Gregory Cooke

ASTROPHYSICS · POSTDOCTORAL RESEARCHER

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Employment

Institute of Astronomy, University of Cambridge; PI: Nikku Madhusudhan — *Cambridge, UK*

Research Associate in Exoplanetary Atmospheres — *August 2023 - present*

- My work centres on simulations of exoplanets in the sub-Neptune regime using one-dimensional (1D) and 3D photochemical models.
- I am exploring the chemical nature of habitable exoplanet atmospheres, assuming different stellar hosts, and various initial conditions.
- I am examining how biologically-produced molecules influence the spectroscopic signature of exoplanet atmospheres.
- I am a supervisor for the Stellar Structure and Evolution 3rd year undergraduate course.

Education

University of Leeds — *Leeds, UK*

PhD in Astrophysics; Thesis title: 3D simulations of oxygenated rocky planetary climates and observational predictions. Advisors: Professor Dan Marsh, Dr Catherine Walsh. — *October 2019 - July 2023*

- My thesis focused on simulating rocky worlds and understanding their climates, chemistry, and habitability. I used and modified the Community Earth System Model (CESM2), mostly the Whole Atmosphere Community Climate Model (WACCM6) configuration.
- I simulated early Earth with a younger Sun and with varied atmospheric oxygen (O_2) concentrations.
- I used the Planetary Spectrum Generator (PSG) to determine how detectable specific planetary properties (e.g. chemical species such as ozone and oxygen; temporal variability) are using the next generation of telescopes (e.g. LUVOIR).
- I performed simulations for tidally locked M dwarf exoplanets (Proxima Centauri and TRAPPIST-1 systems) and predicted observations of these exoplanets.
- I found, for the first time, that it is possible for lethal surface concentrations of O_3 to build up on the surface of habitable zone exoplanets.
- My thesis received recognition for Research Excellence from the Dean of Postgraduate Research Studies.
- I was selected competitively as a Priestley Climate Scholar.

University of Manchester — *Manchester, UK*

MPhys in Physics (First-Class Honours: 81.4%) — *October 2015 - June 2019*

- Two MPhys projects:
  1. Investigating and defining habitability metrics for all known exoplanets.
  2. Designing an optimized telescope search for habitable exoplanets using the Besançon galactic model.
- Most optional courses taken were related to astrophysics (e.g. Astrophysical plasmas, General relativity, Exoplanets).

Funding

University of Leeds — *Leeds, UK*

STFC studentship — *October 2019 - April 2023*

- A 3.5-year STFC studentship (approximately worth £75,000).
- Funding for travel and funding for the conference fee to attend the *3rd Eddy Cross Disciplinary Symposium: Sun, Earth, Planet, Space, Atmosphere and Ocean*, in Vail, Colorado, USA (total $2,800).

Publications

Published:

- **Cooke G. J.** *et al.*, 2024, Lethal surface ozone concentrations are possible on habitable zone exoplanets, The Planetary Science Journal, https://iopscience.iop.org/article/10.3847/PSJ/ad53c3.
- Liu B., Marsh D. R., Walsh C., **Cooke G. J.**, & Sainsbury-Martinez F., July 2024, Eccentric Orbits Enhance the Habitability of Earth-like Exoplanets, Monthly Notices of the Royal Astronomical Society, https://doi.org/10.1093/mnras/stae1758
- **Cooke G. J.** *et al.*, 2023, Degenerate interpretations of O_3 spectral features in exoplanet atmosphere observations due to stellar UV uncertainties: a 3D case study with TRAPPIST-1e, The Astrophysical Journal, https://iopscience.iop.org/article/10.3847/1538-4357/ad0381.
- Liu B., Marsh D. R., Walsh C., & **Cooke G. J.**, June 2023, Higher Water Loss on Earth-like Exoplanets in Eccentric Orbits, Monthly Notices of the Royal Astronomical Society, pp. 1491–1502, https://doi.org/10.1093/mnras/stad1828.
- Ji A., Kasting J. F., **Cooke G. J.**, *et al.*, Comparison between ozone column depths & methane lifetimes computed by one- & three-dimensional models at different atmospheric O_2 levels. R. Soc. open sci. 10: 230056. https://doi.org/10.1098/rsos.230056.
- **Cooke G. J.**, Marsh DR, Walsh C, Rugheimer S, Villanueva GL, January 2023, Variability due to climate & chemistry in observations of oxygenated Earth-analogue exoplanets, Monthly Notices of the Royal Astronomical Society, 518(1), pp. 206–219, https://doi.org/10.1093/mnras/stac2604.
- **Cooke G. J.**, Marsh DR, Walsh C, Black B, Lamarque J-F. 2022 A revised lower estimate of ozone columns during Earth's oxygenated history. R. Soc. Open Sci. 9: 211165. https://doi.org/10.1098/rsos.211165.

