

# Piyushkumar N. Patel

Scientist C @ SRON, Netherlands

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## Research Overview

As an accomplished atmospheric scientist with over a decade of experience at renowned organizations such as the Indian Space Research Organization (ISRO) and NASA Jet Propulsion Laboratory (JPL), I specialize in utilizing advanced satellite remote sensing and ground-based observing technologies to measure and characterize the atmospheric composition and their intricate interactions with climate. My research interests lie in the complex and dynamic relationship between aerosols, clouds, and radiation and their impact on global climate change. With expertise in scientific retrieval algorithms, in-orbit satellite/airborne calibration (covering the visible-shortwave infrared spectrum), and validation of atmospheric and climate-related data products, I have worked with a diverse range of satellite and airborne sensors. My expertise in atmospheric monitoring techniques has enabled me to study aerosol-cloud interaction, air pollution and climate change globally across diverse geographies. With a proven track record of both independent and collaborative scientific contributions, I am a natural team player with the ability to support and lead multi-disciplinary teams and deliver scientific contributions. With a passion for advancing our understanding of the world around us, I am eager to continue exploring the frontiers of knowledge in atmospheric science.

## Research Interest

aerosol-radiation-meteorological feedback, aerosol-cloud-climate interactions and dynamical feedback, satellite remote sensing and process studies of clouds, air pollutant emission estimation from satellite, multiple satellite data analysis, vicarious calibration of optical satellite sensors and radiative transfer

## Education

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| <b>Gujarat University / Space Applications Centre, ISRO, Ahmedabad, India</b><br><i>Ph.D. in Physics (Atmospheric Science)</i><br><i>Topic: Investigation of aerosol-cloud microphysical interaction and associated changes in TOA radiative forcing using remote sensing data</i> | [2014 – 2019]<br>(dissertation submission: Jan 2018 and defense: Aug 2018) |
| <b>Indian Institute of Remote Sensing, ISRO, Dehradun, India</b><br><i>P.G. Diploma in Remote Sensing (Atmospheric Science)</i>  | [2011 – 2012]  |
| <b>Sardar Patel University, Vallabh Vidhyanagar, India</b><br><i>M.Sc. in Condensed Matter Physics</i>   | [2009 – 2011]  |
| <b>Veer Narmad South Gujarat University, Surat, India</b><br><i>B.Sc. in Physics</i>   | [2006 – 2009]  |

## Professional Experience

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|---|-------------------------|
| <b>SRON - Netherlands Institute for Space Research, Leiden, Netherlands</b><br><i>Scientist C</i>   | [April 2024 – Present]  |
| <ul style="list-style-type: none"><li>Developing the quality filters to improve the aerosol retrieval from the multiangle multispectral polarimetry measurements such as POLDER and NASA PACE.</li><li>Retrieving cloud microphysical properties from the multiangle multispectral polarimetry measurements.</li></ul>  |                         |
| <b>MethaneSAT LLC - a wholly owned subsidiary of EDF, Austin, Tx, USA</b><br><i>Remote Sensing Scientist (Consulting)</i>   | [Nov 2022 – March 2024] |
| <ul style="list-style-type: none"><li>Conducting extensive research on global onshore and offshore oil and gas operations to characterize and quantify the emissions of multiple pollutant species, including <math>NO_2</math>, <math>SO_2</math>, PM2.5, black carbon, and formaldehyde.</li><li>Developing innovative methodologies to integrate current and future satellite data from multiple sensors, enabling comprehensive monitoring and analysis of pollutant emissions from oil and gas operations.</li></ul>         |                         |
| <b>NASA Jet Propulsion Laboratory, Caltech, Pasadena, CA, USA</b><br><i>NASA Postdoctoral Program Fellow</i>  | [Sep 2019 – Sep 2022]   |
| <ul style="list-style-type: none"><li>Developed an innovative algorithm to estimate cloud condensation nuclei (CCN) concentrations using spaceborne and airborne lidar measurements of aerosol optical properties.</li><li>Conducted in-depth investigations into the variability of aerosol-CCN activity across diverse environments, employing advanced ground-based observation tools such as scanning mobility particle sizer, CCN counter, condensation particle counter, and aerosol chemical speciation monitor.</li></ul> |                         |

- Explored the profound impacts of aerosol-radiation-meteorological feedback within the boundary layer on smog intensification, leveraging observations from multiple platforms.
- Utilized a comprehensive suite of state-of-the-art atmospheric monitoring techniques, including satellite observations from renowned sources like MODIS, CERES, TROPOMI, CALIPSO, CloudSat, TRMM, along with radiosonde measurements, ground-based observations, and high-quality meteorological reanalysis datasets such as ECMWF and MERRA-2.

