UTM FACULTY OF BUILT ENVIRONMENT & SURVEYING

Land Use/Cover Changes, Environment and Emissions in South/Southeast Asia

Atmospheric Aerosols and Their Driving Factors/Meteorology in South Asia: The Case of Dust Storms

Dr. Dimitris G. Kaskaoutis

Research scientist

NATIONAL OBSERVATORY OF ATHENS
more than 170 years contribution to research and society

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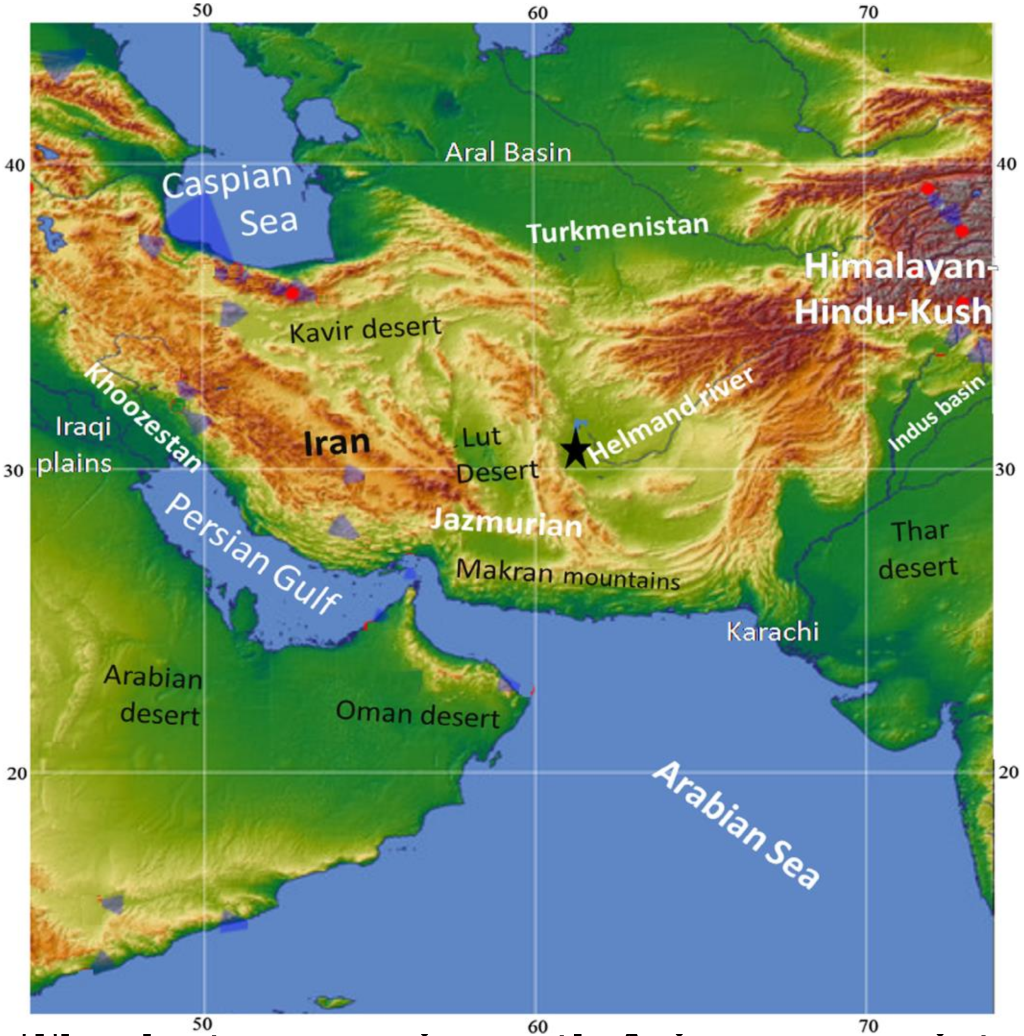
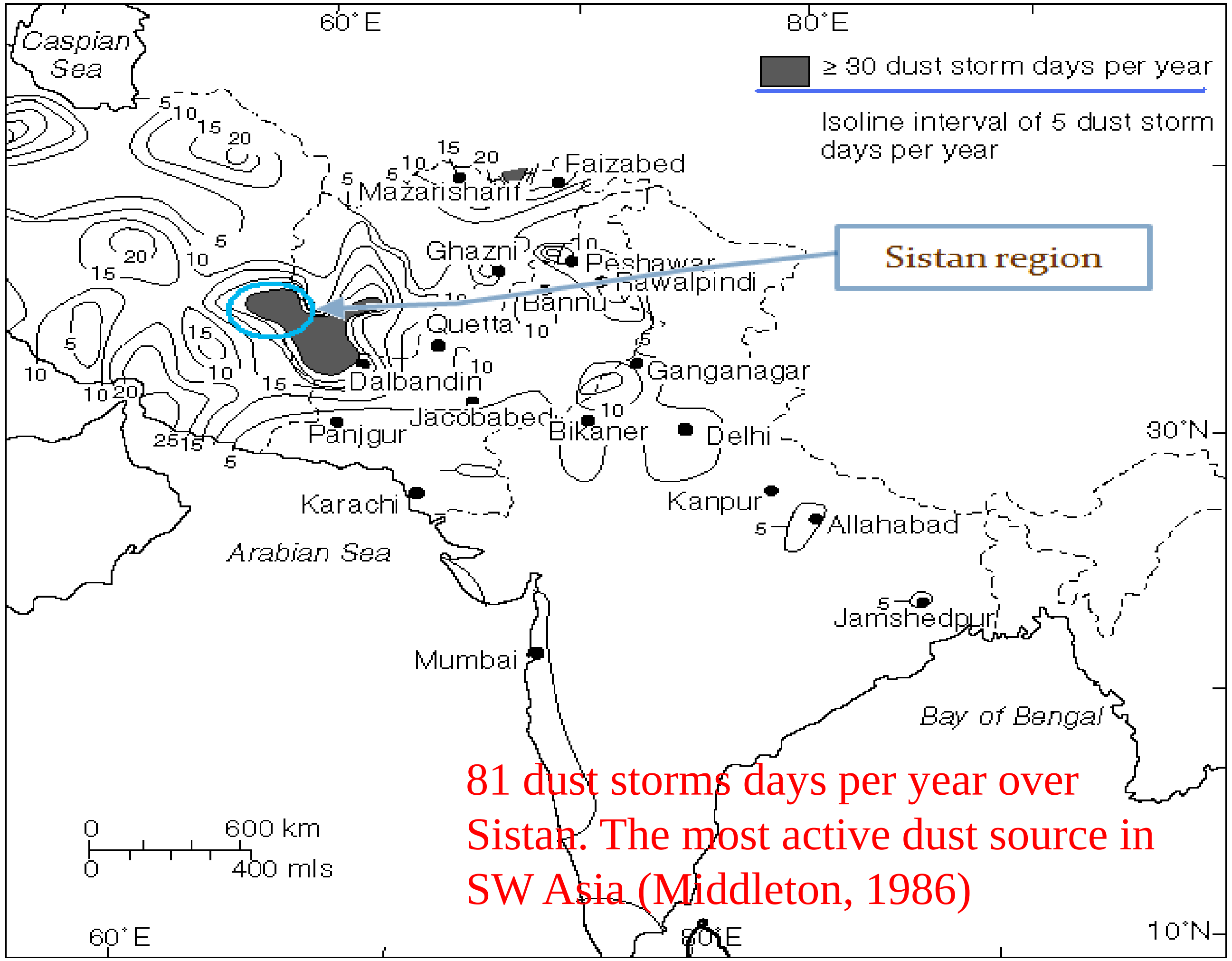
ATMOSPHERIC PHYSICS AND CHEMISTRY GROUP

Dust sources in south Asia



The dust sources in south Asia are associated with topographic-low interior basins or large dried plateaus.



Sistan region

81 dust storms days per year over Sistan. The most active dust source in SW Asia (Middleton, 1986)

Sistan Province/Region/Basin

The

Geographical Journal.

No. 3. SEPTEMBER, 1906. Vol. XXVIII.

RECENT SURVEY AND EXPLORATION IN SEISTAN.*

By Colonel Sir HENRY McMAHON, K.C.I.E., C.S.I.

I come next to another very curious phenomenon in Seistan. This is the wind. If ever a country merits the title of "land of the winds" it is Seistan. Every one who has visited Seistan or written about Seistan has mentioned its celebrated wind, called the "Bad-i-sad-o-bist roz," or wind of 120 days, which blows in the summer. Few of

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THE DEPRESSION OF SISTAN* IN EASTERN PERSIA.

BY

ELLSWORTH HUNTINGTON.

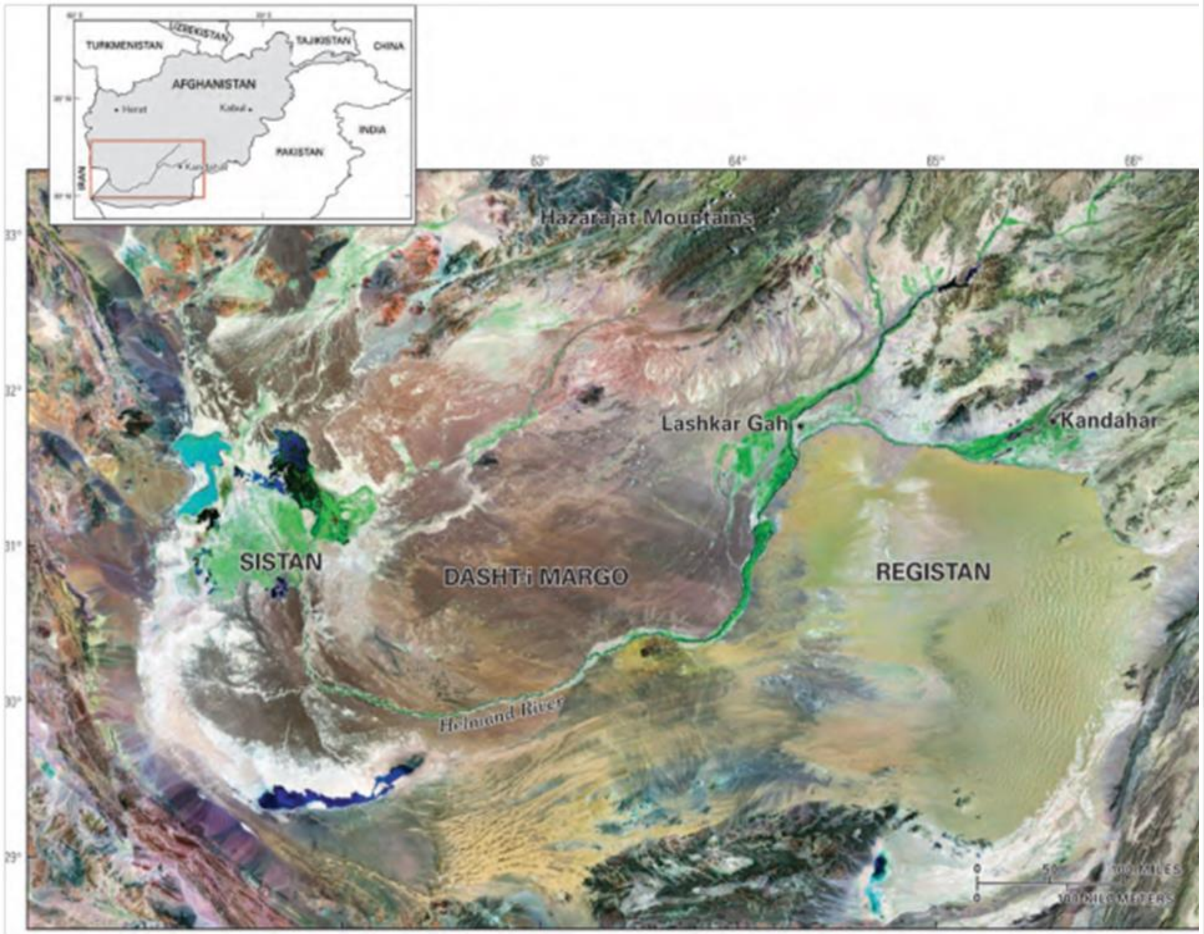
Windy Sistan, once the proud home of Rustum, the Persian Hercules, is a

The wind, like the other physiographic features of Sistan, has a marked influence upon life. During three months of the summer a remarkably constant wind blows night and day with great violence from the north-northwest. It seems to be the northward continuation of the trade-winds deflected to the west by the prevailing trend of the mountains. It is said to blow at a rate of over sixty miles an hour for days at a time without intermission. Its violence is such that the air is thick with flying sand; and huge sand-dunes are formed or blown away with almost the rapidity of snowdrifts.

