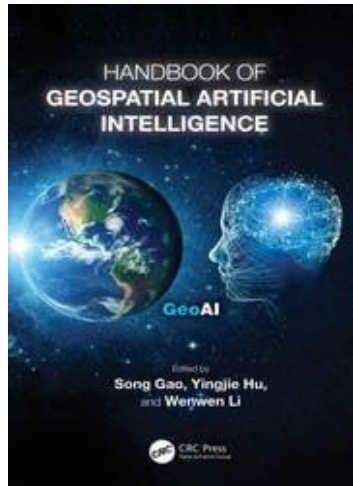


Chapter 5: GeoAI for Spatial Image Processing

Wenwen Li

School of Geographical Sciences and Urban Planning

Arizona State University



<https://doi.org/10.1201/9781003308423-5>

Arundel, S. T., McKeehan, K. G., Li, W., & Gu, Z. (2023). GeoAI for Spatial Image Processing. In *Handbook of Geospatial Artificial Intelligence* (pp. 75-98). CRC Press.

Chapter outline

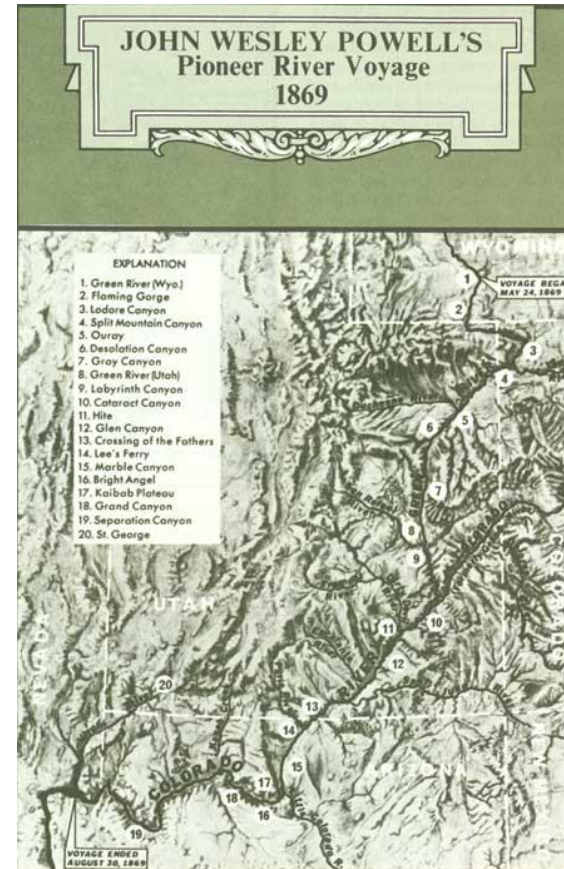
- Introduction
 - Origins of image processing
 - (Digital) image processing in the spatial realm
 - Image processing in the AI realm
- Image processing in the GeoAI domains
- GeoAI-specific methods and challenges
 - The challenge in training data annotation
 - The challenge of scale
 - The challenge of image resolution
 - The challenge of space and time
- Future research
 - Geometric algebra
 - Combining GeoAI with physical modeling
 - Knowledge-guided GeoAI
 - AI ethics

Origin for image processing

- 1830s: cameras became essential tools in laboratories and on geographic expeditions



Anna Atkins published her botanical study of algae in the 1840s using cyanotype images



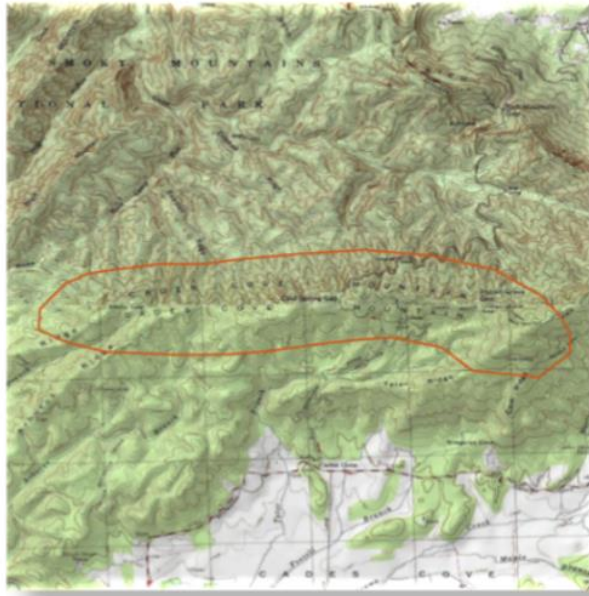
John Wesley Powell 1869 expedition to the Colorado River

Spatial image processing

- What is spatial image?



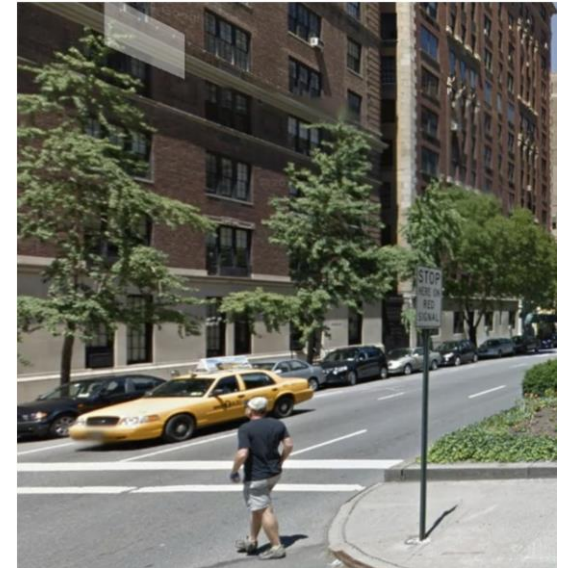
Remote sensing images



Topo maps



Digital Elevation Model
(DEM) data



Street view images

Spatial information processing

- Object-based image analysis (OBIA)
- GEOBIA - "scientific resolution" – create a dynamic multiscale object-based contextual model (Hay and Castilla 2008)

