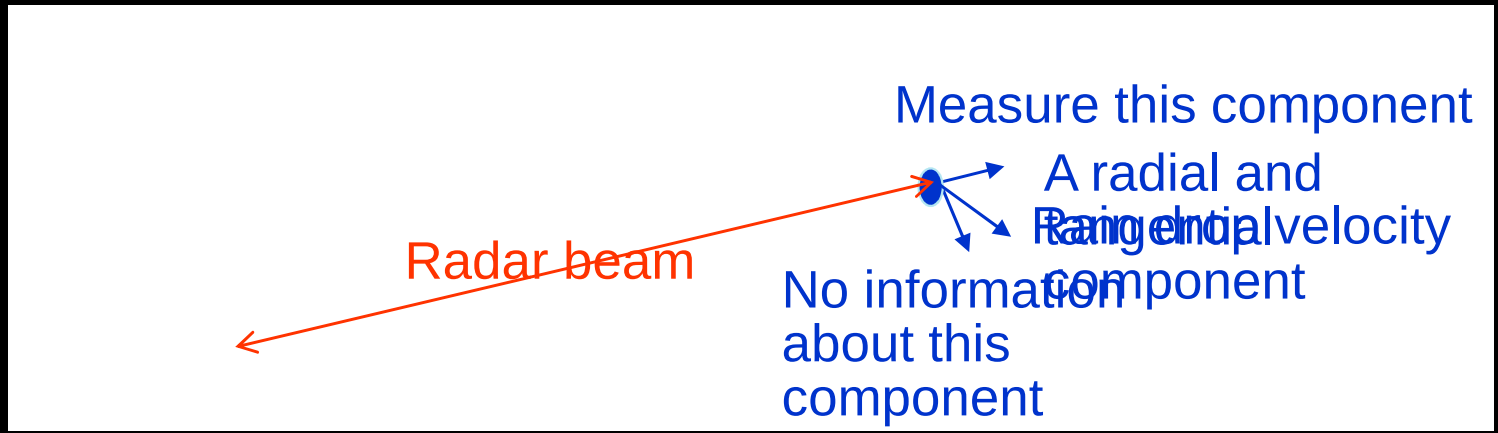
Doppler Radar Assimilation Trials

Helen Buttery ***– David Simonin*** *– Sue Ballard*

Introduction

- Doppler radial winds:
  - Reflected radar beam has a frequency shift due to the velocity along the beam direction of the raindrop (the Doppler effect).
  - Have a measurement of radial velocity anywhere along the radar beam where there is rain.
  - But no information about the tangential velocity.



Introduction

6 radar stations currently providing Doppler radial wind measurements (plans to upgrade whole network)

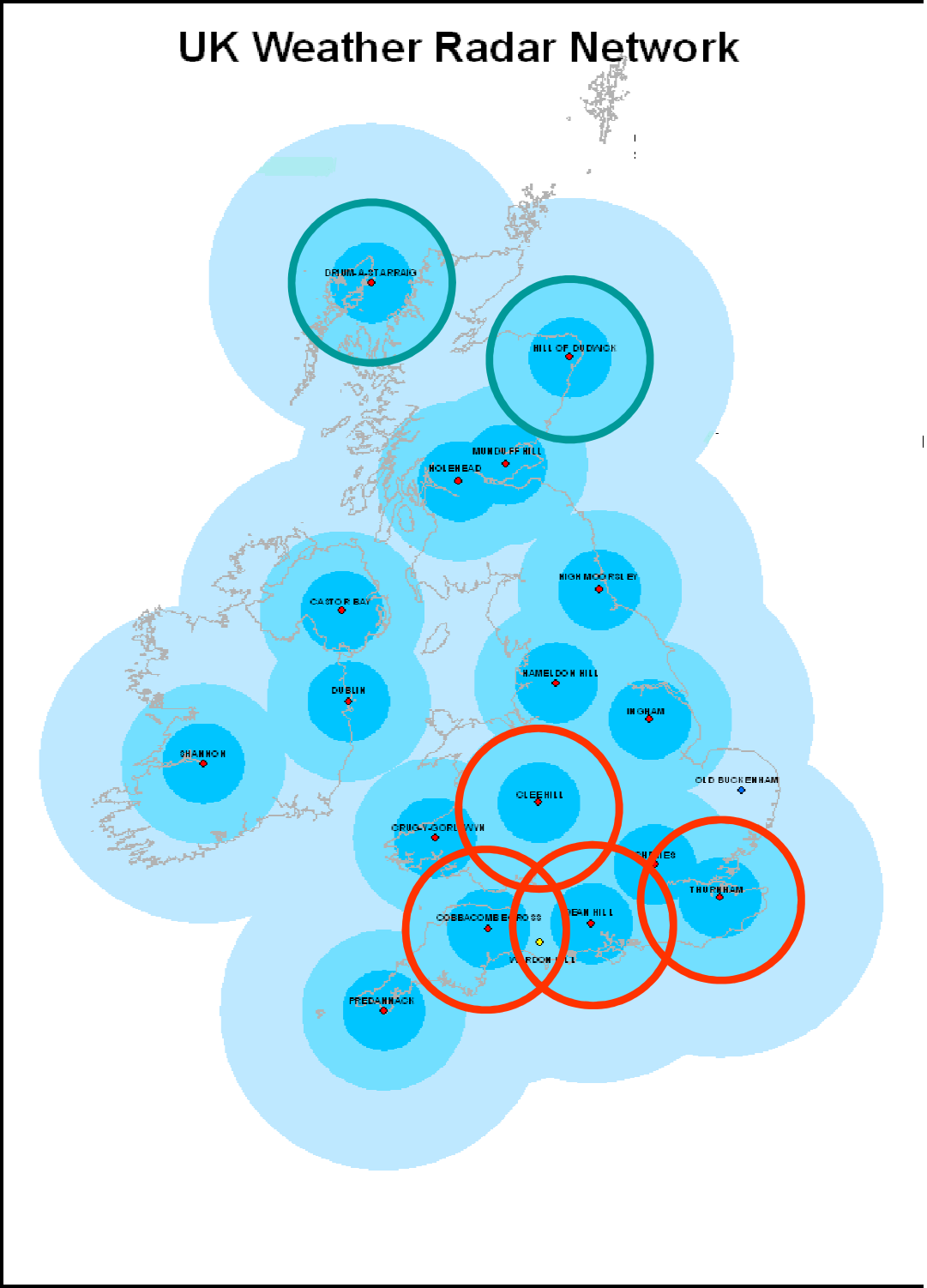
4 used in these trials

100km radius

elevations between 1° and 9°

1° azimuthal 600m radial

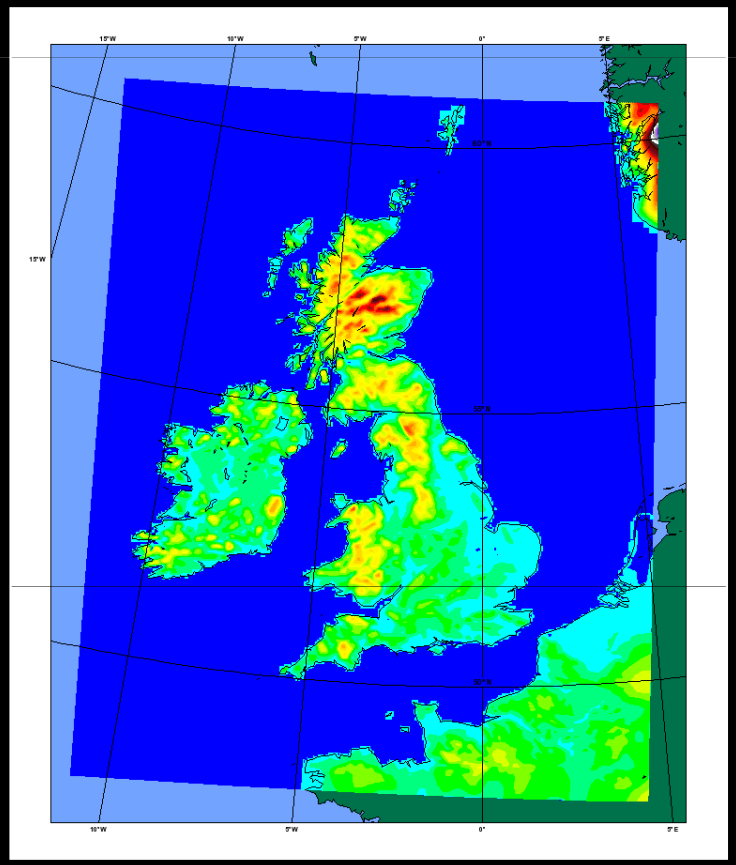
every 5 minutes



Introduction

- During rainfall a very detailed picture of radial wind speed can be obtained.
- Local areas of convergence can be determined

UK 4 km model set-up



3DVAR assimilation (3 hour cycles) of:

- Aircraft and sonde, scatwind, satwind, ground GPS, SEVERI, MOPS cloud observations

Latent-heat nudging of:

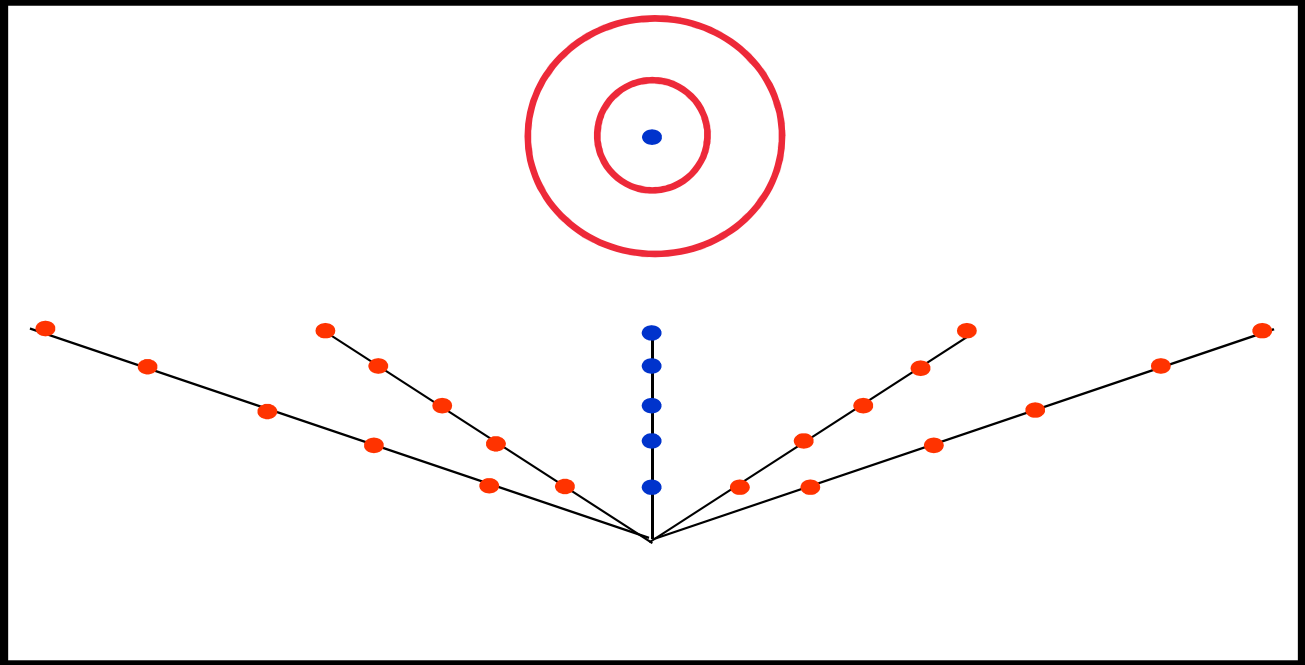
- MOPS precipitation

Adaptive vertical VAR grid

UK 4 km control set-up

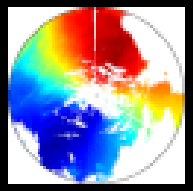
VAD winds:

Doppler radial wind information currently used to produce VAD (velocity azimuthal display) winds.

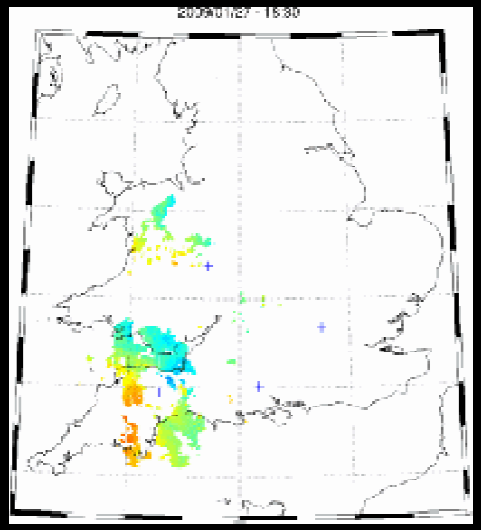


UK 4 km trial set-up

Doppler radial winds:



Detailed radial wind information across the area of the map with Doppler radar coverage (rather than just one vertical profile per radar station).



Both require rainfall to be present

UK 4 km Trial set-up

- Trial Period (rainy periods only)
  - 2010 August 10th 0300 – August 24th 0300 (14 days)
  - 2010 17th November 0300 – 23rd November 0300 (6 days)
  - 2010 29th November 0300 – 4th December 0300 (5 days)
  - 2010 16th December 0300 – 21st December 0300 (5 days)
  - 2010 27th December 0300 – 28th December 0300 (1 day)
  - 2011 24th January 1500 – 26th January 2100 (2 ¼ days)
  - 2011 February 9th 0300 – February 15th February 2100 (6 ¾ days)

Trial Settings

- Observations assimilated at T+0 in a 3 hour window (T-1.5 to T+1.5).
- All periods trialled with “Poisson” thinning to 8km (twice the UM grid).
- Some trials also have simple UM grid thinning or “Poisson” thinning at 4 or 12 km.
  - Poisson thinning randomly selects observations – that must be more than the specified radius away from any other observation. (Shown to give smaller analysis error than other methods by Bondarenko et al, 11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 2007)
  - Individual groups of superobbing cells will certainly be selected by this method whereas they might not be selected on a regular grid.

