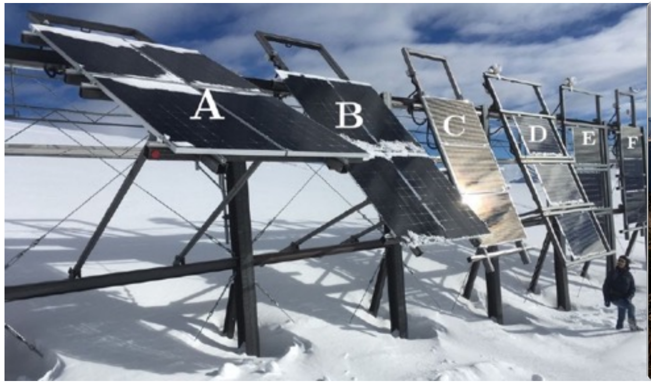



Potential für alpine Energieanlagen im Schweizer Energiesystem

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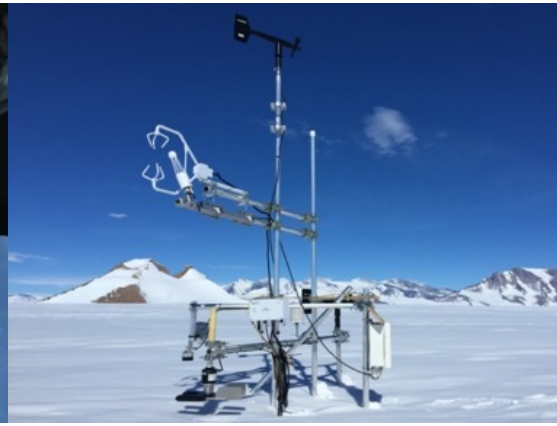
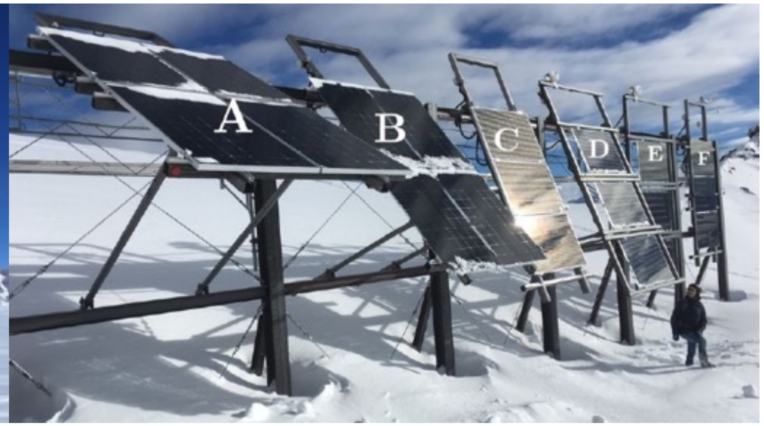
Jérôme Dujardin, Fanny Kristianti, Annelen Kahl, Felix von Rütte

Michi Lehning

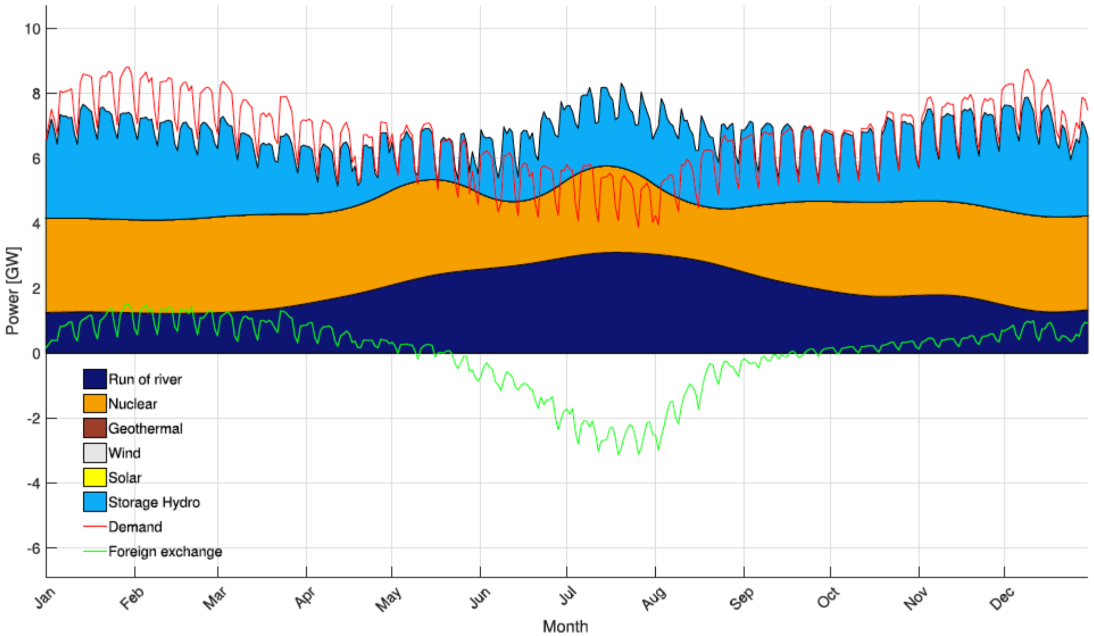
Progress to Report on

- Assessment of scenarios for the Swiss electricity system (OREES model)
- Looking at forward scattering snow at its effects on the surface
- Very high resolution wind modelling in complex terrain with ML
- Assessing the untapped potential of renewable energy in the Alps





