

# Zachary D. Lawrence

CIRES/NOAA PSL Research Scientist

NOAA/PSL, 325 Broadway, Boulder, CO 80305-3328

📞 (505)-974-9062 | ✉️ zachary.lawrence@noaa.gov

🎓 <https://scholar.google.com/citations?user=uUvgRSQAAAAJ>

🆔 <https://orcid.org/0000-0003-0901-3839>

📎 Denote embedded web links

## Education

**PhD in Physics (Atmospheric Physics track)** *Aug. 2019*  
New Mexico Tech (NMT) *Socorro, NM*

**B.S. in Physics (Computer Science track; summa cum laude)** *May 2014*  
New Mexico Tech (NMT) *Socorro, NM*

- Minor in Mathematics

## Professional History

**Research Scientist I** *Oct. 2020 - Present*  
University of Colorado, Cooperative Institute for Research in  
Environmental Sciences (CIRES) & NOAA Physical Sciences Laboratory (PSL) *Boulder, CO*

- Stratospheric dynamics; stratosphere-troposphere coupling
- Subseasonal-to-seasonal (S2S) forecasting and predictability
- Unified Forecast System (UFS) and coupled climate models

**Post-doctoral Research Associate** *Sep. 2019 - Sep. 2020*  
University of Colorado, CIRES & NOAA PSL *Boulder, CO*

**Graduate Research Assistant** *Aug. 2014 - Aug. 2019*  
NMT Physics Dept., Middle & Upper Atmosphere Group *Socorro, NM*

- Stratospheric polar vortex dynamics
- Polar chemical processes and ozone loss

**Summer Research Intern** *May 2013 - Aug. 2013*  
Jet Propulsion Laboratory, Microwave Limb Sounder Science Team *Pasadena, CA*

- Stratospheric meteorology and chemistry monitoring
- Reanalysis intercomparisons

**Research Technician** *Jan. 2011 - May 2012*  
Langmuir Laboratory for Atmospheric Research *Socorro, NM*

- Volcanic lightning measurements
- Lightning Mapping Array software development

# Academic and Professional Activities

## SNAP S2S Biases Activity

June 2020 - Present


Stratospheric Network for the Assessment of Predictability (SNAP) Community Lead

- Lead organizer and author of community effort seeking to quantify stratospheric biases in S2S prediction systems, and assess their impact on forecasts

## StratObserve

Nov. 2018 - Present

Developer & Curator

- Maintainer of  **StratObserve**, a website for near real-time forecasts of stratospheric conditions


## Field Campaign Participation

- **Atlantic Tradewind Ocean-Atmosphere Mesoscale Interaction Campaign**



(Jan 2020 - Feb 2020)

- Provided near real-time archival and visualization of observations from multiple measurement platforms, including satellite, radiosondes, dropsondes, and unmanned aerial vehicles.

## Software Development

-  **pyzome** (Sep. 2021 - present)
  - A python package for computing diagnostics relevant to the zonal mean circulation and middle atmosphere.
  - Currently in a late-alpha stage, with plans to make it a fully-fleshed pip/conda installable package with web documentation.

## Committees

-  **SPARC SNAP** (Nov. 2020 - present)
-  **AMS Middle Atmosphere Committee** (Jan. 2022 - present)

## Journal Reviewer

- Journal of Geophysical Research: Atmospheres
- Geophysical Research Letters
- Journal of Atmospheric Science
- Journal of Climate
- Atmospheric Chemistry and Physics
- Journal of the Meteorological Society of Japan

## Proposal Reviewer

- NOFO - NWS OSTI: Unified Forecast System (Mar. 2022)

## Scientific Contributor

- WMO/UNEP Scientific Assessment of Ozone Depletion: 2022
- SPARC Reanalysis Intercomparison Project – Chapters 7 and 10
- WMO Twenty Questions and Answers About the Ozone Layer: 2014

## Conference Organizing

- Session chair for “*Anomalous events in the polar stratosphere in recent years*” session at AMS 21st Conference on the Middle Atmosphere (Jan. 2022)
- Organizer and tech assistant for 2012 SPARC Data Assimilation Workshop (June 2012)

