Sudhanshu Pandey, Ph.D.

Scientist, Earth Science Section
Jet Propulsion Laboratory, California Institute of Technology
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Date: October 2, 2026

Research Profile

My research has focused on carbon-cycle science, atmospheric composition, and satellite remote sensing. I now develop machine learning and agentic AI methods that extract new physical information from Earth observations and help uncover the mechanisms driving carbon-cycle and atmospheric change. Earth is now observed in far greater detail than we can interpret using conventional approaches, creating an opportunity for AI to accelerate the formulation and testing of physical hypotheses. My future research combines Earth observation, physical machine learning, equation discovery, and agentic AI to build systems that can test competing explanations and discover new physical relationships, for example, how ecosystem respiration responds to warming.

Key contributions. I developed methods to estimate atmospheric CO_2 growth rates from satellite observations. These estimates are now used by the Global Carbon Project and are being developed as a NASA Orbiting Carbon Observatory-2 data product. Because atmospheric growth integrates the response of the carbon cycle to emissions and climate variability, these observations provide an independent constraint on changes in the global carbon budget. I also led the first satellite detection of a previously unreported extreme methane release, helping establish the potential of satellite observations for identifying large methane point sources. More recently, I showed that machine learning can recover information about winds and atmospheric mixing from spatial patterns of trace gases themselves, demonstrating that atmospheric composition contains information about the dynamics that shaped it.

Professional Experience

Scientist *Jan 2022 – Present*
NASA Jet Propulsion Laboratory (JPL), Earth Science Section, Pasadena, CA, USA
Methane Modeling Lead at JPL for the Atmospheric Application and Research Initiative (AARI), the successor to the U.S. Greenhouse Gas Center

Scientist *Aug 2016 – Jan 2022*
SRON Netherlands Institute for Space Research, Utrecht, The Netherlands

Education

Ph.D. in Physics *Aug 2012 – Feb 2017*
Institute for Marine and Atmospheric Research Utrecht (IMAU), Utrecht University, The Netherlands

BS-MS in Earth Sciences *Jul 2007 – May 2012*
Indian Institute of Science Education & Research, Kolkata, India

Grants and Funding

- NASA ROSES-2024 Carbon Cycle Science award (PI), 2026: "Improving Warming Response of Ecosystem Respiration in Carbon Cycle Models Using Monthly Growth Rates of CO_2 and CH_4"
- NASA Earth Science Technology Office (ESTO) Advanced Modeling Technology (AMT) award (PI), 2026: COMPASS

- NASA ROSES Early Career Investigator Program in Earth Science (ECIP-ES) award (PI), 2023: "Using EMIT's Plume Detection Capability in Conjunction with TROPOMI Observations to Improve Methane Inventories"
- JPL Strategic Research and Technology Development, air-quality digital twin (Co-I)
- NASA Earth Action geospatial foundation model decision-support study (team member), 2026

Awards

- JPL North Star Award, 2026
- Best Oral Presentation Award, SRON Netherlands Science Day, 2019
- INSPIRE Fellowship, Department of Science & Technology (DST), India, 2008
- NASA Group Achievement Award, Greenhouse Gas Center Team, 2026

Publications

46 peer-reviewed publications (12 first-author; 1 in press) and 11 more submitted or under review (3 first-author); about 4,000 citations; h-index 27 (September 2026, Google Scholar).

Peer-reviewed Publications

Note: [M] *denotes publications with tracked media mentions.*

[1] Taylor, T. E., ..., **Pandey, S.**, et al. (2026). The OCO-2 and OCO-3 ACOS version 11 XCO_2 data products: A benchmark record for space-based global carbon cycle research. *Earth and Space Science*, in press. doi:10.1029/2026EA005360

[2] Ke, P., Ciais, P., ..., **Pandey, S.**, et al. (2026). Low latency global carbon budget reveals late 2024 carbon losses and contrasting early 2025 land sink recovery signals. *Advanced Science*, e77369. doi:10.1002/advs.77369

[3] Ke, P., ..., **Pandey, S.**, et al. (2026). Low latency global carbon budget reveals land sink decline during 2023 to 2024 El Niño. *iScience*, *29*, 117053. doi:10.1016/j.isci.2026.117053

[4] Worden, J. R., **Pandey, S.**, et al. (2026). Top-down benchmark of US methane inventories reveals regional discrepancies in activity-based estimates. *Atmospheric Chemistry and Physics*, *26*, 8855–8873. doi:10.5194/acp-26-8855-2026

