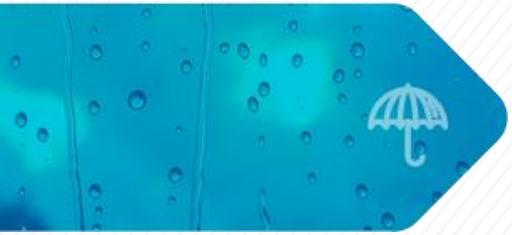
Introduction to Meteorology

36 Medium-range forecast and seasonal prediction

Introduction

The weather forecast mainly aims at the accurate forecast of the weather within one week.
Theoretically, the deterministic weather forecast is limited to about two weeks.
As socioeconomic needs increase the demand for extended range forecasts to several months, medium-range and seasonal forecasts become an area of active research fields.

Contents



1. Medium-range forecast
2. Seasonal prediction

Learning objectives

1. Explain the concept of medium-range forecast and season prediction.
2. Describe the methodology used for medium-range forecast and seasonal prediction.

Learning Activities

1. Medium-range forecast

Medium-range forecast targets to forecast the weather from one week to two weeks.

Currently, the European Center for Medium-Range Weather Forecasting (ECMWF, Europe) and the National Centers for Environmental Prediction (NCEP, US) produce forecasts longer than two weeks.

Medium-range forecasts generally use global circulation models (GCMs) and are tailored to a certain degree of medium-range forecasts, but they are basically similar to short-term forecasts.

It is a numerical forecasting using numerical models and initial condition based on observation.

Learning Activities

1. Medium-range forecast

1) Ensemble forecast

A small difference of the initial values leads to a big difference in the forecasts according to the chaotic nature of the atmosphere. This is because of the “chaotic behavior” of the atmosphere.

Due to the chaos in the atmosphere, small errors in the observations generally amplify with increasing forecast time range. After a number of days, the forecast go wrong showing little or no accuracy in predicting the real atmosphere.

It is well known for the butterfly effect that "a butterfly flapping its wings in Brazil can cause a tornado in Texas", first discovered by E. N. Lorenz in 1963.

It is not possible to make 100% accurate initial conditions. Therefore, chaos can be a serious problem in forecast accuracy. For example, if a upper-level trough is predicted in the 15-day forecast, there is no way to determine whether this is a perfect forecast or an error in the initial data.

To minimize this uncertainty, ensemble forecasting technique is widely used. The ensemble forecast is a forecast of the possible future range, taking into account disturbances caused by initial conditions. The ensemble approach is based on a set of forecasts in which each ensemble member runs with slightly different initial condition.

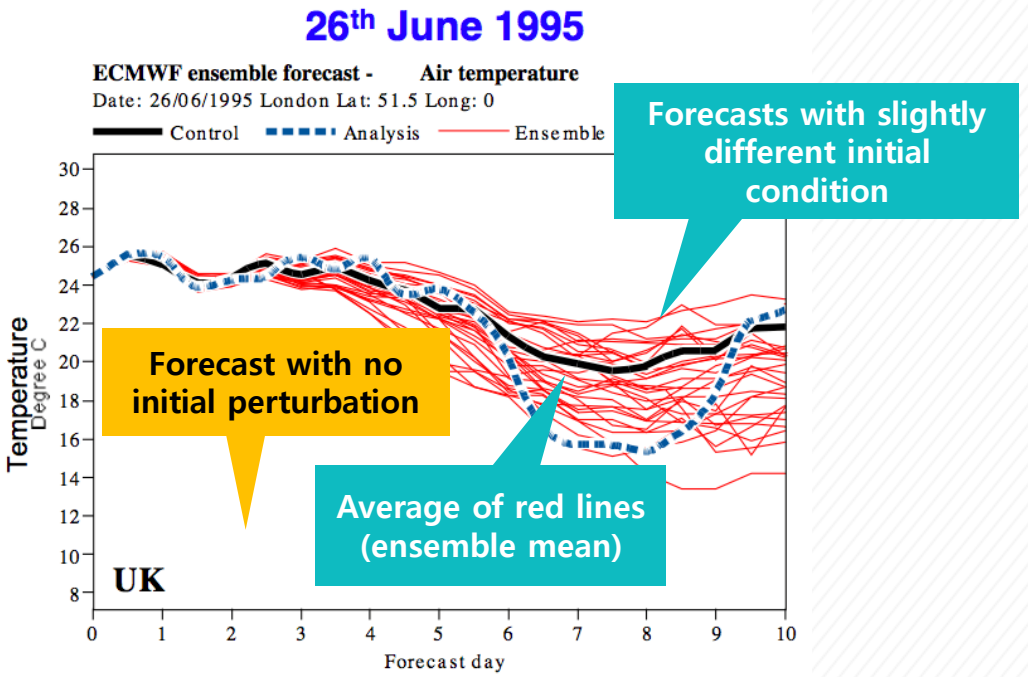
Statistical or dynamical techniques are used to create initial conditions by tweaking the best-guess initial condition in a reasonable way. Repeating this process builds an ensemble forecast.

