A Method to Validate Simulated Mountain Wave Impacts on Hub-Height Wind Speed Using SoDAR Observations

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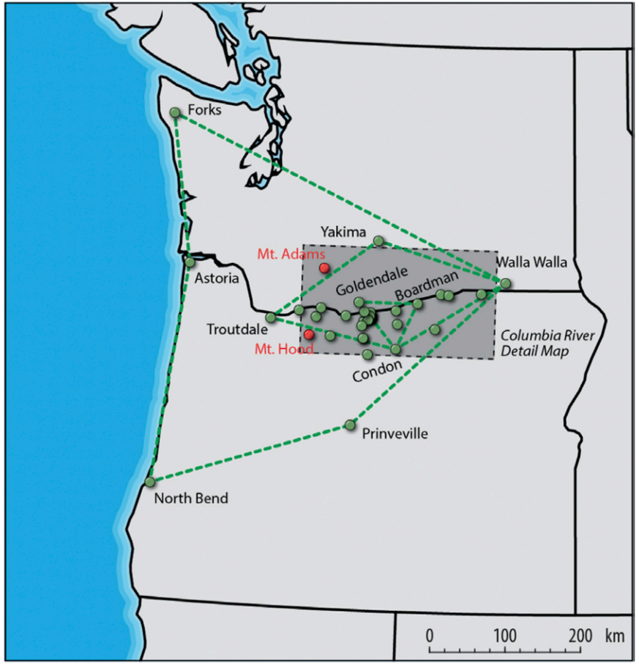
Introduction

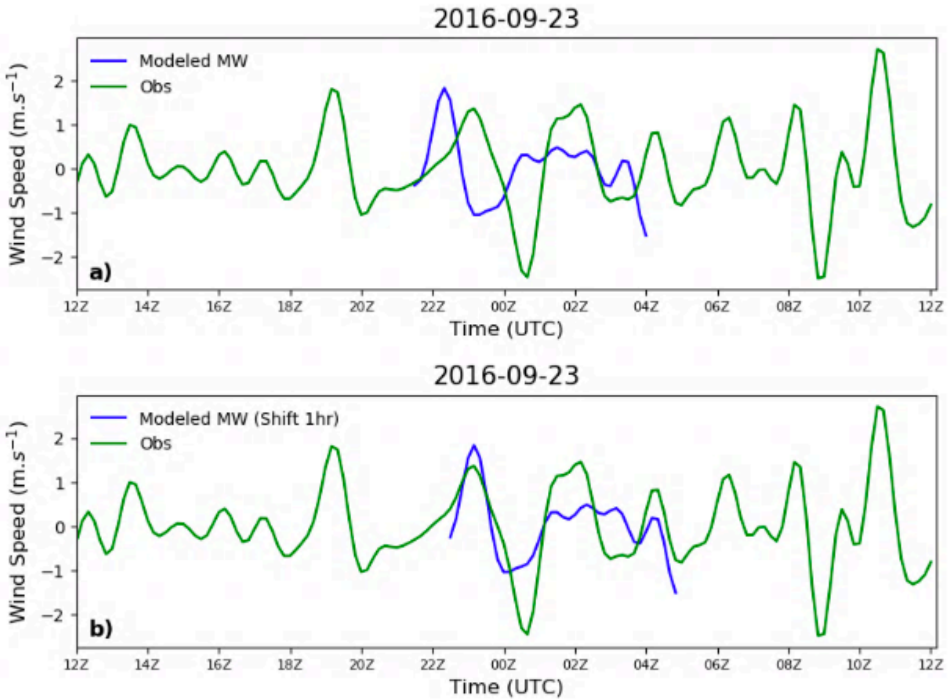
The Second Wind Forecast Improvement Project (WFIP2)



Shaw et al (2019)

- Improve the accuracy of NWP forecasts of wind speed in complex terrain for wind energy applications.
- Columbia basin of eastern Washington and Oregon
- 18 months field campaign (October/2015 to Mar/2017)
- Key weather phenomena: Cold pool, Gap flow and Mountain wave(MW)

Introduction



Draxl et al., (2020)

- Using FFT
- Simulated MWs seems to match well with the observations after 1hour shift

Future work

- Investigate the ability of mesoscale modeling on simulating MWs by conducting multiple MW simulations
- Quantify the uncertainties

