Doppler Radar Assimilation

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Special thanks to the MetOffice Radar Team

Outline

- Introduction
- Doppler Radial Wind at the Met Office
- NDP
- Proposed modifications
- Results
- Conclusion

Introduction

Aim: Develop a NWP-based system to replace our current Lagrangian advection-based nowcasting system to focus on hazardous weather, especially flood risk

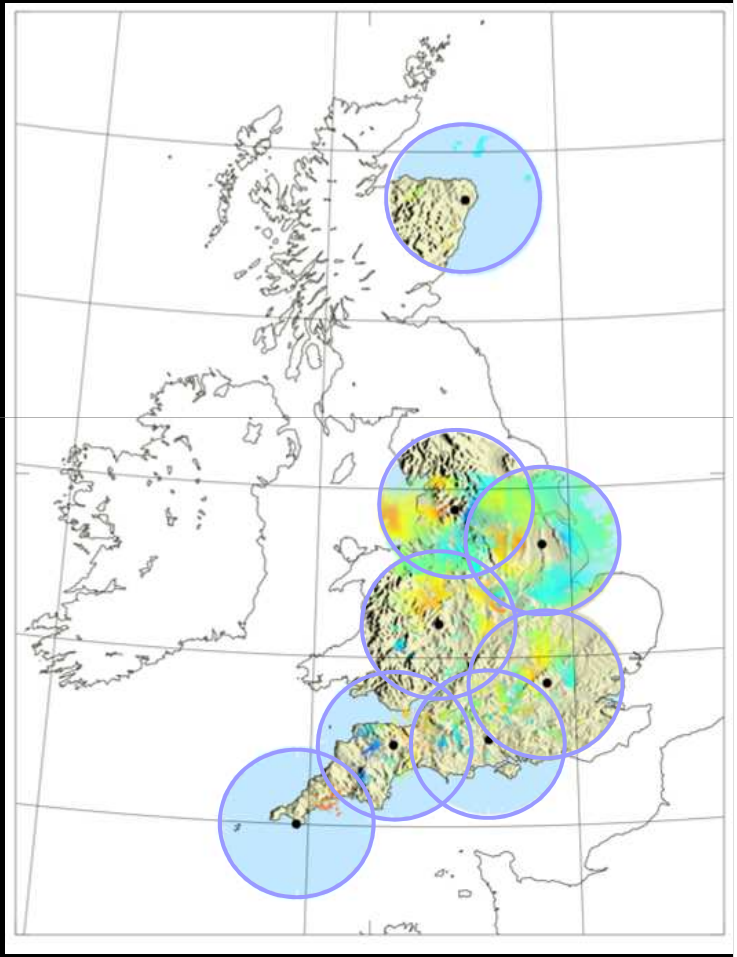
Radar data are the “perfect” candidate for assimilation:

- High resolution / High repetition time / Large coverage

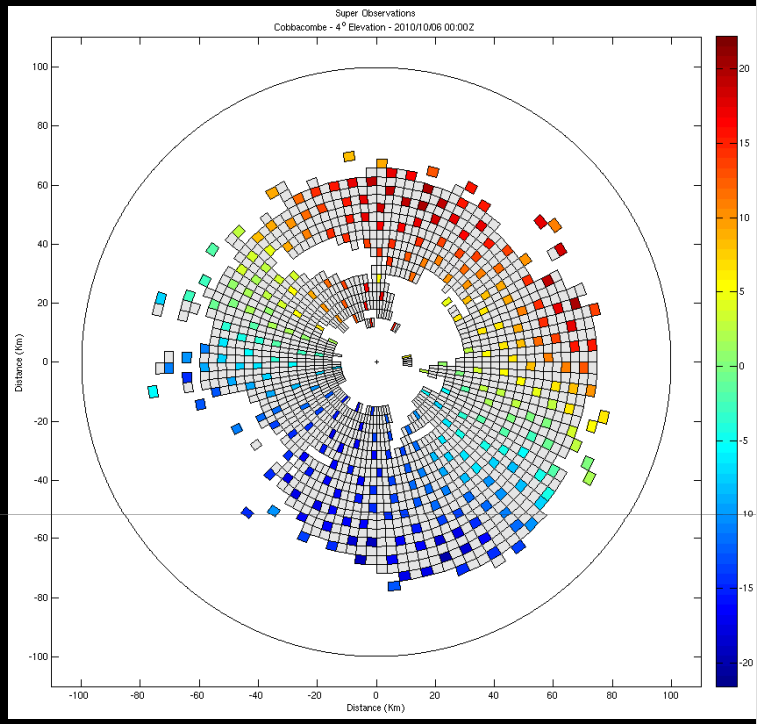
The Nowcasting Demonstration Project (NDP) system has been running in real-time since May 2012

Doppler Wind at the Met Office

- Doppler Radar:
  - 8 Doppler capable Radars (C Band)
  - Unambiguous velocity 48 m/s
  - 5 Elevations (1, 2, 4, 6, 9)
  - One volume scan every 5 minutes
- Preprocessing:
  - Centralised processing and QC (RadarNet)
  - Doppler PPI scan with QC flag
- Before Assimilation:
  - Additional QC (unfolding) using Model Background



Doppler Wind at the Met Office
Operational setup



- Operationally used in UKV and UK4 from June 2011
- PPI scan (1 per Analysis – All elevation):
- Super-Observation:
  - 3 ° x 5 range gates - thinned (6km for UKV – 8km for UK4)
- Observation Operator:

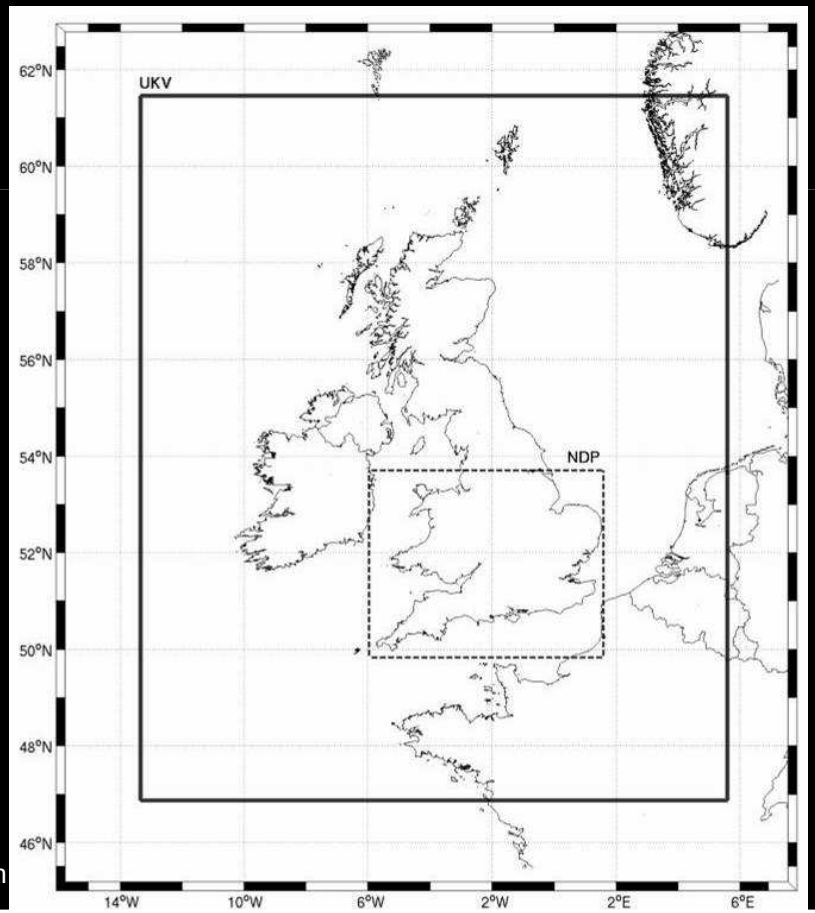
$$v_r = u\sin\phi\cos\theta + v\cos\phi\cos\theta + w\sin\theta$$

