TECHNICAL STUDY 14

RECURRING EASTERN ASIATIC SYNOPTIC FEATURES

BY

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PART I TEXT

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SECTIONS

Sections discussed in this article are:

SECTION I

Introduction and Purpose

Due to rugged terrain over eastern Asia, many pressures plotted on surface charts are doubtful and difficult to draw for on maps the scale of 1:20 million. Smoothing of the isobars is necessary in order to present a neat, professional looking product to weather central customers. However, the analyst should be familiar with certain recurring synoptic features which have important meaning and present clues for future development, redevelopment, rerouting and movement.

It is the purpose of this article to discuss these features and their importance as weather producers. Each of them will be given a name associated with its geographical origin. These nomenclatures help to create a common language among meteorologists which simplifies conversations.

Lows caused by adiabatic downslope across mountains are good evaluators of the strength of approaching impulses aloft. The lower the leeside pressures are, the stronger the impulse. By using approximately 60 meters equal to 8mb of summation dynamics, the strength value of the impulse can be approximated. These leeside lows will be referred to as heat lows in this article.

Figure 1 is a geographical map showing the location of each of the important regions to be discussed.

Figure 2 is a map showing storm tracks which influence the weather in Japan. Various weather regimes created in the Tokyo area are indicated on each storm track. A separate section is devoted to a discussion of these storm tracks.

Figure 3 is a composite - fictitious surface chart showing the location of each of the features. It is not intended to imply that all of them occur simultaneously. The intent is to combine them into a single chart showing each one in its favorite location or origin.

Figure 4 is a summary map showing normal, alert, and "kick-off" pressures, their relationships to timing factors and resultant weather which will be discussed in subsequent sections. Normal pressure is defined as a pressure which indicates that the particular feature has nothing to offer in the way of clues. For example; pressure too high in a low or too low in a high. Alert pressure is defined as a value which invites the forecaster to take a close look in that direction for an approaching impulse. Kickoff pressure is defined as a value which indicates that the impulse has developed and is moving through.

SECTION 2

Seasonal Storm Tracks

Numerous storm tracks, dynamic splits in these storm tracks, and resultant by-product geographical storm track splits, developments and redevelopments are experienced around the northern hemisphere. Storms which develop and move across the Atlantic Ocean fall into two general categories as they approach Europe and Asia: (1) the storms which move northeastward through Iceland, into the Barents Sea, then southeastward through Asia and, (2) the middle latitude storms which move through the Mediterranean Sea as result of a dynamic divergent split in the westerlies aloft. These two basic storm tracks undergo many and various distortions and reroutings as they move across Asia, decided by their long wave peculiarities over specific geographical regions. The following paragraphs are devoted to a discussion of the many splits in these two basic storm tracks across Asia as they approach the Japanese Islands.

Icelandic Storm Track. Defined as those storms which move through Iceland and the Barents Sea then drop southeastward toward Mongolia and get rerouted a few degrees southward by the Mongolian Low.

Siberian Storm Track. Defined as those storms which move through Iceland and are routed northward through Spitsbergen and Franz Josef Land by a sharp amplitude long wave ridge, then drop southward toward the Sea of Japan and get rerouted a few degrees southward by the Chita and Lung Chiong Lows.

Kunlun Mountains Storm Track. Defined as the mid-latitude split of the Mediterranean Storm Track which moves along the northern edge of the Kunlun Mountains toward the Yellow Sea and East China Sea.

Mediterranean Storm Track. Defined as the southern split of Atlantic Storms which move through the Mediterranean Sea, across Asia into the Kirghiz Steppes where it gets rerouted along one of the three split tracks.

Himalayan Storm Track. Defined as the split in the Mediterranean Storm Track caused by geographical distortions of the upper air wind flow by the mountainous terrain to the west of the plateau of Tibet.

Southern Storm Track (of the Westerlies). Defined as the secondary split of the Mediterranean Storm Track caused by the natural tendency of meteorological impulses to seek an oceanic source of moisture. This occurs along the coast of Iran and Pakistan, through the Red Sea and the Persian Gulf, along the Arabian Sea coast of India into the Bay of Bengal.

Yellow Sea - Shanghai - Formosa Storm Tracks. Defined as dynamic by-products of the numerous splits in storm track impulses which move across Asia. Each of these individual tracks and their peculiarities are discussed in another section.

Winter Tropical Low Track. Due to the seasonal suppression southward of the Intertropical Zone of Convergence in winter, rare tropical storms develop near the Equator and move westward through the Celebes and Sulu Seas across the southern portion of the south China Sea through the Gulf of Siam across the Malay Peninsula and Andaman Sea into the Bay of Bengal. Here they get caught in the upper westerlies of the southern storm track and are rerouted northeastward toward east Pakistan and Eastern India. Here the middle level moisture is advected across the mountains of Burma into southern China producing the overrunning mechanism for precipitation patterns and resultant frontogenesis along the boundary between wet and dry air near the coast of China bordering the South China Sea.

An illustrative chart, Figure 2, showing all these storm tracks and various weather regimes produced by each one in the Tokyo area is included in this article.

SECTION 3

Yellow Sea - Shanghai - Formosa Lows

The most important of the recurring synoptic features which influence the weather over Japan are the lows which develop along the coast of China near the Yellow and East China Seas. There are three distinct storm development areas and they will be named Yellow Sea, Shanghai, and Formosa Lows. The three names are necessary because the future track and associated weather regime is different for each one. The object is to establish a common language between individuals as well as different detachments such that, when one forecaster tells another forecaster over the telecon that he thinks a Shanghai Low (for example) is developing, automatically a particular weather regime is plugged into his thinking and the conversation gets started on equal grounds.

Yellow Sea Low. The Yellow Sea Low develops near the Yellow Sea in the area between Shanghai and Osan and tracks on a course which takes it over Korea, through the Sea of Japan and across northern Japan. Over central and southern Japan, strong gusty surface winds are produced, with little precipitation, usually of the showery type. These lows, which track through the Sea of Japan, and deepen are the producers of the dust storms in the Tokyo area during the dusty season (late February to late April). The speed of movement is erratic and depends upon the movement of features aloft and the long wave pattern. An initial approximation of the maximum gust in the Kanto Plains can be obtained when the central pressure of the low is known while it is still in the Yellow Sea. The following three rules can be used as a guide: If the pressure is greater than 1008mb, the gusts will be less than 40kts. 1000-1008mb produces gusts 40-60kts. Less than 1000mb produces gusts greater than 60kts. Maximum gusts will be realized if the timing is such that the low moves through the Sea of Japan during daylight hours rather than at night. Plotting a maximum wind chart for stations in Japan on which the strongest wind in the lower 9000ft. is entered gives another approximation. Watch Mt. Fuji's wind and use it as a guide. The direction of the winds is always southerly.

Figure 5 shows a January pattern in which a strong cold front is moving through China. The low shown over China developed as a heat low in the Province of Honan in advance of the frontal system, then took over as the main low after a dynamic injection aloft.

Figure 6 shows the same low 24 hours later and its average speed and direction of movement. Note the amount of deepening. Note also the high cell southeast of Tokyo which is a co-producer of the tight pressure gradient necessary for development of the strong winds.

Shanghai Low. The most important of the precipitation producers over southern and central Japan are the lows which develop near Shanghai. These lows track eastward on a course which takes them along the southern coast of Japan. The main low center may sometimes track toward the Sea of Japan, but when it does, invariably a secondary low develops to the south of the islands near Shikoku and they move along as a double-eye system till they merge in the Pacific to the east of Honshu. The Shanghai Low often develops to the north of an old stagnating frontal system and a resurfacing process causes associated frontogenesis to occur while the old front frontolyzes.

Figure 7 shows a January Shanghai Low having developed and starting to move eastward.

Figure 8 shows the same low 36 hours later. Its track and average speed and direction of movement are indicated. The rapid deepening is evidenced by the drop in central pressure from 1019mb to 980mb.

The Formosa Low. The Formosa Low develops near the Island of Formosa (Taiwan) as a wave on a stationary but active frontal system. These Formosa Lows have two tracks. One takes them on a course northeastward toward Japan and is normally a heavy precipitation producer in the Tokyo area. Sometimes these lows pass close to Tokyo and are sufficiently deep but produce little precipitation in the Kanto Plains. This is caused by a tight packing of the mean isotherms to the south such that isentropic steepening occurs too far south and provides a protective barrier. The other track takes them on a course eastward such that they pass south of 30° latitude and produce little precipitation over Japan. These lows move with a speed much faster than the Yellow Sea and Shanghai Lows.

Figure 9 shows a February Formosa Low in the developing stage. Figure 10 shows the same low 24 hours later moving along its northeast storm track. Direction and speed of movement are indicated. Note the rapid deepening from 1015mb to 994mb.

