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Erosion risk mapping in Northern Spain comparing two versions of satellite IMERG rainfall data

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Leading Edge Erosion (LEE) in wind turbine blades

Wind turbine blade with damage on the leading edge
Courtesy of Jakob Ilsted Bech

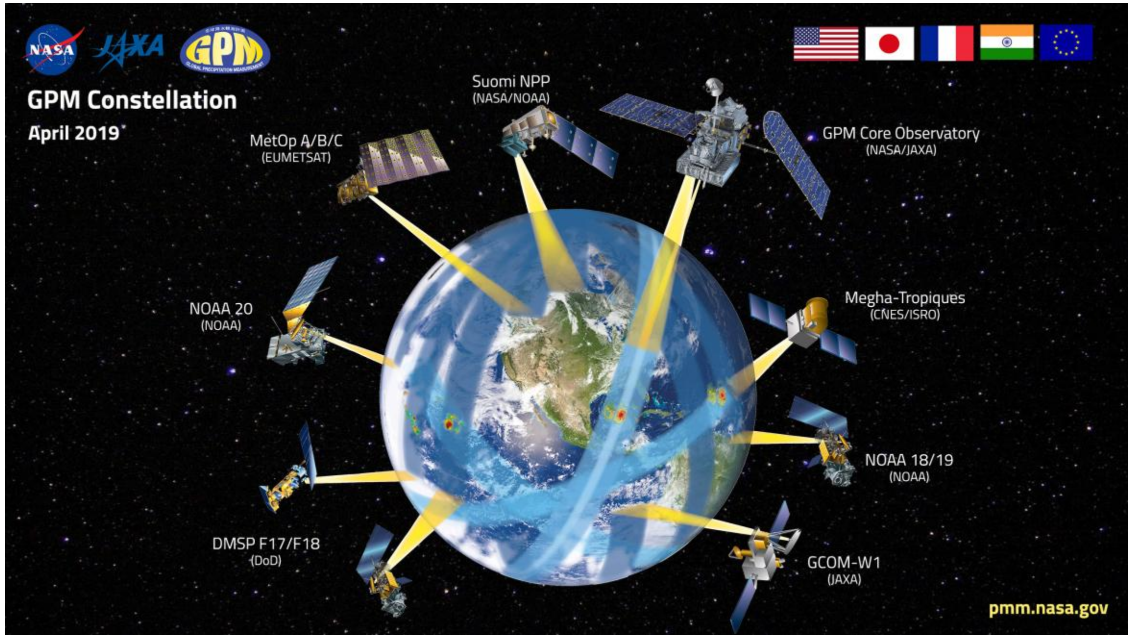
- Degrades blade surface, disrupting airflow
- Reduces lift, increases drag → lowers power output
- High repair/replacement costs
- Poor management can undermine wind farm profitability

We aim to

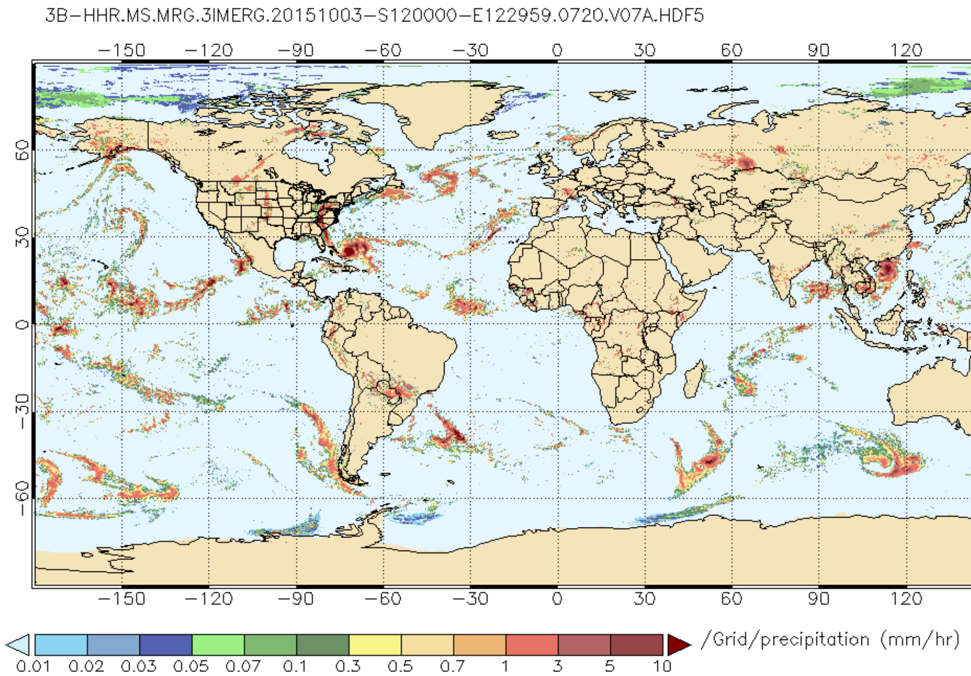
Discuss the differences on detected rainfall from two satellite products

Answer if one of the two is more suitable for erosion risk mapping

Integrated Multi-satellitE Retrievals for GPM (IMERG)