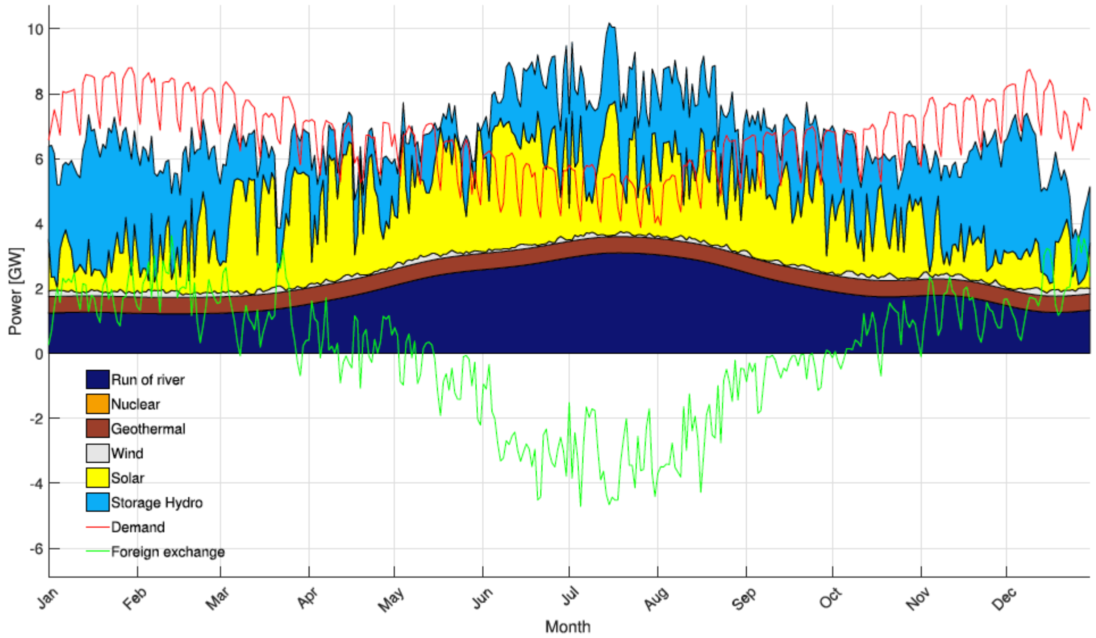
Starting from National Scenarios for PV and Wind



(a) Current

Bartlett, et al. (2018), Charting the course: A possible route to a fully renewable Swiss power system, *Energy*.

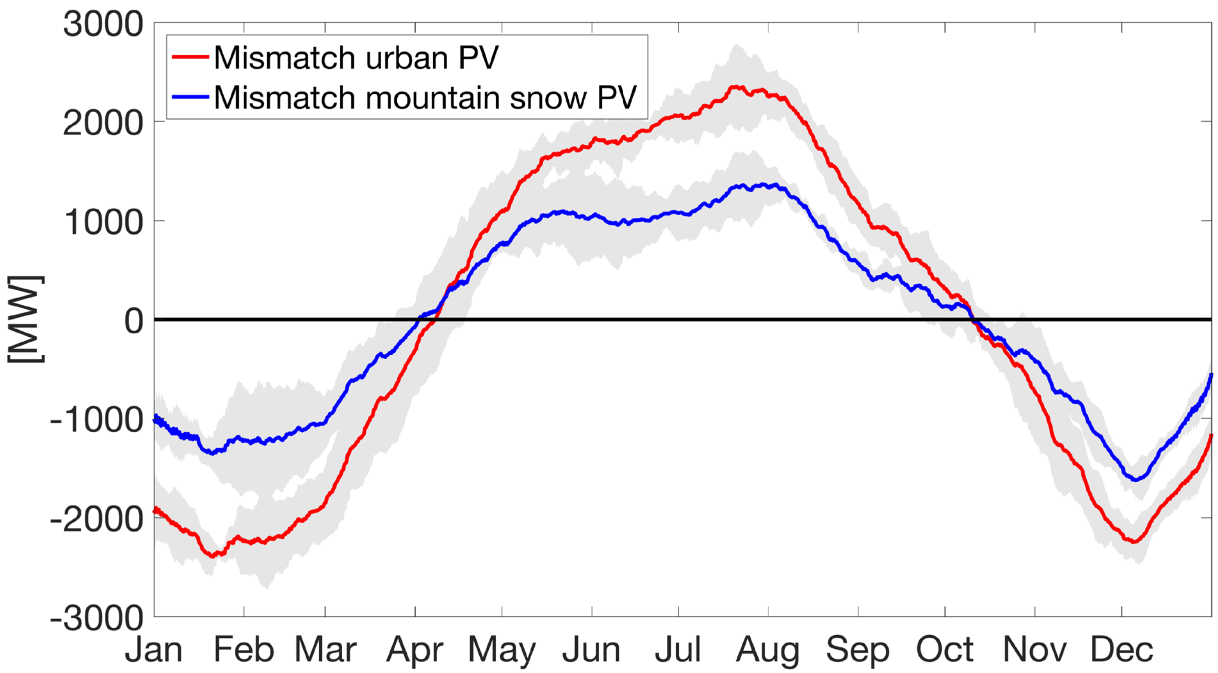
Nuclear Power replaced by wind (little) and PV