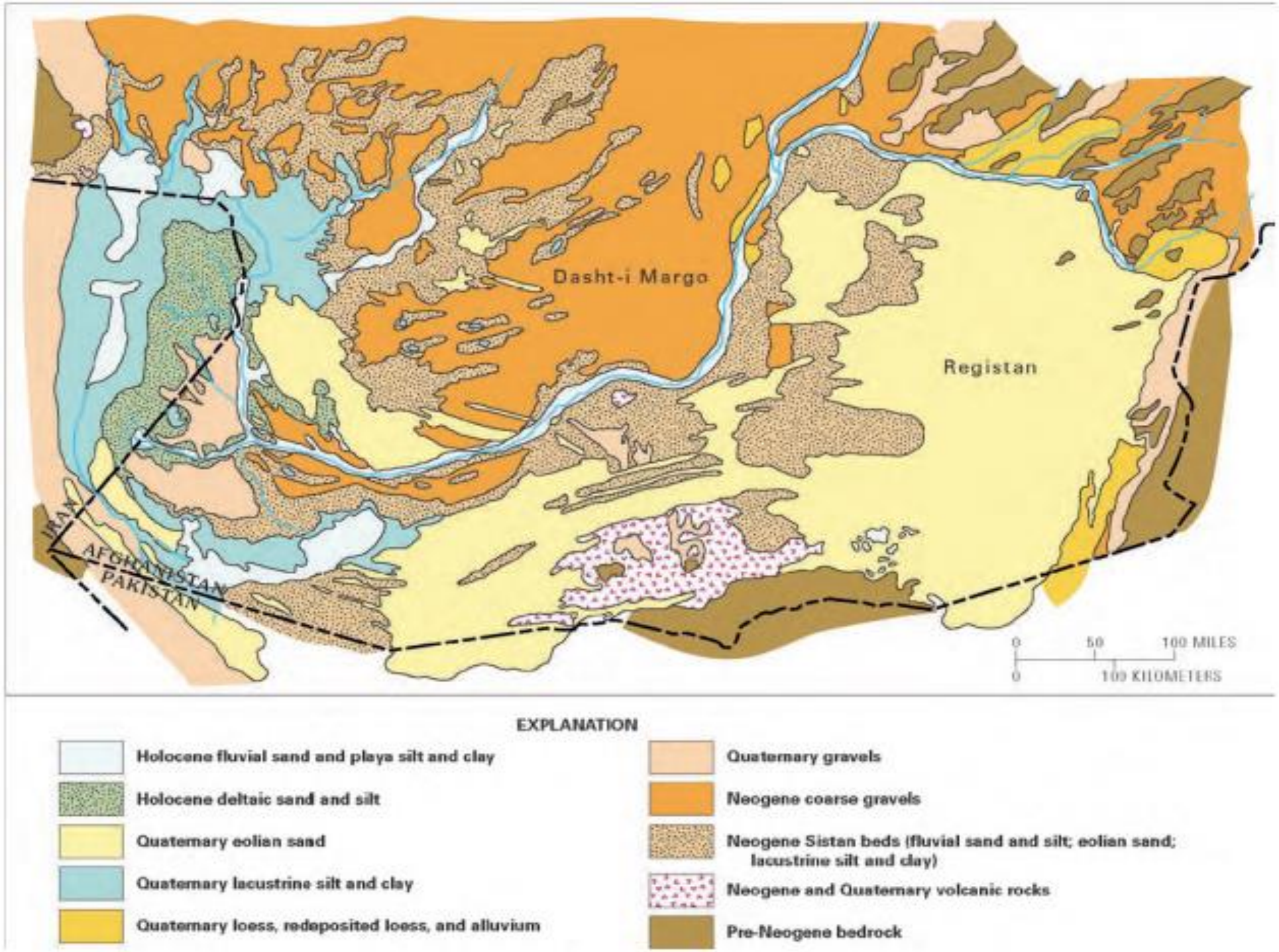
Huntington Theory

The Depression of Sistan in Eastern Persia
Author(s): Ellsworth Huntington
Source: *Bulletin of the American Geographical Society*, Vol. 37, No. 5 (1905), pp. 271-281
Published by: American Geographical Society

Geology of the Sistan Basin

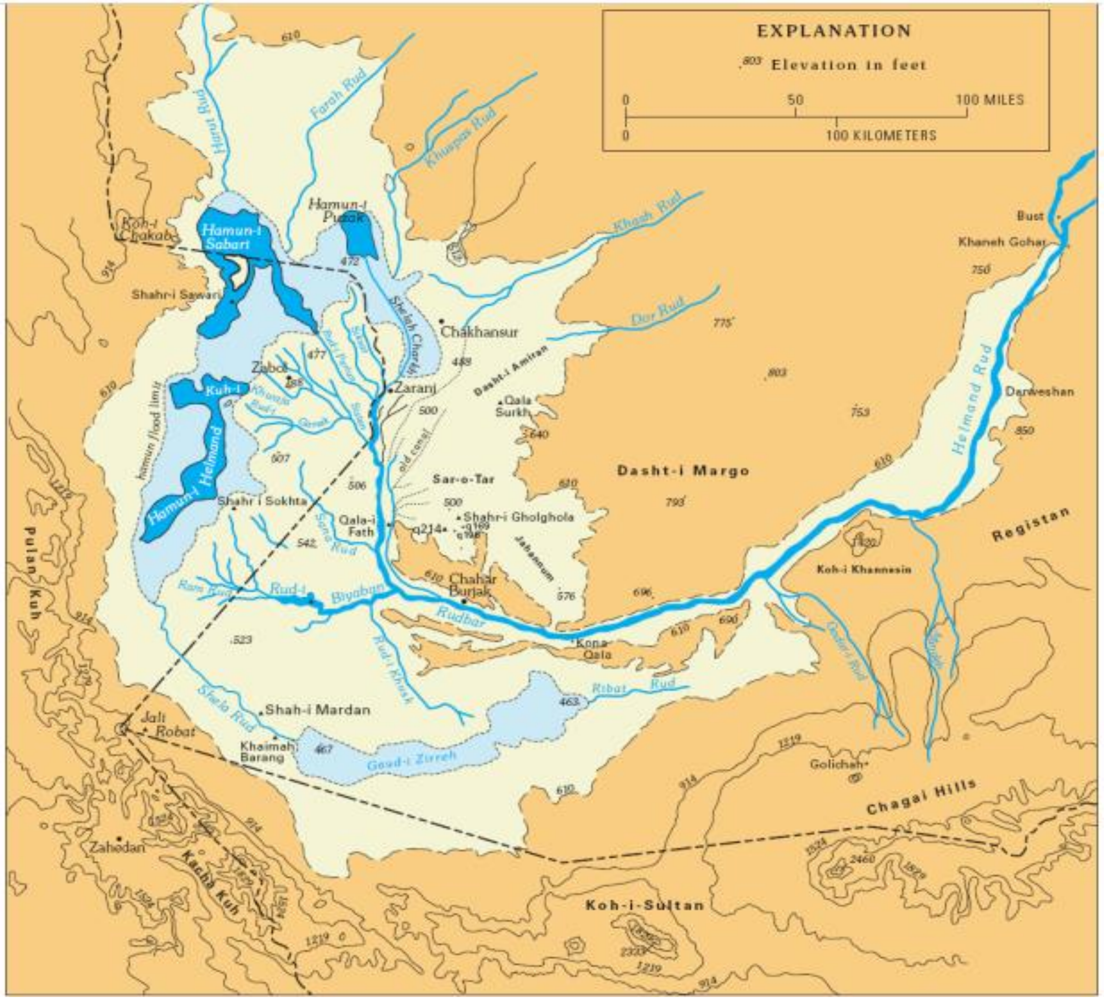


Landsat 5 image showing the lower Hirmand (Sistan) Basin.



Geological map of the Sistan Basin. *[from Wittekind and Weippert (1973) and O'Leary and Whitney (2005a, b)]*

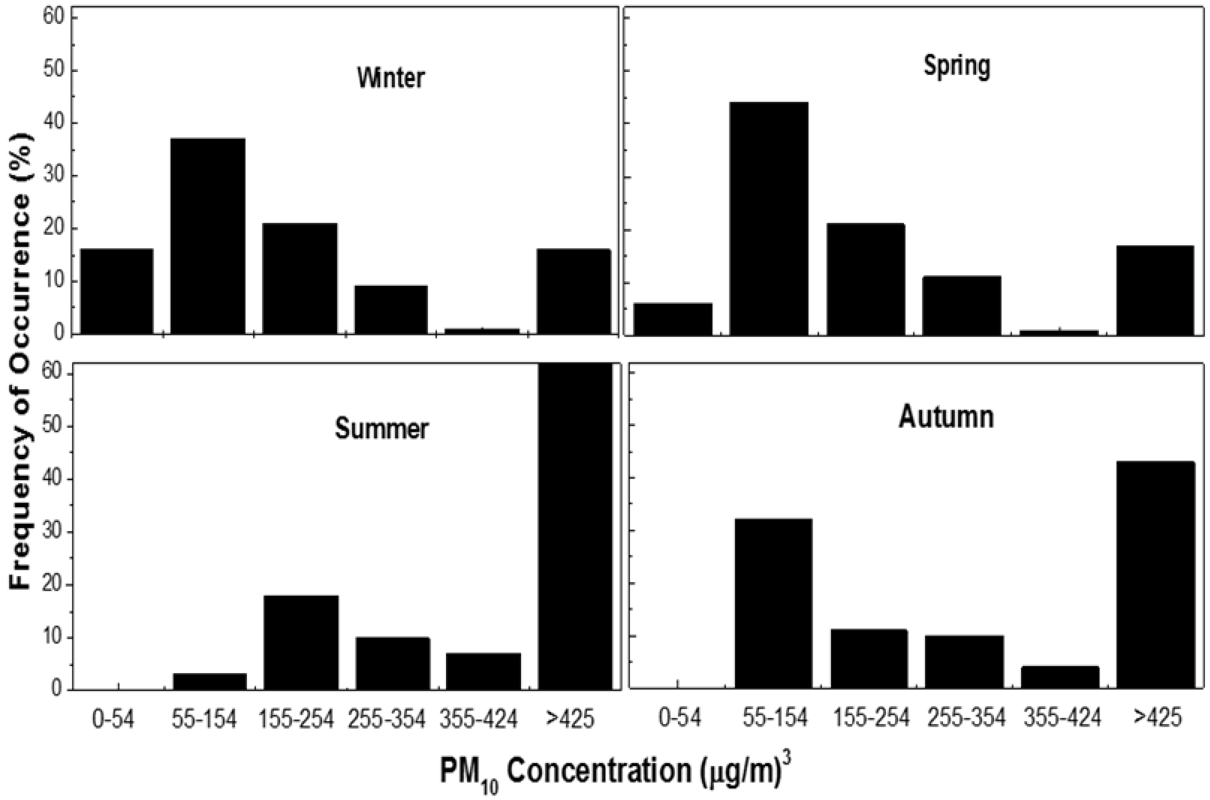
Hydrology of the Sistan Basin



Hydrological network and topographical map of Sistan basin.

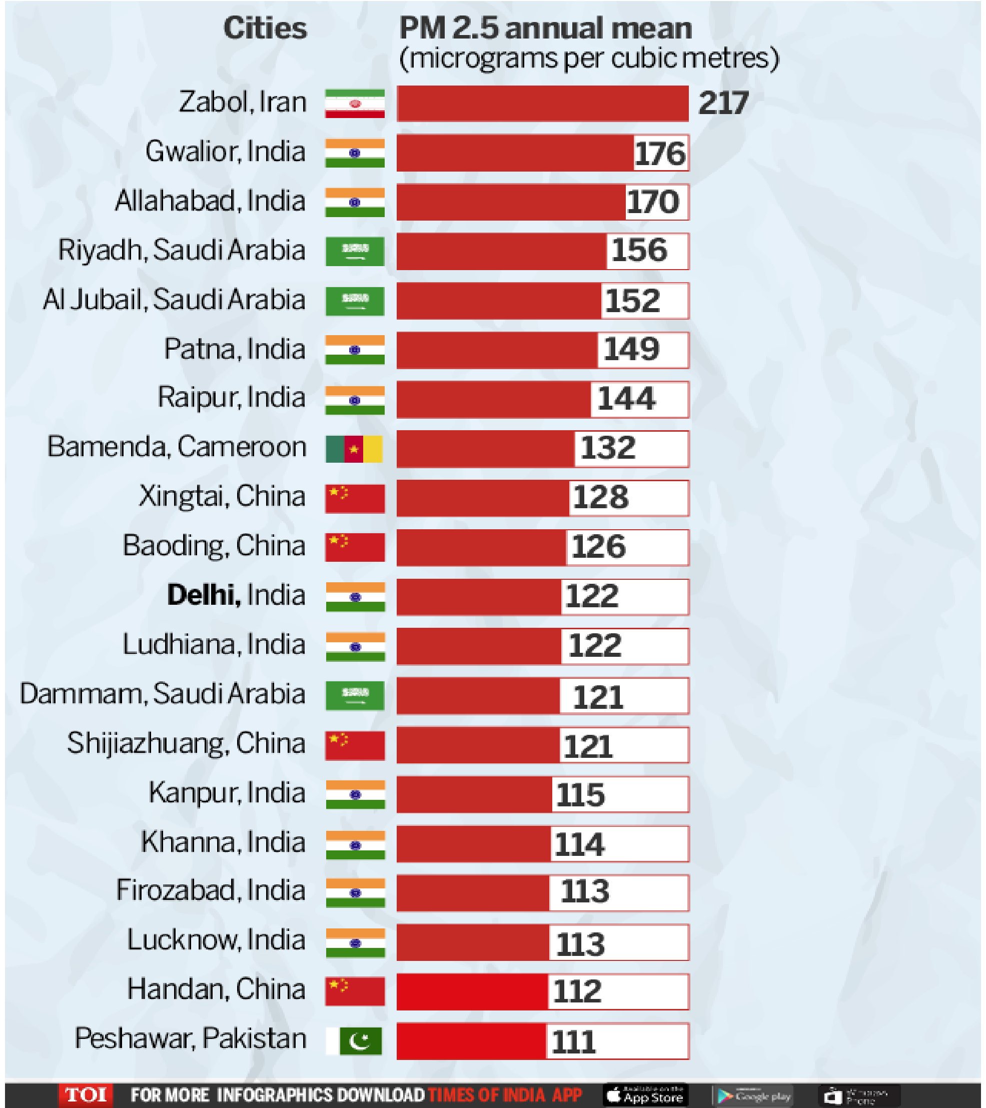
Topographic map of Sistan Basin and catchment area. The location of Zabol is indicated by the white circle (30° 57’N, 61° 34’E).

Sistan Basin: Extremely high dust concentrations

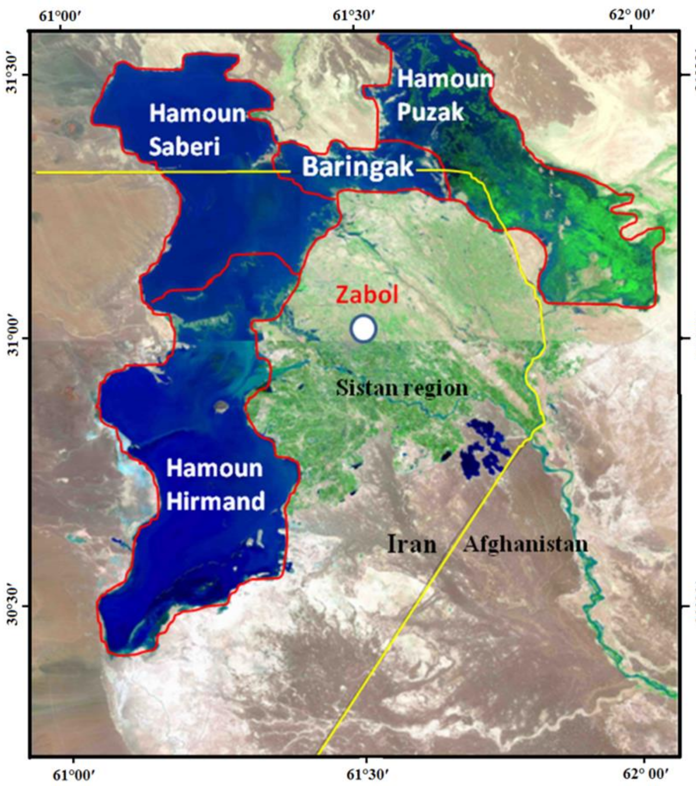


Frequency (%) distribution of the daily PM_{10} for each season in Zabol (September 2010 – July 2011).

