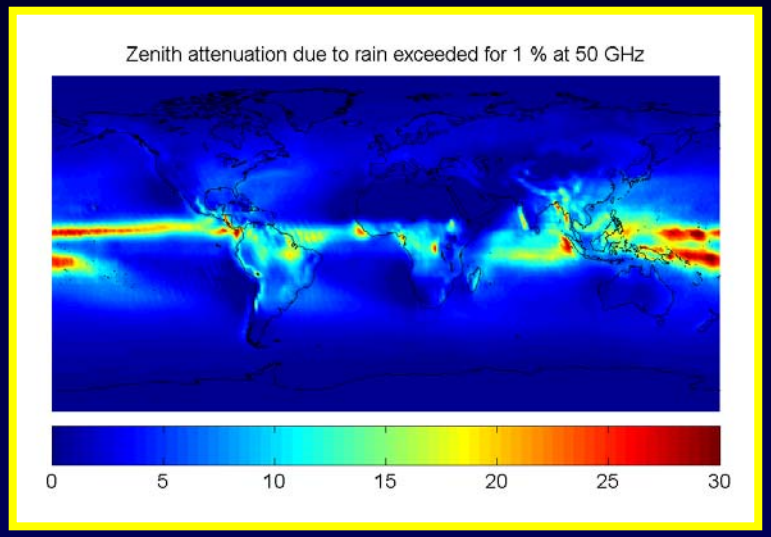
Weather forecasting and fade mitigation

GSAW 2005



Robert J Watson & Duncan D Hodges

r.j.watson@bath.ac.uk & d.d.hodges@bath.ac.uk

Telecommunications, Space and Radio Group

University of Bath

Introduction

- Why bother to forecast propagation conditions …
  - Better performance than "closed-loop" FMT systems?
  - what can *a priori* knowledge of fades do for us?
  - *Proactive* rather than *reactive* fade countermeasures
  - What if the time-of-flight becomes too long?
- Our approach: use meteorological information to determine propagation conditions – can be done in real-time

