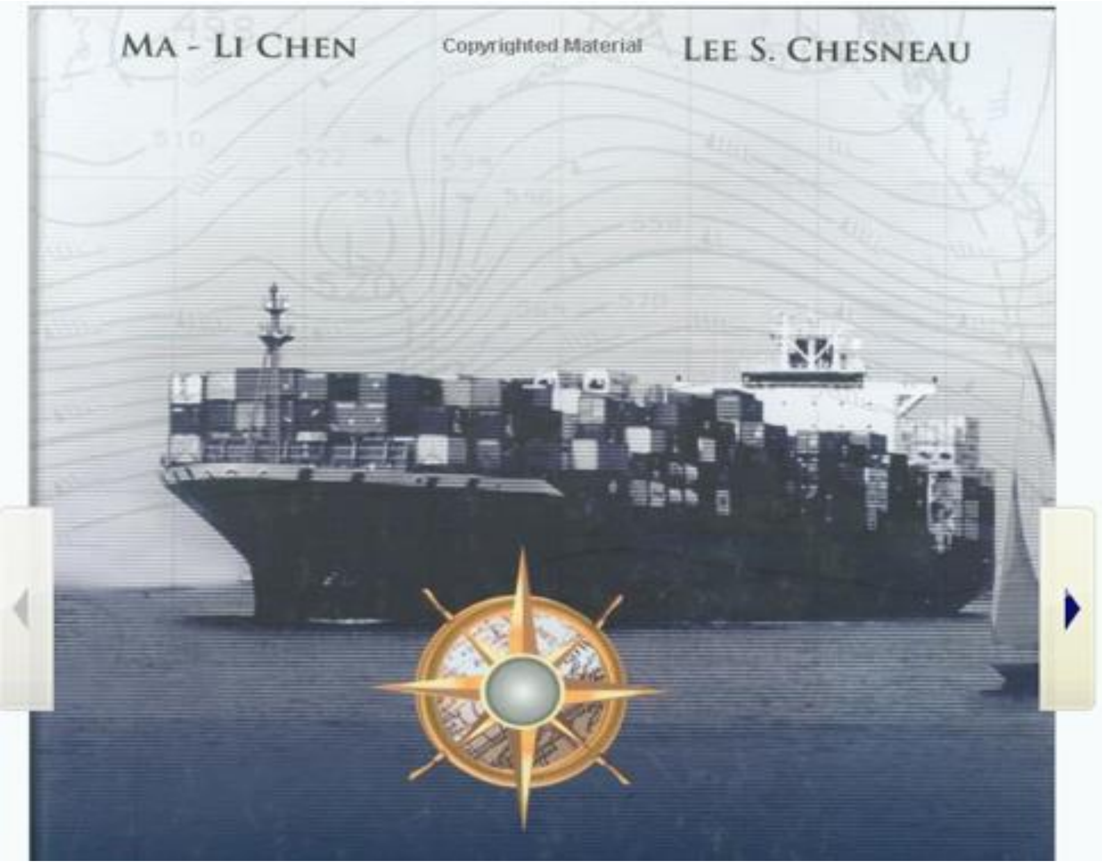
航行中的氣象判斷
(高空500mb氣象圖的運用)

陳馬力船長

Heavy Weather Avoidance and Route Design:
Concepts and Applications of 500 Mb Charts



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Heavy Weather Avoidance and Route Design: Concepts and Applications of 500 Mb Charts Hardcover – October 5, 2008

by Ma-Li Chen (Author), Lee S. Chesneau (Author)

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Originally published as The Technology of 500 Mb High Level Weather Chart on Navigation and Ocean Route Design by Captain Ma-Li Chen in 2002 in Mandarin. © Captain Ma-Li Chen, published by Sense Production, Ltd., Hong Kong. The theories put forward in that edition have been refined and expanded upon by the author and co-author in this edition.

English translation by Weixing Shen , Cover design by Tinashe Rusike, Editing and book design by Linda Morehouse, WeBuildBooks.com, Charts and graphs by Heidi Hackler, of Dolphin Design Tobias Burch, Every effort has been made to assure that this book is accurate, current, and complete as of date of publication.

However, as in the case of all human endeavor, there can be no guarantee that this work does not contain errors or omissions. Therefore, the prudent mariner will not rely only on this or any other single source when guiding his vessel. Please report any errors or omissions to the publisher.

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About author Captain MA-LI CHEN & co-author Mr. LEE CHEANEAU

Captain Ma-Li Chen shares his well-tested routing strategy and describes how it factors in the use of the 500 Mb chart.
His game plan includes a sector analysis of
short wave troughs, breaking them into four distinct zones and prioritizing the
relative safety of navigating through each region. He also discusses the seasonal
migration of the main axis of the strong wind belt, and explains how El Niño and
La Niña events basically shift the position of this mid-atmosphere superhighway.
In short, he puts a real world spin on what Avogadro and subsequent atmospheric
chemists have turned into the scientist's domain.

Lee Chesneau, the Johnny Appleseed of meteorologists, a man whose mission is to train mariners and recreational sailors in the art of making effective forecast decisions based upon a wealth of free information available via SSB weather fax or satellite download. Chesneau lectures to audiences across the country, and his information-rich seminars appeal to both commercial mariners and recreational boaters alike. In this book he has teamed up with (primary author) Master Mariner Ma-Li Chen to create a savvy meteorological text with information that transcends the classroom.

Chen and Chesneau's book is a bridge between the laboratory and the deck of a vessel, and ranks as an essential tool for every blue-water mariner. It's not a one-time read: it's a reference book that goes from the living room to a book rack near the navigator's table—a reference that will be regularly thumbed.

—Ralph Naranjo, Technical Editor Practical Sailor Magazine, past Vanderstar Chair, U.S. Naval Academy

In any event, after studying this book, mariners will never look at the 500 Mb maps as they used to. The authors have made a valuable contribution to shipboard weather routing.

—David Burch, Director of Starpath School of Navigation in Seattle, author of Modern Marine Weather

高空氣象圖運用學

- The Technology of 500mb High Level Weather Chart on Navigation and Ocean Route Design
- 陳馬力編著
- 初版 1998.2
- 再版 2000.2

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4 - 4 氣象損失值參考表綜論
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Uses of Different Constant Pressure Surface

100 Mb…about 53,000 ft or 16,000 meters…Super cell TSTMS, The level which spy planes fly.

250 Mb…about 40,000 ft or 12,000 meters…Commercial eastbound flights, ideal B2 bombing level.

300 Mb…about 30,000 ft or 9,000 meters….Jet stream and divergence measurements, commercial jet westbound flight levels.

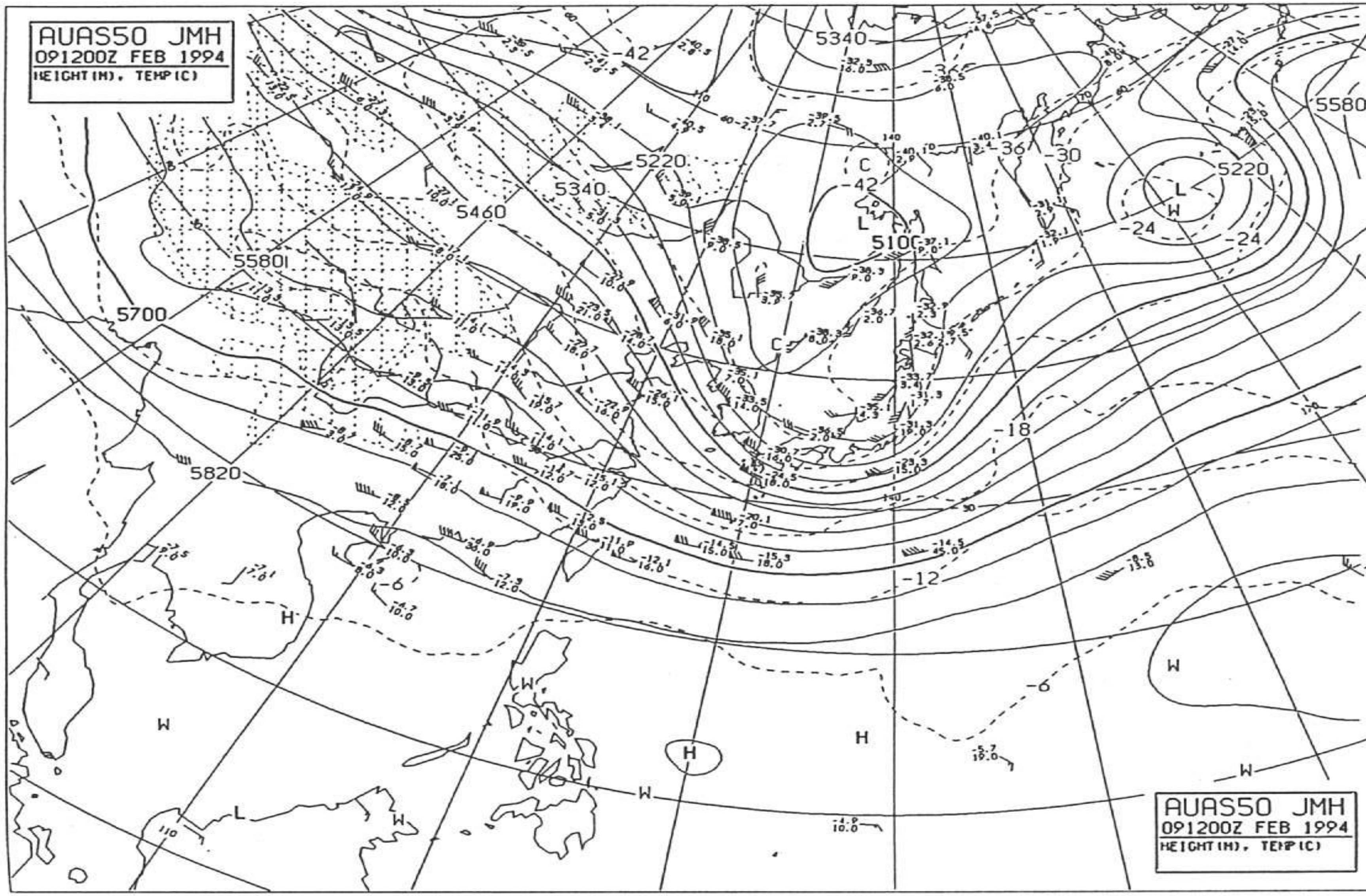
500 Mb…about 18,000 ft or 5,000 meters…Surface storm track.

700 Mb…about 10,000 ft or 3,000 meters….Precipitation forecasts.

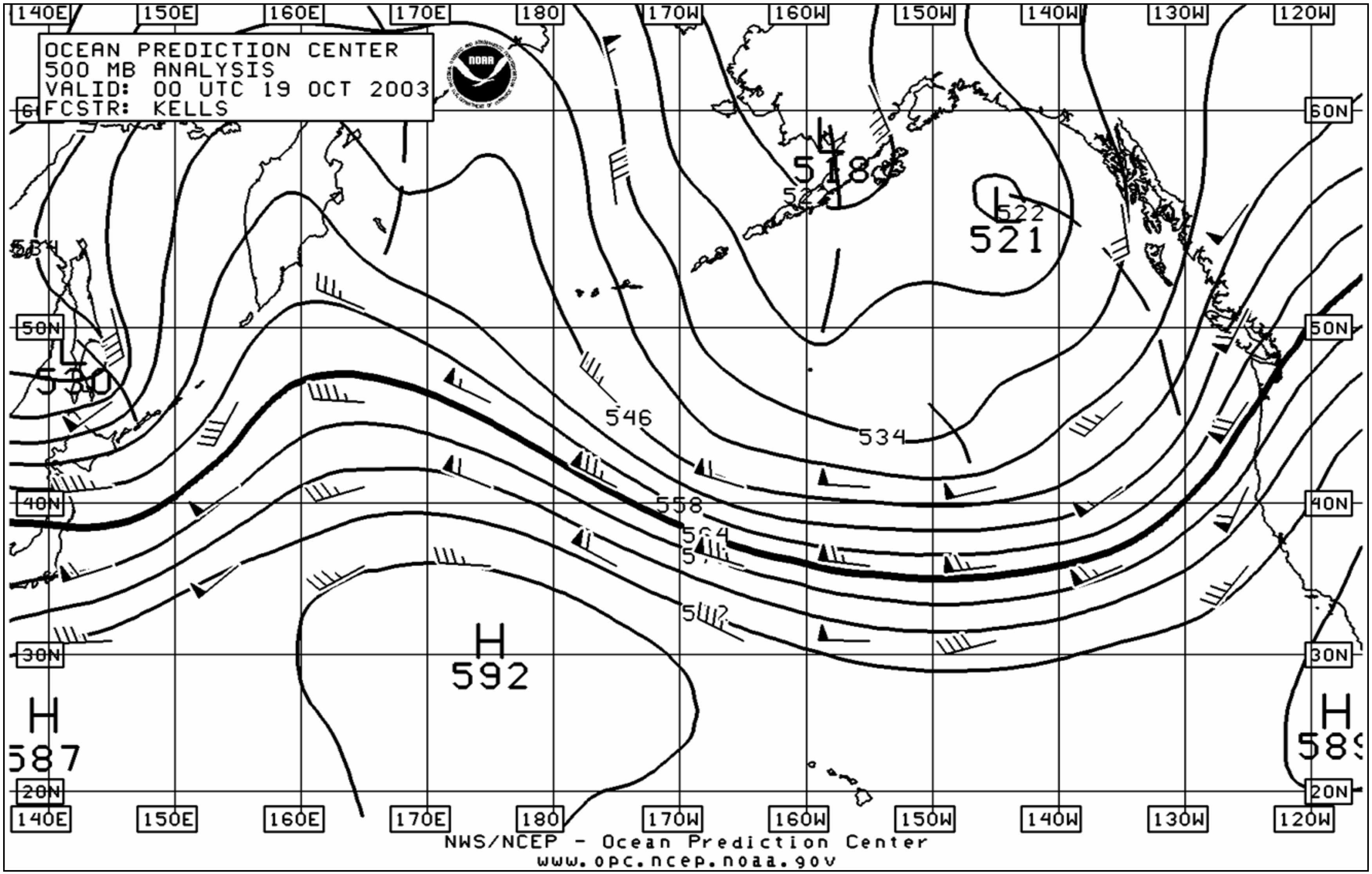
850 Mb or about 5,000 ft or 1,500 meters…Snow vs rain, severe weather i.e., tornadoes. Ideal bombing level for Stealth bombers & carrier based F18 Hornets.

