SIRENE
Satellite Information for Resilience monitoring and Early warning of Ecosystem tipping points

Technical University of Munich
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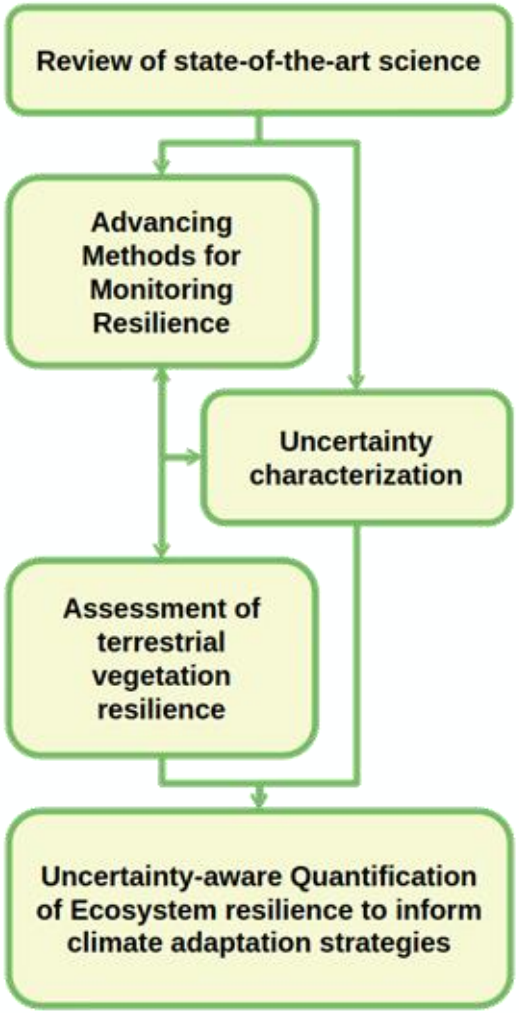
Project Objectives

ITT “CLIMATE-SPACE: TIPPING ELEMENTS ACTIVITY”

1. Review the **knowledge gaps** and provide a definition for the project activities including the development of comprehensive requirements for addressing these knowledge gaps.
2. Develop and define the **methodology for the Tipping Elements scientific analyses** to explore the key knowledge gaps identified in Task T1.
3. Demonstrate the **value of satellite data to investigate the knowledge gaps** in climate science identified by the scientific community, addressing stream 2.
4. Define the **strategy for handling uncertainties, error propagation and validation**, and carry out a verification of the results for the main analysis work, documenting the findings and quantifying uncertainty estimates. This includes ensuring that uncertainties are useable and fit-for-purpose.
5. Manage the project and maximise the impact of the project by promoting its scientific results.

Project Objectives



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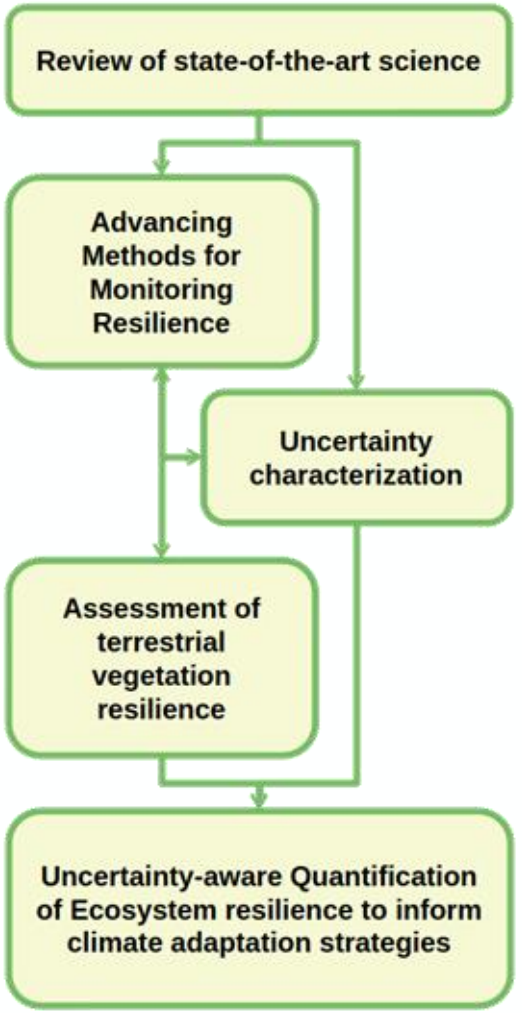


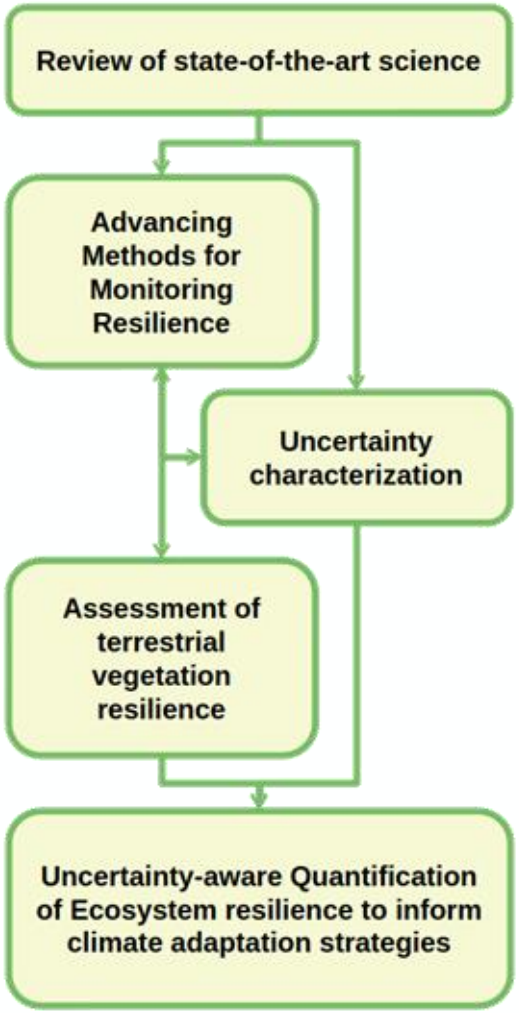
Work package and task description	involved partners	year 1				year 2				year 3			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
TASK 1 – Project definition and science requirements analysis													
Task 1.1: Literature review and project plan	ULEIP, TUM, TUW, NPL, ULISB		D1.1 (v1)						D1.1 (v2)				
Task 1.2: Inventory of data and tools to analyse vegetation resilience	ULISB, TUW, ULEIP, TUM		D1.2										
TASK 2 – Development of method for scientific analysis: advancing methods for monitoring resilience													
Task 2.1: Dataset quality assessment + consolidation	TUW, NPL, ULISB												
Task 2.2: Advancement of resilience metrics	TUM, NPL												
Task 2.3: Consistency assessment and benchmarking of resilience metrics and vegetation indicators	TUM, TUW, ULISB, ULEIP				D2.1 (v1)				D2.1 (v2)				
Task 2.4: Assessment of bistability with space-for-time replacement	TUM, ULISB												
TASK 3 – Tipping Elements scientific analysis: assessment of terrestrial vegetation resilience													
Task 3.1: Global resilience quantification	TUM, TUW										D3.1		
Task 3.2: Assessment of trends and climatic drivers	TUM, ULEIP, TUW												
Task 3.3: Uncertainties in global resilience quantification	TUM, TUW, NPL												D3.2
Task 3.4 Uncertainties in resilience trends and climate drivers	TUM, ULEIP, TUW, NPL, ULISB												D3.3
TASK 4 – Uncertainty characterization													
Task 4.1: Establish integrative framework for uncertainty assessment and propagation	NPL, TUW, TUM				D4.1 (v1)								
Task 4.2: Uncertainty impact assessment and fitness for purpose evaluation	NPL, TUM, ULEIP										D4.1 (v2)		
TASK 5 – Management, outreach and communication													
Task 5.1: Project management and reporting	TUM, TUW, NPL, ULEIP, ULISB	D5.1											D5.2
Task 5.2: Outreach and communication	TUM, TUW, NPL, ULEIP, ULISB												D5.3
Payment Milestones	TUM, TUW, NPL, ULEIP, ULISB		M1		M2		M3		M4		M5		M6
Project review meetings	TUM, TUW, NPL, ULEIP, ULISB	x	x		x		x		x		x		x