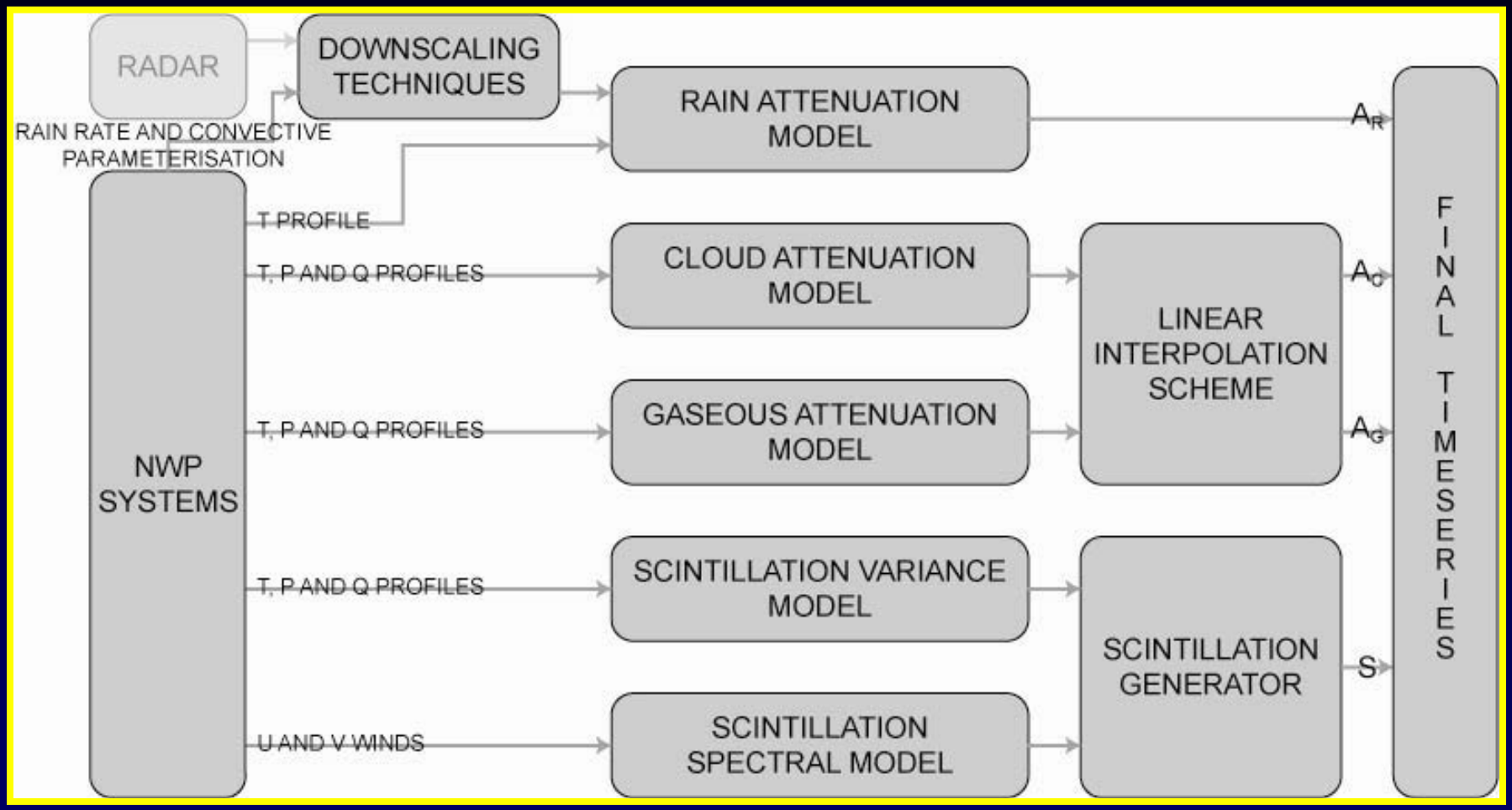
Background to our work

- Fade mitigation technique simulation …
  - Design of FMT systems e.g. power-control, variable rate coding
  - Requirement for synthetic attenuation time-series
- Our approach …
  - recreate the meteorology …
  - …rather than to attempt to model the statistical and dynamic behaviour of attenuation …
  - …and then estimate the resulting propagation conditions

