Application of MM5 and CALPUFF to a Complex Terrain Environment in Eastern Iceland

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Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes
July 2-5, 2007
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Outline

- Overview of site
- Analysis of existing published reports/datasets
- Identification of key modelling issues
  - Meteorological modelling
  - Dispersion modelling
- Modelling approach
- Model performance
- Conclusions

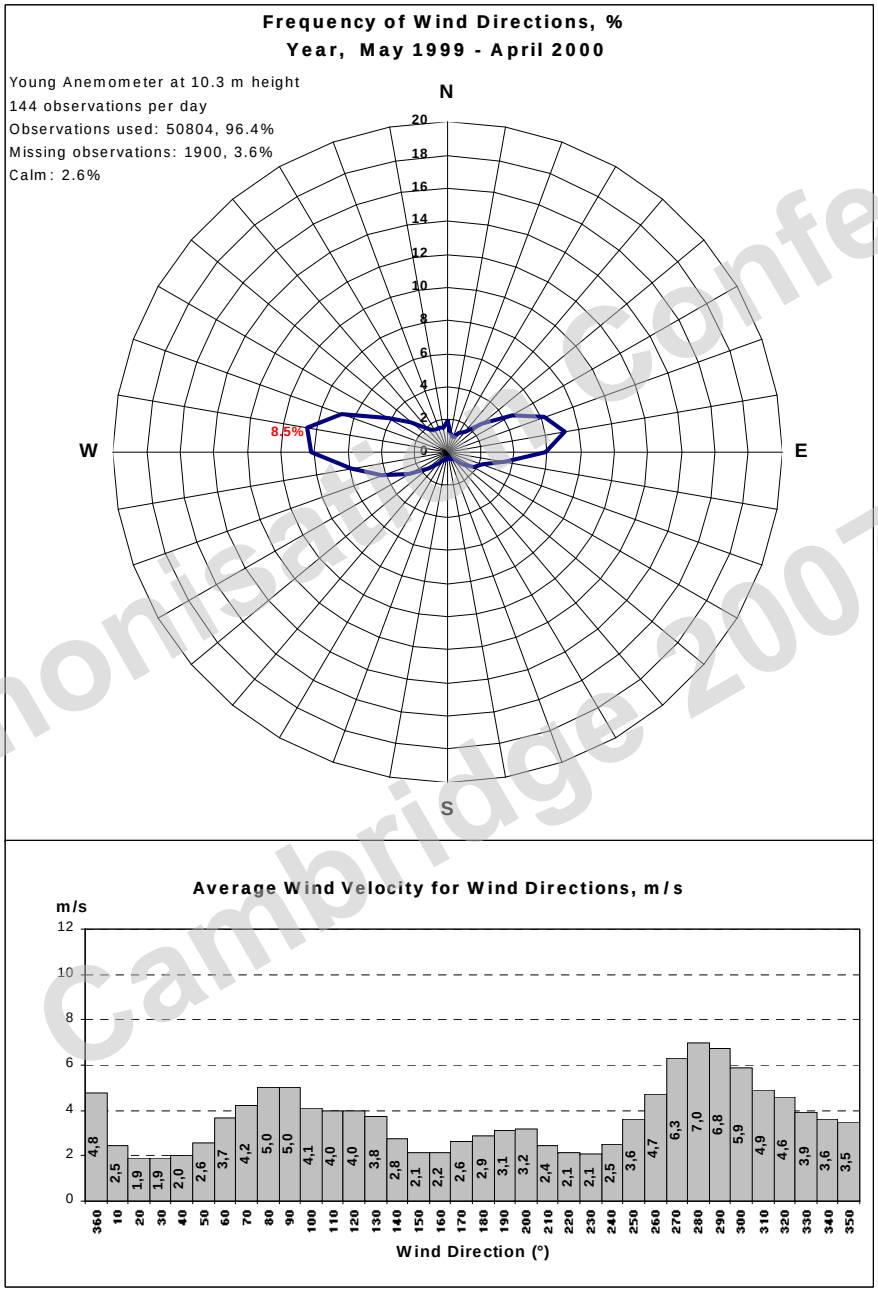
Slide from *Dr. Þórður Arason*

View of Site Looking West

Slide from *Dr. Þórður Arason*

(From Sigurdsson F.H., 1999)

Somastadagerdi



Somastadagerdi plots from Sigurdsson et al. (2000)

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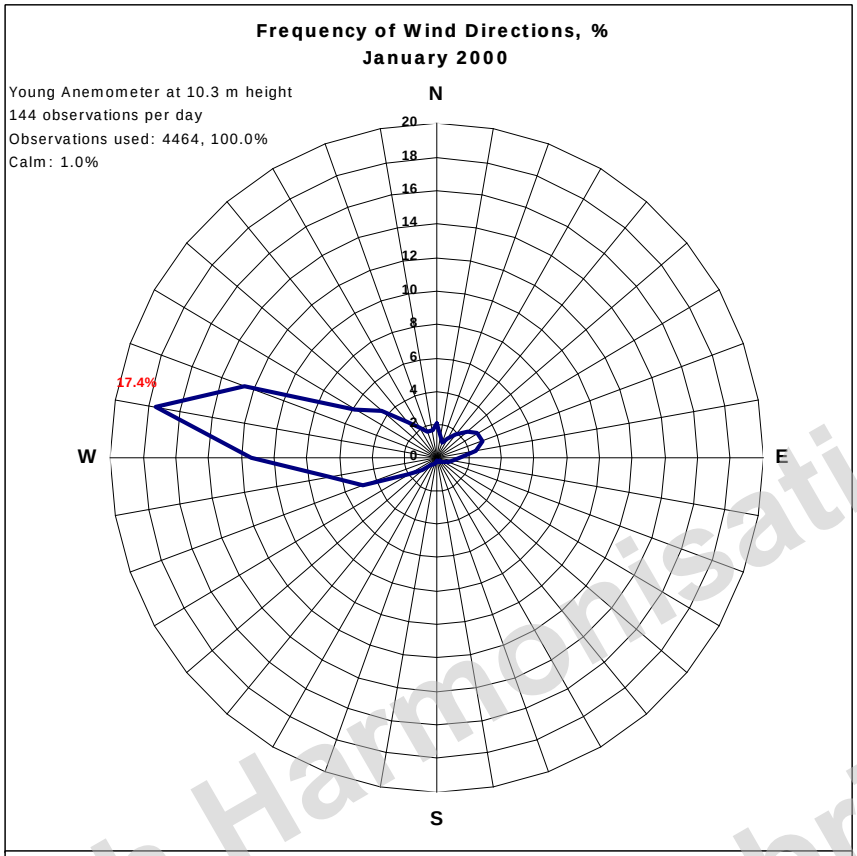

