Z., Melaas, E.K., Gray, J.M., Eklundh, L., Jonsson, P. and **M.A. Friedl** (2019). An Empirical Assessment of the MODIS Land Cover Dynamics and TIMESAT Land Surface Phenology Algorithms, *Remote Sensing*, *11*(19), 2201; https://doi.org/10.3390/rs11192201

25. Moon, M., Zhang,X., Henebry, G.M., Liu,L., Gray., J.M., Melaas, E.K., and M.A. **Friedl** (2019). Long-term continuity in land surface phenology measurements: Acomparative assessment of the MODIS land cover dynamics and VIIRS land surface phenology products, *Remote Sensing of Environment*, 226, pp. 74-92. https://doi.org/10.1016/j.rse.2019.03.034

26. Sulla-Menashe, D., Gray, J.M., Abercrombie, P. and M.A. **Friedl** (2019). Hierarchical mapping of annual global land cover 2001 to present: The MODIS Collection 6 Land Cover product. *Remote Sensing of Environment*, 222, 183-194. https://doi.org/10.1016/j.rse.2018.12.013

27. Zhang, X., Liu, L., Liu, Y., Senthilnath, J., Wang, J., Moon, M., Henebry, G.M., **Friedl**. M.A. and C.B. Schaaf (2018). Generation and evaluation of the VIIRS land surface phenology product, *Remote Sensing of Environment*, 216, pp. 212 229. https://doi.org/10.1016/j.rse.2018.06.047

28. Jönsson, P., Cai, Z., Melaas, E., **Friedl**, M.A., and L. Eklundh (2018), A method for robust estimation of vegetation seasonality from Landsat and Sentinel-2 time series data, *Remote Sensing*, 10(4), 635; doi:10.3390/rs10040635

29. Zhang, X., Senthilnath, J., Liu, L., **Friedl**, M.A., Henebry, G.M., Liu, Y., Schaaf, C.B., Richardson, A.D. and J. Gray (2018) Evaluation of Land Surface Phenology from VIIRS Data using Time Series of PhenoCam Imagery Agricultural and Forest Meteorology, *Agricultural and Forest Meteorology*, (256-257), pp. 137-149, DOI: https://doi.org/10.1016/j.agrformet.2018.03.003

30. Richardson, A.D., Hufkens, K., Aubrecht, D. Chen, M., Gray, J.M., Johnson, M.R., Keenan, T.F., Klosterman, S.T., Melaas, E.K., **Friedl**, M.A. and S. Frolking (2018). Tracking vegetation phenology across diverse North American biomes using PhenoCam imagery, *Scienctific Data*, 5, doi:10.1038/sdata.2018.28.

31. Melaas, E.K., Sulla-Menashe, D. and M.A. **Friedl** (2018). Multidecadal Changes and Interannual Variation in Springtime Phenology of North American Temperate and Boreal Deciduous Forests, *Geophysical Research Letters*, 45(6), pp. 2679-2687. DOI: https://doi.org/10.1002/2017GL076933

32. Sulla-Menashe, D, Woodcock, C.E. and M.A. **Friedl** (2018). Canadian boreal forest greening and browning trends: An analysis of biogeographic patterns and the relative roles of disturbance versus climate drivers. *Environmental Research Letters*, 13(1), DOI: 10.1088/1748-9326/aa9b88

33. Klosterman, S., Melaas, E., Wang, J.A., Martinez, A., Frederick, S., O'Keefe, J., Orwig, D.A. Wang, Z.S. Sun, Q.S., Schaaf, C., **Friedl**, M. and A.D. Richardson, 2018. Fine-scale perspectives on landscape phenology from unmanned aerial vehicle (UAV) photography. *Agricultural and Forest Meteorology*, (248): 397-407. 10.1016/j.agrformet.2017.10.015

34. Hardiman, B.S., J.A. Wang, L.R. Hutyra, C.K. Gately, J.M. Getson, and M.A. Friedl, 2017. Accounting for urban biogenic fluxes in regional carbon budgets, *Science of the Total Environment*, vol 592, pp. 366-373. DOI: 10.1016/j.scitotenv.2017.03.028

35. Wang, J. A., Hutyra, L. R., Li, D., and M.A. **Friedl**, 2017. Gradients of atmospheric temperature and humidity controlled by local urban land use intensity in Boston. *Journal of Applied Meteorology and Climatology*, vol 56, pp. 817-831.

36. Zhang, X, Wang, J., Gao F., Liu, Y., Schaaf, C., **Friedl**, M., Yu, Y. Jayavelu, S., Gray, J., Liu, L., Yan, D., and G. M. Henebry 2017. Exploration of scaling effects on coarse resolution land surface phenology, *Remote Sensing of Environment*, 190(1), pp. 318-330.

37. Melaas, E.K., Sulla-Menashe, D., Gray, J.M., Black, A., Morin, T.H., Richardson A.D. and M.A. Friedl 2016. Multisite analysis of land surface phenology in North American temperate and boreal deciduous forests from Landsat, *Remote Sensing of Environment*, 186(1), pp. 452-464.

38. Chen M., Melaas E.K,. Gray J., **Friedl** M.A. and A.D. Richardson. 2016. A new seasonal-deciduous spring phenology submodel in the Community Land Model 4.5: Impacts on carbon and water cycling under future climate scenarios. *Global Change Biology,* 22(2), pp. 792-805, DOI: 10.1111/gcb.13326.

39. Melaas, E.K., Wang, J.A., Miller, D.L. and M.A. **Friedl**, 2016. Interactions between urban vegetation and surface urban heat islands: a case study in the Boston metropolitan regions, *Environmental Research Letters*, 11(5), DOI: 10.1088/1748-9326/11/5/054020.

40. Sulla-Menashe, D, Friedl, M.A. and C.E. Woodcock, 2016. Sources of bias and variability in long-term Landsat time series of Canadian boreal forests, *Remote Sensing of Environment*, 177, pp. 206-219.

41. Abercrombie, S.P. and M.A. **Friedl**, 2016. Improving the consistency of multitemporal land cover maps using a hidden Markov model, *IEEE Transactions on Geoscience and Remote Sensing*, 54(2), pp. 703-713.

42. Melaas, E.K., M.A. **Friedl** and A.D. Richardson, 2016. Multiscale modeling of spring phenology across deciduous forests in the Eastern United States, *Global Change Biology*, 22(2), pp. 792-805.