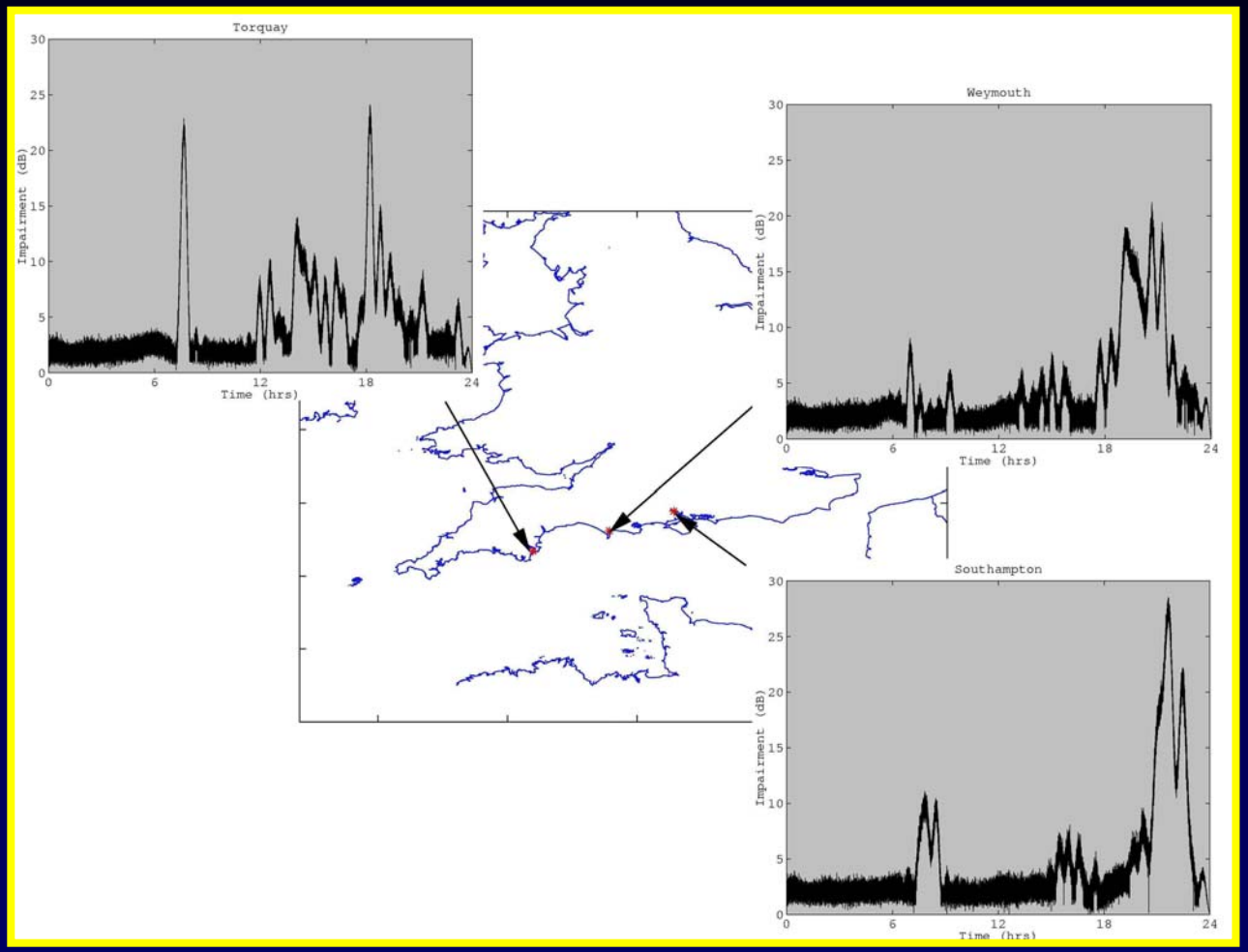
Generation of historical time-series

- Estimate attenuation from combination of
  - archived numerical weather prediction model data (UK Met Office's so-called Unified Model)
  - UK Met Office's weather radar network (15 C-band radars)
- Have the complete "picture" - fade estimates for entire networks that have …
  - correct spatial and temporal statistics (e.g. cdf)
  - correct dynamic characteristics (e.g. fade slope)
  - correct spectral characteristics (e.g. psd)

