PV module moisture ingress modelling

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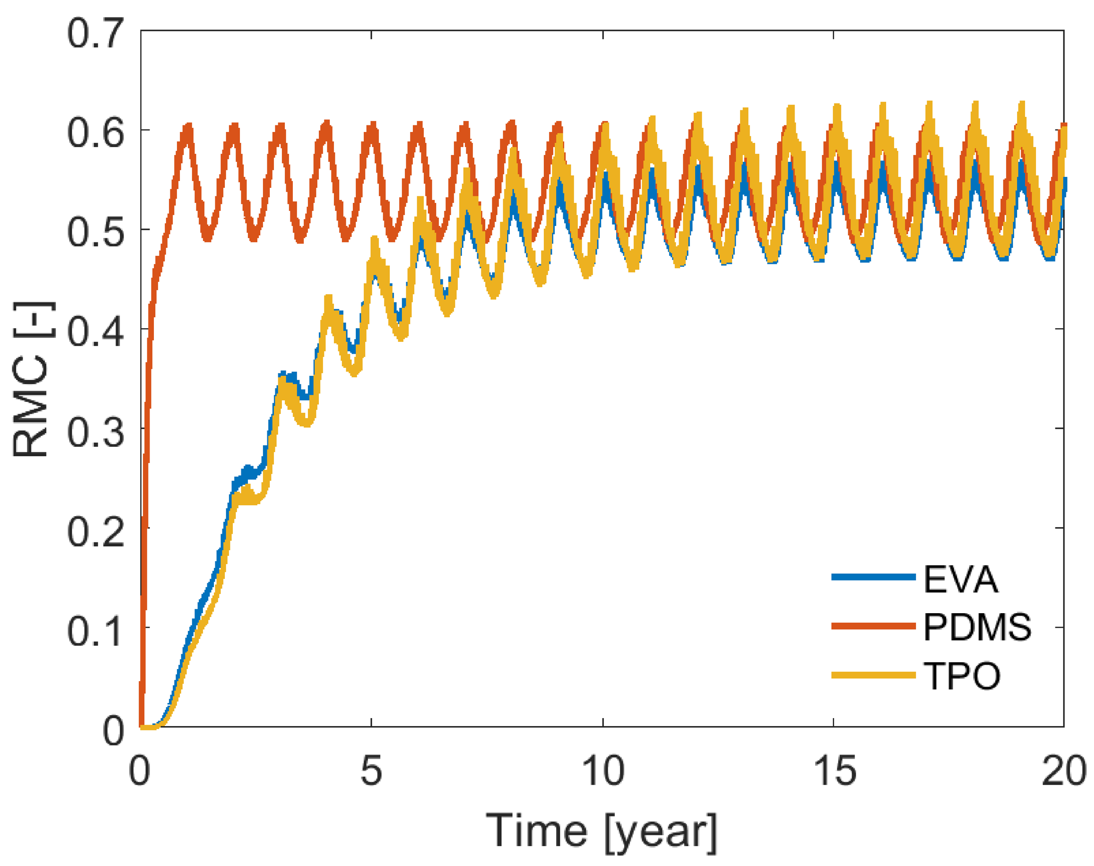
Motivation

- Analytical models relate stress factor, such as temperature, relative humidity (RH), and UV irradiance, to degradation of PV modules[1-3]
- The degradation is influenced by moisture in the module, rather than the RH[4]
- Goal is to integrate the modelling of moisture ingress with analytical degradation models[1-3]

