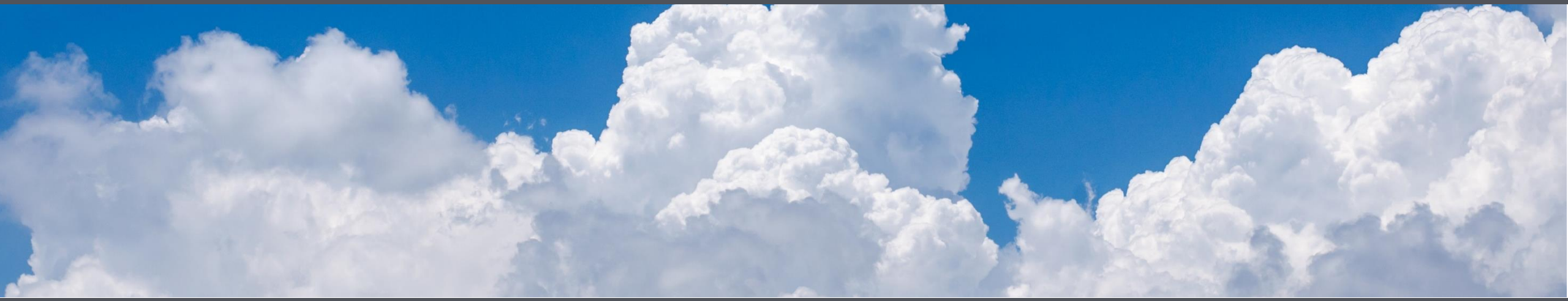
Department of Meteorology
Department of Mathematics & Statistics

University of Reading

Observations and multiple scales in convection permitting data assimilation

Sharing is encouraged



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With thanks to contributors to pre-meeting discussion: Zak Bell, Nancy Nichols, Jacqueline Sugier, David Simonin, Jo Waller

Engineering and Physical Sciences Research Council

Natural Environment Research Council

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

DARE: Data Assimilation for the Resilient City

Motivation – High impact weather

- Convection permitting (km-scale) NWP has been operational in many countries for years (e.g. UK since 2005)

- Particularly suited to hazard forecasting (convective rainfall, windstorms, fog, snow etc)

- Typically hourly cycling, limited area models
- Lead times 0-36 hours
  - Including NWP-based nowcasting and/or blending with extrapolation-based nowcasting in first 6 hours.


Snowfall London 2nd March 2018 © Business Insider UK


Hottest London Marathon 22nd April 2018 ©The Telegraph

Flooding Birmingham 27th May 2018 ©Birmingham Mail

Key issues

- Many of the fundamental problems for km-scale DA have still not been solved (e.g. Dance, 2004, Dance et al, 2019)
  - Rain-out in the early part of the forecast
  - Multi-scaling – how to correct the small scale without destroying large-scale balance
  - Nonlinearity, non-Gaussianity, short predictability timescales
  - Making the most of observations relating to moisture

