Multi-year observation of black carbon and ozone concentration at a remote site in the Kali Gandaki Valley, Jomsom, Nepal.

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TIME

NEPAL

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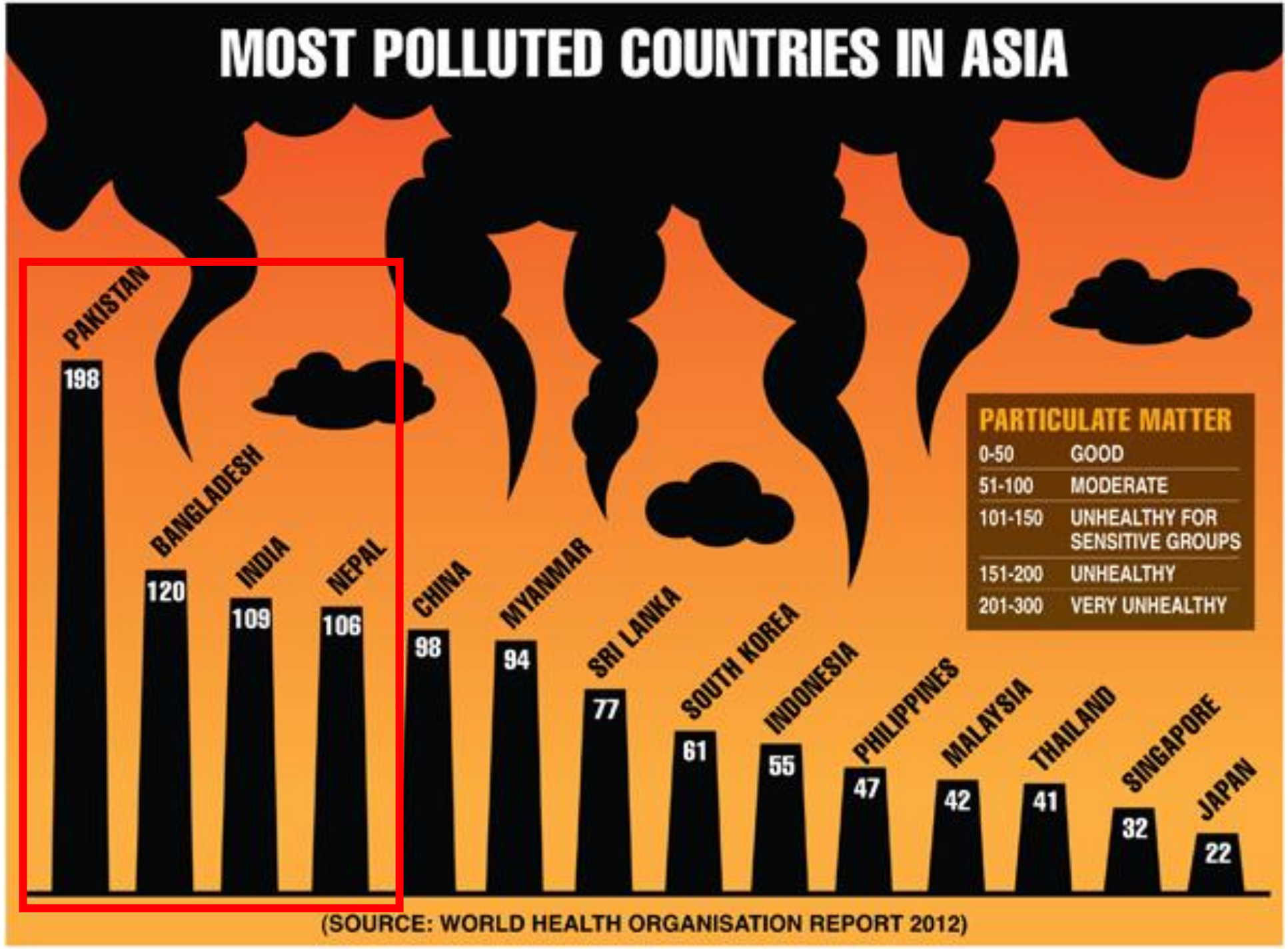
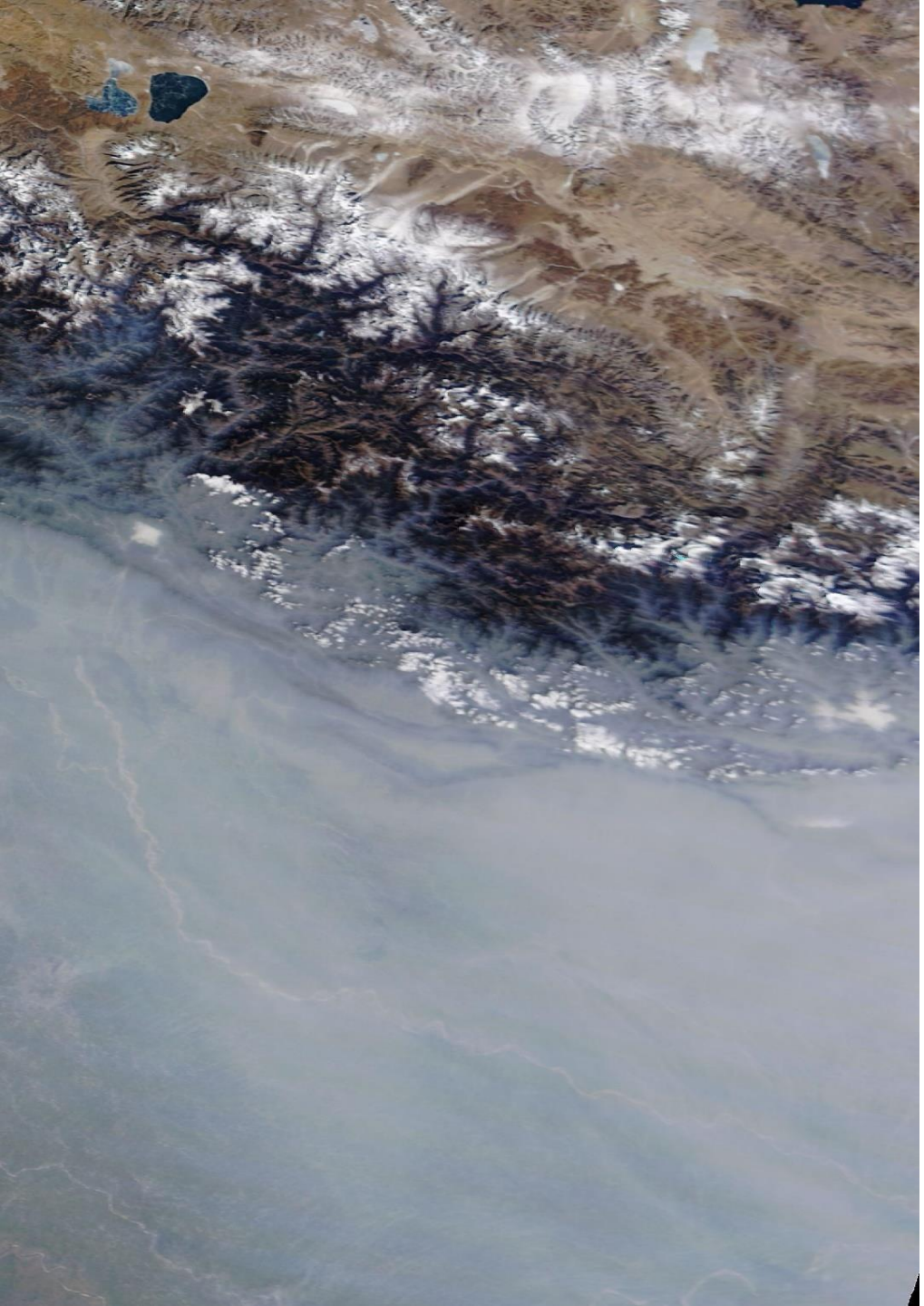
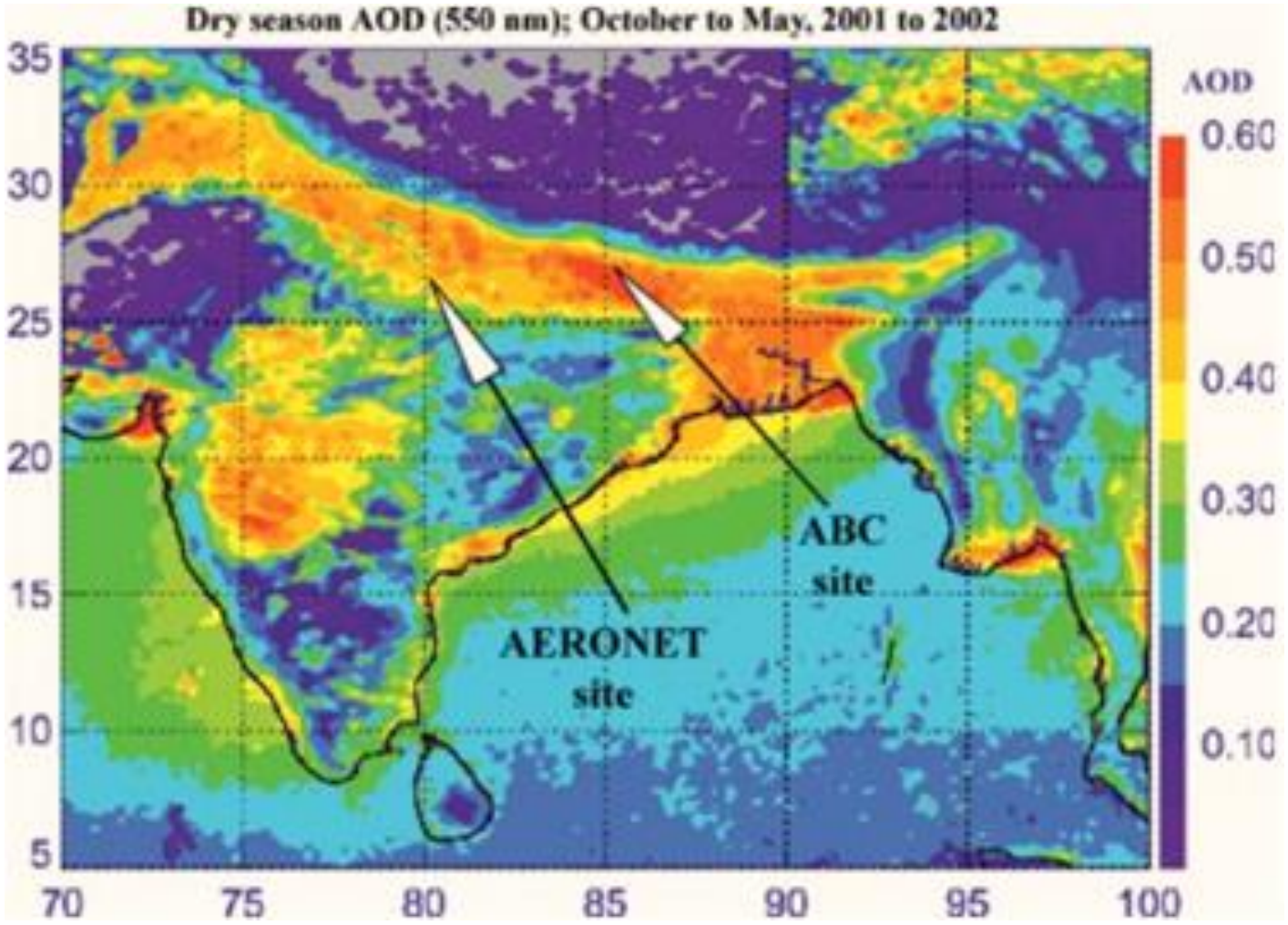

MOST POLLUTED COUNTRIES IN ASIA
PAKISTAN
198
BANGLADESH
120
INDIA
109
NEPAL
106
CHINA
98
MYANMAR
94
SRI LANKA
77
SOUTH KOREA
61
INDONESIA
55
PHILIPPINES
47
MALAYSIA
42
THAILAND
41
SINGAPORE
32
JAPAN
22
PARTICULATE MATTER
0-50 GOOD
51-100 MODERATE
101-150 UNHEALTHY FOR SENSITIVE GROUPS
151-200 UNHEALTHY
201-300 VERY UNHEALTHY
(SOURCE: WORLD HEALTH ORGANISATION REPORT 2012)