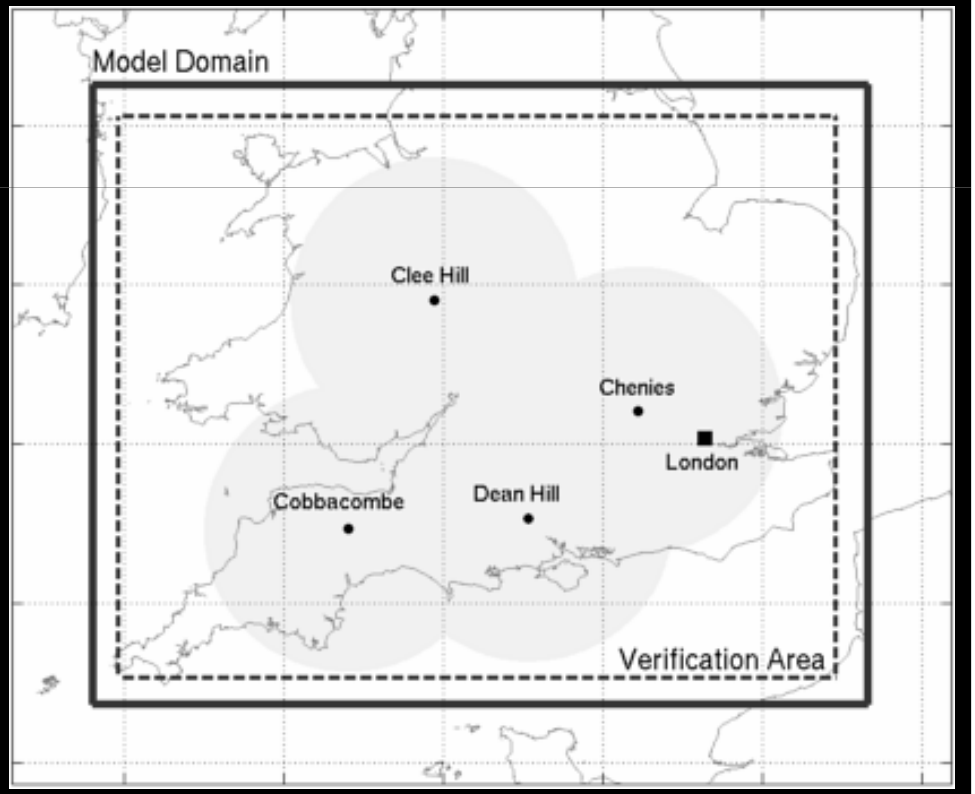
- Observation error:
  - Range from 2 to 3m/s with range

- Motivation
- Doppler Radial Wind at the Met Office
- NDP

NDP
Model Domain

Model	Resolution	VAR	Time Window	Cycling	Forecast Length	Doppler
UKV	1.5km	3D-Var	3	3 h	T+36	1 Vol. Scan
NDP	1.5 km	**4D-Var**	**1**	**1 h**	**T+7**	**6 Vol. Scan**

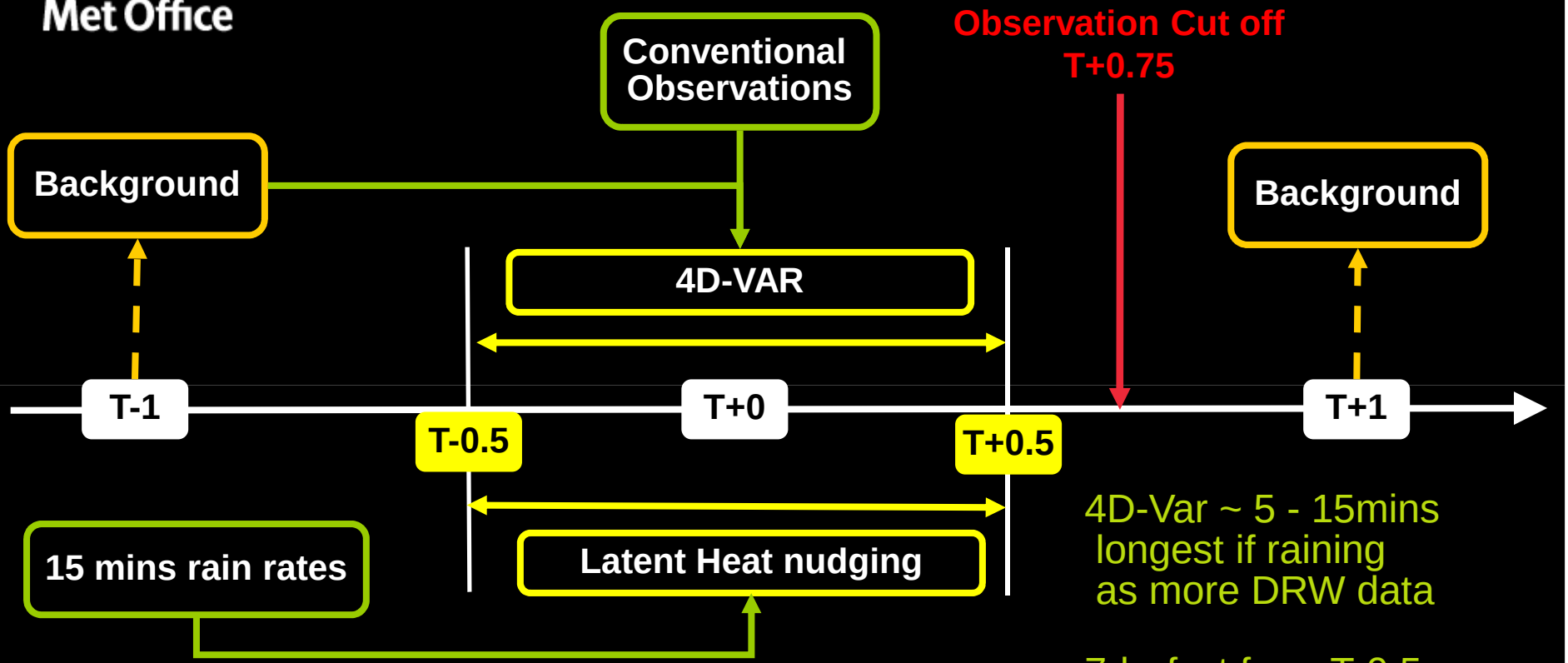




Nested in UKV. LBCs updated every 30mins; refreshed every 6 hours

NDP

Assimilation setup



4D-Var ~ 5 - 15mins
longest if raining
as more DRW data

7-hr fcst from T-0.5
Takes ~10mins

Available at T+1.25

Background Error Covariance:

Training data generated using the NMC method

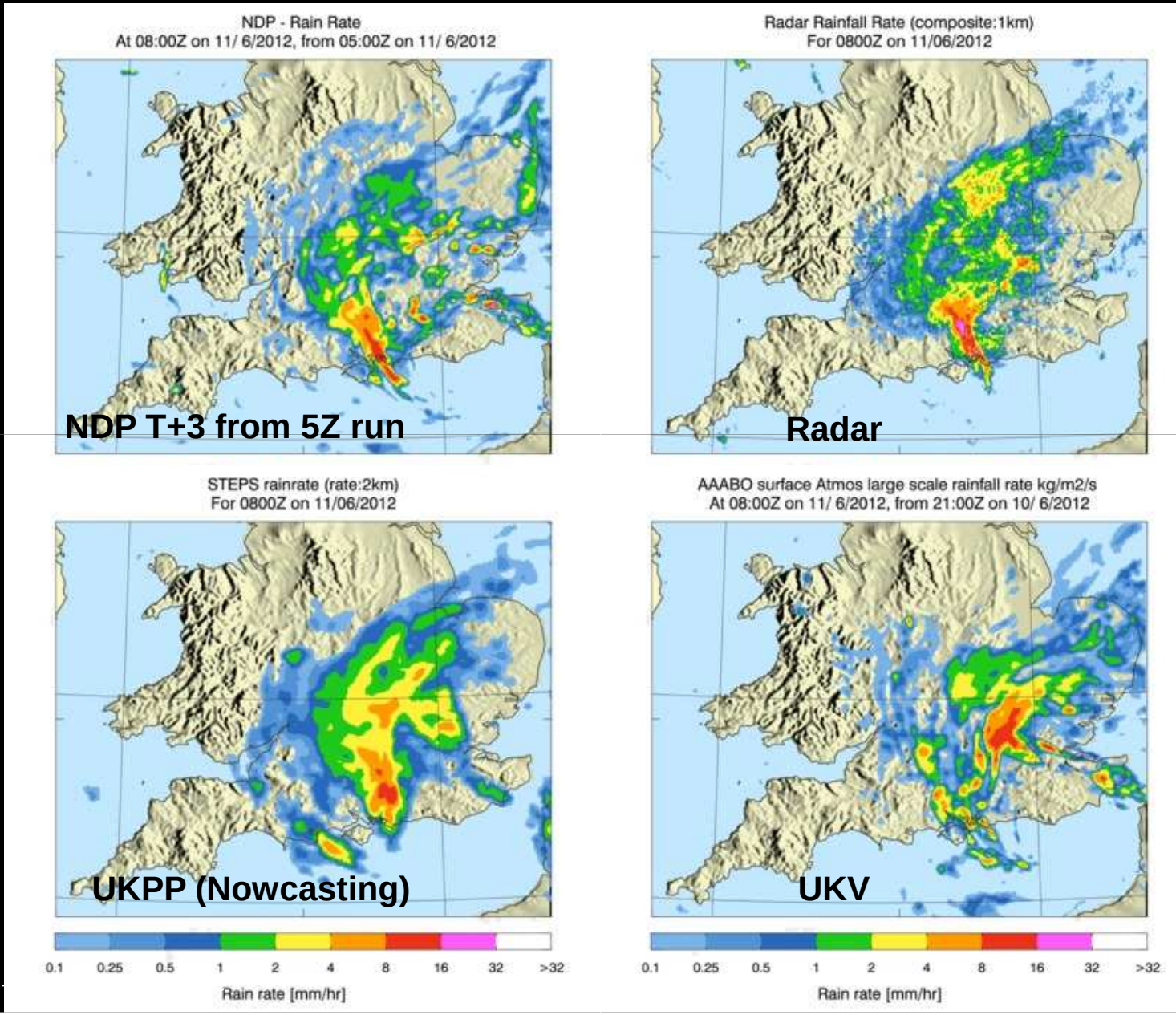
A set of 75 lagged NDP forecast differences (6h-3h) where forecast pairs used the same LBCs

NDP

Observations usage

- 4 radars Doppler radial wind 6 times per hour
- 4 wind profilers every 15mins
- SEVIRI channel 5 (clear and over low cloud) and channel 6 (clear) every 15mins plus clear window channels over sea
- 3D moisture derived from cloud observations (satellite + surface reports)
- AMV (atmospheric motion vector)
- AMDAR 1 per hour
- hourly surface T,RH, wind, P, visibility
- Latent heat nudging with radar derived rain rates every 15mins

NDP Example 11th June 2012



- Motivation
- Doppler Radial Wind at the Met Office
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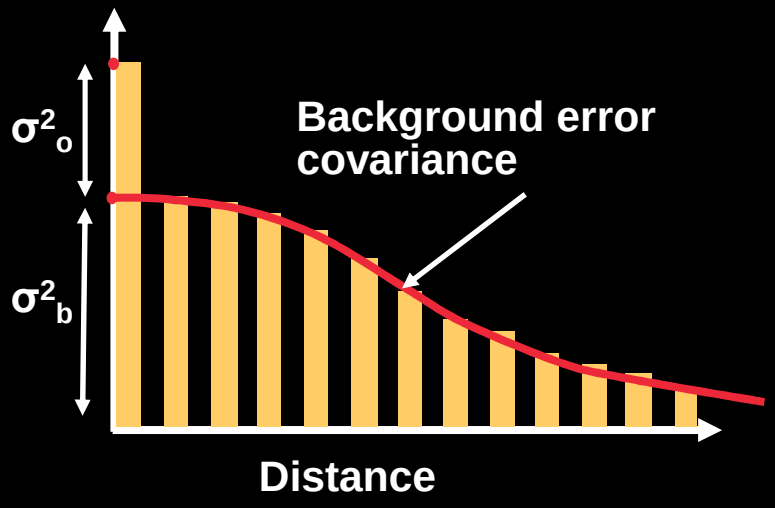
- Proposed modifications
  - Observation Error

Observation Error:

Hollingsworth–Lonnberg

- Rely on the use of departure between the background and observation (innovations)

- Construct a histogram of background departure covariance against distance (d)