1000 Mb or near surface…Bottom pressure surface used in determining atmospheric thickness for frontal analysis. Also used for surface boundary layer wind speeds and direction.

Japan 500mb chart



USA 500mb chart



Specialize & Generalized strong wind belt

- The whole area between 5400m and 5700m contours, their pressure gradient vary seriously, that makes prevailing westerly wind is strong. This area so defined as “specialize strong wind belt”, in fact, as long as there is a streamline, there has prevailing westerly wind, the “specialize strong wind belt” is so defined for the purpose of comparison and analysis.
- The essence for analysis the meteorological condition by using 500mb upper air chart lies on the determination and application of the “specialize strong wind belt”.

- Since the upper and lower limits of the “specialize strong wind belt” are defined by artificial for the convenient of analysis, that’s why this zone is also called “specialize strong wind belt” which completely occurs often in the transition seasons (i.e. spring or autumn season).
- It should be noticed that during summer, the westerly jet will moving to north and the interval between streamlines become wider. The lower limit (5400m contour) is often biased (or we said “cut off” from the belt), so that it usually cannot form a real belt zone with the upper limit (5700m contour). When there is no such a belt, one streamline should be find in this area between the 5400m and 5700m contour, which surrounding the pole in nearly zonal direction, and combine with 5700m contour, deem it as a “specialize strong wind belt”.

While in winter, the jet zone becomes narrower and moving to south, the 5400m and 5700m contour be pressed to flat type (so called “big knife pattern”), it is not so easy to identify where is the short waves. In this case, One should then shift the lower limit (5400m contour) somewhat north and find the most north streamline which between 5100m and 5400m contours of this area, which surrounding the pole in nearly zonal direction, and combine with 5700m contour, deem it as a “specialize strong wind belt”.
For convenience in researching, the choice of the lower limit contour should be in a zonal direction, and at least spans larger than 30 longitudinal degrees (that means at least can showing one upper short wave), The so-resulted “specialize strong wind belt” is practically meaningful for researching.
The defined of “specialize strong wind belt” aims at analysis and research the surface meteorological conditions.

In fact, as long as the streamlines or contours are in a zonal direction, one can deem there must have prevailing westerly wind, so that as long as the streamlines which surrounding the pole in nearly zonal direction, from the pole to this streamlines is so called “generalized strong wind belt”.

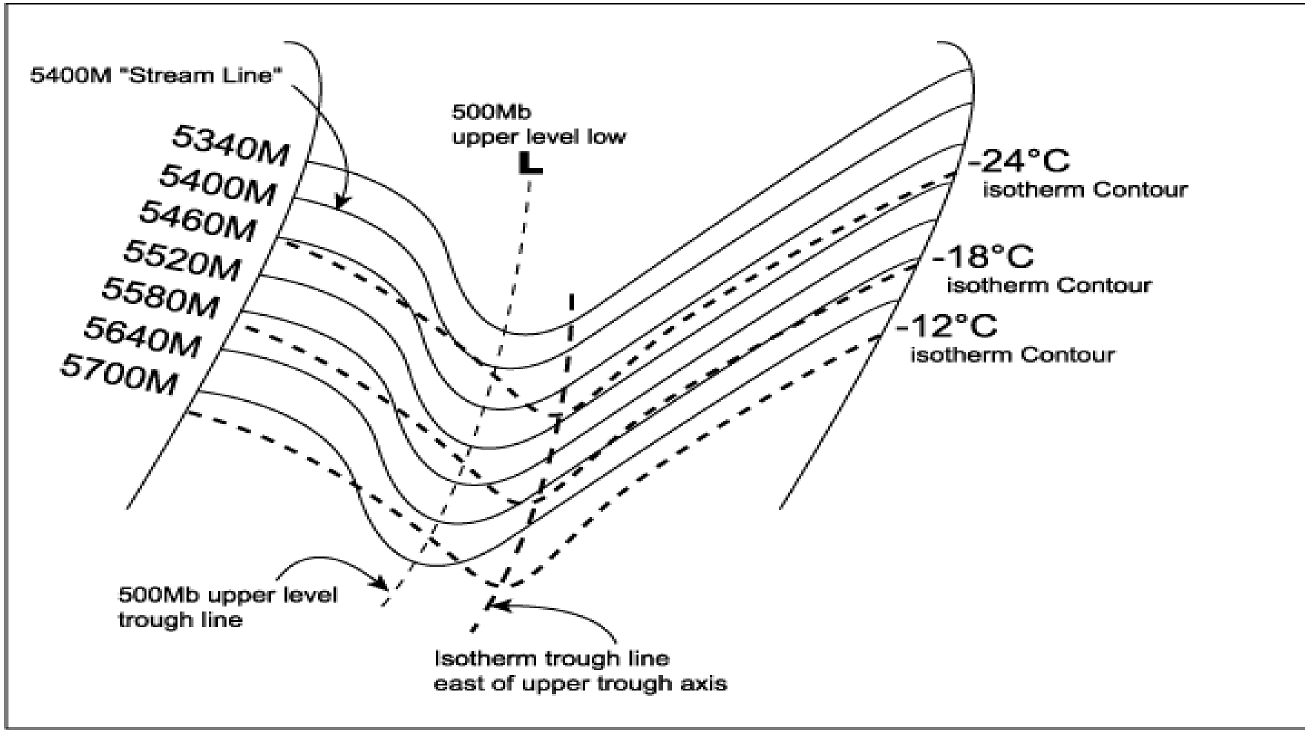
地面低壓可能發生位置的必要條件如下:

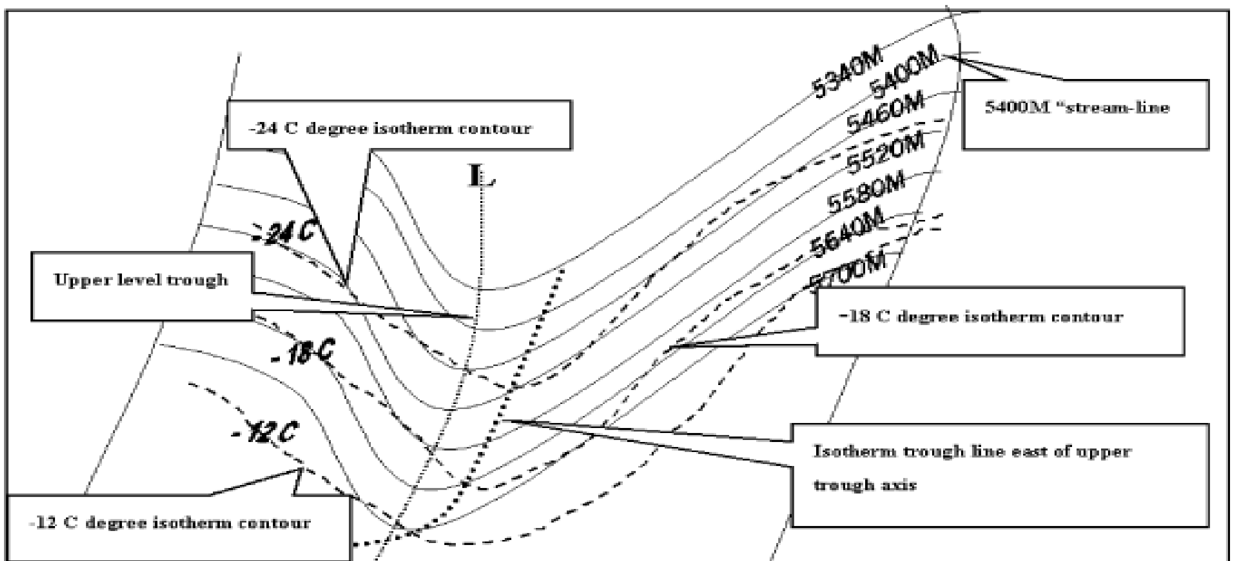
1.必需在高空強風帶範圍之內.

2.必需在高空低壓槽線的東側.

3.必需該地區已有地面鋒系存在.

4.地上鋒面對應高空的等溫線與等壓線交角變大(約15度以上).

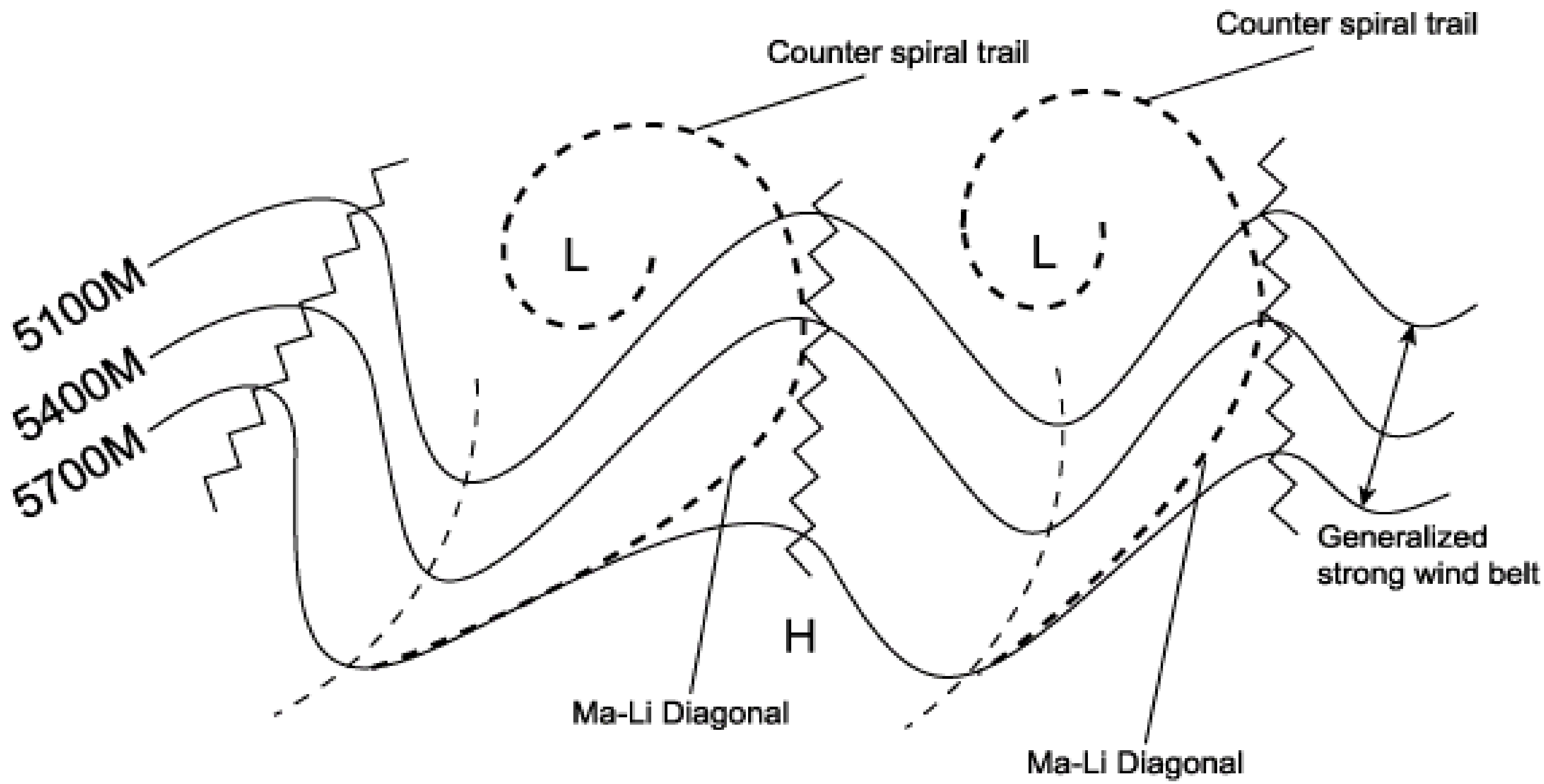

5400M "Stream Line"
500Mb
upper level low
L
5340M
5400M
5460M
5520M
5580M
5640M
5700M
-24°C
isotherm Contour
-18°C
isotherm Contour
-12°C
isotherm Contour
500Mb upper level
trough line
Isotherm trough line
east of upper trough axis


-24 C degree isotherm contour
L
5340M
5400M
5460M
5520M
5580M
5640M
5700M
5400M "stream-line
-24 C
Upper level trough
-18 C
-18 C degree isotherm contour
-12 C
Isotherm trough line east of upper trough axis
-12 C degree isotherm contour


