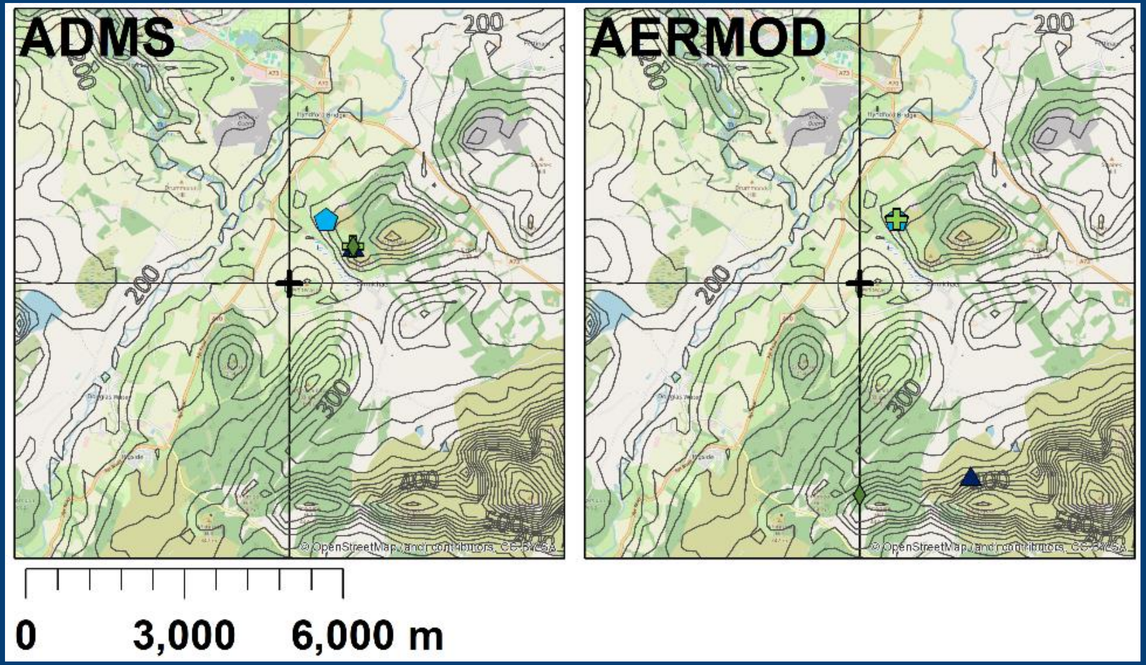
Comparing the influence of input meteorological dataset and local dispersion model choice on regulatory modelling outputs



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10th June 2024, Pärnu

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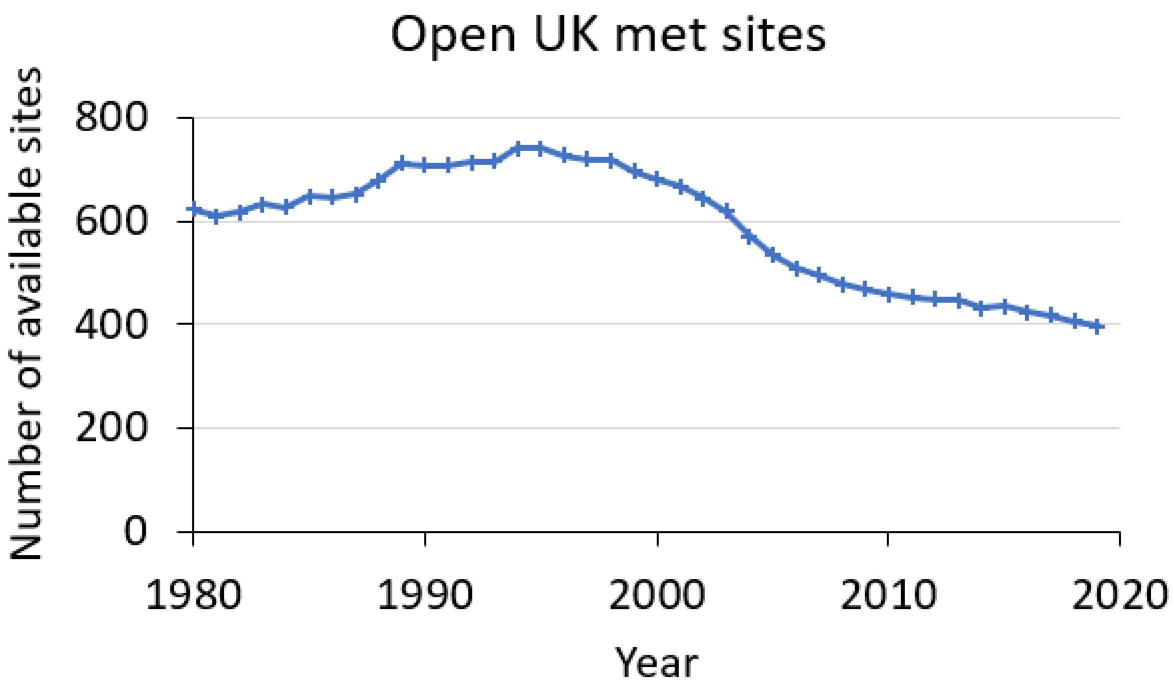
Motivation