43. Huang, X., A. Schneider and **Friedl**, M.A. 2016. Mapping sub-pixel urban expansion in China using MODIS and DMSP nighttime lights, *Remote Sensing of Environment*, 175, pp. 92-108.

44. Verma, M., M.A. **Friedl**, A. Finzi and N. Phillips, 2016. Multi-criteria evaluation of the suitability of growth functions for modeling remotely sensed phenology, *Ecological Modeling*, 323, pp. 123-132.

45. Verma, M., M.A. **Friedl**, B.E. Law, D. Bonal, G. Kiely, T.A. Black, G. Wohlfahrt, E.J. Moors, L. Montagnani, B. Marcolla, P. Toscano, a. Varlagin, O. Roupsard, A. Cecatti, M.A. Arain, P. D'Odorico, 2015. Improving the performance of remote sensing models for capturing intra- and inter-annual variations in daily GPP: An analysis using global FLUXNET tower data, *Agricultural and Forest Meteorology*, 214-215, pp. 416-429.

46. Salmon, J.M. M.A. **Friedl**, S. Frolking, D. Wisser and E. M. Douglas, 2015. Global rain-fed, irrigated, and paddy croplands: A new high resolution map derived from remote sensing, crop inventories, and climate data. *International Journal of Applied Earth Observation and Geoinformation*, 38, pp. 321-334; doi:10.1016/j.jag.2015.01.014.

47. Martellozzo, F, N. Ramankutty, R.J. Hall, D.T. Price, B. Purdy and M.A. **Friedl**, 2015. Urbanization and the loss of prime farmland: a case study in the Calgary-Edmonton corridor of Alberta, *Regional Environmental Change*, 15(5), DOI 10.1007/s10113-014-0658-0.

48. Michael Toomey, Mark A. **Friedl**, Steve Frolking, Koen Hufkens, Stephen Klosterman, Oliver Sonnentag, Dennis D. Baldocchi, Carl J. Bernacchi, Gil Bohrer, Edward Brzostek, Sean P. Burns, Carole Coursolle, David Y. Hollinger, Hank A. Margolis, Harry McCaughey, Russell K. Monson, J. William Munger, Stephen Pallardy, Richard P. Phillips, Margaret Torn, Sonia Wharton, Marcelo Zeri, Andrew D. Richardson, 2015. Greenness indices from digital cameras predict the timing and seasonal dynamics of canopy-scale photosynthesis, *Ecological Applications,* 25(1), pp.99-115.

49. Keenan, T.F., B. Darby, E. Felts, O. Sonnentag, M. **Friedl**, K. Hufkens, J. O'Keefe, S. Klosterman, J.W. Munger, M. Toomey, A.D. Richardson, 2014. Tracking forest phenology and seasonal physiology using digital repeat photography: a critical assessment, *Ecological Applications,* 24, pp.1478–1489, DOI: 10.1890/13-0652.1

50. Gray, J.M, S. Frolking, E.A. Kort, D.K. Ray, C.J. Kucharik, N. Ramankutty, & M.A. **Friedl** 2014, Direct human influence on atmospheric CO_2 seasonality from increased cropland productivity, *Nature*, 515, pp 398-401, doi:10.1038/nature13957

51. Glanz, H., L. Carvalho, D. Sulla-Menashe and M.A. **Friedl**, 2014. A parametric model for classifying land cover and evaluating training data based on mulit-temporal remote sensing data, *ISPRS Journal of Photogrammetry and Remote Sensing*, 97, pp. 219-228; doi: 0.1016/j.isprsjprs.2014.09.004

52. Gray, J.M, M.A. Friedl, S. Frolking, N. Ramankutty, A.Nelson and M. Gumma, 2014. Mapping Asian Cropping Intensity with MODIS. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing,* 7(8), pp. 3373-3379. DOI:10.1109/JSTARS.2014.2344630

53. Sulla-Menashe, D., R. Kennedy, Z. Yang, J. Braaten, O.N. Krankina and **M.A. Friedl** 2014, Detecting forest disturbance in the Pacific Northwest from MODIS time series using temporal segmentation, *Remote Sensing of Environment*, 151, pp. 881-893, DOI: 10.1016/j.rse.2013.07.042.

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2. Moon, M., A.D. Richardson, T. Milliman, and M.A. Friedl. 2022. High Resolution Phenology, Eddy Covariance Tower Sites, North America, 2017-2021. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/2033

3. Zhang, Y., C.E. Woodcock, S. Chen, J. Wang, D. Sulla-Menashe, Z. Zuo, P. Olofsson, Y. Wang, and M.A. Friedl. 2022. ABoVE: Landsat-derived Annual Disturbance Agents Across ABoVE Core Domain, 1987-2012. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1924

4. Wang, J., M.K. Farina, A. Baccini, and M.A. Friedl. 2021. ABoVE: Annual Aboveground Biomass for Boreal Forests of ABoVE Core Domain, 1984-2014. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1808

5. Friedl, M., MuSLI Multi-Source Land Surface Phenology Yearly North America 30 m. 2021, Land Processes DAAC, DOI: 10.5067/Community/MuSLI/MSLSP30NA.011.

6. Melaas, E.K., D. Sulla-Menashe, C.E. Woodcock, and M.A. Friedl. 2019. ABoVE: Annual Phenology Derived from Landsat across the ABoVE Core Domain, 1984-2014. ORNL DAAC, Oak Ridge, Tennessee, USA. DOI: 10.3334/ORNLDAAC/1698

7. Richardson, A.D., K. Hufkens, T. Milliman, D.M. Aubrecht, M. Chen, J.M. Gray, M.R. Johnston, T.F. Keenan, S.T. Klosterman, M. Kosmala, E.K. Melaas, M.A. Friedl, S. Frolking, M. Abraha, M. Alber, M. Apple, B.E. Law, T.A. Black, P. Blanken, D. Browning, S. Bret-Harte, N. Brunsell, S.P. Burns, E. Cremonese, A.R. Desai, A.L. Dunn, D.M. Eissenstat, S.E. Euskirchen, L.B. Flanagan, B. Forsythe, J. Gallagher, L. Gu, D.Y. Hollinger, J.W. Jones, J. King, O. Langvall, J.H. McCaughey, P.J. McHale, G.A. Meyer, M.J. Mitchell, M. Migliavacca, Z. Nesic, A. Noormets, K. Novick, J. O'Connell, A.C. Oishi, W.W. Oswald, T.D. Perkins, R.P. Phillips, M.D. Schwartz, R.L. Scott, O. Sonnentag, and J.E. Thom. 2017. PhenoCam Dataset v1.0: Vegetation Phenology from Digital Camera Imagery, 2000-2015. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1511