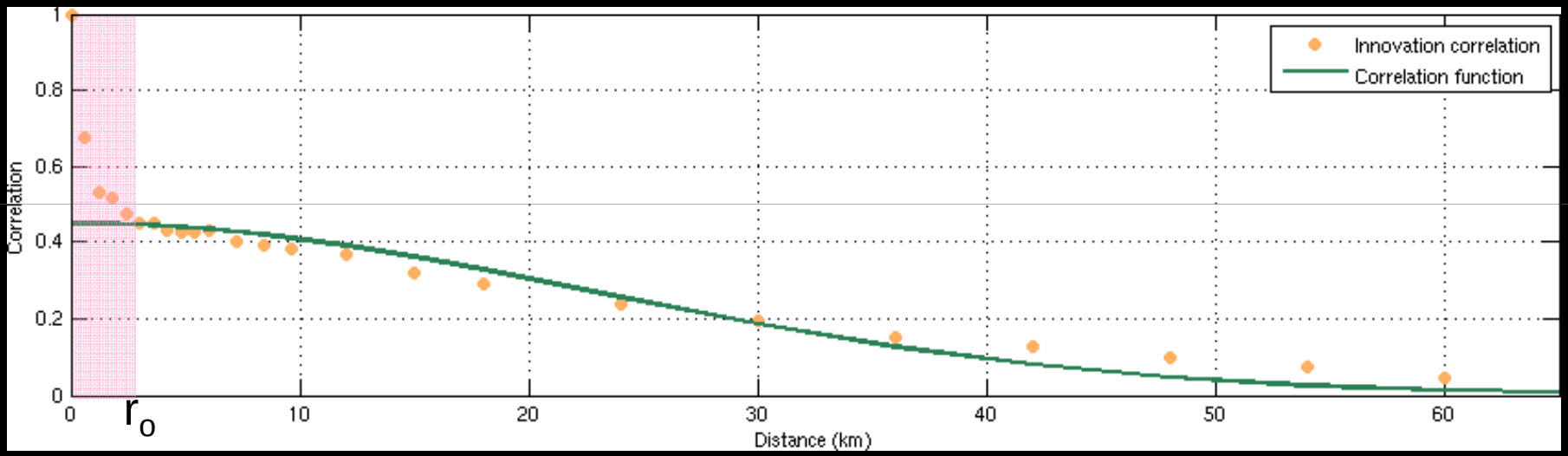
At d = 0 → $\sigma^2_o + \sigma^2_b$
At d > 0 → σ^2_b

σ^2_o = Inst. Error + Rep. Error

Observation Error:

Hollingworth–Lonnberg

Clee Hill – Height: 1700m - Winter

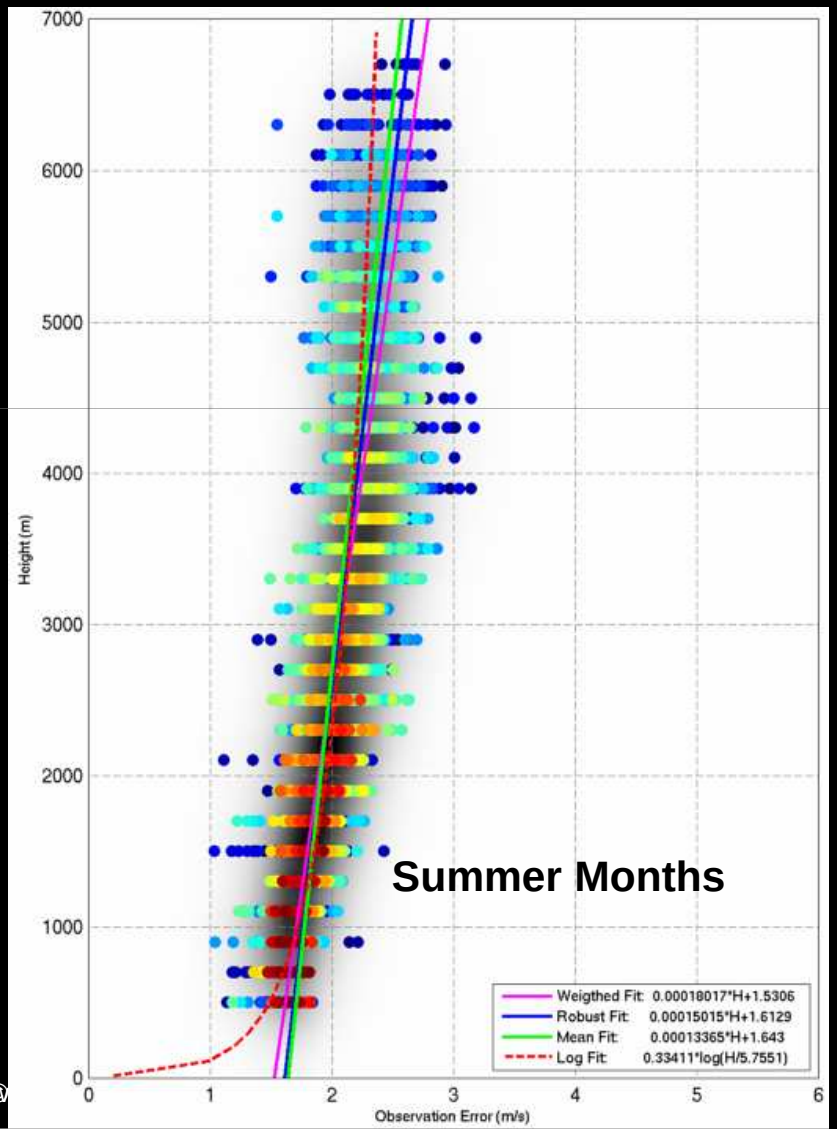


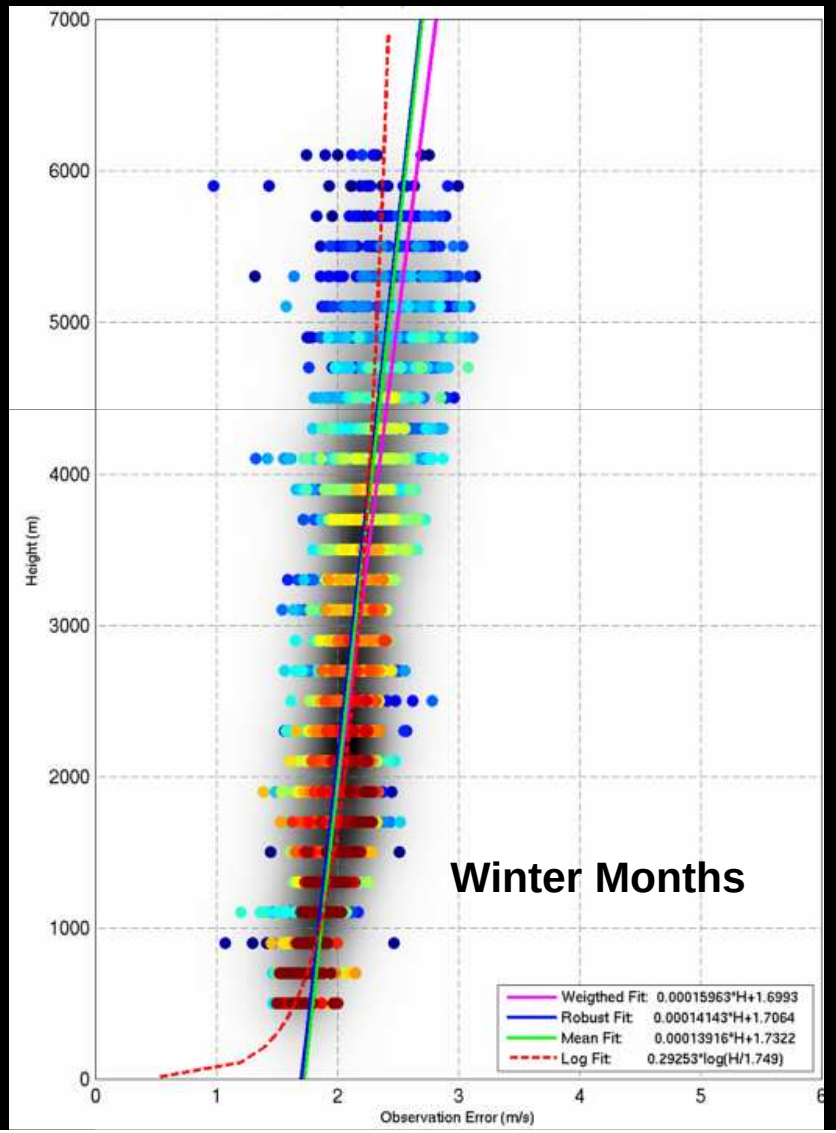
Observation Correlation length: 1-3 km

Equivalent to 2 to 5 gates

Observation Error:

Hollingsworth–Lonnberg





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  - Beam Broadening

New Observation Operator

Radar measurement is a volume measurement

- **Beam broadening:**

$$w(\theta_z) = \exp\left[-3\times\ln 2\left(\frac{\theta_z^2}{\theta_3^2}\right)\right]$$

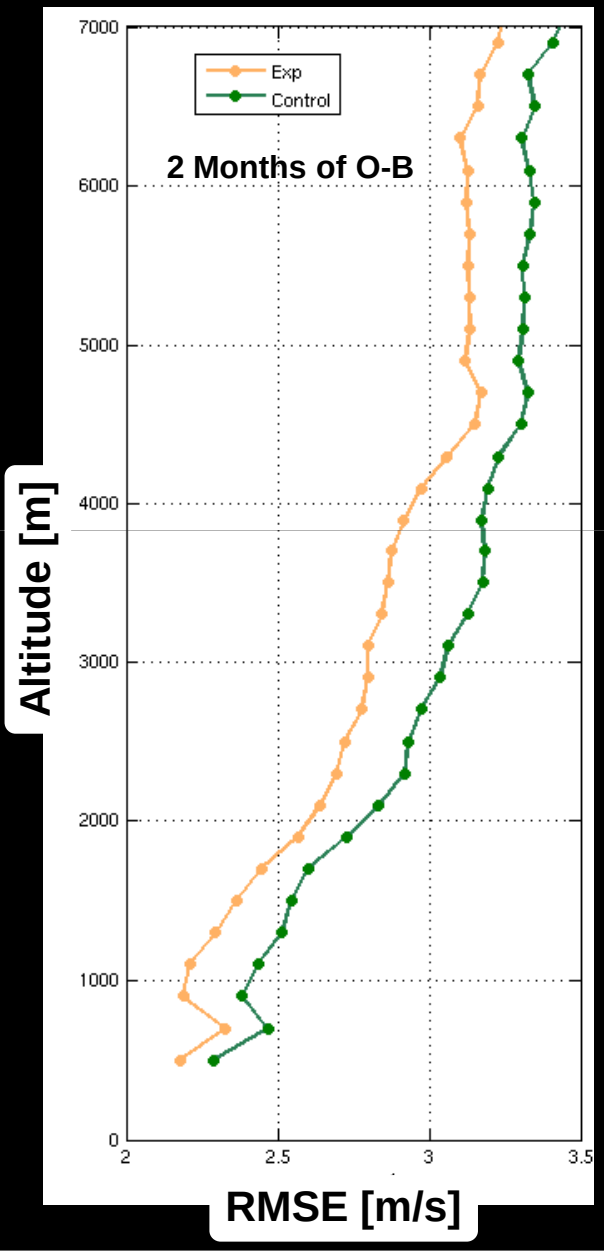
$$\theta_z^2 = \phi^2 - \theta^2$$

$$\theta_3^2 = 1^\circ$$

With Φ the beam elevation and θ the beam centre elevation.

- **Reflectivity weighting:**

Profile Definition
  - -6dB below Bb
  - -2dB above Bb
  - Bb +10 dB



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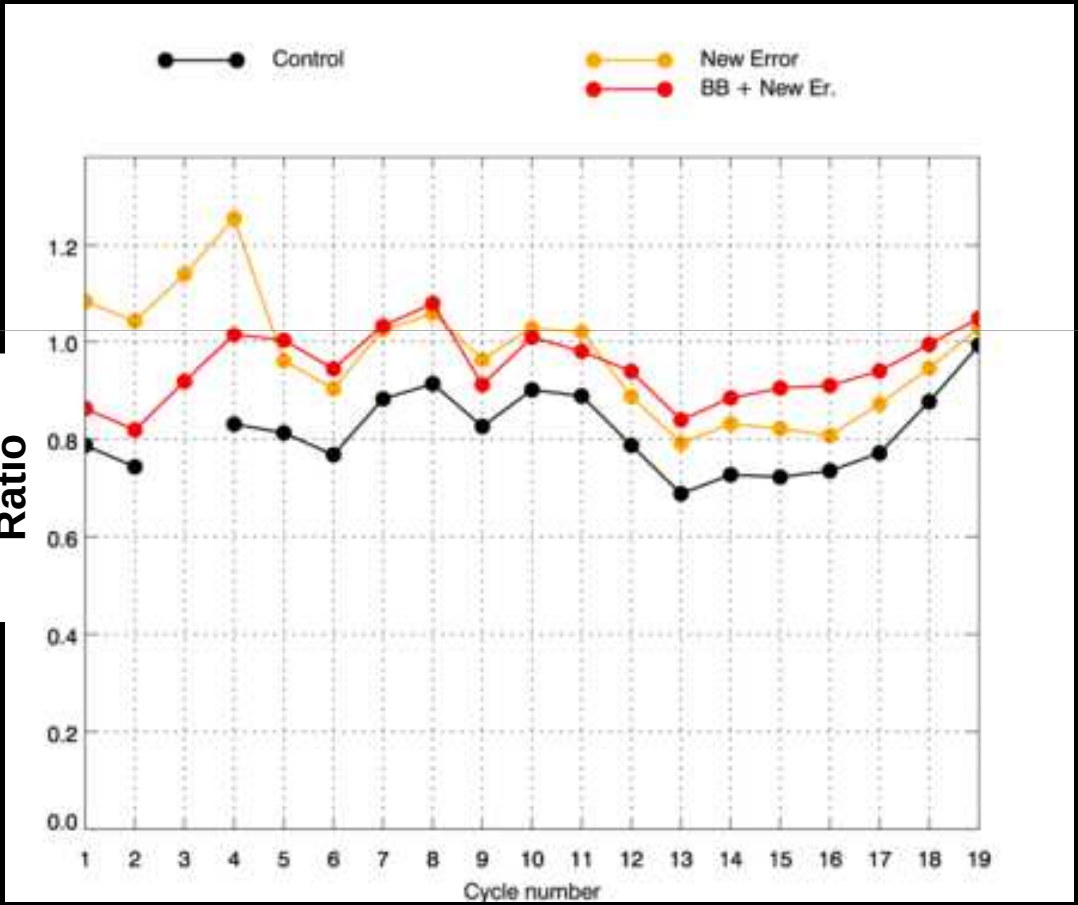
Results

