Assessing the impact of cold plumes from air source heat pumps

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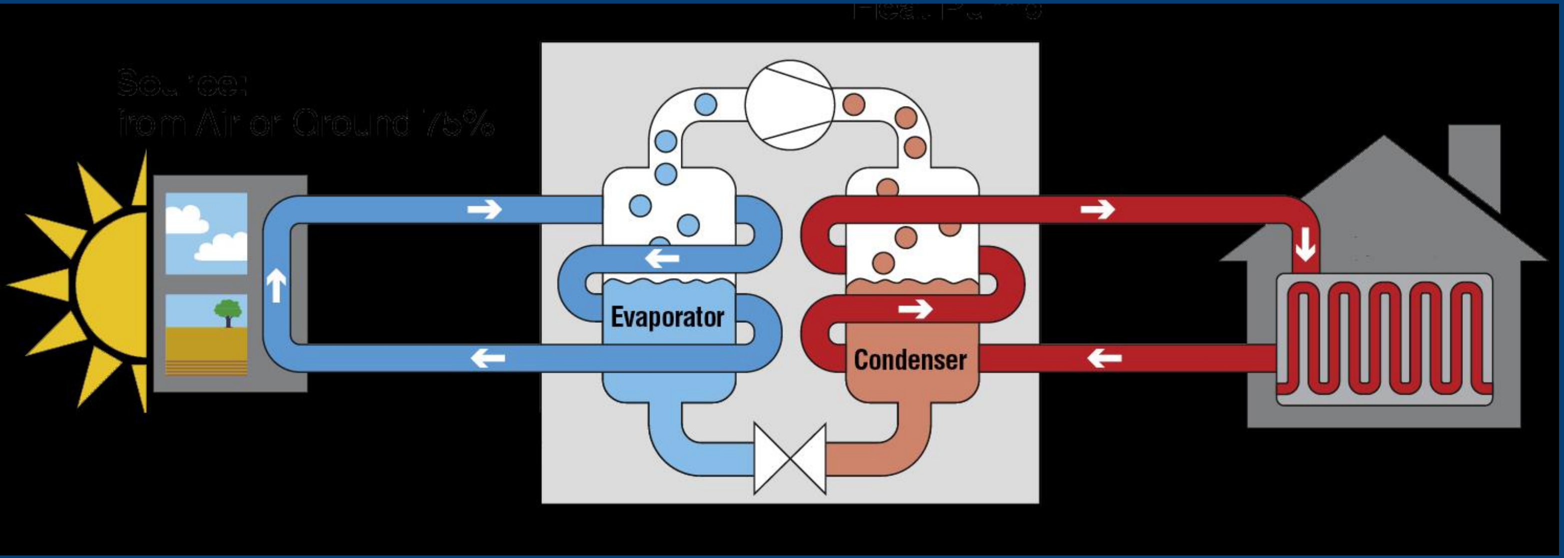

ADMS User Group Meeting

18-19 November 2020

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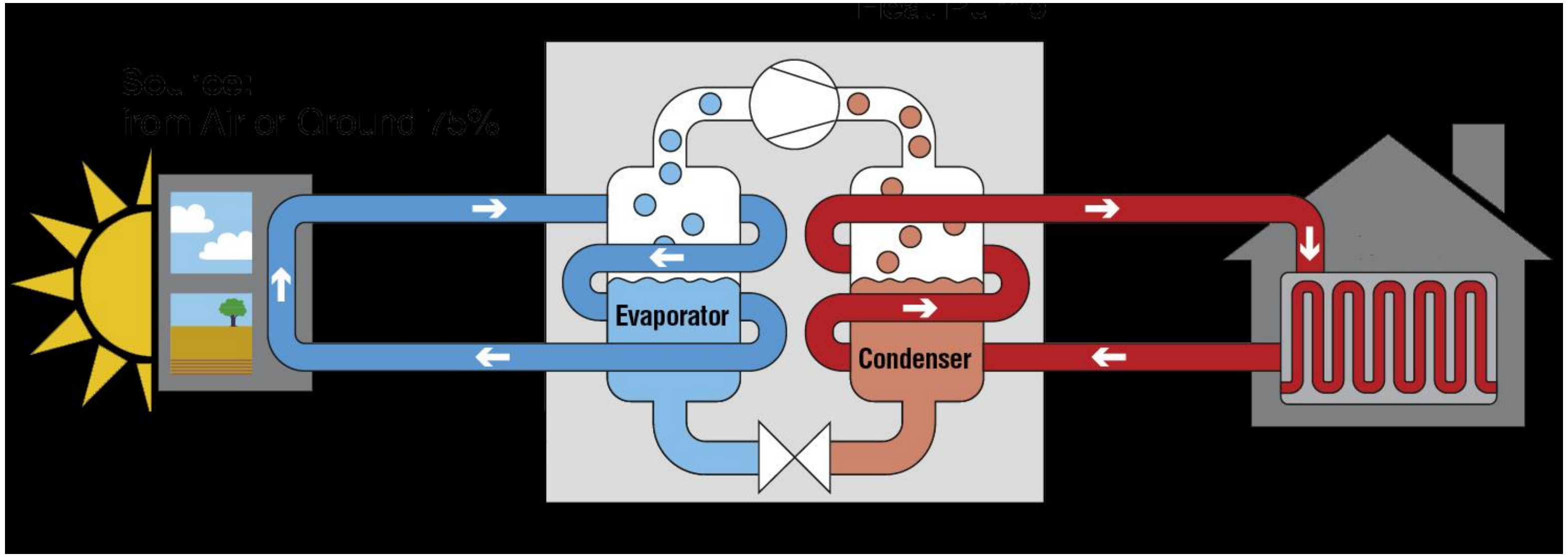
Introduction