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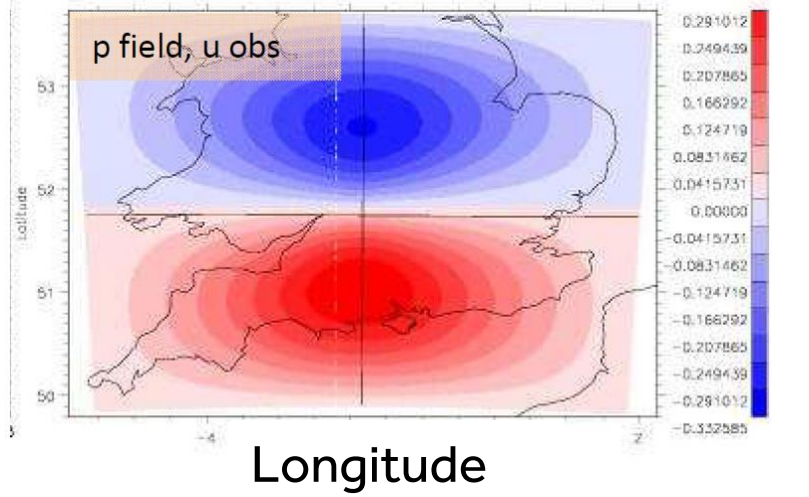
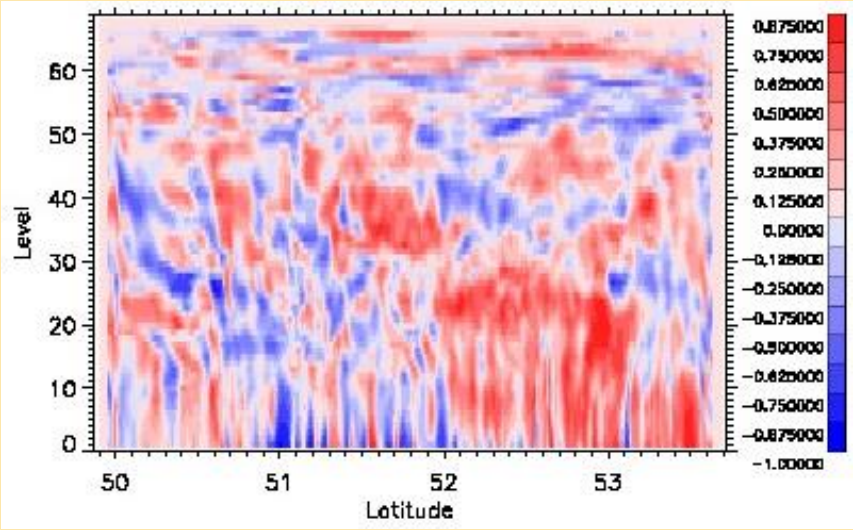
Global DA system increment



Ensemble w-q correlations for 20 July 2011



From Ross Bannister (2013)

Observing gaps

Capability location	Layer	Accuracy		Horizontal spacing		Vertical resolution		Observation cycle		Timeliness	
Surface-based	Near Surface	Land Domain									
		T	w	T	w			T	w	T	w
		q	P	q	P			q	P	q	P
	PBL	T	w	T	w	T	w	T	w	T	w
		q	iwv	q	iwv	q		q	iwv	q	iwv
Space-based	**PBL**	'Cloud free' Domain									
		T	w	T	w	T	w	T	w		
		q		q		q		q			

Shading	
	Meeting OSCAR goal requirement
	Meeting OSCAR breakthrough requirement
	Meeting OSCAR threshold requirement
	Insufficient information available
	Falling below OSCAR minimum requirement

Thanks to Jacqueline Sugier for this Table.