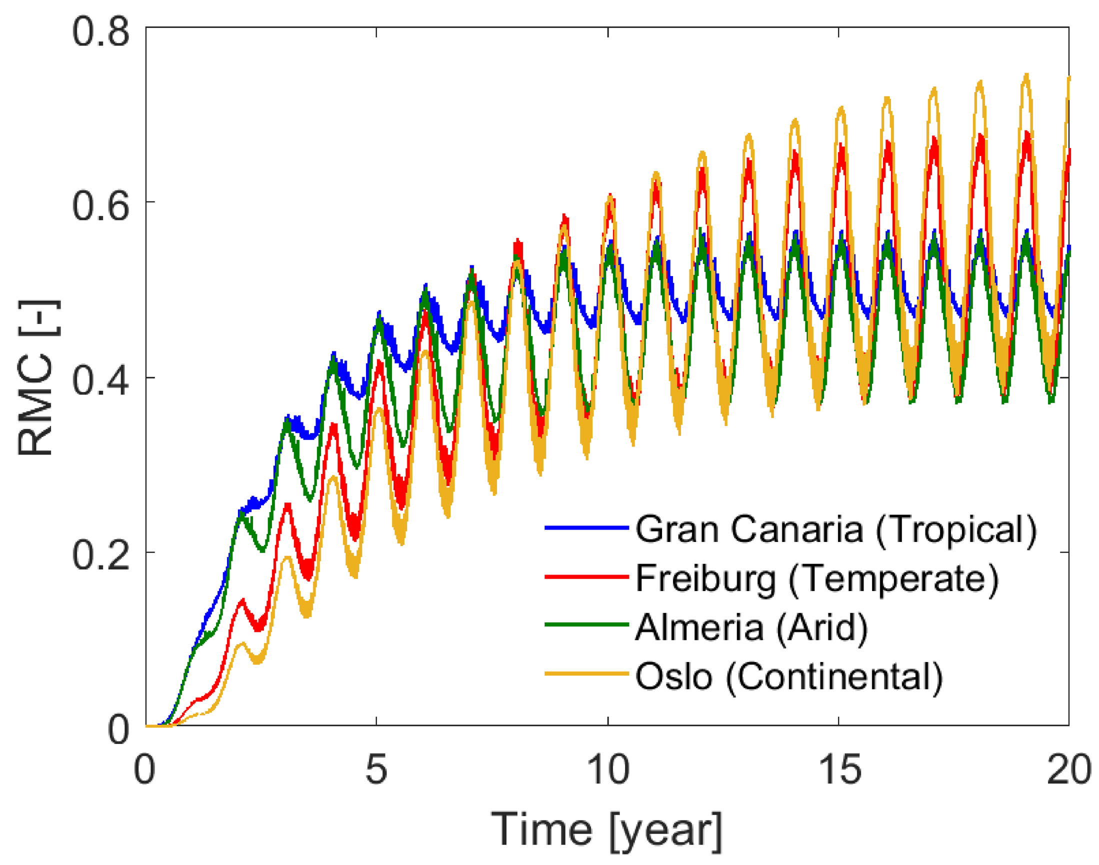
Impact of the material

- Three different encapsulation materials (Simulated for Gran Canaria, Spain)
- Mostly determines saturation time (τ_{sat})



Impact of the location

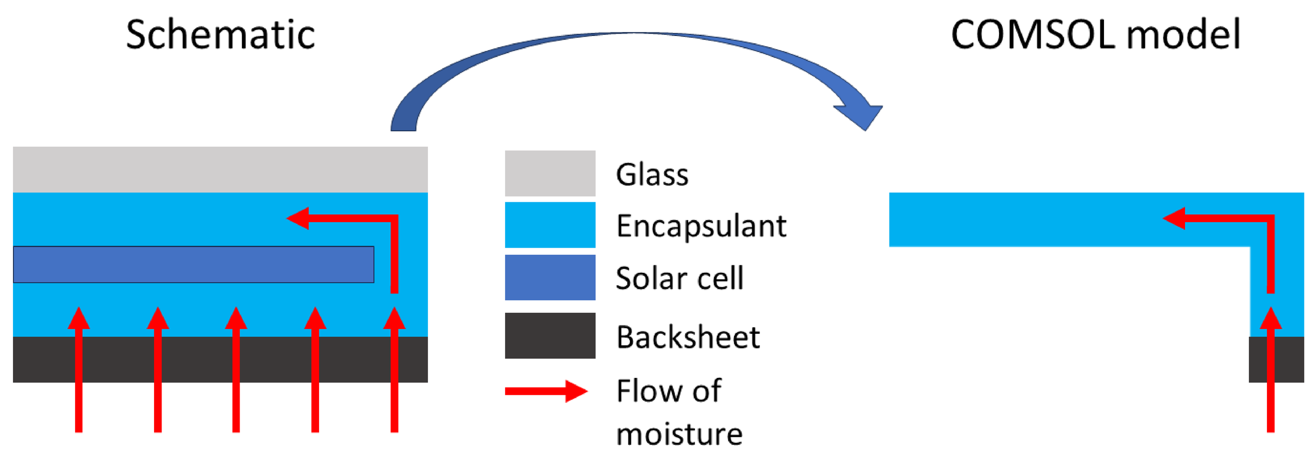
- Four different Koppen-Geiger Climate zones (Simulated with EVA)
- Equilibrium concentration and saturation time follow linear trend



