Hongyu Zhou

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Education Background

Tsinghua University |Department of Electronic Engineering| PhD Candidate   2021.09—2026.06
GPA: 3.94/4.0 (8/115)
Supervisor: *Prof.* Maokun Li
Thesis Title: Research on Multi-physics Joint Inversion Driven by Both Data and Physics.

University of Illinois Urbana-Champaign |CSL[1]| Visiting Student   2024.08—2025.02
Supervisor: *Prof.* Yoram Bresler
Research Topic: Abdominal Adipose Imaging based on Combined Electromagnetic Modalities and Deep Learning.

Tsinghua University |Department of Electronic Engineering| B. Eng in ECE   2016.09—2021.06

Tsinghua University |School of Economics and Management| B.A. in Econ. (Second Degree)

2019.09—2021.06

Working Experience

Qinghai University |RA with the Department of Computer Science   2023.07—2023.08
- Worked on GPU acceleration of GRAPES (numerical weather prediction model).
- Implemented GPU parallelization using CUDA programming in Fortran.

Schlumberger Beijing Geoscience Center |Algorithm Development Intern   2021.08—2021.12
- Developed a flexible fault profile sampling algorithm adaptable to complex geological formations.
- Enabled efficient and accurate dataset construction for training data-driven seismic horizon tracking models.

Research Summaries

- **My research during my PhD studies focused on numerical modeling of physical fields in complex media and the associated optimization problems. I developed novel algorithms**, including fully stochastic physical field modeling and deep learning‑assisted inversion methods with explicit data-fitness controls, and **applied them to real-world geophysical exploration problems.**

  - From a model-driven perspective, **I studied stochastic frameworks for electromagnetic (EM) modeling** and proposed a fully stochastic simulation method tailored for large-scale heterogeneous parallel computing architectures.

  - From a data-driven perspective, **I developed a series of joint inversion algorithms driven by both data and physics**, based on latent-space representations using diverse **deep learning** tools, improving multi-physics consistency and reconstruction quality.

- With training and hands-on experience in physical modeling and AI, my research interests lie in the interaction between **physical laws**, **numerical simulation**, **imaging** and **signal processing**.

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[1]CSL: Coordinated Science Laboratory

Research Details

Magnetotelluric (MT) inversion with the fusion of high resolution seismic information

| Part of PhD Thesis, supervisor: *Prof.* Maokun Li

- **Objective**: MT is sensitive to subsurface conductive structures, but has a lower resolution than seismic exploration. The interpretation knowledge of the experts are also not easy to incorporate into MT inversion. We seek approaches to incorporate multi-scale seismic information and experts' knowledge into MT inversion.

- **Approaches**:
  - *Work1*: Utilized CNN to generate resistivity reference from the seismic section and interpretation knowledge. The CNN is incorporated into the conventional gradient-based optimization as an additional reference regularization. See [J1] for more details.
  - *Work2*: Constructed a texture extraction operator (TEO) based on the pre-trained VGG19 and formed a texture data space with the TEO output span. The texture misfit is included in the objective function and jointly optimized with EM data misfit using ADAM optimization. See [J3] for more details.

- **Outcomes**:
  - Improve the accuracy and resolution of MT inversion.
  - Have been adopted by BGP in CNPC[2], and applied to the interpretation of real-field electromagnetic data from multiple survey regions, including Luzong ore concentration area (Anhui, China) and Tarim Oilfield (Xinjiang, China).
  - **Best Student Paper Award** (1st place) at PIERS 2024[3].

Intelligent EM inversion constrained by deep generative models

| Part of PhD Thesis, supervisor: *Prof.* Maokun Li

- **Objective**: Constrain EM inversion with prior knowledge on parameter distribution patterns, which may be abstract and diverse in informational content and effective region.

- **Approaches**: Studied feature-based EM inversion framework based on variational autoencoders (VAEs). The reconstructed model is expressed with the output of generator. This framework has been used in various EM inversions, including
  - *Work3*: 2D MT inversion. Generated a set of 1D models according to the prior knowledge under the layered media hypothesis, and with which a 1D VAE is trained. The model is expressed with the horizontal concatenation of various 1D VAE outputs, and the continuity is guaranteed with Tikhonov regularization. See [J2] for more details.
  - *Work4*: 2.5D controlled source electromagnetic (CSEM) inversion. The 2D VAE is fine-tuned based on the stable diffusion VAE, balancing the reconstruction ability and generalization ability. The objective function is optimized using projected Gauss-Newton (PGN), to reduce optimization iterations and circumvent local minima. See [J5] for more details.
  - *Work5*: 3D airborne and semi-airborne transient electromagnetic (TEM) inversion constrained semantically introduced prior knowledge in latent space. Related research results will be presented in [J6].

