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Assessment of Weather Anomalies Related to Cyclone *AILA* Using Atmospheric Sounding Indices

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Abstract

North Indian Ocean (NIO) is a favorable place for cyclone development where several tropical cyclones form every year. Bangladesh experiences 52 cyclones from 1960 to 2010, where cyclone *AILA* in 2009 was the most destructive in terms of damage of properties and fatalities. This study assesses the weather anomalies related to cyclone *AILA* using atmospheric sounding indices. During the formation of *AILA* the vertical atmospheric column was seriously unstable over NIO. The Sea Surface Temperature (SST) was increased anomalously and persisted over NIO for three consecutive days. The increased SST was one of the major causes to form depression as well as cyclone over NIO. To assess the weather anomalies several atmospheric sounding indices were used. The Skew-T/Log-P diagram showed positive buoyant and a large temperature difference between air parcel (T_p) and environment (T_e) on May 23, 2009. Both the temperature increment was very sharp which created dry punch within 650–550hPa height zone. The atmospheric sounding indices could be used for cyclone weather forecasting more accurately in this region.

Key words: Atmospheric sounding, Cyclone *AILA*, NIO, Sounding indices, Weather anomalies

Introduction

In Bangladesh there are continuous increases in economic damage and disruption by tropical cyclones in recent decades. Severe cyclonic storm *AILA* attacked Bangladesh on May 25, 2009 that developed over North Indian Ocean (NIO) especially over Bay of Bengal (BB) on May 23 and dissipated over sub-Himalayan West Bengal and neighborhood areas on May 26. According to SAARC Disaster Management Centre (SDMC, 2009), more than three million people were affected by the cyclone *AILA* in Bangladesh, among them 175 people were dead, over 5400 were injured and nearly 842,000 were forced to take refuge on rooftops and rafts. One of the conditions for the formation of tropical cyclone over NIO is that the sea surface should have a minimum temperature of about 26 to 27°C (Ali, 1999). Higher Sea Surface Temperature (SST) would likely to lead more intense tropical and extra-tropical cyclones. The role of SST in the genesis and intensification of tropical cyclones has been well demonstrated by Miller (1958). Atmospheric instability like increase of air temperature, formation of depression as well as trough, upper atmospheric (500hPa) mobile troughs etc. are also the causes for the formation of tropical cyclones. The climatological conditions under which tropical cyclones occur have been well established over decades of research. These include a requirement for warm SST, low vertical wind shear and high values of large scale relative vorticity in the lower layers of the troposphere (Gray, 1968; McBride, 1995). Very recently Farukh and Baten (2015) explained severe cyclone events related to temperature anomaly in the Southern coastal regions of Bangladesh. Khan *et al.* (2015) described weather anomalies behind *AILA* formation using geopotential heights and SST. Nowadays, it has been said that the characteristics of tropical cyclones have changed or will change in a warming climate and if so, it has been the subject of considerable investigation. During the tropical cyclone formation an extreme or severe weather anomaly occurs. Different tools has been applied to assess this anomaly, among them atmospheric sounding indices are more effective and realistic. Therefore, the objective of this study was to assess the weather anomalies during the occurrence of severe cyclonic storm *AILA* using atmospheric sounding indices.

Materials and Methods

The coastal region of BB especially South-Western region on Bangladesh where the destructive cyclone *AILA* attacked in 2009 was selected as study area. The *in-situ* data of air temperature, humidity, sea level pressure (SLP) etc. were obtained from Bangladesh Meteorological Department. SST in °C for the month of May 2009 was obtained from the Remote Sensing Systems of MW+IR OI v3 (~12 UTC) of Global and Indian North. Air temperature at 500hPa in °K was obtained from NCEP (National Centers for Environmental Prediction) Reanalysis of NOAA (National Oceanic and Atmospheric Administration) / ESRL (Earth System Research Laboratory), Physical Science Division, USA. Atmospheric sounding diagrams (Skew T/Log P diagrams) of Calcutta station for the month of May 2009 were obtained from the University of Wyoming to assess and compare the unstable atmospheric conditions of the day of *AILA* occurrence. The sounding diagram for the Calcutta station was selected due to unavailability of sounding stations in Bangladesh as well as its (Calcutta station) close distance from the study area.