UK Index

- Standard way to measure forecast performance before allowing new data to be assimilated
- Includes Equitable Threat Score for surface visibility, 6 hour precipitation accumulation, total cloud amount and cloud base height (with 3/8 cover).
- Includes skill for surface temperature and surface wind speed.
- Averaged over 36 hours over the whole of the UK.

% increase in UK Index over all trials (neutral impact)

Poisson 8 km thinning (44 days)	0.09±0.15
Poisson 8 km thinning (14 days)	0.05±0.27
Poisson 12 km thinning (14 days)	-0.29±0.27
Poisson 4 km thinning (14 days)	-0.23±0.27
UM grid (4 km) thinning (14 days)	-0.03±0.29

Errors calculated by considering the day-to-day variation in the Index

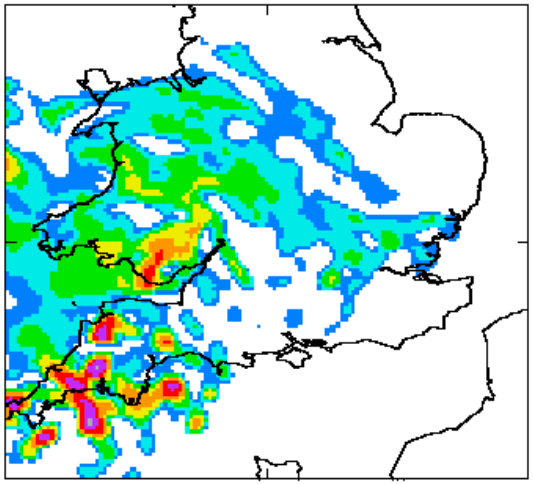
Doppler wind assimilation will be operational by end of June

- Number of VAR iterations required is on average the same as without the Doppler wind measurements:
  - (97±8)%
- OPS times acceptable
- Can go operational
- But can we show a positive impact? Certainly by eye can see some cases where the rainfall location has improved.
- Need to look over shorter timescales and consider other verification methods

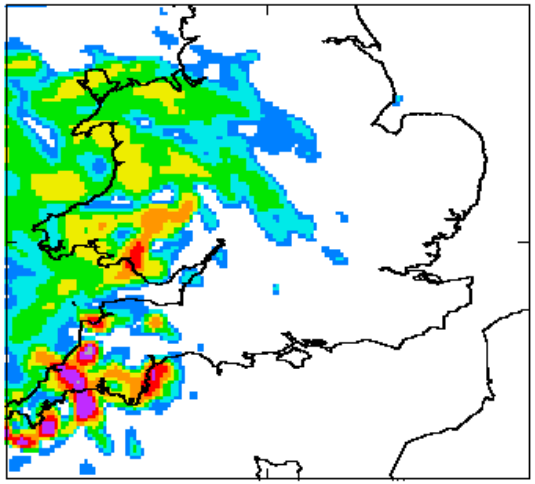
Individual case where rainfall location is seen to be improved

T+4

Control

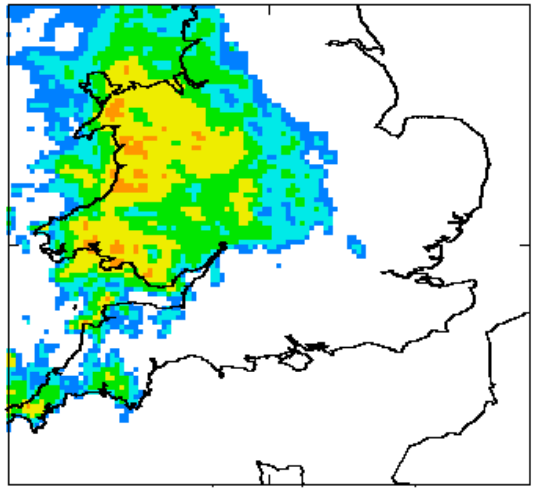


Trial



0.2 0.5 1.0 2.0 4.0 8.0 16.0 32.0
mm/hr

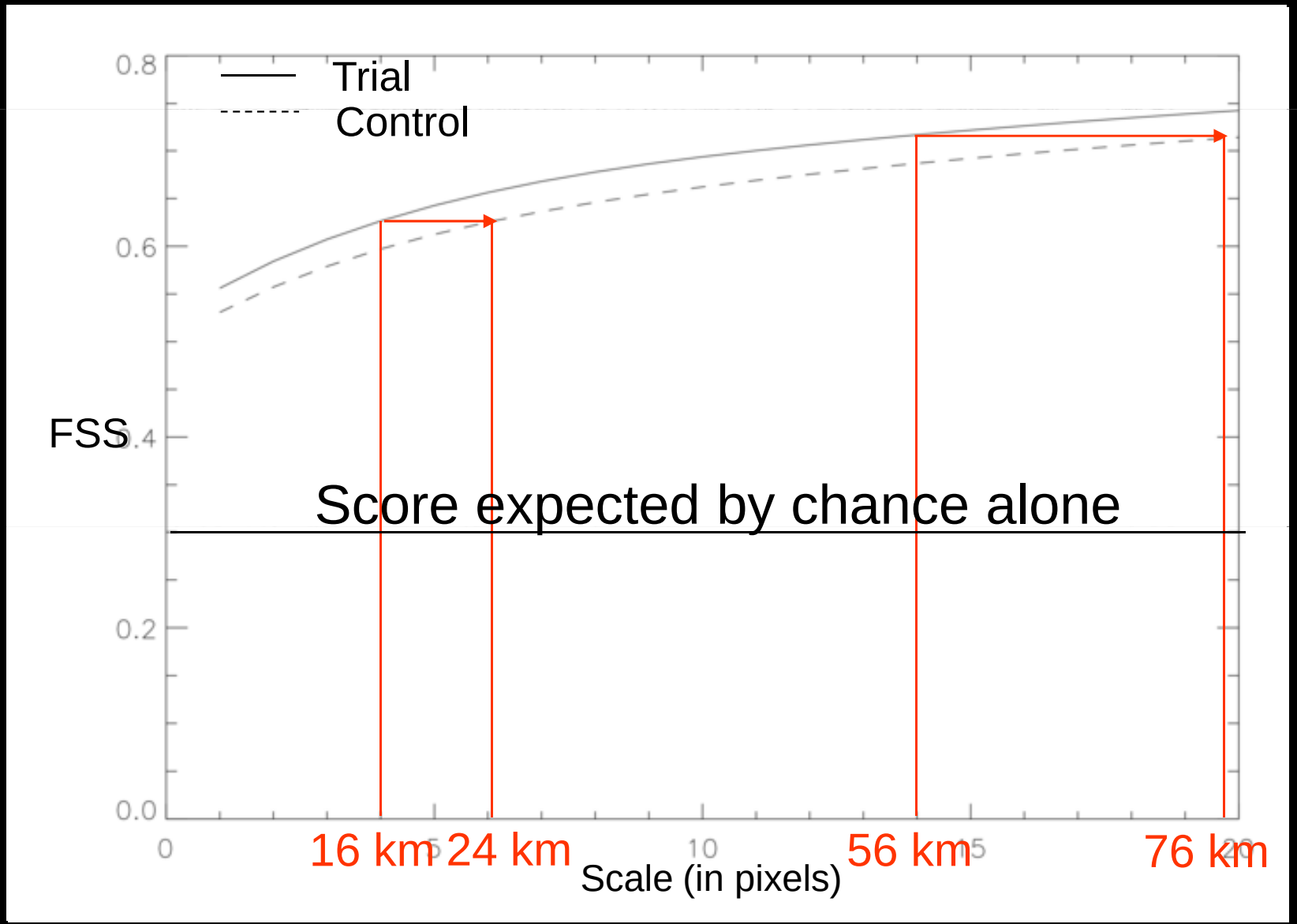
Radar



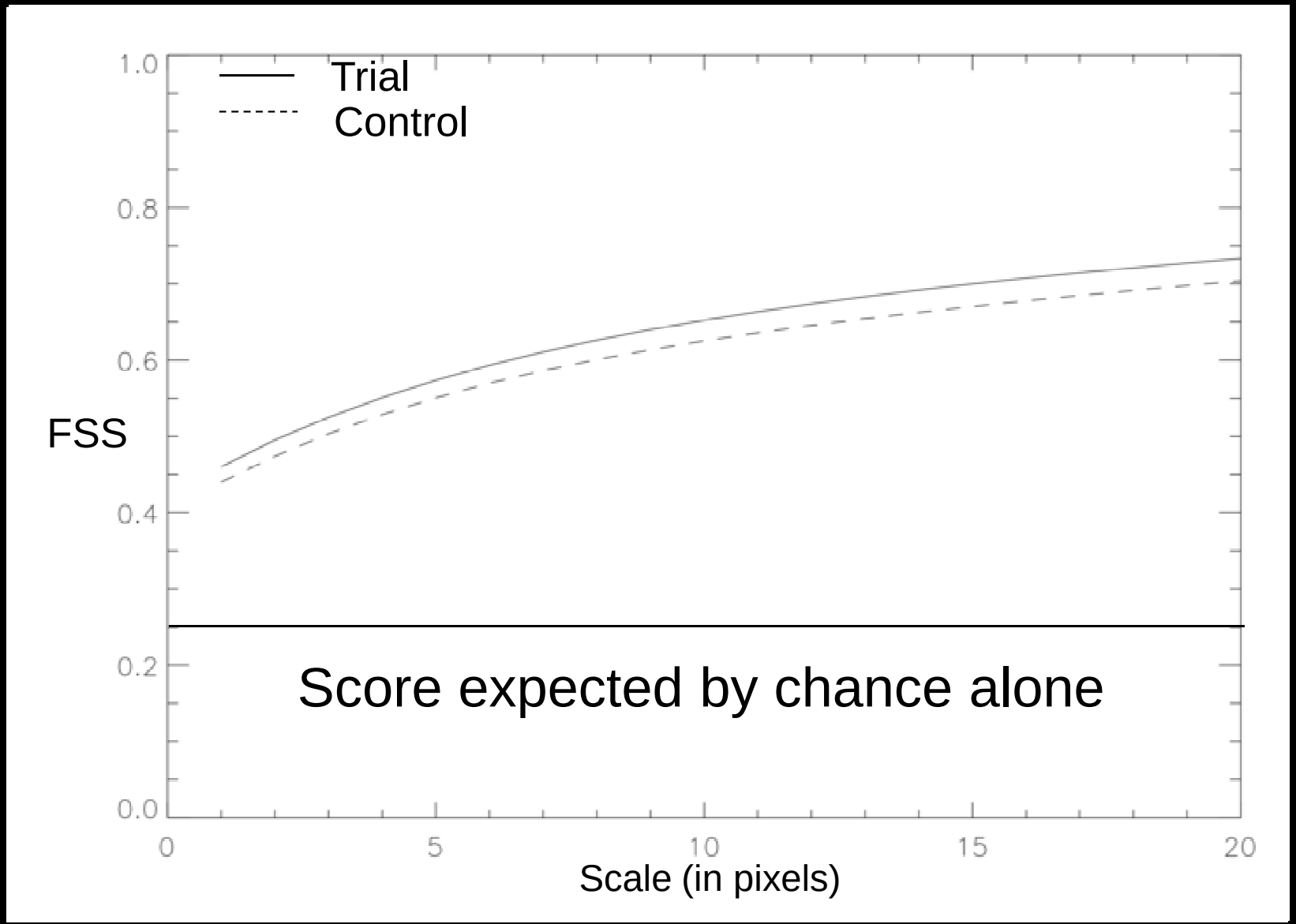
Fraction Skill Score

- Roberts, 2008 Meteorological Applications, 15, 163 – 169
- Look at rainfall within a given box size – you can determine a scale at which the forecast is useful
- Can make allowance for the rainfall in the model being close to that in the observation but not in exactly the same pixel (the UK Index precipitation score only scores positively when the rainfall is in the same pixel).
- Compares precipitation percentiles from radar measurements and model outputs (eliminates bias)
- Considered instantaneous rates (rather than accumulations)
- Score goes from 0 to 1 – 1 being a perfect score