ITAL FLORIDA
TRIESTE
22 06 2007

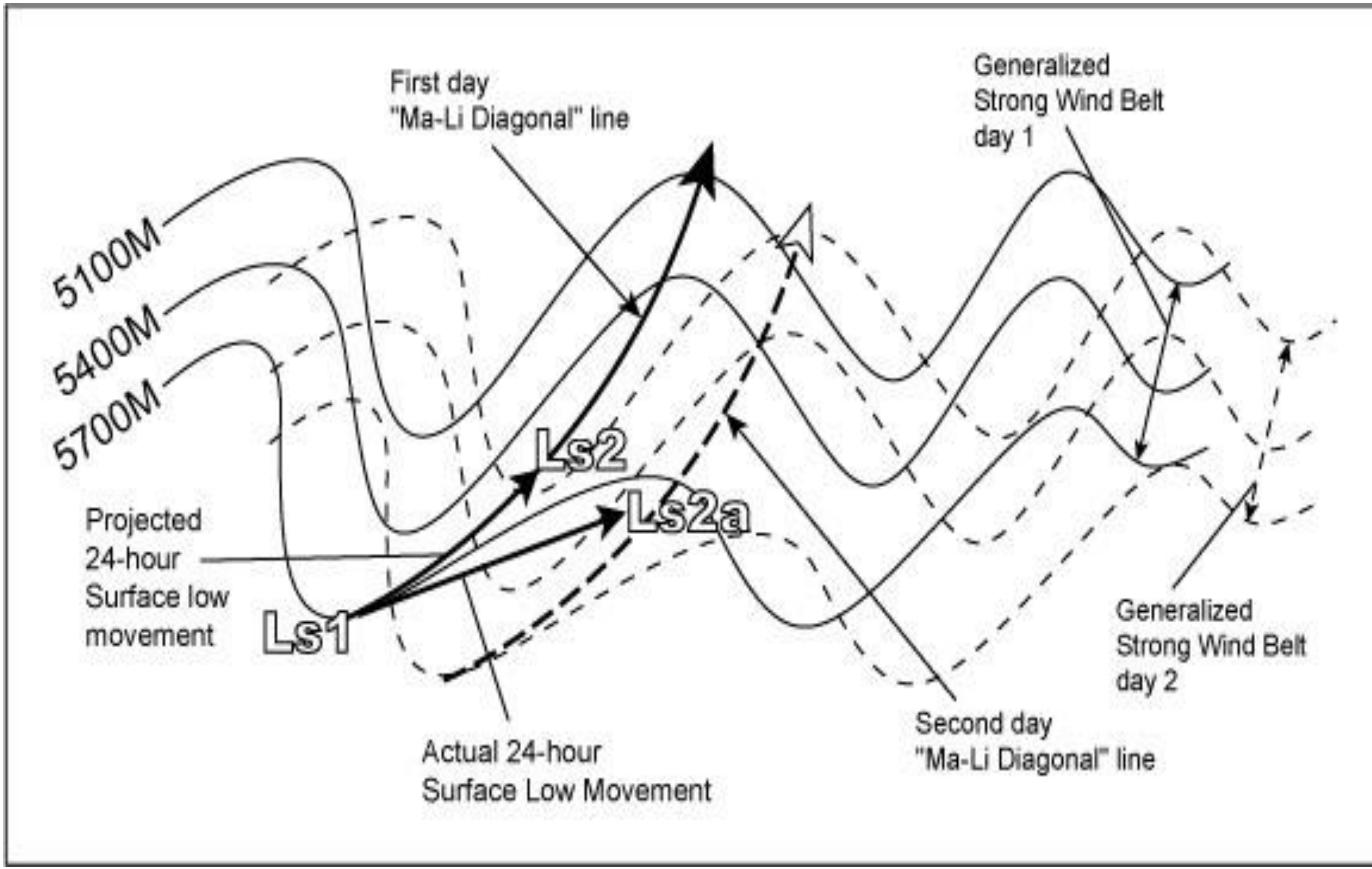

YM TAICHUNG
MAJURO

500mb的名詞定義

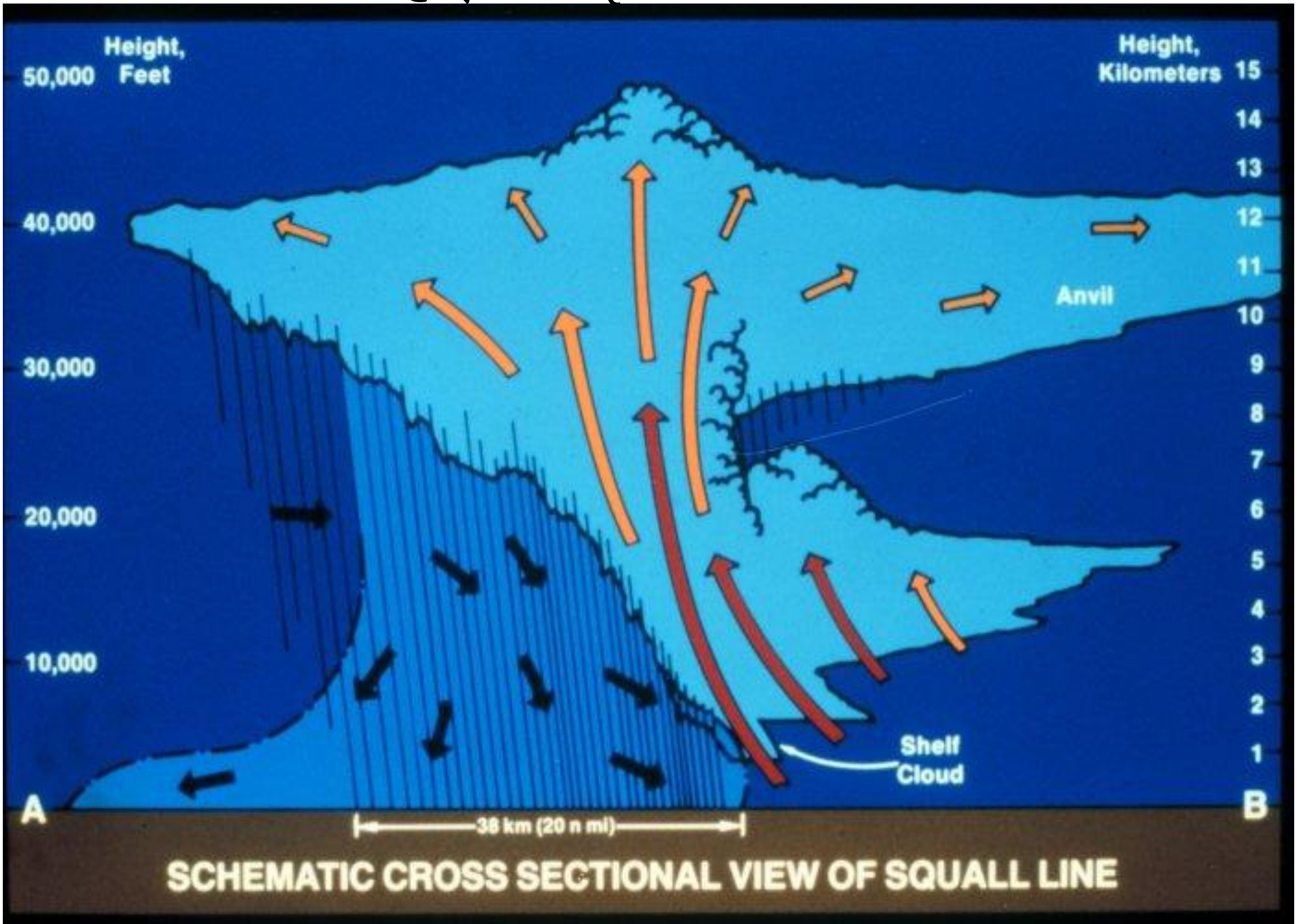


Counter spiral trail
Counter spiral trail
5100M
5400M
5700M
L
L
H
Generalized strong wind belt
Ma-Li Diagonal
Ma-Li Diagonal

地面低氣壓沿馬力對角線的每日位移



颮 線　　SQUALL LINE - 1

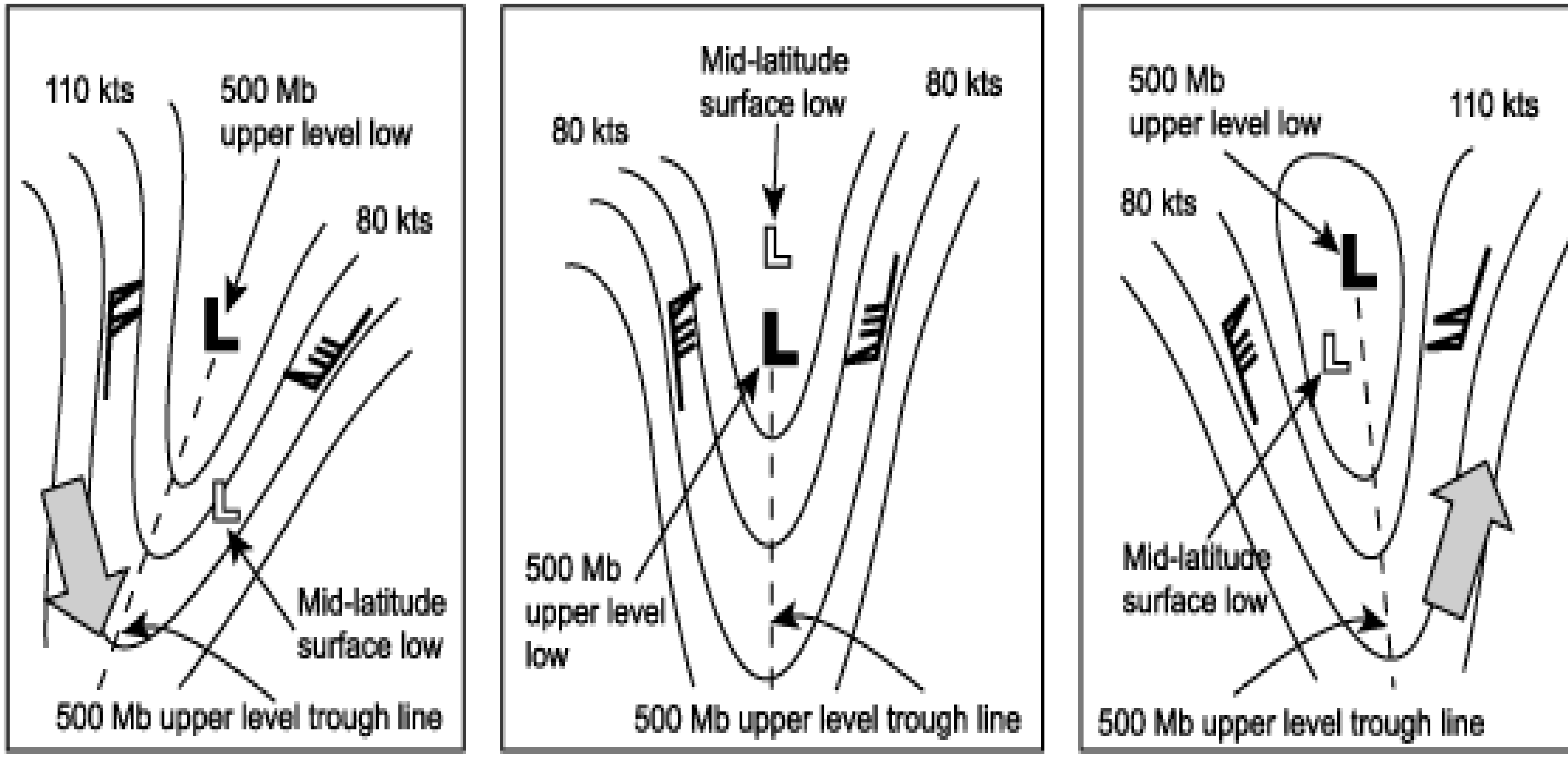


颮 線　SQUALL LINE - 2

- A squall or squall line is a line of thunderstorms aligned on a common leading convection line.

- A squall has the following characteristics:
  - May produce downbursts.
  - Contains heavy precipitation, hail, and frequent lightning, May contain tornadoes and waterspouts.
  - May have dangerous straight line winds, They are sometimes associated with hurricanes or other type cyclones.
  - The squall line tends to create a powerful gust front, Squall lines also develop along strong cold fronts.
  - They can also occur as independent squalls.

高空低壓槽的運動特性

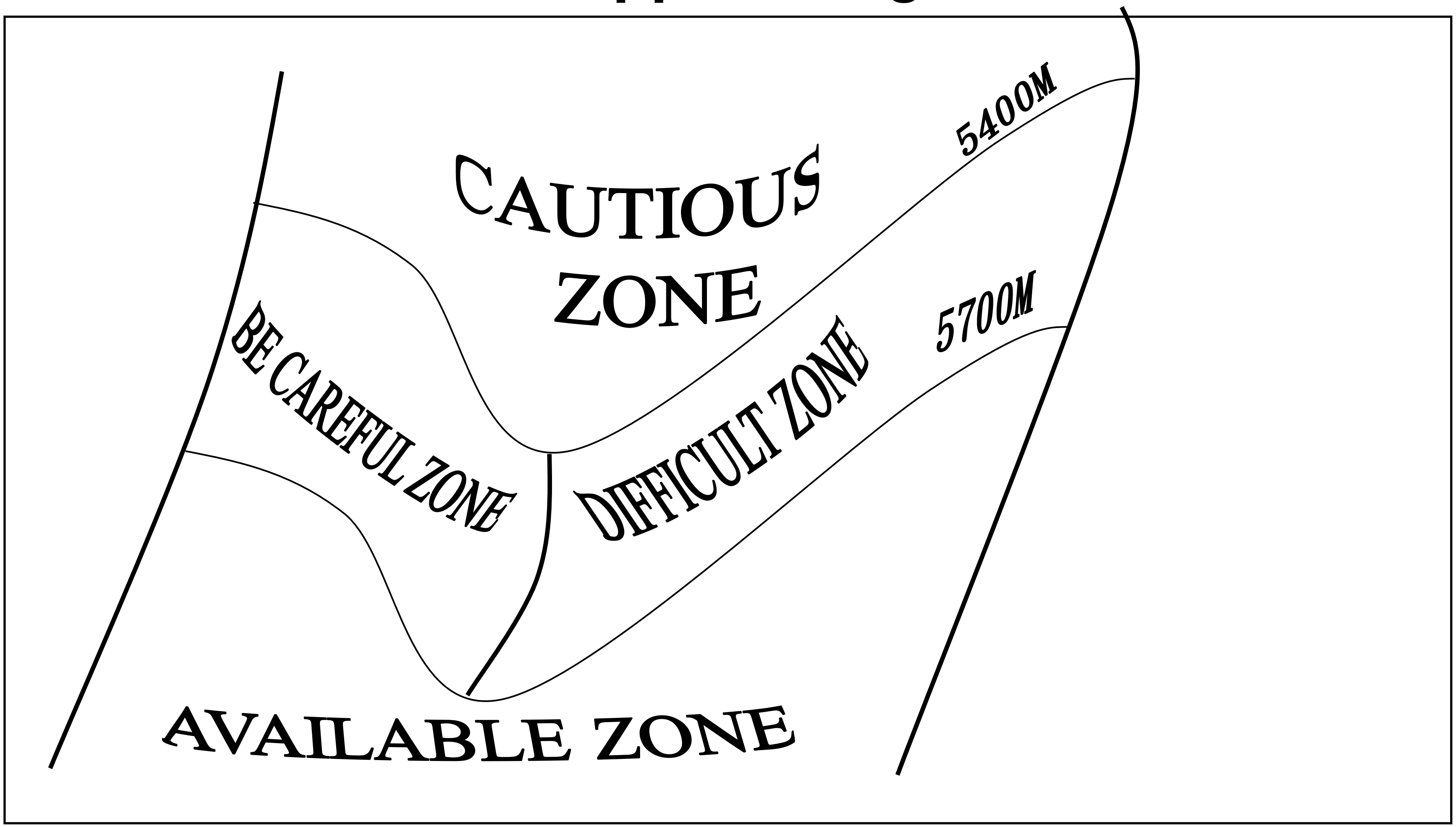


1. 500 Mb winds stronger West of the trough line

2. 500 Mb winds are equal West and East of the trough line

3. 500 Mb winds stronger East of the trough line

Four zones of the surface navigational ocean at upper trough



Determination of Navigation Areas

A Zone (Available Zone)

B Zone (Be Careful Zone)

C Zone (Caution Zone)

D Zone (Difficult Zone)

Tropical Cyclone Analysis

熱帶氣旋分析

Basic Theories and Forecast Applications for Tropical Cyclones (Western Pacific Typhoons)

船舶相對熱 帶氣旋的位置	避航行動
熱帶氣旋 進路正前方	調整航向讓風向從右艉20度吹來,選擇最恰當的航向與航速,以進入熱帶氣旋的左半圓 (即安全半圓).
熱帶氣旋的 右半圓	調整航向讓風向從右艏45度吹來,選擇最恰當的航向與航速,以逃離熱帶氣旋的右半圓 (即危險半圓),此區域內的風與浪,經常能相當的降低船舶前進速度.
熱帶氣旋的 左半圓	調整航向讓風向從右艉45度吹來,選擇最恰當的航向與航速,以增加本船與熱帶氣旋中心的距離.
熱帶氣旋 進路正後方	保持最恰當的航向與航速乘騎海浪,以增加本船與熱帶氣旋中心的距離.