Learning Activities

1. Medium-range forecast

As an example of ensemble forecasting, let's look at the ECMWF medium-range ensemble forecast. You can see that the temperature forecast has a wide range of values after a week due to slightly different initial values. Each red line in the graph represents a different forecast result with slightly different initial conditions. The solid black line is the average of the red lines (ensemble mean), and the blue dotted line is the forecast without initial perturbation.

As you can see from the graph, the possible temperature range is, for example, '14 degrees to about 24 degrees after 10 days'. The average value of the ensemble forecasts is also used.



〈Ensemble forecast example 1
_ECMWF medium-range ensemble forecast〉

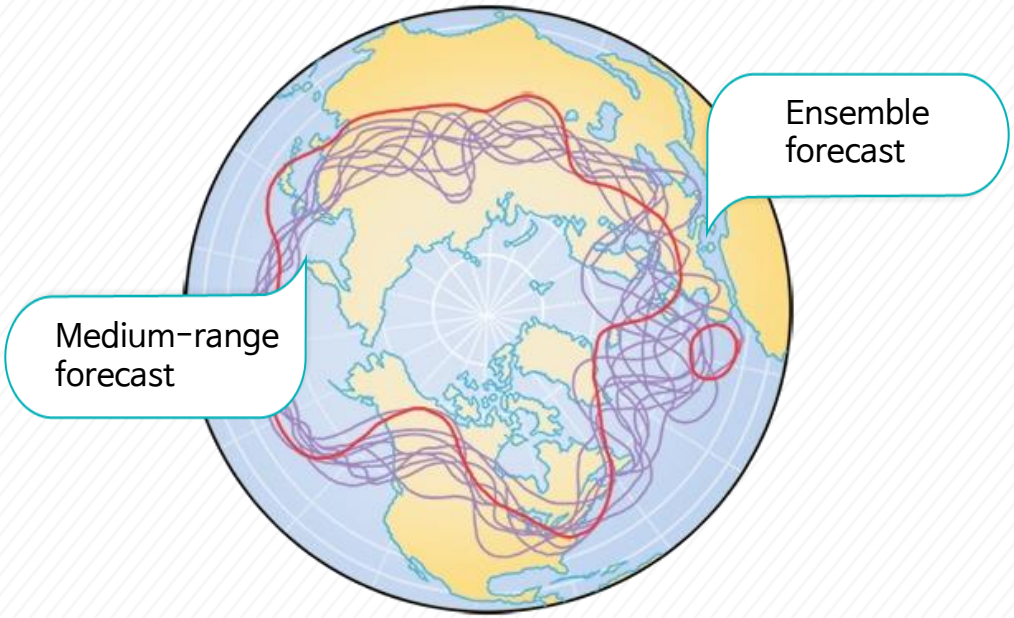
Learning Activities

1. Medium-range forecast

Let's look at another example from the NCEP medium-range ensemble forecast. This is a 10-day ensemble forecast for the Northern Hemisphere. The forecast is a 500hPa height, and only a 5700m contour line is depicted. The red line is the MRF, and the purple lines are the ensemble forecasts. 17 ensembles and the control run are shown.

All of the ensemble members forecast upper-level trough on the western Pacific and match each other fairly well. This means that the errors contained in the initial conditions do not affect the forecast much. In this case, it is very likely that this pattern will develop.

However, in the Central Asia, western Europe, and the North Atlantic, ensembles have a wide spread. In these cases, it is difficult to rely on the forecasts for these regions.