- Regulatory dispersion models such as ADMS and AERMOD were originally developed to use observed meteorological (met) data
- Number of UK high-quality met observation sites has reduced over recent decades
- Numerical weather prediction (NWP) model data is increasingly accurate and available to dispersion modellers

➡ What is the influence on regulatory dispersion model outputs of the choice of observed or NWP met data?



Data for number of open UK met observation sites derived from MIDAS Open research archive

http://catalogue.ceda.ac.uk/uuid/dbd451271eb04662beade68da43546e1

Project background

- Project funded by Atmospheric Dispersion Modelling Liaison Committee (ADMLC): ‘Investigating the impact of applying different grid resolutions of Numerical Weather Prediction (NWP) data in atmospheric dispersion modelling’
- Project components:
  - Literature review of NWP models
  - Evaluation of modelled met variables
  - Comparison of secondary met variables
  - **Comparison of local dispersion model outcomes**
  - Investigation of local terrain modelling with NWP inputs
  - Comparison of probabilistic model outcomes (UKHSA)
  - Recommendations
- Full report is available online:

  https://admlc.com/wp-content/uploads/2024/01/d5.2-finalreport-jan2024.pdf

Project team

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Data suppliers

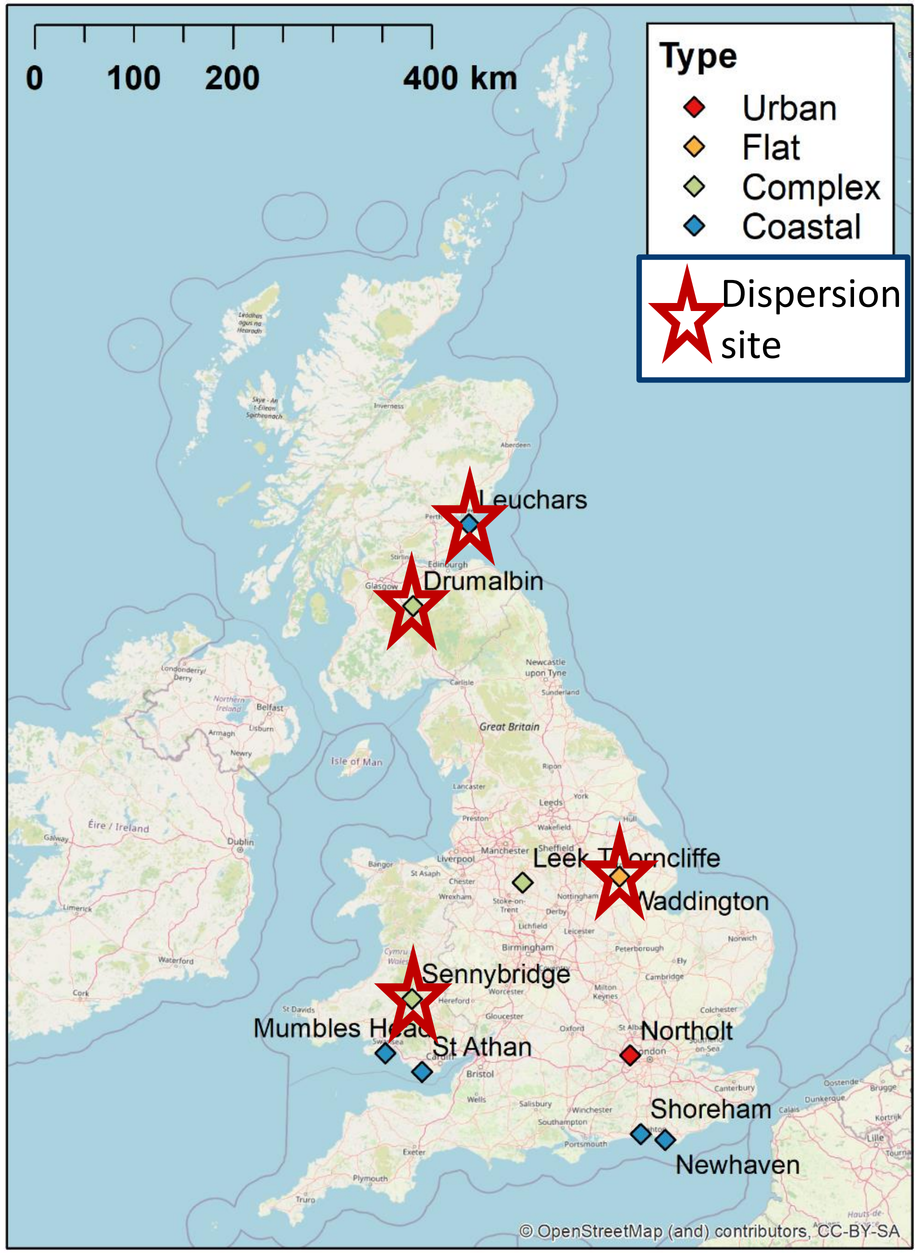
UK Met Office — Met Office

APS — AIR POLLUTION SERVICES

Lakes — Lakes Software

Numerical Weather Prediction (NWP) evaluation

- NWP datasets from
  - Met Office UM – 10 km and 1.5 km grid size
  - APS WRF – 9 km, 3 km and 1 km grid size
  - Lakes WRF – 3 km grid size
- Using measured data from 2019 from 8 sites, evaluation of:
  - Wind speed
  - Wind direction
  - Temperature
  - Cloud cover
  - Precipitation



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NWP evaluation relative to measurement uncertainty

Parameter	Measurement uncertainty	Typical NWP mean bias	Unit
Air temperature	0.2	0.2	K
Wind speed	0.5	0.4	m/s
Wind direction	5	4	°
Cloud cover	2	0.2	Oktas
Precipitation	5	0.01	mm/h

- Typical NWP mean bias ≤ measurement uncertainty for all parameters
- Wider analysis (see full report) showed:
  - Generally good agreement between models and observations for wind speed, direction and temperature
  - More uncertainty in observations and between model and observations for cloud cover and precipitation

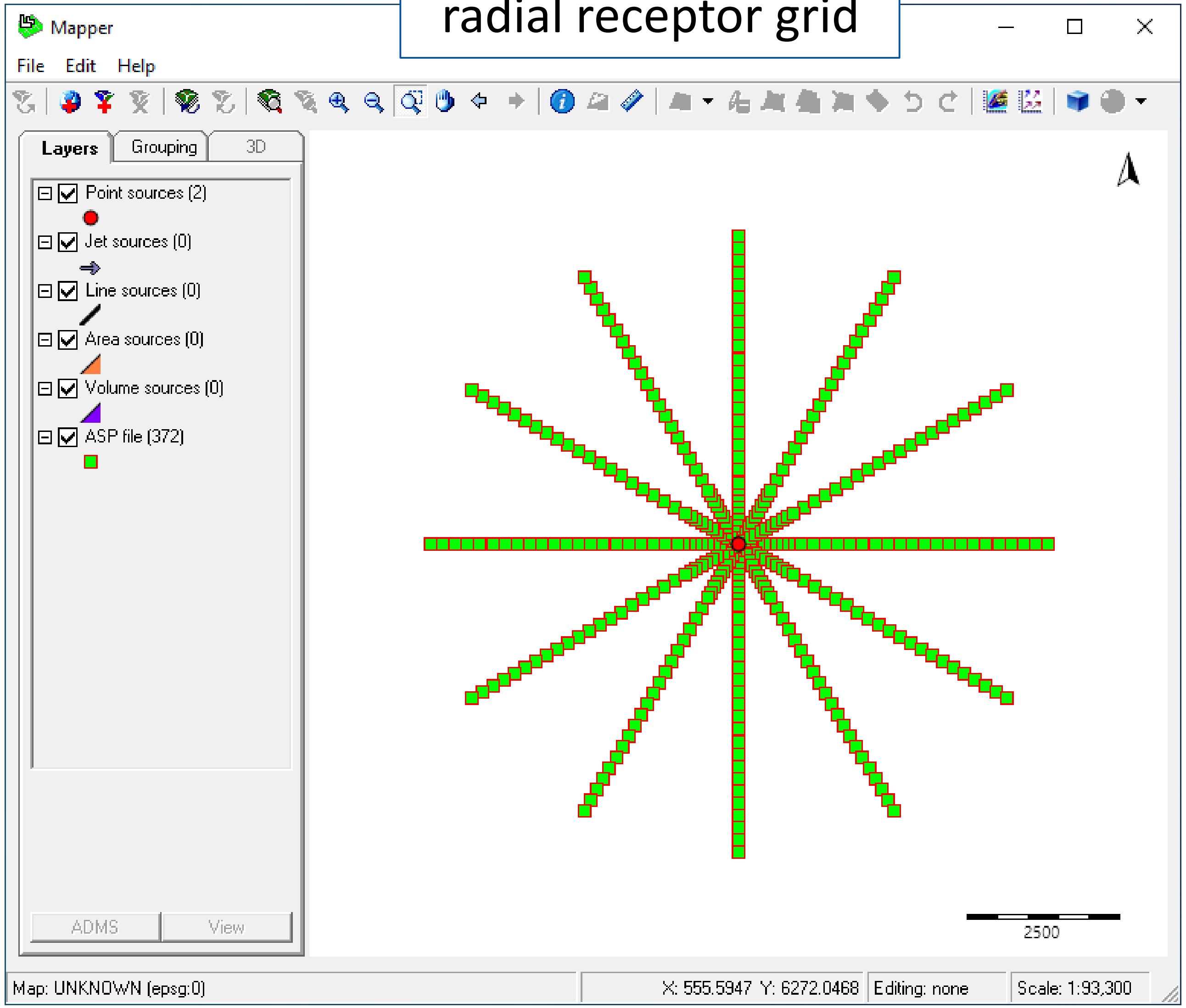
➡ More variation between different NWP models/configurations than due to different model grid resolution for most metrics and sites