The GPM constellation – Source: NASA



GPM IMERG precipitation L3 Half Hourly 0.1° x 0.1 ° – Source: NASA

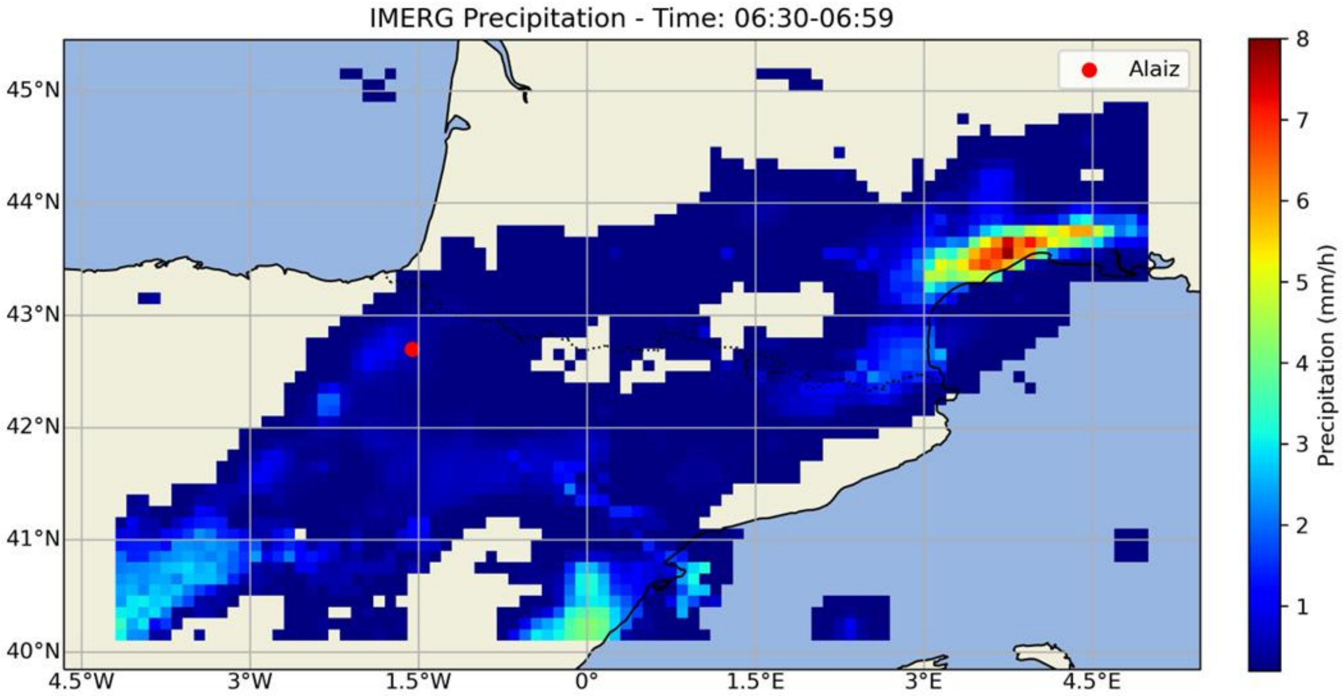
IMERG Final products V60B and V70B

Coverage: 60◦N to 60◦S latitude

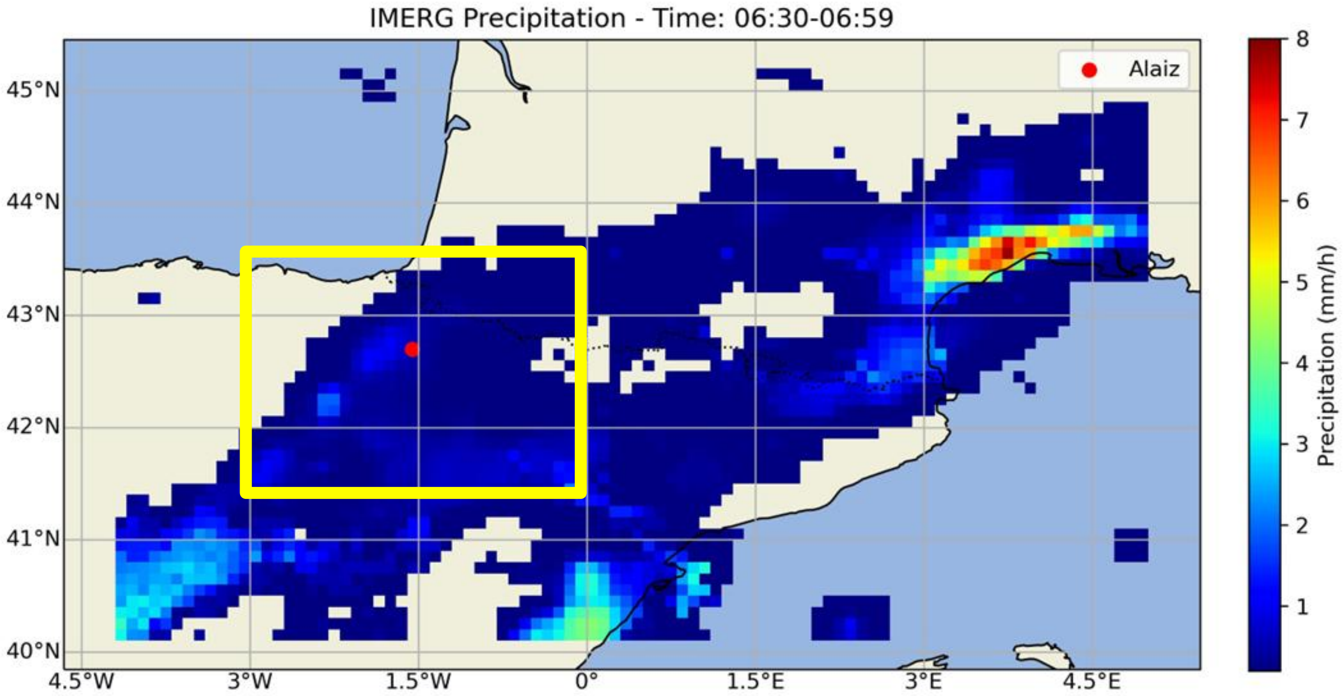
Grid spacing: 0.1◦ (~11 km)

