EXTRATROPICAL CYCLONES AND ANTICYCLONES

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Contents

Summary

Extratropical cyclones and anticyclones - atmospheric eddies of vertical and horizontal scales of several kilometers and thousands of kilometers, respectively, - play a primary role in weather formation in mid- and high latitudes. These eddies are referred to as "lows" and "highs", because they are regions of low and high pressure, respectively. Stormy weather and precipitation are typical of cyclones, while anticyclones, as a rule, are associated with fine weather. Cyclonic activity (generation of lows and highs) is tightly connected with frontal zones. Frontal cyclones originate at atmospheric fronts and undergo typical evolution from (i) incipient disturbance - shallow, wavelike deformation of the front - to (ii) young (deepening) cyclone with well-defined cold and warm fronts, (iii) mature, deep low with maximum intensity of precipitation, and (iv) decaying, occluded, cold cyclone. At the satellite images, lows are represented by typical comma clouds. Anticyclones undergo analogous four stages of evolution, but cold and warm air distribution is opposite to that in the cyclones, so that decaying high is filled with warm air. Also, there are no fronts in the anticyclone. Over warm oceans, a special class of extremely rapidly growing cyclones occurs: their development is referred to as explosive cyclogenesis. Mountains stimulate cyclogenesis and strongly affect migrating eddies.

Deep and vast cyclones and anticyclones can block westerly winds in the troposphere for long time (up to several weeks), they are called blockings. They can develop from frontal eddies as well as originate in different way - by growing from above (unlike frontal cyclones developing from the surface): in this last case, they are referred to as cut-off lows and highs.

Cumulative effects of synoptic eddies lower meridional contrasts of temperature, transferring heat poleward. They also represent a mechanism for stratosphere-troposphere exchange.

Main source of energy for cyclonic activity is available potential energy of airflow in baroclinic frontal zones.

1. Introduction

The terms cyclones and anticyclones are applied to areas of relatively low and high pressure, respectively, together with their revolving wind circulations. The cyclones and anticyclones occurring in the middle and high latitudes, referred to as extratropical cyclones and anticyclones, or extratropical synoptic eddies, have typical sizes of several hundred to 2-3 thousand kilometers: these are atmospheric eddies of synoptic scale. Cyclones have a counterclockwise wind circulation in the Northern Hemisphere and a clockwise one in the Southern Hemisphere. Anticyclones, as atmospheric systems opposite to cyclones, have a clockwise circulation in the Northern Hemisphere and a counterclockwise one in the Southern Hemisphere. Extratropical cyclones and anticyclones are usually neighboring on the weather maps and often are simply referred to as "lows" and "highs", respectively. In the lower troposphere, due to friction effects, wind rotation around the center of cyclone is associated with convergence to the center and with ascending motions in the whole cyclonic area. This leads to a general tendency to cloudy weather, precipitation, and strong winds. On the contrary, in the anticyclones, wind divergence in the lower troposphere is compensated by descending motions (subsidence), with ordinarily fine weather and weak winds. The shape of closed isobars in extratropical highs and lows is usually nearly elliptical. Their major axes are oriented, on average, from SW to NE for lows and from WSW to ENE for highs.

Generation, evolution and motion of extratropical cyclones and anticyclones is referred to as cyclonic activity. Cyclonic activity connected with motion and evolution of airmasses and fronts (q.v.) is the main cause of weather changes in the midlatitudes. This is the central topic of synoptic meteorology.

An overwhelming majority of extratropical synoptic eddies is connected with atmospheric fronts and thus called frontal. It must be noted, however, that under some conditions, lows and highs (rather local) can be observed as not connected with the fronts: their development is due to purely thermal processes. Thermal cyclones arise in summer over land, as a result of strong warming of the air from the underlying surface. Thermal anticyclones are more typical in winter; they occur over continents and often can persist for a long time.

Hereafter, main attention will be paid to frontal cyclones and anticyclones.

Depending on their vertical thickness, the synoptic eddies can be:

- shallow (closed isobars on the weather maps and no closed isohypses above the 850 hPa level);
- of middle depth (closed isohypses up to 700 hPa level);
- deep (closed isohypses above 700 hPa, frequently to 300 hPa and above).

Extratropical eddies migrate constantly with largely varying speeds. The eddies are classified as stationary, slow, and moving, respectively, if their speeds are below 5, 5 to10, and above 10 $km \cdot h^{-1}$. Average speeds of cyclones in Europe and North America are about 30 and 45 $km \cdot h^{-1}$, respectively. Speeds of order of 60 $km \cdot h^{-1}$ are not rare (especially for young cyclones), in extreme cases they reach 80-100 $km \cdot h^{-1}$. Anticyclones move slower, average speeds being of 27 $km \cdot h^{-1}$ in Europe and 36 $km \cdot h^{-1}$ in North America. In general, the extratropical eddies move in the direction close to that of so-called steering flow. The latter is referred to as undisturbed air flow over the eddy (for example, for a shallow cyclone - the flow at 700 hPa level).

2. Typical Cyclone Evolution

2.1. Incipient Disturbance

The initial stage of cyclone development (Figure 1a) is associated with incipient disturbance of the atmospheric front near the surface. This disturbance represents a weak cyclonic circulation (vorticity maximum) causing wave-like deformation of the front.

