Climatology and Spatiotemporal Variations of Synoptic Meteorological Dust /Sand Events Observed over the Middle East and Surrounding Regions during 2003-2016 Period

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5th INTERNATIONAL WORKSHOP ON SAND AND DUST STORMS

(DUST SOURCES AND THEIR IMPACTS IN MIDDLE EAST)

23-25 October 2017, Istanbul, TURKEY

October 24, 2017 - Tuesday

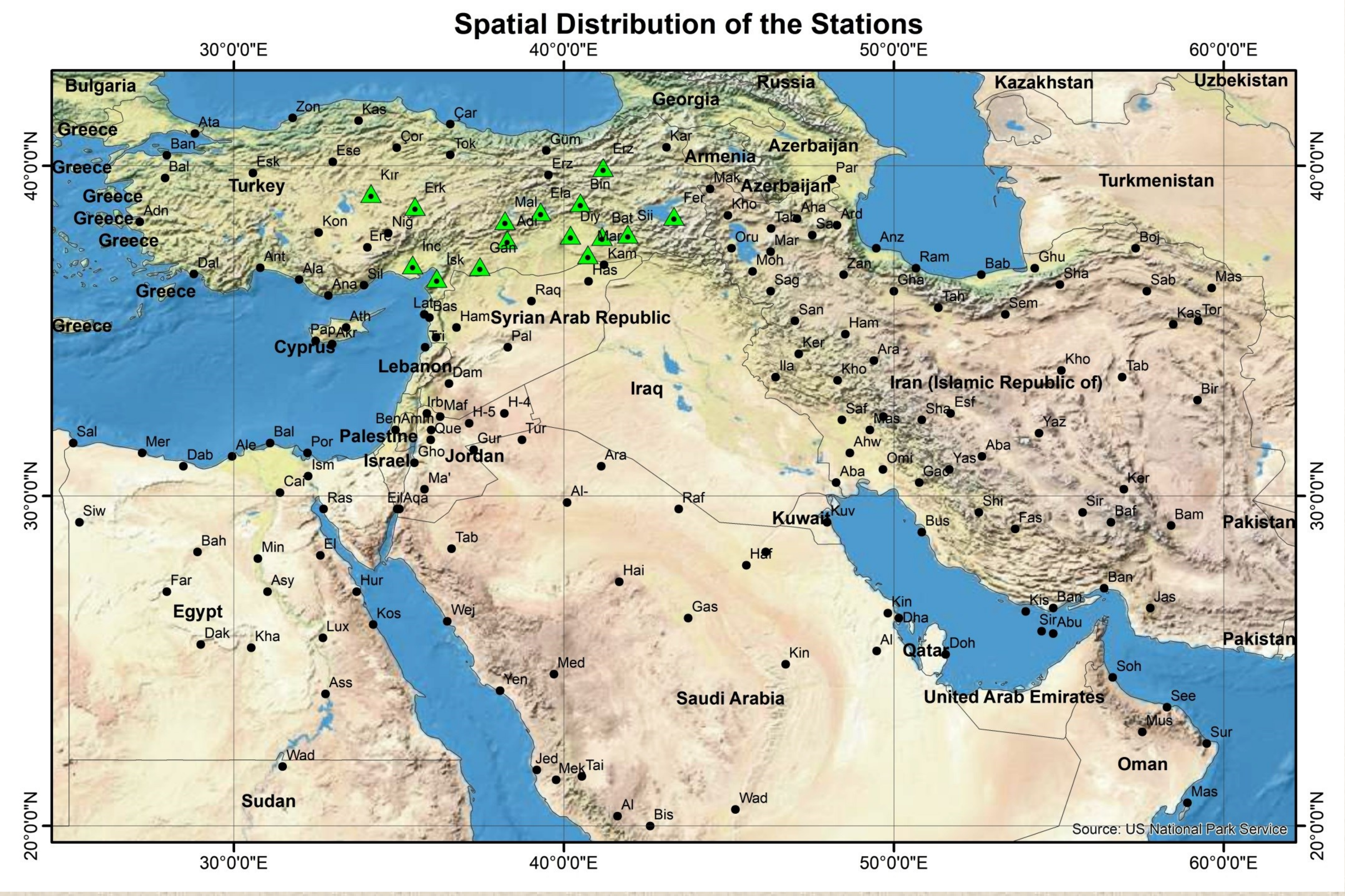
Motivation

- **To investigate «Climatology and Spatiotemporal Variations of Synoptic Meteorological Dust and Sand Events Observed over the Middle East and Surrounding Regions during 2003-2016 Period» via followings:**
  1. Dust Weather Climatology: Spatial and temporal variations and patterns;
  2. Major Atmospheric Drivers and Controls: Some examples;
  3. Inter-annual Variations and Long-term Trends: Regional and country time-series;
  4. Spatial Distribution Pattern of Long-term Trends in the Stations;
  5. Atmospheric Anomalous Circulation Types: Some examples for the year or periods with increased and decreased dust and sand storm related weather events.

Data, Approach, Methodology

- **Study period**: main study period of 2003-2016, and 1981-2010 climatology
- **Geographical regions included in study area:** South-west Asia, Middle East, Northeast Africa and Saudi Arabia Peninsula
- **Number of surface synoptic meteorological stations:** Total 173 was used in general country- and regional-based analysis, and 134 of all stations was used for station-based and country-based time-series analysis (e.g. analysis of correlation, temporal variations and trends etc.)
- **Daily synoptic data source for the WMO** (WMO Code 6677: «Present weather reported from a manned weather station») **Present Weather Dust/Sand Related Weather Events**: www.ogimet.com
- **Data limit**: Short period to analyse, however stations used in the analysis were characterised with a continuous and sufficient number of daily data. For instance almost all stations had about 90 per cent of all daily data that should be observed during the period from 1th January 2003 to 31 December 2016.

Spatial Distribution of Stations



Data and Methodology (short)

- **Data and map source of atmospheric associations and attributions for the synoptic dust/sand weather events by using Monthly/Seasonal Climate Composites, Means, Anomalies and Climatology of atmospheric and climatic variables:** NOAA Earth System Research Laboratory
- https://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl
- **Data source of atmospheric associations and attributions for the synoptic dust/sand weather events by using Aerosol Optical Depth (AOD) and other related data**: https://giovanni.gsfc.nasa.gov/giovanni/#service=ArAvTs&starttime=2003-01-01T00:00:00Z&endtime=2016-12-31T23:59:59Z&bbox=25,20,60,40&data,
- **For example** = MYD08 M3-6-AOD-550 Dark Target Deep Blue Combined Mean Data Field Measurements: Aerosol Optical Depth Data Product Platform, Instrument MODIS-Aqua data;
- Monthly averages of daily means, etc.

Aerosol Optical Depth

- **Aerosol Optical Depth, τ, tau. <u>Definition</u>**:
  "Aerosol Optical Thickness" is the degree to which aerosols prevent the transmission of light by absorption or scattering of light. The aerosol optical depth or optical thickness (τ) is defined as the integrated extinction coefficient over a vertical column of unit cross section.
- The optical thickness along the vertical direction is also called normal optical thickness (compared to optical thickness along slant path length).
- Aerosol Total Optical Thickness is available through Giovanni at 550 nm from MODIS; at 865 and 869 nm from SeaWiFs; at 443, 555, 670, and 865 nm from MISR; and at a number of wavelengths between 342 and 500 nm from Aura/OMI. OMI also provides Aerosol Absorption Optical Depth for near-UV wavelengths.
- The MISR AOD is described in the MISR: Level 2 Aerosol Retrieval ATBD.
  Applications
  (1) Atmospheric correction of remotely sensed surface features
  (2) Air Quality
  (3) Monitoring of sources and sinks of aerosols
  (4) Health and Environment
  (5) Monitoring of volcanic eruptions and forest fire
  (6) Earth Radiation Budget
  (7) Radiative Transfer Model
  (8) Climate Change

Data and Methodology (short)

- **WMO** (WMO Code 6677) **Present Weather Dust/Sand Related Weather Events**:

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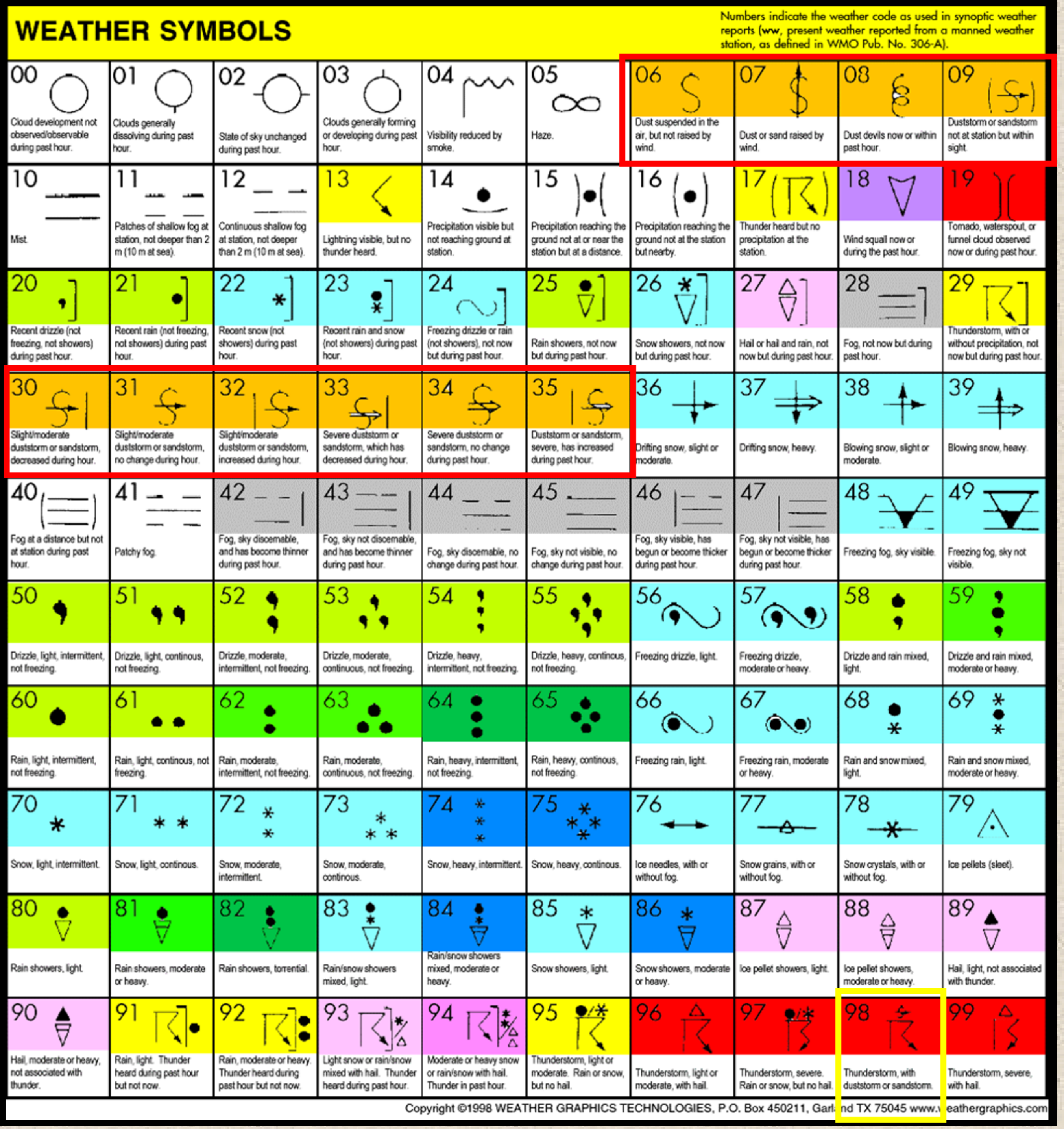
WEATHER SYMBOLS
Numbers indicate the weather code as used in synoptic weather reports (ww, present weather reported from a manned weather station, as defined in WMO Pub. No. 306-A).
00 Cloud development not observed/observable during past hour.
01 Clouds generally dissolving during past hour.
02 State of sky unchanged during past hour.
03 Clouds generally forming or developing during past hour.
04 Visibility reduced by smoke.
05 Haze.
06 Dust suspended in the air, but not raised by wind.
07 Dust or sand raised by wind.
08 Dust devils now or within past hour.
09 Duststorm or sandstorm not at station but within sight.
10 Mist.
11 Patches of shallow fog at station, not deeper than 2 m (10 m at sea).
12 Continuous shallow fog at station, not deeper than 2 m (10 m at sea).
13 Lightning visible, but no thunder heard.
14 Precipitation visible but not reaching ground at station.
15 Precipitation reaching the ground not at or near the station but at a distance.
16 Precipitation reaching the ground not at the station but nearby.
17 Thunder heard but no precipitation at the station.
18 Wind squall now or during the past hour.
19 Tornado, waterspout, or funnel cloud observed now or during past hour.
20 Recent drizzle (not freezing, not showers) during past hour.
21 Recent rain (not freezing, not showers) during past hour.
22 Recent snow (not showers) during past hour.
23 Recent rain and snow (not showers) during past hour.
24 Freezing drizzle or rain (not showers), not now but during past hour.
25 Rain showers, not now but during past hour.
26 Snow showers, not now but during past hour.
27 Hail or hail and rain, not now but during past hour.
28 Fog, not now but during past hour.
29 Thunderstorm, with or without precipitation, not now but during past hour.
30 Slight/moderate duststorm or sandstorm, decreased during hour.
31 Slight/moderate duststorm or sandstorm, no change during hour.
32 Slight/moderate duststorm or sandstorm, increased during hour.
33 Severe duststorm or sandstorm, which has decreased during hour.
34 Severe duststorm or sandstorm, no change during past hour.
35 Duststorm or sandstorm, severe, has increased during past hour.
36 Drifting snow, slight or moderate.
37 Drifting snow, heavy.
38 Blowing snow, slight or moderate.
39 Blowing snow, heavy.
40 Fog at a distance but not at station during past hour.
41 Patchy fog.
42 Fog, sky discernable, and has become thinner during past hour.
43 Fog, sky not discernable, and has become thinner during past hour.
44 Fog, sky discernable, no change during past hour.
45 Fog, sky not visible, no change during past hour.
46 Fog, sky visible, has begun or become thicker during past hour.
47 Fog, sky not visible, has begun or become thicker during past hour.
48 Freezing fog, sky visible.
49 Freezing fog, sky not visible.
50 Drizzle, light, intermittent, not freezing.
51 Drizzle, light, continous, not freezing.
52 Drizzle, moderate, intermittent, not freezing.
53 Drizzle, moderate, continuous, not freezing.
54 Drizzle, heavy, intermittent, not freezing.
55 Drizzle, heavy, continous, not freezing.
56 Freezing drizzle, light.
57 Freezing drizzle, moderate or heavy.
58 Drizzle and rain mixed, light.
59 Drizzle and rain mixed, moderate or heavy.
60 Rain, light, intermittent, not freezing.
61 Rain, light, continous, not freezing.
62 Rain, moderate, intermittent, not freezing.
63 Rain, moderate, continuous, not freezing.
64 Rain, heavy, intermittent, not freezing.
65 Rain, heavy, continous, not freezing.
66 Freezing rain, light.
67 Freezing rain, moderate or heavy.
68 Rain and snow mixed, light.
69 Rain and snow mixed, moderate or heavy.
70 Snow, light, intermittent.
71 Snow, light, continous.
72 Snow, moderate, intermittent.
73 Snow, moderate, continous.
74 Snow, heavy, intermittent.
75 Snow, heavy, continous.
76 Ice needles, with or without fog.
77 Snow grains, with or without fog.
78 Snow crystals, with or without fog.
79 Ice pellets (sleet).
80 Rain showers, light.
81 Rain showers, moderate or heavy.
82 Rain showers, torrential.
83 Rain/snow showers mixed, light.
84 Rain/snow showers mixed, moderate or heavy.
85 Snow showers, light.
86 Snow showers, moderate or heavy.
87 Ice pellet showers, light.
88 Ice pellet showers, moderate or heavy.
89 Hail, light, not associated with thunder.
90 Hail, moderate or heavy, not associated with thunder.
91 Rain, light. Thunder heard during past hour but not now.
92 Rain, moderate or heavy. Thunder heard during past hour but not now.
93 Light snow or rain/snow mixed with hail. Thunder heard during past hour.
94 Moderate or heavy snow or rain/snow with hail. Thunder in past hour.
95 Thunderstorm, light or moderate. Rain or snow, but no hail.
96 Thunderstorm, light or moderate, with hail.
97 Thunderstorm, severe. Rain or snow, but no hail.
98 Thunderstorm, with duststorm or sandstorm.
99 Thunderstorm, severe, with hail.
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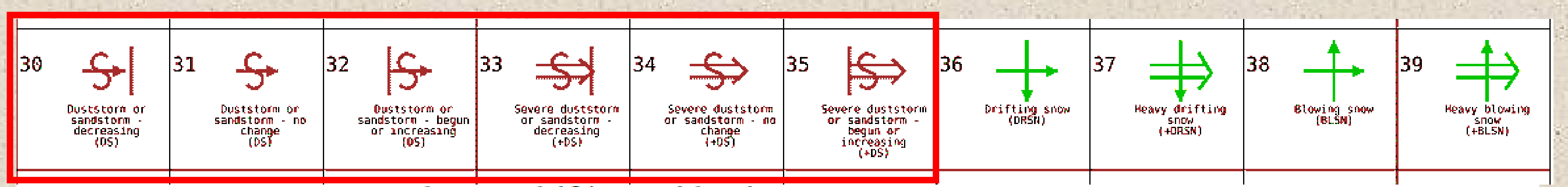