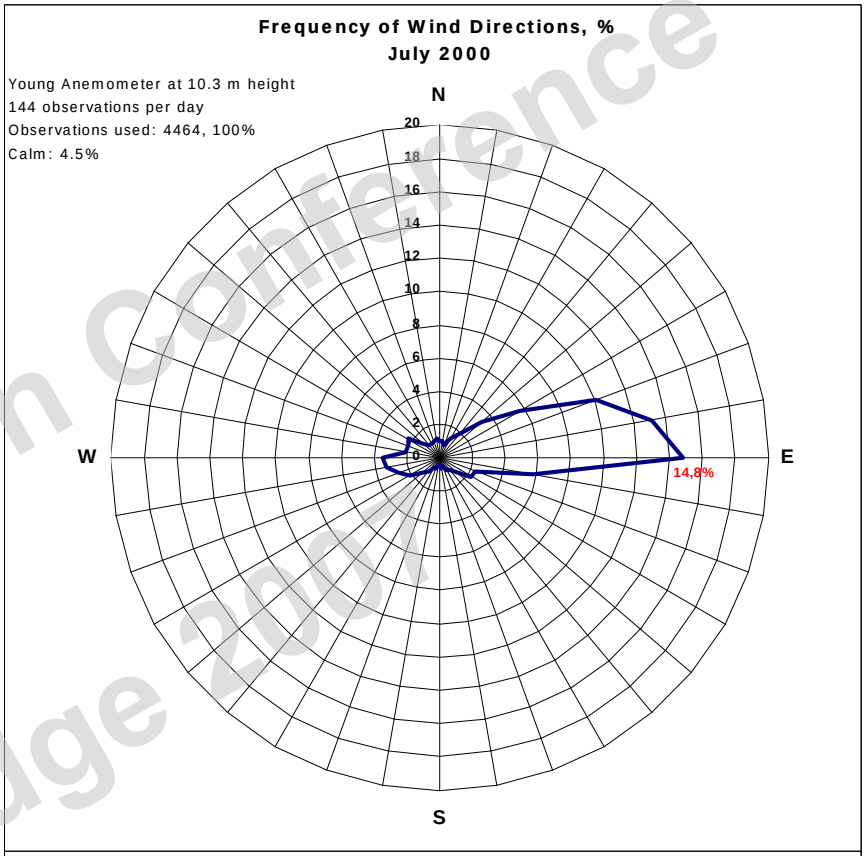

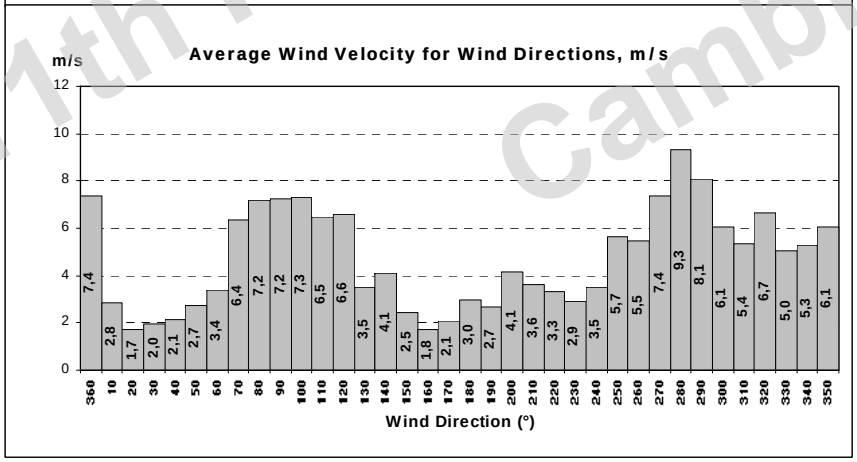

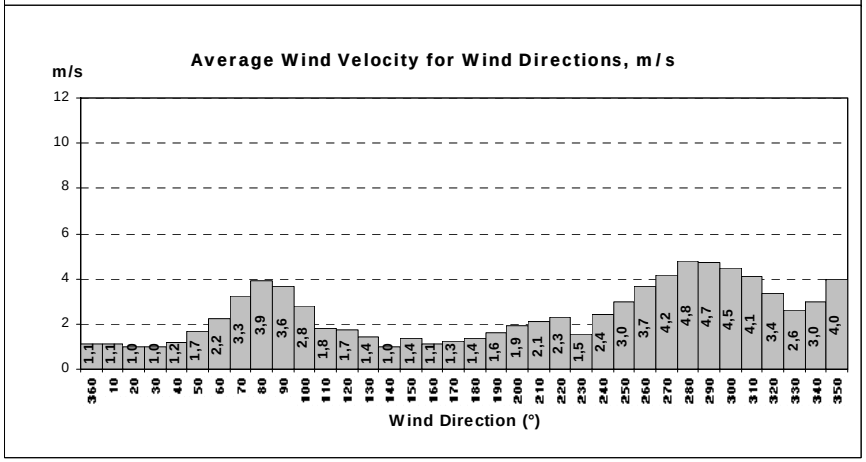

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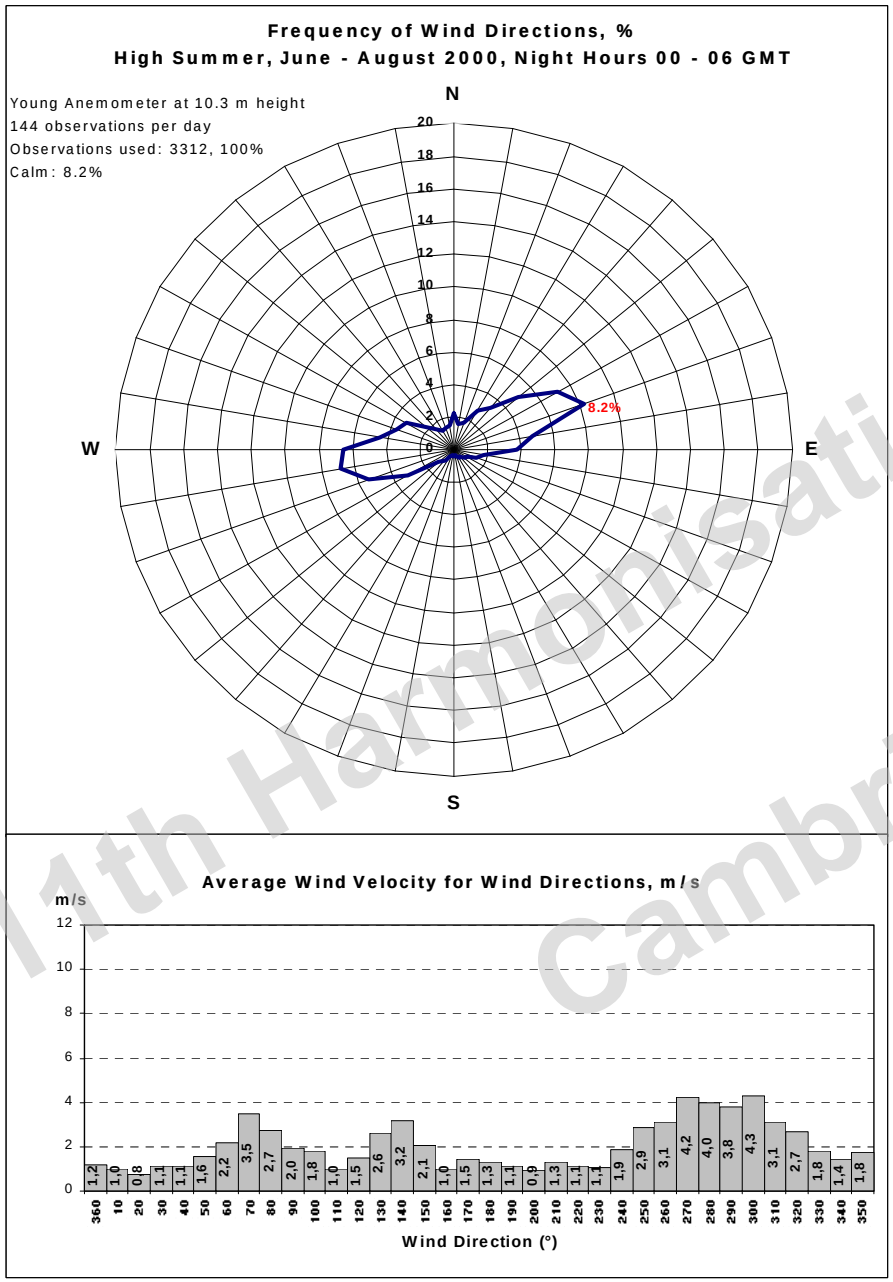
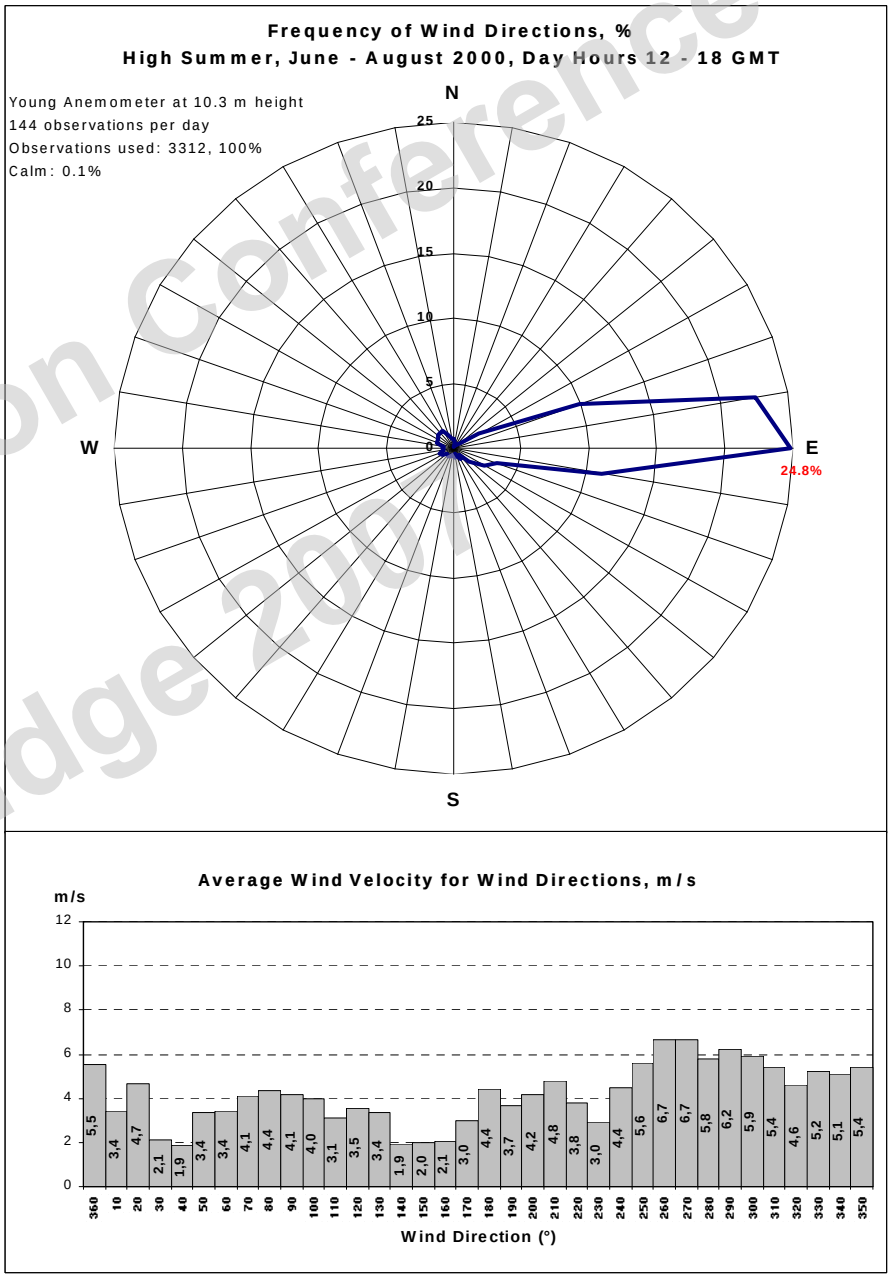




Somastadagerdi plots from Sigurdsson et al. (2000)