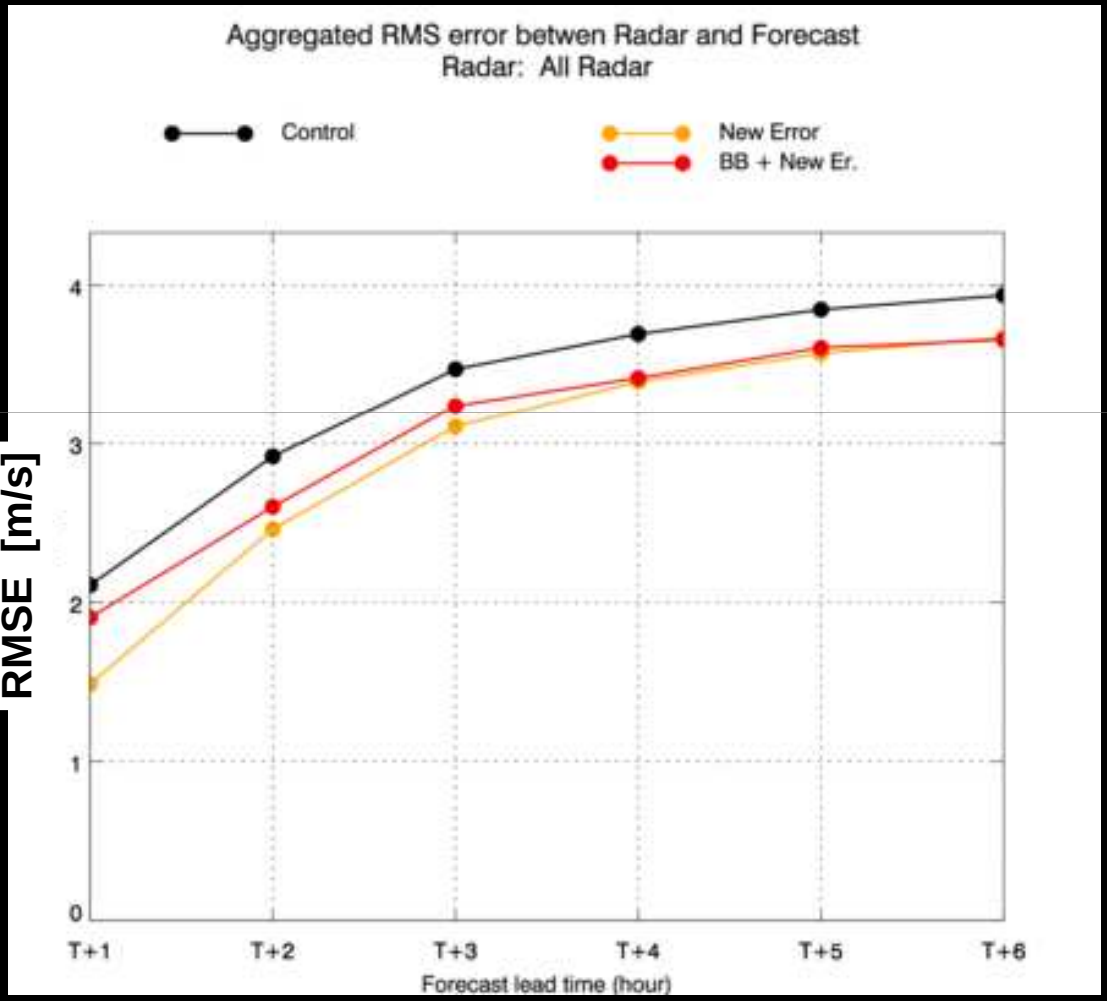
Var Statistics: Bennet and Talagrand Index



Control — New Error — New Obs Op. + New Er.

Results

Verification: Forecast vs Radial wind



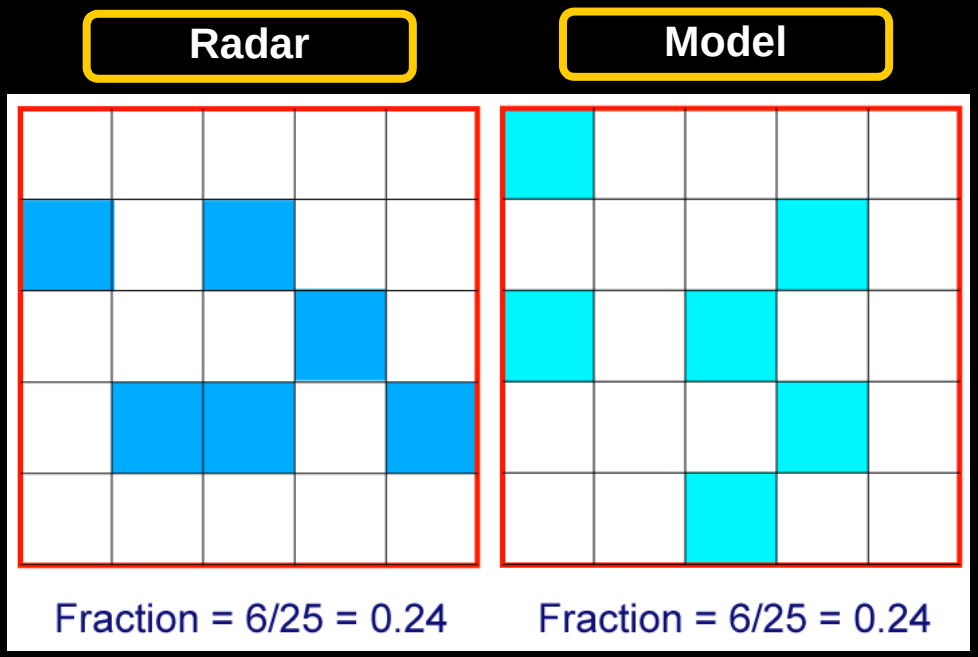
Control — New Error — New Obs Op. + New Er.

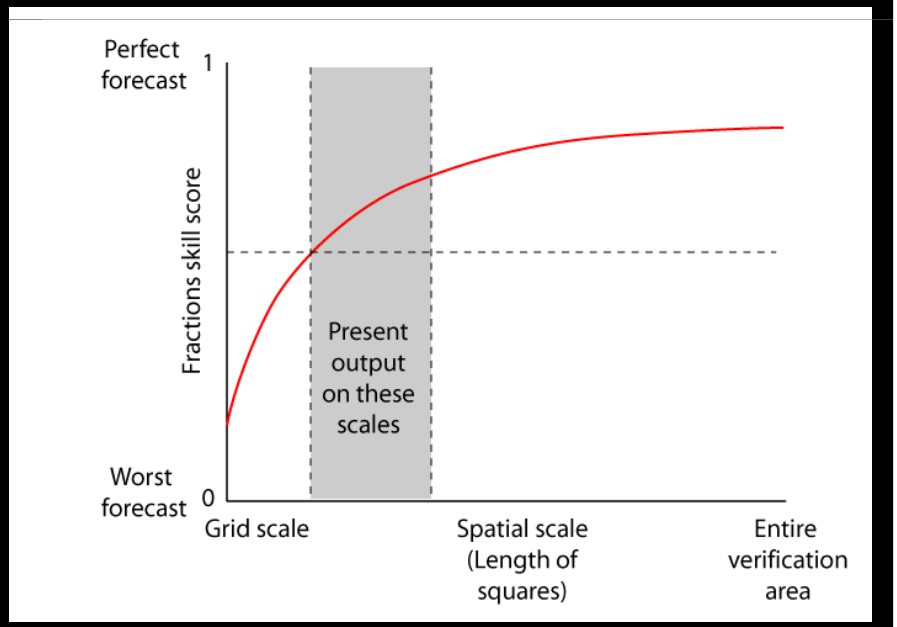
Impact on Precipitation

Fraction Skill Score

Scale-selective verification for rainfall accumulations

Comparing the fraction of rainy pixels for a given acc. threshold between Radar and model field at a given scale