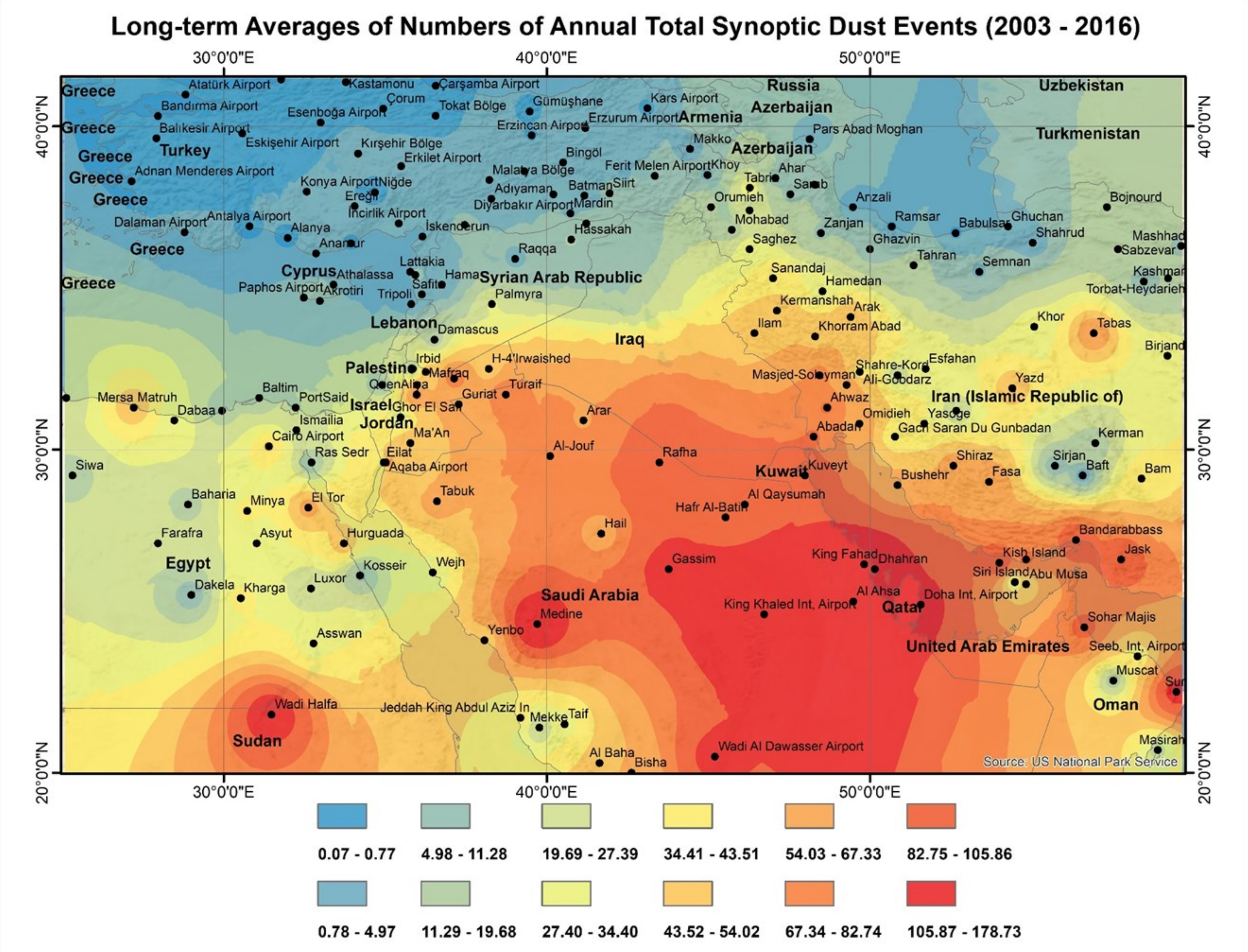
ww = 30-39 Duststorm, sandstorm, drifting or blowing snow

Code figure		
30	Slight or moderate duststorm or sandstorm	- has decreased during the preceding hour
31		- no appreciable change during the preceding hour
32		- has begun or has increased during the preceding hour
33	Severe duststorm or sandstorm	- has decreased during the preceding hour
34		- no appreciable change during the preceding hour
35		- has begun or has increased during the preceding hour

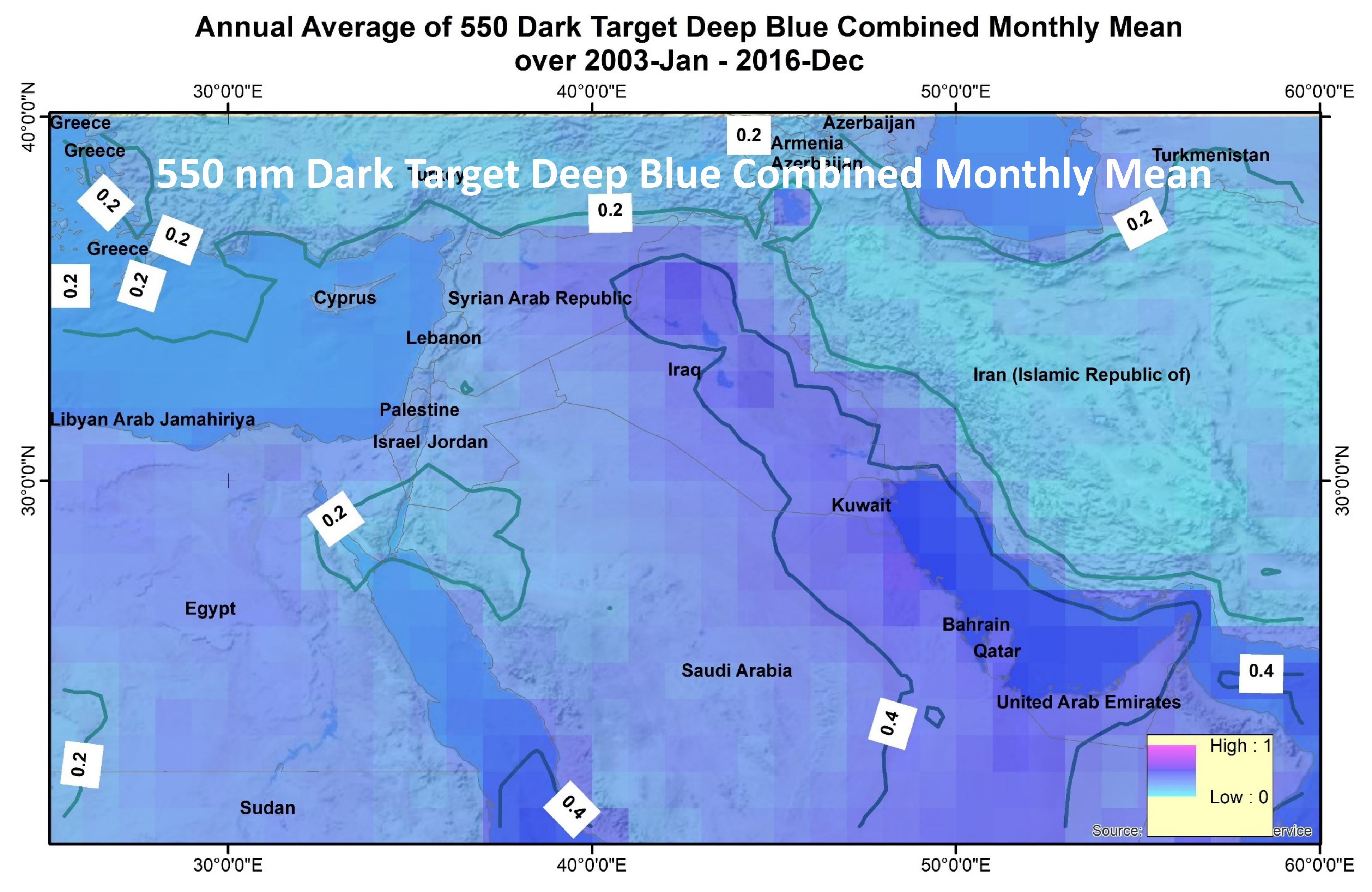
Methodology (short)

- **Pearson correlation coefficient *r* and Spearman rank correlation coefficient R_S** analysis for detecting possible statistical relationships between monthly, seasonal annual variations of number of synoptic dust and sand weather events and variations of AOD, and between AOD and other dust and sand related time-series, etc.;
- **Mann-Kendal rank correlation coefficient (*u*(t)) and *X* (β) coefficient of Least Squares Linear Regression** for detecting whether there is a long-term significant trend in the time-series of number of synoptic dust and sand weather events;
- **Determination of statistical significance of calculated test statistics** (i.e. hypothesis tests performed for the test statistics *r*, R_s, *u*(t) and *t*, etc.)

