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Methods to assess uncertainty of wind resource estimates determined by mesoscale modelling

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Risø DTU
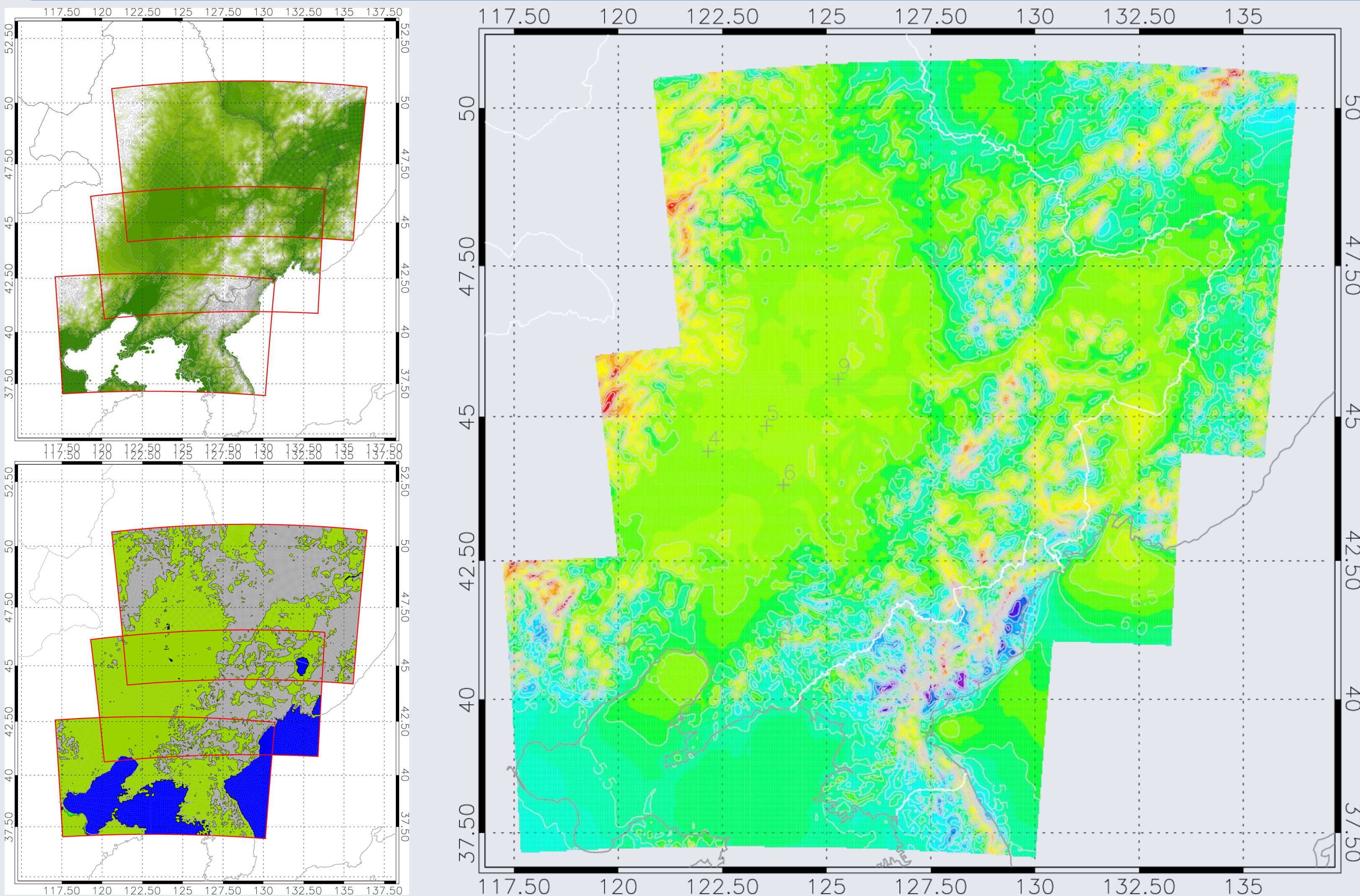National Laboratory
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Figure 1: Mean wind speed at 100 m (main map) and calculation domains' orography (left upper) and surface roughness length (left lower). Locations of wind measurement masts are shown by + symbols and labelled 1-9.
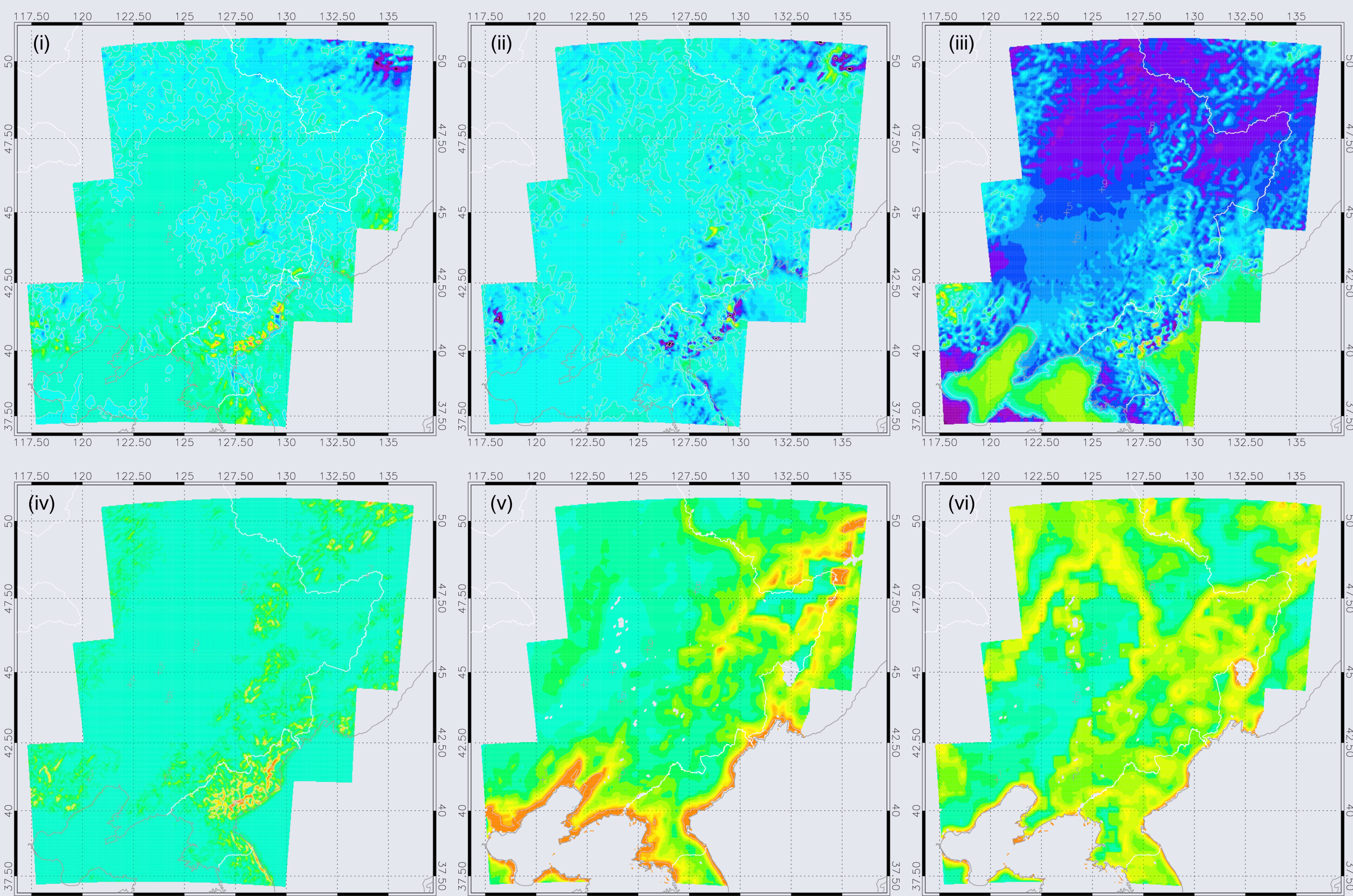

