Investigation of Sea Breeze and Foehn in the Dead Sea Valley with Remote Sensing Observations and WRF Model Simulations

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Kunin, P., Alpert, P., Rostkier-Edelstein, D. Investigation of sea-breeze/foehn in the Dead Sea valley employing high resolution WRF and observations. *Atmos. Res.* 2019, *229*, 240–254

1 Introduction

-The Dead Sea (DS) valley is unique in the world because it is the lowest place on land (430 below MSL) and a very saline water body (DS) in its center

- During the summer the DS weather conditions are dominated by a complex combination of synoptic, mesoscale, and local circulation patterns
- The summer Israel climate is strongly affected by the Mediterranean Sea breeze (MSB)
- During the day the MSB flows up the Judean Mountains and drops into the DS valley in the early evening hours
- It was found that during most of the days (85%) the surface SH decreases while temperature increases (74%) at the MSB arrival time

The objectives here are:

- Investigation of MSB/foehn structure as it penetrates the DS valley
- Elucidation of cases with different outcomes at the DS valley surface with MSB/foehn arrival

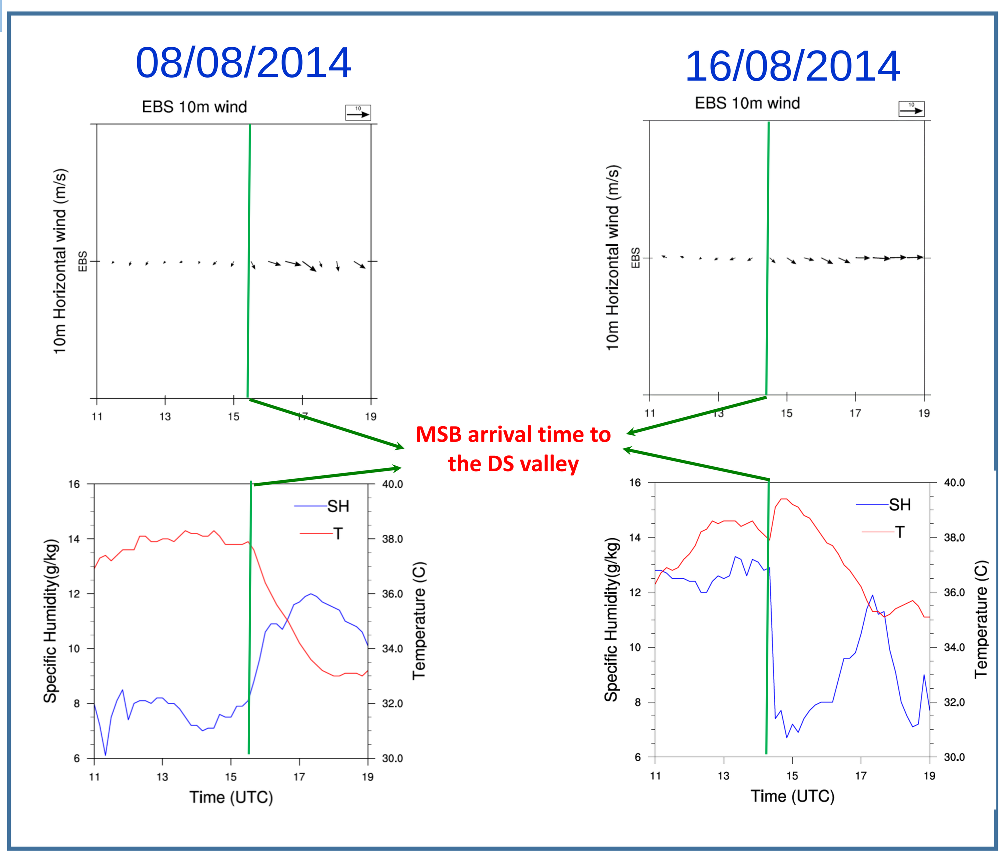
2 Methodology

- Analysis of two events characterized by very different temperature and humidity behavior at the surface at the time of MSB arrival.
- Analysis of the synoptic, mesoscale and local scale atmospheric evolution in the DS valley during these events.

Tools

- High-Resolution (HR) in-situ and ground-based remote sensing observations from the Virtual Institute DEad SEa Research Venue (DESERVE) project during August 2014: Wind lidars (WindCube and WindTracer), radiosondes and radiometer
- Local surface-observations network ("Energy Balance Stations", EBS)
- HR WRF mesoscale model simulations (1.1-km grid size).