Dust Weather Climatology: Observed Spatial Distribution Pattern

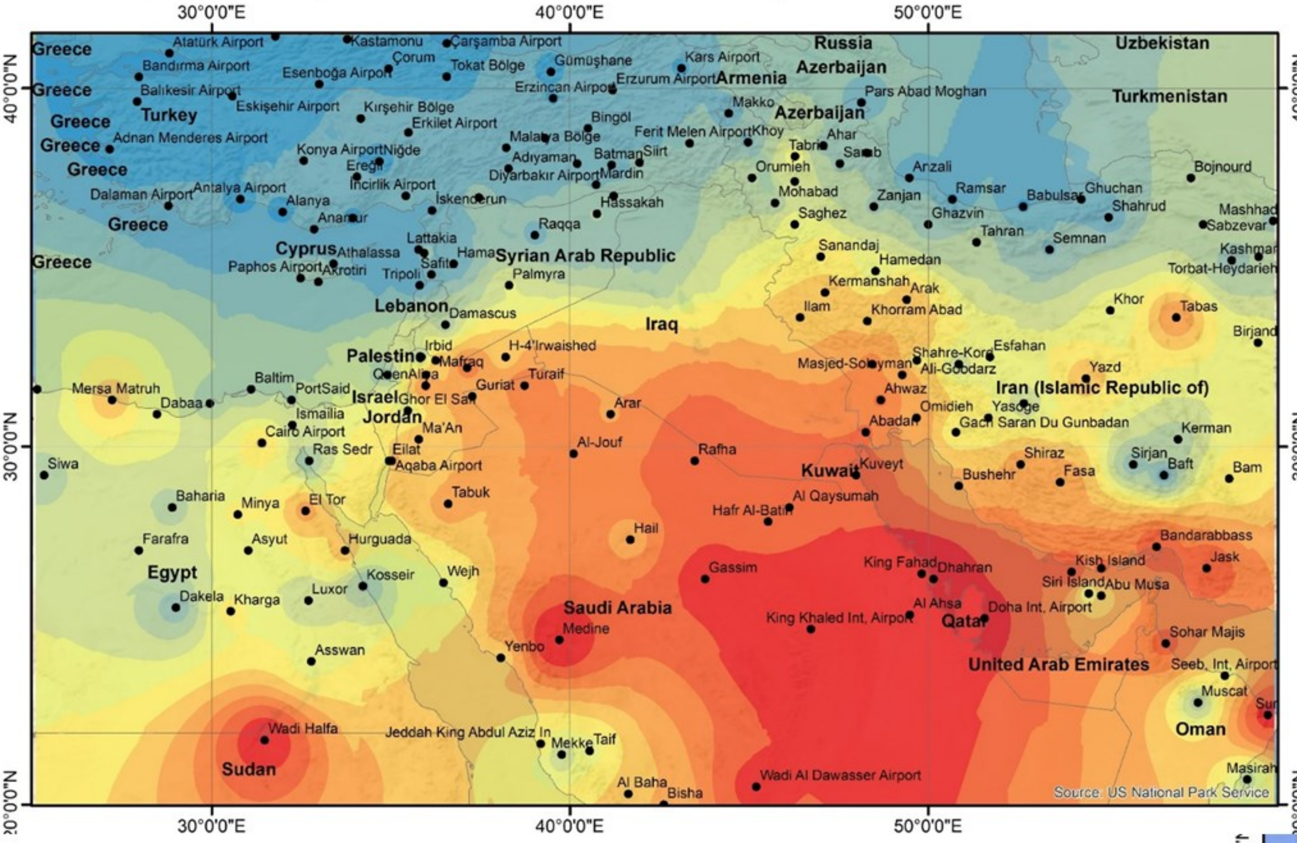


Dust Weather Climatology: Observed Spatial Distribution Pattern

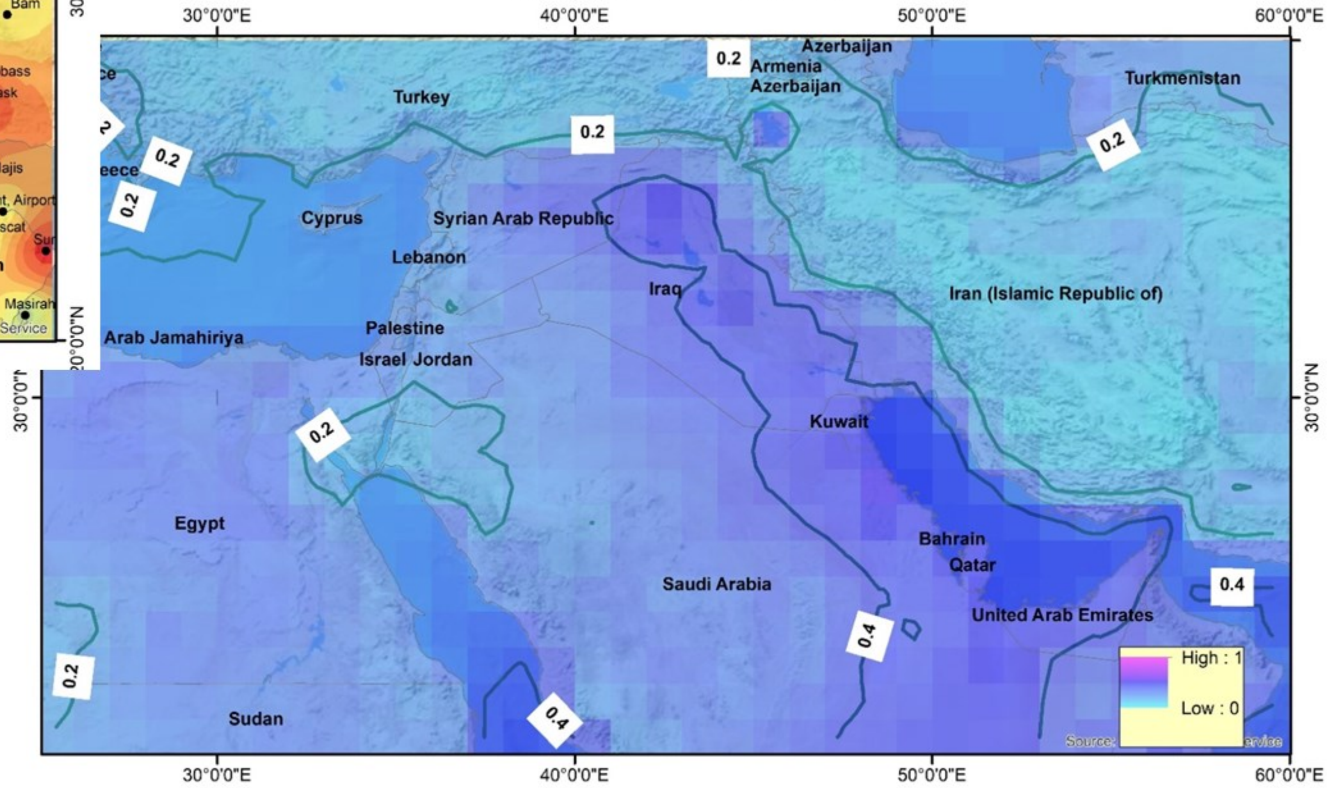


Dust Weather Climatology: Comparison of Spatial Distribution Patterns

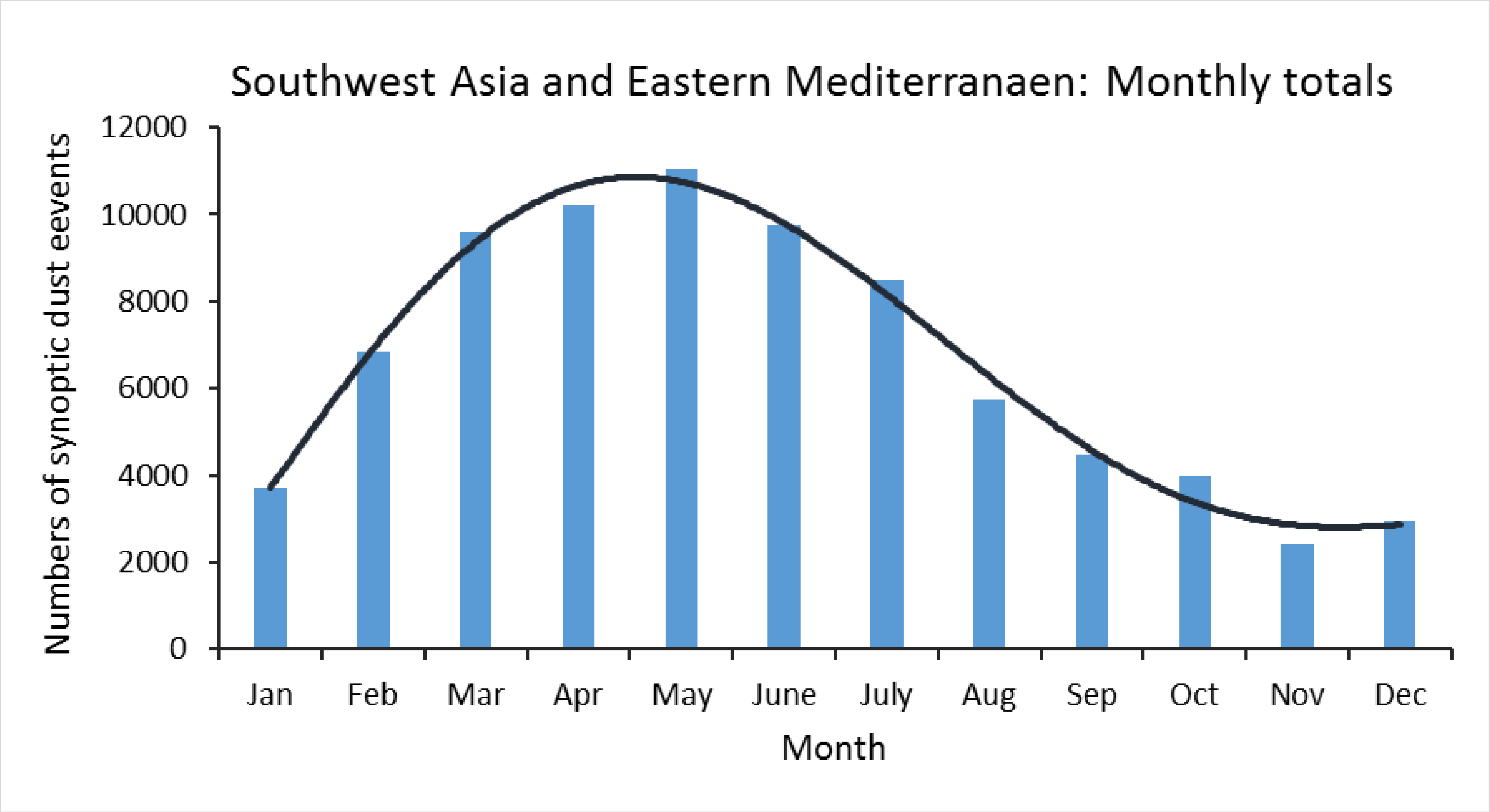
Long-term Averages of Numbers of Annual Total Synoptic Dust Events (2003 - 2016)



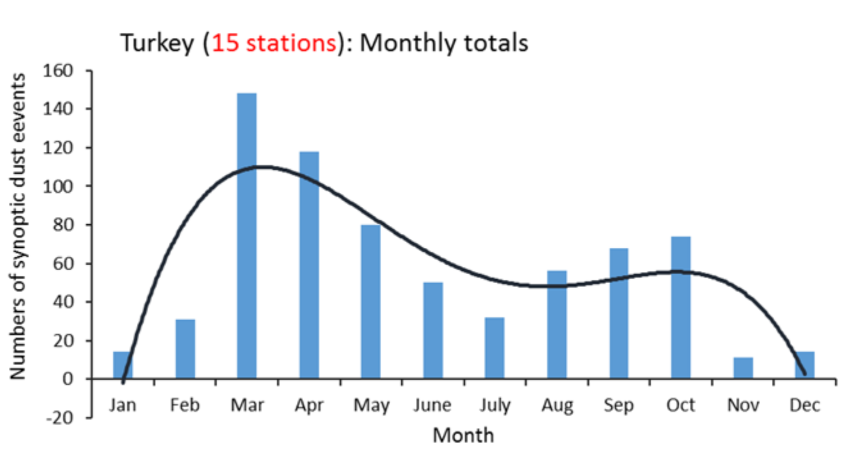
Annual Average of 550 Dark Target Deep Blue Combined Monthly Mean over 2003-Jan - 2016-Dec

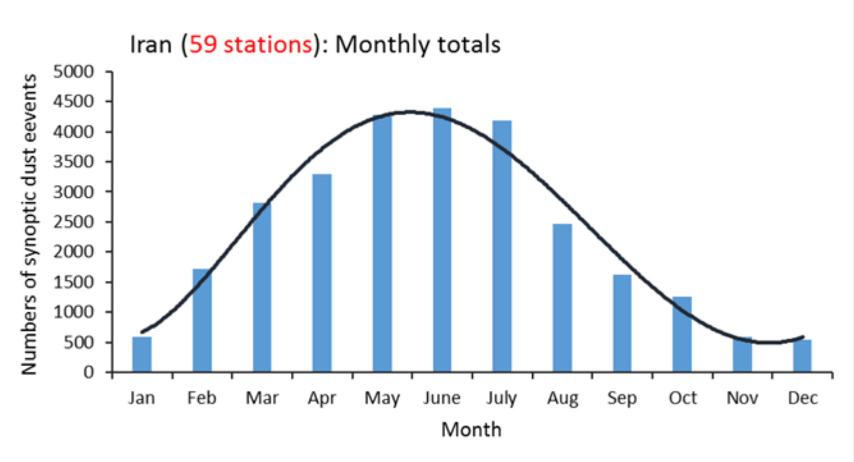


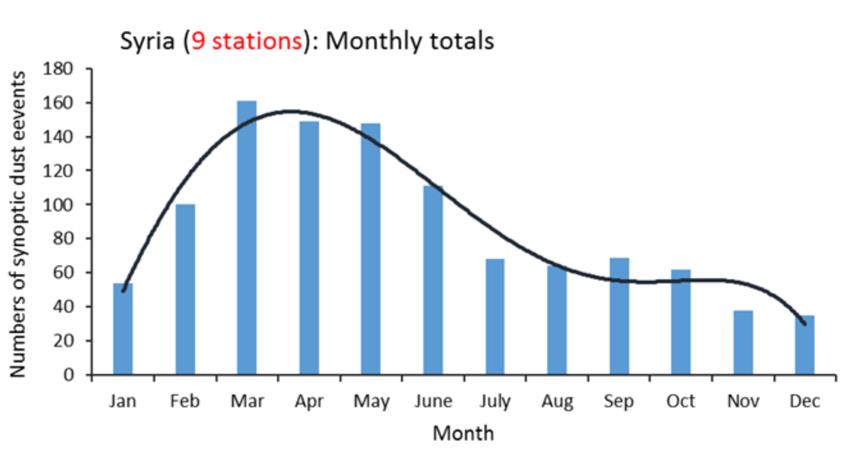
Dust Weather Climatology: Yearly Dust Regime, Monthly Variation

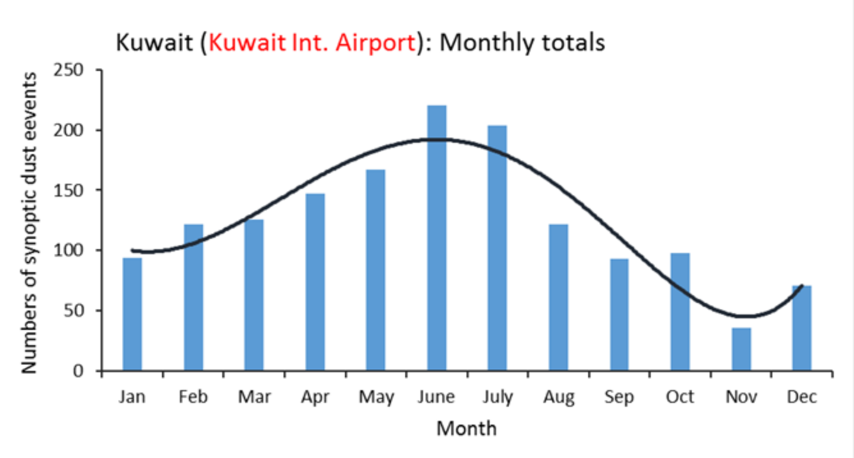


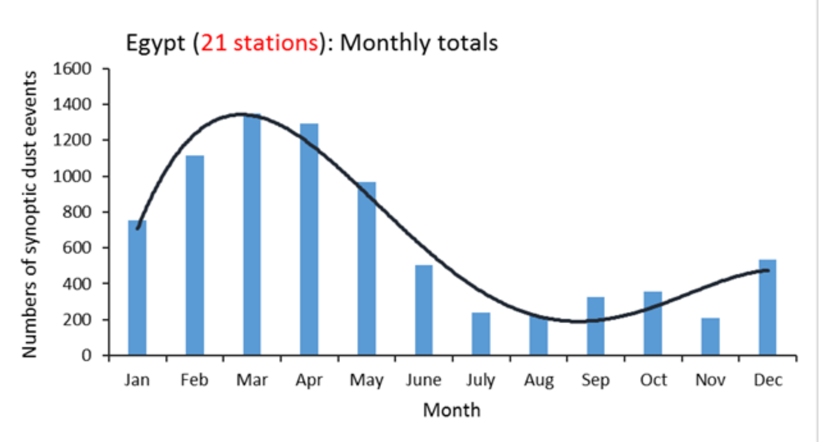
Dust Weather Climatology: Yearly Dust Regime, Monthly Variations for Selected Countries