Figure 11 shows a January Formosa Low developing. Figure 12 shows the same low 36 hours later and its direction and speed of movement. Note that the rate of deepening is much less than in the case of the northeast track and the speed of movement is faster.

Summary. The distinguishing peculiarities of these three lows are:

The Yellow Sea Low produces a variety of weather elements over Japan including snow, rain, thunderstorms, gusty winds, and dust storms in Tokyo during the dusty season.

The Shanghai Low invariably produces heavy precipitation over Japan whether it is a single center or double-eye system, unless, under the influence of strong zonal flow, rapid movement with neutral advection prevent it from deepening until it gets well to the east of the islands.

The Formosa Low may or may not produce heavy precipitation over Japan depending upon its storm track. It is the fastest moving of the three.

SECTION 4

Oshima Low

Autumn Oshima Low. In autumn, when Shanghai Lows first start to develop after the summer recess, precipitation is forecast to begin in the Tokyo area based on the progged movement of the Shanghai Low and the approximate time it crosses near 30°N and 135°E. Oftentimes a low will develop near the island of Oshima (47-675, 50 miles south of Tokyo) well in advance of the approaching Shanghai Low. The Oshima Low causes the precipitation to begin many hours earlier than expected. This low is caused by the development of a low level jet blowing from the south over the island of Hachijojima. The best advance clues are supplied by the hint of a wave developing in the Oshima area on the 850mb chart at the time the Shanghai Low is near 125°E. When development of an Oshima Low is indicated, precipitation should be forecast to begin in the Tokyo area approximately 12-18 hours after the Shanghai Low reaches 125°E. The low level jet is a climatological autumn feature caused by increased thermal packing between the fresh cool air coming off the continent and the stale hot oceanic air which is reluctant to give up its temperature rapidly.

Ship Tango should be monitored for what clues it can supply. A strong southeasterly wind at Tango when the overall synoptic pattern is establishing itself as favorable, indicates the tightening of the gradient to the south and possible cyclogenesis.

Figure 13 for 0600Z, 1 October 1966, shows an October Shanghai Low near 125°E. Figure 14, 24 hours later, shows the old stagnating Shanghai Low and an Oshima Low having developed. Rain and thunder are being reported in the Tokyo area. Precipitation began around 18-21Z. Figure 15 is an 850mb chart for 0000Z, 1 October 1966. Note the long distance between the surface position and the 850mb position of the Shanghai Low. Note the very light circulation around the low near Oshima. Figure 16 for 020000Z shows the old stagnating Shanghai Low and the stronger circulation around the Oshima Low. Note the low level jet over Hachijojima as indicated by the 35kt wind.

Late Winter - Early Spring Oshima Low. In late winter and spring, a variety of weather elements are associated with the Yellow Sea Lows.

Figure 17 shows a late February Yellow Sea Low developing. Figure 18 shows the same system 36 hours later with the front approaching the Tokyo area. Southerly wind gusts up to 50kts were occurring in the Kanto Plains at the time of this chart. The front passed Tokyo at 231100Z bringing overcast skies and occasional very light rain. Figure 19, 12 hours later, shows an Oshima Low having developed, and continuous precipitation has begun along the coast. Continuous rain began in Tokyo at 240000Z and continued until 250000Z. Overcast skies with low ceilings and occasional very light drizzle prevailed until 271200Z, a total of 96 hours of continuous bad flying weather.

The slope of the 700mb trough associated with this type Yellow Sea Low is the tipoff to the development of the Oshima Low which produces the post-frontal bad weather pattern. Figure 20 shows the relative positions of the 700mb trough at 230000Z and the surface front at 230600Z. Figure 21 shows the 700mb chart at 231200Z, the time of fropa in the Tokyo area and the surface front 6 hours later when the Oshima Low developed. If, at the time of frontal passage in the Tokyo area, the 700mb winds are still south of west as far west as Mosulpo (47-187) and Osan (47-122), odds are in favor of development of a post-frontal Oshima Low due to the flow aloft being parallel to the surface front.

Forecasting delayed or instantaneous beginning of continuous post-frontal precipitation in the Tokyo area is directly related to the amount of pre-frontal moisture available. This can be determined by a simple nephanalysis. If skies are almost clear ahead of the approaching front, delayed beginning of continuous precipitation is indicated. If multi-layered clouds and isolated showers are reported in the warm sector, instantaneous beginning of continuous precipitation after frontal passage is dictated.

A long range (72-84 hours) clue that the long wave pattern is positioned such that this post-frontal pattern will occur is supplied by the value of the Takla Makan Desert Low "kick-off" pressure. In February through April, if the Takla Makan Low has a pressure in the 1004-1012mb bracket, it is suggested that impulses will move along the Kunlun Mountains Storm Track and develop a Yellow Sea Low with a Resultant Post-frontal Oshima Low.

SECTION 5

The Kanto Low

The Kanto Low develops in the Tokyo area as a leeside feature as a result of adiabatic downslope over the Japan Alps to the northwest. Mt. Fuji and the range of hills oriented north-south located to the west of the Kanto Plains are specifically responsible for the local turning effect which causes the winds associated with the Kanto Low to always blow out of the south. The Kanto Low normally develops around noontime when diurnal pressure falls set in. Exaggerated diurnal pressure falls normally accompany the Kanto Low. Forecasting the development of a Kanto Low with southerly winds on a day when surface isobars indicate northerly flow is directly related to the isobaric orientation. The normal direction of northerly winds in the Tokyo area is 340° to 020°. When surface isobars are oriented within this range of direction, northerly winds can be expected and will gust in proportion to the pressure gradient between Choshi Point and Wajima (8mb gradient produces gusts above 30kts). If the isobaric orientation is east of 020°, the winds will be northeasterly, usually not very strong. If the isobaric orientation is west of 340°, a Kanto Low should be anticipated and the speed of the gusts is directly related to the isobaric gradient. Kanto Low produced winds rarely exceed 35kts unless an impulse is approaching from the west.

One of the most important occurrences of the Kanto Low is associated with spring and summer thunderstorms in the Kanto Plains. Figure 22 shows a Shanghai Low approaching, and an active stationary front along the southern coast.

Figure 23 for 1800Z, 22 March 1966, shows the Shanghai Low having passed to the east of the Tokyo area. Figure 24 is 12 hours later and shows the Shanghai Low having moved rapidly northeastward, an Oshima Low has developed on the frontal system and a Kanto Heat Low has developed. Figure 25 is a morning 500mb chart. Figure 26 is a 500mb chart 12 hours later; the minus figures are the 12-hour temperature changes. Note the amount of cooling. Thunderstorms were reported in the Kanto Plains late that afternoon. Figure 27 is a skew-T diagram for Tateno (47-646) for 0000Z (temperature and dewpoint solid) and 1200Z (temperature and dewpoint dashed). Thunderstorms are not obvious according to this sounding because of the apparent lack of convective instability. This unusual case was chosen in order to emphasize the amount of moisture which can be advected into the Tokyo area by the Kanto Low.

Prerequisites for forecasting post-frontal thunderstorms in the Kanto Plains in springtime are:

1. A Shanghai Low must pass Choshi Point (47-648) between midnight and nine o'clock in the morning, preferably nearer to six o'clock.

2. The 0000Z Tateno sounding must contain about 10,000 ft of moisture (spread less than 6°C).

3. The sounding at Tateno must be convectively unstable (or at least a zero index).

4. The 850mb winds over southern Honshu must be from a westerly direction.

5. The 700mb and 500mb troughs must be lagging behind far enough to not scoop the moisture out before low level heating occurs.

6. Timing of the thunderstorms is based on the time of passage of the 700mb trough.

7. This type of thunderstorm occurs when the 500mb long wave trough is positioned near 130°E to 135°E.

The morning forecaster can successfully forecast the maximum temperature when this pattern is evident by adding 2°C to the 1200Z 850mb temperature at Tateno and lowering it dry adiabatically to the surface. Lower the 850mb dewpoint moist adiabatically to the surface and approximate the average mixing ratio in the lower 100mb. Compute the wet bulb temperature at 500mb. Lift the lower 100mb to saturation and then along the moist adiabats to 500mb to get an idea of potential convective instability. Scan all hourly weather observations and checkerboards to see if early morning showers or thunderstorms are occurring over western Honshu under the cold trough aloft. If clues point to possible thunderstorm development, a forecast such as "isolated" thunderstorms over the mountains this afternoon" should be issued in the morning. This allows the day forecaster to evaluate the 0000Z data and go either way he wants.

Thunderstorms may accompany the passage of the low when the following prerequisites are met:

1. The low must pass during the afternoon allowing maximum low level heating. The trough aloft should be nearly vertical.

2. The 0000Z Tateno sounding must indicate potential middle level thunderstorms by being convectively unstable from the point of overrunning up.