3 Choice of events: surface observations



On 8 August during MSB arrival

- change in wind direction from eastern to western direction
- speed intensification
- very steep decrease in specific humidity
- increase in temperature

On 16 August during MSB arrival

- Similar change in wind direction and speed intensification like on 8 August
- Increase in specific humidity
- decrease in temperature

Before MSB arrival more humidity on 16 August than on 8 August

The MSB arrived later on 8 August

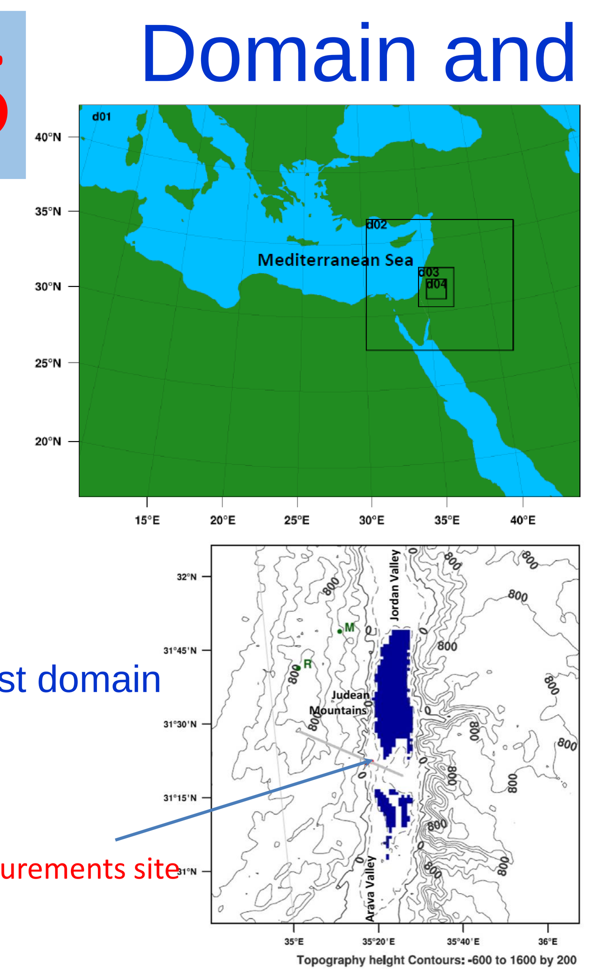
Synoptically, 8 August was dominated by a High, while 16 August was dominated by a Persian Trough

4 Sensitivity simulations for optimal modeling

Simulation number	Landuse	PBL	Number of vertical levels	IC/BC of coarse domain	IC/BC of finest domain	Spin-up time of coarse domains (hours)	Spin-up time of finest domain (hours)
1	USGS	MYJ	32	GFS	GFS	39	39
2	MODIS 30s	MYJ	32	GFS	GFS	39	39
3	MODIS 15s	MYJ	32	GFS	GFS	39	39
4	MODIS 15s	MYJ	40	GFS	GFS	39	39
5	MODIS 15s	MYJ	40	GFS	GFS	39	15
6	MODIS 15s	MYJ	40	GFS	GFS	39	27
7	MODIS 15s	YSU	40	GFS	GFS	39	15
8	MODIS 15s	MYJ	40	GFS	GFS	15	15
9	MODIS 15s	MYJ	40	GFS	Parent domain	39	15
10	MODIS 15s	MYJ	40	ECMWF	ECMWF	39	15
11	MODIS 15s	MYJ	40	ECMWF/ GFS	ECMWF/ GFS	39	15

- Tests for parameters expected to affect MSB, DS breeze and mountain-valley circulations
- 11 simulations
- Features verifications:
- time of MSB arrival
- changes in surface wind, specific humidity and temperature
- changes in vertically integrated water vapor
- horizontal wind vertical profiles
- downward vertical velocity
- #5 was found as the best

