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The Caspian Sea – Hindu Kush Index (CasHKI): definition, meteorological influences and Dust activities over southwest Asia

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Abstract

This work introduces for the first time a new meteorology/climatology Index over Asia, the so-called "Caspian Sea – Hindu Kush Index (CasHKI)", which consists of changes in the mean sea level pressure (MSLP) gradient between two geographical domains over the Caspian Sea (40-50^{o}N, 50-55^{o}E) and Hindu Kush (35-40^{o}N, 70-75^{o}E). CasHKI is defined as the difference in MSLP anomalies between the Caspian Sea and Hindu Kush ($MSLP_{anom.Casp} - MSLP_{anom.HK}$) and is examined during the summer months (June-September) of 2000-2014 in view of modulating the atmospheric and climate dynamics and dust activity over southwest (SW) Asia. The CasHKI intensity and long-term trends are mostly modulated by the evolution in MSLP anomalies over the Caspian Sea, while the respective changes in Hindu Kush contribute to the CasHKI trends. A neutral-to-slight increasing trend (not statistically significant) in CasHKI is shown in all months during 2000-2014. The intensity in CasHKI enhances the MSLP over central Asia and deepens the Indo-Pakistan thermal low associated with the Indian summer monsoon. Larger wind speeds associated with a decrease in visibility, increase in dust emissions and slightly lower temperatures over Zabol are observed for the high CasHKI values. In synopsis, the high CasHKI modes enhance the near-surface and mid-troposphere northerlies over SW Asia, thus increasing the activation of the dust-sources and enhance the Asian continental outflow over the Arabian Sea.

***Keywords*:** CasHKI; MSLP anomalies; atmospheric dynamics; dust emissions; SW Asia

1. Introduction

Several meteorological and climatic indexes have been established as a result of teleconnection patterns between specific locations over the globe. Emphasizing over south and southwest (SW) Asia, although El-Nino Southern Oscillation (ENSO) variations are found to be associated with modulation of the Indian Summer Monsoon (ISM) and accumulation of dust over the Arabian Sea (Abish and Mohanakumar, 2013), North Sea-Caspian Pattern (NCP) variations affect the wind regimes and temperature over northeast Iran (Ghanghermeh et al., 2015), as well as temperature and precipitation rates over Mediterranean, Israel and Europe (Kutiel and Benaroch, 2002). Although atmospheric circulation patterns associated with dust storms are also well known over the Middle East (Saeed et al., 2014), lack of detailed knowledge still exists over SW Asia where changes in synoptic and dynamic meteorology control dust emissions and transport over the Arabian Sea. Therefore, although the major dust sources over SW

Asia and their seasonality are well known (Rashki et al., 2014), the atmospheric circulation and meteorological processes modulating the dust activity have not been evaluated so far.

Recent studies have shown that the development of the Indian thermal low and the strong Levar winds in eastern Iran modulate dust activity over SW Asia and the Arabian Sea (Kaskaoutis et al., 2014). The La-Nina phase was found to be associated with positive precipitation anomalies over the Indian Ocean and negative ones over central and SW Asia, while the El-Nino phase is linked with stronger westerlies at 700 hPa over northern Arabia and Iran (Abish and Mohanakumar (2013). By examining long-term (2000-2012) trends on dusty days over the Sistan region in east Iran, Kaskaoutis et al. (2015) detected a teleconnection pattern of specific variations in both MSLP (mainly) and geopotential height at 700 hPa (Z700) (secondarily) between the Caspian Sea and Hindu Kush. More specifically, positive MSLP anomalies over the Caspian Sea and slightly negative ones over Hindu Kush (associated with an increase in northern Levar wind) were detected during the dusty days of the summer months (June to September).

In the current work, the meteorological anomalies in MSLP between the Caspian Sea and Hindu Kush are evaluated via the Caspian – Hindu Kush Index (CasHKI), which is examined on daily basis during the summer months (June-September) of the period 2000-2014. The main objectives of the analysis are (i) to define and examine the CasHKI values and the long-term trends, (ii) to address any association between changes in the CasHKI intensity and variability in atmospheric circulation patterns over SW Asia, (iii) to examine the influence of CasHKI variations in the meteorological conditions (wind speed, visibility, temperature) over Zabol, east Iran, that are mostly related to changes in dust emissions. This is the first study that defines and examines in detail the CasHKI evolution and trends as well as the associated changes in meteorological patterns.

