

## Sen Zhao, PhD

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### RESEARCH INTERESTS

Climate variability, dynamics, and predictability; Climate impacts and change; multi-scale interactions of the Earth system; El Niño-Southern Oscillation; Climate modeling; Seasonal forecast; Wave dynamics and atmospheric teleconnections; Paleoclimate

### EDUCATION

**Ph.D. Meteorology** 2011– 2016

Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China

Dissertation: “*Theory of Cross-Equatorial Propagation of Planetary Wave in Horizontally Non-Uniform Basic Flow and Its Applications in Atmospheric Teleconnections*”.

**B.S. Atmospheric Sciences** 2007– 2011

College of Atmospheric Sciences, and School of Mathematics and Statistics, Lanzhou University, China

Thesis: “*Evaluation of WRF microphysics and cumulus schemes in simulating Hurricane Katrina*”

### PROFESSIONAL APPOINTMENTS

**SOEST Assistant Researcher** 2021.11 – Present

School of Ocean and Earth Science and Technology (SOEST), University of Hawai'i at Mānoa, USA

Project: Tropical climate dynamics & predictability and sea level science

**Postdoctoral Fellow** 2016.10 – 2021.10

Department of Atmospheric Sciences, University of Hawai'i at Mānoa, USA. Mentor: Fei-Fei Jin

Project: Dynamic diagnosis and modeling of ENSO variability and inter-basin interactions

**Research Assistant** 2012.09 – 2016.09

LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences, China. Advisor: Jianping Li

Project: Interhemispheric Rossby wave propagation theory and atmospheric teleconnections

### GRANTS AND SCHOLARSHIPS

- **NSF grant** (2024-2027), *Dynamics and predictability of coastal El Nino events, and implications for ENSO diversity*, C. Karamperidou (lead PI) and **S. Zhao (co-PI)**, budget \$644,460.
- **DOE grant** (pending), *Quantifying and Understanding Ocean Biogeochemistry-ENSO/TIW Interactions & Feedbacks in Earth System Models*, F.-F. Jin (lead PI), M. Stuecker, F. M. Hoffman, A. Wittenberg, **S. Zhao (Co-I)**.
- **NSF grant** (pending), *Collaborative Research: South America continent, a land bridge for inter-hemispheric teleconnections*, R. Fu (lead PI), F.-F. Jin, **S. Zhao (Co-I)**, and S.Y. Zhao.
- **NOAA MAPP grant** (2023–2026), *Developing Dynamically Constrained Projections of ENSO Activity and Associated Coastal Hazards – An Application to the Hawaiian and US-Affiliated Pacific Islands*. F.-F. Jin (lead PI), M. Stuecker, N. Li, A. Wittenberg, **S. Zhao (co-I)**, J. Boucharel., Z. Yang
- **National Scholarship** (2013), Ministry of Education of China, No. 50257
- **China National Encouragement Scholarship** (2010)
- **First Class Scholarship of Lanzhou University** (2009)
- **China National Encouragement Scholarship** (2008)

## PUBLICATIONS

ORCID: [0000-0002-5597-1109](https://orcid.org/0000-0002-5597-1109) [Google Scholar](https://scholar.google.com/citations?hl=en&user=zhaozhao) (citations ~1700, H-index 20 by June 1<sup>st</sup> 2024)