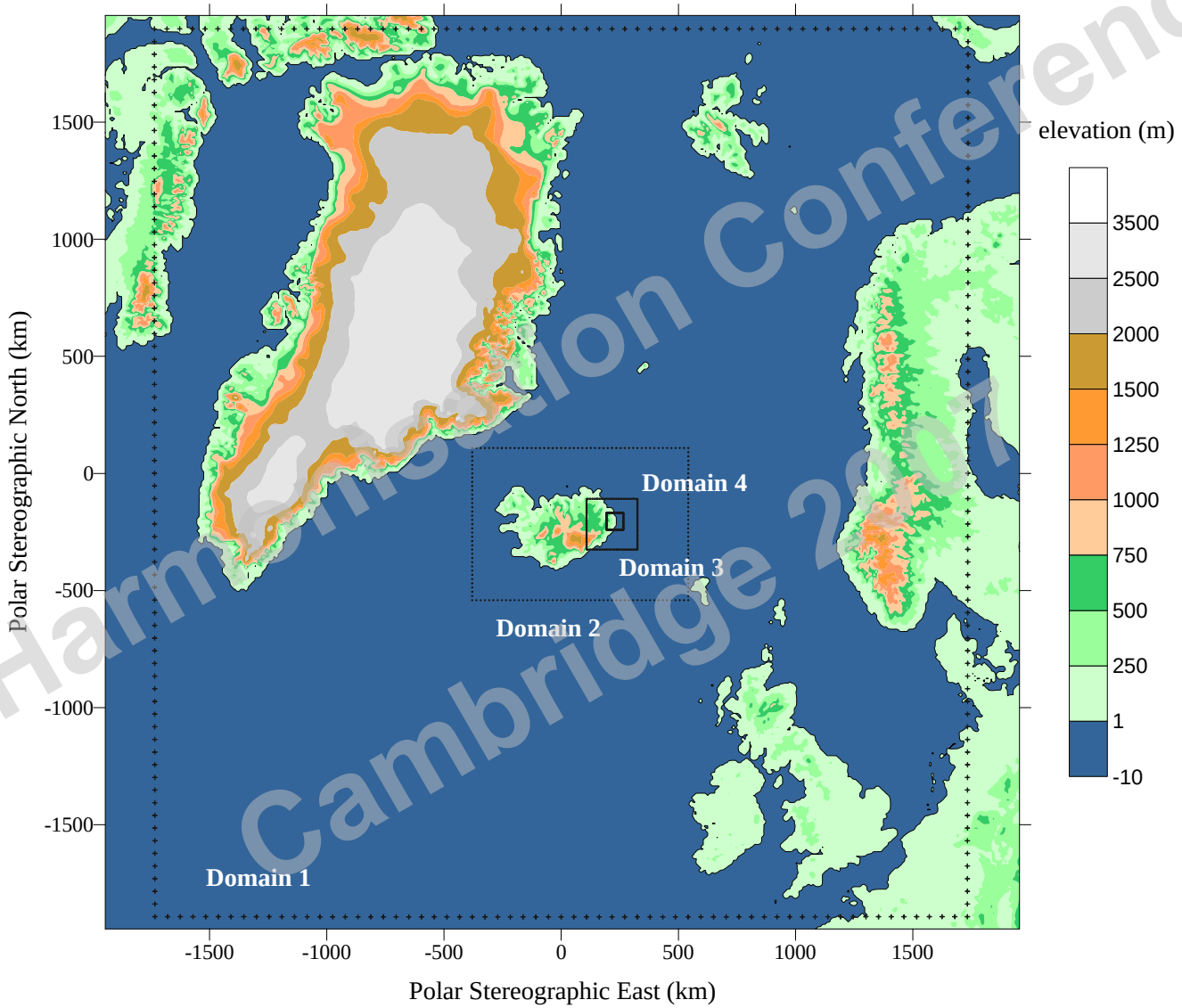
Major Modelling Issues

- Non-steady-state meteorological conditions
  - Spatial variability to flow and dispersion conditions
  - Flow reversals and fumigation
  - Strong seasonal and diurnal variability
  - Stagnation, recirculation, inversion conditions
  - Overwater transport and dispersion
  - Strong terrain channeling effects
  - Drainage flows and upslope flows
  - Sea breeze circulation

Meteorological Modelling Approach

- Mesoscale numerical meteorological model (MM5) for large scale flows
  - 4 nested grids down to 1 km resolution
  - 24 vertical levels
  - Four dimensional data assimilation
- Diagnostic meteorological model (CALMET)
  - 300m horizontal resolution
  - 10 vertical layers below 3000m
  - Seasonal land use parameters to account for snow & ice on albedo, surface roughness length

MM5 Domains over Iceland
Polar Stereographic Center: 67.1 N, 18.5 W
True Latitude: 60 N



Domain 1: 3870 km X 3600 km (87 X 81 - DX = 45 km)
Domain 2: 810 km X 540 km (91 X 61 - DX = 9 km)
Domain 3: 144 km X 144 km (49 X 49 - DX = 3 km)
Domain 4: 75 km X 75 km (76 X 76 - DX = 1 km)

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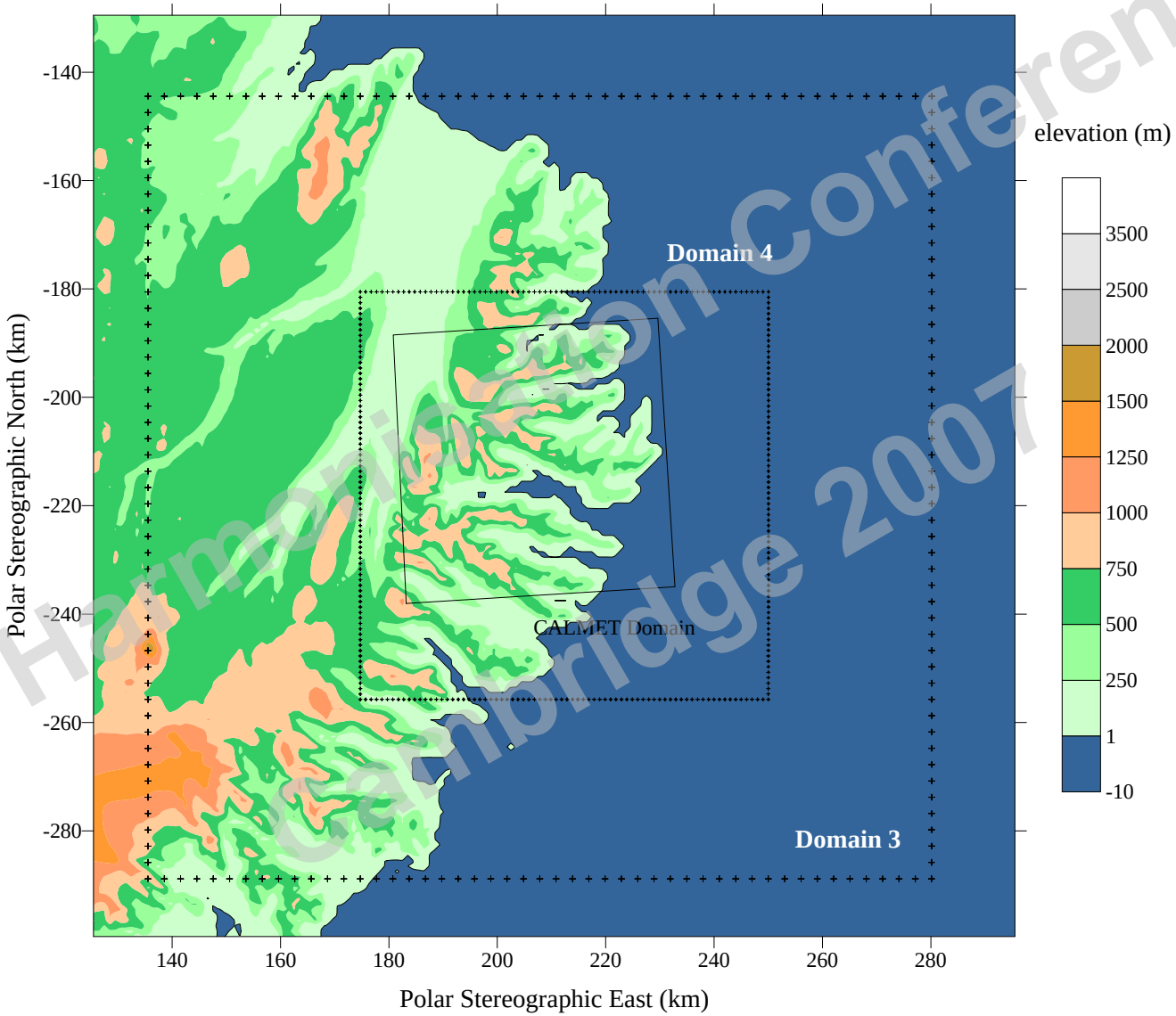
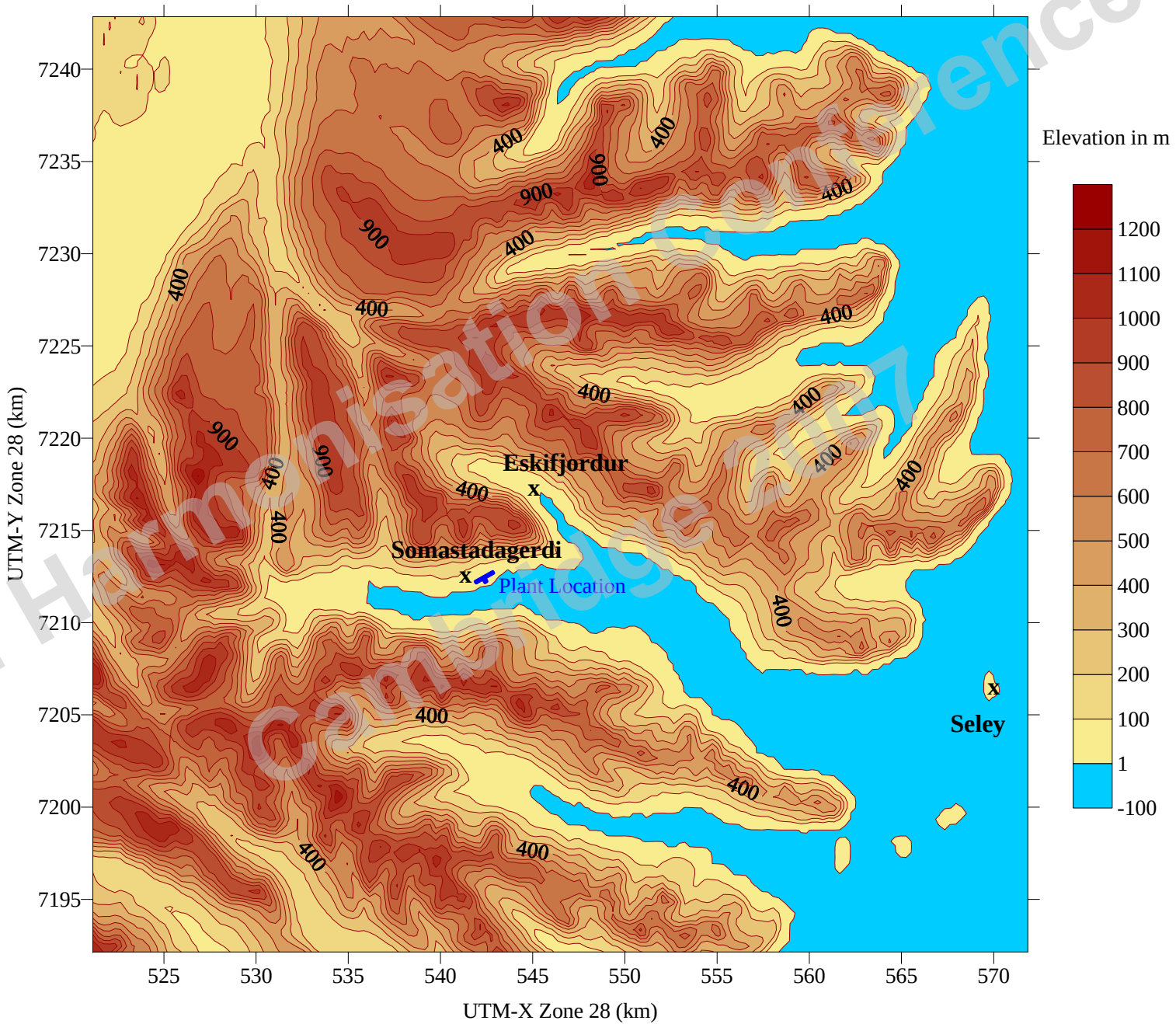
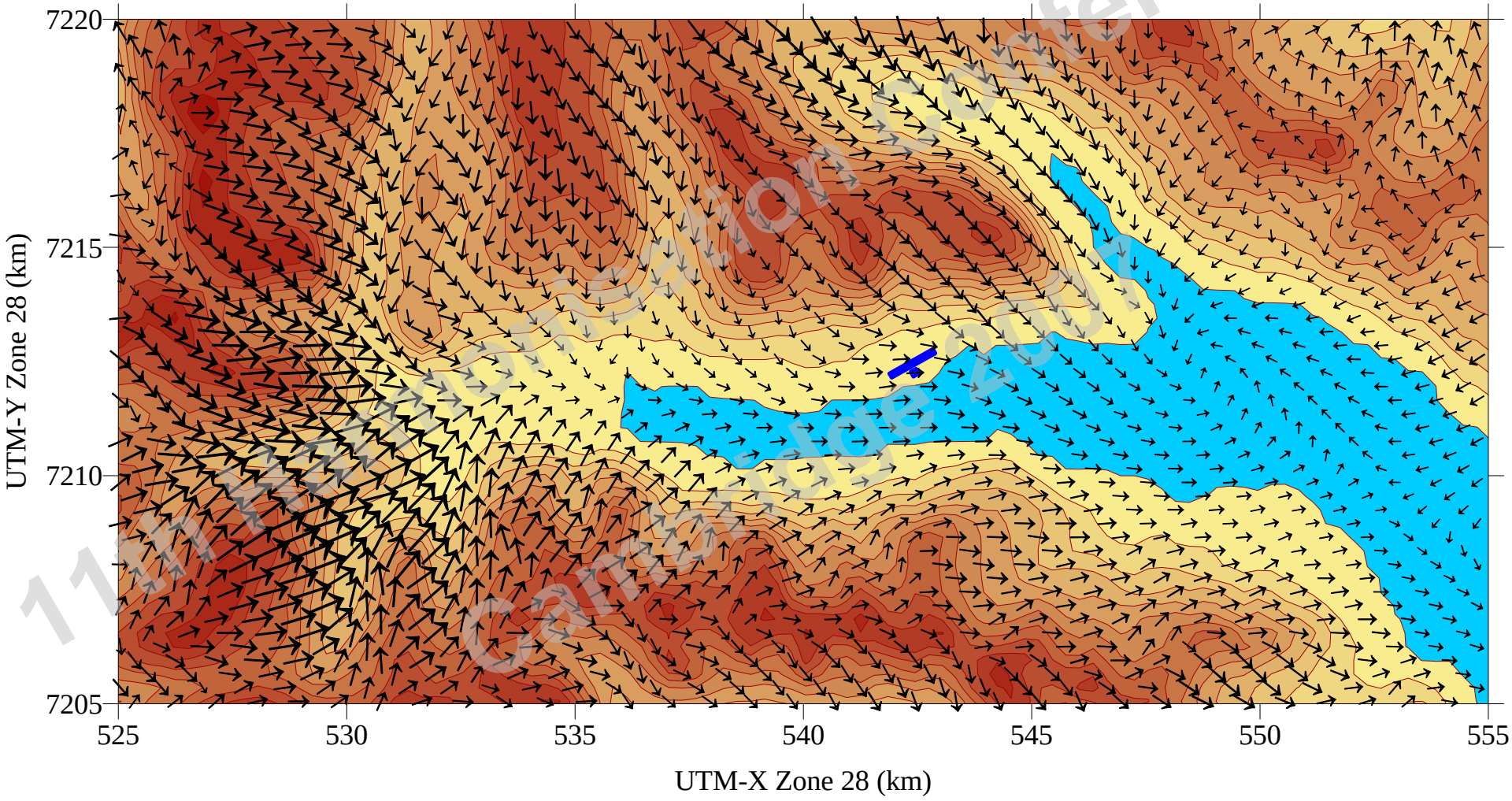


