Topical Discussion Meeting report (ESWW25 TDM13)

A Topical Discussion Meeting aims at active participation or interaction between the participants. The participants work and discuss on a predefined theme or problem heading towards an outcome or target. A working meeting is a 1h informal afternoon meeting with NO abstract submission form and therefore NO poster contributions.

Name of the meeting: Scientific Outlooks for the Analysis of Space Weather Data in the Age of AI
Convener/s: Stefaan Poedts, Panagiotis Gonidakis, Ekaterina Dineva, George Miloshevich
Secretary: Panagiotis GONIDAKIS
Date – Time – Room: Thursday October 30th 2025, 17h00, Room: Idun
# of attendees (approximate): ~50
Speakers, if any (names and institution):

1. Jasmina Magdalenić Zhukov (in person)
    - CmPA, KULeuven, Belgium
    - Royal Observatory of Belgium

2. Hannah Ruedisser (in person)
    - Austrian Space Weather Office

3. Matthew West (in person)
    - Vigil Mission Scientist, European Space Agency (ESA)

4. Savvas Raptis (online)
    - Johns Hopkins University, Applied Physics Laboratory at the Space Exploration Sector.

Form of TDM: Panel Forum

Objective of the TDM

Artificial intelligence is rapidly transforming how we analyze and forecast space weather phenomena. From automated event detection and solar image segmentation to data-driven forecasting models, AI holds great promise for enhancing both scientific understanding and operational capabilities. However, realizing this potential requires overcoming key challenges related to data access, model reliability, interpretability, and interdisciplinary collaboration.
This topical discussion aims to exchange perspectives on the current state and future directions of AI in space weather, exploring the practical steps needed to move from research innovation to trustworthy, operational applications.

The conveners initially suggested covering the following discussion topics:

1. Transition to Operations
2. Open Access and Interdisciplinary Collaboration
3. Trustworthiness and Uncertainty

4. Physics-Informed Learning
5. Event Detection and Annotation
6. Space exploration and onboard AI
7. Foundation Models and Benchmarking

Discussion highlights

The topical discussion TDM13, "Scientific Outlooks for Analysis of Space Weather Data in the Age of AI," brought together researchers, forecasters, and engineers to exchange views on how artificial intelligence can advance space weather science and operations.

The conversation revolved around the trustworthiness of AI models, the transition from research to operations, data accessibility, event detection, onboard applications, and physics-informed approaches. Participants agreed that before AI tools can be integrated into operational environments, they must be both reliable and practical, with rigorous validation processes carried out first by research teams and then collaboratively with forecasting centers.

Ensuring real-time data availability and maintaining human oversight were seen as essential steps, as AI should assist rather than replace human expertise. The importance of data quality and open access was repeatedly highlighted, with the need to construct balanced and transparent datasets that avoid biases and support reproducibility. The forthcoming Vigil mission was mentioned as an encouraging example, providing rapid, multi-level data access to the community.

Participants also discussed the growing interest in physics-informed and foundation models, emphasizing that while these methods hold promise, their integration of physical principles is often superficial and requires clearer terminology and careful validation. Event detection emerged as a key application area, but challenges remain due to conflicting catalogues, subjective annotations, and limited ground truth, suggesting that unsupervised learning and hybrid human–AI systems could play a valuable role.

The discussion also explored the potential of onboard AI for real-time event identification and data prioritization, for example by transmitting coronal data first when a CME is detected, while acknowledging current hardware and calibration limitations. Throughout the session, collaboration between AI engineers and domain scientists was identified as essential to develop tools that are scientifically meaningful, operationally useful, and technically robust. In conclusion, participants agreed that progress in this field depends on transparent validation, open data practices, and continuous cross-disciplinary cooperation, ensuring that AI-driven methods enhance rather than obscure our understanding of the Sun and its effects on space weather.