〈Ensemble forecast example 2
_NCEP medium-range ensemble forecast〉

Learning Activities

1. Medium-range forecast

2) Advantage of ensemble forecast

One of the advantages of the ensemble forecast is that it provides information on forecast uncertainty. Since the ensemble forecast can be used to estimate the likelihood that the forecast is correct, you may not pay too much attention to the forecasts that are deemed unreliable.

Second, ensemble forecast from multi-models can be utilized. Third, the ensemble forecast provides useful information for the medium-range forecast.

Last, the ensemble forecast is useful for estimating the forecast reliability. Up to 10 days, it is known that the ensemble spread is related to forecast error.

Learning Activities

2. Seasonal prediction

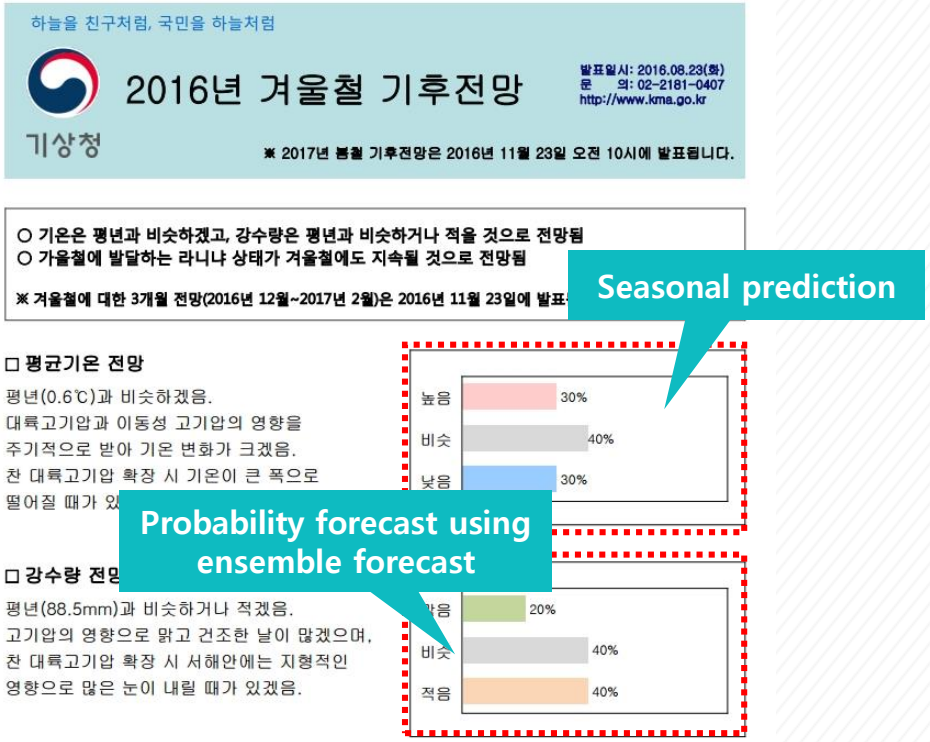
Seasonal prediction is a prediction for longer than a month or a season

The NCEP Climate Prediction Center (CPC), the UK Meteorological Office (UK Met Office), ECMWF, the Bureau of Meteorology, and the Canadian Meteorological Center produce a seasonal prediction.

The Korea Meteorological Administration (KMA) also produces long-term forecasts such as monthly and seasonal predictions in the climate prediction division.

The long-range forecast combines climatology, statistical method, numerical model, and subjective methods. The seasonal prediction is a forecast of an average condition for a given period of time (season).

The following is an example of 3 months forecast provided by the KMA. It shows probabilistic forecast for above normal, normal, and below normal categories.