Domain 3: 144 km X 144 km (49 X 49 - DX = 3 km)
Domain 4: 75 km X 75 km (76 X 76 - DX = 1 km)



CALMET Winds – Level 1 (10m) – Aug 20, 2000 – 2am



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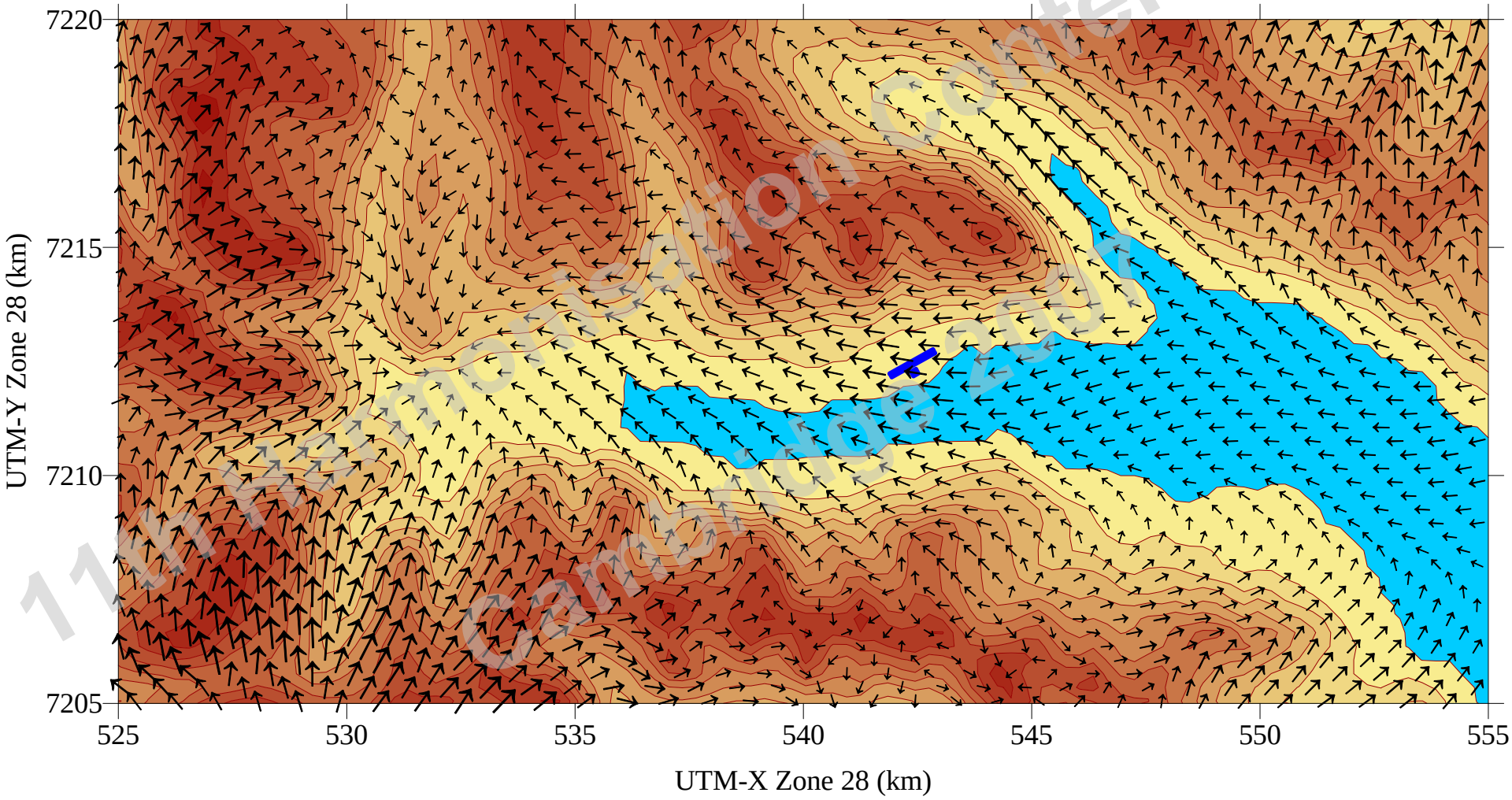
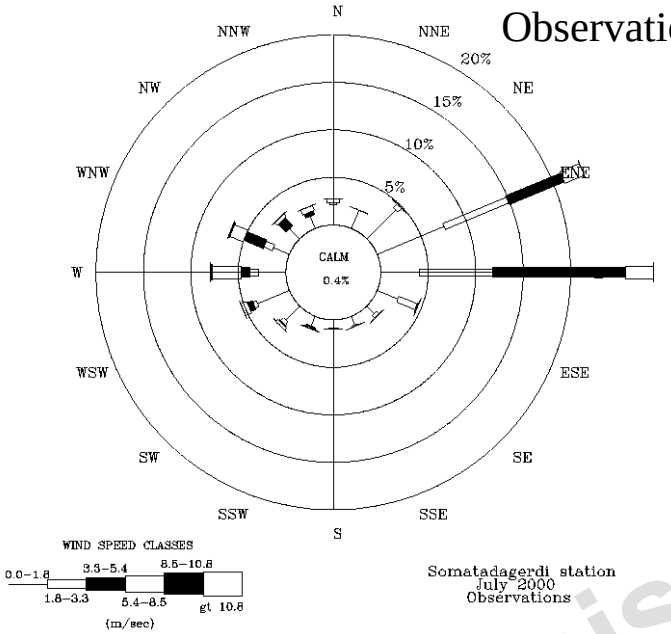
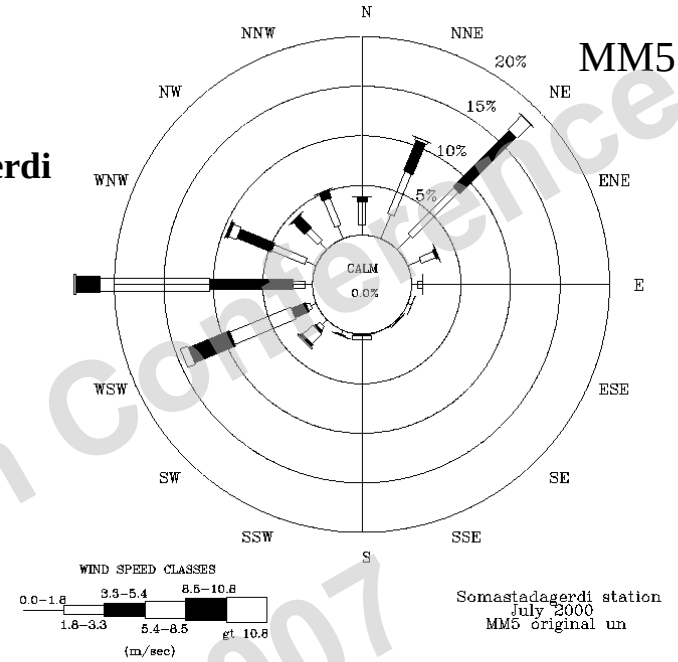