3. The wet bulb potential temperature along the unstable portion of the lapse rate must be 14°C or greater.

4. The base of the overrunning must be below 700mb, and the lower the better.

5. This type of thunderstorm occurs when the 500mb long wave trough is located near 120°E to 125°E.

Figure 28 shows a Shanghai Low passing along the coast at 0600Z, 18 March 1967. Figure 29 is a Skew-T diagram for 0000Z (temperature and dewpoint solid) and 1200Z (temperature and dewpoint dashed), 18 March 1967. Thunderstorms began at Fuchu in the middle of the afternoon just before the time of the surface chart.

Figure 30 is an 0000Z sounding for Tateno on 5 June 1967. This is a very unstable sounding when subjected to a strong lifting mechanism. A 500mb trough passed through late that afternoon and produced gusts to 56kts and golfball size hail up to six inches deep. One method of analyzing this sounding is given below:

1. Compute the average mixing ratio in the lower 100mb.

2. Forecast maximum temperature by adding 2°C to the 850mb temperature and lower dry adiabatically to the surface.

3. Lift the driest point on the sounding between 850mb and 600mb to its LCL.

4. Lift the midpoint of the lower 100mb to saturation, then upward moist adiabatically to the LCL of the dry point.

5. Read the temperature difference between the two lifted parcels at this altitude to obtain the convective instability index (CII). This level was named the "hail conception altitude" in a previous article written by this author.

6. The CII in this case is minus 10 and indicates a very unstable air mass but must be subjected to a triggering mechanism in order to realize its full potential.

SECTION 6

The Honshu Front

During the transition seasons of autumn, late winter and spring when the jet stream and associated thermal packing aloft fluctuate northward and southward over the Japanese Islands, complex surface frontal patterns are generated which require a thorough evaluation of all charts available in order to present an analysis that accounts for the variable weather elements produced. One of these complicated synoptic features involves the natural frontogenetic zone which exists along the southern coast of Japan from Kyushu through the Tokyo area between the coastal stations and Hachijojima which has been named the Honshu Front.

The Honshu Front is a very important feature which influences the weather in the Tokyo area. It frequently becomes active in advance of Shanghai and Yellow Sea Lows and causes precipitation to begin sooner than anticipated, much in the same way as the autumn Oshima Low.

The development and resultant movement of the Honshu Front is directly related to the latitudinal penetration of the cold air aloft. The 1000-500mb thickness chart has proven to be an excellent tool for evaluation of "yes" or "no" warm frontal passages in the Kanto Plains. The magic thickness values in the Tokyo area, evaluated at the time the Yellow Sea or Shanghai Low is located near 125°E are 4460 meters and 5580 meters. If the 4460 meters line is south of the Tokyo area and the 60 meters iso-lines are tightly packed, the Tokyo area will remain in the cold air with cloudy skies and overrunning precipitation. If the 5580 meter line is north of the Tokyo area and the 60 meter intervals are loosely packed, the Honshu Front will become a warm front when associated with a Yellow Sea Low and pass to the north of the Kanto Plains with partly cloudy skies and warm gusty southerly winds. If the 5520 meter line is over the Tokyo area, a borderline situation is indicated and "yes" or "no" passage depends upon the packing of the thickness lines versus the strength of the pressure gradient. A rapidly deepening Yellow Sea Low plus loose thickness packing indicate warm frontal passage. A weak Yellow Sea Low plus tight thickness packing indicate the front will remain stationary to the south.

In a case during which the warm front passes to the north with resultant gusty surface winds, timing of the beginning of the gusty winds depends upon two parameters, the time of passage of the 700mb ridge line versus the time of day the passage occurs. If the ridge passes through the Tokyo area during the day, gusts will begin almost immediately thereafter. If the ridge passes during the night, gusts will begin within a couple of hours after sunrise.

Figure 31 for 0600Z, 24 November 1966, shows a Shanghai Low developing, with frontogenesis introduced. The frontal system which has moved across Asia is approaching from the northwest. The old tropical front to the south has begun to frontalize. The central pressure in the Yunnan Low has dropped to 1001mb which is below the established seasonal "kick-off" value of 1004mb. A break-off high cell has developed near the north-eastern slopes of the Tibet Plateau.

SECTION 7

Chita-Lung Chiong Lows

The Chita Low. Of importance is the low cell which develops in the coal regions near the city of Chita (30-758) located near 52°N and 11[illegible], as a result of adiabatic downslope over the Yablonovy Mountains in advance of winter storms which track along the Siberian Storm Track. When its central pressure is below 1016mb and the 500mb flow is NNW to SSE, the presence of an impulse aloft strong enough to maintain itself and bring troughlike surges of cold air to the Japanese Islands is indicated. These surges normally follow the "kick-off" pressure by 54-66 hours in Tokyo.

The Lung Chiong Low. A secondary downstream feature to the Chita Low is the heat low and troughing which develop near the city of Lung Chiong (50-745) near 47°N and 124°E as result of adiabatic downslope over the Great Khingan Mountains in advance of the impulses which move through the Siberian Storm Track. This troughing causes surge-like breakthroughs of the cold air to the northwest and often produces associated cold frontogenesis as the Siberian Cold Front frontolyzes. The cold surge in Tokyo normally follows development of the Lung Chiong Low by 30-42 hours. The "kickoff" pressure is 1016mb.

Figure 32 for 1800Z, 3 January 1967, shows a low and frontal system moving along the Siberian Storm Track. Figure 33, 1800Z, 4 January 1967, shows the same frontal system and a Chita Low developing and absorbing the original low which has been divorced from the cold front. Figure 34, 1800Z 5 January 1967, shows a Lung Chiong Low developing with frontogenesis introduced. A Shanghai Low is developing to the south along the same longitude. Figure 35, 1800Z, 6 January 1967, shows the resultant movement of the Lung Chiong Low and Shanghai Low and their frontal trains. This is one of the exceptions to the general rule that Shanghai Lows produce heavy precipitation in Tokyo because mass momentum is directed toward the eastsoutheast with neutral thermal advection and little development of the Shanghai Low until it gets well to the east of Tokyo.

A good general rule is that if an impulse aloft is approaching from the northwest at the same time an impulse approaching from the southwest lies near the same longitude, the northwesterly impulse will normally win the race to the Tokyo area with resultant good weather after passage and very little precipitation prior to passage.

Summary. The importance of the Chita and Lung Chiong Lows is that they define a long wave pattern which results in a cold regime over the Japanese Islands with a series of cold frontal passages from the north along the Siberian Storm Track. This is a dry pattern in the Tokyo area with gusty northerly surface winds and an occasional snow flurry accompanying the passages.

SECTION 8

Mongolian Low

The Mongolian Low develops in the area near 46°N and 100°E caused by adiabatic downslope over the Altai Mountains when a strong impulse aloft approaches from the west travelling along the Icelandic Storm Track. In winter the central pressure may be as high as 1036mb when surrounded by extremely cold air and high pressures; but when the central pressure drops to below 1016mb, an initial alert is sounded inviting attention to the west. In spring and summer the central pressure drops to below 1000mb. Diurnal central pressure variations are very large all year round.

The key stations in Mongolia are Tsagaan Olum (44-277), Bayan Ulaan Suma (44-282) and Arbay Heere (44-288). These stations should always be plotted and analyzed for on surface charts.

The tracking of a low pressure center from Iceland through central Asia across the middle latitudes towards the Sea of Japan heralds the approach of an impulse aloft which frequently dips far enough south to furnish the triggering mechanism necessary for development of a low near the Yellow and East China Seas. Close monitoring of the Mongolian Low and its central pressure provides clues for long range forecasting of development of these lows.

Figures 36 and 37 show a February Mongolian Low. Its central pressure is 996mb on Figure 36 and is accompanied by an Icelandic Storm Track synoptic low with a double center. On Figure 37 the Mongolian Low has received an injection aloft and has absorbed the synoptic low and has become the dominating feature. The Honan Low has begun to develop.

Summary. Accurate depiction of the Mongolian Low provides the forecaster with clues to approaching impulses moving along the Icelandic Storm Track which may be future developers of the Yellow Sea and Shanghai Lows. Preliminary long range figures have been developed and will be discussed in a later section. These figures attempt to correlate certain "kick-off" pressures with timing of development off the east coast of China.

SECTION 9

Takla Makan Desert Low - Kunlun Mountains Storm Track

When the long wave pattern is such that a storm track is established through the Mediterranean Sea, these storms move eastward across the continent and become obscure until they reach the Takla Makan Desert. This desert low is initially a heat low caused by adiabatic downslope over the Karakoram Range, until it begins to move eastward and tracks along 40°N latitude on the north side of the Kunlun Mountains until it reaches 100°E where it follows the flatlands and drops southeastward into the province of Honan and then into the Yellow or East China Sea. Here it may deepen and move out as a Yellow Sea or Shanghai Low.

