

TOSHIYUKI BANDAI

Lawrence Berkeley National Laboratory, Berkeley, CA, USA ◊ Earth & Environmental Sciences Area
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CURRENT POSITION

Lawrence Berkeley National Laboratory, USA

February 2022 - present

Title: Postdoctoral Scholar

Division: Earth & Environmental Sciences Area

Supervisor: Dr. Carl I. Steefel

EDUCATION

University of California, Merced, USA

August 2018 - December 2022

Ph.D. in Environmental Systems

Dissertation: “Inverse modeling of soil moisture dynamics: Estimation of soil hydraulic properties and surface water flux”

Supervisor: Dr. Teamrat A. Ghezzehei

The University of Tokyo, Japan

April 2015 - March 2017

Masters in Biological and Environmental Engineering,

Graduate School of Agricultural and Life Sciences

Thesis: “Forced convective heat transport in saturated porous media”

Supervisors: Dr. Taku Nishimura, Dr. Shoichiro Hamamoto

Honor: Graduated with the Dean’s Award for Academic Excellence

The University of Tokyo, Japan

April 2011 - March 2015

Bachelors in Agriculture

Department of Agriculture

RESEARCH INTERESTS

Hydrology, Transport in Porous Media, Soil Physics, Geochemistry, Soil Science, Numerical Modeling, Inverse Modeling, Differentiable Modeling, Physics-Informed Machine Learning, Uncertainty Quantification

PUBLICATIONS

1. **Bandai, T.**, Ghezzehei, T. A., Jiang, P., Kidger, P., Chen, X., Steefel, C. I., 2024. Learning constitutive relations from soil moisture data via physically constrained neural networks. *Water Resources Research*, 60, e2024WR037318. <https://doi.org/10.1029/2024WR037318>
2. Stolze, L., Arora, B., Dwivedi, D., Steefel, C., **Bandai, T.**, Wu, Y., Nico, P. Climate forcing controls on carbon terrestrial fluxes during shale weathering. *Proceedings of the National Academy of Sciences of the United States of America*, 121, 27, e2400230121, <https://doi.org/10.1073/pnas.2400230121>
3. **Bandai, T.**, Sadeghi, M., Babaeian, E., Jones, S. B., Tuller, M., Ghezzehei, T. A. 2024. Estimating soil hydraulic properties from complete dryness using shortwave infrared imaging and inverse modeling. *Journal of Hydrology*, 645, 131132, <https://doi.org/10.1016/j.jhydrol.2024.131132>.
4. **Bandai, T.**, Hamamoto, S., Rau C. G., Komatsu, T., Nishimura, T. 2023. Effects of thermal properties of porous media on local thermal (non-)equilibrium heat transport. *Journal of Groundwater Hydrology*, 65, 2, 125-139, <https://doi.org/10.5917/jagh.65.125>.

5. Shen, C., Appling, A., Gentine, P., **Bandai, T.**, Gupta, H., ..., Lawson, K. 2023. Differentiable modeling to unify machine learning and physical models and advance Geosciences. *Nature Reviews Earth & Environment*, 4, 552-567, <https://doi.org/10.1038/s43017-023-00450-9>.
6. **Bandai, T.**, and Ghezzehei, T. A. 2022. Forward and inverse modeling of water flow in unsaturated soils with discontinuous hydraulic conductivities using physics-informed neural networks with domain decomposition, *Hydrol. Earth Syst. Sci.*, 26, 4469–4495, <https://doi.org/10.5194/hess-26-4469-2022>
7. **Bandai, T.**, Ghezzehei, T. A. 2021. Physics-informed neural networks with monotonicity constraints for Richardson-Richards equation: Estimation of constitutive relationships and soil water flux density from volumetric water content measurements. *Water Resources Research*. 57, 2, e2020WR027642, <https://doi.org/10.1029/2020WR027642>
8. **Bandai, T.**, Hamamoto, S., Rau, C. G., Komatsu, T., Nishimura, T. 2017. The effect of particle size on thermal and solute dispersion in saturated porous media. *International Journal of Thermal Sciences*, 122, 74-84, <https://doi.org/10.1016/j.ijthermalsci.2017.08.003>

MANUSCRIPTS UNDER REVIEW

1. Jiang, P., Kidger, P., **Bandai, T.**, Baldocchi, D., Liu, H., Xiao, Y., Zhang, Q., Wang, C. T., Steefel, C., Chen, X. JAX-CanVeg: A differentiable land surface model.

