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Weather Intelligence
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Scale-dependent evaluation of mesoscale low-level winds obtained with ALADIN MNWP model

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Introduction

In the complex terrain of eastern Adriatic where wind climate is governed by regional and local winds, it is beneficial to utilize a chain of numerical models to refine wind predictions. Verification of these mesoscale flows is a challenging task for which adequate moment-based and spectral approaches must be unified and combined.

Objectives

- to determine whether an increase of model horizontal resolution and/or complexity improves the wind forecast accuracy
- to quantify contributions of different sources of error to RMSE and assess changes with model horizontal resolution
- to perform a scale-dependent model evaluation by spectral decomposition in the frequency domain and relate various spectral scores with the sources of RMSE

Data and methods

Statistical and spectral verification were performed for three different model versions (Tab1.) using measured 10-min wind speed and direction data from Jasenice, Šibenik and Ogulin stations (Fig1.) in period 2010-2012.

For moment-based evaluation we address uncertainty both in time and space („double-penalty" error) by decomposing the RMSE[2]:

$$\overline{(f-o)^2} = (\bar{f}-\bar{o})^2 + (\sigma_f-\sigma_o)^2 + 2\sigma_f\sigma_o(1-r_{fo})$$

where first term on the right side stands for the bias of the mean (BM), second term for the bias of the standard deviation (BSD) and third term for dispersion or phase error (PHE).

For spectral analysis and verification we study: 1) kinetic energy spectra at levels in lower, middle and higher troposphere and 2) near-surface power spectral density (PSD) functions of modelled and observed data.

To assess the relative strength of circulation of diurnal and other periods, we have devided enitre spectral range into the following bands[3]: 1) sub-diurnal (SUB; 6 h < T < 22 h), 2) diurnal (DIU; 22 h < T < 26 h) and 3) larger than diurnal (LTD; 26 h < T < 7 d).