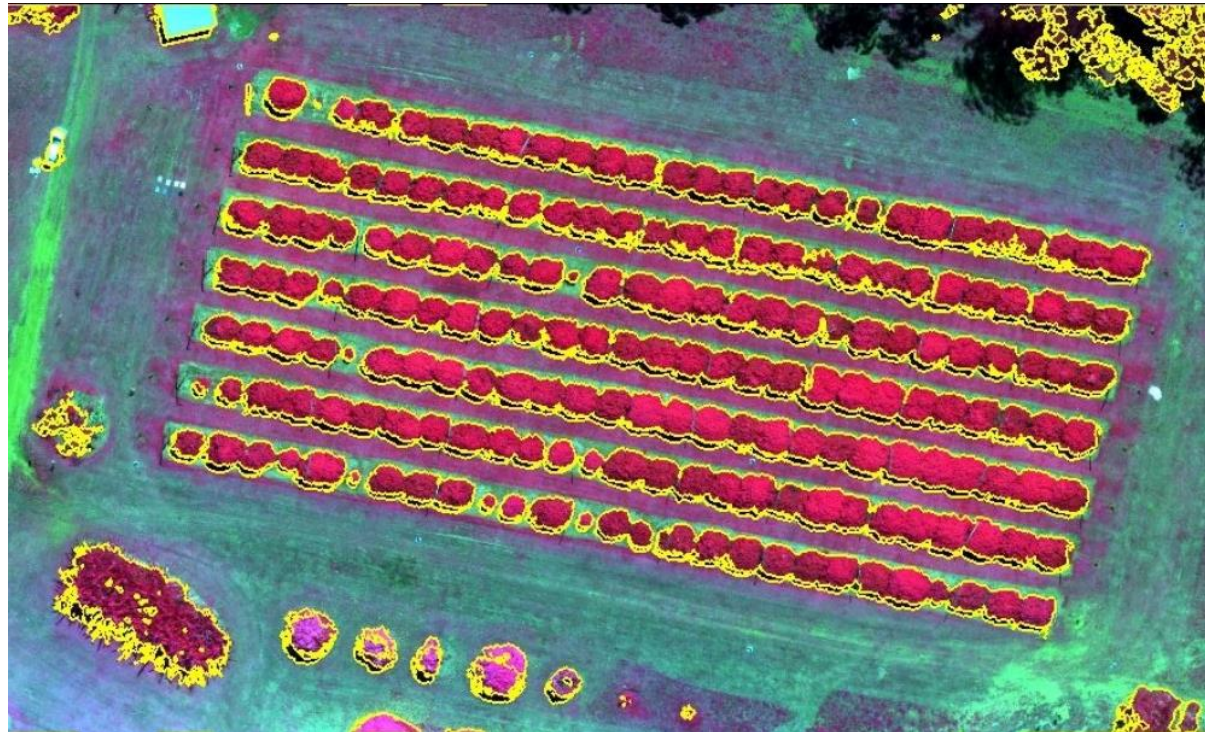
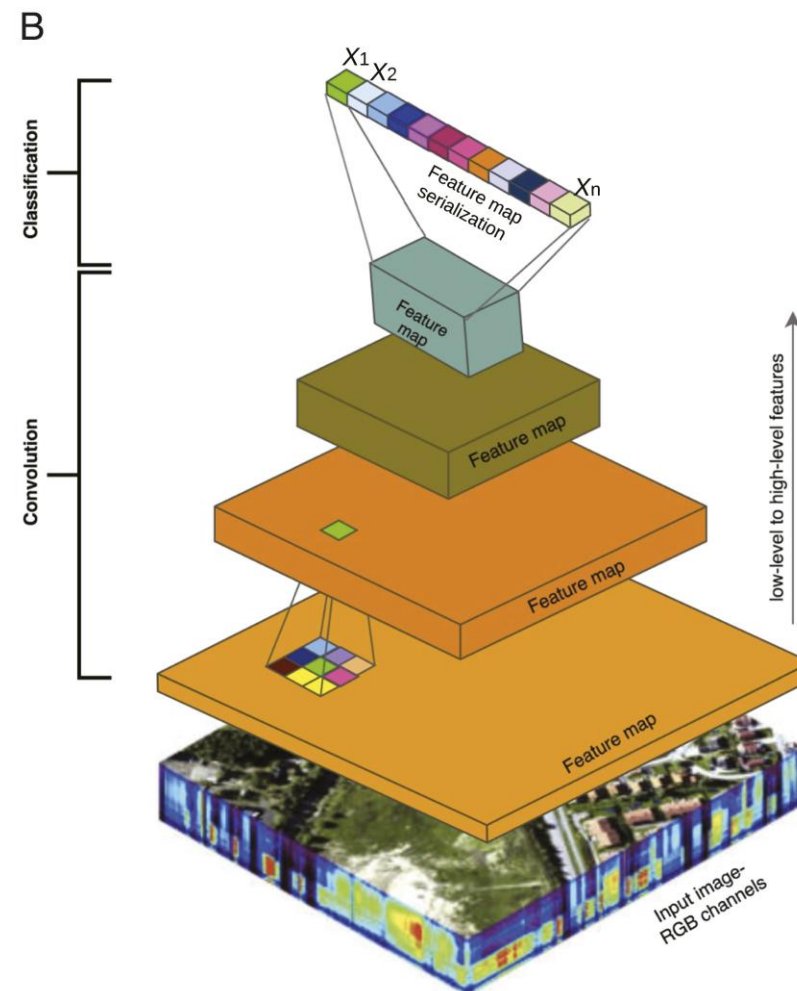
