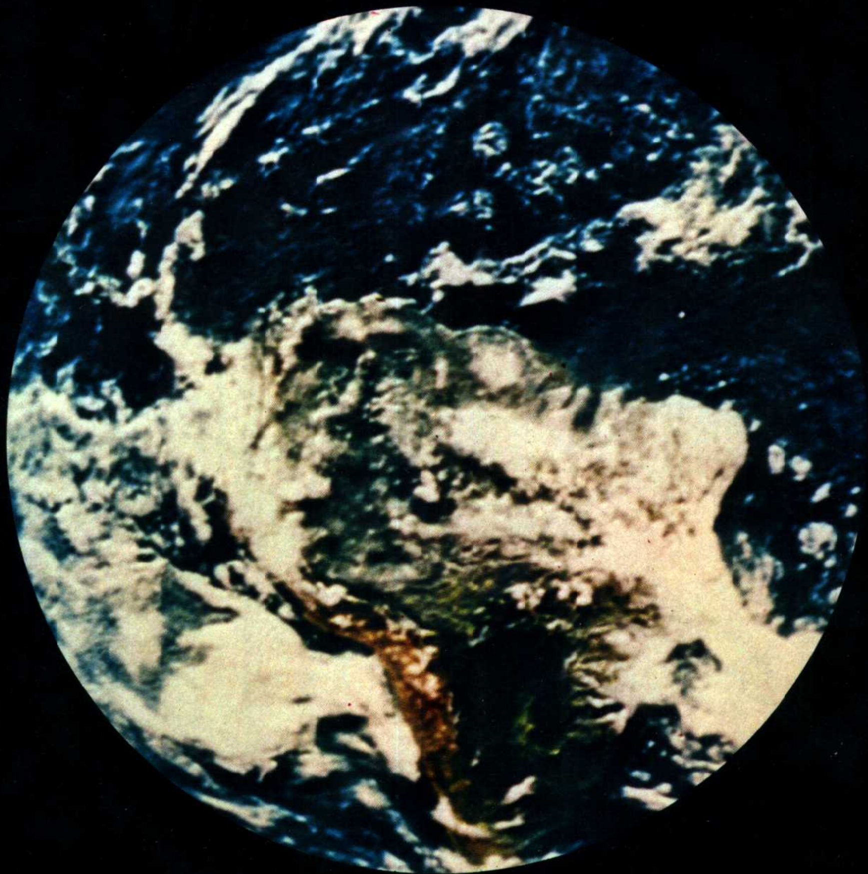
H. E. LANDSBERG
EDITOR IN CHIEF

World Survey of Climatology



VOLUME 9

Climates of Southern and Western Asia

K. TAKAHASHI

World Survey of Climatology Volume 9

Climates of Southern and Western Asia

edited by

K. TAKAHASHI

6-26-15, Seijo
Setagaya-ku
Tokyo 157 (Japan)

and

H. ARAKAWA

Daita 3-5-27
Setagaya-ku
Tokyo 157 (Japan)

ELSEVIER SCIENTIFIC PUBLISHING COMPANY
Amsterdam-Oxford-New York 1981

ELSEVIER SCIENTIFIC PUBLISHING COMPANY
Molenwerf 1, 1014 AG
P.O. Box 211, 1000 AE Amsterdam, The Netherlands

ELSEVIER/NORTH-HOLLAND, INC.
52 Vanderbilt Avenue
New York, New York 10017

Library of Congress Cataloging in Publication Data
Main entry under title:

Climates of southern and western Asia.

(World survey of climatology ; v. 9)
Includes bibliographies and index.
1. Asia, Southeastern--Climate. 2. Near East--
Climate. I. Landsberg, Helmut Erich, 1906- .
II. Arakawa, Hidetoshi, 1907- . III. Takahashi,
Kōichirō, 1913- . IV. Series.
QC980.15.W67 vol. 9 [QC990.A7542] 551.69s 81-1046
ISBN 0-444-41861-X [551.6956] AACR2

Library of Congress Card Number 81-1046
ISBN 0-444-41861-x (vol. 9)
ISBN 0-444-40734-0 (series)
With 50 illustrations and 180 tables