[5] Dasgupta, B., **Pandey, S.**, et al. (2026). Global methane emission estimates from a dual-isotope inversion: New constraints from δD-CH_4. *Atmospheric Chemistry and Physics*, *26*, 8601–8616. doi:10.5194/acp-26-8601-2026

[6] [M] Friedlingstein, P., ..., **Pandey, S.**, et al. (2026). Global Carbon Budget 2025. *Earth System Science Data*, *18*, 3211–3288. doi:10.5194/essd-18-3211-2026

[7] Ciais, P., ..., **Pandey, S.**, et al. (2026). Low latency global carbon budget indicates reduced land carbon sink in the year 2024. *National Science Review*, *13*(2), nwaf594. doi:10.1093/nsr/nwaf594

[8] Varon, D. J., ..., **Pandey, S.**, et al. (2026). Seasonality and declining intensity of methane emissions from the Permian and nearby U.S. oil and gas basins. *Environmental Science & Technology*, *60*(1), 425–435. doi:10.1021/acs.est.5c08745

[9] Dasgupta, B., ..., **Pandey, S.**, et al. (2025). Harmonisation of methane isotope ratio measurements from different laboratories using atmospheric samples. *Atmospheric Measurement Techniques*, *18*, 6591–6607. doi:10.5194/amt-18-6591-2025

[10] [M] **Pandey, S.** (2025). Taking Earth's carbon pulse from space. *AGU Advances*. doi:10.1029/2025AV002085

[11] **Pandey, S.**, et al. (2025). Reduction in Earth's carbon budget imbalance. *Nature Communications*, *16*, 6818. doi:10.1038/s41467-025-61588-2

[12] [M] Bilir, T. E., ..., **Pandey, S.**, et al. (2025). Satellite-constrained reanalysis reveals CO_2 versus climate-process compensation across the global land carbon sink. *AGU Advances*. doi:10.1029/2025AV001689

[13] **Pandey, S.**, et al. (2025). Relating multi-scale plume detection and area estimates of methane emissions: A theoretical and empirical analysis. *Environmental Science & Technology*, *59*(16), 7931–7947. doi:10.1021/acs.est.4c07415

[14] Albuhaisi, A., ..., **Pandey, S.**, et al. (2024). Integrating satellite observations and hydrological models to unravel large TROPOMI methane emissions in South Sudan wetlands. *Remote Sensing*, *16*, 4744. doi:10.3390/rs16244744

[15] [M] **Pandey, S.**, et al. (2024). Toward low-latency estimation of atmospheric CO_2 growth rates using satellite observations: Evaluating sampling errors of satellite and in situ observing approaches. *AGU Advances*, *5*, e2023AV001145. doi:10.1029/2023AV001145

[16] [M] Varon, D. J., ..., **Pandey, S.**, et al. (2024). Quantifying NO_x point sources with Landsat and Sentinel-2 satellite observations of NO_2 plumes. *Proceedings of the National Academy of Sciences*, *121*, e2317077121. doi:10.1073/pnas.2317077121

[17] [M] Byrne, B., ..., **Pandey, S.**, et al. (2024). Carbon emissions from the 2023 Canadian wildfires. *Nature*, *633*, 835–839. doi:10.1038/s41586-024-07878-z

[18] [M] **Pandey, S.**, et al. (2023). Daily detection and quantification of methane leaks using Sentinel-3: A tiered satellite observation approach with Sentinel-2 and Sentinel-5P. *Remote Sensing of Environment*, *296*, 113716. doi:10.1016/j.rse.2023.113716

[19] [M] Schuit, B. J., ..., **Pandey, S.**, et al. (2023). Automated detection and monitoring of methane super-emitters using satellite data. *Atmospheric Chemistry and Physics*, *23*, 9071–9098. doi:10.5194/acp-23-9071-2023

[20] Worden, J. R., **Pandey, S.**, et al. (2023). Verifying methane inventories and trends with atmospheric methane data. *AGU Advances*, *4*. doi:10.1029/2023AV000871

[21] Naus, S., ..., **Pandey, S.**, et al. (2023). Assessing the relative importance of satellite-detected methane super-emitters in quantifying total emissions for oil and gas production areas in Algeria. *Environmental Science & Technology*. doi:10.1021/acs.est.3c04746