〈3 months prediction (seasonally outlook) by KMA〉

Learning Activities

2. Seasonal prediction

1) Methodology

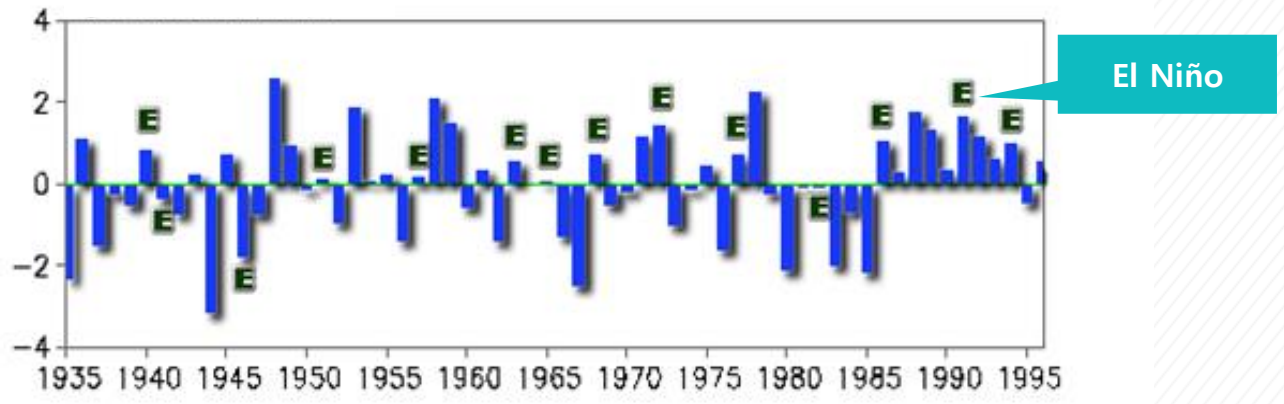
For longer than a week, deterministic predictions are extremely uncertain because of the chaotic nature of the atmosphere. Therefore, prediction can be made in a variety of ways, including statistical methods, numerical modeling techniques, and combining numerical-statistical methods.

Statistical methods include empirical forecast and scientific forecasts. When predicting a season, statistical forecasting methods based on long-term experience have been commonly used. For example, "If there is more snow in winter, the following summer will be warmer" or "It will be warm this winter because of an abnormal amount of rain during summer".

Unlike empirical methods, the scientific forecast is a method that detects the optimal predictors that have affected the predictand based on long-term observations.

Learning Activities

2. Seasonal prediction



〈Korea winter temperature from 1035 to 1996〉

The variation of sea surface temperature in the tropics and temperature in Korea can be used as an example. The graph is showing the relationship between winter temperature in Korea and El Niño from 1035 to 1996. Here E stands for El Niño. During the El Niño period, we can find a tendency for the temperature to be higher in the winter.

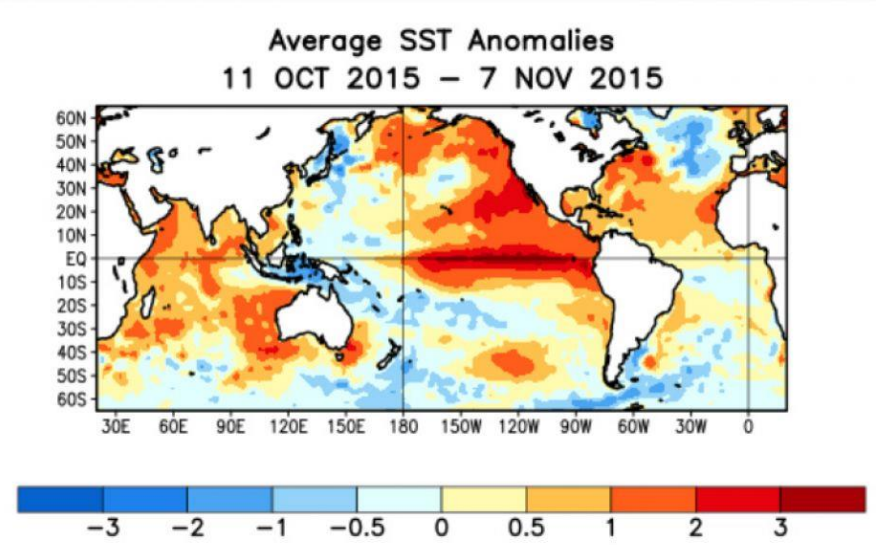
Learning Activities

2. Seasonal prediction

This is because, during the El Niño, the southerly wind is induced in Korea by the warm sea surface temperature in the tropics.

The phenomena that occur in the ocean, such as El Niño, change more slowly than those in the atmosphere.
The El Niño can be predicted well up to six months.
As such, based on the statistical-dynamical relationship, we can predict the winter temperature of Korea using the prediction of El Niño state.

Not only the El Niño, but also the Indian Ocean condition, Tibetan Plateau snow cover, Arctic sea ice, and Eurasia snow cover can be used for long-range prediction.