### Peer-reviewed journal articles

47. Gunnarson J. L., M. F. Stuecker, and **S. Zhao** (2024). [Drivers of Future Extratropical Sea Surface Temperature Variability Changes in the North Pacific](#). *npj Climate and Atmospheric Science*. in press.
46. **Zhao, S.**, F.-F. Jin, M. F. Stuecker, P. R. Thompson, J.-S. Kug, M. J. McPhaden, M.A. Cane, A. T. Wittenberg, and W. Cai (2024). [Explainable El Niño Predictability from Climate Mode Interactions](#). *Nature*, 630(8018), 891-898.
45. Tang, X., J. Li, Y. Zhang, Y. Li, and **S. Zhao** (2023). [Synergistic Effect of El Niño and Negative Phase of North Atlantic Oscillation on Winter Precipitation in the Southeastern United States](#). *J. Climate*, 36(6), 1767–1791.
44. Shi, F., H. Goosse, J. Li, Q. Yin, F. Ljungqvist, T. Lian, C. Sun, L. Wang, Z. Wu, J. Li, **S. Zhao**, C. Xu, W. Liu, T. Liu, T. Nakatsuka, and Z. Guo (2022): [Interdecadal to multidecadal variability of East Asian summer monsoon over the past half millennium](#). *J. Geophys. Res.: Atmos.*, 127 (30), e2022JD037260.
43. Shi, F., C. Sun, A. Guion, Q. Yin, **S. Zhao**, T. Liu, and Z. Guo (2022): [Roman Warm Period and Late Antique Little Ice Age in an Earth System Model Large Ensemble](#). *J. Geophys. Res.: Atmos.*, 127(16), e2021JD035832.
42. **Zhao, S.**, and C. Karamperidou (2022): [Competing Effects of Eastern and Central-Western Pacific Winds in the Evolution of the 2017 Extreme Coastal El Niño](#). *Geophys. Res. Lett.*, 49(15), e2022GL098859.
41. Li, X., Z.-H. Hu, **S. Zhao**, R. Ding, and B. Zhang (2022): [On the asymmetry of the tropical Pacific thermocline fluctuation associated with ENSO recharge and discharge](#). *Geophys. Res. Lett.*, 49(11), e2022GL099242.
40. Tang X., J. Li, H. Zhang, and **S. Zhao** (2022): [Representation of Rossby wave propagation and its effect on the teleconnection between the Indian summer monsoon and extratropical rainfall in the Met Office Unified Model](#). *Climate Dyn.*, 58 (3), 907-924
39. **Zhao, S.**, F.-F. Jin, and M. F. Stuecker (2021): [Understanding Lead Times of Warm-Water-Volumes to ENSO Sea Surface Temperature Anomalies](#). *Geophys. Res. Lett.*, 48(19), e2021GL094366.
38. Chen H.-C., F.-F. Jin, **S. Zhao**, A. T. Wittenberg, and S. Xie (2021): [ENSO Dynamics in the E3SM-1-0, CESM2, and GFDL-CM4 Climate Models](#). *J. Climate*, 34 (23), 9365-9384.
37. **Zhao, S.**, F.-F. Jin, X. Long, and M. Cane (2021): [On the Breakdown of ENSO's Relationship with Thermocline Depth in the Central-Equatorial Pacific](#). *Geophys. Res. Lett.*, 48(9), e2020GL092335.
36. Zhou, X., Q. Chen, Z. Wang, M. Xu, **S. Zhao**, Z. Cheng, and F. Feng (2020): [Longer duration of the weak stratospheric vortex during extreme El Niño events linked to spring Eurasian coldness](#). *J. Geophys. Res.: Atmos.*, 125(16), e2019JD032331.
35. Liu, T., J. Li, Q. Wang, **S. Zhao** (2020): [Influence of the Autumn SST in the Southern Pacific Ocean on Winter Precipitation in the North American Monsoon Region](#). *Atmosphere*, 11(8), 844.
34. Tseng, Y., R. Ding, **S. Zhao**, Y. Kuo, and Y. Liang (2020): [Could the North Pacific Oscillation Be Modified by the Initiation of East Asian Winter Monsoon?](#) *J. Climate*, 33, 2389–2406.
33. Xue, A., F.-F. Jin, W. Zhang, J. Boucharel, **S. Zhao**, and X. Yuan (2020): [Delineating the Seasonally Modulated Nonlinear Feedback onto ENSO from Tropical Instability Waves](#). *Geophys. Res. Lett.*, 47(7), e2019GL085863.
32. **Zhao, S.**, M. F. Stuecker, F.-F. Jin, J. Feng, H. Ren, W. Zhang, and J. Li (2020): [Improved Predictability of the Indian Ocean Dipole using a Stochastic-Dynamical Model compared to the North American Multi-model Ensemble Forecast](#). *Wea. Forecasting*, 35(2), 379–399.
31. Zhang Y., J. Li, **S. Zhao**, F. Zheng, J. Feng, Y. Li, Y. Xu (2020): [Indian Ocean tripole mode and its associated atmospheric and oceanic processes](#). *Climate Dyn.*, 55(5), 1367-1383.
30. Feng, J., J. Li, F.-F. Jin, Z. Liu, and **S. Zhao** (2019): [Effect of El Niño on the Response Ratio of Hadley Circulation to Different SST Meridional Structures](#). *Climate Dyn.*, 53, 3877–3891.

