EarthCARE 2026 Science and Validation workshop

8–12 June 2026 | Rhodes House | Oxford, UK

Quantifying the capabilities and limitations of passive remote sensing of clouds at high latitudes using EarthCARE active measurements

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- EarthCare (**EC**) instrument synergy offers superior cloud data products
  - As well as a unique opportunity to assess the capabilities of individual instruments like the passive Multi Spectral Imager (**MSI**)

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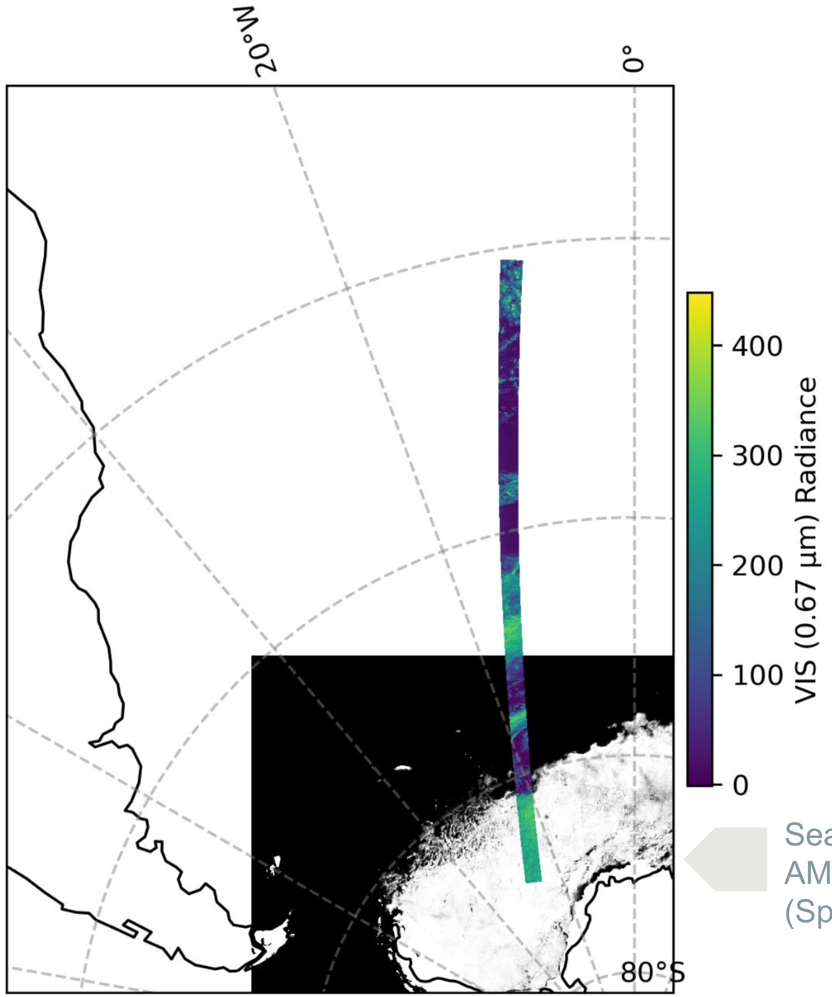
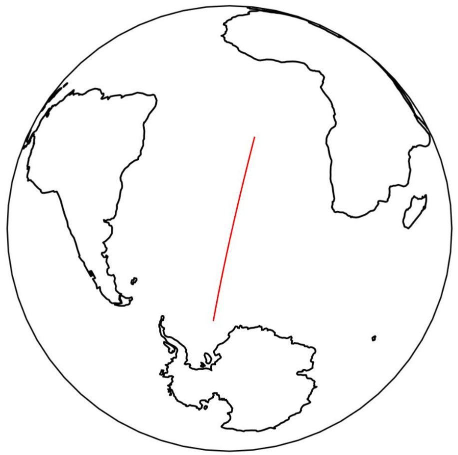
- 2 Vertical Cloud Structures
  - **Homogenous (H)**
    - constant liquid and ice water content along the vertical column
  - **Split (S)**
    - ice water content at the top, liquid water content at the bottom

Results

- Test Case: **2025.11.22**
  - **22-67°** South
  - ca. **15:00** UTC





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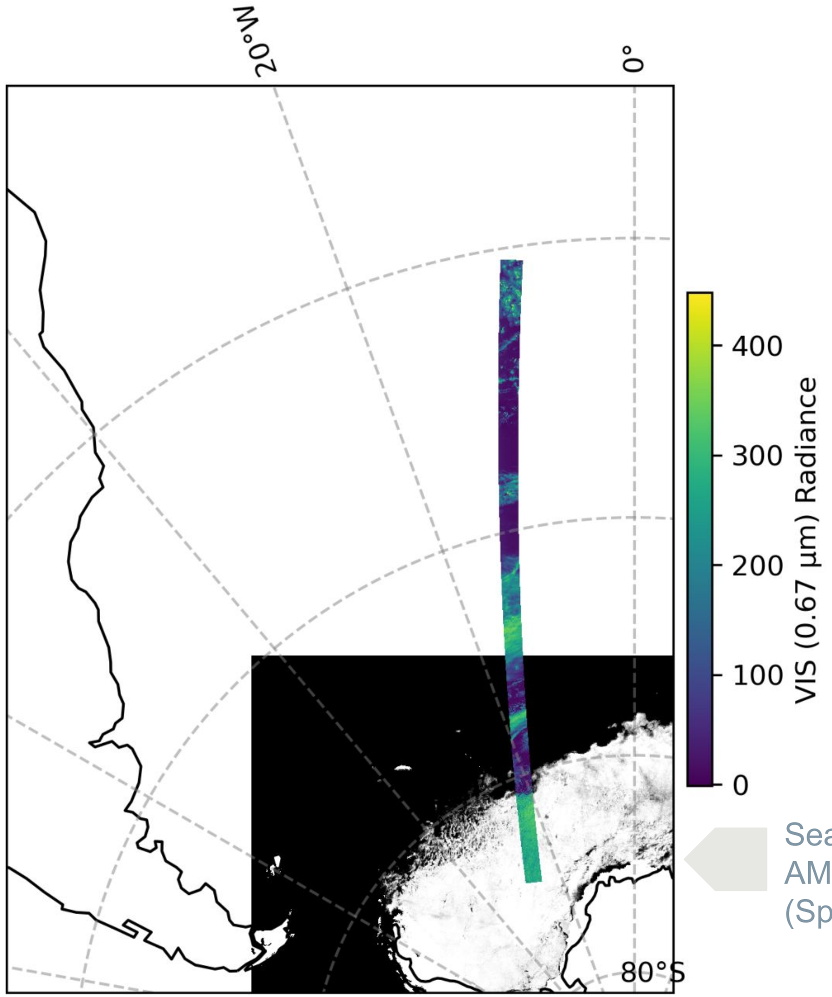