Figure 2: Sensitivity maps showing for (i)-(iii) deviation from control (~130 wind classes) for runs using (i) 3 stability classes, (ii) 350 wind classes, (iii) warmer-land-cooler-sea, and for (iv)-(vi) sensitivity indices based on (iv) horizontal mean wind speed gradient (v) orography complexity and (vi) roughness length complexity.
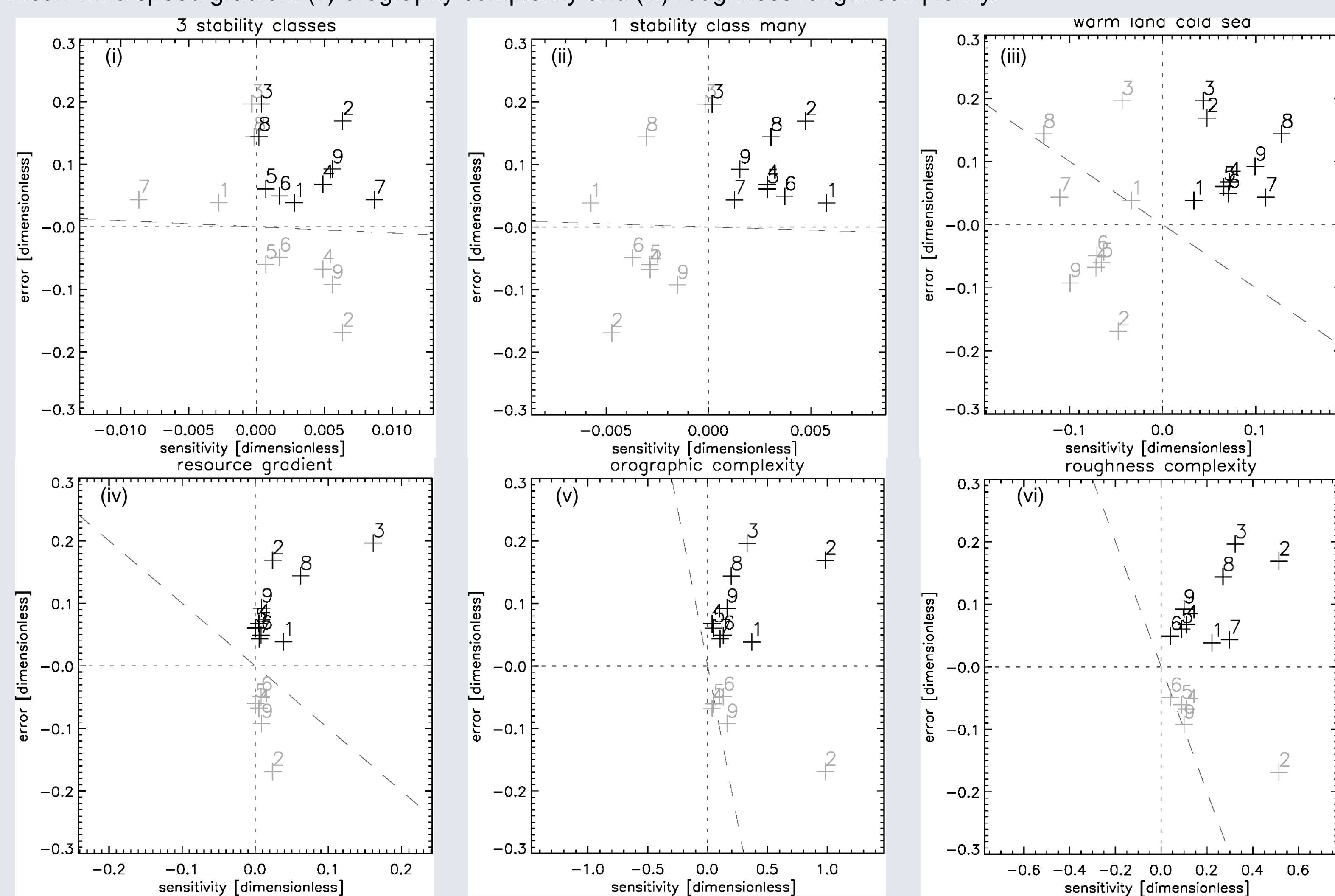