University of Bath model

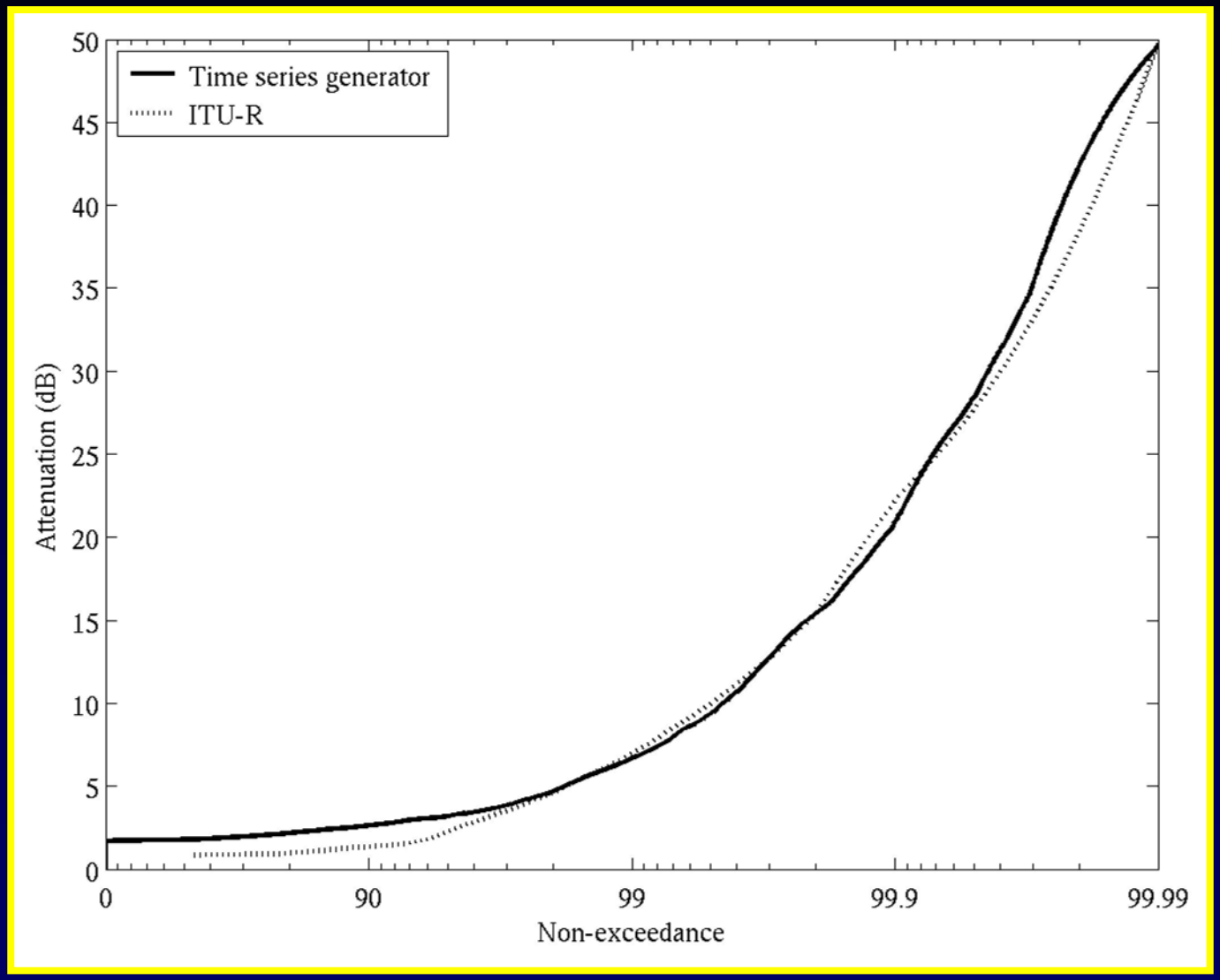


Example time-coincident time series for multiple sites

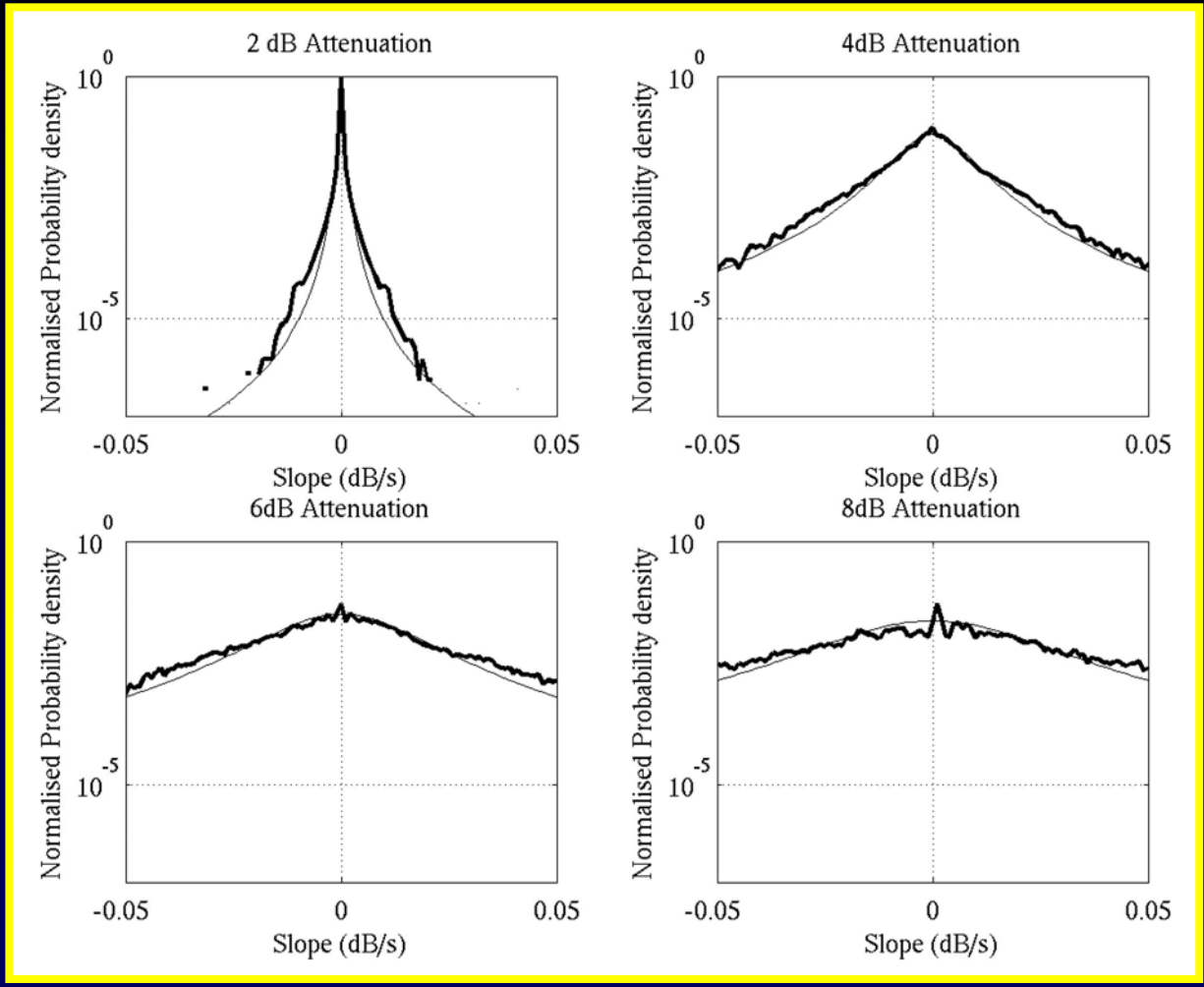


- Data from 22/6/2003
- Fade Level experienced from 50 GHz Downlink
- Geo satellite at 2W