29. **Zhao, S.**, F.-F. Jin, and M. F. Stuecker (2019): [Improved Predictability of the Indian Ocean Dipole Using Seasonally Modulated ENSO Forcing Forecasts](#). *Geophys. Res. Lett.*, 46(16), 9980–9990.
28. Wang, Q., J. Li, Y. Li, J. Xue, **S. Zhao**, Y. Xu, Y. Wang, Y. Zhang, D. Dong, and J. Zhang (2019): [Modulation of tropical cyclone tracks over the western North Pacific by intra-seasonal Indo-western Pacific convection oscillation during the boreal extended summer](#). *Climate Dyn.*, 52(1-2), 913–927.
27. **Zhao, S.**, J. Li, Y. Li, F.-F. Jin, and J. Zheng (2019): [Interhemispheric Influence of Indo-Pacific Convection Oscillation on Southern Hemisphere Rainfall through Southward Propagation of Rossby Waves](#). *Climate Dyn.*, 52(5), 3203–3221.
26. Shi, F., H. Goosse, F. Klein, **S. Zhao**, T. Liu, and Z. Guo (2019): [Monopole mode of precipitation in East Asia modulated by the South China Sea over the last four centuries](#). *Geophys. Res. Lett.*, 46(24), 14713–14722.
25. Li, Y., J. Feng, J. Li, and **S. Zhao** (2018): [The Circle Diagram in the Group Velocity Domain for Rossby Wave under the Horizontally Non-Uniform Flow](#). *SOLA*, 14, 121–125.
24. Li, Y., J. Li, F. Kucharski, J. Feng, **S. Zhao**, and J. Zheng (2018): [Two Leading Modes of the Interannual Variability in South American Surface Air Temperature during Austral Winter](#). *Climate Dyn.*, 51(5-6), 2141–2156.
23. Liu, T., J. Li, Y. Li, **S. Zhao**, F. Zheng, J. Zheng, and Z. Yao (2018): [Influence of the May Southern Annular Mode on the South China Sea Summer Monsoon](#). *Climate Dyn.*, 51(11-12), 4095–4107.
22. Feng, J., J. Li, F.-F. Jin, **S. Zhao**, and J. Zhu (2018): [Relationship between the Hadley circulation and different tropical meridional SST structures during boreal summer](#). *J. Climate*, 31(16), 6575–6590.
21. Stuecker, M. F., C. M. Bitz, K. C. Armour, C. Proistosescu, S. M. Kang, S.-P. Xie, D. Kim, S. McGregor, W. Zhang, **S. Zhao**, W. Cai, Y. Dong, and F.-F. Jin (2018): [Polar Amplification Dominated by Local Forcing and Feedbacks](#). *Nature Climate Change*, 8(12), 1076–1081. ([News & Views](#))
20. Xue, J., J. Li, C. Sun, **S. Zhao**, J. Mao, D. Dong, Y. Li, and J. Feng (2018): [Decadal-Scale Teleconnection between South Atlantic SST and Southeast Australia Surface Air Temperature in Austral Summer](#). *Climate Dyn.*, 50(7-8), 2687–2703.
19. Zhou, X., J. Li, F. Xie, R. Ding, Y. Li, **S. Zhao**, J. Zhang, and Y. Li (2018): [The Effects of the Indo-Pacific Warm Pool on the Stratosphere](#). *Climate Dyn.*, 51(11-12), 4043–4064.
18. Huyan, L., J. Li, **S. Zhao**, C. Sun, D. Dong, T. Liu, and Y. Zhao (2017): [The Impact of Layer Perturbation Potential Energy on the East Asian Summer Monsoon](#). *J. Climate*, 30(17), 7087–7103.
17. Tian, W., Y. Li, F. Xie, J. Zhang, M. P. Chipperfield, W. Feng, Y. Hu, **S. Zhao**, X. Zhou, Y. Yang, and X. Ma (2017): [The relationship between lower-stratospheric ozone at southern high latitudes and sea surface temperature in the East Asian marginal seas in austral spring](#). *Atmos. Chem. Phys.*, 17(11), 6705–6722.
16. Xie, F., J. Li, J. Zhang, W. Tian, Y. Hu, **S. Zhao**, C. Sun, R. Ding, J. Feng, and Y. Yang (2017): [Variations in North Pacific Sea Surface Temperature Caused by Arctic Stratospheric Ozone Anomalies](#). *Environ. Res. Lett.*, 12(11), 114023.
15. Shi, F., **S. Zhao**, Z. Guo, H. Goosse, and Q. Yin (2017): [Multi-proxy reconstructions of May–September precipitation field in China over the past 500 years](#). *Clim. Past*, 13(12), 1919–1938.
14. Stuecker, M. F., A. Timmermann, F.-F. Jin, Y. Chikamoto, W. Zhang, A. T. Wittenberg, E. Widiasih, and **S. Zhao** (2017): [Revisiting ENSO/Indian Ocean Dipole Phase Relationships](#). *Geophys. Res. Lett.*, 44(5), 2481–2492. (**AGU Editor’s Highlight**)
13. Feng, J., J. Li, F.-F. Jin, **S. Zhao**, and F. Xie (2017): [The responses of the Hadley circulation to different meridional SST structures in the seasonal cycle](#). *J. Geophys. Res.: Atmos.*, 122(15), 7785–7799.
12. Qin, J., R. Ding, Z. Wu, J. Li, and **S. Zhao** (2017): [Relationships between the extratropical ENSO precursor and leading modes of atmospheric variability in the Southern Hemisphere](#). *Adv. Atmos. Sci.*, 34(3), 360–370.
11. Ding, R., J. Li, Y.-h. Tseng, K.-J. Ha, **S. Zhao**, and J.-Y. Lee (2016): [Interdecadal change in the lagged relationship between the Pacific–South American pattern and ENSO](#). *Climate Dyn.*, 47(9-10), 2867–2884.