Printed in The Netherlands

World Survey of Climatology

Editor in Chief: H. E. LANDSBERG

Volume 1 General Climatology, 1
Editor: O. ESSENWANGER

Volume 2 General Climatology, 2
Editor: H. FLOHN

Volume 3 General Climatology, 3
Editor: H. E. LANDSBERG

Volume 4 Climate of the Free Atmosphere
Editor: D. F. REX

Volume 5 Climates of Northern and Western Europe
Editor: C. C. WALLÉN

Volume 6 Climates of Central and Southern Europe
Editor: C. C. WALLÉN

Volume 7 Climates of the Soviet Union
by P. E. LYDOLPH

Volume 8 Climates of Northern and Eastern Asia
Editor: H. ARAKAWA

Volume 9 Climates of Southern and Western Asia
Editors: K. TAKAHASHI and H. ARAKAWA

Volume 10 Climates of Africa
Editor: J. F. GRIFFITHS

Volume 11 Climates of North America
Editors: R. A. BRYSON and F. K. HARE

Volume 12 Climates of Central and South America
Editor: W. SCHWERDTFEGER

Volume 13 Climates of Australia and New Zealand
Editor: J. GENTILLI

Volume 14 Climates of the Polar Regions
Editor: S. ORVIG

Volume 15 Climates of the Oceans
Editor: H. VAN LOON

List of Contributors to this Volume

S. A. HARB
Ministry of Civil Aviation
The Meteorological Authority
Koubry El-Quobba
Cairo (Egypt)

M. K. NAGIB
Ministry of Civil Aviation
The Meteorological Authority
Koubry El-Quobba
Cairo (Egypt)

S. NIEUWOLT
c/o MARDI
Bag Berkunci 202
Universiti Pertanian P.O.
Serdang, Selangor
(Malaysia)

K. N. RAO
India Meteorological Department
Meteorological Office
Ganeshkind Road
Poona—5 (India)

Y. P. RAO
B3/33 Azad Apartments
Aurobindo Marg
New Delhi—110016 (India)

M. F. TAHA
Ministry of Civil Aviation
The Meteorological Authority
Koubry El-Quobba
Cairo (Egypt)

A. H. TANTAWY
Ministry of Civil Aviation
The Meteorological Authority
Koubry El-Quobba
Cairo (Egypt)

Contents

Chapter 1. THE CLIMATES OF CONTINENTAL SOUTHEAST ASIA
by S. NIEUWOLT

Chapter 2. THE CLIMATE OF THE INDIAN SUBCONTINENT
by Y. P. Rao

Chapter 1

The Climates of Continental Southeast Asia

S. NIEUWOLT

Introduction

Continental Southeast Asia comprises the territories of the following states: Vietnam, Laos, Kampuchea, Thailand, Burma, Western Malaysia (Malaya) and Singapore. It is a large and highly differentiated region, stretching over 27 degrees of latitude, from 1°20′ (Singapore) to 28°N (northern Burma). It includes the narrow Malayan Peninsula, where maritime conditions prevail, and areas of northern Burma and Thailand, almost 1,000 km from the nearest coast. Extensive lowlands and high mountain ranges are found in this area, which will be referred to as "the region".

In spite of these large differences, the climates of Continental Southeast Asia have one factor in common: they are all controlled to a very large extent by the system of the Asian monsoons. These monsoons have their origin outside Continental Southeast Asia, and their effects are essentially the same over the whole area. A description of these climates should therefore start with the seasons, which are mainly caused by the monsoons.

The northeast monsoon season

This season lasts approximately from November to March. Fig.1 illustrates the surface conditions during January, a fairly typical month of this season. Conditions in the atmosphere, both at the surface and aloft, are quite stable during this season. The average conditions, as shown on the maps and described below, are therefore similar to actual conditions on a large number of days (RAMAGE, 1952, p.407).

Pressure conditions in the low latitudes are always dominated by a regular diurnal oscillation, with maxima at 10h00 and 22h00, and minima at 04h00 and 16h00 local time. The diurnal range of pressure in Singapore is around 3.5 mbar and at Phu-Lien (near Hanoi) approximately 4.6 mbar (BRUZON et al., 1940, p.26; WATTS, 1955a, pp.13–15). However, these diurnal variations have no climatic consequences and they can therefore be disregarded here.

In the low latitudes, pressure differences are usually quite small compared to conditions in the higher latitudes. But during the northeast monsoon, there is a fairly strong pressure gradient from north to south over the region (Fig.1B).