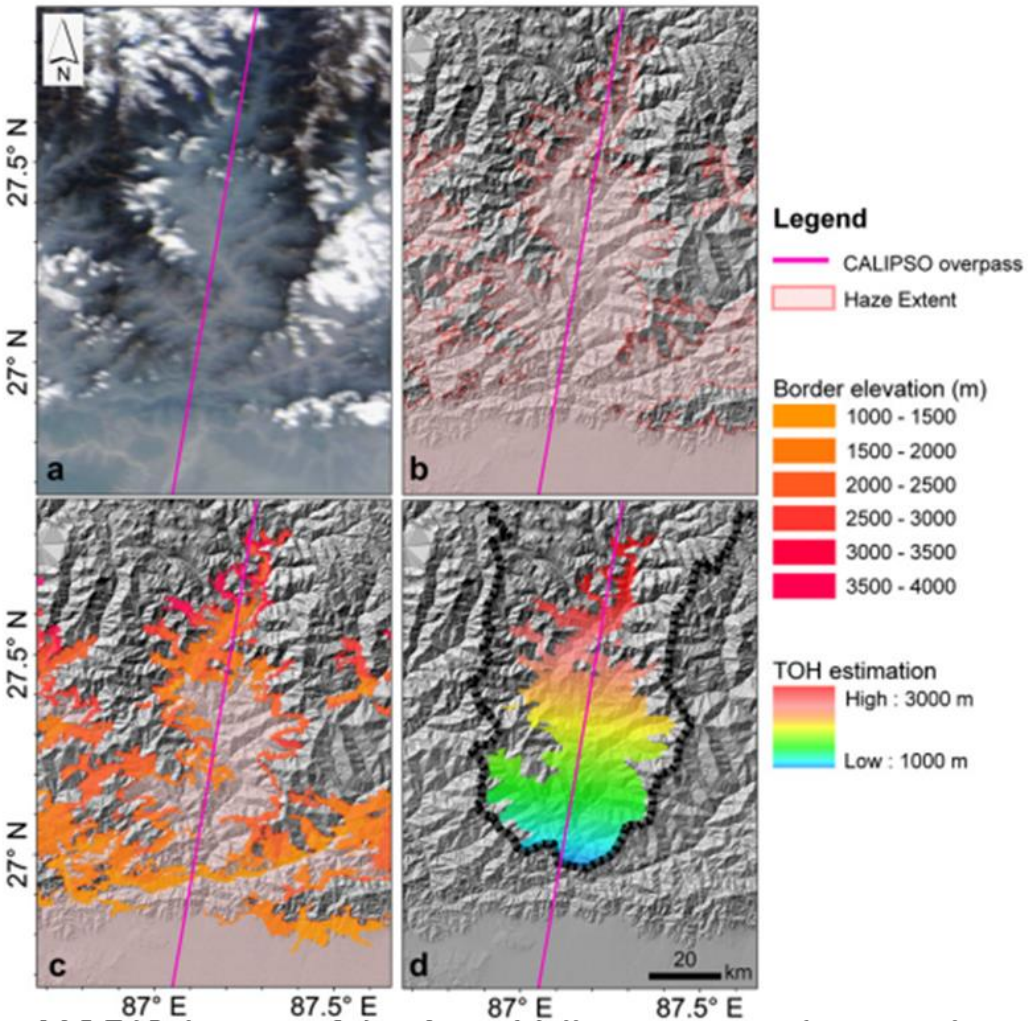
(Ramanathana and Ramana, 2005)

- Satellite images show thick layer of haze over the Indo-Gangetic plains
- Does this get transported via valleys to the Himalayas?

Transport of pollutants and the Himalayas

- Pollutants intrude to the mountainous regions of the Himalayas via the Himalayan valleys *(Brun et al., 2011)*

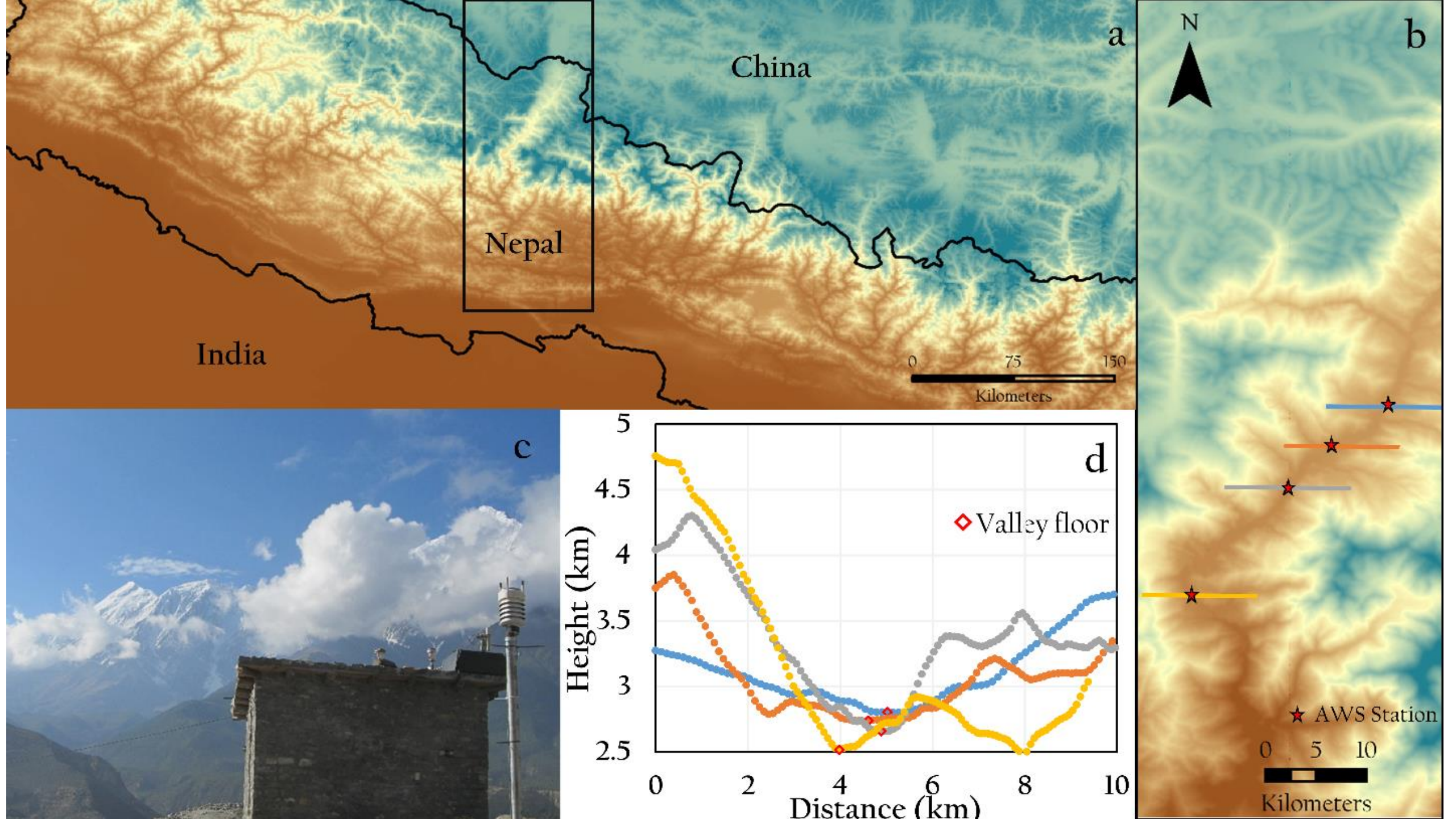
- Well developed Himalayan wind system.

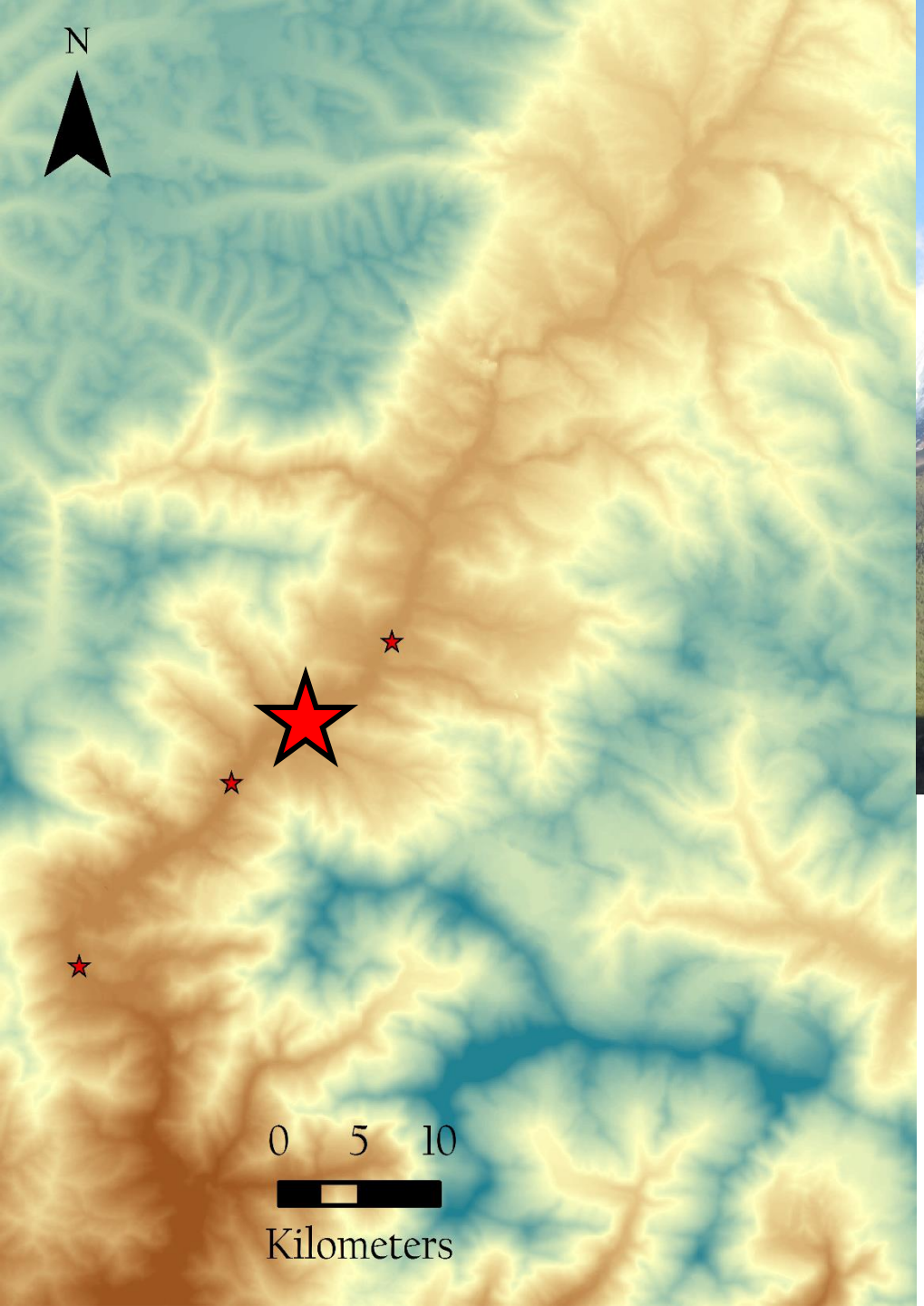


MODIS image of the Arun Valley; extracted aerosol plume; TOA height; TOA within the valley. (**Brun et al., 2011**)

Glacial Melting in the Himalayas

- Increased atmospheric warming
- Glacial retreat
- Increased melting of snow and ice
- Anomaly in Indian monsoon

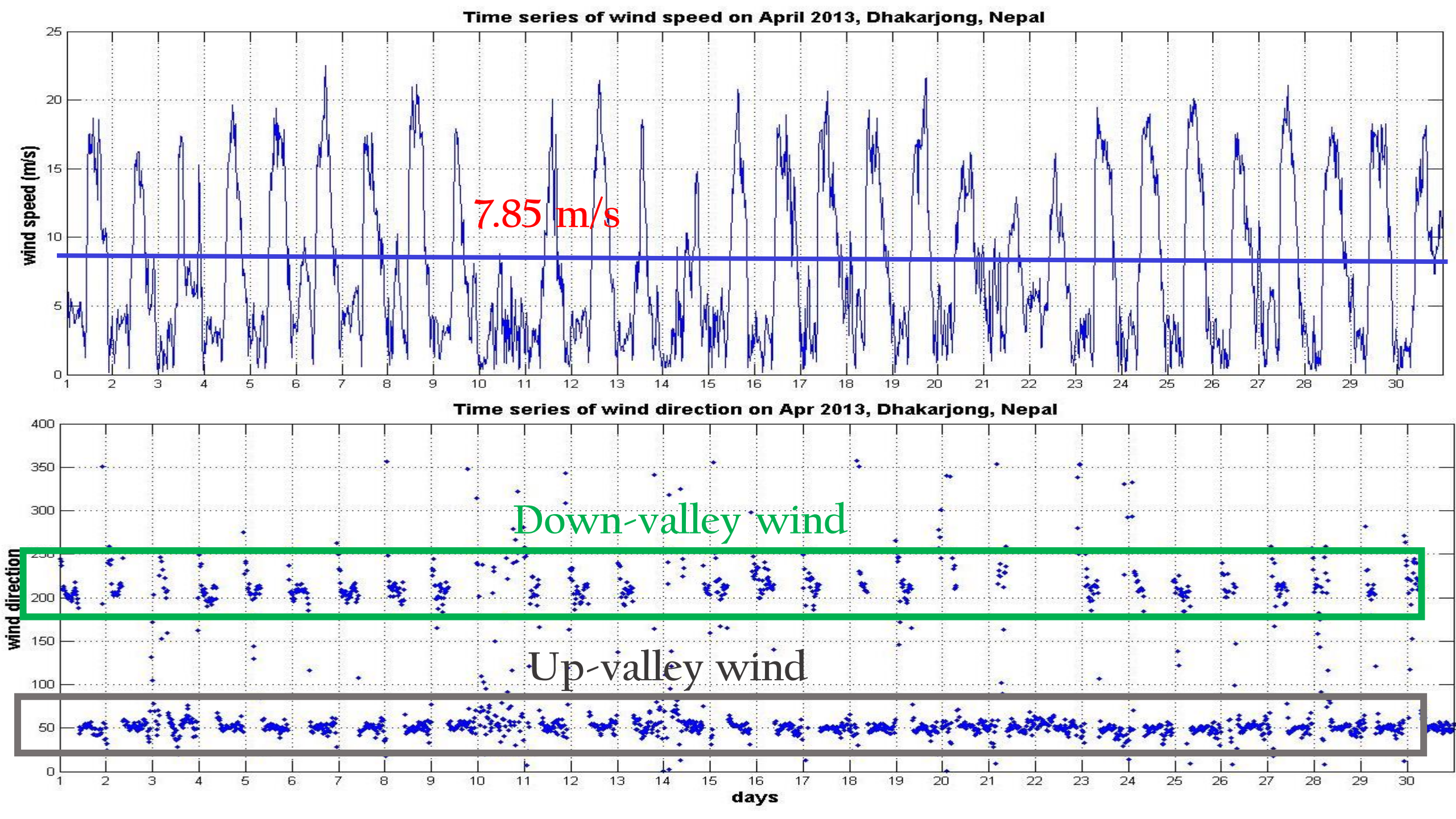

a
China
Nepal
India
0
75
150
Kilometers
b
N
AWS Station
0
5
10
Kilometers
c
d
Valley floor
Height (km)
5
4.5
4
3.5
3
2.5
0
2
4
6
8
10
Distance (km)