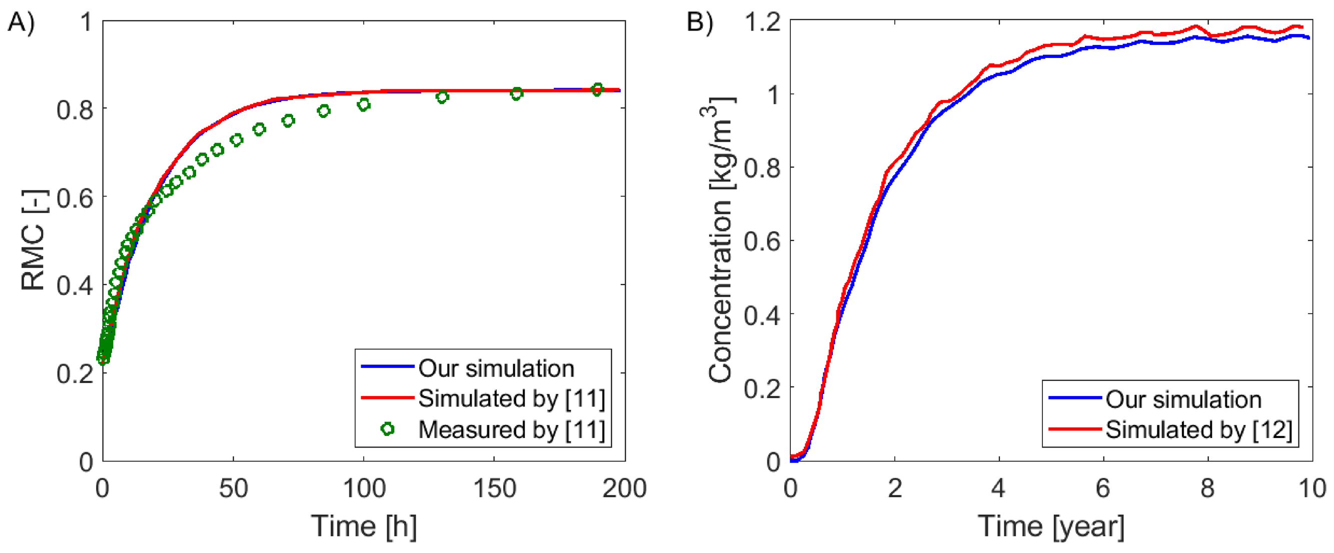
Conclusion

- Investigated effect of encapsulant and climate on moisture ingress
- Reconstructing moisture ingress to avoid computational simulations
- Integrated moisture ingress into analytical degradation models

Model and Validation



- 2D Finite Element Method (FEM) model in COMSOL®
- Half of a middle cell
- Glass and solar cell to be impermeable



A) RMC inside the backsheet and encapsulation during a damp-heat experiment [11]

B) Water concentration inside a PV module under real world conditions (Manaus in Brazil)[12]