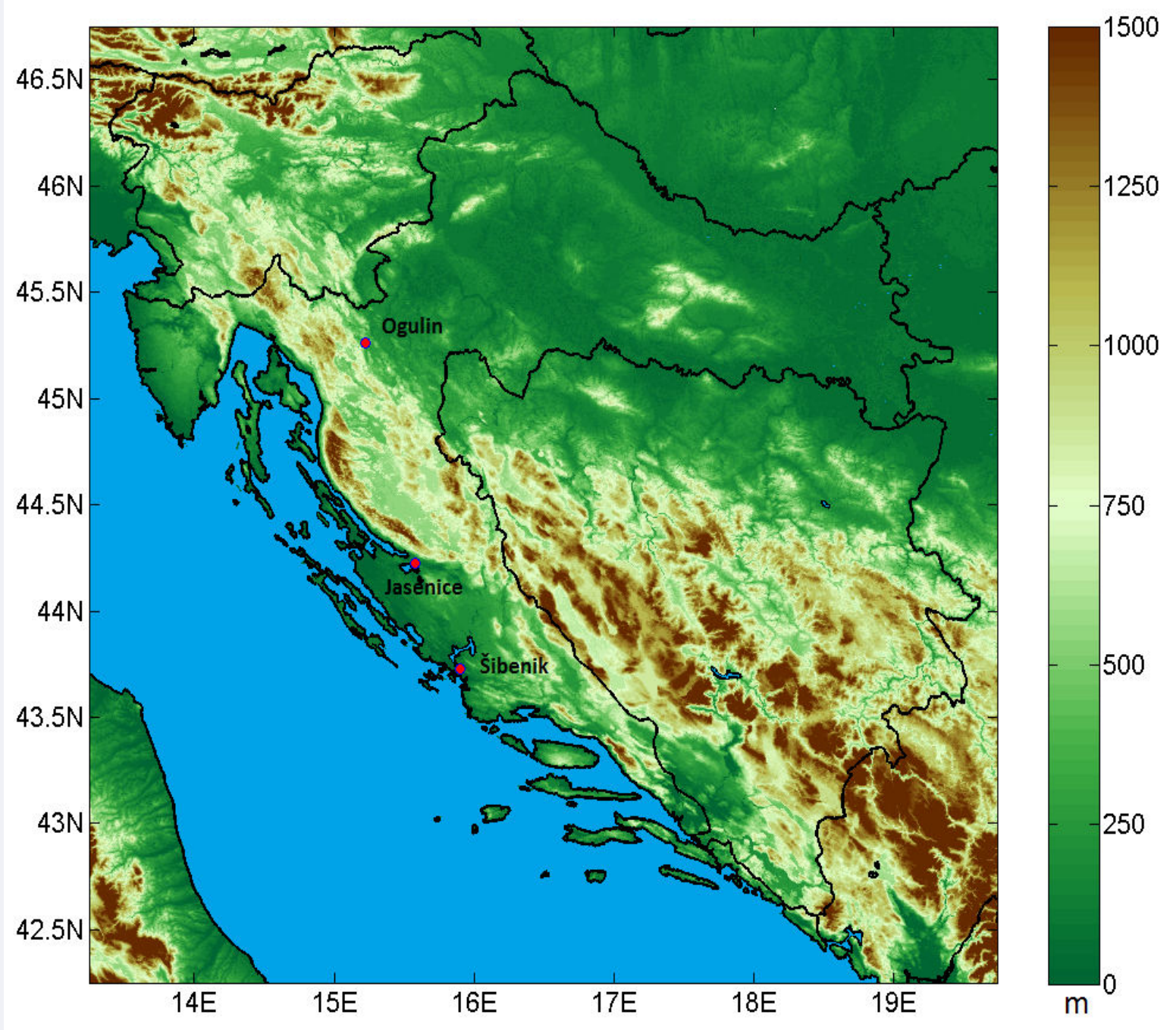

Fig1. Location of representative stations inside Croatian territory.

Model	AL8-ALADIN / ALARO 8 km	DA2-ALADIN / DADA 2 km[1]	AL2-ALADIN / ALARO 2 km
Cycle	AL32T3	AL29T2-mxl	AL36T1
Type	hydrostatic	hydrostatic	non-hydrostatic
Grid points	229 x 205	439 x 439	439 x 439
Vert. levels	37	15	37
Initialization	00 UTC	00 UTC	00+06 UTC
Range	72 h	72 h	24 h
Output-LBCf	3 h	3 h	1 h
Spin-up allowed	9 h	9 h	3 h

Table1. Basic information about verified model versions with spin-up period based on lead time dependant KE spectra analysis.

