Sensitivity of wind turbine array downstream effects to the parameterization used in WRF

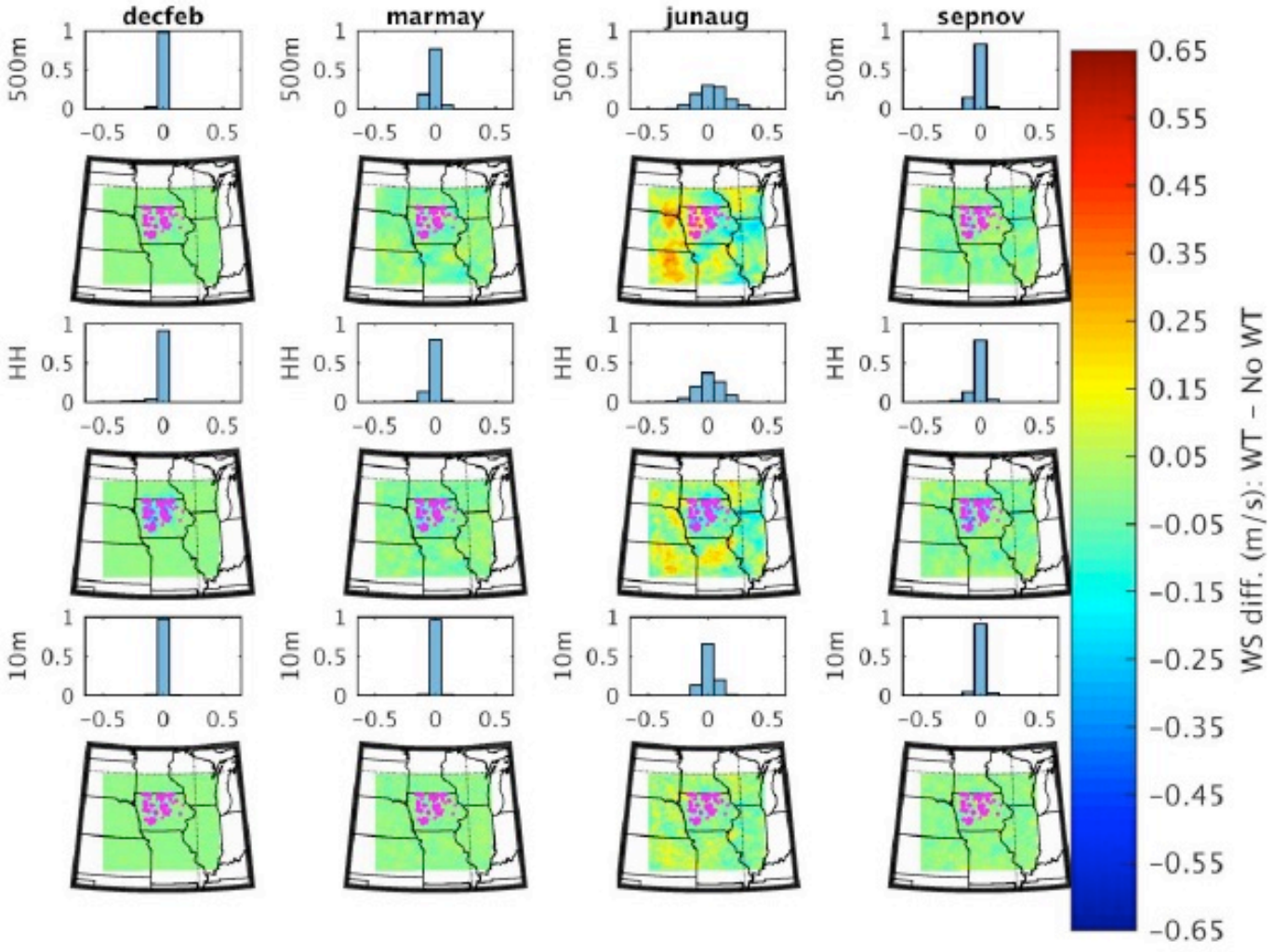
Tristan J. Shepherd[1], P. Volker[2], R.J. Barthelmie[1], A. Hahmann[2], S.C. Pryor[1]

[1]Cornell University

[2]Technical University of Denmark

tristan.shepherd@cornell.edu

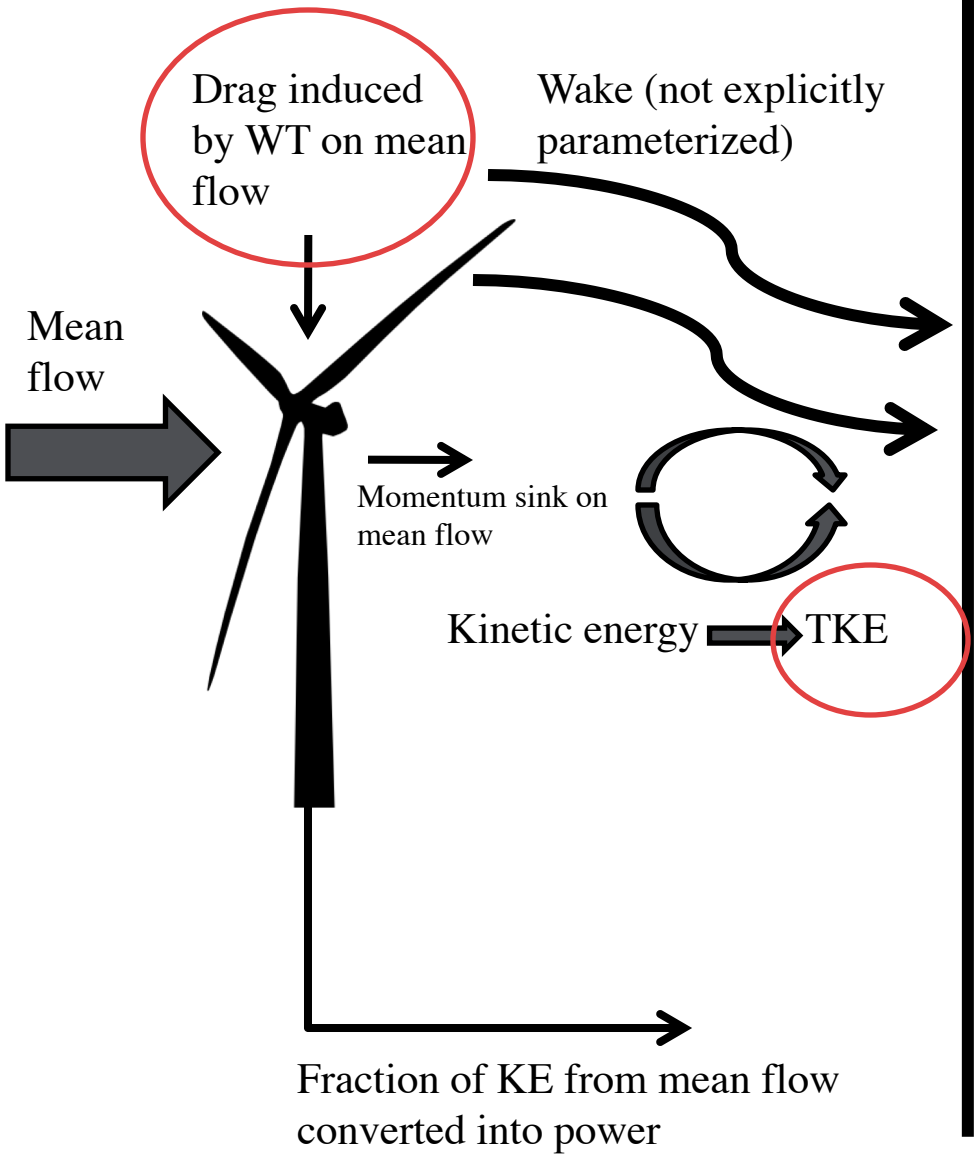
Acknowledgments: US Department of Energy (DE-SC0016438) and Cornell University's Atkinson Center for a Sustainable Future (ACSF-sp2279-2016). Computing resources: NSF ACI-1541215, NSF ACI-1548562 and DoE National Energy Research Scientific Computing Center (DE-AC02-05CH11231).