(c) Renewable

Bartlett, et al. (2018), Charting the course: A possible route to a fully renewable Swiss power system, *Energy*.

How to reduce the seasonal mismatch?



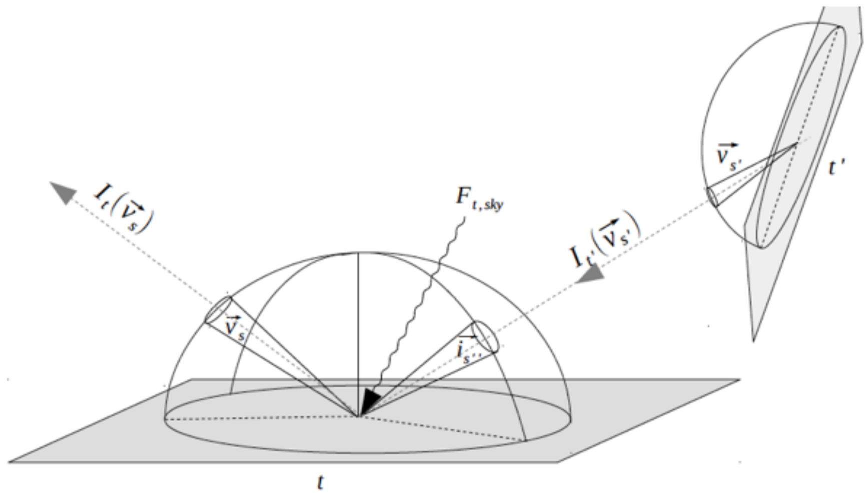
→ Need to fully understand potential of mountain PV:

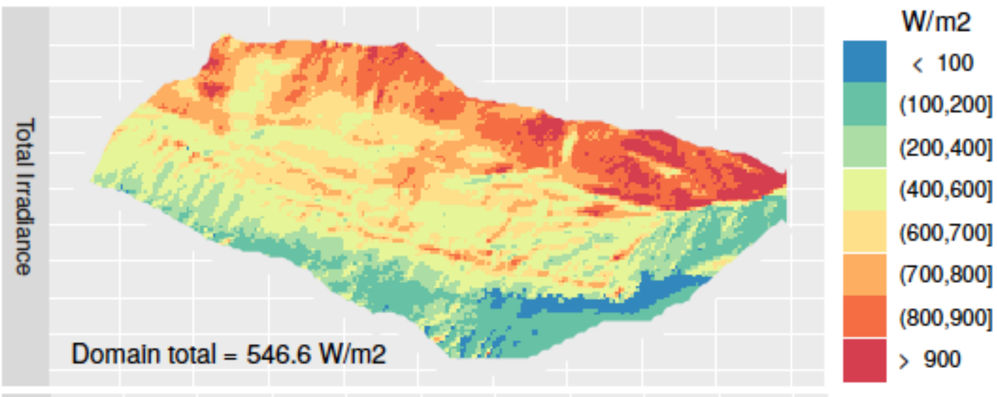
- Incoming Radiation
- Existing Infrastructure
- Acceptance
- Finance

Annelen Kahl, Jérôme Dujardin, Michi Lehning, PNAS 2019;116:4:1162-1167

Consider the role of Snow in Radiative Transfer

- **Snow scatters** light (high albedo) but does so **anisotropically**
- Not considered in any model of radiative transfer
- Combine snow modelling with near surface atmospheric modelling to assess influence on **surface energy balance** and yield of **solar panels** (PV) in snow environments
- Current models perform poorly
- Use for **potential assessment** and **operational forecasting**





