Diurnal course of evaporation from the Dead Sea in summer: a distinct double peak induced by solar radiation and night sea breeze

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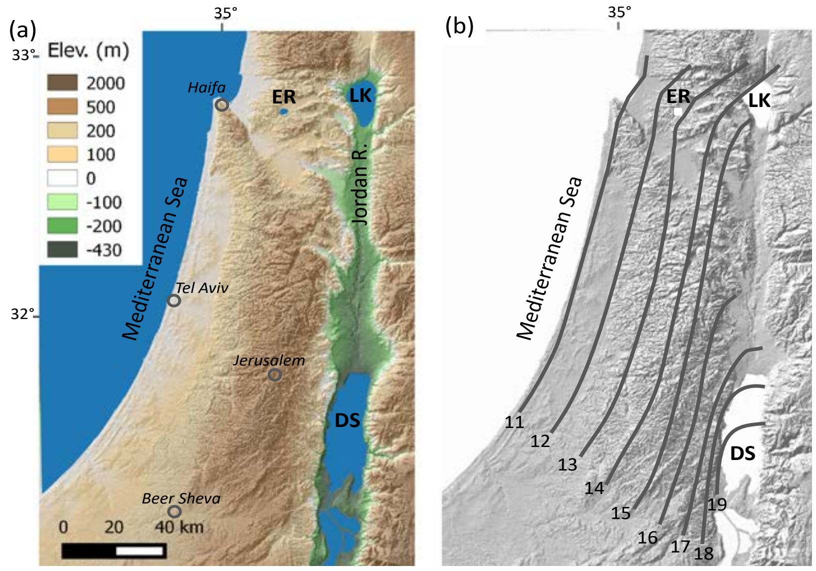