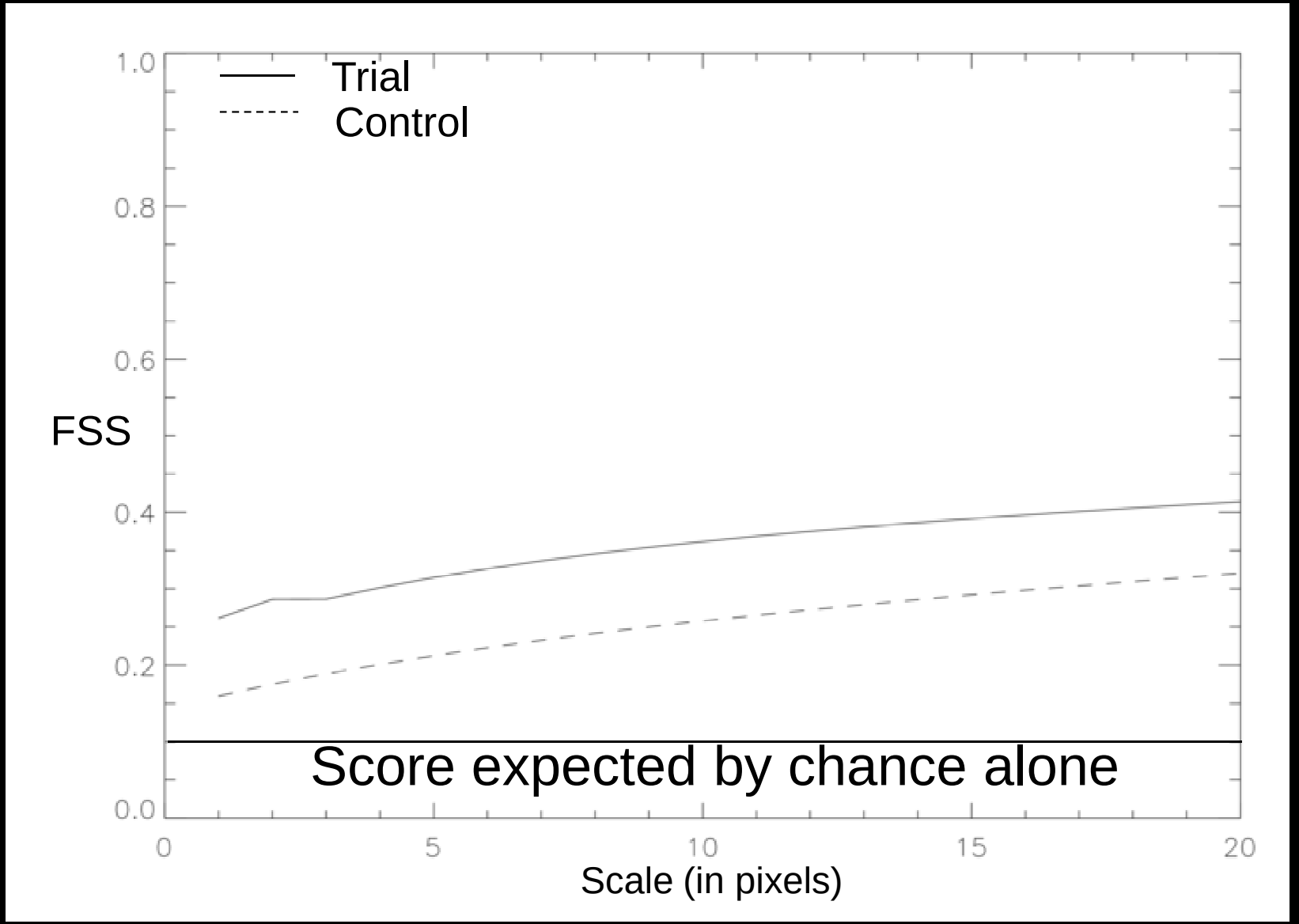
Fraction Skill Score 75th percentile Control and Trial with Poisson thinning at 8 km plotted against scale (1st run, 1st timestep)



Fraction Skill Score 75th percentile Trial with Poisson thinning at 8 km plotted against scale (average of 1st 5 runs)



Fraction Skill Score 90th percentile Trial with Poisson thinning at 12 km plotted against scale (average of first 36 runs)

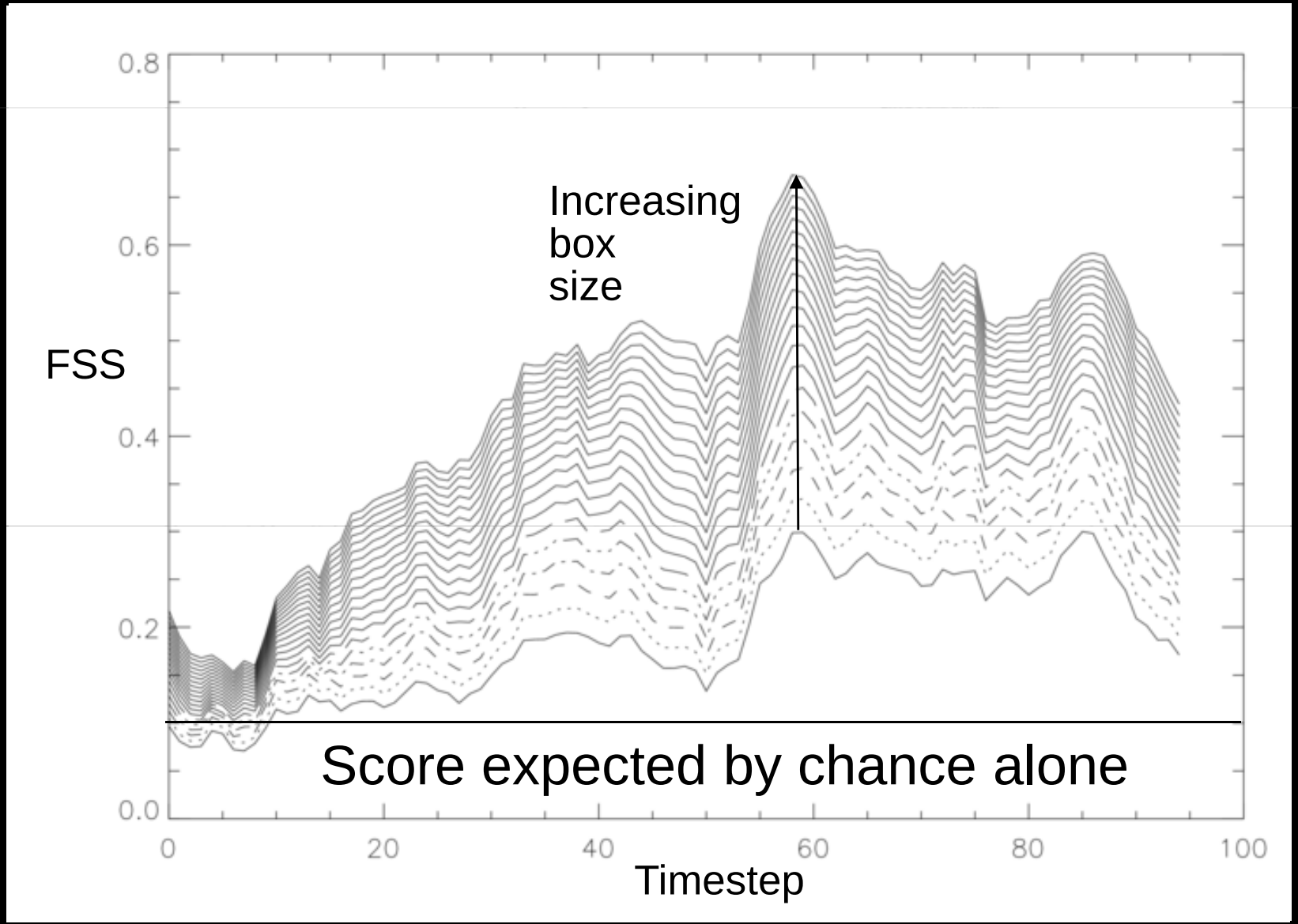


Conclusions

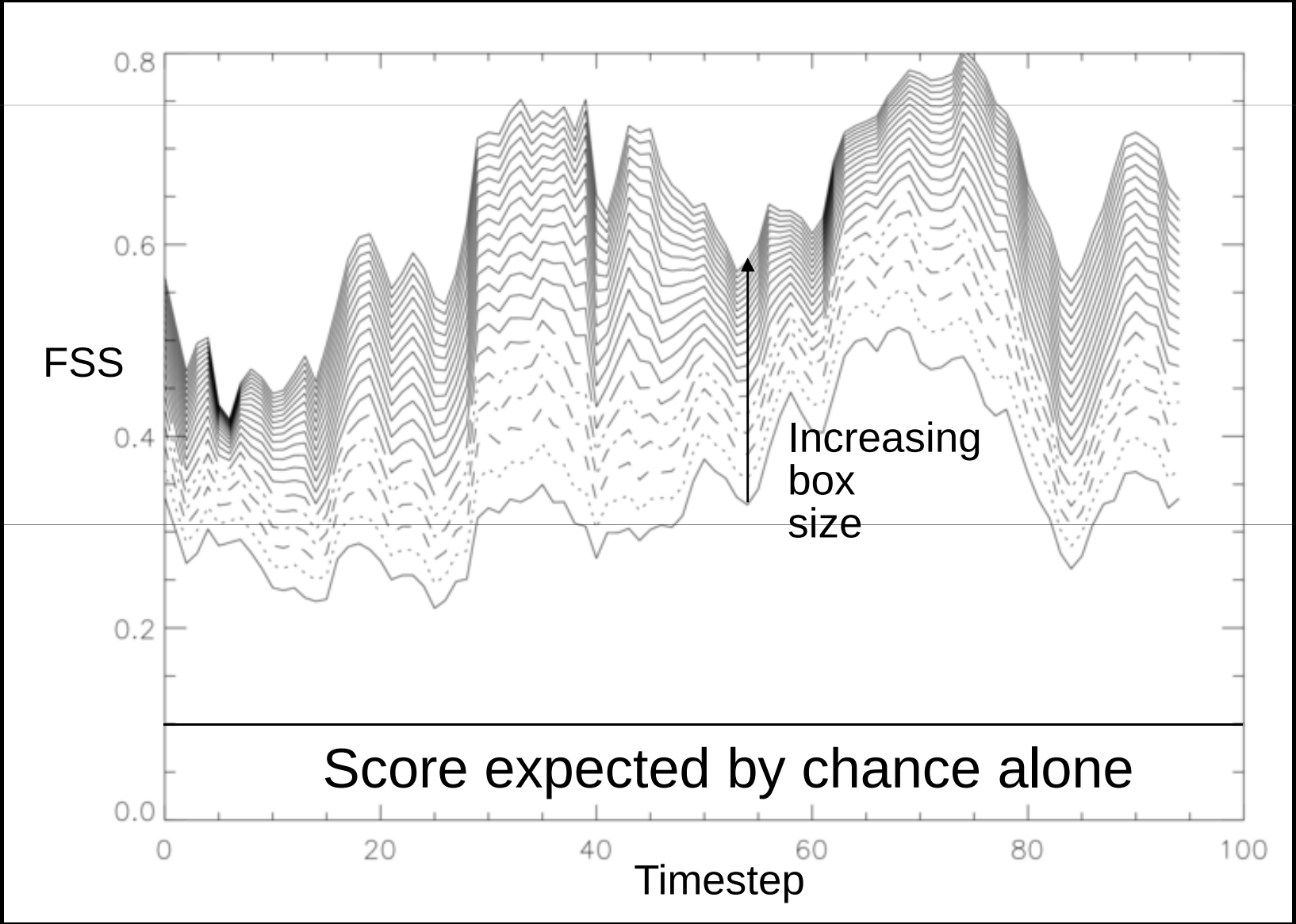
- Doppler radial winds will be assimilated operationally from June.
- Overall neutral impact on the UK Index
- Improvement seen in the rainfall location

Any Questions?

Fraction Skill Score 90th percentile Control (without radial winds) plotted against timestep (6th run only)



Fraction Skill Score 90th percentile Trial (with radial winds thinned to 8 km) plotted against timestep (same run)

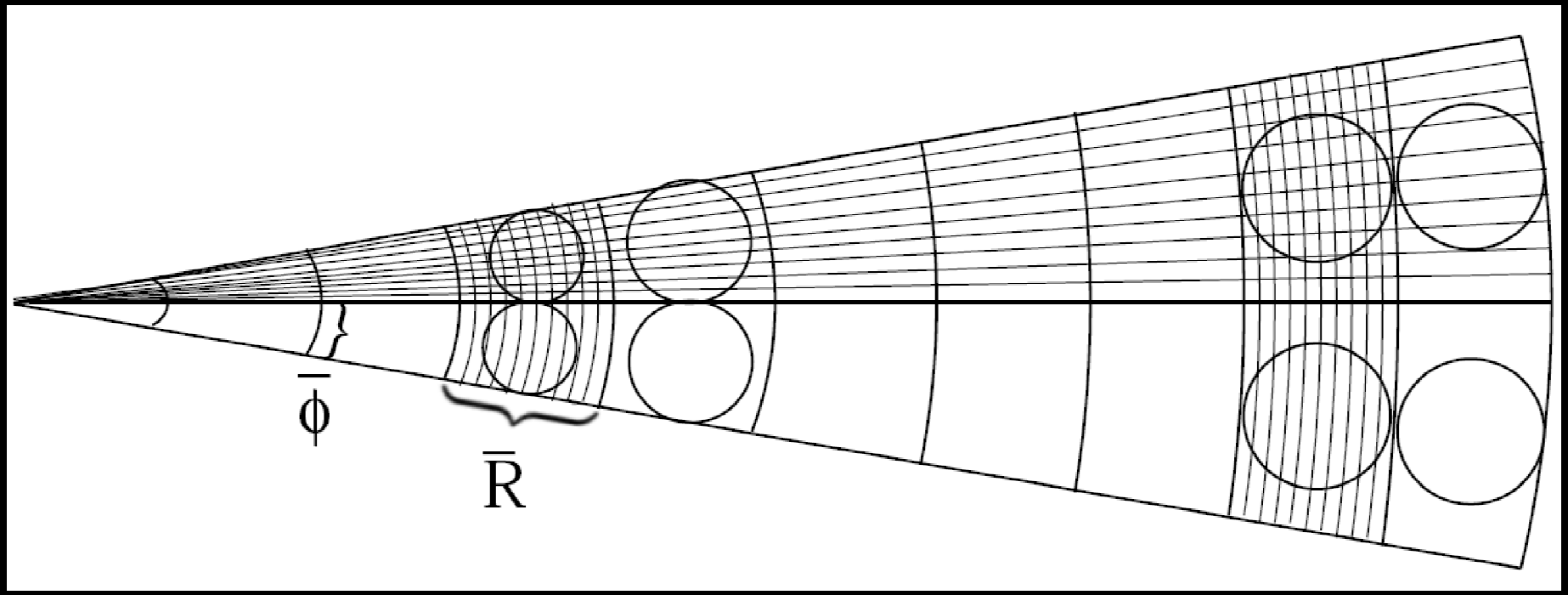


Quality Control

- Isolated groups of 2 or fewer pixels are rejected
- A 3x3 Laplace filter is applied – which rejects pixels that are too different from their neighbours
- Observations with a difference of greater than 10 ms^{-1} to the background are discarded
- Raw observations falling outside of 1 standard deviation of the mean of the superobbing cell are rejected
- If a superobservation cell contains only one observation it is rejected.