Results

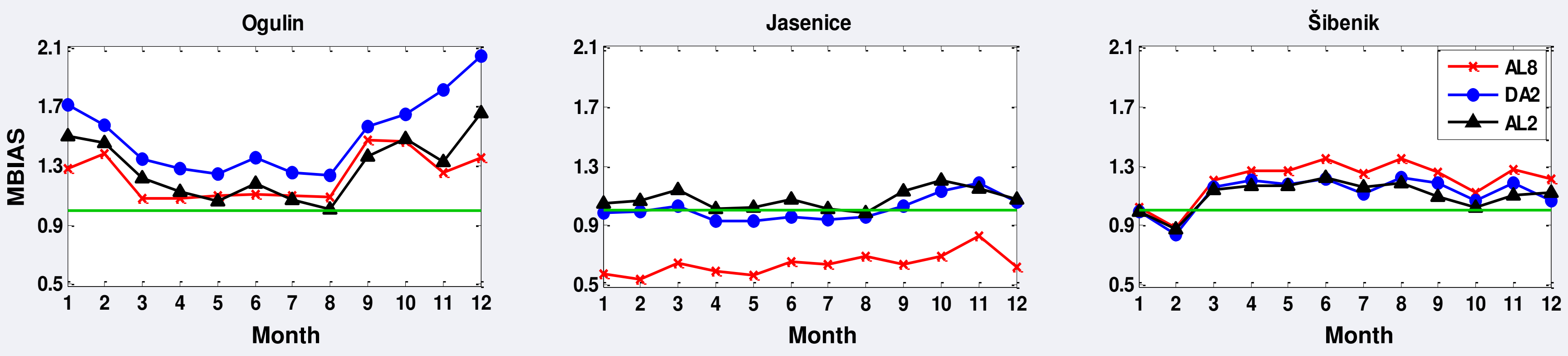

Fig2. Monthly averaged values of MBIAS for ALADIN/ALARO 8 km (AL8), ALADIN/DADA 2 km (DA2) and ALADIN/ALARO 2 km (AL2) forecasts at representative stations (green line points out to the ideal value of MBIAS which equals one – no systematic error).

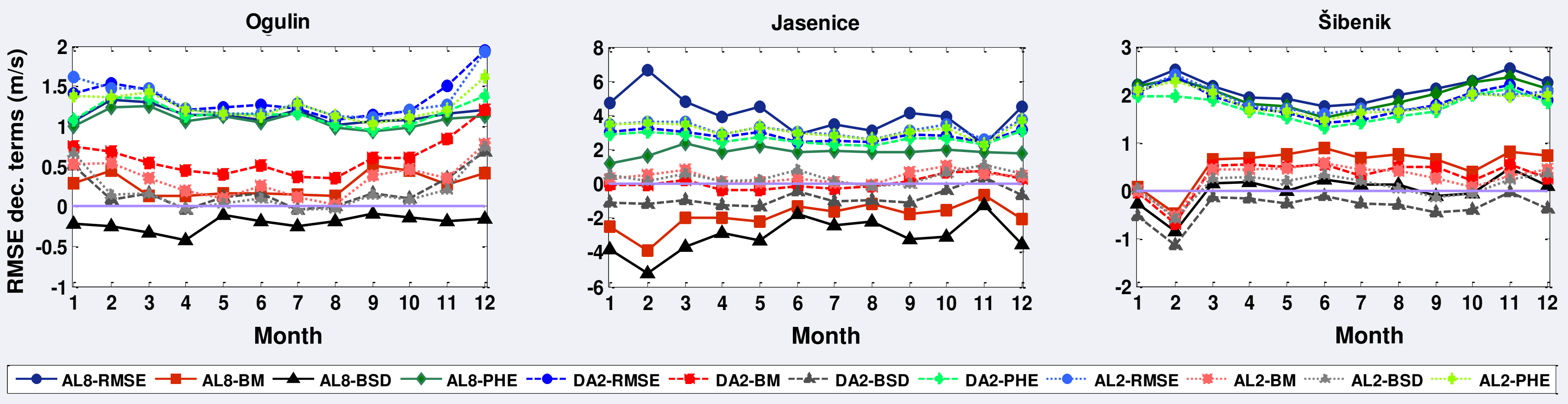

Fig3. Monthly averaged values of RMSE components for ALADIN/ALARO 8 km (AL8), ALADIN/DADA 2 km (DA2) and ALADIN/ALARO 2 km (AL2) forecasts at representative stations (violet line points out to the ideal value of RMSE which equals zero – no error).