8. Melaas, E.K., M.A. Friedl, and D. Sulla-Menashe. 2018. Landsat-derived Spring and Autumn Phenology, Eastern US - Canadian Forests, 1984-2013. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1570

9. Sulla-Menashe, D., M.A. Friedl, C. Woodcock, and E.K. Melaas. 2018. ABoVE: Peak Greenness for Canadian Boreal Forest from Landsat 5 TM Imagery, 1984-2011. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1587

10. Milliman, T., B. Seyednasrollah, A.M. Young, K. Hufkens, M.A. Friedl, S. Frolking, A.D. Richardson, M. Abraha, D.W. Allen, M. Apple, M.A. Arain, J.M. Baker, D. Baldocchi, C.J. Bernacchi, J. Bhattacharjee, P. Blanken, D.D. Bosch, R. Boughton, E.H. Boughton, R.F. Brown, D.M. Browning, N. Brunsell, S.P. Burns, M. Cavagna, H. Chu, P.E. Clark, B.J. Conrad, E. Cremonese, D. Debinski, A.R. Desai, R. Diaz-Delgado, L. Duchesne, A.L. Dunn, D.M. Eissenstat, T. El-Madany, D.S.S. Ellum, S.M. Ernest, A. Esposito, L. Fenstermaker, L.B. Flanagan, B. Forsythe, J. Gallagher, D. Gianelle, T. Griffis, P. Groffman, L. Gu, J. Guillemot, M. Halpin, P.J. Hanson, D. Hemming, A.A. Hove, E.R. Humphreys, A. Jaimes-Hernandez, A.A. Jaradat, J. Johnson, E. Keel, V.R. Kelly, J.W. Kirchner, P.B. Kirchner, M. Knapp, M. Krassovski, O. Langvall, G. Lanthier, G.l. Maire, E. Magliulo, T.A. Martin, B. McNeil, G.A. Meyer, M. Migliavacca, B.P. Mohanty, C.E.

Moore, R. Mudd, J.W. Munger, Z.E. Murrell, Z. Nesic, H.S. Neufeld, W. Oechel, A.C. Oishi, W.W. Oswald, T.D. Perkins, M.L. Reba, B. Rundquist, B.R. Runkle, E.S. Russell, E.J. Sadler, A. Saha, N.Z. Saliendra, L. Schmalbeck, M.D. Schwartz, R.L. Scott, E.M. Smith, O. Sonnentag, P. Stoy, S. Strachan, K. Suvocarev, J.E. Thom, R.Q. Thomas, A.K. Van den berg, R. Vargas, J. Verfaillie, C.S. Vogel, J.J. Walker, N. Webb, P. Wetzel, S. Weyers, A.V. Whipple, T.G. Whitham, G. Wohlfahrt, J.D. Wood, J. Yang, X. Yang, G. Yenni, Y. Zhang, Q. Zhang, and D. Zona. 2019. PhenoCam Dataset v2.0: Digital Camera Imagery from the PhenoCam Network, 2000-2018. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1689.

11. Seyednasrollah, B., A.M. Young, K. Hufkens, T. Milliman, M.A. Friedl, S. Frolking, A.D. Richardson, M. Abraha, D.W. Allen, M. Apple, M.A. Arain, J. Baker, J.M. Baker, D. Baldocchi, C.J. Bernacchi, J. Bhattacharjee, P. Blanken, D.D. Bosch, R. Boughton, E.H. Boughton, R.F. Brown, D.M. Browning, N. Brunsell, S.P. Burns, M. Cavagna, H. Chu, P.E. Clark, B.J. Conrad, E. Cremonese, D. Debinski, A.R. Desai, R. Diaz-Delgado, L. Duchesne, A.L. Dunn, D.M. Eissenstat, T. El-Madany, D.S.S. Ellum, S.M. Ernest, A. Esposito, L. Fenstermaker, L.B. Flanagan, B. Forsythe, J. Gallagher, D. Gianelle, T. Griffis, P. Groffman, L. Gu, J. Guillemot, M. Halpin, P.J. Hanson, D. Hemming, A.A. Hove, E.R. Humphreys, A. Jaimes-Hernandez, A.A. Jaradat, J. Johnson, E. Keel, V.R. Kelly, J.W. Kirchner, P.B. Kirchner, M. Knapp, M. Krassovski, O. Langvall, G. Lanthier, G.l. Maire, E. Magliulo, T.A. Martin, B. McNeil, G.A. Meyer, M. Migliavacca, B.P. Mohanty, C.E. Moore, R. Mudd, J.W. Munger, Z.E. Murrell, Z. Nesic, H.S. Neufeld, T.L. O'Halloran, W. Oechel, A.C. Oishi, W.W. Oswald, T.D. Perkins, M.L. Reba, B. Rundquist, B.R. Runkle, E.S. Russell, E.J. Sadler, A. Saha, N.Z. Saliendra, L. Schmalbeck, M.D. Schwartz, R.L. Scott, E.M. Smith, O. Sonnentag, P. Stoy, S. Strachan, K. Suvocarev, J.E. Thom, R.Q. Thomas, A.K. Van den berg, R. Vargas, J. Verfaillie, C.S. Vogel, J.J. Walker, N. Webb, P. Wetzel, S. Weyers, A.V. Whipple, T.G. Whitham, G. Wohlfahrt, J.D. Wood, S. Wolf, J. Yang, X. Yang, G. Yenni, Y. Zhang, Q. Zhang, and D. Zona. 2019. PhenoCam Dataset v2.0: Vegetation Phenology from Digital Camera Imagery, 2000-2018. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1674.

12. Wang, J.A., D. Sulla-Menashe, C.E. Woodcock, O. Sonnentag, R.F. Keeling, and M.A. Friedl. 2019. ABoVE: Landsat-derived Annual Dominant Land Cover Across ABoVE Core Domain, 1984-2014. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1691

Invited Seminars and Presentations at International Meetings & Workshops

1. **Friedl, M.A**. (2021). Using Multi-Sensor ARD Imagery to Monitor Phenology (or, Are Analysis Ready Data Really Analysis Ready?), Invited Presentation, Analysis Ready Data 2021 (ARD21), October 28, 2021 (online)

2. **Friedl, MA**., Gray, J.M., Richardson, A.D. and M. Moon (2021). Observing and Modeling Phenology at Local to Global Scales Using Remote Sensing, Invited Presentation, *Fall Meeting of the American Geophysical Union*. Dec 15, 2021, New Orleans, LA.