Budapest, April 10, 2018

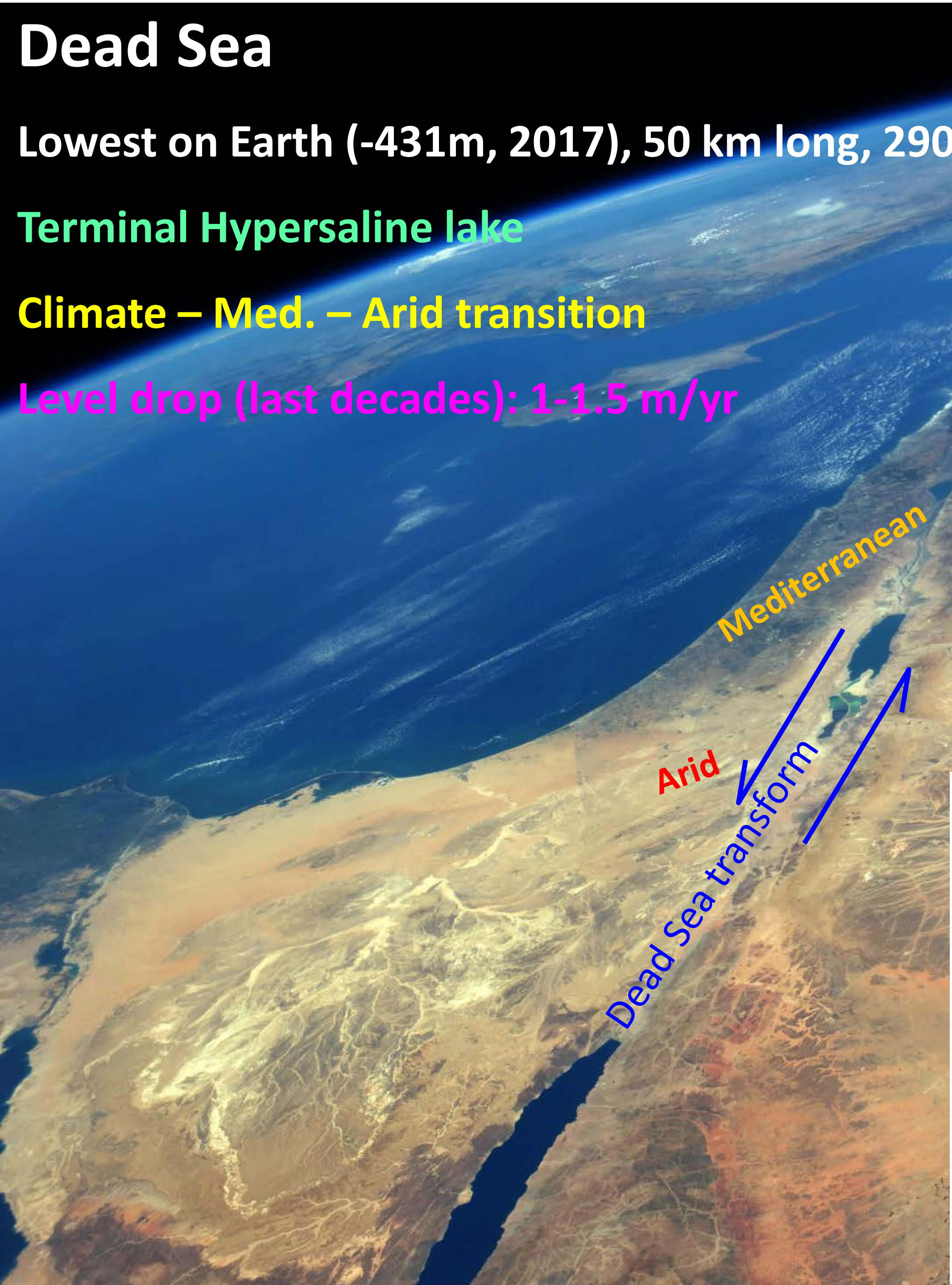
Dead Sea

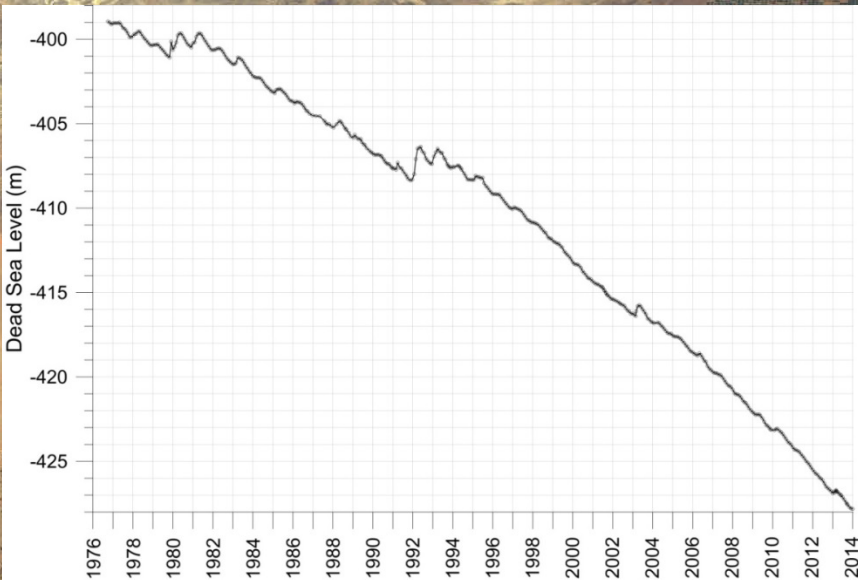
Lowest on Earth (-431m, 2017), 50 km long, 290m deep.

Terminal Hypersaline lake

Climate – Med. – Arid transition

Level drop (last decades): 1-1.5 m/yr





Dead Sea


Dead Sea Level (m)
-400
-405
-410
-415
-420
-425
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Wharf in 1994
1994
-407 m
2004
-417 m
2014
-428 m

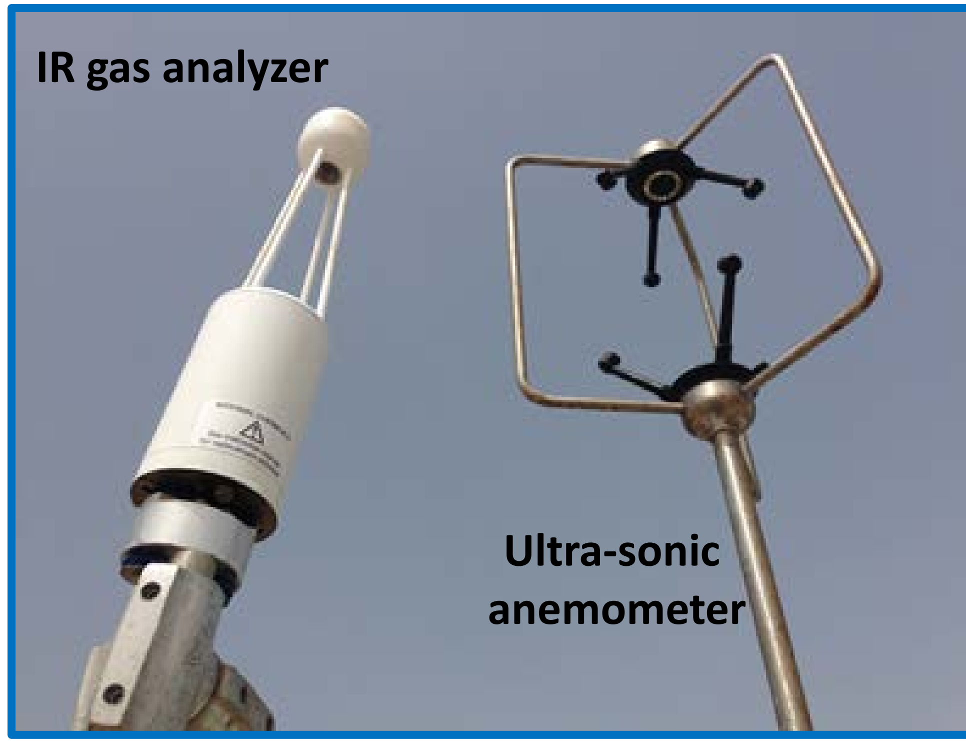
Motivation

- Declining water level - Sinkholes
- Chemical industry - Potash
- Arid region – high evaporation rate
- Hyper-salinity – low evaporation rate
- Understanding water balance