Measurement uncertainty values from WMO "Guide to Instruments and Methods of Observation: Volume 1 – Measurement of Meteorological Variables"

Dispersion modelling study

- ADMS and AERMOD annual average and high percentile hourly concentration outputs were generated for:
  - Idealised near-ground or elevated source, 1 g/s emission rate
  - 4 locations: Waddington (flat), Leuchars (coastal), Sennybridge (complex) and Drumalbin (complex)
  - Met datasets
    - Observed
    - Met Office (MO) Unified Model (UM) 10 km and 1.5 km
    - Air Pollution Services (APS) Weather Research and Forecasting (WRF) 9 km and 1 km
  - Outputs on radial grids of receptors, 30 degree sectors

Dispersion modelling radial receptor grid



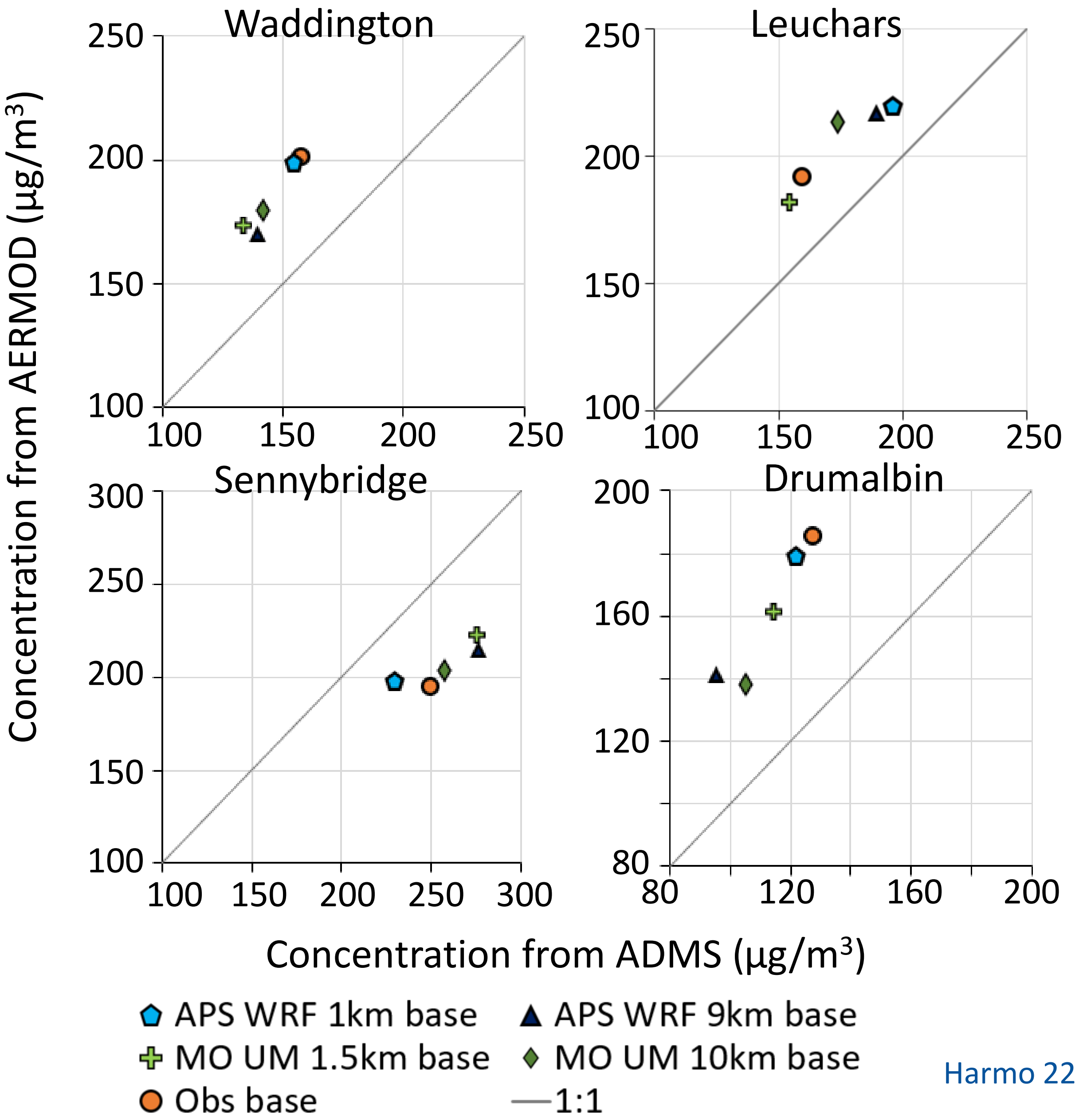
Dispersion modelling study

- Focus on overall maximum value and location for each output metric
  - Annual average, 98th percentile hourly and maximum hourly concentration
  - Annual average wet deposition (proportional to deposited mass): ADMS only