## Professional Memberships

- Since 2013 – **American Geophysical Union**
- Since 2013 – **American Meteorological Society**
- Since 2013 – **Sigma Pi Sigma** (Physics Honor Society)
- Since 2011 – **American Physical Society**

## Mentorship and Advising

- NMT Physics Undergraduate Students (June 2016 - May 2020)
  - Nick Sheerin
  - Sean Palmer
  - Noah d’Antonio

## Funded Grants/Proposals

### Process-oriented diagnostics of dynamical coupling between the troposphere and stratosphere in Earth System Models

PIs: Amy H. Butler (NOAA CSL) and Zachary D. Lawrence (CIRES)

Co-Is: Judith Perlwitz (NOAA PSL)

Funder: NOAA Climate Program Office MAPP

Budget: \$517,700, FY2022-2025

## Outreach Activities

### Letters to a Pre-Scientist (LPS)

STEM Penpal

*Sep. 2020 - Present*

### New Mexico Tech Student Research Spotlights

Speaker


*May 2021 and 2022*

### New Mexico Science Olympiad






Meteorology subject organizer and administrator

*2016 and 2017*

## Honors & Awards

<b>Appreciation Award for exceptionally engaging letters</b> Awarded by Letters to a Pre-Scientist	<i>June 2022</i>
<b>EOS Research spotlight on  2020 Polar Vortex</b> Chosen by editors from Journal of Geophysical Research: Atmospheres	<i>Nov 2020</i>
<b>Albert Petschek Award for excellence in theoretical physics</b> Awarded by NMT Physics Department	<i>May 2019</i>
<b>Langmuir Award for outstanding published research paper</b> Awarded by New Mexico Tech	<i>May 2018</i>
<b>Outstanding graduate student presentation award</b> Awarded by American Meteorological Society for 19th Conference on Middle Atmosphere	<i>June 2017</i>
<b>NASA Earth and Space Science Fellowship</b> Awarded by National Aeronautics and Space Administration (NASA)	<i>2016 - 2019</i>
<b>NMSGC Graduate Scholarship</b> Awarded by New Mexico Space Grant Consortium (NMSGC)	<i>Jan. 2016</i>
<b>Abraham and Ester Brook Award for excellence in undergraduate physics</b> Awarded by NMT Physics Department	<i>May 2013</i>

## Media & News Features (titles are links)

 <b>"What exactly is the polar vortex?"</b> The Conversation (USA)	<i>Feb. 2021</i>
 <b>"Why we removed an article on the 'drunk' polar vortex"</b> The Conversation (CA)	<i>Mar. 2019</i>
 <b>"A Closer Look at the Polar Vortex's Dangerously Cold Winds"</b> The New York Times	<i>Jan. 2019</i>
<b>2019 Stratospheric polar vortex split animation</b> Multiple sources	<i>Jan. 2019</i>
<ul style="list-style-type: none"><li> <b>"Brace for the Polar Vortex; It May Be Visiting More Often"</b> – The New York Times</li><li> <b>"The polar vortex has fractured, and the eastern U.S. faces a punishing stretch of winter weather"</b> – The Washington Post</li></ul>	