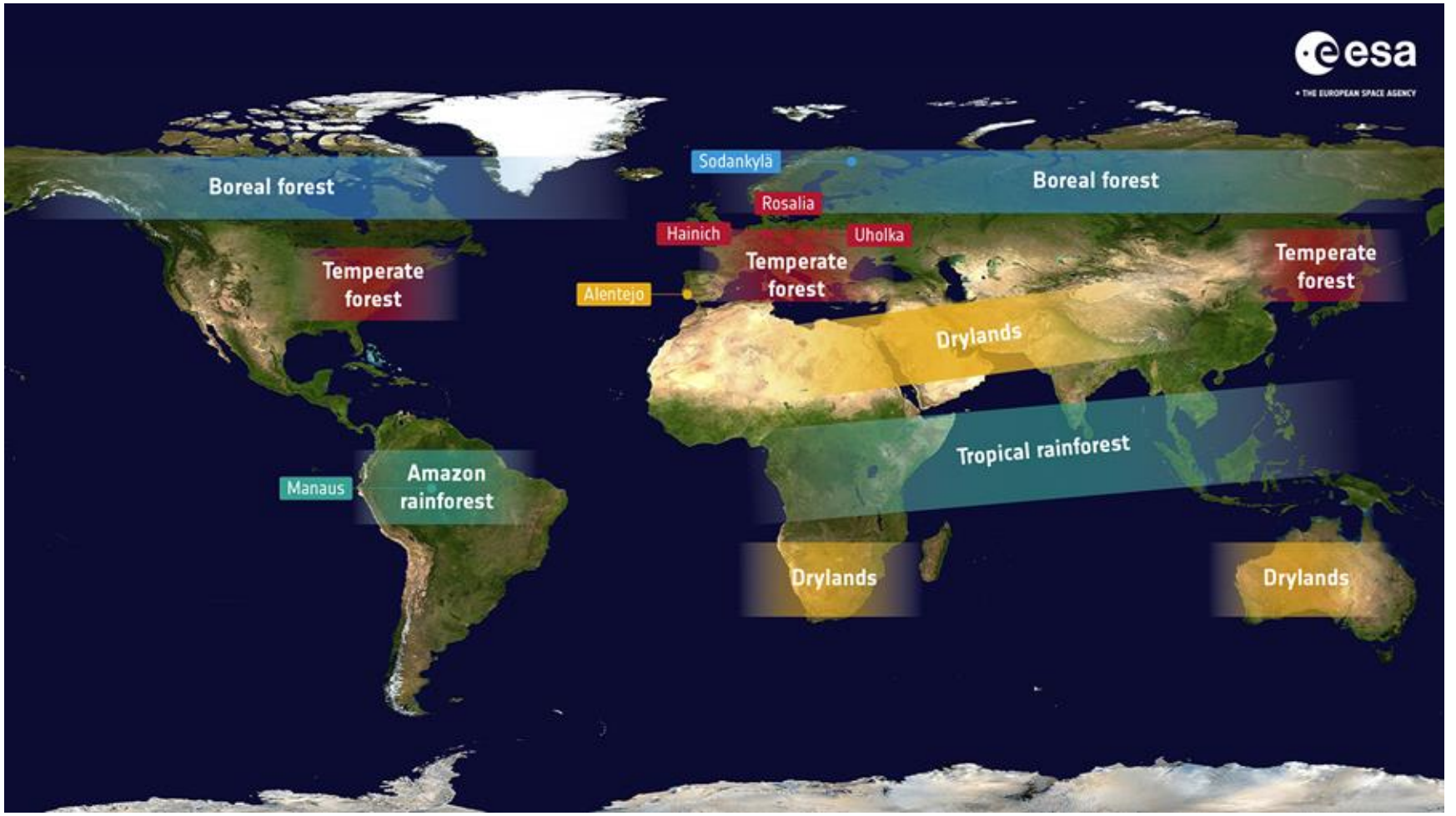
Project Objectives

Connections with:

- CriticalEarth (Horizon2020 ITN)
- ClimTip (HorizonEurope RIA)
- FORTRACK (ESA)
- ForestPaths (HorizonEurope RIA)
- AI4Forest (BMBF)
- NGGM/MAGIC (ESA)
- SING
- NRT-Carbon Extremes (ESA)
- *DeepExtremes (ESA)*
- *ForExD (EU-ERC)*
- *TiPES (Horizon2020 RIA)*
- …

