Validation of Phast dispersion model for USA LNG siting applications

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UDM validation against PHMSA LNG experimental database

- 1. Introduction and previous UDM model validation
- 2. UDM validation against PHMSA experiments
  - Experiments
  - Model input
  - Model results and validation statistics
  - Conclusions

1. Introduction and Previous Validation

PHMSA and exclusion zone modelling

- Pipeline and Hazardous Materials Safety Administration (PHMSA) sets standards for siting LNG facilities in the US
- Exclusion Zones
  - Areas potentially exposed to flammable clouds or unsafe thermal radiation levels
  - Calculated using approved models
    - DEGADIS
    - FEM3A
    - Potential for other models to be approved
- Late 2010 – process put in place by which approval could be obtained
  - Likely increase in number of LNG facilities
  - Uncertainties in understanding LNG dispersion
  - Validation against large-scale experiments a key component
  - Formal submission to PHMSA
- Purely relates to UDM (Dispersion) modelling within Phast

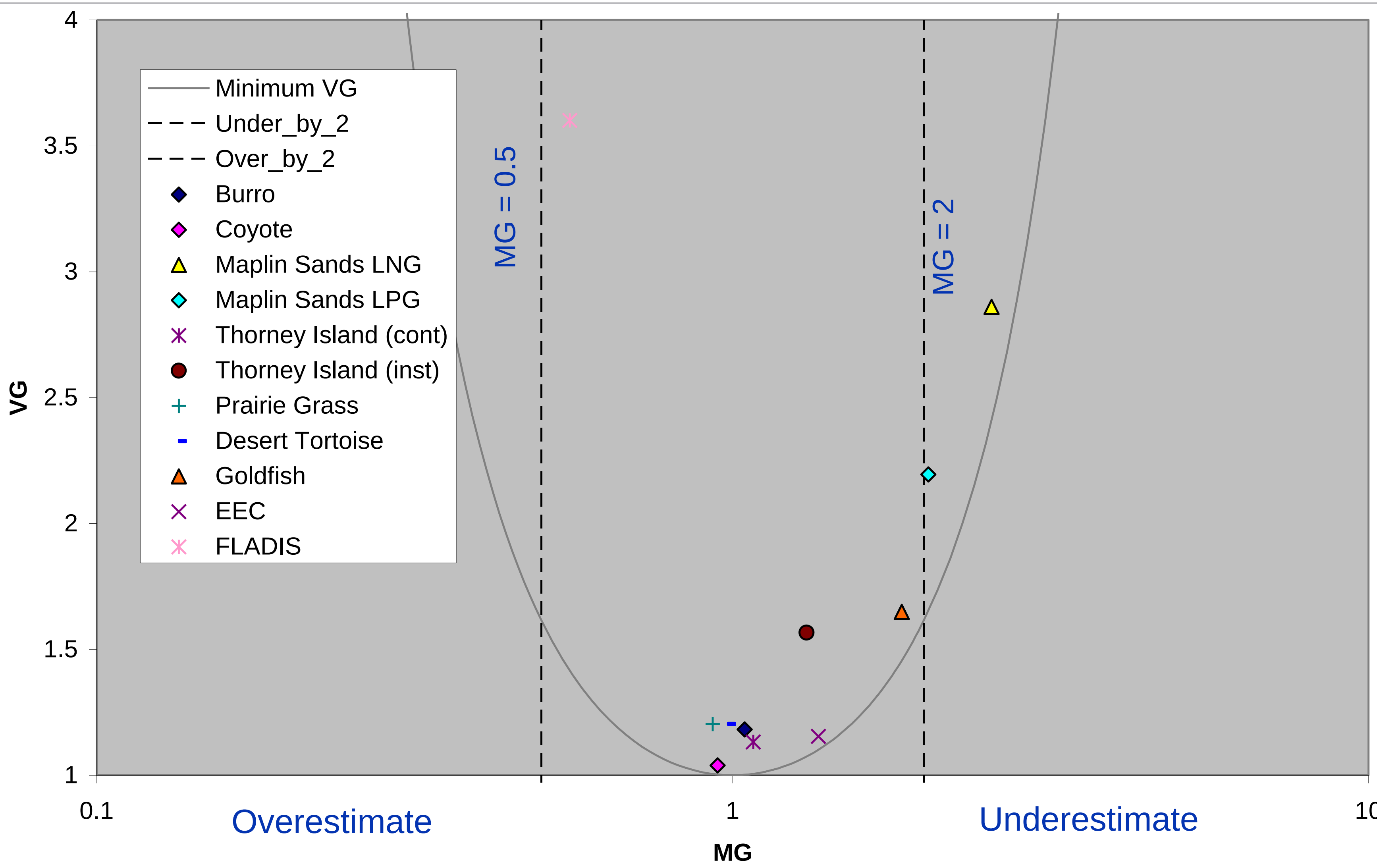
Previous UDM evaluation/validation

- Hanna (early nineties)
  - MDA experimental database
  - Independent Model validation by external consultant
- EU Project SMEDIS: ‘Scientific Model Evaluation DISpersion Models’ (late nineties)
  - REDIPHEM experimental database – focus on two-phase pressurised releases
  - Model Evaluation Protocol (MEP)