Data and Methodology

Observational Data

- MODIS satellite reflectance (W m–2 μm–1 sr–1) at 620–670 nm (250-m resolution)
- SoDAR wind speed measurements (Van Glider and Prineville)

Selected MW Cases:

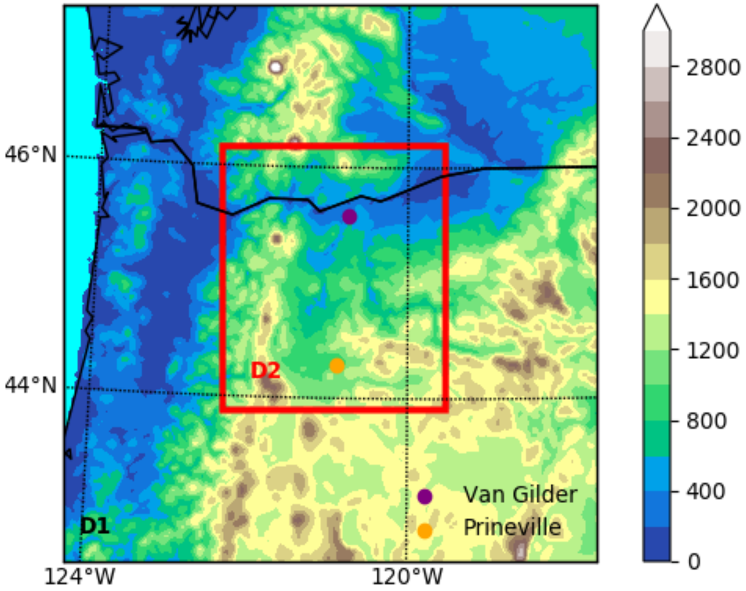
- High significance (Eventlog)
- Two cases (2015/11/11; 2016/02/14), captured by MODIS
- One case (2016/04/04), not captured by MODIS

Data and Methodology

Model configuration (Similar to Draxl et al., 2020)

Physic Options	Scheme
Microphysics	Thompson-Aerosol awareness
Shortwave and Longwave Radiation	RRTM
PBL	YSU
Surface Layer	Revised MM5
LSM	Noah

Simulation Design	Detail
WRF Version	4.2.1
Number of Domain, Resolution	2 ; 3km, 750m
Forcing	ERAI
Model integration	2.5 days; first 12 hour is treated as spin up



