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Lake Effect Snow Phenomenon and its Role on Heavy Snowfall in the Southwest of the Caspian Sea

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Introduction

Geographical factors directly create some weather phenomena or indirectly are effective on increasing or decreasing of atmospheric features intensity. One of these geographic factors consists of lakes or small to medium closed water bodies within the continent areas which have various effects on atmospheric conditions of their surrounding areas and have been historically known. Lake effect on climate covers micro to synoptic scale and varies with extent, depth and shape of the lake, speed and direction of winds, winter ice cover and global climate conditions facing the lake. One of the phenomena caused by the lake is the lake snow effect phenomenon. This is one of the reasons for the formation of snow, in addition to mountainous forcing,

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frontal and convergence activities. Lake snow distribution depends on various elements. The most important climatic factors are the difference between the temperature of lake surface and the temperature of air above it, wind speed and direction, stability, latent heat, and relative humidity. In addition to weather conditions, the geographical conditions of environment such as the extent of ice cover, passing path (fetch) etc. play a major role. Also several case studies have been done about Guilan heavy snows most of which related to synoptic patterns. In this study, we have tried to study the role of Caspian Sea on the heavy snowfall in Guilan plains using atmospheric, marine and land data and to answer the question that whether the mechanism of lake snow effect phenomenon is involved in heavy snowfall of Guilan central plains?

Materials and Methods

In this study, in order to test the occurrence conditions of lake snow effect in the southwest of the Caspian Sea as a well-known phenomenon which has a specific mechanism to heavy snowfall, factors affecting the formation and evolution of atmospheric systems caused heavy snowfall in southern coast of the Caspian Sea were studied for the first time using atmospheric, environmental and marine data. Thus, the research is organized into two main sections:

In the first section, in order to study the meso-scale structure of atmospheric circulations and identify of synoptic-dynamic pattern in heavy snowfall hazard event of Guilan plains, the synoptic method of "environment to circulation" is used. To determine the days with heavy snowfall, data of snow height in Rasht meteorological station as the main station were used during (2012-1982). Based on the threshold index and local experiences, reviewing historical sources and long-term statistics and due to the extension of the crisis in society, snow depth of 40 cm in 24 hours was selected as the heavy snowfall. Guilan plain has experienced 7 years with heavy

snowfall during the past 30 years. In the next step, in order to synoptic-dynamic study of these identified systems, the daily re-analysis data of sea level pressure and temperature fields, geopotential height, zonal wind vectors and vertical velocity of lower, middle and upper levels of atmosphere were collected from National Center for Environmental Prediction (NCEP/NCAR) on network including Iran, with horizontal resolution of 2.5 degrees. In the second section, the daily data of sea surface temperature (SST) of Caspian Sea were derived from AVHRR sensor of NOAA satellite in 0.25 degrees scale to prove the impacts of the Caspian Sea on the systems and investigation of physical and thermodynamic properties on the intensification of snowfall. Daily and monthly means of SST maps and maps of difference between SST and the 2-meters air temperature and also the sea surface temperature anomalies were produced and examined for these systems using GIS software.

Discussion

The mentioned systems, were classified into two main categories of combined pattern of low pressure and high pressure and high pressure pattern based on the main sources of air mass at the surface which create them. In the next step, these two categories were separated into more distinct categories and studied based on the type of high pressure air masses with different origins such as polar, oceanic and continental, as follows: 1- Combined pattern of low pressure and high pressure (February 2005), 2- high pressure pattern which includes: 2.1- Siberian high pressure pattern (March 1985, January 2001), 2.2- European polar high pressure pattern (southeast of Scandinavia) (February 1993, January 2008), 2.3- migratory high pressures pattern of Europe West (January 1989, February 1982). In total, the high pressure air masses with different origins such as polar, oceanic and continental are exist in all 7 waves of heavy snowfall, which from the higher latitudes, alone or as

pairs with lower latitudes low pressures (Mediterranean low pressures) led to heavy snowfall in the southern coast of the Caspian sea with dynamic and thermodynamic mechanisms that carry the heat flux and proper humidity. In addition, the mean daily of SST map show the warm area on the southern half of the Caspian Sea surface before snowfall. The high temperature contrast was on the southwest of Caspian Sea because of the transmission and the existence of cold air during the snowfall. In other words, cooling of the air in low troposphere creates temperature difference that cause the interaction between temperature and moisture characteristics of the two fluid and transmission of the surface fluxes to the air masses crossing over it. Despite these differences in the origins of air masses formation, there are some similarities in the mechanism and function of these systems; it seems that the vast water area of the Caspian sea has the significant impact on the transfer of moisture to the passing air and increasing its degree of instability.

Conclusion

Like the other mid-latitude lakes, location of the Caspian Sea on the poleward face of subtropical high areas has faced it to the cold polar and sub polar air masses. So the environmental conditions have provided a suitable conditions for the formation of lake snow effect phenomenon. The location of southwest coast of the Caspian Sea and the direction of coast line in the Guilan central plain face to the entry of atmospheric systems, flow direction and wind convergence have provided the conditions for the occurrence of this phenomenon and heavy snowfall in the Guilan plains. The shape of Caspian sea and its meridional extension lead to air advection in polar high pressure systems and, which pass fetch about 700 to 1000 km on the Caspian Sea. The fetch of flow over the Caspian Sea is more than all the water bodies in the northern hemisphere. The higher depths of the Caspian sea in the central and southern parts, are prevented from sea freezing in these parts. This issue removes

one of the limiting factors in the occurrence of lake snows effect. In addition, the SSTs of southern parts of the Caspian sea are 10.5 and 10 degrees Celsius during the year in January and February, thus the Caspian sea is as a source of heat and moisture for transferring the surface fluxes and instability of air.

In all 7 identified systems, high pressure air masses with strong (1040 hPa) and with various origins such as oceanic or continental aspects play the main role in the mechanism of heavy snowfall. Their clockwise circulation in low troposphere on the Caspian Sea cause to enter of air flow to Guilan plains. Studying the 2- meter temperature and 10-meter wind show the transmission of cold air from higher latitudes to the southern coasts of the Caspian sea and air cooling in the low troposphere during the systems deployment. Daily and monthly mean of sea surface temperature (SST) of Caspian sea indicate the existence of warm water area, according to the maximum specific humidity over the South Caspian. The southward streams cause the advection of moisture to southwestern regions of the Caspian Sea. The difference of 2-meter air temperature and sea surface temperature (SST) on the Caspian, indicate the mean temperature contrast about 25 degrees Celsius. Surface fluxes patterns (latent heat flux and sensible heat flux) indicate maximum values of the two physical parameters on the south Caspian areas among the cold air masses from the high-latitudes and warm masses of water which represent the exchange of heat and moisture characteristics in the low troposphere.