Skeleton overview of the approach





Focus regions of SIRENE and locations of ground-based data

ECVs being used

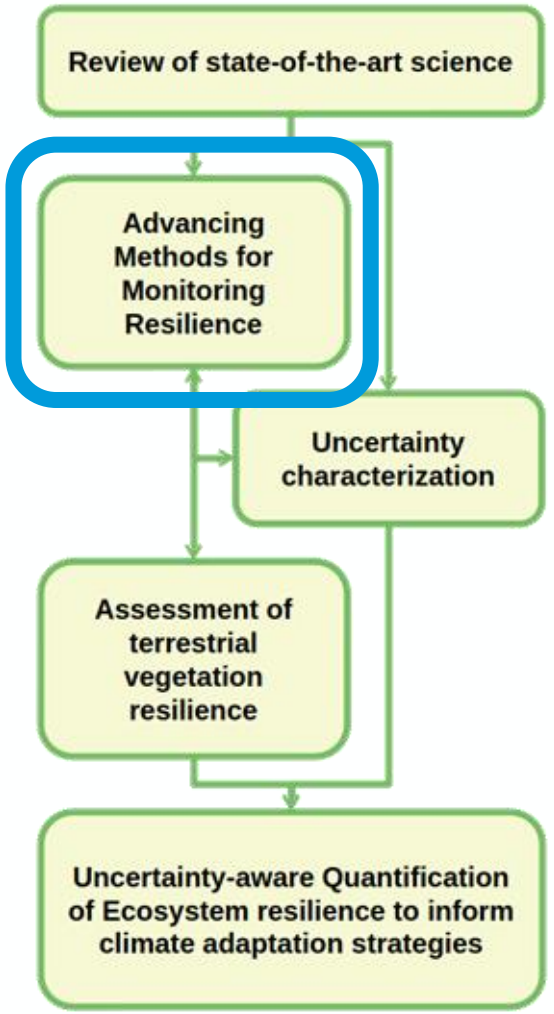
Variables of interest

- Leaf area index (LAI)
- Fraction of absorbed photosynthetically active Radiation (fAPAR)

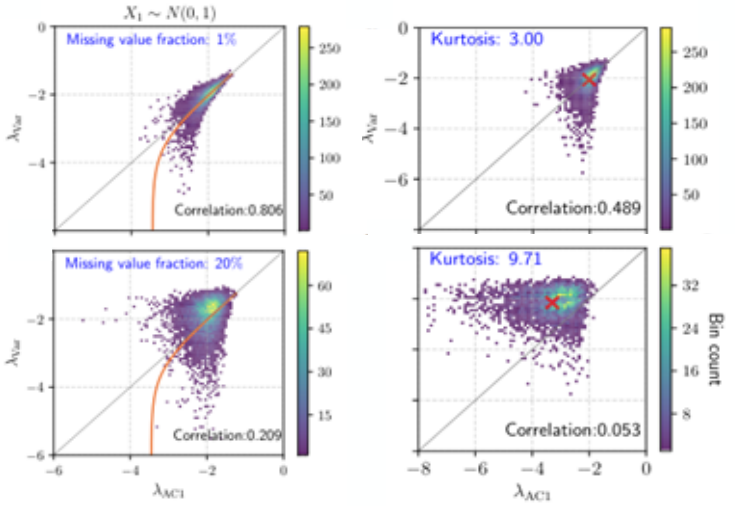
In process of deciding for data sets, available LAI and fAPAR datasets are

- JRC-TIP
  - Full posterior error covariance matrix
  - global
- CCI vegetation
  - Uncertainty for each time step (most mature)
  - not global (yet)
- CGLS
  - Uncertainty estimates for each time step (moderate maturity)
  - global
- MODIS
  - Standard deviation layers for each time step
  - global
- AVHRR
  - Nothing
  - global

(Preliminary) results



1. Understanding data imperfections



Teng Liu, Andreas Morr, Sebastian Bathiany, Lana L. Blaschke, Zhen Qian, Chan Diao, Taylor Smith, Niklas Boers. Data gaps and outliers distort critical slowing down-based resilience indicators. *Science Advances,* 2026. https://doi.org/10.1126/sciadv.aee1916

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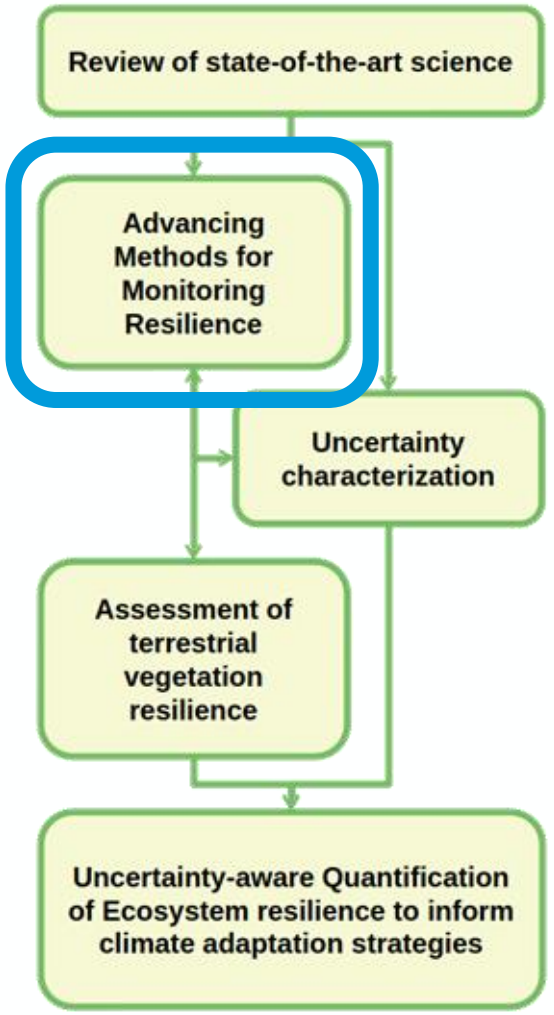