- **Key questions**:
  - What is the sensitivity of dispersion model outputs to choices of observed or NWP met data?
  - What is the importance of NWP model grid resolution for dispersion modelling?
  - How does the sensitivity to met data compare to the difference between ADMS and AERMOD with observed data?

Dispersion modelling: annual average, near-ground source

- Maximum **value** of annual average concentration from **near-ground source**
- More difference between ADMS and AERMOD with observed met than due to different base NWP met datasets input to the same model in most cases
- AERMOD predicts higher concentrations than ADMS at all sites except Sennybridge
- Relatively small differences due to NWP resolution alone
- **Location** of maximum annual average concentration from **near-ground source** consistent across all datasets



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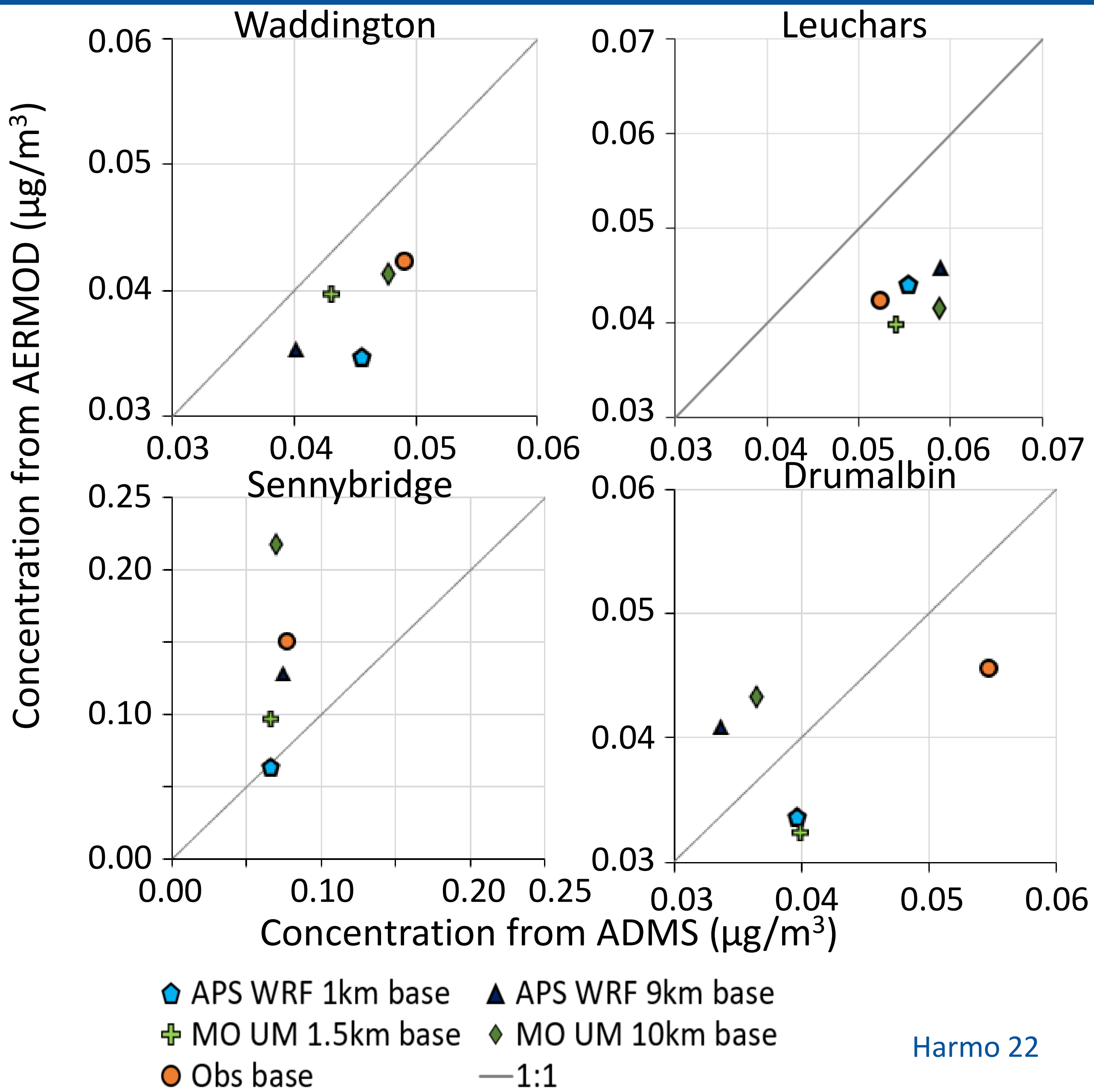
Dispersion modelling: annual average, elevated source

