LONG-RANGE WEATHER FORECASTING

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Keywords: A priori quality assessment, atmospheric action center, general circulation of the atmosphere, hydrodynamics, lead-time interval, long-range weather forecasting, low frequency, macro-meteorology, natural synoptic season, numerical experiment, predictability limit, predictor, predictand, statistics, synoptics, weather mode, weather pattern, weather regime

Contents

Summary

Methods of long-range weather forecasting and main principles of their organization are discussed, against a historical background, as far as the framework of the chapter allows it. In line with the tradition of the past few decades, the main methods fall into synoptic, statistical and hydrodynamic ones. It is underscored that the historical development of the above approaches from the synoptic to the dynamic methods is directly connected with the development of the observation systems and electronic means of data processing.

Complementary interaction of the theories, methodologies and routines is emphasized, e.g., by a wide use of such notions as atmospheric circulation modes and their alternation, practical stability, and others. Weaknesses of all methods proceeding from the complexity of the analyzed structures and the inherent temporal predictability limits are pointed out.

1. Introduction

Methods of long-range weather forecasting (*LRWF*) are grouped into synoptic, statistical and hydrodynamic on the basis of analogy, average characteristics estimation and application of physical regularities. In Greek, "synopsis" stands for visual observation, and, in the practice of weather forecasting the synoptic method in simple terms, means analysis of weather maps. In a situation with numerous maps, the most convenient method of analysis is to estimate numerical characteristics, such as mean values, standard deviation, correlation, and others. The hydrodynamic approach is based on major physical laws (the energy conservation, the momentum, and the mass conservation laws). Obviously, all of the above methods are interrelated and their division is a mere homage to tradition. In this context, the "blending" of methods seems to better suit the needs of long-range weather forecasting.

Before the 20th century methods of long-range weather forecasting could hardly be called scientific. Religious scripts carry examples of precise super-long-range forecasts based on the interpretation of dreams, e.g. the Biblical Joseph's dream about a seven-year drought which was to follow the seven years of rich harvests. Long-range forecasts with the help of card fortune-telling are also a historical fact. For a number of centuries astrological horoscopes, Chinese calendars, and revelations of famous fortune-tellers (e.g. Nostradamus) were a source of wisdom for the elite in many countries. The rulers used them to formulate their strategy, which today could be called the strategy of decision-making. Incidentally, predictions concerned not only the weather, but also economics, politics, epidemics, etc. For example, the Bruce calendar foretold wars and peace periods for centuries ahead. Equally widespread was weather forecasting based on omens (especially among the common people). One-day weather characteristics or phenological properties of one day were commonly used to build season long forecasts.

The development of scientific methods of long-range weather forecasting started at the turn of the century. At the suggestion of the prominent German scientist Baur, the branch of synoptic meteorology engaged in developing long-range forecasts got the name of *macro-meteorology*.

The macro-meteorological theory has been lately substantiated by statistical studies, resulting in new notions such as *teleconnection*. Macro-meteorology deals with the *general circulation of the atmosphere* as a totality of large-scale movements in the troposphere and the stratosphere, to create and improve forecast methods.

Research into the general atmospheric circulation goes far beyond the description of the air mass movement, and includes a study of processes forming heat sources and runoffs, seasonal and non-periodic changes in the stratospheric and tropospheric temperature-pressure fields, and characteristics and a degree of impact of external geophysical and cosmic factors.

Long-range meteorological forecasting may aim at periods of several weeks, a month, a season, or several seasons. Forecasts for the period of several years are usually referred to as super-long-range ones, and forecasts for dozens of years - as forecasts of temporary climatic changes.

2. Synoptic long -range Weather Forecasting

The synoptic trend in the long-range weather forecasting is based on the qualitative methods of research, and aims at establishing macro-scale regularities, identified in the course of a visual analysis of temporal and spatial aspects of meteorological fields.

2.1. General Overview

The synoptic method of long-range weather forecasting evolved through a number of stages.