Pryor, S.C., Barthelmie, R.J., and Shepherd T.J. (2018): The influence of real-world wind turbine deployments on local to mesoscale climate. *Journal of Geophysical Research: Atmospheres*. doi: 10.1029/2017JD028114

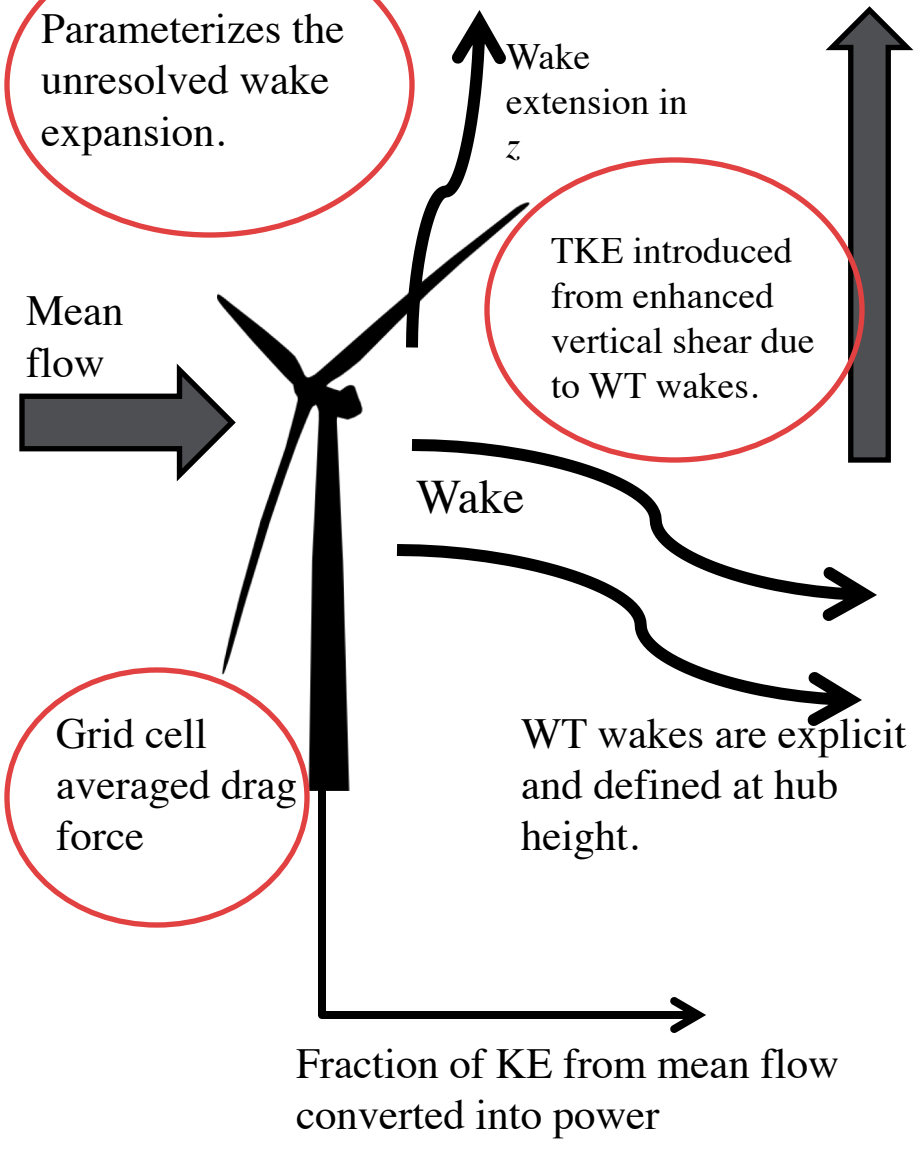
Fitch parameterization

(Fitch et al. 2012)



Explicit wake parameterization

(Volker et al. 2015)