- **Outcomes：**

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[2]BGP: Bureau of Geophysical Prospecting, CNPC: China National Petroleum Corporation

[3]2024 Progress In Electromagnetics Research Symposium

- *Work3*: An improvement of 75% in model misfit compared to conventional inversion. Successfully processed South Africa MT Experiment data (SAMTEX).
- *Work4*: Improvements ranging from 50% to 75% in metrics such as MSE and SSIM compared to conventional inversion. Successfully processed Norway North Sea dataset (Troll Field).
- *Work5*: I have completed the development of 3D airborne and semi-airborne forward modeling and Jacobian computation algorithms, and this work is currently ongoing.
- **Best Student Presentation Award** (3rd place) at PIERS 2025[4].

Stochastic EM modeling leveraging intrinsic parallel mechanism

| NSFC[5] Student Project, supervisor: *Prof.* Maokun Li

- **Objective**: High performance EM simulation highly relies on massive parallel computation hardware. Existing EM algorithms based on solving linear systems lack enough intrinsic parallelism. We reformulate and solve the EM equations under the stochastic framework to improve the parallel efficiency to the largest margin and make them better adapted to HPC (high performance computation) platforms.

- **Approach**:
  - *Work6*: For 2D MT modeling, we rewrite the Helmholtz equation as the formulation of stochastic path integral (SPI) based on the stochastic differential equation theory, hence transforming the main computation overhead from solving linear system to matrix-vector multiplication (MatVec). We build a surrogate model, partitioning the computation into the offline Monte Carlo simulation and online MatVec operations, therefore gain considerable parallelism, scalability and speedup. See [J4] for more details.

- **Outcomes:**
  - Achieve up to a 550x speedup compared with conventional modeling and 30% memory reduction at the relative error of 1.2%.
  - **Best Student Paper Award** at ACES-China 2025[6].
  - Funded by 2024 **NSFC Young Students Basic Research Program**[7].

Abdominal adipose imaging based on combined EM modalities and deep learning

| Visiting Project at UIUC-CSL, supervisor: *Prof.* Yoram Bresler

- **Objective:** Abdominal fat has been an important predictor of all-cause mortality. Leveraging favorable features such as high convenience, low cost and no ionization of bio-impedance imaging, we aim to realize abdominal fat monitoring with EM imaging and improve the prediction accuracy of previous research.

- **Approach**:
  - *Work7*: EMIT forward modeling and inverse problem algorithms are developed, tackling both electric/magnetic excitations and electric/magnetic responses. Physics-encoded neural network was

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[4]2025 Progress In Electromagnetics Research Symposium

[5]National Natural Science Foundation of China

[6]2025 International Applied Computational Electromagnetics Society Symposium

[7]The NSFC Young Students Basic Research Program, established in 2023, is a highly competitive national funding scheme designed to support original and independent research ideas proposed by undergraduate and doctoral students in China. For doctoral applicants, the submitted proposal must be clearly distinct from the doctoral dissertation. Applicants are required to independently design the research plan, prepare and defend the proposal, and take responsibility for project implementation, progress management, and fund usage. The program imposes high standards on applicants' research independence, technical competence, and project management capability. In the 2024 funding cycle, only approximately 500 projects were awarded nationwide across all research areas, highlighting the highly selective nature of the program. For more information, please refer to this official report.

built using deep unrolling strategy, and the neural units are built with Graph Neural Operators (GNOs) to tackle variable meshes.

- **Outcomes**:
  - Direct prediction of subcutaneous and visceral fat distribution from measured combined EM modality data.
  - Achieved a prediction IoU of 0.95 and Dice coefficient of 0.97 on the test set. See [C9] for more details. This work is still ongoing.

Technical and Research Capability

- **Expertise in physical field computation**
  - I developed classical physical field simulation and inversion algorithms, including circuit-theory-based 2D electrostatic field solvers, differential-equation-based 2.5D frequency-domain and 3D time-domain electromagnetic solvers, as well as adjoint-equation-based inversion algorithms.
  - I implemented deep learning operators tailored for physical field computation, including CNN-based multi-physics information fusion operators, style-transfer-based texture constraint operators, deep generative model‑based feature operators, and neural-operator-based update learning operators, together with deep learning inversion algorithms embedded with these operators.
  - I developed stochastic electromagnetic simulation algorithms, including Monte Carlo simulation of 2D diffusive field in complex media, and further constructed a practically deployable, highly efficient, fully parallel three-stage stochastic simulation framework.