Temporal resolution: 30 min

Study area and datasets



Study area and datasets



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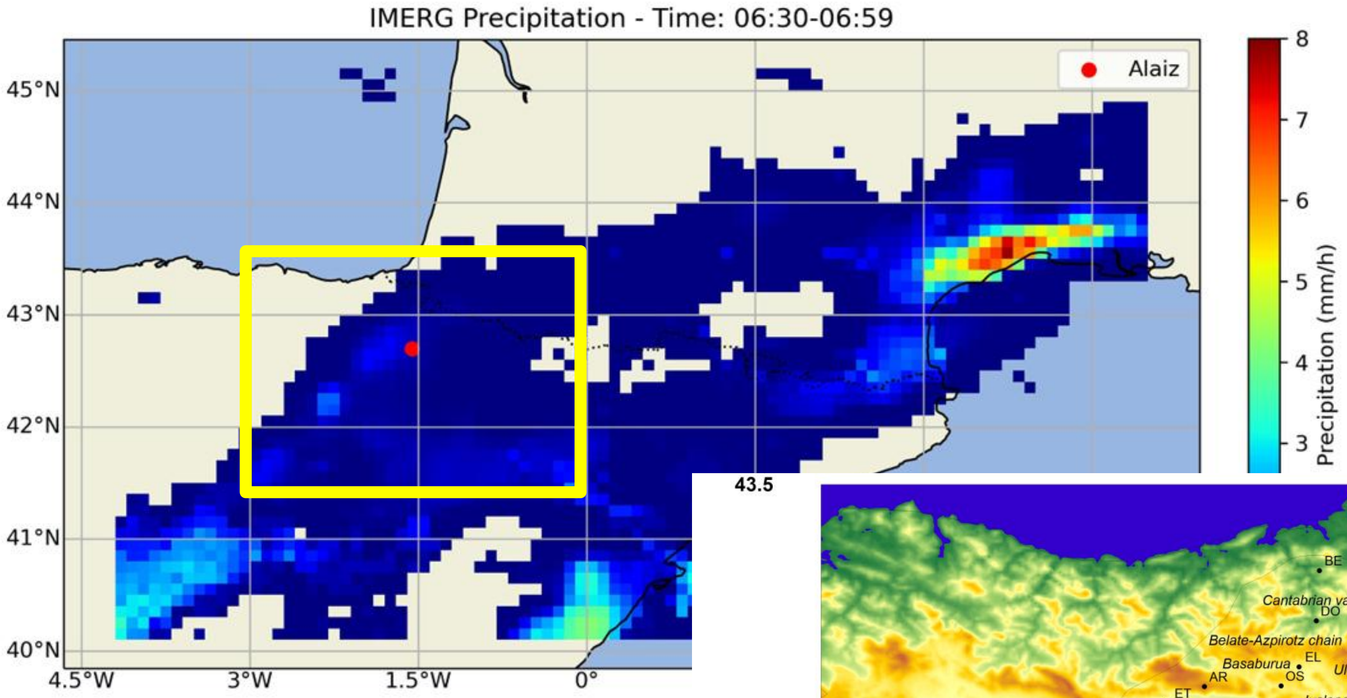
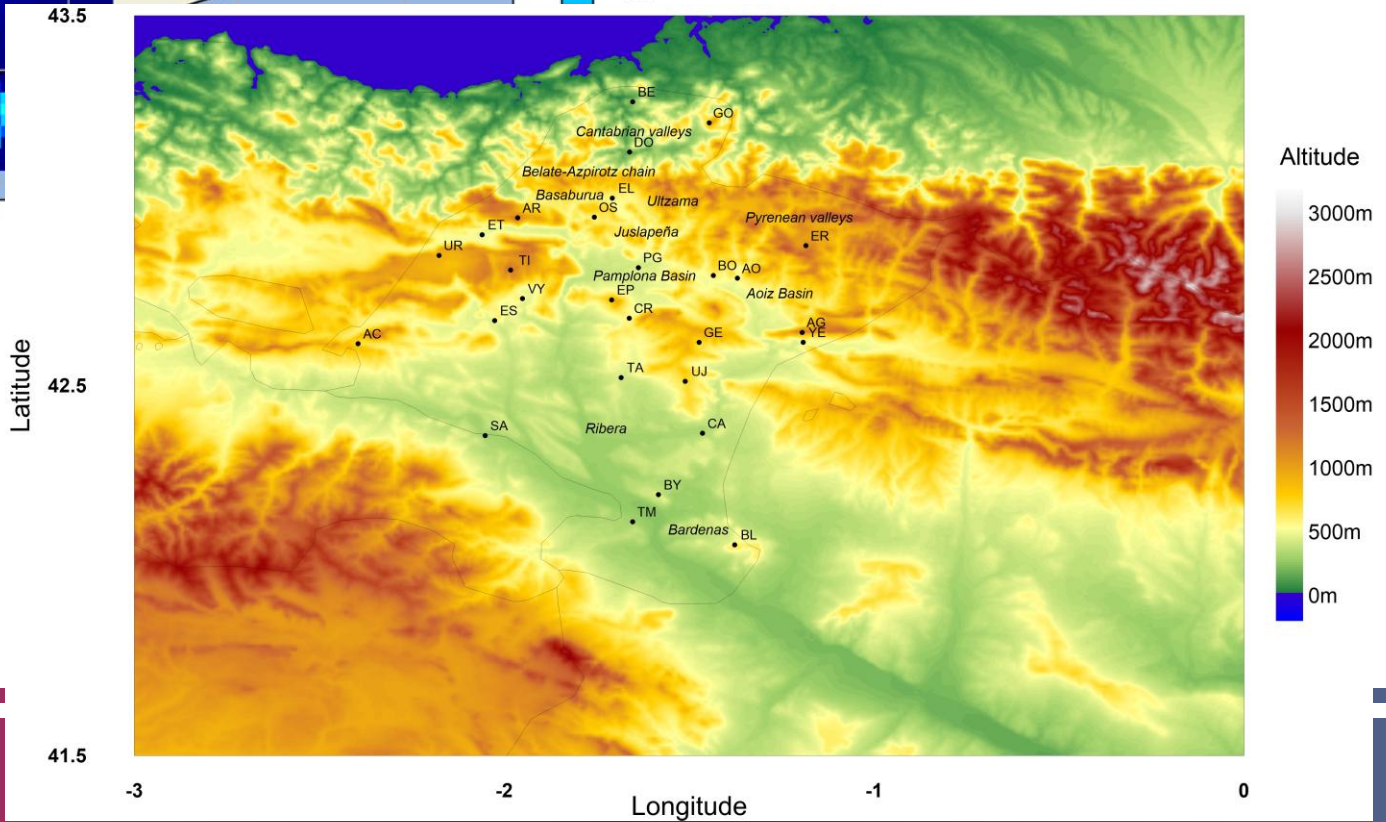