Careful analysis of the surface isallobars and scrutiny of auxiliary charts is required in order to accurately follow one of these lows across and through the Kunlun Mountains Storm Track. Ideal circulation is rare because of the mountain and valley breezes, but when circulation is present, it is definite that a future storm will develop. These lows move eastward at 25-30kts until they recurve near Japan where they deepen and often accelerate.

The key stations are Khotan (51-828), Yar Tung Ku (51-839) and Charchan (51-855) along the southern border of the Takla Makan Desert and the northern edge of the Kunlun Mountains.

The importance of the Takla Makan Desert Low is to provide long range clues to the future development of the lows in the Yellow and east China Seas. "Kick-off" pressures vary from year to year depending on the weather regime as dictated by the long wave pattern. In some years, the February-March "kick-off" pressure is approximately 1012mb, which suggests that impulses will move along the Kunlun Mountains Storm Track and resultantly produce a Yellow Sea Low followed probably by a post-frontal Oshima Low. In other years, the February-April "kick-off" pressure is below 1000mb and suggests that the Mediterranean Storm Track impulses are stronger, and their energy is diverted southward along the Himalayan Storm Track and produce the Formosa-Shanghai Lows.

The difference in the two regimes as concerns the Tokyo area is that, when 1012mb is the "kick-off" pressure and a Yellow Sea Low develops, the Kanto Plains experiences pre-frontal duststorms and post-frontal precipitation for extended periods. When below 1000mb is the "kick-off" pressure, moderate to heavy precipitation precedes the Formosa-Shanghai Lows followed on occasion by afternoon thunderstorms after the middle of March. One notable exception to the 1000mb regime is that it is possible to have a Yellow Sea Low develop when preceded by a Takla Makan Low less than 1000mb. Watch the Kunlun Mountains Storm Track closely, especially the isallobaric pattern, and if a Yellow Sea Low is indicated, chances are the Yellow Sea Low will have a pressure less than 1000mb and a long range forecast of very strong winds in Tokyo can be issued.

Figure 38 shows a 1011mb Takla Makan Low for 0600Z, 28 February 1967. Note the isallobaric field which indicates that the low is on the move. Figure 39 shows the same low 36 hours later still accompanied by an isallobaric rise pattern. The Honan Low is developing in advance of the approaching impulse. Note the central pressure in the Yunnan Low. Figure 40 shows a Yellow Sea Low having developed. This low moved through the Sea of Japan and produced wind gusts up to 50kts in the Tokyo area followed by an Oshima Low with low ceilings, drizzle and rain for 72 hours.

Figure 41 shows a 993mb Takla Makan Low for 0600Z, 3 March 1966. Note also the 995mb pressure in the Yunnan Low. This means that strong impulses are passing through aloft. Figure 42, 72 hours later, shows a Shanghai Low moving out. Note the deep Yunnan Low and rapid filling of the Takla Makan Low. This Shanghai Low passed south of the Tokyo area and produced heavy rain with rapid clearing afterward.

<u>Summary</u>. Accurate depiction of the Takla Makan Low provides the forecaster with clues to approaching impulses aloft moving along the Mediterranean Storm Track which may be future developers of the Yellow Sea, Shanghai or Formosa Lows. Three important features to watch in analysis are the value of the pressure, wind circulation, and three-hour pressure tendencies from Khotan eastward along the slopes of the Kunlun Mountains. Preliminary long range figures have been developed and will be discussed in a later section. These figures attempt to correlate certain "kick-off" pressures with timing of development off the east coast of China. In late winter and spring a low should be shown in the Takla Makan Desert any time the pressure drops to below 1016mb after pressures have been consistently high.

SECTION 10

Honan Low

A notable area of leeside troughing extends from Peking (54-511)(or Peiping) southward through the coal basins of the provinces of Honan and Hopeh. A heat low may appear anywhere in this area but it more common near An Yang (53-898) located near 36°N and 114°E. This troughing is most evident when a strong impulse aloft tracks eastward along the Kunlun Mountains Storm Track and produces strong westerly flow across the Taihangshin Range resulting in adiabatic downslope to the east of the mountains. However, the Honan Low often develops in association with the Mongolian Low also.

The Honan Low is more prominent during late winter and is an important "set-up" feature to the Takla Makan Desert Low associated with development of Yellow Sea Lows. The Honan Low is a temporary feature which gives short range clues to timing of development of these Yellow Sea Lows. The "kick-off" pressure in late winter is below 1016mb and drops to below 1004mb during spring until it loses its importance in summer. A Yellow Sea Low normally follows the first appearance of a Honan Low by 12-24 hours after the "kick-off" pressure is reached.

Figures 5 and 6 show a winter low which was originally a Honan Low, then became a dynamic low and produced a Yellow Sea Low. Figure 39 shows a March Honan Low in advance of a Takla Makan Low.

SECTION 11

Yunnan Low

Impulses which travel through Asia along the Himalayan and Southern Storm Track of the westerlies travel over regions of sparse and unreliable upper air information which is often missing. The most important recurring heat low over southern China which gives warning of the approach and strength of these impulses develops in the province of Yunnan. When the approximate climatological and diurnal pressure variations in this low are known, the strength of the approaching impulse aloft can be estimated by comparison of the actual reported pressure with this climatological pressure.

The Yunnan Low is caused by adiabatic downslope over the mountains in Burma of air originating in the Bay of Bengal. It is a semipermanent feature located near 25°N and 100°E which disappears for short periods of time during the winter under the influence of cold surges from the north and northeast. The normal central pressure in winter is approximately 1014mb which lowers gradually during spring to near 1000mb. It becomes obscure and meaningless in summer due to widespread low pressures over all of southern China. The normal pressure in autumn is 1008mb.

The two key stations in the Yunnan Low are Lintsang (56-951) and Yuanmao (56-763). These two stations should be plotted on and analyzed for on all surface charts. This heat low is an important feature associated with development of Yellow Sea, Shanghai and Formosa Lows.

Examples of the Yunnan Low can be seen on numerous charts throughout this series.

SECTION 12

Sea of Okhotsk Low

In autumn and winter it is often possible to analyze a stationary low in the Sea of Okhotsk, both on the surface chart and the 500mb chart. Normally this is the anchor point indicating that the long wave trough position is along 150°E. As long as this low is evident, and impulses are tracking through the northern storm tracks, a dry season is indicated. When strong impulses are moving through the central and southern storm tracks during the cold season and the Okhotsk Low is present, future development of Shanghai and Formosa Lows is abetted by the capability of the Okhotsk Low to join forces with the southern storm and retrograde by replacement the long wave trough temporarily on a northeast to southwest orientation.

Later domination by the Verkhoyansk High indicates a break in this particular long wave pattern. The Verkhoyansk High shoves the Okhotsk Low to the east of the Kamchatka Peninsula.

Figures 32, 33, 34 and 35 show a stationary low in the sea of Okhotsk in January. Note the absense of the Verkhoyansk High. Under this particular pattern, storms were moving along the Siberian Storm Track and several all-time low temperature records were set in Japan. Under split flow aloft, an occasional Shanghai Low is triggered as shown in Figure 34 but little precipitation occurs.

SECTION 13

Forecasting Development and Movement of Yellow Sea-Shanghai-Formosa Lows

For every recurring synoptic feature there is an upstream anchor point which furnishes the necessary clues for future development if it can be found. A preliminary study has disclosed that the principal anchor point for development of the Shanghai and Formosa Lows is the heat low of Yunnan. It also precedes development of Yellow Sea Lows on occasion. The normal pressure in the Yunnan Low in winter is approximately 1014mb. When this central pressure drops to below 1012mb an initial alert is sounded and when the pressure drops to below 1008mb (kick-off) a Shanghai, Formosa or Yellow Sea Low is in the process of developing. The significance of the 1008mb "kick-off" pressure as compared to the normal of 1014mb is that the difference is a surface reflection of some dynamic feature aloft equivalent to approximately 45 meters of 500mb height falls, thickness rises, stratospheric fluctuations, etc. This impulse may not be detectable on constant pressure charts due to scarcity and lack of reliability of upper air data to the west. The "kick-off" pressure drops gradually from 1008mb in winter to 1004mb in March to below 1000mb in spring. The normal pressure drops from 1014mb in winter to 1008mb in March to below 1000mb by April. In autumn the normal pressure is 1010mb and the "kick-off" pressure is 1006mb. The average lag time between the time the Yunnan Low drops to a couple of millibars below its normal pressure and the time of development of Shanghai, Formosa or Yellow Sea Lows is 18-30 hours.

An important provider of short range clues to development of Yellow Sea Lows is the Honan Low which is usually developed by the influence of approaching Mongolian or Takla Makan Desert Lows. An average lag time of 12-24 hours between the time the Honan Low drops to a couple of millibars below its normal pressure of 1016mb in winter, 1010mb in March-April and 1004mb in April-May-June and the time of development of a Yellow Sea Low has been computed. The Honan Low is sometimes associated with Shanghai and Formosa Lows but is more important and reliable with Yellow Sea Lows.