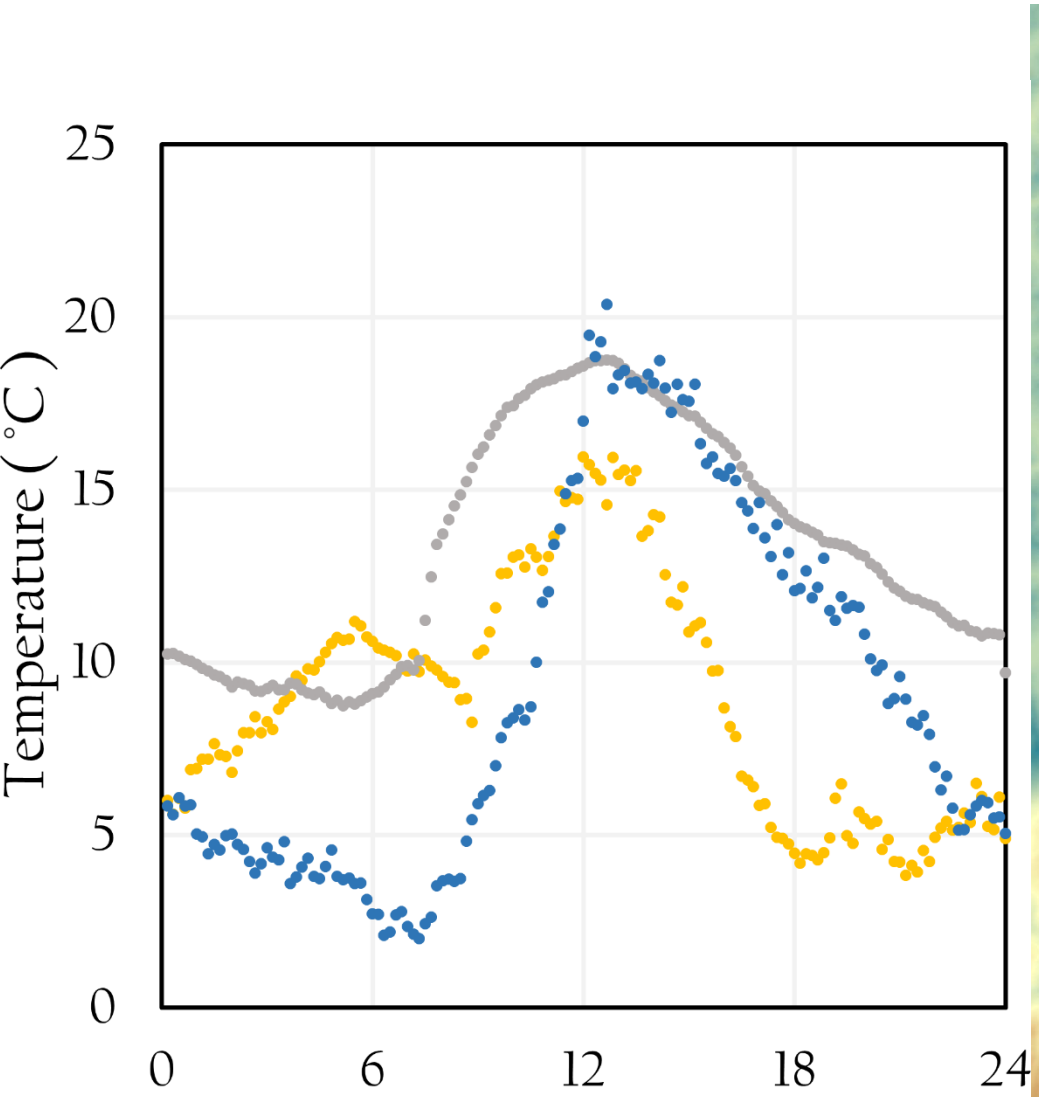
Data presented

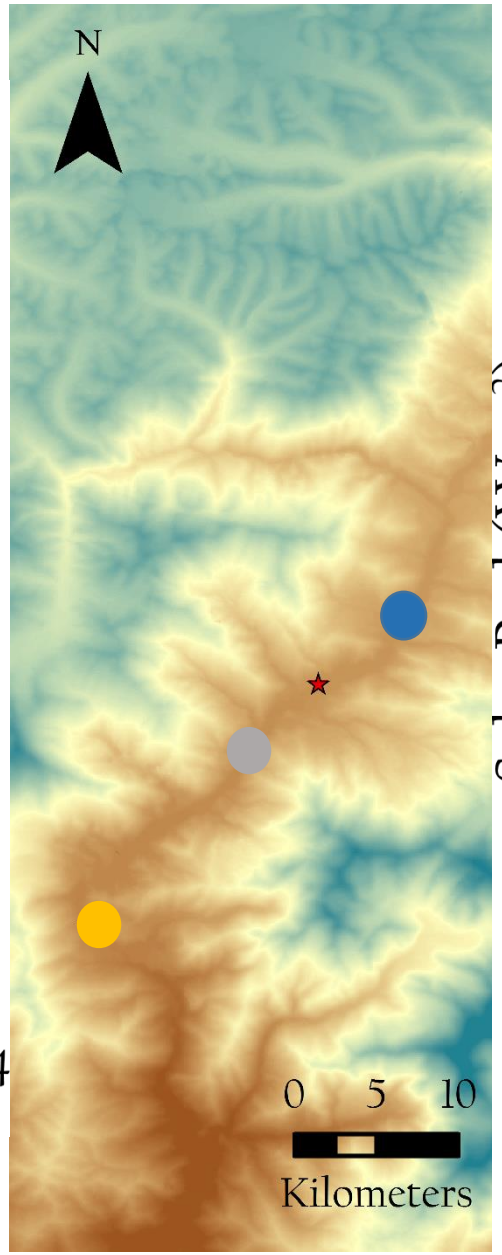
- Jomsom station : Black carbon and ozone

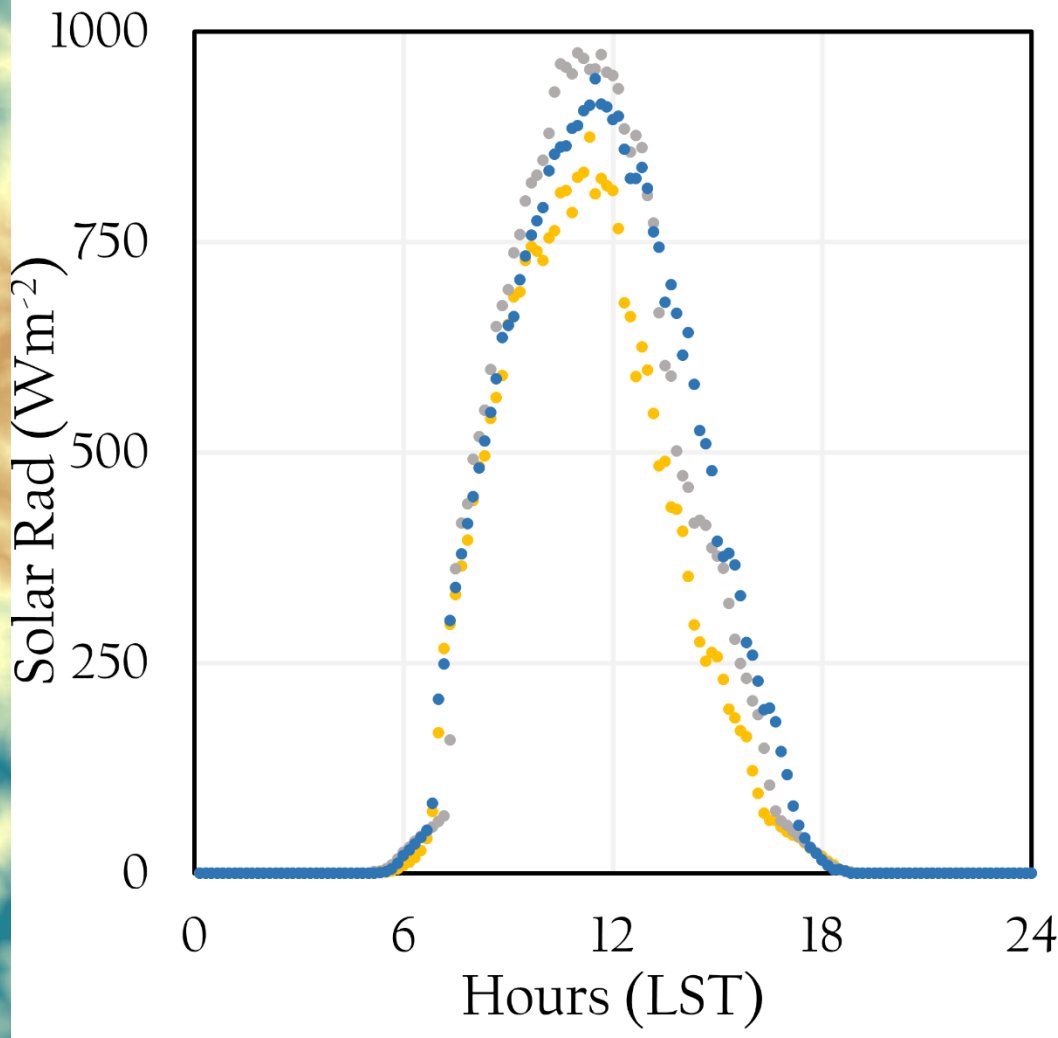
- AWS: Lete
  Marpha
  Jomsom
  Dhakarjong
  LoManthang


Time series of wind speed on April 2013, Dhakarjong, Nepal
wind speed (m/s)
7.85 m/s
Time series of wind direction on Apr 2013, Dhakarjong, Nepal
wind direction
Down-valley wind
Up-valley wind
days