Research Goals

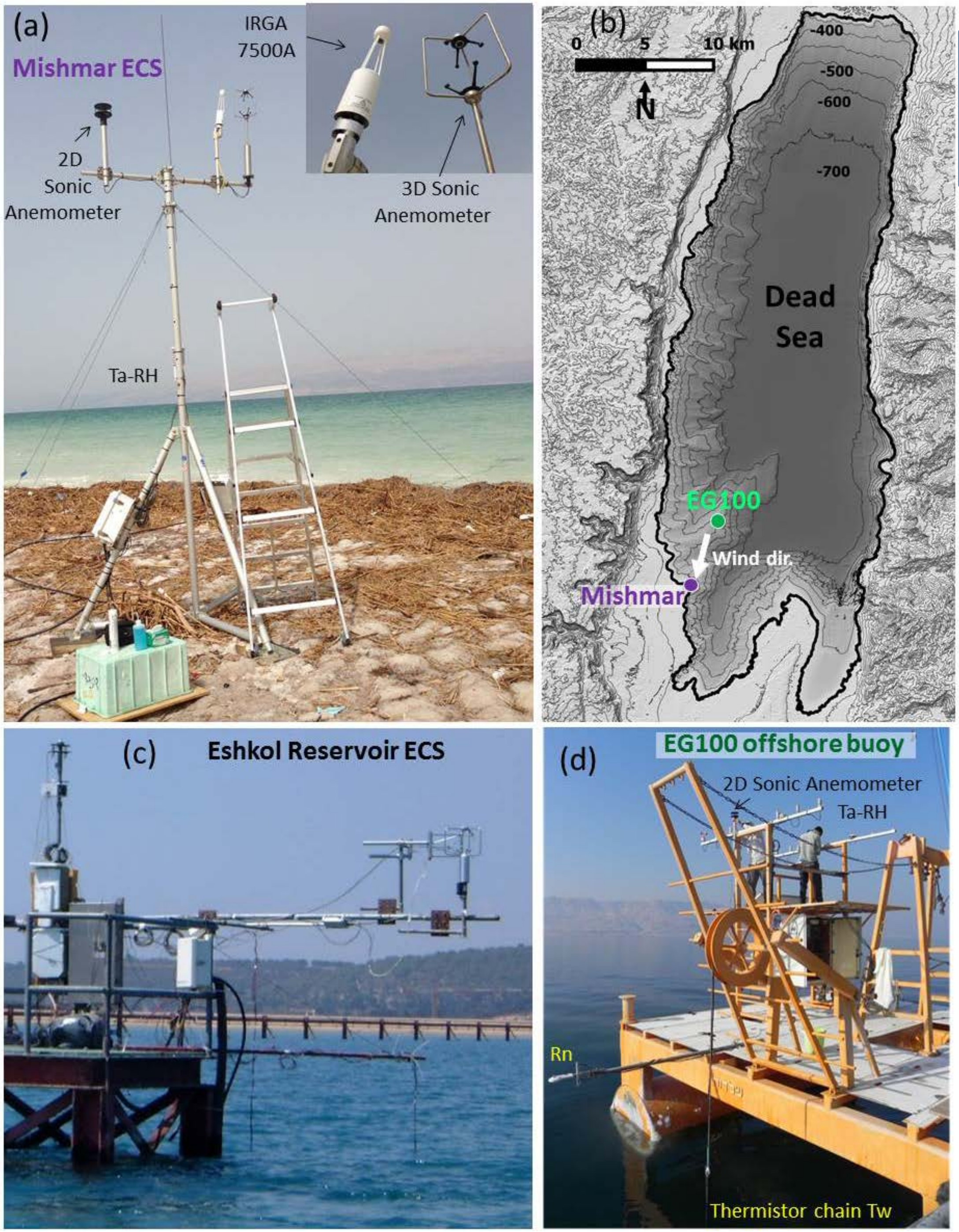
- Direct measurements of evaporation rate
- Understanding the controlling variables

Eddy Covariance: direct evaporation measurements



LE-Latent heat flux

H- Sensible heat flux



Eddy covariance & energy budget measurements

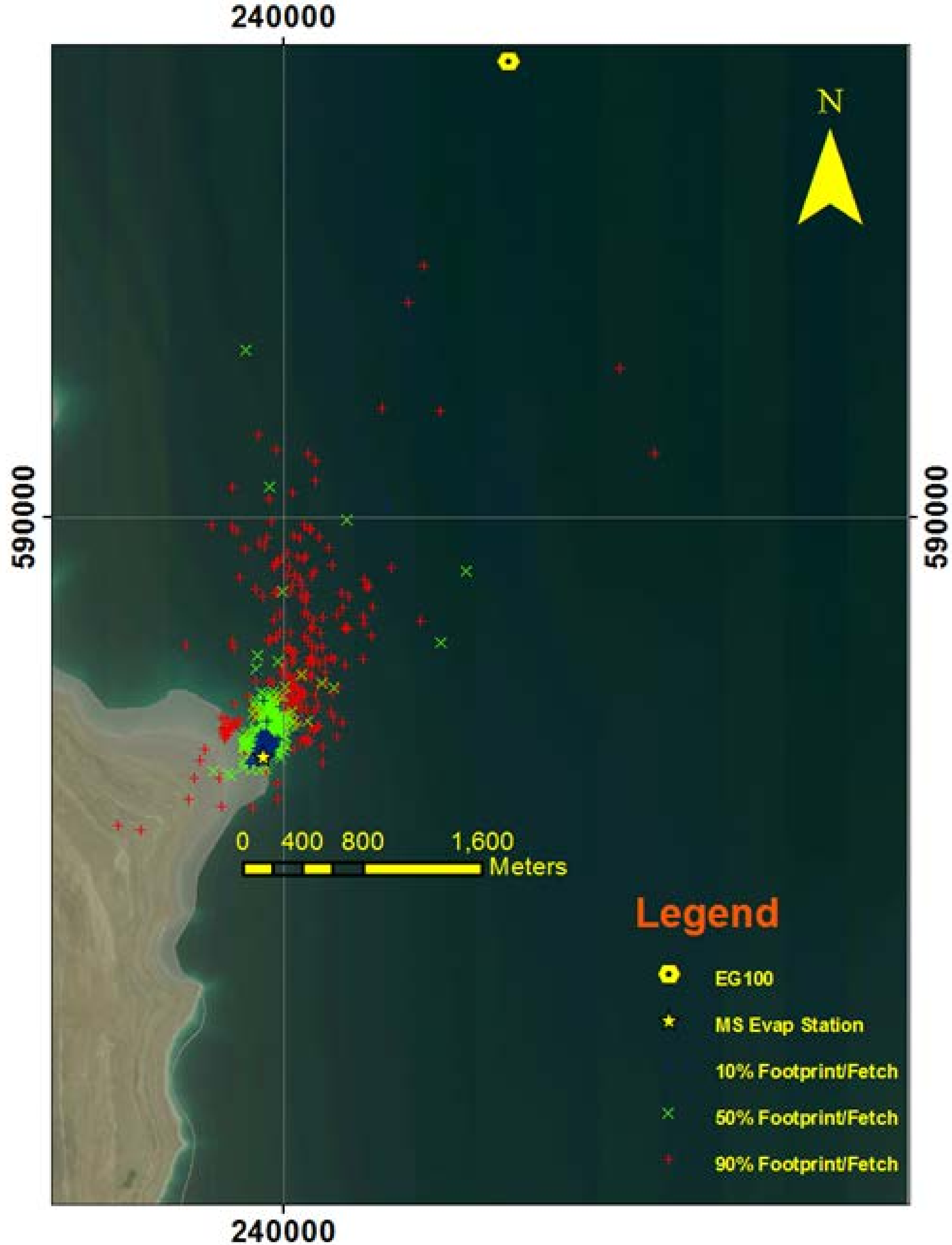
Assumptions:

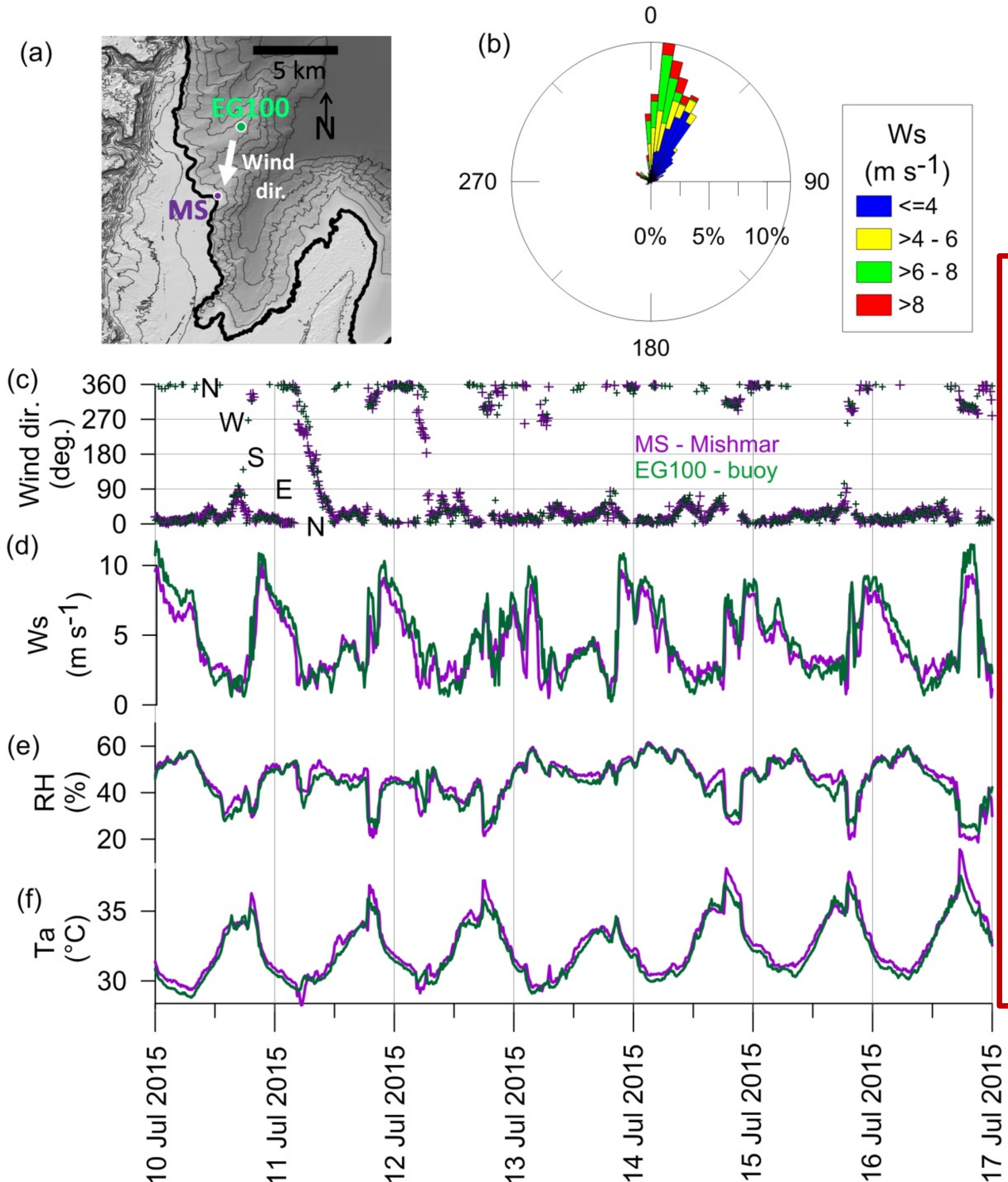
- ❖ Measurements at a point represent an upwind area (footprint).
- ❖ Measurements are done inside the boundary layer of interest.
- ❖ Flux is fully turbulent – most of the net vertical transfer is done by eddies.
- ❖ Air flow is not disturbed! (installation & terrain).