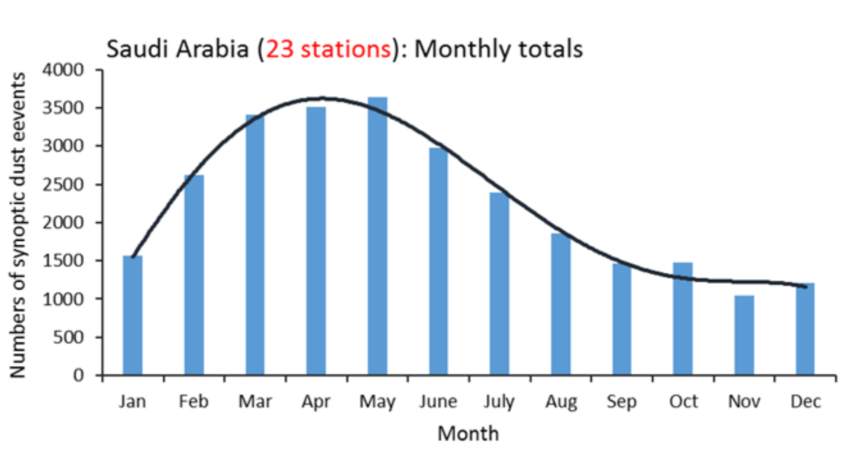


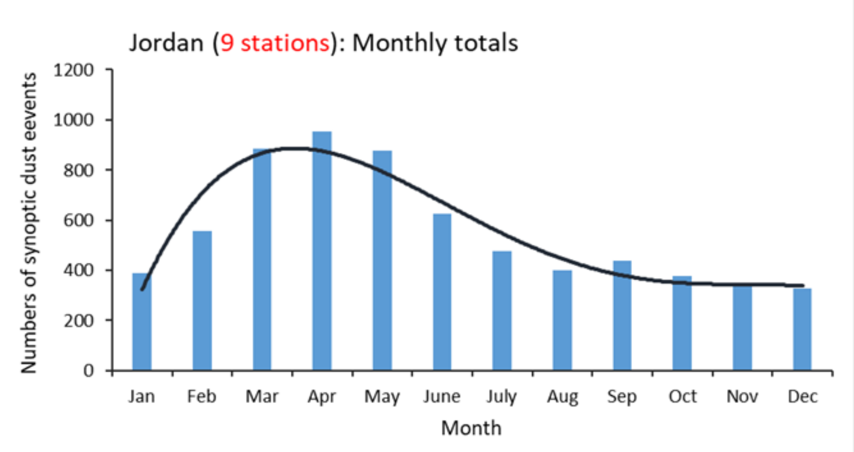


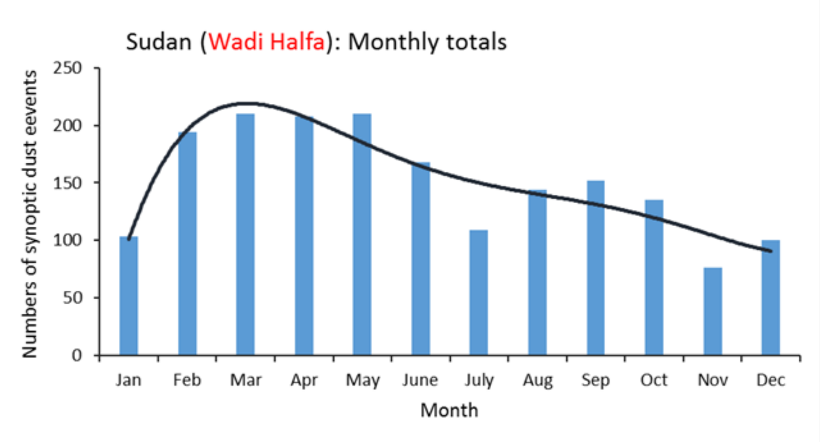






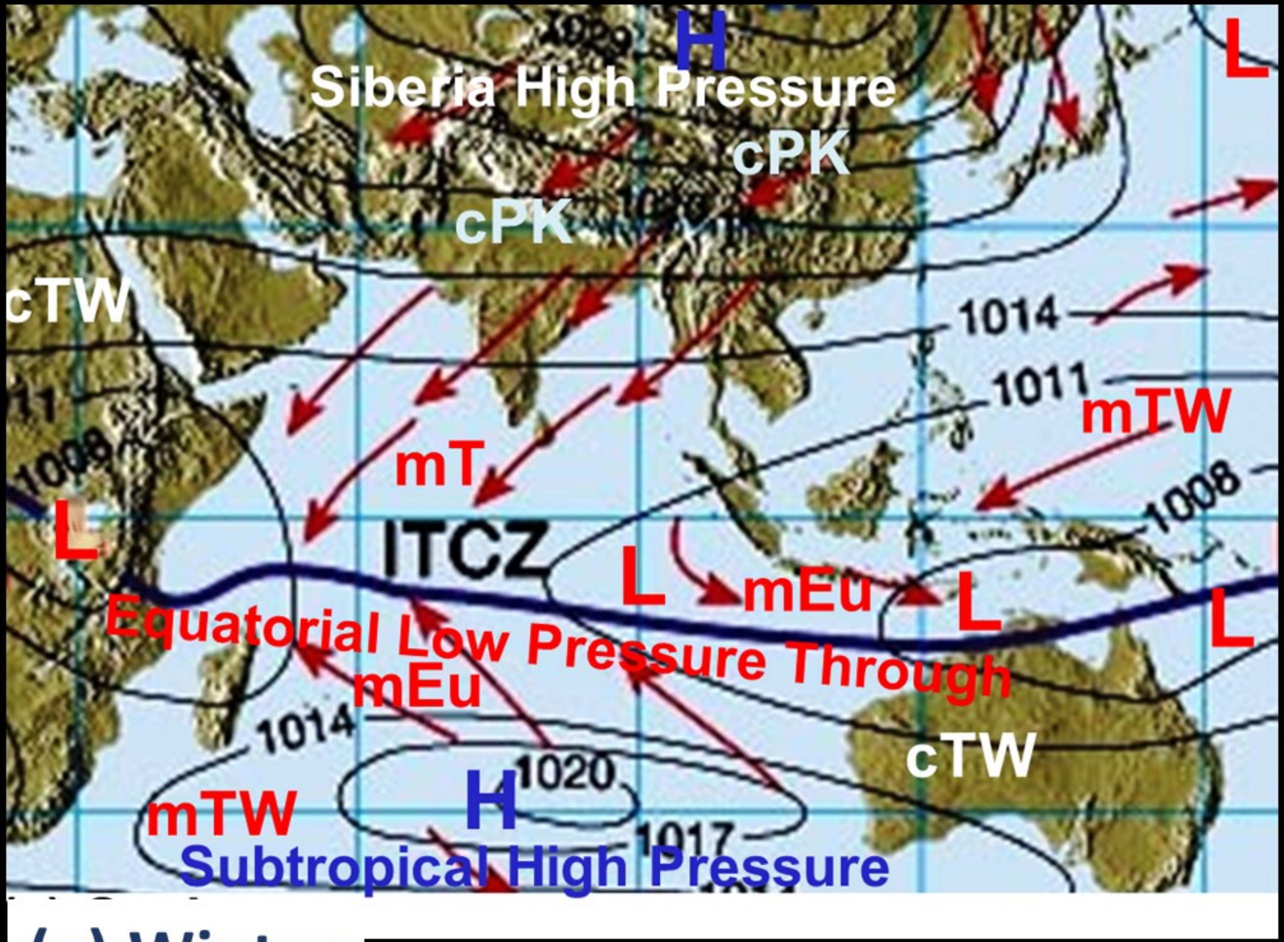




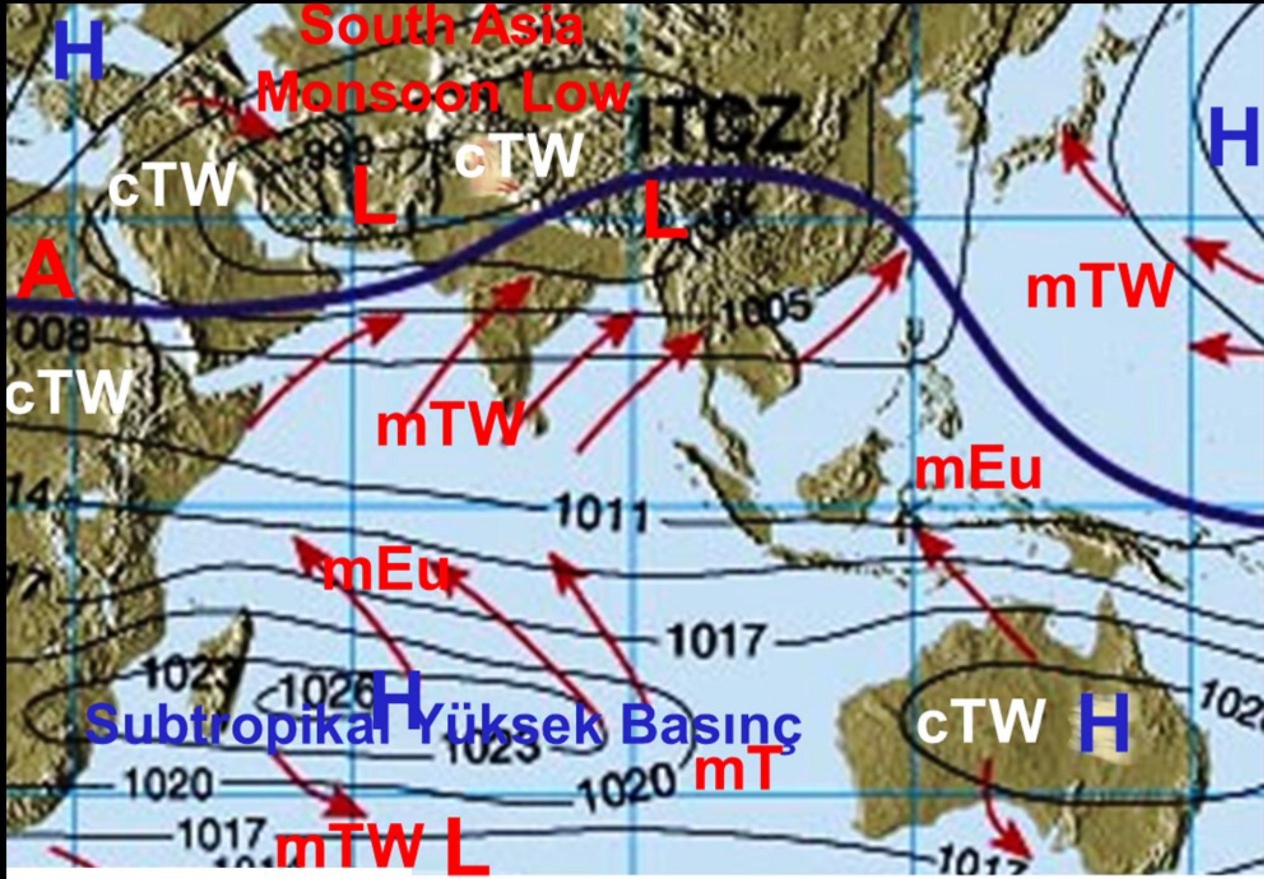


Synoptic Climatology and Meteorology: Major Atmospheric Controls and Drivers

(Türkeş, 2017)



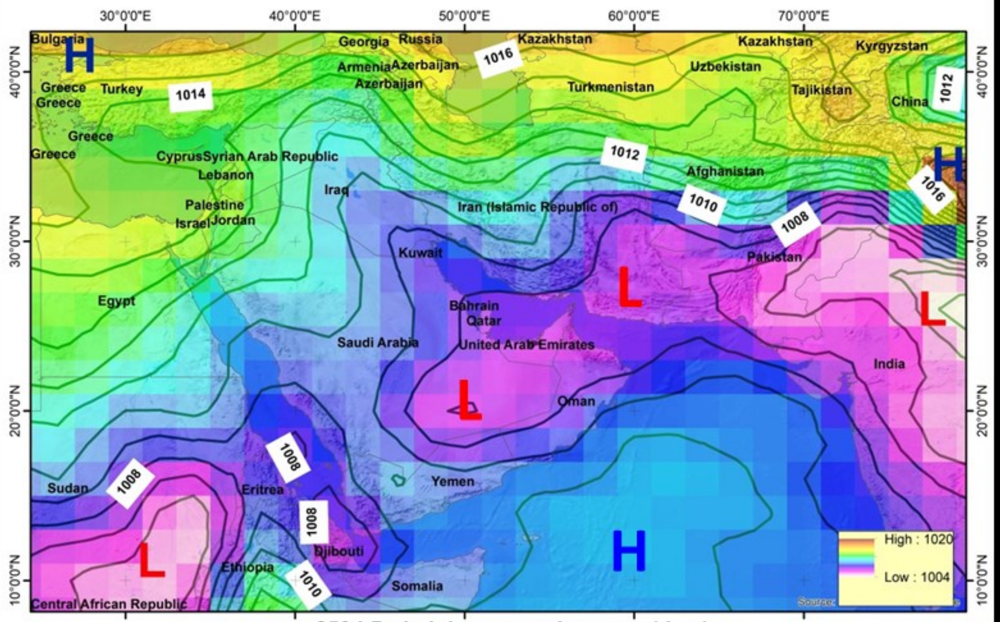
(a) Winter



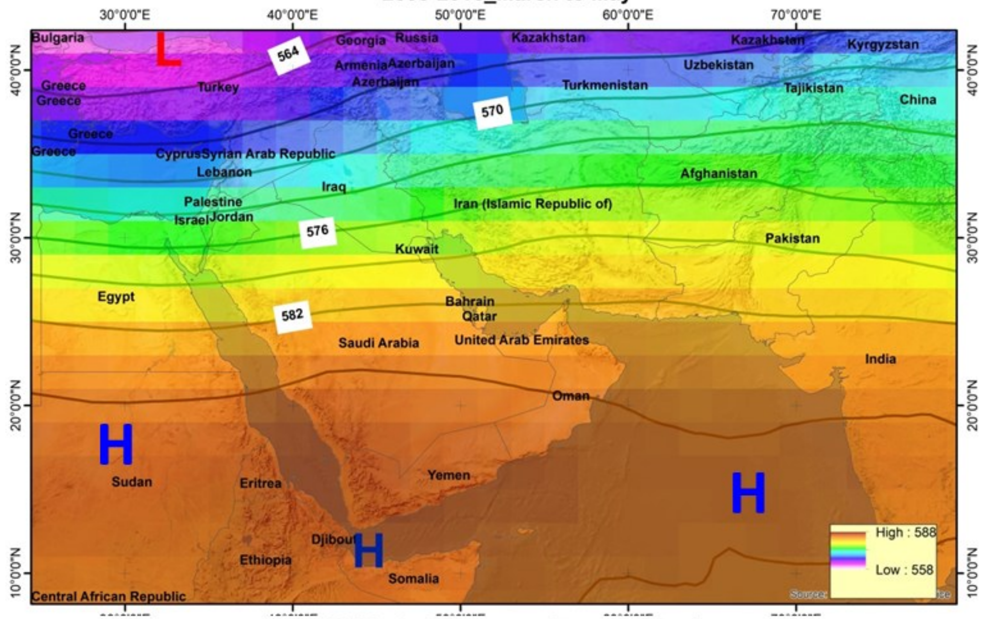
(b) Summer

2003-2016 Climatology: Atmospheric Controls and Drivers: Some Examples

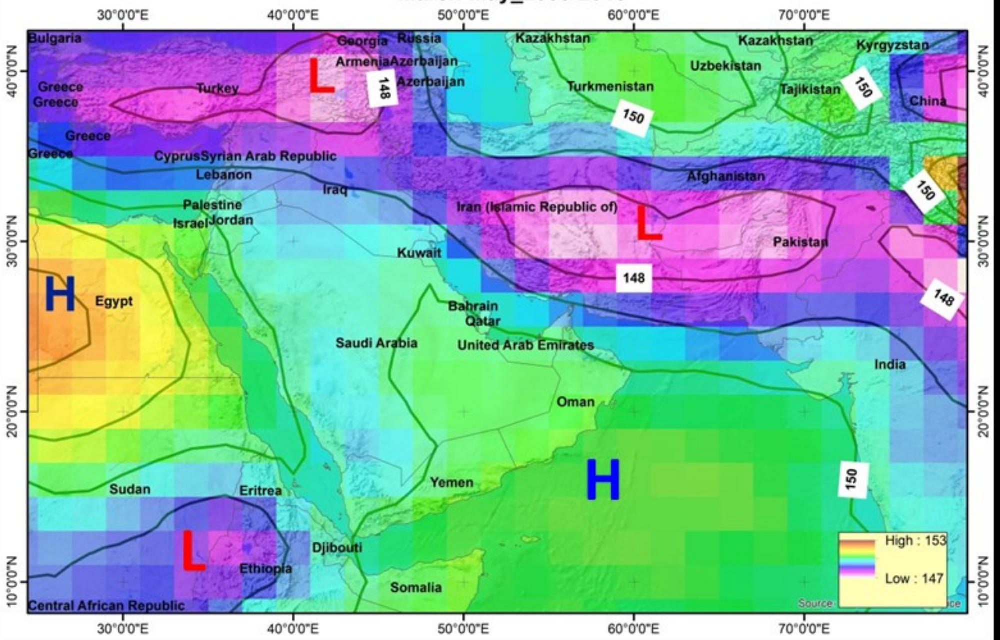
SLP (hPa) composite mean_2003-2016_March to May



