Fields of Resources, Energy, the Environment, and Social Infrastructure

Achievement

Establishment of a scientific foundation for understanding and predicting extreme weather events

Prof. Sir Brian J. Hoskins (UK)
Born: May 17, 1945 (Age: 78)
Professor, Department of Meteorology,
University of Reading

Prof. John Michael Wallace (USA)
Born: October 28, 1940 (Age: 83)
Professor Emeritus, Department of Atmospheric Sciences,
University of Washington

Teleconnection – an essential element of numerical weather and climate prediction

One of the most important achievements made by Prof. Sir Brian Hoskins and Prof. John Wallace is their clarification of the conditions and mechanisms underlying "teleconnection," which explain how abnormal weather in one region affects weather in distant regions. Figure 1 illustrates how distinct weather trends are produced from highly persistent fluctuations mainly in the tropical atmosphere-ocean coupled system to affect winter and summer in the mid-high latitudes in the northern hemisphere. The "westerlies" are prevailing winds that blow from the west at mid-latitudes (shown by the dashed yellow line with arrows), and their continuous meandering leads to abnormal weather.

When using numerical weather and climate prediction, it is necessary to understand that atmospheric conditions in one region are constantly susceptible to fluctuations and changes due to the influence of atmospheric, oceanic, and sea ice conditions in distant regions. This is particularly true for seasonal weather prediction in the mid-latitudes on scales greater than two weeks, as it is understood that such predictions can be based upon teleconnection effects from highly persistent climatic fluctuations such as the El Niño/La Niña phenomena – in which trade winds and oceanic changes interact with each other in the equatorial Pacific – and decadal fluctuations in the Pacific Ocean. Those persistent fluctuations in the tropics can therefore act as sources of predictability of mid-latitude weather conditions on seasonal scales via "teleconnection".

Data-based and theoretical explanation for the Pacific-North American Pattern

Figure 2 provides a more detailed look of the left side of Figure 1, and shows Wallace's 1981 discovery of the "Pacific-North American Pattern," which arises out of the teleconnection effects of El Niño. That same year, Hoskins provided a theoretical explanation of the dynamic processes that form such fluctuations in atmospheric patterns. During El Niño, the water becomes warmer than usual across an area of the equatorial Pacific Ocean from around the International Date Line to the Peruvian coast of South America. Precipitation there increases, becoming a source of heat and generating large-scale atmospheric waves called "Rossby waves." Figure 2 illustrates how such waves result in alternating anticyclonic (H– clockwise in the northern hemisphere) and cyclonic (L – counterclockwise in the northern hemisphere) atmospheric circulation anomalies thousands of kilometers wide.

Subtropical and mid-latitude westerlies (or jet streams) play an important role in forming these patterns. The anticyclonic and cyclonic patterns generated by Rossby waves tend to move westwards, but strong westerly winds in winter and other periods halt that westward movement and holding those patterns in place, as is seen in the Pacific-North American Pattern. When this occurs, energy propagates with the pattern, resulting in the effects of El Niño being felt throughout North America and as far as the North Atlantic Ocean. The westerlies (red arrows in Figure 2) meander to a great extent due to their overlapping with Rossby waves, thereby resulting in abnormal weather that is persistent.