Mishmar Station Location and Footprint

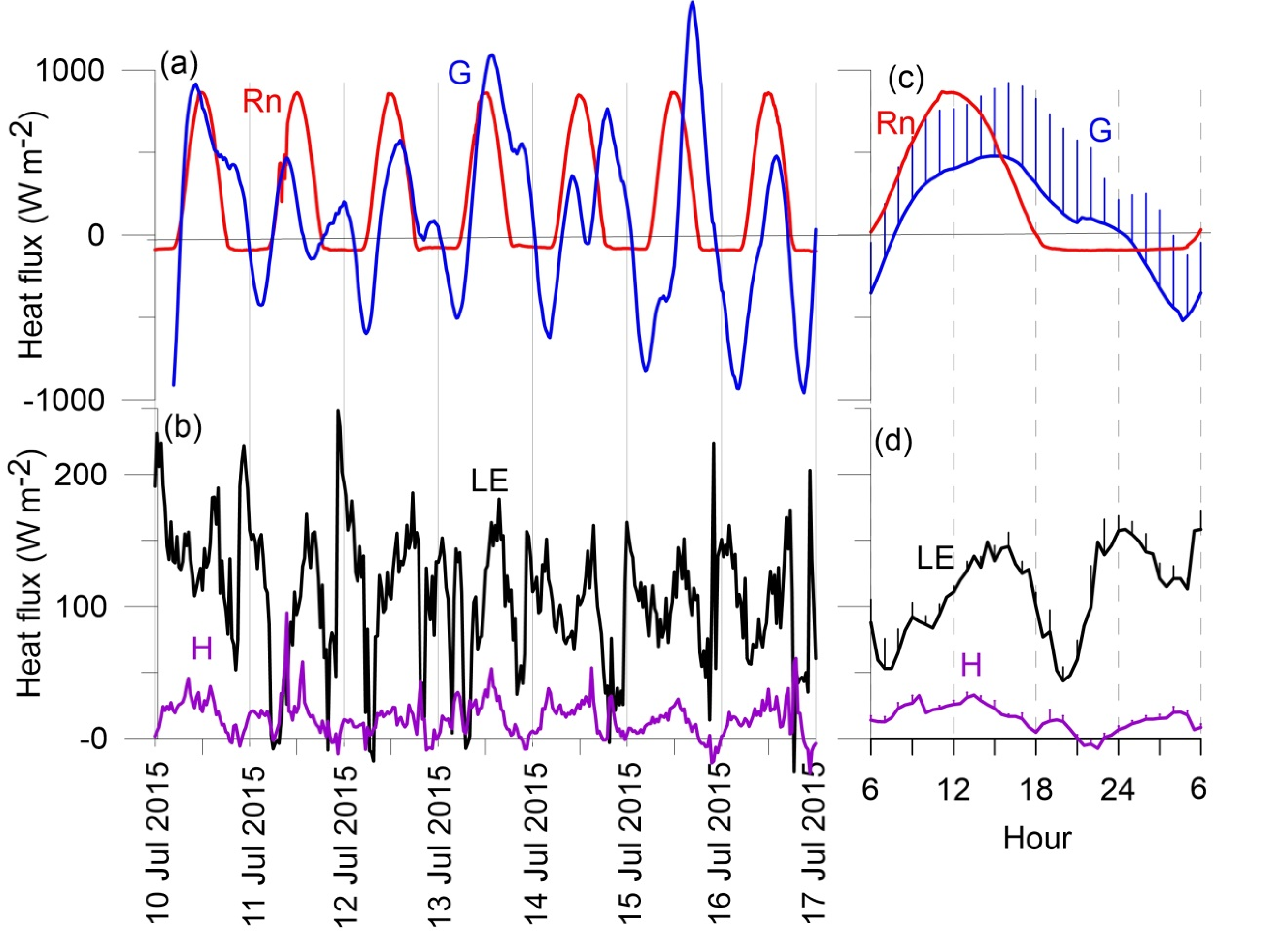
Most data originate from the sea

Data from land is filtered out

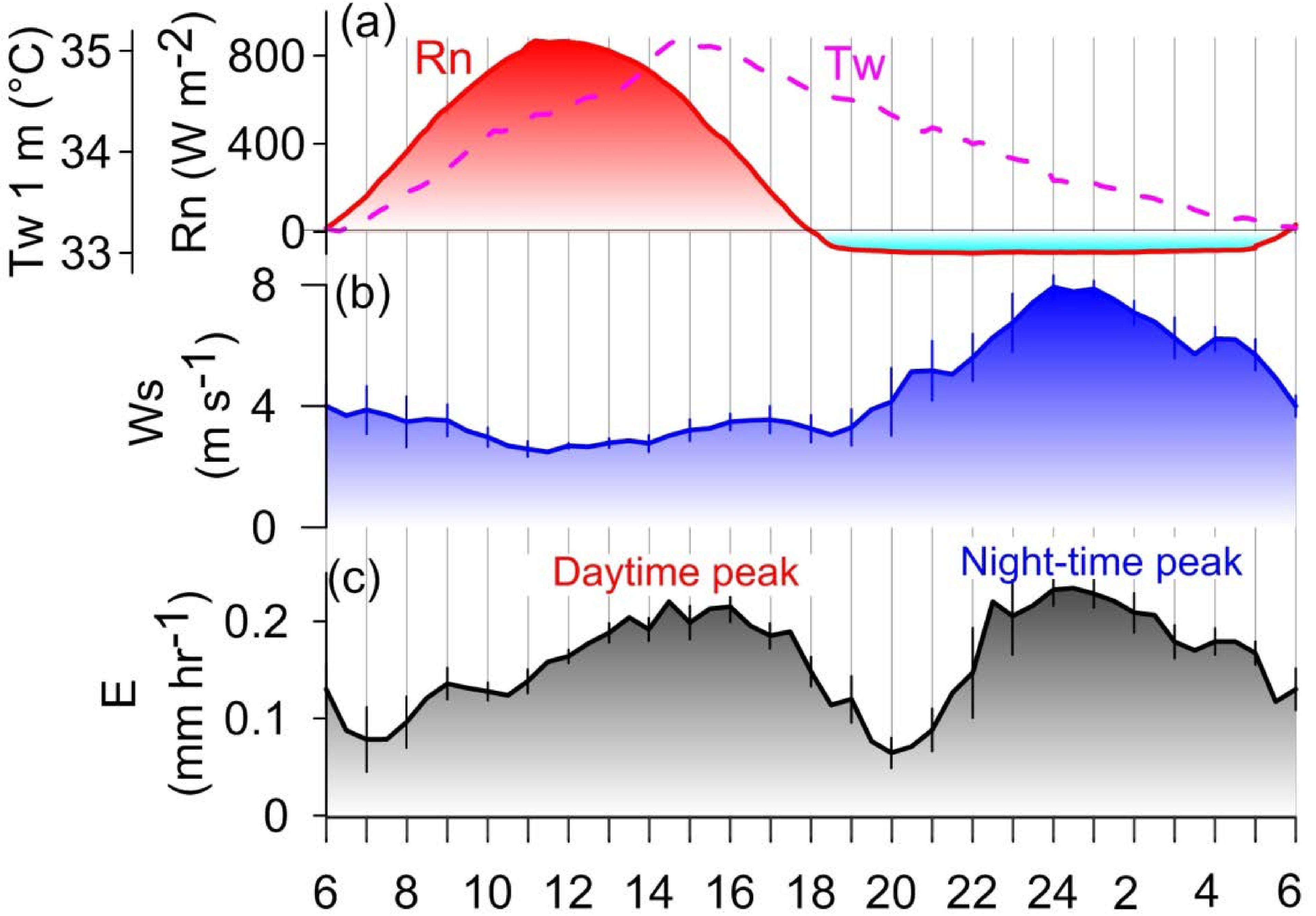




Comparison between on-shore (MS) and off-shore (EG100) meteorological data