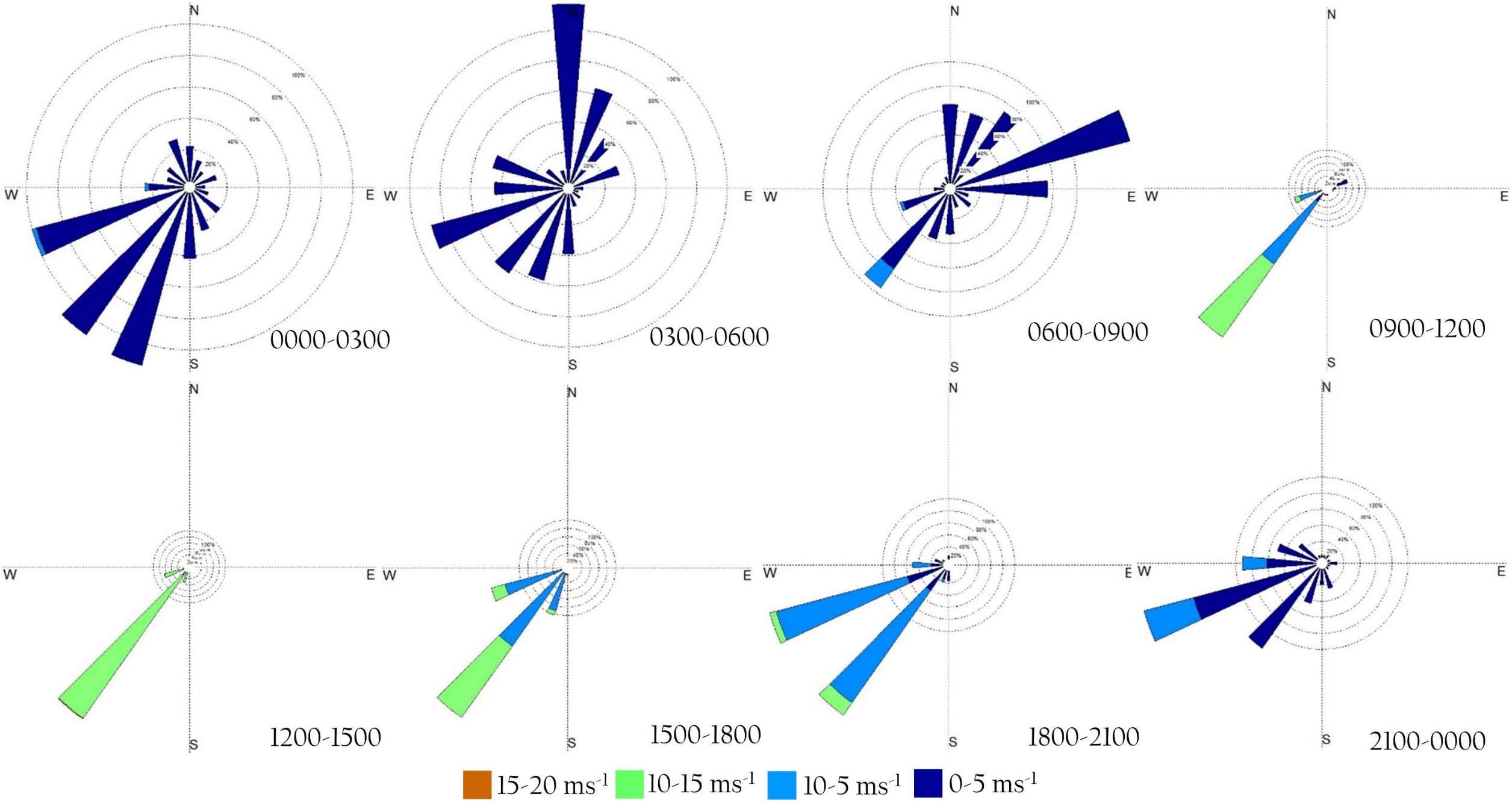
Pressure Driven Wind

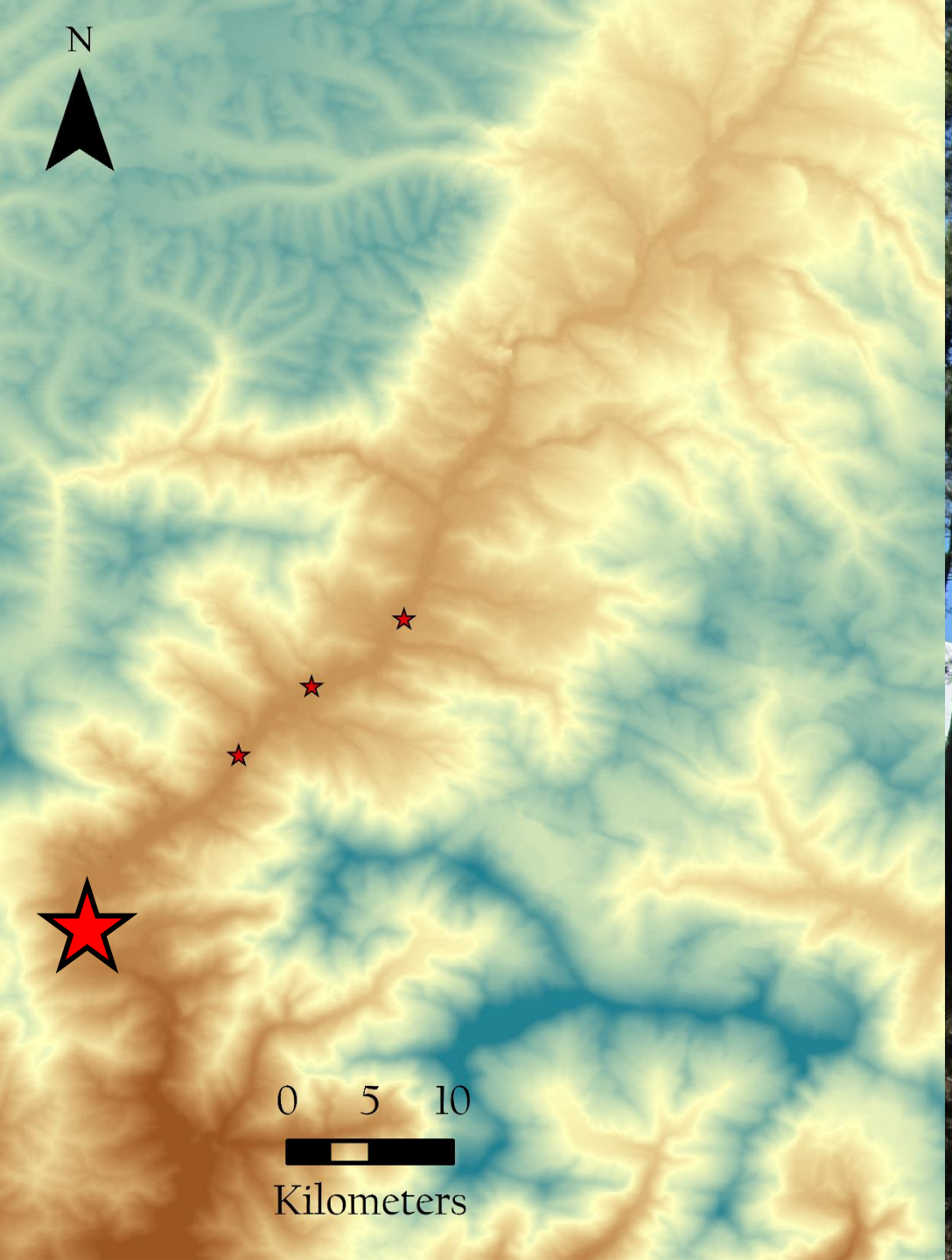


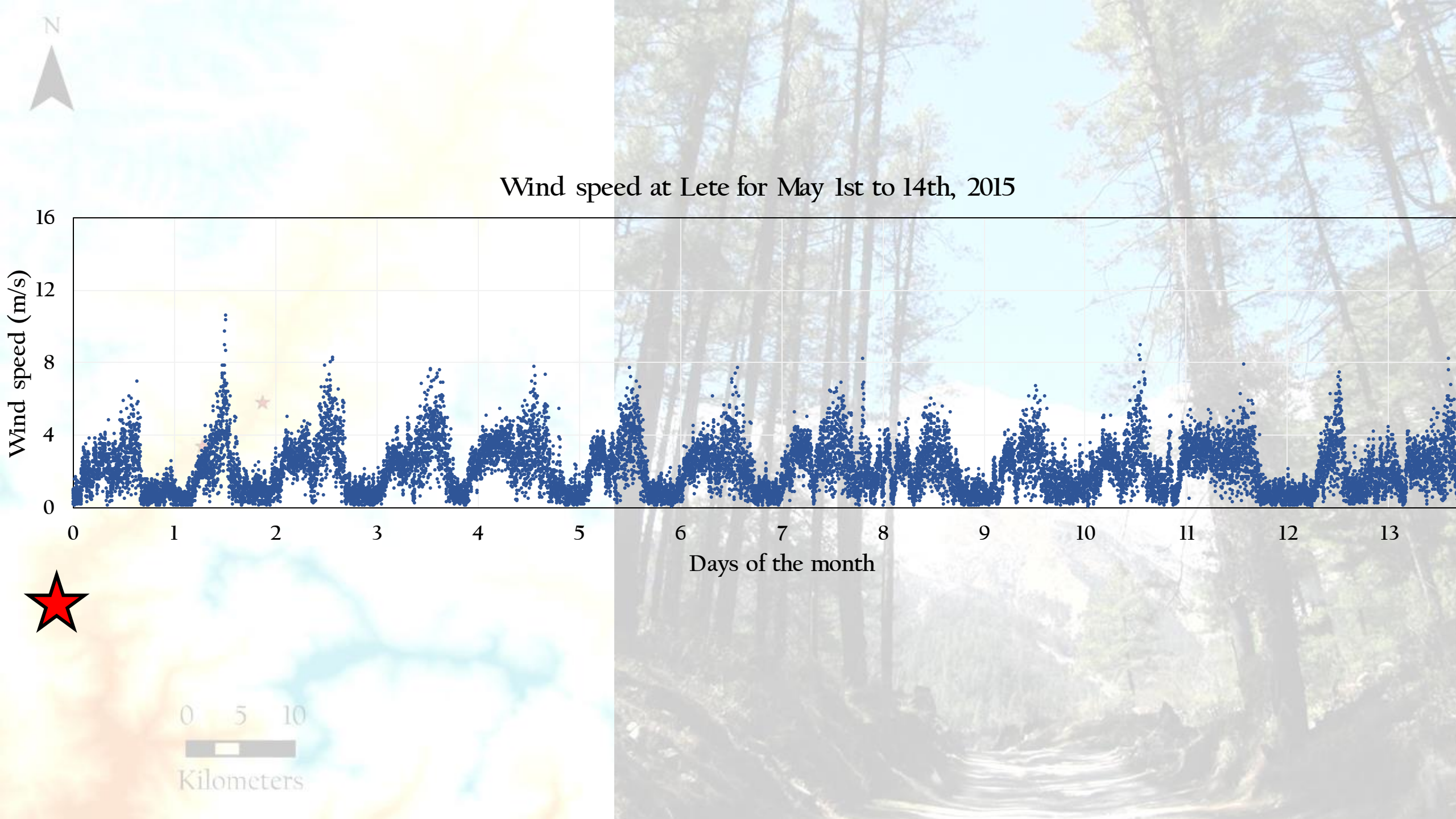


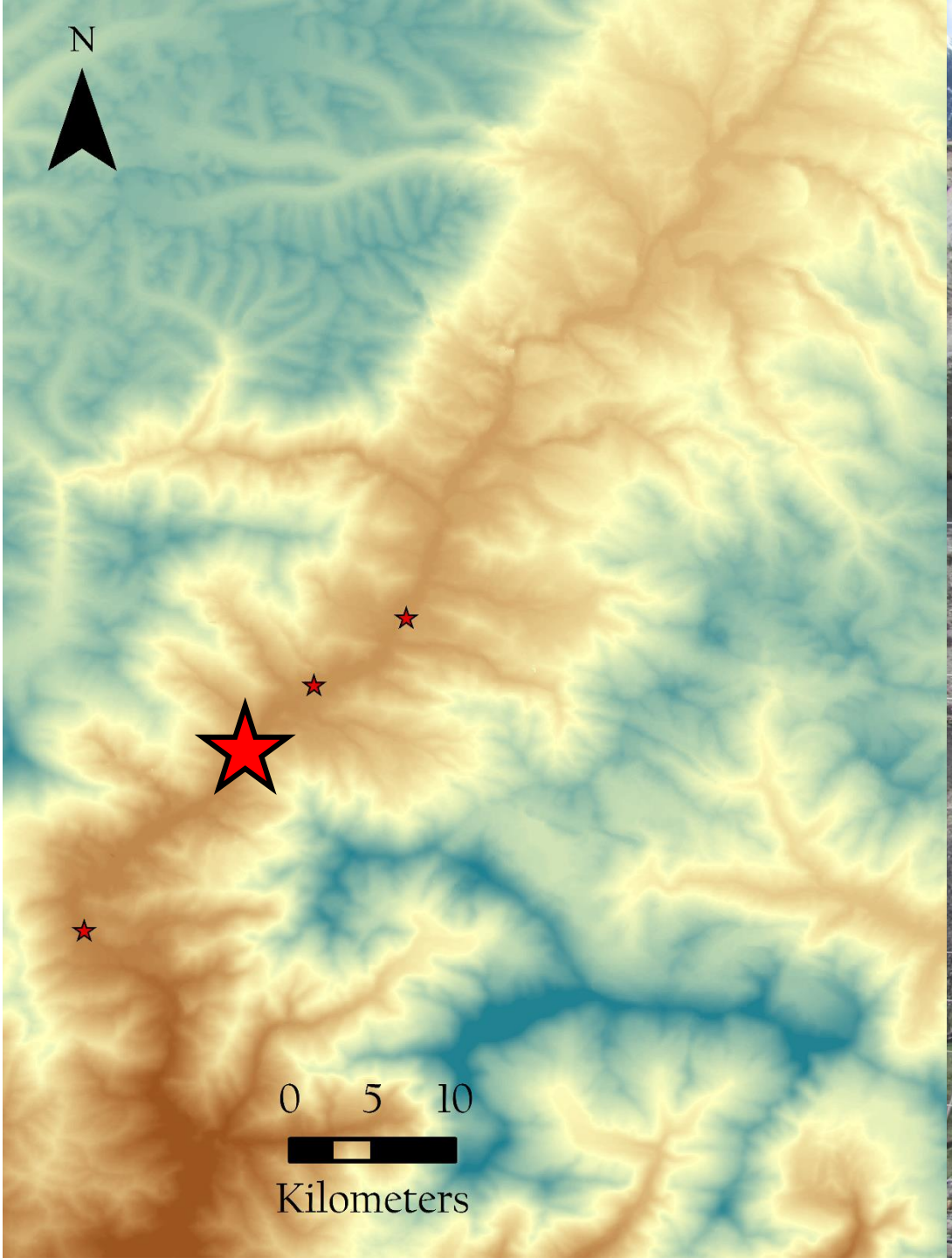


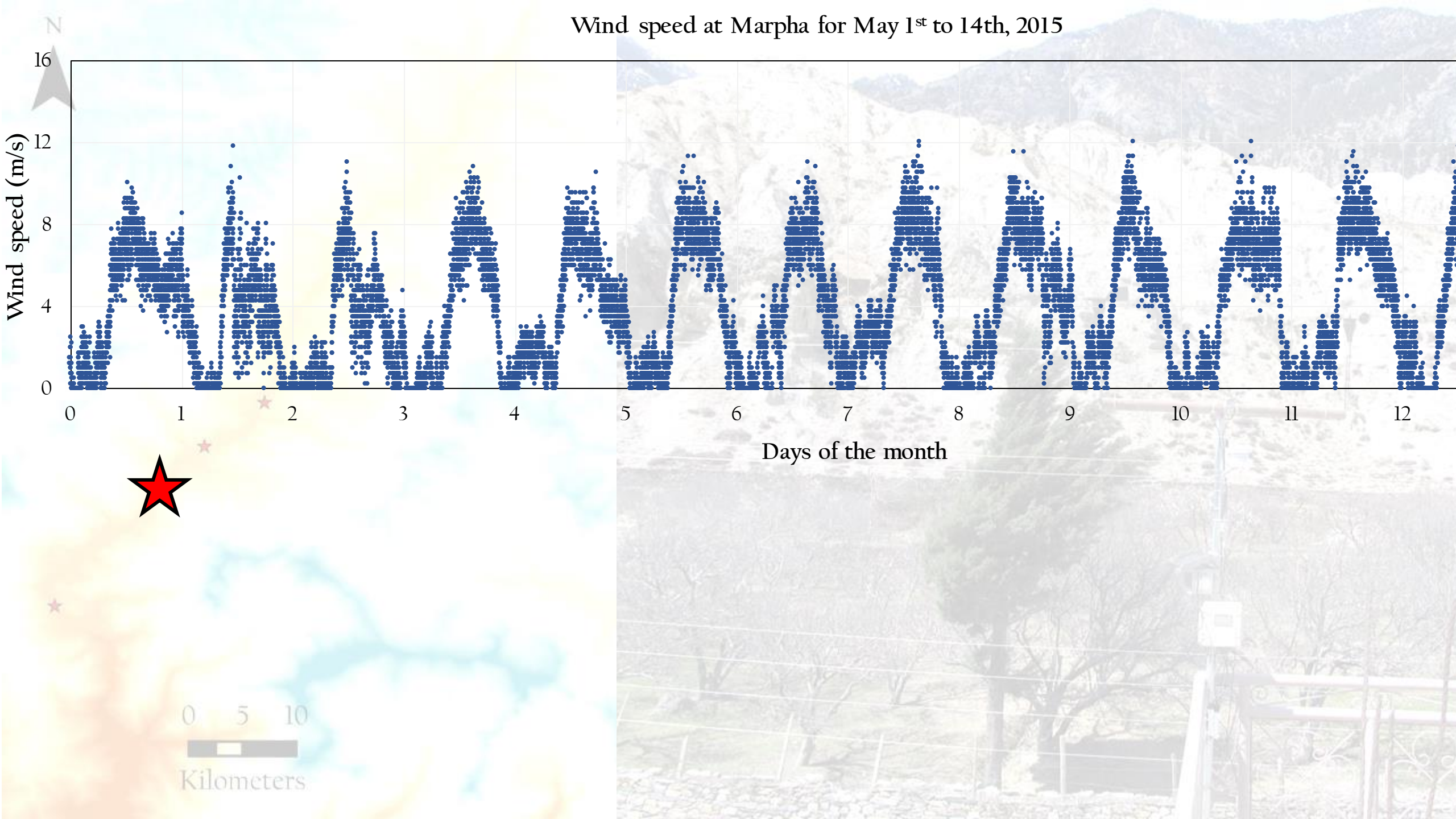
Three-hour average wind rose for May 8th-14th, 2015, Jomsom, Nepal.