Requirement from WMO OSCAR RRR

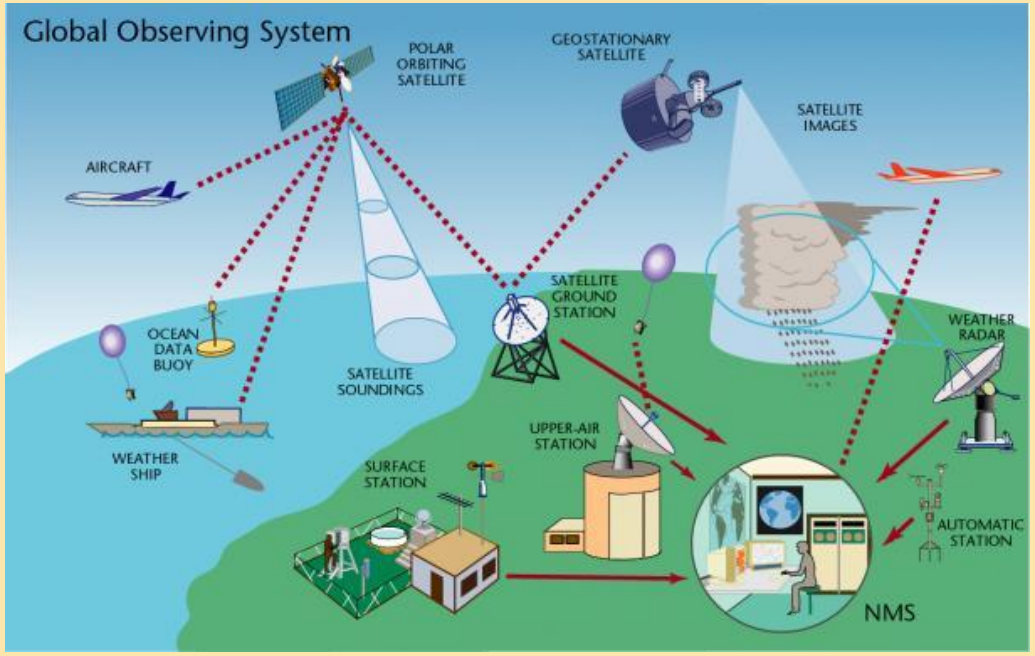


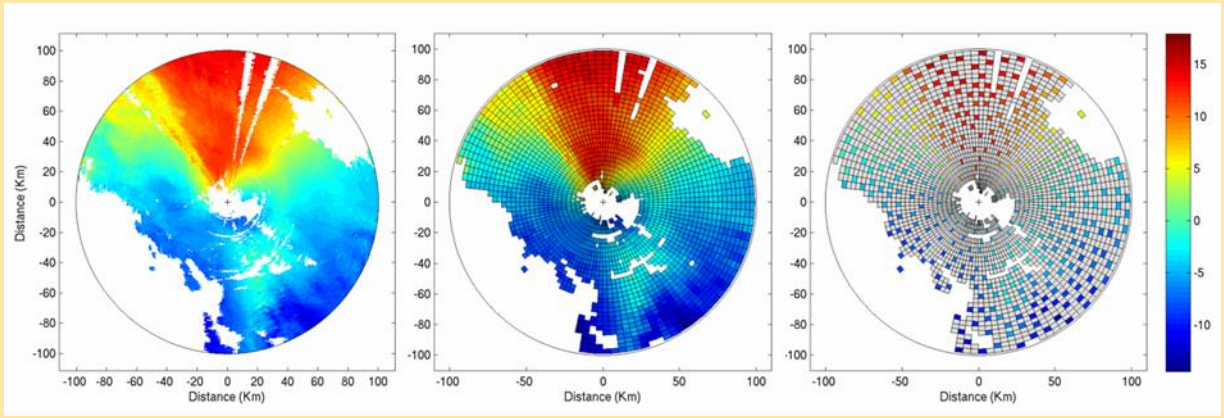
Image from https://public.wmo.int/en/programmes/global-observing-system

- High priority variables for km-scale forecasting: Humidity, wind and temperature
- Major gaps in horizontal spacing and observation cycle
- MTG will help narrow the gap for humidity and temperature but less so in the PBL

Closing observation gaps

Too expensive/impractical to close the observation gap with conventional scientific observations alone

- Make better use of the observations we do have



We only use 5% of some observation types due to thinning.

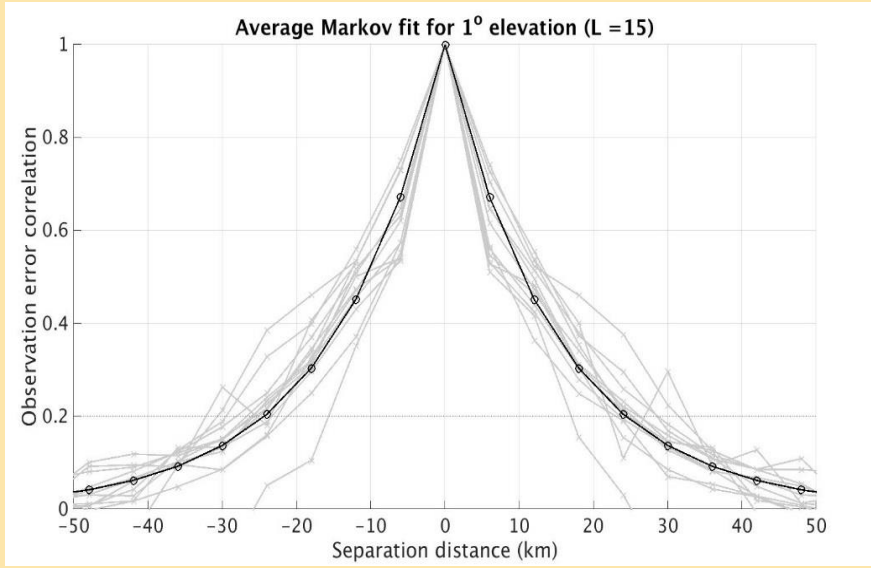
Example: Doppler radar winds (*old* Met Office system from Jo Waller/David Simonin)