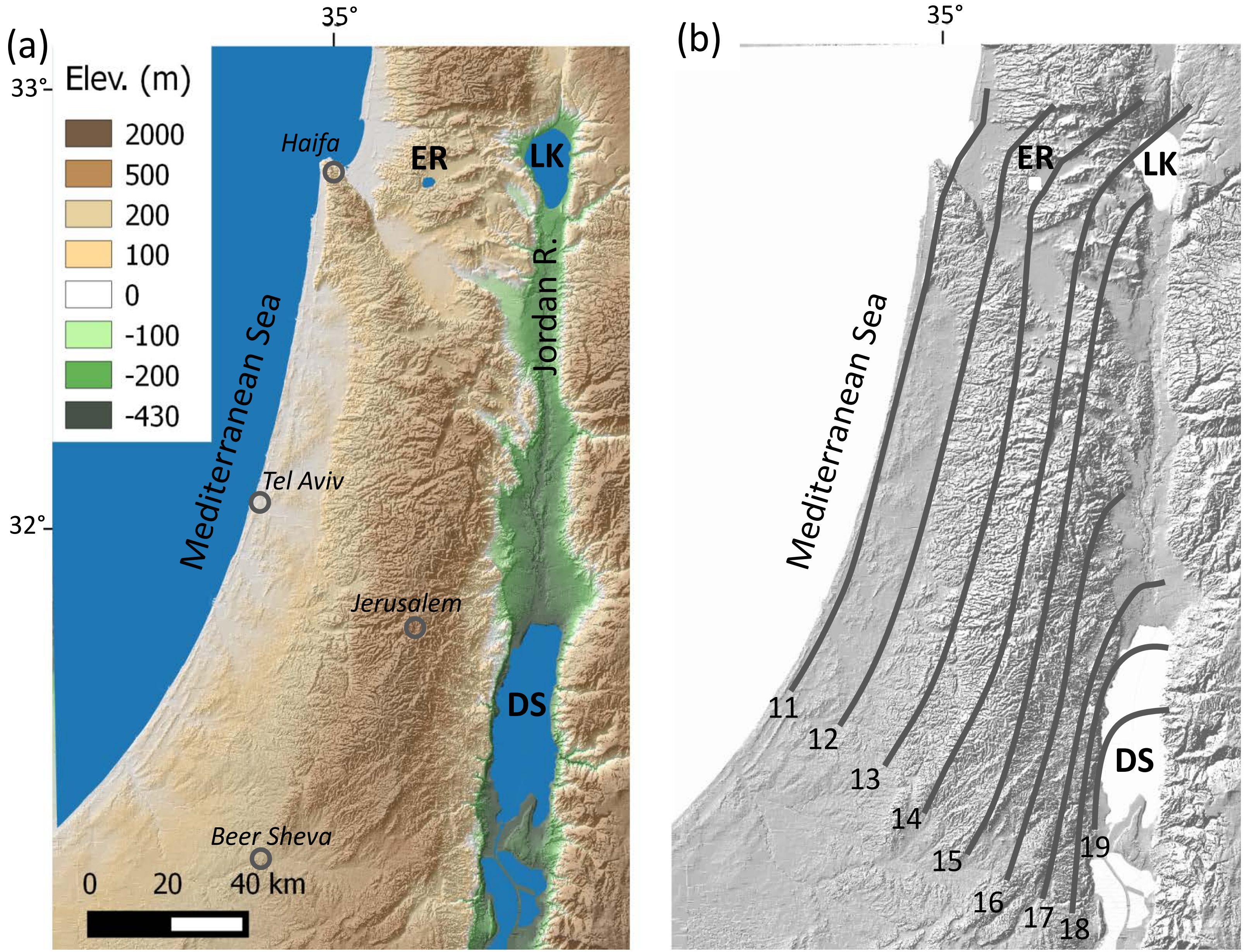


(a)
(b)
(c)
(d)
Rn
G
LE
H
Heat flux (W m-2)
Heat flux (W m-2)
1000
0
-1000
200
100
-0
10 Jul 2015
11 Jul 2015
12 Jul 2015
13 Jul 2015
14 Jul 2015
15 Jul 2015
16 Jul 2015
17 Jul 2015
6
12
18
24
6
Hour