Figure 3: Plots of measured error against sensitivity (grey) and absolute error against absolute sensitivity (black), based on the same sets as in Figure 2, for measurement masts labelled 1-9.
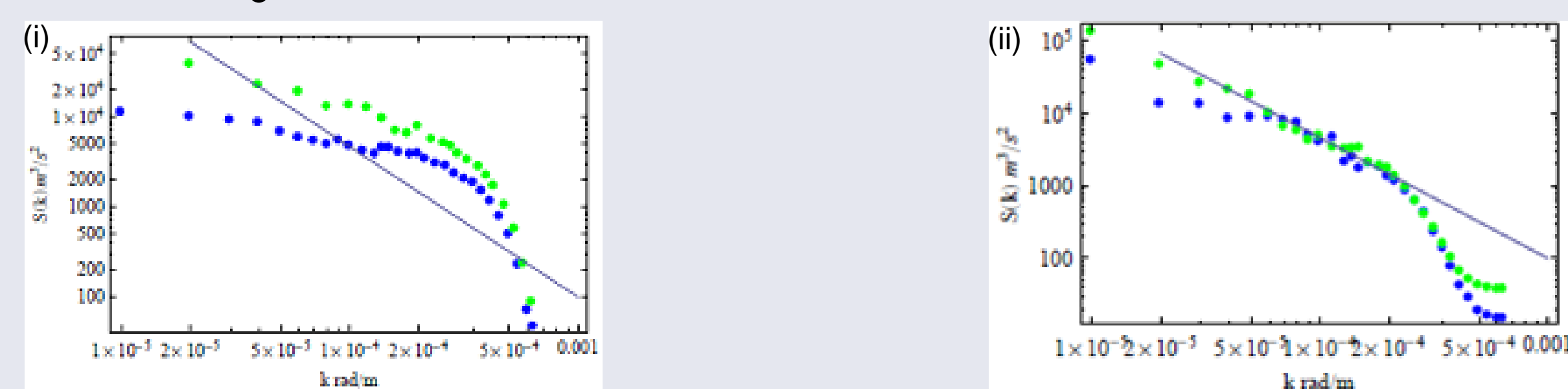

