Jet streams- A Conceptual Review

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Introduction

Jet stream are a band of long, narrow, high-speed winds that generally blow from west to east across the globe particularly in the middle and upper troposphere or lower stratosphere (8 to 15km vertically). Mostly, the main jet streams are formed near the altitude of the tropopause and are moving as westerly winds, characterized by strong vertical shearing action, which is thought to be largely responsible for clear air turbulence (**Shapiro & Keyser, 1990).**

Wasaburo Oishi (Japanese meteorologist) detected the jet stream during 1920's from a site near Mount Fuji when he tracked pilot balloons (used to determine atmospheric conditions) as they moved upward into the atmosphere. Flyers consistently noticed westerly tailwinds excess of 160 km/hr in flights. Similarly, in 1944 a team of American meteorologists in Guam, including Reid Bryson, had enough observations to forecast very high west winds that would slow bombers (Lewis, 2003).

Horizontal differences in temperature causes the movement of air due to horizontal pressure gradient that drives geostrophic and gradient winds. Jet streams are positively correlated with horizontal temperature differences and encircle the Earth in meandering paths, shifting position as well as speed with the seasons. During the winter their positions are nearer the equator with higher speed than during the summer (Matthew, 2018).

Types of Jet streams

Region of both the Northern and Southern hemispheres are facing various jet streams, although the jet streams of northern hemisphere are more forceful due to greater temperature variations. Generally, two group of jet streams are created in the upper atmosphere viz., Permanent jet streams (Subtropical jet stream and Polar front jet) and Temporary Jet Streams (Tropical Easterly Jet or African Easterly Jet and The Somali Jet) (Krishnamurthi and Bhalme 1976). The details of these jet stream formations are detailly given below of this paper.

Sub-tropical jet stream (STJ)

- Sub-tropical Jet Streams used to develop during winter and early spring seasons with a maximum speed of 300 knots. These jets give predominantly fair weather in areas they pass over and sometimes they used to drift northward and merge with a polar-front jet. The formation of sub-tropical jet stream is detailly explained below.
- The sub-tropical jet streams are produced due to Coriolis force and temperature difference between tropical and sub – tropical regions where the velocity of the earth

rotation produces a greatest deflective force in the atmosphere. As a result of this rotation, the rising air deflected to right in the northern hemisphere and to the left in the southern hemisphere at about 30° latitude which spreads out northwards and southwards, moves faster than the latitudes over which it is blowing and it becomes concentrated as the subtropical jet streams (Figure 1).

- During winter, nearly continuous STJ are produced in both the hemispheres which exists in southern hemisphere all the years whereas, intermittent in the northern hemisphere and during summer it migrates to northern side.
- The STJ was one of the last tropospheric features discovered by direct human observation and can be temporarily displaced when strong mid-latitude troughs extend into subtropical latitudes. When occurrence of these displacements, the subtropical jet could merge with the polar front jet creating Cloudbursts. These type of jet streams are closely connected with the Indian and African summer monsoons.

Polar front jet (PFJ)

- Polar front jet (PFJ) are also called as midlatitude jet streams, a belt of world's most powerful upper level wind force moves generally in westerly direction and forms in the junction between the Ferrell and Polar cells. As a consequence of formation of these jets manifest themselves as front, unstable and breakup into Rossby waves.
- Polar Front jet stream is a fast-flowing air at the boundary between the troposphere and stratosphere and more variable position than the sub-tropical jet. In summer, its position shifts towards the poles and in winter towards the equator whereas, in winter, jets are stronger and more continuous.
- It greatly influences the temperature difference of two different air masses lying close to 50°-60° N/S region is where the polar jet located. It determines the path, speed and intensity of temperate cyclones (Fig. 1). The polar jet streams used to form several miles deep and more than 100 miles wide, with the strongest winds typically 8 to 16 km above the ground. These types of jet stream are typically more common in North America and Europe.

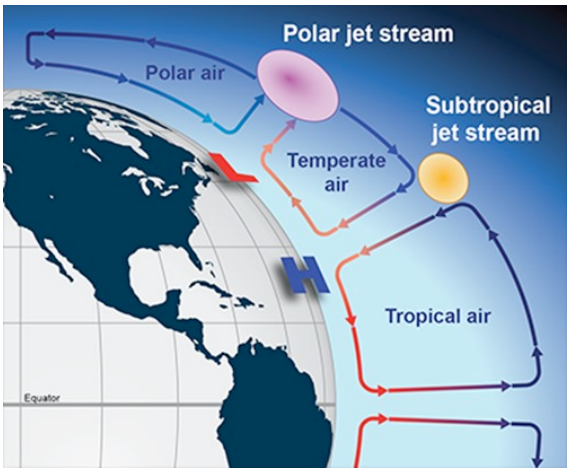

Fig. 1: Polar and Sub-tropical Jet Streams **(Source:** http://www.weather.gov/**)**

Temporary jet streams

Permanent jet streams (polar and subtropical jet streams) are the best known and most studied at world level whereas, other jet streams are also formed when wind speeds crossed above 94 km/hr in the upper atmosphere at about 9 to 14.5 km above the ground surface. Most important temporary jets are Polar night jets, Somali Jet and The African Easterly jet.