#### Physical Research Laboratory, Ahmedabad, India

[Jan 2018 – Sep 2019]

##### Postdoctoral Fellow

- Conducted an extensive analysis of various satellite observations to study the interaction between dust and ice clouds during the Indian Summer Monsoon.
- Evaluated the dynamic feedback resulting from dust-ice cloud interactions in different cloud regimes and their cumulative effects on precipitation patterns during the Indian Summer Monsoon. This analysis involved utilizing multiple satellite observations such as MODIS, MISR, CERES, CALIPSO, CloudSat, TRMM, as well as meteorological parameters from ground-based observations and reanalysis data.)

#### Space Applications Centre, ISRO, Ahmedabad, India

[Aug 2012 – Aug 2017]

##### Research Fellow

- Monitored and calibrated VIS/SWIR channels of geostationary satellites (e.g., INSAT-3D, INSAT-3DR) and the airborne hyperspectral sensor (AVIRIS-NG) to ensure accurate measurements.
- Validated level-2 geophysical products such as aerosol optical depth, cloud properties, precipitation, and meteorological parameters.
- Conducted comprehensive studies on atmospheric aerosols and their influence on the regional radiative budget utilizing in-situ observations and radiative transfer simulations.
- Developed and operated satellite CAL-VAL facilities and ground-based instruments (e.g., spectrometer, sunphotometer, micro rain radar, disdrometer, MicroTops) for precise calibration and validation.
- Formulated project goals, conducted ground-based field experiments, and analyzed data from diverse platforms (satellite, airborne, balloon-borne, ground-based) along with radiative transfer simulations.
- Produced detailed scientific reports, collaborated with the data team, and published research results in reputable journals and conferences.

In parallel with my professional endeavors, I dedicated myself to pursuing a doctorate focused on the intricate field of aerosol-cloud-radiation interactions. This research centered on leveraging satellite observations to gain profound insights into the complex interplay between aerosols, clouds, and radiation in the Earth's atmosphere.

## Awards & Achievements

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<b>NASA Postdoctoral Program Fellowship</b>   NASA Jet Propulsion Laboratory	[2019]
<b>Postdoctoral Research Fellowship</b>   Physical Research Laboratory	[2018]
<b>Senior Research Fellowship</b>   Space Applications Centre, ISRO	[2014]
<b>Junior Research Fellowship</b>   Space Applications Centre, ISRO	[2012]
<b>Best Poster Presentation</b>   International workshop in Ansal University, Gurgaon, India	[2015]
<b>Travel Grants</b>   ICTP (Italy), Department of Science and Technology (India), IIT-Delhi	[2015, 2016]

## Invited Talk

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<b>Guest Lecture at ACAM Training School</b>   Dhaka, Bangladesh <i>Aerosol Monitoring from Satellites: A Comprehensive Overview</i>	[Jun 06, 2023]
<b>SANGAM University</b>   Bhilwara, Rajasthan, India <i>Satellite Remote Sensing for Monitoring Climate Change</i>	[Sep 16, 2022]
<b>University of Nizwa</b>   Oman <i>Atmospheric Aerosols in the Changing Climate from the Satellite Perspective</i>	[Apr 21, 2022]
<b>S. V. National Institute of Technology</b>   Surat, Gujarat, India <i>Role of Atmospheric Pollution in Climate Change</i> <i>Training Program on Air pollution: sources, Control and Modelling</i>	[Feb 17, 2021]
<b>P. P. Savani University</b>   Surat, Gujarat, India <i>How Human-Caused Air Pollution Changing Our Climate?</i>	[Jun 25, 2020]
<b>Guest lecture at ACAM</b>   Malaysia <i>Satellite Remote Sensing for Monitoring Climate Change</i>	[Jun, 2019]
<b>NASA Jet Propulsion Laboratory</b>   Pasadena, CA, USA <i>Strengthened Indian summer monsoon precipitation susceptibility linked to dust-induced ice cloud modifications</i>	[Oct 30, 2018]