  - Model validation by model developers (Phast - UDM by DNV Software)
  - Independent Model Evaluation Report (MER) by external consultant (UDM by Rex Britter)
  - Accompanied by rigorous UDM quality improvement with detailed verification and validation
- More recent
  - Droplet Modelling JIP (From 2001)
  - Pool vaporisation (UCL sponsored Ph.D.)

Dispersion – Validation against large scale experiments

- Continuous passive dispersion
  - SO_2 (Prairie Grass [SMEDIS/MDA])
- Continuous elevated two-phase jet
  - Ammonia (Desert Tortoise [SMEDIS/MDA] and FLADIS [SMEDIS])
  - Propane (EEC [SMEDIS])
  - HF (Goldfish)
  - CO_2 (SpadeAdam – BP and Shell)
- Continuous dispersion from pool
  - LNG (Maplin Sands, Burro, Coyote [PHMSA/MDA])
  - LPG (Maplin Sands [MDA])
- Continuous and finite-duration dispersion from area source
  - CO_2 (Kit Fox)
- Continuous low-momentum horizontal release
  - Freon/Nitrogen (Thorney Island [PHMSA])
- Instantaneous un-pressurised
  - Freon/Nitrogen (Thorney Island [MDA])

Phast v6.7 validation – concentration



2. PHMSA UDM validation

PHMSA Requirements and Submission

- ‘Model evaluation protocol’ (MEP)
  - HSL (Ivings et al., 2007)
  - Based on SMEDIS
- ‘Model evaluation report’ (MER)
  - DNV Energy (Robin Pitblado)
  - Update of Rex Britter SMEDIS report
- Performance against validation database
  - HSL (Coldrick et al., 2010)
  - Excel spreadsheet & report
- Supplementary
  - Technical reference
  - Phast PSU file