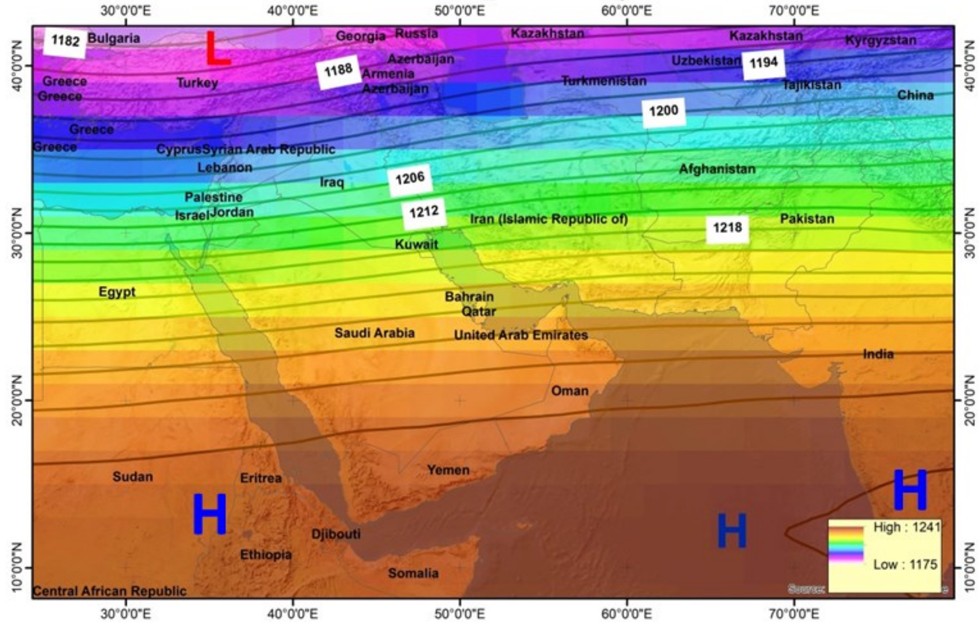
500 hPa height composite mean (dam)
2003-2016_March to May



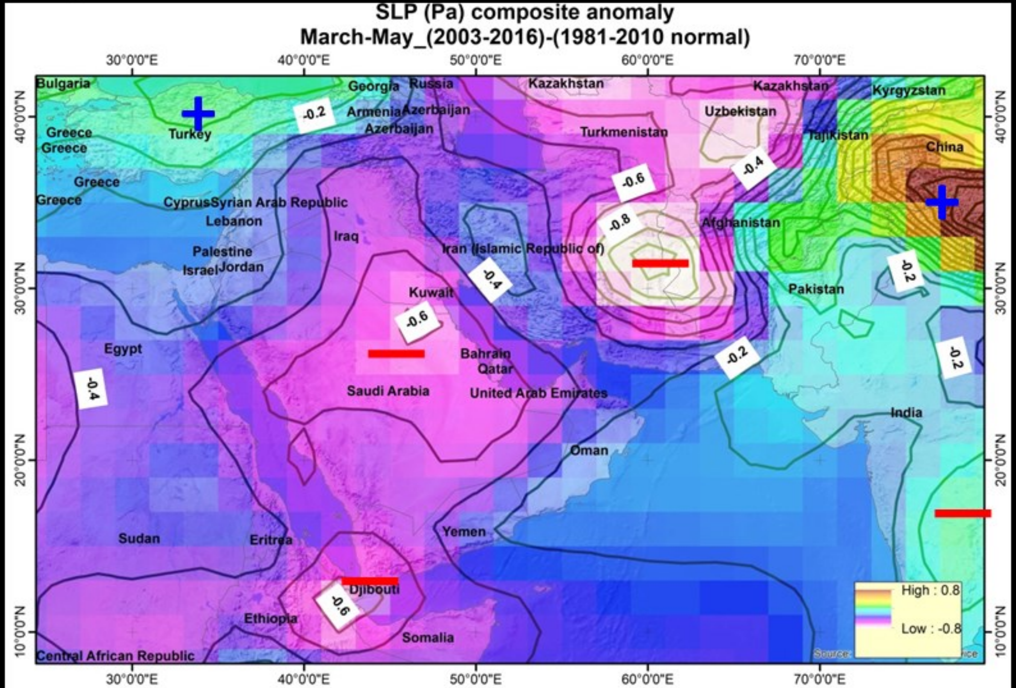
850 hPa height composite mean (dam)
March-May_2003-2016

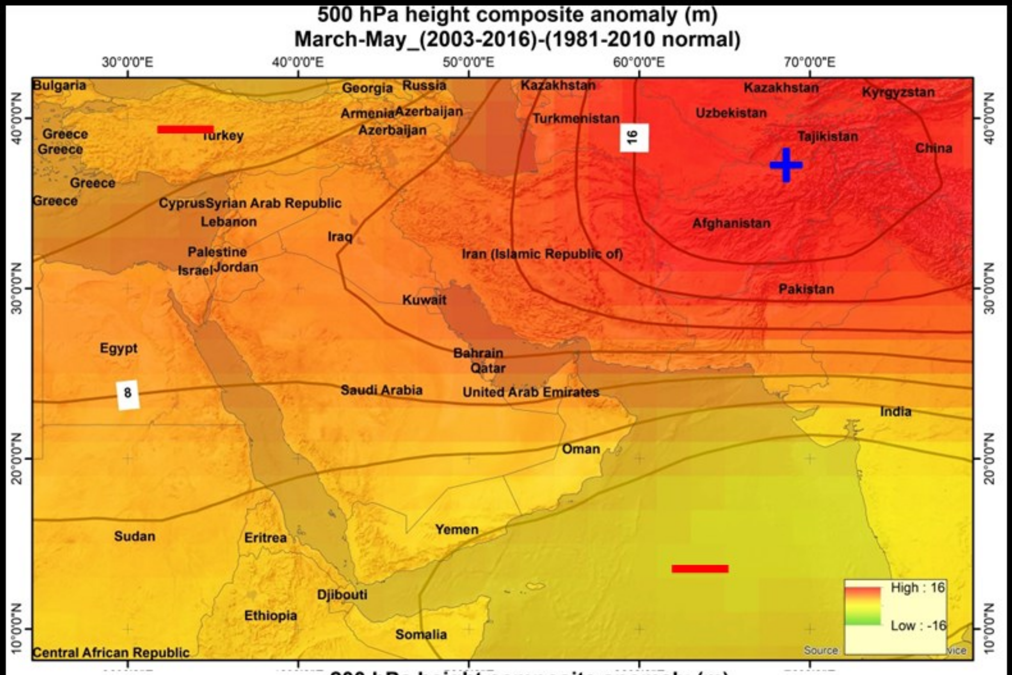


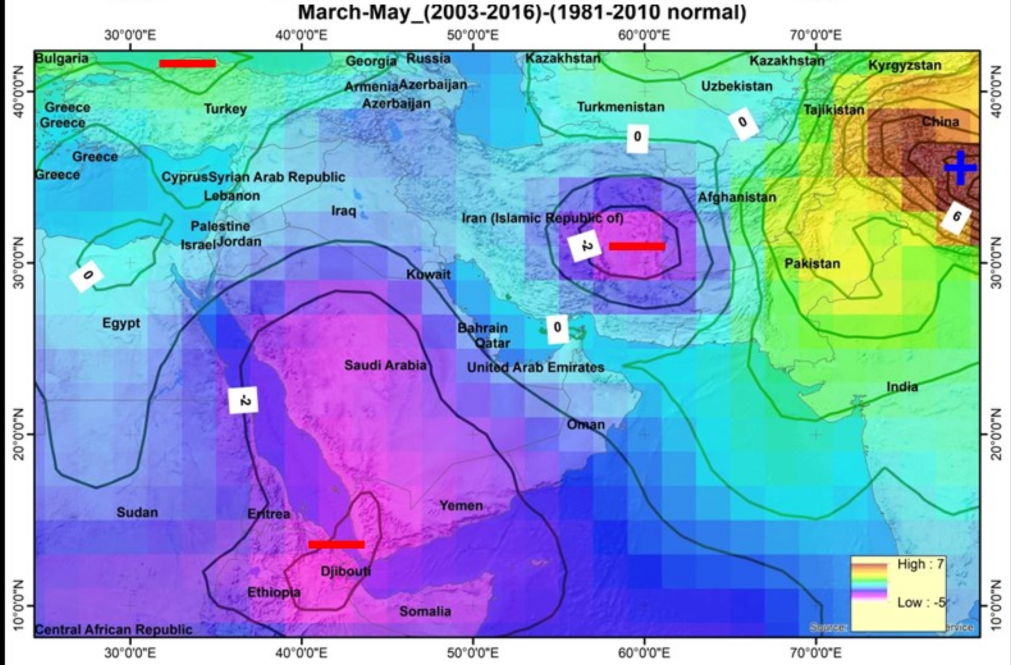
200 hPa height composite mean (dam)
2003-2016_March to May