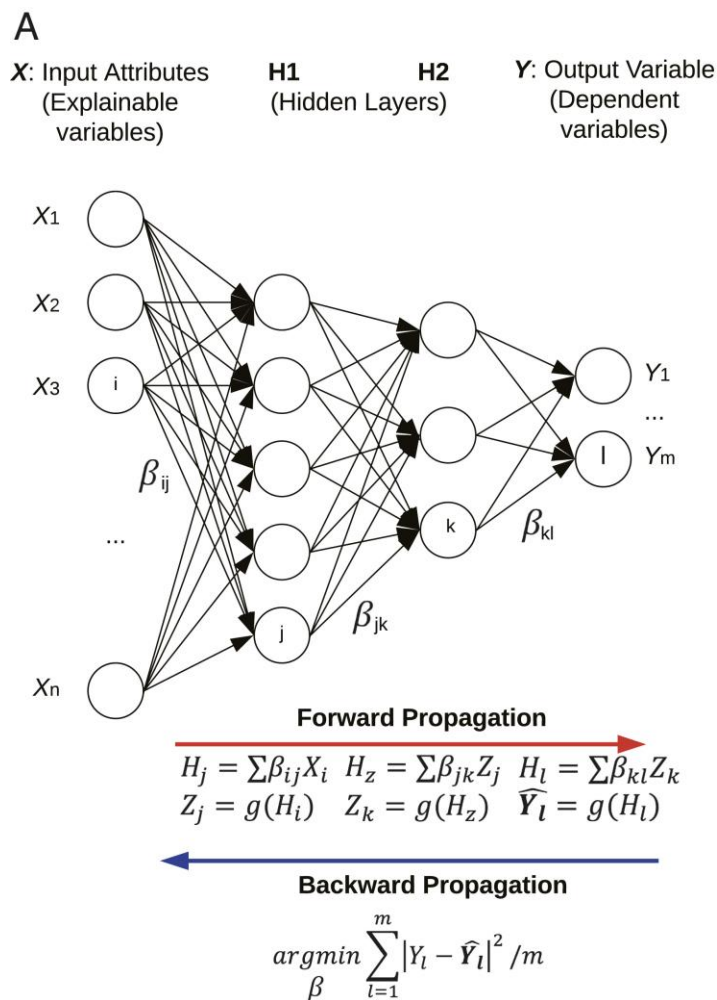