- 28 meteorological stations in Navarra, Spain, placed at elevations ranging from 125 m to 1353 m
- Time series of rainfall from gauge measurements, IMERG6, and IMERG7 from 2015 – 2020



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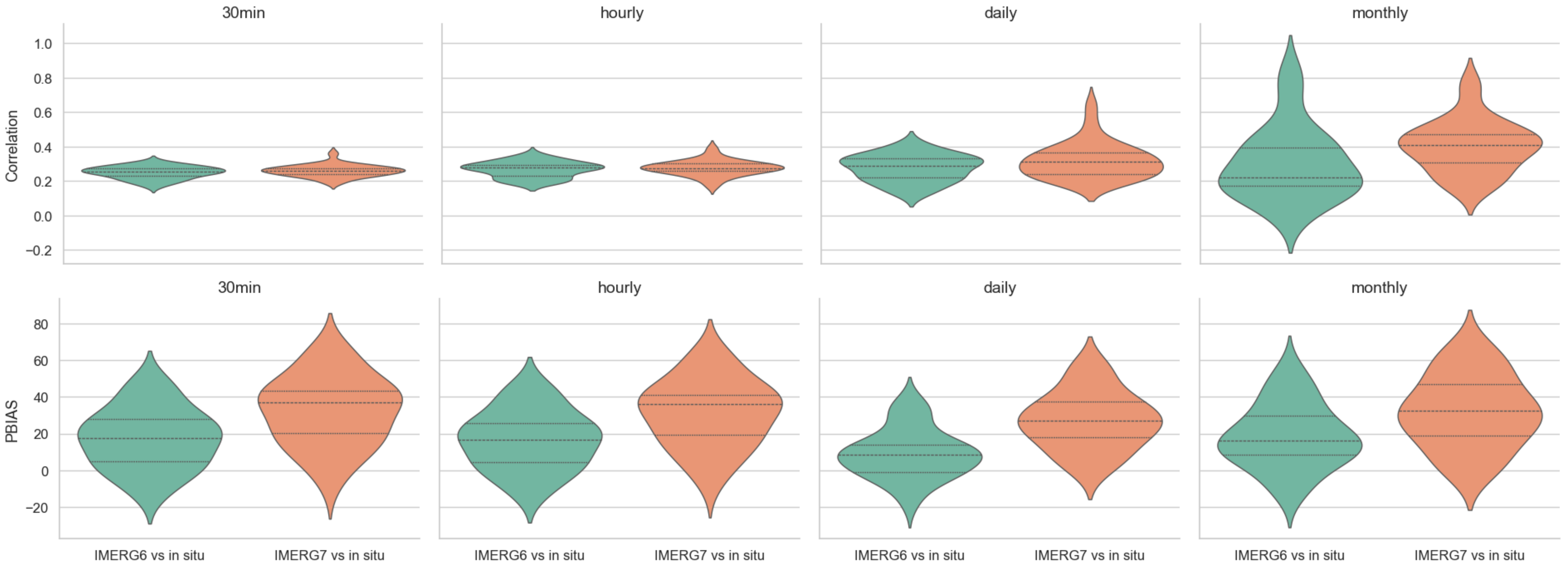
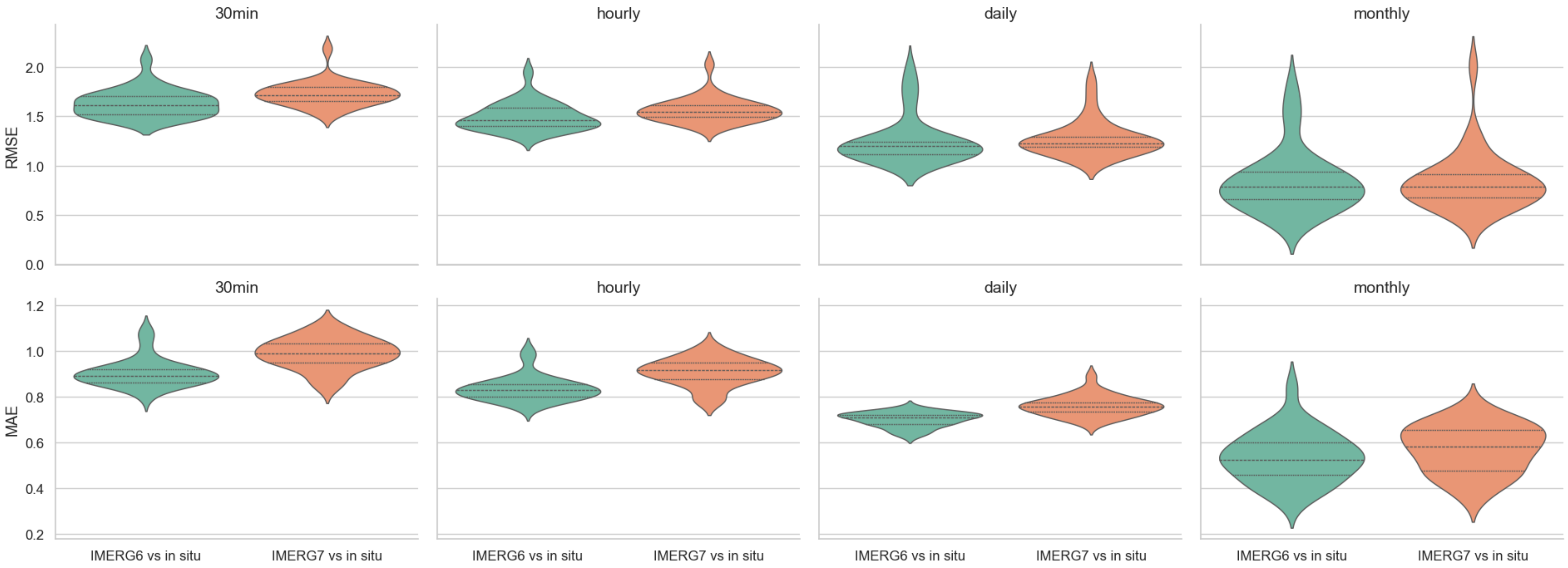
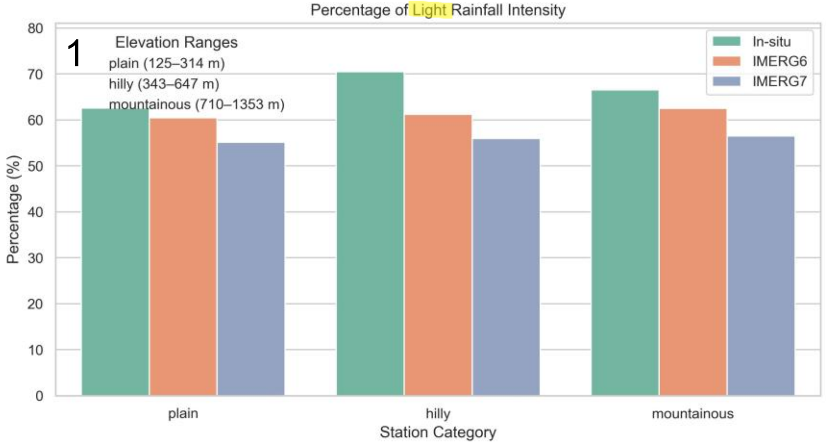
IMERG6 & 7-in situ data validation in different temporal scales