## Journal Publications

- Wang, F., Xu, Y., **Patel, P. N.**, Gautam, R., Gao, M., Liu, C., Ding, Y., Chen, H., Y, Y., Zhou, Y., Carmichael, G. R., McElory, M.B., (2024) Arctic amplification induced decline in West and south Asia dust warrants stronger anti-desertification towards carbon neutrality, *Proceedings of the National Academy of Sciences*. <https://doi.org/10.1073/pnas.2317444121>
- **Patel, P. N.**, Jiang, J. H., Gautam, R., Gadhavi, H., Kalashnikova, O. V., Garay, M. J., Gao, L., Xu, Feng., Omar, A., (2024) A Remote Sensing Algorithm for Vertically-Resolved Cloud Condensation Nuclei Number Concentrations from Airborne/Spaceborne Lidar Observations, *Atmospheric Chemistry & Physics*. <https://doi.org/10.5194/acp-24-2861-2024>
- Gautam, R., **Patel, P. N.**, Singh, Liu, T., Mickley, L. J., Jethva, H., DeFries, R., (2023) Extreme smog challenge of northern India intensified by increasing lower tropospheric stability, *Geophysical Research Letter*. (**Contributed equally to this work as first authors**). <https://doi.org/10.1029/2023GL103105>
- Liu, T., Mickley, L. J., **Patel, P. N.**, Gautam, R., Jain, M., DeFries, R., and Marlier, M. E., (2022) Cascading Delays in the Monsoon Rice Growing Season and Post-Monsoon Fires Likely Exacerbate Air Pollution in North India, *Journal of Geophysical Research -Atmosphere*. <https://doi.org/10.1029/2022JD036790>
- Dumka, U.C., Kosmopoulos, P.G., **Patel, P. N.**, & Sheoran, R. (2022). Can forest fires be an important factor in the reduction of solar power production in India?, *Remote Sensing*. <https://doi.org/10.3390/rs14030549>
- **Patel, P. N.**, & Jiang, J. H. (2021). Cloud condensation nuclei characteristics at the Southern Great Plains site: role of particle size distribution and aerosol hygroscopicity, *Environmental Research Communications*. <https://doi.org/10.1088/2515-7620/AC0E0B>
- **Patel, P. N.**, Gautam, R., Michibata, T., & Gadhavi, H. (2019). Strengthened Indian Summer Monsoon Precipitation Susceptibility Linked to Dust-Induced Ice Cloud Modification, *Geophysical Research Letters*. <https://doi.org/10.1029/2018GL081634>
- Babu, K. N., Mathur, A., Thompson, D. R., Green, R. O., **Patel, P. N.**, Prajapati, R. P., Bue, B. D., Geier, S., Eastwood, M. L., Helmlinger, M. C. (2019). An empirical comparison of calibration and validation methodologies for airborne imaging spectroscopy, *Current Science*. 116(7), 1101-1107
- **Patel, P. N.**, Babu, K. N., Prajapati, R. P., Sitapara, V., & Mathur, A. K. (2018). Day-1 INSAT-3DR Vicarious Calibration Using Reflectance-Based Approach Over Great Rann of Kutch, *Journal of the Indian Society of Remote Sensing*. <https://doi.org/10.1007/s12524-017-0729-z>
- **Patel, P. N.**, Dumka, U. C., Babu, K. N., & Mathur, A. K. (2017). Aerosol characterization and radiative properties over Kavaratti, a remote island in southern Arabian Sea from the period of observations, *Science of the Total Environment*. <https://doi.org/10.1016/j.scitotenv.2017.04.168>
- **Patel, P. N.**, Quaas, J., & Kumar, R. (2017). A new statistical approach to improve the satellite-based estimation of the radiative forcing by aerosol–cloud interactions, *Atmospheric Chemistry & Physics*. <https://doi.org/10.5194/acp-17-3687-2017>
- **Patel, P. N.**, Dumka, U. C., Kaskaoutis, D. G., Babu, K. N., & Mathur, A. K. (2017). Optical and radiative properties of aerosols over Desalpar, a remote site in western India: Source identification, modification processes and aerosol type discrimination, *Science of the Total Environment*. <https://doi.org/10.1016/j.scitotenv.2016.09.023>
- **Patel, P. N.**, & Kumar, R. (2016). Dust Induced Changes in Ice Cloud and Cloud Radiative Forcing over a High Altitude Site, *Aerosol and Air Quality Research*,. <https://doi.org/10.4209/aaqr.2015.05.0325>
- **Patel, P. N.**, Bhatt, H., Mathur, A. K., Prajapati, R. P., & Tyagi, G. (2016). Reflectance-based vicarious calibration of INSAT-3D using high-reflectance ground target, *Remote Sensing Applications: Society and Environment*. <https://doi.org/10.1016/j.rsase.2015.12.001>
- **Patel, P. N.**, & Kumar, R. (2015). Estimation of aerosol characteristics and radiative forcing during dust events over Dehradun, *Aerosol and Air Quality Research*. <https://doi.org/10.4209/aaqr.2015.02.0077>
- **Patel, P. N.**, & Shukla, A. K. (2015). Aerosol optical properties over marine and continental sites of India during pre-monsoon season, *Current Science*. 108(4), 666–676.
- Kant, Y., **Patel, P.**, Mishra, A. K., Dumka, U. C., & Dadhwal, V. K. (2012). Diurnal and Seasonal Aerosol Optical Depth and Black Carbon in the Shiwalik Hills of the North Western Himalayas: a Case Study of the Doon Valley, India, *International Journal of Geology, Earth and Environmental Sciences*. 2(2), 173–192.

