Synoptic conditions of fog and haze formation

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The data of diurnal observations on the territory of Western Europe and Soviet Union in 1963 and 1964 and surface synoptic maps (00:00 and 12:00 GMT) are used to study the conditions of formation of fogs and meteorological hazes in different meteorological situations. In contrast to the widespread opinion, fogs and even hazes are more often formed in cyclones than in anticyclones. Data on the frequency of occurrence of fogs and hazes as a function of air pressure, type of the pressure system, and distance to the center of synoptic vortex make it possible to conclude that the main role in fog and haze formation belongs to the dynamic factors: advective and turbulent flows of heat and water vapor, as well as to heat influx from the soil.

Data of diurnal observations in 1963 and 1964, obtained in 00:00 and 12:00 GMT, and mapped on near-ground synoptic maps, are invoked to estimate the influence of synoptic situation on fog and haze formation on the territory of the Soviet Union and Western Europe.

According to Table 1, fogs in which meteorological visibility range (MVR) is less than 1 km, and meteorological hazes (1 km ≤ MVR < 10 km) approaching them with regards to formation conditions, are formed both in cyclones and anticyclones.

Table 1. Frequency of occurrence (%) of fogs and hazes in different synoptic situations (from here on, *N* is the sample volume)

Year	Season	Fogs			Hazes		
		cyclone	anti-cyclone	*N*	cyclone	anti-cyclone	*N*
1963	Fall	75	25	129	62	38	442
	Winter	68	32	162	53	47	401
1964	Fall	56	44	212	46	54	271
	Winter	48	52	216	37	63	443

In 1963, hazes and especially fogs were observed more frequently (by up to a factor of 2–3 for fogs) in cyclones than in anticyclones. In 1964, the formation of fogs is practically equiprobable, while the hazes had formed somewhat more frequently in anticyclones than in cyclones. In any case, these data make it possible to conclude that quite a widespread opinion about more favorable conditions of fog and haze formation in anticyclones (owing to more effective heat losses during night) is not supported by observations.

The same can also be concluded from the data of Tables 2 and 3. The fog and haze are observed in a wide range (from 980 to 1040 hPa) of air pressure. It can only be noted that the general background of pressure field observed during fog and haze formation was higher in 1964 than in 1963.

Fogs have maximum frequency of occurrence between 1000 and 1010 hPa in 1963 and between 1010 and 1020 hPa in 1964.

The hazes are also observed in a wide pressure range; however, from comparison of Tables 2 and 3 it follows that they are more frequently formed in higher-pressure regions than the fogs: haze formation is virtually equiprobable in all the three pressure intervals from 1010 to 1040 hPa.

When pressure is high (in anticyclonic activity) the near-ground layer is typically dominated by strongly stable (inversion-type) stratification favoring increase of concentration of solid admixtures (aerosols) in this layer. These latter introduce an additional contribution (above that caused by purely meteorological factors) to reduction of MVR in hazes (whereas in fogs the contribution of aerosol is small).

Table 2. Frequency of occurrence (%) of fogs as a function of air pressure at sea level

Year	Season	Pressure, hPa							*N*
		980–990	990–1000	1000–1010	1010–1020	1020–1030	1030–1040	>1040	
1963	Fall	4	24	35	16	17	4	–	129
	Winter	7	17	36	13	9	18	–	162
1964	Fall-winter	1	1	16	29	26	22	5	428

Table 3. Frequency of occurrence (%) of hazes as a function of air pressure at sea level

Year	Season	Pressure, hPa							*N*
		980–990	990–1000	1000–1010	1010–1020	1020–1030	1030–1040	>1040	
1963	Fall	3	9	15	48	11	14	–	442
	Winter	2	5	8	51	14	20	–	401
1964	Fall-winter	1	1	14	25	23	24	12	714

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Table 4. Frequency of occurrence (%) of fogs as a function of distance to the center of cyclone (C) or anticyclone (Ac)

Year	Season		Distance to center, km					*N*
			< 100	100–200	200–500	500–1000	>1000	
1963	Fall	C	3	8	20	28	41	97
		Ac	3	6	16	31	44	32
	Winter	C	7	5	24	35	29	110
		Ac	2	17	12	52	17	52
1964	Fall	C	12	10	17	45	15	117
		Ac	42	9	16	20	13	93
	Winter	C	10	5	24	23	39	103
		Ac	26	16	27	17	15	113

Table 5. Frequency of occurrence (%) of hazes as a function of distance to the center of cyclone (C) or anticyclone (Ac)

Year	Season		Distance to center, km					*N*
			< 100	100–200	200–500	500–1000	>1000	
1963	Fall	C	1	14	27	33	25	273
		Ac	1	16	29	32	22	169
	Winter	C	2	23	35	24	16	211
		Ac	–	23	36	25	16	190
1964	Fall	C	14	8	18	36	24	126
		Ac	37	10	19	19	15	145
	Winter	C	11	10	25	27	27	164
		Ac	26	15	24	24	11	279

To estimate the contributions from different factors in fog and haze formation, Tables 4 and 5 are composed. They give no unambiguous conclusion about the role of vertical synoptic-scale motions in the fog and haze formation.

The vertical motions differ in sign: they may be ascending in cyclone and descending in anticyclone. However, since their velocity is zero on the earth's surface, in the near-ground layer (up to 200–300 m height) it is small in absolute value. Nevertheless, in cyclone (anticyclone) it favors (complicates) the formation of fog and haze because, due to vertical velocity, the air temperature at fixed levels decreases (increases) in time. From data for 1963 it follows that practically the dependence on vertical velocity is absent: both in the central part ($r < 100$ km) and at distances up to 500 km the probabilities of fog and haze formation practically coincide. They are 31% (25%) in fall and 36% (31%) in winter for fogs and 42% (46%) in fall and 60% (61%) in winter for hazes in case of cyclones (anticyclones).

In 1964, the probabilities of fog and haze formation only for $r < 100$ km are significantly (up to 3–4 times) higher in anticyclones than in cyclones.

However, such a difference is caused, in any case, not by the vertical velocity because, as indicated above, in the case of its determining influence its relation to the frequencies of occurrence would be reverse.

At other distances no significant differences between frequencies of occurrence of fog and haze formation in cyclones and anticyclones is observed. From analysis of the initial equations and numerical simulation results[1, 2] it follows that the main factors of the fog and haze appearance and evolution are the advective and turbulent influxes of heat and water vapor in the atmosphere, as well as their molecular influxes to roughness layer from the soil.

References

1. O.V. Gudoshnikova and L.T. Matveev, Atmos. Oceanic Opt. **14**, No. 4, 276–280 (2001).
2. O.V. Gudoshnikova and L.T. Matveev, Atmos. Oceanic Opt. **16**, No. 2, 149–154 (2003).