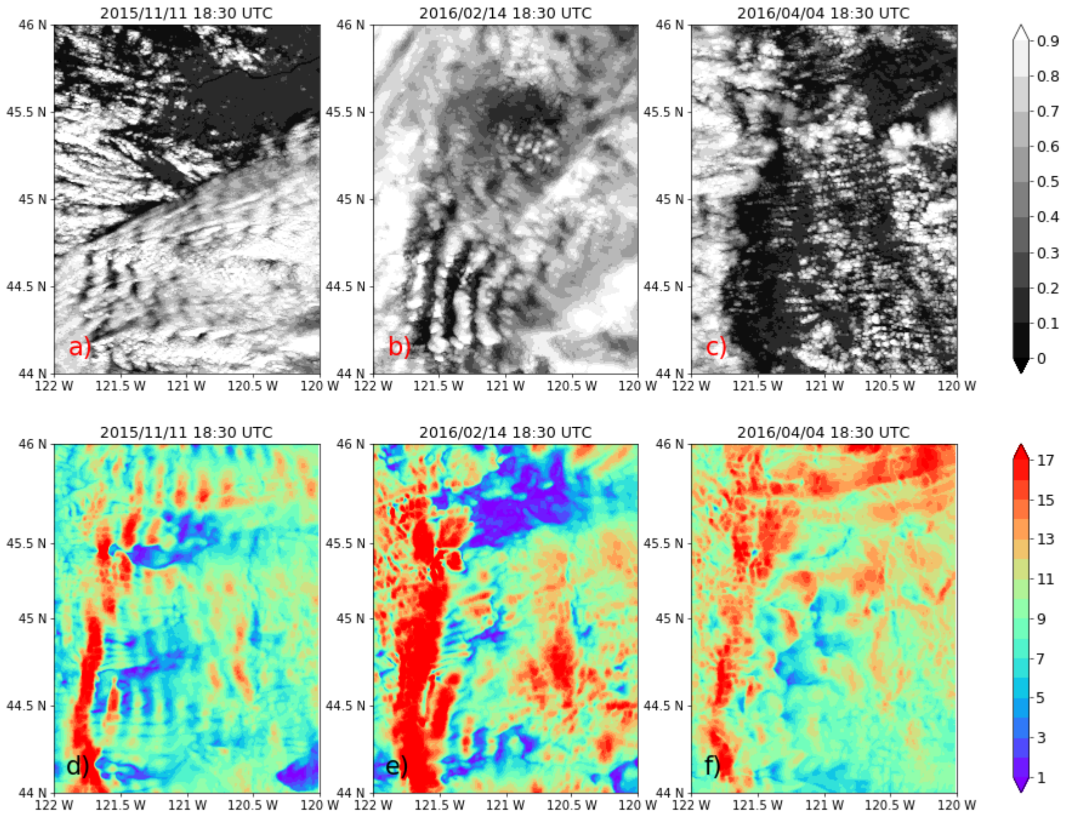
Data and Methodology

Targeted MWs:
- Wavelength : 8 ~ 20 km (wind farm scale, renewable energy purpose)
- Wave period: 1 ~ 4 hr   (separate from large-scale waves)

Disentangling simulated MW signals from the total wind field using spectral method
- Reconstructed the simulated wind speed using the wavelength constraint.
- Reconstructed the simulated wind speed using the wave period constraint.

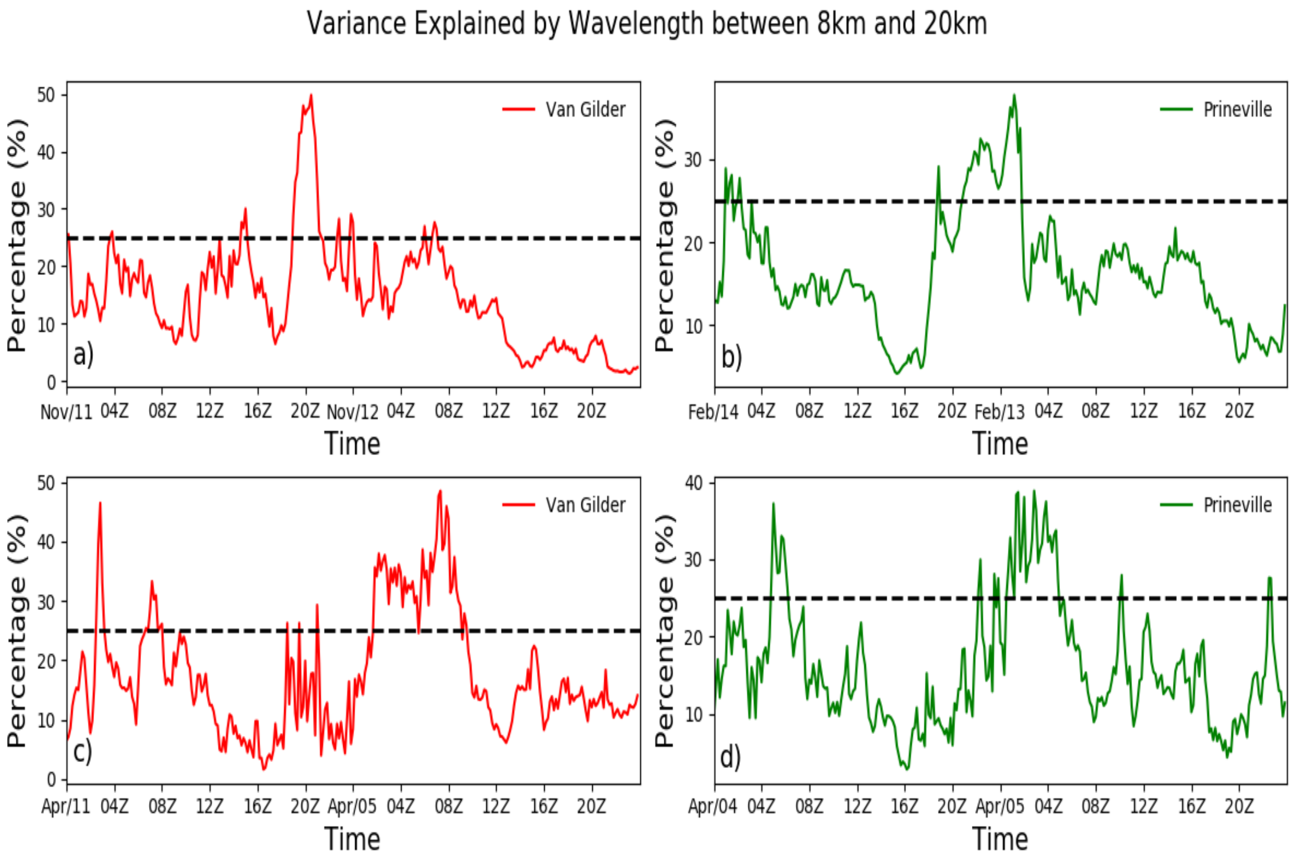
Significant MW event
- In this study, a MW event was considered significant when the power variance explained by the targeted wavelength range exceeds 25 % of the total variance for at least 3 hours.