## Publications

- (24) **Lawrence, Z. D.**, Perlwitz, J., Albers, J., Davis, N. A. (in prep) Influence of Stratospheric Circulation Biases on Downward Wave Reflection Events in Subseasonal-to-Seasonal Forecast Models.
- (23) **Lawrence, Z. D.**, Elsbury, D., Butler, A. H., Perlwitz, J., Albers, J. R., Ciasto, L., Ray, E. (under revision) Evaluation of processes related to stratosphere-troposphere coupling in GEFSv12 subseasonal hindcasts. *Submitted to Monthly Weather Review*
- (22) Manney, G. L., Millán, L. F., Santee, M. L., Wargan, K., Lambert, A., Neu, J. L., Werner, F., **Lawrence, Z. D.**, Schwartz, M. J., Livesey, N. J., & Read, W. G. (2022). Signatures of Anomalous Transport in the 2019/2020 Arctic Stratospheric Polar Vortex. *Journal of Geophysical Research: Atmospheres*, 127(20), e2022JD037407. <https://doi.org/10.1029/2022JD037407>
- (21) Karpechko, A. Yu., Afargan-Gerstman, H., Butler, A. H., Domeisen, D. I. V., Kretschmer, M., **Lawrence, Z. D.**, Manzini, E., Sigmond, M., Simpson, I. R., & Wu, Z. (2022). Northern Hemisphere Stratosphere-Troposphere Circulation Change in CMIP6 Models: 1. Inter-Model Spread and Scenario Sensitivity. *Journal of Geophysical Research: Atmospheres*, 127(18), e2022JD036992. <https://doi.org/10.1029/2022JD036992>
- (20) **Lawrence, Z. D.**, Abalos, M., Ayarzagüena, B., Barriopedro, D., Butler, A. H., Calvo, N., de la Cámara, A., Charlton-Perez, A., Domeisen, D. I. V., Dunn-Sigouin, E., García-Serrano, J., Garfinkel, C. I., Hindley, N. P., Jia, L., Jucker, M., Karpechko, A. Y., Kim, H., Lang, A. L., Lee, S. H., ... Wu, R. W.-Y. (2022). Quantifying stratospheric biases and identifying their potential sources in subseasonal forecast systems. *Weather and Climate Dynamics*, 3(3), 977–1001. <https://doi.org/10.5194/wcd-3-977-2022>
- (19) Manney, G. L., Butler, A. H., **Lawrence, Z. D.**, Wargan, K., & Santee, M. L. (2022). What's in a Name? On the Use and Significance of the Term "Polar Vortex." *Geophysical Research Letters*, 49(10), e2021GL097617. <https://doi.org/10.1029/2021GL097617>
- (18) Manney, G. L., Hegglin, M. I., & **Lawrence, Z. D.** (2021). Seasonal and Regional Signatures of ENSO in Upper Tropospheric Jet Characteristics from Reanalyses. *Journal of Climate*, 34(22), 9181–9200. <https://doi.org/10.1175/JCLI-D-20-0947.1>
- (17) Manney, G. L., Santee, M. L., **Lawrence, Z. D.**, Wargan, K., & Schwartz, M. J. (2021). A Moments View of Climatology and Variability of the Asian Summer Monsoon Anticyclone. *Journal of Climate*, 34(19), 7821–7841. <https://doi.org/10.1175/JCLI-D-20-0729.1>
- (16) Lim, E.-P., Hendon, H. H., Butler, A. H., Thompson, D. W. J., **Lawrence, Z. D.**, Scaife, A. A., Shepherd, T. G., Polichtchouk, I., Nakamura, H., Kobayashi, C., Comer, R., Coy, L., Dowdy, A., Garreaud, R. D., Newman, P. A., & Wang, G. (2021). The 2019 Southern Hemisphere Stratospheric

Polar Vortex Weakening and Its Impacts. *Bulletin of the American Meteorological Society*, 102(6), E1150–E1171. <https://doi.org/10.1175/BAMS-D-20-0112.1>

(15) Millán, L. F., Manney, G. L., & **Lawrence, Z. D.** (2021). Reanalysis intercomparison of potential vorticity and potential-vorticity-based diagnostics. *Atmospheric Chemistry and Physics*, 21(7), 5355–5376. <https://doi.org/10.5194/acp-21-5355-2021>

(14) **Lawrence, Z. D.**, Perlwitz, J., Butler, A. H., Manney, G. L., Newman, P. A., Lee, S. H., & Nash, E. R. (2020). The Remarkably Strong Arctic Stratospheric Polar Vortex of Winter 2020: Links to Record-Breaking Arctic Oscillation and Ozone Loss. *Journal of Geophysical Research: Atmospheres*, 125(22), e2020JD033271. <https://doi.org/10.1029/2020JD033271>