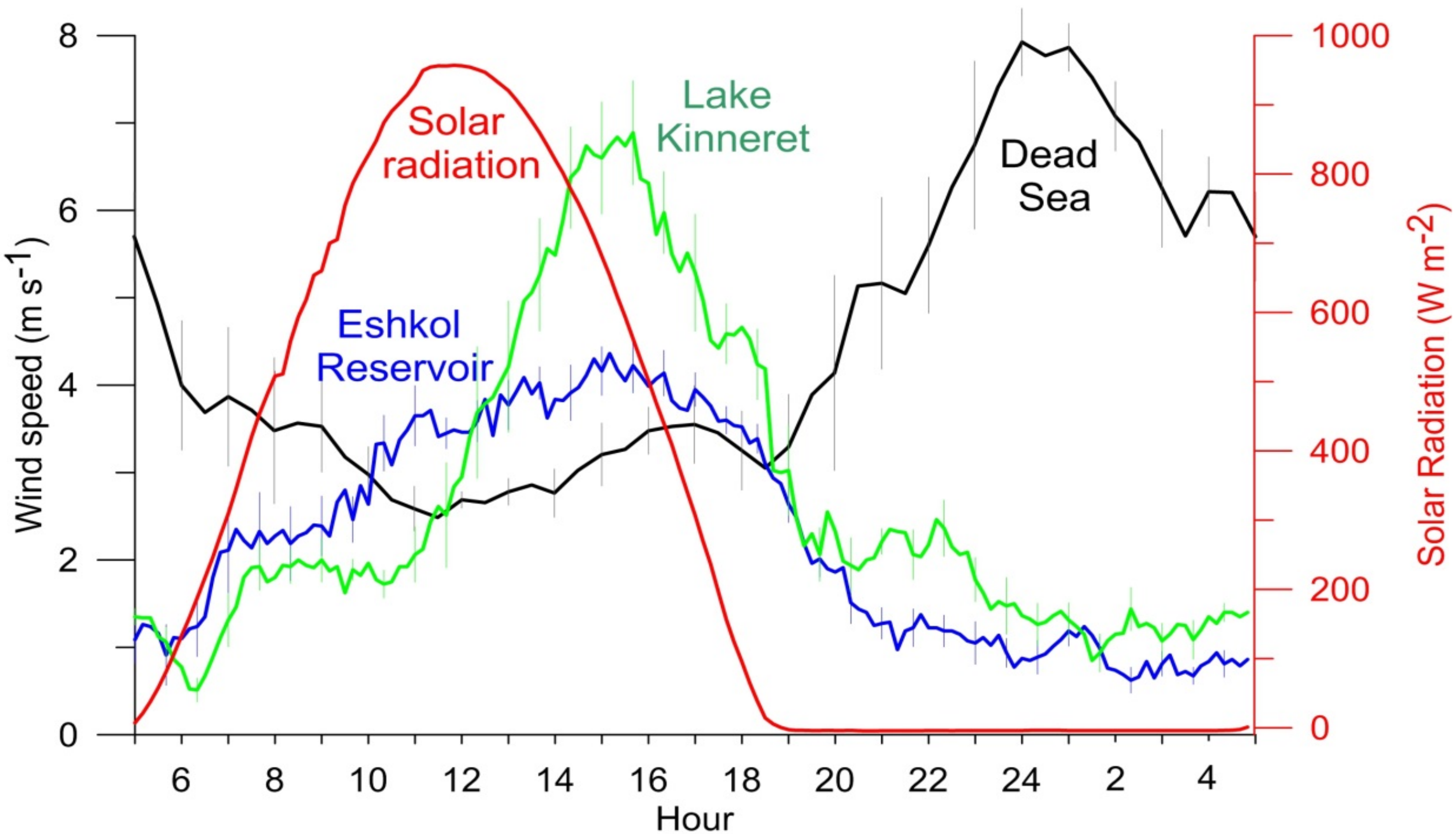


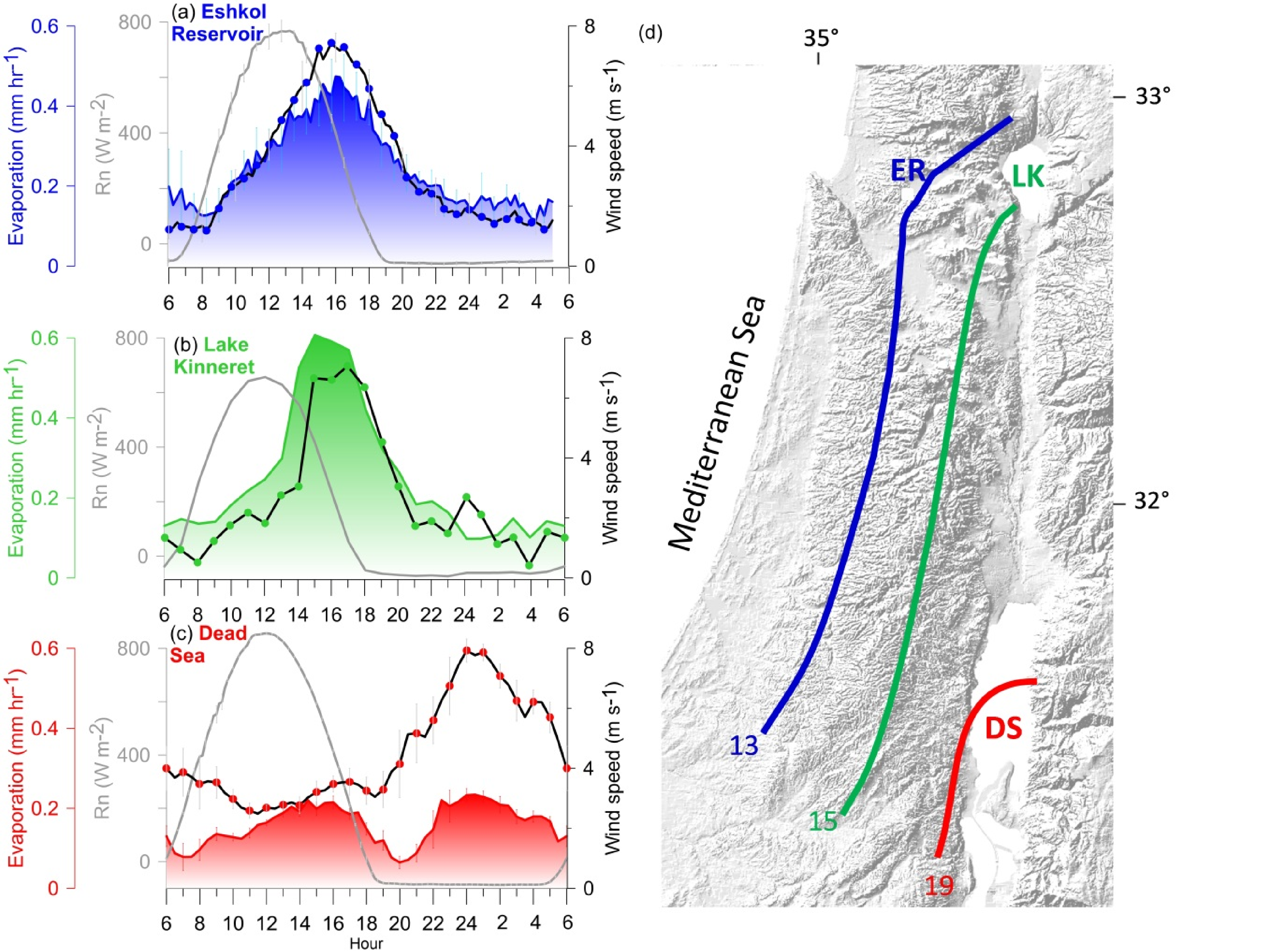
(a)
Rn
Tw
Tw 1 m (°C)
35
34
33
Rn (W m-2)
800
400
0
(b)
Ws (m s-1)
8
4
0
(c)
Daytime peak
Night-time peak
E (mm hr-1)
0.2
0.1
0
6
8
10
12
14
16
18
20
22
24
2
4
6

The Mediterranean Sea Breeze



Wind Speed and Radiation distribution at 3 sites





(a) Eshkol Reservoir
(b) Lake Kinneret
(c) Dead Sea
Evaporation (mm hr-1)
Rn (W m-2)
Wind speed (m s-1)
Hour
(d)
35°
33°
32°
Mediterranean Sea
ER
LK
DS
13
15
19

Summary

1. A distinct evaporation double peak characterizes the diurnal course of evaporation in summer.
2. The early afternoon peak is related to the radiative heat supply and corresponds, with a short delay, to the peak in net radiation, whereas the night peak is concomitant with the peak in wind speed.
3. During the observation period (10–16 July 2015), the amplitudes of the two peaks in a mean diurnal evaporation rate cycle were similar, indicating an equal contribution of the radiative and the aerodynamic components to evaporation during that period.

Penman Equation (1948)

$$\lambda E = \frac{\Delta}{\Delta + \gamma^*}(Rn - G) + \frac{\gamma^*}{\Delta + \gamma^*} f(u)[e_s(T) - e]$$

Evap. = Radiative term + Aerodynamic term