- Exploit crowdsourcing, citizen science and opportunistic data (Hintz et al, 2019)

Treating correlated observation error for Doppler radar winds (Simonin et al, 2019)

- Old 6km thinning reduced to 3km by treating spatial observation error correlations
- Spatial correlations estimated offline using Desroziers et al (2005) method
- New parallelization and smart load balancing

⇒ can assimilate 4x as many observations without an increase in wall-clock time



Joint work using Met Office UKV

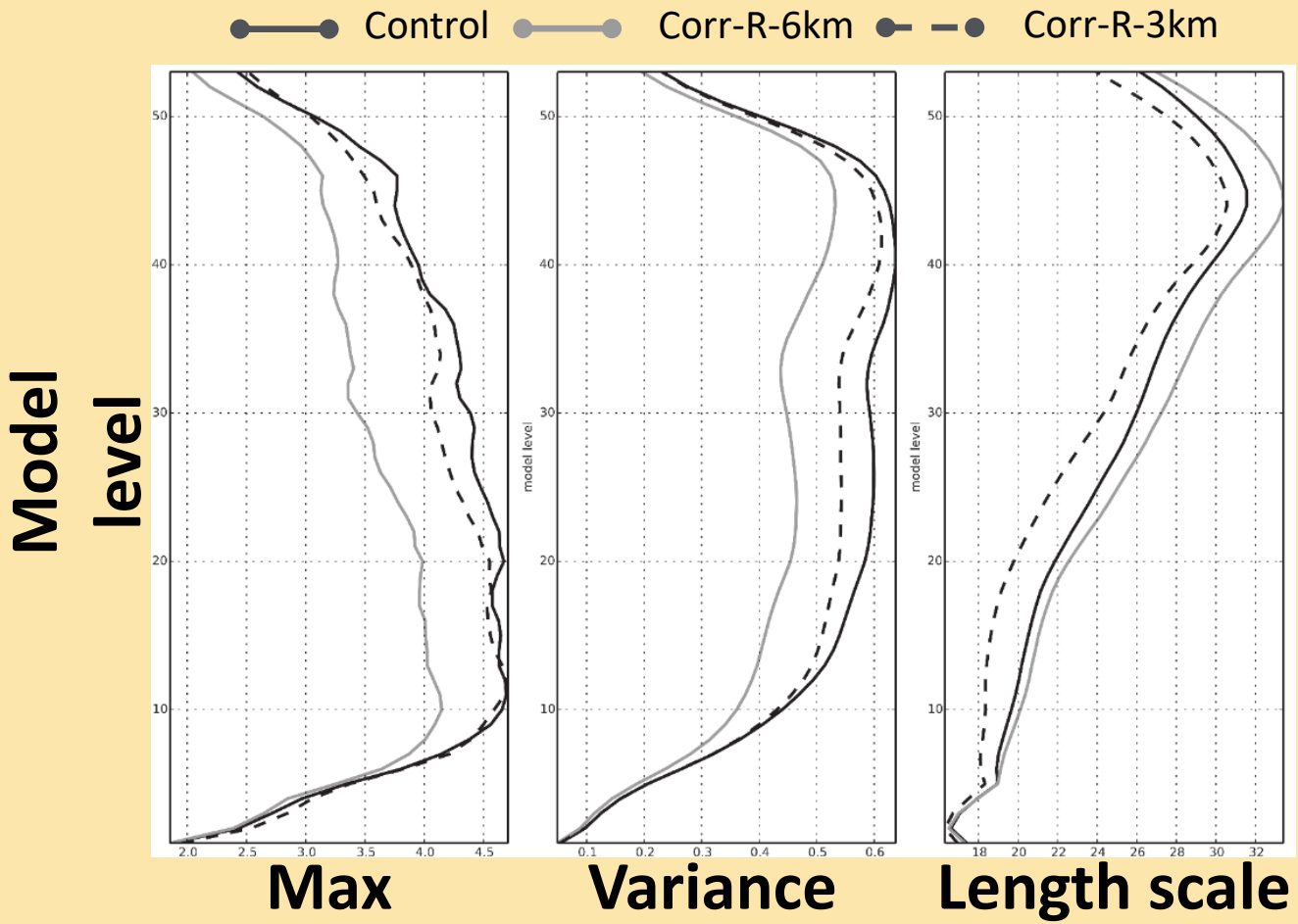
Effect on wind increments (Simonin et al 2019)