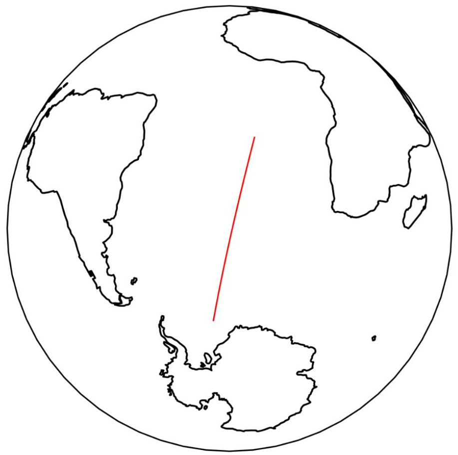

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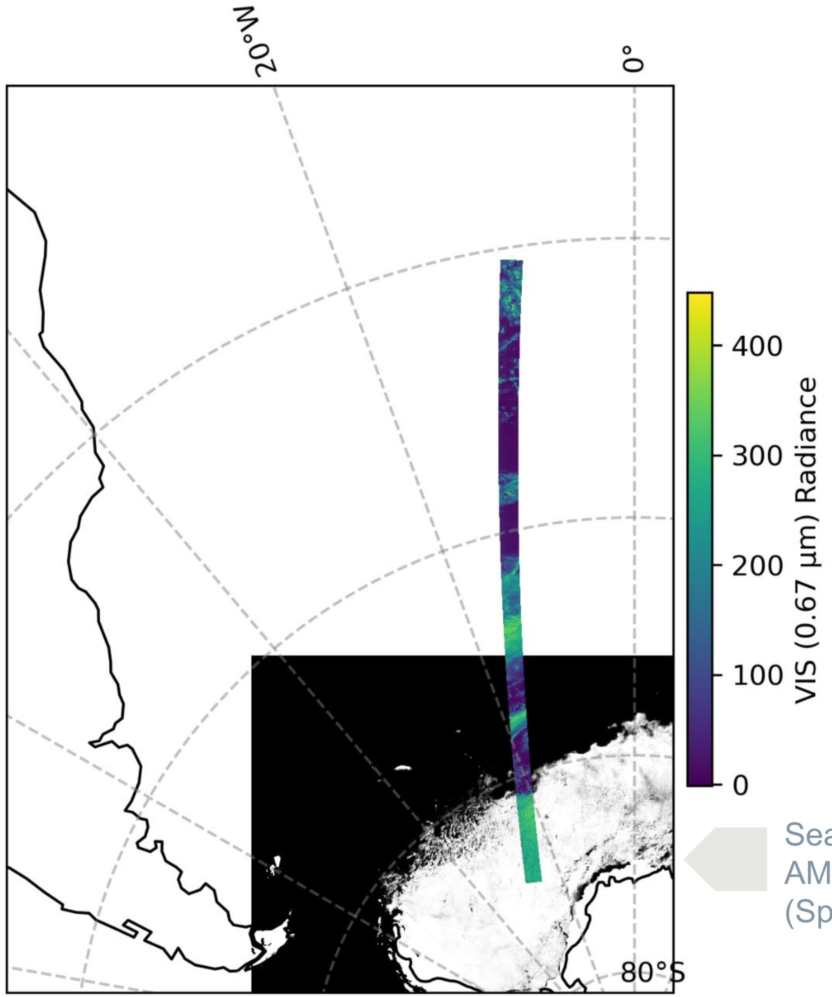
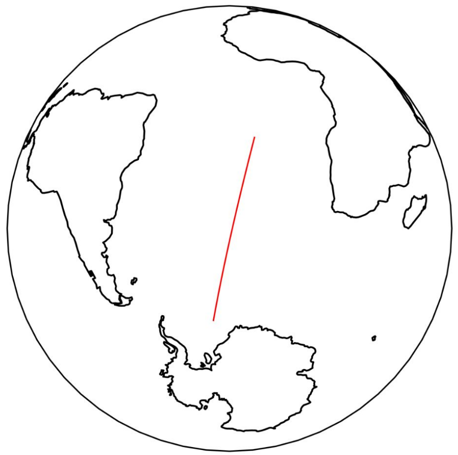
  - A heterogeneous selection of cloud and surface types





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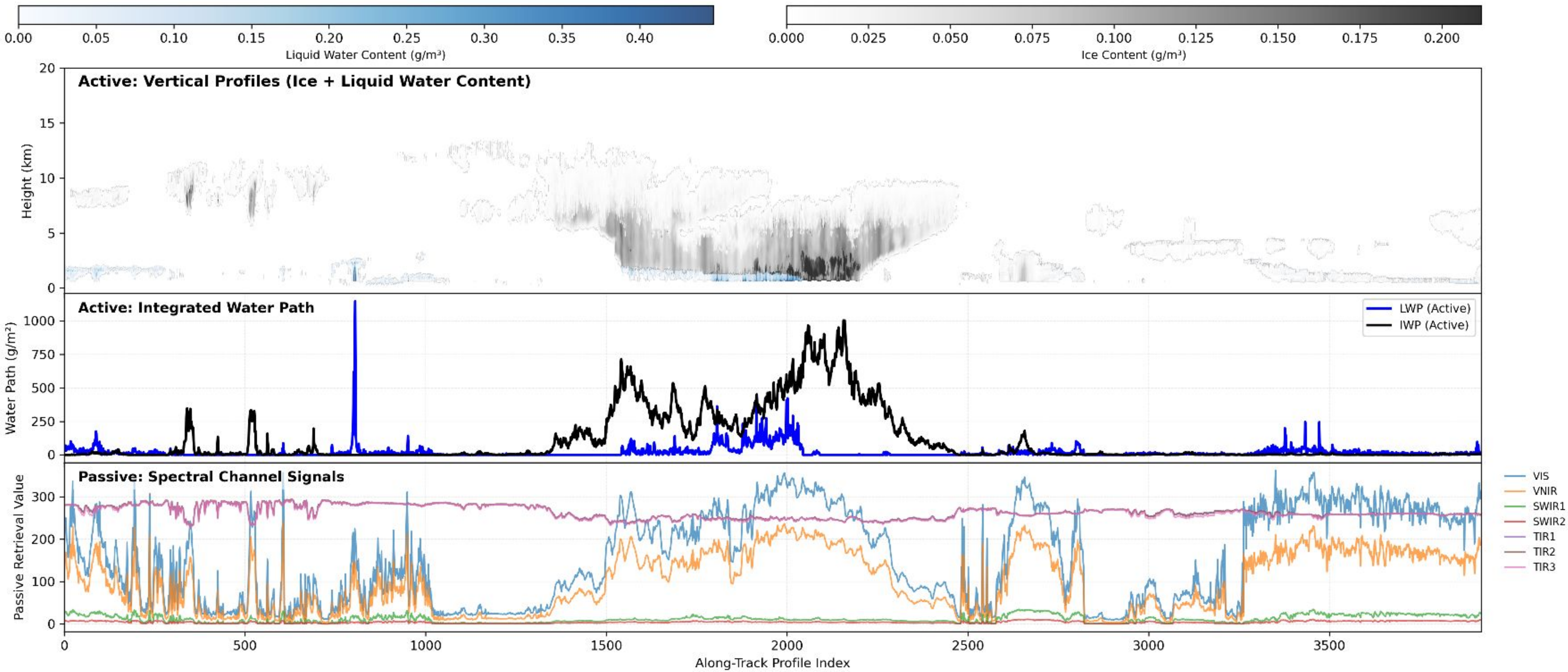