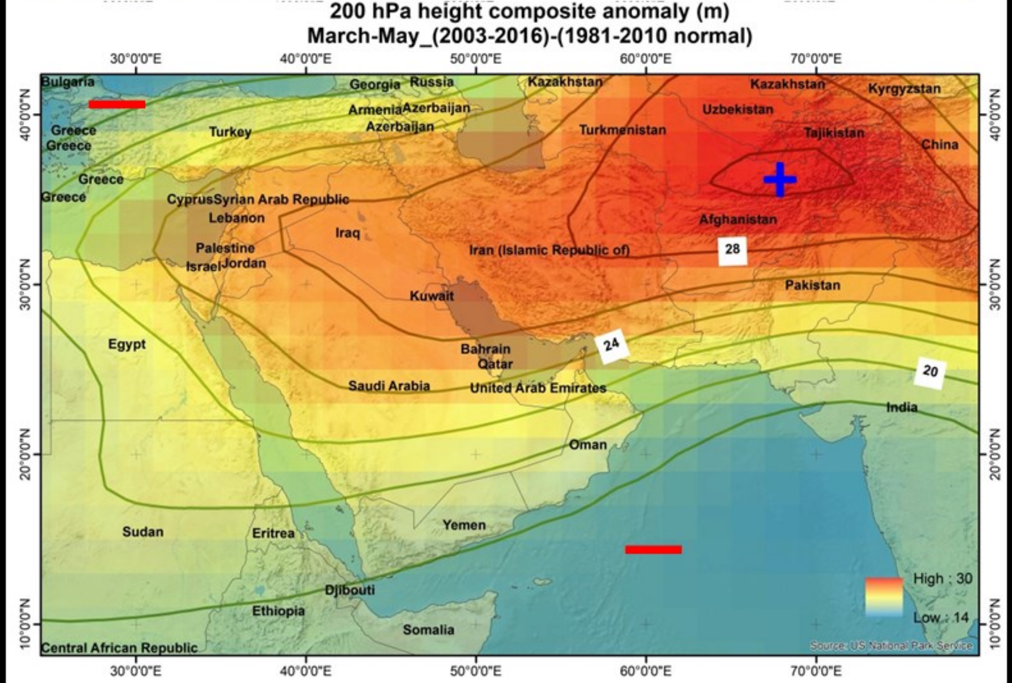


Comparison of 2003-2016 Climatology with 1981-2010 Climatological Normal



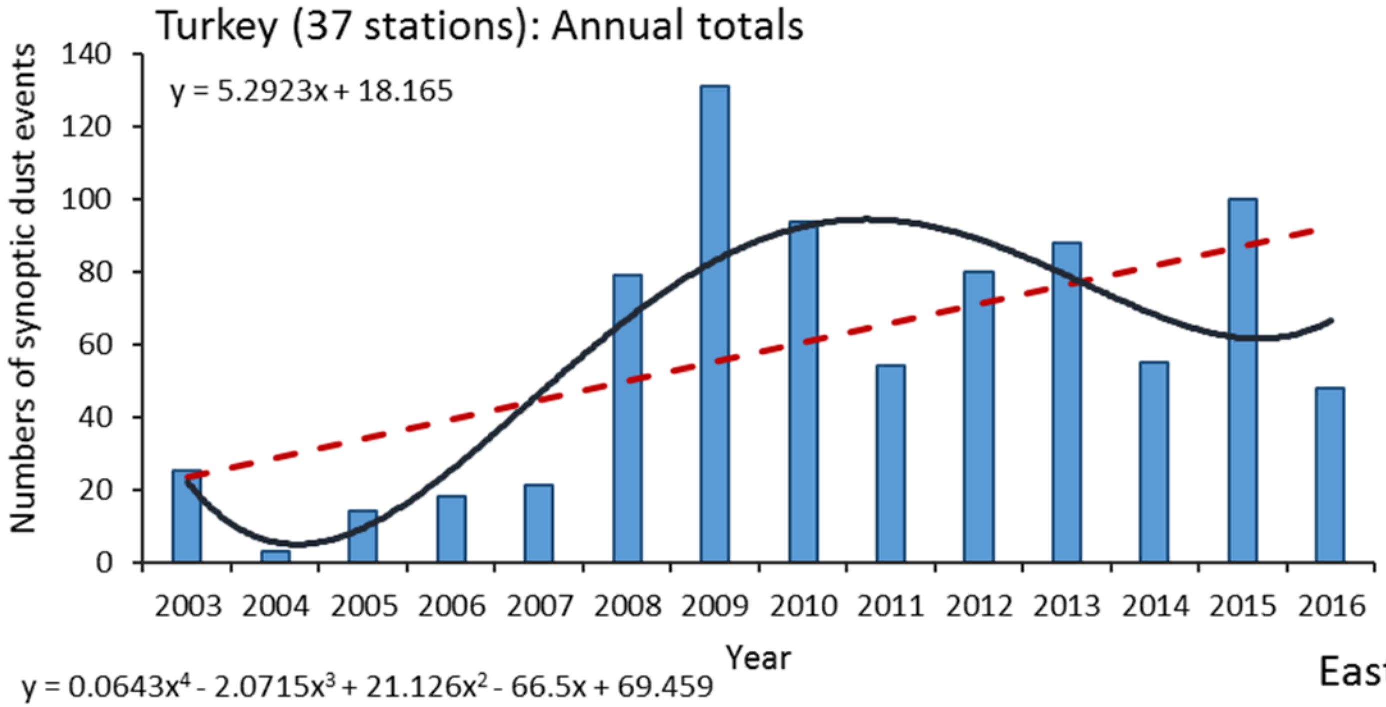


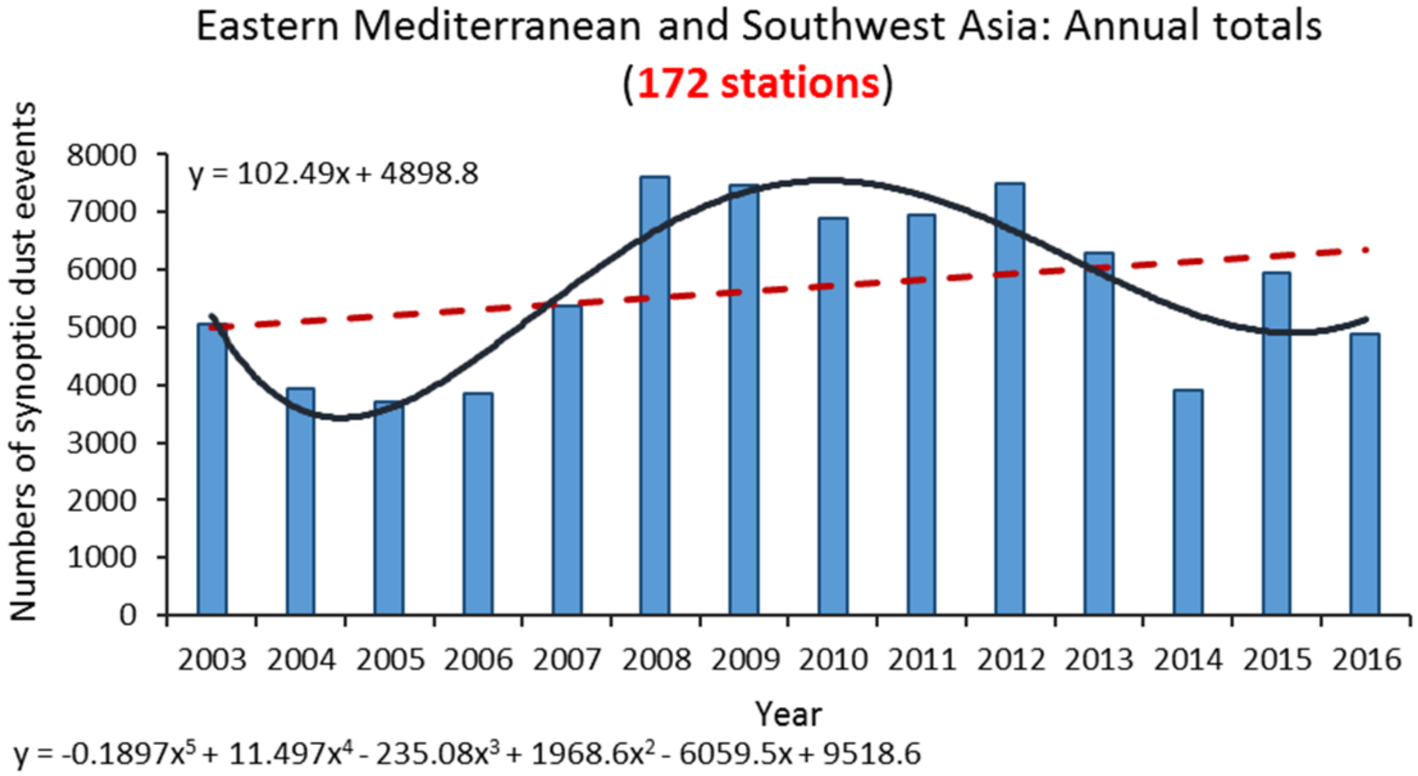




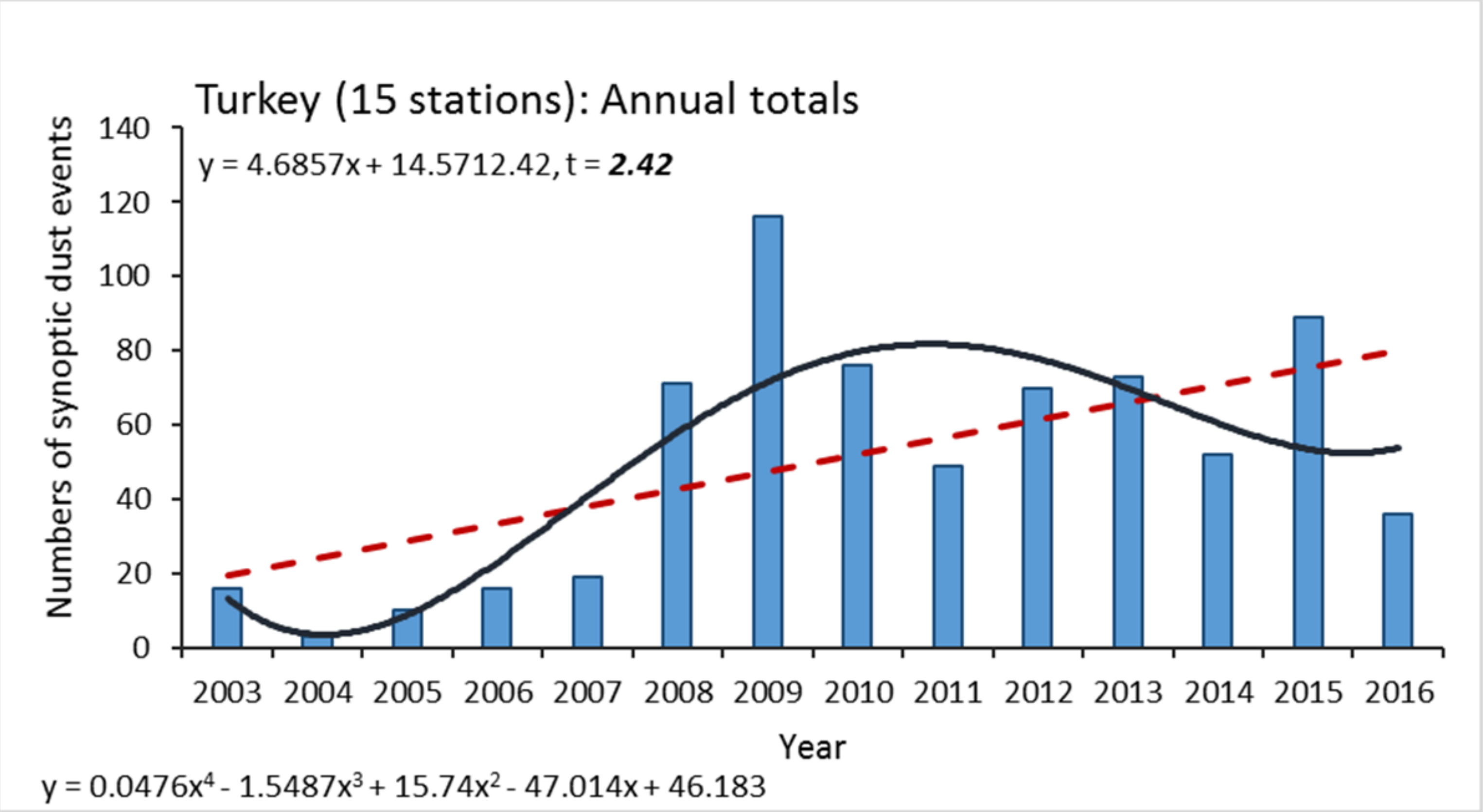
Inter-annual Variations and Long-term Trends in Regional and Country Time-series