10. Yang, F., N. Wang, F. Shi, F. C. Ljungqvist, **S. Zhao**, and T. Liu (2016): [The spatial distribution of precipitation over the West Qinling region, China, AD 1470–2000](#). *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 443, 278–285.
9. Zheng, F., J. Li, Y. Li, **S. Zhao**, and D. Deng (2016): [Influence of the Summer NAO on the Spring-NAO-Based Predictability of the East Asian Summer Monsoon](#). *J. Appl. Meteor. Climatol.*, 55(7), 1459–1476.
8. Zheng, J., Q. Wu, Y. Guo, and **S. Zhao** (2016): [The Impact of Summertime North Indian Ocean SST on Tropical Cyclone Genesis over the Western North Pacific](#). *SOLA*, 12, 242–246.
7. Kazmi, D. H., J. Li, C. Ruan, **S. Zhao**, and Y. Li (2016): [A Statistical Downscaling Model for Summer Rainfall over Pakistan](#). *Climate Dyn.*, 47(7–8), 2653–2666.
6. **Zhao, S.**, J. Li, and C. Sun (2016): [Decadal Variability in the Occurrence of Wintertime Haze in Central Eastern China Tied to the Pacific Decadal Oscillation](#). *Sci. Rep.*, 6, 27424. (**Top 100 read Scientific Reports articles in 2016**)
5. Shi, F., Q. Ge, B. Yang, J. Li, F. Yang, F. C. Ljungqvist, O. Solomina, T. Nakatsuka, N. Wang, **S. Zhao**, C. Xu, K. Fang, M. Sano, G. Chu, Z. Fan, N. P. Gaire, and M. U. Zafar (2015): [A Multi-Proxy Reconstruction of Spatial and Temporal Variations in Asian Summer Temperatures over the Last Millennium](#). *Climatic Change*, 131(4), 663–676.
4. Zhu, G., W. Lin, **S. Zhao**, and Y. Cao (2015): [Spatial and temporal variation characteristics of ocean waves in the South China Sea during the boreal winter](#). *Acta Oceanol. Sin.*, 34(1), 23–28.
3. Sun, C., J. Li, and **S. Zhao** (2015): [Remote Influence of Atlantic Multidecadal Variability on Siberian Warm Season Precipitation](#). *Sci. Rep.*, 5, 16853.
2. Li, Y., J. Li, F.-F. Jin, and **S. Zhao** (2015): [Interhemispheric Propagation of Stationary Rossby Waves in a Horizontally Nonuniform Background Flow](#). *J. Atmos. Sci.*, 72(8), 3233–3256.
1. **Zhao, S.**, J. Li, and Y. Li (2015): [Dynamics of an Interhemispheric Teleconnection across the Critical Latitude through a Southerly Duct during Boreal Winter](#). *J. Climate*, 28(19), 7437–7456.