Trial Settings

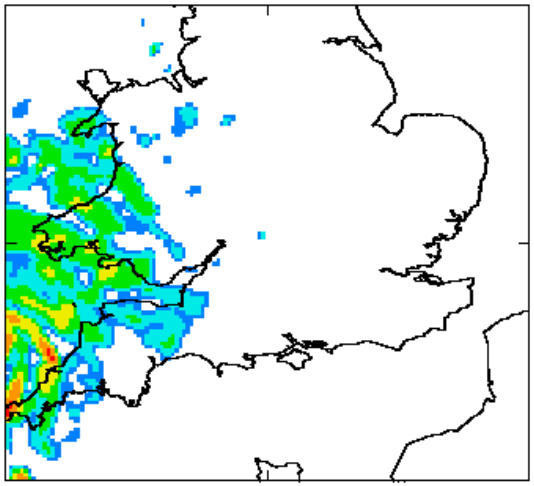
- Superobbing – Circle Near the radar, circle area limited by the arc distance. After the arc distance exceeds the value of range bin spacing, the data selection area is defined by the range bin spacing.



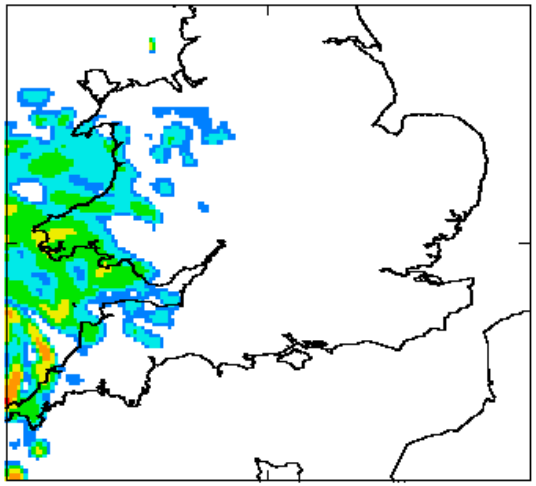
Individual case where rainfall location is seen to be improved

T+1

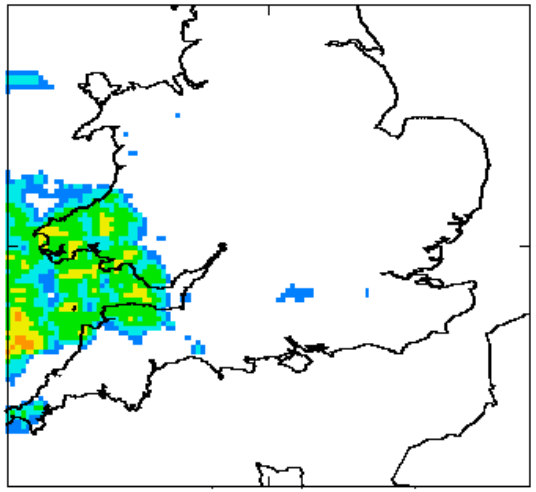
Control



Trial



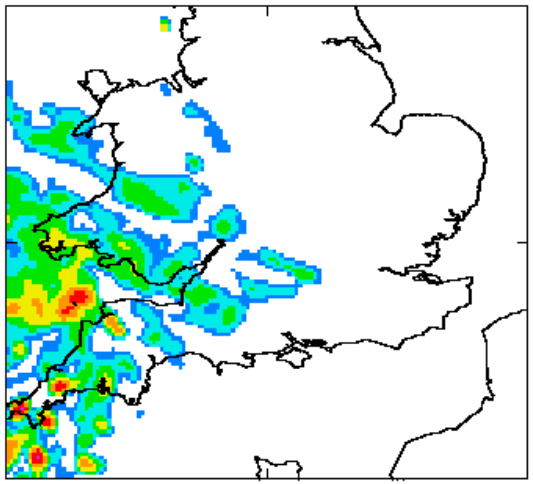
Radar



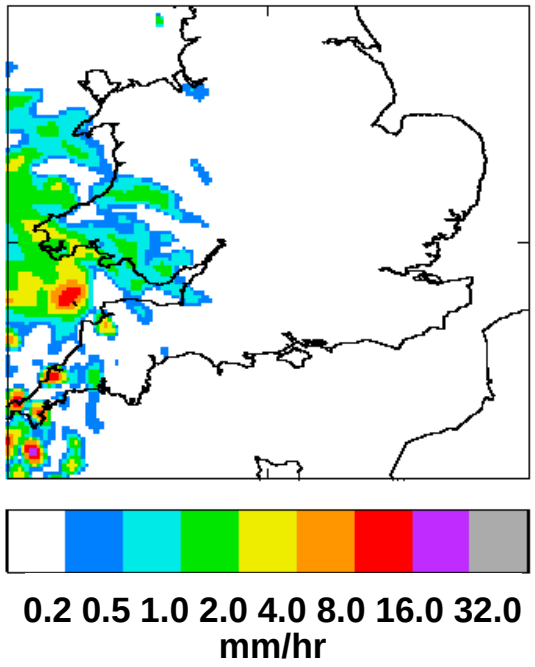
Individual case where rainfall location is seen to be improved

T+2

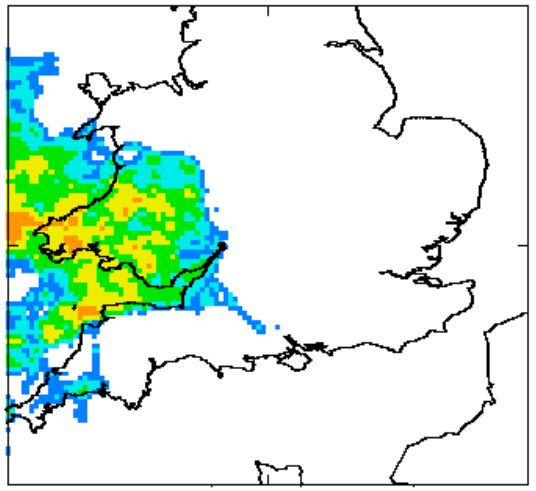
Control



Trial



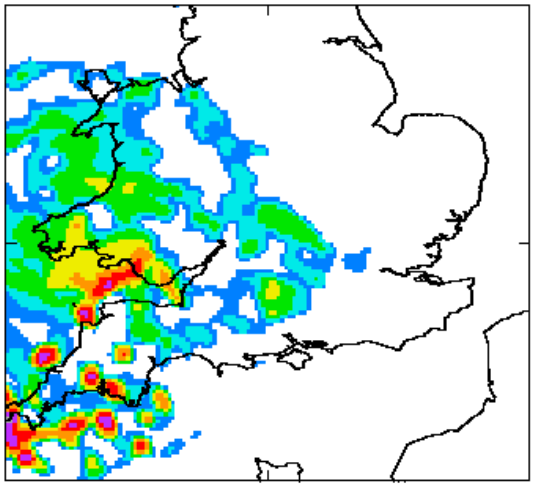
Radar



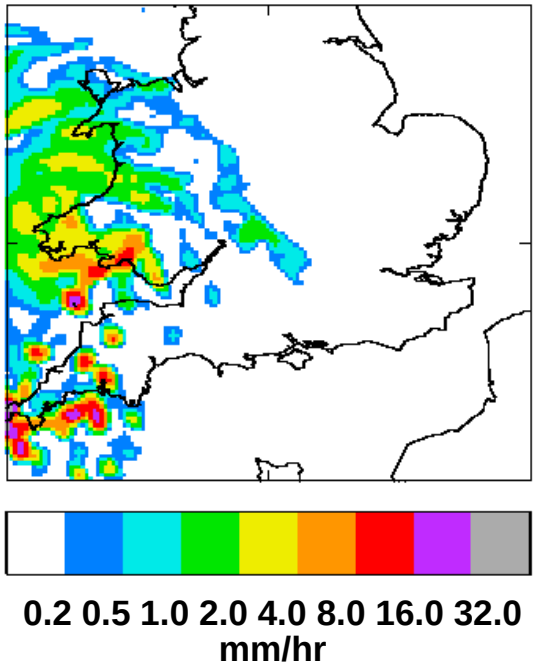
Individual cases where rainfall location is seen to be improved

T+3

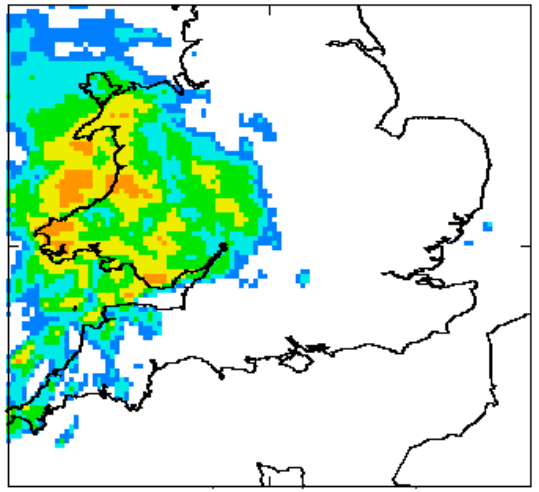
Control



Trial



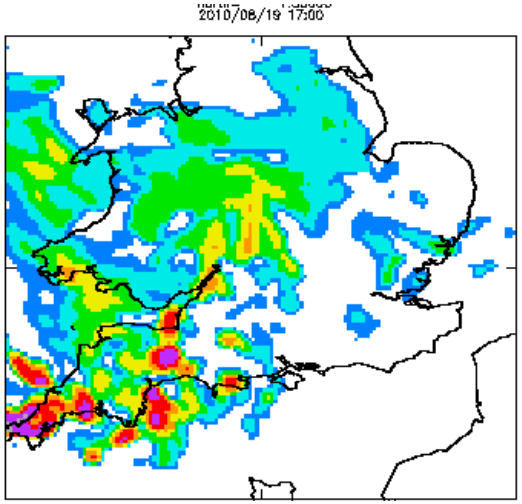
Radar



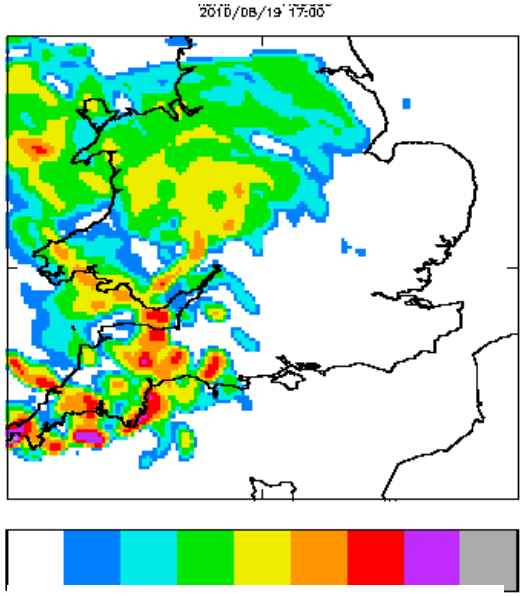
Individual case where rainfall location is seen to be improved

T+5

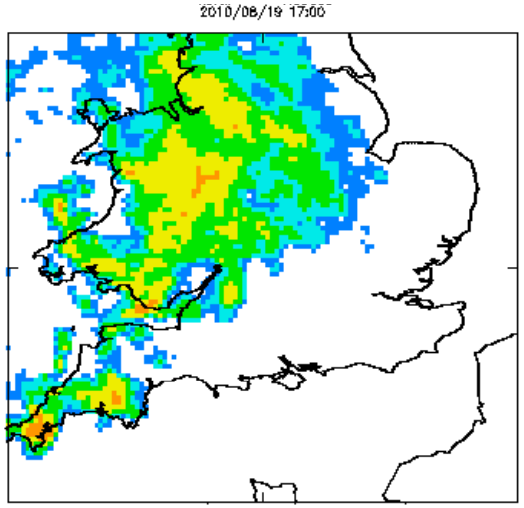
Control



Trial



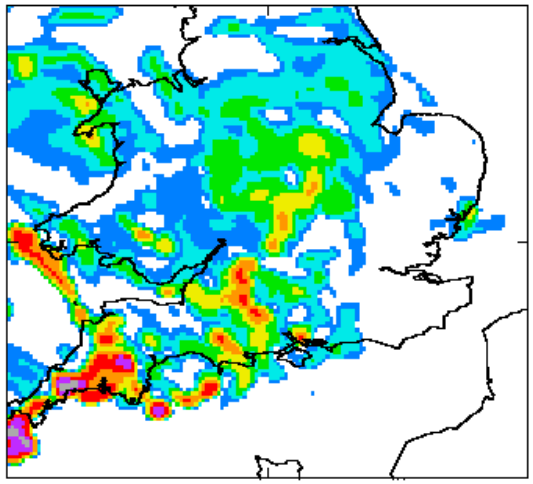
Radar



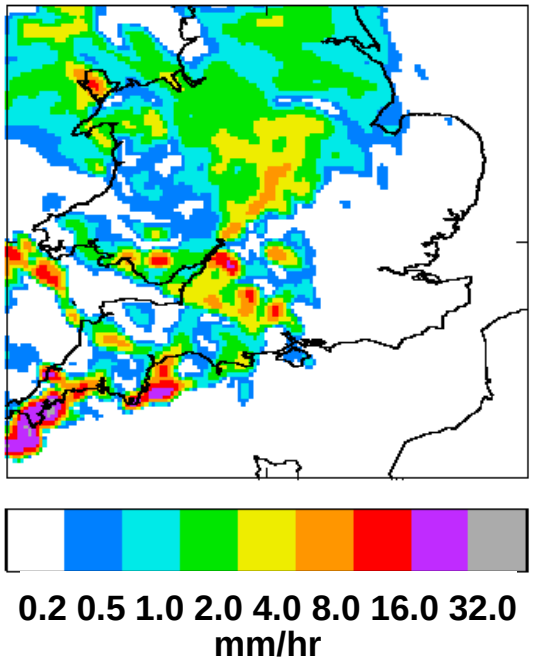
Individual case where rainfall location is seen to be improved