Figure 6: Spatial spectral energy density of the mean wind speed fluctuation as function of wave number for a single domains using (i) KAMM and (ii) WRF/WERAS. The solid line indicates a slope of -5/3.

Abstract

What is the uncertainty of a wind resource map? The numerical wind atlas methodology developed at Risø DTU and based on KAMM[2] mesoscale modelling has been used in a large number of different configurations in order to estimate the sensitivity of the wind resource assessment on the set-up of the model system. A number of physical phenomena provide mechanisms for creating areas with a locally high sensitivity, or conversely, areas with locally low sensitivity to adjustment in the model system. Here, these sensitivities, as well as horizontal gradient of mean wind speed and measures of topographical complexity, are used to estimate an uncertainty map of the wind resource calculation.

Method and Results

The idea is to relate model sensitivities, wind climate gradients and topographical complexity to uncertainty in the final wind resource estimate. Within the Dongbei wind mapping project[1], verification of numerical wind atlas results against measured wind climates using the WAsP generalization process[3] at 9 sites was carried out. The calculated climatological mean wind speed at 100 m is shown in Figure 1.

A selection of model sensitivities is shown in Figure 2. The sensitivities have different magnitude and sign for different locations in the region of interest. In Figure 3 the measured error is plotted against the sensitivity at the 9 sites. There is a significant scatter of the data points, which suggests that the error is made up of many contributions from different sensitivites, or indeed that the error may be unrelated to the sensitivity.

Figure 4 (i) is a schematic plot showing a hypothetical relationship between sensitivity and error. For locations with low absolute sensitivity there is a low (no-zero) absolute error, and increasing sensitivity gives increasing error. The plot also shows the appropriateness of taking the absolute values of error and sensitivity; also plotted in Figure 3.