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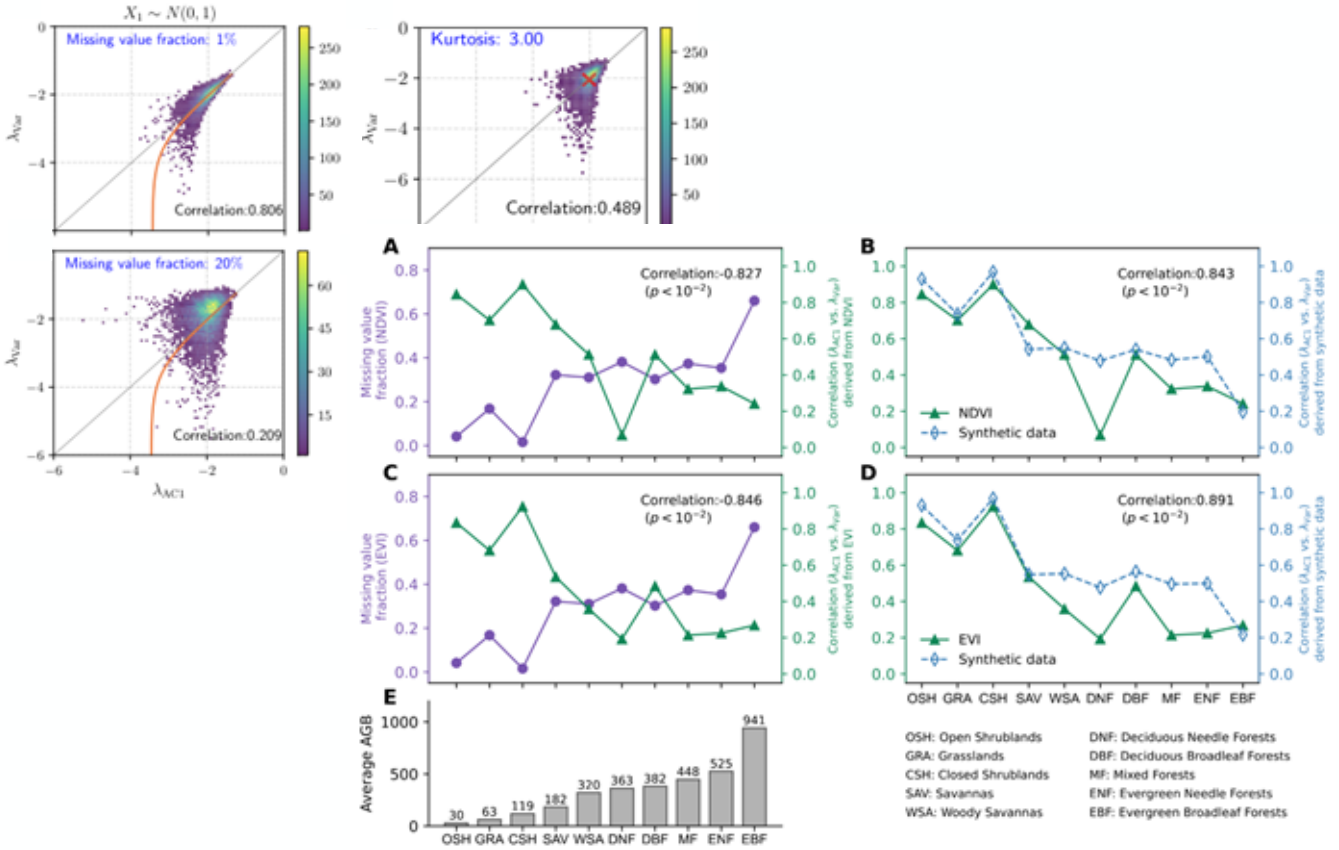

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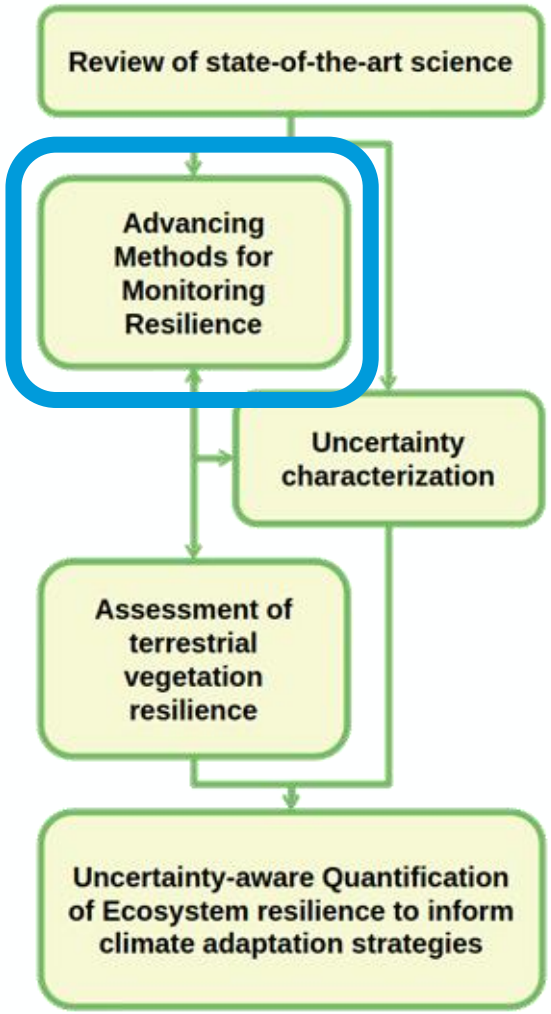
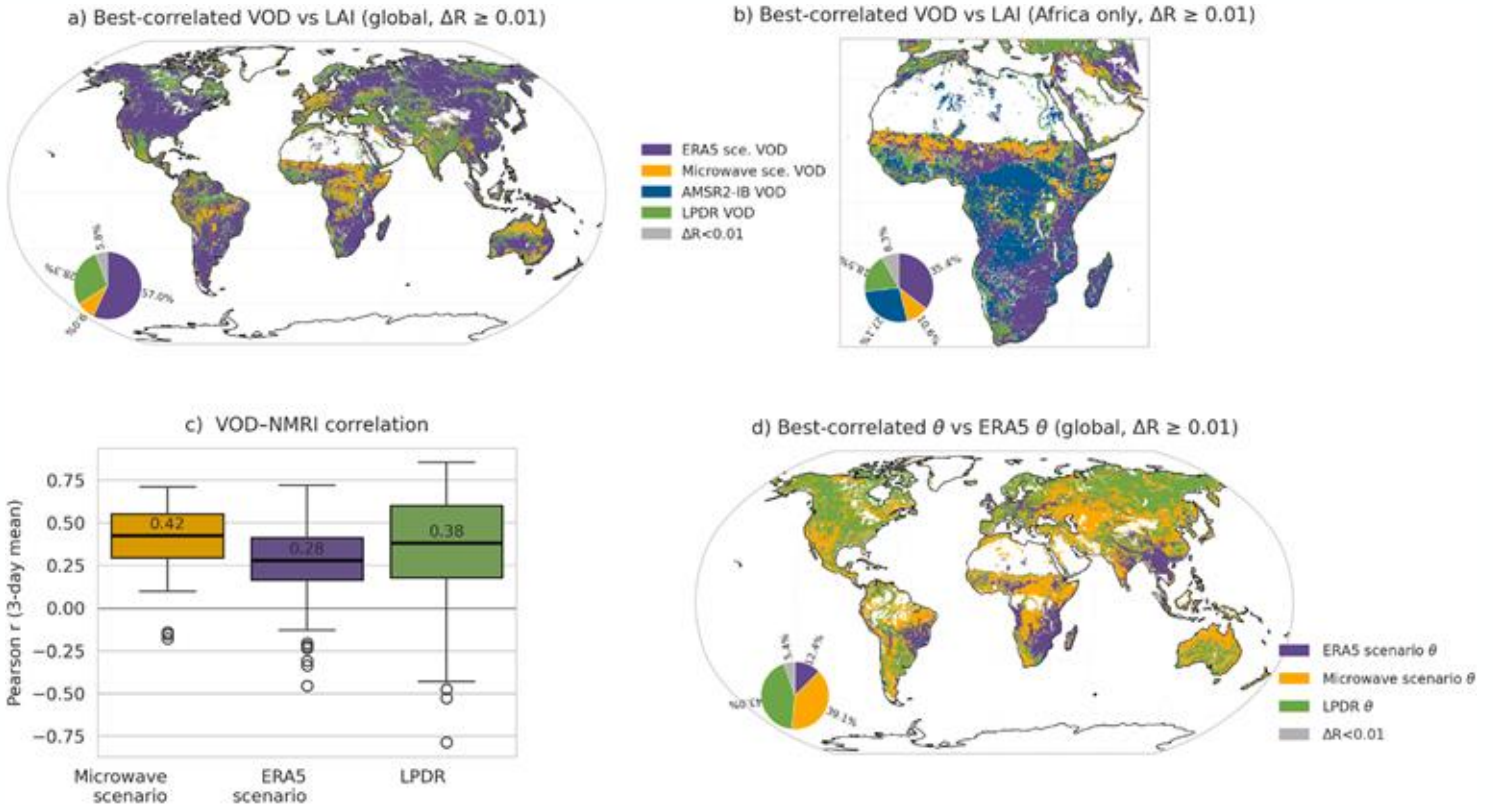