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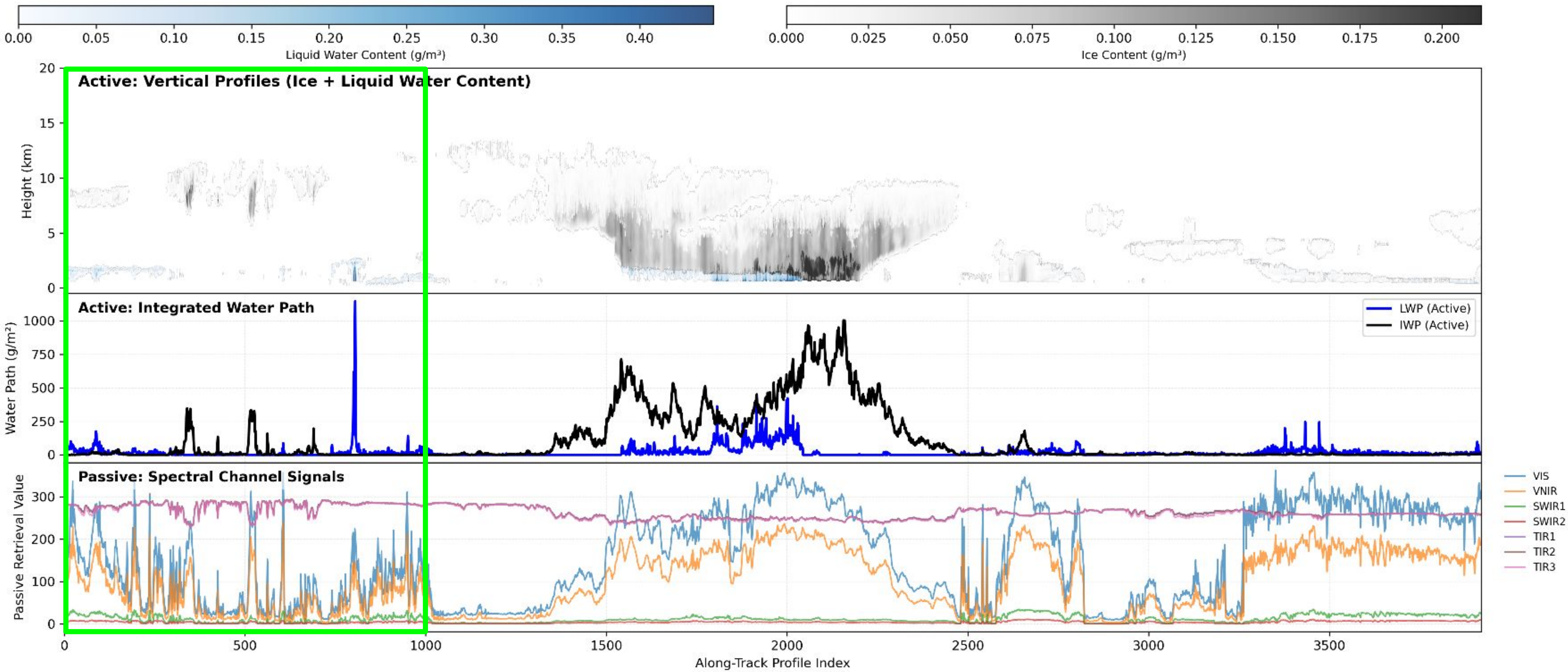

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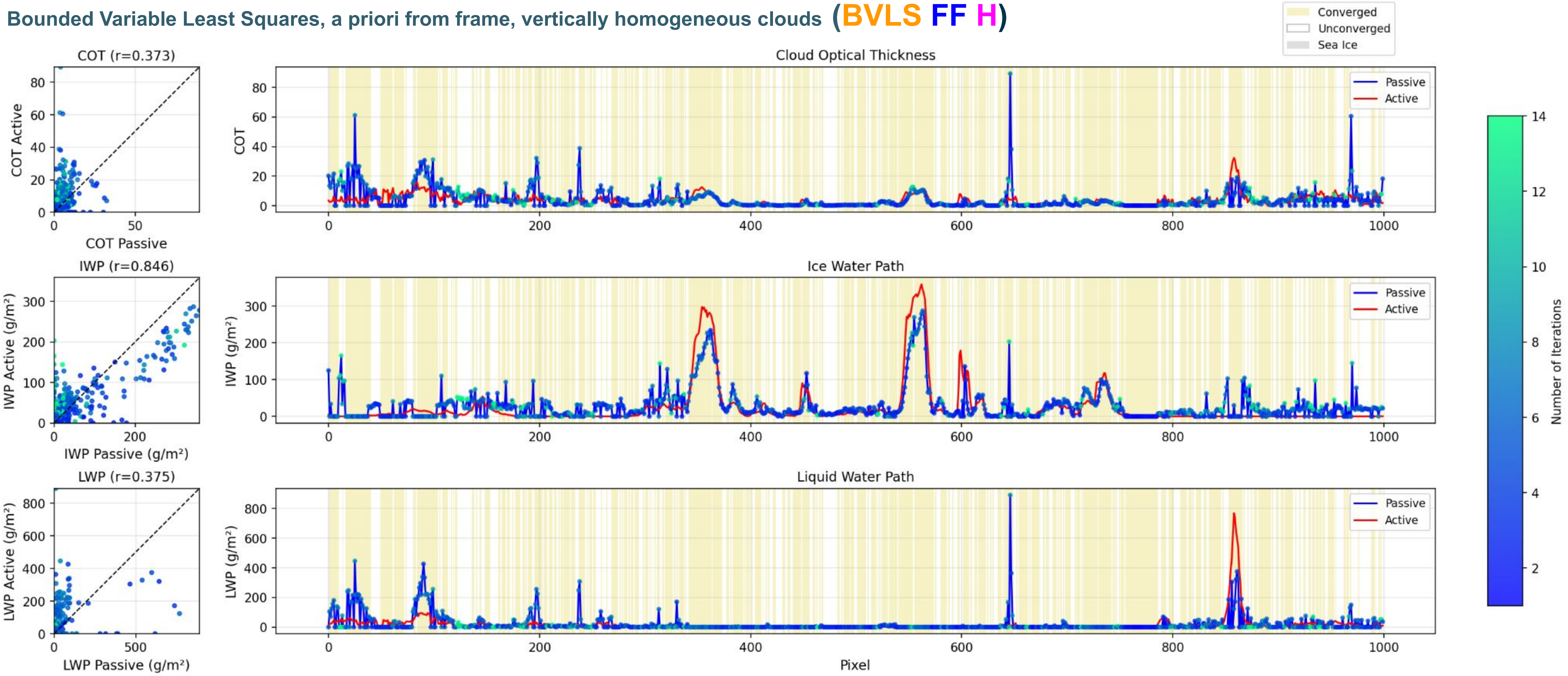