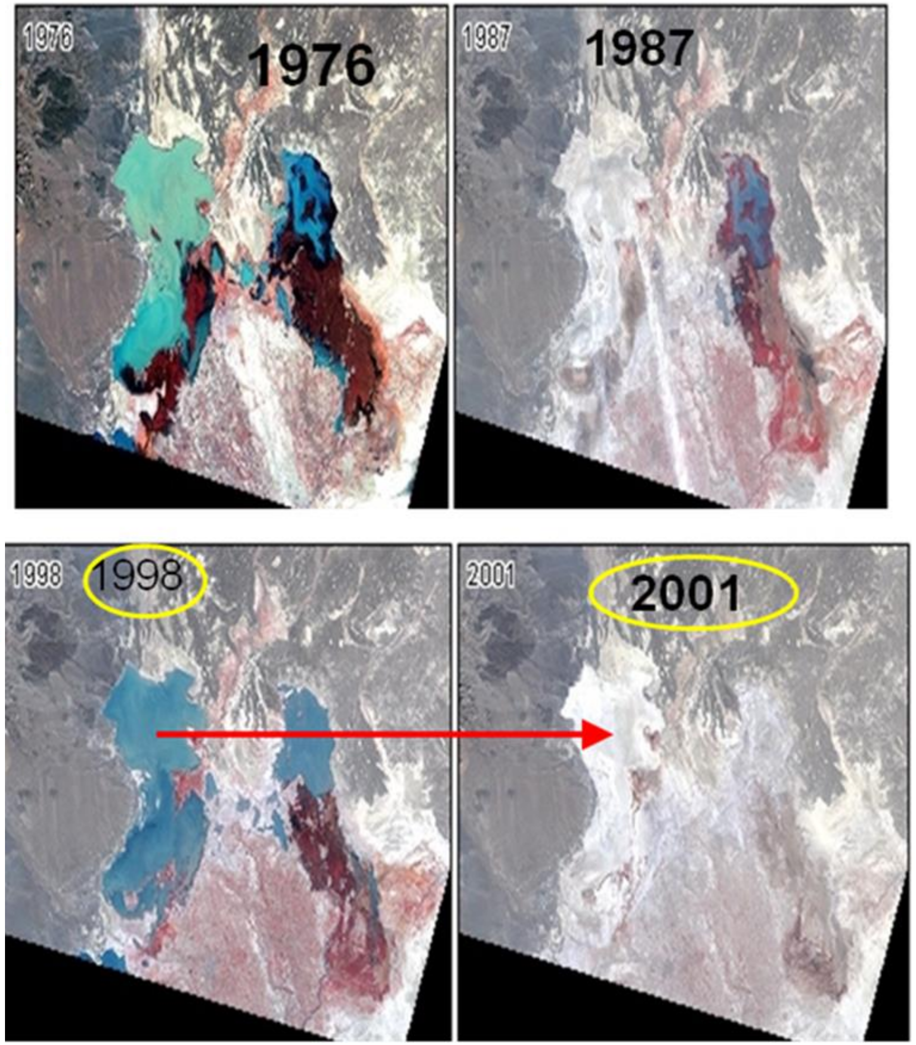
WHO report of 2016, 3000 cities in 103 countries

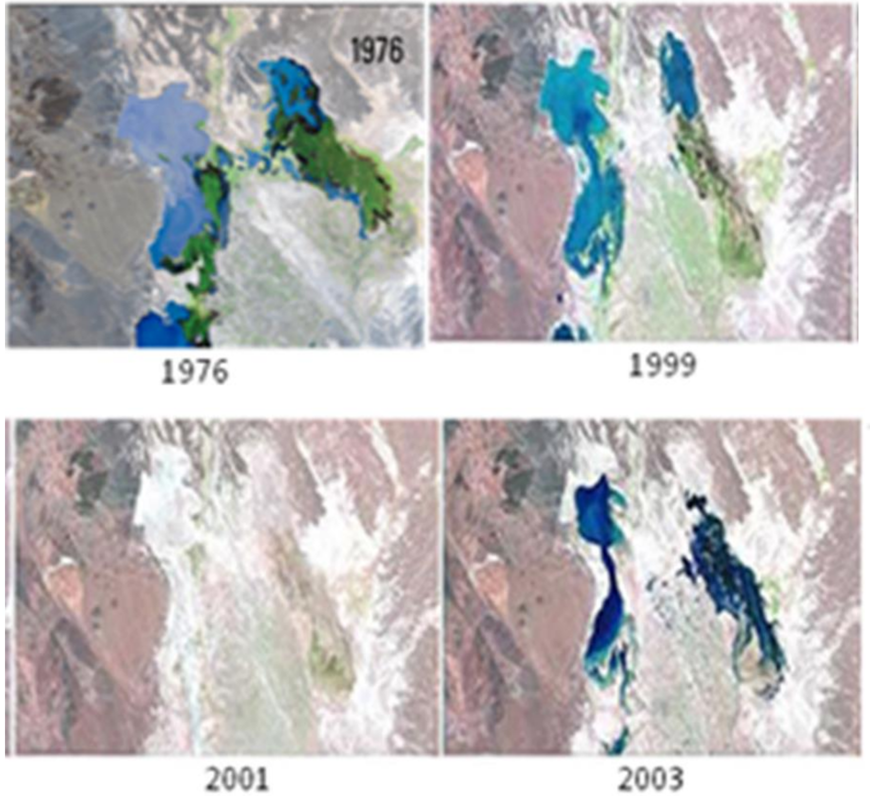


The Hamoun lakes



Hamoun lakes complex:
-largest fresh water ecosystem of the Iranian Plateau
- one of the first wetlands in the Ramsar Convention.



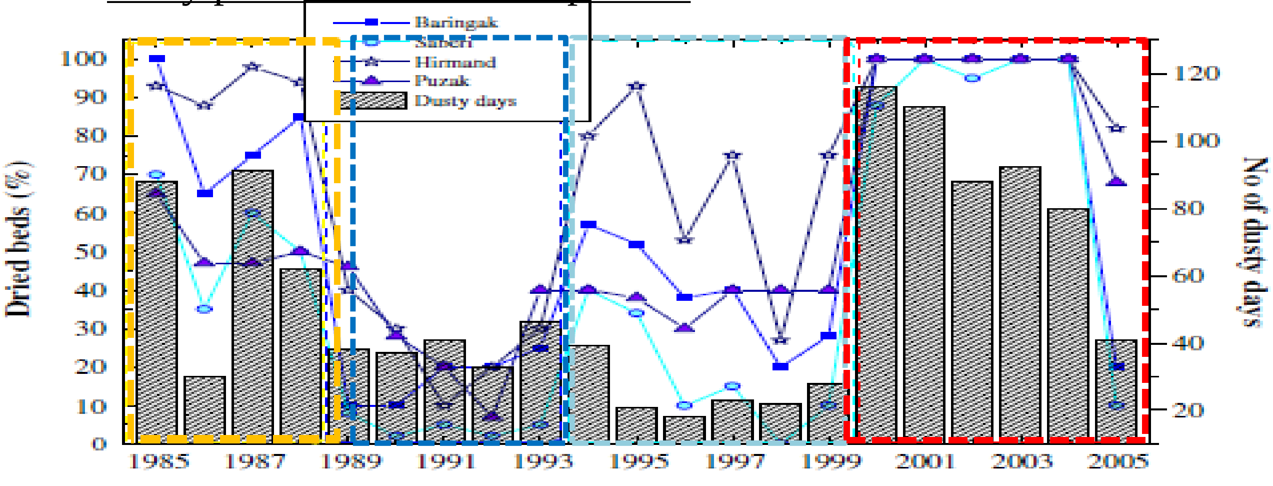


Landsat MSS false color composite (bands 4, 2, and 1) images of the Hamoun lakes (1976-1987). Landsat 7 ETM+ false color composite (bands 4, 3, and 2) for 1998-2003.

Dryness of Hamouns

Yearly variations of Hamoun lakes water surface identified four periods from 1985 to 2005:

- 1. A low-water period from 1985 to 1988
- 2. A high-water period from 1989 to 1993:
- 3. A medium-water period from 1994 to 1999:
- 4. A dry period from 2000 to present

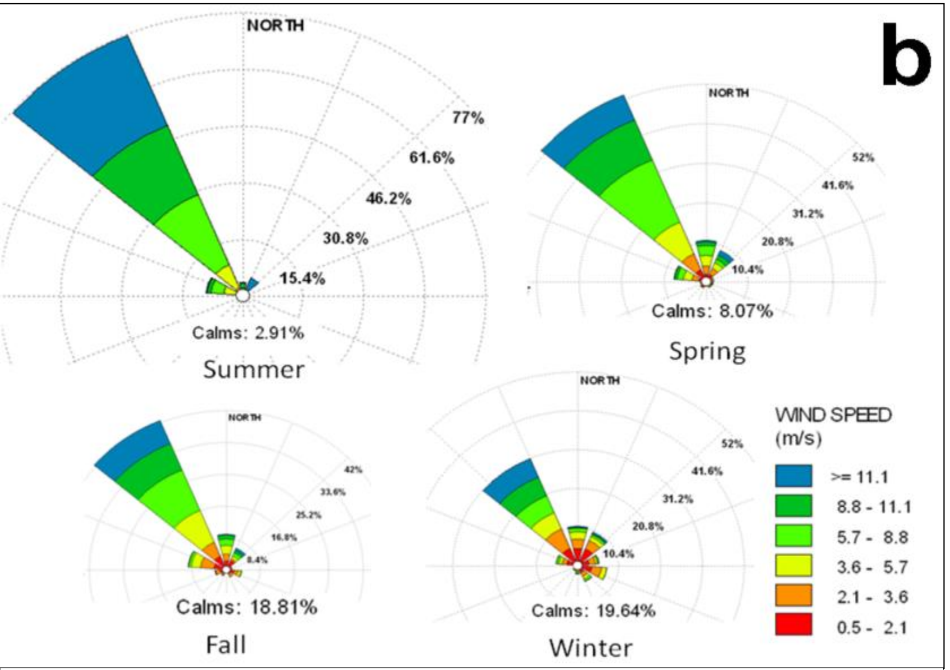


Hamoun Lakes	Baringak	Hamoun Saberi	Hamoun Hirmand	Hamoun Puzak	Precipitation	Dusty days
Baringak	1					
Hamoun Saberi	0.96**	1				
Hamoun Hirmand	0.84**	0.80**	1			
Hamoun Puzak	0.80**	0.89**	0.74**	1		
Precipitation	-0.59**	-0.63**	-0.35	-0.54	1	
Dusty days	0.82**	0.88**	0.60**	0.81**	-0.730**	1

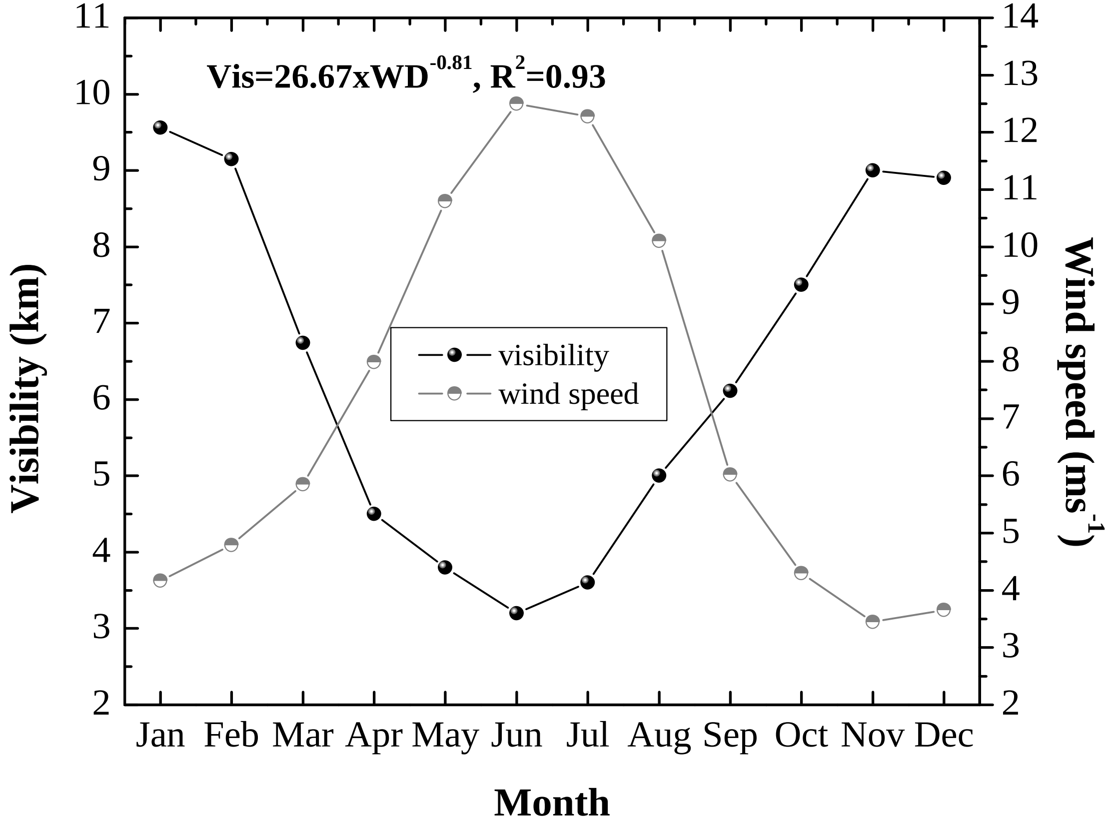
Percentage of water surface in July in Hamoun lakes, as well as the annual precipitation and number of dusty days during the period 1985-2005.