Observations



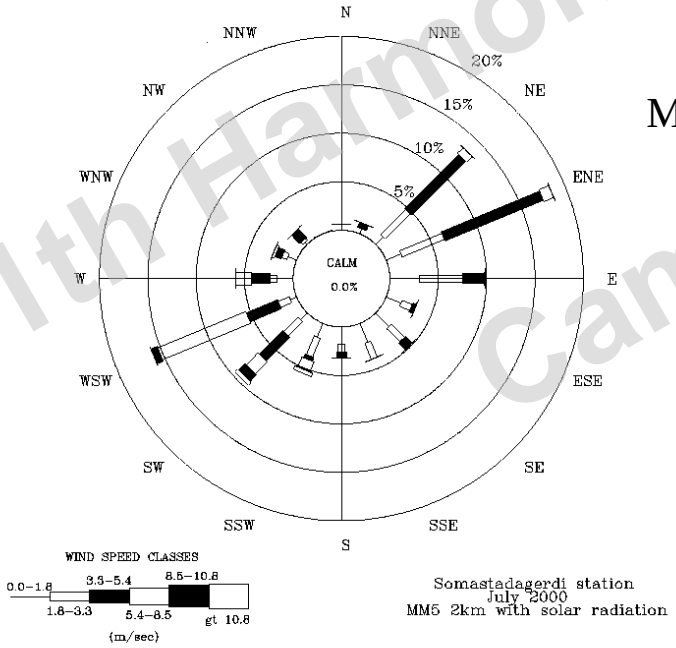
Somastadagerdi

MM5 - 2km

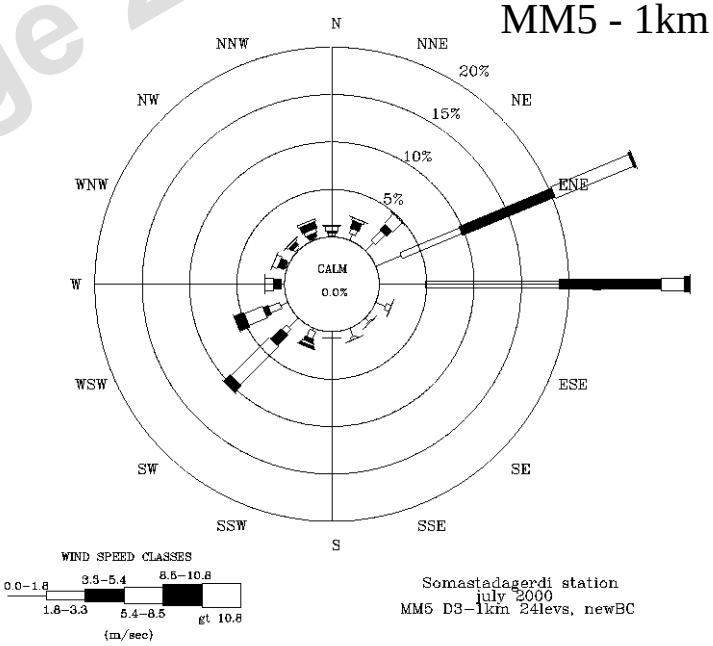


JULY 2000

MM5-2km+sol

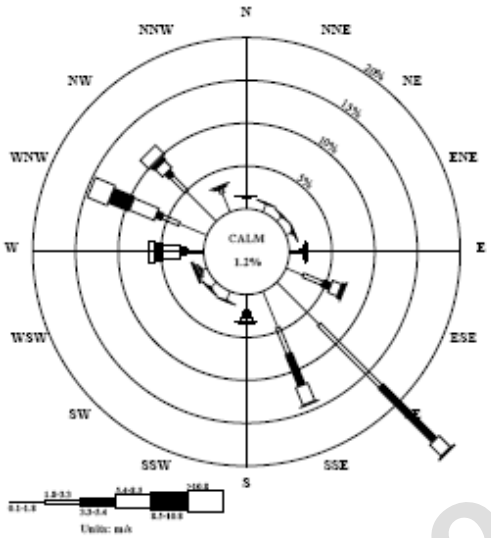


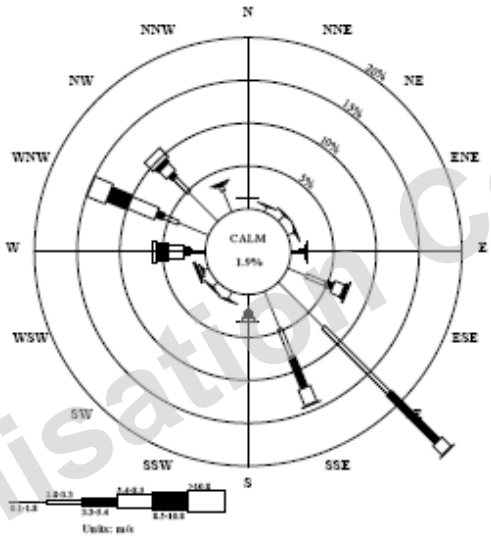
MM5 - 1km

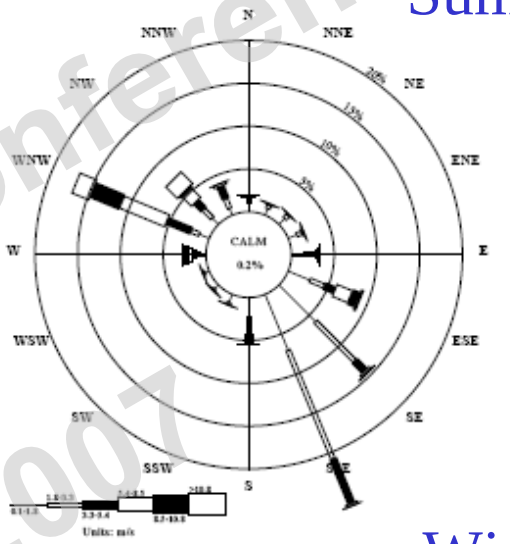


Eskifjordur Station

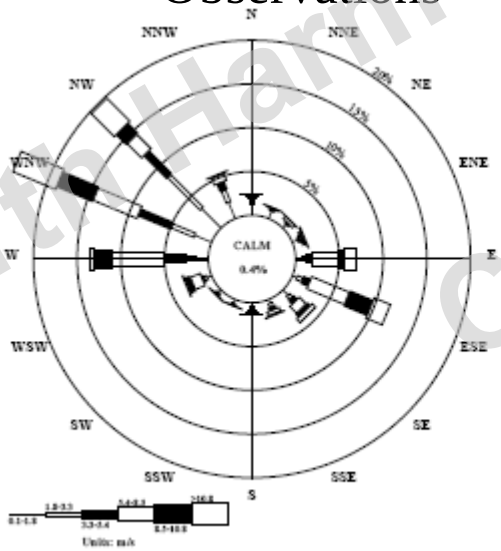
Summer



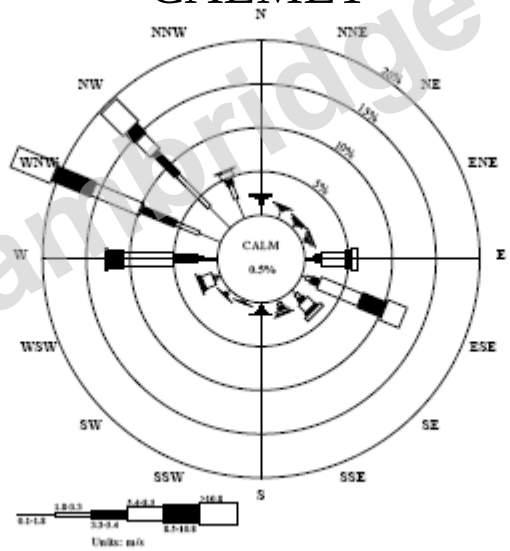




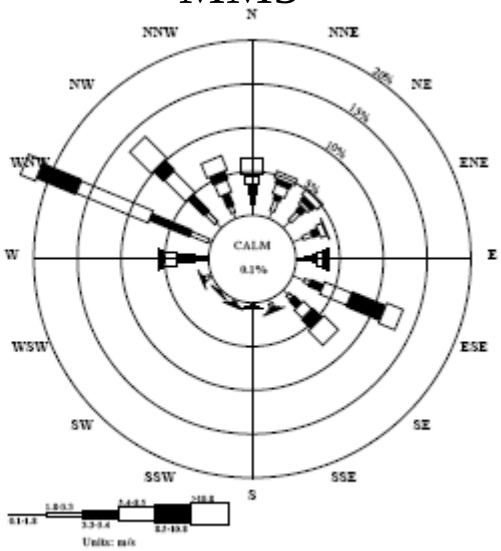
Observations



CALMET



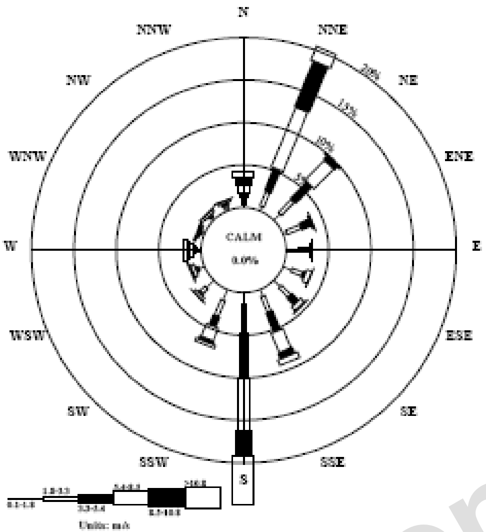
MM5

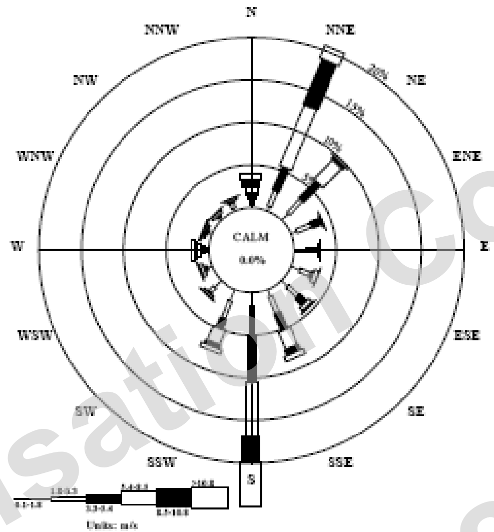


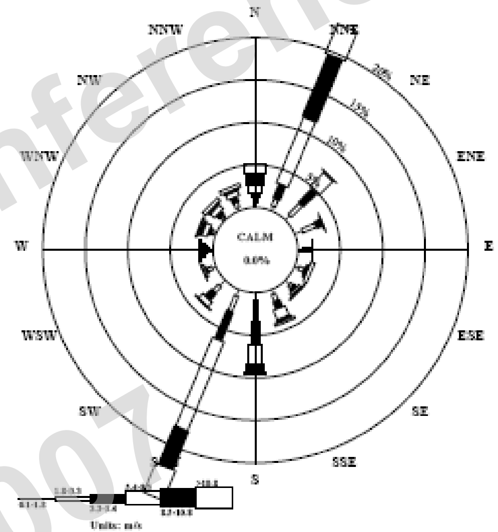