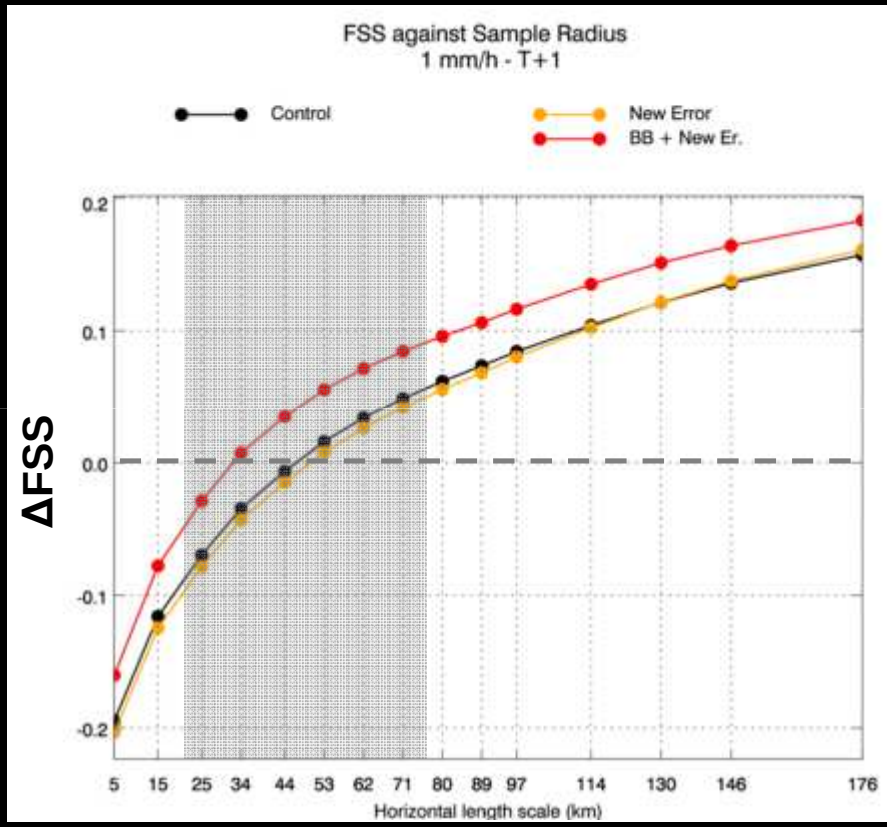


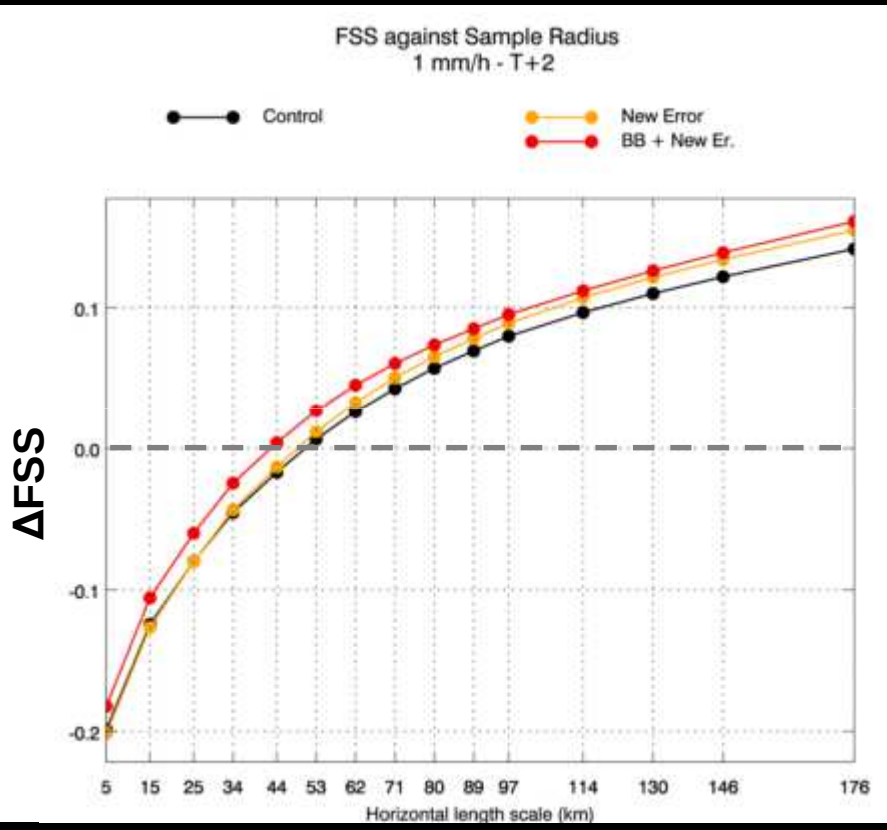


Roberts, N. M. & Lean, H. W. (2008)