2. Optimization of remote sensing vegetation products



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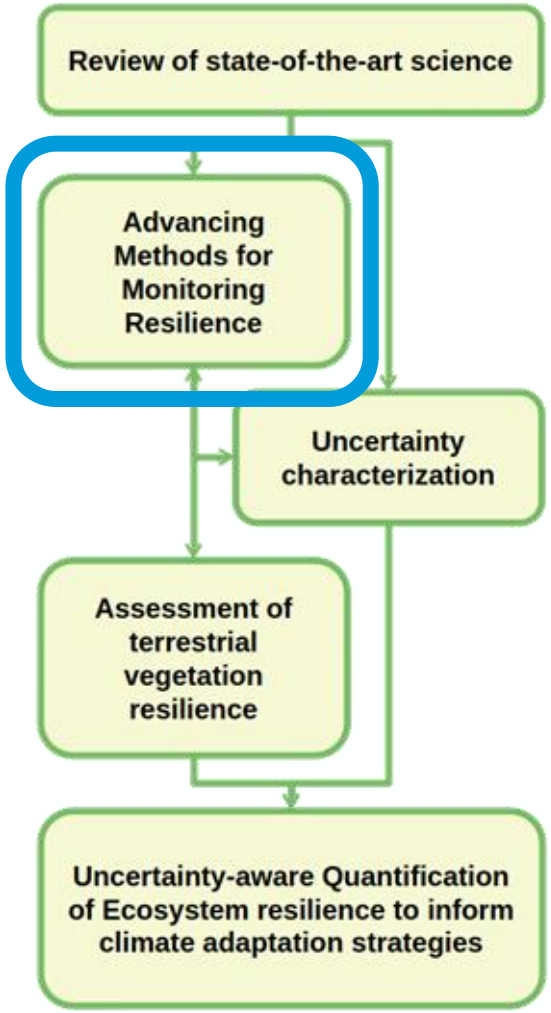
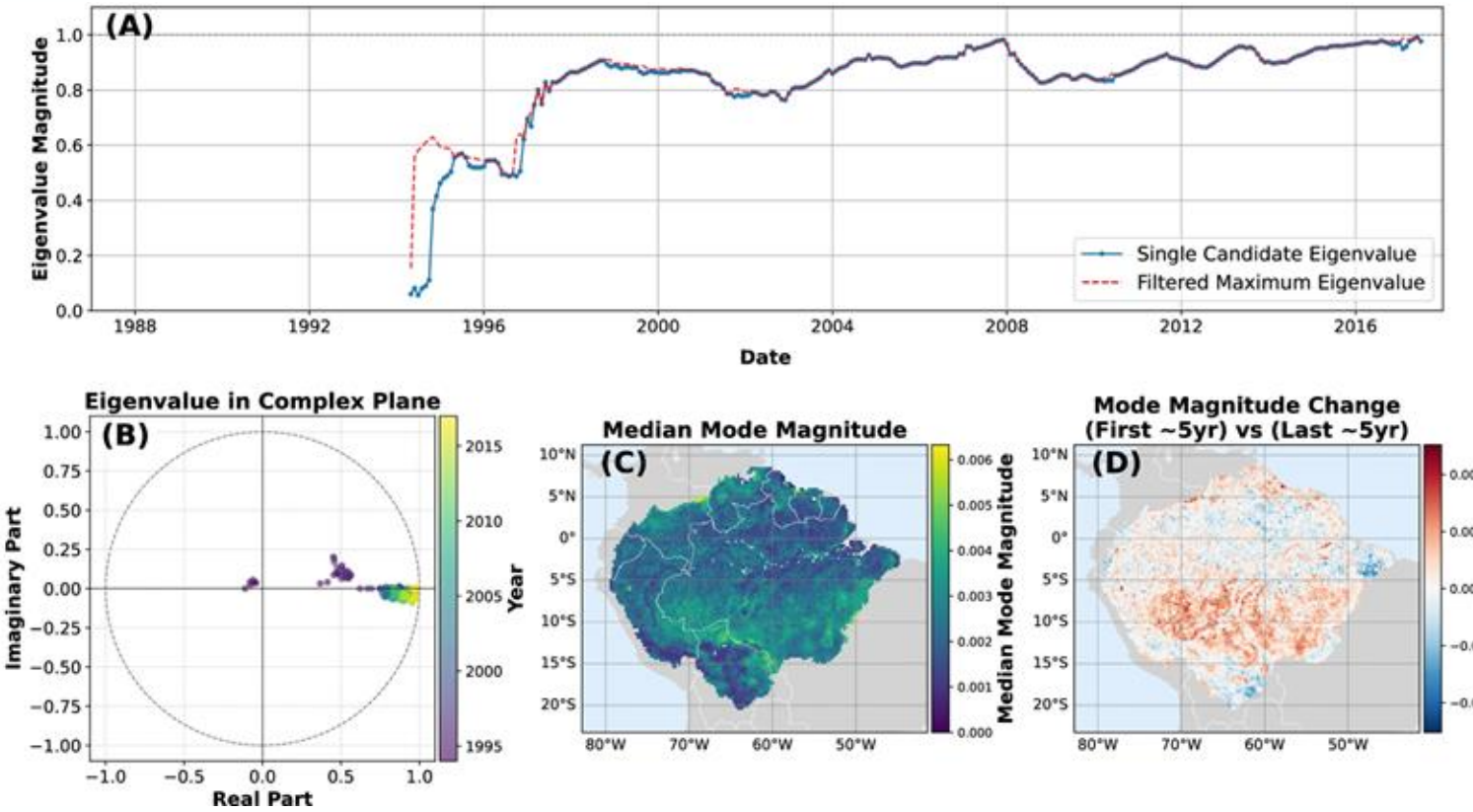