Results and Discussion

Sea surface temperature (SST)

The role of SST in the genesis and intensification of tropical cyclones has been well studied. The maximum number of world's total tropical cyclones (~ 33%) form in the Western-North Pacific, which is a vast area of very warm water surface of about 30°C (Frank, 1985). During the formation of cyclonic storm *AILA* the SST over NIO was increased from 31 to 34^{0}C (Table 1). The SST over NIO was 31°C on May 22, 2009 (Table 1). On May 23, SST increased up to 34°C. This anomalous

SST prevailed over BB up to May 24. This increased SST (~ 3°C) was the main cause behind the formation of severe unstable atmospheric column over BB. Positive correlations between the North Atlantic cyclonic activity and SST in West-Africa, and also in the ocean around Australia have been well documented (McBride, 1995). Emanuel (1987) also developed a relationship between maximum sustained wind speed and SST. This leads to the speculation that any rise in SST is likely to be accompanied by an increase in cyclone frequency as well as intensity over the BB area (Ali, 1999).

Table 1. Surface air temperature, 500hPa air temperature, humidity, SLP, and SST in the second half of May 2009

Date/2009	Surface air temperature (^{0}C)	500hPa air temperature (^{0}K)	Humidity (%)	SLP (hPa)	SST (^{0}C)
May 15	28.6	268	79	1004	29
May 16	27.9	270	76	1006	29
May 17	29.6	269	79	1006	29
May 18	30.1	271	74	1005	30
May 19	30.6	272	74	1005	30
May 20	31.7	270	72	1005	30
May 21	31.5	270	69	1004	31
May 22	**31.3**	**271**	**71**	**1004**	**31**
May 23	**32.0**	**272**	**67**	**1001**	**34**
May 24	**28.4**	**272**	**80**	**998**	**34**
May 25	**26.7**	**274**	**91**	**987**	**32**
May 26	29.4	270	78	999	31
May 27	30.1	269	78	1002	31
May 28	30.6	269	78	1003	30
May 29	30.8	268	77	1003	30
May 30	30.4	269	76	1002	30

Atmospheric sounding indices

Skew-T/Log-P diagram is an extremely effective method of reading a vertical slice of the atmosphere. It enables us to see the vertical component, which is essential in weather forecasting. Temperature of environment (T_e) also known as Environmental Lapse Rate (ELR) and temperature of air parcel (T_p) are the most important indicators to determine instability of upper weather. The values of several important atmospheric sounding indices are given in Table 2. However, the larger the difference between T_p and T_e the stronger the instability of that corresponding area. The Skew-T/Log-P diagram showed positive buoyant on May 23 where the difference between T_p and T_e was larger (Fig. 1(b)). This difference was largest within 650–550hPa area. Temperature increment was very rapid and the dry punch within 650–550hPa area implies a huge unstable atmospheric layer. On the following day (May 24), the atmospheric column showed positive buoyant with a large difference between T_p and T_e (Fig. 1(c)). On May 25, T_p and T_e followed the same line from ground to 500hPa but created a positive buoyant area with a larger temperature difference between T_p and T_e (Fig. 1(d)). Therefore, unstable upper atmosphere with relatively stable lower atmosphere could create favorable conditions to form a cyclonic storm.

Assessment of SHOW

The showalter index (SHOW) is a measure of storm potential and severity. A negative SHOW indicates that the upper Planetary Boundary Layer (PBL) is unstable with respect to the middle troposphere. The more negative the SHOW the more unstable the troposphere and the more buoyant the acceleration will be for rising parcels of air from the upper PBL. On May 22, the SHOW was 6.24 while on the following days (23-25 May) the SHOW was 3.58, 0.42 and -1.28, respectively (Table 2). These numerical values of SHOW indicate that the weather was going to unstable from May 22 to May 25. The negative SHOW on May 25 indicates a thunderstorm and on this day the cyclone *AILA* attacked on Southern part of Bangladesh and West Bengal of India.

Assessment of LIFT

The lifted index (LIFT) is the temperature difference between an air parcel (*Tp*) lifted adiabatically to the environment (*Te*) at a given pressure height in the troposphere usually at 500hPa height. The LIFT can be used in thunderstorm forecasting very efficiently (Farukh *et al.* 2011). A negative LIFT indicates that the PBL is unstable with respect to the middle troposphere. The more negative the LIFT the more unstable the troposphere and the more buoyant the acceleration will be for rising parcels of air from the PBL. However, the LIFT was -1.55, -3.47, -2.51, and 0.04 from 22 to 25 May, respectively (Table 2) suggests severely unstable upper atmosphere that may provide huge scope to originate and spread of a cyclonic storm.

Assessment of KINX

The k index (KINX) is a measure of thunderstorm potential based on the vertical temperature lapse rate, and the amount and vertical extent of low-level moisture in the atmosphere. The higher the KINX the higher the possibility of storm. The gradual increment of KINX from 22 to 25 May indicates the occurrence of cyclonic storm.