2. Materials and Methods

Gridded meteorological dataseries of MSLP, geopotential height at 700 hPa (Z700) and surface meridional winds were obtained from the National Center for Environmental Prediction / National Center for Atmospheric Research (NCEP-NCAR) reanalysis (Kalnay et al., 1996) during June-July-August-September (JJAS) of the period 2000-2014. The MSLP anomalies were analysed on daily basis and the CasHKI values were calculated as the difference of the spatially-averaged MSLP anomalies between the Caspian Sea (40-50^{o}N, 50-55^{o}E) and Hindu Kush (35-40^{o}N, 70-75^{o}E) (CasHKI = $MSLP_{anom.Casp.}$ – $MSLP_{anom.HK}$). Ground-based meteorological data (air temperature, visibility, wind speed and direction) at Zabol were obtained in JJAS 2000-2014. More specifically, 3-hr meteorological recordings were analysed on daily and monthly basis and correlated with the CasHKI values. The Infrared Difference Dust Index (IDDI) values from the satellites Meteosat 5 located at 63°E (2000-2006) and Meteosat 7 located at 57°E (2007-2014) were used over the Sistan Basin. The IDDI values correspond to retrievals over 6 pixels centered at 31^{o}N, 61^{o}E and were analysed against the CasHKI values and the meteorology parameters in Sistan. Radiance data in the thermal infrared (10.5-12.5 μm) are commonly used for dust detection over desert and arid terrains, based on the thermal contrast introduced by the presence of a dusty layer above a hotter surface (Legrand et al., 2001). NCEP-NCAR reanalysis data for MSLP, Z700, surface meridional wind, along with meteorological records at Zabol and IDDI values are analysed as a function of CasHKI values in order to examine the influence of CasHKI variations on local and synoptic meteorology.

3. Results and Discussion

Fig. 1 shows the daily variability and trend of CasHKI for JJAS during 2000-2014. Different values and multi-year patterns are shown for each month. The trends in CasHKI are not statistically significant at 95% confidence level, except the increasing trend in June during 2000-2009. The analysis shows that in all months the CasHKI values are mostly controlled by the MSLP variations over the Caspian Sea.

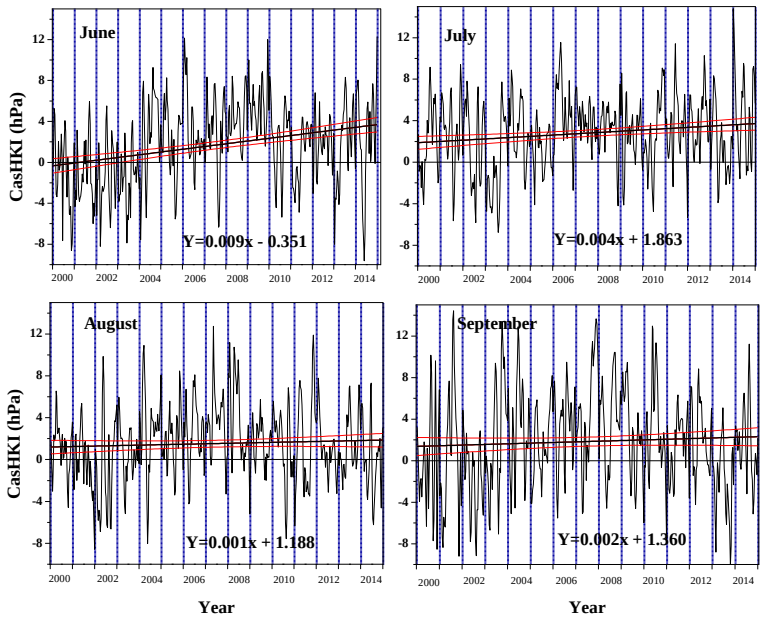
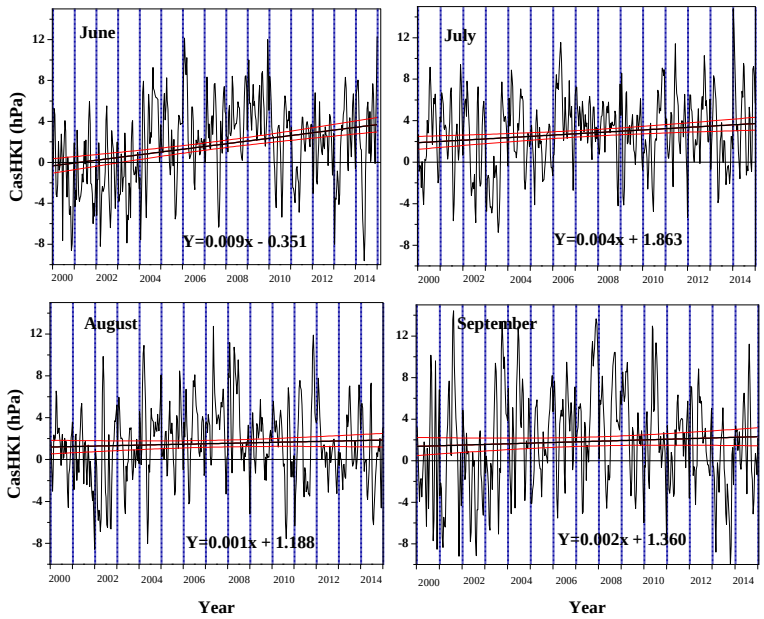