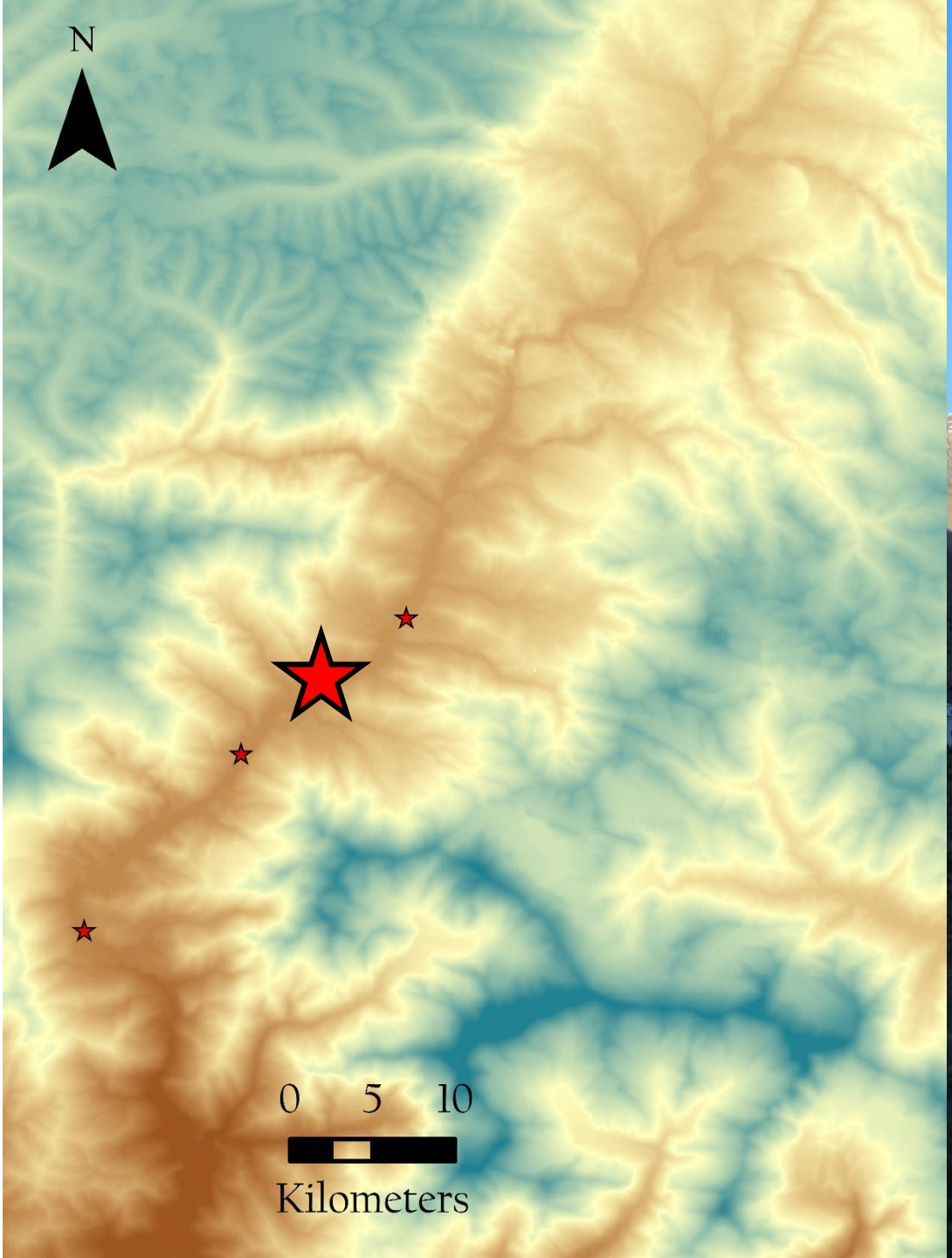


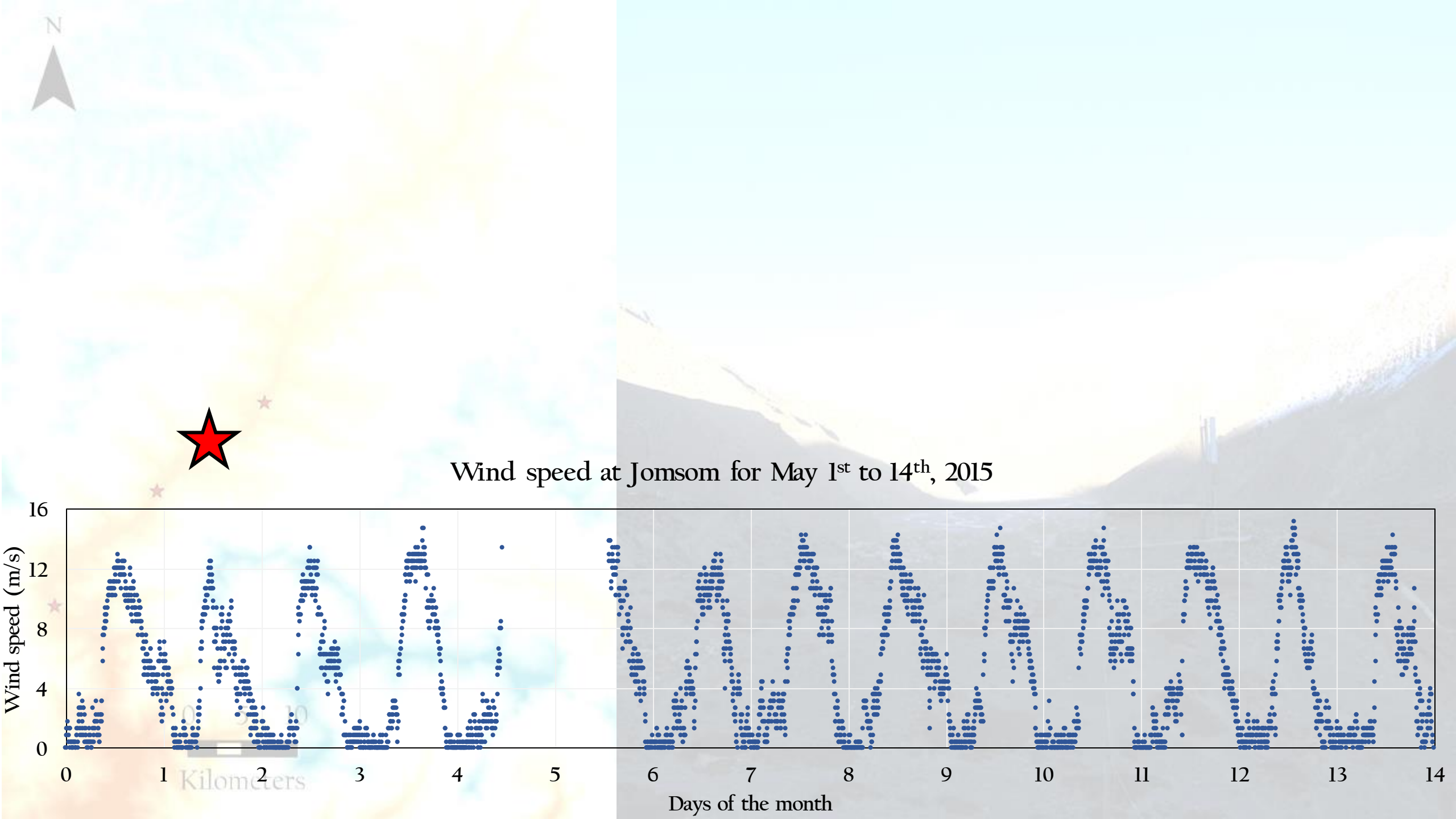

N
0 5 10
Kilometers

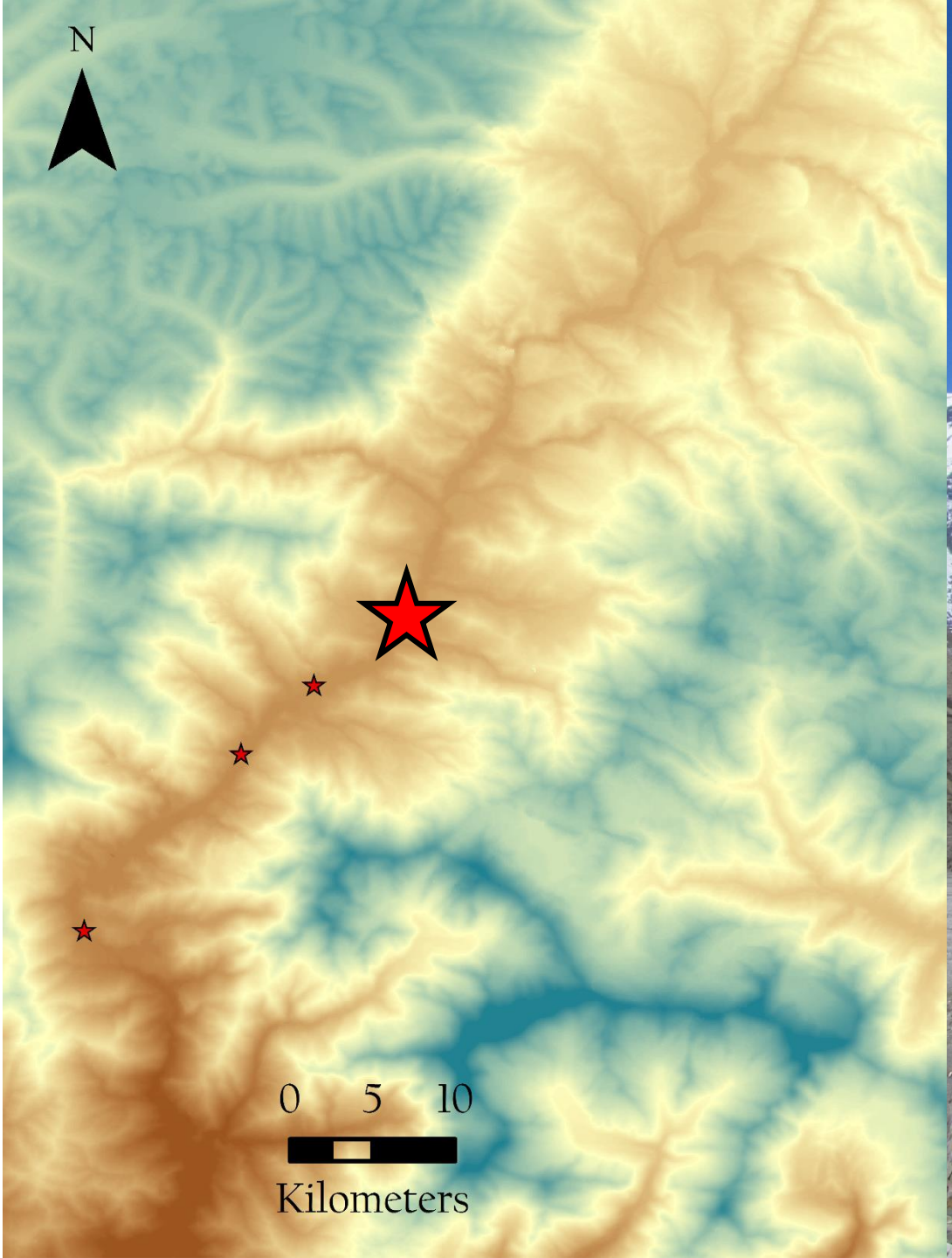

Wind speed at Lete for May 1st to 14th, 2015
Wind speed (m/s)
16
12
8
4
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Days of the month
N
0 5 10
Kilometers

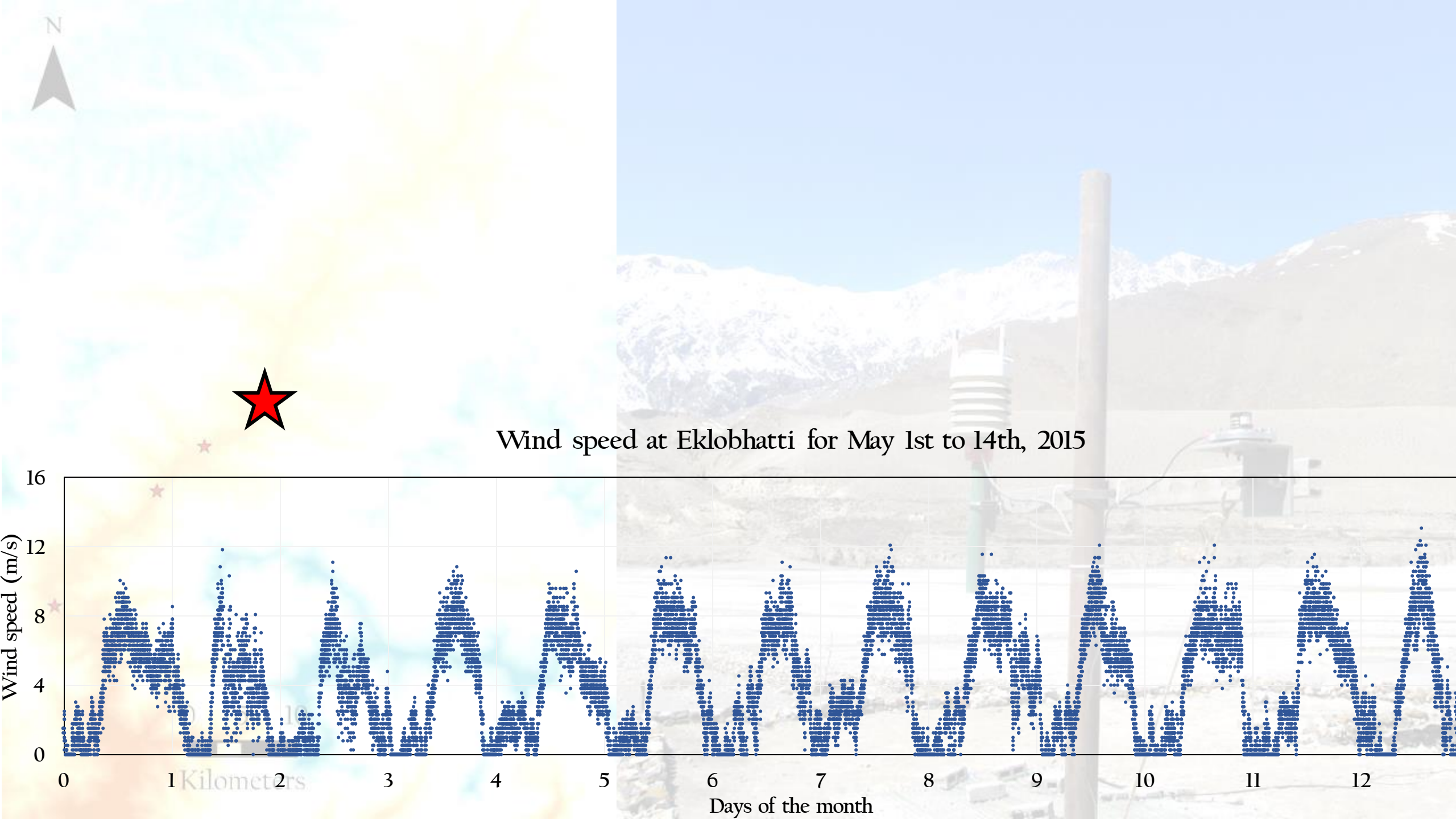

N
0 5 10
Kilometers