Winter

Seley Station

Summer





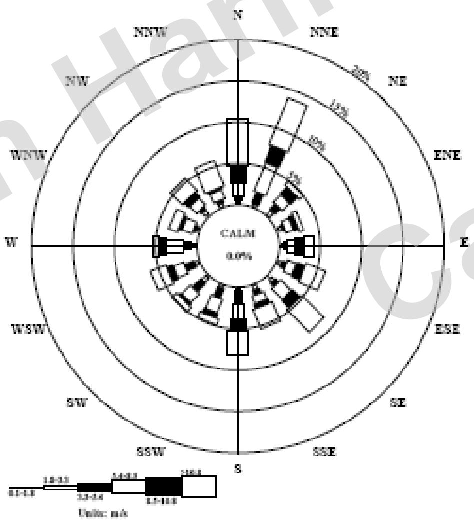


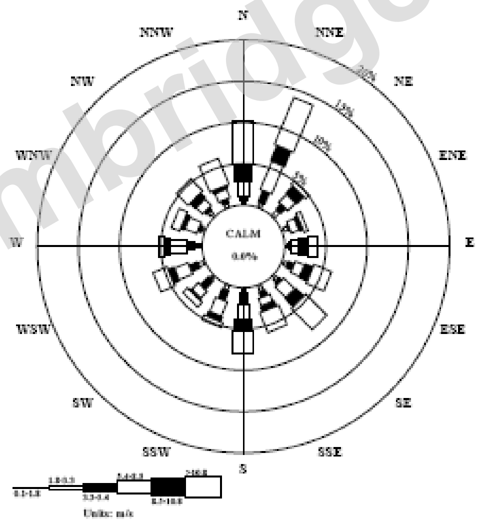
Observations

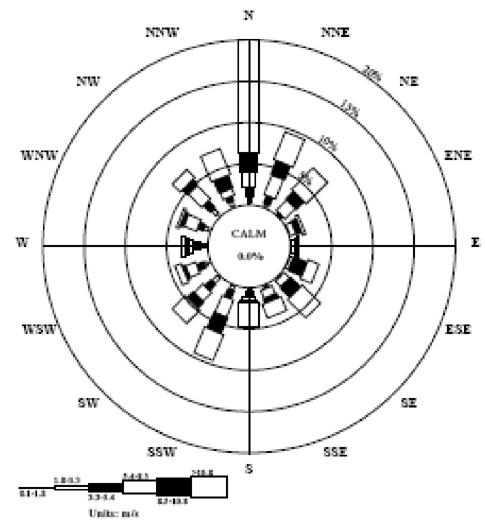
CALMET

MM5

Winter



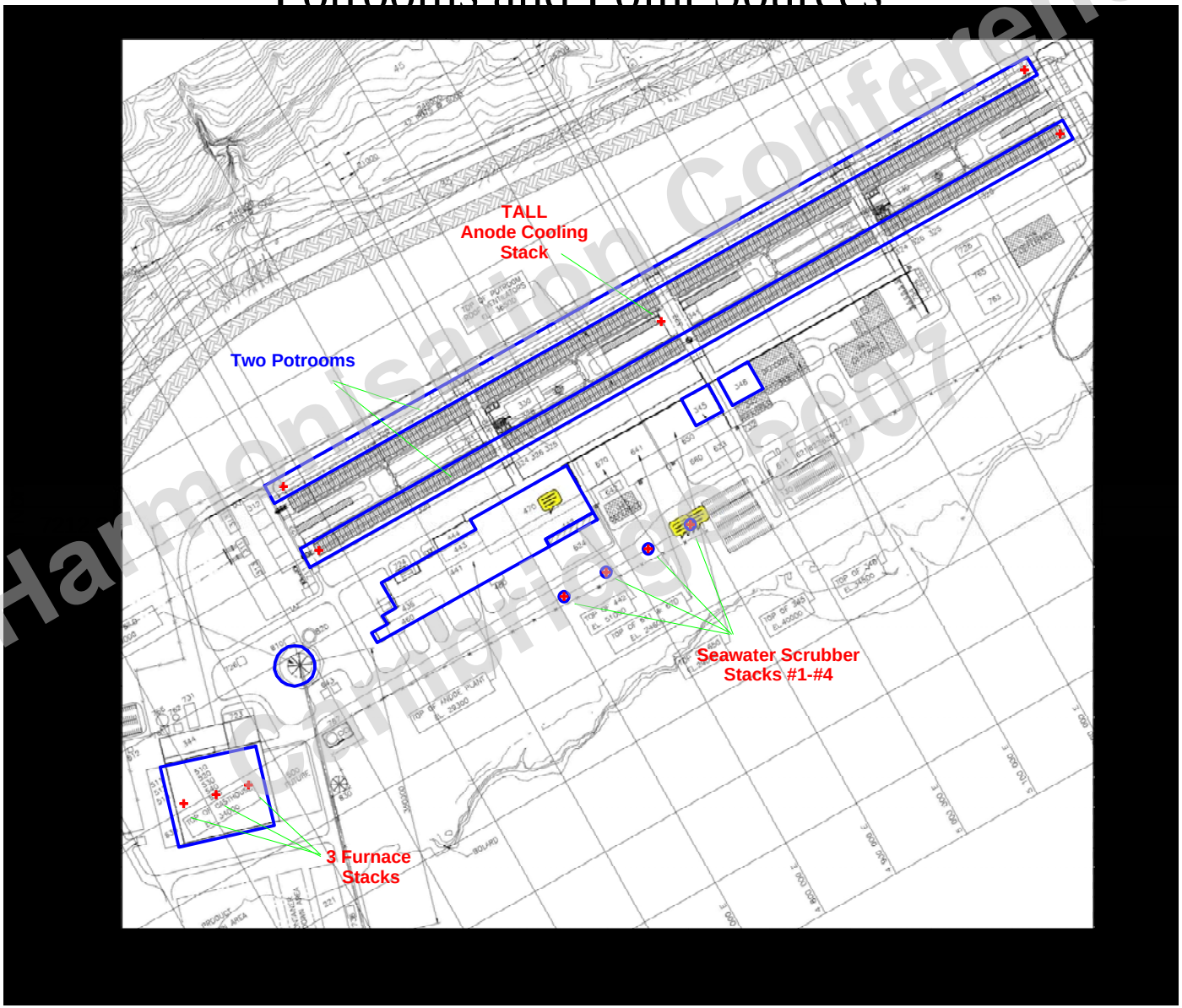




Conclusions - Meteorological Modelling

- Importance of evaluation of model performance
  - METEVAL software package
- MM5 grid resolution required to resolve land-water boundary was more constraining than that needed to resolve terrain
- MM5 performed reasonably well at 1 km grid spacing in reproducing observed diurnal and seasonal flow patterns