CERC was approached to model the impact of plumes of cold air from an array of air source heat pumps

- Energy Centre for district heating scheme
- Concern regarding potential impact of cold air
  - on surrounding vegetation?
  - on railway tracks?
- Emitted air ~4 °C colder than ambient
- Dense plume compared to ambient air: use GASTAR?

How does an Air Source Heat Pump (ASHP) work?

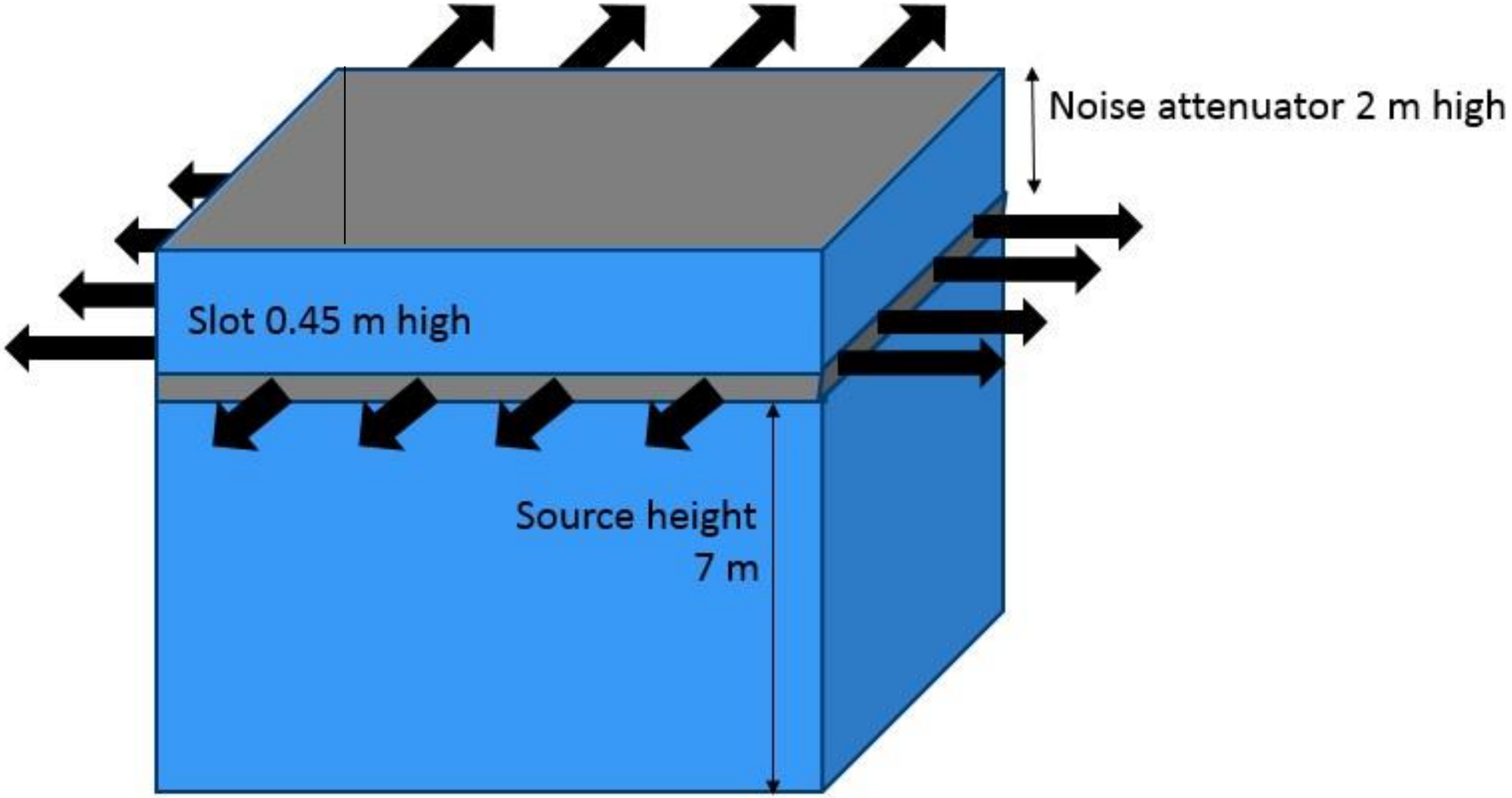
- An ASHP works like a refrigerator in reverse. It consists of an evaporator, a compressor and a condenser.
- Heat from the ambient air, drawn in by a fan, is absorbed into a fluid at low temperature.
- The compressor increases the temperature of the fluid and transfers that heat to the building.