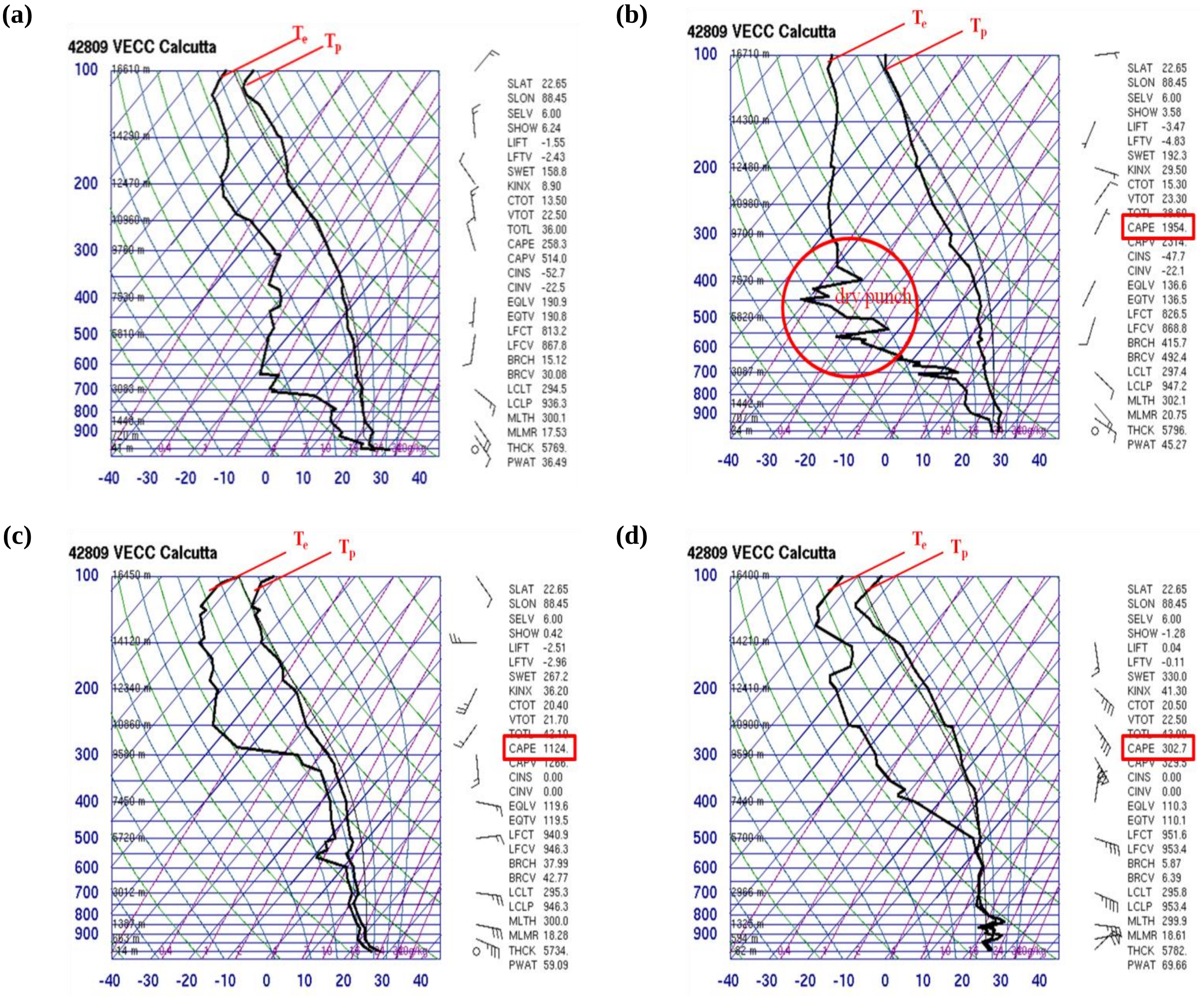

Fig. 1. Skew T/Log P diagrams (00Z) show severe upper atmospheric conditions from 22-25 May, 2009 (a-d, respectively) with their wind profile

Assessment of CAPE

Convective available potential energy (CAPE) is the measurement of an area between T_p and the ELR (T_e) where the air parcel is to the right of the ELR. The larger the CAPE the more unstable the atmosphere is, and large CAPE often correspond with severe cyclonic storm development. Such phenomena was emerged on May 23, 2009 where CAPE was 1954 (Table 2) and, therefore, severe cyclonic storm *AILA* was formed very easily. On May 24 and 25, CAPE was 1124 and 302.7, respectively when the weather was moderately unstable. This unstable weather condition was favorable to form severe cyclonic storm *AILA.*

Assessment of CINS

The convective inhibition (CINS) is a measure of the stability of the atmosphere and defines the vertically integrated negative buoyancy of a rising air parcel. In most cases when CINS exists, it covers a layer from the ground to the Level of Free Convection (LFC). The layer of air dominated by CINS is warmer and more stable than the layers above or below it. Typically, an area with high CINS is considered stable and has very little likelihood of developing a storm. The CINS from May 23 to 25 were very low numerically 0.00 (Table 2). These values of CINS indicate that the weather was significantly unstable to form a cyclonic storm.