The resultant surface wind is the northeast monsoon. Its velocity is relatively high for this part of the world, being generally around 4–6 m/sec, with somewhat higher speeds in the northern parts of the region, where the pressure gradient is larger, than in the

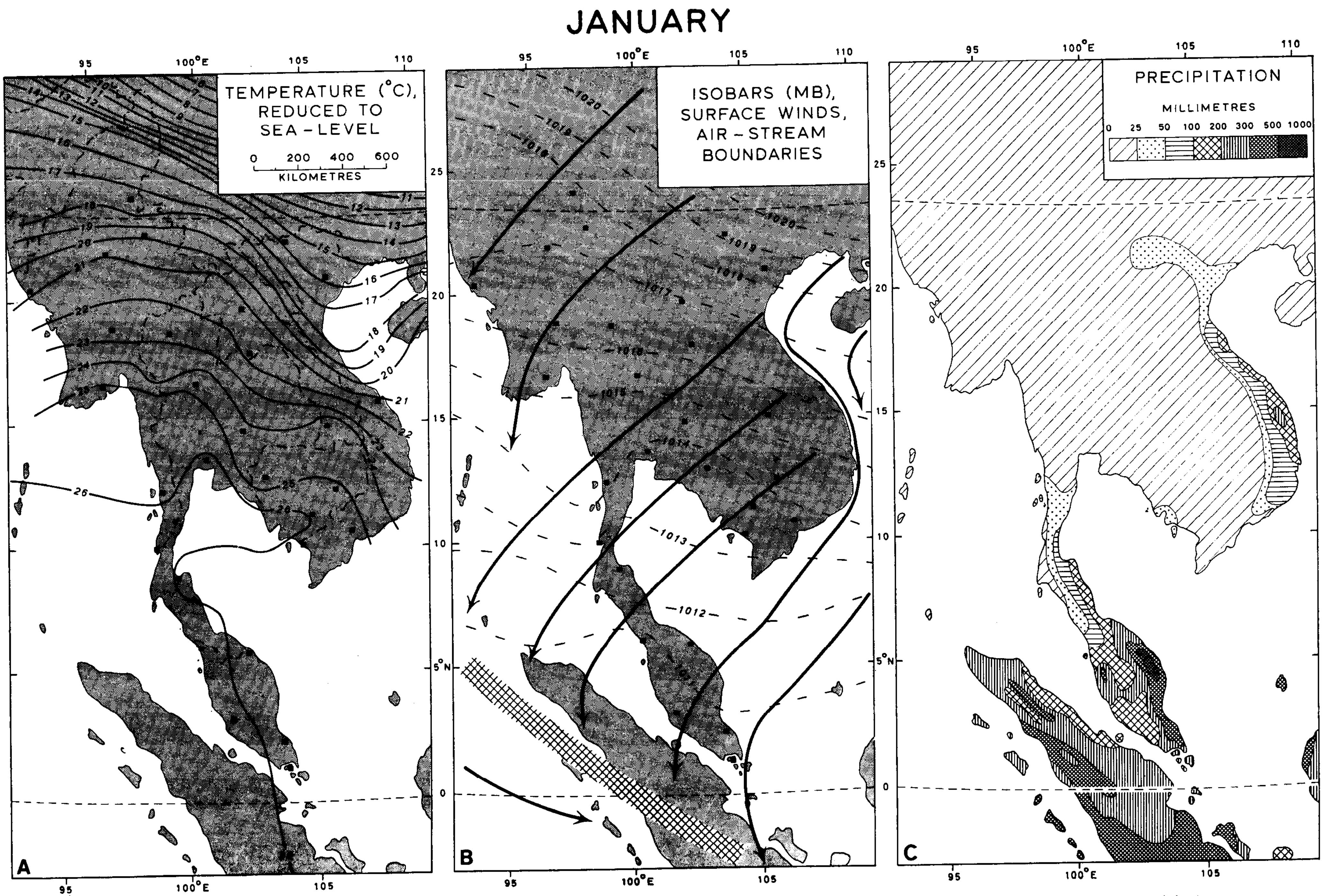


Fig.1. Conditions during January: A. mean temperatures at sea level; B. mean atmospheric pressure, surface winds and average position of air-stream boundaries; C. mean precipitation.

south. The monsoon winds are locally deflected by mountain ranges, as over the mountains of Annam, but over the sea they are very constant in direction, reaching a constancy figure of over 75%. This means that more than three-quarters of all observations were within 45° on the main wind direction (DALE, 1956, p.14).