[22] Varon, D. J., ..., **Pandey, S.**, et al. (2023). Continuous weekly monitoring of methane emissions from the Permian Basin by inversion of TROPOMI satellite observations. *Atmospheric Chemistry and Physics*, *23*, 7503–7520. doi:10.5194/acp-23-7503-2023

[23] Maasakkers, J. D., ..., **Pandey, S.**, et al. (2022). Reconstructing and quantifying methane emissions from the full duration of a 38-day natural gas well blowout using space-based observations. *Remote Sensing of Environment*, *270*, 112755. doi:10.1016/j.rse.2021.112755

[24] [M] Maasakkers, J. D., ..., **Pandey, S.**, et al. (2022). Using satellites to uncover large methane emissions from landfills. *Science Advances*, *8*, 1–9. doi:10.1126/sciadv.abn9683

[25] Sadavarte, P., **Pandey, S.**, et al. (2022). A high-resolution gridded inventory of coal mine methane emissions for India and Australia. *Elementa*, *10*, 1–14. doi:10.1525/elementa.2021.00056

[26] **Pandey, S.**, et al. (2022). Order-of-magnitude wall-time improvement of variational methane inversions by physical parallelization: A demonstration using TM5-4DVAR. *Geoscientific Model Development*, *15*, 4555–4567. doi:10.5194/gmd-15-4555-2022

[27] **Pandey, S.**, et al. (2021). Using satellite data to identify the methane emission controls of South Sudan's wetlands. *Biogeosciences*, *18*, 557–572. doi:10.5194/bg-18-557-2021

[28] [M] Cusworth, D. H., ..., **Pandey, S.**, et al. (2021). Multi-satellite imaging of a gas well blowout enables quantification of total methane emissions. *Geophysical Research Letters*, *48*(2), 1–9. doi:10.1029/2020GL090864

[29] [M] Sadavarte, P., **Pandey, S.**, et al. (2021). Methane emissions from super-emitting coal mines in Australia quantified using TROPOMI satellite observations. *Environmental Science & Technology*, *55*(24), 16573–16580. doi:10.1021/acs.est.1c03976

[30] [M] Mazzini, A., ..., **Pandey, S.**, et al. (2021). Relevant methane emission to the atmosphere from a geological gas manifestation. *Scientific Reports*. doi:10.1038/s41598-021-83369-9

[31] Zavala-Araiza, D., ..., **Pandey, S.**, et al. (2021). A tale of two regions: Methane emissions from oil and gas production in offshore/onshore Mexico. *Environmental Research Letters*. doi:10.1088/1748-9326/abceeb

[32] Ma, S., ..., **Pandey, S.**, et al. (2021). Satellite constraints on the latitudinal distribution and temperature sensitivity of wetland methane emissions. *AGU Advances*, *2*(3), 1–12. doi:10.1029/2021AV000408

[33] [M] Zhang, Y., ..., **Pandey, S.**, et al. (2020). Quantifying methane emissions from the largest oil-producing basin in the United States from space. *Science Advances*. doi:10.1126/sciadv.aaz5120

[34] [M] **Pandey, S.**, et al. (2019). Satellite observations reveal extreme methane leakage from a natural gas well blowout. *Proceedings of the National Academy of Sciences*, *116*(52), 26376–26381. doi:10.1073/pnas.1908712116

[35] **Pandey, S.**, et al. (2019). Influence of atmospheric transport on estimates of variability in the global methane burden. *Geophysical Research Letters*, *46*, 2302–2311. doi:10.1029/2018GL081092

[36] [M] Ganesan, A. L., ..., **Pandey, S.**, et al. (2019). Advancing scientific understanding of the global methane budget in support of the Paris Agreement. *Global Biogeochemical Cycles*, *33*(12), 1475–1512. doi:10.1029/2018GB006065

[37] [M] Varon, D. J., ..., **Pandey, S.**, et al. (2019). Satellite discovery of anomalously large methane point sources from oil/gas production. *Geophysical Research Letters*. doi:10.1029/2019GL083798

[38] Dekker, I. N., ..., **Pandey, S.**, et al. (2019). What caused the extreme CO concentrations during the 2017 high pollution episode in India? *Atmospheric Chemistry and Physics*, *19*, 3433–3445. doi:10.5194/acp-19-3433-2019

[39] Borsdorff, T., ..., **Pandey, S.**, et al. (2019). Carbon monoxide air pollution on sub-city scales and along arterial roads detected by the Tropospheric Monitoring Instrument. *Atmospheric Chemistry and Physics*, *19*, 3579–3588. doi:10.5194/acp-19-3579-2019