T+6

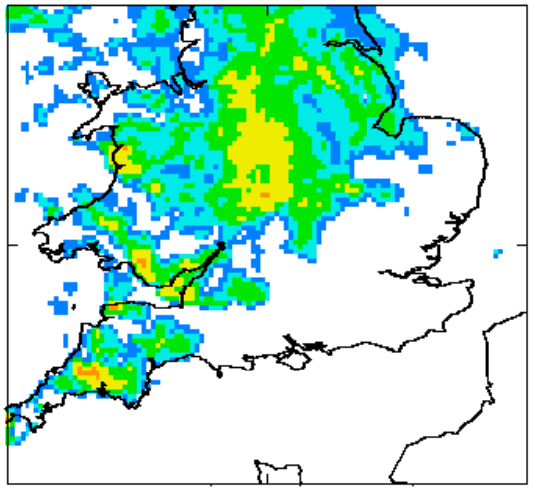
Control



Trial

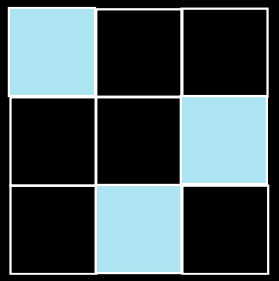


Radar

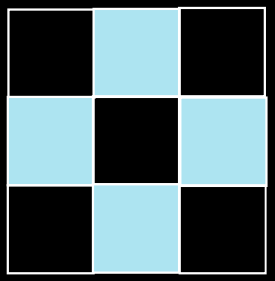


Fraction Skill Score

- Roberts, 2008 Meteorological Applications, 15, 163 – 169
- Take a box of certain dimension e.g. 3x3 pixels
- Calculate how may pixels are above a threshold in forecast and observations



Model:
Rainfall above Threshold in 3/9 pixels



Observation:
Rainfall above Threshold in 4/9 pixels

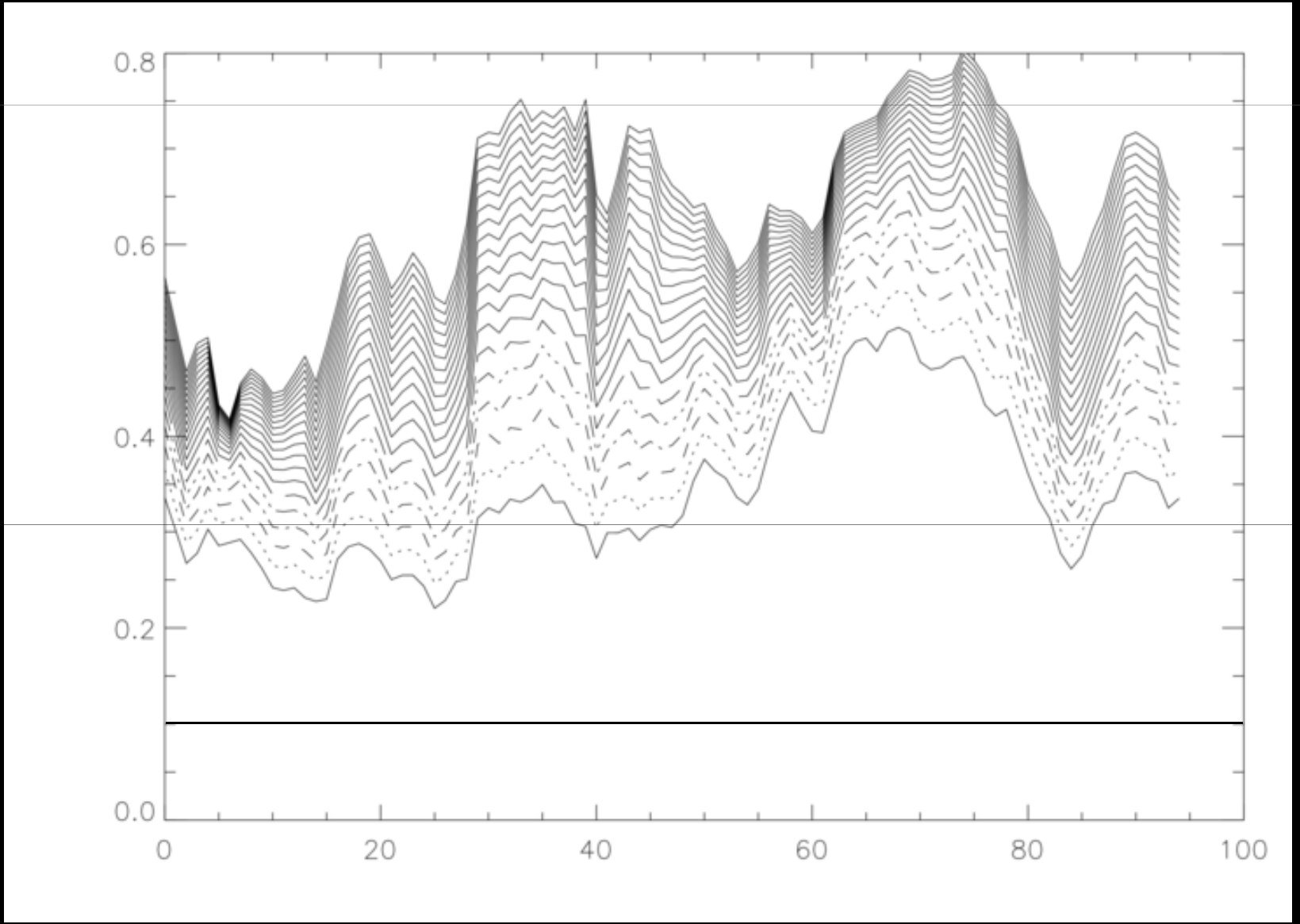
Model fraction M_j=3/9

Observation fraction O_j=4/9

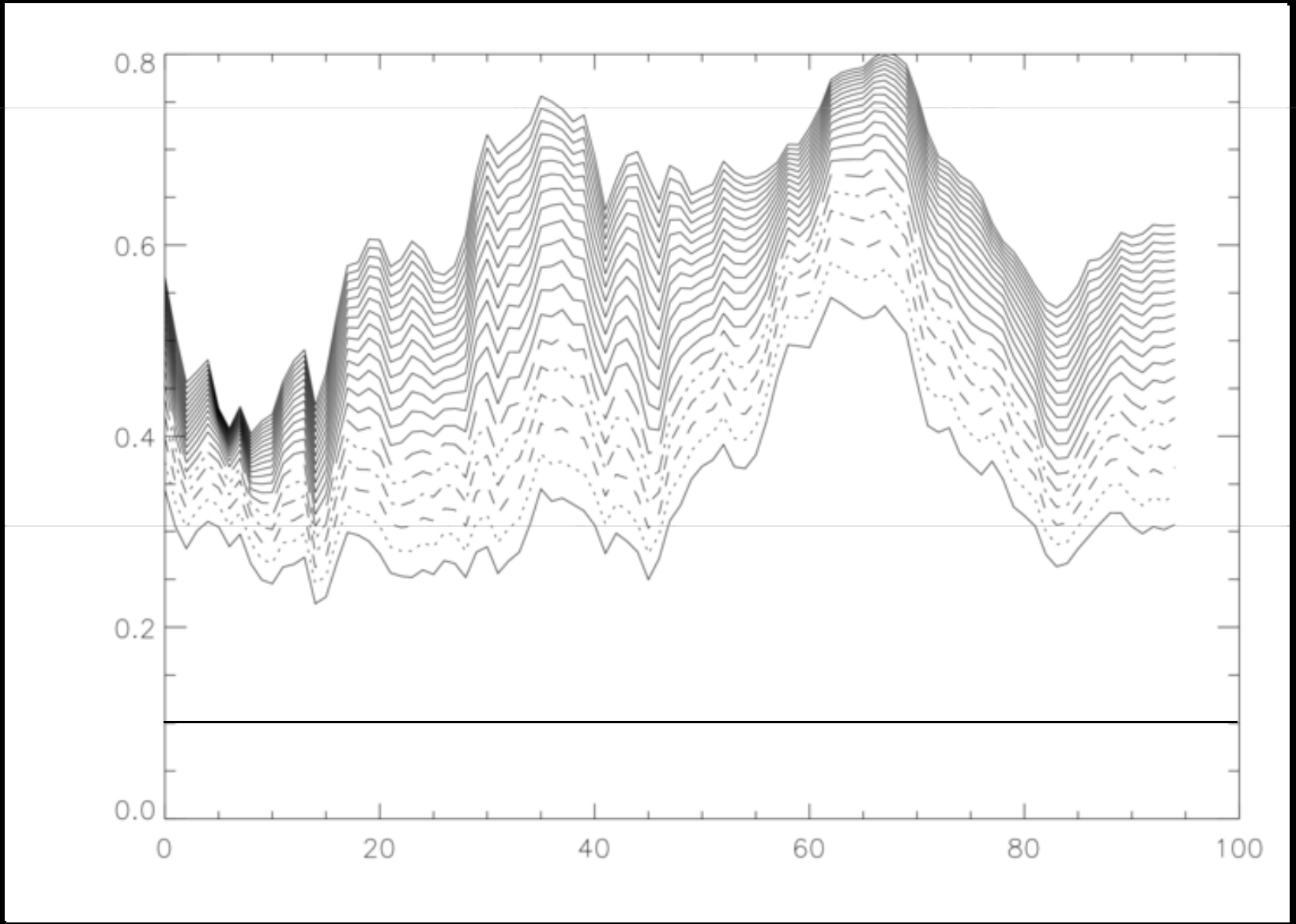
Fraction Skill Score

- $FBS = \frac{1}{N} \sum_{j=1}^{N} (O_j - M_j)^2$
- $FSS = 1 - (FBS / FBS_{worst})$
- FBS_{worst} when no non-zero fractions are colocated in forecast and observations
- $FBS_{worst} = \frac{1}{N} \sum_{j=1}^{N} (O_j^2 + M_j^2)$
- Varies between 0 and 1, 1 being a perfect score and 0 being the worst

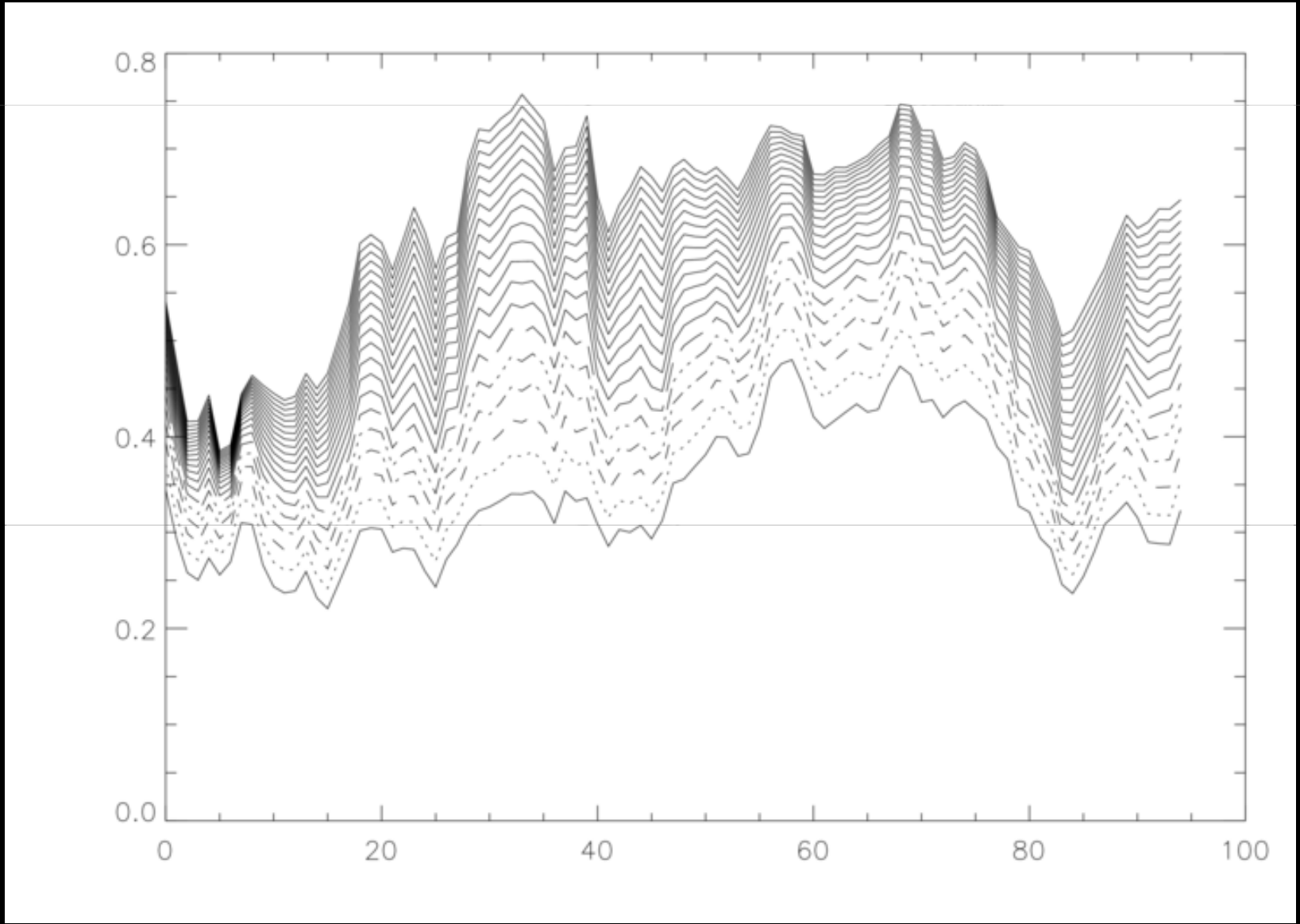
Fraction Skill Score 90th percentile Trial with Poisson thinning at 8 km plotted against timestep (same run)