ITU-R verification – Bath, UK 50 GHz



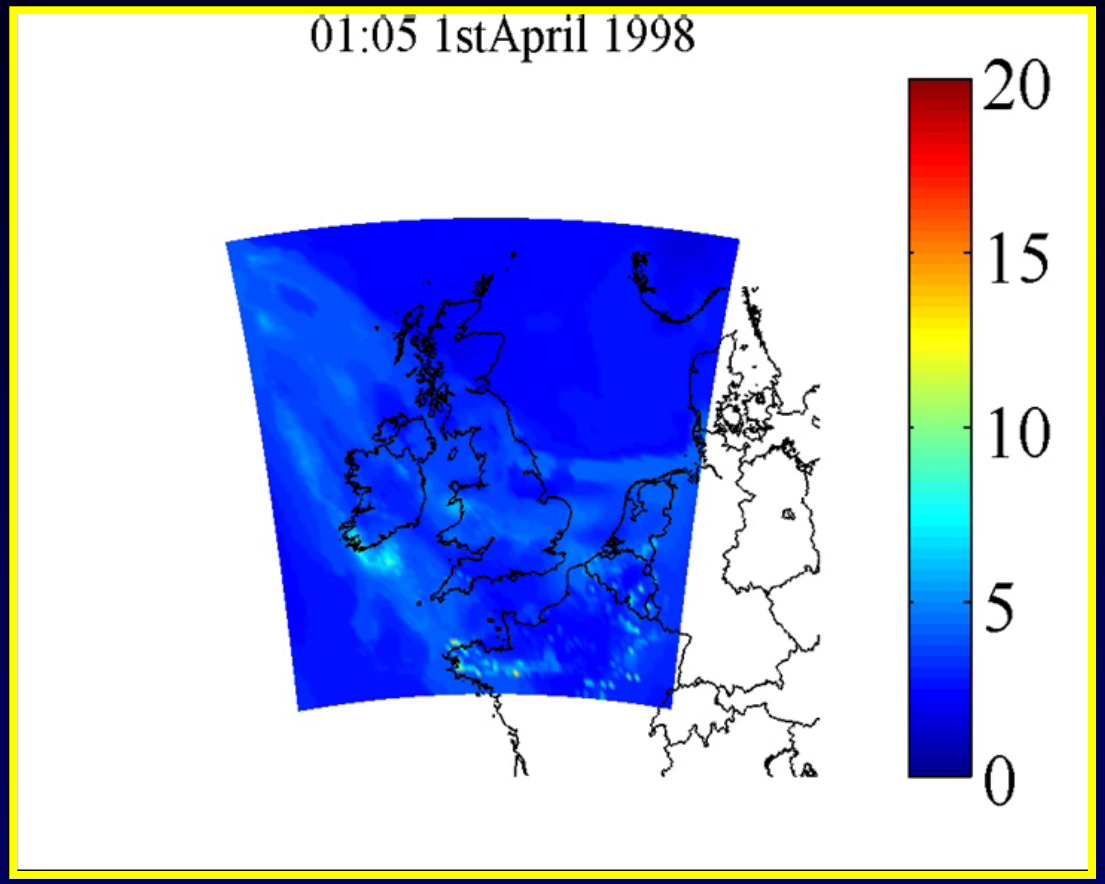
Fade slope



- The thin line represents the VDK theoretical model, the thick line represents the analysis from the output time series.