Results



- Qualitatively, the wave activities as well as their geographical locations are well simulated for the 20151111 and 20160214 cases
- No evident wave activities are simulated for 20160404 case

Results



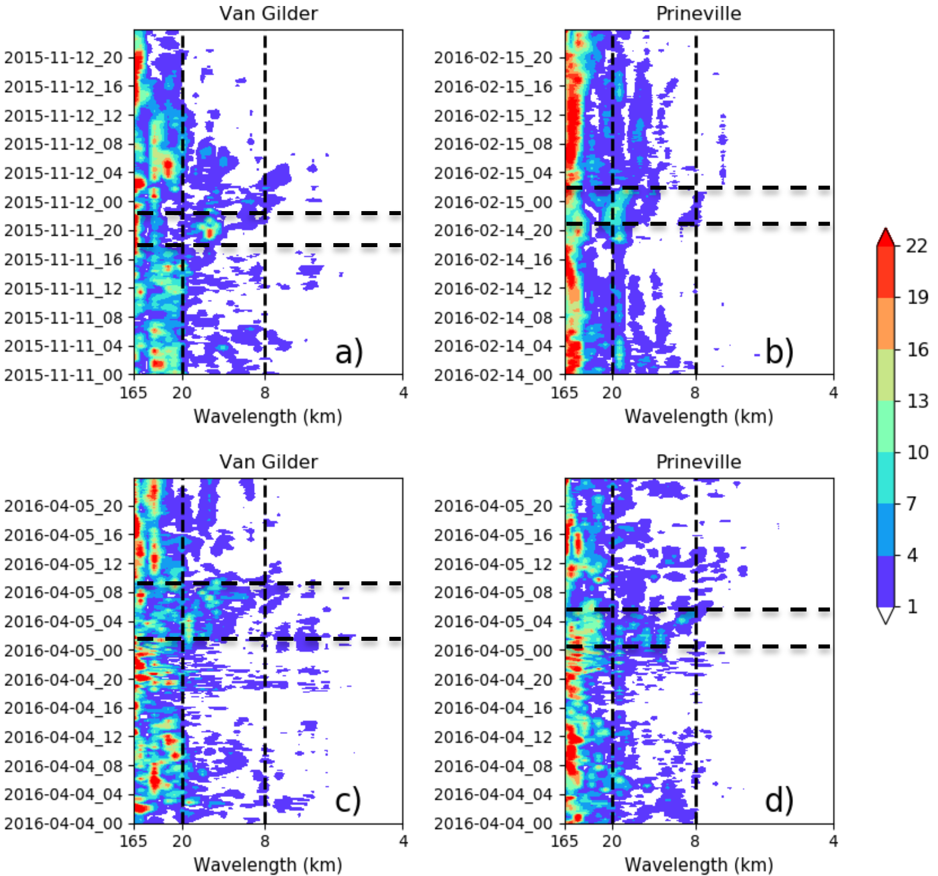
First MW event:
- Nov/11/2015
- 18 UTC to 22 UTC