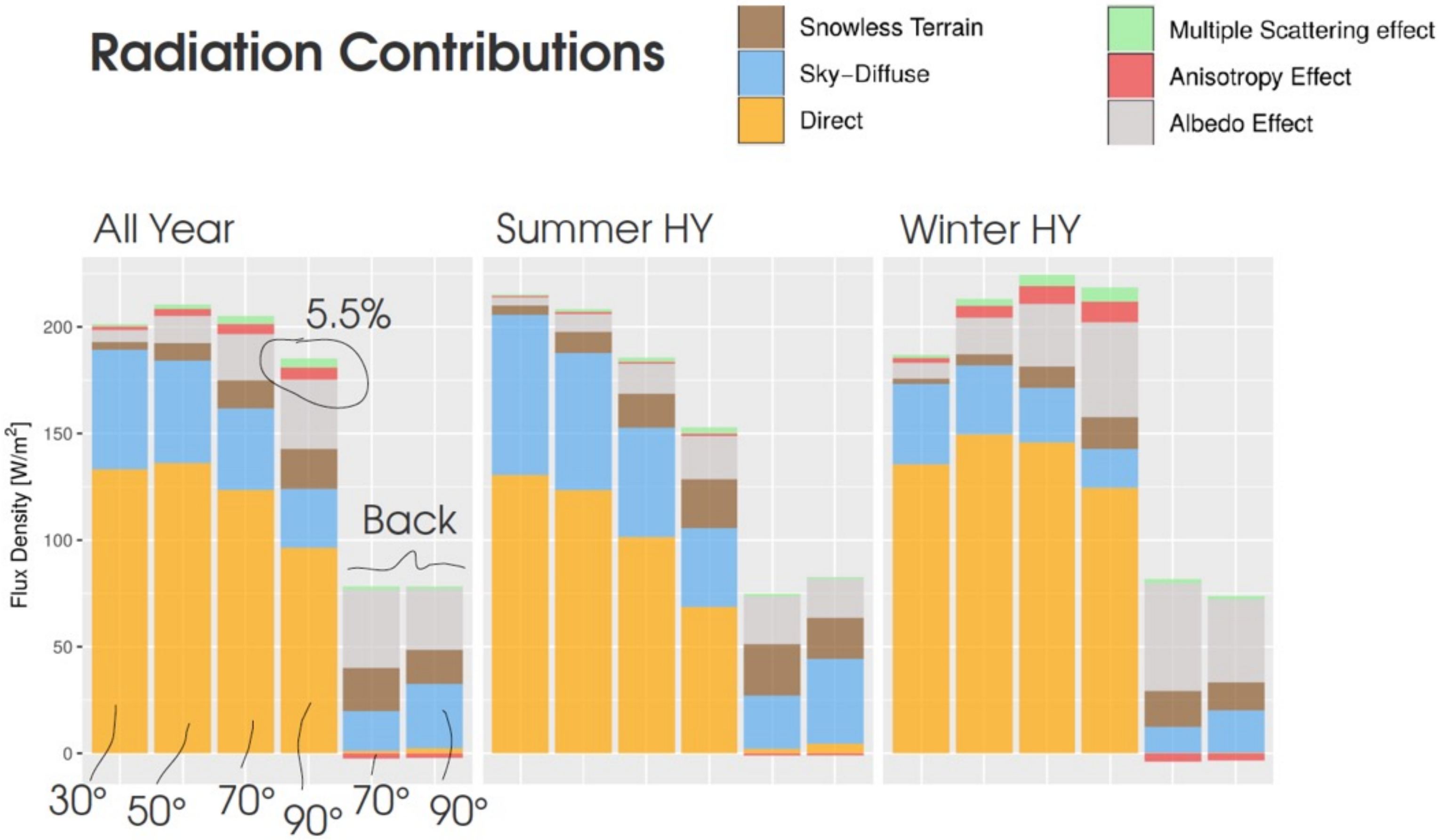
$$I_t(\vec{v}_s) = \underbrace{\frac{\alpha}{\pi}R(\vec{v}_s,\vec{i}_{sun})F_{direct,t} + \frac{\alpha}{\pi}F_{diffuse,t}}_{I_{t,sky}(\vec{v}_s)} + \sum_{s''=1}^{S} I_{t'(t,s'')}(\vec{v}_{s'(t,s'')})R(\vec{i}_s'',\vec{v}_s)\alpha f_{s''}$$

Iterative Solution

$$I_{t,k+1}(\vec{v}_s) = I_{t,sky}(\vec{v}_s) + \sum_{s''=1}^{S} I_{t'(t,s''),k}(\vec{v}_{s'(t,s'')})R(\vec{i}_s'',\vec{v}_s)\alpha f_{s''}$$