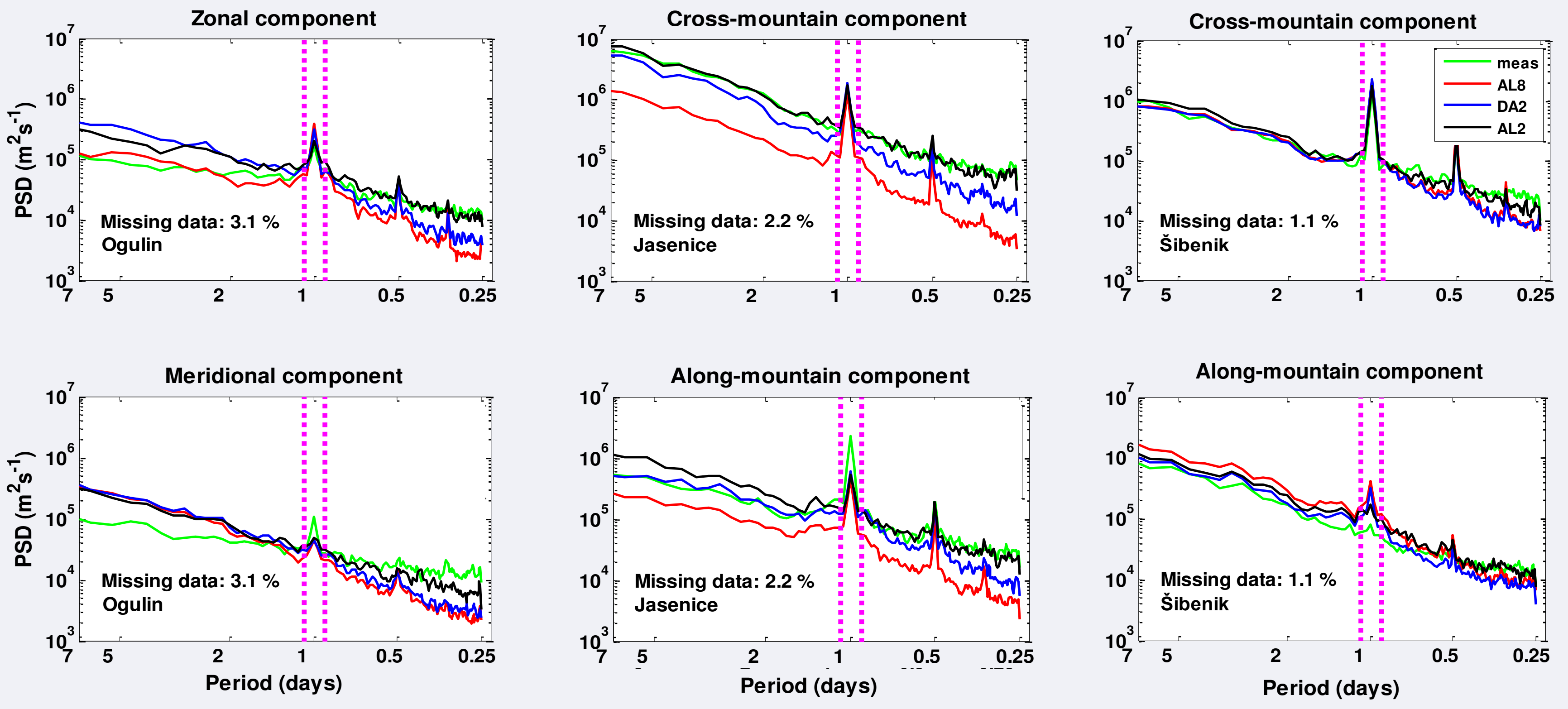

Fig4. Power spectral density (PSD) of zonal and meridional wind component (Ogulin station) and cross/along-mountain wind components (Jasenice and Šibenik stations) for measurements (meas), ALADIN/ALARO 8 km (AL8), ALADIN/DADA 2 km (DA2) and ALADIN/ALARO 2 km (AL2) forecasts.