- Maximum **value** of annual average concentration from **elevated source**
- More variation due to different met datasets than local model at all sites except Sennybridge
- AERMOD predicts generally lower concentrations than ADMS at all sites except Sennybridge – opposite pattern from near-ground sources
- No consistent pattern of influence from NWP resolution
- Sennybridge and Drumalbin show variation of terrain modelling between ADMS and AERMOD – also clear in locations (next slide)



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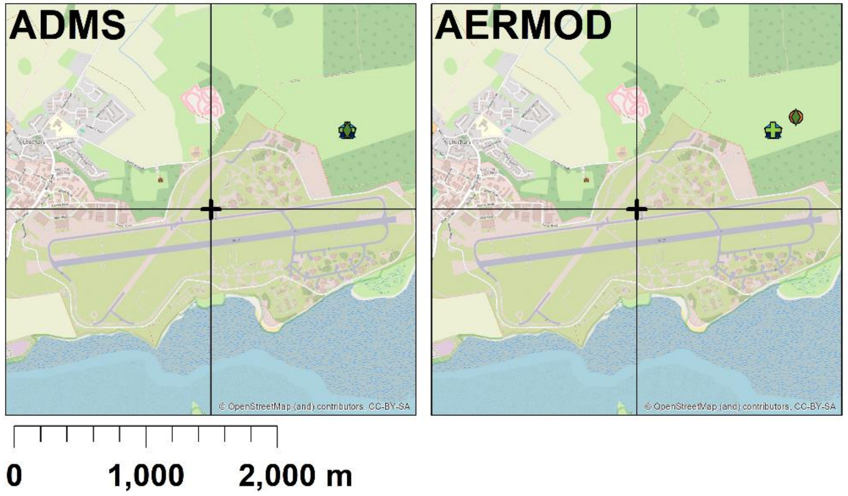
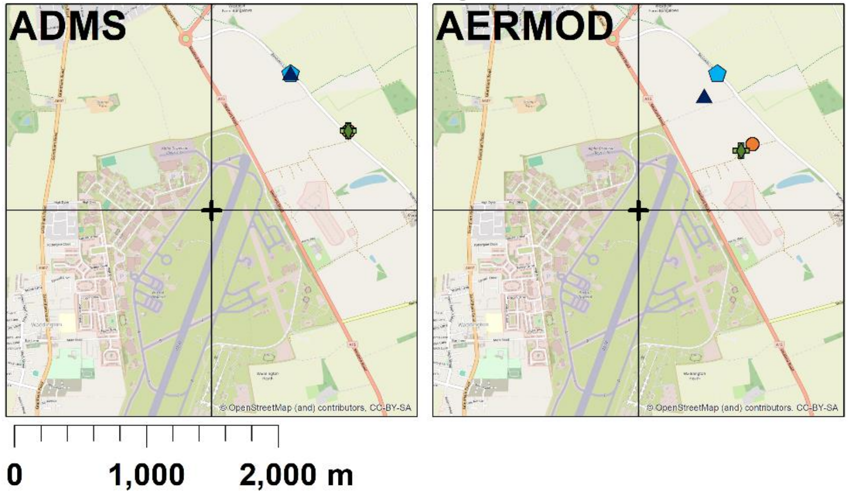
Dispersion modelling: annual average, elevated source

- **Location** of maximum annual average concentration from **elevated** source
- Broadly consistent location predictions for flat terrain: points overlay on maps
- Significant differences in complex terrain:
  - Fairly consistent locations from ADMS
  - Inconsistent locations from AERMOD: maximum annual average concentration predicted 4–5 km downstream for some met datasets: modelled plume centreline impacting on terrain (unphysical)