Von Rütte, Kahl and Lehning, JGR, 2021

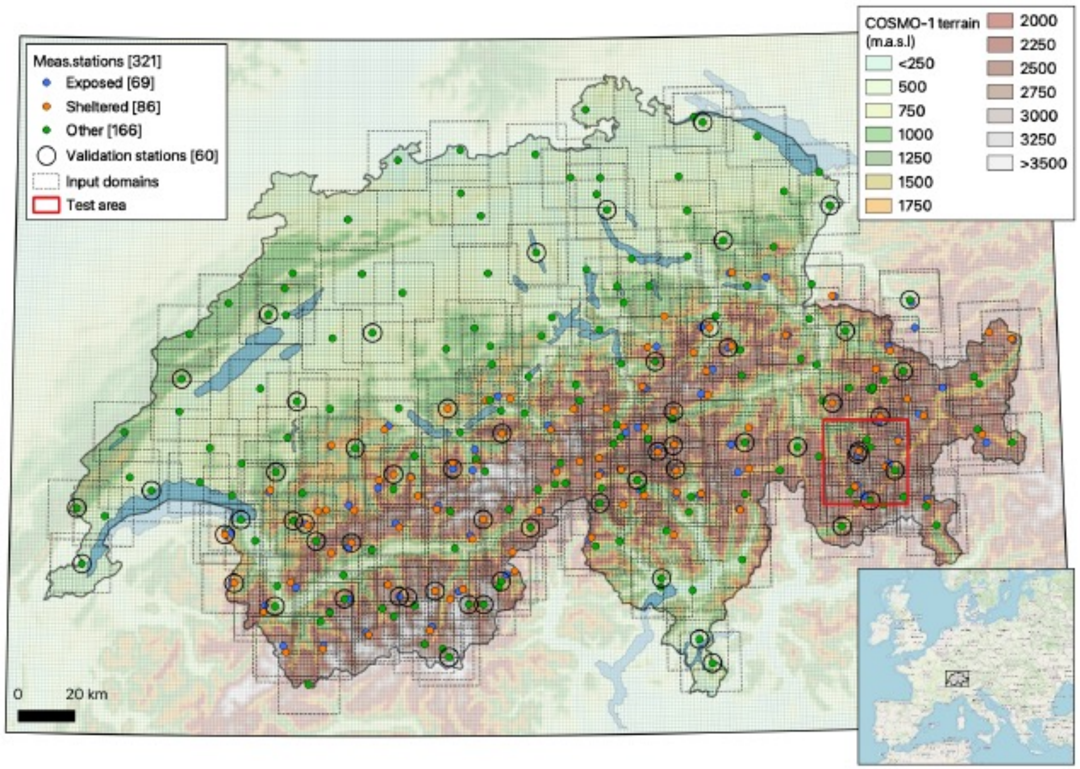
Consider the role of Snow in Radiative Transfer



Von Rütte, Kahl and Lehning, JGR, 2021

Does it matter in practice? – Even on a Rooftop

Make HR Wind Fields Computationally Affordable with ML



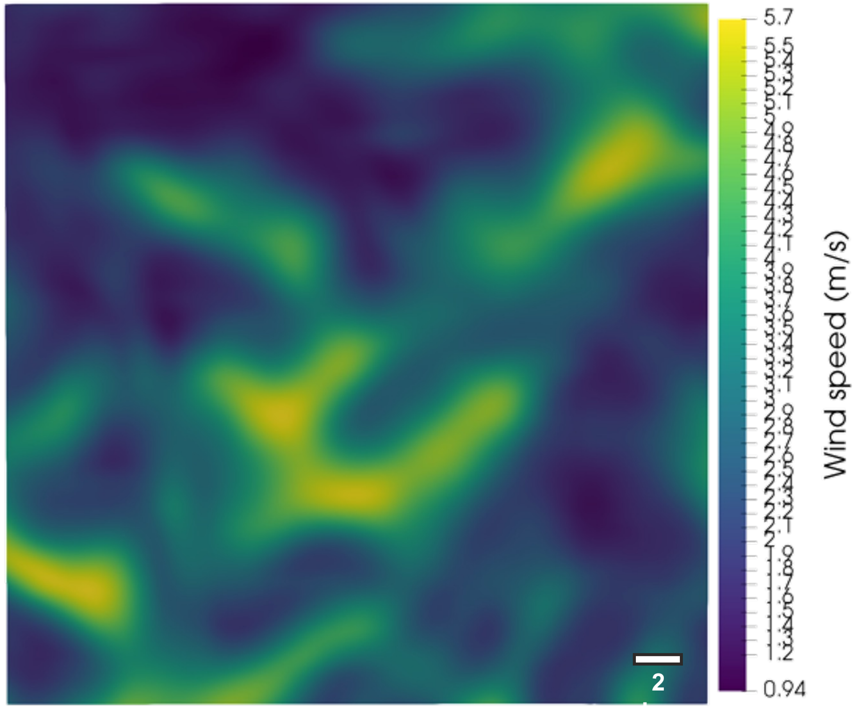
Dujardin and Lehning, QJRMS, 2022

- Try **machine learning** (ML) and specifically convolutional neural networks with training on weather station data (MeteoCH and IMIS)
- **Topographic Parameters** determined in an environment around the grid point of interest and characterizing wind exposure → make the wind turn as it hits topography
- Find a suitable **Loss Function,** which not only minimizes the error but also preserves the distributions of modelled winds as expressed by e.g. Weibull parameters