## Under Preparation

- **Patel, P. N.**, Gautam, R., Omara, M., Zavala-Araiza, D., Satellite-based Quantifications of NO<sub>x</sub> Emissions from Global Oil and Gas Fields, *to-be submitted*.
- **Patel, P. N.**, & Jiang, J. H., A 15-year record of satellite-based 3D cloud condensation nuclei data, *in-preparation*.

## Conference Presentation/Publication

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- **Patel, P. N.**, Jiang, J. H., Gautam, R., 3D Climatology of Cloud Condensation Nuclei Concentrations Derived from Spaceborne Lidar, ACAM 2023, Dhaka, Bangladesh.
- **Patel, P. N.**, Gautam, R., Omara, M., Zavala-Araiza, D., Satellite-based Quantification of  $\text{NO}_2$  Emissions from Global Natural Gas Flaring with a Focus on Asia, ACAM 2023, Dhaka, Bangladesh.
- **Patel, P. N.**, Jiang, J. H., Global 3D Climatology of Cloud Condensation Nuclei Concentrations Retrieved from Spaceborne Lidar – CALIOP/CALIPSO, AGU Fall Meeting 2022, USA.
- **Patel, P. N.**, Gautam, R., Singh, Liu, T., Mickley, L. J., Jethva, H., DeFries, R., Long-term Observation of Smog Intensification over Northern India Associated with Aerosol-Radiation-Meteorological Feedbacks, AGU Fall Meeting 2022, USA.
- Liu, T., Mickley, L. J., **Patel, P. N.**, Gautam, R., Jain, M., DeFries, R., and Marlier, M. E., Cascading Delays in the Monsoon Rice Growing Season and Post-Monsoon Agricultural Fires Likely Exacerbate Air Pollution in North India, AGU Fall Meeting 2022, USA.
- Dayanandan, B., **Patel, P. N.**, Tiwari, P., Al-Amri, I., Thakadiyil, S., Al-Badi, H., Al-Riyami, K., Climatology and trend of aerosol optical depth and associated changes in radiative budget over Middle East, AGU Fall Meeting 2021, USA.
- **Patel, P. N.**, & Jiang, J. H., Estimation of CCN concentrations from Spaceborne Lidar measurements, AGU Fall Meeting 2021, USA.
- Dayanandan, B., **Patel, P. N.**, Tiwari, P., Al-Amri, I., Thakadiyil, S., Al-Badi, H., Al-Riyami, K., Long-term changes in aerosol loading and observed impacts on radiative budget over Middle-East, ECAS 2021.
- **Patel, P. N.**, Jiang, J. H., Atmospheric nucleation and its effect on cloud condensation nuclei abundance at the US DOE Southern Great Plains field site, AGU Fall Meeting 2020, USA.
- **Patel, P. N.**, Gautam, R., A Satellite-based Assessment of Long-term Trends in Extreme Smog and Haze and Their Radiative Impacts over the Indo-Gangetic Plains, AGU Fall Meeting 2020, USA.
- **Patel, P. N.**, Gautam, R., Michibata, T., Gadhavi, H., Response of Indian Summer Monsoon to Dust-Induced Modification in Ice-Clouds, ACAM 2019, UKM, Malaysia.
- Gautam, R., **Patel, P. N.**, Liu, T., Singh, M., Extreme smog over northern India during post-monsoon crop burning season: quantifying long-term changes in aerosol loading and radiative effects using satellite data, ACAM 2019, UKM, Malaysia.
- **Patel, P. N.**, Gautam, R., Michibata, T., Gadhavi, H., Impacts of Dust-Ice cloud Interactions on Precipitation Susceptibility, IASTA 2018, IIT Delhi, India.
- Babu, K.N., Prajapati, R.P., **Patel, P. N.**, and Mathur, A. K., Calibration of AVIRIS-NG hyperspectral imager over natural targets, Science results of phase-I airborne hyperspectral campaign with AVIRIS-NG over India, 2017, SAC-ISRO, Ahmedabad, India.
- **Patel, P. N.**, Babu, K. N., Prajapati, R. P., et al., Day-1 INSAT-3DR vicarious calibration using reflectance-based approach over Great Rann of Kutch, ISRS-ISG National Symposium 2016, Dehradun, India.
- Babu, K.N., Suthar, N. M., **Patel, P. N.**, and Mathur, A. K., Aerosol measurements and validation of satellite-derived optical depth over the Kavarratti Cal-Val site, SPIE Asia-Pacific Remote Sensing, 2016, New Delhi, India.
- **Patel, P. N.**, Aerosol-Cloud-Climate Interaction, Science Workshop on Nanosatellite for Earth Monitoring and Observation - Aerosol Monitoring (NEMO-AM), 2015, SAC-ISRO, Ahmedabad, India.
- **Patel, P. N.**, Babu, K. N., and Kumar, R., Contribution of sea-salt aerosol and the impact of cloud microphysics over the Arabian Sea using satellite measurements, National symposium on weather and climate extremes, TROPMET 2015, Chandigarh, India.
- **Patel, P. N.**, and Kumar, R., Aerosol-Cloud interaction over India and surrounding ocean using satellite data, International workshop on Assessing the Impact of Aerosols & Changing Climate on Monsoon & Extreme Events 2015, Ansal University, Gurgaon, India.
- **Patel, P. N.**, Bhatt, H., and Shukla, A.K., Absolute vicarious calibration of recently launched Indian meteorological satellite: INSAT-3D Imager, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., ISPRS Technical Commission VIII symposium 2014, Hyderabad, India.
- **Patel, P. N.**, and Kant, Y., Influence of episodic dust event on the aerosol optical properties over Dehradun, IASTA 2012, BARC, Mumbai, India.