An important provider of long range clues to development of Yellow Sea, Shanghai or Formosa Lows is the Mongolian Low when impulses are moving along the Icelandic Storm Track. An average lag time of 48-60 hours between first appearance of the Mongolian Low and development of a Yellow Sea, Shanghai or Formosa Low has been computed using the following qualifications:

1. That the Mongolian Low first appears 12 hours prior to the arrival of the impulse from the northwest travelling on the Icelandic Storm Track.

2. That the Mongolian Low then becomes the dominating low and moves eastward at a speed of 25-30 knots.

3. That there is approximately a 7° longitudinal lag of the Yellow Sea, or Shanghai Low behind the Mongolian Low.

The Mongolian Low is most often associated with the Yellow Sea Low, next most with the Shanghai Low and least of all with the Formosa Low.

The Takla Makan Desert Low provides equal long range clues to development of all three lows off the China coast. Sometimes the impulses aloft which produce the Takla Makan Desert Low travel eastward along the Kunlun Mountains Storm Track while at other times they travel southeastward along the Himalayan Storm Track.

An average lag time of 72-84 hours between first appearance of the Takla Makan Desert Low and development of the Yellow Sea, Shanghai and Formosa Lows has been computed using the following qualifications:

1. The Takla Makan Desert Low first appears 12 hours prior to arrival of the impulse aloft travelling along the Mediterranean Storm Track.

2. The "kick-off" pressure is above 1004mb.

3. The Takla Makan Low then moves eastward at an average speed of 25 to 30kts.

4. An average lag figure of 48-72 hours has been computed for those seasons in which the "kick-off" pressure is below 1000mb.

A prerequisite is a well developed precipitation pattern over southeastern China east of the Yunnan Low which indicates overrunning and isentropic upslope which contribute to general pressure falls over the entire area. Cyclogenesis is encouraged under the influence of an impulse aloft approaching from the west colliding with strong southerly flow in the low levels near the east China Sea.

Timing and placing of the Yellow Sea, Shanghai and Formosa Lows on prog charts is a direct function of prognosis of 500mb height fall centers approaching from the west. When potential development is indicated, actual subtractions, station by station, of the 500mb heights must be made in order to detect small magnitude centers which are capable of producing the triggering mechanism. Actual subtractions are necessary in order to pinpoint the position of the centers such that good continuity can be established, and to compensate for smoothing of contours on analysis which leads to inaccuracies in graphical computations. Future speed and direction of movement depend upon movement and changes in intensity and amplitude of the associated impulses aloft. Upper air progs must be accurate if they are going to help in placing the surface lows. However, normally the intensification is indicated by the surface and auxiliary charts which require adjustments of the upper air progs.

Figure 7 shows a January Shanghai Low developing. A Yunnan Low with central pressure of 1010mb developed 36 hours prior to this chart and sounded an alert. Figure 8 shows the development of a downrush high pressure cell to the rear of the Shanghai Low.

Figures 9 and 10 show the development of a Formosa Low which tracked northeastward through the Tokyo area. Clues for this direction of movement are furnished by the deep low over Russia which is indicative of the position of a long wave or strong short wave trough near that longitude which in turn means southwesterly flow over Japan. Note also that the central pressure in the Yunnan Low is less than its "kick-off" pressure of 1008mb which means that the Formosa Low is ready to move out. Note also the cutoff high to the rear of the developing Formosa Low which is indicative of strong cold downrush behind a short wave trough aloft which means that a sharpening of the amplitude is occurring, resulting in more southerly winds in advance of the trough.

Figures 11 and 12 show the development of a Formosa Low which tracked eastward. Note in this case that an intense high cell is located over Russia whereas, in the above paragraph, a low was located near this longitude. The high indicates the presence of a long wave ridge near that longitude which means that large scale momentum aloft is directed more eastward and northwesterly flow aloft prevails over the Tokyo area. The downrush high is missing, indicating little change in amplitude.

SECTION 14

Verkhoyansk - Bodaybo - Dzindzilk Highs

Due to long hours of darkness and extensive periods of radiation over vast cold land masses, many regions of Asia are favorite high pressure producers in winter. Due to their method of reduction to sea level, many misleading pressures are reported and are difficult to draw for. There are three notable areas of stagnating winter high pressure cells which will be discussed here. They are predominantly cold weather features which disappear and lose their importance in summer. The main importance of their existence and depiction on surface analyses is to give the forecaster a "first-glance" clue to the presence or absence of blocks to certain storm tracks.

Verkhoyansk High. The Verkhoyansk High is a semi-permanent feature located near the city of Verkhoyansk (24-266) in the valley near the Verkhoyansk and Chersskiy Mountains, which disappears for short periods of time when strong impulses travel through the Siberian Storm Track. Its presence indicates that a storm is not moving along the Siberian Storm Track.

Bodaybo High. The Bodaybo High cell is a semi-permanent feature located in the cold mountain regions to the northeast of Lake Baykal, which disappears for short periods of time under influence of strong impulses travelling along the Siberian or Icelandic Storm Tracks. Under stagnant conditions aloft when the Verkhoyansk and Dzindzilk Highs are also intense, the center of a smoothed high pressure pattern may be shown when the central value of the Bodaybo High is the largest. Its presence indicates the presence of a block to the two northern storm tracks. The key station is Bodaybo (30-253).

Dzindzilk High. The Dzindzilk High is a semi-permanent feature of the Sayan Mountains which disappears for short periods of time under influence of impulses travelling along the Icelandic Storm Track. When the Dzindzilk High is the dominating feature, it is suggested that storms can no longer move along the Icelandic Storm Track but must either travel along the southernmost or the Siberian Storm Tracks. Pressures at Dzindzilk have been related to snow patterns in the Tokyo area in another section of this article. The Dzindzilk High has the highest central pressure of any high cell in the northern hemisphere reaching as high as 1088mb in very cold winters.

Numerous examples of these high cells can be seen throughout this article. Figure 49 shows all of them occurring simultaneously.

SECTION 15

Takla Makan High

In winter, spring and fall it is possible to analyze a high in the Takla Makan Desert caused by cold, dry air drainage over the mountains to the north and northeast. This high has little significance as a weather producer. However, its presence can be used negatively. As long as there is a high in the Takla Makan Desert it is suggested that impulses are not moving along the Kunlun Mountains Storm Track. When an impulse does approach, these high pressures can fall very rapidly.

Figures 6, 8 and 9 show Takla Makan Highs which have replaced Takla Makan Lows which preceded Yellow Sea, Shanghai and Formosa Lows.

SECTION 16

Downrush High

Another frequently recurring feature is the high cell which develops to the rear of some of the Shanghai or Formosa Lows near 25-30°N and 115-120°E. This high cell is produced by downrush of cold dry air to the rear of the associated trough aloft. Usually this high cell tracks eastward along 30°N but sometimes will stagnate in its region of origin. The importance of the development of the downrush high is that it indicates presence of air sufficiently dense to the rear of the trough aloft to contribute to amplitude changes and steer systems more northeasterly than indicated on current analysis. Systems also deepen more rapidly when the downrush high develops.

Figure 8 shows a January downrush high cell to the rear of a Shanghai Low. Figures 9 and 10 show a February downrush high behind a Formosa Low.

SECTION 17

Tokyo Snow Pattern

In this section a case study of a heavy snow pattern in the Tokyo area will be related to the Dzindzilk High, the Yunnan Low and the Himalayan Storm Track.

Climatology suggests that substantial snowfall will occur in the Tokyo area approximately every three years and that severe snowstorms occur approximately every ten to fifteen years. This section is presented to show the synoptic pattern associated with the snowstorm of 10-12 February 1967 during which approximately sixteen inches of snow fell in the Kanto Plains with accumulations measured at ten to twelve inches.

A hazardous driving condition existed during this storm and numerous traffic accidents were reported. It is important that the weather forecast be firmly worded during these storms to warn American personnel of this hazard.

Drizzle and rain began in Tokyo at 080900Z with occasional periods of slush and continued until continuous snow began at 092100Z. Numerous waves developed on the stationary Honshu Front along the southern coast, reminiscent of the frontal structure associated with the summer Bai-U. Snow continued to fall until 121300Z.

Figure 43 shows the surface synoptic pattern at 080000Z, 9 hours before liquid precipitation began and 45 hours before snow began. The pressure at Dzindzilk is 1064mb and Verkhoyansk reports 1037mb. The pressure in the Yunnan Low is 1007mb. A wave has developed near Kyushu and the high pressure ridge crosses Honshu near 40°N.

Figure 44 is a 500mb chart for 080000Z showing a short wave trough moving along the Himalayan Storm Track.

