P3.1

Wind Forecast Verification during Various Bora Events at Dubrovnik Airport

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1. Introduction

Several airports are situated in the lee side of the Dinaric Alps where the bora flow is well-known. Bora reduces air traffic operations especially if its direction is perpendicular to the runway direction as is the case at Dubrovnik airport (LDDU). Surrounded by very complex terrain at the Adriatic coast, its position is ideal for studying this complex type of flow.

The Terminal Aerodrome Forecast (TAF) is important in decision making during the flight planning process. Forecasters are not focused on model prediction of the surface wind but on its vertical profile. Based on forecaster's experience the type of bora is determined empirically by applying several integral criteria.

The main goal is to find the climatology, model and TAF verification depending on the type of bora.

2. Data and method

Data 2009-2014 :
ALADIN wind profile for LDDU (38 vertical levels, 8km horizontal resolution)
METAR LDDU (observation report)
TAF LDDU (Terminal Aerodrome Forecast for 24h)

Bora type classification (based on ALADIN wind profile (+6-+17) extended from (Drobac 2006))

1. Criteria for one hour
   - Nocturnal gap flow („burin"): u' (*1) (<250m) mean>=2.5ms^{-1} and max<5ms^{-1} and absolute max v' component (250-1100m) <5ms^{-1} and hour between 6-18UTC
   - Bora: u' (<1200m) mean>3m/s and max >6m/s
   - Deep bora: not jet-like(*2) and u' (1200-5500m) mean>7m/s
2. Time filter of individual events time series with function MofN (at least 3 events in 5 hours)
3. Order of final bora type time series: deep bora , bora, nocturnal gap flow

The verification method for TAF is similar to Austrocontrol's verification system, Mahringer (2008). It is based on verifying the conditions between forecast and observation for each hour. Since the criteria for cross wind (bora at LDDU) is ± 5ms^{-1}, the measure of diagonal ± 1 class is used as a performance measure.

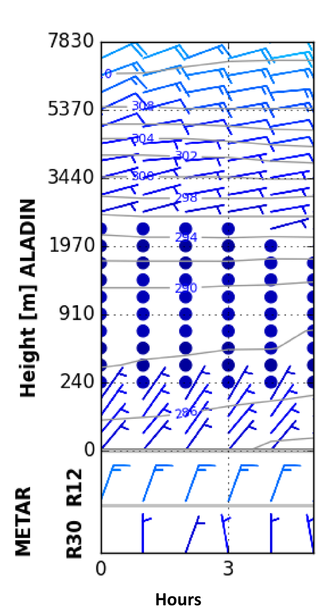
(*1) u' is rotated component to direction 020°
(*2) jet-like test: if min u' (<2500m) above max (<1200m) is less then 70%

3. Results

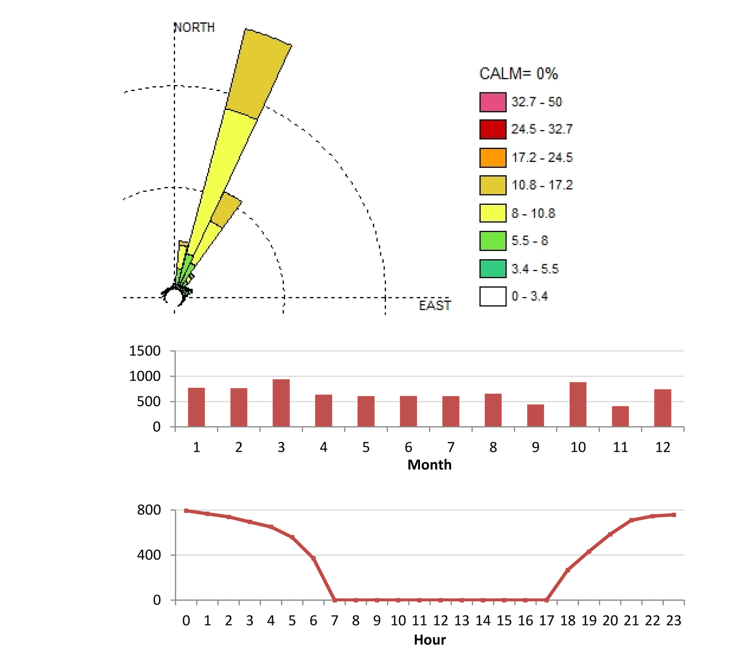
Nocturnal gap flow

Climatology

Profile example 26.10.2014.