PHMSA UDM validation - experiments and modelling

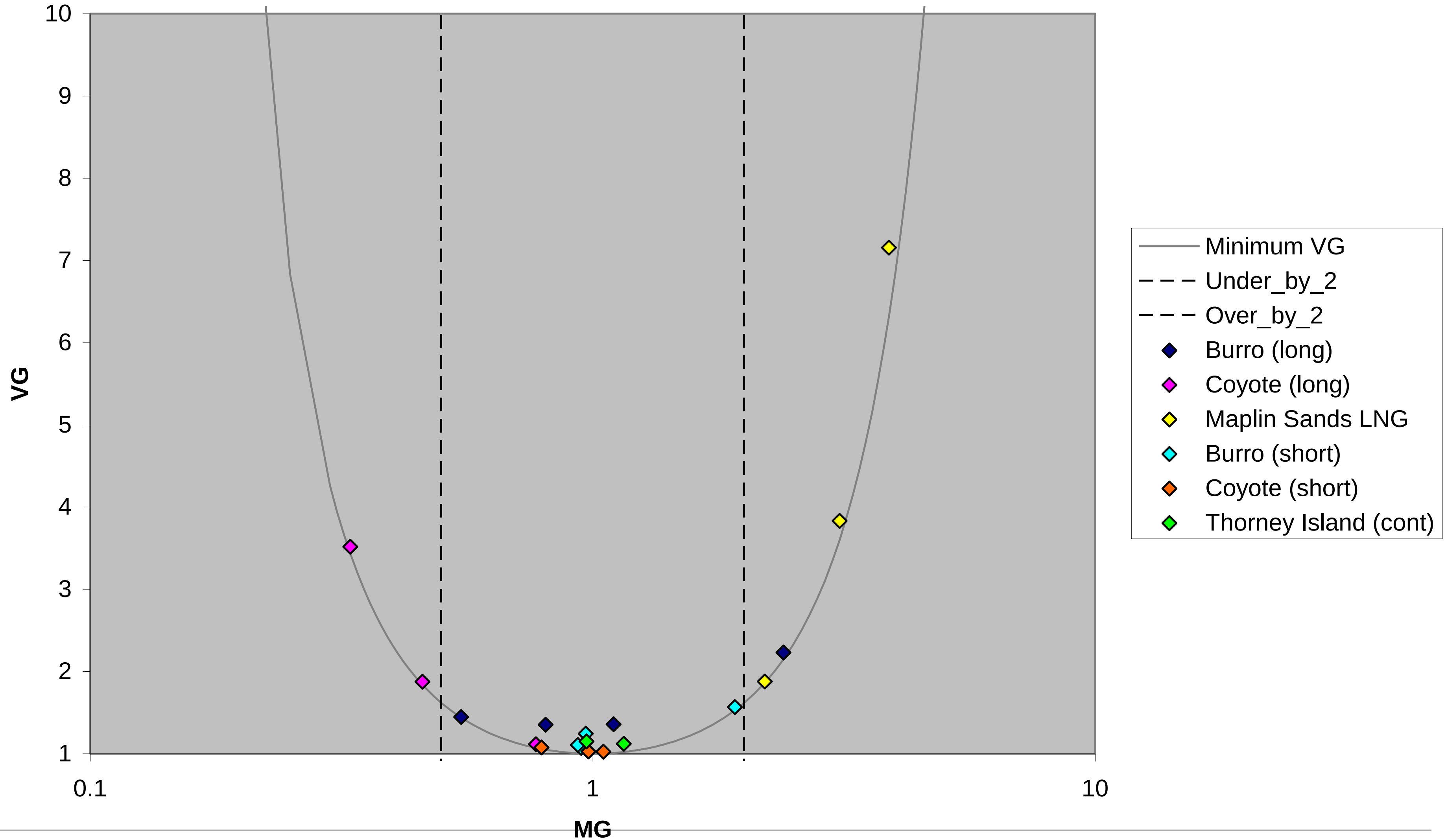
- Selection of experiments
  - PHMSA database includes only unpressurised releases - UDM validated against much wider dataset including two-phase pressurised releases
  - Experiments without obstructions selected only
- Wind-tunnel experiments modelled at full-scale

  (UDM default assumptions are based on typical outdoor ambient turbulence)
- Modelling assumptions
  - Phast used ‘out of the box’ with all v6.7 default parameters
  - Exception: core averaging time = required averaging time – recommended for best results
  - Field experiments: user-defined ‘leak’ scenario
  - Wind tunnel: user-defined ‘pool source’ scenario
- Requested UDM concentration results
  - Maximum concentration and cloud width (across arc)
  - Point-wise concentration at given downwind distance x, crosswind distance y, height z
  - UDM predicts centre-line temperature and therefore no values given for off-centre line temperatures (as for SMEDIS)

PHMSA UDM Validation

Experiment	Trial Number	Field (F) or Windtunnel (WT)	Material	Modelled by UDM as
Maplin Sands	27 34 35	F	LNG	Low momentum elevated horizontal release
Burro	3 7 8 9	F	LNG	Low momentum elevated horizontal release
Coyote	3 5 6	F	LNG	Low momentum elevated horizontal release
Thorney Island	45 47	F	Freon&N_2	Low momentum ground-level horizontal release
CHRC	A	WT	CO2	Ground-level vapour pool source
BA-Hamburg	DA0120 DAT223	WT	SF_6	Ground-level vapour pool source
BA-TNO	TUV01 FLS	WT	SF_6	Ground-level vapour pool source