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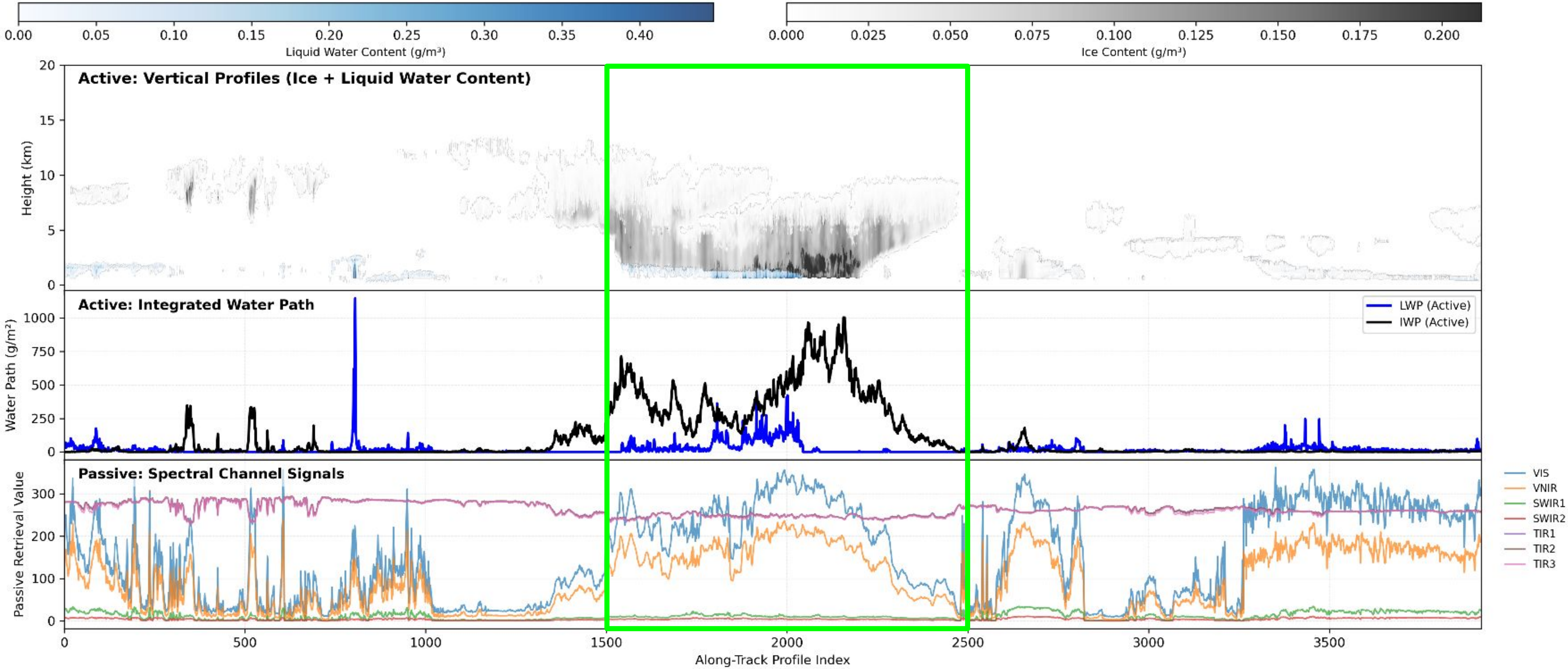

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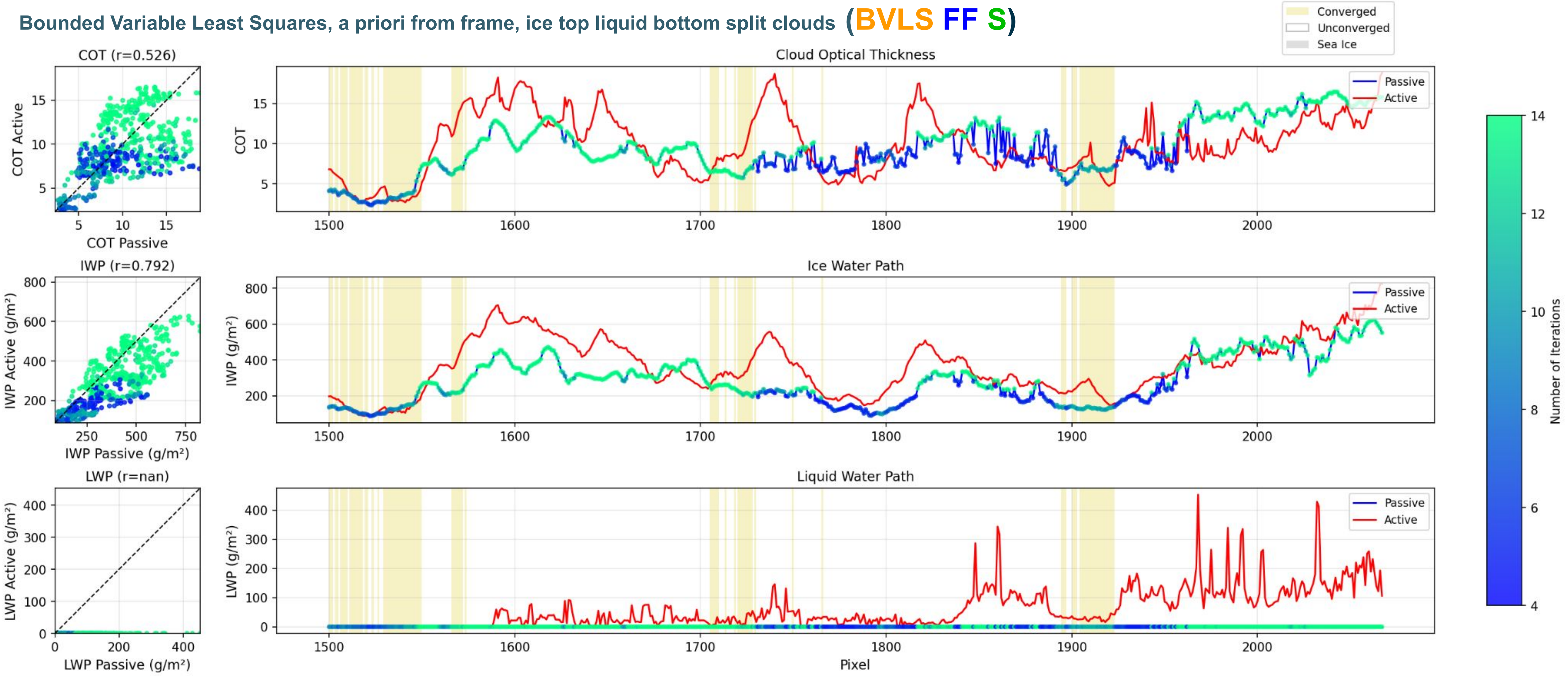

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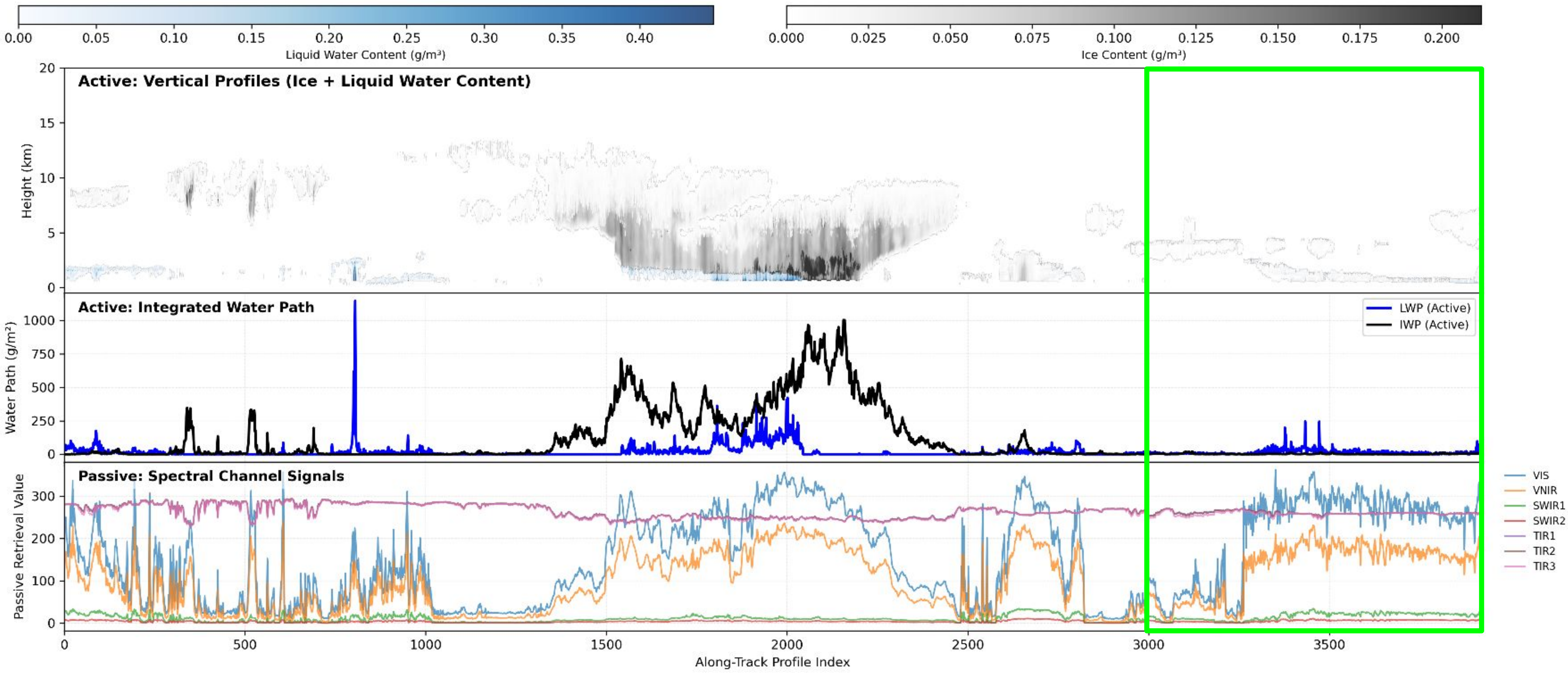