Year	Baringak	Saberi	Hirmand	Puzak	precipitation	Dusty days
1985	0	30	7	35	25.6	88
1986	35	65	12	53	72.8	30
1987	25	40	2	53	8.7	91
1988	15	50	6	50	69.5	62
1989	90	92	60	54	26.1	38
1990	90	98	70	72	96.1	37
1991	80	95	90	80	85.8	41
1992	80	98	80	93	80.9	33
1993	75	95	70	60	52.4	46
1994	43	60	20	60	116.6	39
1995	48	66	7	62	76.2	21
1996	62	90	47	70	84.3	18
1997	60	85	25	60	76.4	23
1998	80	100	73	60	61.4	22
1999	72	90	25	60	87.7	28
2000	0	12	0	0	26.8	116
2001	0	0	0	0	7.2	110
2002	0	5	0	0	37.5	88
2003	0	0	0	0	32.3	92
2004	0	0	0	0	51.1	80
2005	80	90	18	32	129.5	41

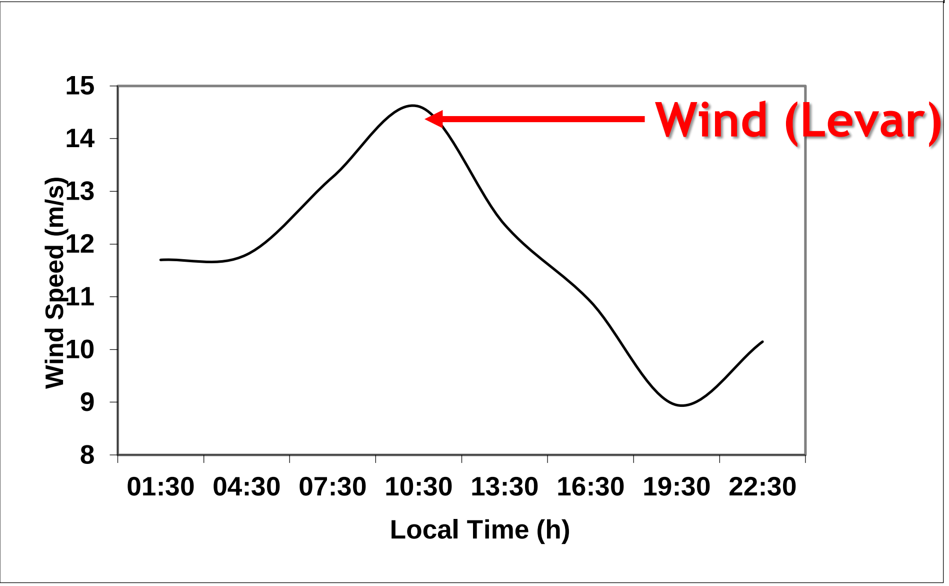
Sistan meteorology/climatology



Flow chart of the seasonal wind speed and direction in Zabol during the period 1963-2010. The percentage of calm periods is shown in the bottom of each wind rose.

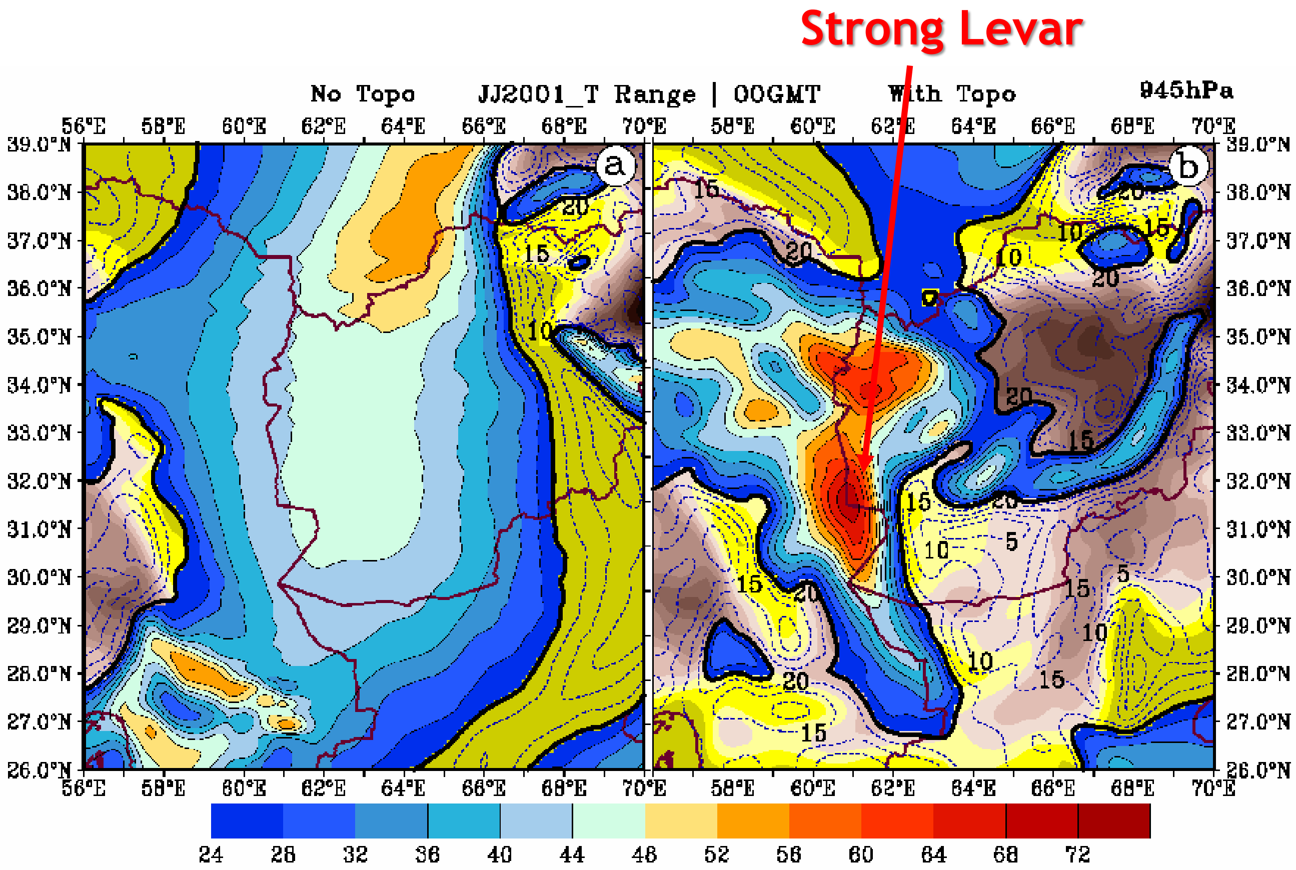


Monthly mean variation of the visibility (km) and wind speed (ms^{-1}) in Zabol during the period 1963–2009.

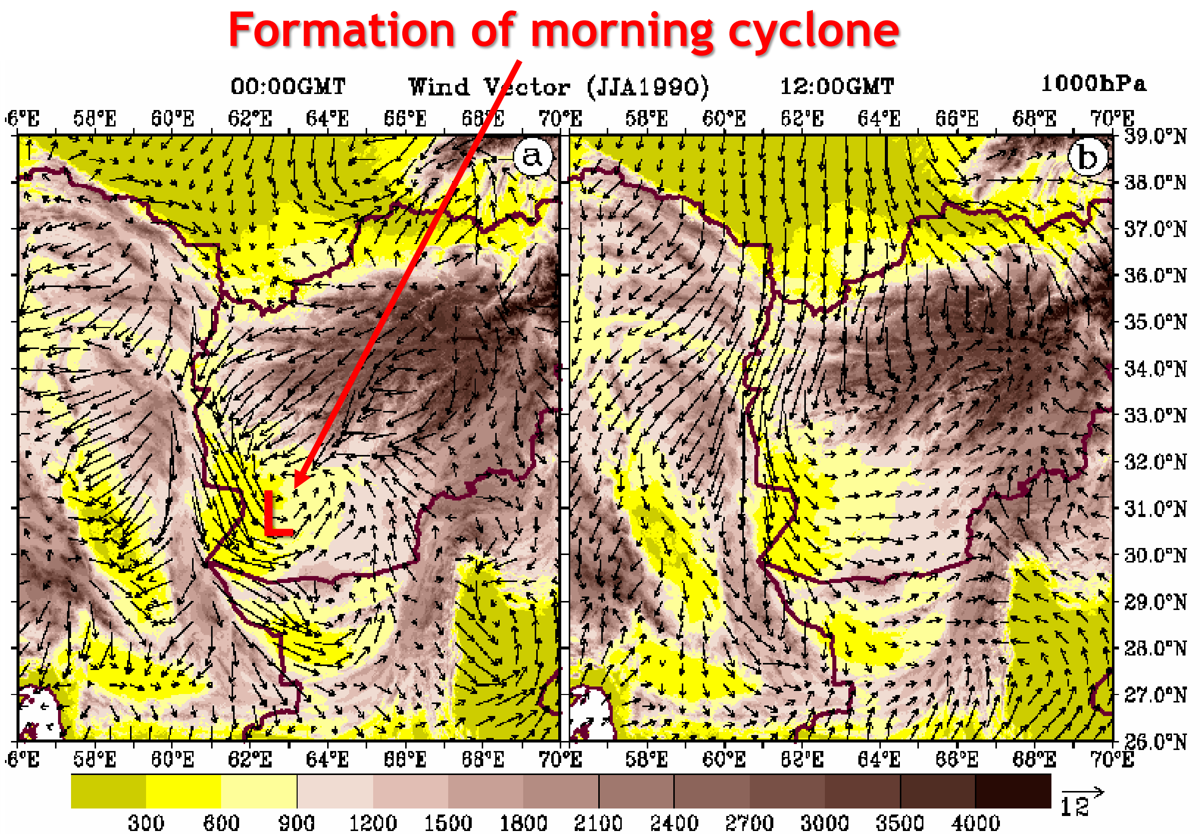


Wind (Levar) peaks in morning

Impact of topography on wind regime

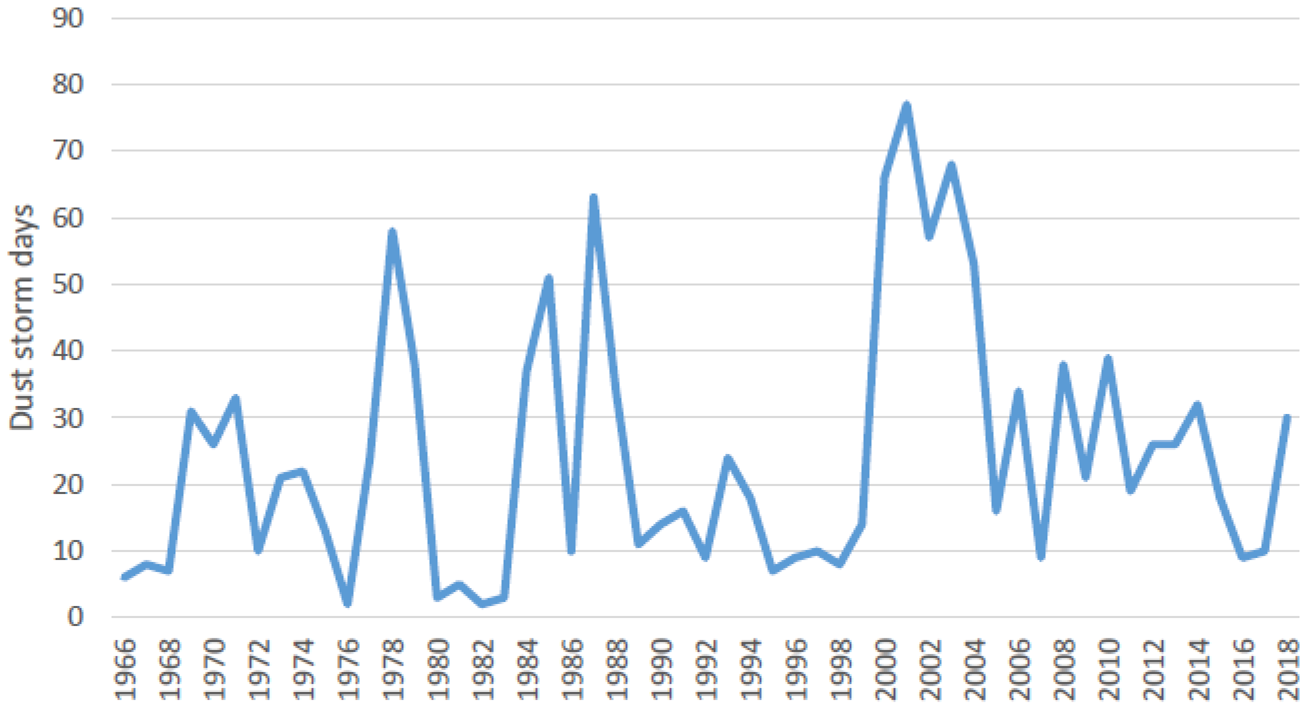


RegCM4 simulations of wind velocity at 925 hPa in JJ 2001 over Sistan, with and without topography. Acceleration of the wind just north of the Sistan Basin due to topography.