Key Study Points

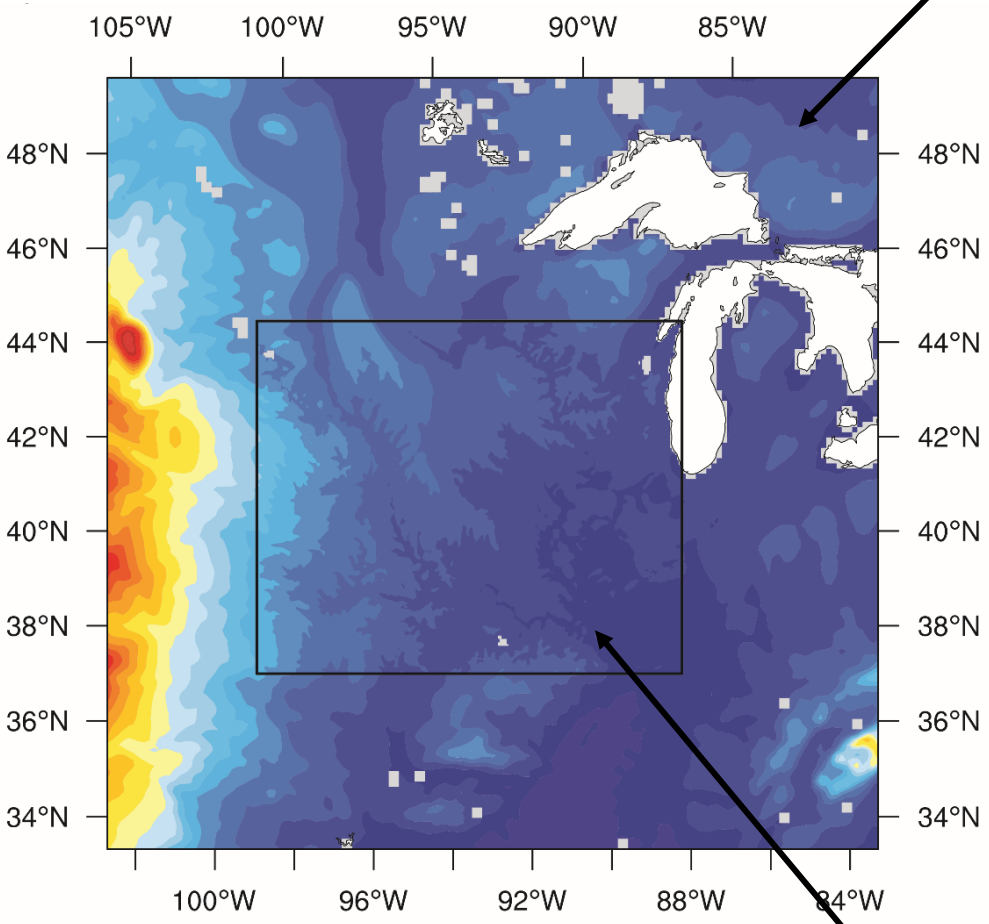
- Continuous year long simulation for 2008 (near neutral climate conditions).
- WRF applied at convection-permitting resolution. Actual WT locations and specs (from USGS database) applied to multi-nested model domain.
- Multi-nested domain means all identical nests receive the same conditions from the parent.
- Running multi-domain eliminates the stochastic sensitivity resulting from conducting separate simulations in the cloud.
- Centred over Iowa as current US state with highest WT density.
- Goal: Assess the degree to which the results differ dependent on the precise WT parameterization used in WRF.

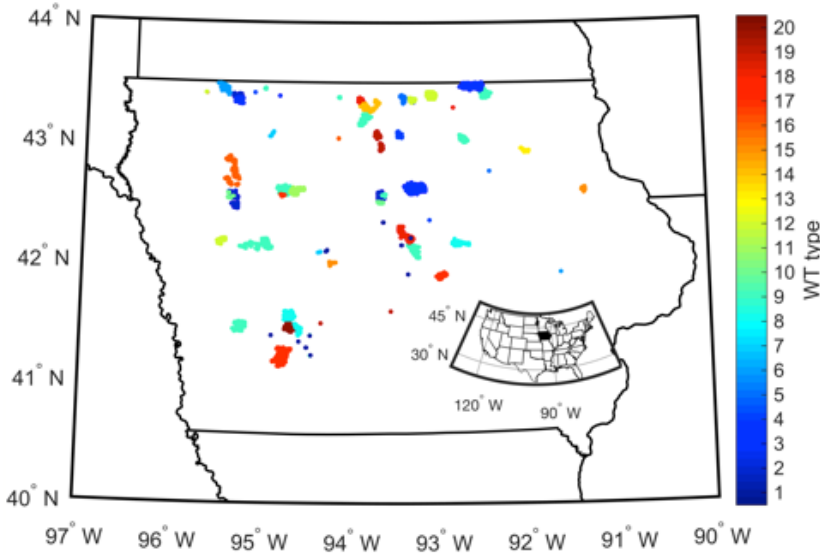
Model configuration and physics settings (v3.8.1)

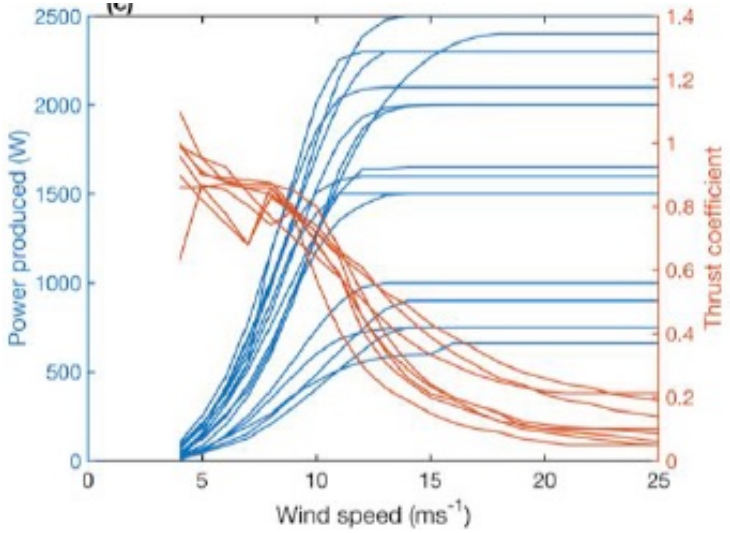
Simulation settings	Values
Vertical resolution	41 levels up to 50 hPa (18 in lowest 1 km)
Time step for physics	72 seconds
Physics option	**Adopted scheme**
Microphysics	5. Eta (Ferrier) (Ferrier et al. 2002)
Longwave radiation	1. Rapid radiative transfer model (RRTM) (Mlawer et al. 1997)
Shortwave radiation	1. Dudhia (Dudhia 1989)
Surface layer physics	1. MM5 similarity scheme (Beljaars 1995)
Land surface physics	2. Noah land surface model (Tewari et al. 2004)
Planetary boundary layer	5. MYNN 2.5 (Nakanishi and Niino 2006)
Cumulus parameterization	1. Kain-Fritsch (Kain 2004) (None in d02/3/4)