## Research Skills

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- Experience in working/handling/reprocessing various **satellite datasets** (*MODIS, MISR, CERES, CALIPSO, Cloud-Sat, TRMM, TROPOMI, AIRS, OMI, INSAT-3D, INSAT-3DR*) in **HDF/NetCDF** formats.
- Experience in working with various **ground-based observations, airborne datasets, and reanalysis data** (*ECMWF, MERRA for winds, planetary boundary layer height, vertical temperature profiles*)
- Modeling simulations with **radiative transfer codes** (*6S, SBDART*), **Mie Scattering Codes** (*bhmie, Wiscombe, T-matrix*), **OPAC, HYSPLIT**
- Experience in several **land and ocean-based field campaigns** both **independently** and in **collaboration with the team**.

## Technical Skills

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**Programming:** Fortran, Python, Generic Mapping Tool (GMT), Google Earth Engine, GDAL, CDO, bash scripting

**Libraries:** HDF, NetCDF

**Applications:** LaTeX, MS Office, Origin

**Operating Systems:** Linux, macOS, Windows

Experience in working on supercomputing platforms & Parallel Programming

## Scientific Services

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**Member** | AGU Atmospheric Science Early Career Committee

[2022-Present]

**Proposal Panel Reviewer** | NASA

**Journal Reviewer:** *Geophysical Research Letters, Environmental Research Letters, Atmospheric Chemistry and Physics, Remote Sensing of Environment, Remote Sensing, Atmosphere, Journal of Earth System Science, Journal of Applied Remote Sensing*

## Professional Membership

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American Geophysical Union (AGU), European Geophysical Research (EGU)

## Research Projects

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- PI: NASA POSTDOCTORAL PROGRAM (NPP) Fellowship, “Vertical distribution of CCN concentrations and their impacts on cloud properties using space-borne lidar measurements.”
- CO-I: Research TRC2021, University of Nizwa, Oman, “A synergy of ground-based and satellite measurements for atmospheric aerosol monitoring over the middle east.”

## Supervising Scholars

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**Pravash Tiwari**, Ph.D. Student | China University of Mining and Technology, China

**Shishir Dahal**, Researcher | International Centre for Integrated Mountain Development, Nepal

**Tatsat Thakore**, Senior Software Engineer | Stack Summation, India

**Mihir Patel**, Master Student | Sardar Vallabhbhai National Institute of Technology, India

**Master Students** | University of Nizwa, Oman