5 Domain and Experimental Setup



Finest domain

Measurements site

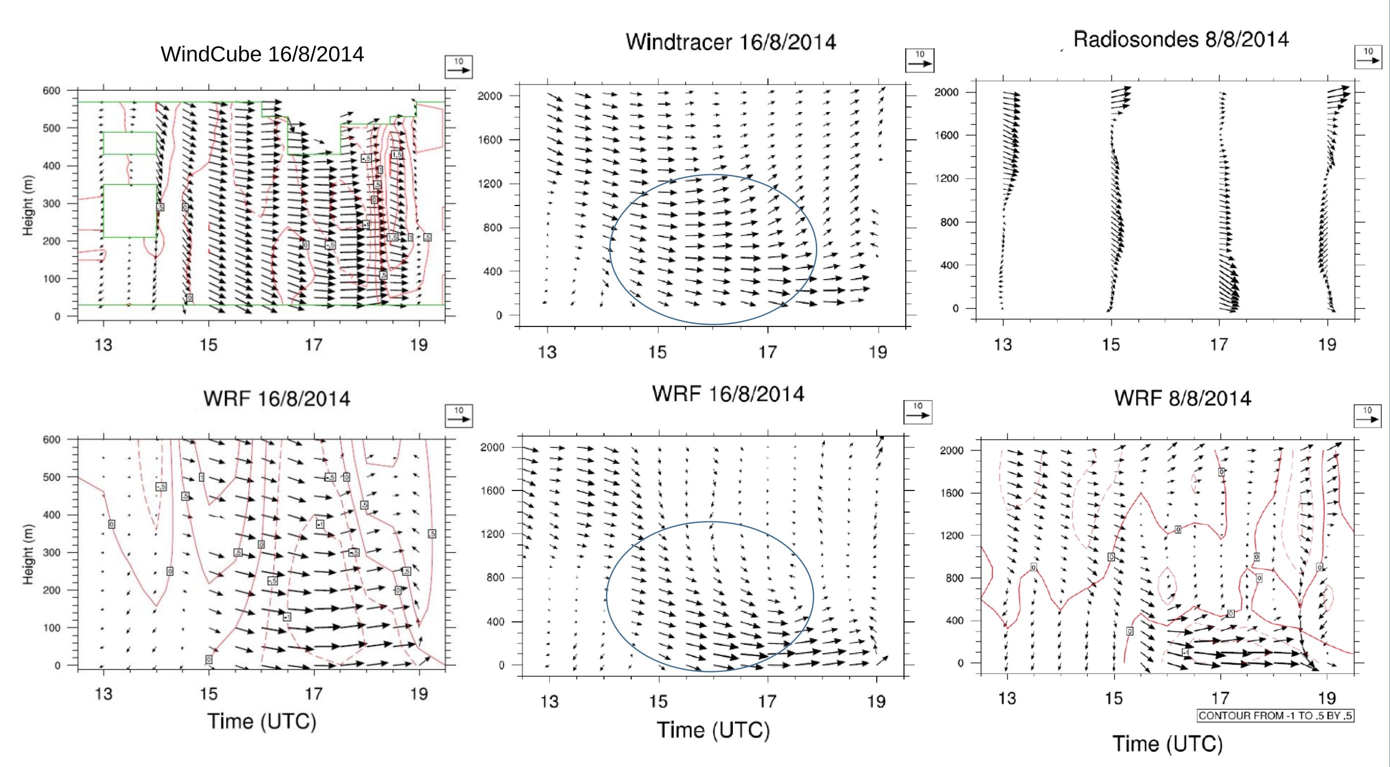
- 4 nested domains with 30, 10, 3.3 and 1.1 km grid spacing
- 40 vertical levels
- Meteorological and soil initial conditions from GFS global model
- The three coarser domains were initialized on the 15 August and 7 August, 00 UTC, for the 16 and 8 August events
- The finest domain was initialized 24 hours later to diminish error growth from the lateral boundaries

6 Results: Wind profiles

Solid line - upward vertical velocity
Dashed line - downward vertical velocity
Height – meters above ground

16 August
-MSB between 14 and 18 UTC
- Horizontal wind speed up to ~10 m/s
- In the simulation, the MSB enters 0.5 later than in observations
- In the simulation the MSB depth is thinner
- Before MSB arrival vertical wind close to 0
- After: vertical wind up to 1 m/s

8 August:
- Horizontal wund speed up to ~10 m/s
- Thinner MSB depth
- Change in wind direction from north-west to south-west between 13 and 15 UTC