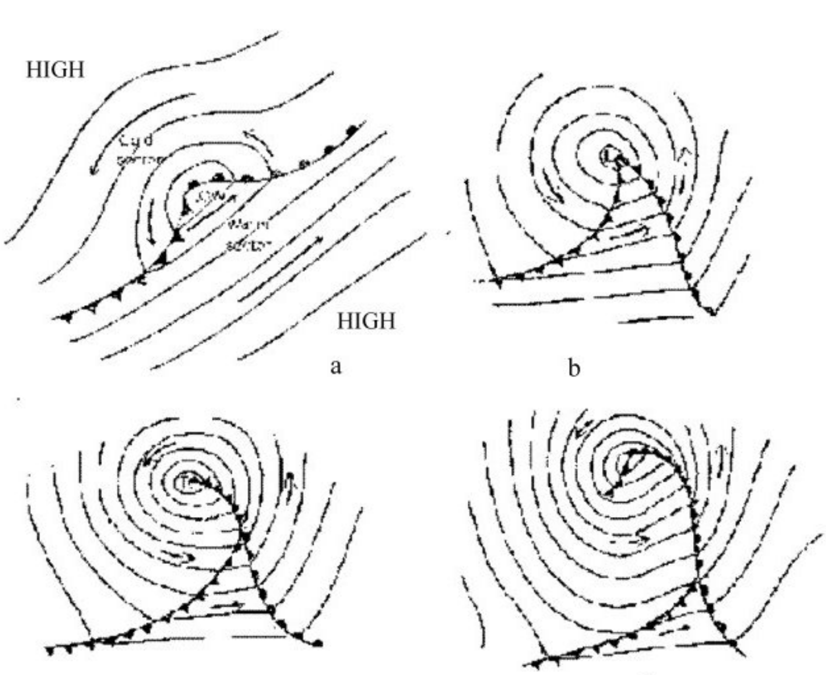

Figure 1: Extratropical cyclone evolution: a - initial stage, b - young cyclone, c - maturity, d - decay. Solid lines are isobars; rotation direction is shown by arrows

The wave crest corresponds to the circulation center. At this stage, the first closed isobar appears. The pressure falls near the wave crest. Deformation of the front manifests itself in origin of its warm and cold sections. The shallow incipient disturbance, which can be seen at the surface only (that is, on the weather map) moves rapidly along the tropospheric frontal zone. The warm front is located in the leading part (along the direction of motion) of the eddy. Behind the warm front, the warm airmass forms the warm sector, which is bounded from the rear by the cold front. Both fronts become sharper (*frontogenesis*), the frontal cloud band becomes denser and wider at the wave crest. The stage of incipient growth usually lasts less than 12 h.

2.2. Young Cyclone

The young cyclone (Figure1b) is a rapidly developing eddy. At this stage, the warm sector is well-defined, the number of closed isobars increases, the central pressure falls (the most frequently by about 5 hPa $(12h)^{-1}$). The cyclone becomes deeper: by the end of this stage, closed isohypses appear at 700 hPa. The center of young cyclone at higher levels is displaced, with respect to the surface center, towards the cold airmass. The tropospheric *jet stream*, connected with the frontal zone, acquires a significant wave-like bend. The cloud field is characterized by two spirals corresponding to warm and cold fronts. The center of cloud vortex corresponds to the cyclone center at 700 hPa. The vortex usually lies within the area bounded by the outer closed isobar (see Section 3.6). The center at 700 hPa is shifted to the cold airmass, with respect to the surface center.

There are three regions with different weather in the young cyclone. Ahead of the warm front, the cloud cover thickens, its base lowers, and widespread precipitation begins; in a number of cases (especially in summer), showers and thunderstorms can occur as a manifestation of *embedded convection*. In the warm sector, stratification is stable. In winter, inversions, stratiform clouds, and fogs are typical. In summer, if the warm air is moist enough, bands of convective clouds develop. The 3rd region is the cold rear of cyclone, behind the cold front. Here, cooling is associated with clearing up. Convective bands are the most typical for this part of cyclonic eddy. This stage usually lasts 1.5 - 2 days or less.

2.3. Maturity

This stage begins with the beginning of occlusion process. Near the surface, by this time, cyclone is outlined by many closed isobars (Figure 1c). It becomes a deep eddy. The slope of its axis increases with respect to that of young cyclone. The jet stream bend also increases. In the central part of the eddy, cloud spirals of cold and warm fronts join together. Near the surface center, a section of occluded front appears. Below its outer end (“occlusion point”) precipitation is especially heavy. In the other parts of the cyclone, the weather is like in the young cyclone; the most intense convective bands in the rear are connected with secondary fronts.

2.4. Decay

This is the stage of cyclone filling with cold air (Figure 1d). The pressure starts increasing, the cyclone becomes deep and cold, the jet stream is now situated to the right of the cyclone center. The frontal cloud bands disappear, along with the fronts themselves. Secondary fronts only remain well-defined with cloud bands. This stage, as well as the maturity one, lasts on average 3 to 4 days, till the last closed isobar disappears.

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Biographical Sketch

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Education:

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Hydrodynamic instability of atmospheric flows; dynamics of atmospheric fronts, cyclones, tropopause; severe weather (heavy precipitation, convective storms) diagnostic studies and forecasting; significant weather forecasting for aviation.

Publications:

About 35 presentations at International and National conferences and meetings.

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- "*Dynamics of the atmospheric fronts and cyclones***"**, Gidrometeoizdat, Leningrad, 1985, 264 p. In Russian.
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