Second MW event:
- Feb/14/2016
- 21 UTC to 02 UTC the next day

Third MW event:
- Apr/05/2016
- 02 UTC to 09 UTC

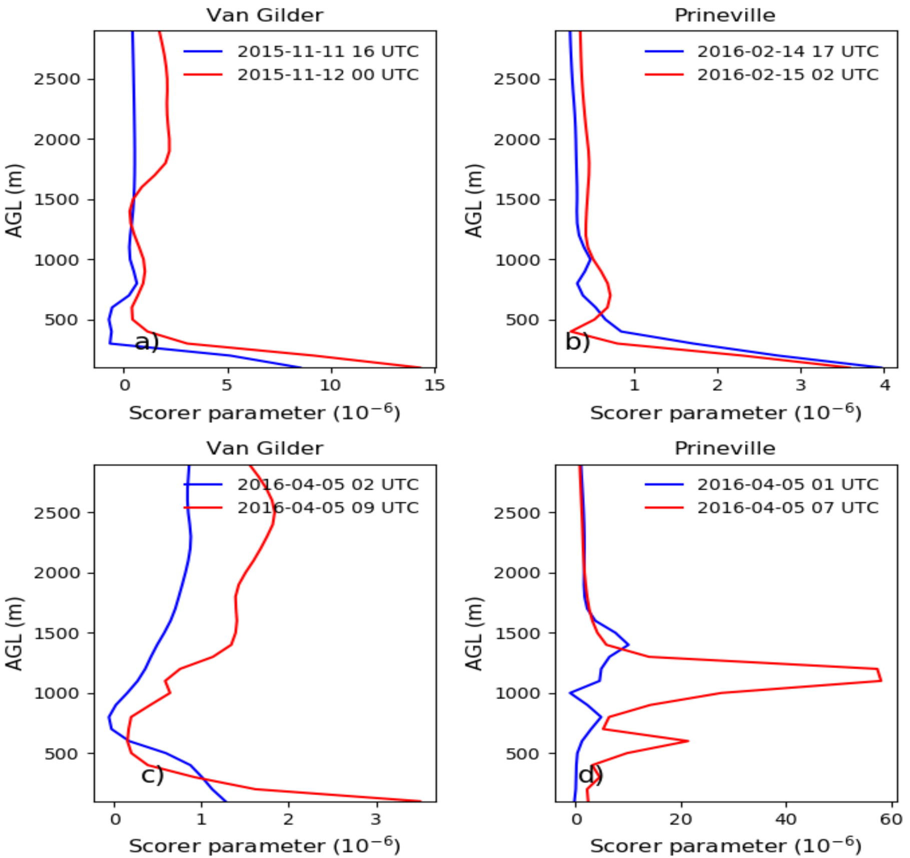
Fourth MW event:
- April/05/2016
- 01 UTC to 05 UTC

Results



- About 75 % of the atmospheric variabilities are explained by the large wave patterns
- The simulated MWs from each event differ in terms of wave characteristics
- For wavelengths shorter than 8 km, the associated power variance is small

Results

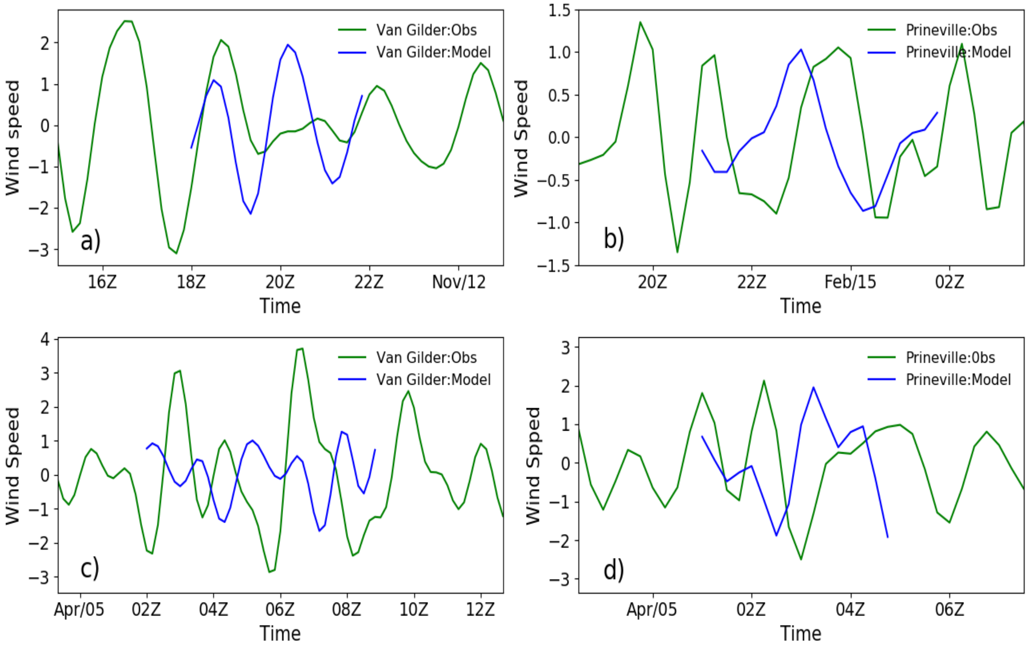


Trapped lee waves are likely to occur when Scorer Parameter:

- Decreases with height
- Dividing the troposphere into two regions, a lower layer with large values (high stability) and an upper layer with small values (low stability)

*The simulated atmospheric conditions throughout the targeted wave periods **are in favor** for trapped lee waves development in all four cases.*

Results



- In general, the simulated wave activities match well with the observations in terms of both pattern and magnitude.
- However, there seems to be a time lag in terms of wave activities between the model and observations.

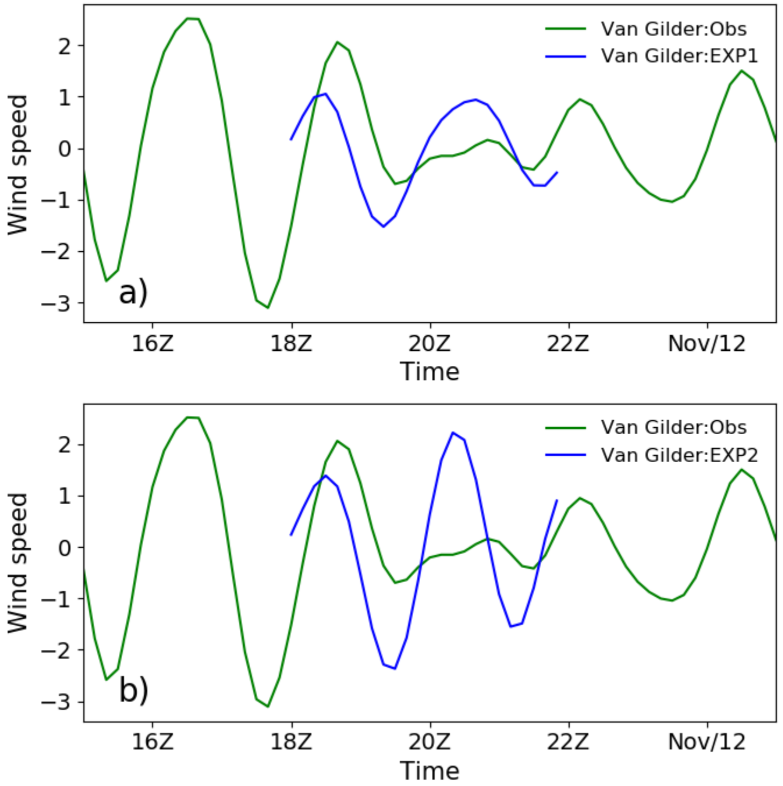
Results

Time Lag Correlation Between Observed and Simulated Hub-Height Wind Speeds From the Four MW Events

	-60m	-50m	-40m	-30m	-20m	-10m	0	+10m	+20m	+30m	+40m	+50m	+60m
VG 2015/11/11	-0.24	-0.48	-0.56	-0.50	-0.33	-0.07	0.25	**0.47**	**0.47**	0.30	0.05	-0.21	-0.47
PR 2016/02/14	0.05	-0.24	-0.44	-0.59	-0.63	-0.48	-0.02	**0.48**	**0.74**	**0.74**	**0.53**	0.17	-0.23
VG 2016/04/04	-0.02	-0.11	-0.18	-0.23	-0.27	-0.31	-0.35	-0.34	-0.24	-0.06	0.13	**0.30**	**0.40**
PR 2016/04/04	-0.12	-0.09	0.10	-0.04	-0.52	-0.70	-0.31	0.18	0.34	0.33	0.43	**0.47**	0.29

- From -1 hr to 0 hr, almost all the correlations are negative
- From 0 hr to 1hr, 75 % of the correlations are positive (bold values are statistically significant)