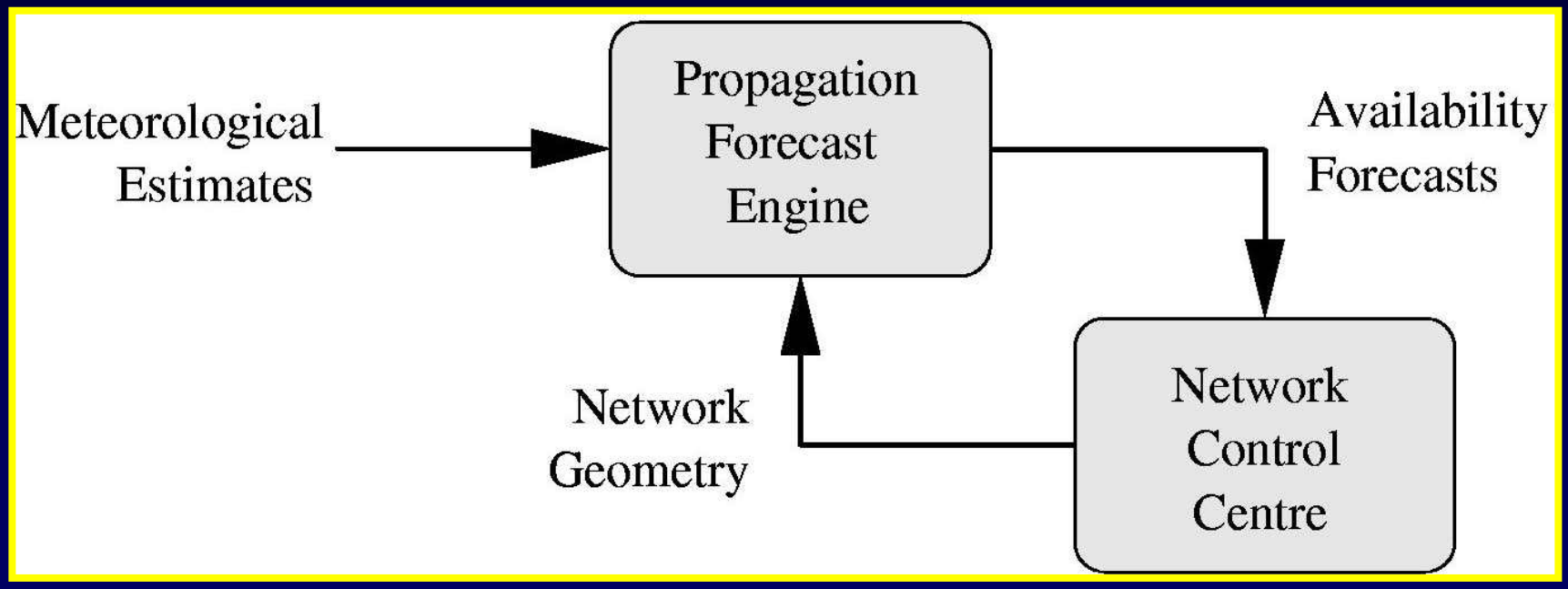
Example model output

- Data from UM (5 minute intervals)
- 1st April 1998
- Fade Level (dB) experienced from 50 GHz Downlink
- Geo satellite at 2W



Forecasting for resource management

- If run in real-time the model can provide forecasts of network availability – can be used for network control
- The components that model stochastic small scale structures are disabled – you can't predict the *actual* scintillation



Advantages of employing forecasting techniques

- Can take time to get accurate signal quality measurements (BER, PER etc), or the coding used may be so strong that the PER dynamic range is insufficient
- Allows “proactive” resource management systems such as time diversity techniques to create service availabilities that exceed link availabilities
- Can be used when time-of-flight is longer than the channel can be considered stationary

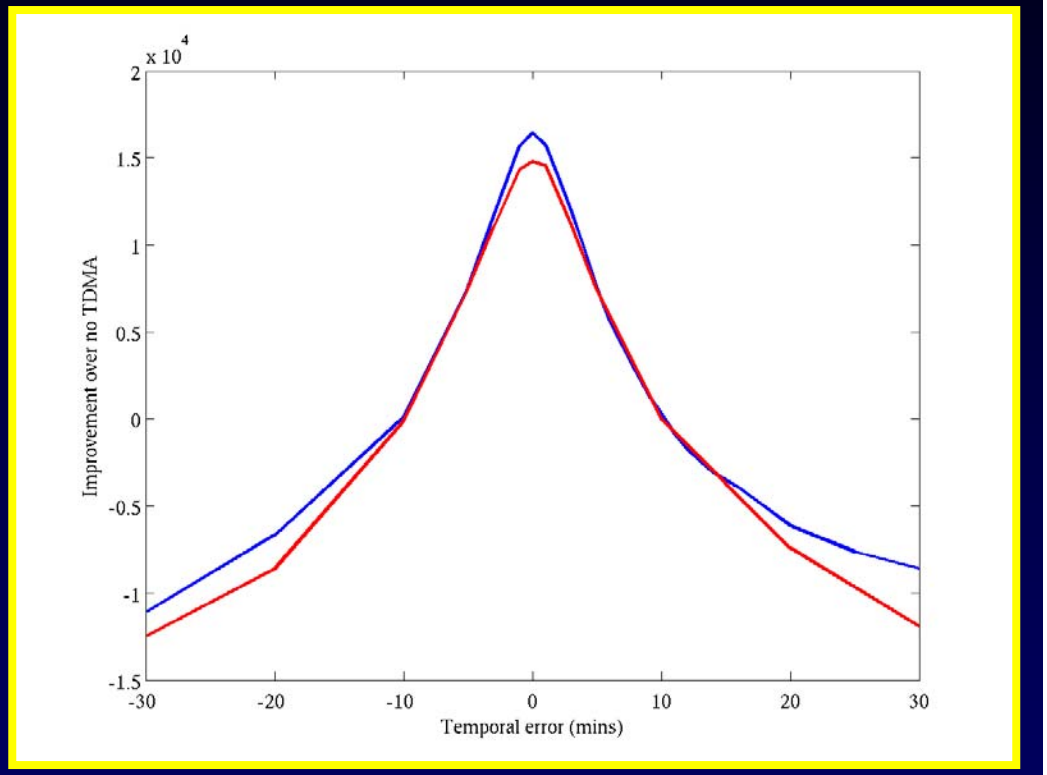
Errors – what if it goes wrong?