### ***Peer-reviewed book chapter***

1. Jin F.-F., H.-C. Chen, **S. Zhao**, M. Hayashi, C. Karamperidou, M. F. Stuecker, R. Xie, and L. Geng (2020): [Simple ENSO Models](#). In: Santoso A, Cai W, McPhaden MJ (eds) *El Niño Southern Oscillation in a Changing Climate*, 119–151.

### ***Submitted***

- Zhao, S.**, N. Li, F.-F. Jin, K. F. Cheung, Z. Yang (2024). Strong El Niño Influence on Island-scale Wave Climate in Hawaii. *Communications Earth & Environment*, in revision.

### ***In preparation***

**Zhao, S.**, P. R. Thompson, F.-F. Jin. Influence of ENSO on the compounding effect of sea level and ocean waves.

**Zhao, S.**, F.-F. Jin: A Robust Assessment of the Bjerknes-Wyrtki-Jin Indices for ENSO Linear Stability and Periodicity.

Vialard, J., et al.: The ENSO recharge oscillator conceptual model: Past achievements, future prospects. In preparation for *Reviews of Geophysics*.

Kim, S.-K., et al.: The Community Recharge Oscillator Model. In preparation for *Geoscientific Model Development*.

## PRESENTATIONS

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### *Talks*

- Competing Effects of Eastern and Central-Western Pacific Winds in the Evolution of the 2017 Extreme Coastal El Niño and Implication for El Niño Diversity, *IRCC-KIST-IPRC Joint Workshop on Climate Change and Prediction*, East West Center, Honolulu, 01/2023
- Advances in Understanding of ENSO's Relationship with Equatorial Pacific Thermocline, *Climate Dynamics Group Seminar, visual*, 05/2022
- Understanding Lead Times of Warm-Water-Volumes to ENSO Sea Surface Temperature Anomalies, *SIO-UH Oahu Workshop on Ocean-Atmosphere Interactions and Climate Predictability*, Honolulu, 03/2022
- Dynamics and Implications for ENSO's Subsurface Ocean Temperature Vertical Dipole Anomalies in the Central Equatorial Pacific, *Ocean Science Meeting 2022*, Honolulu, 02/2022
- Advancing Understanding of ENSO's Relationship with Equatorial Pacific Thermocline, *Atmospheric Sciences Seminar, University of Hawai'i at Mānoa*, Honolulu, 09/2021
- Improved Predictability of the Indian Ocean Dipole Using Seasonally Modulated ENSO Forcing, *AOGS 15th Annual Meeting*, Honolulu, June 03–08, 2018
- Decadal Variability in the Occurrence of Wintertime Haze in Central Eastern China Tied to the Pacific Decadal Oscillation, *AOGS 15th Annual Meeting*, Honolulu, June 03–08, 2018

### *Posters*

- A robust assessment of the Bjerknes-Wyrtki-Jin indices for ENSO growth rate and periodicity, *AGU Fall Meeting 2019*, San Francisco, USA, December 9–13, 2019
- Interhemispheric influence of the Indo-Pacific convection oscillation on Southern Hemisphere rainfall, *AOGS 13th Annual Meeting*, Beijing, China, July 31–August 5, 2016
- Interhemispheric influence of the Indo-Pacific convection oscillation on Southern Hemisphere rainfall, *The 13th General Circulation Model Simulations of the East Asian Climate (EAC) workshop*, Beijing, China, March 24–25, 2016
- The Hemispheric Propagation of Stationary waves in Atmosphere, *EGU General Assembly 2013*, Vienna, Austria, April 7–12, 2013
- The Hemispheric Propagation of Stationary waves in Atmosphere, *ICDM Workshop 2012*, Kunming, China, August 6–9, 2012