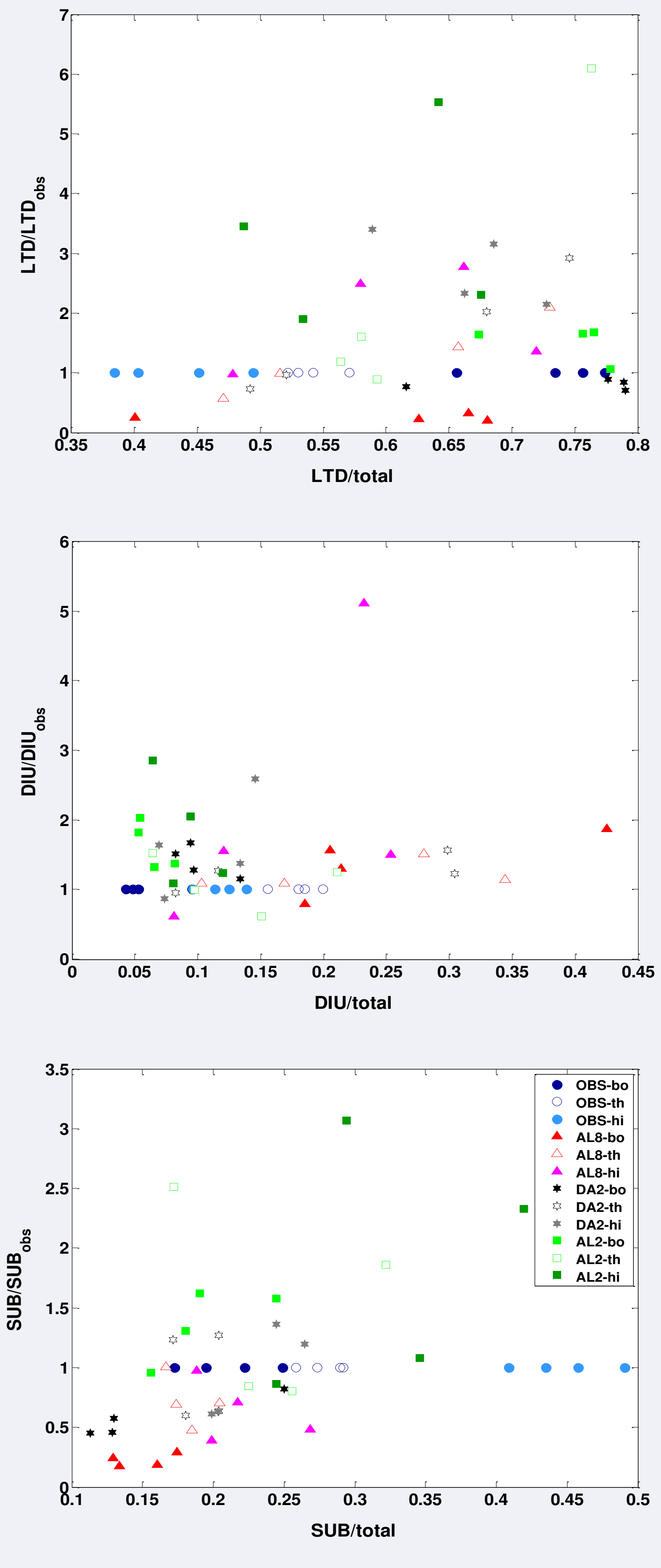

Fig5. Spectral power at each station in larger than diurnal (LTD), diurnal (DIU) and sub-diurnal (SUB) spectral bands normalized by the spectral power in the same spectral range of observations plotted against the share of power in particular spectral band. Figure legend associates symbols to various data sets (modeled or observed) and groups of stations (bo - bora dominated coastal stations, th - coastal stations with significant portion of thermally driven flows and hi - highland valley and mountain stations).