(13) Lee, S. H., **Lawrence, Z. D.**, Butler, A. H., & Karpechko, A. Y. (2020). Seasonal Forecasts of the Exceptional Northern Hemisphere Winter of 2020. *Geophysical Research Letters*, 47(21), e2020GL090328. <https://doi.org/10.1029/2020GL090328>

(12) Manney, G. L., Livesey, N. J., Santee, M. L., Froidevaux, L., Lambert, A., **Lawrence, Z. D.**, Millán, L. F., Neu, J. L., Read, W. G., Schwartz, M. J., & Fuller, R. A. (2020). Record-Low Arctic Stratospheric Ozone in 2020: MLS Observations of Chemical Processes and Comparisons With Previous Extreme Winters. *Geophysical Research Letters*, 47(16), e2020GL089063. <https://doi.org/10.1029/2020GL089063>

(11) Butler, A. H., **Lawrence, Z. D.**, Lee, S. H., Lillo, S. P., & Long, C. S. (2020). Differences between the 2018 and 2019 stratospheric polar vortex split events. *Quarterly Journal of the Royal Meteorological Society*, 146(732), 3503–3521. <https://doi.org/10.1002/qj.3858>

(10) **Lawrence, Z. D.**, & Manney, G. L. (2020). Does the Arctic Stratospheric Polar Vortex Exhibit Signs of Preconditioning Prior to Sudden Stratospheric Warmings? *Journal of the Atmospheric Sciences*, 77(2), 611–632. <https://doi.org/10.1175/JAS-D-19-0168.1>

(9) **Lawrence, Z. D.**, Manney, G. L., & Wargan, K. (2018). Reanalysis intercomparisons of stratospheric polar processing diagnostics. *Atmospheric Chemistry and Physics*, 18(18), 13547–13579. <https://doi.org/10.5194/acp-18-13547-2018>

(8) **Lawrence, Z. D.**, & Manney, G. L. (2018). Characterizing Stratospheric Polar Vortex Variability With Computer Vision Techniques. *Journal of Geophysical Research: Atmospheres*, 123(3), 1510–1535. <https://doi.org/10.1002/2017JD027556>

(7) Albers, J. R., Perlwitz, J., Butler, A. H., Birner, T., Kiladis, G. N., **Lawrence, Z. D.**, Manney, G. L., Langford, A. O., & Dias, J. (2018). Mechanisms Governing Interannual Variability of Stratosphere-to-Troposphere Ozone Transport. *Journal of Geophysical Research: Atmospheres*, 123(1), 234–260. <https://doi.org/10.1002/2017JD026890>

(6) Manney, G. L., Hegglin, M. I., **Lawrence, Z. D.**, Wargan, K., Millán, L. F., Schwartz, M. J., Santee, M. L., Lambert, A., Pawson, S., Knosp, B. W., Fuller, R. A., & Daffer, W. H. (2017). Reanalysis

comparisons of upper tropospheric–lower stratospheric jets and multiple tropopauses.

Atmospheric Chemistry and Physics, 17(18), 11541–11566.

<https://doi.org/10.5194/acp-17-11541-2017>

(5) Manney, G. L., & **Lawrence, Z. D.** (2016). The major stratospheric final warming in 2016: Dispersal of vortex air and termination of Arctic chemical ozone loss. Atmospheric Chemistry and Physics, 16(23), 15371–15396. <https://doi.org/10.5194/acp-16-15371-2016>

(4) Minschwaner, K., Manney, G. L., Petropavlovskikh, I., Torres, L. A., **Lawrence, Z. D.**, Sutherland, B., Thompson, A. M., Johnson, B. J., Butterfield, Z., Dubey, M. K., Froidevaux, L., Lambert, A., Read, W. G., & Schwartz, M. J. (2015). Signature of a tropical Pacific cyclone in the composition of the upper troposphere over Socorro, NM. Geophysical Research Letters, 42(21), 9530–9537.