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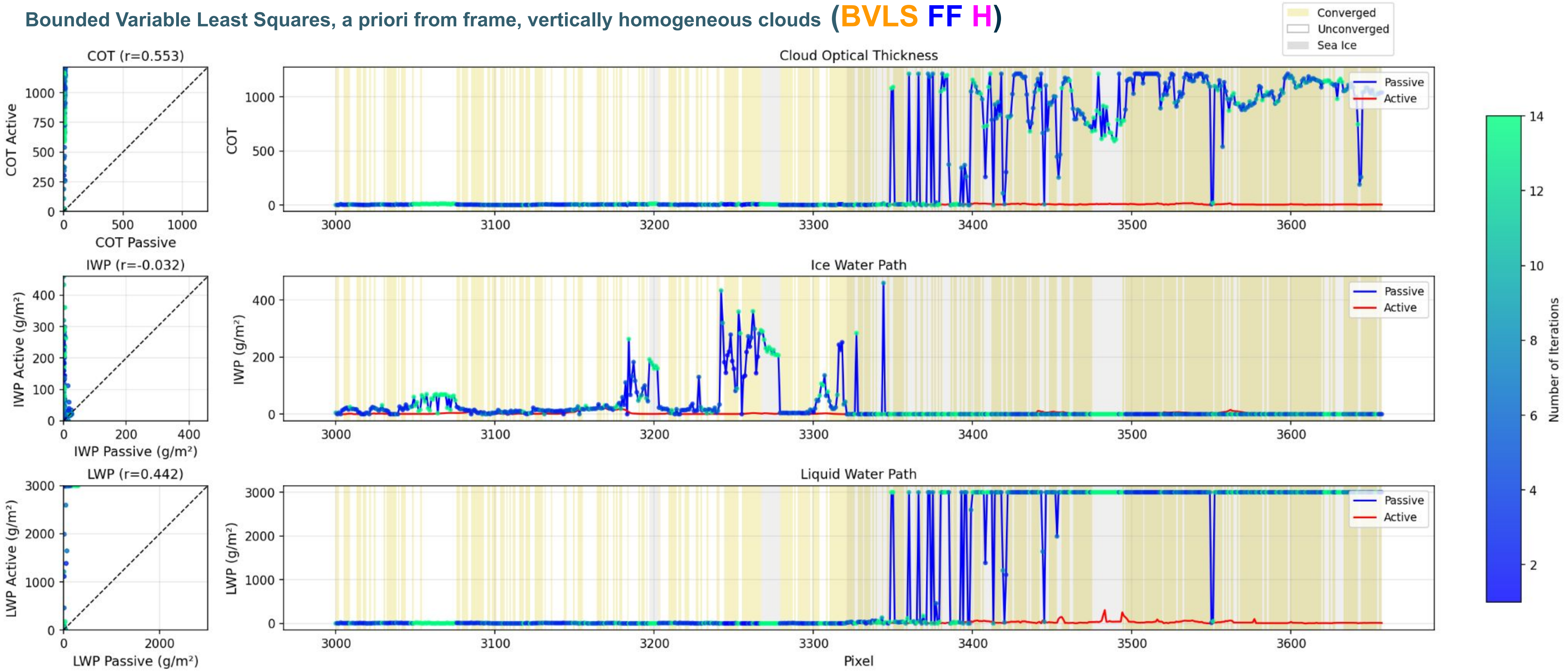

Conclusion

- SCIATRAN **BVLS** picks up on IWP, and to a lesser extent on LWP, over open ocean without pre-retrieval cloud phase classification

- A priori information, especially on the structure of clouds, matters

- **PRSC** over bright sea ice currently not possible with the data and methods used in this study

Outlook

- **EC** instrument synergy enables straightforward comparison of spatiotemporally coincident active and passive datasets
  - This provides a means to quantify the capabilities and limitations of **PRSC**
    - *Importantly*, the comparison spans the entire **EC** data record, rather than a small overlapping subset

References

- Sato, K., Okamoto, H., Nishizawa, T., Jin, Y., Nakajima, T. Y., Wang, M., Satoh, M., Roh, W., Ishimoto, H., and Kudo, R.: JAXA Level 2 cloud and precipitation microphysics retrievals based on EarthCARE radar, lidar, and imager: the CPR_CLP, AC_CLP, and ACM_CLP products, Atmos. Meas. Tech., 18, 1325–1338, https://doi.org/10.5194/amt-18-1325-2025, 2025.
- V. Rozanov, A. Rozanov, A. Kokhanovsky, and J. Burrows, "Radiative transfer through terrestrial atmosphere and ocean: Software package SCIATRAN," J. Quant. Spectrosc. Radiat. Transf., vol. 133, pp. 13–71, Jan. 2014.
- Mei, L., Rozanov, V., Rozanov, A., and Burrows, J. P.: Modeling of radiative transfer through cryospheric Earth system: software package SCIATRAN, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-4846, 2025.
- Spreen, G., L.Kaleschke, and G.Heygster (2008), Sea ice remote sensing using AMSR-E 89-GHz channels, J. Geophys. Res., 113, C02S03, doi:10.1029/2005JC003384.