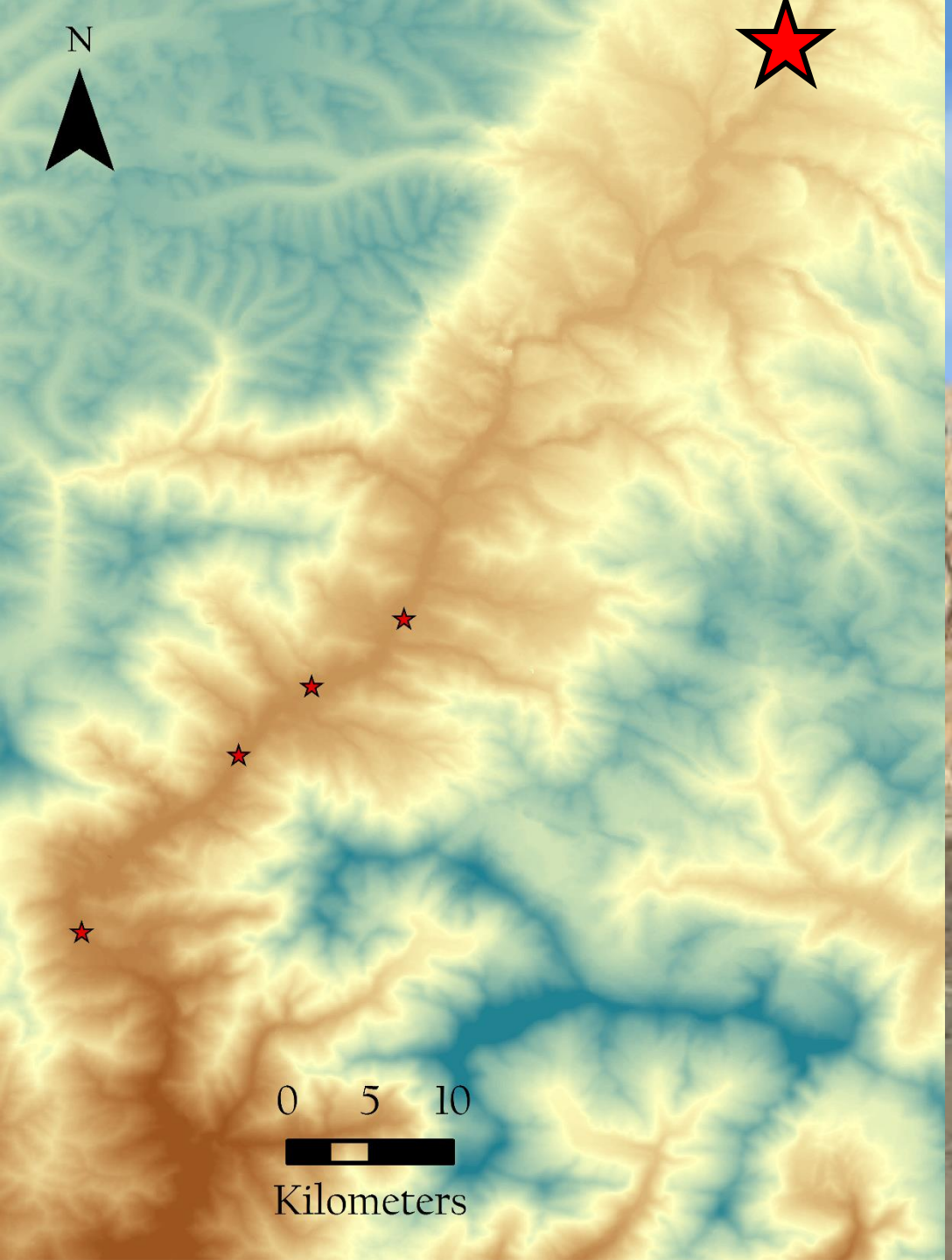

Wind speed at Marpha for May 1st to 14th, 2015
Wind speed (m/s)
16
12
8
4
0
0
1
2
3
4
5
6
7
8
9
10
11
12
Days of the month
N
0
5
10
Kilometers

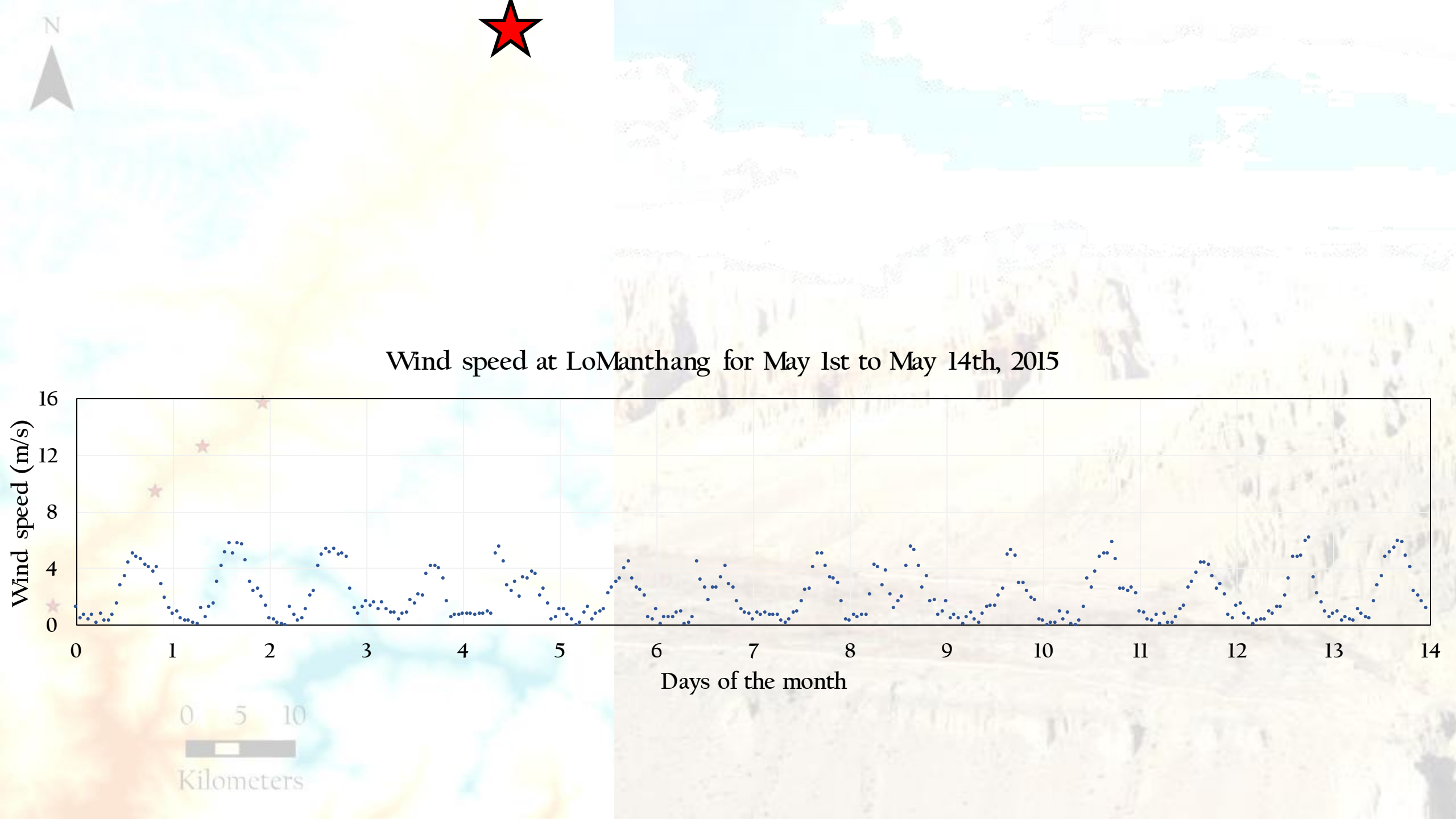

N
0 5 10
Kilometers


N
Wind speed at Jomsom for May 1st to 14th, 2015
Wind speed (m/s)
16
12
8
4
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Days of the month
Kilometers