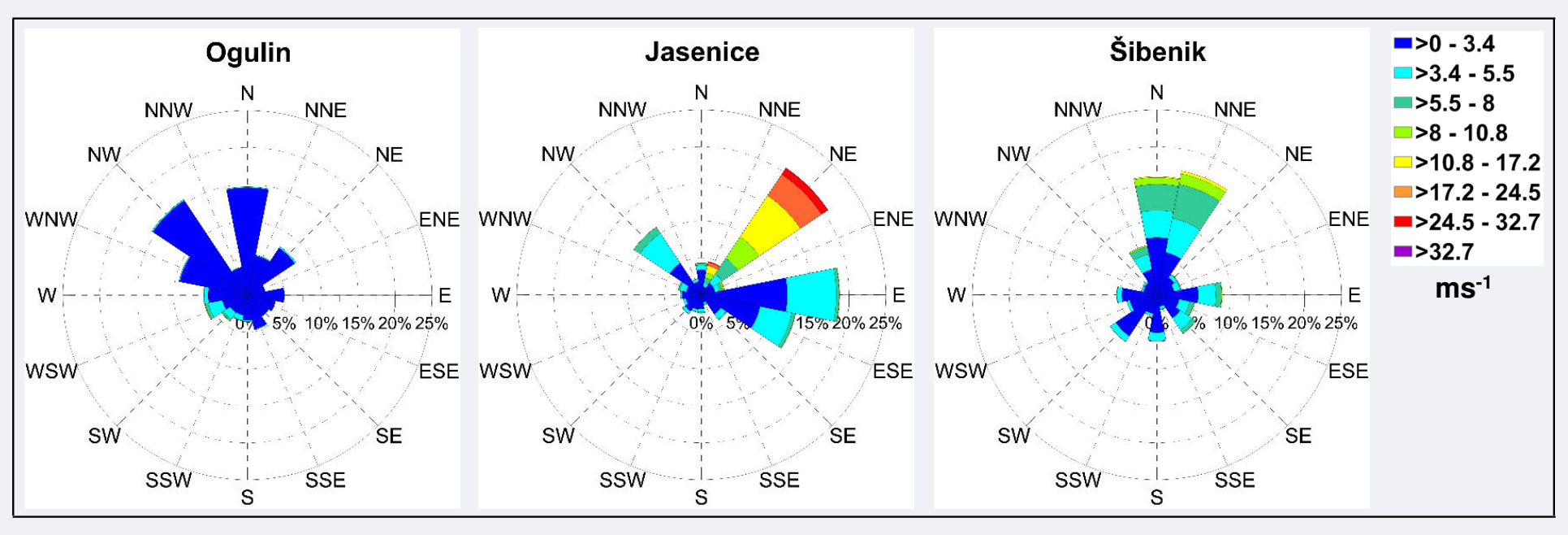

Fig6. Wind roses for representative stations of groups with different wind regimes.