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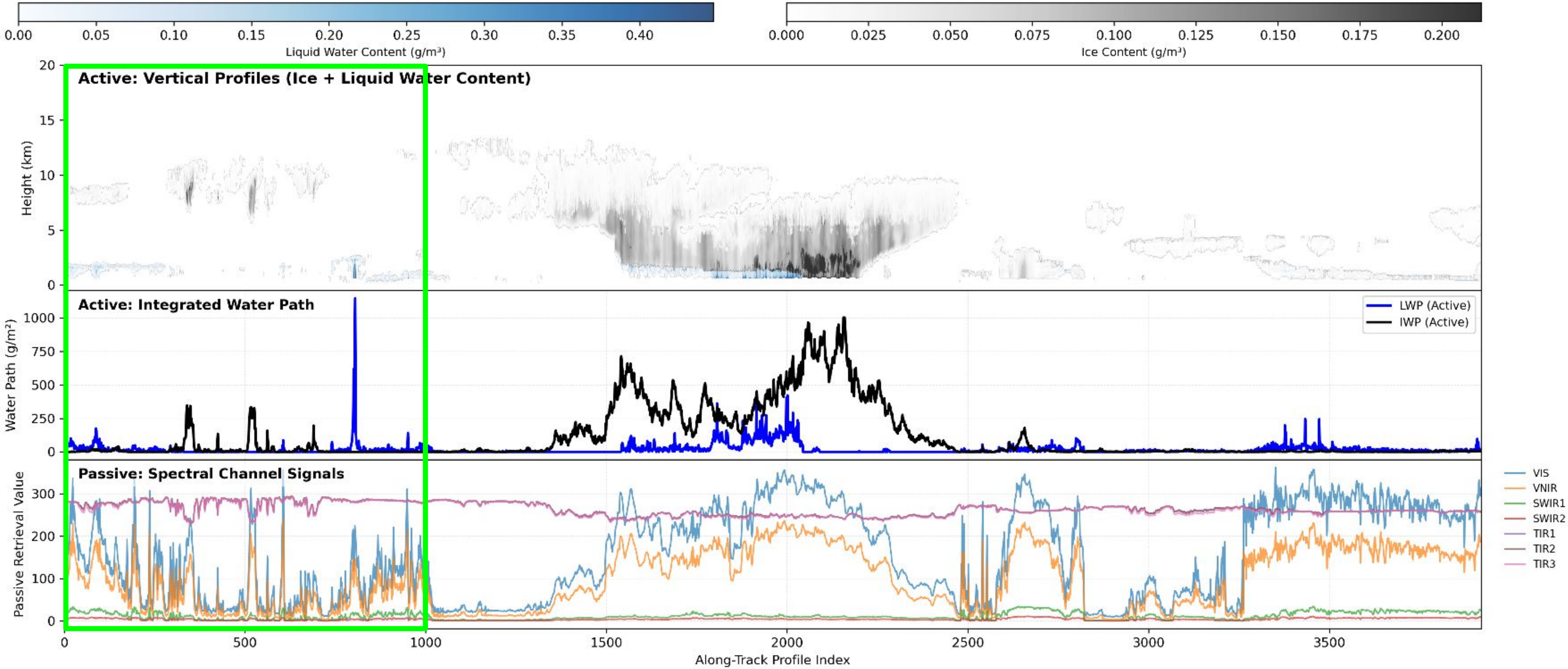
Extra Slides



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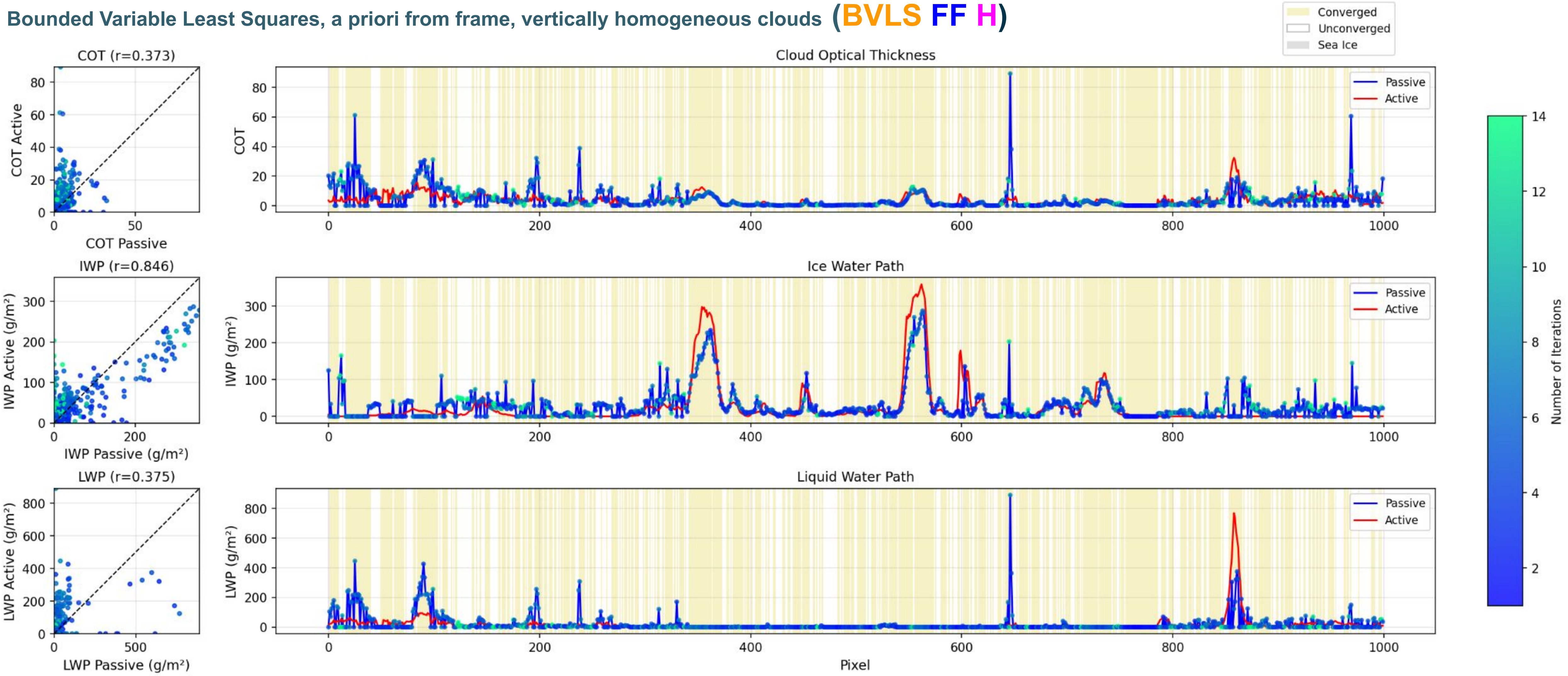

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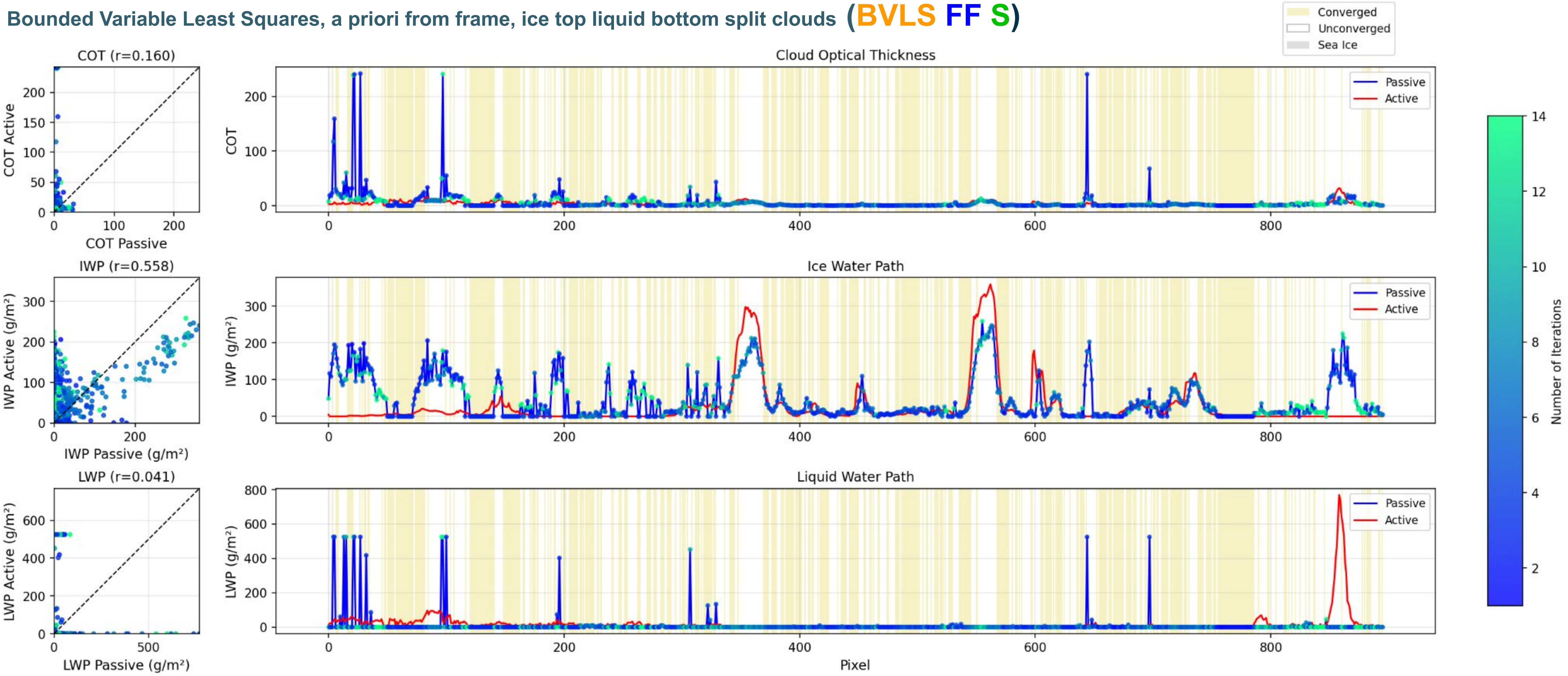