N
0 5 10
Kilometers


N
Wind speed at Eklobhatti for May 1st to 14th, 2015
Wind speed (m/s)
16
12
8
4
0
0
1
2
3
4
5
6
7
8
9
10
11
12
Days of the month


N
0 5 10
Kilometers



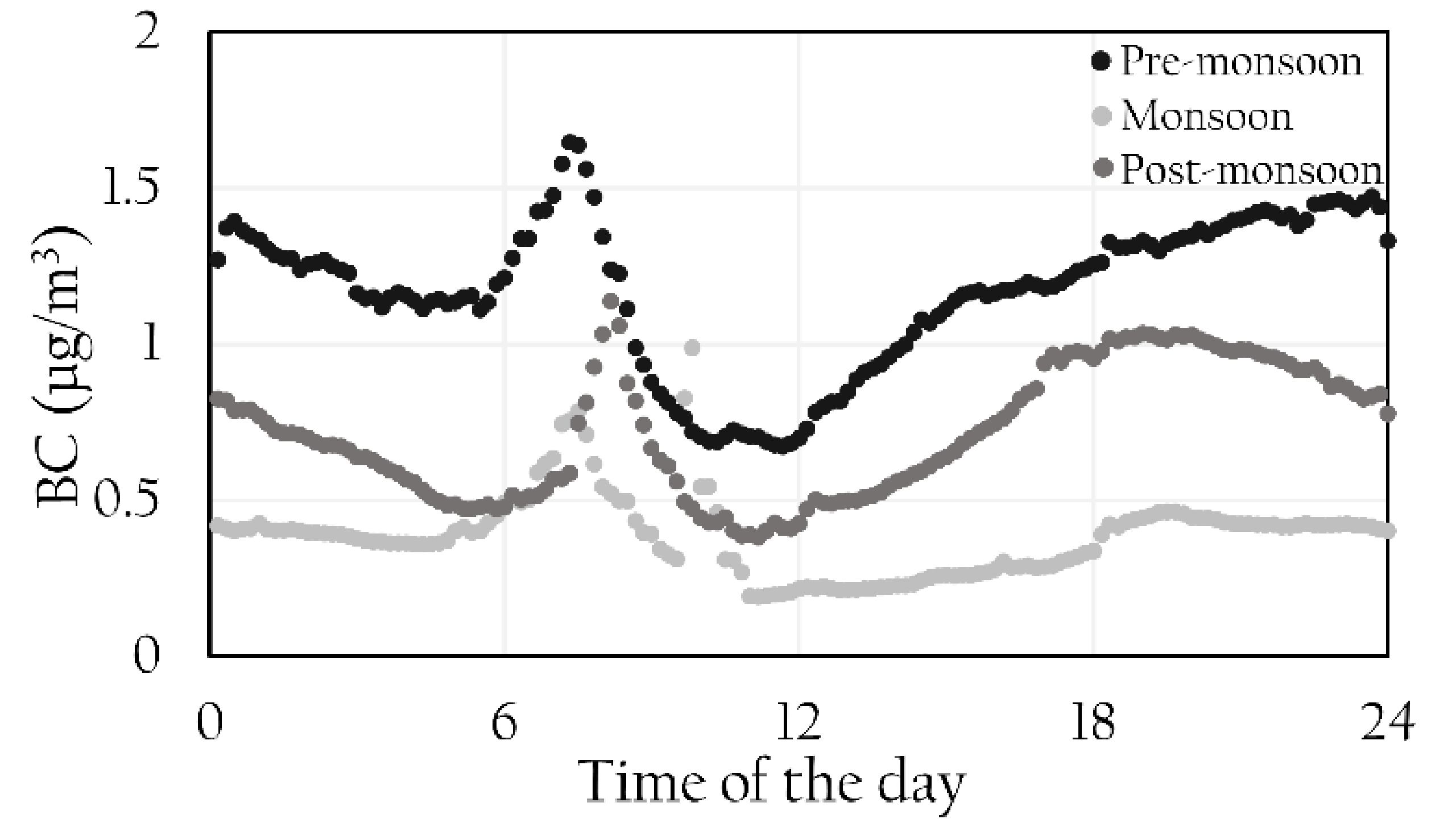
Wind speed at LoManthang for May 1st to May 14th, 2015

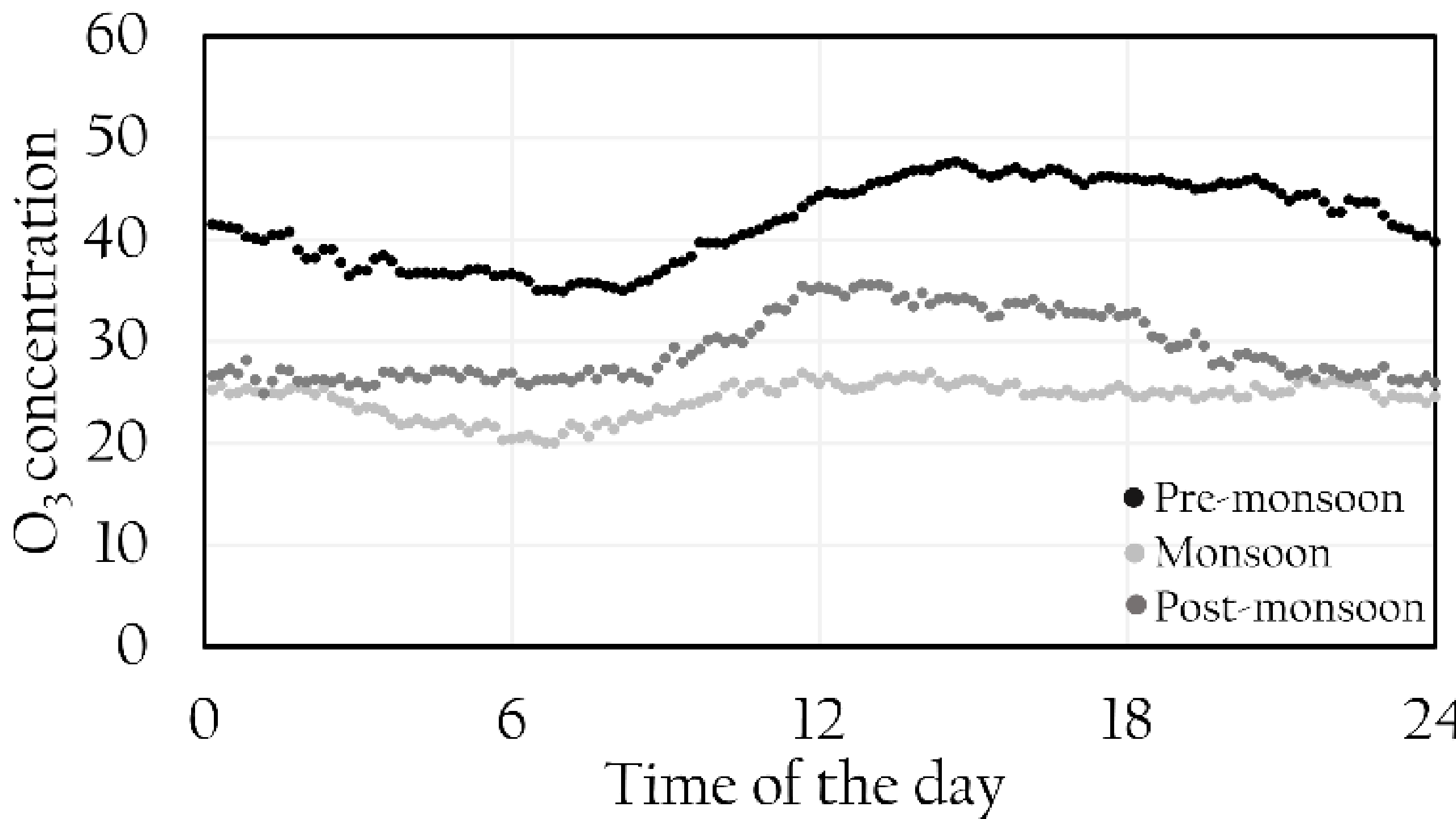
Wind speed (m/s)