Summary results table for all field experiments



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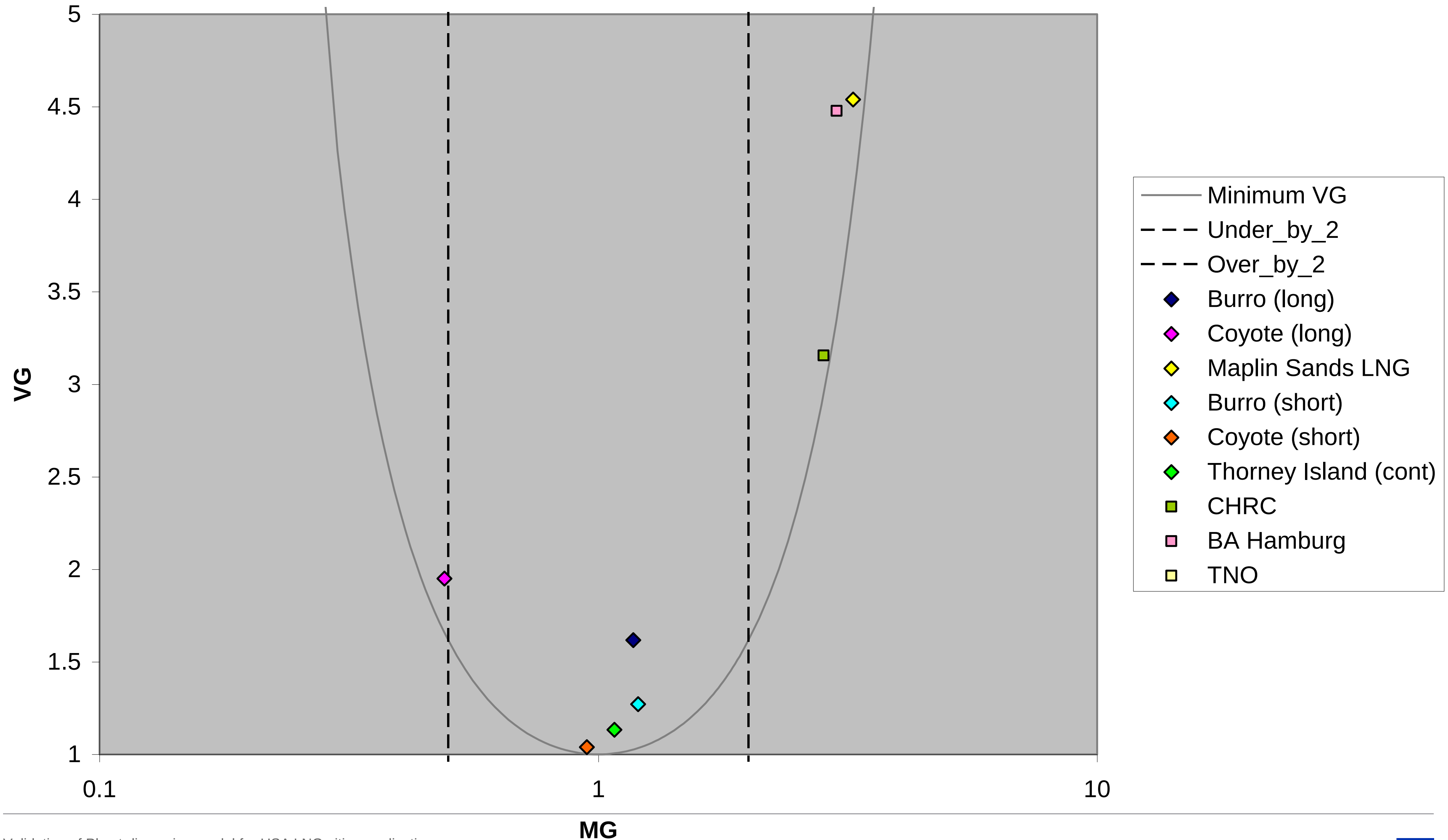
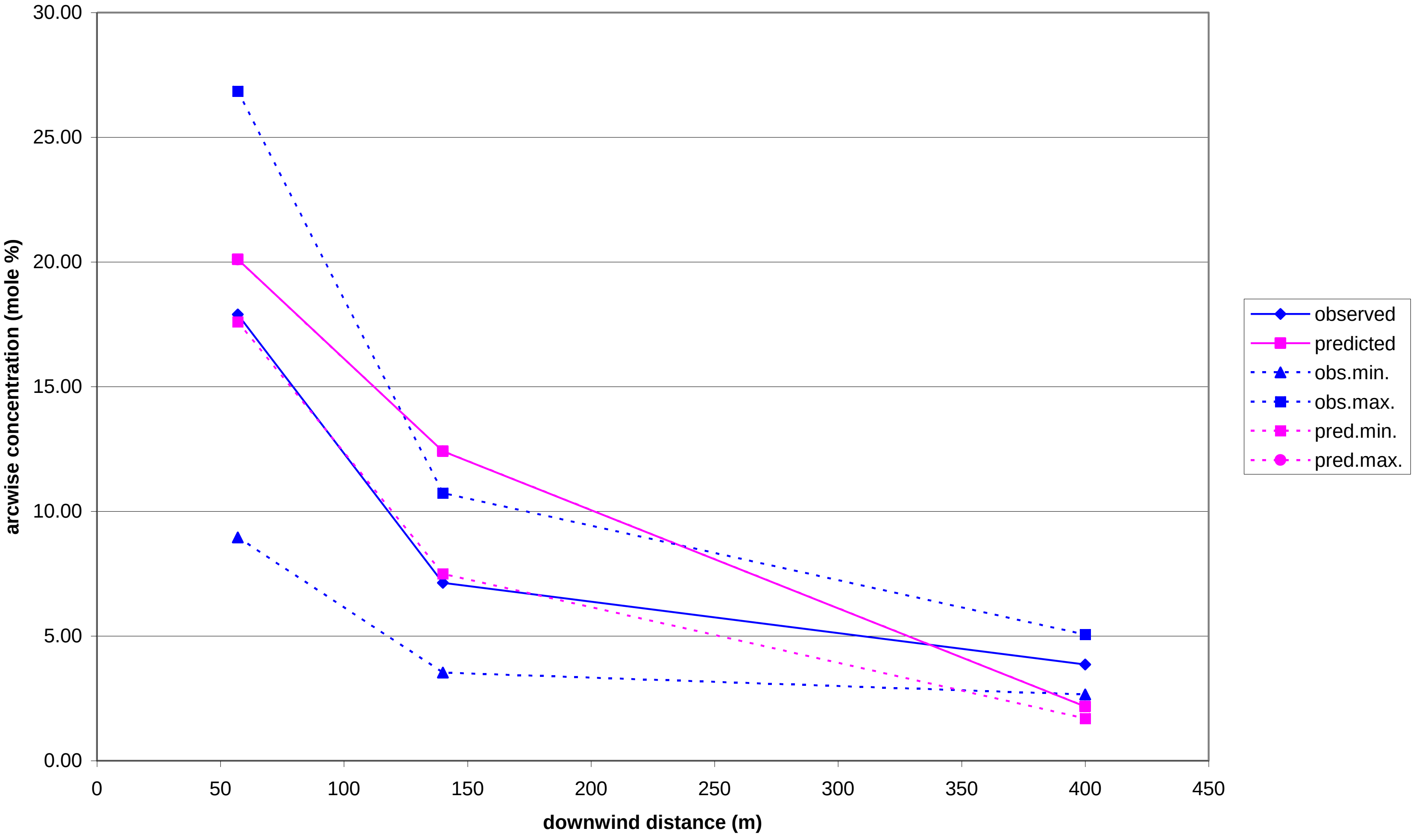
Summary results figures for all groups of experiments



Sensitivity/uncertainty analysis – measured versus observed concentrations

(Burro 7 – short averaging times)



Validation results – discussion and conclusions

- Field experiments
  - Short averaging times:
    - Burro and Coyote (excellent)
    - Maplin Sands under-prediction, consistent with other models assessed?
    - Time-averaging can lead to under-prediction of highly dynamic pools
  - Long averaging times
    - Thorney Island (excellent)
    - Burro (good)
    - Coyote (slight over-prediction)
    - Difficulty with selecting correct dispersion ‘segment’ to match time-averaging window
- Wind-tunnel experiments
  - Consistent under-prediction of concentrations
  - Possibly caused by scaling?
- Current and future work
  - Improved pool modelling (including multi-component logic)
  - Improved short duration and time varying modelling (including from pools)

Approval

- Phast formally approved October 2011
  - Applies to Phast 6.6 (UDM version 2) and 6.7

- Appropriate for modelling LNG dispersion from
  - Circular or low aspect ratio pools
  - Any release direction

- May not be appropriate for
  - Trenches or high aspect ratio pools
  - Multiple coincident releases
  - Varying terrain
  - Between large obstructions that cause wind channelling

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