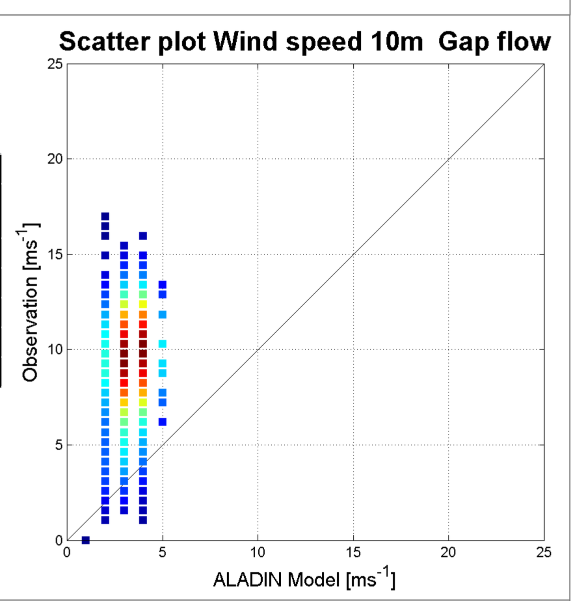


Total N' hours: 2025 (38%)



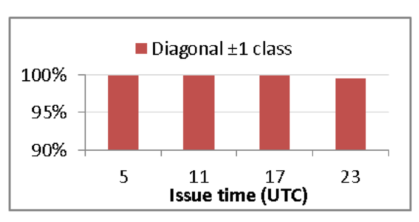
ALADIN verification

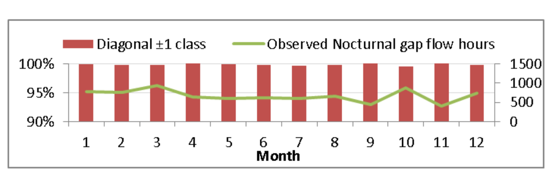
Contingency table					
FC \ OBS	<7,5	7,5-<15	15-<12,5	>=12,5	SUM
<7,5	27,1%	66,0%	6,9%	0,0%	100%
7,5-<15	0,0%	0,0%	0,0%	0,0%	0%
15-<12,5	0,0%	0,0%	0,0%	0,0%	0%
>=12,5	0,0%	0,0%	0,0%	0,0%	0%
SUM	27%	66%	7%	0%	

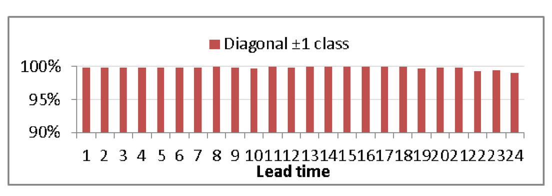


TAF verification

Contingency table					
FC \ OBS	<7,5	7,5-<15	15-<12,5	>=12,5	SUM
<7,5	12,0%	10,6%	0,2%	0,0%	23%
7,5-<15	14,9%	50,5%	5,1%	0,0%	70%
15-<12,5	0,2%	4,7%	1,6%	0,0%	6%
>=12,5	0,0%	0,3%	0,0%	0,0%	0%
SUM	27%	66%	7%	0%	