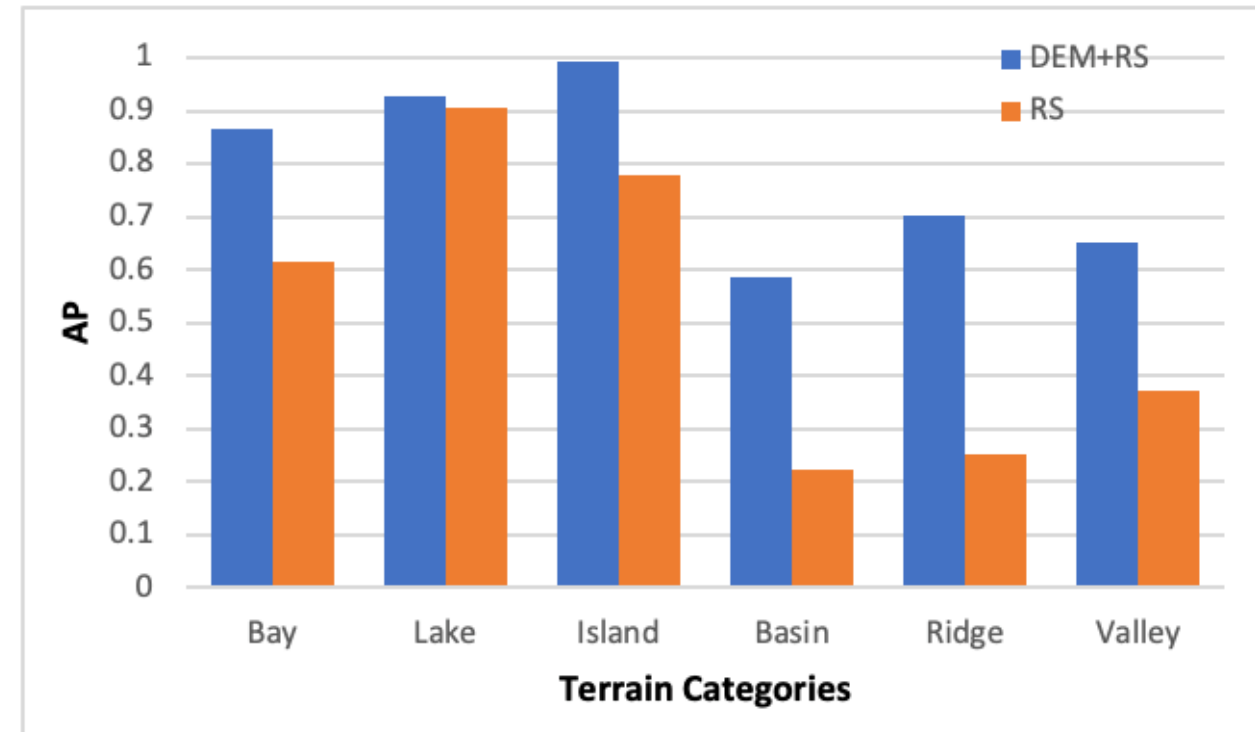
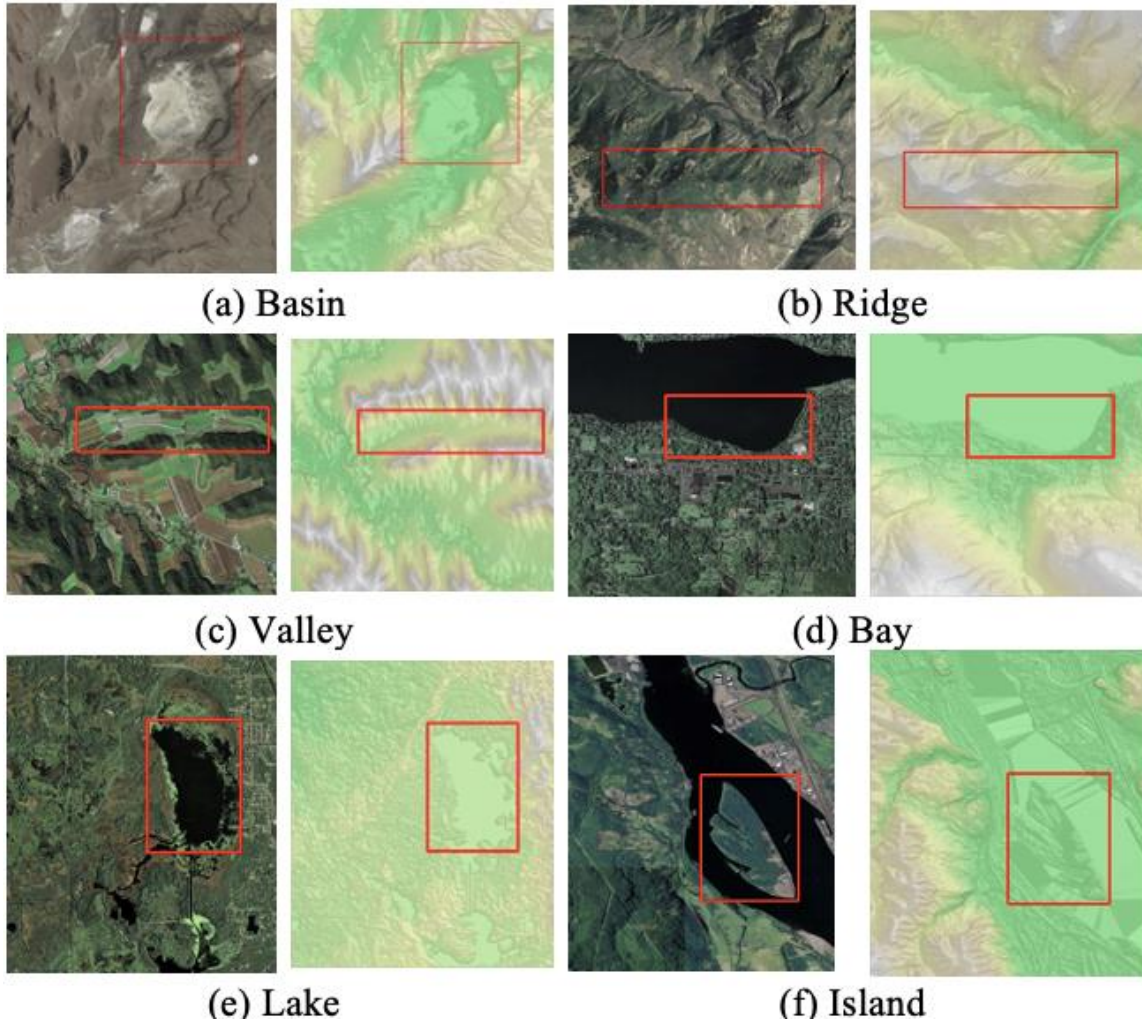
Image credit:
<https://www.rsrc.org.au/geobia-research>