Figure 45 is a 500mb chart for 090000Z showing many short wave wind shift lines moving along the Takla Makan and Himalayan Storm Tracks.

Figure 46 is a 24 hour 500mb height change chart for 090000Z analyzed for increments of height falls based on station by station subtractions. The total height change centers i. [illegible]

Figure 47 is a surface chart for 081800Z, 27 hours before snow began. Note the numerous waves on the frontal system. The pressure at Dzindzilk is 1070mb while Verkhoyansk reports 1038mb. The pressure in the Yunnan Low is 1006mb. The high pressure ridge remains near 40°N.

Figure 48 is a surface chart for 090600Z. The main features remain basically unchanged.

Figure 49 is a surface chart for 091800Z. Note the pressures at Verkhoyansk, Bodaybo, Dzindzilk and Yunnan indicating a tighter packing of the "big-picture" thermal gradient.

Figure 50 is an 850mb chart for 090000Z. Note the tight thermal packing near Tokyo. Figure 51 shows the 850mb 24 hour temperature changes approaching Tokyo.

Figure 52 is an 850mb chart for 091200Z. Figure 53 shows the 850mb zero change line passing through Tokyo.

Figure 54 is a surface chart for 111200Z approximately 24 hours before the snow ended. The numerous ripples along the front to the south have disappeared and an organized low has begun to intensify.

Figure 55 shows the strength and direction of the jet stream at 080000Z indicating high level overrunning, strong southwesterly flow, and upslope isentropic motion. The speed of the southern jet (215kts) represents tight diagonal thermal packing.

Figure 56 is a RAOB sounding for 091200Z and 100000Z. The wet bulb potential temperature totals at 850mb, 700mb and 500mb is 28 on the 100000Z sounding. Using the quantitative precipitation table at the end of this section, 0.9 inches of precipitable water is available. Using the conversion to snow factor table, 9 inches of snowfall per 12 hours is indicated. However, accumulations reached only half this figure because of the warm ground.

<u>Summary</u>. The presence of the Dzindzilk, Bodaybo and Verkhoyansk Highs indicates a blocking of any storms which attempt to move along the Icelandic or Siberian Storm Tracks. This leaves only the Takla Makan,

Himalayan and Southern Storm Tracks open. The pressure at Dzindzilk is the key to the presence of air sufficiently dense to continually surge further and further southward. The pressure in the Yunnan Low indicates that warm impulses aloft are moving through the Himalayan Storm Track. Somewhere, the two contrasting forces must collide. Climatological jet stream positions suggest this collision in the Tokyo area.

Note that the pressure at Dzindzilk rose to above 1060mb at the same time the Yunnan Low dropped to less than 1008mb. This occurred 9 hours before liquid precipitation began and 45 hours before snow began. The pressure at Dzindzilk rose to 1070mb 27 hours before snow began. The pressure at Bodaybo rose to above 1050mb 3 hours before snow began. While these pressures were rising the Yunnan pressure continued to fall. Correlations are certain to exist between these various pressure gradients and refinements can be obtained by using such parameters as the 850mb temperature change cooling centers for timing factors.

Heavy snow in the Tokyo area in December is rare. However, usually a few very light snow showers occur around Christmas time. These flurries are not important as a weather hazard but forecasting them merits a moral victory. It has been noted that when the pressure in the Dzindzilk or Bodaybo High approaches 1080mb Tokyo will get its first snow flurry with the passage of the next 850mb temperature change cooling center.

TABLE 1
Precipitable Water Table

θ' TOTALS	AMOUNT (in.)
72	12.0
66	9.0
60	7.0
54	5.0
48	3.0
42	2.0
36	1.5
30	1.0
26	0.8
22	0.6
18	0.4
4	0.2
-6	0.1
-14	0.08
-22	0.06
-30	0.04
-38	0.02
-40	0.01

TABLE 2
Conversion to Snow Table

SFC TEMP. (F°)	FACTOR
38 to 32	10
31 to 26	11
25 to 21	12
20 to 16	14
15 to 11	18
10 to 00	25

Instructions for using the tables.

1. Compute the wet bulb potential temperature for the 850mb, 700mb and 500mb levels.

2. Add them together to get θ' totals.

3. Enter table one to obtain quantitative amount of precipitation (12 hours).

4. In the case of snow, determine the factor to be used by forecasting the temperature range during the snowfall.

5. Multiply this factor by the amount of precipitation to get inches of snowfall.

SECTION 18

Chungning High Related to SEA Frontal Surges

In autumn and winter, pressures reported in the area near 40°N and 105°E make it possible to show a high pressure cell on surface analysis. It is not important to show this high cell unless auxilliary charts indicate possible future movement. However, there is a direct relationship between the pressures in this region and potential penetration southward through southeast Asia (SEA) of frontal surges. The station which has proven most reliable in evaluating the weight of this air is Chungning (53-705). During autumn and winter a "kick-off" pressure of 1050mb indicates the presence of air sufficiently dense to cause the front to surge southward all the way through South Vietnam. If the pressure peaks out near 1050mb, then starts to fall, the front will produce gusts in South Vietnam in the order of 20-35kts. If the pressure continues to rise to a peak as high as 1056mb, gusts in South Vietnam will be in the 35-50kts bracket. The direction is north to northeast. In late winter the normal "kick-off" pressure is 1044mb and the peak pressure indicating gusts in the 35-50kts bracket is 1048mb. In late February and March a pressure of 1030mb at Chungning indicates the presence of air sufficiently dense to cause frontal surges through North Vietnam but will not penetrate all the way through South Vietnam. Frontal surges through South Vietnam normally begin in November and end in February. They are difficult to follow on the surface chart.

The key chart for analyzing and forecasting frontal surges through South Vietnam is the 850mb chart. Various values of 850mb wet bulb temperature definitives of frontal boundaries have proven very reliable in evaluating transitional frontal jumps when used in conjunction with the pressure at Chungning. Watch closely the 6°, 11° and 15°C values.

Timing of the beginning of the frontal surge southward into North Vietnam has been related to the following factors:

1. The "kick-off" pressure at Chungning for the appropriate season.

2. The time of passage of a surface low in the Tokyo area.

3. The time of passage of a 500mb 24 hour height fall center to the east of 135°E in the middle latitudes. This factor can be used in long range forecasting of these surges when extrapolating 500mb height fall centers from western Europe using an average speed of 10° of longitude per day.

The above relationships state that a frontal surge will begin in North Vietnam on occasions when all three prerequisites are satisfied.

Figure 57 is a surface chart for 1800Z, 29 November 1966. Note the pressure at Chungning. The pressure peaked out at 1058mb. The front surged through South Vietnam and produced heavy rains at some places and

and gusts of 40kts at Cam Rhan Bay.

Figures 58, 59 and 60 show 850mb frontal positions for the period 0000Z, 28 November 1966 to 0000Z 30 November 1966. Figure 58 shows the front near the 6°C isotherm. Figure 59 shows the front near the 11°C isotherm. Figure 60 shows the front near the 15°C isotherm. These transitional frontal jumps occurred repititiously during 1966-1967. Figure 60 shows the pressures at Chungning at various times.

SECTION 19

Rainy Season in Tokyo (Bai-U)

The Bai-U is so named because it comes at the time of year when the plums are getting ripe and require a lot of rain to produce a bumper crop. The rainy season normally begins about the 5th to 15th of June and continues through the 10th to 20th of July. Sunshine is rare and the weather is generally muggy with frequent periods of drizzle and rain. Tropical storms recurving from the south and short wave impulses aloft from the west cause occasional short periods (less than 24 hours) of moderate to heavy rain.

The synoptic pattern associated with the Bai-U is a simple one. The surface chart shows a quasi-stationary frontal system between the southern coast of Japan and 30°N. Numerous disorganized waves or ripples appear along the front due to paralleling southwesterly flow aloft. The 500mb chart shows a quasi-stationary long wave low near Korea which varies in location between 30°N and 45°N and between 120°E and 135°E. Short wave impulses drop into this low and cause it to alternately progress and retrograde. The short waves rotate around its periphery and finally become a part of the stationary long wave low. Each of these short waves brings with it a 500mb height fall center which is the triggering mechanism for developing organized surface lows along the quasi-stationary frontal system. **A surface high exists to the east of the Japanese Islands.**

Due to the tightening of the diagonal and horizontal thermal gradient aloft associated with these short waves, 700mb winds increase rapidly to above 40kts and 500mb winds reach as high as 80kts. After the low passes to the east of Japan these winds aloft decrease to near their normal of 10-5 kts.

Tropical storms which develop near the Philippine Islands have a climatological track which brings a few of them toward the Tokyo area during the rainy season.