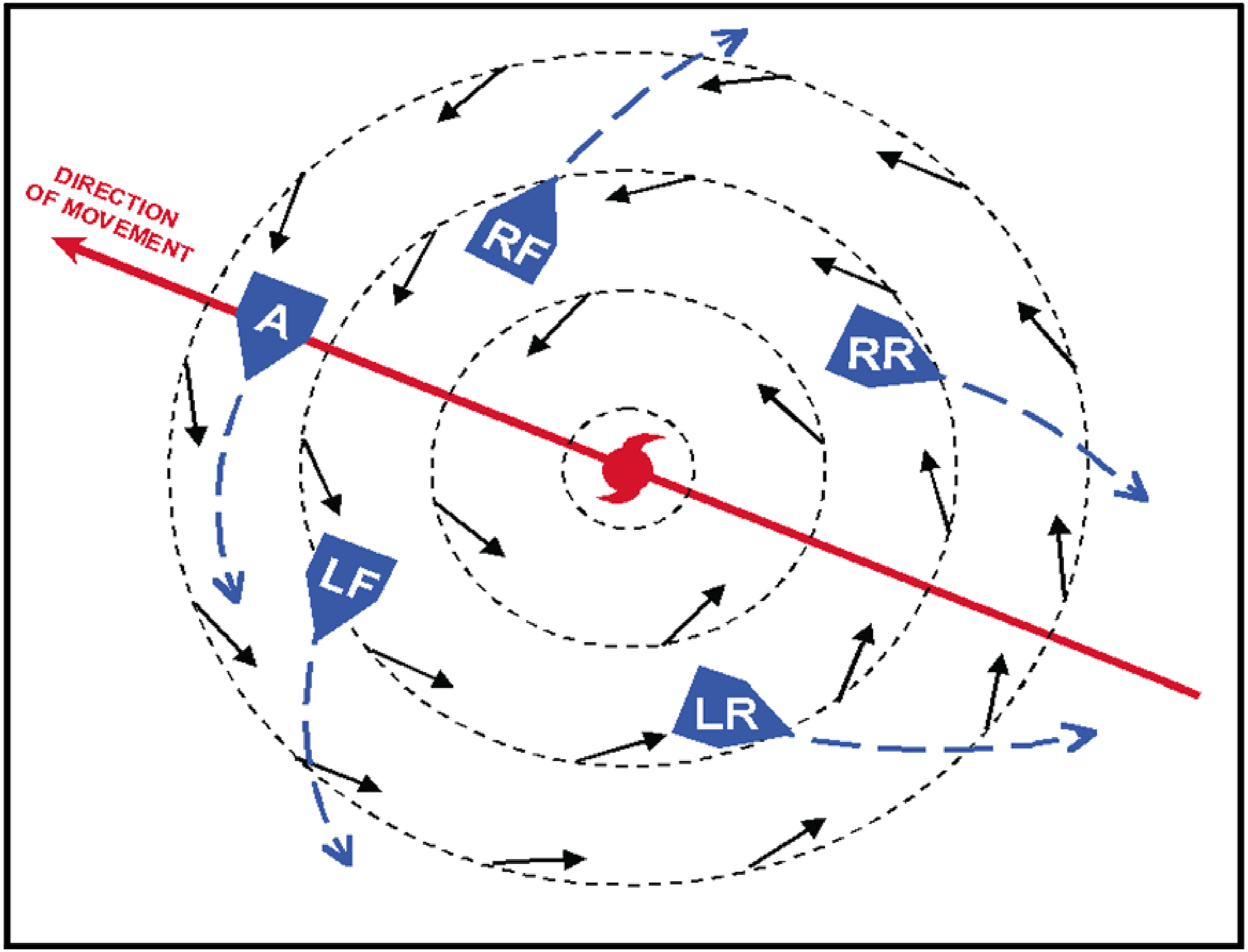

DIRECTION OF MOVEMENT
RF
A
RR
LF
LR

Fig. 5.2

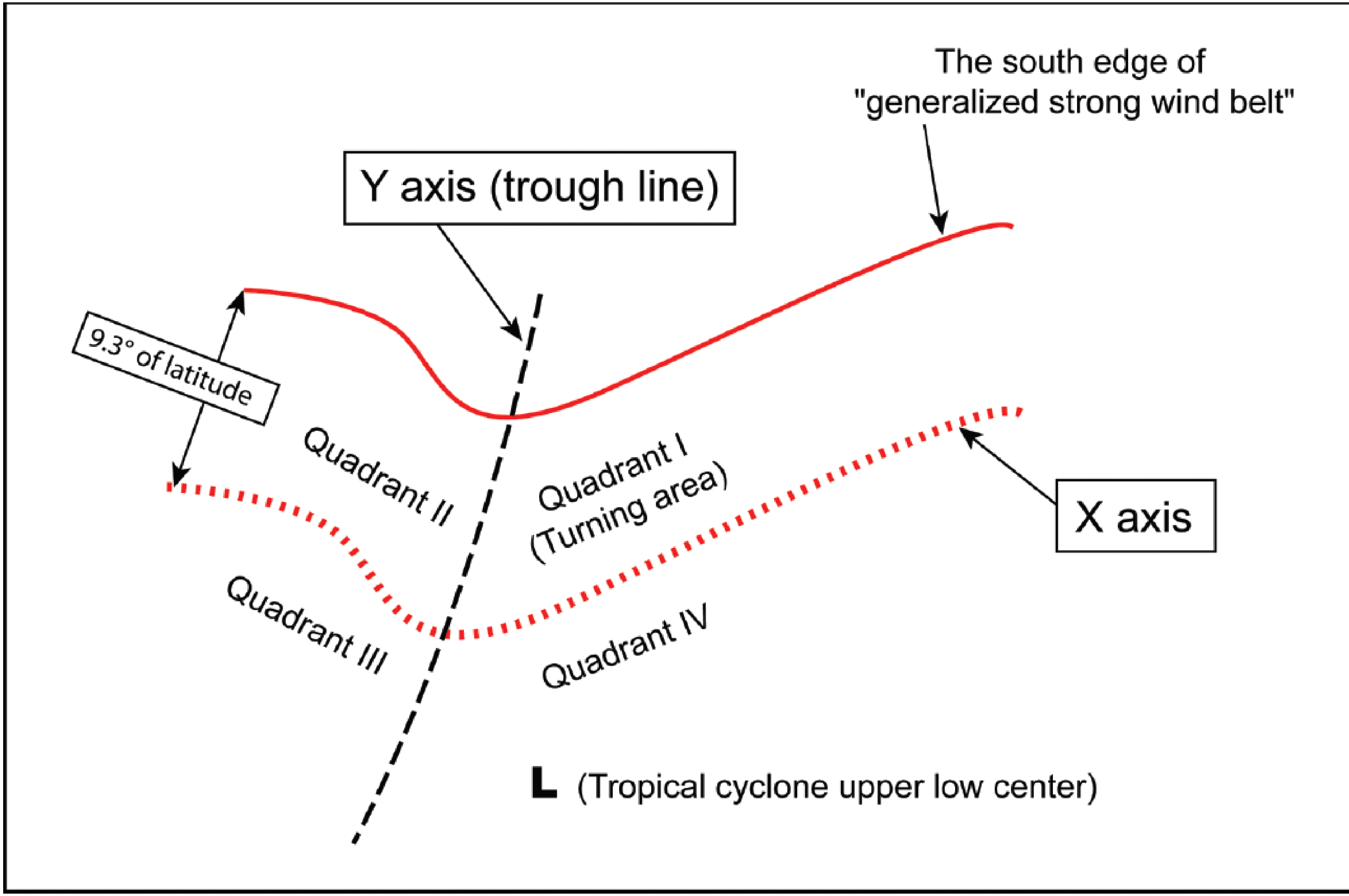


Fig. 5.2 illustrates the four-quadrant approach for determining the TC turning or recurving point.

熱帶氣旋的移動判別

- 選出與熱帶氣旋有關的高空低壓槽,並在該系統中找出廣義強風帶之最南緣流線,在此流線以南之A區向赤道方向選量9.3度緯度距離作一平行線平行最南緣流線,此平行線定為X軸,另外由該高空低壓系的高空低壓中心沿高空低壓槽線形成為Y軸,此XY座標軸可將A區劃分為四象限,吾人可以轉述以上必要條件為:

- 在第一象限中的地面熱帶氣旋,必定會轉向,而在第二/三/四象限的地面熱帶氣旋,必定不會轉向(即保持原有的方向及速度).
- 在第二/三/四象限的地面熱帶氣旋,有類似溫帶氣旋的特性,也即它會根據附近高空指向流的方向為移行方向, 指向流速 30%~50%為移行速率,
- 如果熱帶氣旋附近無指向流標示,則可以採用最接近此熱帶氣旋的高空流線段,以該段的向西方的方向為移行參考方向.在正常情況下,當地面熱帶氣旋判別為不轉向時,均是向西方移動,同時因盛行西風的影響而漸漸北昇(由西行到西北行或北行均有可能),但是絕對不會轉向.

一旦地面熱帶氣旋進入第一象限後,則該地面熱帶氣旋必定會轉向,而其轉向的研判則依照下列的從屬條件來決定之:

a.扼阻高壓對熱帶氣旋的進路有阻礙作用,當熱帶氣旋的北面有扼阻高壓時,熱帶氣旋將不能轉向北上,只能依原路徑受高層指向流的影響,但是熱帶氣旋的東西側如存有扼阻高壓(該位置指向流為南北向),而此時熱帶氣旋北面上層如有強盛西風流,則熱帶氣旋有向北移行之傾向.

b.熱帶氣旋有向著5820至5880等高線之間巷道行進之傾向,此乃因該兩等高線間恰為層積雲之所在,經常發生局部性豪雨,有足夠濕度,而熱帶氣旋為了補充能量以維持生命,傾向於趨近溫濕的地區之故.

c.在地面圖上,熱帶氣旋中心,距離冷鋒面緯度五度以內時,也會有上項原因的傾向,因此會隨著冷鋒面方向而移行.

d.若無以上條件, 則熱帶氣旋會向地面上的溫暖地區前進.

如配合相對之高空圖觀測,其它條件也符合,則熱帶氣旋的移動方向必為肯定.