Inter-annual Variations and Trends



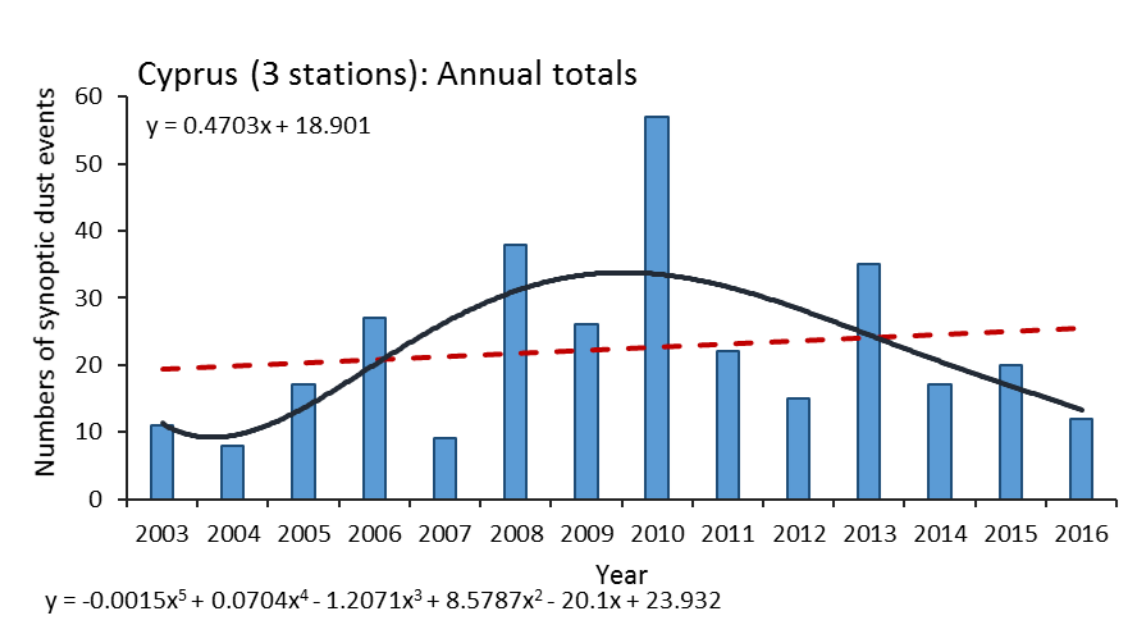


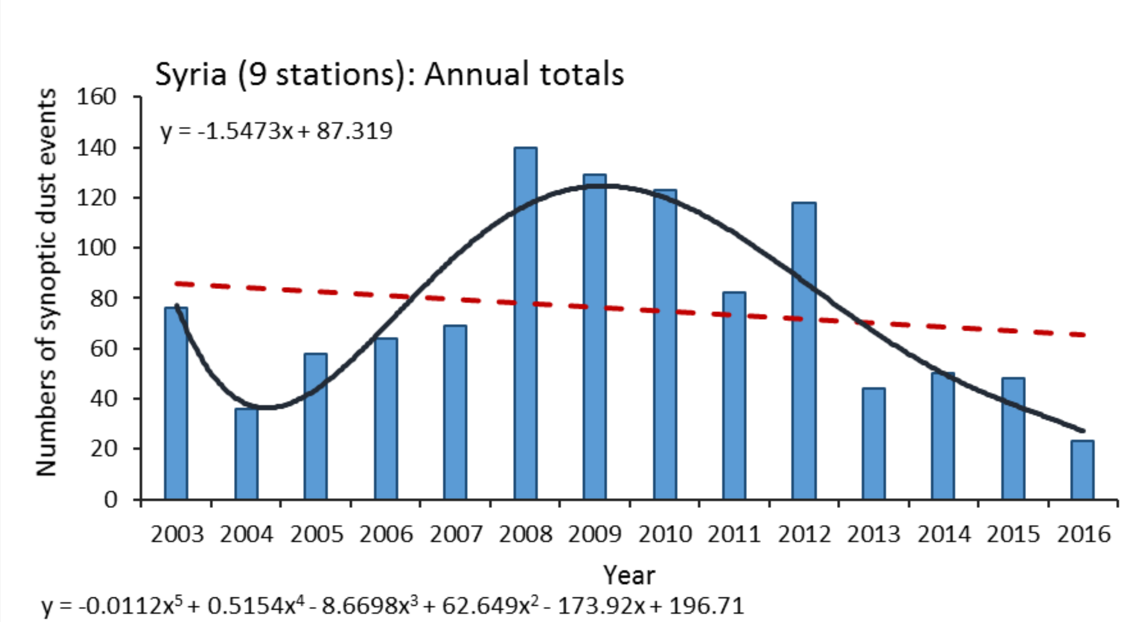
Inter-annual Variations and Trends

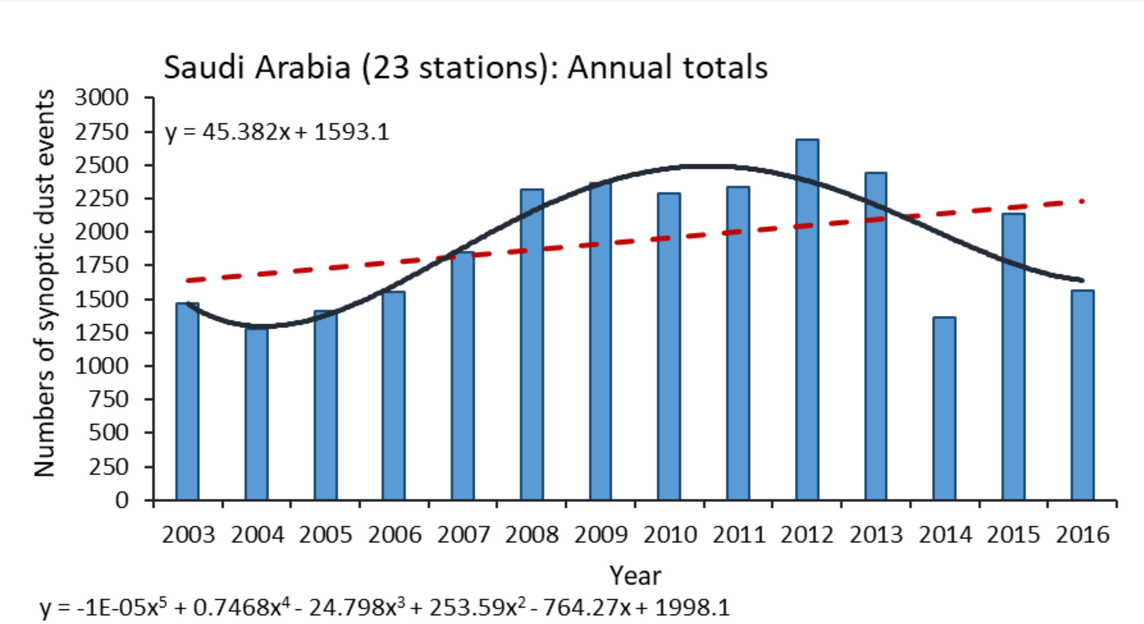


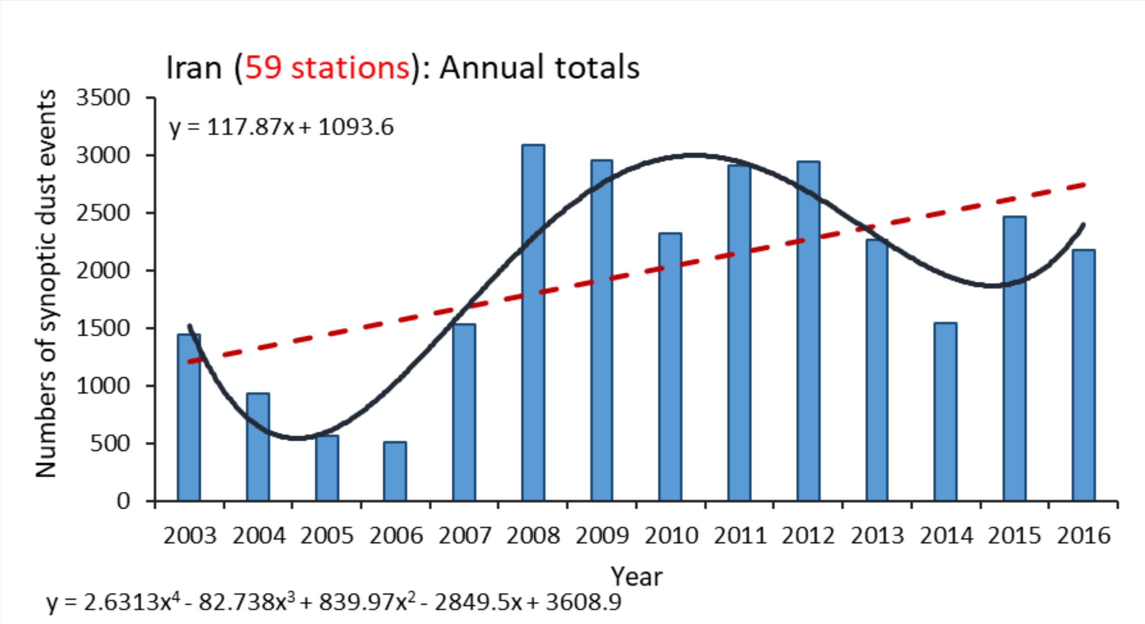
	Trend test statistics	
	Linear regression	Mann-Kendall rank correlation
Country	*t*	*u*(*t*)
Turkey	**2.42**	**2.19**
Cyprus	0.51	0.55
Syria	-0.61	-0.93
Lebanon	0.89	0.11
Israel	-1.18	-0.93
Jordan	-2.11	-1.70
Saudi Arabia	**2.91**	**2.57**
Kuwait	-0.45	-0.44
Iran	**2.28**	1.15
Egypt	**-2.58**	-2.03
Sudan	-1.83	-1.34

Inter-annual Variations and Trends

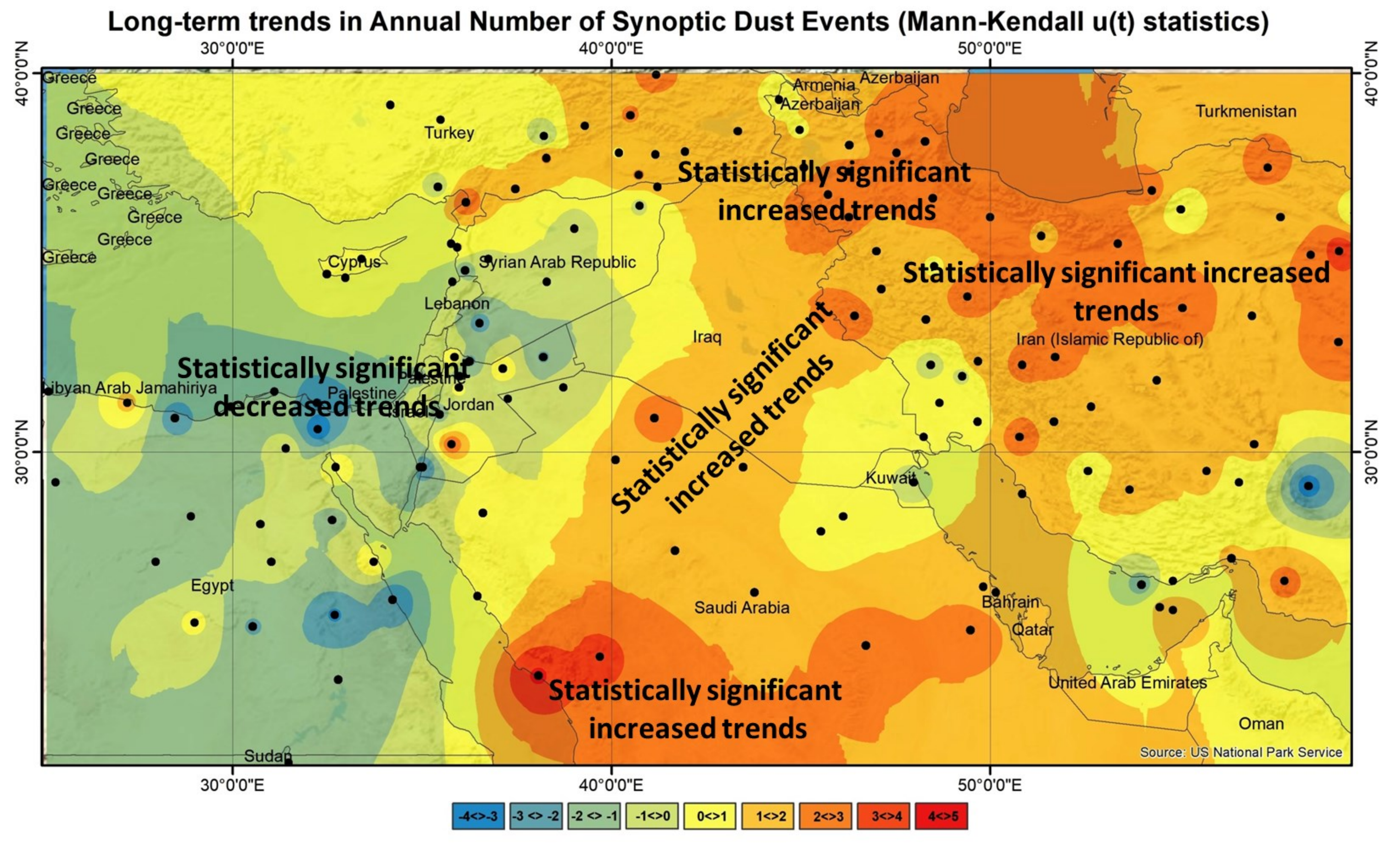








Spatial Distribution Pattern of Long-term Trends in the Stations



Some Examples of Atmospheric Anomalous Circulation Types for the Year or Periods with Increased and Decreased Dust and Sand Storm Related Weather Events

- Standardized monthly and annual anomaly series of Turkey for the period from 2003 to 2016:

Monthly average		1.00	2.21	10.57	8.43	5.71	3.57	2.29	4.00	4.86	5.29	0.79	1.00	Turkey
Monthly StD		1.52	3.42	10.19	6.93	6.80	5.96	3.47	5.16	12.18	5.11	1.48	1.47	Annual average
Normalized Value	2003	-0.66	-0.65	-0.74	-1.07	0.48	-0.60	-0.66	-0.58	-0.40	-0.84	-0.53	0.00	-0.52
	2004	-0.66	-0.65	-1.04	-0.93	-0.84	-0.60	-0.66	-0.78	-0.32	-1.04	-0.53	-0.68	-0.73
	2005	-0.66	-0.65	-0.94	-1.07	-0.69	0.24	-0.66	-0.78	-0.40	-1.04	0.15	0.00	-0.54
	2006	-0.66	-0.65	-0.55	-0.21	-0.84	-0.60	-0.66	-0.39	-0.32	-1.04	-0.53	0.00	-0.54
	2007	-0.66	-0.06	-0.94	-1.22	0.63	-0.43	-0.37	-0.78	-0.40	-0.64	0.82	-0.68	-0.39
	2008	-0.66	-0.65	0.43	1.38	-0.69	-0.43	0.78	2.13	0.50	-0.64	-0.53	1.36	0.25
	2009	2.63	1.40	1.42	0.52	2.25	3.26	-0.08	1.16	-0.23	0.73	-0.53	-0.68	0.99
	2010	1.32	1.98	1.51	0.37	0.34	-0.26	-0.66	-0.58	-0.15	0.53	-0.53	2.73	0.55
	2011	0.00	-0.06	0.04	1.24	-0.25	-0.43	2.80	-0.78	-0.40	-0.84	-0.53	-0.68	0.01
	2012	-0.66	-0.35	-0.15	0.23	1.81	-0.26	1.07	1.36	-0.32	1.32	-0.53	-0.68	0.23
	2013	0.66	-0.65	2.01	1.96	-0.11	-0.60	0.49	-0.78	-0.40	0.73	-0.53	-0.68	0.18
	2014	-0.66	-0.65	0.04	-0.35	-0.84	0.24	-0.66	0.97	-0.23	1.90	2.18	-0.68	0.10
	2015	0.66	1.98	-0.84	-0.21	-0.55	0.24	-0.66	-0.58	3.38	0.92	2.18	0.00	0.54
	2016	0.00	-0.35	-0.25	-0.64	-0.69	0.24	-0.08	0.39	-0.32	-0.06	-0.53	0.68	-0.13

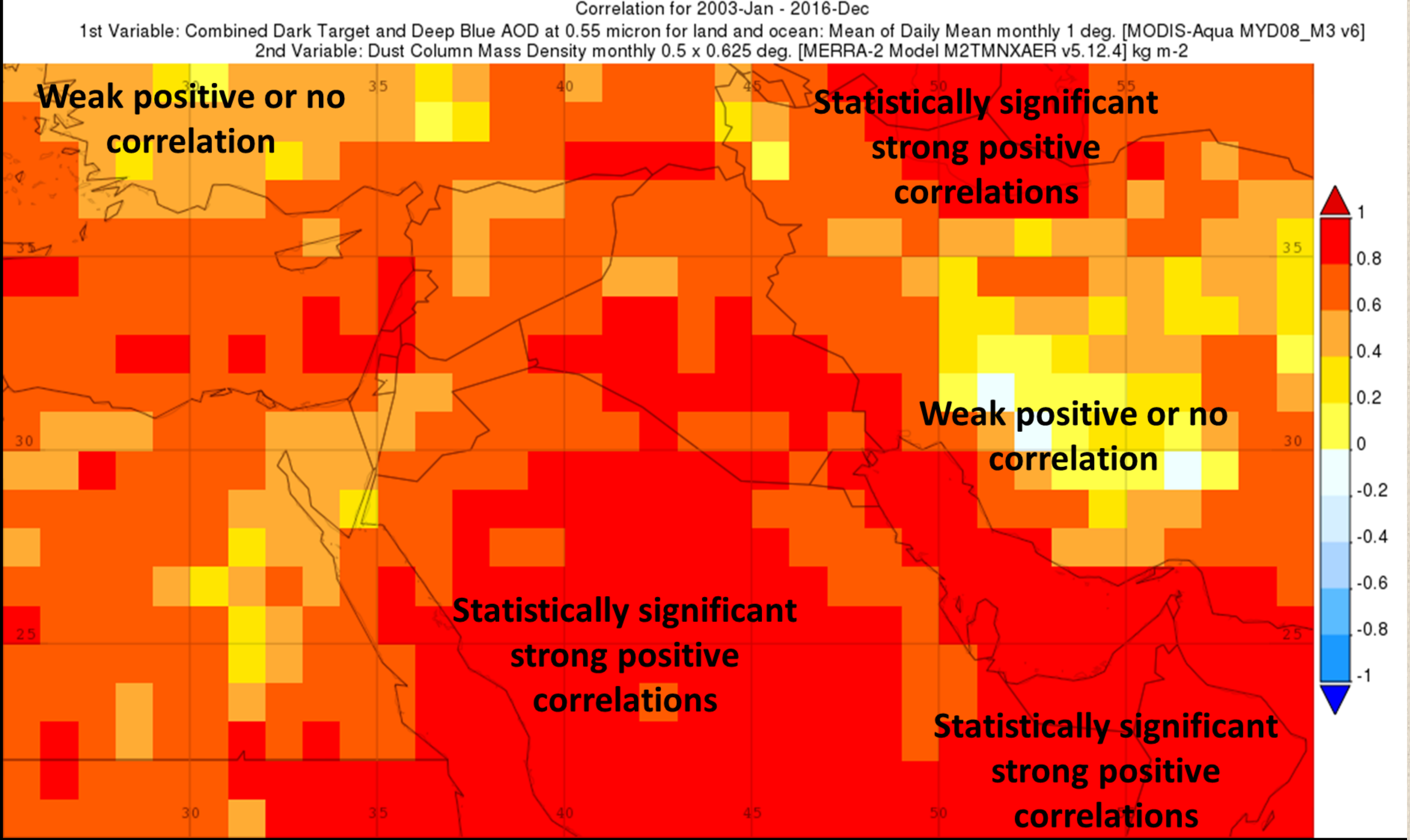
Relationships Between Number of Dust and Sand Storm Related Weather Events and AOD based on Country Time-series