〈Example of scientific long-range forecast〉

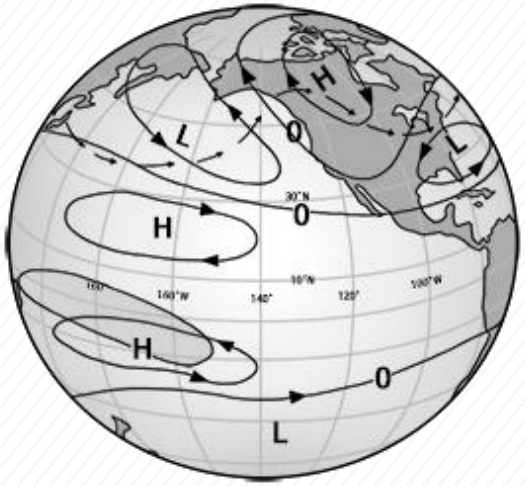
※ Source: https://en.wikipedia.org

Learning Activities

2. Seasonal prediction

2) Statistical method

So how does the El Niño event in the Pacific, thousands of kilometers away, affect the climate in Korea? When the sea surface temperature in the tropics gets warmer, the tropical convection becomes active. Then, the upper atmospheric circulation is disturbed and affects the atmosphere in distant areas.



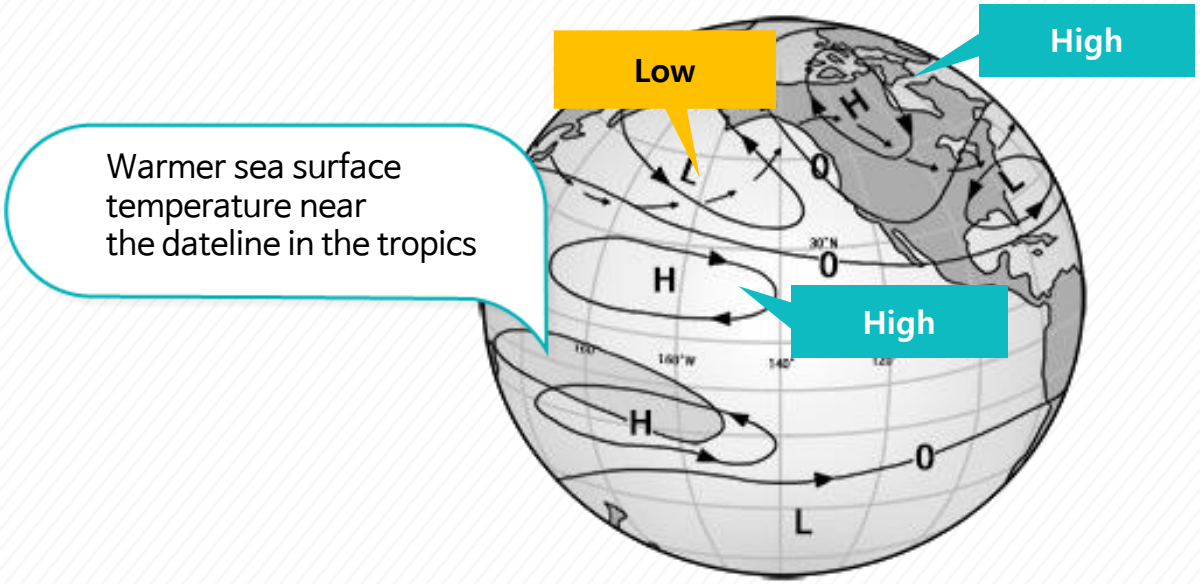
Example of teleconnection

PNA (Pacific-North American)

Therefore, the fluctuation of pressure or temperature can be closely related to two regions that are more than thousand kilometers away. This is called the teleconnection. A well-known teleconnection is the Pacific-North American (PNA) pattern.