Fig. 1. Daily variations in CasHKI values and linear regression trends for June – September months during 2000-2014. The red lines denote the 95% upper and lower limits of the regression.

Composite-mean maps of MSLP (Fig. 2), Z700 (Fig. 3) and surface meridional wind (Fig. 4) are examined for the low and high CasHKI modes in July, while similar maps were observed for the other months. Fig. 2 reveals that the Indian-Pakistan low is deeper in the high CasHKI modes than in the low ones. However, these differences (about 2 hPa) are much lower than those observed over the Caspian Sea, where, for the high CasHKI modes, MSLP is found to be up to 12 hPa higher than for the low ones. This suggests that the main factor that modulates the CasHKI evolution and any related change in atmospheric and meteorological dynamics over SW Asia is the variability in MSLP over the Caspian Sea. The above MSLP changes in the two CasHKI centers of action imply changes in MSLP gradient between northwestern India-Pakistan and Caspian Sea, leading eventually to significant changes in atmospheric circulation patterns and wind field over SW Asia. These changes are able to trigger large variations in the intensity and frequency of dust emissions and modification in dust-plume pathways (Rashki et al., 2015). These findings are very well illustrated at the Z700 hPa anomalies (Fig. 3) where considerably high and low anomaly values (from +50 to -60 gpm) are seen only over Caspian Sea area in every month, confirming, thus, that this CasHKI center of action plays the major role in the formation of the teleconnection. An increase in CasHKI intensity is associated with a strengthening in northerly winds (more negative values for meridional winds) along the east Iranian borders with Afghanistan and Pakistan, i.e. in the area affected by the 120-day Levar wind (Fig. 4). This indicates that the changes in MSLP over the Caspian Sea and Hindu Kush are key factors for modulating the meridional wind over SW Asia. Studying the meridional wind anomalies, the highest differences between the low and high modes are detected over SW Asia, since the low CasHKI modes are associated with weaker northerlies (positive meridional anomalies), which become much more intense (change up to 4 ms^{-1}, in the meridional direction) during the high modes (negative meridional anomalies).