3. **Friedl, M**., & et al. (2018). Towards A Moderate Spatial Resolution Data Record of 21st Century Global Land Cover, Land Use, and Land Cover Change, Invited Presentation, *Fall Meeting of the American Geophysical Union*. Washington, DC.

4. **Friedl, M**., & et al.. (2018). Mapping Annual Land Cover and Phenology from MODIS: Global Data Sets Supporting Modeling and Global Change Science, Invited Presentation, *Fall Meeting of the American Geophyiscal Union*. Washington DC.

5. **Friedl, M.A**. (2018). Ecosystems in Flux: Changing Seasons in an Era of Climate Change, Invited Presentation, *Boston University Research on Tap, Understanding and Forecasting Change in Our Natural World*, Nov, 7, 2018.

6. **Friedl, M.A.** (2018). Changes in Temperate and Boreal Forests Based on Three Decades of Landsat Imagery, *Invited Seminar, Center for Geospatial Analytics,* College of Natural Resources, North Carolina State University, Sept 6, 2018.

7. **Friedl, M.A**. (2018). Some Perspectives on Global Land Cover Mapping, invited presentation, *Workshop on Machine Learning for Global Land Cover Classification,* June 14-15, 2018, Washington, D.C.

8. **Friedl, M.A**. (2018). Crop Phenology and Crop Species Mapping, *Workshop on Emerging Technologies and methods in Earth Observation for Agricultural Monitoring*, United States Department of Agriculture, Beltsville Maryland, Feb 13, 2018.

9. **Friedl, M.A**. (2018). Changes in Temperate and Boreal Forests Based on Three Decades of Landsat Imagery. *Invited Seminar, Department of Geography Colloquium Series*, Clark University, February 15, 2018.

10. **Friedl, M.A**. (2017). From Photons to Food: Remote Sensing, Geospatial Data, and Agriculture, symposium on *Big Data and Ecoinformatics in Agricultural Research, College of Agricultural and Life Sciences, University of Wisconsin, April 27, 2017.*

11. **Friedl**, M.A. (2016). Food, Forests and Phenology. Invited seminar presentation, Geospatial Sciences Center of Excellence, South Dakota State University, March 17, 2016.

12. **Friedl**, M.A., E. Melaas, D. Sulla-Menashe and J. Gray (2014). Using Time Series of Landsat Data to Improve Understanding of Short- and Long-Term Changes to Vegetation Phenology in Response to Climate Change (invited), *Fall Meeting of the American Geophysical Union*, Dec 5-9, 2014, San Francisco, CA.

13. **Friedl,** MA. Characterizing the Sensitivity of Temperate Forest Growing Season Dynamics to Climate Change*, Earth Observation Data for Climate Science,* NASA Earth Exchange (NEX) Virtual Workshop and Challenge, *NASA Ames Research Center*, April 21, 2014.

14. **Friedl,** MA. Characterizing the Sensitivity of Temperate Forest Growing Season Dynamics to Climate Change*, Arthur Robinson Lecture,* The Ohio State University, Columbus Ohio, April 4, 2014.

15. **Friedl**, M.A. Using Time Series of Landsat, MODIS, and Ground Measurements to Characterize and Quantify the Sensitivity of Temperate Forest Phenology to Climate Change. Invited oral presentation, *Fall Meeting of the American Geophysical Union*, Dec 13, 2013, San Francisco, CA.

16. **Friedl**, M.A. *Using In-Situ and Satellite Data to Characterize the Sensitivity of New England Forest Phenology to Climate Change*. Invited seminar presentation, Biogeosciences Seminar Series, Boston University, Nov. 13, 2013.

17. **Friedl,** M.A. *Three Decades of Variation in Northeastern Temperate Forest Phenology from In-Situ and Remotely Sensed Observations*. Invited seminar presentation, Earth Systems Research Center, University of New Hampshire, Nov. 8 2013.

18. **Friedl**, M.A. *Characterizing the Sensitivity of Temperate Forest Growing Season Dynamics to Climate Change*. Invited seminar presentation, Global Environmental and Climate Change Center, McGill University, Oct. 15, 2013.

19. **Friedl**, M.A, E. K. Melaas, J. Gray, A. D. Richardson, J. O'Keefe, and A. Bailey 2013. Using Remote Sensing to Characterize and Model Forest Phenology in New England, *24th Annual Harvard Forest Ecology Symposium*, March 20, 2013, Petersham, MA.

20. **Friedl**, M.A., A.D. Richardson, R. Pless, S. Frolking, T.E. Milliman, S. Klosterman, M.P. Toomey, and J.M. Gray. Phenocam: A continental observatory in support of monitoring, modeling, and forecasting Phnological responses to climate change. Invited oral presentation, *Fall Meeting of the American Geophysical Union*, Dec 3-7, 2012, San Francisco, CA.

21. **Friedl**, M.A. 2012. Understanding the Response of Ecosystem Phenology to Climate Change: Recent Anomalous Spring Climate and Phenology in the Northeastern United States, oral presentation, *Phenology 2012*, September 10, 2012, Milwaukee, WI

22. **Friedl**, M.A. 2012. Observing and Modeling Phenology Across Multiple Scales, Invited seminar, *Harvard University Herbarium Seminar Series*, September 5, 2012.

23. **Friedl**, M.A, K. Hufkens, E. K. Melaas, A. D. Richardson, J. O'Keefe, and A. Bailey 2012. Response of Ecosystem Phenology to Anomalous Spring Warmth in the Northeastern United States in 2010. Oral presentation, *American Meteorological Society First Conference on Atmospheric Biogeosciences,* May 30, 2012, Boston, MA.

24. Schneider, A., **Friedl**, M.A. and D. Potere 2009. A new map of global urban extent from MODIS 500m data. *Invited paper, Fall Meeting of the American Geophysical Union*. December 16, 2009. San Francisco, CA.

25. **Friedl**, M.A. 2009. Seasonal Patterns in Phenology, Microclimate, and Remotely Sensed Vegetation Properties in northeastern Forests, Seminar in Terrestrial Biogeosciences, *Boston University*, September 23, 2009.

26. **Friedl**, M.A. Land Surface Phenology from Moderate Resolution Remote Sensing: Biospheric Datasets for Studies of Global Ecology. *Invited seminar, Department of Geography, University of Southamption*, U.K., July 1, 2009.