Compared to the Control with diagonal **R** and 6km thinning

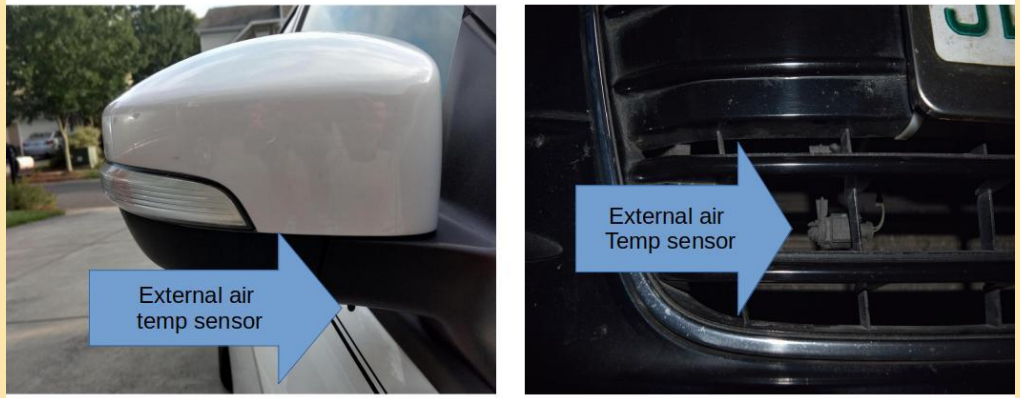
The **Corr-R-3km** wind's increments show more small scale features with smaller range

Compares well with theory (Fowler et al 2018)

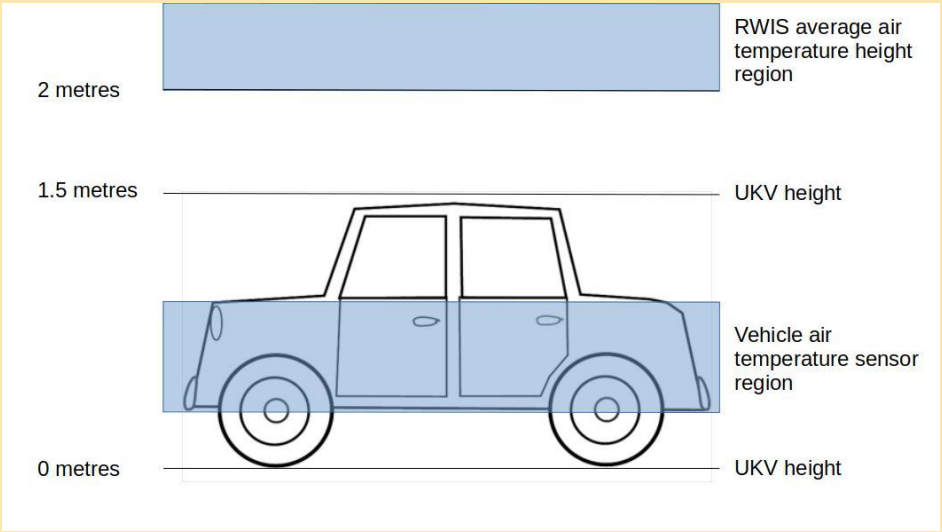
We also found improvements in forecast skill – particularly for convective rainfall.