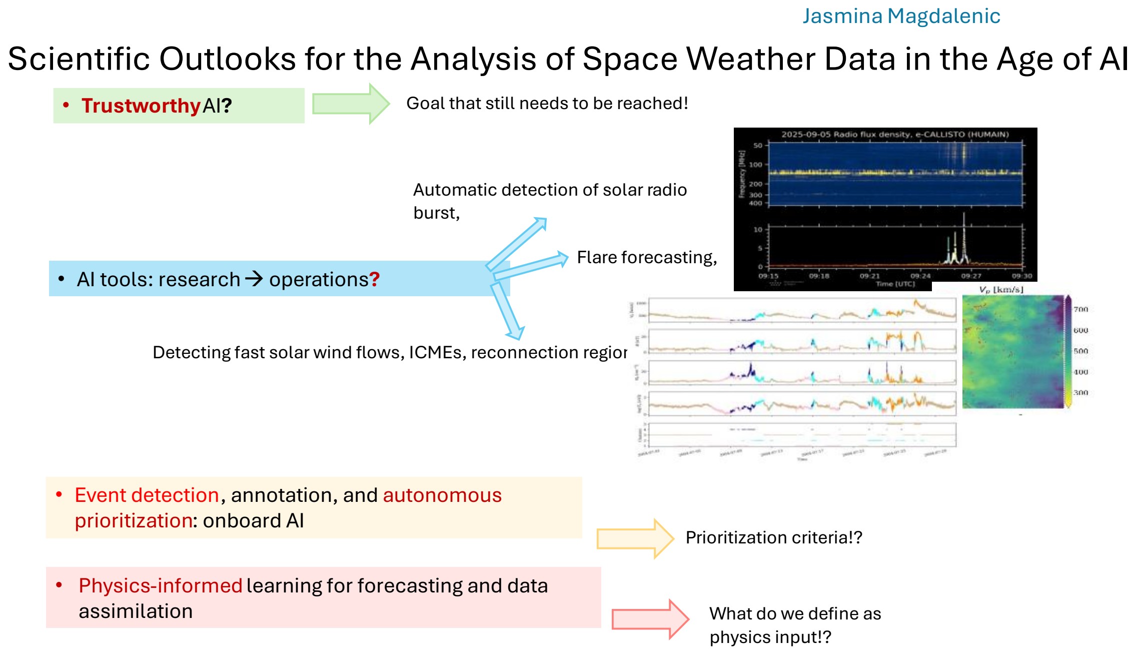
Main conclusion of the meeting

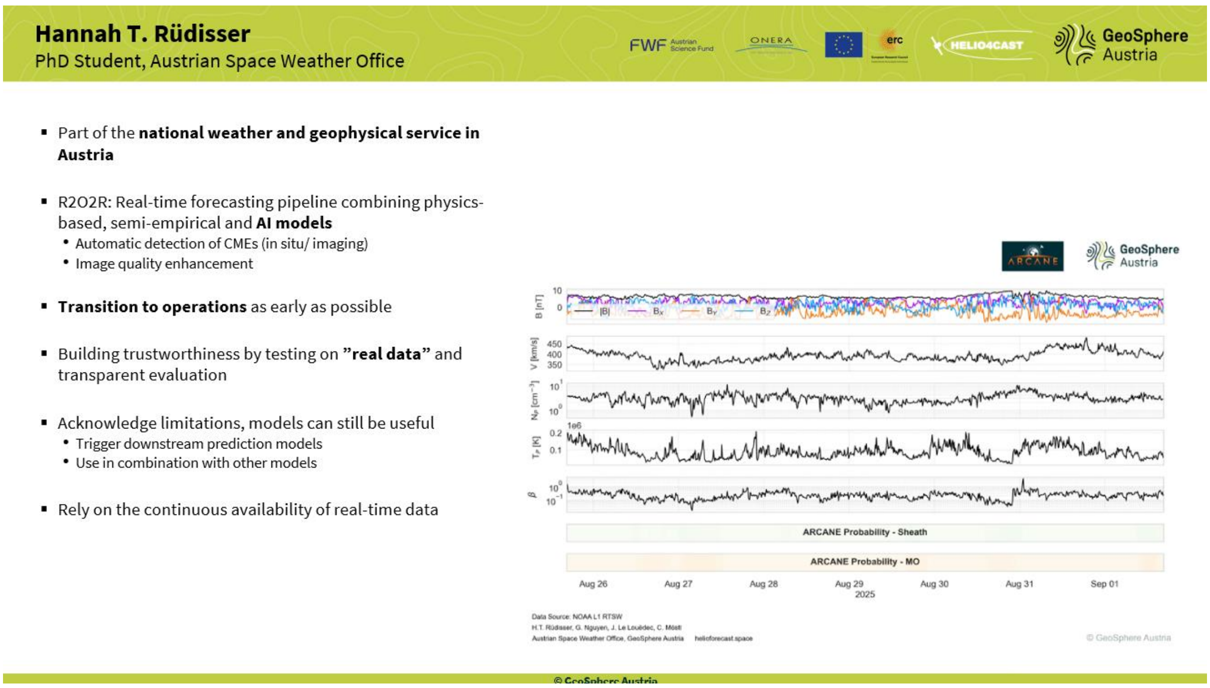
The main conclusion of TDM13 was that trustworthy, transparent, and well-validated AI methods can significantly advance space weather forecasting, but their successful adoption depends on close collaboration between researchers, engineers, and operational forecasters. Participants agreed that open, high-quality data and reproducible workflows are essential to ensure both scientific credibility and operational usability. While physics-informed and foundation models offer exciting possibilities, they must be critically evaluated for their true physical relevance and robustness across solar cycles.