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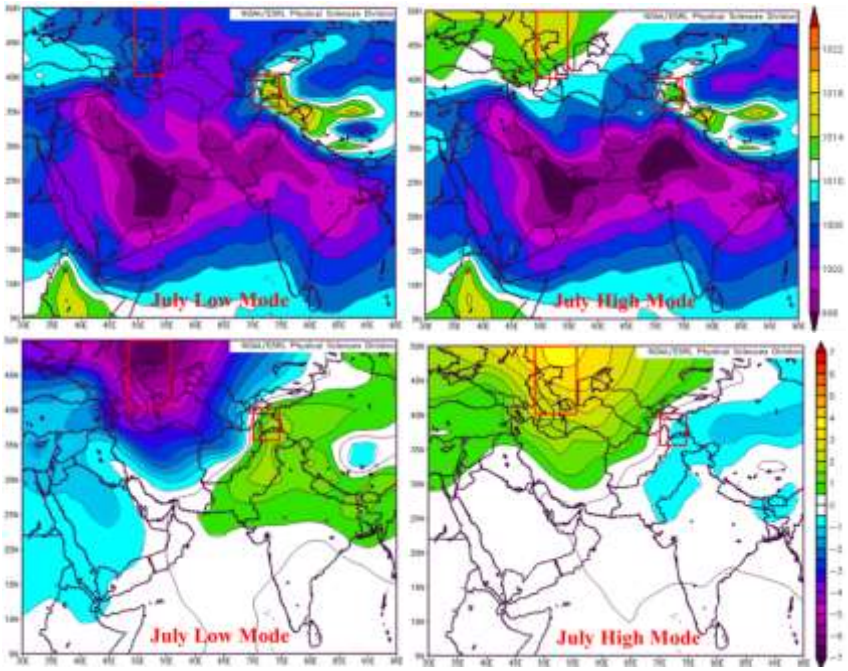

Fig. 2. Composite means of MSLP (upper panels) and anomalies from the mean climatology (lower panels) 1981-2010 over SW Asia for low and high CasHKI modes during July 2000-20014.

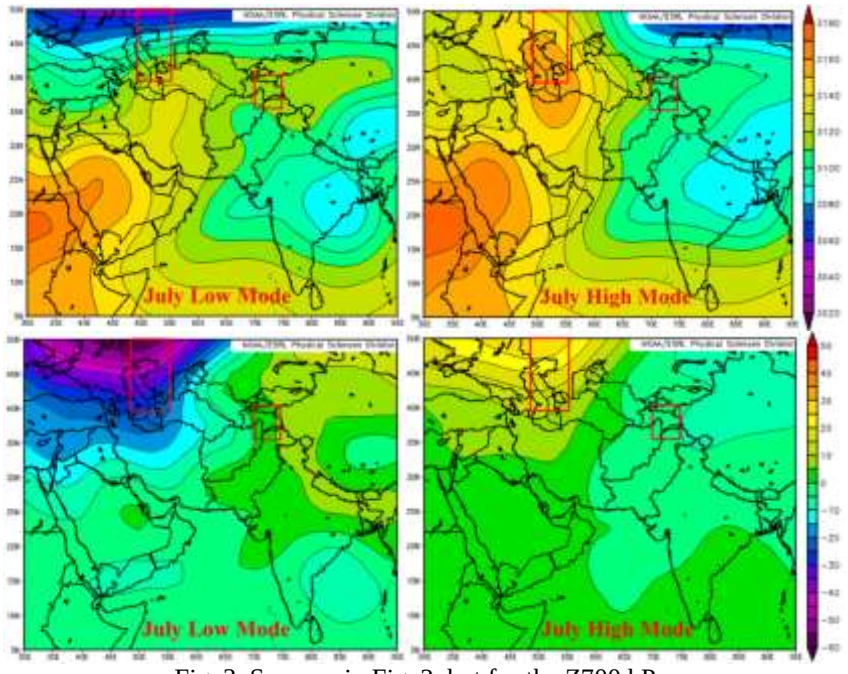

Fig. 3. Same as in Fig. 2, but for the Z700 hPa.