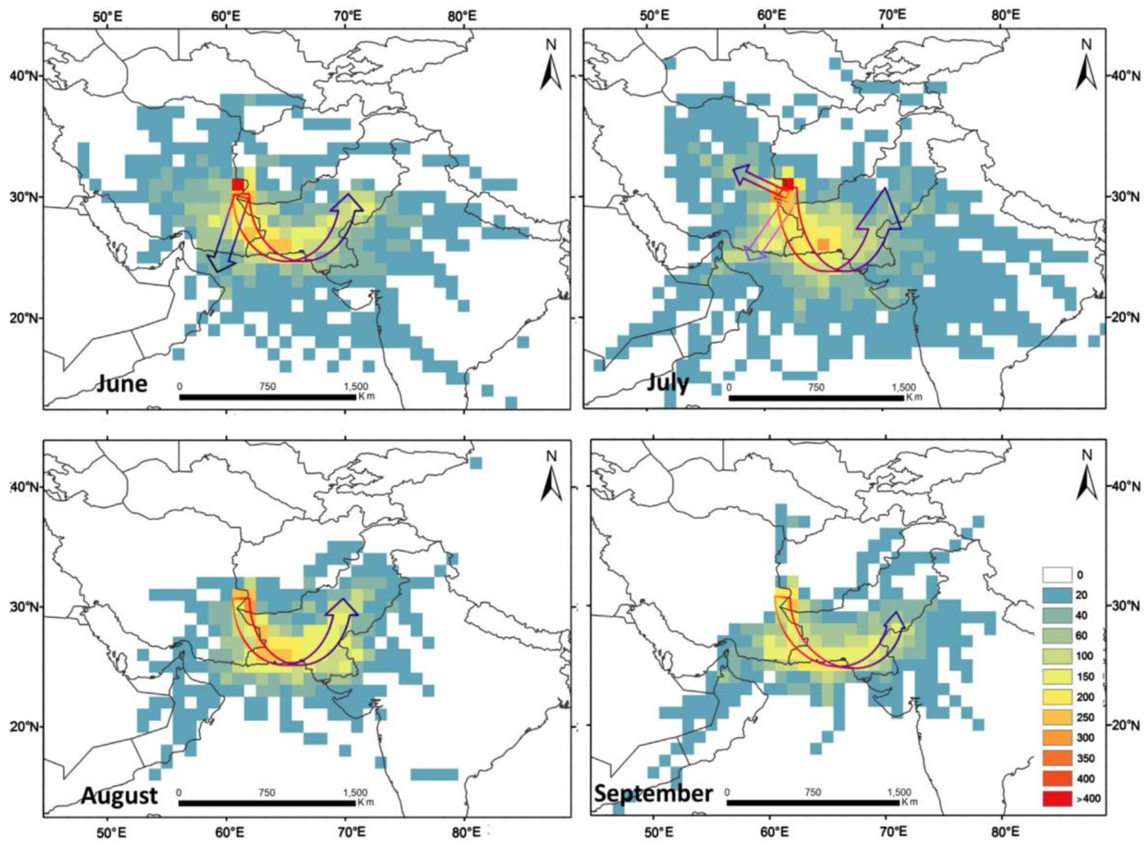


RegCM4 simulations of vector wind at 1000 hPa in JJA 1990 for nighttime and daytime over Sistan. Very high (usually above 12 ms^{-1}) winds over the Sistan Basin.

Sistan dust activity

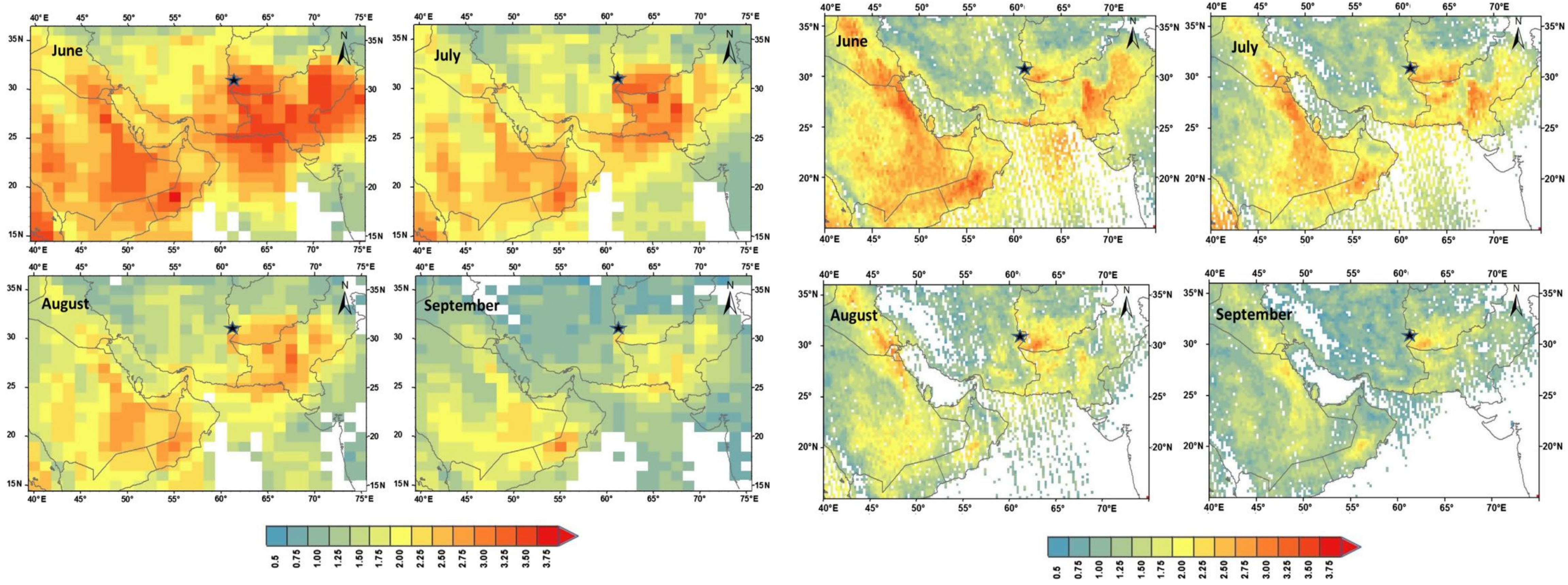


Annual frequency of dust-storm days 1966–2018 at Zabol (31.09° N, 61.54° E). (Data source: Zabol Meteo station)



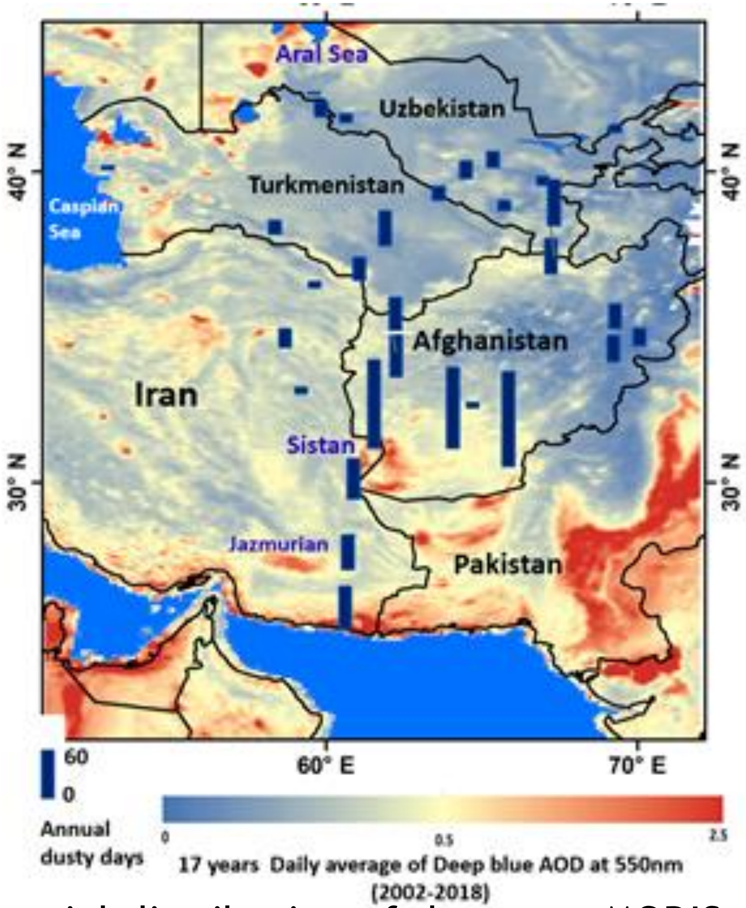
Density plot of the 5-day forward air-mass trajectories originated from the Sistan/Hamoun basin at 500 m above ground level on the dust-storm days for the June–September months during the period 2001–2012.

Satellite observations of Sistan aerosol

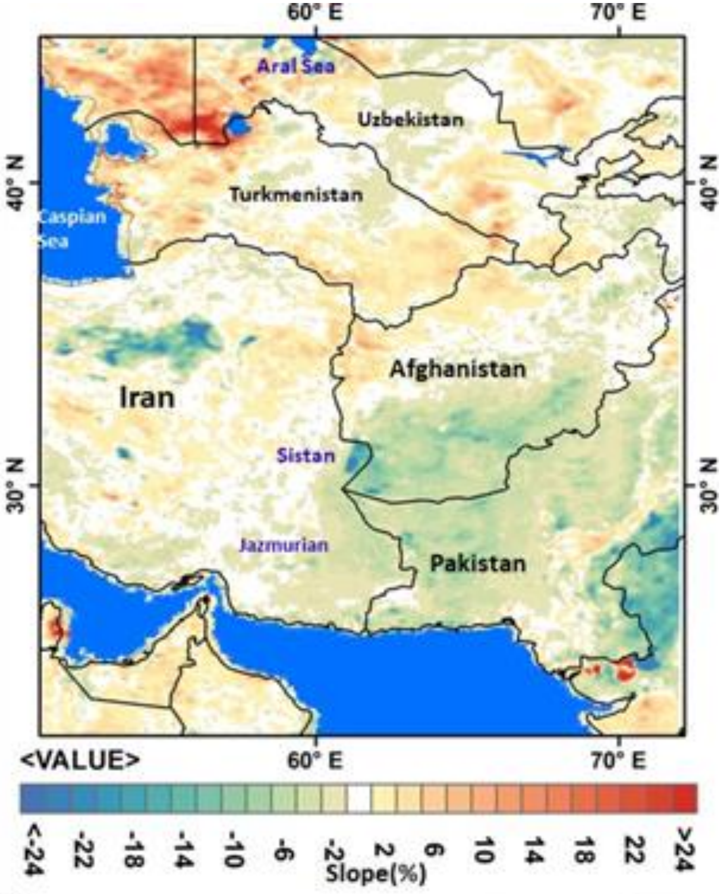


Monthly-mean spatial distribution of the Earth-Probe TOMS (left) and Aura-OMI (right) AI values over Middle East and South Asia on the Sistan dust-storm days during 2001–2005 and 2006 – 2010, respectively. The star denotes the Zabol station.

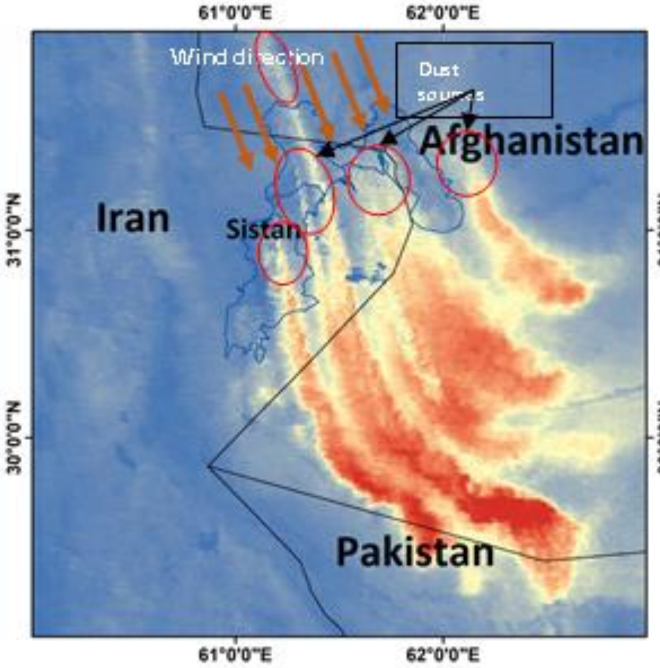
Satellite observations of Sistan aerosol



Spatial distribution of the mean MODIS-AOD_{550} during the period 2002 – 2018 over SW Asia, superimposed by bars corresponding to the number of the annual dusty days at selected stations during the period 2002-2018

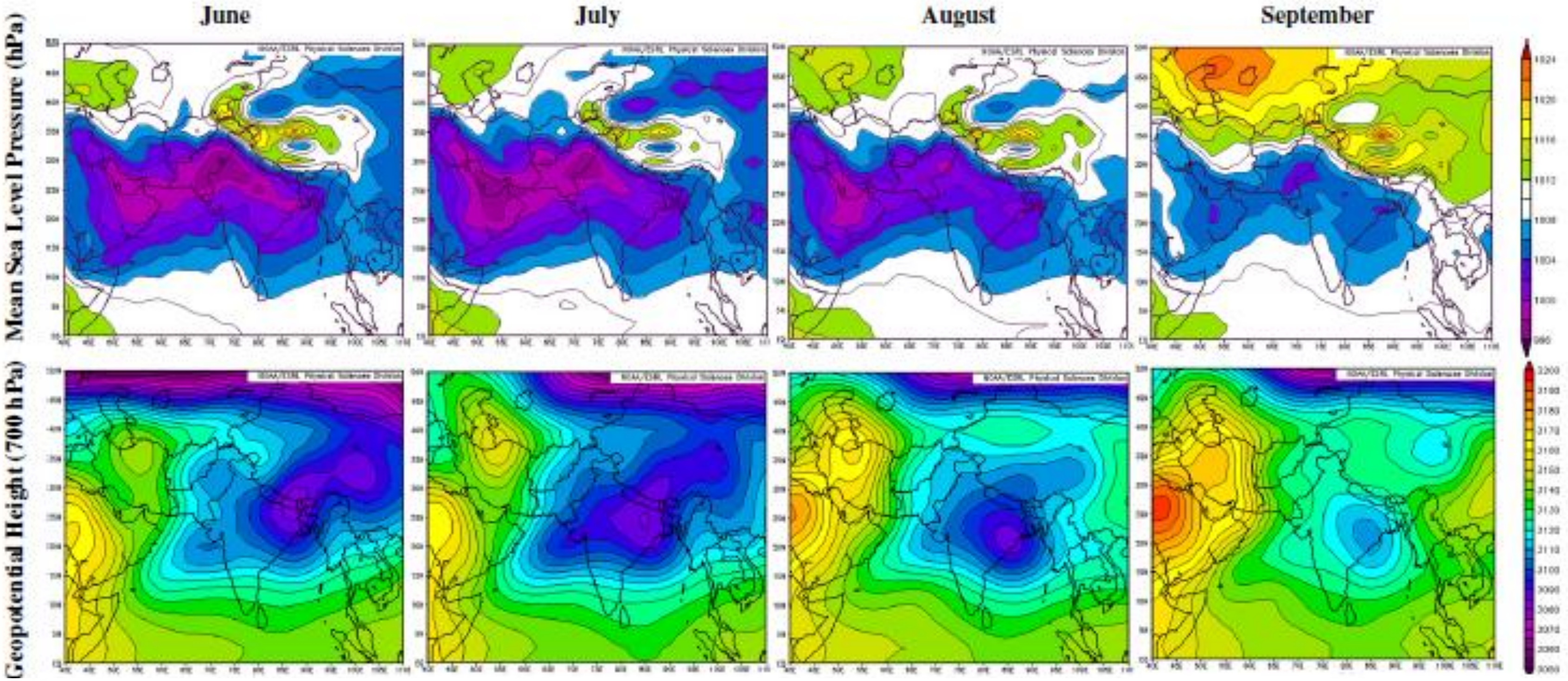


Spatial distribution of the slope values (%) obtained from the linear regression of the MODIS-AOD trends during 2002 – 2018