- Suppose the forecast is wrong – what effect does that have on the network performance?
  - can we make things worse?

- How can the forecast go wrong?
  - Temporal errors - e.g. a fade is correctly predicted - but occurs earlier/later than forecast
  - Spatial errors - e.g. rain cells occur that the forecast does not predict
  - Fade depth errors - e.g. fade is deeper than predicted – variability in raindrop size distribution

Temporal error results

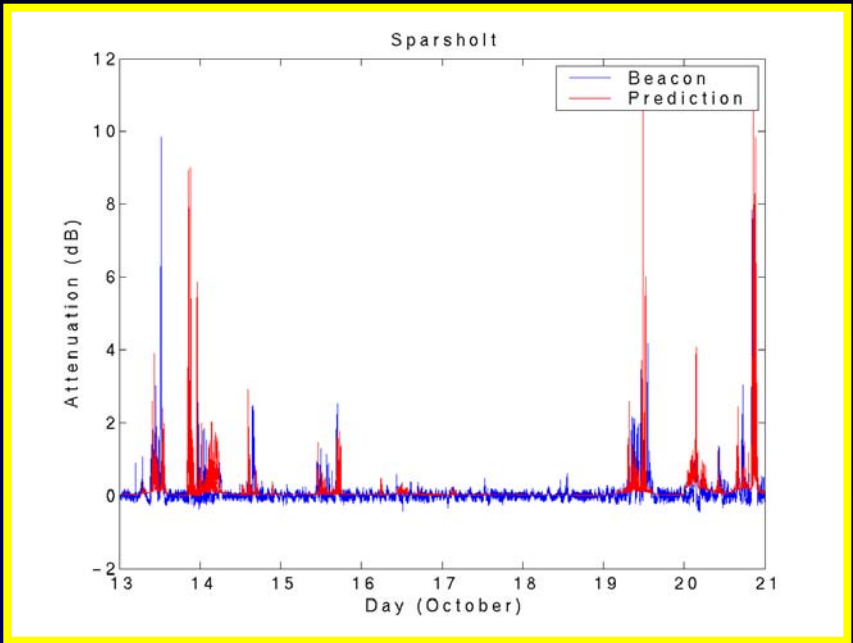
- If we sum all the terminal error performances, we can get a measure of the overall network performance.
- From a network point of view we get an improvement over the temporal error ranges:
  - Terminal set 1:
    - -10.17 to 10.24 mins,
  - Terminal set 2:
    - -9.92 to 10.04 mins.