Air Source Heat Pump configuration

- 16 unit air source heat pump (ASHP) array
- One unit emits 30 kg/s (25 m^3/s) of cold air ~4 °C below ambient
- Located on 7 m high building, dimensions 18 m by 17 m
- Noise attenuation screen extends a further 2 m upwards
- Cold air emitted via horizontal slot, vertical dimension 0.45 m, at height of 7 m, along all four sides
- Cold air emitted over total area 31.5 m^2

Schematic of ASHP configuration



Model set-up

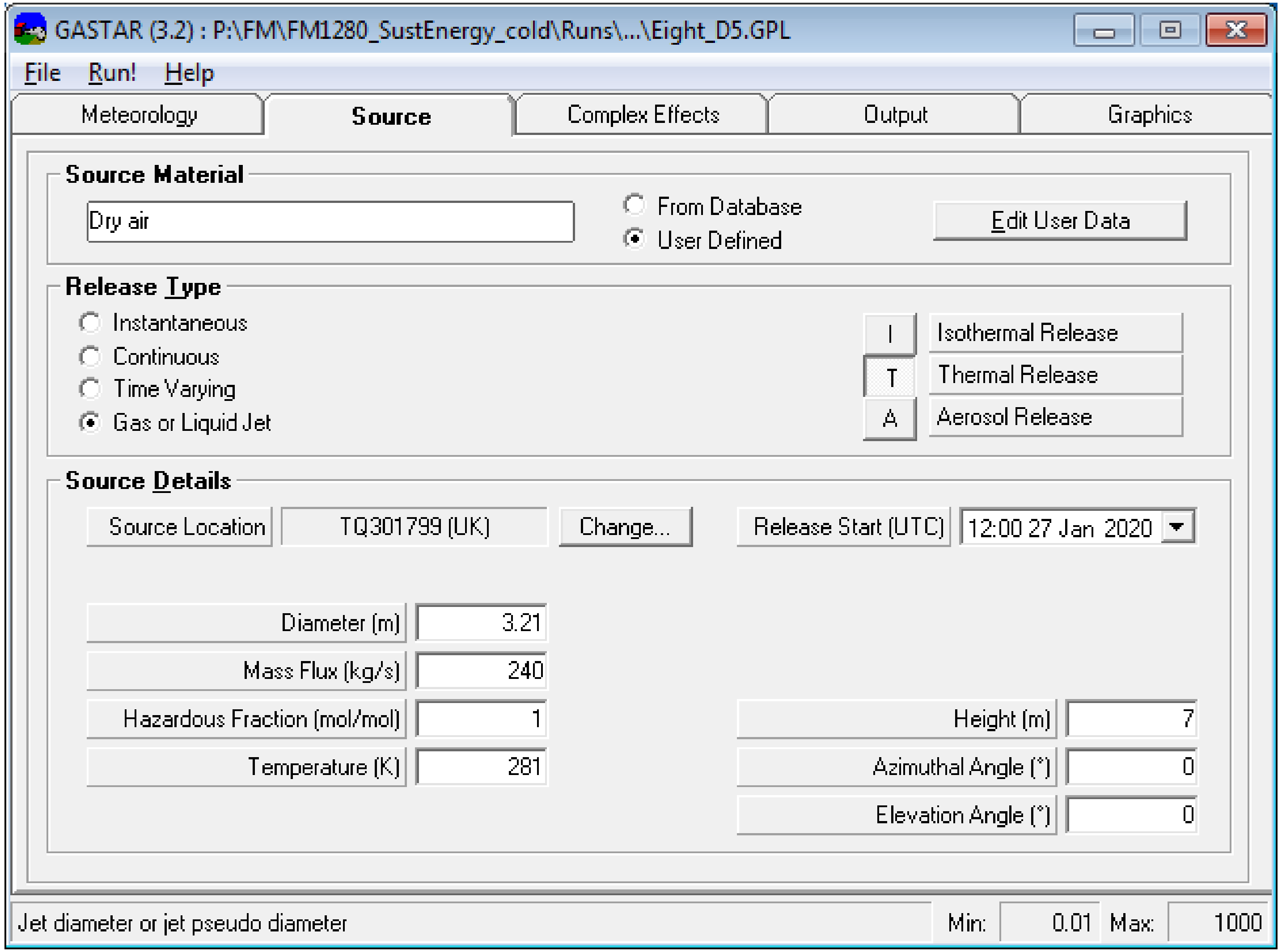
- Modelled as a horizontal jet in both ADMS 5 and GASTAR
- Modelled emissions from one side of the building only
- Single jet modelled to represent a single unit / combined emissions along the whole of one side, because:
  - Multiple plumes in ADMS 5 don't interact
  - GASTAR can only model a single source
- Total area of aperture was used to determine representative source diameter and efflux velocity
- Assumed ambient temperature 12 °C, plume temperature 8 °C