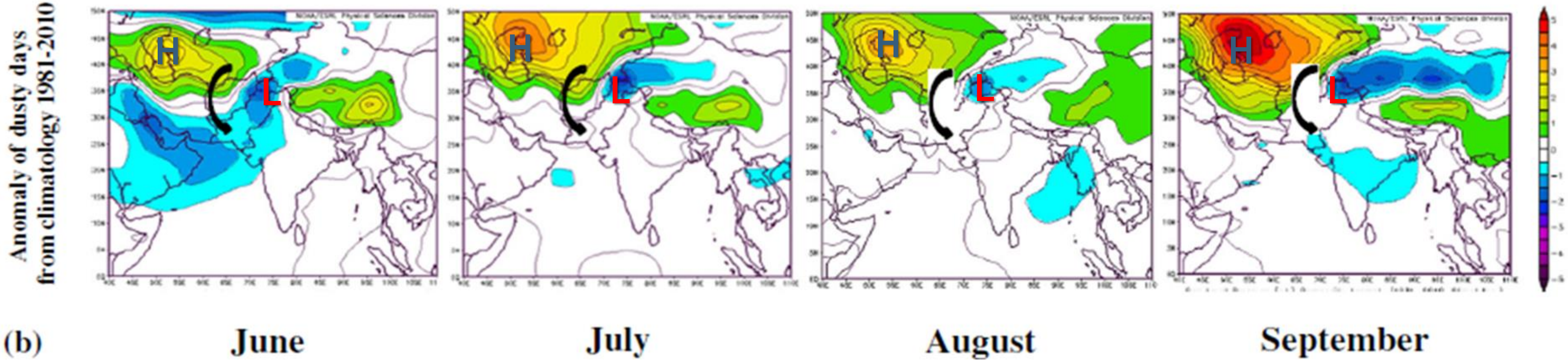


Spatial distribution of 1-km AOD from MODIS over the Sistan Basin on 23 August 2018. The high AOD values show the emission and movement of an intense dust storm.

Synoptic meteorology



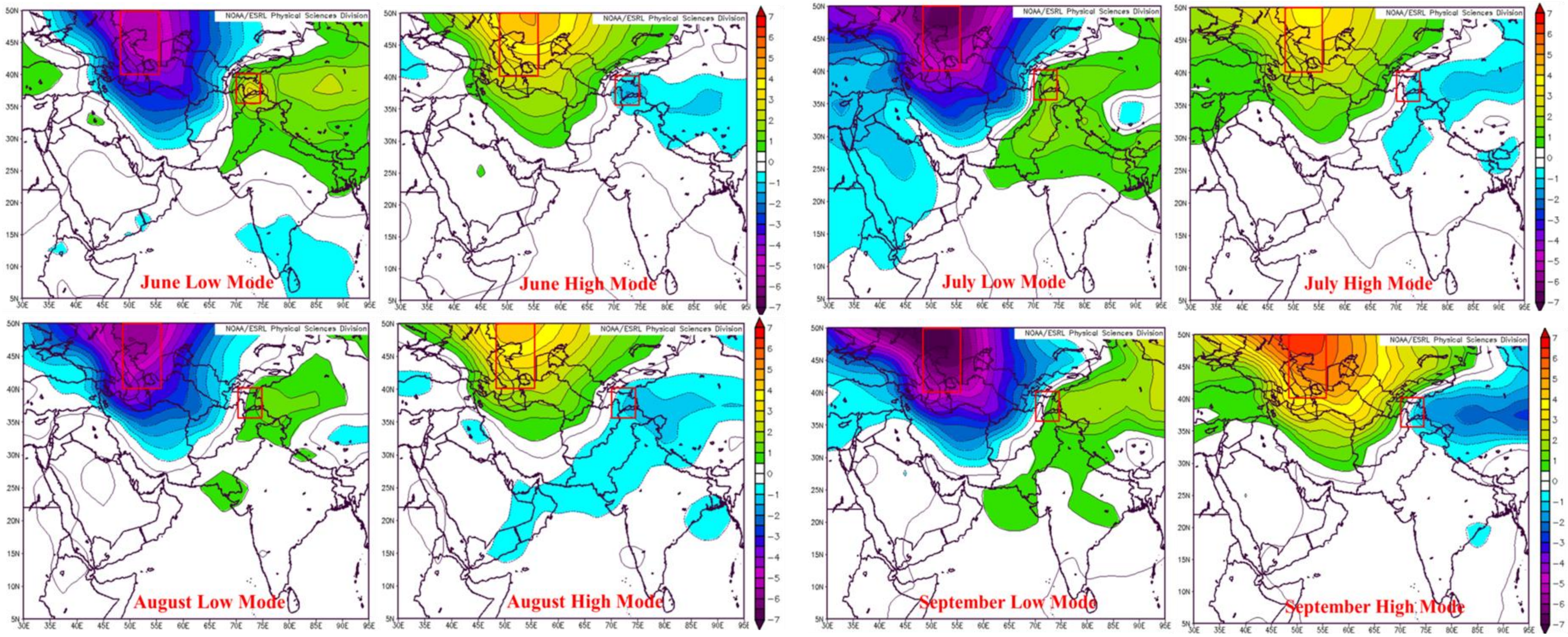
Composite-mean MSLP maps (upper panels) and Geopotential Height at 700 hPa (lower panels) for the summer (JJAS) months during Sistan dust-storm days (vis< 1 km; 354 cases) of the period 2001–2012.



Composite-mean MSLP anomalies during the Sistan dust storms in summer months of the period 2001–2012.

CasHKI [Caspian Sea – Hindu Kush Index]

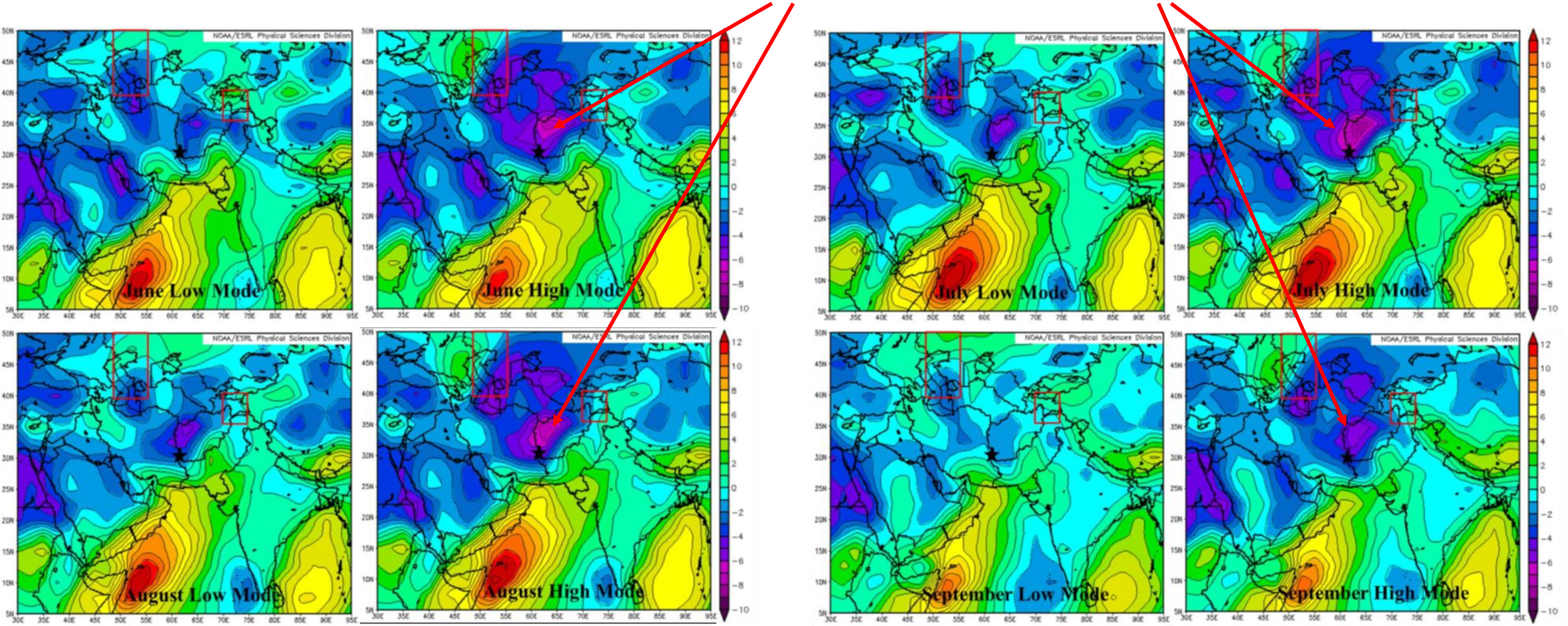
CasHKI = MSLPanom.CS – MSLPanom.HK



MSLP anomalies for the low (< mean – 1 stdev) and high (>mean + 1 stdev) CasHKI modes in Jun-Sep during 2000-2014.

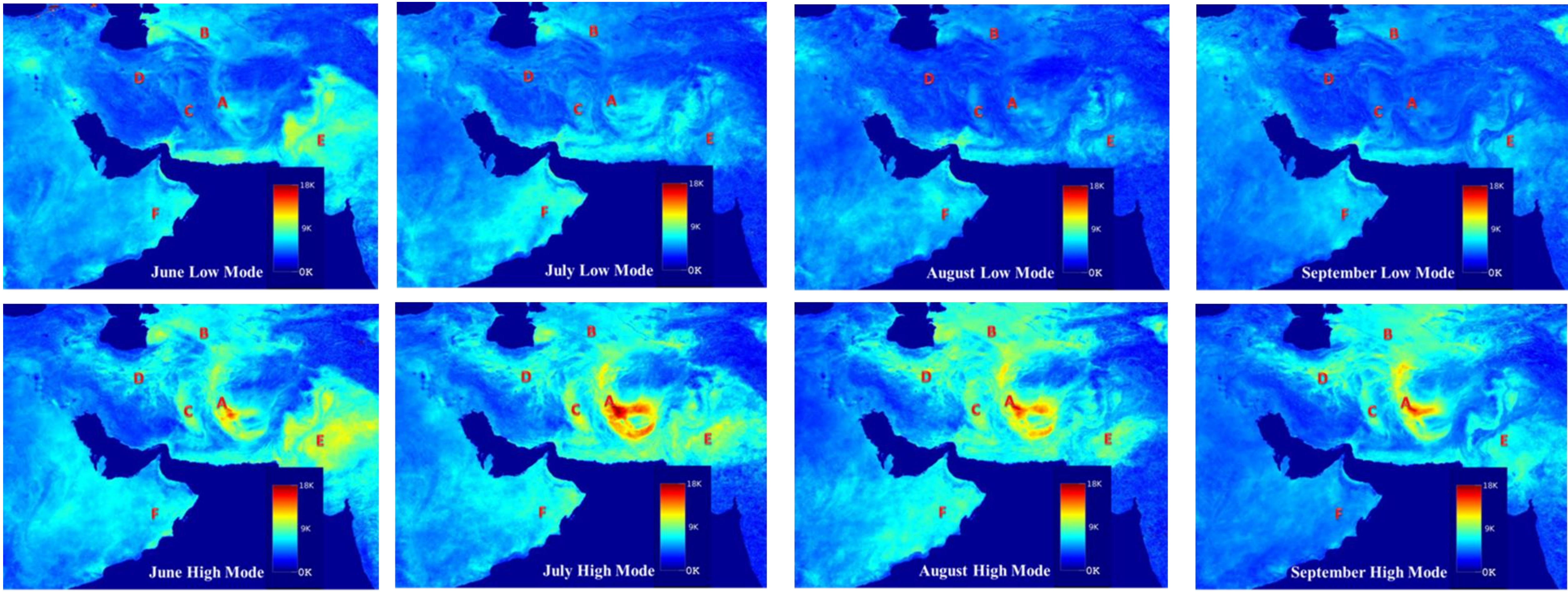
CasHKI modes

Remarkable increase in northern wind over Sistan



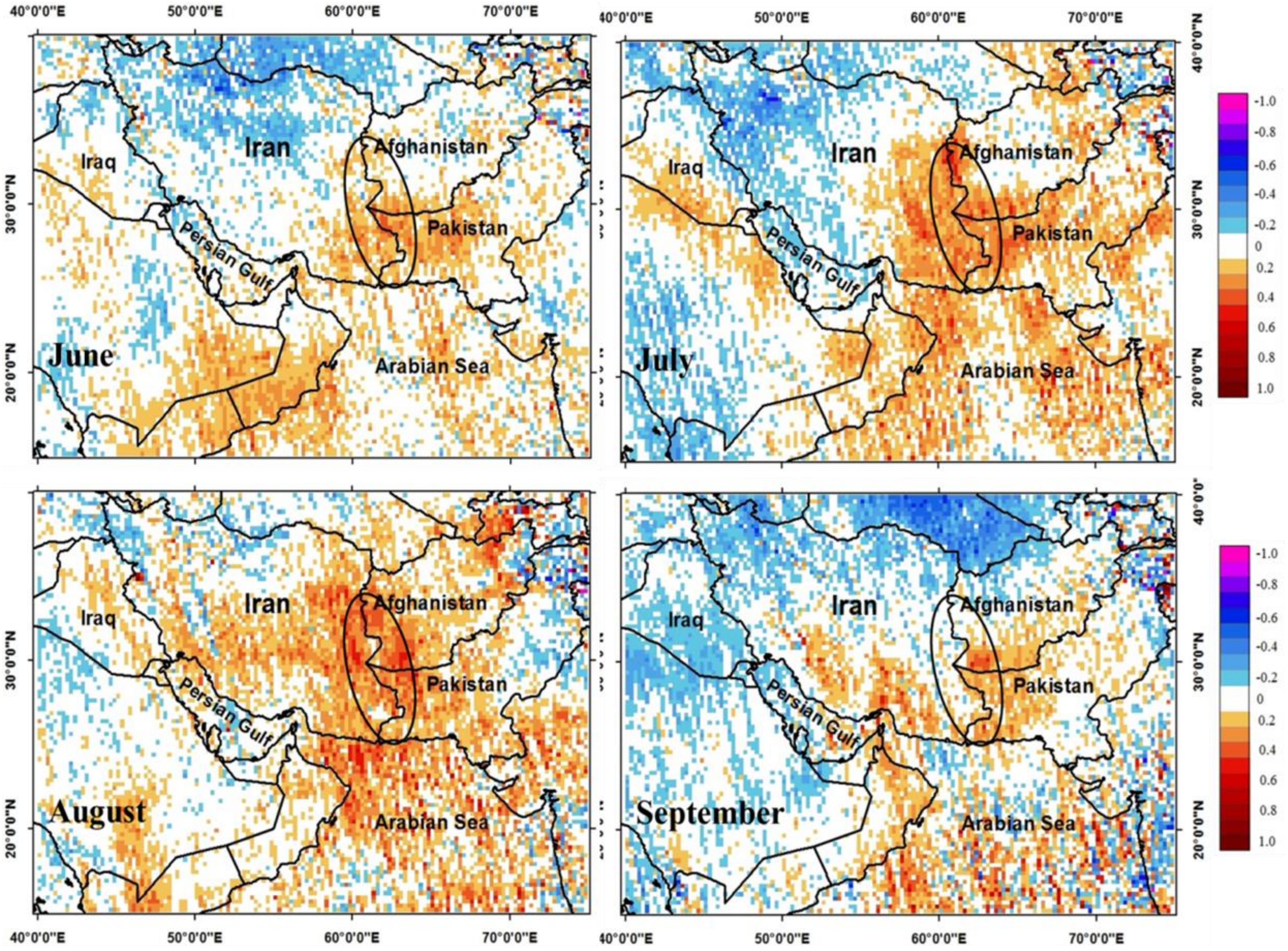
Maps of composite means of surface meridional winds over SW Asia for low and high CasHKI modes during JJAS 2000 - 2014.