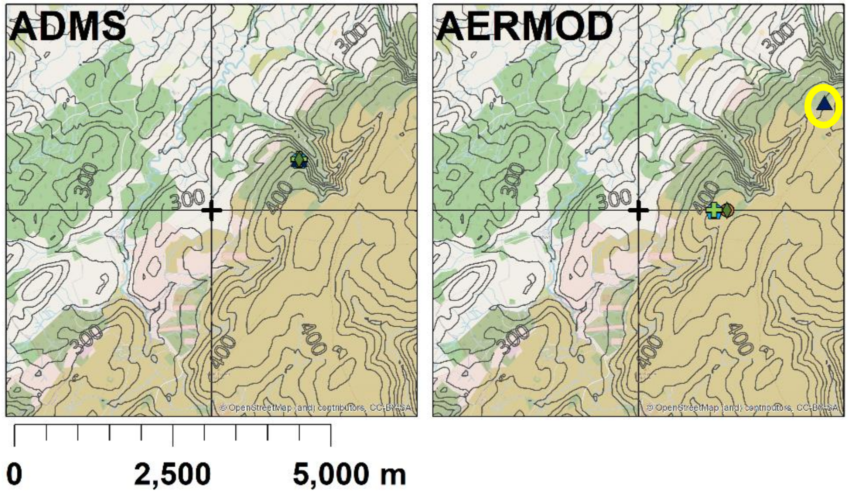
Leuchars



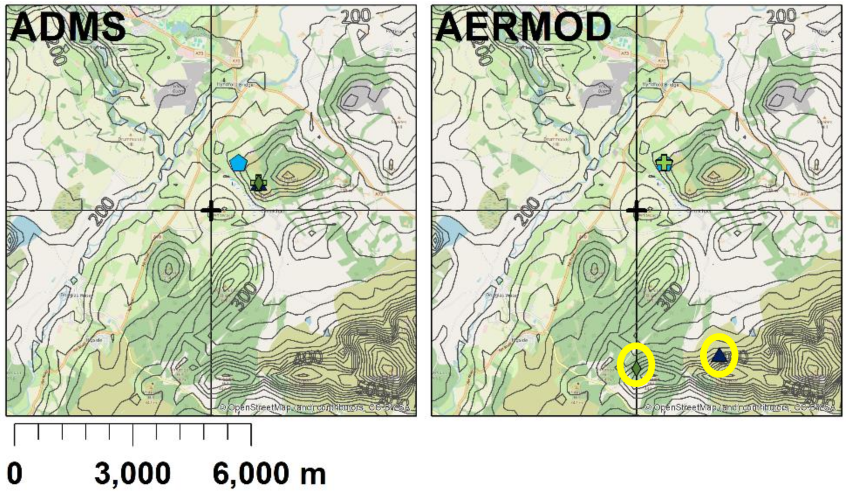
Waddington



Sennybridge



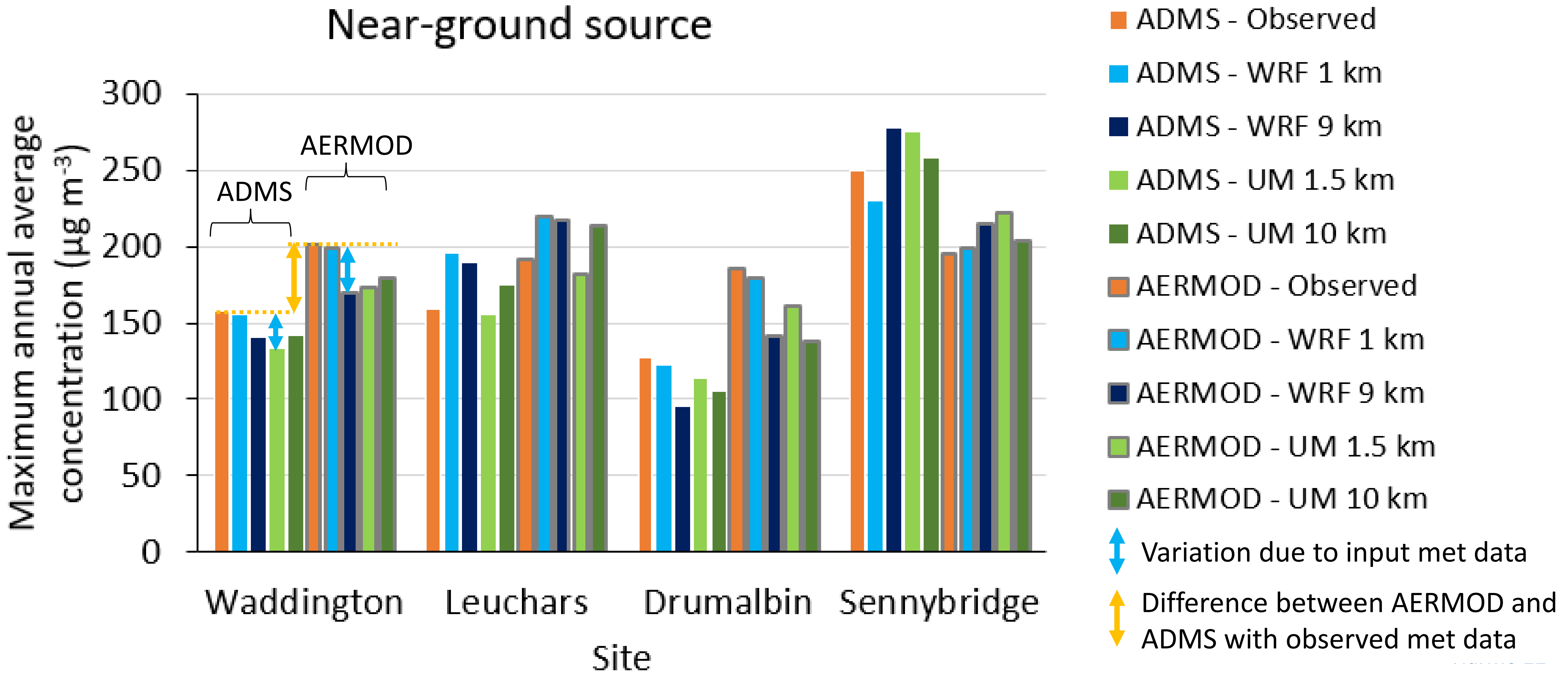
Drumalbin



APS WRF 1km base | APS WRF 9km base | Obs base
MO UM 1.5km base | MO UM 10km base | Source

Dispersion modelling: sensitivity

- Compare range of values with observed or NWP met ( ) to corresponding value with observed met
- Compare ADMS and AERMOD values with observed met ( )



Dispersion modelling: summary

Source type	Site type	ADMS 6 sensitivity			AERMOD 22112 sensitivity		
		AAve	P98	P100	AAve	P98	P100
Near-ground	Flat terrain	Low	Low	Medium	Low	Low	Low
	Coastal	Medium	Low	Medium	Medium	Low	Medium
	Complex terrain	Medium	Medium	Low	Medium	Low	High
Elevated	Flat terrain	Low	Low	Medium	Low	Low	Very high
	Coastal	Low	Medium	High	Low	Medium	High
	Complex terrain	Medium	Low	Medium	Very high	High	Medium

- Sensitivity of model outputs to choice of **input met dataset**
  - Based on range of outputs with observed and base NWP datasets (↕) normalised by value with observed met (▮)
  - Categories: **Low** < 0.2; **Medium** 0.2 – 0.4; **High** 0.4 – 1.0; **Very high** > 1.0
  - Low sensitivity for annual averages, flat terrain
  - Higher sensitivities for higher percentile outputs (P98, P100), complex terrain

⇒ Likely to lead to higher uncertainties in these outputs

Dispersion modelling: summary

Source type	Site type	AERMOD - ADMS sensitivity		
		AAve	P98	P100
Near-ground	Flat terrain	Medium	Medium	High
	Coastal	Low	Medium	High
	Complex terrain	Medium	Medium	Very high
Elevated	Flat terrain	Low	Low	High
	Coastal	Medium	Low	High
	Complex terrain	High	High	Very high

Relevant ADMS – AERMOD model differences

- Plume rise algorithm and/or plume spread parameters
- Dispersion in complex terrain
  - ADMS flowfield model (FLOWSTAR)
  - AERMOD combination of terrain-following and terrain-impacting solutions

- Sensitivity of model outputs to choice of **local model**
  - Based on ratio (AERMOD - ADMS)/(0.5(ADMS + AERMOD)), maximum across the two complex terrain sites