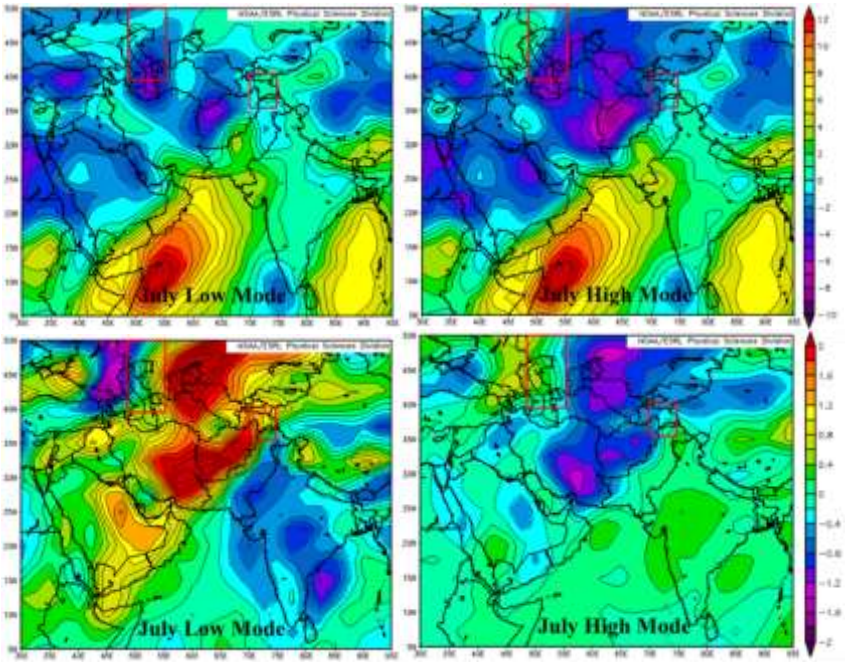

Fig. 4. Same as in Fig. 2, but for the surface meridional winds.

Fig. 5 correlates the CasHKI values with the daily-mean wind speed at Zabol as a function of visibility (colored scale). The analysis shows that CasHKI affects the wind speed over Sistan leading to a statistically significant (95% confidence level) increasing trend despite the large scatter of the data points. The current analysis reveals for the first time that an increase in CasHKI intensity is significantly related to an increase in wind speed and a decrease in visibility at Zabol, suggesting natural causes for modulating dust activity over Sistan.

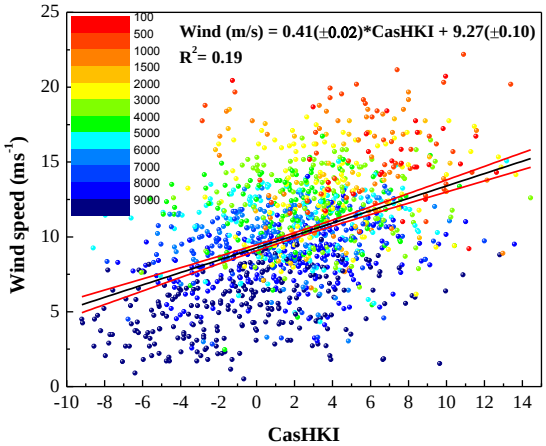

Fig. 5. Correlation between CasHKI values and wind speed (ms^{-1}) for various visibility levels (colored scale in meters) at Zabol during JJAS 2000-2014. The black line is the best-fit linear regression; the red lines represent the 95% upper and lower limits.

Fig. 6 correlates the IDDI values over Sistan with CasHKI as a function of the wind speed (colored scale) revealing a positive correlation associated with 12% of the variance. Low visibility is associated with intense winds and high IDDI values suggesting increase in dust emissions.

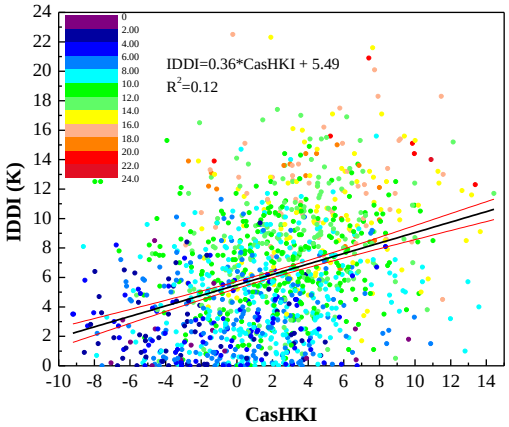

Fig. 6. IDDI vs CasHKI values as a function of wind speed (colored scale with values in ms^{-1}) over Sistan Basin during 2000-2014. The black line is the best-fit linear regression; the red lines represent the 95% upper and lower limits.

4. Conclusion

In synopsis, the dust emissions over Sistan basin are significantly related to changes in CasHKI intensity, while stronger winds are responsible for large increase in dust emissions and visibility degradation. Therefore, CasHKI is considered as a major regulatory factor for atmospheric dynamics and dust outflows over central and SW Asia.

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