Complex Source Configuration - Layout of Potrooms and Point Sources



Major Modelling Issues

- Buoyant line sources
  - Plume rise from line source is different than point sources
    - Point source plume rise: $\sim F^{1/3} X^{2/3}$
    - Line source plume rise: $\sim F^{1/2} X$
  - Function of wind-direction, number of line sources, spacing between lines and buoyancy parameter
  - Multiple source plume rise enhancement
  - Building downwash effects
- Buoyant point sources
  - Building downwash effects

Major Modelling Issues

- Complex dispersion situation
  - Terrain-plume interactions
  - Plume impingement
  - Overwater and over-land boundary layers
  - Strong inversion conditions
  - Coastal fumigation and inversion breakup conditions
  - Light wind speed/calm wind dispersion
  - Strong spatial inhomogeneities in wind and turbulence fields

Dispersion Modelling Approach

- CALPUFF non-steady-state dispersion model
  - Uses 3-D meteorological fields produced by MM5/CALMET
  - Contains special buoyant line source plume rise, building downwash and dispersion algorithms
  - Complex terrain effects
  - Calm wind dispersion, fumigation effects
  - Wet and dry deposition effects
  - Overwater dispersion and coastal interaction effects
  - Dense (100m, 200m) receptor density in fiord

Representation of a line source as a series of point sources

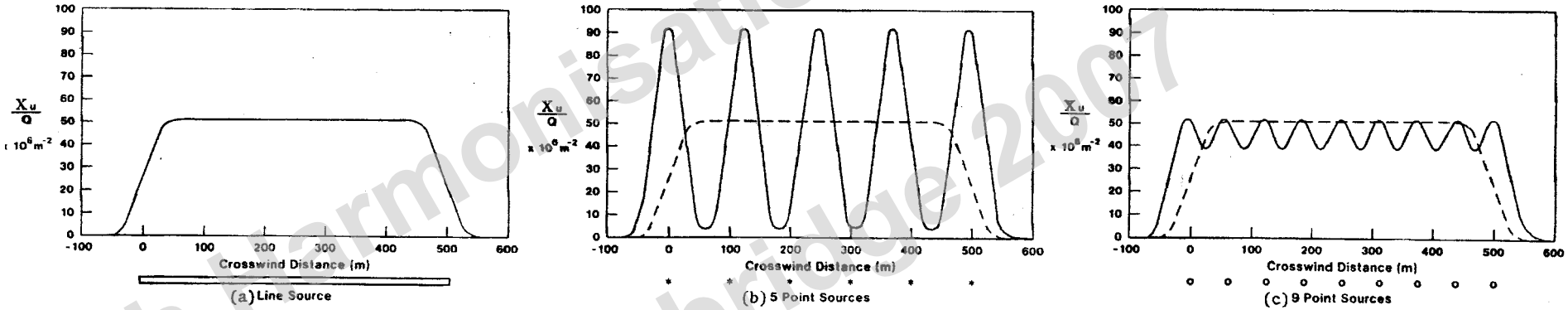
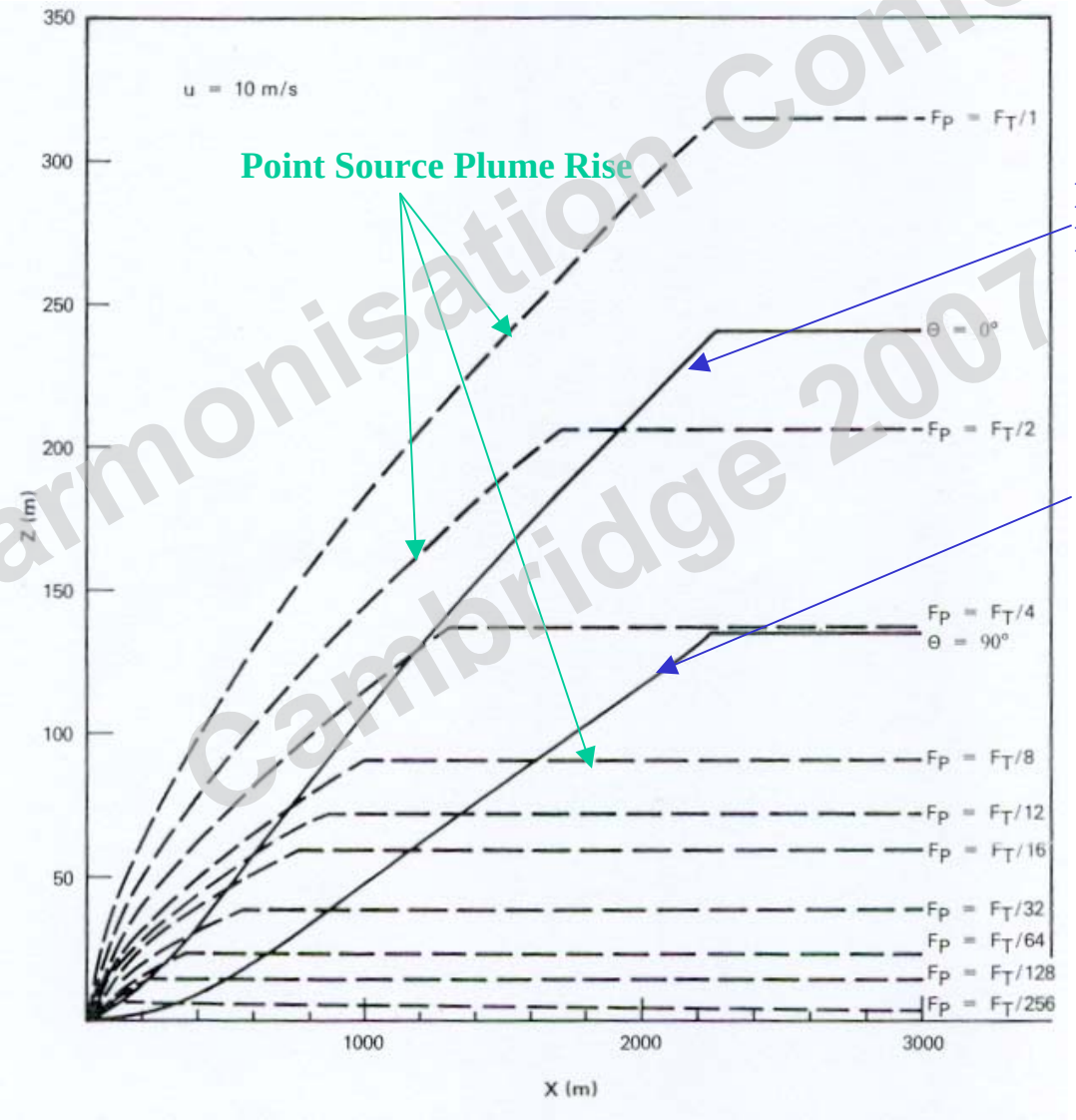
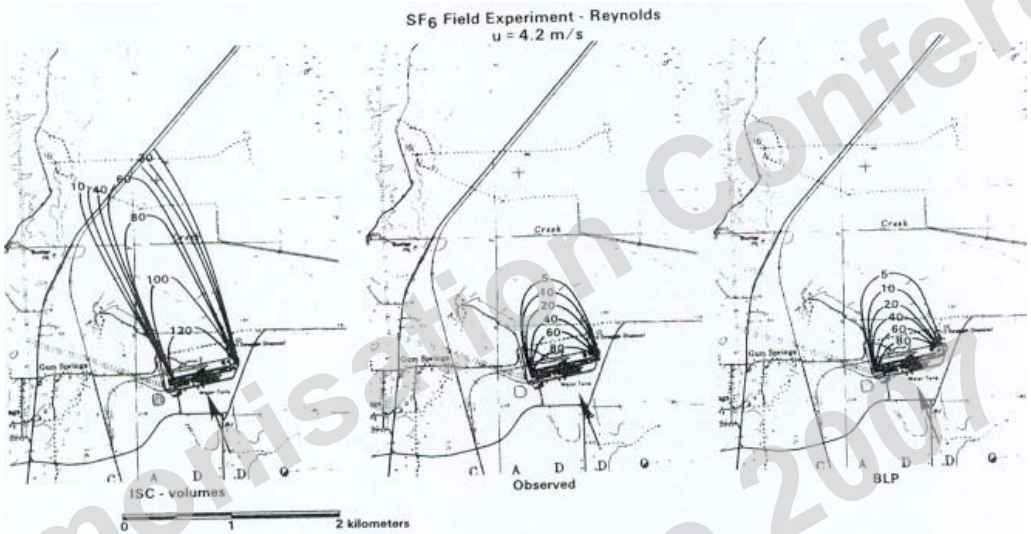


Figure 3 Crosswind line source and point source xu/Q profiles (E stability, x = 300 m).