GeoAI and Deep learning for spatial image processing



GeoAI specific methods and challenges

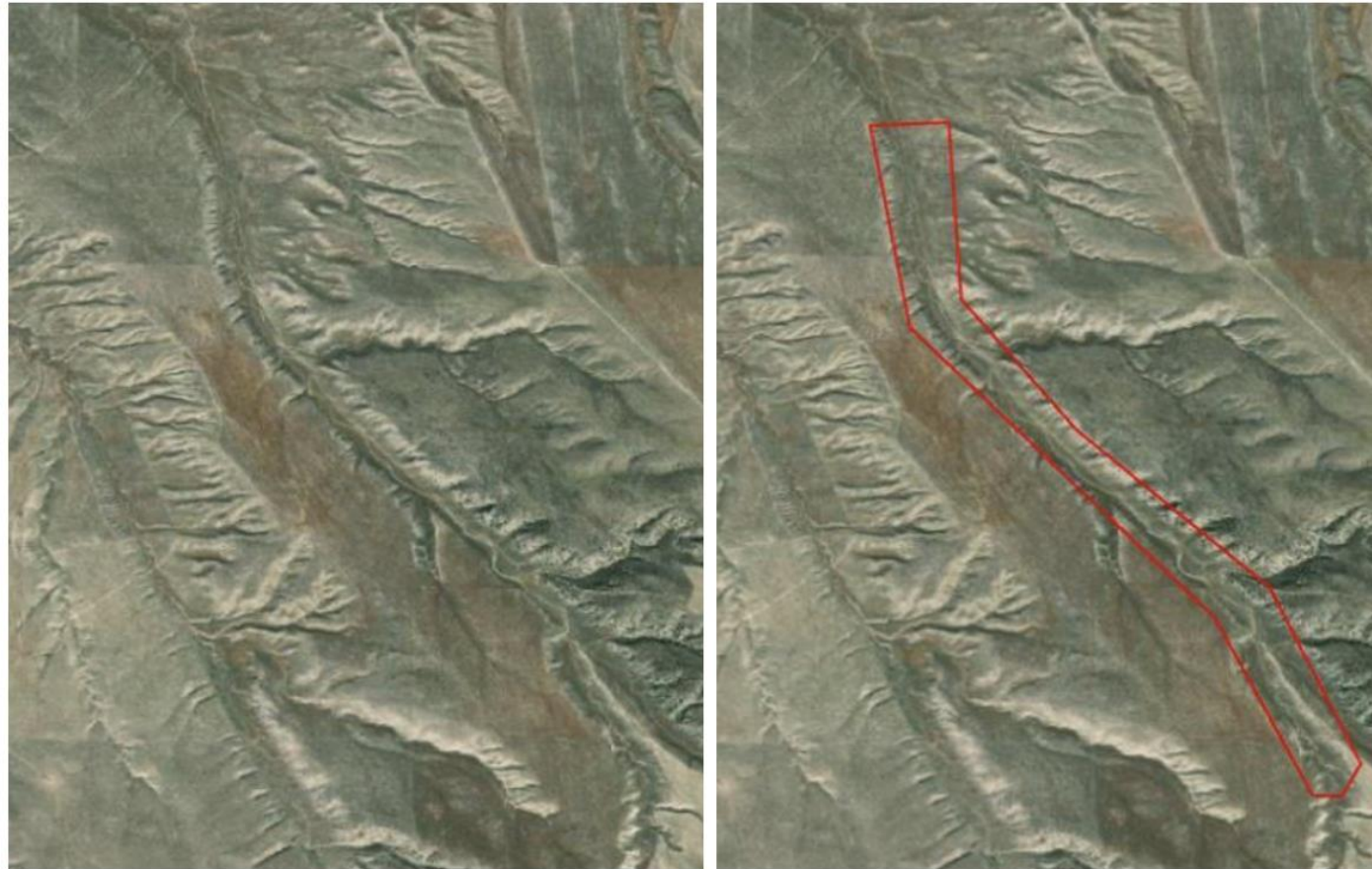
- Multi-source GeoAI



Wang and Li (2021), CEUS

GeoAI specific methods and challenges - 2

- Training data annotation



Bachelor Canyon, Montana

GeoAI specific methods and challenges - 3

- Scale

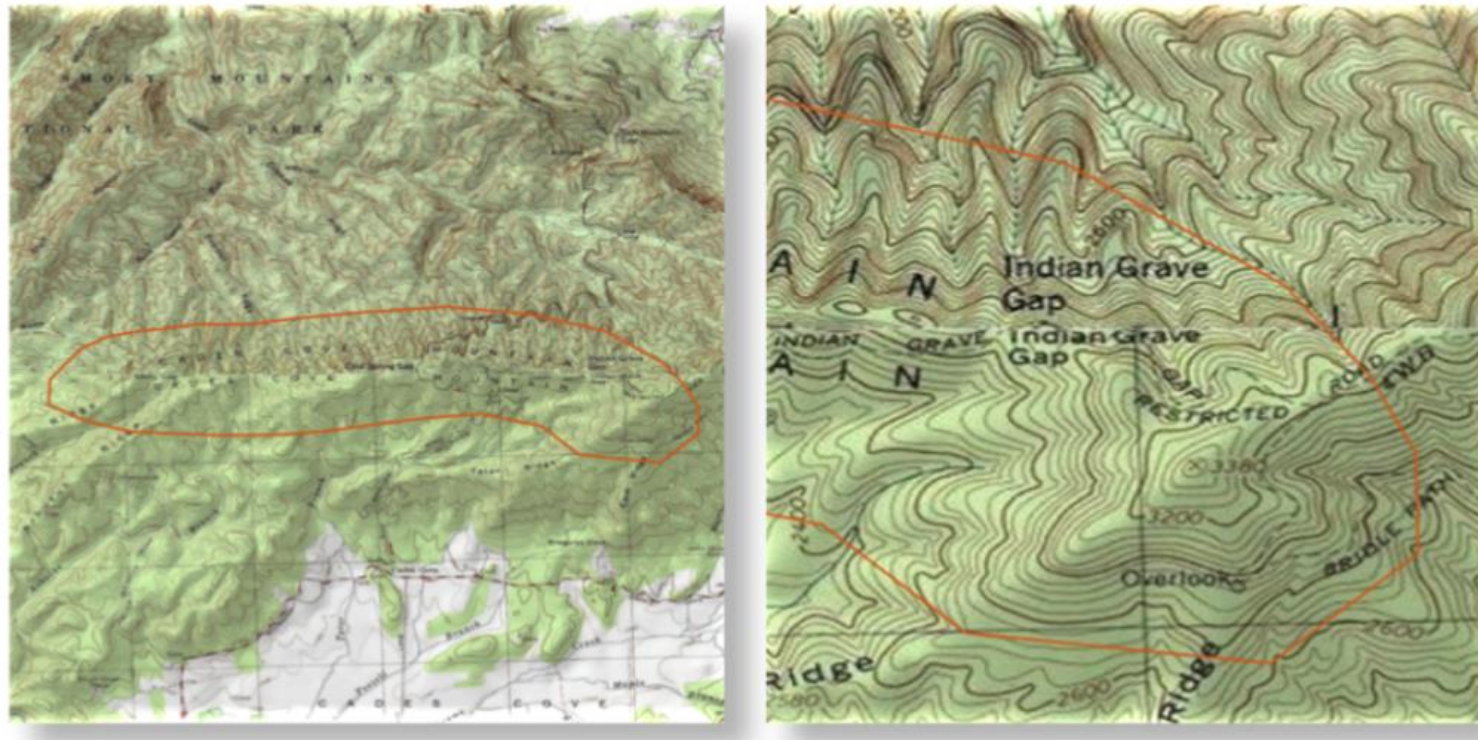


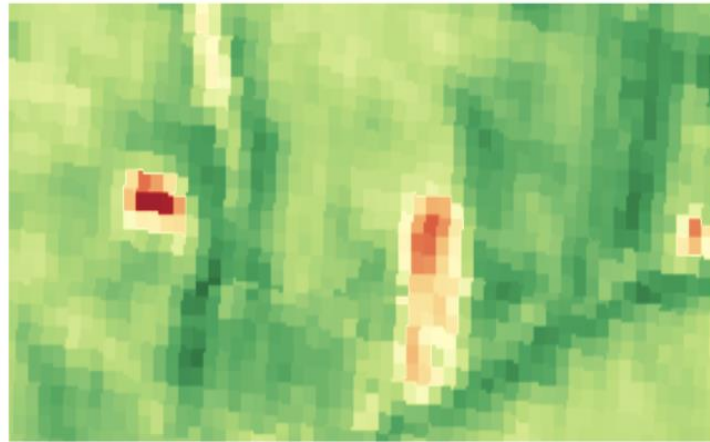