Opportunistic data -Vehicle-based temperature observations (Bell et al, 2022)

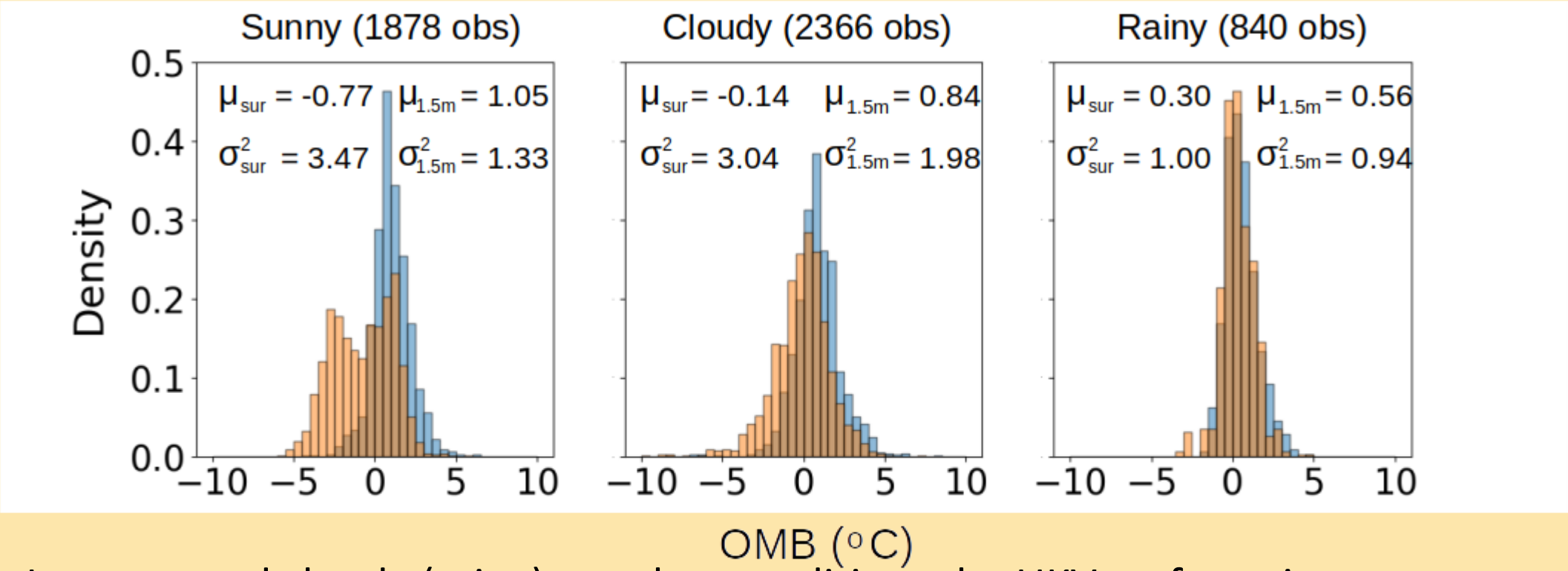


- **Volunteers**: 29
- **When**: 20/02/18 - 30/04/18
- **Total number of observations**: 67959
- **Observations**: dry bulb temperature, engine intake temperature, air pressure
- **Precision**: 1C for temperatures, 10hPa for pressure
- **Metadata**: date/time, speed, vehicle identifier, GPS location



O-B experiments

- Extensive QC – 75% of dataset rejected
- Biggest problem is moving platform – GPS update frequency insufficient



- In sunny and cloudy (rainy) weather conditions the UKV surface air temperature is warmer (colder) than the vehicle observations.
- Vehicle - surface is more variable than Vehicle – 1.5m regardless of weather type

Conclusions

- Convection-permitting DA is increasingly important for hazardous weather prediction in a changing climate
- However, forecast accuracy is limited by large observation gaps in the boundary layer
- Making the most of existing observations by treatment of spatially correlated errors.
  - Improved forecast skill has been demonstrated. Now operational for Doppler radar winds at the Met Office.
  - Working on numerical techniques for geostationary satellite data (Hu and Dance 2021)
- Use of opportunistic observations
  - Vehicle-based observations show promise, but better data collection protocols needed.

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