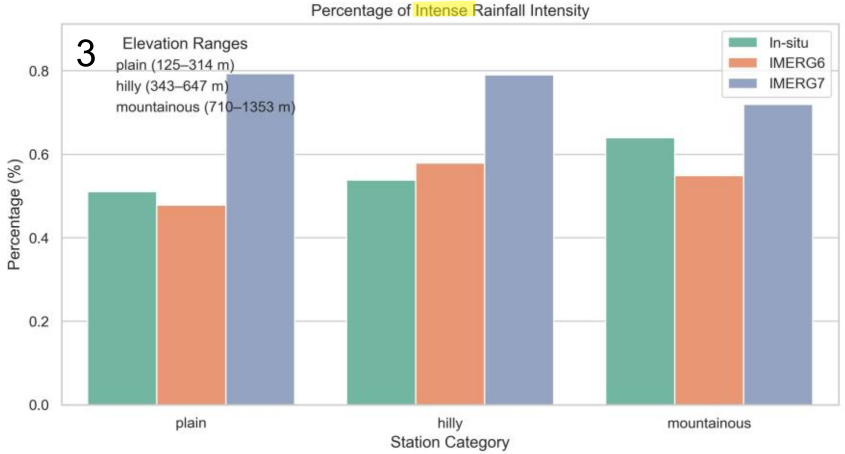


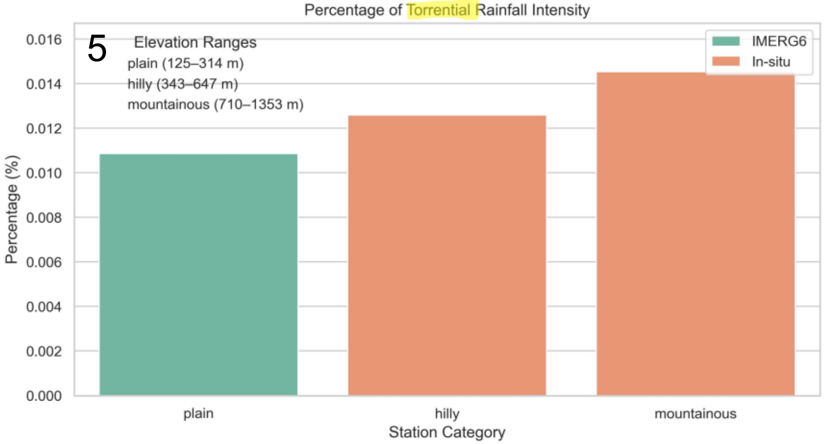
IMERG6 & 7-in situ data validation in different temporal scales