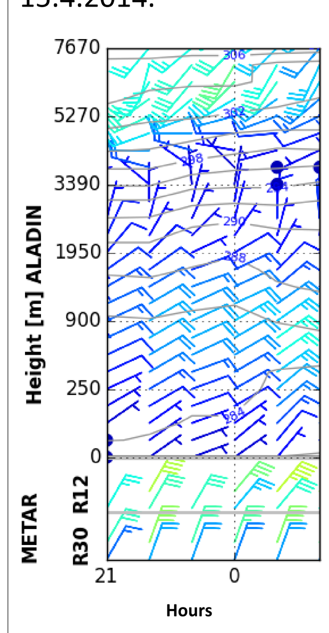




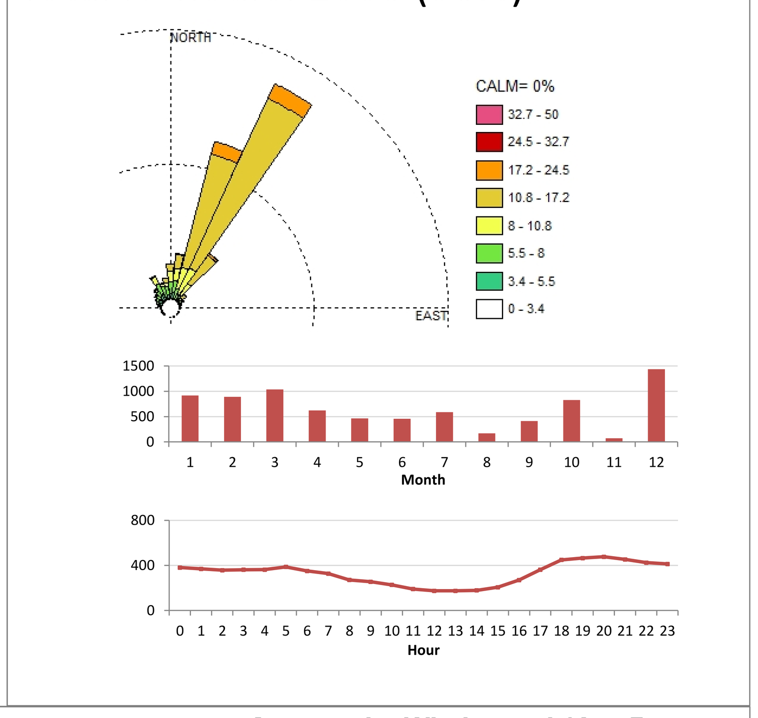
Bora

Climatology

Profile example 15.4.2014.

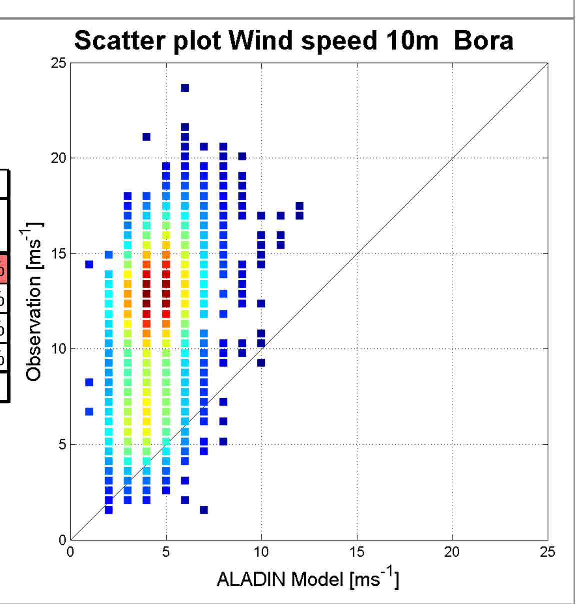


Total N' hours: 2008 (38%)



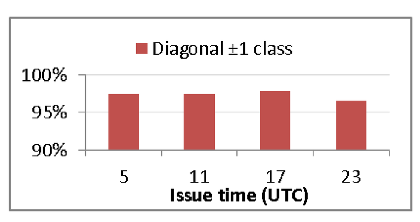
ALADIN verification

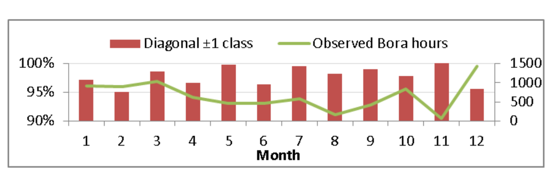
Contingency table					
FC \ OBS	<7,5	7,5-<15	15-<12,5	>=12,5	SUM
<7,5	25,6%	32,3%	34,7%	3,3%	96%
7,5-<15	0,1%	0,9%	1,9%	1,0%	4%
15-<12,5	0,0%	0,0%	0,0%	0,0%	0%
>=12,5	0,0%	0,0%	0,0%	0,0%	0%
SUM	26%	33%	37%	4%	