The first stage in the development of synoptic macro-meteorology, initiated by Multanovsky (former USSR) and Walker (UK) at the beginning of the 20th century, lasted on to the 1930s. This stage yielded a number of essential outcomes. The continuous practice of analyzing the earth's surface synoptic maps revealed an alternation of zonal and meridional processes in the atmospheric circulation of large regions. It was established that certain macro-processes take several days or several weeks to develop, and are followed by a relatively quick transformation with a new start of a different variant of geographic localization having a different character of the weather systems movement, including the *atmospheric action centers*. A change in the macro-processes is inevitably accompanied by considerable changes in the macro-weather of larger regions.

In certain periods, macro-processes become unusually stable and create circulation conditions leading to large weather anomalies. In the early 20th century a classification of synoptic processes made for Europe and other regions, showed that the character of the weather for larger regions is determined by atmospheric macro-processes.

With the help of mean pressure maps compiled in the course of many years, quasi-stationary centers of atmospheric action were identified, such as the Iceland depression, the Azores anticyclone, and the Siberian winter anticyclone. It was shown that the macro-weather is shaped primarily by the position and intensity of atmospheric action centers in a given region (Tiesserene de Bort, France).

The ideology of these action centers and their temporal and spatial dynamics have been actively exploited in the schemes of long-range meteorological forecasting up to the present day.

In Russia, Multanovsky enriched the notion of the atmospheric action centers and proposed new methods of the macro-synoptic analysis of atmospheric circulation. Together with his follower Pagava he laid down the fundamentals of the long-range prediction synoptic school, and was the first to create methods of long-range forecasting with a focus on the principles of the rhythm of atmospheric situations, which he called "*synoptic repers*".

According to the research data, the synoptic processes behind the "repers" repeat every three to five months under certain conditions, which is a significant disturbance of the east-west transfer (e.g. ultra-polar processes). Should four or five "repers" be identified for any prognostic month, the sequence of macro-meteorological processes is bound to occur within the given month.

Another important principle of the long-range weather forecasting formulated by Multanovsky-Pagava, is the principle of the archive-based selection of an analogous sequence of meteorological processes within a three-to-five month interval preceding the month of the forecast. The principle of synoptic analogy relies on the assumption that should two analogous situations be observed within a long time period, the analogy can well be extrapolated onto the future.

According to another important research outcome, dealing with the so-called *natural synoptic season***,** and developed with the help of the Multanovsky-Pagava theory, the temporal boundaries are not overtly connected with both the astronomic and calendar dates. Six natural synoptic seasons were identified in a year, the beginning and the end of each natural synoptic season determined by the conditions of the horizontal heat exchange between the Ocean and the Continent for the given year. While synoptic processes during this season are to a large degree analogous, synoptic situations untypical for the given season (called forerunners) describe large-scale atmospheric conditions for the subsequent natural synoptic season. Thus, the reper-processes provide for a detailed description of the temporal and spatial aspects of the natural synoptic season forecast.

The second stage in the development of synoptic macro-meteorology (1930-1970) is marked by the introduction of pressure maps into forecasting practice and by an expansion of the meteorological stations network, which allowed us to reach out to the extra-tropical zones of the Northern Hemisphere. Research carried out in Russia contributed to the theory of long waves, showing a direct impact of the movement of the latter on medium-range atmospheric forecasting. At the same period, high-altitude frontal zones, and related jet streams were discovered.

The classification of atmospheric macro-processes, undertaken by Wangengeim in Russia and Baur in Germany, relies on the character of the predominant tropospheric processes in larger regions. The research undertaken by Namias and his followers in the USA focuses on the circulation forecasting in the middle troposphere. The works of Wiese and Schuleykin in the former USSR and Sandstroem in Norway, started off research of the ocean heat impact on the weather in Europe.

Wangengeim and Girs pioneered a new trend in the long-range forecasting, namely the macro-circulation method, which is now used for regular forecasting for Polar Regions.