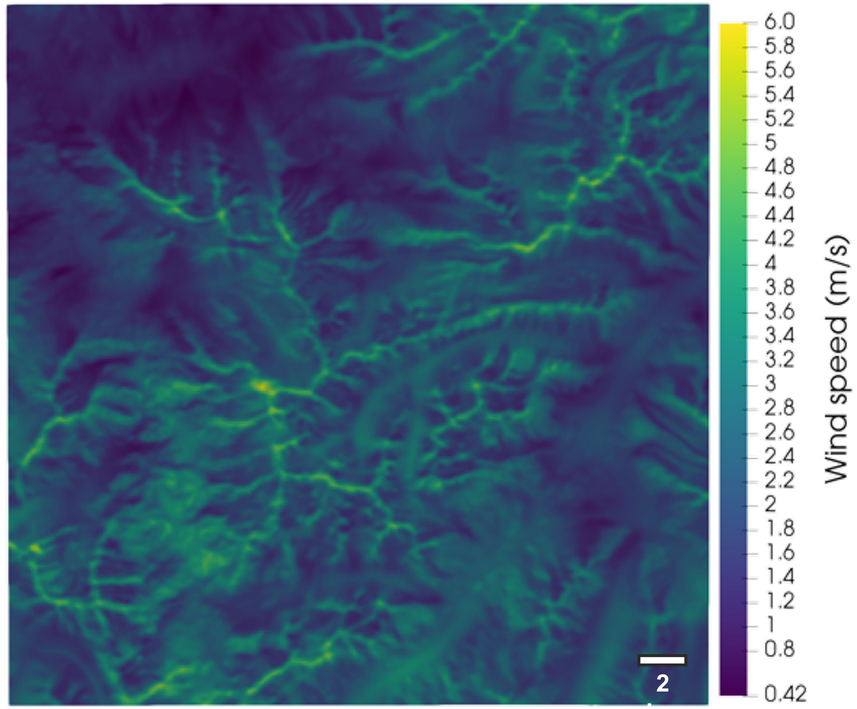
Make HR Wind Fields Computationally Affordable with ML

Average wind speed (1 year, hourly)