The northeast monsoon brings two main air masses to Continental Southeast Asia.

(*1*) Air from a large high pressure cell over Siberia and Mongolia. This polar continental air is originally very cold, dry and stable. But when it reaches Continental Southeast Asia it is always thoroughly modified, especially if it has moved over the relatively warm China Sea. It is not a deep air mass: over southern China its thickness rarely exceeds 3,000 m, and on its way southwards it becomes shallower so that in Singapore it is usually not more than 1,350 m thick (JOHN, 1950, p.7). Occasionally a surge of the northeast monsoon brings this type of air to northern Vietnam via a land route, and in this case its modification is limited, with a consequent drop in temperature. Although these surges of the monsoon are not frequent, they explain the large temperature gradients over Vietnam, as shown in Fig.1A. On its way southwards over Vietnam the air is rapidly warmed.

(*2*) The second air mass has its origin over the Pacific Ocean, north of the Equator. It is tropical maritime air, carried by the northeastern trade winds, and it is generally warm and stable, as a consequence of the trade wind inversion. This air mass being warmer than the first type it generally moves over the polar air when the two air masses meet. On its way westwards this air mass is humidified over the China Sea. Normally this type of air occurs quite frequently over Continental Southeast Asia, especially in the southern part of the region. However, during surges of the northeast monsoon the trade wind system usually retreats far eastwards to the Pacific and the first air mass dominates over the area.

The boundary between these two air masses forms part of the polar front. Its position at sea level during January is around 25°N, but it frequently moves over large distances and can be as far south as 10°N (RAMAGE, 1952, p.406). At higher levels the front is further south: at 600 m its position is around 15°–20°N from southwest to northeast over the region (THOMPSON, 1951, p.572). Even over Singapore the front is still discernible at higher levels, though the temperature differences between the two air masses become very small near the Equator, as both are rapidly warmed from below.

Upper air conditions over Continental Southeast Asia are not very well known because of a scarcity of observations. Interpretation of the limited amount of information which is available is somewhat controversial, as it is not generally accepted that there are major differences between upper-air and sea-level conditions (THOMPSON, 1951; WATTS, 1955a). Until more observations are made, the following generalizations are possible. At about 3,000 m the position of the polar front is approximately the same as at 600 m. North of it upper westerlies prevail, and these increase in velocity with elevation. At approximately 12,000 m there is a strong westerly jet stream around 25°N, the result of the confluence of the two branches of the jet stream, north and south of the Himalayan–Tibetan massif (TREWARTHA, 1958, pp.208–210). South of the upper polar front, easterlies from the Pacific dominate the circulation at the 3,000 m level. At the extreme south of the region equatorial westerlies replace these easterlies (THOMPSON, 1951, p.572).

During the northeast monsoon season most disturbances associated with the polar front pass north of Continental Southeast Asia (RAMAGE, 1952, p.405). South of the jet stream strong subsidence prevails in thick layers of the atmosphere. This explains not only the rarity of invasions of polar air from the north to lower latitudes than about 15°N, but also the general lack of rainfall over most of the region during this season (Fig.1C).

There are only two areas with widespread precipitation during the northeast monsoon season: eastern and northern Vietnam, and the Malay Peninsula, south of about 10°N (Fig.1C).

The precipitation in Vietnam is largely caused by disturbances, which follow tracks near the polar front, situated not far to the north. Rainfall from these disturbances is locally increased by orographic lifting, as for instance in the mountains of Annam. But the importance of orographic lifting should not be overestimated, as there is no doubt that the main source of the precipitation are the disturbances. This is demonstrated by the intermittent and irregular character of the rainfall, by the occurrence of rain in the predominantly flat Red River Basin, and by the fact that there is no close correlation between the strength of the monsoon winds and the amounts of rainfall received (PÉDELABORDE, 1958, p.130). On the western slopes of the mountains the rain shadow effect reduces the rainfall to less than 25 mm per month.

Conditions in northern Vietnam, locally known as "crachin", are also related to disturbances of the polar front. This type of weather occurs in periods of 3–5 days. It is characterized by fogs or heavily overcast skies, and light drizzle, but only small amounts of actual precipitation. These conditions occur when a shallow depression is situated over the Gulf of Tonkin. The main season of "crachin" is from the end of January to April.