A search was made to the south and to the west of the Tokyo area looking for clues to long range forecasting of the establishment of the Bai-U pattern and the following correlations were found:

The Beginning. A search was made upstream on the 500mb charts in order to detect a mechanism which might control the approximate beginning of the Bai-U. In both 1965 and 1966 it was discovered that the rainy season began approximately 12 days after the first appearance of a closed low at 500mb in the Steppe regions to the north of Tashkent, Russia (38-450). The significance of this Tashkent 500mb low is that it is a downstream by-product of lows which move along the Mediterranean Storm Track. The appearance of the first one indicates that the long wave pattern over the Atlantic Ocean is favorably located for the establishment of an active Mediterranean Storm Track with more impulses to come. These lows aloft then track eastward near the Kunlun Mountains Storm Track until they arrive in the Korean area and resultantly establish the quasi-stationary long wave low at 500mb.

The difference between these summer impulses along the Mediterranean Storm Track and the Takla Makan Desert Lows of other seasons (previously discussed) is that the summer ones may not be reflected at the surface due to instability over the rugged terrain which produces an erratic surface reflection due to "jump-type" lows depending upon geographical location of certain reporting stations.

The Ending. A search was made in the tropics in order to detect a mechanism which might control the approximate ending of the Bai-U. In both 1965 and 1966 it was discovered that the Bai-U ended approximately 12 days after the first appearance of a wind as strong as 100kts in the Equatorial easterly jet stream which flows across the Philippines into southeast Asia. The significance of the 100kts wind speed is that it is a product of the increased thermal packing caused by the clash between the tropical ridge, which is stubborn to move northward, and the mass movement northward of air from the Equator which migrates with the sun. The tropical ridge is stubborn because the middle latitude westerlies are reluctant to move. Therefore a transition period is necessary. The 100kts wind indicates that the mass migration northward of the Equatorial air is strong enough to become the domineering feature and start to push everything out of the way. The net result is that the tropical ridge is shoved northward which causes the frontal system to be spilled over the mountains into the Sea of Japan where it remains during the hot season except for a few short-lived trips southward.

The "big picture" 500mb pattern associated with the Bai-U shows a cut-off low along the west coast of the United States balanced on the other side of the hemisphere by the Tashkent Low. A closed low in the mid-Pacific with troughing near 180°. A cut-off high or ridging in the Sea of Okhotsk. A quasi-stationary low near Korea. Tropical ridge along 20°N.

Figure 61 is a surface chart for June 1st and shows the frontal system pushed well to the south of 30°N by strong impulses aloft in the westerlies. Note the Dzindzilk High cell and that it is still strong. Figure 62 is a 500mb chart for June 1st, also, which shows the short wave near Tokyo associated with the front. Note the Tashkent Low near 45°N and 70°E. This was the first appearance in this series of this Tashkent Low. The tropical ridge is near 20°N.

Figure 63 is a surface chart for June 13th and shows a well organized low to the south of Japan and the frontal zone north of 30°N. Two low cells extend from the Takla Makan Desert toward the Sea of Japan. The Dzindzilk High is weakening slightly. Note also the downrush high cell. This was the beginning of the rainy season. Figure 64 is a 500mb chart also for June 13th and shows the quasi-stationary long wave low near Korea. Two more lows appear along 105°E and the Tashkent Low is slightly north of its original position. The tropical ridge remains near 20°N. Also shown is the short wave trough moving into the long wave low.

Figure 65 is a 200mb chart for July and using maximum wind data to locate the [illegible] positions. The Equatorial easterly jet is shown and this was the first day of evidence of a wind in excess of 100kts. The tropical ridge is near 30°N. Note that the westerlies are still strong and extend southward almost to the tropical ridge line.

Figure 66 is a surface chart for July 14th showing the frontal system having spilled across the mountains into the Sea of Japan. This was the ending of the rainy season. Note that general low pressures now prevail over Asia. Figure 67 is a 500mb chart for July 14th. The tropical ridge has moved northward to near 30°N. The quasi-stationary low near Korea has migrated northward to a position north of its normal location. A separate high cell is evident to the south of the Japanese Islands. Figure 68 is a 200mb chart for July 14th showing the tropical ridge north of 30°N. The Equatorial Jet is also shown.

Figures 69 and 70 show 500mb comparisons between June 1966 which was a normal, wet Bai-U and June 1967 which was an abnormal, dry year. Figure 69 shows all the features in approximately the right place. Figure 70 shows none of the features in exactly the right place. The entire atmosphere appears to be tilted 5-10° latitude from Tashkent toward the cutoff low on the west coast of the United States. The lows over Asia are 10° latitude too far north. Ridging covers the mid Pacific. At the same time, the tropical ridge is almost 5° latitude further south giving the impression that the entire atmosphere has been stretched, with a net result of loose thermal packing and weak frontal boundaries.

SECTION 20

Typhoon Season And The Return of Autumn

The rainy season which ends in mid-July is followed by 3 to 6 weeks of hot humid weather over Japan during which time relief from the heat comes only in the form of air mass showers or thunderstorms and short lived surges southward of the surface frontal system. The hot season is in turn followed by a seasonal transition period during which the frontal system alternately surges southward then northward until autumn returns to stay. This transition period is also the period when maximum tropical storm and typhoon activity occurs, making September the wettest month of the year.

The return of the cool air and its timing is directly associated with the passage of typhoons which have a climatological track that has been readjusted by the shift in the long wave pattern such that an Icelandic Storm Track is re-established. When a strong impulse aloft moves through the Icelandic Storm Track, it is capable of magnetically turning a typhoon northward and heading it toward Japan. In the absence of a typhoon, these impulses aloft sometimes develop a Yellow Sea or Shanghai Low. The cold front surges southward after the passage of each typhoon or northeastward tracking low. It gradually frontolyzes as the transition zone widens, then moves northward as a warm front when the next typhoon or low approaches

During this season the typhoons produce strong wind gusts because the sea surface temperatures are warm and allow the storm to remain a warm core system and maintain its pressure gradient. In other seasons, when tropical storms move through Tokyo, cooler sea surface temperatures combat the normal warm core characteristics of the storm and diminish the storms circulation but produce heavy rains as a substitute.

Figures 71, 72 and 73 show favorite regions of development and tracking of typhoons in September. T.D. 27 became typhoon Ida and got caught in the circulation of Helen. Ida passed through Tokyo with wind gusts above 90kts in the Kanto Plains.

Table 3 is a climatological summary showing, by month, favorite areas of development, latitude of dissipation or becoming extratropical, and the record number of tropical cyclones for any one year. Data used covered a 17 year period.

TABLE 3

Month	Area of Development	Typical Latitude of Dsptn/Xtrtrpcl	Record Number
January	5-10°N/135-155°E	15°N	1
February	5-10°N/135-155°E	15°N	1
March	5-10°N/135-155°E	15°N	1
April	5-10°N/135-155°E	25°N	1
May	7-12°N/130-155°E	35°N or above	2
June	8-15°N/130-155°E	Ditto	3
July	9-20°N/130-160°E	Ditto	6
August	11-25°N/130-160°E	Ditto	8
September	8-20°N/135-165°E	Ditto	5
October	7-20°N/135-170°E	Ditto	5
November	6-15°N/140-170°E	33°N	5
December	5-10°N/140-160°E	25°N	3

SECTION 21

Climatology - Synoptic Check List - Tokyo

JANUARY

January is the coldest month. Minimum temperatures drop into the teens but rarely remain below freezing for an entire 24 hour period. Appreciable snowfall occurs approximately every 3 years and heavy snowfall around every 12 years. Thunderstorms and typhoons are nonexistent.

Yellow Sea, Shanghai or Formosa Lows may develop. Storms move along all tracks but rarely along the Kunlun Mountains Track. Yellow Sea Lows are secondary in importance to Shanghai and Formosa Lows, which dominate during cool, wet years. The Lung Chiong Low dominates in cold, dry years. Watch the pressure in the Dzindzilk High.

EARLY FEBRUARY

Features are almost identical to those of January.

LATE FEBRUARY

A rapid warming trend comes in late February as Yellow Sea Lows begin to develop after the winter recess. The first duststorm may occur if winter was dry. Inevitably the duststorms come in early March. Thunderstorms nonexistent but possible within a 200 mile radius. Average precipitation takes an upward trend.

Storms move along all tracks but are rare along Siberian Storm Track, occurring only in extremely cold years.

MARCH

Temperatures may drop to near 20°. Mean precipitation starts its gradual rise as quantitative precipitable water increases with decreased mean densities. 2 to 3 thunderstorm days can be expected in the Kanto Plains. Duststorms accompany Yellow Sea Lows.

Storms move along all tracks but are rare along Siberian Storm Track, occurring only in extremely cold years.

APRIL

Warming trend continues but temperature may drop as low as the upper 20's. Mean precipitation about same as March. 3 to 4 thunderstorm days can be expected and the possibility of a squall line rolling off the hills must be considered.