Figure 3. Demonstration of where scale could impact the effective prediction of a landform feature (Codes Cove Mountain, Tennessee), particularly as related to the image resolution at the smaller scale (left).

GeoAI specific methods and challenges - 4

- Resolution & data quality



Optical image



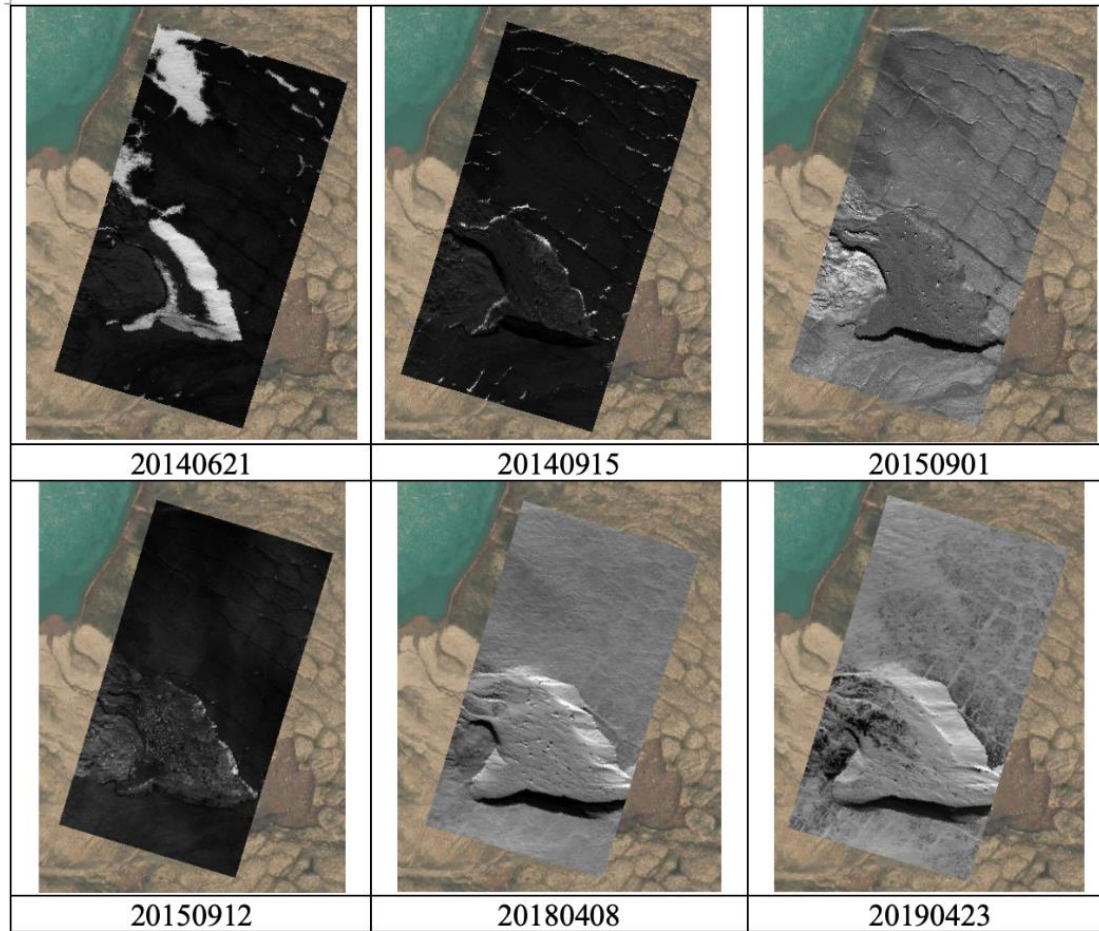
NDVI
(Normalized Difference
Vegetation Index)