<https://doi.org/10.1002/2015GL065824>

(3) Manney, G. L., **Lawrence, Z. D.**, Santee, M. L., Read, W. G., Livesey, N. J., Lambert, A., Froidevaux, L., Pumphrey, H. C., & Schwartz, M. J. (2015). A minor sudden stratospheric warming with a major impact: Transport and polar processing in the 2014/2015 Arctic winter.

Geophysical Research Letters, 42(18), 7808–7816. <https://doi.org/10.1002/2015GL065864>

(2) Manney, G. L., **Lawrence, Z. D.**, Santee, M. L., Livesey, N. J., Lambert, A., & Pitts, M. C. (2015).

Polar processing in a split vortex: Arctic ozone loss in early winter 2012/2013. Atmospheric Chemistry and Physics, 15(10), 5381–5403. <https://doi.org/10.5194/acp-15-5381-2015>

(1) **Lawrence, Z. D.**, Manney, G. L., Minschwaner, K., Santee, M. L., & Lambert, A. (2015).

Comparisons of polar processing diagnostics from 34 years of the ERA-Interim and MERRA reanalyses. Atmospheric Chemistry and Physics, 15(7), 3873–3892.

<https://doi.org/10.5194/acp-15-3873-2015>

## **Presentations** (past 3 years only)

### **2022**

**Stratosphere & Stratosphere-Troposphere Coupling Biases in Subseasonal-to-Seasonal Forecast Models: An International SNAP Community Effort**

7th SPARC General Assembly (invited talk)

**Quantifying stratospheric biases and the role of stratosphere-troposphere coupling in S2S models: An update on recent SPARC SNAP initiatives**

NCAR Advanced Study Program Summer Workshop on S2S (invited talk)

**Evaluation of the stratosphere and stratosphere-troposphere coupling in recent UFS prototypes**

NOAA EMC Gravity Wave Physics Developer Meeting (invited talk)

**Process-oriented diagnostics of dynamical coupling between the troposphere and stratosphere in Earth System Models**

Model Diagnostics Task Force Meeting (talk)

**Stratosphere & Stratosphere-Troposphere Coupling Biases in Subseasonal-to-Seasonal Forecast Models: An International SNAP Community Effort**  
2022 American Meteorological Society Annual Meeting (invited talk)

## **2021**

**Evaluation of the stratosphere and stratosphere-troposphere coupling in UFSp5 and p6**  
NOAA EMC Coupled Global Modeling Seminar (invited talk)

**A diagnostic toolbox for the verification and validation of subseasonal stratosphere-troposphere coupling processes in NOAA's Unified Forecast System**  
UFS R20 Annual Workshop: Breakout Session on MRW and S2S

**A Brief Overview of Pangeo, Python, & Big Data in the Cloud (including CMIP6)**  
NOAA CSL Chemistry & Climate Processes Group Meeting

**The Remarkably Strong Arctic Stratospheric Polar Vortex of Winter 2020: Links to Record-Breaking Arctic Oscillation and Ozone Loss**  
NOAA PSL Flash Seminar

**Stratosphere-troposphere coupling: An overview of concepts and links to recent climate extremes**  
NOAA Climate Prediction Center (CPC) Seminar (invited talk)

**A Toolbox for Verification & Validation of Stratosphere-Troposphere Coupling Processes in Current and Future NOAA S2S Forecast Systems**  
NWS OSTI Weeks 3-4 Seminar (invited talk)

## **2020**

**The Remarkably Strong Arctic Stratospheric Polar Vortex of Winter 2020: Links to Record-Breaking Arctic Oscillation and Ozone Loss**  
American Geophysical Union Fall Meeting 2020 (lightning talk & poster)

**ATOMIC Weather Briefings**  
PSL Flash Seminar (invited talk)

**ATOMIC Weather Briefings**  
2nd ATOMIC Science Telecon (invited talk)

**Using time series motifs to examine preconditioning of the stratospheric polar vortex**  
100th American Meteorological Society Annual Meeting (poster)

**An Equivalent Latitude Formulation of the Stratospheric Northern Annular Mode**  
100th American Meteorological Society Annual Meeting (poster)