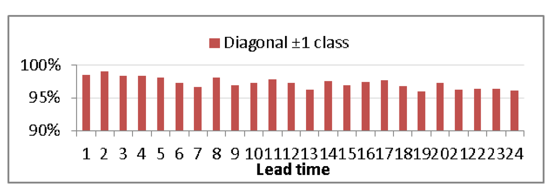


TAF verification

Contingency table					
FC \ OBS	<7,5	7,5-<15	15-<12,5	>=12,5	SUM
<7,5	4,9%	2,1%	1,0%	0,0%	8%
7,5-<15	15,9%	20,3%	14,3%	0,9%	52%
15-<12,5	4,3%	9,4%	19,6%	2,7%	36%
>=12,5	0,3%	1,1%	2,2%	0,8%	4%
SUM	25%	33%	37%	4%	



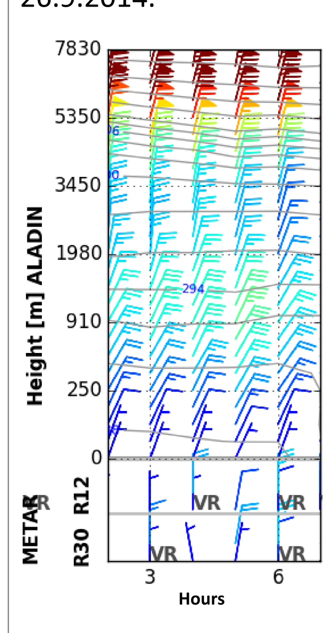




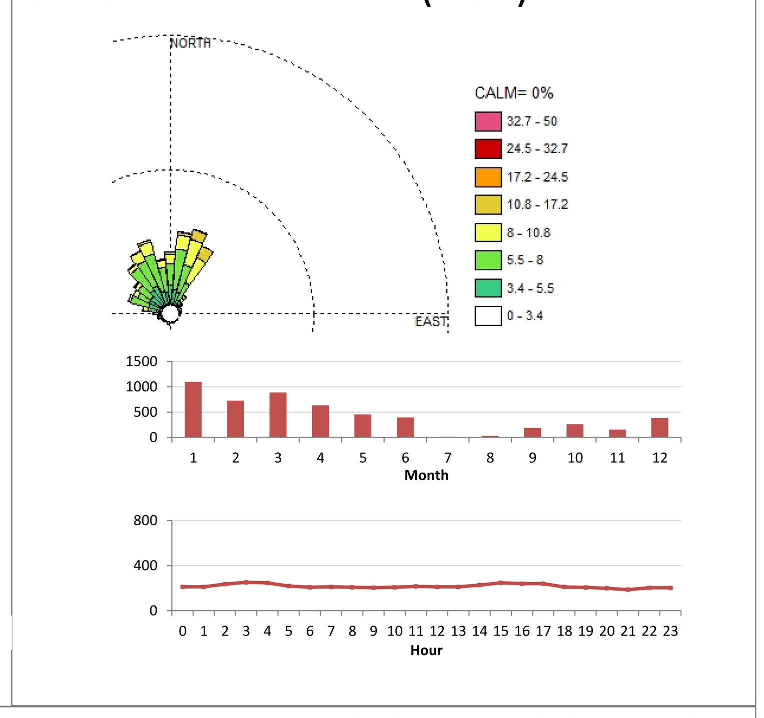
Deep bora

Climatology

Profile example 26.9.2014.

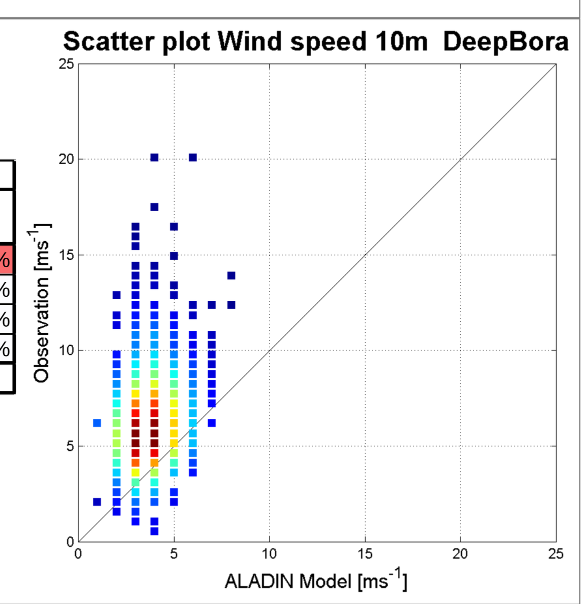


Total N' hours: 1313 (24%)