DEM

GeoAI specific methods and challenges - 5

- Space and time



Future research

- Geometric algebra \rightarrow feature embedding

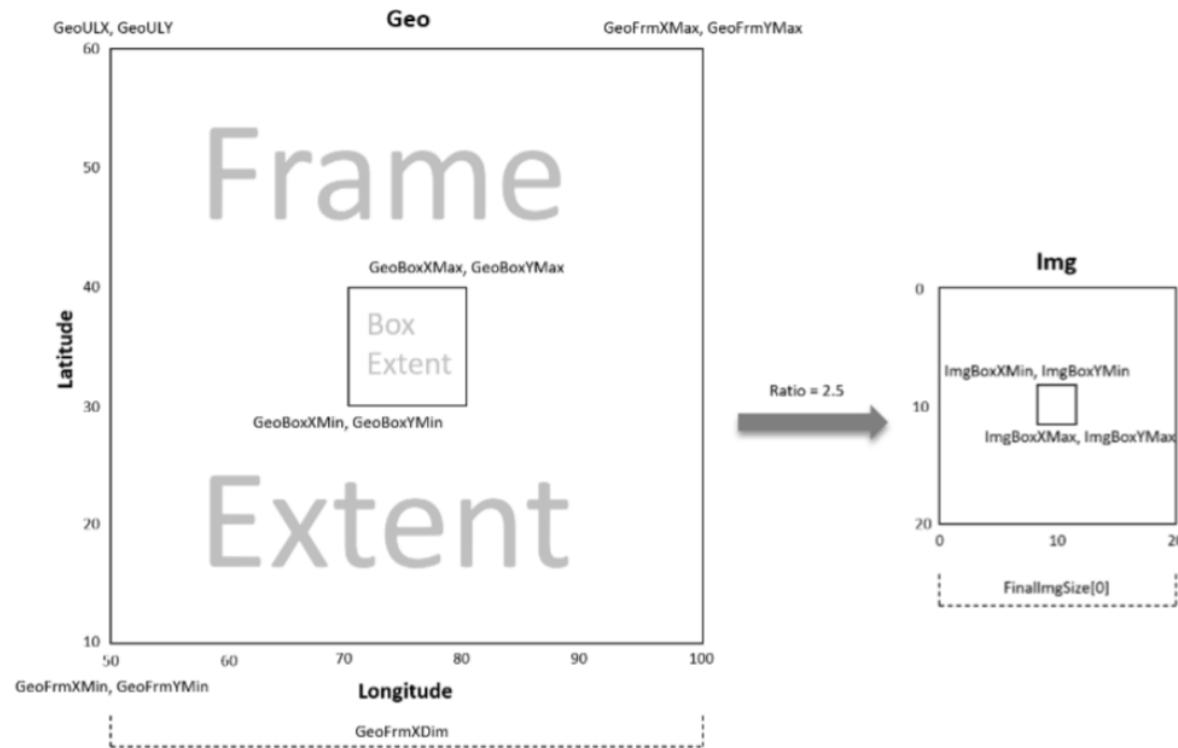
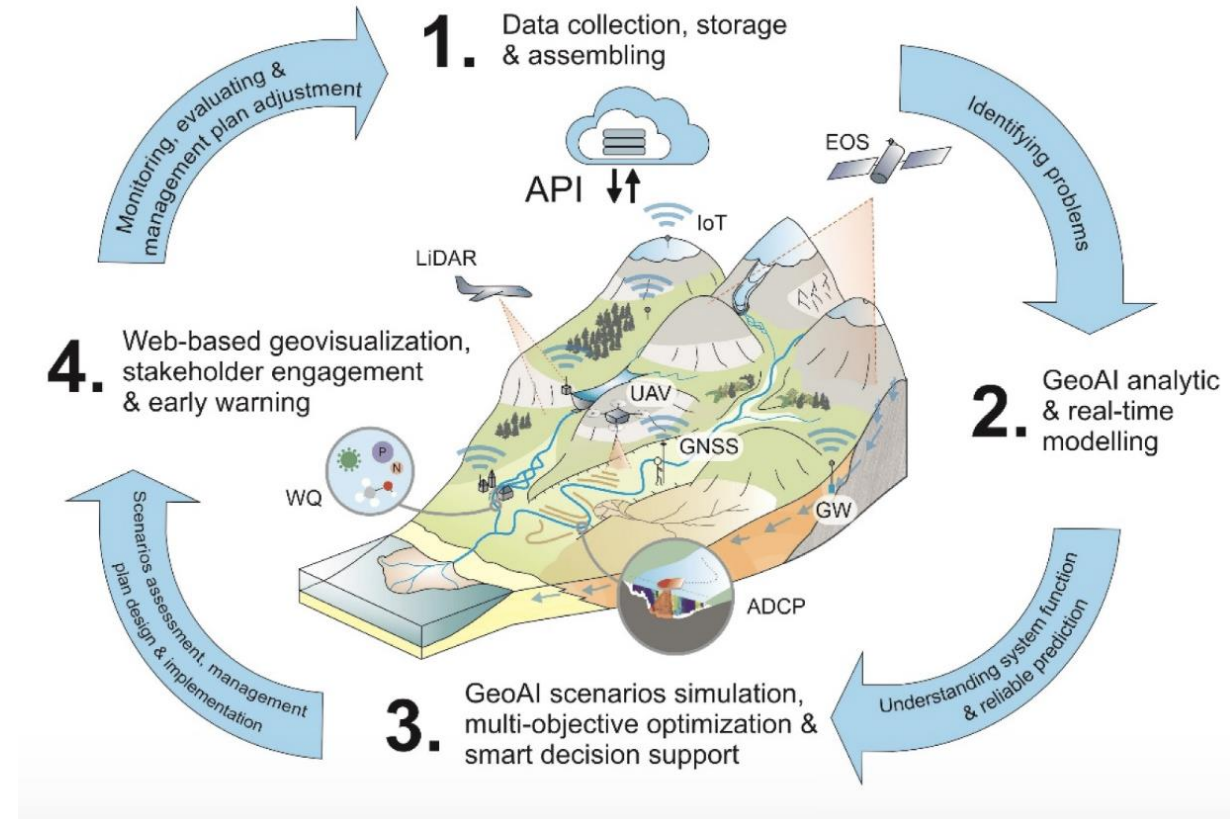


Figure 2. An illustration for coordinate transformation from a geographical extent to an image extent.