Results



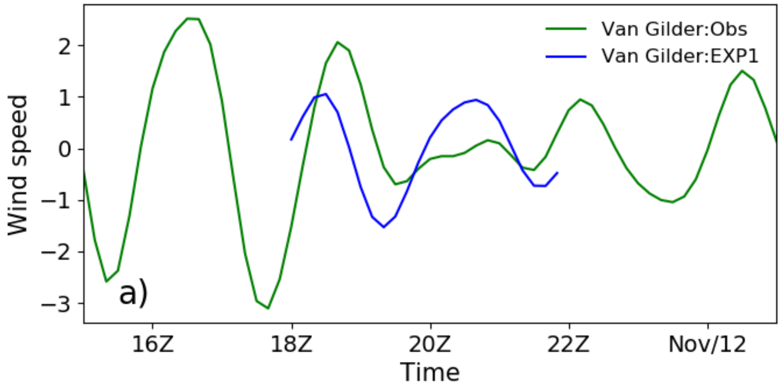
EXP1

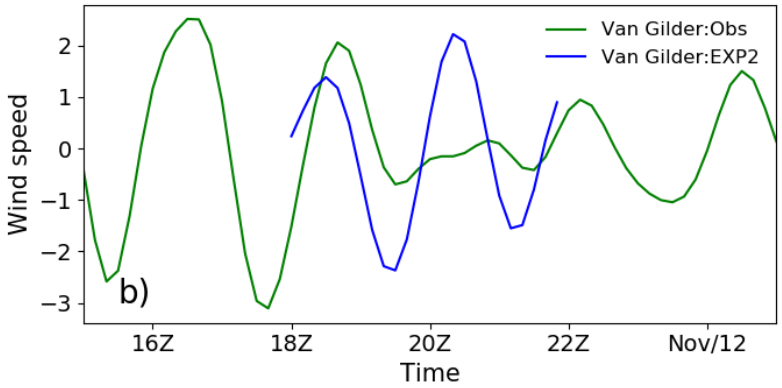
- Change the number of vertical layers from 44 to 66