15.1 Example One: Tropical Cyclone Ivy (9115)

Fig. 15.1a

500 Mb Chart, Ivy, Day One

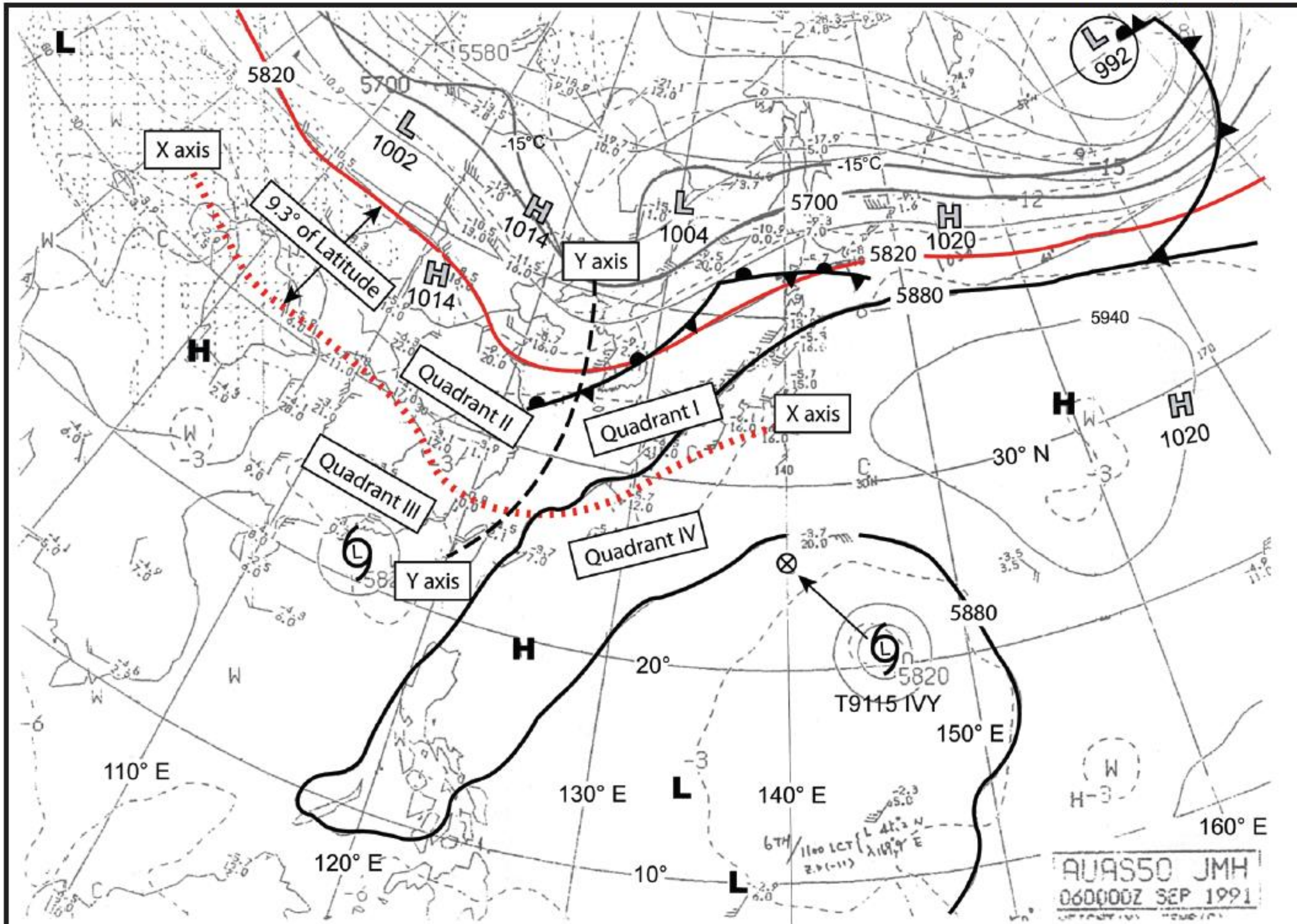


Fig. 15.1b 500 Mb Chart, Ivy, Day Two

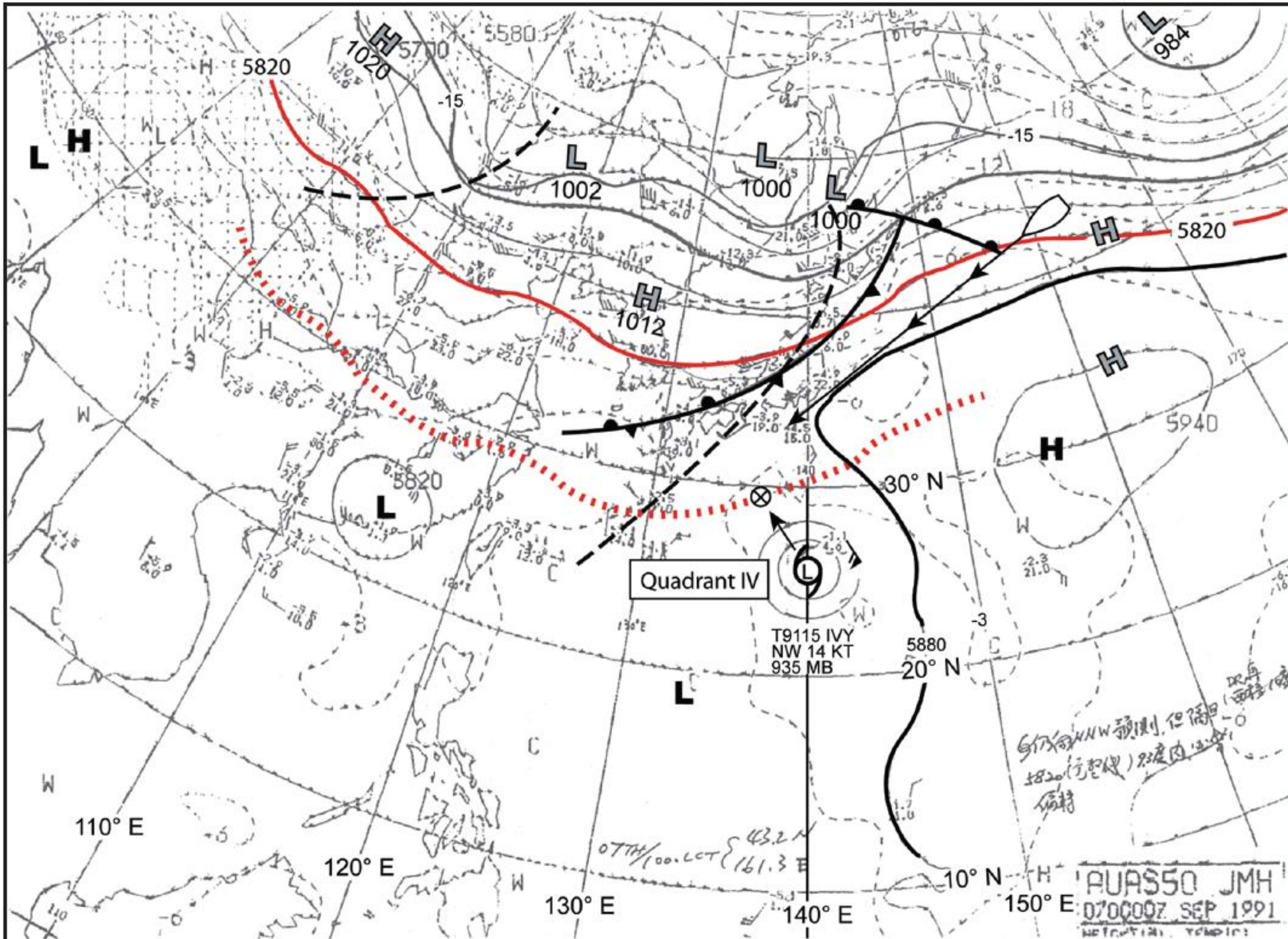
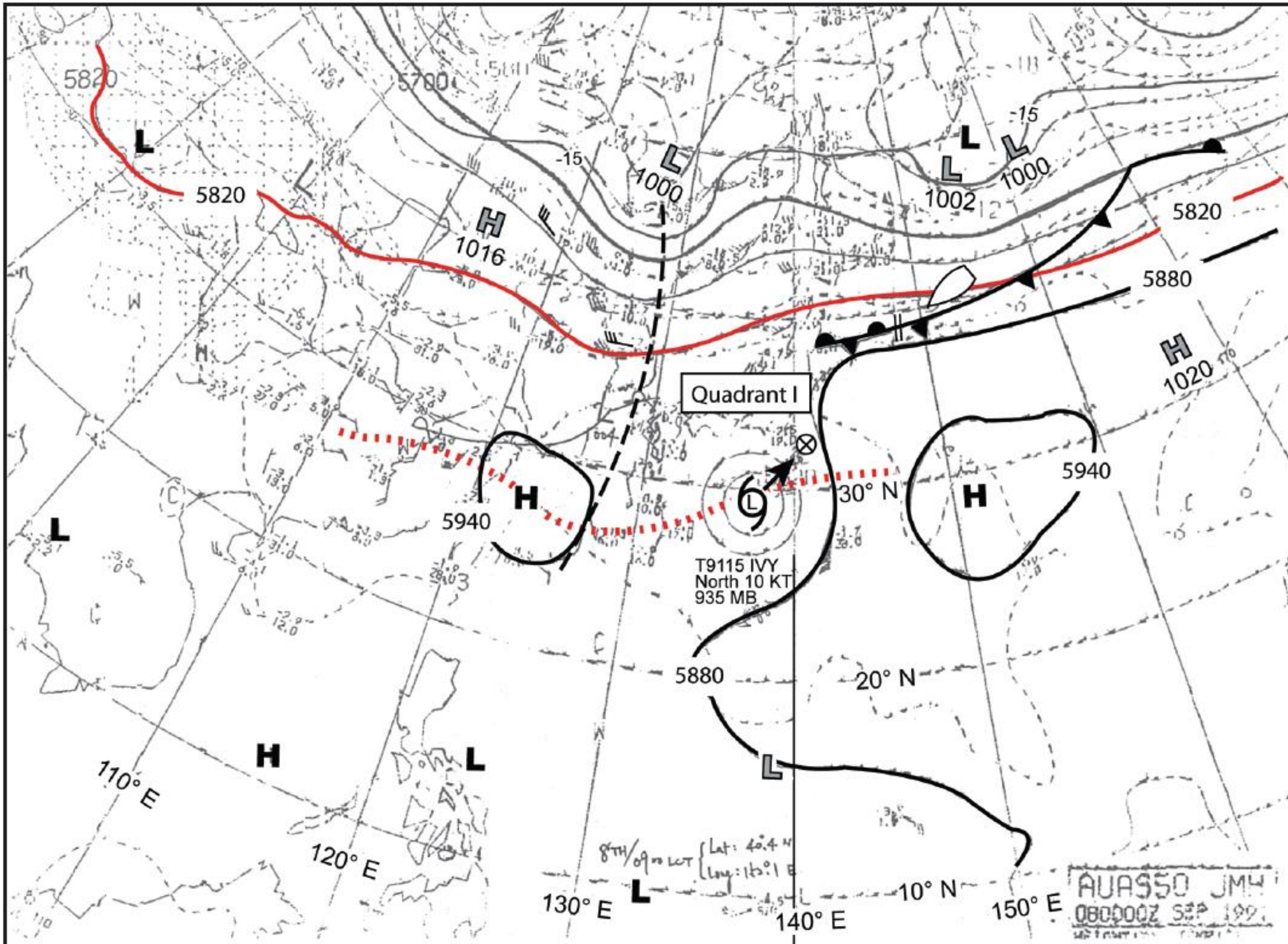


Fig. 15.1c 500 Mb Chart, Ivy, Day Three



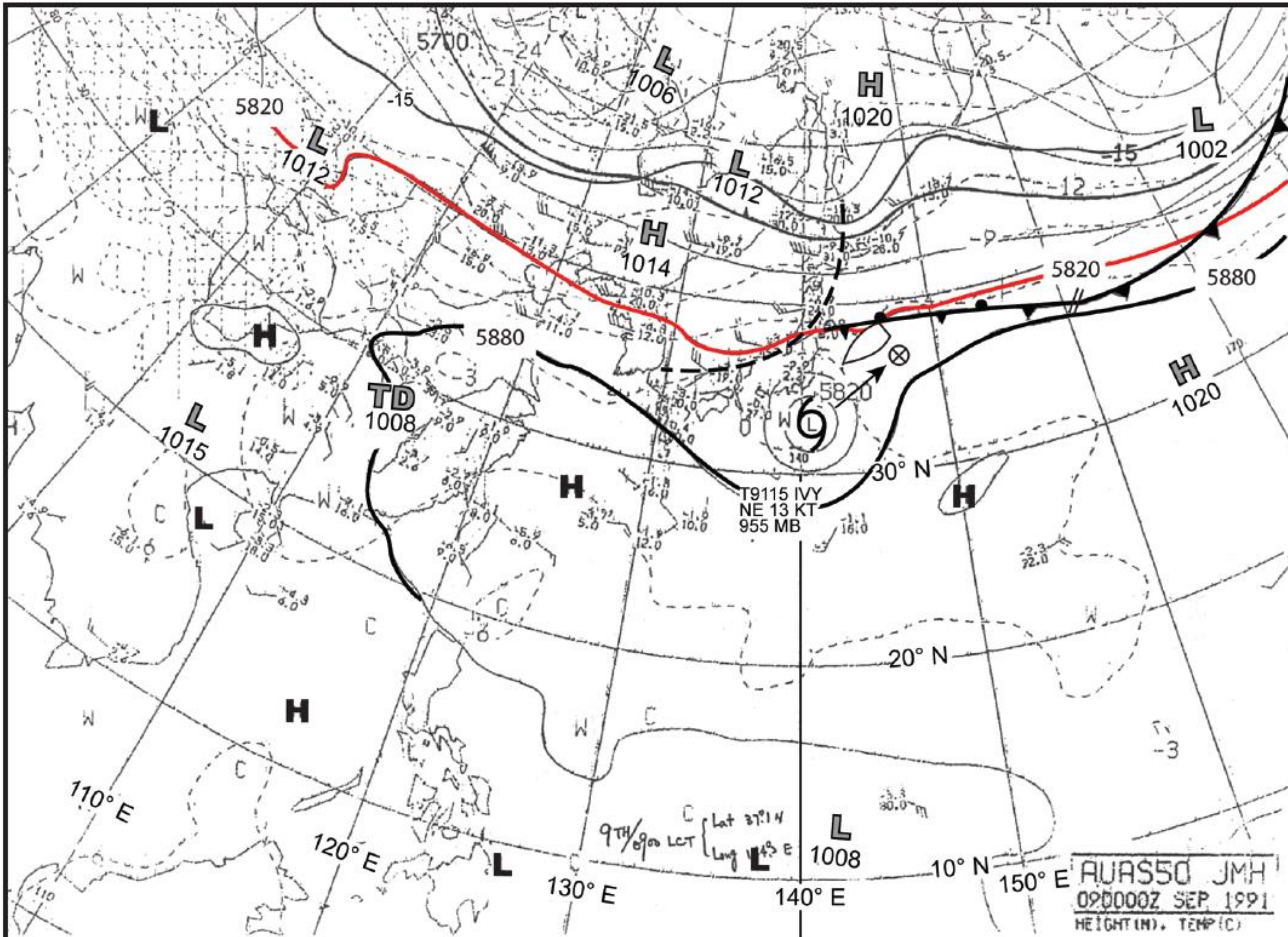
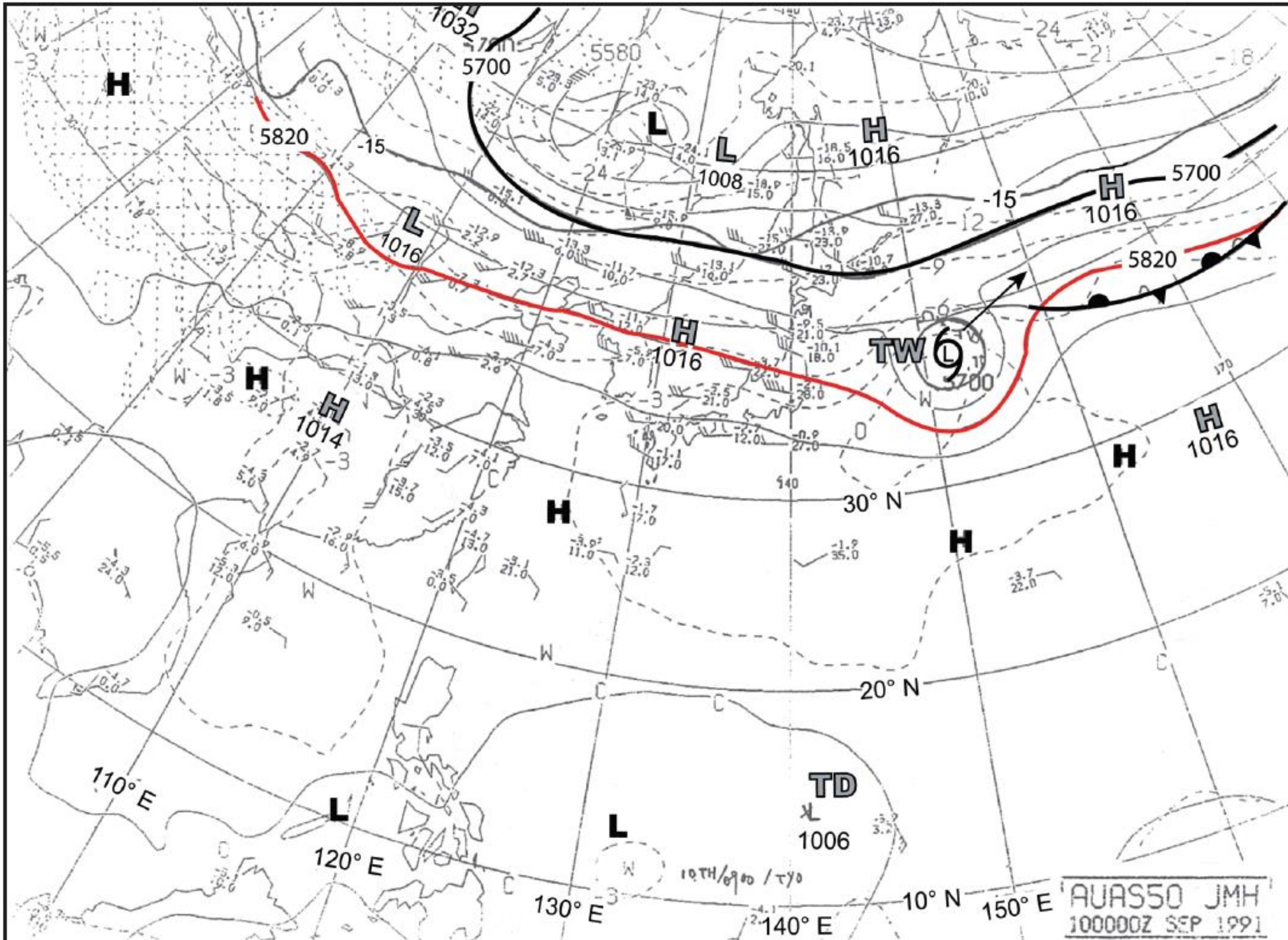