[40] Naus, S., ..., **Pandey, S.**, et al. (2019). Constraints and biases in a tropospheric two-box model of OH. *Atmospheric Chemistry and Physics*, *19*(1), 407–424. doi:10.5194/acp-19-407-2019

[41] Nechita-Banda, N., ..., **Pandey, S.**, et al. (2018). Monitoring emissions from the 2015 Indonesian fires using CO satellite data. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1760), 20170307. doi:10.1098/rstb.2017.0307

[42] [M] Bruhwiler, L. M., ..., **Pandey, S.**, et al. (2017). U.S. CH_4 emissions from oil and gas production: Have recent large increases been detected? *Journal of Geophysical Research: Atmospheres*, *122*(7), 4070–4083. doi:10.1002/2016JD026157

[43] [M] Worden, J. R., ..., **Pandey, S.**, et al. (2017). Reduced biomass burning emissions reconcile conflicting estimates of the post-2006 atmospheric methane budget. *Nature Communications*, *8*(1), 2227. doi:10.1038/s41467-017-02246-0

[44] **Pandey, S.**, et al. (2017). Enhanced methane emissions from tropical wetlands during the 2011 La Niña. *Scientific Reports*, *7*. doi:10.1038/srep45759

[45] **Pandey, S.**, et al. (2016). Inverse modeling of GOSAT-retrieved ratios of total column CH_4 and CO_2 for 2009 and 2010. *Atmospheric Chemistry and Physics*, *16*(8), 5043–5062. doi:10.5194/acp-16-5043-2016

[46] **Pandey, S.**, et al. (2015). On the use of satellite-derived CH_4:CO_2 columns in a joint inversion of CH_4 and CO_2 fluxes. *Atmospheric Chemistry and Physics*, *15*(15), 8615–8629. doi:10.5194/acp-15-8615-2015

Manuscripts Submitted, Under Review, or Under Revision

[1] **Pandey, S.** (2026). Recovering atmospheric dynamics from atmospheric composition snapshots using machine learning. Under review, *Nature Communications*. Preprint: doi:10.21203/rs.3.rs-10781568/v1

[2] **Pandey, S.**, et al. (2026). Time-varying errors in the atmospheric CO_2 growth rate. Under review, *Nature Geoscience*.

[3] **Pandey, S.**, et al. (2026). Regional synchrony amplifies the fire signal in global CO_2 growth rate. Submitted to *Nature*.

[4] Ciais, P., & **Pandey, S.** (2026). Atmospheric CO_2 reversals do not diagnose land-carbon recovery. Submitted to *Nature Climate Change*.

[5] Palmer, P. I., & **Pandey, S.** (2026). Climate science in the age of AI: why physics matters more than ever. Perspective, submitted to an AIP Publishing journal.

[6] Cusworth, D. H., ..., **Pandey, S.**, et al. (2026). Satellite remote sensing of methane point sources: A review of capabilities and applications. Submitted to *Atmospheric Chemistry and Physics*.

[7] Nesser, H., **Pandey, S.**, et al. (2026). Mind the Methane Gap. Perspective, *Environmental Research Letters*, under revision.

[8] Yun, J., Liu, J., **Pandey, S.**, et al. (2026). Record tropical land carbon sink during the 2022 La Niña. Submitted to *Nature Geoscience*.

[9] Wu, L., Liu, J., Bowman, K. W., **Pandey, S.**, et al. (2026). Sensitivity of atmospheric CO_2 transport to horizontal resolution and its implications for hemispheric flux estimation. Submitted to *Geophysical Research Letters*.

[10] Ke, P., ..., **Pandey, S.**, et al. (2026). Low latency global carbon budget reveals strong land sink recovery in 2025. Submitted to *National Science Review*.

[11] Yun, J., **Pandey, S.**, et al. (2025). Unprecedented role of Amazon fires in the record atmospheric CO_2 growth in 2024. Under review in *Science Advances*. doi:10.22541/essoar.175874118.83695562/v1

Other Publications

[O1] Varon, D. J., ..., **Pandey, S.**, et al. (2025). Reply to Chen et al.: Coarse simulations overestimate the distance to recover NO–NO_2–O_3 photochemical steady state in fresh NO_x plumes. *Proceedings of the National Academy of Sciences*, *122*(7), e2425976122. doi:10.1073/pnas.2425976122