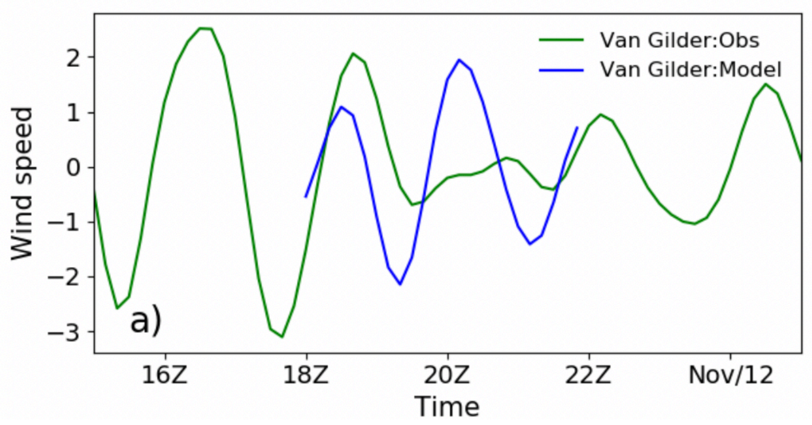
EXP2

- PBL scheme changes from YSU to MYNN

Results



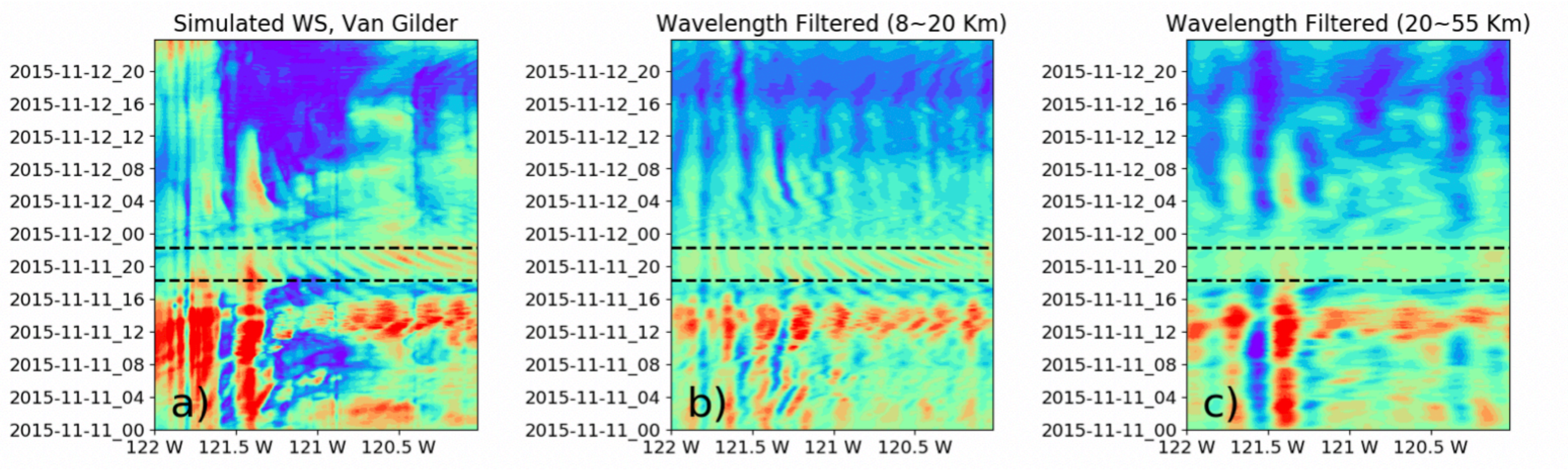




Our result is **not very sensitive** to the choice of PBL scheme and vertical resolution

Uncertainty: Wavelength

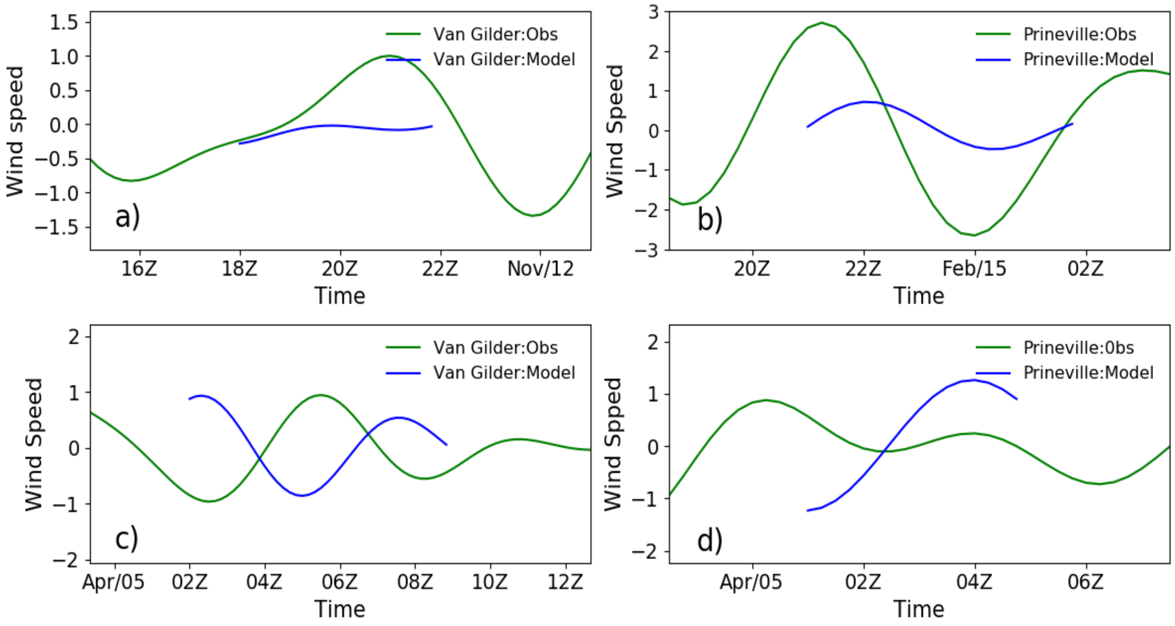
2015/11/11: Van Gilder



Our choice of wavelength range is **sufficient** to capture most of the simulated MW impacts on hub-height wind speed

Uncertainty: Wave period

Wave periods: 4 hr to 8 hr



- Overall, there is **much less consensus** in terms of both wave pattern and magnitude between the model and observations when the wave period increases.
- This could mostly attribute to the fact that MWs, specially trapped lee waves, are **high frequency signals**.

Conclusions

1. The WRF model has moderate skill in simulating observed MW.
2. Given WRF predictions of wavelength range and wave period, the Fast Fourier Transform can calculate the simulated MW impact on hub-height wind speed.
3. The resulting wind speeds agree well with SoDAR observations in terms of both magnitude and pattern.
4. For the simulated cases, WRF consistently predicts impacts of significant MW events about an hour earlier than the actual observations.