3. Improved resilience metrics



Taylor Smith, Andreas Morr, Bodo Bookhagen, and Niklas Boers. Predicting instabilities in transient landforms and interconnected ecosystems. *Nature Communications volume*. 2026. https://doi.org/10.1038/s41467-026-68944-w

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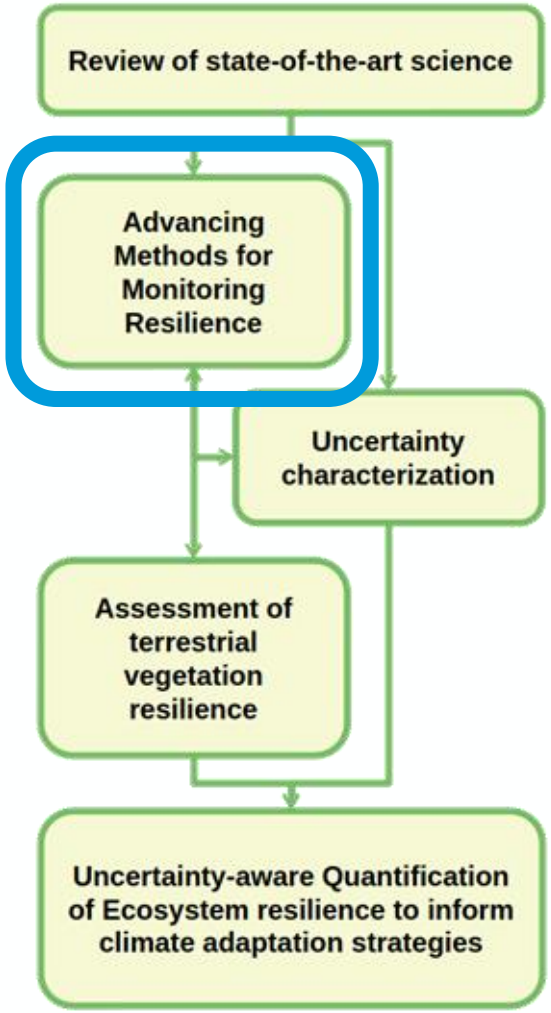
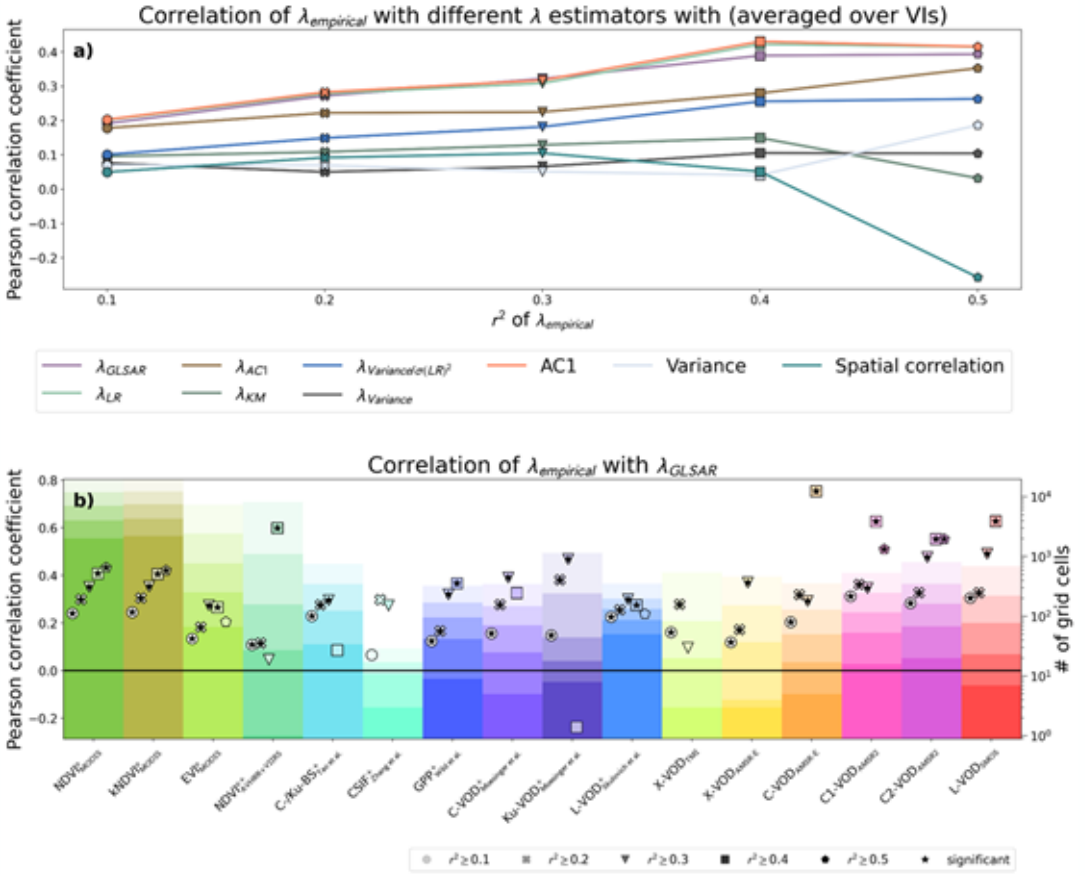