Polar night jet streams

- PNJS are also known as the stratospheric sub-polar jet streams and it is developed at the height of 30 km during winter, become very strong due to the steep temperature variations in the stratosphere around the poles and moves westerly but the velocity decrease during summers and the direction becomes easterly.
- It causes the circulation of polar vortex and warmer air could only move along the edge of the polar vortex, but not enter it.

The Tropical Easterly Jet or African Easterly Jet

- High velocity winds in the lower troposphere called as low-level jets (LLJs) or Tropical Easterly Jet (TEJ) the well-known prominent of these is the African Easterly Jets and it is found near the latitude between 5° and 20°N. These unique and dominant feature of the northern hemisphere is observed over southern Asia and northern Africa during summer months (Figure 2).
- TEJ are upper level easterly wind that are fairly persistent in position, direction, and intensity which starts in late June and continues until early September. The strongest development was noticed at about 15 km above the earth surface over Indian Ocean.
- It's existence is found quickly after the Sub Tropical Jet (STJ) has shifted to the north of the Himalayas (Early June) and during the south Asian summer monsoon it induces secondary circulations that enhance convection over South India and nearby ocean thus causing strong southwest monsoon **(Hastenrath and Stefan, 1985).**

The Somali Jet

- Among the most well-known of the tropical LLJs is the Somali Jet, a low-level south westerly jet, formed the Arabian Sea of India in the summer months and the coast of Somalia. Somali jet supported the movement of the southwest monsoon towards India which originates close to "Mascarene high" near Madagascar in the southern hemisphere being intense from June to August (Figure 2).
- Boos and Emanuel (2009) examined the onset of Somali jet and the associated monsoon and observed that the Jet onset is accompanied by a large (100 W/m2) increase in surface enthalpy flux over the Arabian Sea that increases in deep tropospheric ascent. It is a major cross-equatorial flow from the southern Indian Ocean to the central Arabian Sea.

Influence of Jet Streams on Weather

- Helps in maintenance of latitudinal heat balance by mass exchange of air and influence the mid-latitude weather disturbances. When jet streams are interfering with surface wind systems cause severe storms.
- Jet streams influence the path of temperate cyclones thereby influence the distribution of precipitation**.** Also, an influence on movement of air masses is observed which may cause prolonged drought or flood conditions over the earth system. Eg: Polar vortex cold wave over North America in 2014 winters.

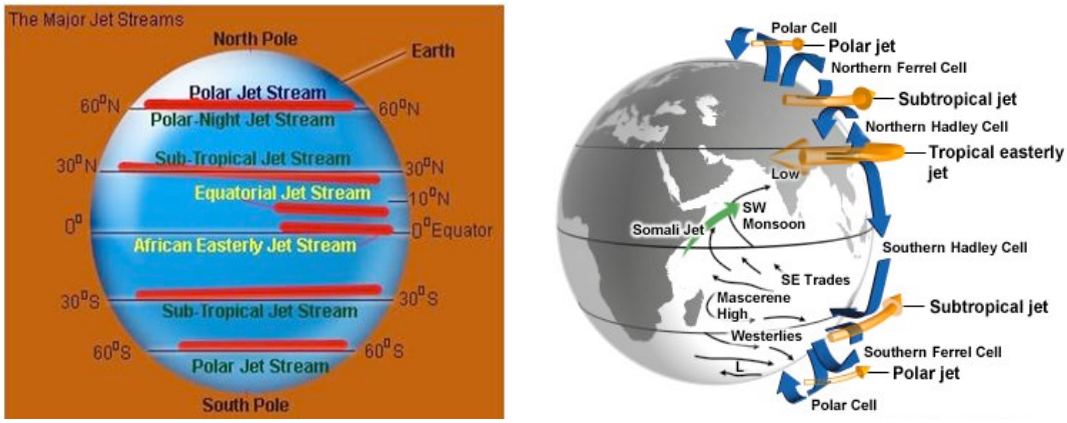

Fig. 2: Somali Jet (Source: www.pmfias.com **)**

Role of Jet Streams in Indian Rainfall

1. Winter Rainfall: Transport the western disturbances (temperate cyclones) originating over the Mediterranean Sea and brings rain to north western part of India.
2. Southwest monsoon – withdrawal of STJS from the south Himalayas decides the onset of SW monsoon in Indian sub-continent.
3. Tropical cyclones – Easterly jet stream steers tropical depressions and cyclones from the Pacific Ocean towards Indian Ocean and brings rainfall over the east coast regions.

Conclusion

From the above context it is concluded jet streams, which are discontinuous in time, space and with notable wind speed and elevation variations, is a westerly circulating air flow that tends to push the cold wind from upper atmosphere to the surface of the earth. During the process, dry winds from this high-pressure area start blowing towards the low-pressure area. After reaching the Oceans through the westerly flow under the influence of Ferrel's cell they form north east monsoon which gives rainfall.

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