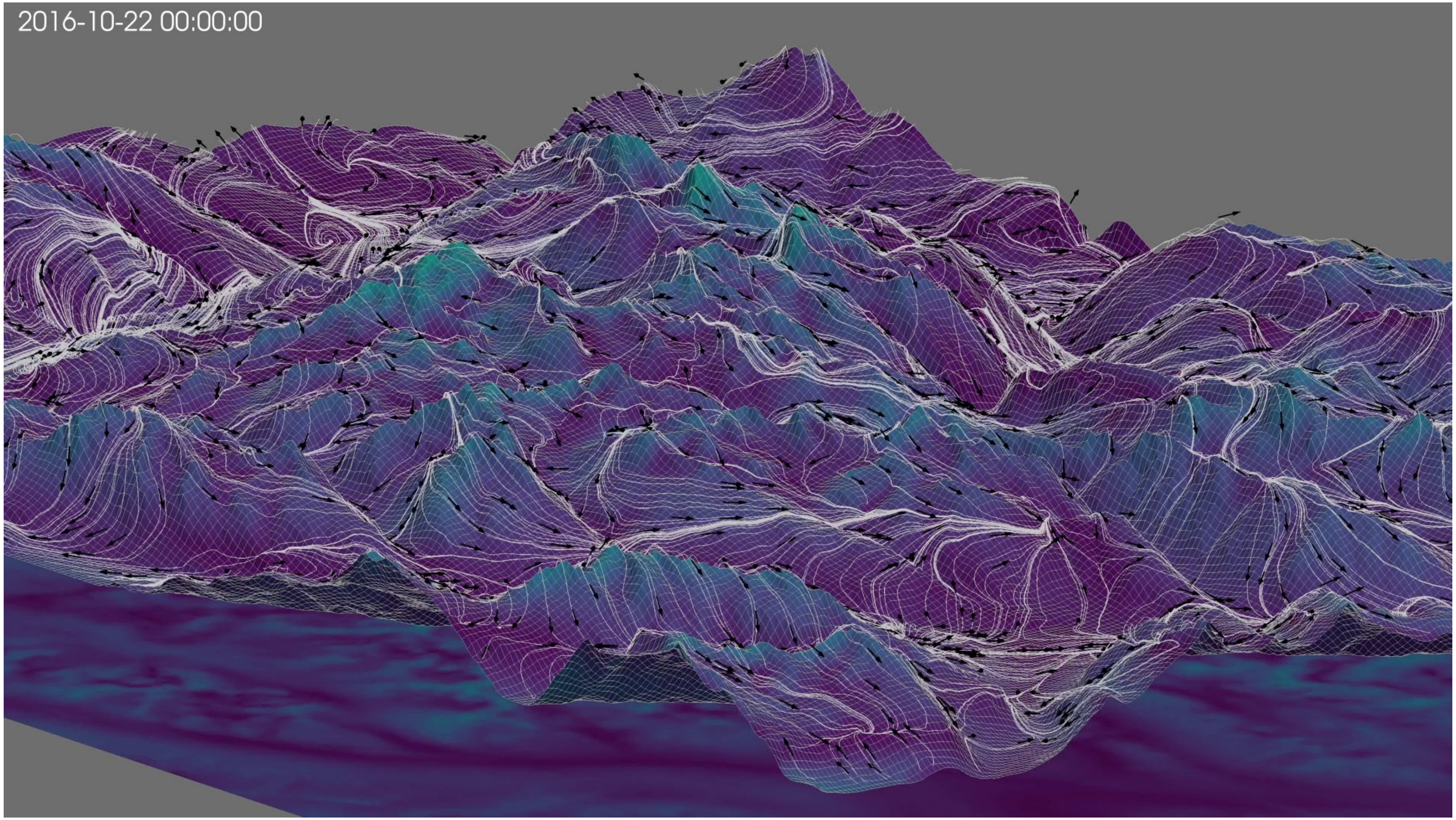
COSMO-1



Wind-Topo



Make HR Wind Fields Computationally Affordable with ML

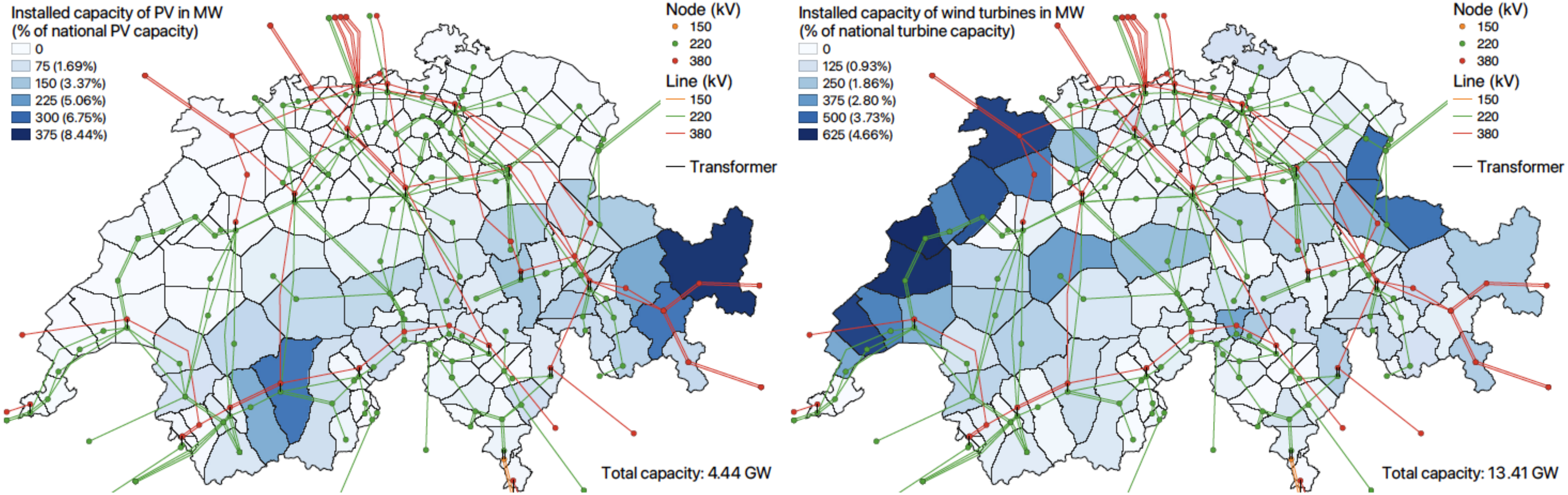


WSL

SLF

EPFL

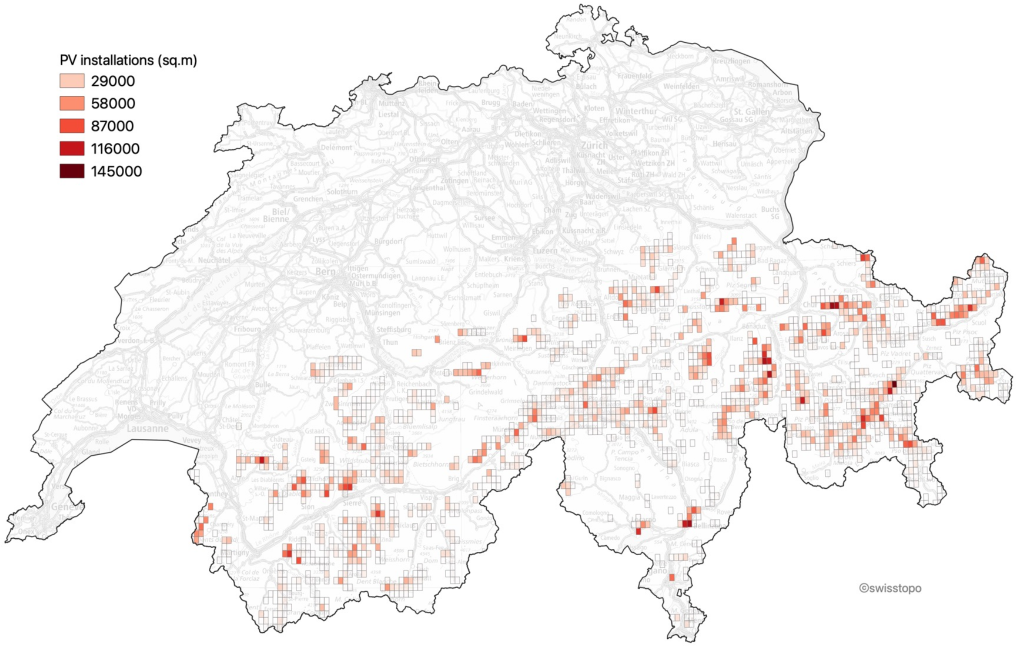
What is the optimal placement of PV and Wind? (for self-sufficiency)