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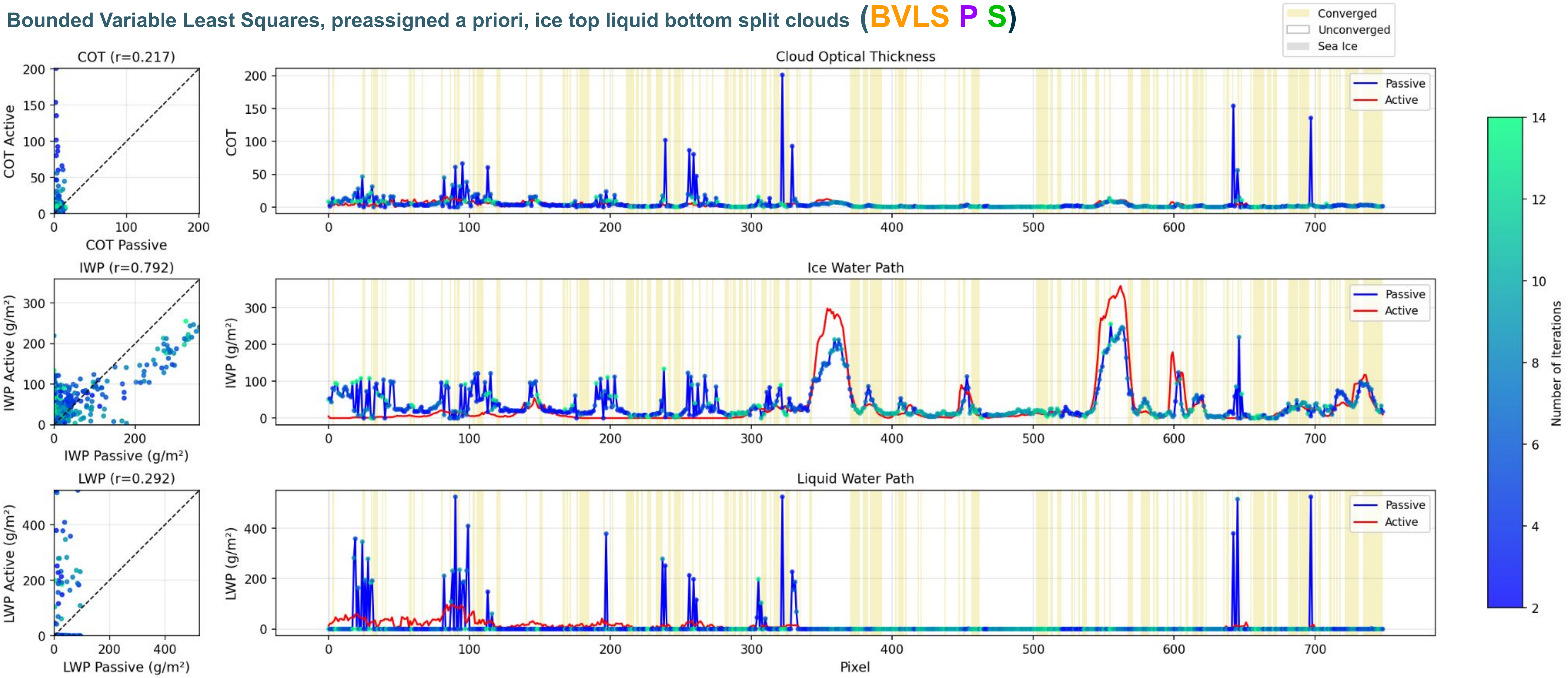
Bounded Variable Least Squares, preassigned a priori, ice top liquid bottom split clouds (BVLS P S)



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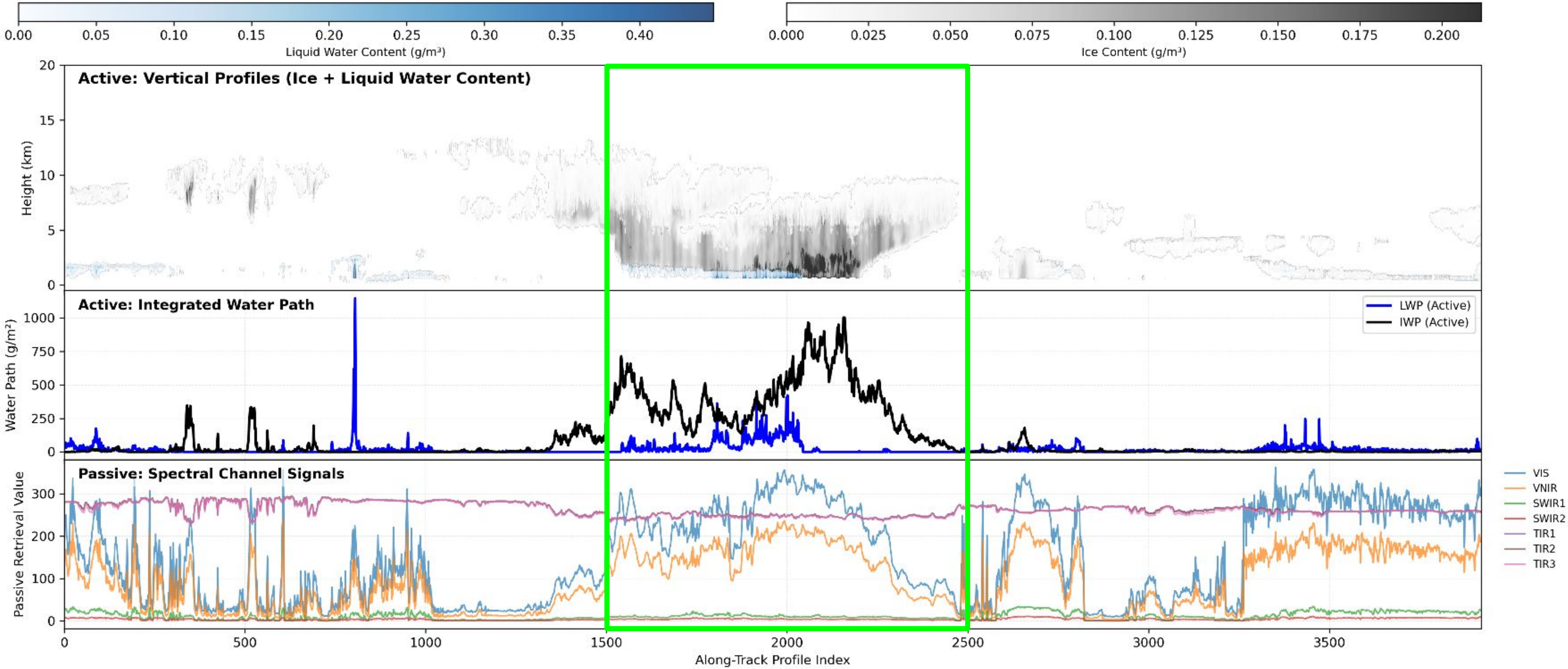