In the 1950s long-range weather forecasting methods based on the earth’s surface air temperature persistence became highly popular. According to Baur, in the temperature mode forecasting a warm December is followed by a warm winter; after a warm July, August and September hot and dry weather is expected; while the “October-July connection” has proved anti-persistent: a warm October would be followed by a cold winter and a hot June, July and August - by cold and rainy weather.

At this period long-range forecasting based on analogy became highly popular. For example, calculating the monthly mean temperature field for the month preceding the month of the forecast, the British meteorologist Craddoc chose the best analog from the archives to "reconstruct" the temperature of the forecast month. Hoffman in Germany and Bagrov in the former USSR also used the method of analogs. The principle of analogs was used in the USA for monthly and seasonal forecasting by Willet. The method proceeded from the assumption that the general atmospheric circulation depends on solar activity. On the whole, the use of solar-earth connections became widespread in the long-range weather forecasting in the second half of the 20th century.

2.2. Prospects

The analysis of approaches to the long-range weather forecasting before the 1970s shows that to meet the forecast goals advocates of the synoptic trend developed practically all relevant methods and techniques of the qualitative analysis of the meteorological fields and situations. However, their practical application proved controversial.

Stable and reliable global or regional schemes failed to be developed. Petterssen and Meinardus established a connection between the water temperature condition in the Northeast Atlantic in November-January and the air temperature anomalies in Europe (Sweden, the Baltic area, Central Europe) using the synoptic-empirical analysis. Namely, a warm Gulf Stream is followed by a positive anomaly in the air temperature, and a cold one - by negative anomalies. The connection was explained in terms of the ocean-atmosphere interaction, with the positive water temperature anomaly in the Norwegian Sea treated as a cause of cyclonic activity which strengthens the positive anomalies by enhancing southern air transfers.

To check the connection established by Petterssen and Meinardus, Baur and Bergsson proved its instability in time: the correlation coefficient for 1861-1890 equaled 0.73, while for 1891-1920 it dropped to -0.30.

It should be underpinned that the changing character of the interaction of large-scale hydrometeorological phenomena is by no means infrequent and constitutes a major challenge in developing long-range weather forecast methods. A good connection in the future is in no way contingent on a similar connection in the past. After the 1970s, interest in the synoptic long-range weather forecast research has fallen. As of now, synoptic analysis schemes used in practice only supplement the statistical or hydrodynamic approaches described below.

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Biographical Sketches

Muraviev Anatoly Vladimirovich, was born in Ryazan Region, Russia, USSR on 18 July 1949. In 1971 he graduated from the Translation Faculty of the Moscow Institute for Foreign Languages, in 1977 he graduated from the Faculty of Mathematics of the Moscow Pedagogical Institute. In 1980 he started working in the field of meteorology, since 1982 he has been working at the Hydrometeorological Research Center of Russia, presently he is the Senior Scientific Officer of the Center. His field of specialty is as follows: long-range weather forecasting using hydrodynamical-statistical methods, hydrodynamical modeling of the atmospheric circulation, statistical analysis of weather regimes and climate change.

Bibliography of his scientific papers counts about 60 items. He has the PhD degree . His international activity covers participation in conferences, symposia, workshops primarily associated with the branch of ensemble hydrodynamical modeling of the atmospheric circulation with statistical interpretation of numerical products for long-range predictions.

Vilfand Roman Mendelevich, was born on 13 June 1948 in Kiev, Ukraine, USSR. In 1971 he graduated from the Faculty of Geography of Moscow State University. Since February 1973 he has been working at the Hydrometeorological Research Center of Russia, occupying different positions. Presently he is the Director of the Center.

My fields of specialization are the following: general circulation of the atmosphere, climate change analysis, long-range weather forecasting, application of statistical methods in meteorology.

Bibliography of his scientific papers counts about 80 items. He has the scientific degree of Ph.D. He is an invited lecturer of the Moscow State University on Long-range weather forecasting.

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