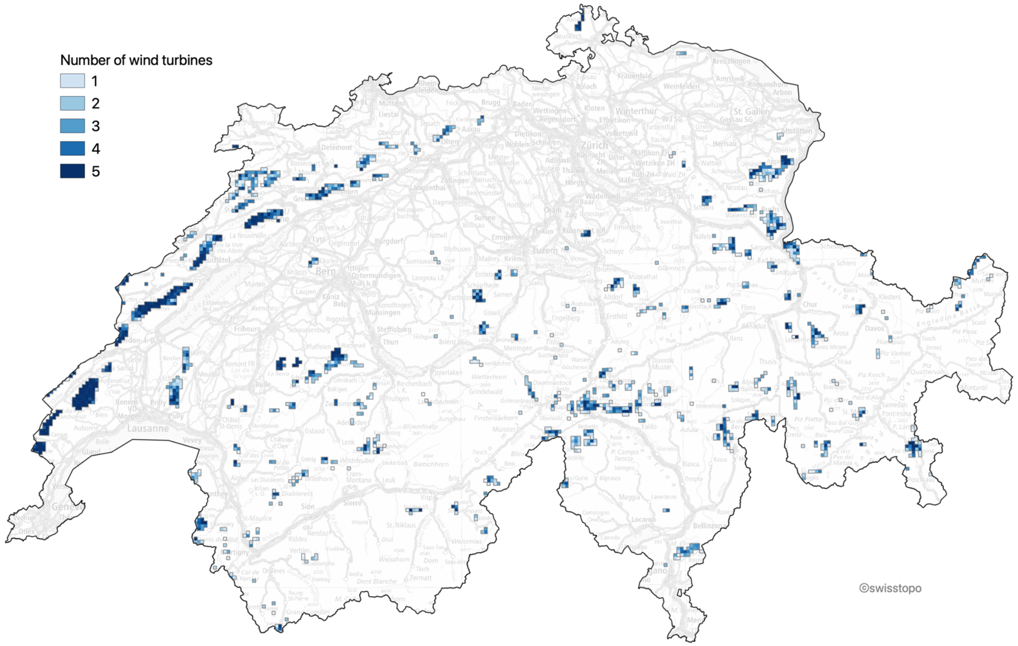
Dujardin, J., A. Kahl, and M. Lehning (2021), Synergistic optimization of renewable energy installations through evolution strategy, *Environ Res Lett*, *16*(6), doi: ARTN 064016, 10.1088/1748-9326/abfc75.

Optimization for minimizing winter deficit
(29 TWh generation in 2016)

Optimal PV installations: 4.44 GW_{peak}

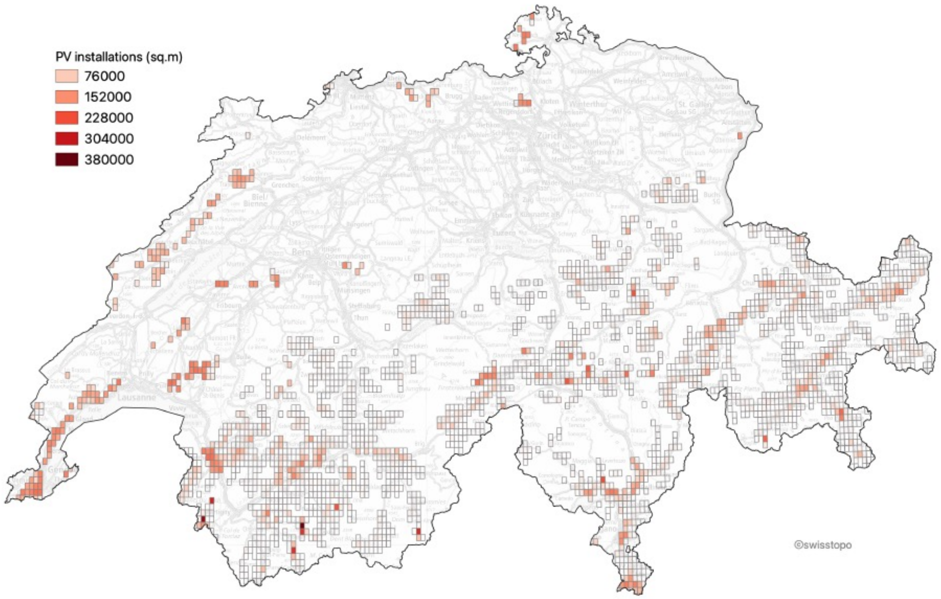


Optimal wind power installations: 13.41 GW_{peak}



Optimization for maximizing revenues
(25 TWh generation in 2019)

Optimal PV installations: 13.64 GW_{peak}



Optimal wind power installations: 1.18 GW_{peak}

Fresh from the Press: Jérôme Dujardin

Actionable Conclusion: Facilitate High-Mountain Installations of both PV and Wind

Recipe of Success:

100 km^2 of PV Panels (50% in the mountains) – 10 GW

1000 Wind Turbines – 3 GW

→ 10 TWh of Additional Storage

From: https://twitter.com/ParmelinG/status/1528745252500164609

SLF

EPFL