27. **Friedl**, M.A. Global Land Cover and Land Surface Phenology from Moderate Resolution Remote Sensing. *Invited seminar, International Institute for Geoinformation Science and Earth Observation*, Enschede, Netherlands, July 15, 2009.

28. **Friedl, M.A**. Data Mining and Knowledge Discovery of Land Cover and Terrestrial Ecosystem Processes from Global Remote Sensing Data, *Conference on Intelligent Data Understanding*, NASA Headquarters, Washington, D.C., Sept. 8-9, 2008.

29. **Friedl**, M.A. Global Land Use Mapping from MODIS, Global Land Use Workshop, *Institute of Social Ecology*, Klagenfurt University, Vienna, Austria, May 22-23, 2008.

30. **Friedl**, M.A. Remote Sensing of Land Surface Phenology from Moderate Resolution Remote Sensing, *Department of Geography, Clark University*, Worcester, MA. Nov. 29, 2007.

31. **Friedl**, M.A., An Overview of the Current Status and Collection 5 MODIS Land Cover and Land Cover Dynamics Products, *Global Observations of Forest Cover and Land Dynamics Implementation Team Meeting*, October 25, 2007. Boston, MA.

32. **Friedl**, M.A., Moderate Resolution Remote Sensing of Phenology, *Coordinating a Northeast Phenology* Network, Durham, NH, Nov., 8-9, 2007.

33. **Friedl**, M.A., Algorithm Refinements in the Collection 5 MODIS Land Cover and Land Cover Dynamics Products, *MODIS Land Products User Workshop*, January 24, 2007.College Park, MD.

34. **Friedl**, M.A. Remote Sensing of Global Land Cover and Phenology: Biospheric Data Sets for Studies of Global Change. *Department of Biology, Boston University, November 11, 2006.*

35. **Friedl**, M.A. Monitoring and Mapping Wetlands from MODIS, Workshop on the Role of Earth Observation for Understanding Ecosystem Function of Northern Hemisphere Wetlands, *Global Environmental and Climate Change Centre, McGill University*, Montreal, Quebec. May 5, 2006.

36. **Friedl,** M.A. Remote Sensing of Global Vegetation Phenology: Biospheric Data Sets for Studies of Global Change. *Department of Atmospheric Sciences, Dalhousie University*, Halifax, Nova Scotia. March 17, 2006.

37. **Friedl**, M.A. Global Vegetation Phenology from Remote Sensing: Seasonal Dynamics and Interannual Variability from MODIS. *NOAA Geophysical Fluid Dynamics Laboratory*, Princeton, NJ, February 16, 2006.

38. **Friedl**, M.A. and X.Y. Zhang 2005, Monitoring Global Vegetation Phenology From MODIS: Spatio-Temporal Correspondence Between Climate and Vegetation Activity at Regional to Global Scales. *Fall Meeting of the American Geophysical Union*, San Francisco, CA., Dec. 8, 2005

39. **Friedl,** M.A., X. Zhang, J.C.F Hodges and A.H. Strahler. MODIS Global Land Cover and Global Vegetation Phenology. MODIS Vegetation Workshop II. *School of Forestry, University of Montana*, Missoula, MT, August 18, 2004.

40. **Friedl**, M.A. Remote Sensing of Global Land Cover and Vegetation Phenology: Methods and Data Sets in Support of Global change Research. *Department of Geography, University of Waterloo*, March 27, 2004.

41. **Friedl**, M.A. Global Land Cover and Vegetation Phenology From MODIS: Land Surface Data Sets in Support of Global change Research. *Center for Sustainability and the Global Environment, University of Wisconsin*, Madison, WI., March 21, 2004.

42. **Friedl** M.A., Zhang, X. and C. Van Dellen 2004. Using Multitemporal Remote Sensing to Map Global Land Cover and Vegetation Dynamics. Spring Meeting of the American Geophysical Union, Montreal, Quebec. May 18, 2004.

43. Baccini, A., M.A. **Friedl**, C.E. Woodcock and R. Warbington 2003. Estimating Forest Biomass over Large Areas Using Remote Sensing, Topographic, and Climate Data. *Department of Evolutionary and Organismal Biology, Harvard University*, May 14, 2003.

44. **Friedl**, M.A. 2003. Using Supervised and Unsupervised Methods in Remote Sensing, Examples, Perspectives, and Opportunities. *Department of Mathematics and Statistics, Boston University*, March 20, 2003.

45. **Friedl**, M.A., X. Zhang and E. Tsvetsinskaya 2003. Observing and Deriving Land Cover Properties and Dynamics for use in Weather and Climate Models. *Annual Meeting of the American Meteorological Society,* Long Beach California. February 8, 2003.

46. **Friedl**, M.A. McIver, D and C.E. Brodley 2002. Integration of Domain Knowledge in the Form of ancillary Map Data into Supervised Classification of Remotely Sensed data. *International Geoscience and Remote Sensing Symposium (IGARSS)*, Toronto, Ontario, July 21, 2002.

47. **Friedl**, MA. and C.E. Brodley 2002. Supervised Learning From Large, High Dimensional Remote Sensing Data Sets, paper presented at *Interface 2002*, April 18, 2002, Montreal, Quebec.

48. **Friedl**, M.A. Mapping Global Land Cover From MODIS: New Data Sets for Global Land Surface Parameterization. Spring Meeting of the American Geophysical Union, Boston, MA. May 30, 2001.

49. Lotsch, A., **Friedl**, M.A. and B.T. Anderson 2002. Mining global Geophysical Space-Time Data Sets Using Linear and Non-Linear Techniques. *Computing, Information and Communications Technology Branch, NASA Ames Research Center*, Dec. 9, 2002.

50. **Friedl,** M.A. and Brodley, C.E. 1999: Mining Satellite Images for Land Cover Classification. *NASA workshop on Issues in the Application of Data Mining to Scientific Data,* Huntsville Al, October 13, 1999.

51. **Friedl**, M.A. 1999: Modeling Fluxes of Heat and Moisture Between Land Surfaces and the Atmosphere: In-situ Measurements and Remote Sensing Observations, *Department of Geography and Cooperative Institute for Research in the Environmental Sciences*, University of Colorado, Boulder, CO, April 23, 1999.

52. **Friedl**, M.A. 1999: Forward and Inverse Modeling of Land Surface Energy Balance. *Center for Climate and Global Change Research, McGill University,* Montreal, Quebec, April 7, 1999.