Learning Activities

2. Seasonal prediction

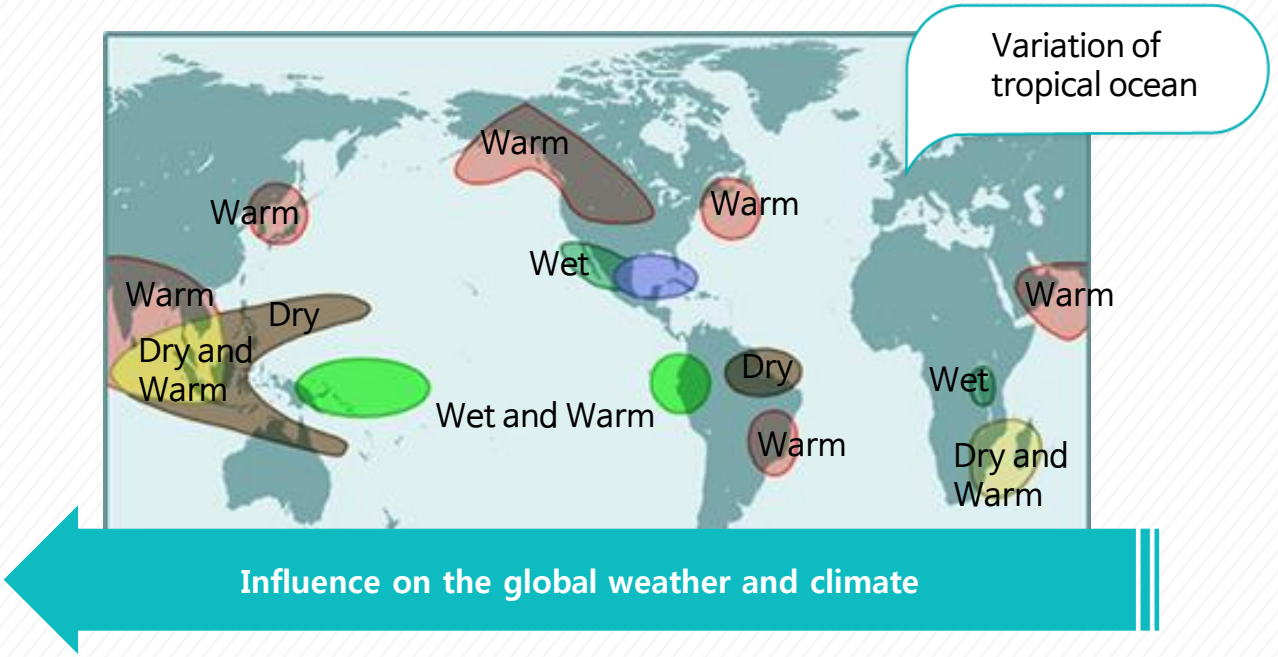


〈Example of the PNA (Pacific-North American) pattern〉

When the sea surface temperature in the tropical dateline warms, a pattern of high (H), low (L), high (H) develops to the northeast. The Aleutian Low is strengthened.

Learning Activities

2. Seasonal prediction



〈Influence on the global weather and climate during El Nino〉

Due to the teleconnection, the variation in the tropical ocean induces a significant impact on weather and climate in different parts of the globe.

Learning Activities

2. Seasonal prediction

3) Numerical method

Global climate model (GCM) is used for long-range prediction. GCMs simulate interactions between the atmosphere-ocean-land. For long-range prediction, it is necessary that the GCMs simulate climate variability such as the El Niño.

Like short-term predictions, initial conditions and numerical models are used in the long-range prediction, but the effect of the initial condition is relatively negligible.

In long-term forecasts, processes which change much more slowly than the atmosphere are very important. In addition to the tropical sea surface conditions, the snow cover and sea ice conditions also have low-frequency variation and can be used for long-range forecasts of Korea.

Therefore, the long-range forecast requires tremendous resources, such as the atmosphere-ocean-land coupled model, the global observation network with satellite data, and the supercomputer to simulate the model.

Summary

1. Medium-range forecast

- The weather forecast up to two weeks is referred to as "medium-range forecasts".
- Medium-range forecasts generally use global circulation models (GCMs) and are tailored to a certain degree of medium-range forecasts, but they are basically similar to short-term forecasts.
- It is a numerical forecasting using numerical models and initial condition based on observation.
- Ensemble prediction is needed because of the atmosphere's chaotic nature.

Summary

2. Seasonal prediction and long-range forecast

- Forecasts over a longer lead time than the medium-range forecast is called long-range forecast or seasonal prediction.
- Statistical methods, numerical model, and numerical-statistical hybrid methods are used.
- The fluctuation of pressure or temperature can be closely related to two regions that are more than thousand kilometers away. This is called the teleconnection.
- The long-range forecast requires tremendous resources, such as the atmosphere-ocean-land coupled model, the global observation network with satellite data, and the supercomputer to simulate the model.