- Water diffusion within each material Fick's second law of diffusion[5]

$$\frac{\partial C(x,y,t)}{\partial t} = D \cdot \nabla^2 C(x,y,t)$$

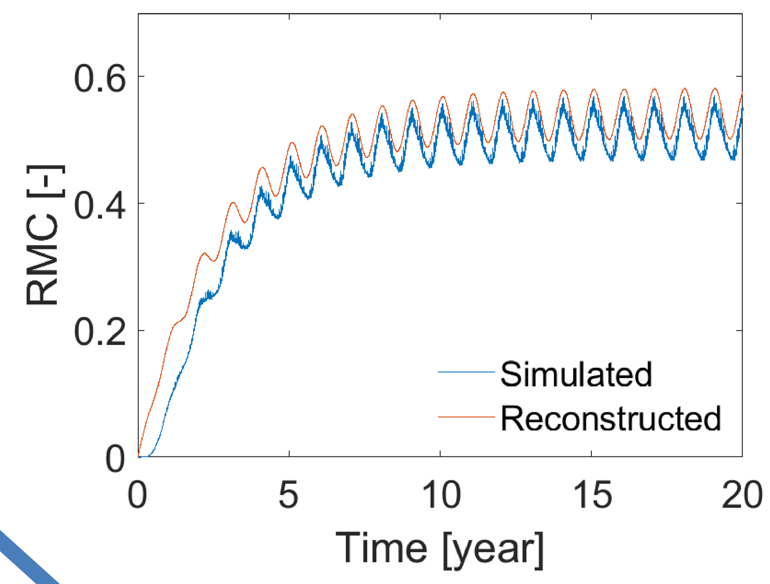
- Interfaces Henry's law[5,6]

$$C_1 / C_2 = S_1 / S_2$$

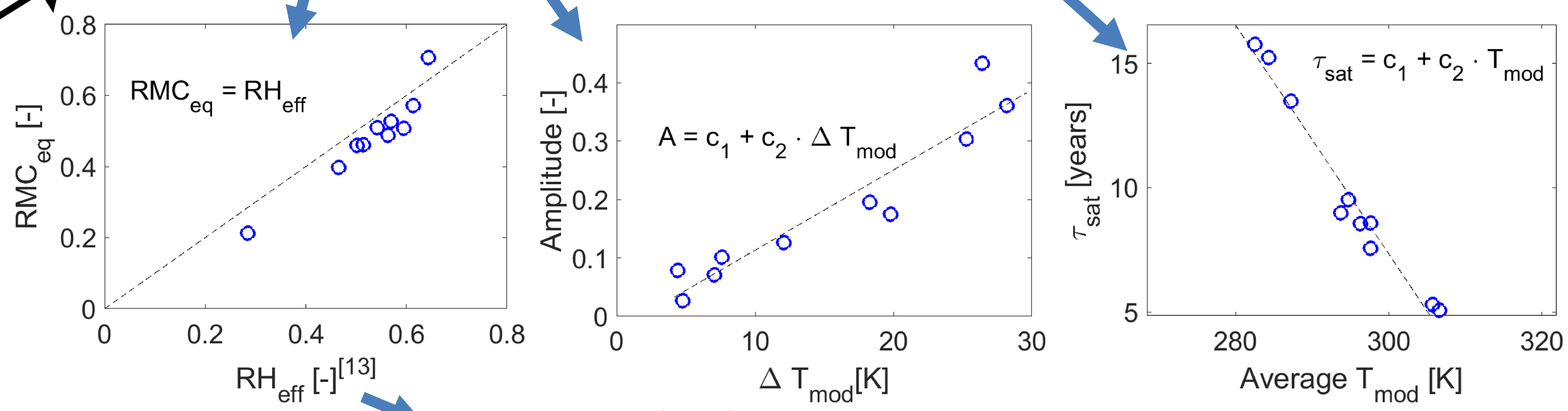
- Temperature dependence of **diffusion coefficient D** and **solubility S** via an Arrhenius relationship[7,8]
- Other moisture ingress models[10-12] use **concentration C** of water as metric
- We use the **relative moisture content (RMC)**, as this is better suited for the estimation of the materials' degradation[4]