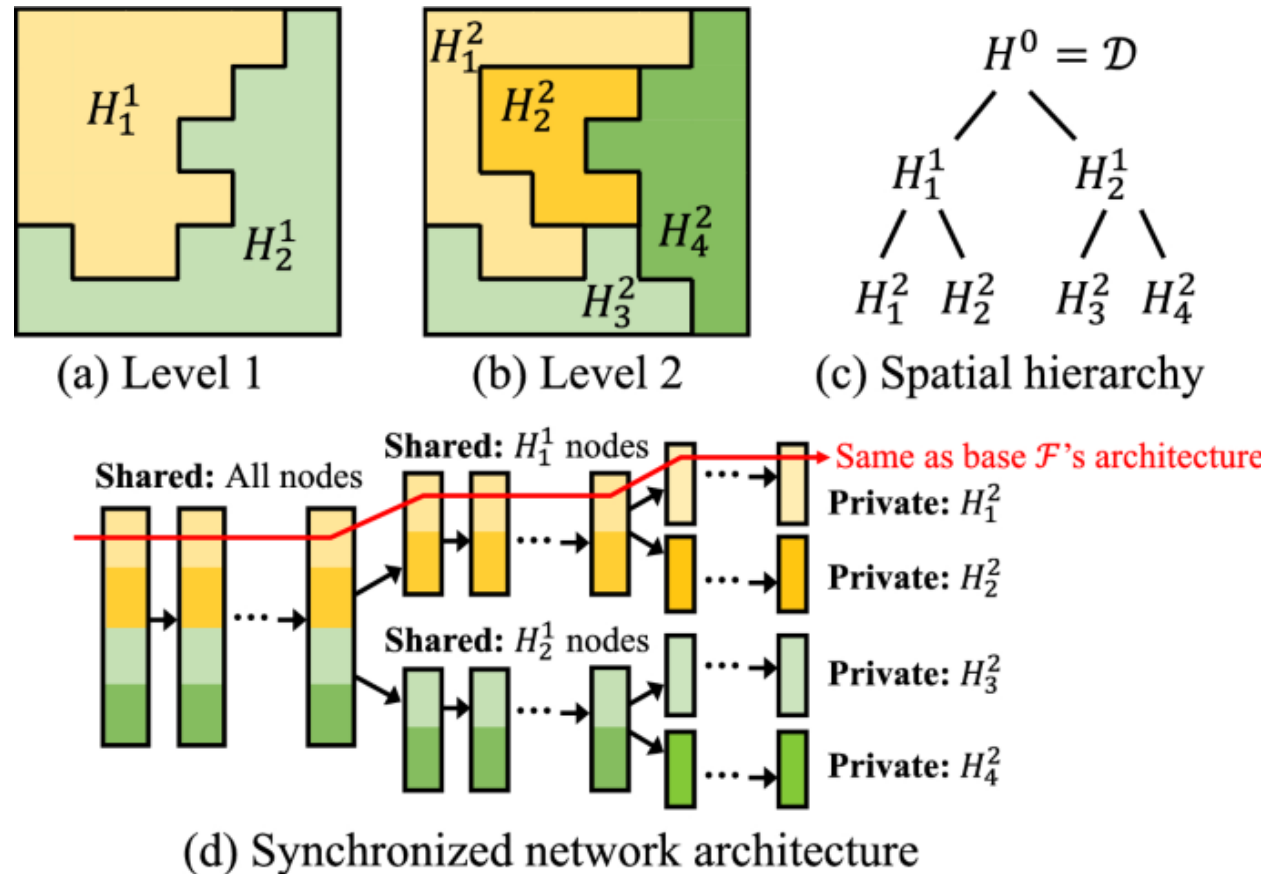
Future research -2

- Integration with physics-based models
 - AI-based calibration
 - Forecasting



Future research -3

- Geo-knowledge based learning – spatial explicit modeling



References

- Arundel, S. T., McKeehan, K. G., Li, W., & Gu, Z. (2023). GeoAI for Spatial Image Processing. In *Handbook of Geospatial Artificial Intelligence* (pp. 75-98). CRC Press.
- Li, W., Arundel, S., Gao, S., Goodchild, M., Hu, Y., Wang, S., & Zipf, A. (2024). GeoAI for Science and the Science of GeoAI. *Journal of Spatial Information Science*, (29), 1-17.
- Li, W. (2020). GeoAI: Where machine learning and big data converge in GIScience. *Journal of Spatial Information Science*, (20), 71-77.
- Janowicz, K., Gao, S., McKenzie, G., Hu, Y., & Bhaduri, B. (2020). GeoAI: spatially explicit artificial intelligence techniques for geographic knowledge discovery and beyond. *International Journal of Geographical Information Science*, 34(4), 625-636.
- Li, W., & Hsu, C. Y. (2022). GeoAI for large-scale image analysis and machine vision: Recent progress of artificial intelligence in geography. *ISPRS International Journal of Geo-Information*, 11(7), 385.
- Xie, Y., Jia, X., Chen, W., & He, E. (2023). Heterogeneity-Aware Deep Learning in Space: Performance and Fairness. In *Handbook of Geospatial Artificial Intelligence* (pp. 151-176). CRC Press.
- Mai, G., Li, Z., & Lao, N. (2023). Spatial Representation Learning in GeoAI. In *Handbook of Geospatial Artificial Intelligence* (pp. 99-120). CRC Press.
- Wang, S., & Li, W. (2021). GeoAI in terrain analysis: Enabling multi-source deep learning and data fusion for natural feature detection. *Computers, Environment and Urban Systems*, 90, 101715.
- Gonzales-Inca, C., Calle, M., Croghan, D., Torabi Haghighi, A., Marttila, H., Silander, J., & Alho, P. (2022). Geospatial artificial intelligence (GeoAI) in the integrated hydrological and fluvial systems modeling: review of current applications and trends. *Water*, 14(14), 2211.