Domain and WTs

Domain 1: 150 × 150 cells, 12 km

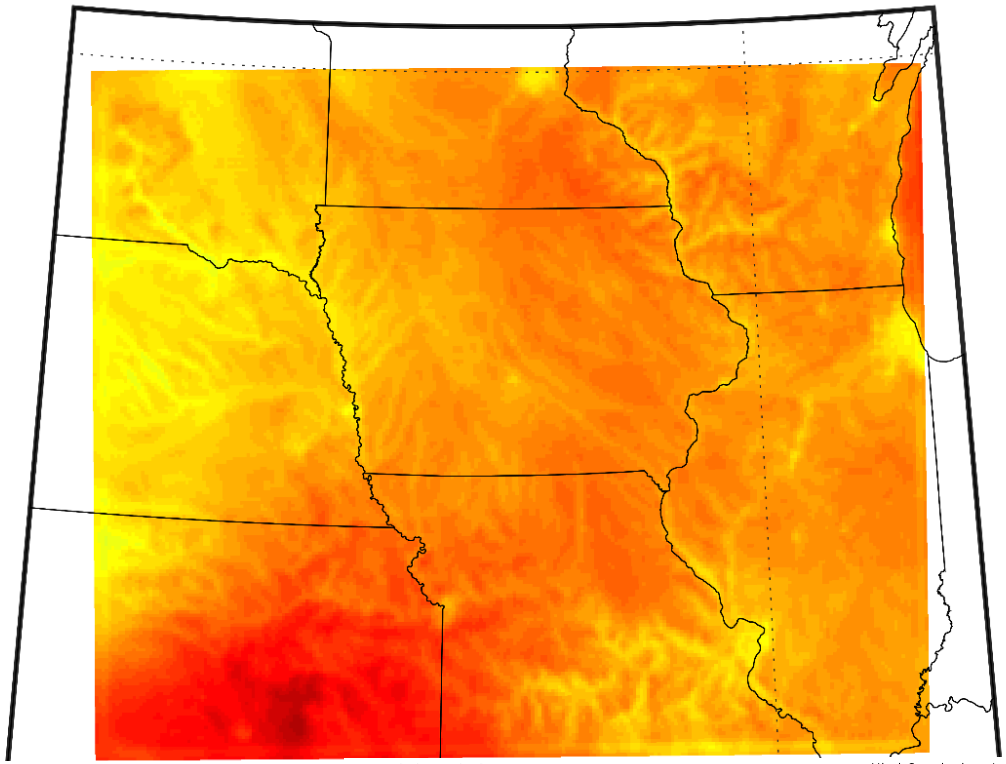


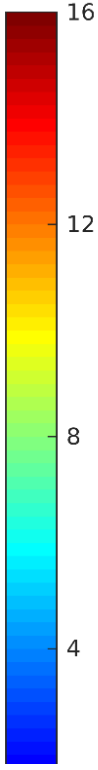


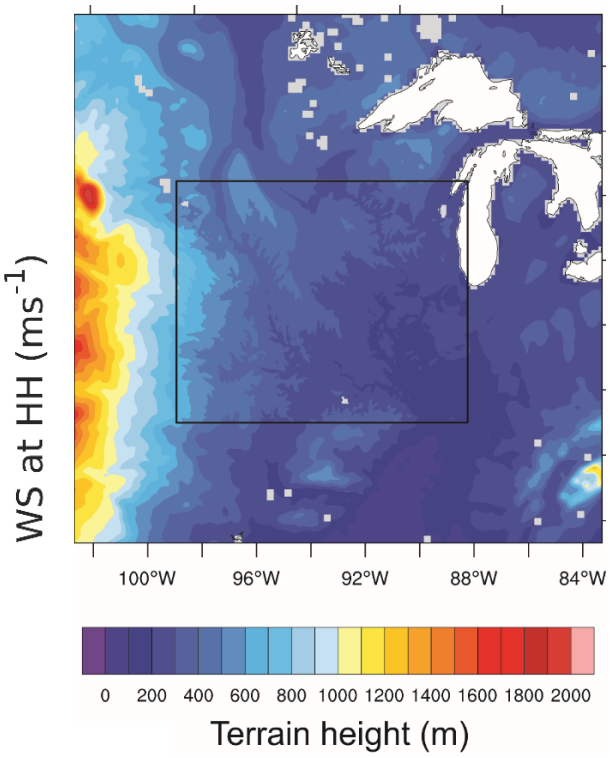


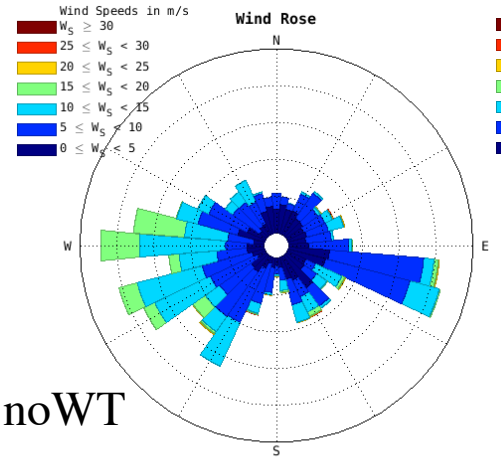
Domain 2,3,4: 247 × 206 cells, 4 km

Mean wind speed / wind roses (June)