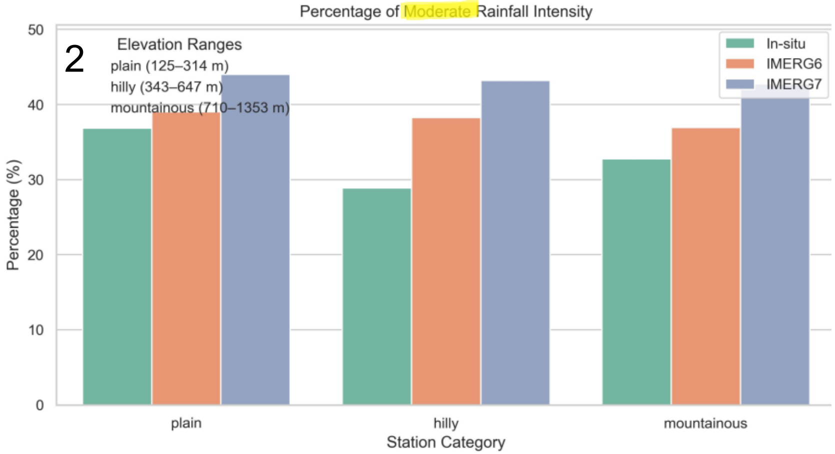


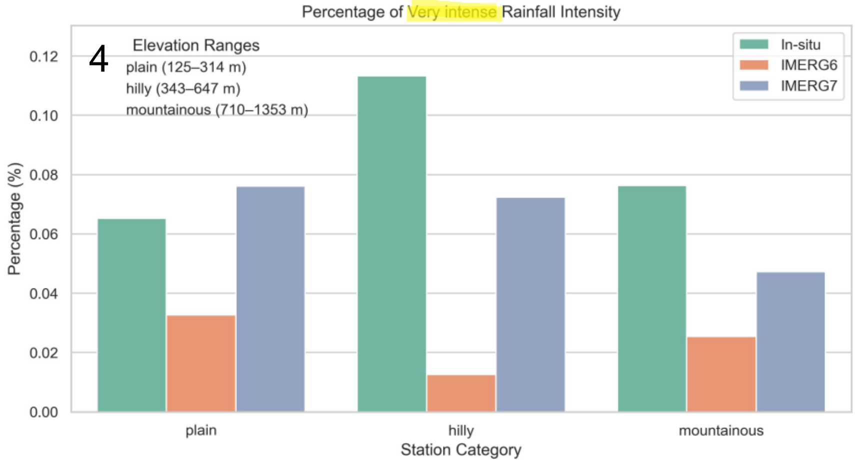
In situ, IMERG6 & 7 rainfall intensities in Navarra (2015-2020)











Rain intensities (according to Agencia Estatal de Meteorología -AEMET, adjusted for mm/30 min)
0.1≤ I ≤1: light
0.1< I ≤7.5: moderate
7.5< I ≤15: intense
15< I ≤30: very intense
I>30: torrential

The 28 stations in Navarra are grouped according to their elevation heights in plain, hilly and mountainous categories.

1. Navarra stations experienced nearly 70% of light rainfall during the 5 years.
1. IMERG 6 and 7 underestimate light rainfall intensity in all station elevations.
2., 3. IMERG 6 and in situ show similar percentages of moderate and intense rainfall intensity in all station elevations.
4. IMERG 7 and in situ are closer to agreement in very intense rainfall intensities, while IMERG 6 appears to detect very little.
5. IMERG 6 and 7 no detection of torrential rainfall intensity in the hilly and mountainous stations, though IMERG 6 can in stations in the plains.

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Impingement damage model for blade lifetime estimation

IMERG6 rainfall – NEWA wind speeds at 90 m

IMERG7 rainfall – NEWA wind speeds at 90 m

In situ rainfall – NEWA wind speeds at 90 m

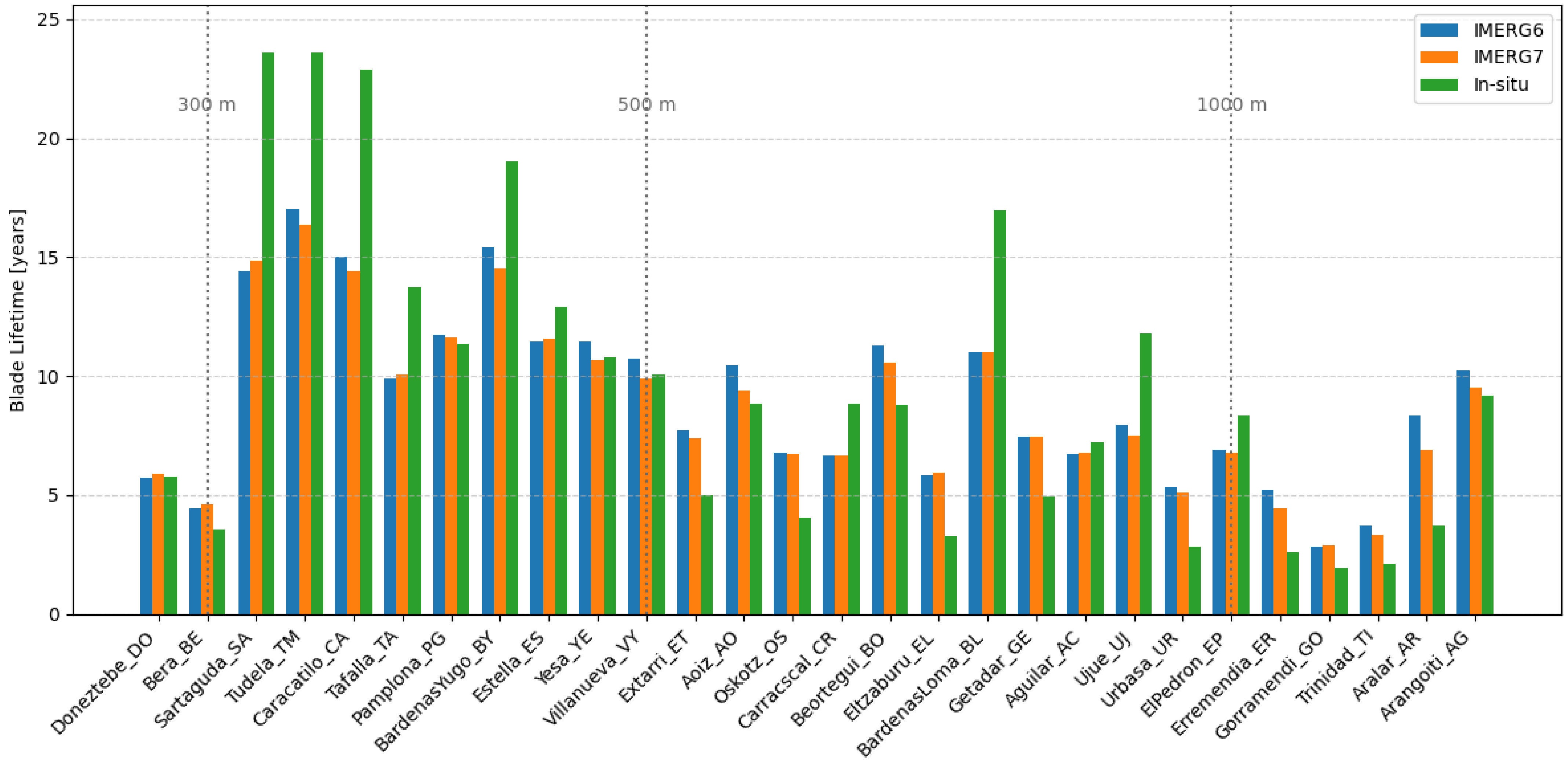
Impingement damage model
-
NREL 5 MW reference wind turbine