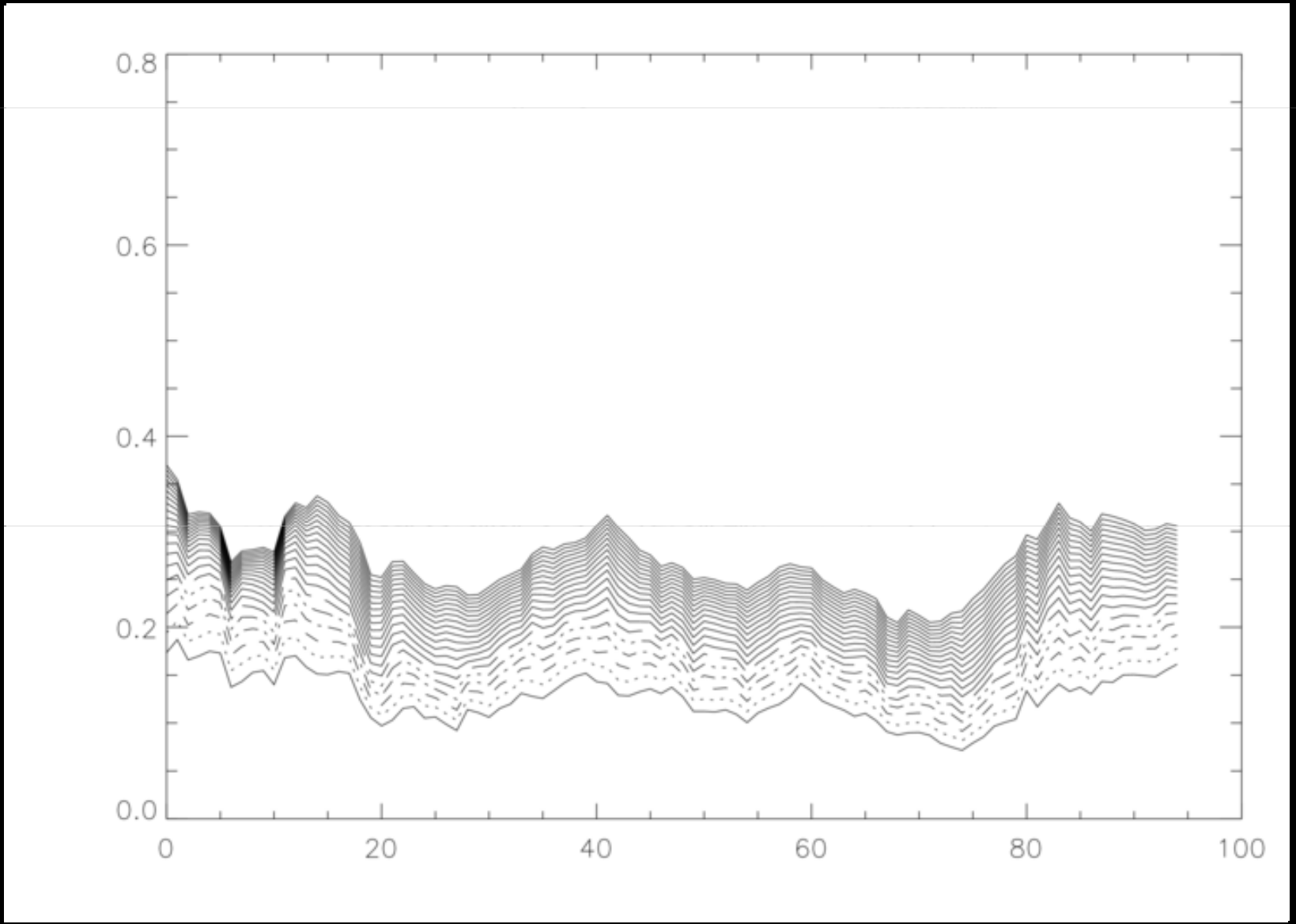
Fraction Skill Score 90th percentile Trial with Poisson thinning at 12 km plotted against timestep (same run)



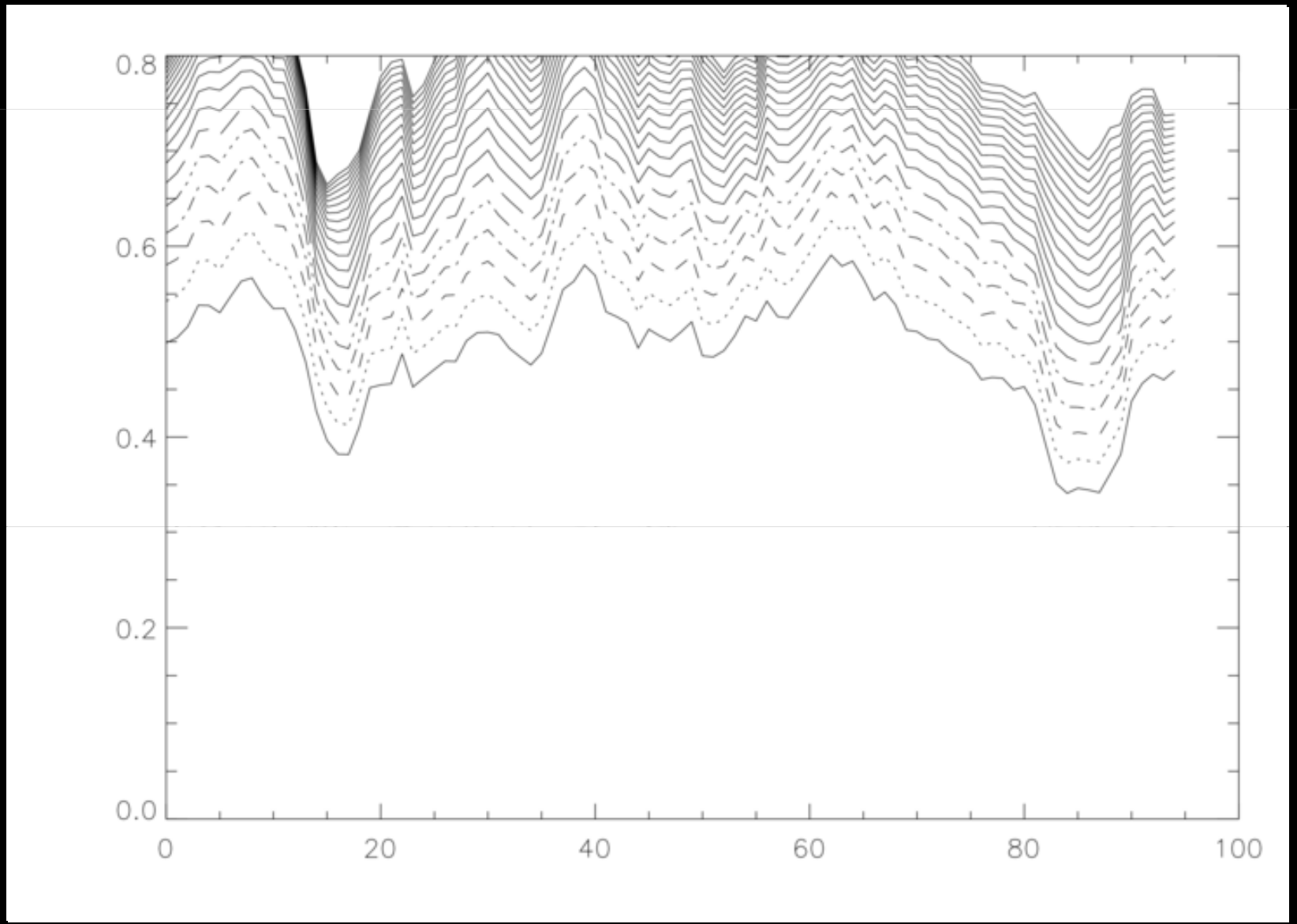
Fraction Skill Score 90th percentile Trial with grid thinning at 4 km plotted against timestep (same run)



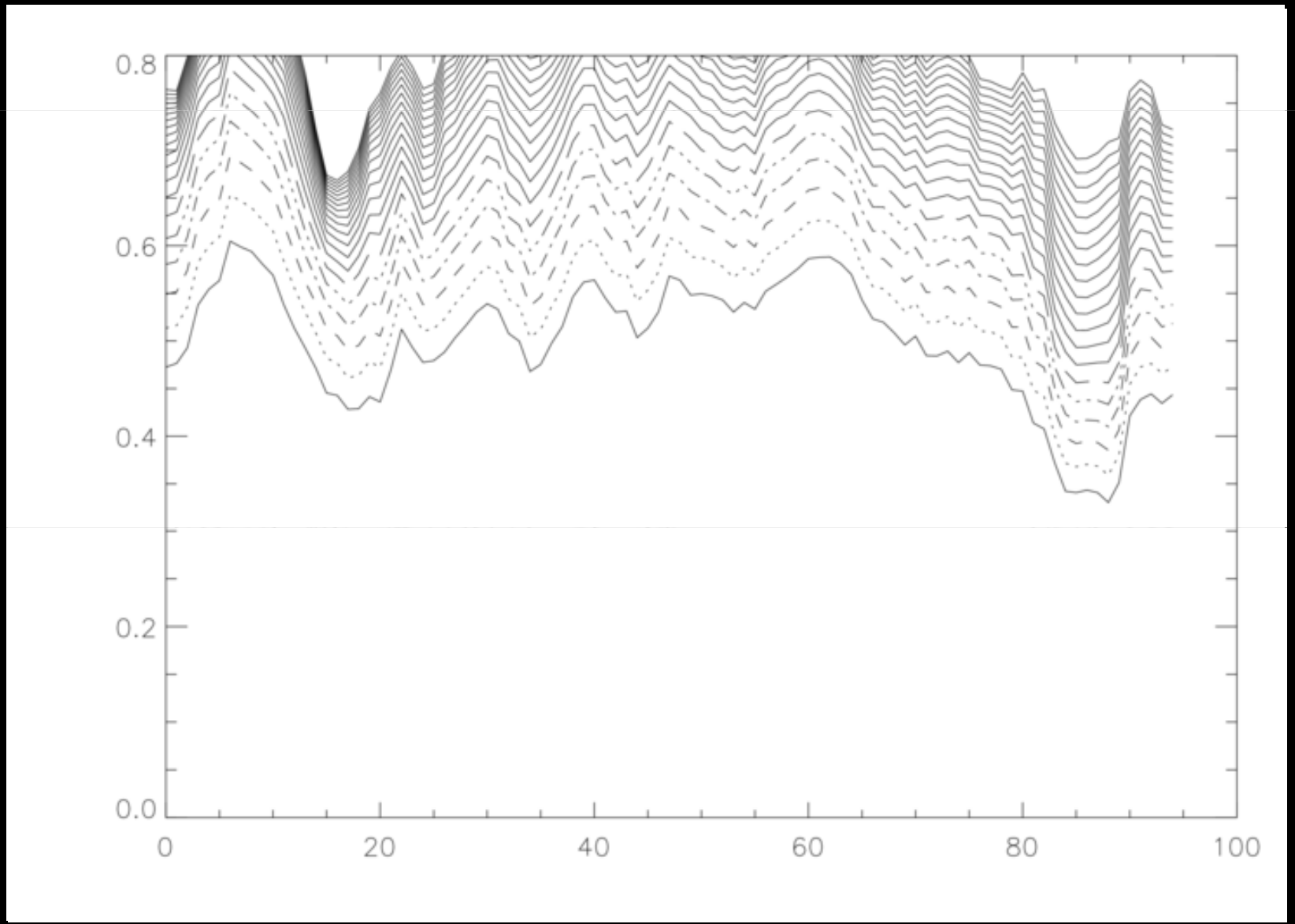
Fraction Skill Score 90th percentile Control plotted against timestep (24th run only)