53. **Friedl**, M.A. 1999: Remote Sensing-based Modeling of Heat and Moisture Fluxes Between Land Surfaces and the Atmosphere. *Department of Geography, University of Toronto*, January 22, 1999.

54. **Friedl**, M.A. 1998: Land Cover Prototyping Activities for MODIS. *USGS EROS Data Center*, Sioux Falls, South Dakota, July 24, 1998.

55. **Friedl**, M.A. 1998: Remote Sensing, Land Surface Processes, and Earth System Science. *Department of Geography, University of Utah*, January 30, 1998.

56. **Friedl**, M.A. 1997: An Overview of Uncertainty in Remotely Sensed Data. *National Center for Ecological Analysis and Synthesis Workshop on Uncertainty in Ecological Data*, Sept. 29, 1997, Santa Barbara, CA.

57. **Friedl**, M.A. and C.E. Brodley 1996: Using Homogeneous and Heterogeneous Classification Trees to Map Land Cover from Remotely Sensed Data. *Symposium on Artificial Intelligence Research in Environmental Science (AIRIES'96),* August 28, 1996 Boston, MA.

58. **Friedl**, M.A. 1994: Modeling Surface Energy Balance Using Remotely Sensed Data: Experiences From FIFE. *Department of Civil and Environmental Engineering, Massachusetts Institute of Technology*, Cambridge, MA, Nov. 18, 1994.

59. **Friedl**, M.A. 1994: First Principles Scene Simulation Modeling of Remotely Sensed Imagery. *NASA Kennedy Space Center*, Cape Canaveral, Florida, March 18, 1994.

SPONSORED RESEARCH

Current

1. *Quantifying Disturbance and Global Change Impacts on Multi-decadal Trends in Aboveground Biomass and Land Cover across Arctic-boreal North America,* Jonathan A. Wang (Principal Investigator), James T. Randerson, **Mark Friedl** and Michael Goulden (co-Investigators), $196,911 for period 1/1/2023-12/31/2025, National Aeronautics and Space Administration.

2. *Long-Term Changes and Variability in Global Ecosystem Phenology From MODIS*, **Mark Friedl**, Principal Investigator, Josh Gray, Co-Investigator, Andrew Richardson Collaborator, $766,711 for period 9/1/2021-8/30/2024, National Aeronautics and Space Administration.

3. *A Moderate Spatial Resolution Data Record of 21ˢᵗ Century Global Land Cover, Land Use, and Land Cover Change*, **Mark Friedl**, Principal Investigator, Curtis Woodcock, Pontus Olofsson and Tom Loveland, Co-Investigator, $4,039,454 for period 6/15/2018-6/14/2023, National Aeronautics and Space Administration.

4. *An Operational Multisource Land Surface Phenology Product from Landsat and Sentinel 2*, **Mark Friedl**, Principal Investigator, Josh Gray, Co-Investigator, $1,048,134 for period 1/15/2018-1/14/2021, National Aeronautics and Space Administration.

5. *New Opportunities Using the Landsat Temporal Domain: Monitoring Ecosystem Health, Condition and Use*", USGS Landsat Science Team, C.E. Woodcock, Principal Investigator, **Mark Friedl** and Pontus Olofsson, Co-Investigators, 12/10/17-12/9/22, $1,238,013.

6. *Improved Understanding of Feedbacks between Ecosystem Phenology and the Weather-Environment Nexus at Local-to-Continental Scales*, Andrew Richardson, Principal Investigator, **Mark Friedl**, Toby Ault, and Steve Frolking, Co-Investigators, $395,753 for period 8/2/2017-8/1/2022, National Science Foundation.

Completed

1. *Dynamics of Global Rangelands: Modeling Vulnerabilities and Monitoring Impacts from Humans and Climate Change*, NASA Earth and Space Science Fellowship to Radost Stanimirova; Principal Investigator, **Mark Friedl**. 9/12017-8/31/2020.

2. *A Multi-Scale Satellite-Based Indicator of Climate Change Impacts on Land-Surface Phenology,* Joshua Gray, Principal Investigator, **Mark Friedl**, Xiaoyang Zhang, Alyssa Rosemartin and Jake Weltzin, Co-Investigators*, $443,463 for period 6/1/16/-5/31/19, National Aeronautics and Space Administration.

3. *Landscape-Scale Histories and Active Monitoring of Disturbance, Seasonality and Greenness Trends for ABOVE from Landsat,* Curtis Woodcock, Principal Investigator, **Mark Friedl**, Co-Investigator*, $300,000 for period 9/1/15/-8/30/19, National Aeronautics and Space Administration.

4. *Multisource Imaging of Seasonal Dynamics in Land Surface Phenology: A Fusion Approach Using Landsat and Sentinel-2*, **Mark Friedl**, Principal Investigator**, Eli Melaas and Joshua Gray, Co-Investigators, $739,114 for period 7/1/15/-6/30/18, National Aeronautics and Space Administration.

5. *Development and Validation of a Global Land Surface Phenology Product from NPP VIIRS for EOS-MODIS Continuity,* Xiaoyang Zhang, Principal Investigator, **Mark Friedl** and Geoffrey Henebry, Co-Investigators, Boston University budget $243,077, for period 11/14/14-11/13/17, National Aeronautics and Space Administration.

6. *Quantifying Carbon Signatures Across Urban-to-Rural Gradients: Advancing the Capacity for Monitoring, Reporting, and Verification Through Observations, Models, and Remote Sensing,* Lucy Hutyra, Principal Investigator; **Mark Friedl**, Thomas Nehrkorn, Steve Raciti, Pamela Templer, Steven Wofsy, and Curtis Woodcock, Co-Investigators. $795,495 for period 8/1/14-7/31/18. National Oceanic and Atmospheric Administration.

7. *Using Three Decades of Landsat Data to Characterize Changes and Vulnerability of Temperate and Boreal Forest Phenology to Climate Change*, Mark **Friedl**, Principal Investigator, Curtis Woodcock, and Eli Melaas, Co-Investigators, $680,444 for period 1/16/14-12/31/18, National Aeronautics and Space Administration

8. *Incorporating a New Urban Dataset from SeaWinds into a Multi-Sensor Analysis of Global Daytime and Nighttime Urban Heat Islands*, Steve Frolking, Principal Investigator, Mark **Friedl**, Annemarie Schneider and Jingfeng Xiao, Co-Investigators, Boston University budget $86,759 for period 8/1/14-7/31/17, National Aeronautics and Space Administration.