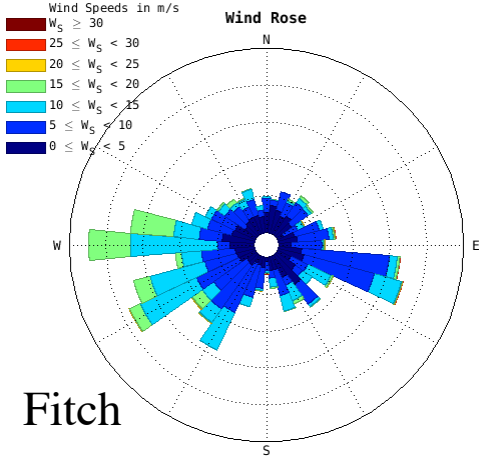




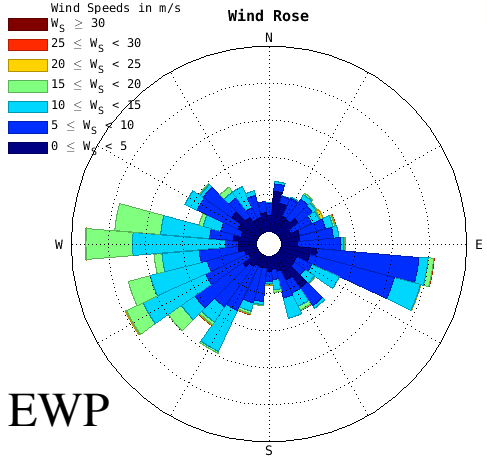




noWT

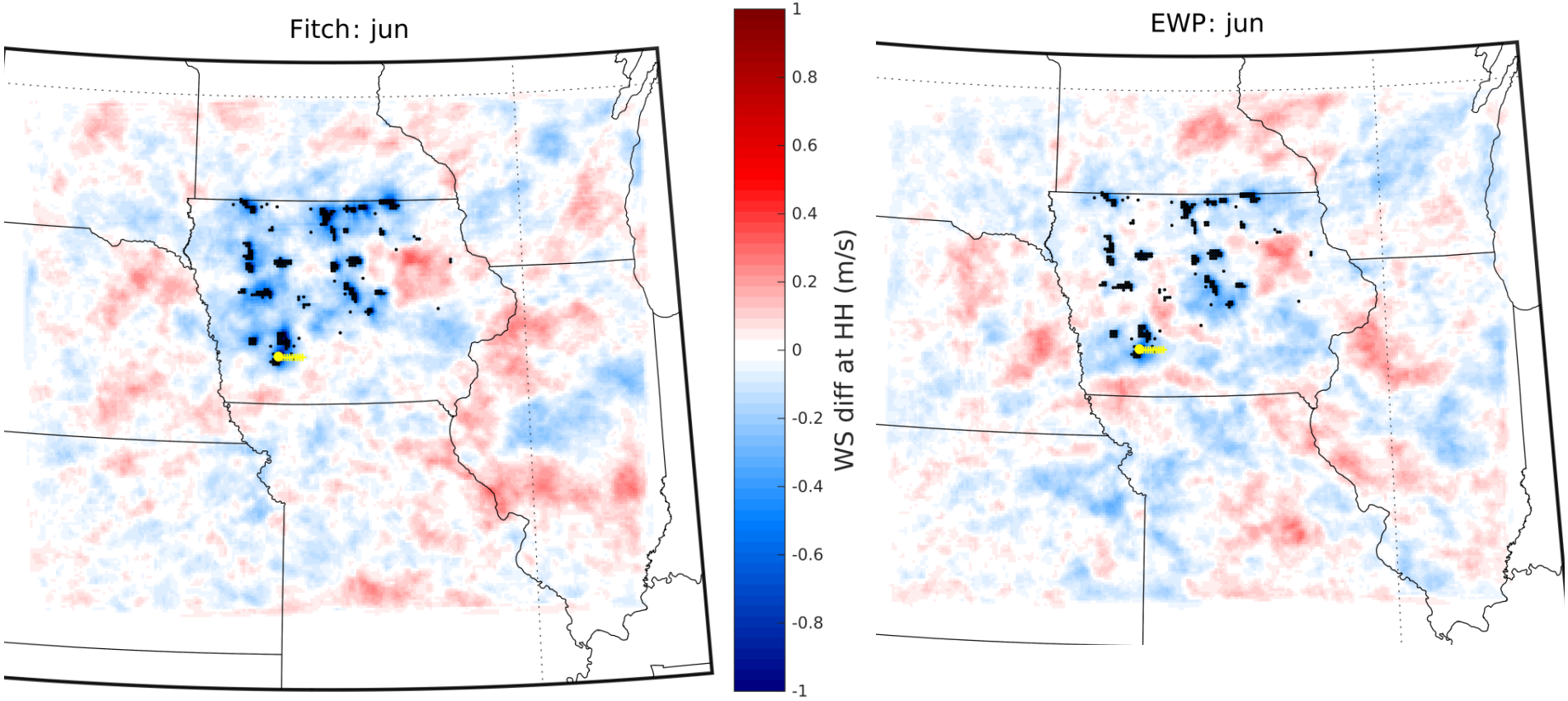


Fitch

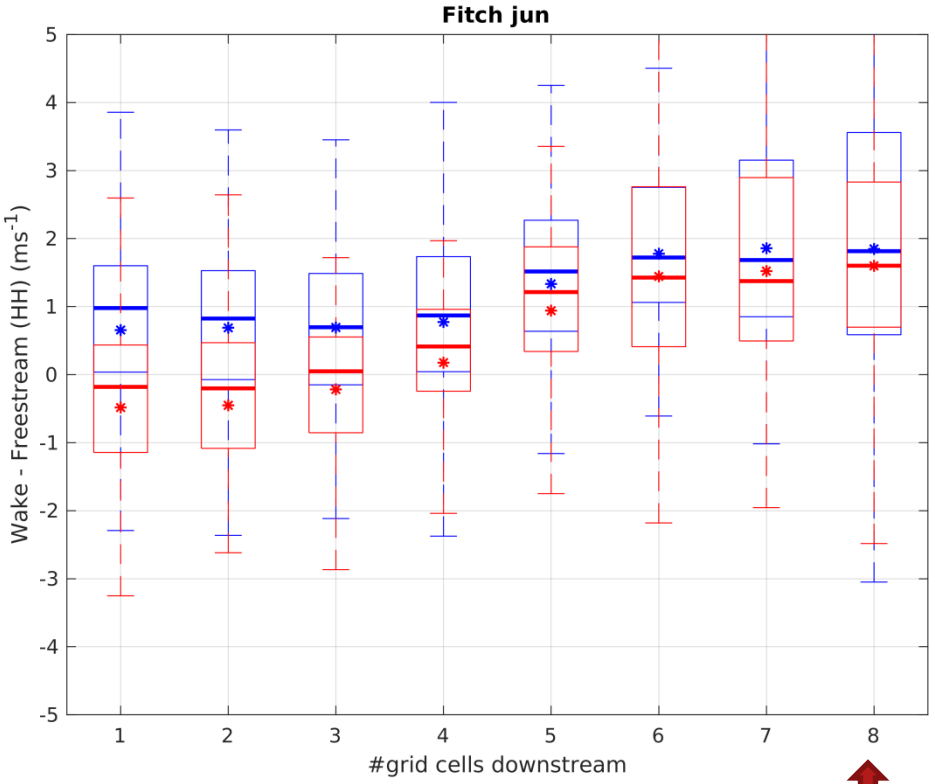


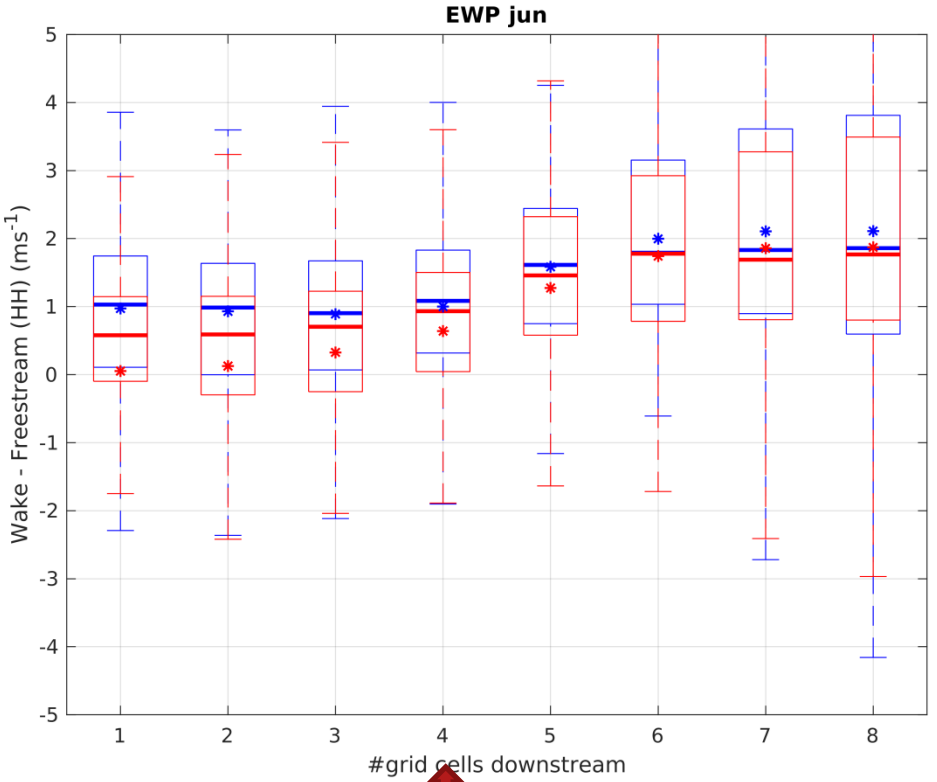
EWP

Downstream WT impact (xWT – noWT)