  - Categories: **Low** < 0.2; **Medium** 0.2 – 0.4; **High** 0.4 – 1.0; **Very high** > 1.0

➡ Sensitivity to local model choice similar to or greater than sensitivity to met dataset

Project recommendations

- High quality NWP data at horizontal resolutions of 1 – 9 km and hourly temporal resolution can be an adequate substitute for observed meteorological data for use in regulatory dispersion modelling, where locally representative observed data are not available
- Providers of modelled met data should provide supporting information about model configuration and evaluation
- Only use 'base' input variables when using NWP for ADMS: wind speed and direction, temperature, cloud cover, precipitation
- When using FLOWSTAR complex terrain modelling in ADMS, choose NWP data resolution similar to domain size where possible
- Consider using spatially-averaged fine resolution NWP data for larger domains (~10 km)
- Further investigation needed for very large domains (> 50 km) which may require spatially-varying meteorology: possible extension of Multi-model Air Quality System (MAQS) coupled system approach

Choosing met data for modelling

- Are locally representative observed data available with good data quality?
- What is the size of the modelling domain?
  - Single or multiple sources?
  - Near-ground or elevated source(s)?
- How complex is the local terrain?
- What is the acceptable uncertainty in magnitude and/or location of high concentrations?

Modelling domain length scale	Example modelling scenario and met options

1 km	• Single near-ground source
	  • Local observations
	  • Fine-resolution NWP

10 km	• Single elevated source, group of near-ground sources
	  • Local observations (not affected by complex terrain)
	  • Spatially averaged fine resolution NWP or coarser resolution NWP for sources in complex terrain

> 50 km	• Multiple sites with elevated sources • Spatially-varying meteorology

Discussion

Thank you for your attention!

Any remaining questions?

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Project partners: UKHSA

https://admlc.com/wp-content/uploads/2024/01/d5.2-finalreport-jan2024.pdf