9. *Better Use of the Landsat Temporal Domain Monitoring Land Cover Type, Condition and Change*, Curtis Woodcock, Principal Investigator, Mark **Friedl** and Pontus Olofsson, Co-investigators, $1,017,798 for period 9/1/12-8/31/17, United States Geological Survey.

10. *Final Maintenance and Refinement of the MODIS Land Cover Product,* Mark **Friedl**, Principal Investigator**, Damien Sulla-Menashe and Joshua Gray, Co-Investigators, $303,783 for period 7/1/14/-6/30/17, National Aeronautics and Space Administration

11. *4-D Modeling of the Regional Carbon Cycle in and Around Urban Environments: An Interdisciplinary Study to Advance Observational and Modeling Foundations,* Mark **Friedl**, Principal Investigator, Curtis Woodcock, Lucy Hutyra, Kelly Chance and Steve Wofsy, Co-Investigators, $1,282,141 for period 7/1/12-6/30/15, National Aeronautics and Space Administration.

12. *Continental-scale monitoring, modeling and forecasting of phenological responses to climate change;* Mark **Friedl**, BU Principal Investigator; Andrew Richardson Project principal investigator; Steve Folking, Robert Pless, Co-Investigators. Boston University Budget $268,034 for period 5/1/11-4/30/16. National Science Foundation.

13. *Crops, Climate, Canals, and the Cryosphere in Asia – Changing Water Resources Around the Earth's Third Pole,* Mark **Friedl**, BU Principal Investigator; Steve Frolking, Project Principal Investigator; Richard Lammers, Dominik Wisser, Karen Fisher-Vanden, Ian Sue-Wing, Co-Investigators, Boston University budget $224,014 for the period 10/1/10 - 9/30/14. National Science Foundation.

14. *Using MODIS to Monitor Dynamics in Land Cover and Phenology at Seasonal to Decadal Time Scales*, Mark **Friedl**, Principal Investigator, Curtis Woodcock, Robert Wolfe, and Bin Tan, Co-Investigators, $588,725 for period 1/1/11-6/30/14, National Aeronautics and Space Administration

15. *Towards and Land Cover Climate Data Record from VIIRS*, Mark **Friedl**, Principal Investigator, Curtis Woodcock, Co-Investigator; $628,995 for period 5/1/11-4/30/14, National Aeronautics and Space Administration

16. *Development and Validation Support for the Surface Type EDR from Suomi NPP VIIRS,* Mark **Friedl**, Principal Investigator, $80,694 for period 9/6/13-5/31/14, National Oceanic and Atmospheric Administration.

17. *Science and Management Support for NPP VIIRS Surface Type Environmental Data Record*, Mark **Friedl** Principal Investigator. $130,893 for period 09/01/11/-03/31/13. National Oceanographic and Atmospheric Administration.

18. *Data-model fusion and forecasting 21st-Century environmental change in northeastern North America*, Aaron Ellison, Principal Investigator, Andrew Richardson, Mark **Friedl** and Nsalambi Nkongolo, Co-Investigators, $420,000 for period 12/1/10-11/30/13. National Aeronautics and Space Administration.

19. *Effects of winter climate Change on growing season sap flow and carbon exchange in the northern hardwood forest*; Pamela Templer Principal Investigator; Nathan Phillips and Mark **Friedl**, Co-investigators**;** $131,391 for period 9/1/09-8/31/012, Northeastern States Research Cooperative.

20. *Functional Data Modeling of Climate-Ecosystem Dynamics,* Surajit Ray, Principal Investigator, Mark **Friedl**, Co-Principal Investigator, $350,000 for period 09/01/09-8/31/12. National Science foundation.

21. *Vegetation phenology and enhanced vegetation index products from multiple long term satellite data records,* Kamel Didan, Principal Investigator, Mark **Friedl**, BU-Principal Investigator, Boston University Budget $316,332 for period 08/01/08-07/31/13. National Aeronautics and Space Administration.

22. *Metabolism of Boston: Developing an integrated research strategy for long-term analysis of the Boston Region*. Nathan Phillips and Lucy Hutyra Co-principal Investigators; Mark **Friedl**, Robert Kaufmann and Suchi Gopal, Co-investigators. $300,000 for period 9/1/09/-8/31/12. National Science Foundation.

23. *Future Trend of Irrigation Water Demand Using Integrated Remote Sensing and Physical Models,* Mark **Friedl**, Principal Investigator (NASA ESS Fellowship for Jessica Salmon). $90,000 for period from 9/1/09-8/31/12. National Aeronautics and Space Administration.

24. *Establishing a Satellite Product Validation Framework Based on SPEC;* Crystal Schaaf, Principal Investigator; Mark **Friedl**, Co-investigator. $145,000 for period 05/01/09-6/30/10. National Oceanic and Atmospheric Administration.

25. *The history of agricultural irrigation expansion: Developing useful datasets of geography and water use from remote sensing and hydrologic modeling,* Mark **Friedl**, Principal Investigator, $287,709 for period 10/01/07-02-09/31/10. National Aeronautics and Space Administration.

26. *Remote Sensing Data Sets to Support Pan-Tropical Forest Mapping, Nadine Laporte, Principal Investigator;* Mark **Friedl** BU-Principal Investigator, Boston University Budget $99,881 for period 04/01/09-03/31/11. Google-Moore Foundation.

27. *MODIS Algorithm Refinement and Earth Science Data Record Development for Global Land Cover and Land Cover Dynamics*, Mark **Friedl**, Principal Investigator, Alan Strahler, Bin Tan and Crystal Schaaf, Co-Investigators. $911,716 for period from 12/25/07-12/26/10. National Aeronautics and Space Administration.

28. *Monitoring and validating the distribution and change in land cover across northern Eurasia*, Olga Krankina PI, Mark **Friedl** (and seven others) co-investigator. Boston University budget $163,542 (Friedl, BU PI) for period from 1/1/06-12/31/08. National Aeronautics and Space Administration.

29. *Real time estimation and assimilation of remotely sensed surface properties for numerical weather prediction models***,** Mark **Friedl**, Principal Investigator, Bruce Anderson, Xiaoyang Zhang and Feng Gao, Co-Investigators. $200,000 for period 8/1/04-7/31/07. National Oceanic and Atmospheric Administration.

30. *Global land cover and land cover dynamics from MODIS: Algorithm refinement in support of global change research*, Mark **Friedl**, Principal Investigator, Alan Strahler and Xiaoyang Zhang Co-Investigators. $672,237 for period from 1/1/04-12/31/07. National Aeronautics and Space Administration.