WT array wakes

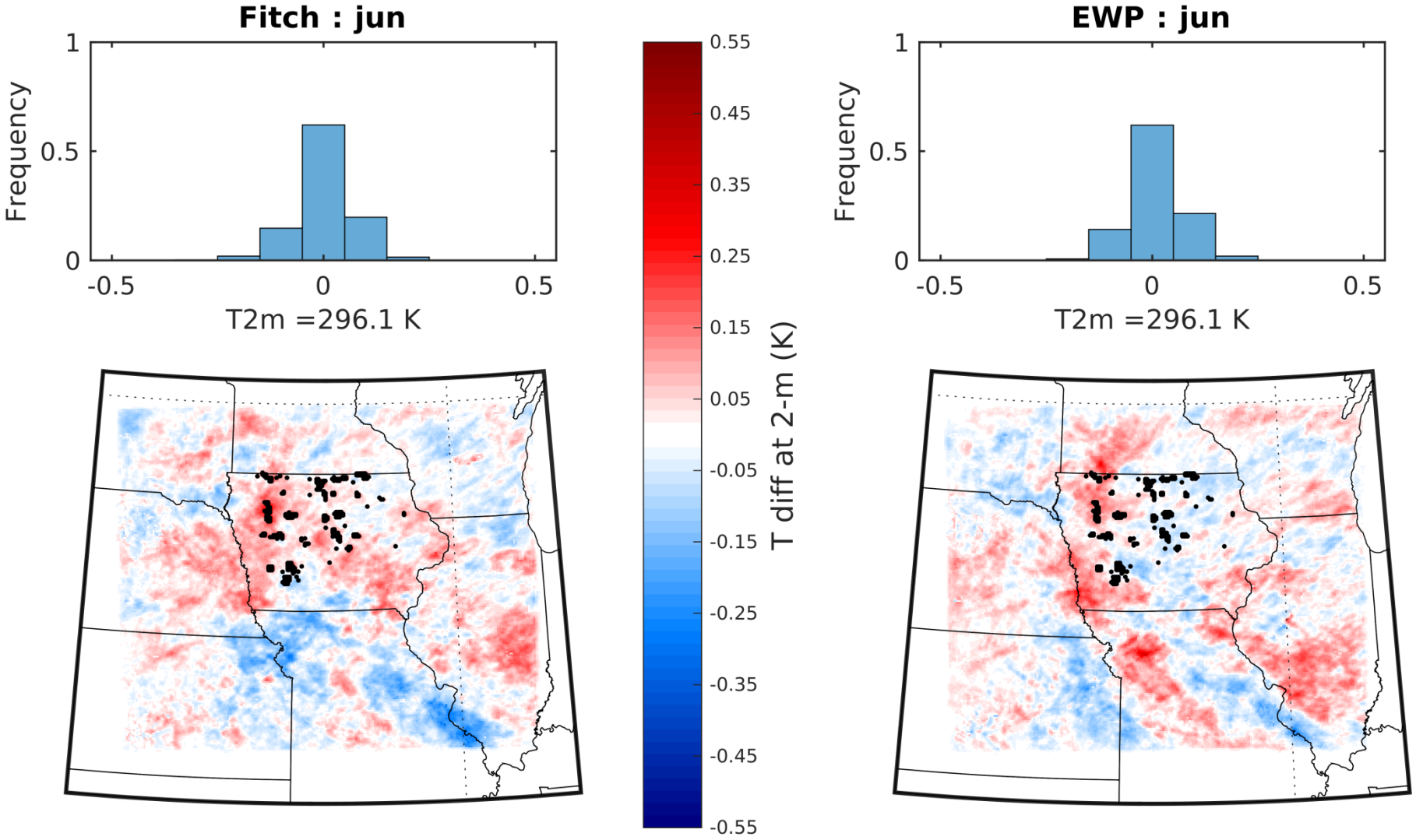




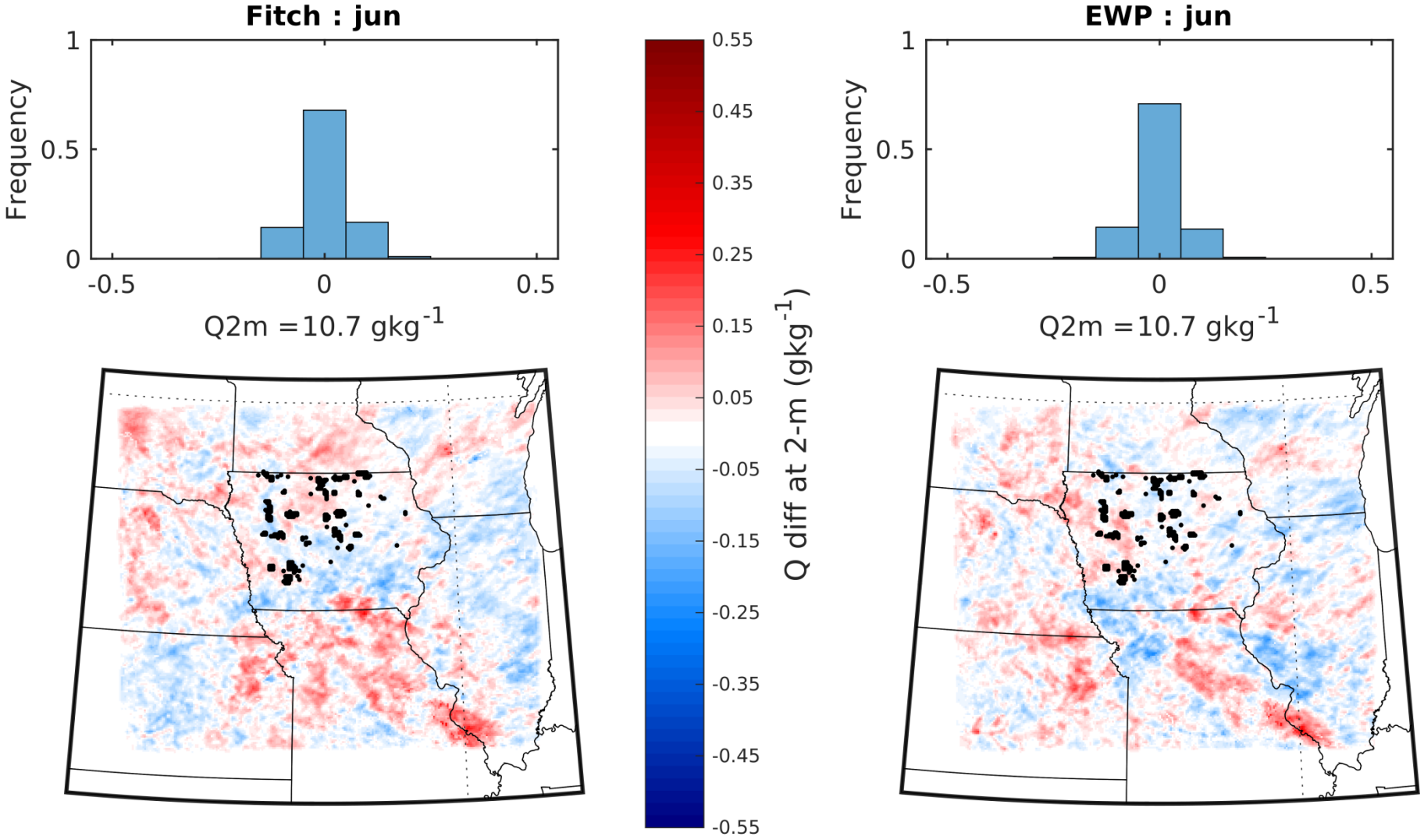
Downstream propagation of the velocity deficit is greater in Fitch (32 km v 16 km EWP).

Consistent with previous study for a theoretical wind farm (30 km Fitch v 17 km EWP) (Volker et al. 2017).