CasHKI affects dust activity



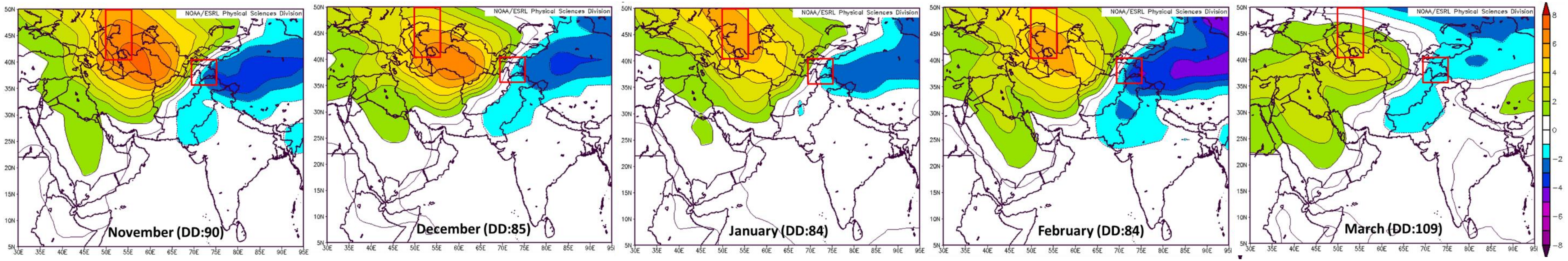
- Composite mean Infrared Differential Dust Index images for low and high CasHKI modes in JJAS via the synergy of Meteosat 5 (2000-2006) and Meteosat 7 (2007-2014) satellites. The M5 projection (63°) was used for the mapping and data from M7 (57°) are re-projected to M5. The major dust source regions over SW Asia are highlighted as A: Sistan Basin, B: Karakum desert, C: Dahst-e-Lut, D: Dahst-e-Kavir, E: Thar desert, F: Oman desert. Large increase in dust activity over Sistan and surroundings for the high CasHKI modes, lower influence over southeastern Arabian Peninsula.

CasHKI affects dust activity

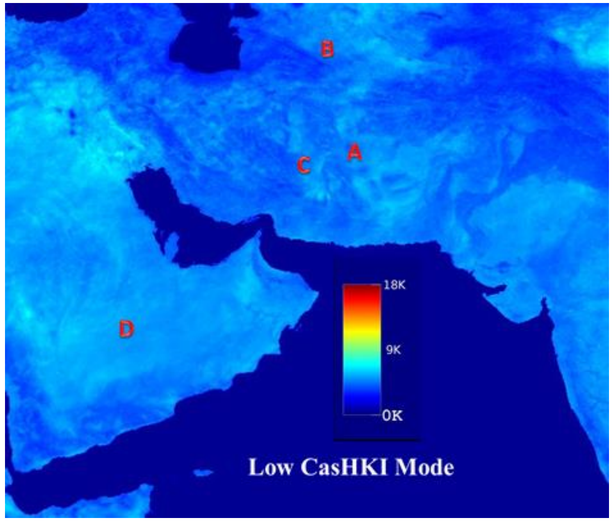


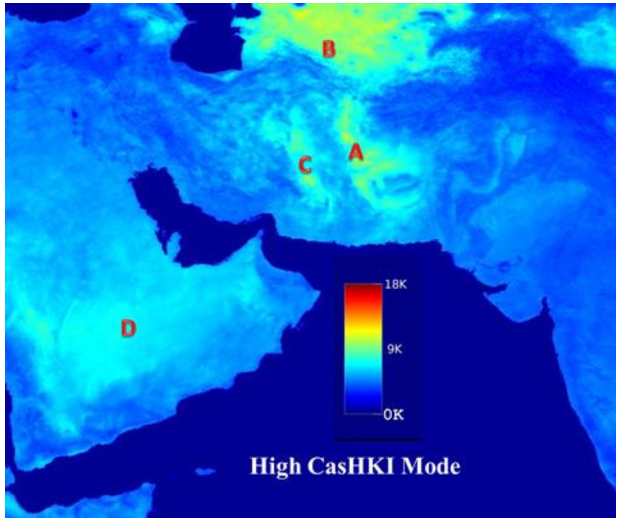
- Spatial distribution of the correlation coefficients between CasHKI values and OMI-Aerosol Index over each pixel in the study domain in Jun – Sep 2000 - 2014.
- The high correlations over Sistan, eastern Iran, and downwind areas, like northern Arabian Sea, western Pakistan, etc, influenced by Sistan-originated dust storms, indicate that the high CasHKI values are associated with high OMI-Aerosol Index, suggesting larger dust presence over these regions.

CasHKI affects dust activity [winter]



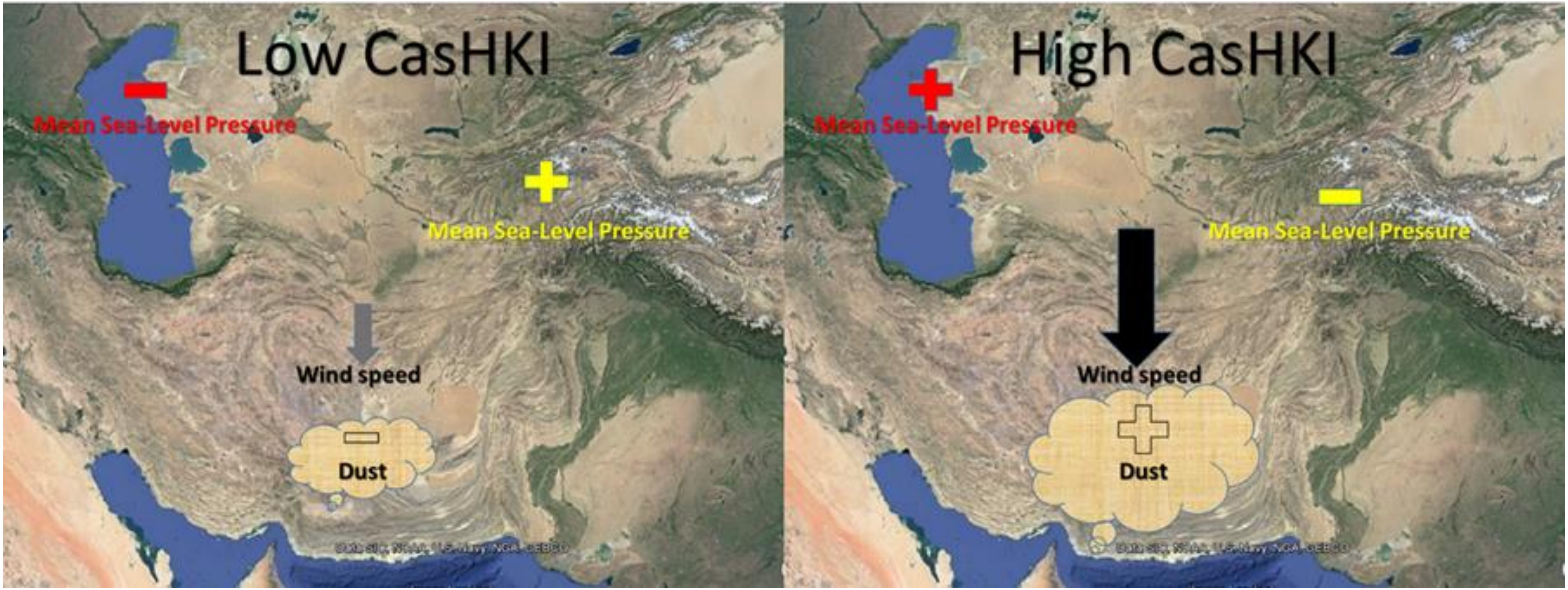
MSLP anomalies from the 1981 - 2010 climatology for the dusty days of the period 1963 – 2014. The red shapes correspond to the CS and HK domains. The number of DDs is shown in the graph for each month.



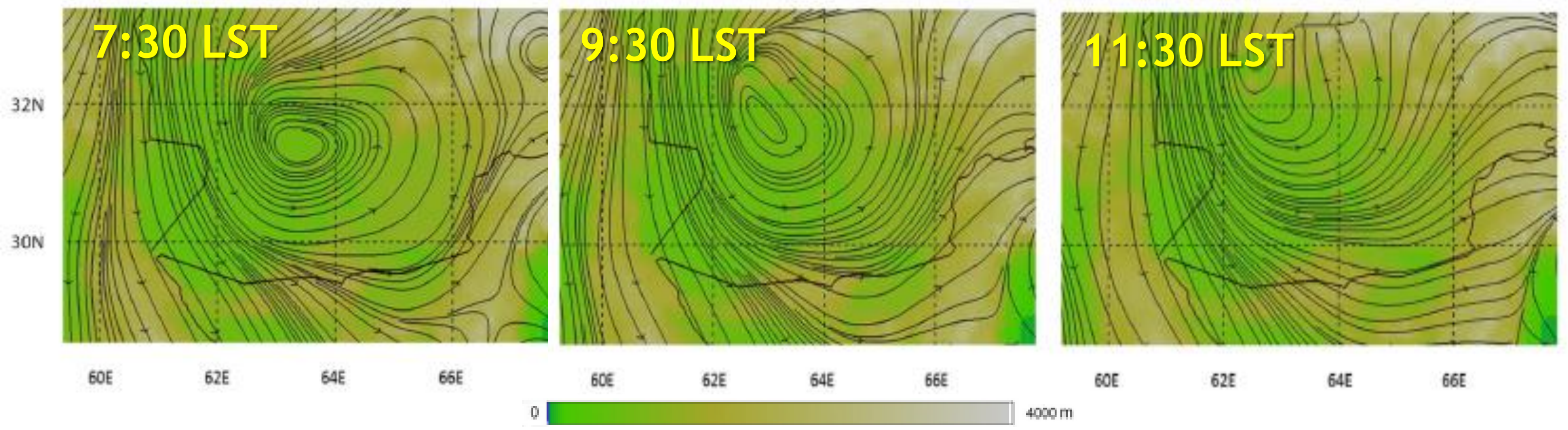


Composite-mean spatial distribution of IDDI values from the 2000 - 2014 Meteosat imagery over SW Asia for low and high CasHKI modes during winter months (November – March).

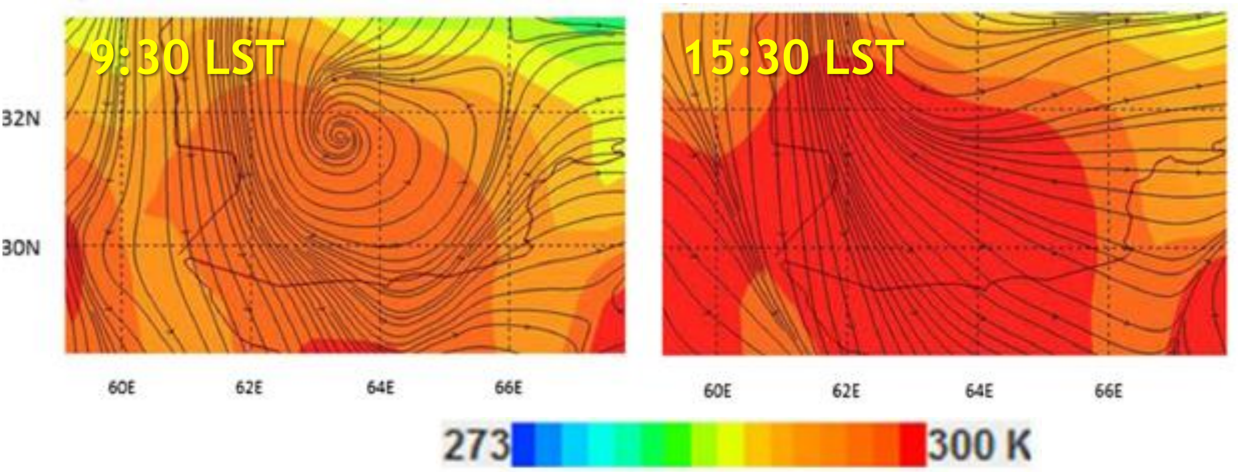
CasHKI affects dust activity

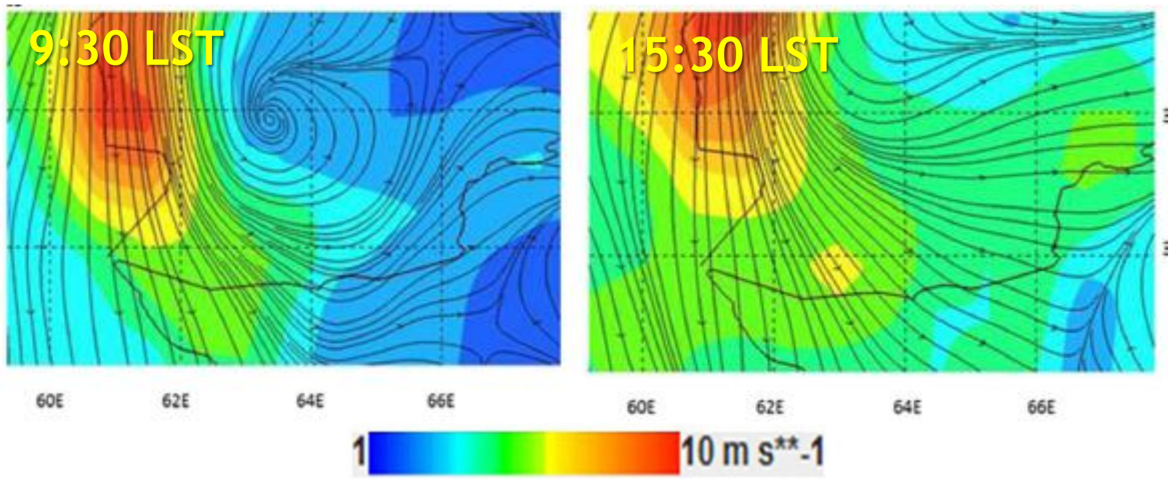


Local dynamic processes



10 m wind streamline maps from NASA-MERRA on 18 July 2014. The formation, expansion, and gradual disappearance of the morning cyclone.