5700
5820
5880
T9115 IVY
NE 13 KT
955 MB
TD
1008
1006
1020
1002
1012
1014
1015
1008
30° N
20° N
10° N
110° E
120° E
130° E
140° E
150° E
AUAS50 JMH
090000Z SEP 1991
HEIGHT(M), TEMP(C)

Fig. 15.1e 500 Mb Chart, Ivy, Day Five



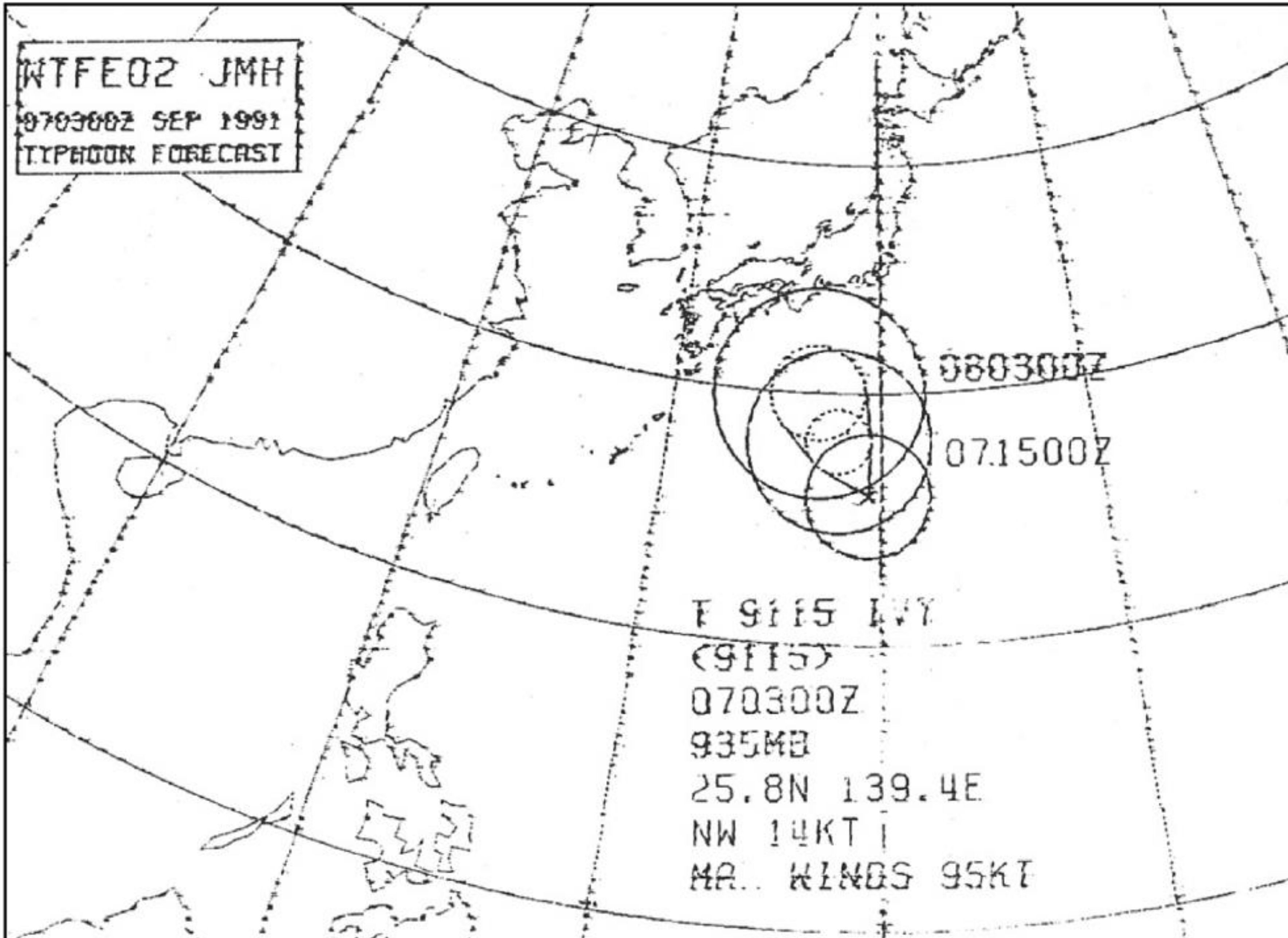

WTFE02 JMH
070300Z SEP 1991
TYPHOON FORECAST
080300Z
071500Z
T 9115 IVY
(9115)
070300Z
935MB
25.8N 139.4E
NW 14KT
MAX WINDS 95KT

Fig. 15.1g

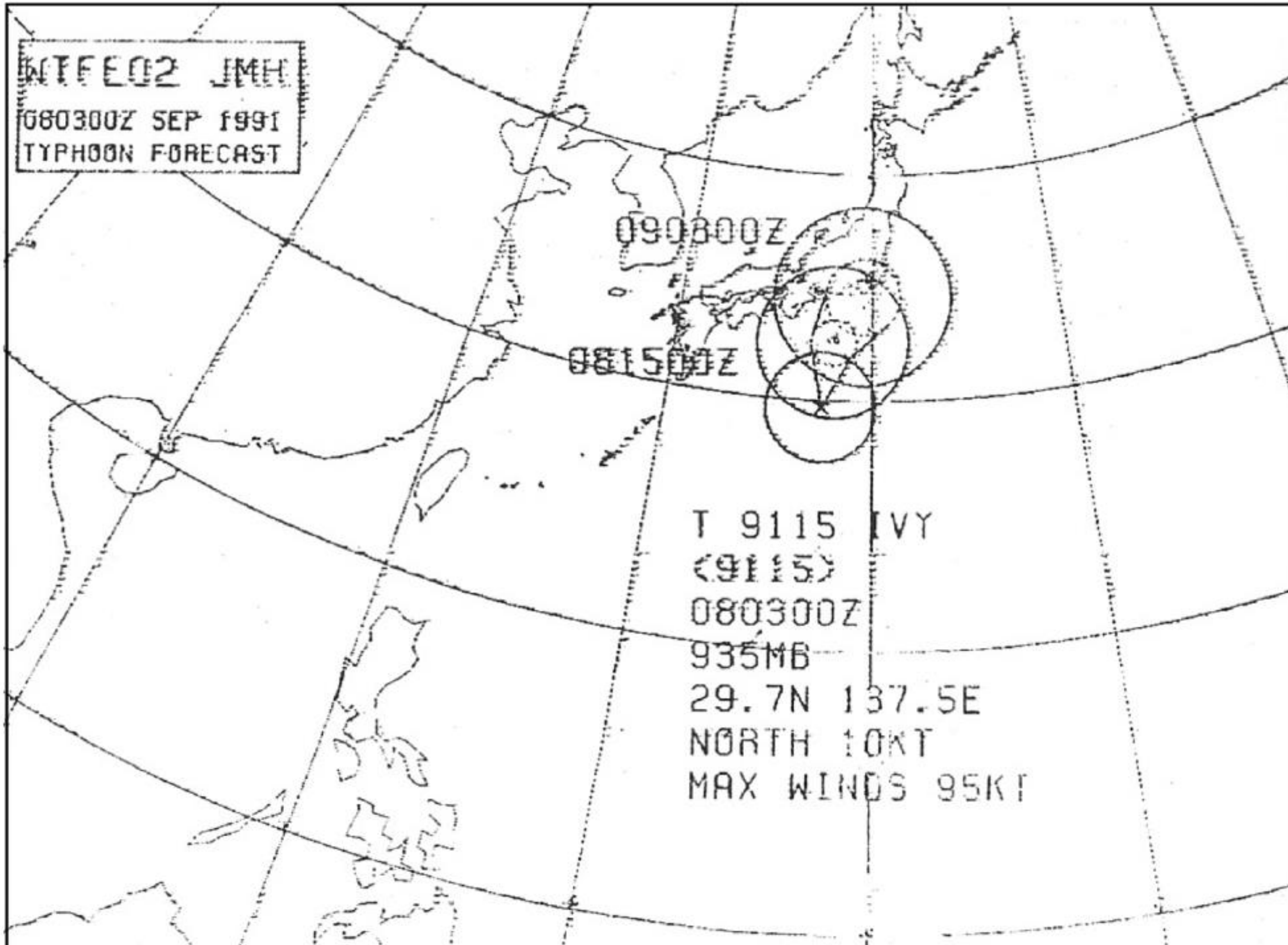
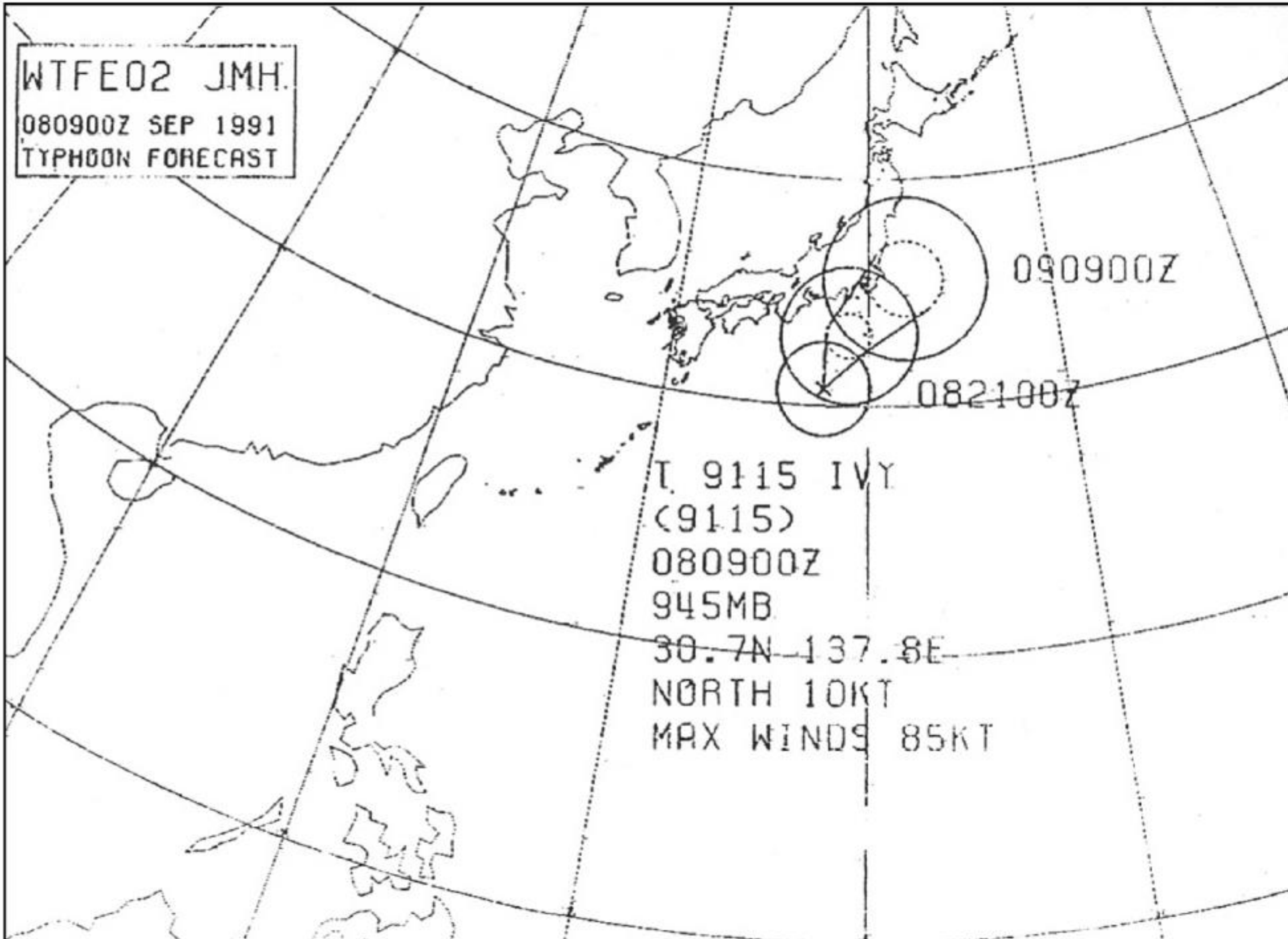
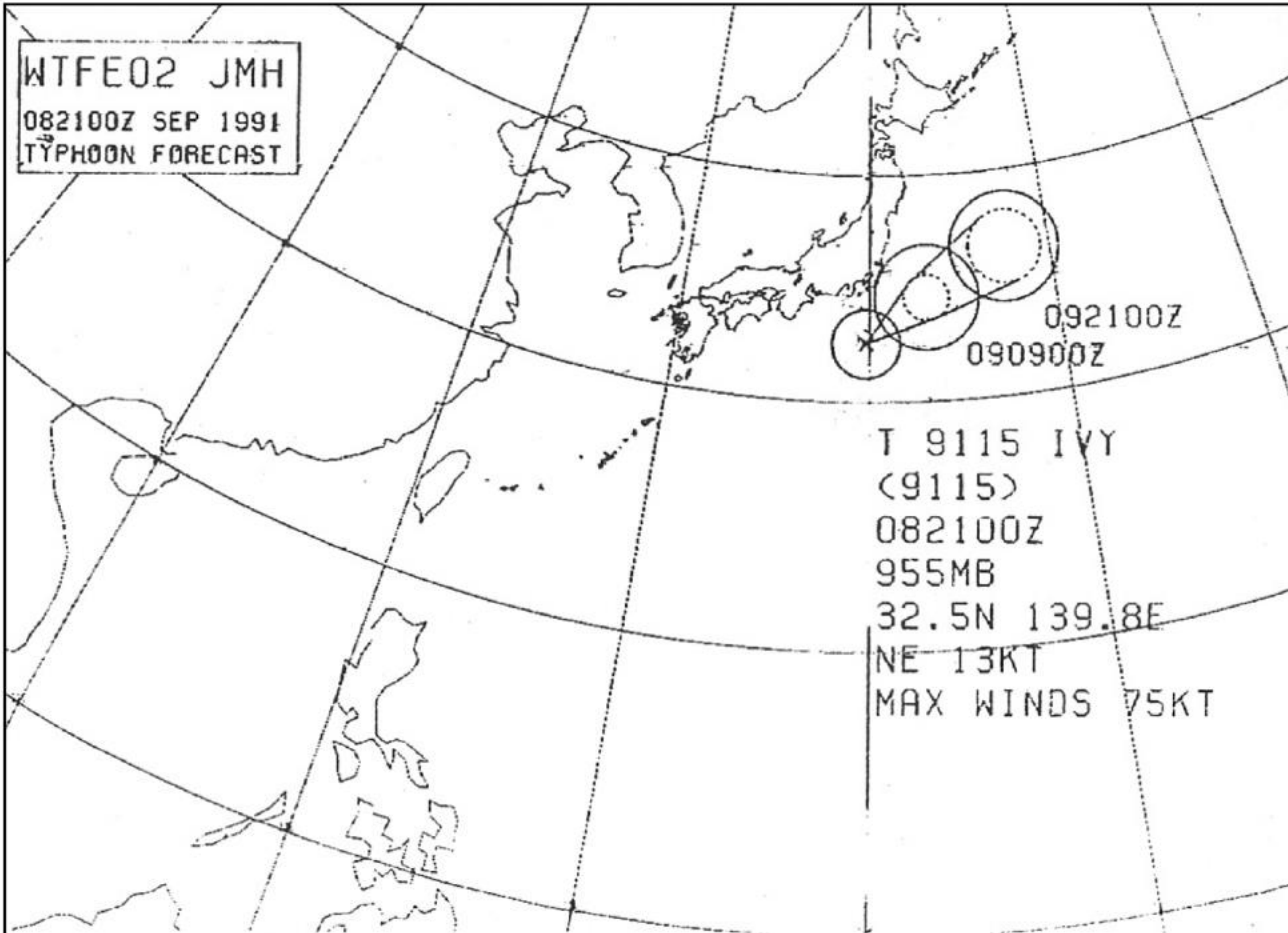