4. Benchmarking resilience metrics and vegetation products



(performance for tropical forests)

Lana Blaschke, Sebastian Bathinay, Marina Hirota, Niklas Boers. Resilience Loss of Tropical Forests in recent decades. *Submitted.* https://doi.org/10.21203/rs.3.rs-7264282/v1

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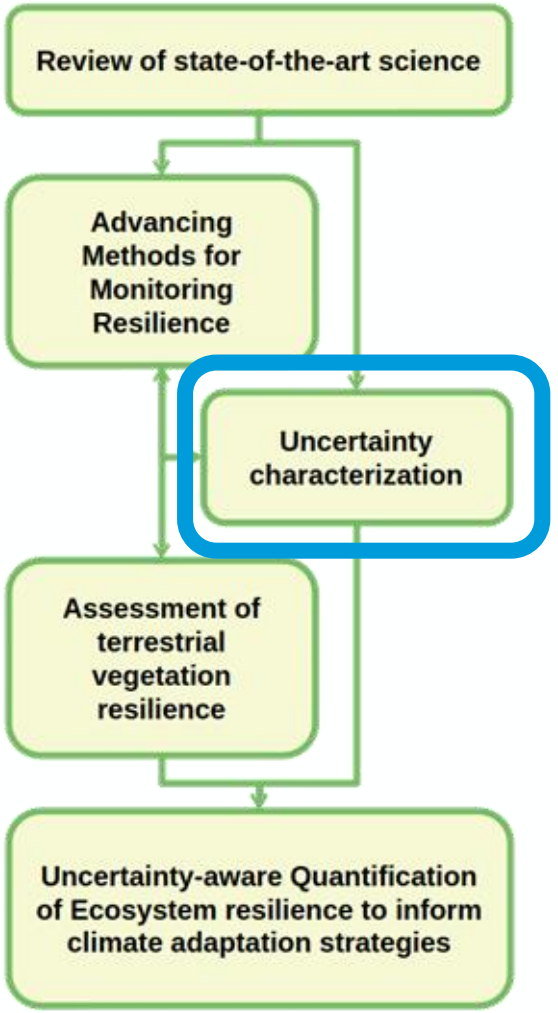
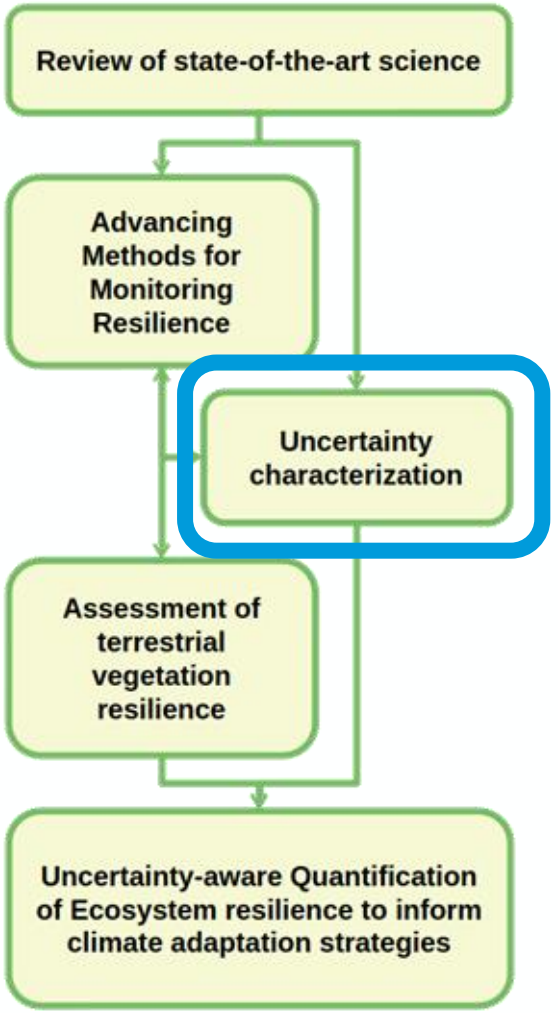