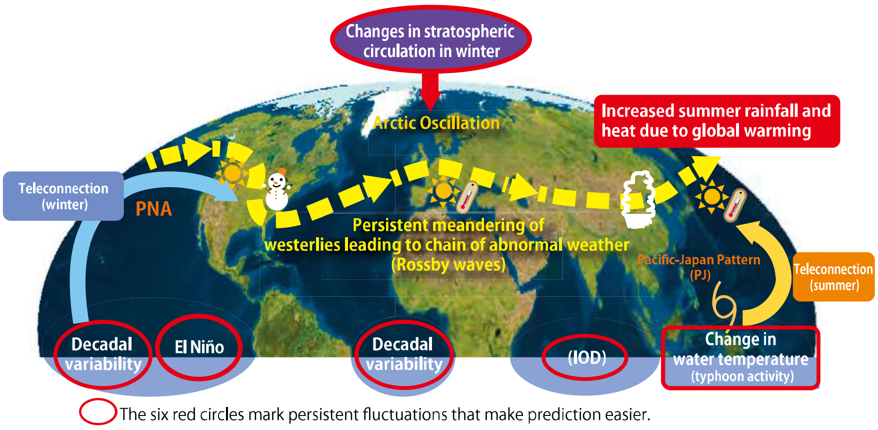
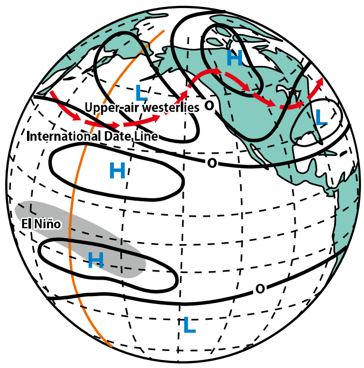


Figure 1: Illustration of how the "teleconnection" phenomenon established by Hoskins and Wallace can be applied to describe natural climate variations

This reveals the teleconnection effects of variations in tropical atmosphere-ocean coupled systems (El Niño/La Niña, Indian Ocean Dipole (IOD), decadal variability) and demonstrates the predictability of seasonal weather events. The IOD is a climate change phenomenon that occurs every few years from summer to autumn in the Indian Ocean tropical region.



J.D.Horel, J.M.Wallace, *Mon. Wea. Rev.* **1981**, *109*, 813.

Figure 2: The Pacific-North American Pattern generated by El Niño.

El Niño generates anticyclonic (H) and cyclonic (L) circulation anomalies through teleconnection.

Making weather and climate prediction possible

Hoskins numerically calculated how stagnant Rossby waves are excited when a simulated heat source with increased precipitation is placed near 15 degrees north latitude, and how that will lead to anticyclonic (H) and cyclonic (L) circulation anomalies forming in the upper atmosphere (see left side of Figure 3).

Meanwhile, Wallace conducted a statistical analysis of roughly fifteen years of objective weather observation data from various regions in the northern hemisphere that had been gathered to provide initial values for numerical weather forecasts. In that data, he discovered several types of atmospheric pressure fluctuation patterns with alternating and persistent anticyclonic and cyclonic circulation anomalies.

The righthand illustration of Figure 3 depicts the typical distribution of pressure anomalies that eventually appear in the middle troposphere after the arrival of an often-observed teleconnection pattern in the western Atlantic. This pattern coincides well with Hoskins' numerical calculations (lefthand illustration of Figure 3), and it was an extremely important discovery that greatly advanced the predictability of persistent weather anomalies.

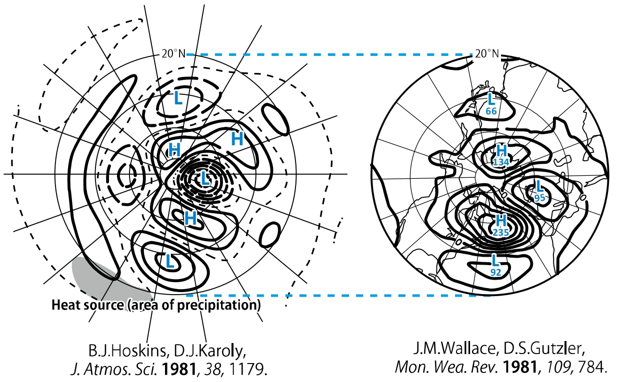


Figure 3: Atmospheric circulation anomalies as derived theoretically (left, Hoskins) and from observational data (right, Wallace). Both views are shown from above the North Pole.