MANUSCRIPTS IN PREPARATION

1. **Bandai, T.**, Ghezzehei, T. A., Petra, N. Estimation of surface water flux from soil moisture measurement: Comparison between physics-informed neural networks and adjoint method (Chapter 3 of Ph.D. dissertation).

PROFESSIONAL EXPERIENCE

Postdoctoral scholar in Earth & Environmental Sciences Area at Lawrence Berkeley National Laboratory *February 2023 - present*

Summer intern for the Next Generation Workforce – Ingenuity Internship program, Lawrence Berkeley National Laboratory *June 2022 - August 2022*

Graduate Teaching Assistant, University of California, Merced *August 2021 - May 2022*

Graduate Research Assistant, University of California, Merced *January 2021 - August 2021*

Graduate Teaching Assistant, University of California, Merced *August 2018 - December 2020*
Research Fellow DC1

Japan Society for the Promotion of Science, Japan *April 2017 - June 2018*
Research Fellow DC1

UNSW Sydney, Australia *October 2016 - December 2016*
Junior Visiting Research Fellow
Supervisor: Dr. Gabriel C. Rau

RESEARCH FUNDING

AI-assisted multi-scale modeling of mass and energy transport in variably saturated soils (Role: PI, \$30,000) *October 2023 - September 2024*

EESA Early Career Development Grant 2024
Lawrence Berkeley National Laboratory

Development of predictive model of scale-dependent thermal dispersivity in aquifer (Role: PI, 900,000 JPY for research, 2,400,000 JPY for effort) *2017*
Grant-in-Aid for JSPS fellow
Japanese Society for the Promotion of Science

The effect of heat exchange between the solid and liquid phases on thermal dispersion in porous media (Role: PI, 250,000 JPY) *2016*
Grants-in-Aid of Groundwater Research for Young Investigators
Japanese Association of Groundwater Hydrology

FELLOWSHIP

Graduate Dean's Dissertation Fellowship (\$11,000) *August 2022*
University of California, Graduate Group

Kirkham Conference Travel Grant (\$2,000) *August 2022*
Soil Science Society of America

Summer 2022 ES Professional Development Fellowship (\$1,000) *May 2022*
Environmental Systems Graduate Program, University of California, Merced, USA

Travel Grant (\$500) *May 2022*
HydroML conference

Applied Mathematics Excellence in Service Award (\$200) *Spring 2022*
University of California, Graduate Group

Henry Lin Travel Grant to attend the ASA, CSSA, and SSSA Annual Meeting (\$1,000)
November 2021
Soil Science Society of America

Graduate Student Summer Fellowship (\$7,000) *May 2020 - August 2020*
Environmental Systems Graduate Program, University of California, Merced, USA

Graduate Fellowship Incentive Program Award (\$200) *February 2020*
Graduate Division, University of California, Merced, USA

Graduate Student Summer Fellowship (\$7,000) *May 2019 - August 2019*
Environmental Systems Graduate Program, University of California, Merced, USA

Research Fellowship for Young Scientists (200,000 JPY/month 3,000,000 JPY in total)
April 2017 - June 2018
The University of Tokyo, Japan Society for the Promotion of Science, Japan

Overseas Research Program (600,000 JPY) *September 2016 - December 2016*
Agricultural and Life Sciences, The University of Tokyo

ACADEMIC AWARD

Sponsored AAAS/Science Membership *2019*

Outstanding Student Presentation Award, JPGU-AGU Joint Meeting *2017*

The Dean Award for Academic Excellence, Graduate School of Agricultural and Life Sciences, The University of Tokyo *2017*

Grants-in-Aid of Groundwater Research for Young Investigators, Japanese Association of Groundwater Hydrology *2016*

Best Oral Presentation Award, The Japanese Geotechnical Society Meeting *2015*

ORAL PRESENTATIONS

Bandai, T., Steefel C. Fast and robust neural network training in differentiable modeling for vadose zone hydrology. HydroML Symposium, Richland, USA (May 2024).