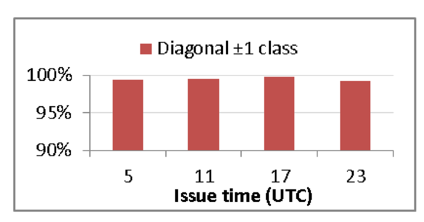
ALADIN verification

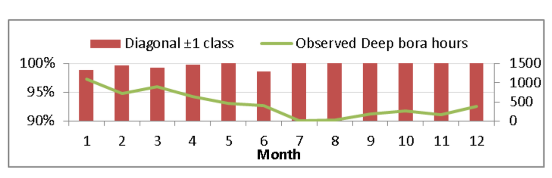
Contingency table					
FC \ OBS	<7,5	7,5-<15	15-<12,5	>=12,5	SUM
<7,5	69,2%	28,6%	1,9%	0,2%	100%
7,5-<15	0,0%	0,2%	0,1%	0,0%	0%
15-<12,5	0,0%	0,0%	0,0%	0,0%	0%
>=12,5	0,0%	0,0%	0,0%	0,0%	0%
SUM	69%	29%	2%	0%	

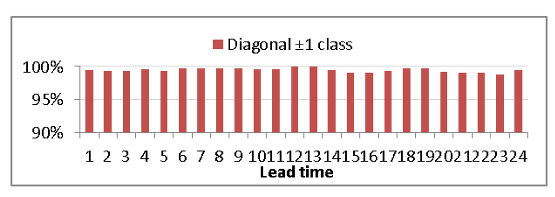


TAF verification

Contingency table					
FC \ OBS	<7,5	7,5-<15	15-<12,5	>=12,5	SUM
<7,5	20,3%	5,4%	0,1%	0,0%	26%
7,5-<15	45,1%	21,7%	1,3%	0,1%	68%
15-<12,5	3,6%	1,6%	0,4%	0,0%	6%
>=12,5	0,0%	0,2%	0,1%	0,0%	0%
SUM	69%	29%	2%	0%	







4. Discussion

ALADIN model forecasts and TAF forecasts are verified against measurements depending on the type of bora flow. In absence of low level synoptic forcing the nocturnal gap flow at LDDU often exceeds 10ms^{-1} (Klaić et all 2009). Wind speeds are underestimated by model and slightly overestimated in TAF. Nocturnal gap flow does not affect air traffic.

Standard bora is marked by a low level jet-like profile and is most prominent in cold part of the year. The observed wind speeds are almost two times higher than the modelled ones with significant scattering. TAF forecasts show significant improvements for events outside of diagonal ±1 classes (from 19% to 3%). Forecasts could be improved for 23UTC issue time, in April and December and towards the end of the forecast validity period.

Although standard type of bora shows the highest wind speed that sometimes prevents aviation traffic, deep bora is potentially the most unsafe due to observed occasional gusts that could even be three times higher than the mean wind speed (Drobac 2006).

Deep bora is more frequent in winter and spring. Its diurnal change shows lack of jet like profile during the day. While modelled wind speed is underestimated, TAF wind speeds are almost overestimated.

5. Conclusion

- **Bora flow classification was made from a forecaster point of view (from the ALADIN model)**
- **ALADIN underestimates wind speed at 10m for all types of bora flow**
- **ALADIN wind profile is very useful for forecasters in determining the type of bora and in forecasting wind speeds and gusts**
- **TAF forecasts give better verification results than ALADIN**
- **Diagnostic TAF verification results give detailed insight required for forecast improvements**

References:
Drobac, M. 2006: Neke specifičnosti ponašanja bure na području aerodroma Dubrovnik. *Jadranska Meteorologija*, **51**, 10-24.
Klaić, Z., Pasarić, Z., Tudor, M. 2009: On the interplay between sea-land breezes and Etesian winds over the Adriatic. *Journal of Marine Systems*, **78**, 101-118.
Mahringer, G. 2008: Terminal aerodrome forecast verification in Austro Control using time windows and ranges of forecast conditions. *Meteorol. Appl.*, **15**, 113–123.
Wilks, D. S., 2006: *Statistical methods in the atmospheric sciences*. 2nd edn. Academic Press, San Diego, 627 pp.