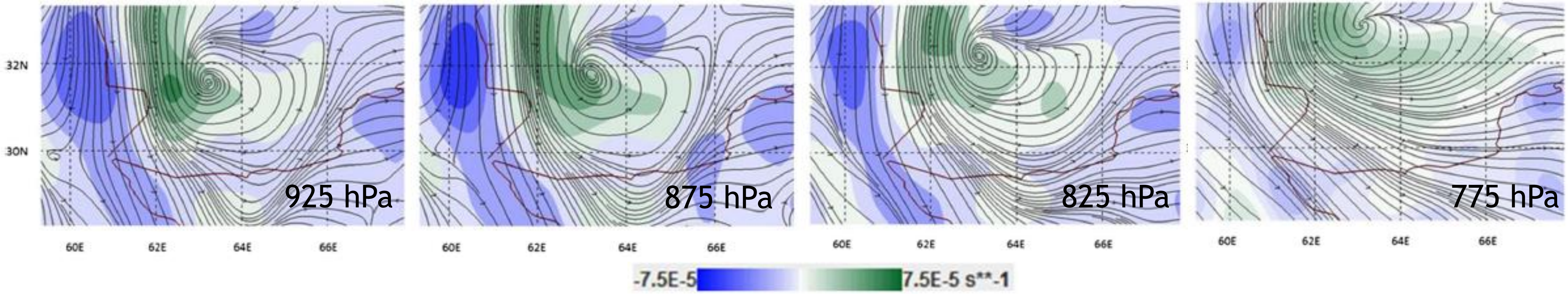




Average of 10-m wind streamlines in 36 years (1979 to 2015) over Sistan Basin at 9:30 and 15:30 LST from ERA-Interim, superimposed at average 2-m temperature and 10-m winds

Dissipation of the morning cyclone during noon due to updraft of anabatic winds, increased turbulence and divergence.

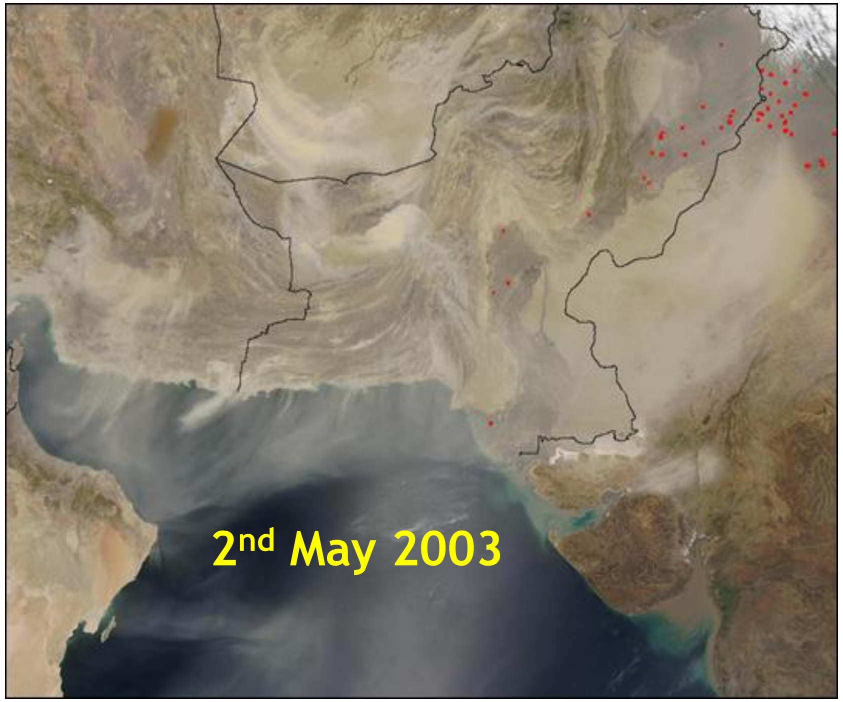
Local dynamic processes

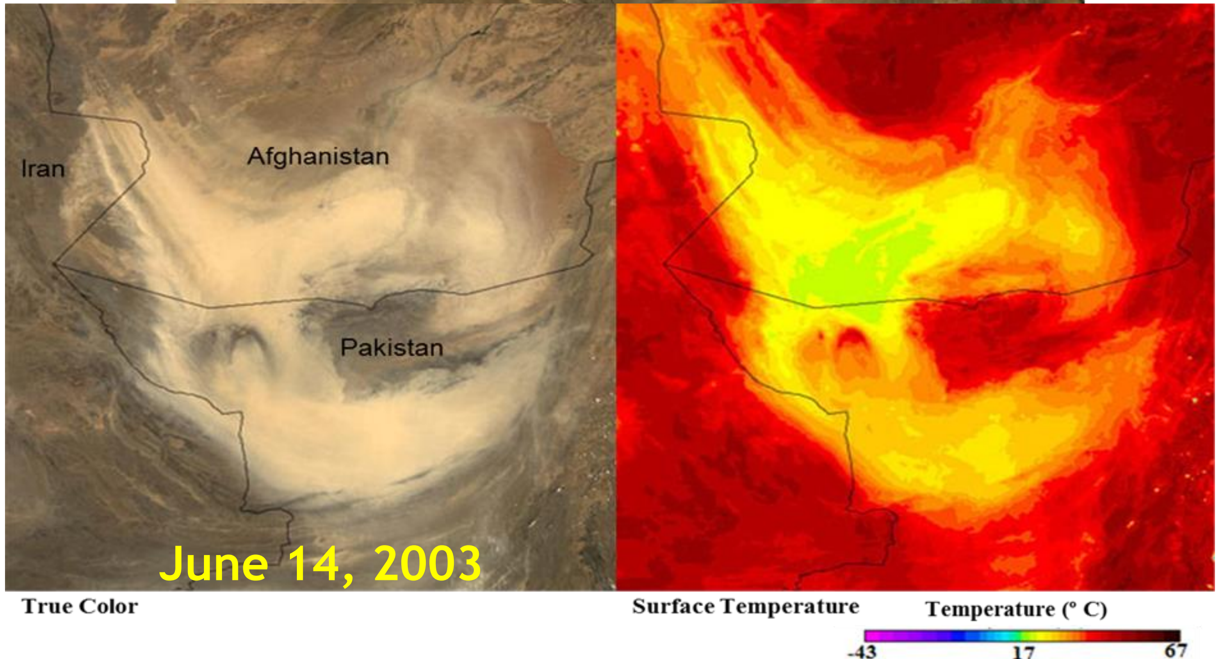


The average streamlines and relative vorticity (× 10–5 s^{-1}) in the Sistan Basin at 9:30 LST in different atmospheric levels during 36 years (1979 to 2015) from ERA-interim.

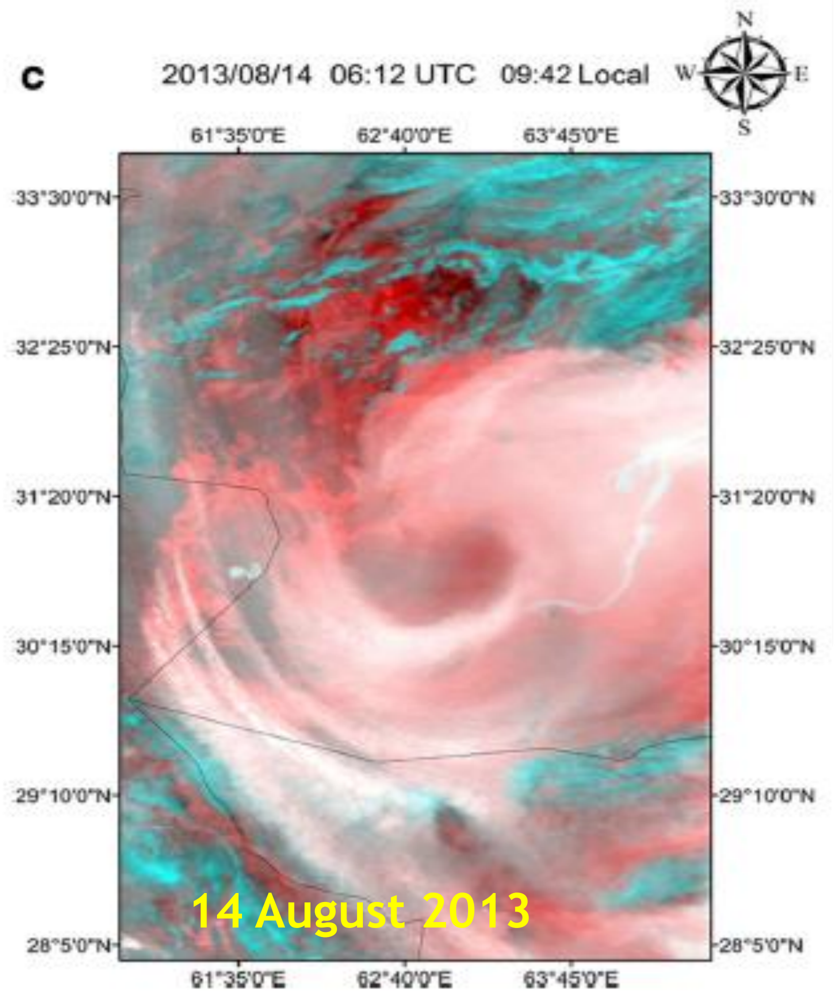
Progressive dissipation of the morning cyclone with increasing height (low-level cyclone).

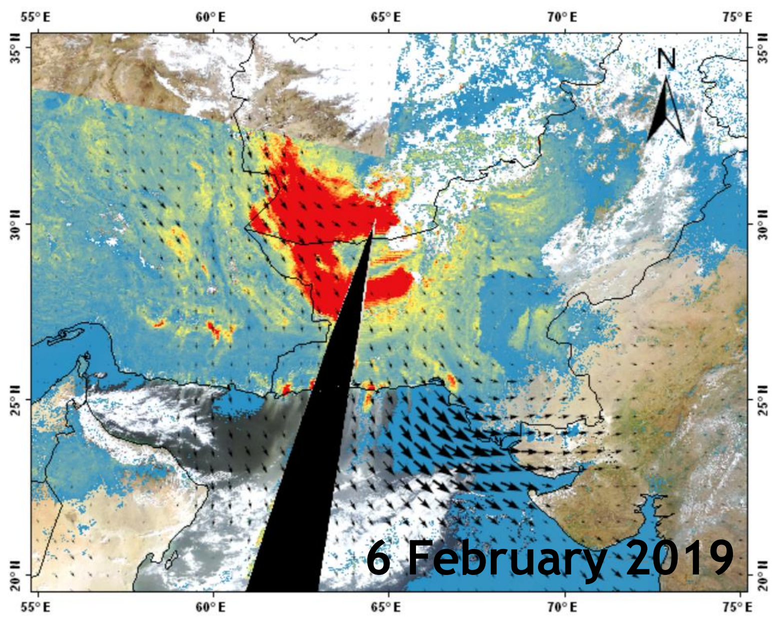
Sistan dust storms from space

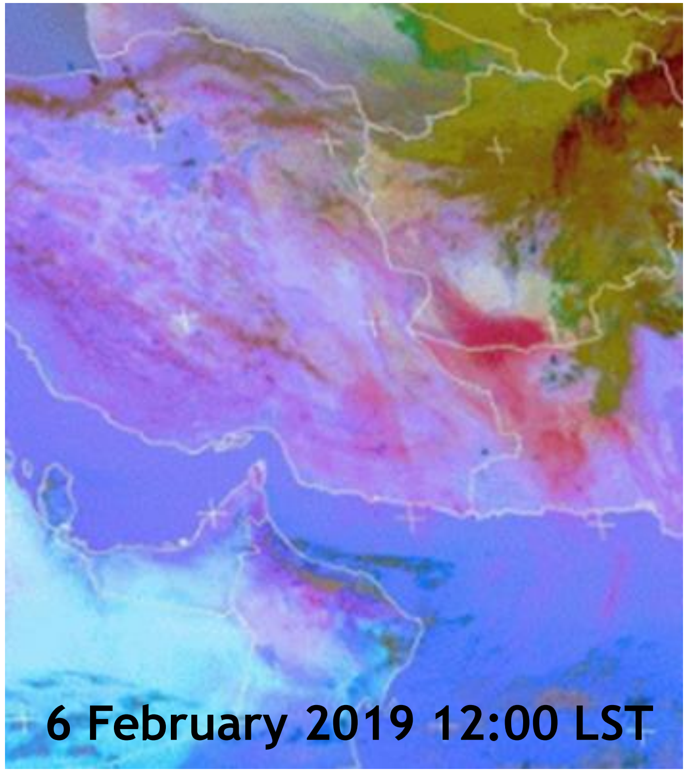




Sistan dust storms from space







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