Dr. Sen Zhao

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Research Interests

Climate Dynamics and Predictability; Climate Modeling; Air-Sea Interactions; ENSO; Wave Dynamics and Atmospheric Teleconnections; Paleoclimate

Professional Appointments

Assistant Researcher 2021.10 - Present

School of Ocean and Earth Science and Technology (SOEST), University of Hawaii at Mānoa.
Research on tropical climate dynamics and sea level science

Postdoctoral Fellow 2016.10 – 2021.09

Department of Atmospheric Sciences, University of Hawaii at Mānoa. Advisor: Fei-Fei Jin
Working on dynamic diagnosis and modeling of ENSO variability and related topics

Education

Ph.D. Meteorology 2011.09 – 2016.08

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"*. Advisor: Jianping Li

B.S. Atmospheric Sciences 2007.09 – 2011.08

College of Atmospheric Sciences, and School of Mathematics and Statistics, Lanzhou University
Thesis: "*Evaluation of WRF microphysics and cumulus schemes in simulating Hurricane Katrina*"

Publications

Totally 40 SCI articles (7 as first author) and 1 book chapter with air-sea interactions numbered in red, Rossby wave and teleconnections in blue and Paleoclimate in green, respectively. Total Google Scholar citations are 868, Publons SCI citations are 663 as of October 25, 2021.

Peer-reviewed book chapters

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.

Peer-reviewed journal articles

40. 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.

39. 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,*** *in press.*

38. Tang X., J. Li, H. Zhang, and **S. Zhao** (2021): 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.***, *in press*

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.

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. **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.

1. 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.

Papers submitted or in preparation

Zhao, S., and F.-F. Jin: A Robust Assessment of the Bjerknes-Wyrtki-Jin Indices for ENSO Linear Stability and Periodicity. Part I: Ensemble of Ocean Reanalyses. to be submitted.

Zhao, S., and F.-F. Jin: A Robust Assessment of the Bjerknes-Wyrtki-Jin Indices for ENSO Linear Stability and Periodicity. Part II: CMIP5 and CMIP6 models. in preparation.

Zhao, S., J. Li, F.-F. Jin, M.F. Stuecker, J. Feng, and Y. Li: Rossby wave phase tracing theory on a horizontally non-uniform flow with application to understand the structure of the Pacific-Japan teleconnection. to be submitted

Presentations

Talks

- Advancing Understanding of ENSO's Relationship with Equatorial Pacific Thermocline, *Atmospheric Sciences Seminar, University of Hawai'i at Mānoa*, 09/2021
- Improved Predictability of the Indian Ocean Dipole Using Seasonally Modulated ENSO Forcing, *AOGS 15th Annual Meeting*, Honolulu, USA, 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, USA, 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

- **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

Professional Services and Experience

Journal reviewer

- Geophysical Research Letters
- Journal of Climate
- Climate Dynamics
- Journal of the Atmospheric Sciences
- Journal of Geophysical Research-Atmosphere
- Earth-Science Reviews
- Scientific Reports
- Atmosphere

- Theoretical and Applied Climatology
- Earth and Space Science

Scientific Societies

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

Contributed Projects

- **U.S. National Science Foundation:** "Further Studies of Dynamics for El Nino-Southern Oscillation (ENSO) Diversity and Complexity" (PI: Fei-Fei Jin), 2018-2021
- **U.S. Department of Energy:** "Understanding ENSO Diversity and Changes in Climate Models and Observations" (PI: Fei-Fei Jin), 2018-2021
- **National Science Foundation of China:** "Temporal and Spatial Characteristics of Interhemispheric Atmospheric Teleconnections in the Boreal Summer and Mechanism on the Theory of Cross-Equatorial Propagation of Planetary Wave" (PI: Yanjie Li), 2016-2019
- **National Science Foundation of China**: "New theory of the planetary wave propagation in divergent atmosphere and its characteristics over the Asian-Australian Monsoon region" (PI: Yanjie Li), 2013-2015
- **National Science Foundation of China**: "On the new theory of planetary wave on non-uniform basic flow and interactions between Asian and Australian monsoon systems" (PI: Jianping Li), 2011-2014

Honors, Awards, and Scholarships

- **National Scholarship**, Ministry of Education of China, No. 50257, 2013
- **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
- **Contemporary Undergraduate Mathematical Contest in Modeling Award,** National Second Prize and Special Prize of Gansu Province**,** CSIAM, 2009
- **First Class Scholarship of Lanzhou University**, 2009
- **China National Encouragement Scholarship**, 2008, 2010

Self-Development Toolkits and 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

- **Mathematical reasoning**
- **Modeling using General Circulation Models (NCAR CESM and GFDL models):**
    - CAM5 SST/SIC sensitivity experiments
    - POP2 momentum and buoyancy fluxes forced experiments
    - CESM Fully-coupled and slab-ocean experiments

    - GFDL CM2.1/CESM pacemaker experiments
    - CESM aqua-planet 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
- **Coding**: Python, Fortran, Matlab, CDO, NCO, NCL, Ferret, Gnuplot, R, Linux Shells, LATEX, C++
- **Languages**: English and Mandarin Chinese

Last updated: October 25, 2021