[O2] Sadavarte, P., **Pandey, S.**, et al. (2024). Rebuttal to Correspondence on "Methane emissions from super-emitting coal mines in Australia quantified using TROPOMI satellite observations." *Environmental Science & Technology*. doi:10.1021/acs.est.4c01510

[O3] Maity, A., ..., **Pandey, S.**, et al. (2024). Atmospheric CO_2 inversion models overestimate northern extratropical land and ocean carbon uptake as assessed at background in situ sites. *Research Square* [preprint]. doi:10.21203/rs.3.rs-3960558/v1

[O4] Bergamaschi, P., ..., **Pandey, S.**, et al. (2018). Atmospheric monitoring and inverse modeling for verification of greenhouse gas inventories. *Publications Office of the European Union*. doi:10.2760/759928

[O5] **Pandey, S.** (2017). Advancing the use of satellites to constrain atmospheric methane fluxes. Ph.D. dissertation, Utrecht University. link

[O6] Chevallier, F., ..., **Pandey, S.**, et al. (2017). Climate assessment report for the GHG-CCI project of ESA's Climate Change Initiative. *Publications Office of the European Union*. link

Teaching Experience

- **Teaching Assistant, Introduction to Climate Change** (Utrecht University, 2012–2013): led problem-solving sessions on radiative forcing, feedbacks, and climate variability for approximately 30 first-year students.
- **Teaching Assistant, Remote Sensing of the Earth** (Utrecht University, 2014 and 2015): led laboratory sessions on retrieval principles, spectral analysis, uncertainty, and hands-on analysis of satellite greenhouse-gas data for approximately 15 students per offering.

Mentoring and Supervision

- **Master's Thesis Projects (9 months, full-time each):** Main supervisor for Simon van Diepen (TU Delft) and Dr. Maria Tsivlidou (Utrecht University). Co-supervisor for Pieter Bijl (TU Delft).
- **Internship Supervision at JPL:** Ansh Tiwari (Caltech), Julia Gao (Caltech), Kayley Butler (USC), Zijian Qiu (Harvard University), Monica Amezquita (Cal Poly Pomona via JPL's Maximizing Student Potential (MSP) Program), Patrick Wiecko (University of Colorado Boulder).
- Supervised seven university student projects at SRON, the Netherlands, each lasting 3–6 months, including TU Delft master's students Pratik Sutar and Maarten van Nistelrooij, both coauthors of Pandey et al. (2023, *Remote Sensing of Environment*).

Presentations

Invited Presentations

- **AGU Fall Meeting, 2025:** "Accurate, low-latency monitoring of whole-atmosphere CO_2 growth rates with satellite observations."

- **The Methane Emissions Technology Alliance (META), 2025:** "Relating multi-scale plume detection and area estimates of methane emissions."
- **NOAA, 2023:** Global growth-rate estimates of CO_2 from satellite observations
- **U.S. EPA, 2021:** Satellite reveals extreme leakage from a natural gas well blowout
- **Indian Institute of Tropical Meteorology (IITM), Pune, India, 2019:** Atmospheric monitoring using ESA's TROPOMI satellite
- **NASA JPL, 2019:** Satellite reveals extreme CH_4 leakage from a natural gas well blowout
- **NASA GISS, 2018:** TROPOMI detection of CH_4 leakage from a gas well blowout
- **NASA JPL, 2018:** CH_4 monitoring using ESA's TROPOMI satellite

Selected Conference Presentations

- **American Geophysical Union (AGU) Fall Meetings:** 2015, 2018, 2019, 2021, 2022, 2023, 2024, and 2025
- **European Geosciences Union (EGU) General Assembly:** 2017, 2018, and 2019
- **ESA Living Planet Symposium:** 2013 and 2016
- **International Carbon Dioxide Conference (ICDC):** 2017
- **International Workshop on Greenhouse Gas Measurements from Space (IWGGMS):** 2014, 2018, 2021, and 2023

Community Service

- **Reviewer for scientific journals:** Nature, Science Advances, Nature Climate Change, Atmospheric Measurement Techniques, Atmospheric Chemistry and Physics, Carbon Management, Journal of Geophysical Research, Remote Sensing of Environment, Environmental Science & Technology, Environmental Research Letters, Geophysical Research Letters, and Remote Sensing.
- **Review Editor:** Frontiers
- **Proposal Review:** Scientific research proposals for NOAA and NASA.
- **Poster Judge:** EGU and AGU annual meetings.
- Hosted a remote sensing session at the CEOS-GHG (Paris) 2023 meeting.