31. *Using EOS data to characterize impacts of land use/cover change on surface hydrological processes in climate models*, Robert Dickinson Principal Investigator, Mark **Friedl** (and 17 others) co-investigator. Boston University budget $300,000 (approx). National Aeronautics and Space Administration: Interdisciplinary Science Team.

32. *Assessment of aerosol, and albedo and surface type environmental data records (EDRs) from VIIRS,* Crystal Schaaf, Principal Investigator, Mark **Friedl**, Feng Gao, Shunlin Liang and and Alan Strahler Co-Investigators, $470,996 for period from 9/1/03-8/31/06. National Aeronautics and Space Administration

33. *Vegetation Control of Ecohydrological Processes*, Nathan Phillips, Principal Investigator, Mark **Friedl** and Guido Salvucci, Co-investigators, $ 338,412 for period 01/01/03-12/31/06. Hydrologic Sciences Program, National Science Foundation.

34. *Developing Next-Generation Tools for Remote Sensing in Support of LANDFIRE,* Mark **Friedl**, Principal Investigator, Curtis Woodcock and Alessandro Baccini, Co-Investigators, $164,693 for period 7/15/02-7/14/05. United States Geological Survey.

35. *Retrieval of time-varying land cover and vegetation properties from MODIS in support of the NCEP-WRF land surface model,* Mark **Friedl**, Principal Investigator, Bruce Anderson, Xiaoyang Zhang and Feng Gao, Co-Investigators. $100,000 for period 8/1/03-7/31/04. National Oceanic and Atmospheric Administration.

36. *Estimation of Land Surface Energy Balance and Surface Properties using Remotely Sensed Observations*, Mark **Friedl** Principal Investigator. $74,000 for period from 9/1/01-8/31/04;￼ National Aeronautics and Space Administration; NASA Earth System Science Fellowship Program

37. *The Effects of Agricultural Expansion on regional Hydrology in Southeastern Turkey*, Guido Salvucci, Principal Investigator, Curtis Woodcock, Mark **Friedl**, Bruce Anderson, and Mutlu Ozdogan, Co-Investigators; $541,982 for period 9/1/01-8/31/04 . National Aeronautics and Space Administration: Land Use Land Cover Change Program.

38. *Machine Learning and Data Mining for Intelligent Data Understanding of High Dimensional Earth Science Data,* Carla Brodley and Mark **Friedl**, Co-Principal Investigators, $586,177 for period 5/30/01- 7/31/04, National Aeronautics and Space Administration: Intelligent Systems Program.

39. *Improving the Representation of Land in Climate Models by Application of EOS Observations,* R.E. Dickinson, Principal Investigator, G.B. Bonan, R.S DeFries, M.A. **Friedl**, S.N. Goward, M. Jin, Y. Knyazikhin, R.B. Myneni, C.B. Schaaf, K.J. Schaudt, A.H. Strahler, Z-L. Yang, and X. Zeng, Co-Investigators. $1,800,000 (approx) for period 1/1/01/-12/31/04. National Aeronautics and Space Administration: Interdisciplinary Science Team.

40. *Investigation of Aerodynamic and Radiometric land Surface Temperatures:* Mark **Friedl**, Principal Investigator; $65,906, for period 6/1/99-5/31/02. National Aeronautics and Space Administration: Land Surface Hydrology Program (in collaboration with Rich Crago (University of Illinois) and Bill Kustas (USDA)).

41. *Modeling Fluxes of Radiation and Heat Over Heterogeneous Land Surfaces: Parameterization of Spatial Heterogeneity in Vegetation for Studies of Land Surface-Atmosphere Interaction.* Mark **Friedl**, Principal Investigator; $170,000 for period 09/01/98-/08/31/01. NASA- /NSF-/DOE/USDA/NOAA: Joint Program On Terrestrial Ecology and Global Change (TECO*).*

42. *A Simple Model for Land Surface Parameterization and Modeling.* Mark **Friedl**, Principal Investigator; $80,693 for period 1/6/98-31/5/01. National Science Foundation: Hydrologic Sciences.

43. *Geometric-Optical Modeling of Directional Thermal Radiance for Improvement of Land Surface Temperature Retrievals from MODIS, ASTER and Landsat-7 Instruments*. Xiaowen Li, Principal Investigator, M.A. **Friedl** and A.H. Strahler, Co-Investigators, $300,236 for period 05/01/98-04/30/01. National Aeronautics and Space Administration: Terrestrial Ecology Program.

44. *Machine Learning to Improve Land Cover Classifications from Multisensor and Multitemporal Data*. Mark **Friedl**, Principal Investigator; $84,433 for period 05/01/98-04/30/01. National Aeronautics and Space Administration: Terrestrial Ecology Program (In collaboration with Ruth DeFries (UMD) and Carla Brodley (Purdue)).

45. *Direct Estimation of the Form and Scale-dependence of Soil Moisture Control on Land Surface Water Balance*, Guido Salvucci, Principal Investigator, Mark **Friedl**, Co-Investigator; $50,000, for period 6/1/99-5/31/00. National Aeronautics and Space Administration: Land Surface Hydrology Program.

46. *Algorithm Development for NPOESS*. Crystal Schaaf, Principal Investigator; M. **Friedl**, J. Key, A. Strahler and C. Woodcock Co-Principal Investigators. $606,450 for period 9/22/97- 1/30/00; subcontract from Atmospheric and Environment Research, Inc., Cambridge, MA.

47. *Quantification of Uncertainty in Spatial Data for Ecological Applications*. C. Hunsaker, Principal Investigator; C. Ehlschlaeger, T. Case, M. **Friedl**, M. Goodchild, and P. Stine, Co-Investigators; $127,450 for period 01/06/96-31/05/99; National Science Foundation (through the National Center for Ecological Analysis and Synthesis*)*.

48. *Center for Excellence in Remote Sensing at Boston University*. Curtis Woodcock, Principal Investigator; F. El-Baz, C. Cleveland, M. **Friedl**, S. Gopal, R. Kaufmann, J. Key, D. Dye, R. Myneni, G. Salvucci, and A. Strahler, Co-Investigators. $444,310 for period 01/01/97- 12/31/98. National Aeronautics and Space Administration.

49. *Scale Dependence In Area Averaged Fluxes Over the FIFE Site*: F.W. Davis, Principal Investigator; M.A. **Friedl**, J. Michaelsen and D.S. Schimel, Co-Investigators; $170,000 for period 06/92-06/94; National Aeronautics and Space Administration.