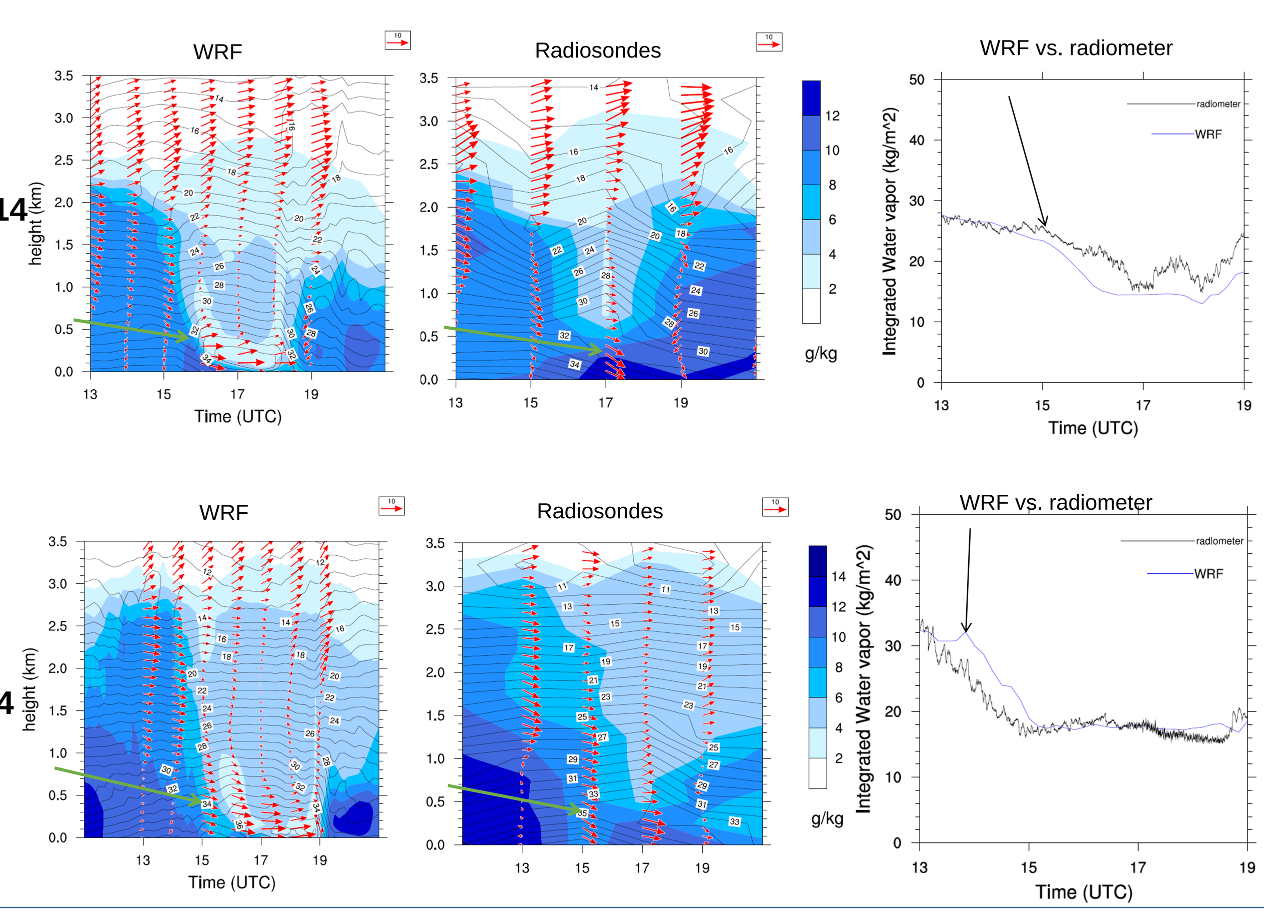
7 Results: Humidity and temperature profiles

8 August:
- The near surface SH was increased when integrated water vapor decreased

-An increase of SH and a decrease of temperature below 400m

-A decrease of SH and an increase of temperature between 400-1000m

16 August:
- A sharp decrease in specific humidity (SH) and in integrated water vapor with the MSB arrival
- An increase in temperature