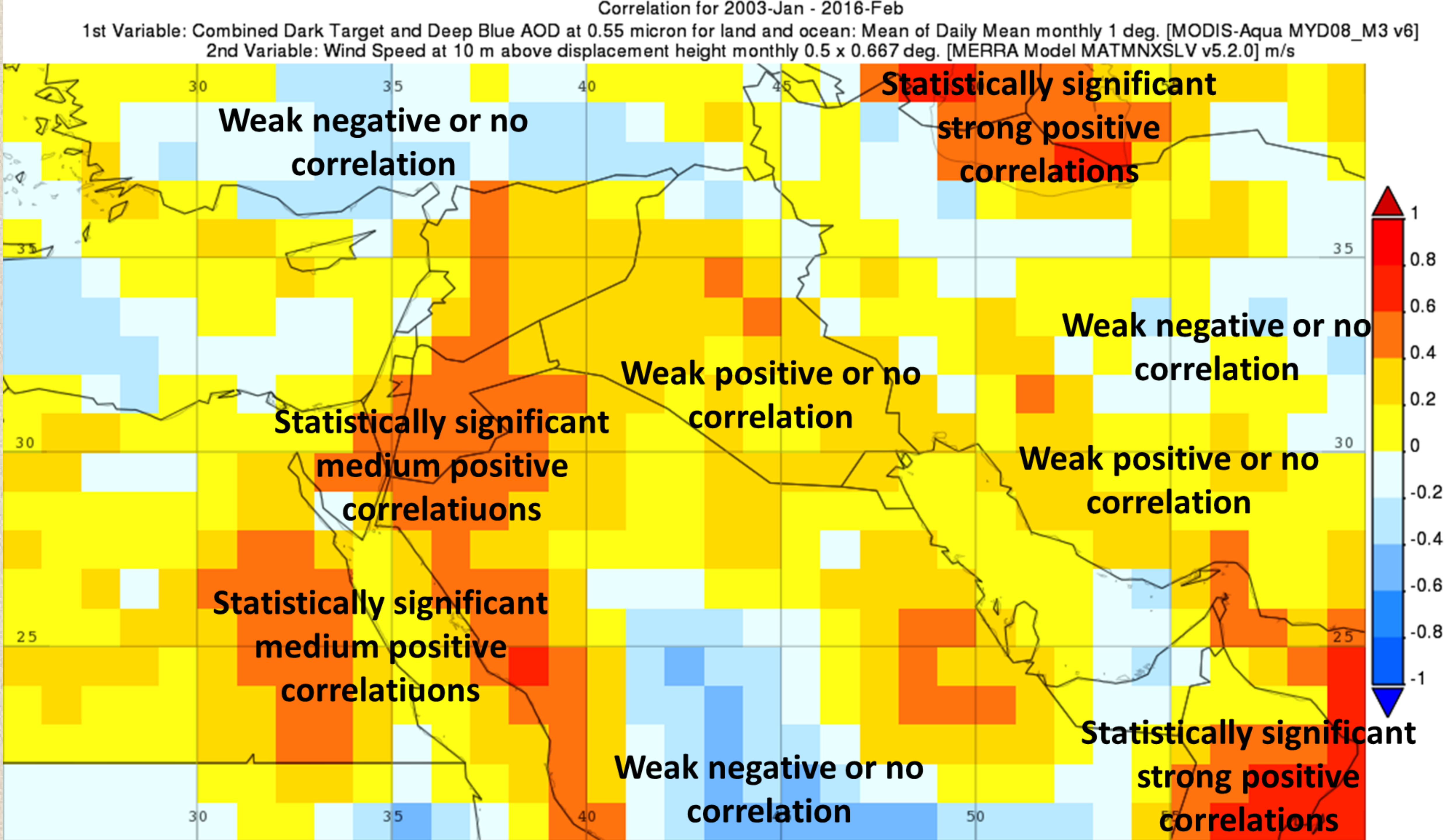
		Turkey-AOD	Cyprus-AOD	Syria-AOD	Israel-AOD	Jordan-AOD	Saudi Arabia-AOD	Kuwait-AOD	Iran-AOD	Qatar-AOD	Oman-AOD	Egypt-AOD	Sudan-AOD
Turkey	Pearson Cor. *r*	**0.402**	0.393	0.528	**0.534**	0.444	0.366	0.464	0.375	0.347	0.075	0.299	0.151
	Sig. (2-tailed)	**0.000**	0.000	0.000	**0.000**	0.000	0.000	0.000	0.000	0.000	0.333	0.000	0.051
	N	167	167	167	167	167	167	167	167	167	167	167	167
Cyprus	Pearson Cor. r		**0.460**	0.325	**0.355**	0.178	0.032	0.189	0.193	-0.006	-0.187	0.140	-0.106
	Sig. (2-tailed)		**0.000**	0.000	**0.000**	0.021	0.680	0.015	0.012	0.934	0.015	0.071	0.174
Syria	Pearson Cor. r			**0.686**	0.624	0.568	0.497	**0.667**	0.620	0.485	0.175	0.360	0.176
	Sig. (2-tailed)			**0.000**	0.000	0.000	0.000	**0.000**	0.000	0.000	0.024	0.000	0.023
Israel	Pearson Cor. r				**0.462**	**0.276**	0.102	0.221	0.241	0.148	-0.130	0.215	-0.061
	Sig. (2-tailed)				**0.000**	**0.000**	0.190	0.004	0.002	0.056	0.095	0.005	0.431
Jordan	Pearson Cor. r					**0.576**	0.429	0.472	0.493	0.380	0.133	**0.505**	0.231
	Sig. (2-tailed)					**0.000**	0.000	0.000	0.000	0.000	0.088	**0.000**	0.003
Saudi Arabia	Pearson Cor. r						**0.484**	0.449	**0.456**	0.427	0.291	0.243	0.201
	Sig. (2-tailed)						**0.000**	0.000	**0.000**	0.000	0.002	0.009	0.031
Kuwait	Pearson Cor. r							**0.794**	**0.757**	0.705	0.626	0.569	0.531
	Sig. (2-tailed)							**0.000**	**0.000**	0.000	0.000	0.000	0.000
Iran	Pearson Cor. r								**0.828**	**0.739**	0.644	0.581	0.511
	Sig. (2-tailed)								**0.000**	**0.000**	0.000	0.000	0.000
Qatar	Pearson Cor. r									**0.753**	**0.681**	0.567	0.566
	Sig. (2-tailed)									**0.000**	**0.000**	0.000	0.000
Oman	Pearson Cor. r										**0.748**	**0.598**	0.578
	Sig. (2-tailed)										**0.000**	**0.000**	0.000
Egypt	Pearson Cor. r											**0.306**	-0.077
	Sig. (2-tailed)											**0.000**	0.322
Sudan	Pearson Cor. r												**0.263**
	Sig. (2-tailed)												**0.001**

Relationships Between Number of Dust and Sand Storm Related Weather Events and AOD based on Country and Regional Time-series

		Country averages of AOD	Eastern regional AOD series	All ME and surroundings
Turkey	Pearson Cor. *r*	**0.412**	**0.392**	**0.494**
	Sig. (2-tailed)	**0.000**	**0.000**	**0.000**
	N	167	167	167
Cyprus	Pearson Cor. *r*	0.135	0.124	**0.291**
	Sig. (2-tailed)	0.083	0.110	**0.000**
Syria	Pearson Cor. *r*	**0.568**	**0.564**	**0.671**
	Sig. (2-tailed)	**0.000**	**0.000**	**0.000**
Israel	Pearson Cor. *r*	0.172	0.151	**0.277**
	Sig. (2-tailed)	0.027	0.052	**0.000**
Jordan	Pearson Cor. *r*	**0.493**	**0.497**	**0.561**
	Sig. (2-tailed)	**0.000**	**0.000**	**0.000**
Saudi Arabia	Pearson Cor. *r*	**0.416**	**0.434**	**0.470**
	Sig. (2-tailed)	**0.000**	**0.000**	**0.000**
Kuwait	Pearson Cor. *r*	**0.764**	**0.780**	**0.781**
	Sig. (2-tailed)	**0.000**	**0.000**	**0.000**
Iran	Pearson Cor. *r*	**0.808**	**0.836**	**0.929**
	Sig. (2-tailed)	**0.000**	**0.000**	**0.000**
Qatar	Pearson Cor. *r*	**0.799**	**0.817**	**0.788**
	Sig. (2-tailed)	**0.000**	**0.000**	**0.000**
Oman	Pearson Cor. *r*	**0.747**	**0.754**	**0.742**
	Sig. (2-tailed)	**0.000**	**0.000**	**0.000**
Egypt	Pearson Cor. *r*	0.195	**0.212**	**0.382**
	Sig. (2-tailed)	0.012	**0.006**	**0.000**
Sudan	Pearson Cor. *r*	**0.395**	**0.420**	**0.470**
	Sig. (2-tailed)	**0.000**	**0.000**	**0.000**

Relationships between Inter-annual Variations of Gridded AOD (550 nm Dark Target Deep Blue Combined Mean Data) and Related (other AOD variables, e.g. atmospheric dust column mass density, wind speed at 10 m, etc.) Time-series


Correlation for 2003-Jan - 2016-Dec
1st Variable: Combined Dark Target and Deep Blue AOD at 0.55 micron for land and ocean: Mean of Daily Mean monthly 1 deg. [MODIS-Aqua MYD08_M3 v6]
2nd Variable: Dust Column Mass Density monthly 0.5 x 0.625 deg. [MERRA-2 Model M2TMNXAER v5.12.4] kg m-2
Weak positive or no correlation
Statistically significant strong positive correlations
Weak positive or no correlation
Statistically significant strong positive correlations
Statistically significant strong positive correlations
30
35
40
45
50
55
35
30
25
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1


Correlation for 2003-Jan - 2016-Feb
1st Variable: Combined Dark Target and Deep Blue AOD at 0.55 micron for land and ocean: Mean of Daily Mean monthly 1 deg. [MODIS-Aqua MYD08_M3 v6]
2nd Variable: Wind Speed at 10 m above displacement height monthly 0.5 x 0.667 deg. [MERRA Model MATMNXSLV v5.2.0] m/s
Weak negative or no correlation
Statistically significant strong positive correlations
Weak negative or no correlation
Weak positive or no correlation
Statistically significant medium positive correlatiuons
Weak positive or no correlation
Statistically significant medium positive correlatiuons
Weak negative or no correlation
Statistically significant strong positive correlations
30
35
40
45
50
35
30
25
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

Thank you very much for your interest

Selected References- 1

- Öztürk, T., Ceber, Z. P., Türkeş, M. and Kurnaz, M. L. 2015. Projections of climate change in the Mediterranean Basin by using downscaled global climate model outputs. *International Journal of Climatology* 35: 4276–4292. DOI: 10.1002/joc.4285
- Şahin, S., Türkeş, M., Wang, S-H., Hannah, D. and Eastwood, W. 2015. Large scale moisture flux characteristics of the Mediterranean Basin and their relationships with drier and wetter climate conditions. *Climate Dynamics* 45(11): 3381-3401. DOI 10.1007/s00382-015-2545-x
- Tatlı, H. and Türkeş, M. 2011. Empirical orthogonal function analysis of the Palmer drought indices. Agricultural and Forest Meteorology 151(7) (July 2011): 981–991. doi:10.1016/j.agrformet.2011.03.004.
- Turp, M. T., Öztürk, T., Türkeş, M. and Kurnaz, M. L. 2014. RegCM4.3.5 bölgesel iklim modelini kullanarak Türkiye ve çevresi bölgelerin yakın gelecekteki hava sıcaklığı ve yağış klimatolojileri için öngörülen değişikliklerin incelenmesi. *Ege Coğrafya Dergisi* **23**(1): 1-24.

Selected References - 2

- Türkeş M. 1998. Influence of geopotential heights, cyclone frequency and southern oscillation on rainfall variations in Turkey. *International Journal of Climatology* **18**: 649–680.
- Türkeş M. 1999. Vulnerability of Turkey to desertification with respect to precipitation and aridity conditions. *Turkish Journal of Engineering and Environmental Sciences* **23**: 363-380.
- Türkeş, M. 2010. Klimatoloji ve Meteoroloji. Birinci Baskı, Kriter Yayınevi - Yayın No. 63, Fiziki Coğrafya Serisi No. 1, ISBN: 978-605-5863-39-6, 650 + XXII sayfa, İstanbul.
- Türkeş, M. 2011. Akhisar ve Manisa yörelerinin yağış ve kuraklık indisi dizilerindeki değişimlerin hidroklimatolojik ve zaman dizisi çözümlemesi ve sonuçların çölleşme açısından coğrafi bireşimi. *Coğrafi Bilimler Dergisi* **9**: 79-99.
- Türkeş, M. 2012. A detailed analysis of the drought, desertification and the United Nations Convention to Combat Desertification. Marmara Journal of European Studies Çevre Özel Sayısı 20 (1): 7-56.
- Türkeş, 2013a. İklim Verileri Kullanılarak Türkiye'nin Çölleşme Haritası Dokümanı Hazırlanması Raporu. T.C. Orman ve Su İşleri Bakanlığı, Çölleşme ve Erozyonla Mücadele Genel Müdürlüğü Yayını, ISBN: 978-6054610-51-8, 57 sayfa: Ankara.

Selected References - 3

- Türkeş, M. 2013b. Türkiye'de gözlenen ve öngörülen iklim değişikliği, kuraklık ve çölleşme. *Ankara Üniversitesi Çevre Bilimleri Dergisi 4* (2): 1-32.
- Türkeş, M. 2014a. İklim Değişikliğinin Tarımsal Gıda Güvenliğine Etkileri, Geleneksel Bilgi ve Agroekoloji. *Turkish Journal of Agriculture - Food Science and Technology* **2**(2): 71-85.
- Türkeş, M. 2014b. Türkiye'deki 2013-2014 kuraklığının ve klimatolojik/ meteorolojik nedenlerinin çözümlenmesi. *Konya Toprak Su Dergisi* **2**: 20-34.
- Türkeş, M. 2017. General Climatology: Fundamentals of Atmosphere, Weather and Climate. Revised Second Edition, Kriter Publisher Physical Geography Series No: 4, ISBN: 978-605-9336-28-4, xxiv + 520 pp. Kriter Publisher, Berdan Matbaası: İstanbul. (In Turkish)
- Türkeş, M. 2015. Biogeography: A Paleogeography and Ecology Approach. Revised Second Edition, Kriter Publisher - Physical Geography Series No: 3, ISBN: 978-605-4613-87-8, 457 + XXXL pp. Sonçağ Yayıncılık Matbaacılık Reklam ve Sanayi Tic. Ltd. Şti: Ankara. (In Turkish)

Selected References - 4

- Türkeş, M. and Erlat, E. 2003. Precipitation changes and variability in Turkey linked to the North Atlantic Oscillation during the period 1930-2000. International Journal of Climatology, 23: 1771-1796.
- Türkeş, M. and Erlat, E. 2005. Climatological responses of winter precipitation in Turkey to variability of the North Atlantic oscillation during the period 1930–2001. Theoretical and Applied Climatology, 81: 45–69.
- Türkeş, M. and Erlat, E. 2009. Winter mean temperature variability in Turkey associated with the North Atlantic Oscillation. Meteorology and Atmospheric Physics 105: 211–225. DOI: 10.1007/s00703-009-0046-3
- Türkeş, M. ve Tatlı, H. 2008a. Aşırı kurak ve nemli koşulların belirlenmesi için yeni bir standartlaştırılmış yağış indisi (yeni-SPI): Türkiye'ye uygulanması. IV. Atmosfer Bilimleri Sempozyumu Bildiri Kitabı, 528-538. İstanbul.
- Türkeş, M. and Tatlı, H. 2009. Use of the standardized precipitation index (SPI) and modified SPI for shaping the drought probabilities over Turkey. International Journal of Climatology 29: 2270–2282. DOI: 10.1002/joc.1862