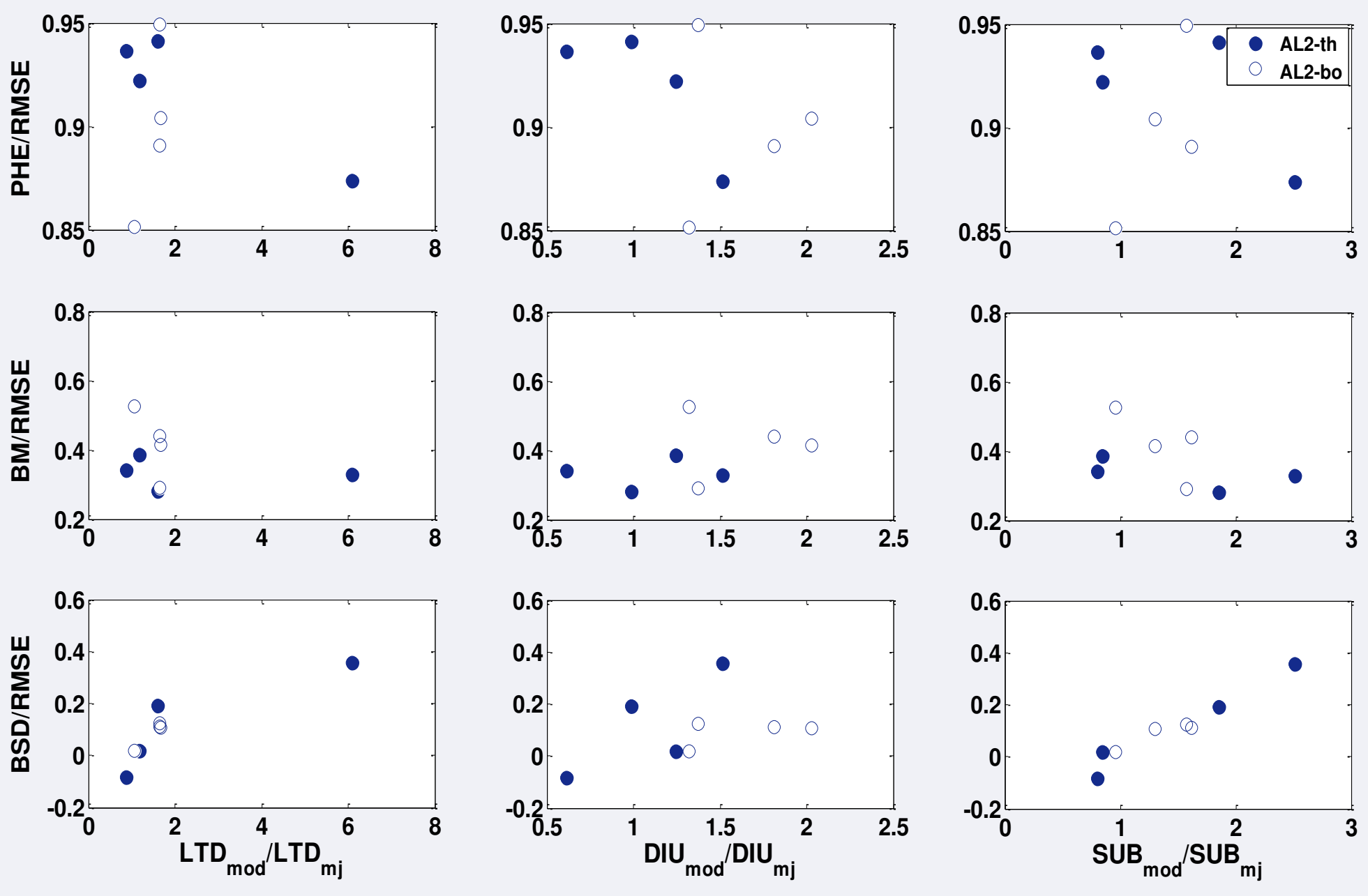

Fig7. Share of individual RMSE components at each station for the ALADIN/ALARO 2 km (AL2) forecasts plotted as a function of the ratio of modeled and observed spectral power in larger than diurnal (LTD), diurnal (DIU) and sub-diurnal (SUB) spectral bands.