Bandai, T., Sadeghi, M., Steefel C. Revisiting scaling approach to describe heterogeneity of soil hydraulic properties through the lens of differential modeling. American Geophysical Union Fall Meeting 2023, San Francisco, USA, (December 2023).

Jiang, P., Kidger, P., Bisht, G., **Bandai, T.**, Pressel, K. G., Steefel, C. I., Chen, X. Differentiable land surface modeling using JAX. American Geophysical Union Fall Meeting 2023, San Francisco, USA, (December 2023).

Chang, C., Borglin, S. E., Chou, C., Zheng, L., Wu, Y., Kneafsey, T. J. Nakagawa, S., **Bandai, T.**, Birkholzer, J. Laboratory bench-scale column tests on bentonite buffer for geologic disposal of high-level radioactive waste. American Geophysical Union Fall Meeting 2023, San Francisco, USA, (December 2023).

Bandai, T., Steefel C. Advancements in numerical simulations of saturated-unsaturated flow using differentiable solvers. HydroML Symposium, Berkeley, USA (May 2023).

Bandai, T., Ghezzehei, T. A., Petra, N. Estimation of surface flux from soil moisture measurements through PDE-constrained optimization. Kirkham Conference, Skukuza, South Africa, (August 2022).

Bandai, T., Ghezzehei, T. A., Petra, N. Estimation of rainfall rates from soil moisture measurements through PDE-constrained optimization. HydroML Symposium, Pennsylvania, USA, (May 2022).

Bandai, T., Sadeghi, M., Babaeian, E., Tuller, M., Jones, S. B., Ghezzehei, T. A. Characterization of unsaturated water flow in soils using short-wave infrared imaging through inverse modeling. ASA, CSSA, SSSA International Annual Meeting 2021, Salt Lake City, USA (November 2021).

Bandai, T., Ghezzehei, T. A. Numerical simulation of soil moisture dynamics using physics-informed neural networks Jppan Geoscience Union Meeting 2021, Online, (June 2021, **Invited**).

Bandai, T., Ghezzehei, T. A. Application of physics informed neural networks for modeling soil water dynamics. InterPore, Online, (May 2021, **Invited**).

Bandai, T., Ghezzehei, T. A. Estimation of constitutive relationships and soil water flux density from volumetric water content measurements using physics-informed neural networks. ACS International Annual Meeting 2020, Online, (November 2020).

Bandai, T., Ghezzehei, T. A. Inverse solution of soil water dynamics using physics-constrained machine learning. American Geophysical Union Fall Meeting 2019, San Francisco, USA, (December 2019).

Bandai, T., Hamamoto, S., Imoto, H., Nishimura, T., Komatsu, T. Effects of particle size and thermal properties on thermal dispersion characteristics in porous media. Japan Geoscience Union Meeting 2015, Chiba, Japan, (May 2015).

POSTER PRESENTATIONS

Stolze, L., Dwivedi, D., Arora, B., Steefel, C. I., **Bandai, T.**, Wu, Y., Nico, P. Model-based interpretation of hydrochemical fluxes from a hillslope in a high-elevation watershed. American Geophysical Union Fall Meeting 2023, San Francisco, USA, (December 2023).

Ghezzehei, T. A., **Bandai, T.** Simulation of near-surface soil moisture measurement without boundary conditions using physics-informed neural networks. American Geophysical Union Fall Meeting 2021, New Orleans, USA, (December 2020).

Bandai, T., Ghezzehei, T. A. Application of physics-informed neural networks to near-surface soil moisture dynamics. American Geophysical Union Fall Meeting 2020, Online, (December 2020).

Bandai, T., Hamamoto, S., Imoto, H., Nishimura, T., Komatsu, T. Experimental and numerical evaluation of LTNE in saturated porous media under forced convection. JpGU-AGPU Joing Meeting, Chiba, Japan, (May 2017).

Bandai, T., Hamamoto, S., Imoto, H., Nishimura, T., Komatsu, T. Thermal non-equilibrium between solid and liquid phases in force convective heat transport. Japan Geoscience Union Meeting 2016, Chiba, Japan, (May 2016).

Bandai, T., Hamamoto, S., Imoto, H., Nishimura, T., Komatsu, T. Experimental study on the validation of thermal equilibrium assumption between solid and liquid phases in convective heat flow in porous media. American Geophysical Union Fall Meeting 2015, San Francisco, USA, (December 2015).