Reconstructing moisture ingress

- COMSOL simulations are computationally intensive
- Moisture ingress can be reconstructed based on characteristics



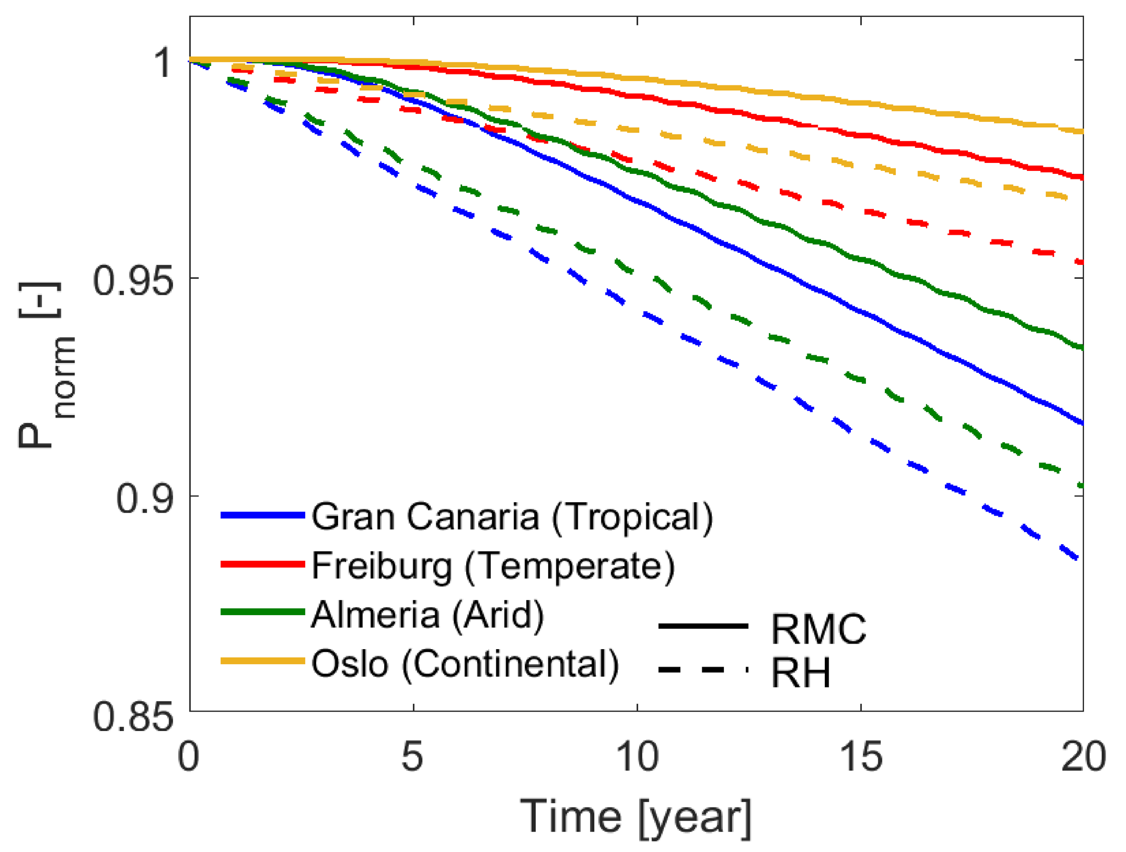
$$RMC(t) = \left(RMC_{eq} + \frac{A}{2}\cos(2\pi \cdot t - \phi)\right) \cdot \left(1 - e^{\frac{t}{\tau_{sat}}}\right)$$



$$RH_{eff} = RH \frac{P_{sat}(T_{amb})}{p_{sat}(T_{mod})}$$

Effect on degradation trend

- Calculating effect of moisture induced degradation with the Peck model[1-3]
- Highest moisture-induced degradation in tropical climate (Gran Canaria)
- Solid lines use **RMC -> non-linear degradation**, expected in literature[14]
- Dashed lines use **RH_{eff} -> linear degradation**



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