Erosion onset time and initial blade failure

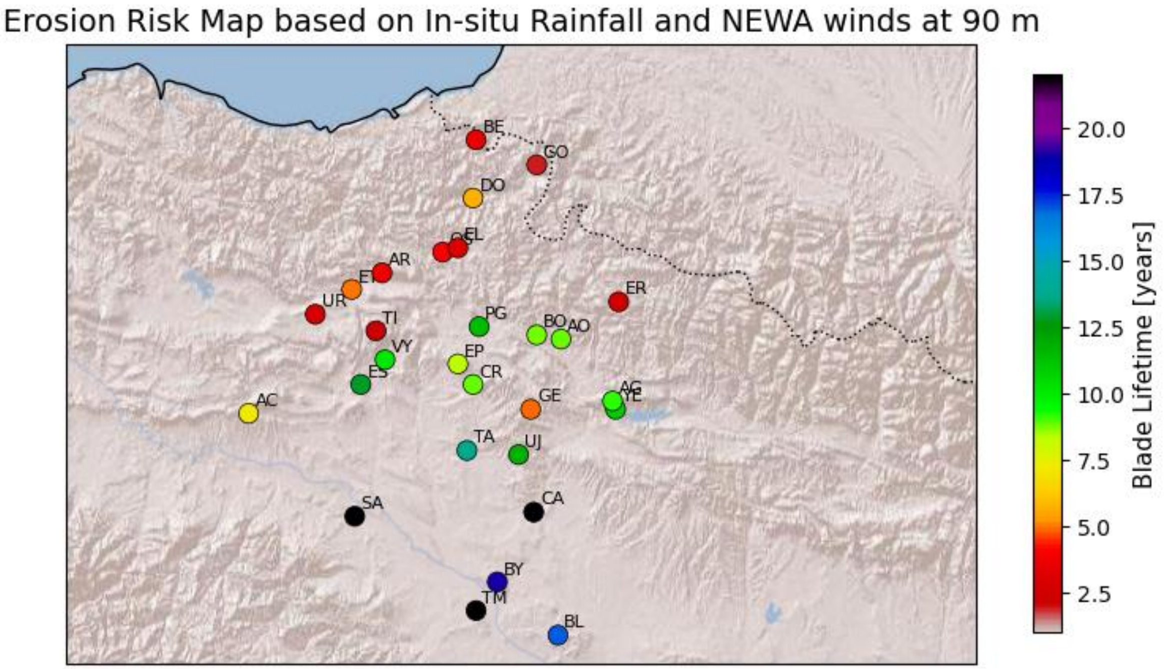
x 28 stations

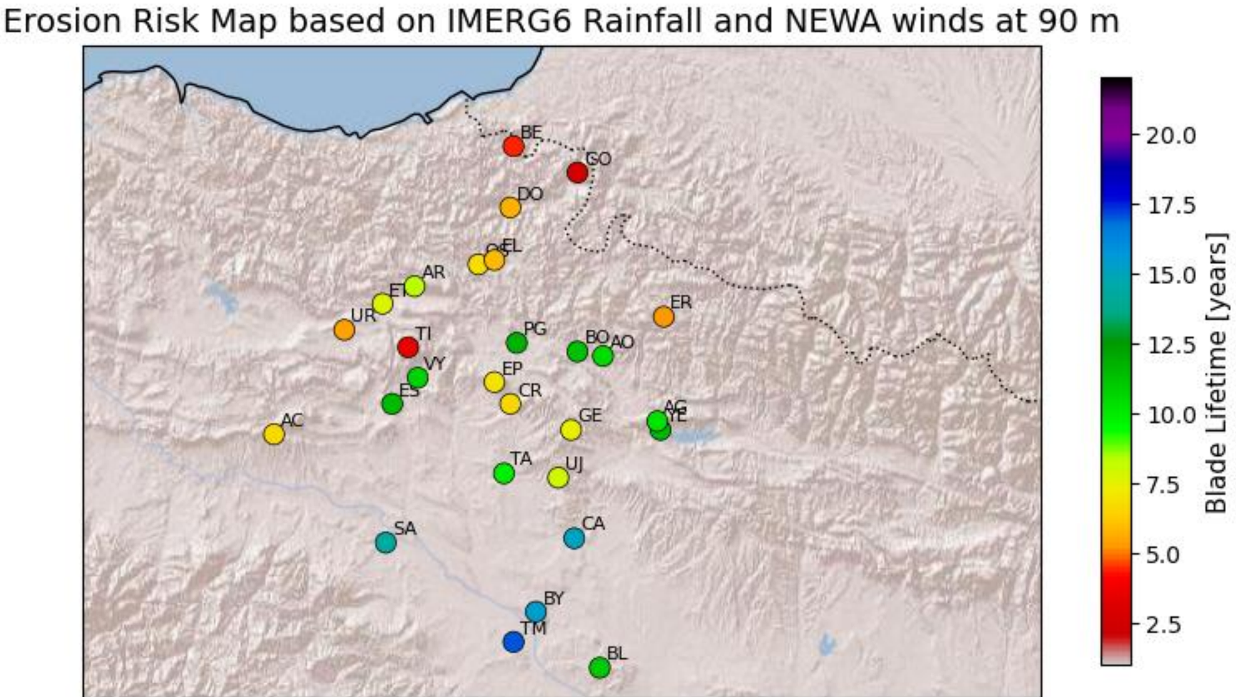
Bech et al., Experimental study on the effect of drop size in rain erosion test and on lifetime prediction of wind turbine blades, Renewable Energy, Volume 197, 2022, Pages 776-789, ISSN 0960-1481, https://doi.org/10.1016/j.renene.2022.06.127.