Results

Impact on Precipitation



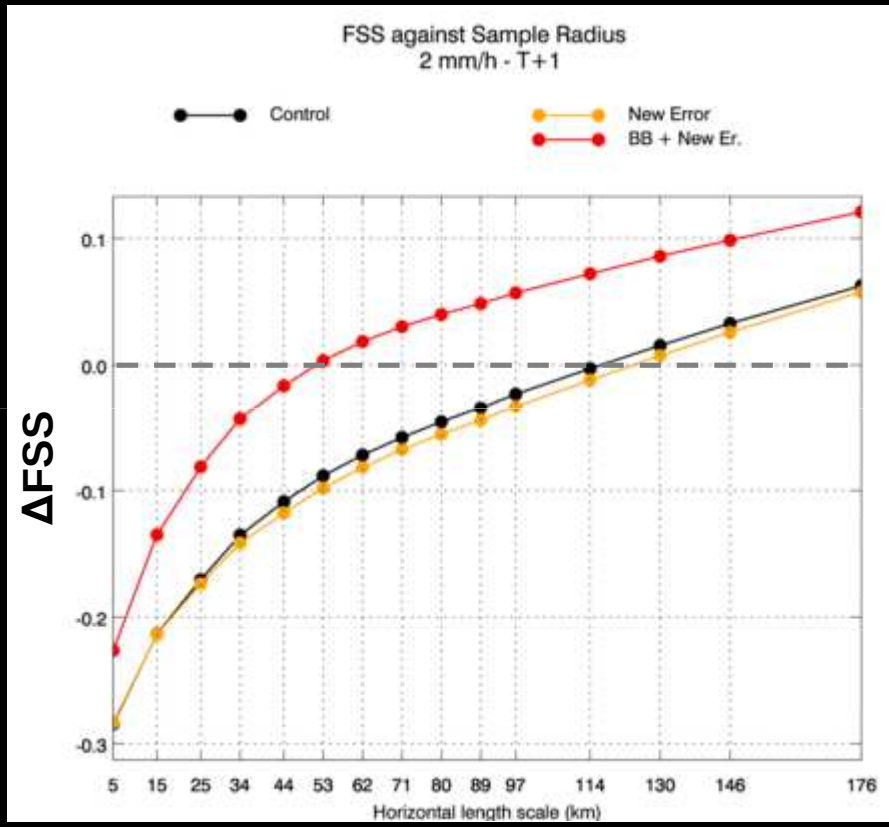


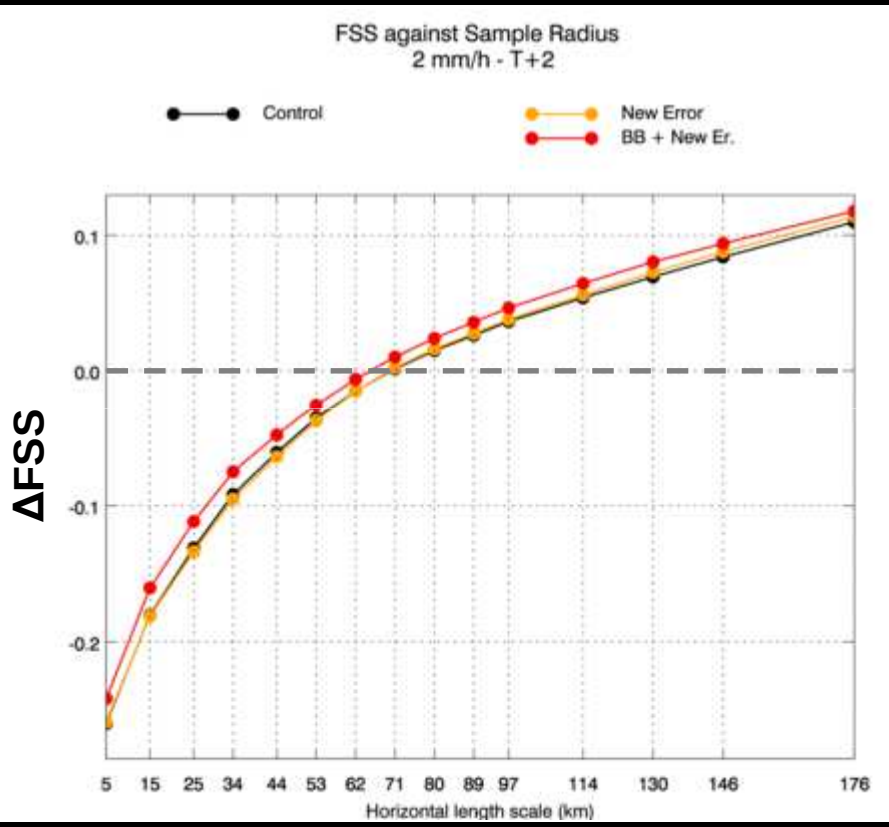
Scale of interest

Control — New Error — New Obs Op. + New Er.

Results

Impact on Precipitation





Control New Error New Obs Op. + New Er.

Conclusion

- New and more realistic observation operator for Doppler radial wind
- New definition of the observation error for Doppler radial wind

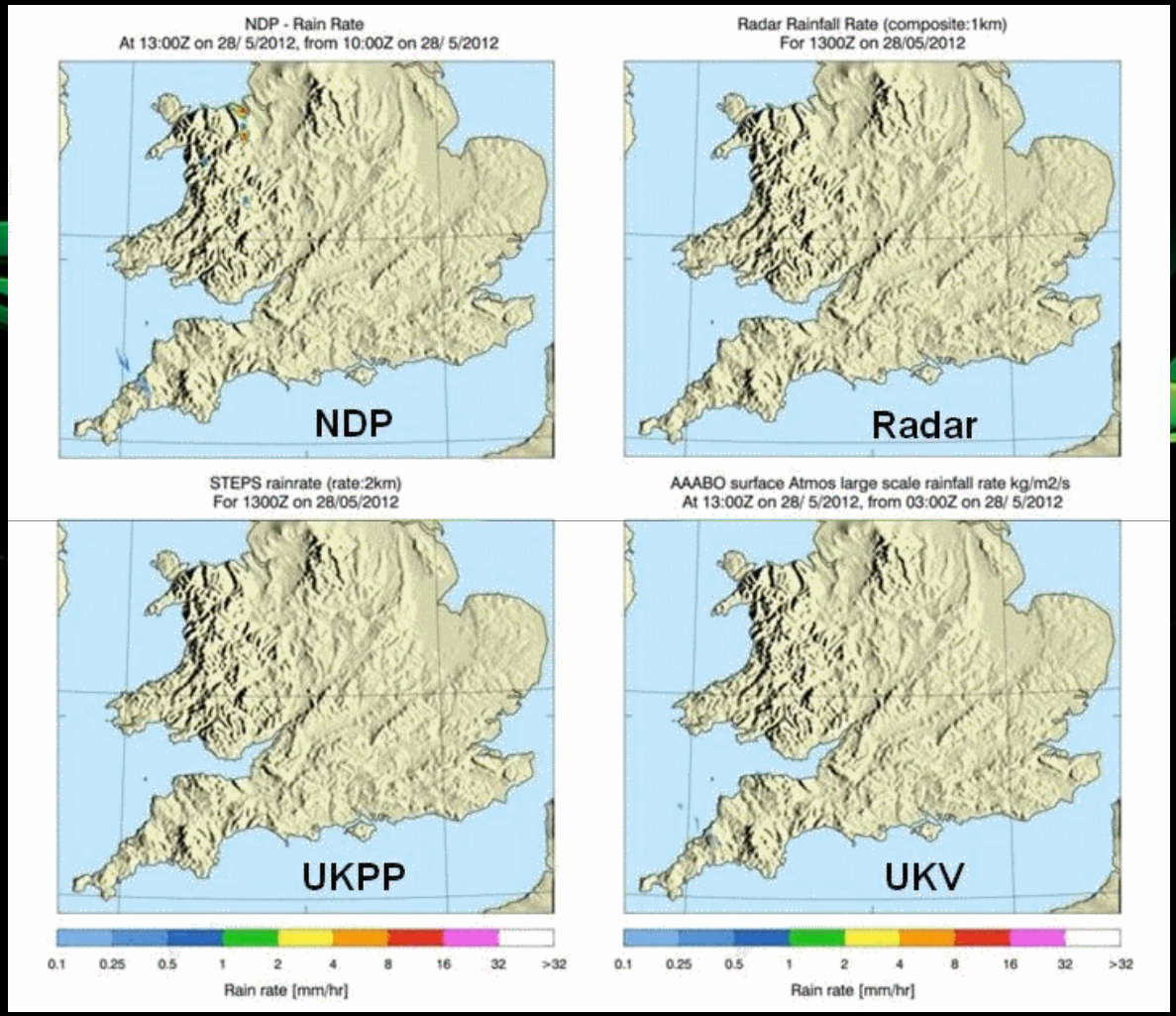
Assimilation

- No extra cost
- More balance

Forecast

- Positive impact on precipitation up to T+2/T+3
- Improvement at low predictability scale

Questions?



NDP run @ 10:00 Z on the 28th June 2012
From T+3 to T+6