## TEACHING AND MENTORING

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- **Guest Lecturer**, “Applied Atmospheric Dynamics” (ATMO 402), Instructor: Fei-Fei Jin, UH Mānoa spring semester 2020.
- **Co-Instructor**, “Dynamics of El Niño–Southern Oscillation Phenomenon” (ATMO 752), Instructor: Fei-Fei Jin, UH Mānoa spring semester 2019
- **Guest Lecturer**, “Applied Atmospheric Dynamics” (ATMO 402), Instructor: Fei-Fei Jin, UH Mānoa spring semester 2019
- Informally Mentored students: Jacob Gunnarson (UH, Oceanography), Xinyi Yang (UH, Atmospheric Sciences)

## OTHER PROFESSIONAL SERVICES AND EXPERIENCE

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### *CLIVAR working group member: ENSO conceptual models (2022 – Present)*

### *Reviewer for international journals*

Proceedings of the National Academy of Sciences of the United States of America (*PNAS*), Geophysical Research Letters, Journal of Climate, Climate Dynamics, npj Climate and Atmospheric Science, Atmospheric Chemistry and Physics, Environmental Research Letters, Journal of Geophysical Research-Atmosphere, Journal of Geophysical Research-Oceans, Journal of the Atmospheric Sciences, Scientific Reports, Deep-Sea Research Part I, Atmosphere,

Theoretical and Applied Climatology, Progress in Oceanography, Agronomy Journal, Earth and Space Science, Frontiers of Earth Science

### ***Scientific Societies***

American Geophysical Union (AGU), Asia Oceania Geosciences Society (AOGS), European Geosciences Union (EGU)

### **OTHER SELECTED HONORS AND AWARDS**

- **Contemporary Undergraduate Mathematical Contest in Modeling Award**, National Second Prize and Special Prize of Gansu Province, CSIAM, 2009
- **Outstanding Student Leader**, University of the Chinese Academy of Sciences, 2012, 2013, 2014
- **Outstanding Student**, University of the Chinese Academy of Sciences, 2012, 2013, 2014, 2015
- **Outstanding Graduate**, Lanzhou University, 2011

### **DEVELOPED TOOLKITS AND MODELS**

- **An extended nonlinear recharge oscillator model (XRO)**. The XRO exhibits skillful ENSO forecasts better than global climate models and comparable to the most skillful AI ENSO models.
- **A simple stochastic-dynamical IOD prediction system**. The system exhibits generally higher skill and longer lead times for predicting IOD events than current operational forecast systems.
- **An intermediate tropical ocean model (iTOM)**. This is a linear continuously stratified ocean model extended to all tropical oceans with a more realistic coastline and a space dependent background stratification, show improved performance than Zebiak-Cane type ocean model.
- **Rossby wave ray and phase tracing**. A software package for investigating the Rossby wave propagation and its phase evolution in a horizontally non-uniform basic flow.

### **SKILLS**

- **Modeling using General Circulation Models (NCAR CESM and GFDL models):**
  - CESM1/2 OGCM POP2 momentum and buoyancy fluxes forced experiments.
  - CESM1/2 Fully coupled and slab-ocean experiments.
  - CESM AGCM SST/SIC sensitivity experiments and aqua-planet experiments.
  - GFDL CM2.1/CESM pacemaker experiments.
- **Modeling using Intermediate and Simple Models:**
  - Linear Baroclinic Models
  - Isca
  - Intermediate tropical ocean model
  - Zebiak-Cane ENSO Model
  - SPEEDY
  - Gill-Matsuno Model
  - Shallow Water Model for Global Ocean
  - Barotropic Model
  - Recharge Oscillator Model
- **Mathematical reasoning**
- **Coding:** Python, Fortran, Matlab, CDO, NCO, NCL, Ferret, Gnuplot, R, Linux Shells, LATEX, C++
- **Languages:** Mandarin (native) and English (fluent)

Last updated: June 28<sup>th</sup>, 2024