1. Inventory of data

(Preliminary) results



1. Inventory of data

Check out our website

https://climate.esa.int/de/tipping-points-research/about-sirene/

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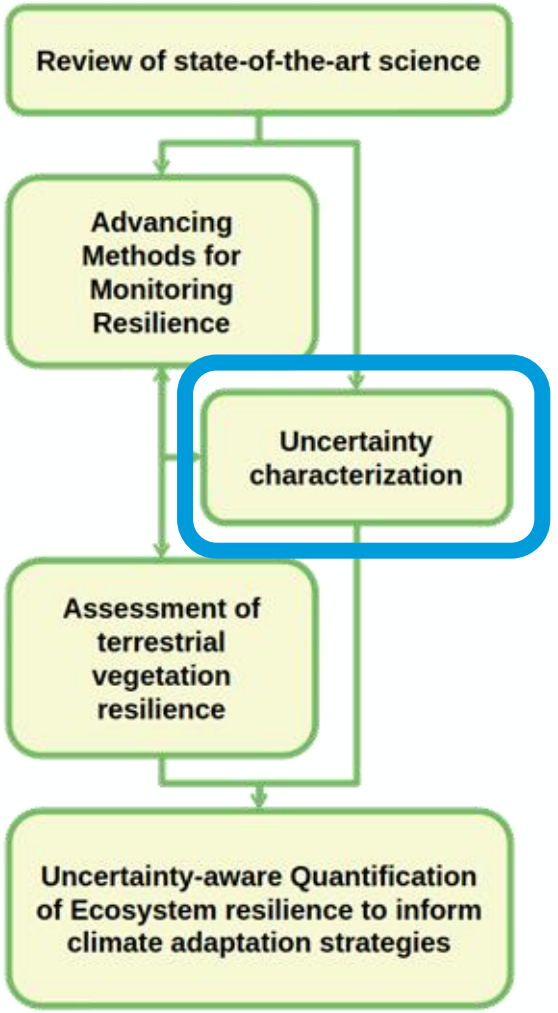
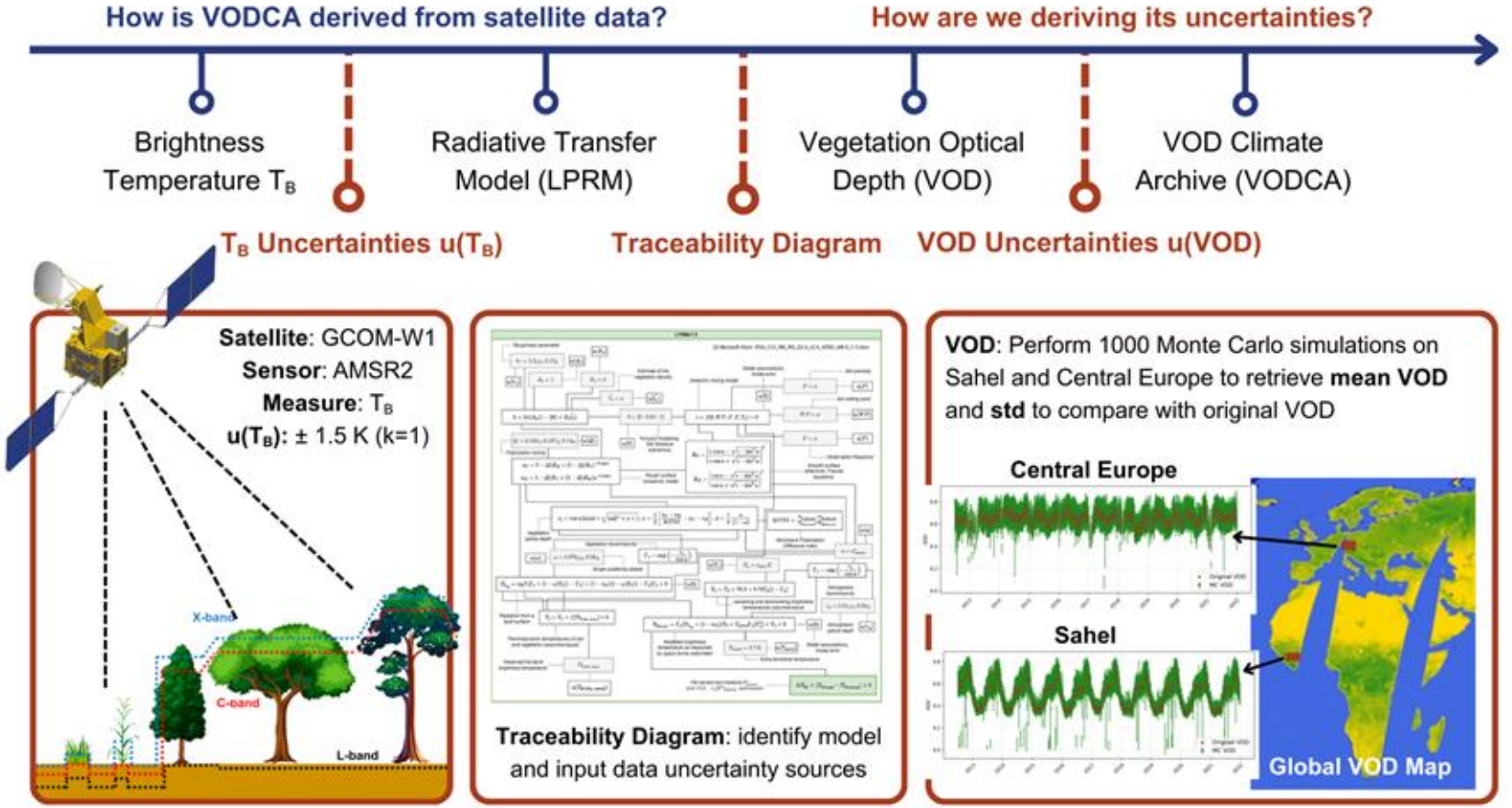




(Preliminary) results

Review of state-of-the-art science

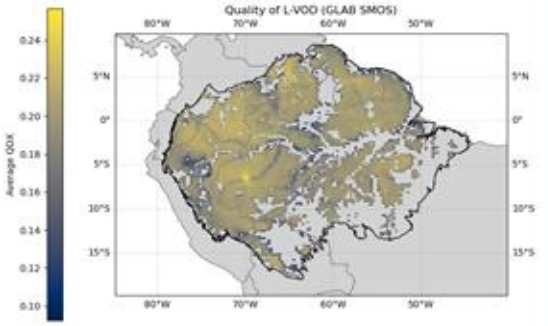
Advancing Methods for Monitoring Resilience

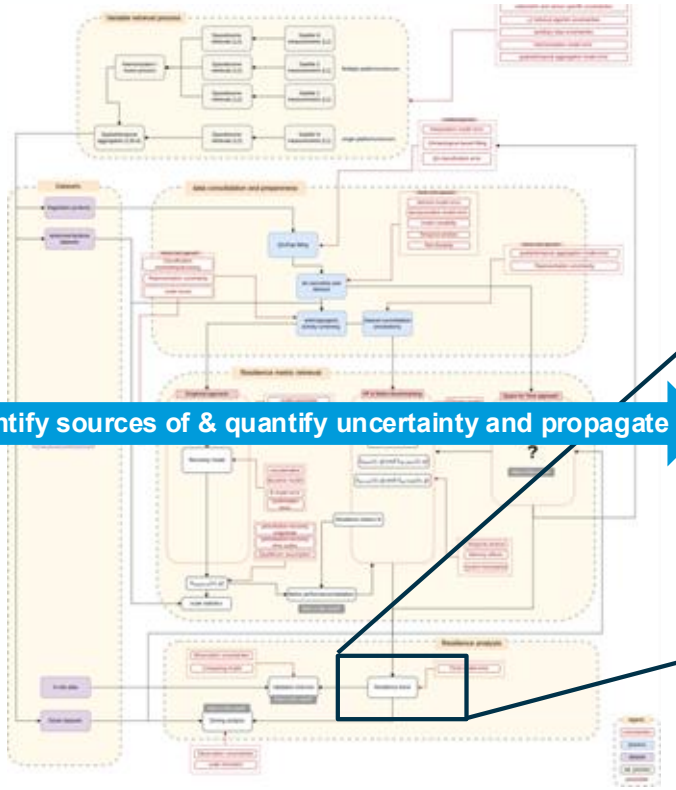
Uncertainty characterization

Assessment of terrestrial vegetation resilience

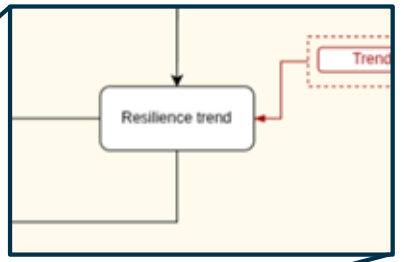
Uncertainty-aware Quantification of Ecosystem resilience to inform climate adaptation strategies

1. Uncertainty characterization and propagation





Identify sources of & quantify uncertainty and propagate



Thank you

References

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