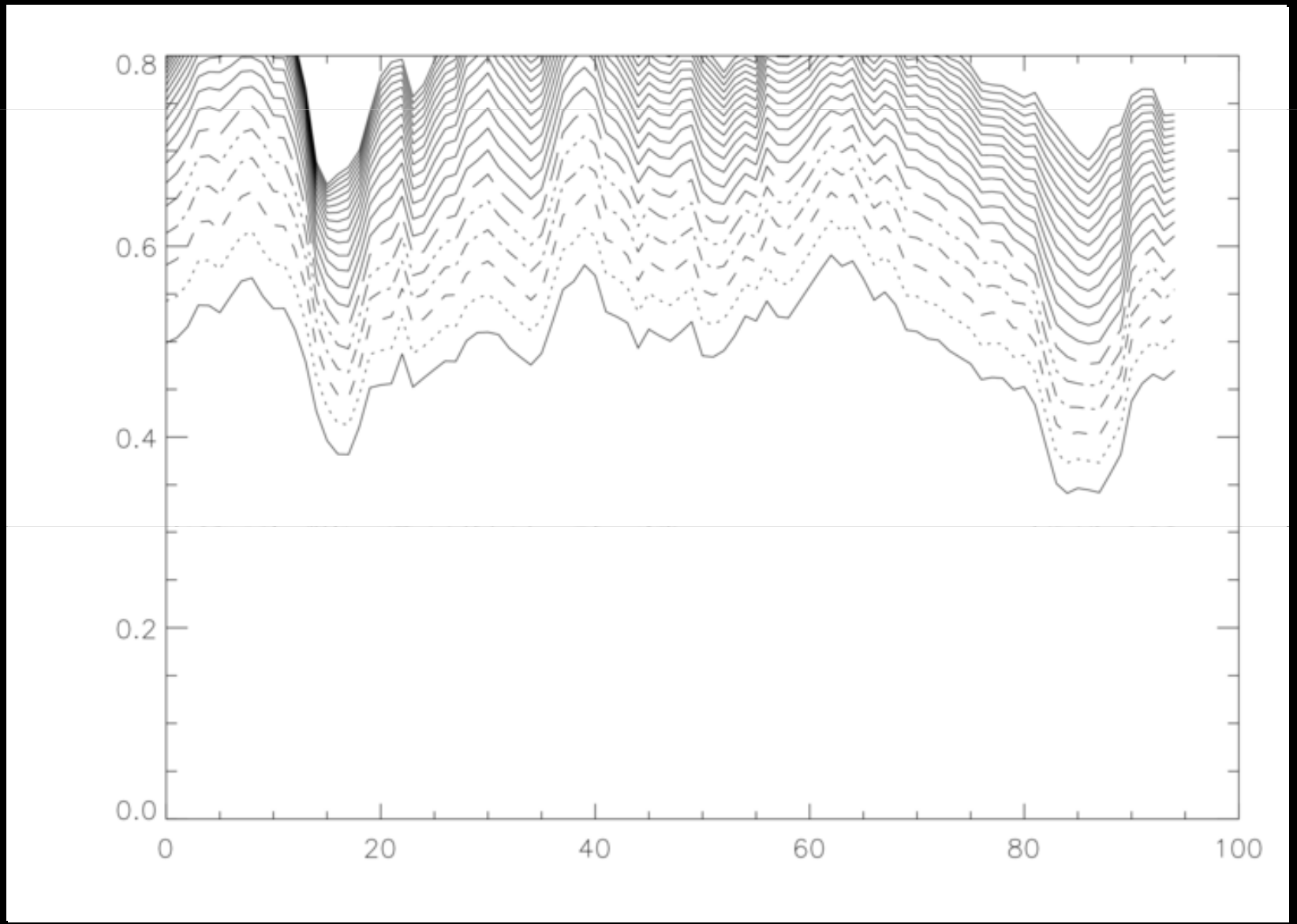
Fraction Skill Score 90th percentile Trial with Poisson thinning at 8 km plotted against timestep (same run)



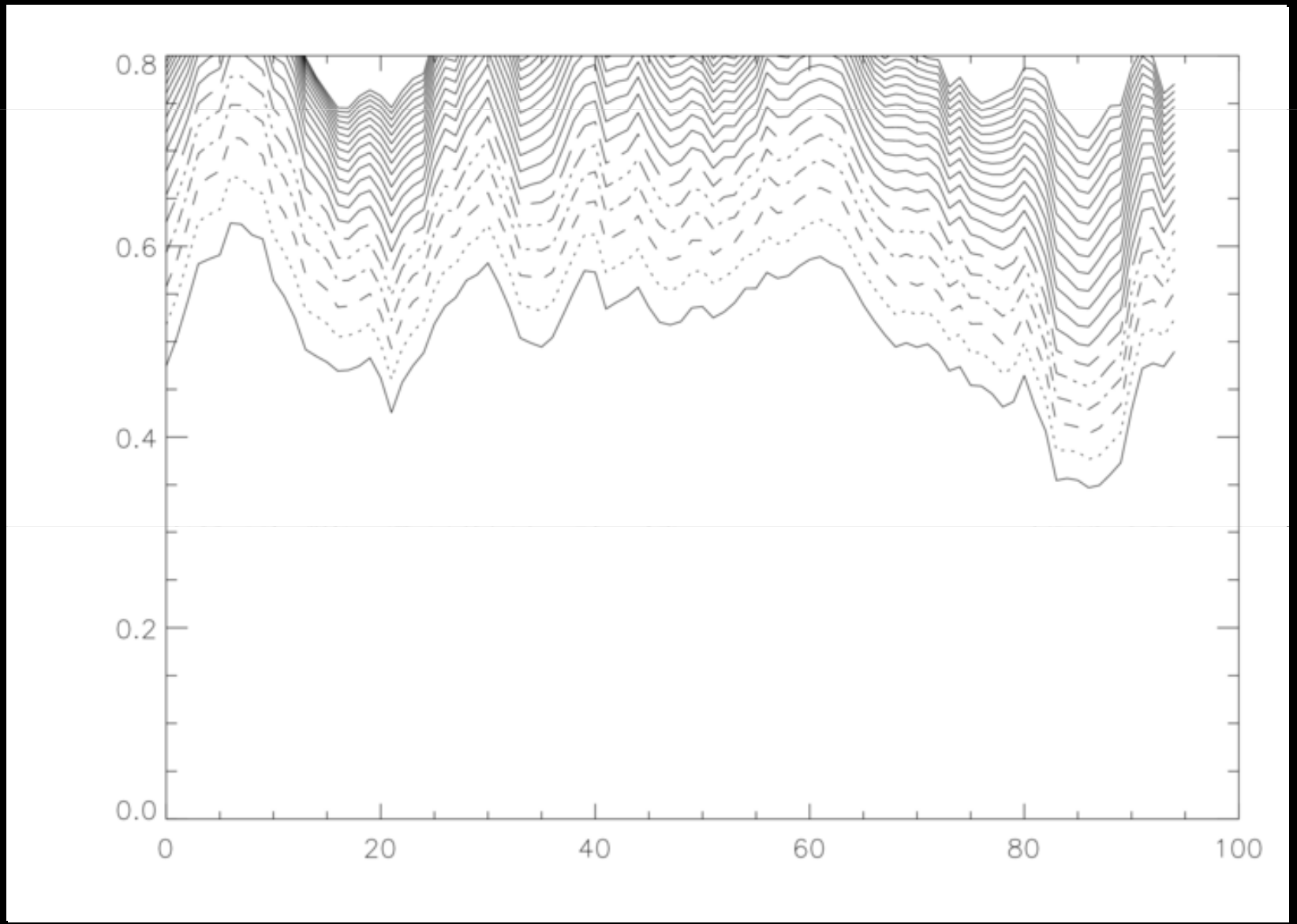
Fraction Skill Score 90th percentile Trial with Poisson thinning at 12 km plotted against timestep (same run)



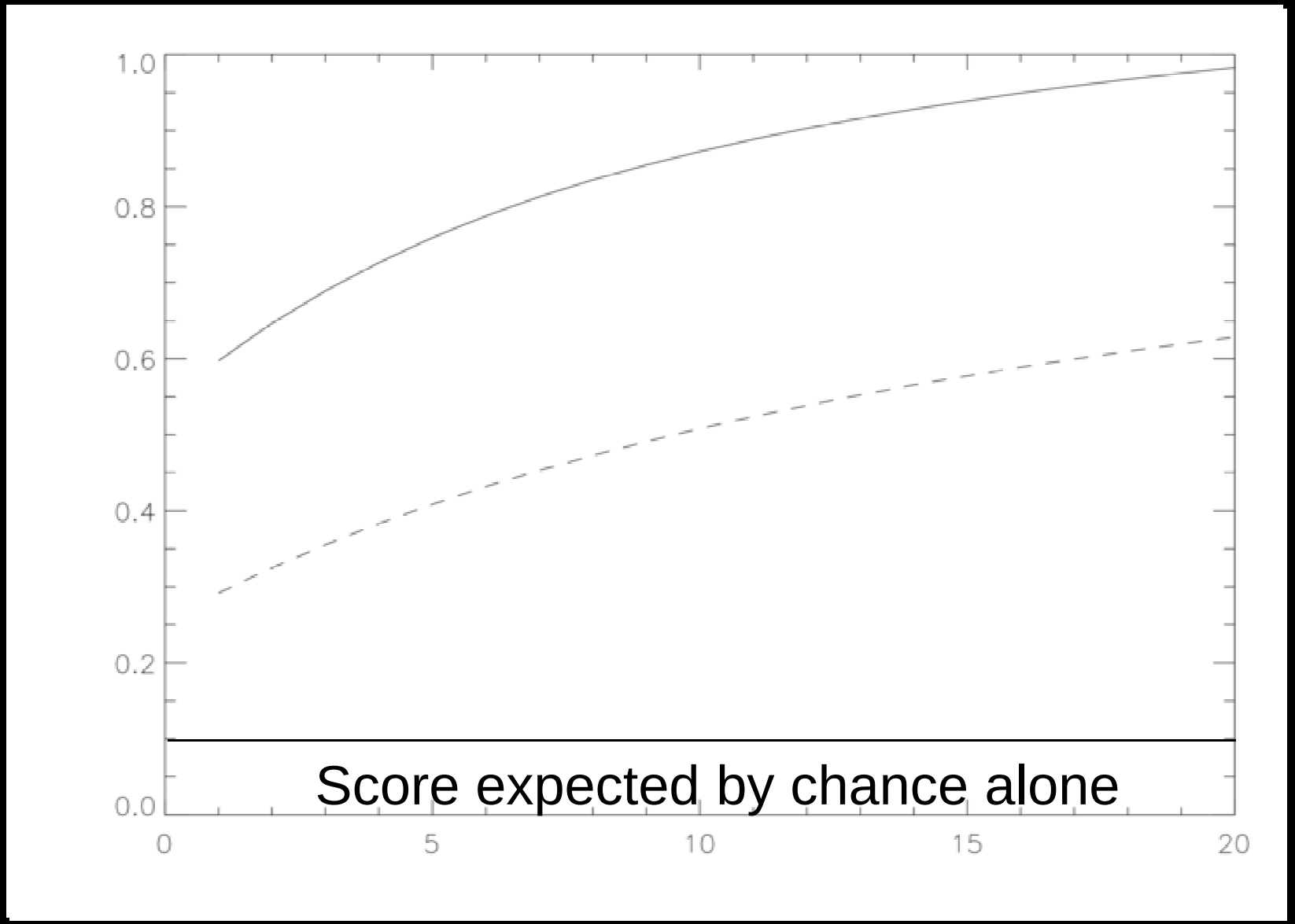
Fraction Skill Score 90th percentile Trial with Poisson thinning at 8 km plotted against timestep (same run)



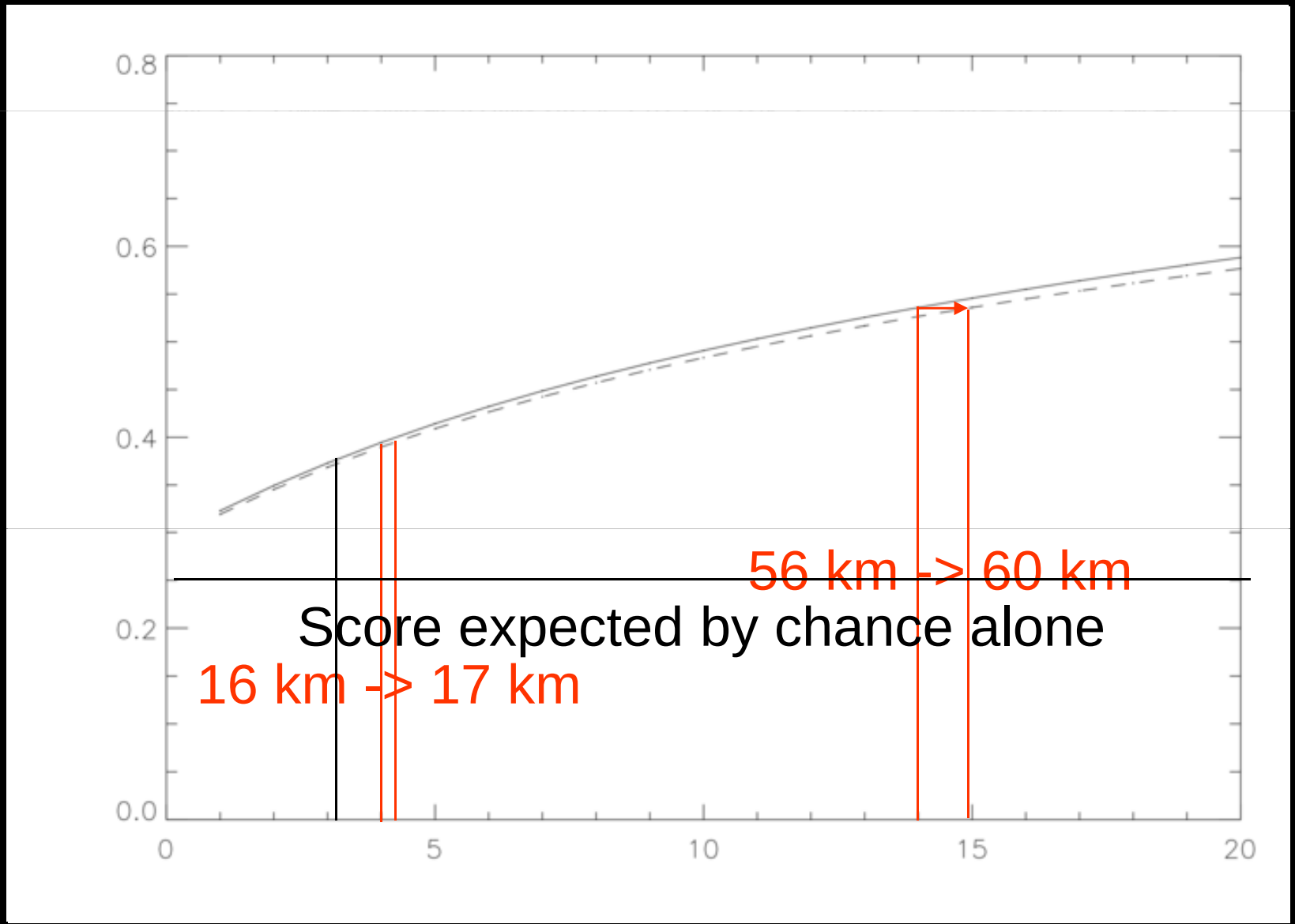
Fraction Skill Score 90th percentile Trial with grid thinning at 4 km plotted against timestep (same run)