Overall, AI should be seen as a supportive tool that enhances human decision-making rather than replaces it, enabling a more reliable and efficient transition from research to operations.

Annexes

Panelists' initial reflections shared with the conveners prior to the TDM:





Matthew West – Vigil Mission Scientist

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1. Transition to Operations: Vigil's long-term calibrated data enable robust AI training and validation for operational forecasting.

2. Open Access and Interdisciplinary Collaboration: Vigil data will be openly available, fostering transparent collaboration.

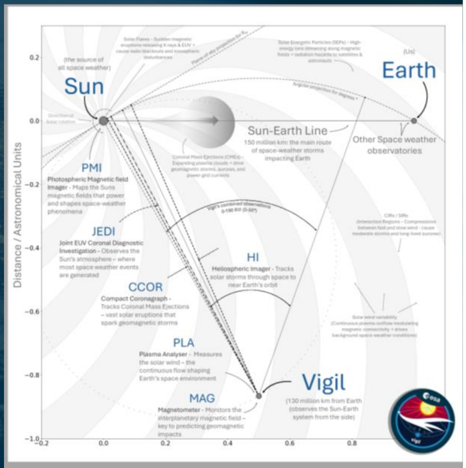
3. Trustworthiness and Uncertainty: Science-quality calibration and metadata traceability will "enable" reliable AI model development and quantifiable uncertainty.

4. Physics-Informed Learning: Vigil's stable, multi-instrument dataset supports hybrid AI-physics models.

5. Event Detection and Annotation: Best defined by end-user needs and operational priorities.

6. Autonomous Event Prioritization: Future Vigil missions may use onboard AI for adaptive data prioritization.

7. Foundation Models and Benchmarking: Vigil based models can be used with L1 data providers for benchmarking.



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Savvas Raptis
Johns Hopkins Applied Physics Laboratory (JHU/APL)

LMAG25

Initial Reflections:

- Operations: We need simpler, robust methods with extreme statistics analysis
- Open Access: Yes! ☺
- Physics-Informed Learning: Potentially limited? All plasma descriptions (MHD/Vlasov etc.) can be less descriptive than observations. *Relying on theoretical frameworks = bias towards specific descriptions*
- Event Detection and Annotation : We need a straightforward way to generate lists and cross -validate

Key challenges I see:

Data sparsity remains challenging. We require more data, better intercalibration, and coordinated efforts

Metrics for extremes must target rare events specifically, not average behavior, averages are predictable and misleading due to frequent quiet periods

https://savvasraptis.github.io

Relevant meeting 2 weeks ago (meeting report and presentations soon!): https://www.lmag25.com