Wind speed and direction

Wind blew from SE to NW direction with a speed of 7.73 ms^{-1} (15 knot) at ground level and SW to NE direction with a speed of 5.15 ms^{-1} (10 knot) at 500hPa height on May 23, 2009 (Fig. 1(b)). On the following day (May 24) wind blew with more speed (18.03 ms^{-1}) from SE to NW direction at ground level and E to W direction with a speed of 7.73 ms^{-1} (Fig. 1(c)). On May 25, it was 18.03 ms^{-1} at ground and also at 500hPa height. The direction of wind was E to W at ground level and at 400hPa height it was from SE to NW. This different direction of wind at ground to 500hPa height triggers to form circular wind flow that supports the formation of cyclonic storm *AILA.*

Conclusions

Atmospheric sounding indices are very effective tools to assess upper atmospheric severe weather conditions. The severe weather conditions behind *AILA* formation was the consequences of increased SST (up to 34°C) over NIO and severely unstable atmospheric layers from ground to 400hPa height. The results would be very useful and important findings for the environmental scientists to forecast as well as to study the causes of destructive cyclones.

Table 2. The values of atmospheric sounding indices in the second half of May 2009

Date/2009	SHOW	LIFT	KINX	CAPE	CINS
May 15	-0.02	-6.55	32.7	1852	-29.4
May 16	-0.13	-0.34	27.3	38.94	-520
May 17	-2.98	-9.80	39.8	3355	-0.62
May 18	-0.01	-6.66	25.9	3952	0.00
May 19	-1.89	-3.42	38.4	1012	-282
May 20	-6.83	-7.81	42.6	3898	-35.6
May 21	-0.66	-6.23	34.9	3365	-0.06
May 22	**6.24**	**-1.55**	**8.9**	**258.3**	**-52.7**
May 23	**3.58**	**-3.47**	**29.5**	**1954**	**-47.7**
May 24	**0.42**	**-2.51**	**36.2**	**1124**	**0.00**
May 25	**-1.28**	**0.04**	**41.3**	**302.7**	**0.00**
May 26	5.54	2.20	33.9	94.89	-1458
May 27	-1.38	-8.00	37.5	4632	0.00
May 28	0.75	-3.59	8.3	1282	-160
May 29	-6.14	-9.69	40.2	4982	-34.2
May 30	0.16	1.36	32.6	1.62	-252

Legend: SHOW – showalter index, LIFT – lifted index, KINX – k index, CAPE – convective available potential energy, CINS – convective inhibition

References

Ali, A. 1999. Climate change impacts and adaptation assessment in Bangladesh. *Climate Research*, 12:109-116.

Emanuel, K. A. 1987. The dependence of hurricane intensity on climate. *Nature*, 326:483-485.

Farukh, M. A. and Baten, M. A. 2015. Temperature anomaly and severe cyclone events in the Southern coastal regions of Bangladesh. *Journal Environ. Sci. & Natural Resources*, 8(1):35-40, DOI: http://dx.doi.org/10.3329/jesnr.v8i1.24661.

Farukh, M. A., Hayasaka, H. and Kimura, K. 2011. Characterization of lightning occurrence in Alaska using various weather indices for lightning forecasting. *Journal of Disaster Research*, 6(3):343-355.

Frank, W. M. 1985. Tropical cyclone formation. In: RL Elsberry (Editor) Global view of tropical cyclones based on the International Workshop on Tropical Cyclones, Nov.25–Dec.5, Bangkok, Thailand, US Office of Naval Research Marine Meteorological Program, pp. 53–90.

Gray, W. M. 1968. Global view of the origin of tropical disturbances and storms. *Monthly Weather Review*, 96:669-700.

Khan, M. N. H., Sattar, M. A. and Farukh, M. A. 2015. Assessment of weather anomalies for severe cyclonic storm *AILA* in 2009. *Bangladesh Journal of Environ. Sci.*, 28:119-124.

McBride, J. L. 1995. Tropical cyclone formation. In: RL Elsberry (Editor) Global perspectives on tropical cyclone. WMO Tech. Doc. WMO/TD-No. 693, Report No. TCP-38, WMO, Geneva. pp. 63–105. (reprinted 1996)

Miller, B. I. 1958. On the maximum intensity of hurricanes. *Journal of Meteorology*, 15:184–195.

SDMC, 2009. SAARC Disaster Management Centre, South Asia Disaster Report 2008, SDMC, New Delhi, India.