SEMINAR TALKS

Differentiable modeling with implicit differentiation, W.A.T.E.R. Workshop, Texas A&M University, Online (June 2024, **Invited**), Recording.

Learning constitutive relations from soil moisture data via physically constrained neural networks, MIC Modeling semimonthly meeting, Lawrence Berkeley National Laboratory, Berkeley, USA (December 2023, **Invited**)

Large-scale inverse modeling of soil moisture data using physics-informed neural networks and adjoint methods, Tokyo University of Agriculture and Technology, Fuchu, Japan (January 2023, **Invited**)

Inverse solution of Richards' equation using physics informed neural networks. Optimization Seminar, University of California, Merced, Merced, USA (February 2020).

OUTREACH TALK

Pros and Cons of PhD studies in the US, Tokyo University of Agriculture and Technology, Fuchu, Japan (January, 2023)

MEDIA COVERAGE

1. A Q&A With Ingenuity Intern Toshiyuki Bandai, August 4, 2022, Lawrence Berkeley National Laboratory, <https://eesa.lbl.gov/a-qa-with-ingenuity-intern-toshiyuki-bandai/>

TEACHING

Teaching Assistant at University of California, Merced *2018-2022*

Spring 2022

MATH022 Calculus for Physical Sciences and Engineering (discussion)

Fall 2021

MATH022 Calculus for Physical Sciences and Engineering (discussion)

Fall 2020

ESS020 Fundamentals of Geology (lab)

Spring 2020

ESS170 Fundamentals of Soil Science (lab)

Fall 2019

ESS 001 Introduction to Earth Systems Science (lab and discussion)

ESS 110 Hydrology and Climate (discussion)

Spring 2019

ESS170 Fundamentals of Soil Science (lab)

Fall 2018

ESS 001 Introduction to Earth Systems Science (lab and discussion)

ESS 110 Hydrology and Climate (discussion)

Teaching Assistant at the University of Tokyo

2015-2017

Fall 2017

JST Sakura Science Project (intensive seminar for international students)

Spring 2016

First-Year Seminar for Natural Sciences Students

Fall 2015

Soil Physics Experiment

TEACHING CERTIFICATE

Foundation of Teaching and Learning

Summer Session 2019

Center for Engaged Teaching and Learning, University of California, Merced

UTokyo Future Faculty Program

Spring 2017

Center for Research and Development of Higher Education, The University of Tokyo

SESSION CONVENER

Process-augmented ML models

2023

HydroML Symposium

PROFESSIONAL SERVICES

Reviewer

2021-present

Journal of Hydrology, Pedosphere, Soil and Tillage Research, Vadose Zone Journal, Water Resources Research

EESA IDEA Committee

2024

Lawrence Berkeley National Laboratory

Technical support, HydroML Symposium

2023

Lawrence Berkeley National Laboratory

Co-organizer, Enviro-Lunch seminars

2021

University of California, Merced

Student Editor

2016

The Japanese Geotechnical Society

Scientific Networking Program

2015-2016

Graduate School of Agricultural and Life Sciences, The University of Tokyo, Japan

PROFESSIONAL MEMBERSHIPS

American Geophysical Union

2015 - present

Soil Science Society of America

2019 - present

American Association for the Advancement of Science

2019 - 2020

Japanese Geotechnical Society

2015 - 2017

Japanese Society of Soil Physics

2015 - 2017

Japan Geoscience Union

2015 - 2016

REFERENCES

Dr. Teamrat A. Ghezzehei (Ph.D. Advisor)

Professor of Soil Physics

Life and Environmental Sciences Department, University of California, Merced

Email: taghezzehei@ucmerced.edu

Dr. Noemi Petra (Ph.D. Thesis Committee Member)

Associate Professor of Applied Mathematics

Applied Mathematics Department, University of California, Merced

Email: npetra@ucmerced.edu

Dr. Carl I. Steefel (Current Supervisor)

Geochemistry Department Head

Earth and Environmental Sciences Area, Lawrence Berkeley National Laboratory

Email: cisteefel@lbl.gov

Dr. Gabriel C. Rau (Collaborator)

Lecturer of Hydrogeology

School of Environmental and Life Sciences, The University of Newcastle, Australia

Email: gabriel.rau@newcastle.edu