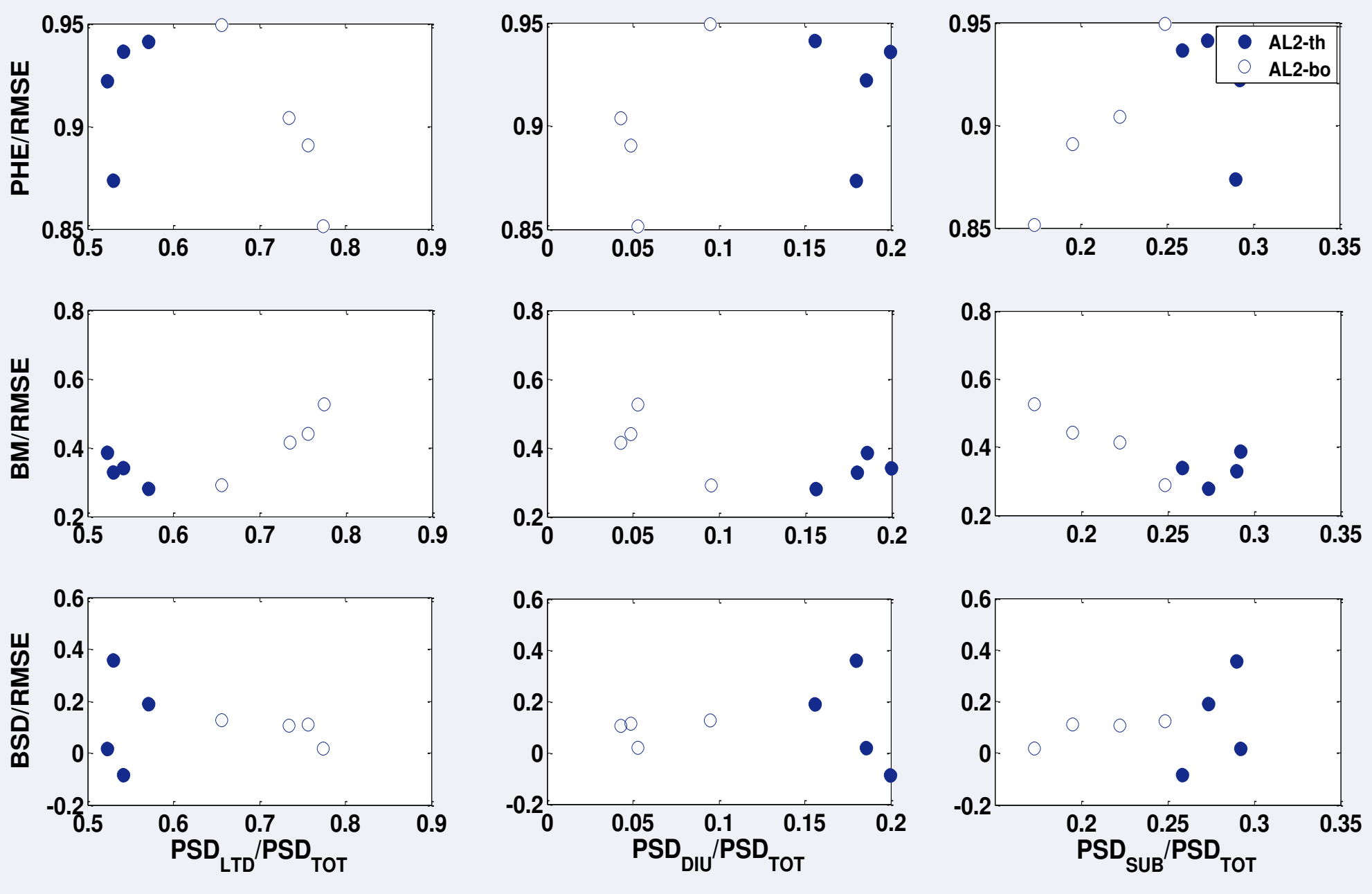

Fig8. Share of individual RMSE components at each station for the ALADIN/ALARO 2 km (AL2) forecasts plotted as a function of the share of observed spectral power in larger than diurnal (LTD), diurnal (DIU) and sub-diurnal (SUB) spectral bands.

Based on wind climate characteristics (Fig6.) and spectral decomposition in the frequency domain (Fig4-5.) we have classified 12 stations in three different groups. So, here we present the results for representative stations of these groups.

Increasement of horizontal resolution of DA2 and AL2 forecasts has led to improvement (decrease of MBIAS and RMSE) over AL8 at two coastal groups of stations (Fig2-3.). Phase errors are major source of RMSE (Fig3.) and their contribution generally increases with horizontal resolution and complexity.

Spectral decomposition in the frequency domain (Fig4-5.) suggests that the most significant increase of accuracy with more complex model at 2 km grid spacing was found for diurnal and sub-diurnal periods of motions in the cross-mountain direction.

AL2 model ability to propery simulate the amount of spectral power in different spectral bands is highly correlated with the share of BSD (Fig7.). Significant relationship between the share of observed power by spectral bands and the share of RMSE components was found only for bora dominated stations (Fig 8.).

References

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2. Horvath, K., Koračin, D., Vellore, R., Jiang, J. And Belu, R. 2012.: Sub-kilometer dynamical downscaling of near-surface winds in complex terrain using WRF and MM5 mesoscale models, *J. Geophys. Res.* **117**, D11111, doi:10.129/2012JD017432
3. Rife, D. L., Davis, C. A. and Liu, Y. 2004.: Predictability of low-level winds by mesoscale meteorological models, *Mon. Wea. Rev*, **132**, 2553-2569.

Conclusions

Based on various statistical scores and spectral measures, it was found that increase of horizontal resolution and model complexity improves the wind forecast accuracy in coastal part of Croatia, especially at bora dominated stations.

The largest portion of RMSE errors can be attributed to phase errors, whose share increases with model horizontal resolution and complexity.

Spectral analysis in the frequency domain has shown that the most significant increase of accuracy was found for diurnal and sub-diurnal periods of motions in the cross-mountain direction.

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