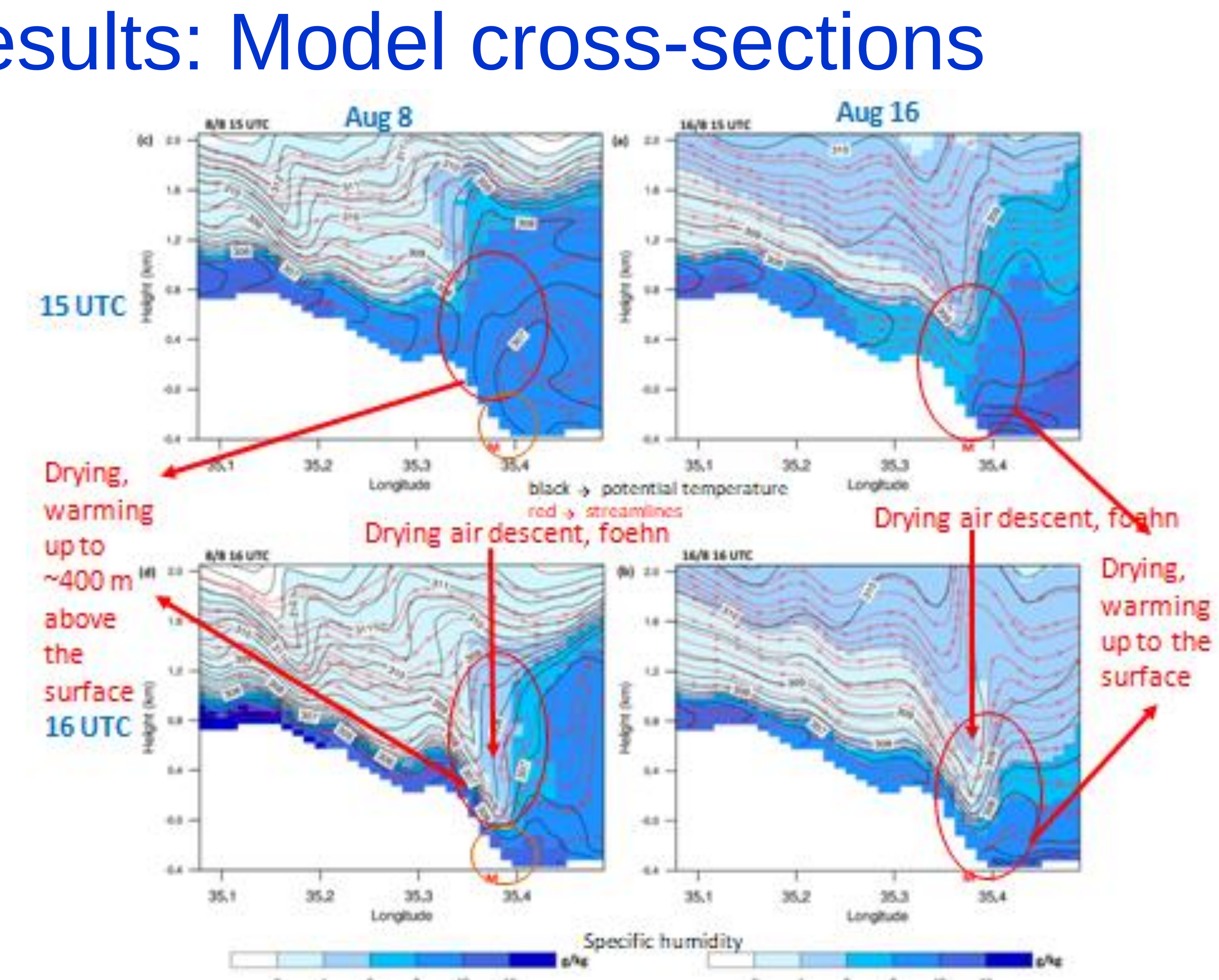
8 Results: Model cross-sections

- At 16 August we see the descent of drying air down valley, and we see that this descent, this foehn, dries and warms up the valley air up to the surface

- At 8 August on the other hand, we see that the foehn phenomena is taking place up to about 400 m above the surface only
- The opposite takes place below it

- We also see downward stream lines up to 1.5 km above the ground on the 16, while only up to about on 1 km on the 8

- In addition, on 8 August more humidity came with MSB than on 16



Summary

- Our study shows that foehn develops in the lee side of the Judean Mountains and Dead Sea Valley in the afternoon hours when the Mediterranean Sea breeze reaches the area
- The simulations and observations show similar dynamic behavior at the time of MSB penetration
- **In the synoptic scale**, the depth of the seasonal pressure trough at sea level and the height of inversion layers play a significant role in determining the breeze and foehn characteristics
- **In the mesoscale**, the intensity of the Dead Sea breeze and the humidity brought by it determines the outcomes at the time of Mediterranean Sea breeze penetration and foehn development
- **Dynamically**, the foehn is associated with a hydraulic jump
- The forecasting feasibility of foehn and the sudden changes in the Dead Sea valley 24 hours in advance using WRF is suggested following the present study
- These forecasts can be most valuable for the region affected by pollution penetration from the metropolitan coastal zone

The German Helmholtz Association is gratefully acknowledged for (partly) funding this project within the Virtual Institute DESERVE (Dead Sea Research Venue) under contract number VH-VI-527. Special thanks to our German partners Jutta Metzger and Ulli Corsmeier for much help with the data and useful comments