Articles in review:

- **Cooke G. J.** & Madhusudhan N., Considerations for Photochemical modeling of Temperate Sub-Neptunes.
- Bhongade A., Marsh D. R., Sainsbury-Martinez F., & **Cooke G. J.**, Asymmetries in the simulated ozone distribution on TRAPPIST-1e due to orography.
- Sainsbury-Martinez F., Walsh C., **Cooke G. J.**, & Marsh D. R., How Land-Mass Distribution Influences The Atmospheric Dynamics of Tidally Locked Terrestrial Exoplanets.

Articles undergoing internal review:

- Sainsbury-Martinez F., Walsh C. & **Cooke G. J.**, The Impact of Icy Cometary 'impacts' on Exoplanetary Atmospheres 1: Tidally-Locked Terrestrial Exoplanets.

Articles in prep:

- Braam M. & **Cooke G. J.**, A chemistry-climate comparison for Proxima Centauri b simulations.
- **Cooke G. J.** et al., Oxygen's control on hydrogen escape in Earth-like atmospheres across FGKM dwarf stars.
- **Cooke G. J.** & Madhusudhan N., Title to be confirmed.

Contributed talks

Mar 2024	**LCLU Annual Science Day**, *Lethal surface ozone concentrations are possible on habitable zone exoplanets.*	*Cambridge, UK*
Jan 2024	**Rocky Worlds III**, *Lethal surface ozone concentrations are possible on habitable zone exoplanets.*	*Zurich, Switzerland*
Nov 2023	**Habitable Worlds Observatory – UK community workshop**, *3D simulations of exoplanet climates and observational predictions*	*Leicester, UK*
Jul 2022	**Rocky Worlds II**, *A revised lower estimate of ozone columns during Earth's oxygenated history.*	*Oxford, UK*
Jul 2022	**ResCompLeedsCon2022**, *Simulations of tidally locked exoplanet atmospheres in 3D.*	*Leeds, UK*
Jun 2022	**3rd Eddy Cross Disciplinary Symposium**, *3D whole-atmosphere modelling of rocky exoplanet systems and synthetic telescope observations.*	*CO, USA*
Jun 2021	**CESM Workshop**, *Viewing the Earth and its exoplanet analogues through time.*	***Virtual***
Apr 2021	**UK Exoplanet Meeting**, *Oxygen's 2.4 billion year control on Earth's atmosphere with consequences for exoplanet biosignatures.*	***Virtual***

Invited and internal seminars

Mar 2024	**Invited, University of Oxford**, *Ozone in habitable zone exoplanet atmospheres: observational ambiguities and lethality to life.*	*Oxford, UK*
Mar 2024	**Invited, University of Leeds**, *Ozone in habitable zone exoplanet atmospheres: observational ambiguities and lethality to life.*	*Leeds, UK*
Nov 2023	**Internal, University of Cambridge**, *Imposter syndrome.*	*Cambridge, UK*
Oct 2023	**Internal, University of Cambridge**, *3D simulations of oxygenated rocky exoplanet atmospheres and observational predictions.*	*Cambridge, UK*
Feb 2023	**Invited, University of Edinburgh**, *A revised lower estimate of ozone columns during Earth's oxygenated history.*	*Edinburgh, UK*
Oct 2022	**Internal, University of Leeds**, *Variability due to climate and chemistry in observations of oxygenated Earth-analogue exoplanets.*	*Leeds, UK*
May 2022	**Invited, National Center for Atmospheric Research**, *A revised lower estimate of ozone columns during Earth's oxygenated history.*	*CO, USA*
Mar 2022	**Internal, University of Leeds**, *A revised lower estimate of ozone columns during Earth's oxygenated history.*	*Leeds, UK*
May 2021	**Invited, University of Cambridge**, *Oxygen's 2.4 billion year control on Earth's atmosphere with consequences for exoplanet biosignatures.*	*Virtual*
Oct 2020	**Invited, National Center for Atmospheric Research**, *Oxygen as a control over 2.4 billion years of atmospheric evolution.*	*Virtual*

Posters

Jun 2024	**Exoplanets V**, *Oxygen's control over hydrogen escape on Earth-like exoplanets.*	*Lieden, NL*
Jun 2024	**Exoplanets V**, *Is K2-18 b a mini-Neptune or a Hycean World?*	*Leiden, NL*
Jun 2023	**Exoclimes VI**, *Characterising stellar UV to improve the interpretation of observations: a 3D case study with TRAPPIST-1 e*, **poster PDF here**.	*Exeter, UK*
Sep 2022	**UK Exoplanet Meeting**, *Accurate UV stellar spectra measurements required to use O_3 as an indicator for O_2 abundance*, **virtual poster**.	*Edinburgh, UK*
May 2022	**Exoplanets IV**, *Variability due to climate in observations of oxygenated Earth-analogue exoplanets.*	*LV, NV, USA*
Jun-Jul 2021	**European Astronomical Society Annual Meeting**, *Oxygen's 2.4 billion year control on Earth's atmosphere with consequences for exoplanet bisoignatures.*	***Virtual***
Jun 2021	**The Coupling, Energetics, and Dynamics of Atmospheric Regions workshop**, *Atmospheric escape on oxygenated Earth-like exoplanet atmospheres.*	*Virtual*
Jul 2020	**Exoplanets III**, *Variable detectability of biosignatures on inhabited worlds.*	*Virtual*