- **Full-cycle research experience**
  - Led the **end-to-end development** of EM modeling and inversion research, **acting as the primary contributor** to algorithm design, implementation, large-scale numerical experiments, and manuscript preparation, with iterative technical discussions with collaborators throughout the research process.
  - The developed algorithms were validated on real-field datasets and deployed in industrial interpretation workflows.

- **Independent research funding acquisition**
  - Conceived and executed **a competitively funded NSFC** Young Students Basic Research **Project** distinct from the doctoral thesis, involving independent proposal design, defense, project execution, and budget management.

- **Independent international collaboration**
  - **Initiated direct academic communication with Prof. Yoram Bresler**, which developed into a six-month visiting research collaboration at **UIUC-CSL**.
  - Led problem formulation, modeling, and algorithm development through weekly research discussions, resulting in joint publications and ongoing collaborative projects.

Selected Awards and Honors (in chronological order)

1. **Best Student Presentation Award** (3rd Place, Track 3), PIERS 2025, 2025.11
2. **National Scholarship of China** (Top national-level graduate award), Ministry of Education, 2025.9
3. **Best Student Paper Award**, ACES-China 2025, 2025.08
4. **Young Students Basic Research Grant**, National Natural Science Foundation of China (NSFC), 2024.12

5. **Scholarship for Overseas Graduate Studies**, Tsinghua University, 2024.07

6. **Best Student Paper Award** (1st Place, SC.5[8]), PIERS 2024, 2024.05

7. **Excellent Social Work Scholarship** (Postgraduate), Tsinghua University, 2022.12

8. **Excellent Comprehensive Scholarship** (Postgraduate), Tsinghua University, 2022.11

9. **Outstanding Undergraduate Thesis Award**, Tsinghua University, 2021.06

Teaching and Academic Services

1. TA，including：

   (a) Theory and Methods in Electromagnetic Inverse Problems (Tsinghua, 80231023-0, 2024.03-2024.06)

   (b) Numerical Methods in Electromagnetics (Tsinghua, 70230173-0, 2023.09-2023.12)

   (c) Electromagnetic Field and Microwave Experiment (Tsinghua, 40230821-0, 2022.03-2022.06)

2. Undergraduate research mentoring, including:

   (a) Yutong Li (Tsinghua University, Research on Text-to-Geological Structure Generator for Deep Resource Prospecting, 2022.08-2023.08)

   (b) Zihao Lian & Ieva Bagdonaviciute (UIUC, Joint Inversion of EMIT and Ultrasound Imaging based on Deep Learning, 2024.08-2025.02)

   (c) Haoxuan Wang & Xi Chen (Tsinghua University, EM Inversion based on Deep Generative Models, 2025.03-Present)

3. I have served as reviewer for several leading journals, including

   (a) IEEE Transactions on Geoscience and Remote Sensing

   (b) IEEE Transactions on Antennas and Propagation

   (c) Geophysics

Publications

- **Journals**

[J1] **Zhou H**, Guo R, Li M, et al. An intelligent MT data inversion method with seismic attribute enhancement[J]. **IEEE Transactions on Geoscience and Remote Sensing**, 2023, 61: 1-14.

[J2] **Zhou H**, Guo R, Li M, et al. Feature-based magnetotelluric inversion by variational autoencoder using a subdomain encoding scheme[J]. **Geophysics**, 2024, 89(1): WA67-WA83.

[J3] **Zhou H**, Guo R, Li M, et al. Super-resolution magnetotelluric data inversion with seismic texture constraint[J]. **Geophysics**, 2025, 90(3): WA153-WA168.

[J4] **Zhou H**, Li M, Yang F, et al. Two-Dimensional Magnetotelluric Modeling based on Stochastic Path Integral: TE Case[J]. **IEEE Transactions on Geoscience and Remote Sensing**, doi: 10.1109/TGRS.2025.3618304.

[J5] **Zhou H**, Sun H, Guo R, et al. Feature-based 2.5D Controlled Source Electromagnetic Inversion using Generative Priors[J]. **IEEE Transactions on Geoscience and Remote Sensing**, *Major Revision.*

[J6] **Zhou H**, Sun H, Guo R, et al. Three-dimensional Airborne Transient Electromagnetic Inversion with Semantic Constraints[J]. **Nature Communications**, *In preparation.*

- **Conferences**

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[8]SC.5: Remote Sensing, Inverse Problems, Imaging, Radar and Sensing

[C1] **Zhou H**, Guo R, Tao D, et al. Joint inversion of audio-magnetotelluric and seismic travel time data using attribute fusion based on deep learning[C]//2021 International Applied Computational Electromagnetics Society (**ACES-China**) Symposium. IEEE, 2021: 1-2.