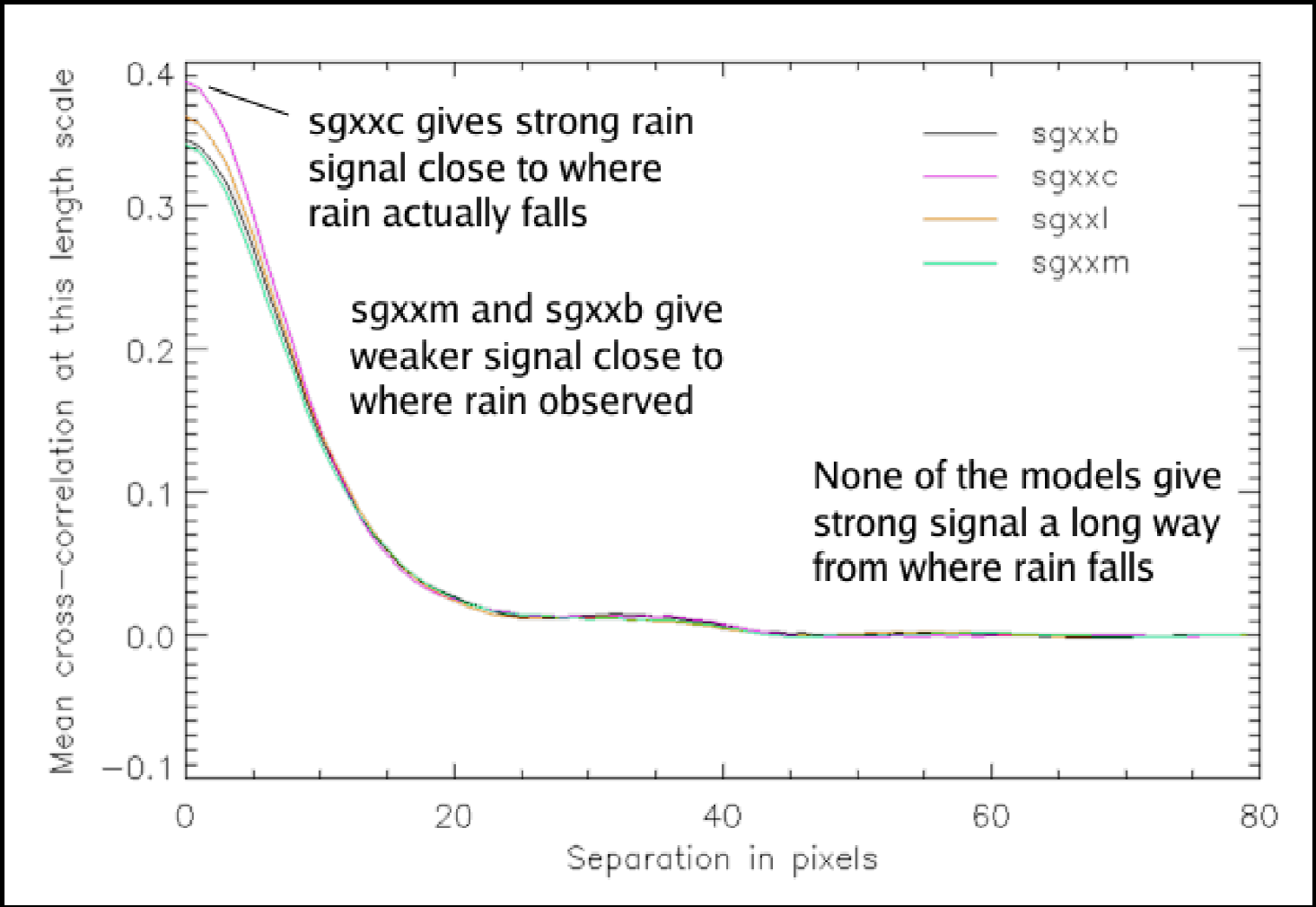
Fraction Skill Score 90th percentile Trial with Poisson thinning at 12 km plotted against scale (average of 5 runs)



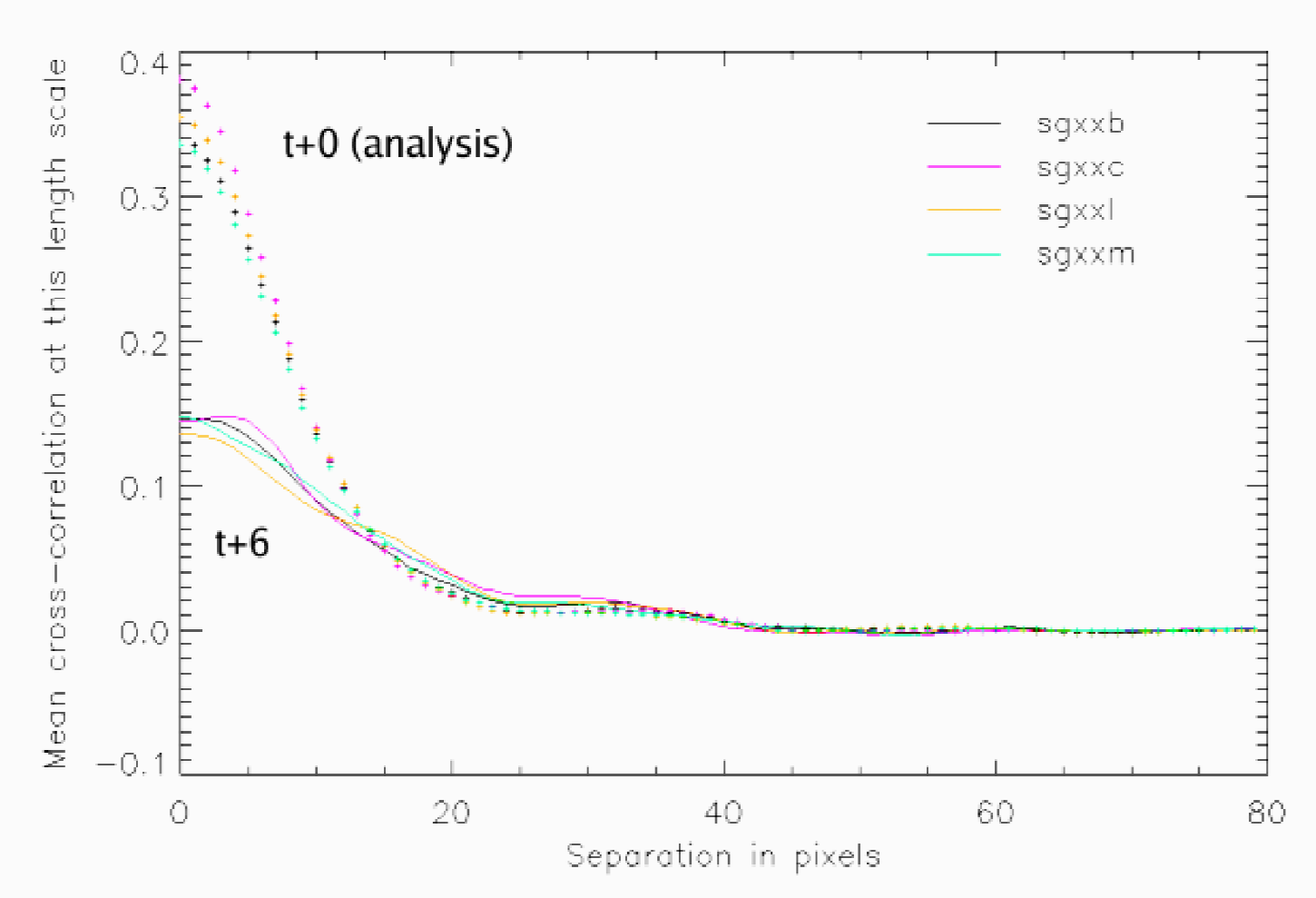
Fraction Skill Score 75th percentile Control and Trial with Poisson thinning at 8 km plotted against scale (1st run, all timesteps)



Cross correlation

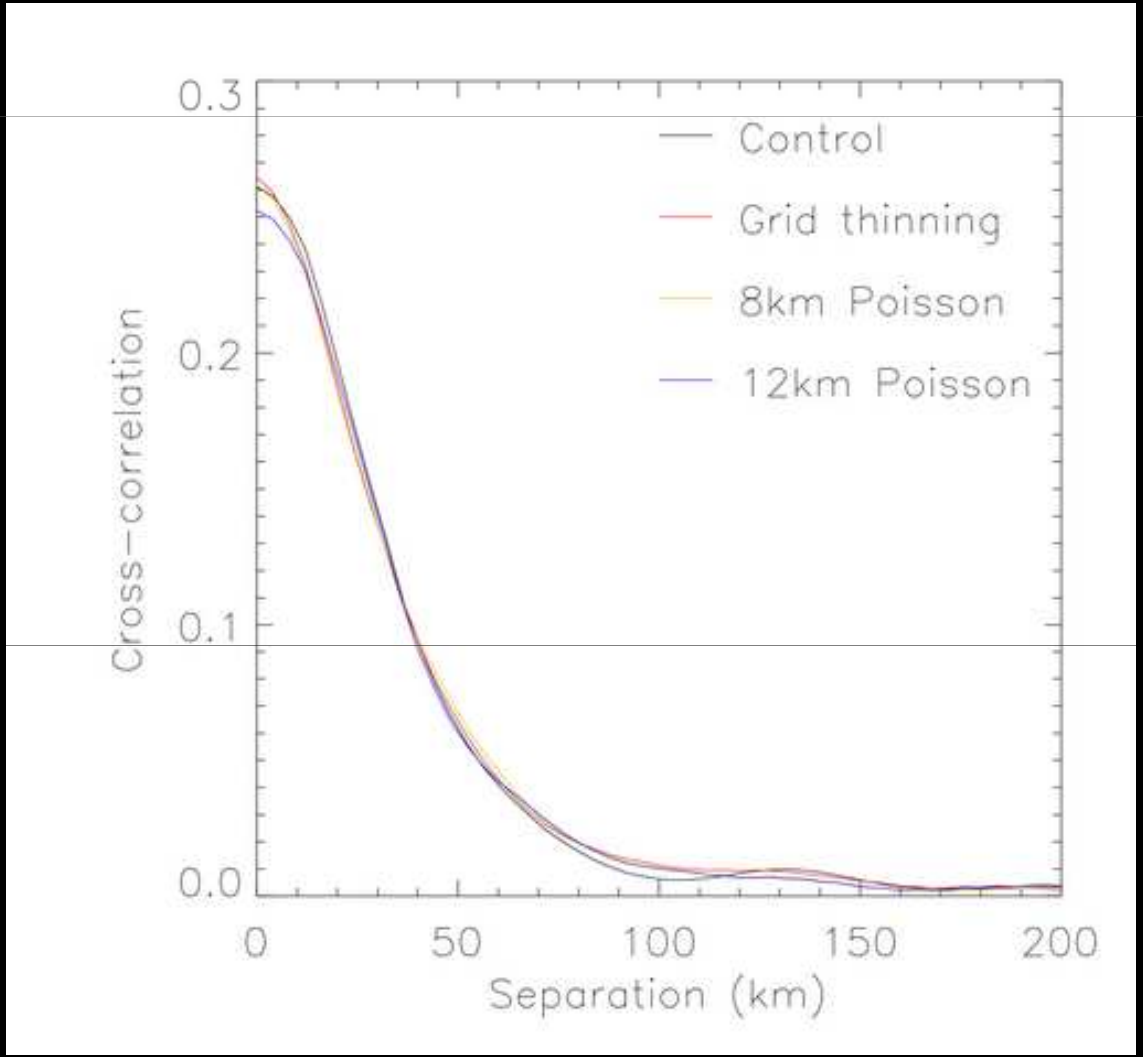


Cross correlation



Cross correlation at T+1

- Shows how likely you are to get rainfall predicted in a pixel at a given separation from an observed rainfall pixel
- Width of the function gives an idea of the useful forecast scale



Width of cross correlation