The increasing importance of numerical weather and climate prediction

The primary success of the work of these two researchers was their discovery of global-scale fluctuations in the westerlies driven by El Niño, and this has become one of the foundations of seasonal weather prediction around the world. However, their work resulted in more advancements that could be listed here, but included the identification of mechanisms through which extratropical cyclones are generated and the regions in which they are active, both of are essential for daily weather forecasting; the dynamics behind the formation of blocking anticyclones (or blocking highs) which cause abnormal weather; the discovery of hemisphere-scale fluctuations in the westerlies (the Arctic Oscillation); and the identification of decadal fluctuations in the Pacific atmosphere-ocean coupled system that accelerate and decelerate increases in the global temperature. Many of these successes were achieved through Hoskins constructing theoretical models and Wallace understanding actual conditions using observational data, and their work has become the cornerstone of useful, practical, and promising numerical weather and climate prediction. It also led to the use of atmospheric reanalysis data in monitoring climate change.

In addition, their work is also useful in studying weather anomalies arising from global warming, a subject that is of growing concern, by showing how regional weather effects can be described using the knowledge of meteorology and climate dynamics that has been accumulated over the years. Numerical weather and climate prediction will become an increasingly important part of the social infrastructure that protects human lives.

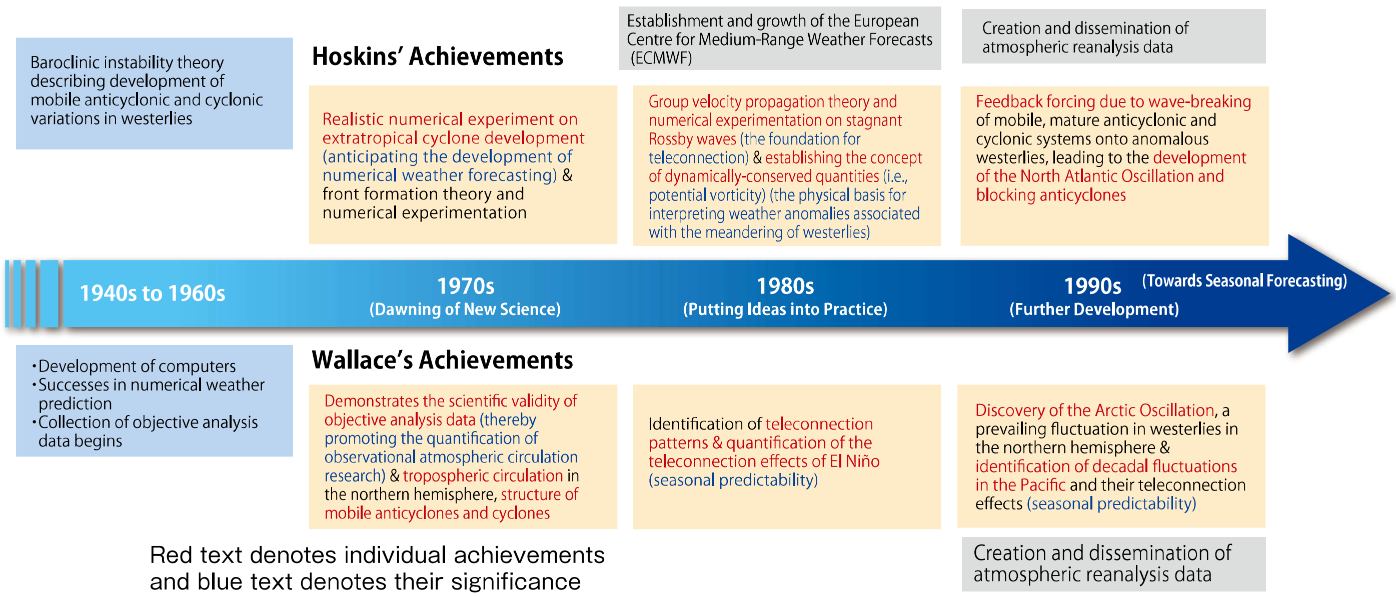


Figure 4: A selection of contributions made by Hoskins and Wallace to the advancement of weather and climate prediction.