[C2] **Zhou H**, Guo R, Li M, et al. Joint inversion of magnetotelluric and seismic travel time data with intelligent interpretation of geophysical models[C]//Second International Meeting for Applied Geoscience & Energy (**SEG Annual Conference**). Society of Exploration Geophysicists and American Association of Petroleum Geologists, 2022: 1900-1904.

[C3] **Zhou H**, Guo R, Li M, et al. An intelligent MT data inversion method constrained by seismic texture[C]//2023 International Applied Computational Electromagnetics Society Symposium (**ACES-China**). IEEE, 2023: 1-2.

[C4] **Zhou H**, Guo R, Li M, et al. Magnetotelluric Data Inversion Using Subdomain Encoding Scheme with Variational Autoencoder[C]//2023 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting (**USNC-URSI**). IEEE, 2023: 255-256.

[C5] **Zhou H**, Guo R, Li M, et al. An MT data inversion method constrained by seismic texture[C]//Third International Meeting for Applied Geoscience & Energy (**SEG Annual Conference**). Society of Exploration Geophysicists and American Association of Petroleum Geologists, 2023: 1049-1053.

[C6] **Zhou H**, Guo R, Hu Z, et al. High-resolution Magnetotelluric Data Inversion Constrained with Seismic Texture[C]//2024 Photonics & Electromagnetics Research Symposium (**PIERS**, **Best Student Paper Award**). IEEE, 2024: 1-9.

[C7] **Zhou H**, Guo R, Hu Z, et al. High resolution MT data inversion with the seismic texture constraint[C]//International Workshop on Gravity, Electrical & Magnetic Methods and Their Applications (**GEM**), Shenzhen, China, May 19–22, 2024. Society of Exploration Geophysicists and Chinese Geophysical Society, 2024: 356-359.

[C8] **Zhou H**, Li M, Yang F, et al. Modeling Magnetotelluric Surveys Based on Stochastic Path Integral[C]//2024 IEEE International Symposium on Antennas and Propagation and INC/USNC-URSI Radio Science Meeting (**AP-S/INC-USNC-URSI**). IEEE, 2024: 2545-2546.

[C9] **Zhou H**, Lin Z, Zhang K, et al. Deep-E2M2IT: Deep learning-based combined electromagnetic impedance tomography for abdominal fat segmentation[C]//**Journal of Physics: Conference Series**. IOP Publishing, 2025, 3014(1): 012032.

[C10] **Zhou H**, Li M, Yang F, et al. MT-SPI: An Intrinsically Parallel Electromagnetic Modeling with Application to 2D Magnetotellurics[C]//2025 International Applied Computational Electromagnetics Society Symposium (**ACES-China**, **Best Student Paper Award**). IEEE, 2025: 1-3.

- **Others**

[O1] Zhang H, Zhang T, **Zhou H**, et al. A microwave thorax imaging system based on symmetrical dipole antenna and one-step supervised descent method[J]. **IEEE Transactions on Microwave Theory and Techniques**, 2022, 70(11): 5000-5007.

[O2] Li Y, **Zhou H**, Guo R, et al. Generating geophysical models from text for constructing the dataset of learning-based MT inversion[C]//Third International Meeting for Applied Geoscience & Energy (**SEG Annual Conference**). Society of Exploration Geophysicists and American Association of Petroleum Geologists, 2023: 1040-1043.

[O3] Guo R, **Zhou H**, Wei X, et al. Deep joint inversion of electromagnetic, seismic, and gravity data[C]//International Workshop on Gravity, Electrical & Magnetic Methods and Their Applications (**GEM**), Shenzhen, China, May 19–22, 2024. Society of Exploration Geophysicists and Chinese Geophysical Society, 2024: 360-363.

[O4] Guo R, **Zhou H**, Wei X, et al. Deep joint inversion of multiple geophysical data with U-net reparameterization[J]. **Geophysics**, 2024, 90(3): WA61-WA75.

[O5] Ma J, Deng Y, Li X, Guo R, **Zhou H**, Li M. Recent Advances in Machine Learning-Enhanced Joint Inversion of Seismic and Electromagnetic Data[J]. **Surveys in Geophysics**, 2024: 1-29.

Patents and Copyrights

Based on my research outcomes, I have applied for

1. six Chinese patents. One has been certified, the others are undergoing examination.

2. two Chinese software copyrights. Both have been certified (2021SR1542315, 2021SR1471064).

References

- *Prof.* Maokun Li, supervisor of my PhD study
  Department of Electronic Engineering, Tsinghua University, Beijing, China
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- *Prof.* Yoram Bresler, mentor for my study at UIUC
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