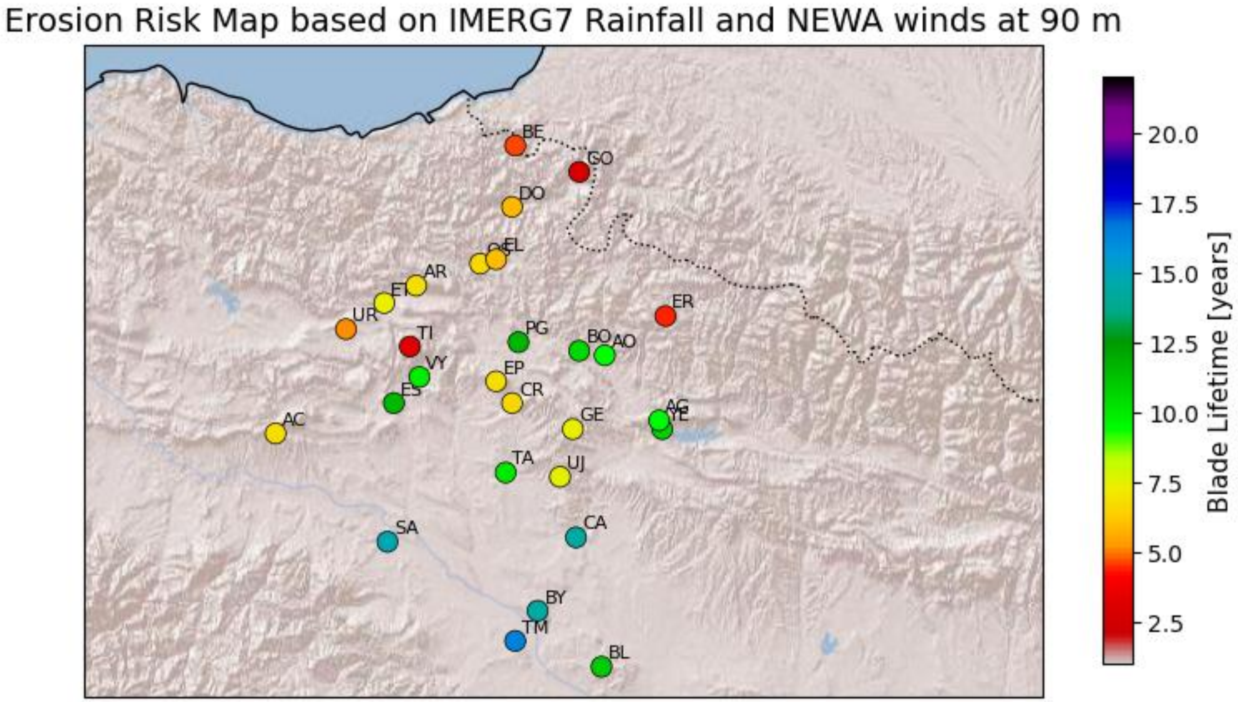
Blade lifetime estimation using IMERG6, IMERG7 and in situ rainfall



Erosion risk mapping in Northern Spain







Outcomes

Rain intensity in Northern Spain (2015-2020):

- Light rainfall intensity dominance (70%). Underestimation from IMERG6 & 7
- Moderate and intense rainfall: Best agreement between IMERG6 and in situ
- Very intense rainfall: Best agreement between IMERG7 and in situ
- Torrential: In situ only with IMERG 6 to detect only in the plains

IMERG6 & 7 - in situ data validation:

- Correlation between IMERG6/7 - in situ increases when aggregating data in longer time periods
- RMSE and MAE are minimized when aggregating data in longer time periods

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Outcomes

Erosion risk maps:

- In situ indicate a dryer rain climate than IMERG6 & 7
- All datasets agree on lowest blade lifetimes (<5 y) in all stations close to the coast - erosion criticality in the area.
- In situ: Gradual increase of blade lifetimes from coast (<5 y) to mountains (~10y) to plains (~20y)
- IMERG6 & 7: Gradual increase of blade lifetimes from coast (<5 y) to mountains (~8y) to plains (~15y)
- IMERG6 & 7: Lower blade lifetimes than in-situ (1-8y in all stations)
- IMERG 7 lowest blade lifetimes of the 3 datasets

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Take away messages

- IMERG 6 & 7 similar performance, preferably use IMERG7 as it is the latest updated satellite precipitation dataset (enhanced light rain and snow detection, improved orographic precipitation estimates, and reduced satellite artifacts such as striping).

- Satellite rainfall data can be proven an asset in erosion risk mapping
    - Near-global coverage
    - Available offshore, where in situ measurements are challenging
    - Consistent & uniform observations
    - Capturing Rainfall Over Oceans and Remote Terrain
    - Integration with Models and Ground Data

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Thank you!

Reach out! ☺

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Acknowledgements

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