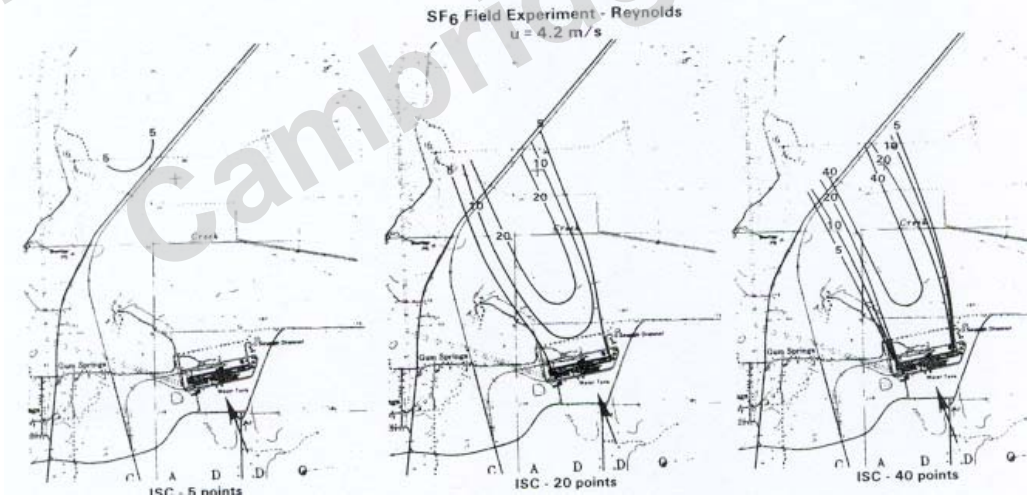
Line vs. Point Source Plume Rise



SF_6 Tracer Experiment (1979) - Comparison of Line Source Dispersion with Point/Volume Dispersion – Light Winds

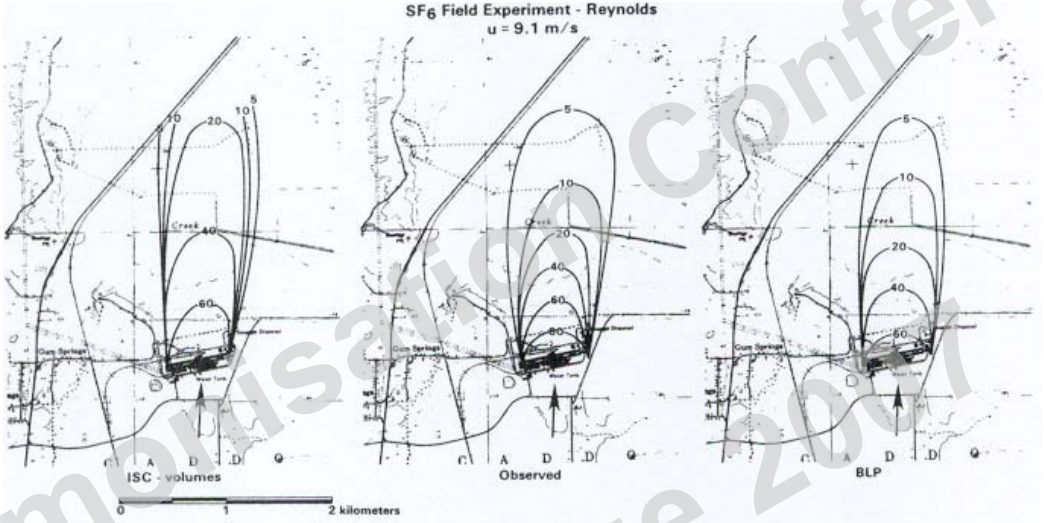


Non-Buoyant Volumes **Observed** **Buoyant Lines**

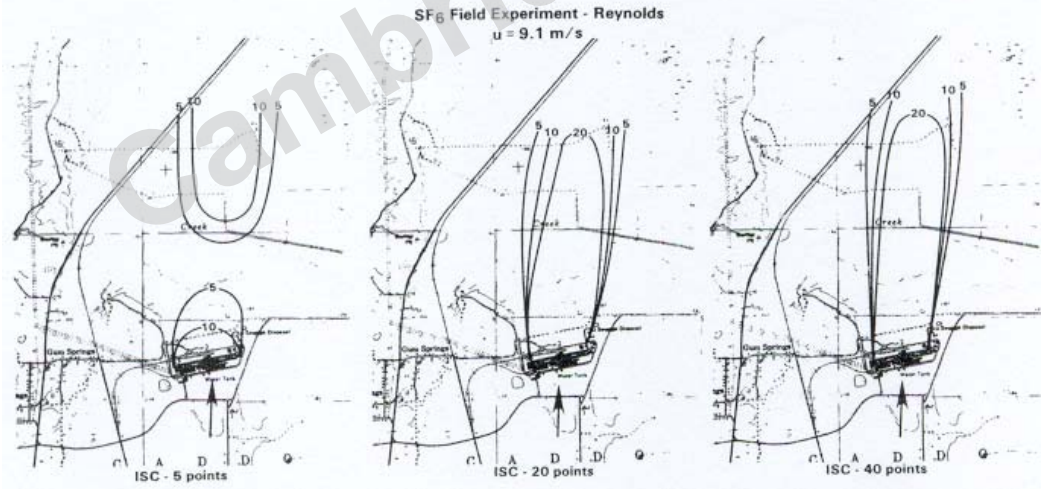


Buoyant Points: 5 pts **20 pts** **40 pts**

SF_6 Tracer Experiment (1979) - Comparison of Line Source Dispersion with Point/Volume Dispersion – High Winds



Non-Buoyant Volumes **Observed** **Buoyant Lines**



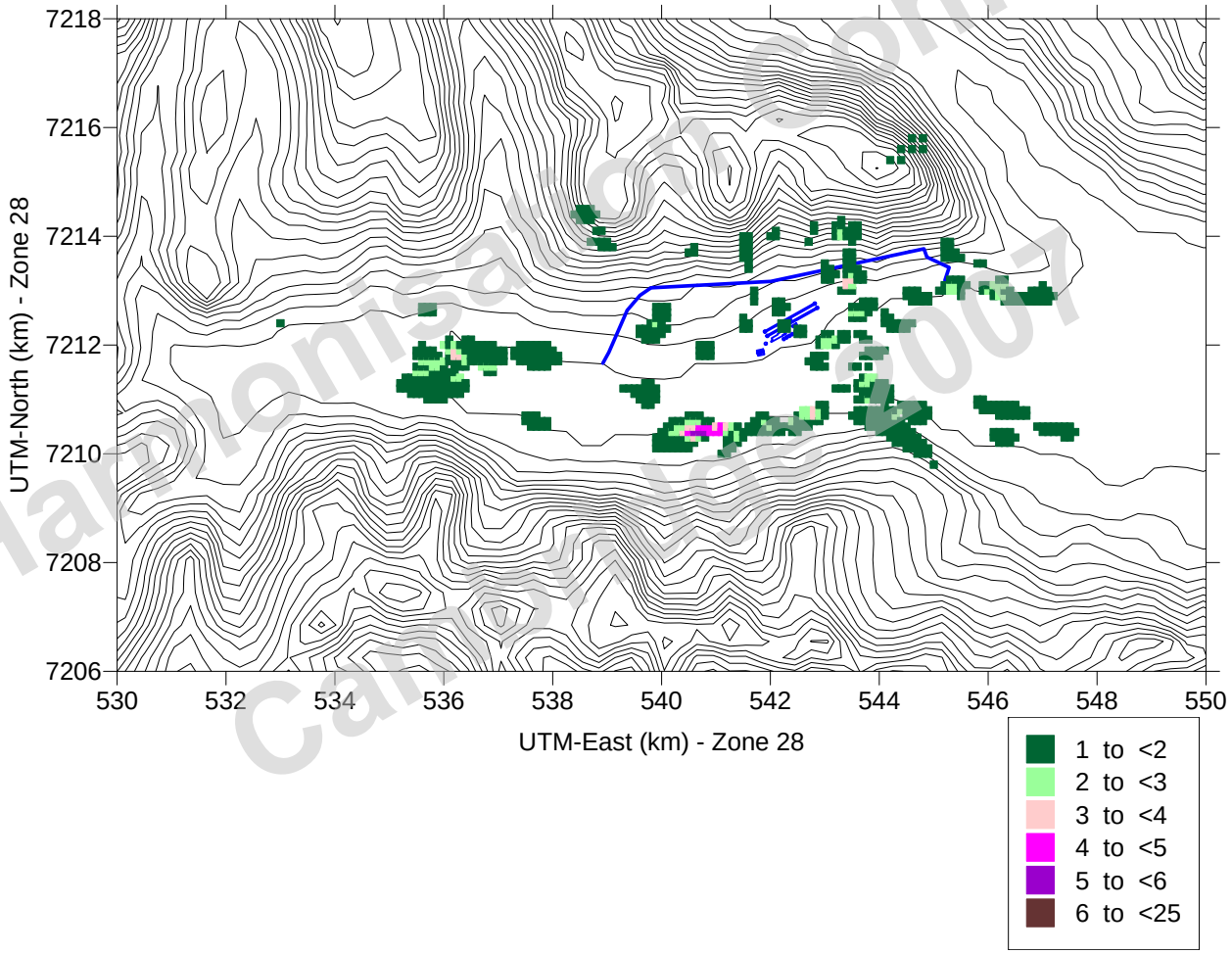
Buoyant Points: 5 pts **20 pts** **40 pts**

Conclusions on Line Source Modelling Approach

- Plume Rise
  - Line source plume rise has a different functional relationship with buoyancy and distance than point source plume rise
  - Other effects include directionality and multiple source enhancements effects
  - Cannot reproduce proper line source buoyant rise with point source model (potentially large under or over estimation of impacts, depending on N)
  - Treatment of potrooms as non-buoyant volume sources significantly overestimates concentrations

1-Hour SO_2 – Number of hours exceeding 350 $\mu g/m^3$

(Allowed exceedances: 24/year)



Conclusions - Dispersion Modelling

- Ability to treat line source dispersion and plume rise properly is critical
  - Line source plume rise cannot be represented with traditional point source equations
- Concentration patterns reflect impact of terrain channeled flow, recirculation, convergence and overwater transport
- High impact areas at base of fjord and across water on opposite shore