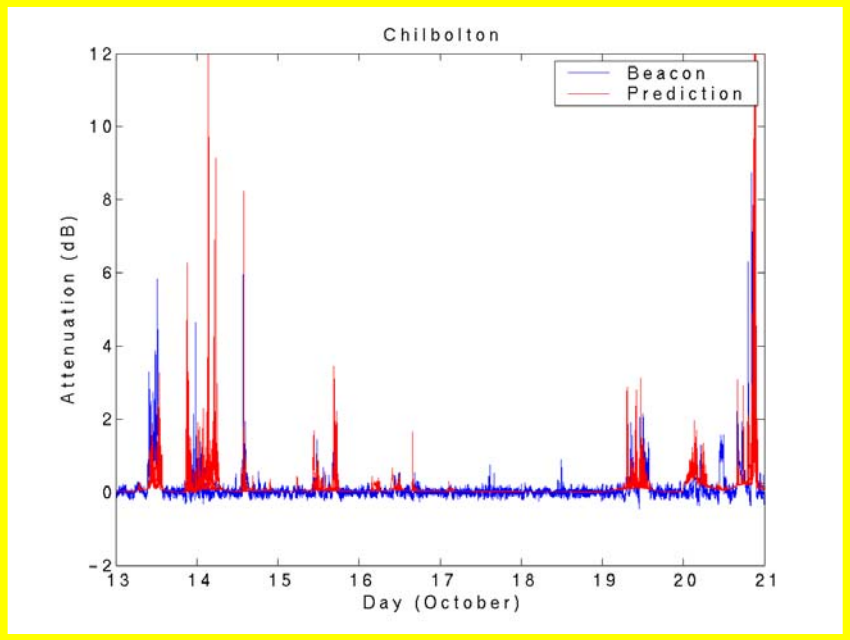


20.7 GHz GBS (23W) Beacon
Chilbolton & Sparsholt

- Currently the only live Ku / Ka / V band beacon measurements in the UK
- US military satellite – ephemeris is not precisely known
- We have taken an example week 13-20th October 2004 of beacon measurements, filtered to remove most of the scintillation component
- The model outputs were taken for a 3x3 0.11 degree grid around the relevant receiver

20.7 GHz GBS (23W) Beacon
Chilbolton & Sparsholt

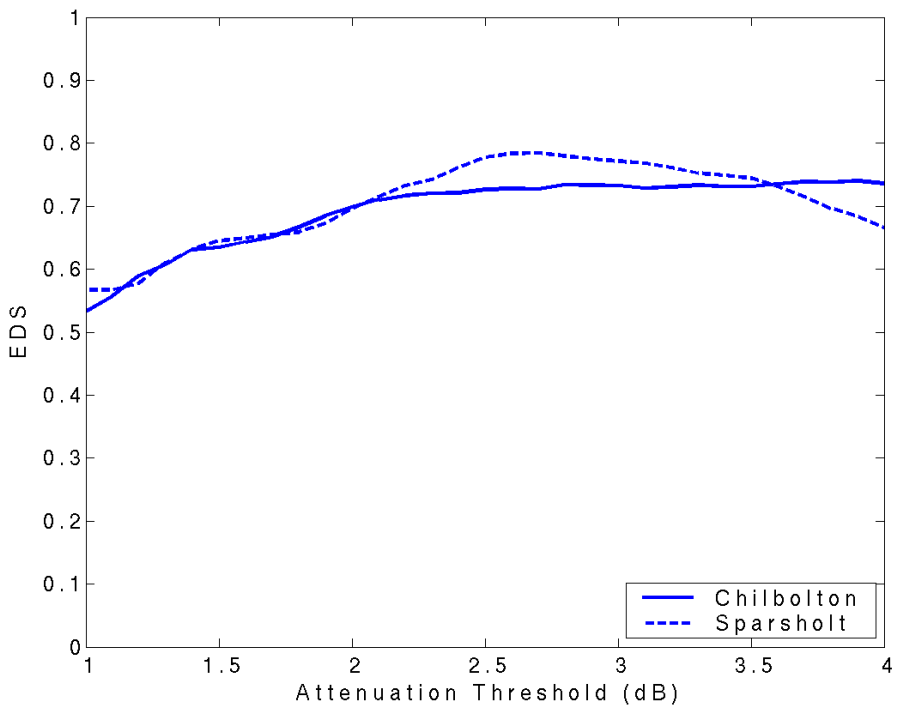




20.7 GHz GBS (23W) Beacon
Chilbolton & Sparsholt

- Simulating operational ‘tactical’ deployment
- Measure the ability to predict an attenuation threshold being exceeded
  - Fade warning or suggested data rate change etc
- Measure forecasting skill as a Extreme Dependency Score (EDS)
  - More appropriate than Equitable Threat Score (ETS) for rare events, EDS is not explicitly dependent on bias or base rate
- Initial investigations showed that the greatest skill was demonstrated with an umbrella point of 1

20.7 GHz GBS (23W) Beacon
Chilbolton & Sparsholt



- Example ETS measures for 24 precipitation forecasts at 10mm/hr threshold - compared to NIMROD radar system:
  - HIRLAM (Finnish Met. Inst.) (22km) 0.45
  - ALADIN (Meteo France) (10km) 0.55
  - Lokal Modell LM (DWD, Germany) (7km) 0.60
  - UM (UK Met Office) (12km) 0.70

The Future

- NWP model development …
  - Smaller grid lengths – improves resolution and accuracy
  - Improvements in the modelling of convection
- UK Met Office has operational European domain model – encompasses all of Europe on a 12 km grid
- Future work …
  - more experimental beacon data – increase confidence
  - does it work for other climate zones – tropical regions?

Acknowledgements

- This work is funded by the UK Engineering and Physical Sciences Research council and (in part) BAE SYSTEMS

- We thank the UK Met Office, the British Atmospheric Data Centre and the Rutherford Appleton Laboratory (GBS beacon data)