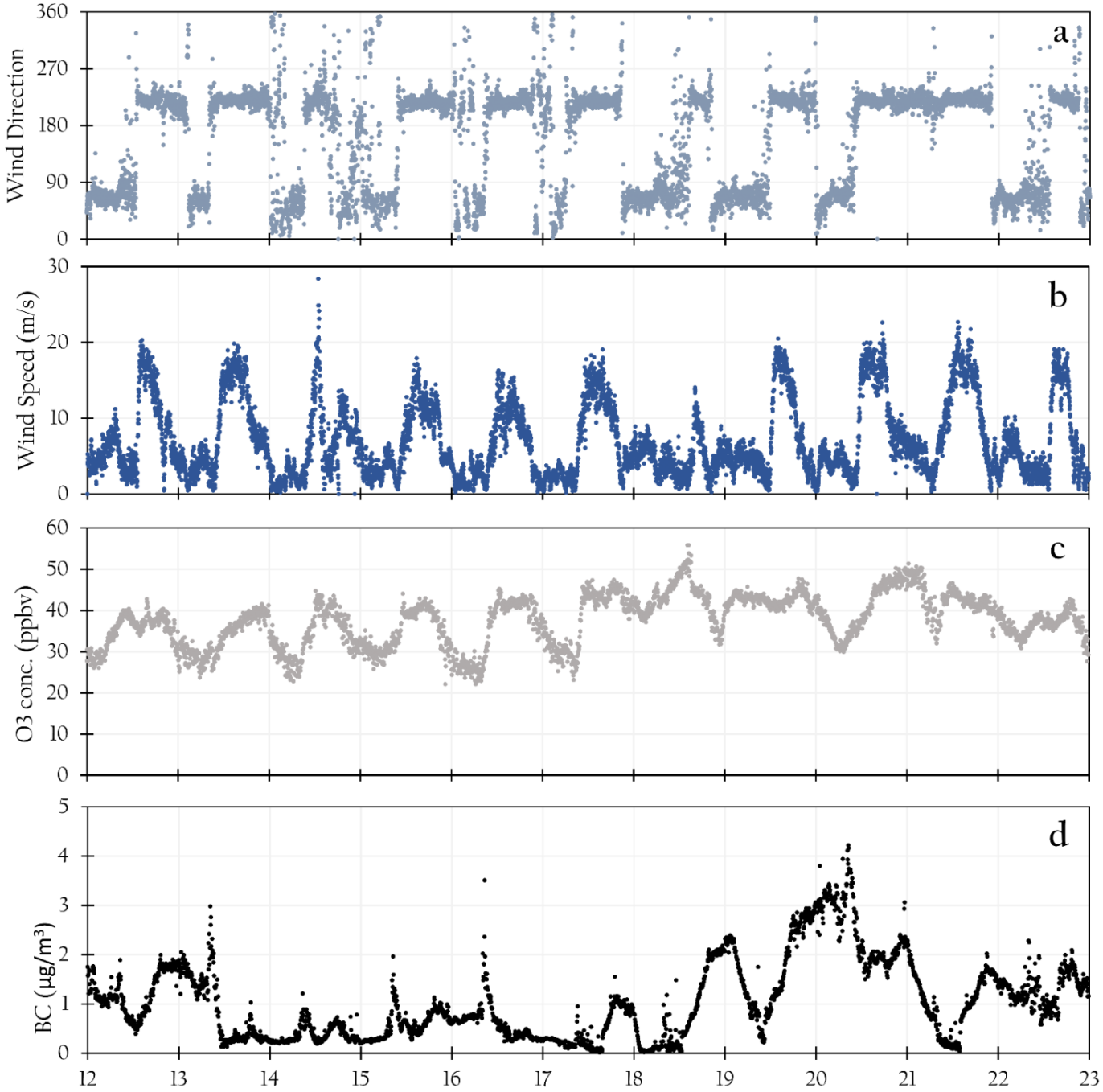
16
12
8
4
0

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Days of the month

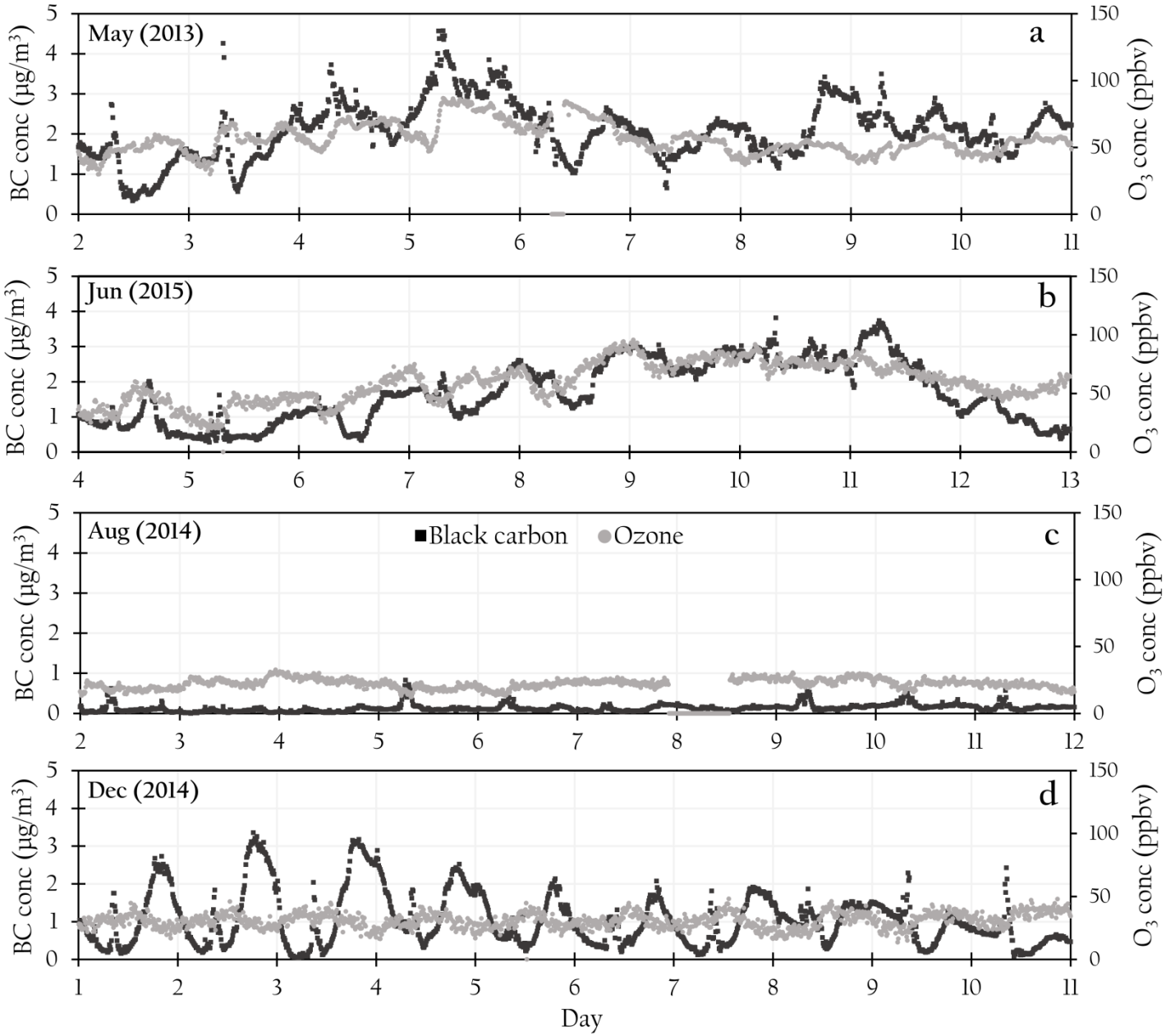

Pre-monsoon
Monsoon
Post-monsoon
BC (µg/m3)
2
1.5
1
0.5
0
0
6
12
18
24
Time of the day


60
50
40
30
20
10
0
O_3 concentration
0
6
12
18
24
Time of the day
Pre-monsoon
Monsoon
Post-monsoon



- Wind direction switches from down-valley to up-valley flow around 0900 LST
- High wind speed associated with the up-valley wind.
- Ozone and BC concentration in the valley is highly influenced by the wind system.
- On the 17th and 20th, Ozone concentration remains high due wind direction and wind speed.

Time series of wind direction (a), wind speed (b), ozone concentration (c) and black carbon (d) from March 12th-23rd, 2013.



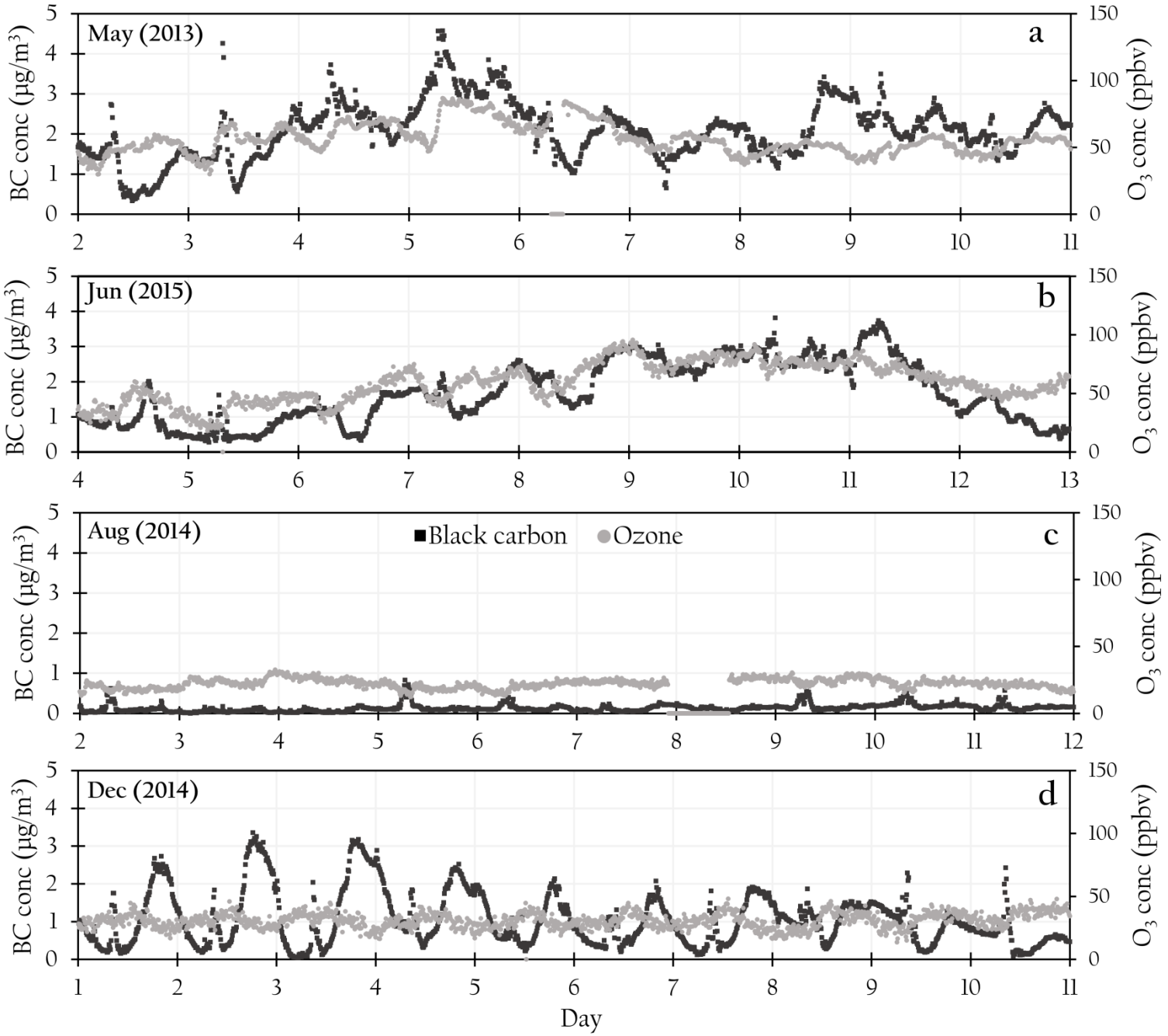
Patterns of black carbon and ozone concentration along the Kali Gandaki valley.

Transport patterns in the valley

- A sudden increase in BC conc. that lasts for a couple days. O3 follows the pattern.
- A gradual increase in BC conc. that lasts almost a week. ozone conc. follows pattern.
- Very low BC and ozone conc. with very low diurnal variabililty.
- A constant pattern of diurnal concentration with lowest conc. In the early morning and highest in the late afternoon.

Causes

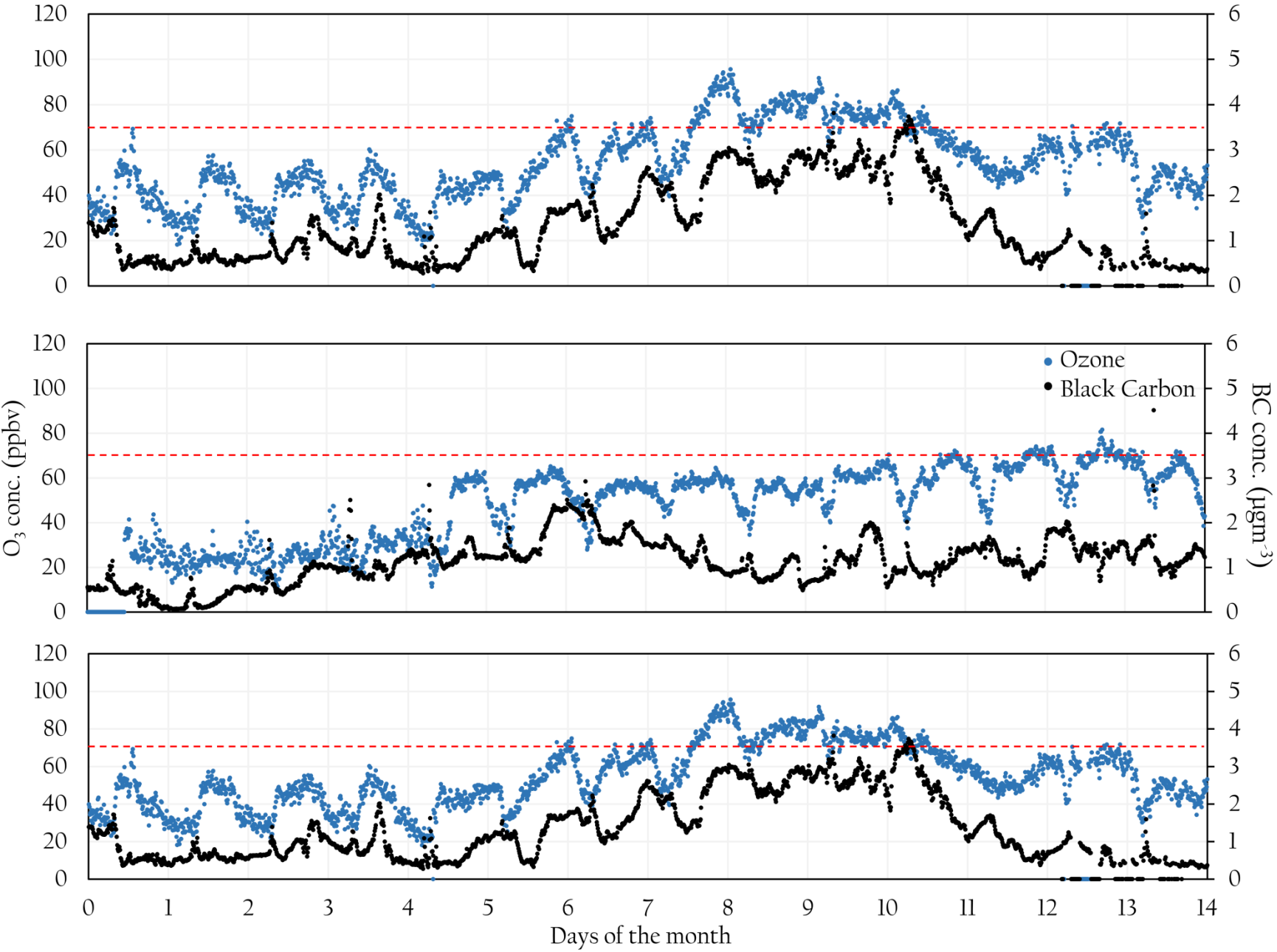
- Agricultural fires in India and Pakistan, Forest fires in Northern India and western Nepal.



Patterns of black carbon and ozone concentration along the Kali Gandaki valley.

Are these **regional transport episodes**?

- Transport episodes coincides with extensive haze in the region
- Transport episodes are common in dry season when there is agricultural burning in the Punjab region of India and Pakistan and extensive haze.
- Increase in more than 65% rise in BC conc. In the valley.



Transport episodes observed in Jomsom during pre-monsoon season when the concentration level of BC and O_3 are extremely high.

- During transport episodes not only BC conc increases but there is high conc. of O_3 as well.
- O_3 regularly exceeds the National Ambient Air Quality Standards (NAAQS) for ground-level ozone

Summary

- Himalayan valleys have well developed local wind patterns that transport air masses from the foothills through the trans-Himalayan Valley.
- BC and O_3 has dial and seasonal signature in the Kali-Gandaki valley.
- Frequent transport during pre-monsoon and post-monsoon season.
- During regional transport episodes BC conc. increases by 3 folds and O_3 exceed the air quality standards.

Work in Progress

- Stratification of PM using GRIMM data on board a motorized glider in collaboration with the MWP project in Jan 2014.

- Looking at stratification of O3 using ozonesonde in the southern Himalaya, from Pokhara Jan 2016.

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