Siberian Storm Track disappears. Yellow Sea, Shanghai and Formosa Lows still dominate.

MAY

Temperature rises to above freezing to stay. Mean precipitation continues to increase. 4 to 6 thunderstorm days can be expected. A tropical storm or two will recurve near the Philippines and move through the area.

Storm pattern unchanged from April. In late May look for Tashkent 500mb low for long range clues to development of the Bai-U pattern.

JUNE

Temperatures continue to increase with average maximum in the upper 70's. Precipitation reaches its secondary maximum as the rainy season (Bai-U) begins around the 10th of the month. Typhoons are rare but possible. Thunderstorms occur on about 4 to 6 days. Damp, humid and moldy days begin.

Shanghai and Yellow Sea Lows prevail as Formosa Low begins to disappear. In late June look for 100kts wind in the Equatorial easterly jet stream for clue to ending of the Bai-U.

EARLY JULY

The Bai-U continues till about the middle of the month with little difference from late June weather. Damp, humid and moldy days continue until the tropical front is dumped over into the Sea of Japan. Typhoon expectancy remains unlikely. Himalayan Storm Track begins to weaken. The Yunnan Low gradually loses its importance.

LATE JULY - AUGUST

This is the hot, humid season with maximum temperatures and humidities in the 80's. 6 or 8 days of air mass thunderstorms may be expected. Mean precipitation drops because of the lack of frontal weather. Typhoons become more frequent.

Weak impulses move through the Icelandic and Kunlun Mountains Storm Tracks but most of them get torn up by vertical motions over the rugged terrain of eastern Asia. Now and then an impulse is strong enough to produce a Yellow Sea Low which may cause brief frontal passages in Tokyo. The Yunnan Low is gone. Shanghai and Formosa Lows are gone.

SEPTEMBER

Temperatures drop to an average maximum of 80° but humidity remains about 85%. This is the maximum typhoon month and the beginning of the return of autumn with frontal precipitation. These two factors make it the wettest month of the year. Thunderstorm frequencies drop from that of August due to longer days in the cold air behind frontal surges.

Stronger impulses move through the Icelandic and Kunlun Mountains Storm Tracks. The Himalayan Track gradually returns and this re-establishes the Yunnan Low. Yellow Sea and Shanghai Lows return. Formosa Low is still gone. Watch for Oshima Low preceding Shanghai Low in latter part of month.

OCTOBER

Average maximum temperatures drop to 70° but humidity remains near 80 %. Minimum temperatures remain above freezing. Typhoon and Thunderstorm frequencies drop but mean precipitation remains high due to more frequent Shanghai Lows.

Impulses move through the Icelandic, Kunlun Mountains and Himalayan Storm Tracks. Shanghai and Yellow Sea Lows prevail. Formosa Low may reappear. Watch for Oshima Low in front of Shanghai Lows.

NOVEMBER

Average maximum temperature drops to 60° and the first freeze of the year occurs. Humidity drops gradually. Typhoons rare but possible. Precipitation drops rapidly as jet shifts southward. Snow flurry rare but possible.

Impulses track through the Icelandic, Kunlun Mountains and Himalayan Tracks as the Siberian Track begins its return. Yellow Sea and Shanghai Lows prevail with occasional Formosa Low. Watch for Oshima Low ahead of Shanghai Lows.

DECEMBER

Average maximum temperatures drop to the low 50's as the mean minimum drops to 32° with a possible min as low as 20°. Mean precipitation continues to drop. The first snow flurry may occur after the middle of the month with little chance of accumulation. Typhoons and thunderstorms nonexistent.

Impulses move through all storm tracks. Shanghai and Formosa Lows dominate as the Yellow Sea Low takes a back seat. Watch the pressure at Dzindzilk and Bodaybo.

SECTION 22

Long Wave Concepts

Seasonal weather regimes in the Tokyo area vary from year to year and on occasions completely reverse themselves from those of the previous year or two. These seasonal changes are controlled by the long wave patterns as indicated on the 500mb chart. The careful forecaster must first back off a little way from the 500mb chart and take a look at the "big picture" pattern in order to establish preconceived ideas before proceeding to narrow the parameters down into a pinpoint forecast.

When a long wave trough is positioned between 145°E and 160°E, a dry season in Tokyo is dictated because upper level flow is northwesterly. When the long wave trough is located between 115°E and 130°E, a wet season is indicated because upper level flow is southwesterly. Forecasting weather in Japan would be easier if we had a simple method of locating and controlling the long wave features within a 5° logitudinal zone. However, scarcity of data and distortions caused by strong short wave troughs make it difficult to locate some features within a 15° longitudinal zone. Also, the zone between 120°E and 150°E is the most notorious deepening region in the northern hemisphere because of the clash between lowlevel warm, moist air over the most expansive ocean in the world colliding with cold air aloft coming off the coldest continent in the world. This deepening zone often gives the impression of being the long wave trough, when in reality the long wave feature is a few degrees to the west.

Normally, the atmosphere of the northern hemisphere is composed of five or six long wave troughs. On rare occasions in winter there may be only four with resultant near zonal flow and in summer it is possible to have seven troughs on occasions when two or three lower latitude cutoffs exist. The numerical count is easier to determine when a hemispheric 500mb analysis and auxilliary charts are available. When the number of troughs is known, a close approximation of the location of doubtful features can be made by assuming a constant spacing between each trough (e.g. 6 troughs divided into 360° equals 60° spacing between each trough) and measuring upstream or downstream from firmly established features such as a stationary low or an omega block.

Certain long wave features in the Pacific Ocean and over the Asiatic continent are persistent and easy to locate at 500mb because of geographical and recurring climatological influences. Examples are: A closed low in the Tashkent area near 45°N and 65°E, a stationary low or high in the Sea of Okhotsk, a stationary low or omega high in the central Pacific, a stationary trough or ridge off the west coast of the United States.

I am not sure that the following statements are true for the entire northern hemisphere because I have not had enough hemispheric analyses available, however, numerous observations make them seem plausible as concerns weather regimes in the Tokyo area.

Under a six wave structure a few recurring specific patterns have been noted. When a stationary low is in the Tashkent region, a long wave trough can be anticipated along 125°E. This is normally true during the rainy season of Japan (Bai-U). When a stationary high is in the Sea of Okhotsk near 150°E, a long wave trough can be anticipated near 120°E.

This is also true during the rainy season of Japan and its significance is that a stationary surface high is reflected nearby which produces continued northeasterly low level flow into the Tokyo area. When a stationary low is in the Sea of Okhotsk, a long wave trough along 150°E is indicated which produces a dry regime in Tokyo. When an omega blocking high is located near 180° longitude between 40°N and 60°N, long wave troughs should be located along 150°E and 150°W with stationary lows near these two longitudes and approximately 5-10° south of the latitude of the omega high. This produces a dry regime in Tokyo. When a stationary low is located near 180° longitude between 40°N and 60°N, a long wave trough can be anticipated near 120°E. This is a wet regime for Tokyo.

Determination of the existence of a five wave structure is difficult. One notable example is that when a stationary low and long wave trough is positioned off the west coast of the United States along 130°W and measurement of 60° of longitude westward (170°E) shows a ridge where there would normally be a trough under a six wave pattern, a ridge or near zonal flow can be anticipated along 110°E which produces a dry regime in the Tokyo area. This is especially true during the dusty season and very strong wind gusts are produced in the Kanto Plains.

In the springtime when a long wave trough is located near 130°E, numerous Shanghai Lows should be anticipated producing a very wet season. After the passage of each low, the clouds disappear rapidly. In the wake of each storm which passes in the early morning, thunderstorms can be anticipated during the afternoon because the low level winds return to a southwesterly direction producing a Kanto Low with resultant southerly influx of warm moisture in the low levels at the same time that upper level cooling is dropping into and out of the long wave trough.

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13. ABSTRACT

Synoptic models designed to improve weather forecasts in the Tokyo, Japan area are presented. The most important weather producers for Tokyo are low pressure centers which develop near Shanghai, China, and in the Yellow and East China Seas. Rugged terrain over Eastern Asia reroutes and distorts synoptic features approaching Japan from the west. The more important geographical effects and the clues they give to low development are discussed. The development of mesoscale features near Japan in advance of major lows is stressed. All synoptic features are named to identify their location or origin. Examples of development and movement of each feature are presented. Included are case studies of heavy snowfall, thunderstorms, typhoons, the rainy season (Bai-U), extended poor flying weather, etc., affecting Tokyo. Preliminary relationships are established between frontal surges over Southeast Asia and passage of synoptic features near Tokyo. Figures showing synoptic feature geography, storm tracks, a composite map of recurring synoptic features, and a descriptive summary of each feature are presented. Brief climatological summaries of Tokyo area weather and monthly typhoon frequency are included. Long wave patterns are related to Tokyo weather in generalized form.

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