Ecosystem greenhouse gas fluxes respond directly to weather not climate

Exploring the relationship of global circulation, Föhn frequency, and winter weather to northern Alps regional ecosystem phenology and carbon cycling

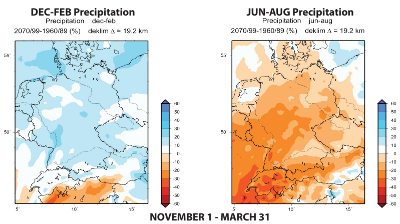
Ankur R Desai[1,*], Georg Wohlfahrt[2], Matthias J Zeeman[3], Genki Katata[3,4], Matthias Mauder[3], Hans-Richard Knoche[3] and Hans Peter E Schmid[3]

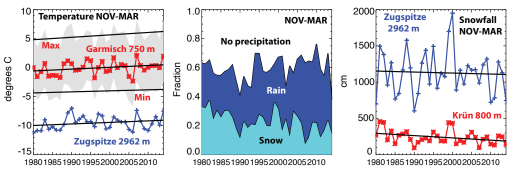
(1) University of Wisconsin Madison, Madison, WI, United States, (2) University of Innsbruck, Innsbruck, Austria, (3) Karlsruhe Institute of Technology IMK IFU, Garmisch-Partenkirchen, Germany, (4) Japan Atomic Energy Agency, Ibaraki, Japan

* desai@aos.wisc.edu +1-608-520-0305 http://flux.aos.wisc.edu

1. The climate change-weather nexus

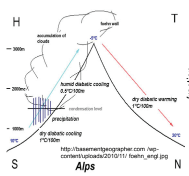
- Regional carbon cycle responses to climate warming are not straightforward
- In the Northern Alps, high resolution climate models (right) project increasing precipitation in winter and decline in summer by 2070-2100
- How do mountain local climate, weather, and ecosystems respond to this?

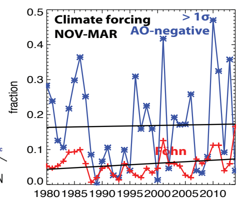




- Valley and mountain winter (Nov-Mar) temperatures (left) increasing in N Alps
- No clear trend in winter precipitation, except decline in snowfall
- But interannual variability is quite large. *What explains this?*

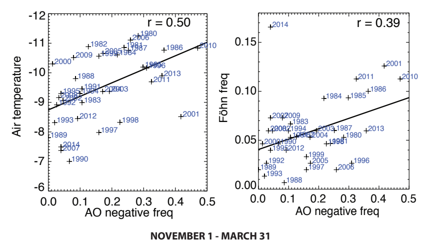
- Föhn southerly downslope flow (right) promotes drying and warming in Northern and Central Alps
- Frequency objectively determined w/mountain & valley wind velocity and temperature gradients
- Föhn is increasing in frequency and follows Arctic Oscillation (AO) negative pressure anomaly, though AO- frequency has not increased

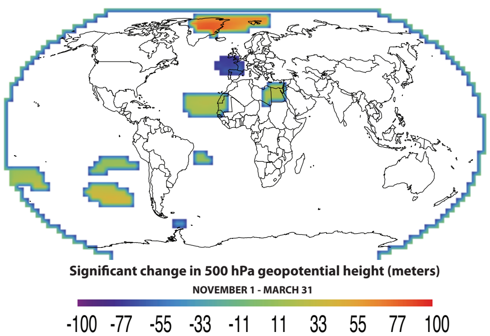




2. Climate dynamics of the "snow-eater" / "hair-dryer"

- Arctic oscillation negative pattern promotes southerly flow pattern
- AO negative day frequency determines mean winter air temperature (left panel)
- It also partly explains Föhn frequency (right panel),except in highest Föhn years
- Global circulation drives local meteorology

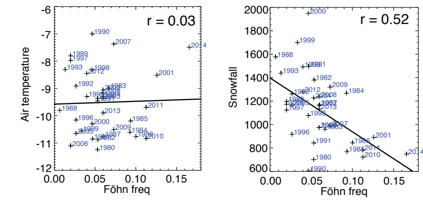




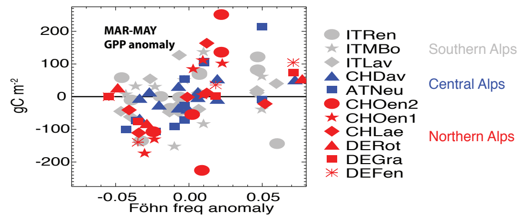
- Top 25% of Föhn years' 500 hPa geopotential height anomaly (left) shows significant differences (ANOVA F-test 99%) to low Föhn years in North Atlantic
- A Western Europe / N. Greenland dipole enhances the Föhn flow
- Recent research has related this pattern to shifts in N Atlantic gulf stream front or Arctic sea ice anomalies
- Climate projections show changes in this blocking pattern with future warming

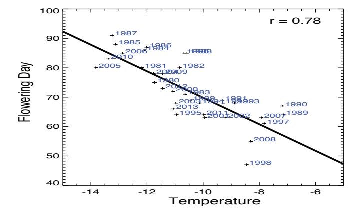
3. Local effects of regional circulation

- Frequency of Föhn flow does not explain winter temperature, since Arctic Oscillation determines synoptic conditions that influence air mass origin
- However, snowfall is inversely related to Föhn conditions, as Föhn promotes drying and inhibits precipitation (right panel)
- How do these responses influence grassland and forest gross primary productivity (GPP)?



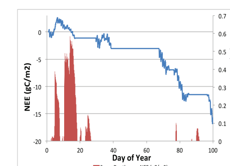
- Multi-year flux tower observations at 11 sites (bottom left) show positive response of spring (Mar-May) GPP anomalies to modest Föhn frequency relative anomalies in winter (Nov-Mar), especially in northern (red) and central (blue) Alps. GPP response muted in strong Föhn years
- One mechanism of spring GPP response is phenology (bottom right), exemplified by decrease in spring flowering day with warmer winters at Austrian Alpine flower monitoring plots

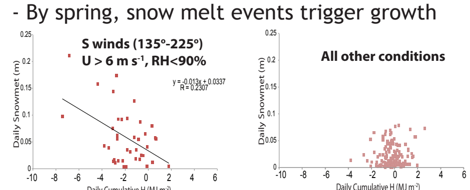




4. Simulations with Föhn and conclusions

- SOLVEG multi-layer land surface model deployed for multi-year simulation at a grassland flux tower site in German Alps
- Föhn conditions promote snow melt (right). For a short period, carbon emissions increase with snow melt, but long term effect is net uptake
- By spring, snow melt events trigger growth





- In model, southerly flow conditions drive snowmelt that occurs under presence of strong negative heat flux (left)
- Vegetation dynamics could be considered in model to understand snowmelt frequency and grassland mortality relationships

For many ecosystems, shifts in regional circulation may be just as important as general climate trends for driving key responses of ecosystem carbon fluxes to global warming

- For N Alps, winter Föhn flows, triggered by negative Arctic Oscillation and N Atlantic dipole, promote snow melt, early green-up, enhanced spring GPP, and other impacts

Acknowledgments:

We thank the support of KIT IMK-IFU, the Universiy of Wisconsin sabbatical leave program, and the Helmholtz Society / MICMOR fellowship program. We also thank PEP725 project for phenology observations and the DWD for German weather data. We are indebted to the providers and funders of the eddy covariance flux tower observations, the FLUXNET program, and its database.