Rainfall in the Malay Peninsula during this season is also mainly caused by disturbances, but these are of a different origin. They travel with the monsoon current and are related to the air mass boundary between the two air masses of the northeast monsoon, or to convergence within the monsoon currents (WATTS, 1949, p.13). The amounts of rainfall in this region are higher than in Vietnam, due to the intensive humidification of the monsoon air masses over the warm South China Sea. Orographic lifting further increases the amounts of rainfall in eastern coastal areas. Convection over land, frequent in these low latitudes where temperatures are quite high, is the third cause of rainfall. There is, however, no doubt that the disturbances are the main factor, as is demonstrated by the intermittent and irregular character of the rainfall along the east coast of Malaya, and by the inverse correlation which exists between the strength of the monsoon and the amounts of rainfall received, so that stronger monsoon winds usually bring less rainfall than relatively weak winds (NIEUWOLT, 1966a, p.171).

From the coastal areas of eastern Malaya the amounts of rainfall decrease both towards the west and towards the north, (Fig.1C). The decrease to the west is due to the rain-shadow effect of the mountain ranges of the peninsula. The decrease to the north is caused by the shorter trip of the monsoonal air masses over the South China Sea, which limits their humidification to relatively shallow layers.

The final destination of the air masses of the northeast monsoon is in the Southern Hemisphere, where they become the northwest monsoon of Indonesia, reinforced by equatorial westerlies from the Indian Ocean (Fig.1B).

November–December

Conditions during January are representative for the whole of the northeast monsoon season, from November to March. The upper-air circulation shows no basic changes during these five months (THOMSON, 1951, pp.571–582). But the first two months show some interesting differences from the described conditions in January.

The northeast monsoon starts its move southwards over Continental Southeast Asia in October, and by the end of that month it normally reaches the south coast of Indo-China. It is usually well established in Singapore by the middle of December. But the southward movement is very irregular and often even temporarily reversed. During November and December equatorial westerlies still occur frequently over the southern part of the region, and they collide with the advancing northeast monsoon. The resulting air mass boundary zone is always accompanied by widespread and heavy rainfall. This is especially the case in the eastern coastal areas of the Malay Peninsula, where orographic lifting increases the amounts of precipitation considerably. November is therefore the wettest month of the year in the northern parts of the peninsula, as in Bandon and Kota Bharu. In the south, December is usually correlated with surges of the monsoon and close proximity of the air mass boundary. Disturbances play a much lesser role than during January (GAN TONG LIANG, n.d., pp.7, 8).

In Vietnam, November and December are normally considerably wetter than January. Here the typhoons continue to bring large amounts of precipitation until the end of the year, though their frequency of occurrence decreases gradually during these two months. Still, they bring the strongest winds of the northeast monsoon season (BRUZON et al., 1940, p.14). In Malaya, however, the strongest winds occur during January (NIEUWOLT, 1966a, pp.173, 177).

February–March

While the basic conditions remain the same as in January, the last two months of the northeast monsoon season bring some changes. The most important development is the general decrease in the velocity of the northeast monsoon over the whole region, and the gradual change to more easterly wind directions. This development is, of course, related to the slow weakening of the high pressure cell over continental Asia and the consequent attenuation of invasions of polar air. In Hongkong the thickness of the polar air shows a general decrease from October, when it reaches about 3,000 m, to about 2,000 m in January, to only 1,500 m in March (AIR MINISTRY, 1937, Vol.II, p.147). This decrease proceeds even more rapidly further south, and as the importance of the polar air mass diminishes, the trade wind air from the Pacific Ocean takes over, and increases its frequency of occurrence over most of the region. As this air mass is originally stable up to a high level, the result is a lessening in precipitation, compared to January, at the eastern coast of Vietnam.

A second change is the rapid rise in surface temperatures by 5°–7°C between January and March in the inland areas north of about 12°N. This is due to increased insolation, caused by longer days and higher elevations of the sun. The high daytime temperatures give rise to convective thunderstorms. These bring the "mango-rains" of Thailand and Burma, which are of great importance for agriculture, although the total amounts of rainfall received are not high. But they indicate the end of the dry season. These local disturbances may be connected with the eastward movement of a tropical trough at the 500 mbar level from southern India. This movement creates convergence at lower levels, which favours the development of thunderstorms (RAMAGE, 1955, p.257).