Model set-up for ADMS 5

- Building effects cannot be modelled with jets
  - Considered relatively unimportant due to high horizontal momentum: 12.7 m/s
  - See CERC's ADMLC report on non-point sources https://admlc.files.wordpress.com/2014/05/fm1019_cerc_admlc_final_mar16.pdf
- Included .aai file to request temperature output
  - 'Short term temperature output for downstream jets'

Model set-up for GASTAR

- Mass flow (not volume flow) specified
- User defined source material ‘dry air’



Meteorological inputs

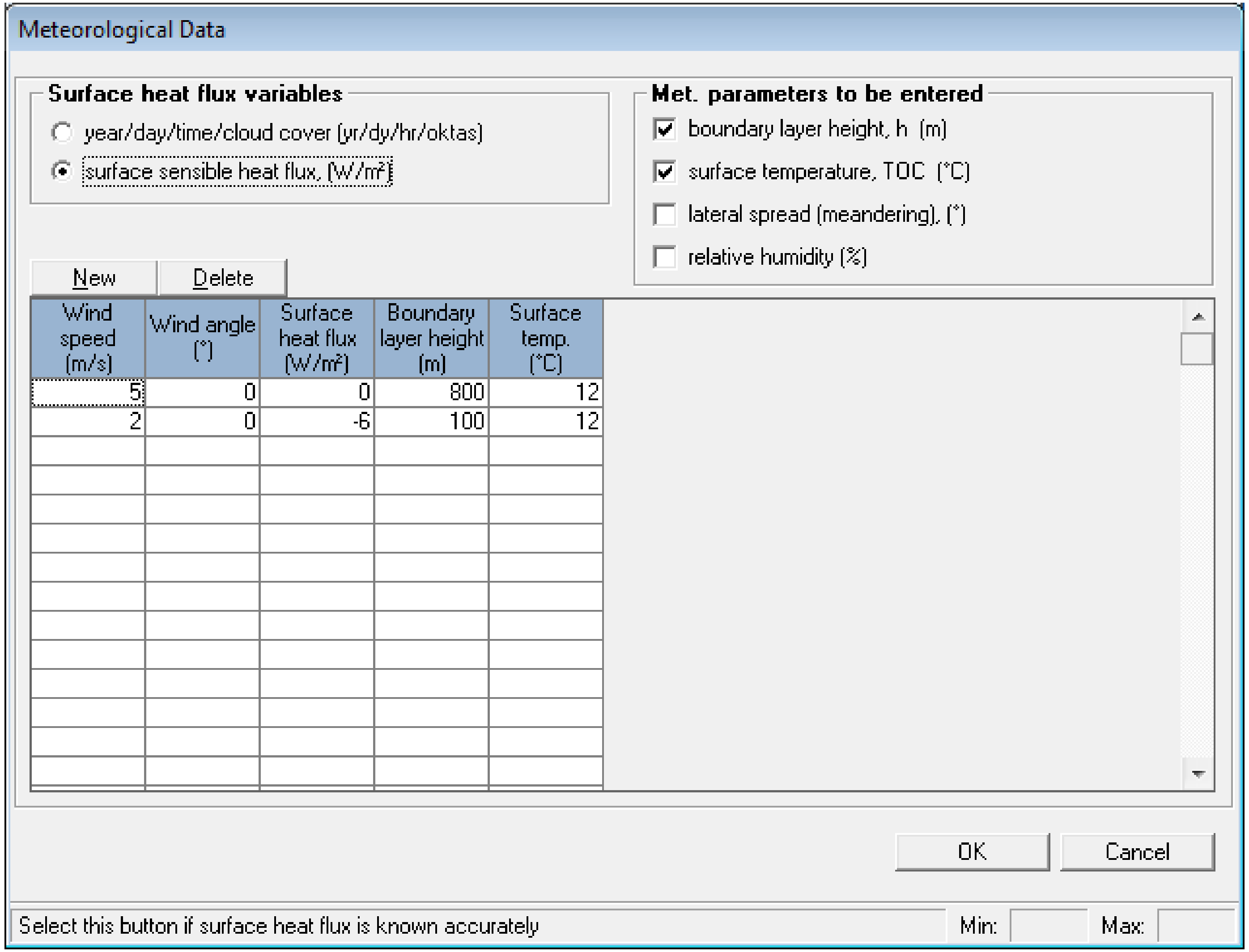
- HSE Safety Report Assessment Guide (SRAG) guidance for a dense gas release:

"D5 weather conditions occur frequently in the UK and should be used to calculate the hazard range for daytime releases… Dispersion is reduced under stable atmospheric conditions, hence F2 weather, which characterises night time conditions, generally produces the greatest hazard range".

- Standard practice to include these conditions for risk assessment scenarios:
  - D5 (category D with wind speed 5 m/s): prevailing daytime conditions in the UK
  - F2 (category F with wind speed 2 m/s): less common, occurring 10% of the time

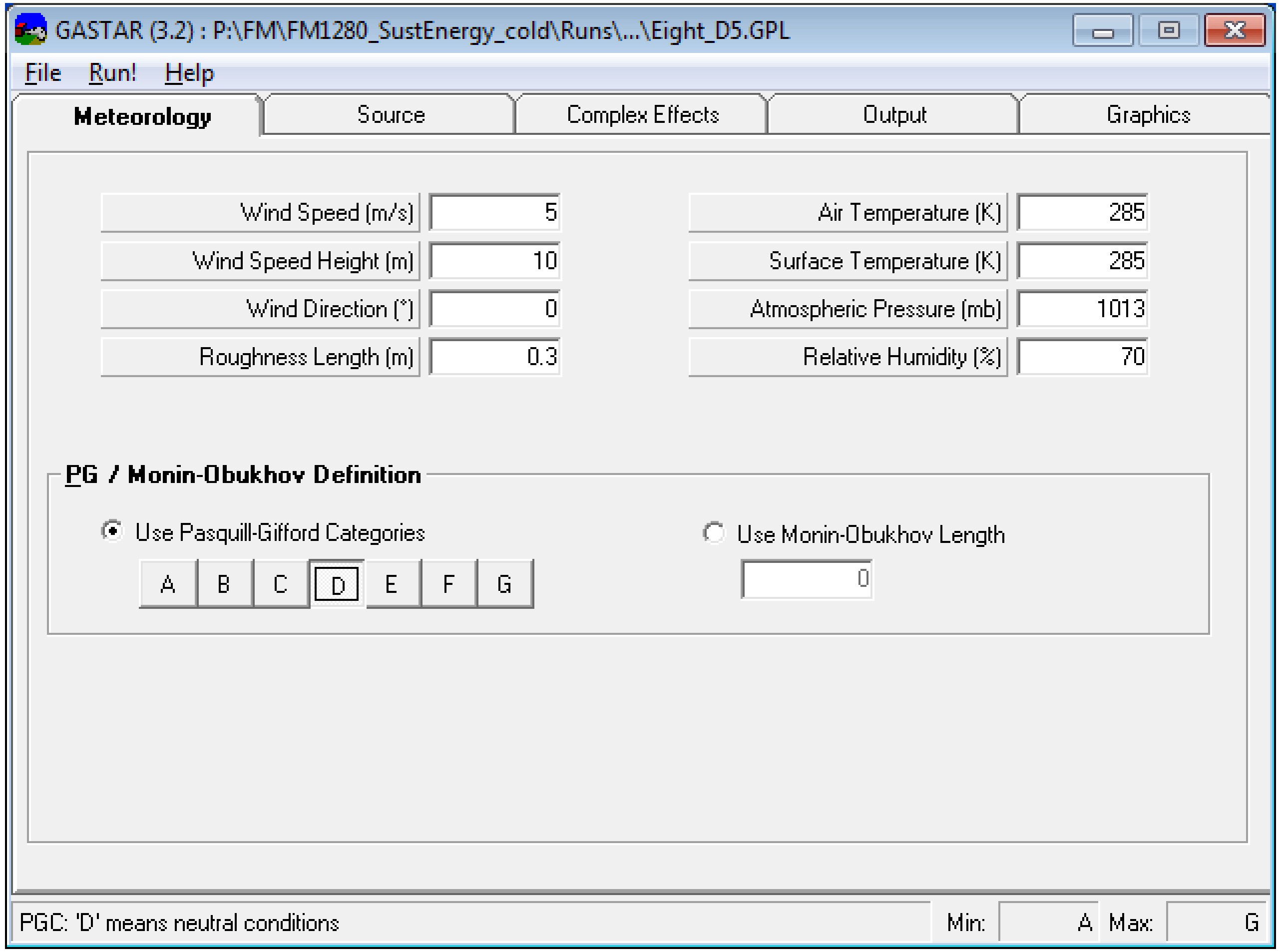
ADMS 5 meteorological data screen

- D5 and F2 represented using data from <R91A-G.met>
- Jet pointing downstream

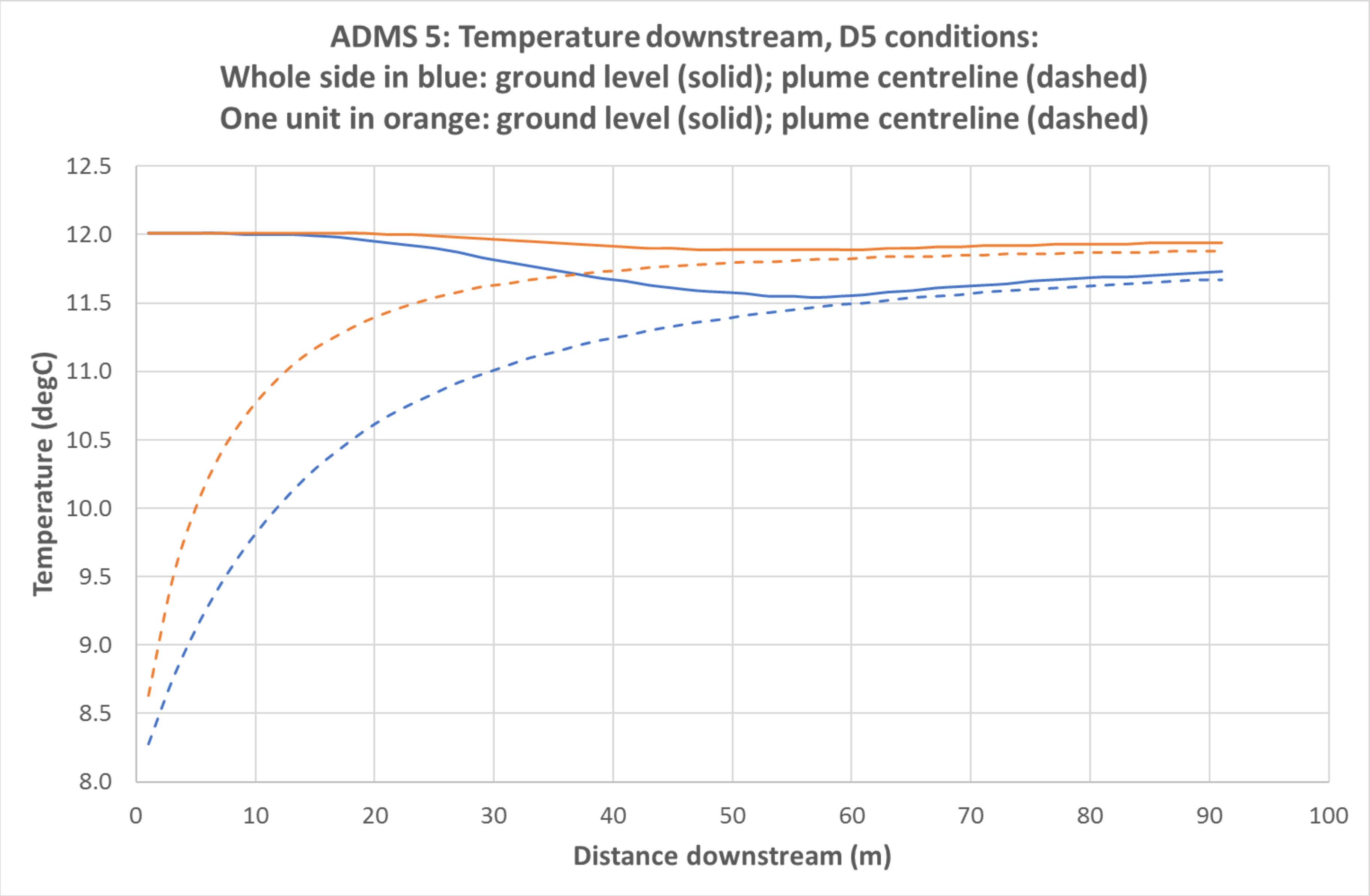


GASTAR meteorological data screen

- D5 and F2 set up as standard conditions in GASTAR
- Jet pointing downstream



Downstream temperatures, ADMS 5



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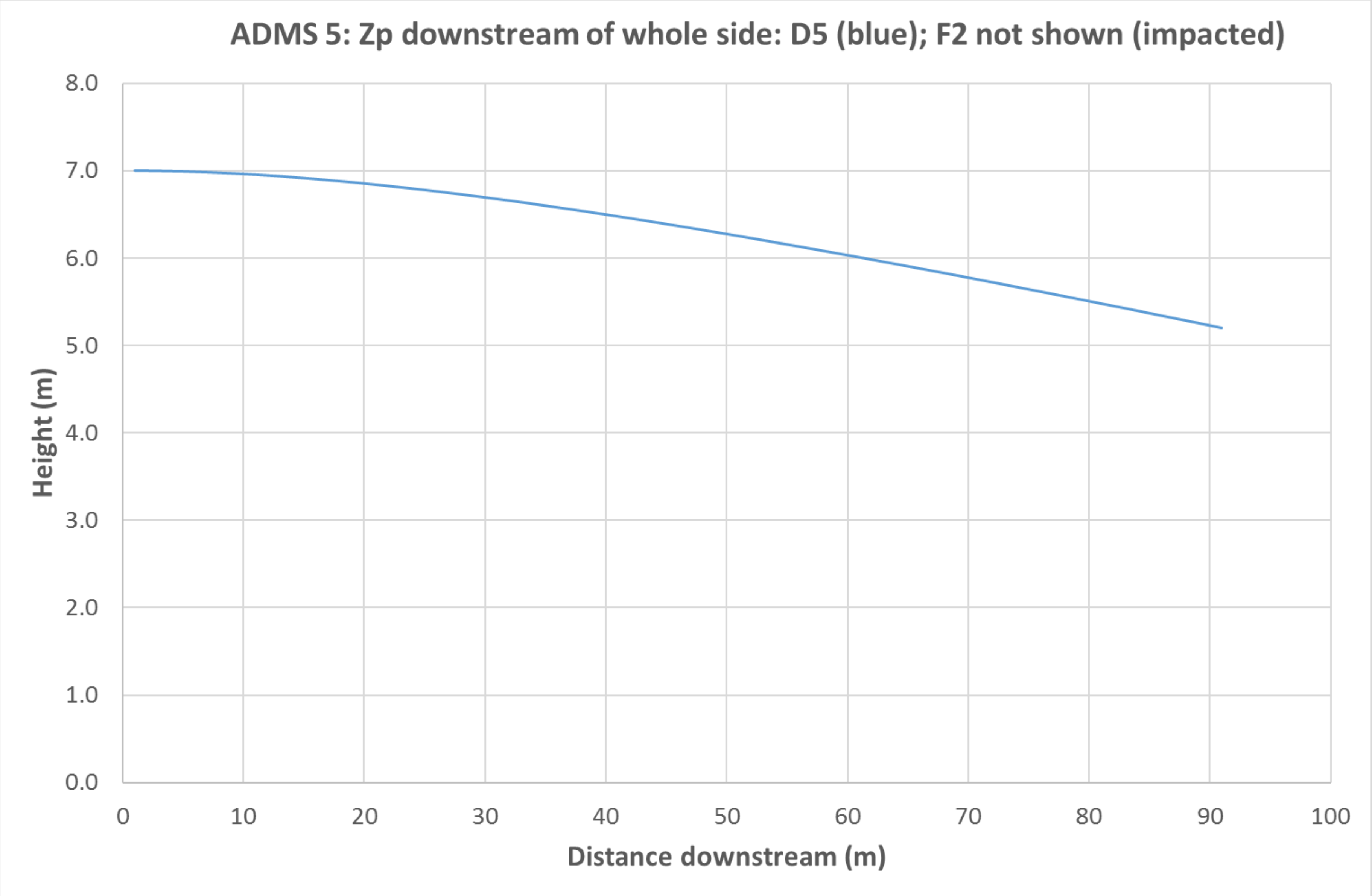
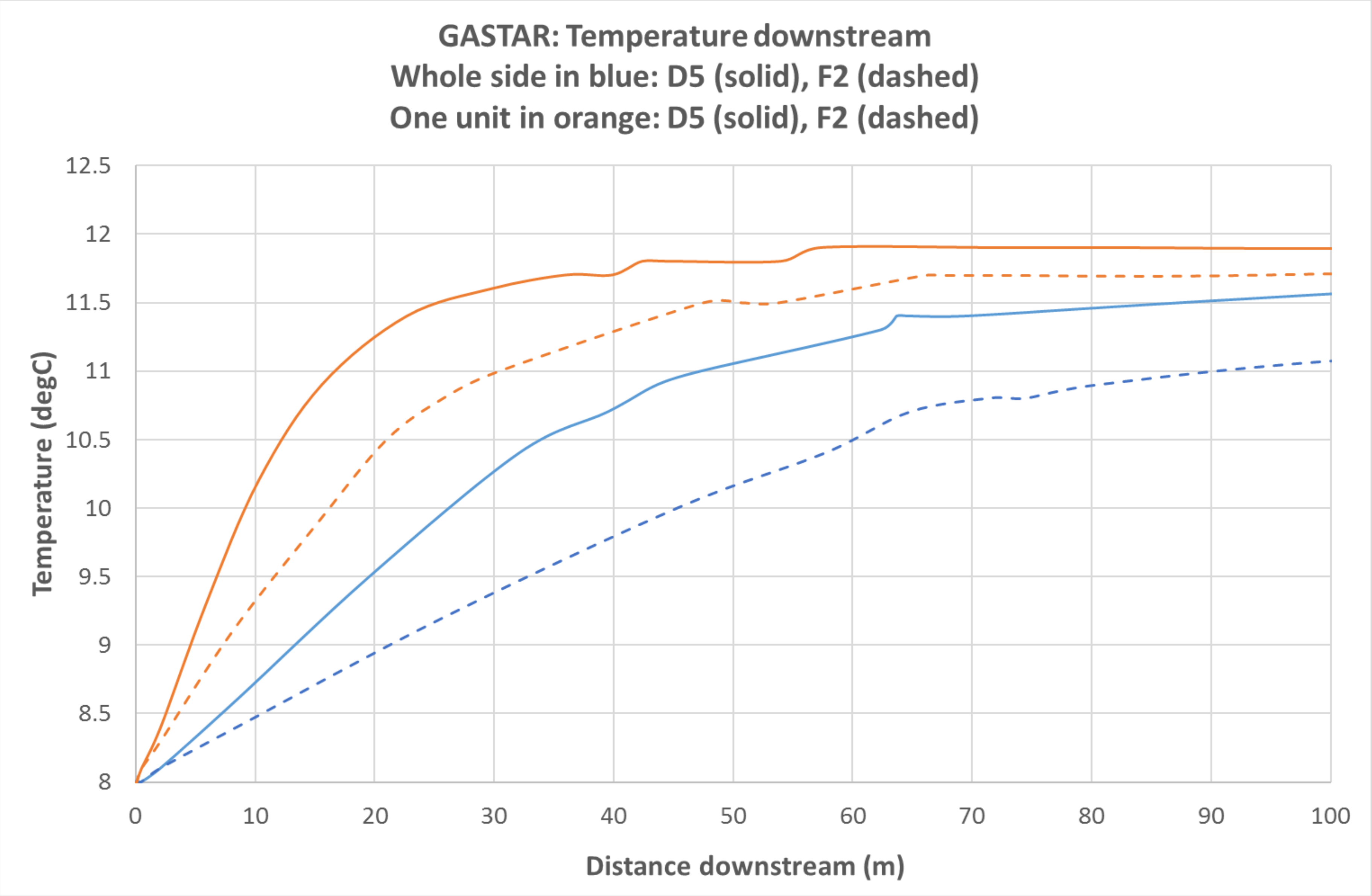
Plume centreline height, ADMS 5



Downstream temperatures, GASTAR



Tentative conclusions

- Results indicate that ground level temperature downwind of the release will be no more than 1 °C lower than ambient
- i.e. by the time the plume reaches ground level, the plume temperature has increased to at least 11 °C
- ADMS 5 indicates maximum ground level temperature deficit at around 60 m downstream

Further work

- Neither ADMS 5 or GASTAR can consider all aspects of the problem
  - ADMS can treat multiple sources
  - GASTAR can model dense gas effects at the ground
- Model for a range of ambient conditions (nearby meteorological station)
- Produce contour plots of temperature deficit
- Generate results at different heights above ground level
- Meteorological conditions of most interest – light wind, stable stratification - are the most difficult to model accurately, so there will be uncertainty
- To give confidence, compare rate of cooling due to ASHPs with typical rates of radiative cooling/heating and turbulent heat fluxes

Any questions?

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