$$|\varepsilon_{\mathrm{pred}}| = \alpha_0 + \sum_{i=1}^{N} \alpha_i |S_i|$$

Linear regression is used to find combinations of sensitivities to yield error estimates. Only combinations with positive coefficients are permitted. Results from two combinations are given in Figure 4 (ii) and (iii). The multicorrelation is 0.760 and 0.854, respectively. Applying the linear relationships for the whole area of interest gives estimated uncertain maps given in Figure 5.
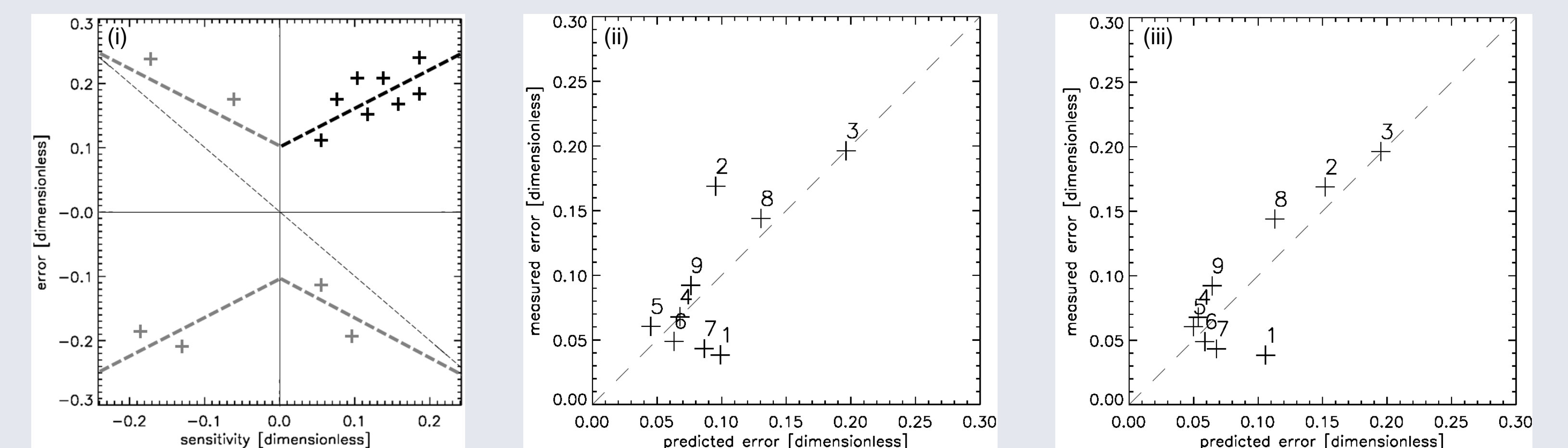