Software experience

- I am an advanced user of Python for atmospheric data analysis, e.g., matplotlib, pandas, numpy, and xarray.
- I have used and modified the FORTRAN codes `Atmos` and `Photochem` which model planetary atmospheres in 1D.
- I have used and developed an open-source 3D climate model model (`CESM2`-`WACCM6`). I have read Fortran-90 code to understand how certain calculations in `WACCM6` are made. I modified the Fortran-90 code to set up different planetary conditions (e.g. altered upper boundary conditions, tidally locked the model, and implemented absorption in the Schumann–Runge bands for H_2O and CO_2).
- I have developed Python code in Jupyter Notebook to analyse vast amounts of climate data that can switch between different types of plots and datasets. I developed the Stellar Wind and Irradiance Module (`SWIM`), a flexible notebook for multi-model use that downloads **Mega-MUSCLES** stellar spectra and scales the exoplanet to any exoplanet chosen by the user.
- I used and developed a pipeline to convert `WACCM6` output to interact with the Planetary Spectrum Generator (`PSG`). I used new methods (where I swapped particular atmospheric components) to analyse the results for the `WACCM6` oxygenated scenarios.
- Coding experience in C++ during my master's degree. The final project was to design a chess game using C++.

Teaching

University of Cambridge *Cambridge, UK*

Supervisor Stars and Stellar Evolution *October 2023 - present*

- Supervised the third year (part II) Stars and Stellar Evolution lecture course delivered by Max Pettini.
- Supervised student groups between the sizes of 1-3 students.

University of Leeds *Leeds, UK*

Introductory python course *September 2022*

- Introduction to Python lesson during a Community Earth System Model (CESM) tutorial.
- I demonstrated data visualisation using Xarray, Matplotlib, and Cartopy in functions combined with IPyWidgets in a Jupyter notebook.

University of Leeds *Leeds, UK*

Lab demonstrating *October 2019 - May 2022*

- I taught experiments in the Phys 10001 undergraduate laboratory to 1st year students including: the determination of Planck's constant; measurement of Earth's magnetic field, spectrometer measurement of sodium lines; the viscosity of glycerine; and electrical circuits.
- I marked lab workbooks and formal reports on several of these experiments.

University of Leeds *Leeds, UK*

Informal MPhys student supervision *October 2021 - March 2022*

- I aided B. Butcher to produce and analyse transmission spectra of Jupiter-sized exoplanets.
- I helped I. Willis analyse WACCM data and produce figures using Python.

Organisation and citizenship

University of Leeds *Leeds, UK*

Internal seminars chair *January 2020 – October 2022*

- I arranged and chaired internal seminars for the University of Leeds Astrophysics group.
- I organised and led weekly informal science sessions where members of the group get together to discuss their current work.
- I led a journal club that ran every three weeks.

University of Leeds Priestley scholars *Leeds, UK*

Priestley Climate Scholar *January 2020 – December 2021*

- I attended multiple seminars on interdisciplinary topics relating to climate change, including transport, climate finance, climate modelling, and climate justice.
- I co-organised a seminar on climate finance, as well as a monthly journal club focussed on climate science topics.

University of Manchester Men's Hockey Club *Manchester, UK*

Treasurer *May 2017 - May 2018*

- I was elected out from a club of approximately 80 members.
- I managed ∼£20,000 in financial transactions between the club, club members, the Athletic Union, and several different organisations.

Public engagement and press

- Invited talk at Bradford Astronomical Society (2024, TBC).
- Public talk on *Jill Tarter and the Search for ExtraTerrestrial Intelligence* (March 2024).
- Public talk on *A Brief History of Women in Astronomy* for International Women's Day (March 2024).
- Invited talk at Sidney Sussex Wilson-Walker Natural Sciences Society (March 2024).
- Invited talk at Harrogate Astronomical Society (February 2024).
- Public talk at the Institute of Astronomy, University of Cambridge, *Exoplanet Atmospheres* (November 2023). **YouTube**.
- Invited talk at Wakefield and District Astronomical Society (July 2023).
- Invited talk at Bradford Astronomical Society (April 2023).
- **Everything Astronomy** virtual session for Xavier Space Solutions (February 2022).
- I have written a number of astronomy news articles for the astronomy magazine **Popular Astronomy**.

- TikTok Video summarizing my research for COP 26 and how it is important for understanding our planet (2021).
- **Live YouTube talk** for the University of Leeds Be Curious festival on planet habitability (2021).
- **Priestley Scholar Twitter spotlight**. I was retweeted by the Priestley Scholar Twitter account for a whole day as I tweeted about my research and scientific interests (2021).