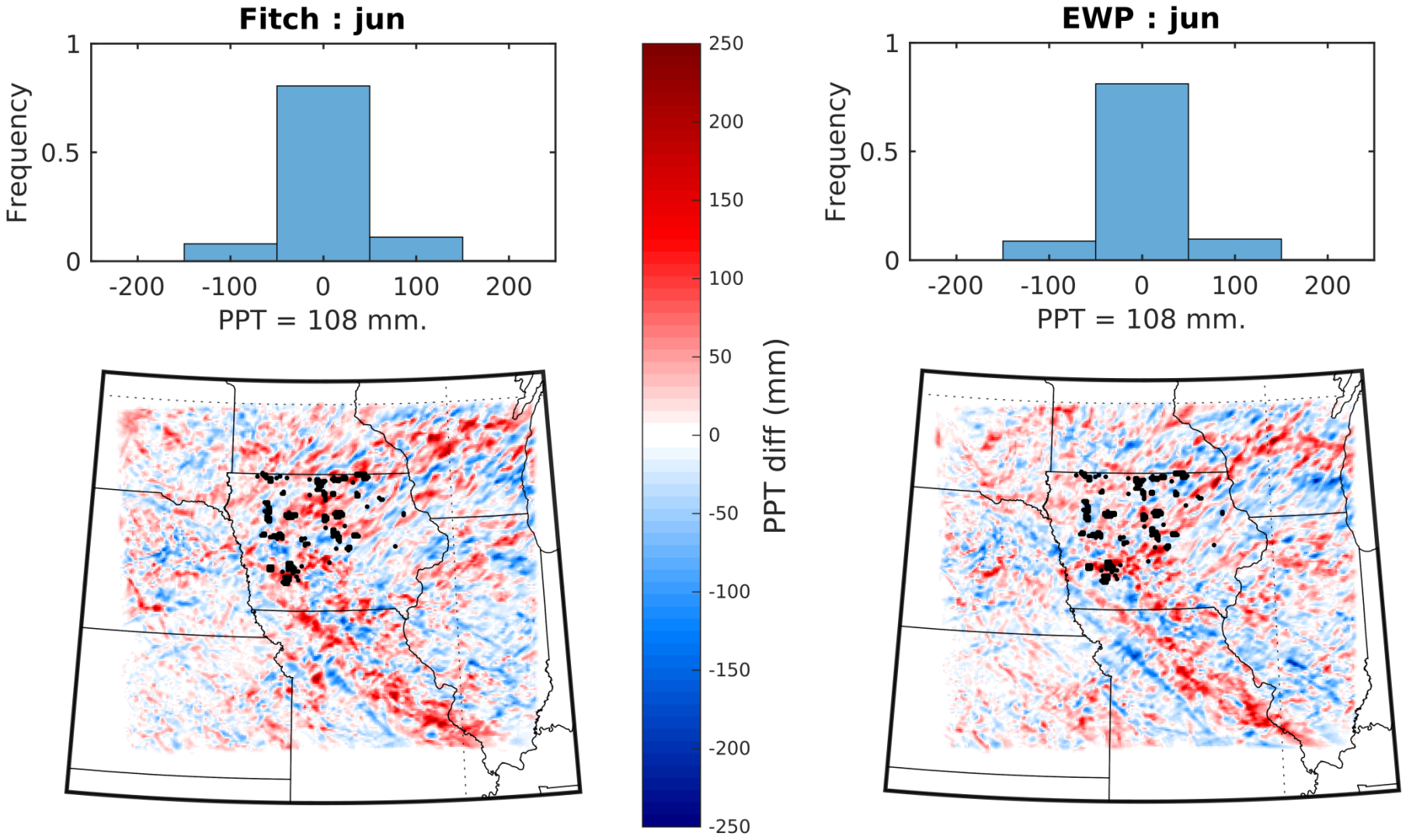
Climate impacts: 2m Temp



Climate impacts: Specific Humidity

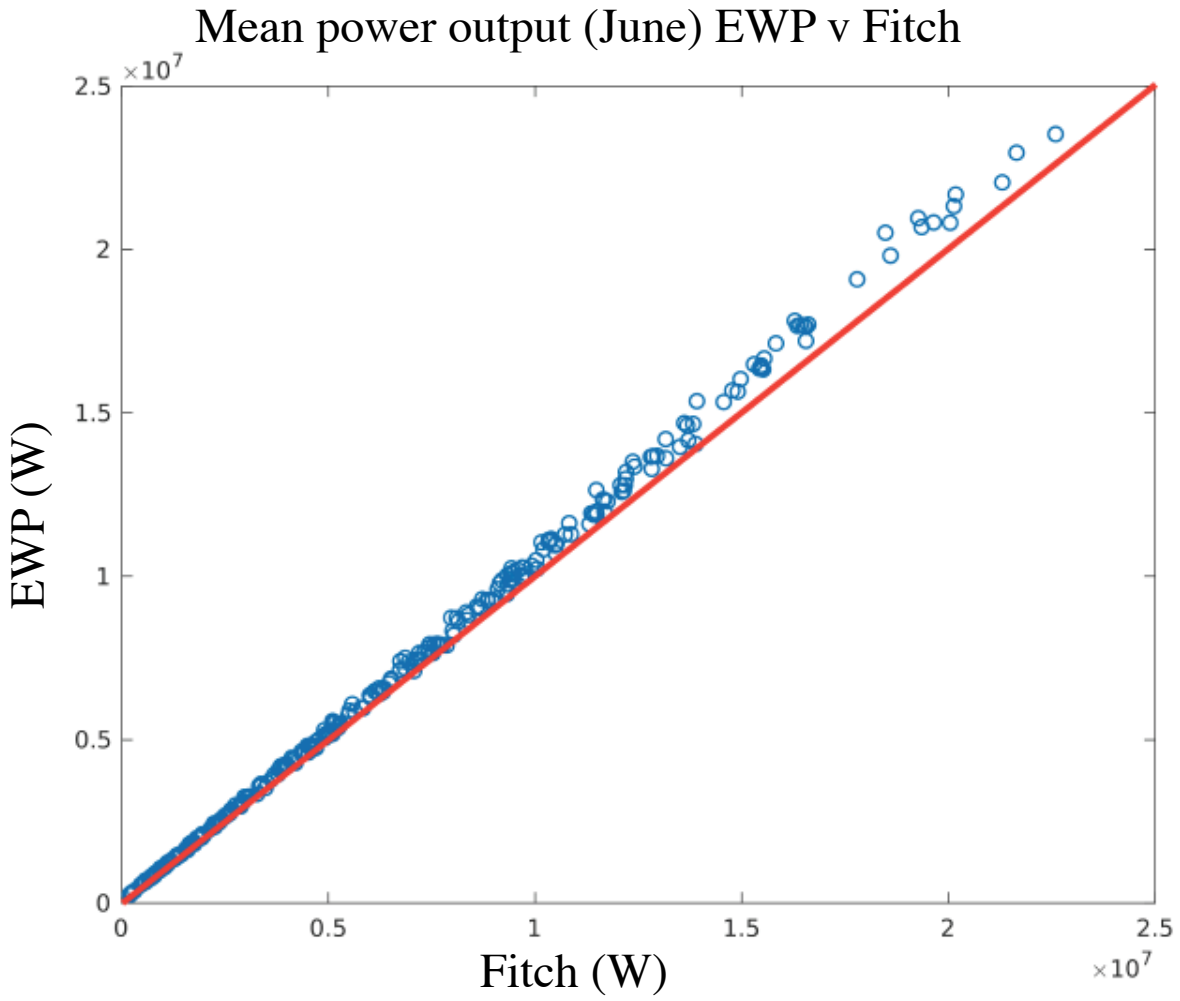


Climate impacts: Precipitation



Power production

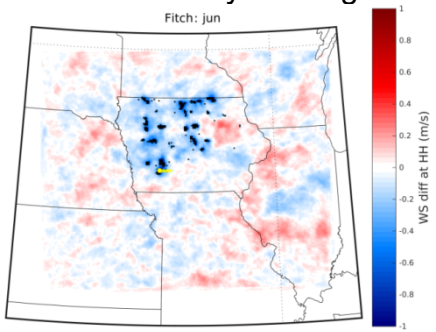
Month	CF (Fitch) %	CF (EWP) %
June	38	40

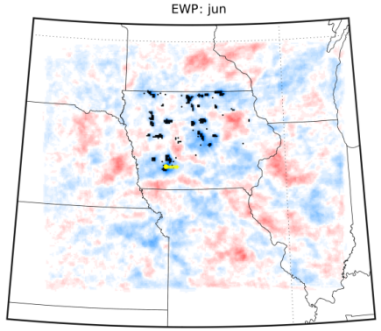


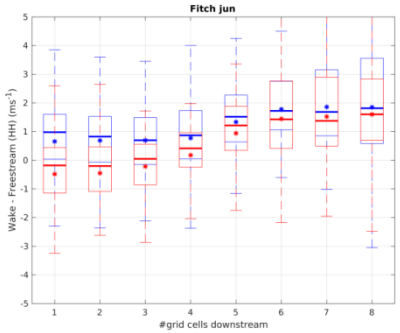
Concluding remarks

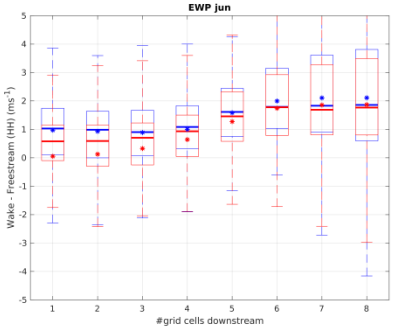
- Minimal climate impact from WT installations.
- Faster wake recovery in EWP nested domain.
- EWP wake recovery leads to smaller climate impacts and reduced array-array interactions than in Fitch nested domain.
- At a system-wide scale, this result leads to an improved efficiency in total power output, with a CF in EWP 2% greater than Fitch for the month of June.

- Pryor, S.C., Barthelmie, R.J., and Shepherd T.J. (2018): The influence of real-world wind turbine deployments on local to mesoscale climate. *Journal of Geophysical Research: Atmospheres*. doi: 10.1029/2017JD028114
- Pryor, S.C., Barthelmie, R.J., and Shepherd T.J. (2018): Limited impacts from increased wind capacity on system efficiency and regional climate. *Nature Communications (under review).*









Acknowledgments:
US Department of Energy (DE-SC0016438) and Cornell University's Atkinson Center for a Sustainable Future (ACSF-sp2279-2016). Computing resources: NSF ACI-1541215, NSF ACI-1548562 and DoE National Energy Research Scientific Computing Center (DE-AC02-05CH11231).