Figure 4: (i) Schematic of error plotted against sensitivity, (ii) and (iii) measured absolute error plotted against estimated error derived from linear regression based on sensitivities to (ii) stability classes, number of wind classes, warmer-land-cooler-sea and horizontal mean wind speed gradient, and (iii) horizontal mean wind speed gradient, orography complexity and roughness length complexity.
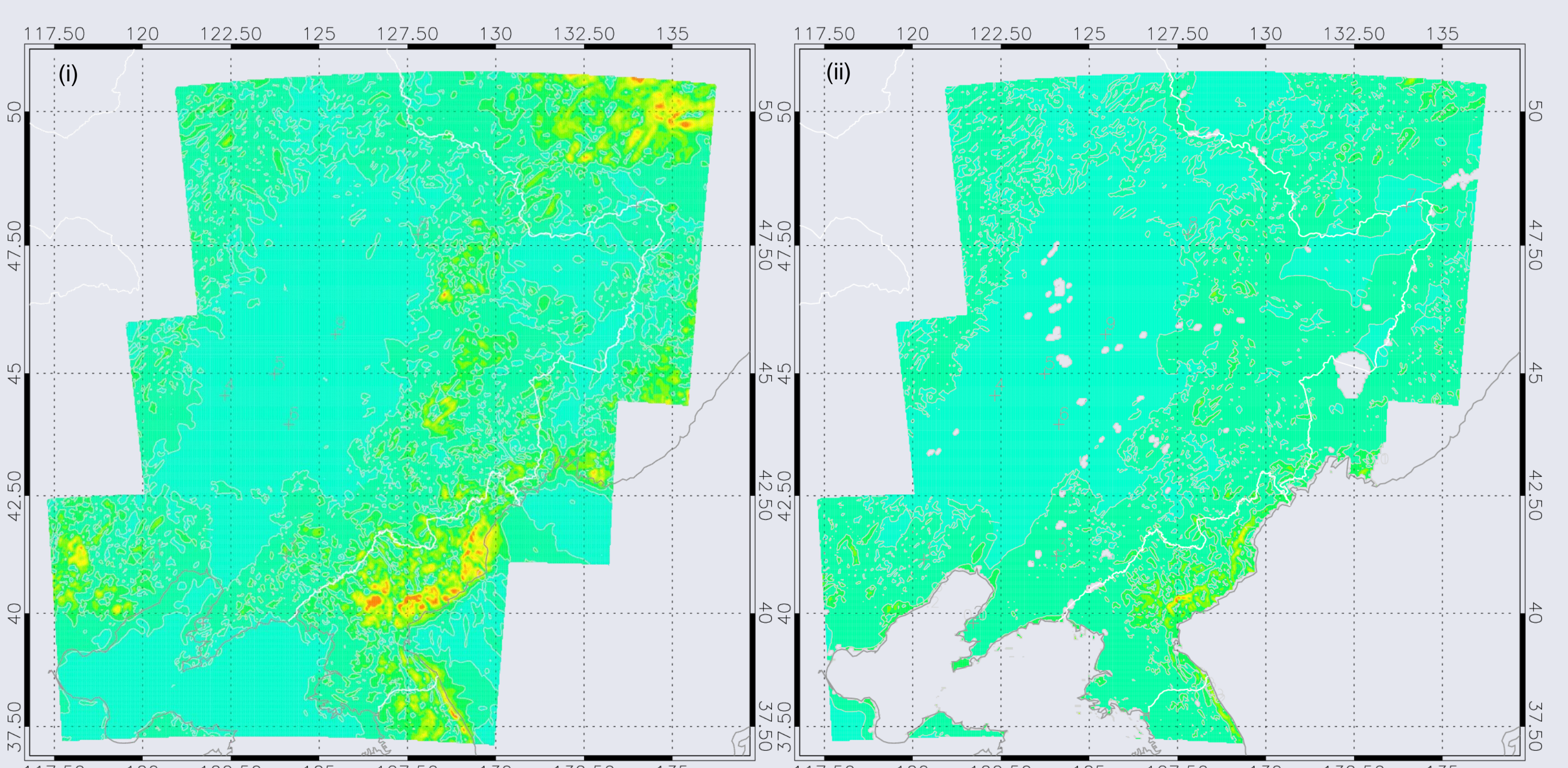

Figure 5: Estimated absolute error maps derived from linear regression based on sensitivities to (i) stability classes, number of wind classes, warmer-land-cooler-sea and horizontal mean wind speed gradient, and (ii) horizontal mean wind speed gradient, orography complexity and roughness length complexity.

Conclusions and Discussion

The uncertainty has been mapped by using a linear regression to determine a linear relationship between model sensitivity, horizontal gradient of mean wind speed and complexity of topography. Two different combinations have been used. The former has the advantage that the an uncertainty can be estimated over sea, whereas for the latter this is not possible because the topography complexity definition is not appropriate over water bodies.

A simple improvement to this study would be afforded by having a larger number of measurement masts, set in diverse locations, including over sea, so that a greater data population can be used for the linear regression. This is perhaps difficult in the standard configuration of resource assessment projects, where masts are procured and located for the purpose of estimating and verifying wind resource. To verify uncertainty estimation either a larger number of masts is required, or, less accurate but more achievable in practice, a pooling of many resource assessment projects and their associated verification studies is recommended.

The investigation of error and causes of error can benefit from another important technique to characterize the wind resource maps via inspection of the horizontal spectra of mean wind speed maps. This allows for identification of model limits, related to spatial resolution and also introduction of errors inherent in the estimation methodology. Figure 6 shows the spectra of KAMM/WAsP[3] and WRF/WERAS[4]. At large wavenumber it is seen that KAMM/WAsP has more energy compared to WRF/WERAS, perhaps indicative of a less diffusive model or an issue with model spin-up. At low wavenumber KAMM has less energy than WRF/WERAS, perhaps indicative of missing variance at synoptic scales due to the way the mesoscale model is forced by sets of horizontally uniform winds. The investigation of spectral aspects of resource estimation will need to be pursued further in current and future wind resource assessment studies.

Acknowledgements and References

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