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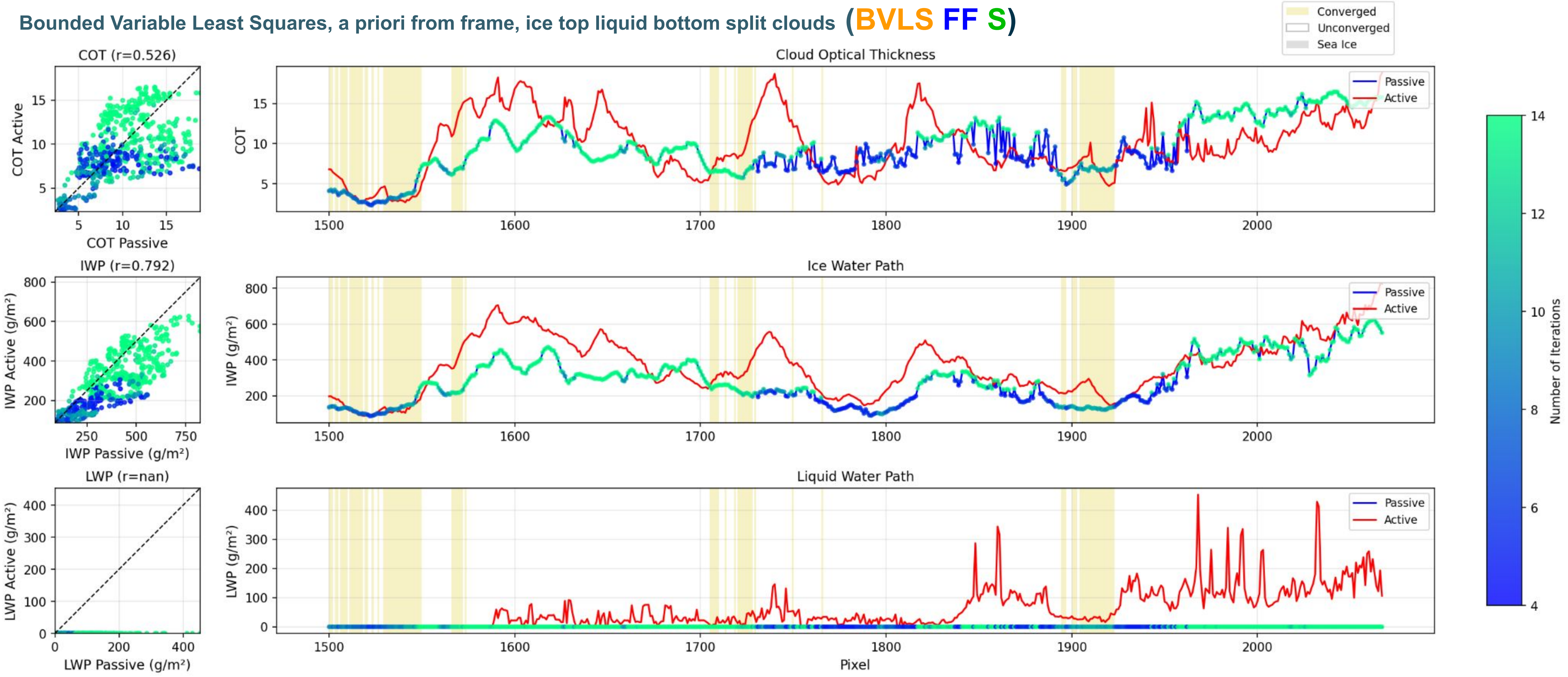

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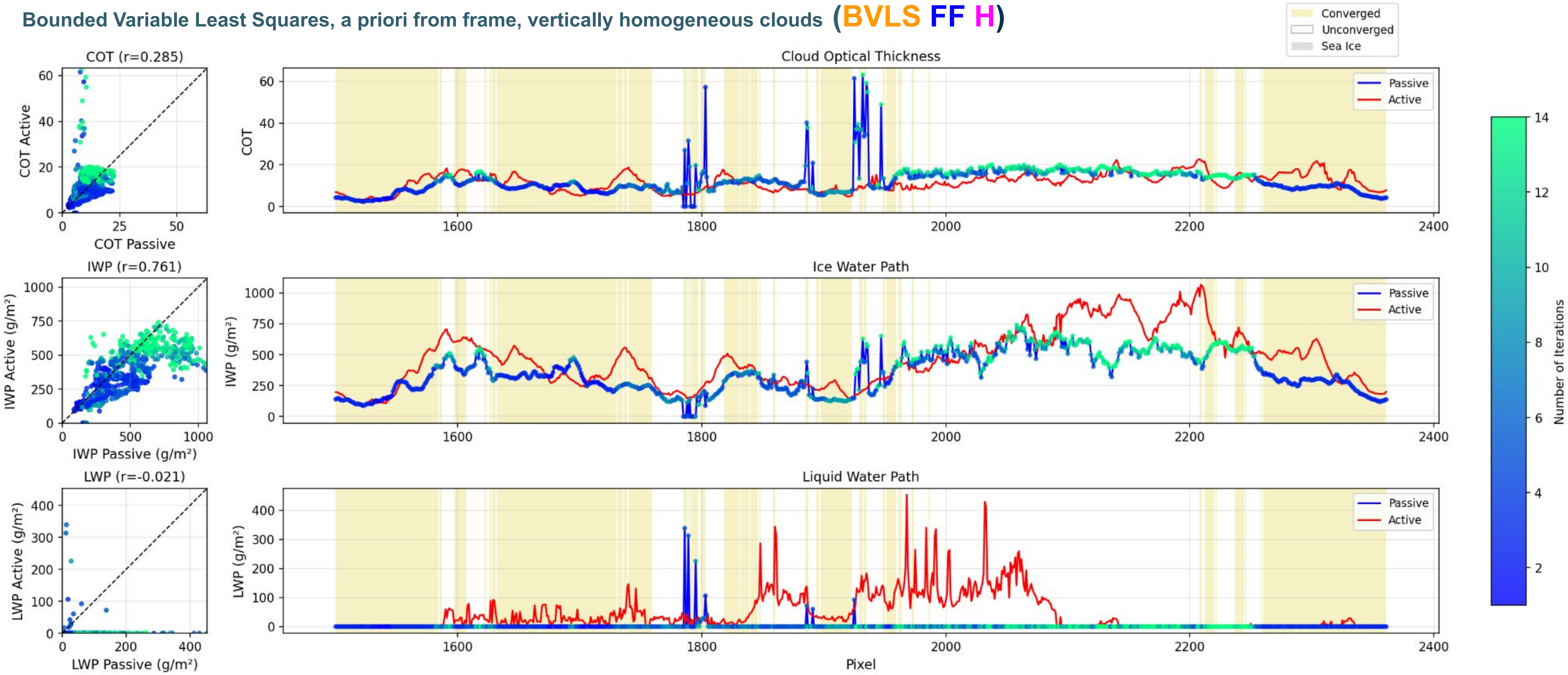

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