WTFE02 JMH
080300Z SEP 1991
TYPHOON FORECAST
090300Z
081500Z
T 9115 IVY
<9115>
080300Z
935MB
29.7N 137.5E
NORTH 10KT
MAX WINDS 95KT

Fig. 15.1h Surface Forecast, Ivy, Day Three




WTFE02 JMH
082100Z SEP 1991
TYPHOON FORECAST
092100Z
090900Z
T 9115 IVY
(9115)
082100Z
955MB
32.5N 139.8E
NE 13KT
MAX WINDS 75KT

15.2 Example Two: Tropical Cyclone Kinna (9117)

Fig. 15.2a 500 Mb Chart, Kinna, Day One

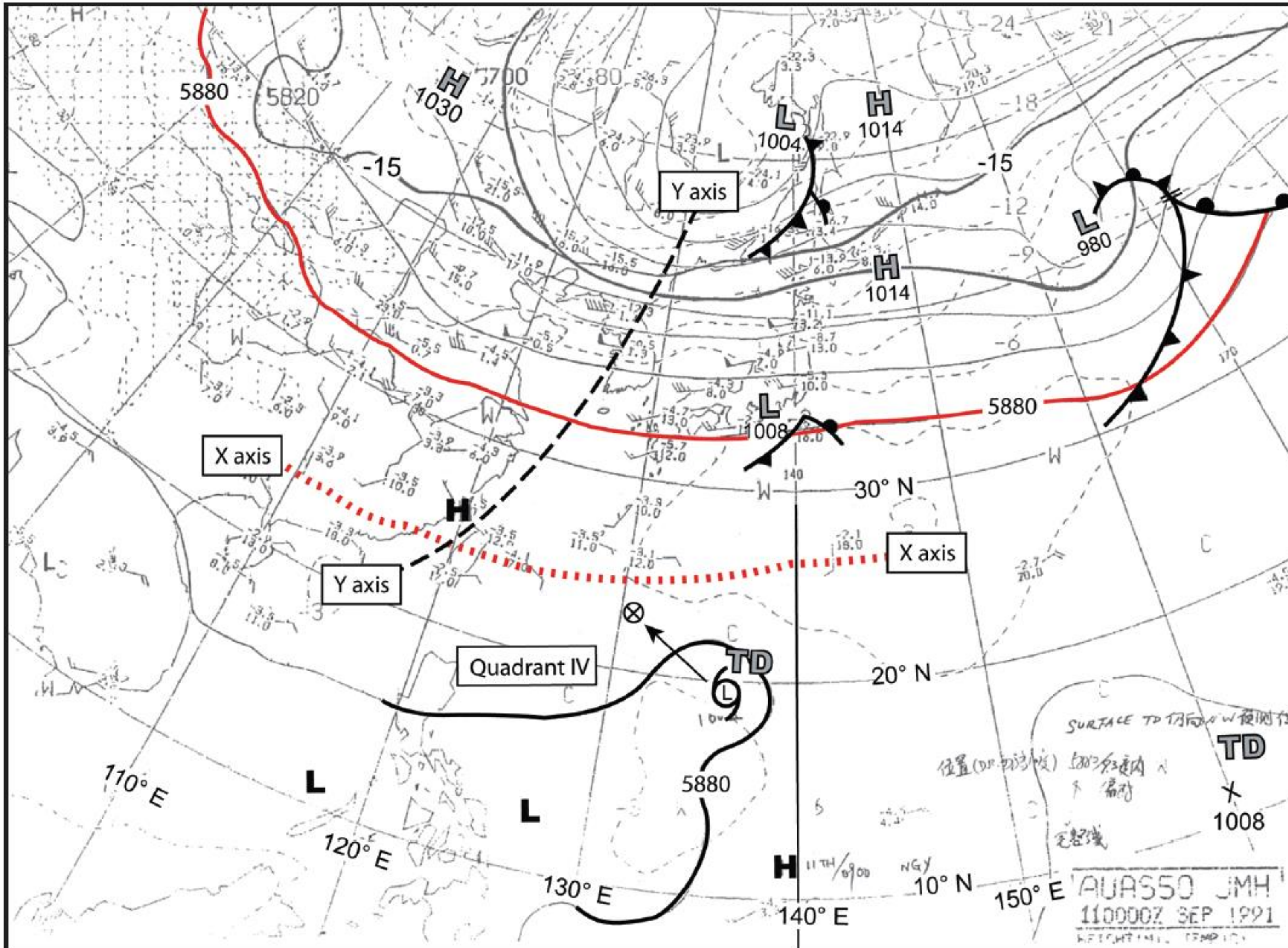


Fig. 15.2b 500 Mb Chart, Kinna, Day Two

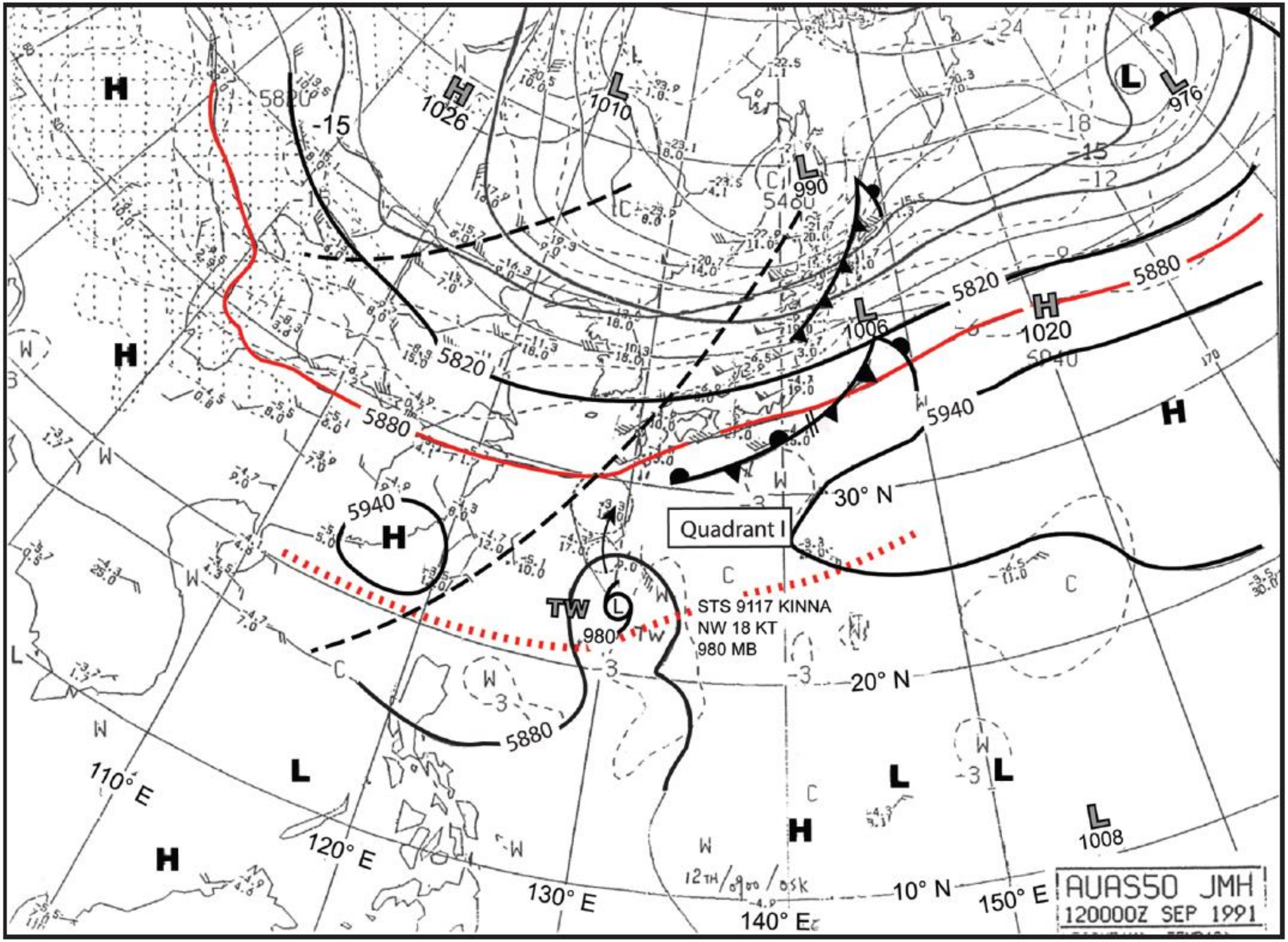


Fig. 15.2c 500 Mb Chart, Kinna, Day Three

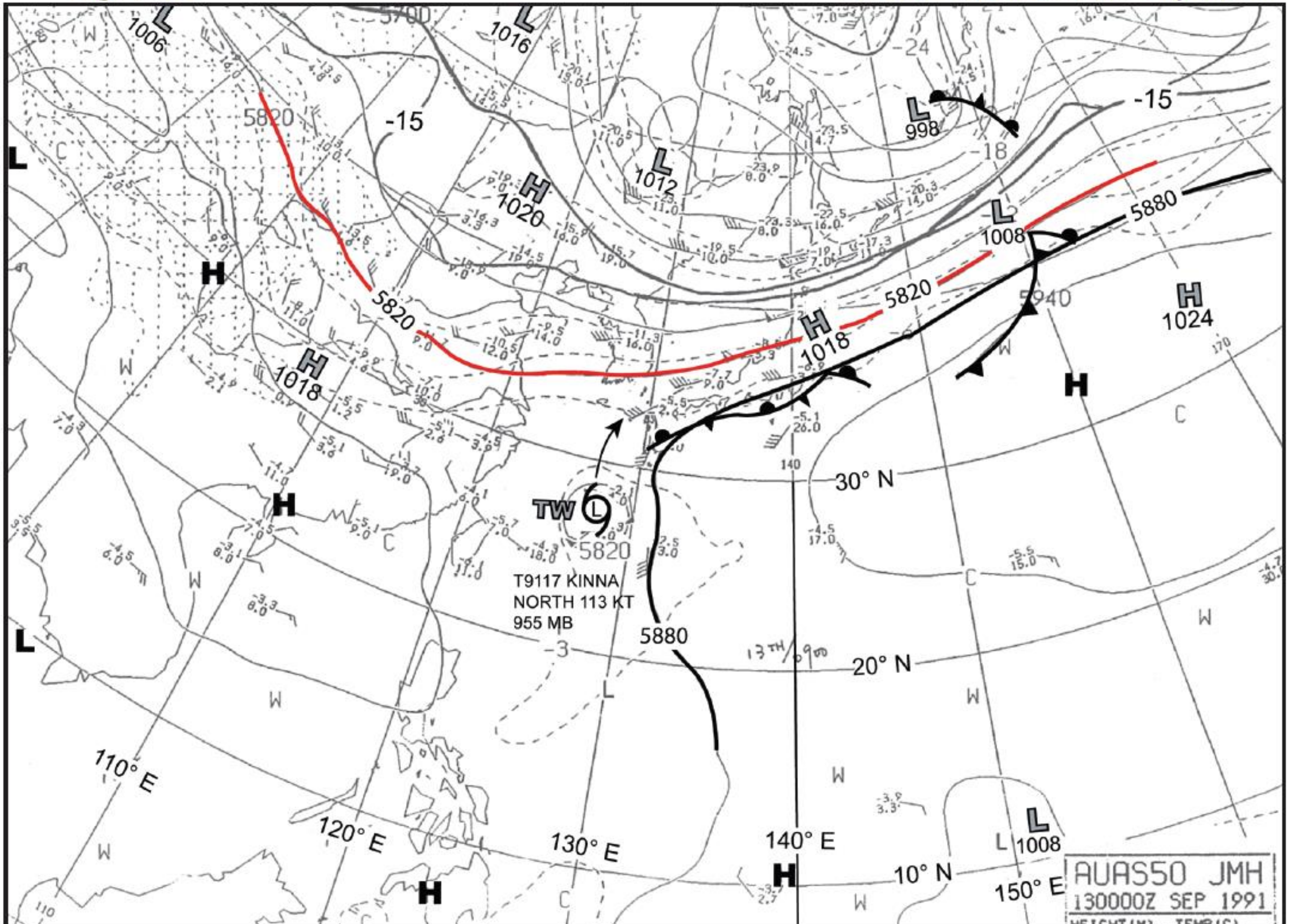


Fig. 15.2d 500 Mb Chart, Kinna, Day Four

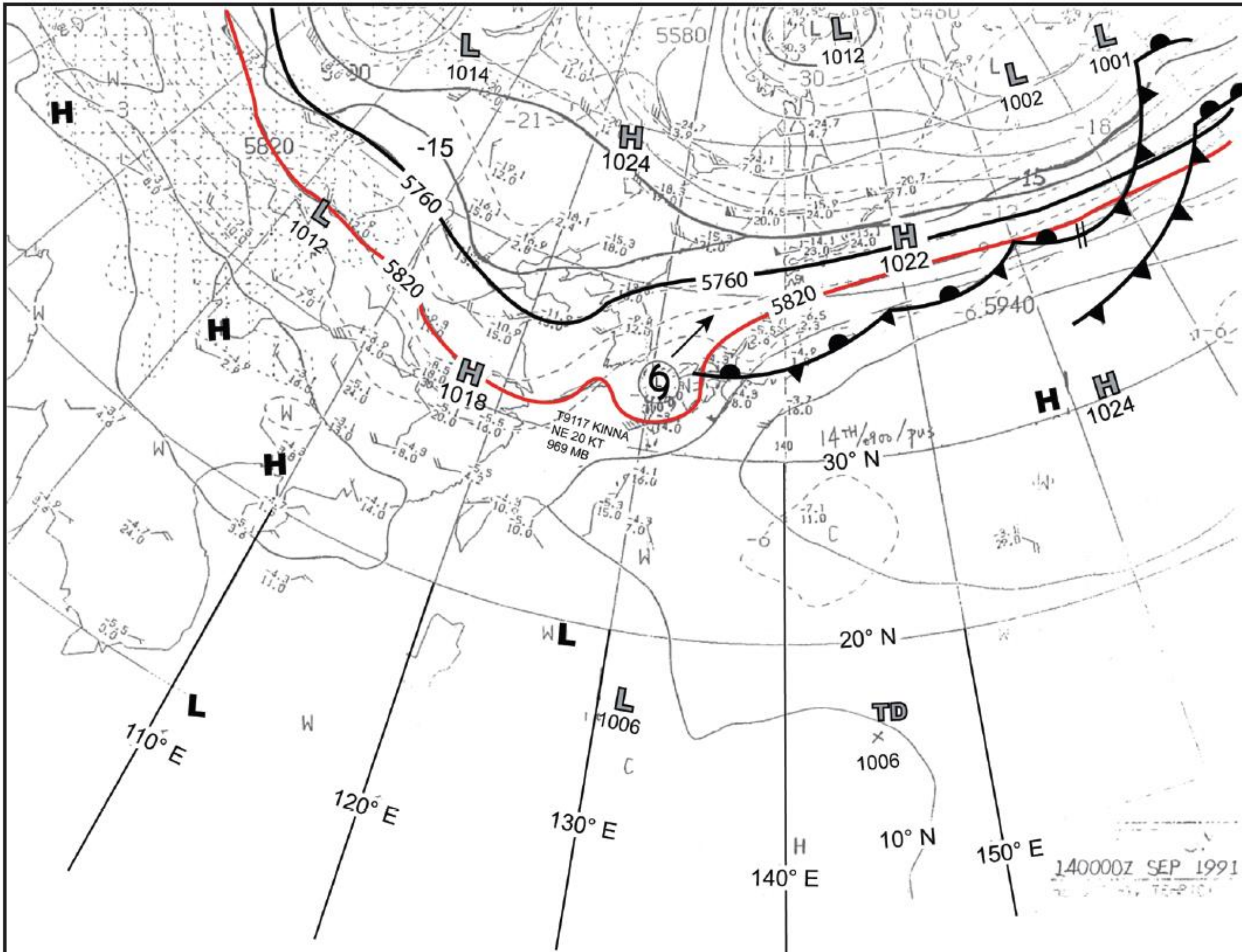
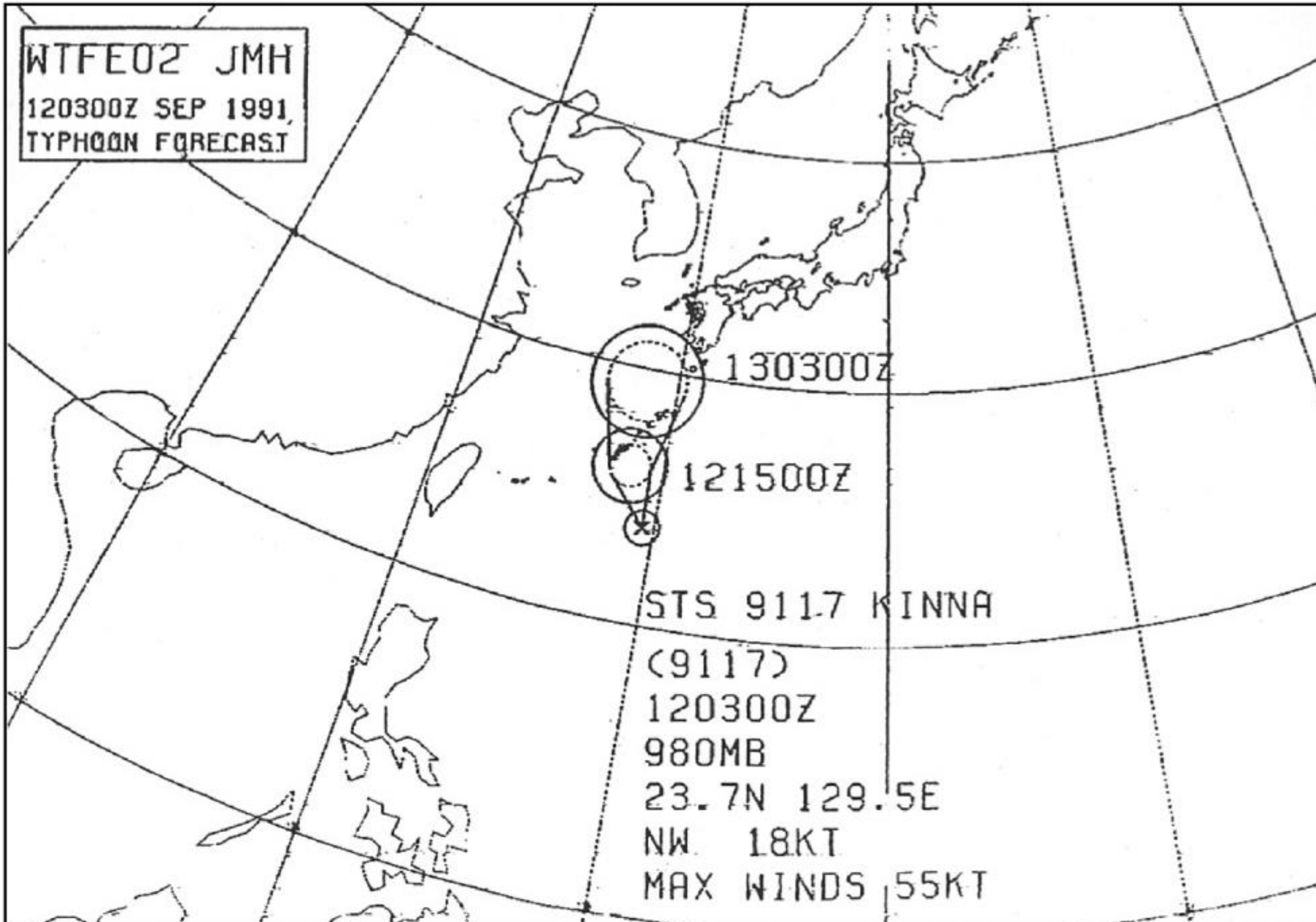


Fig. 15.2e

Surface Forecast, Kinna, Day One



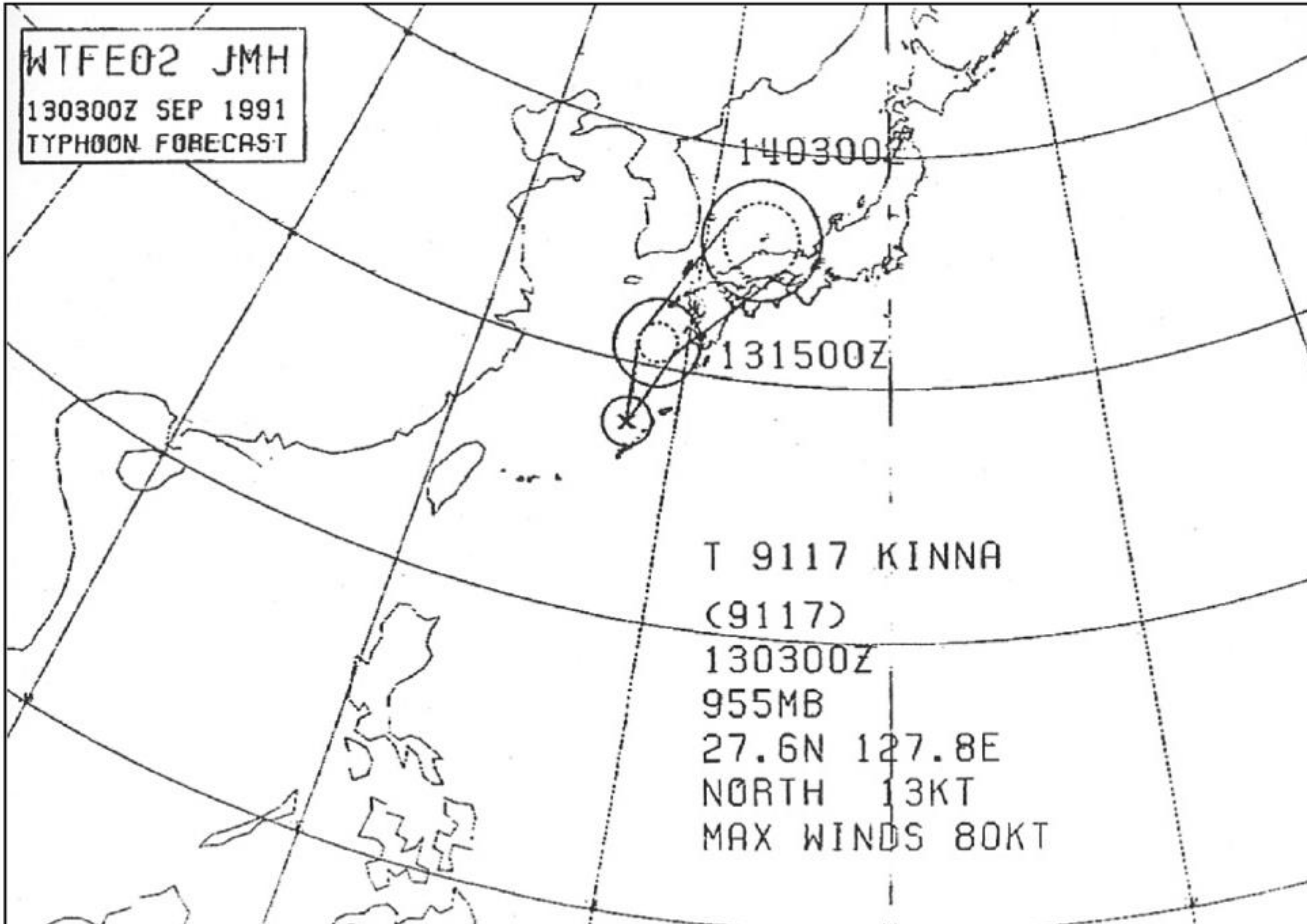
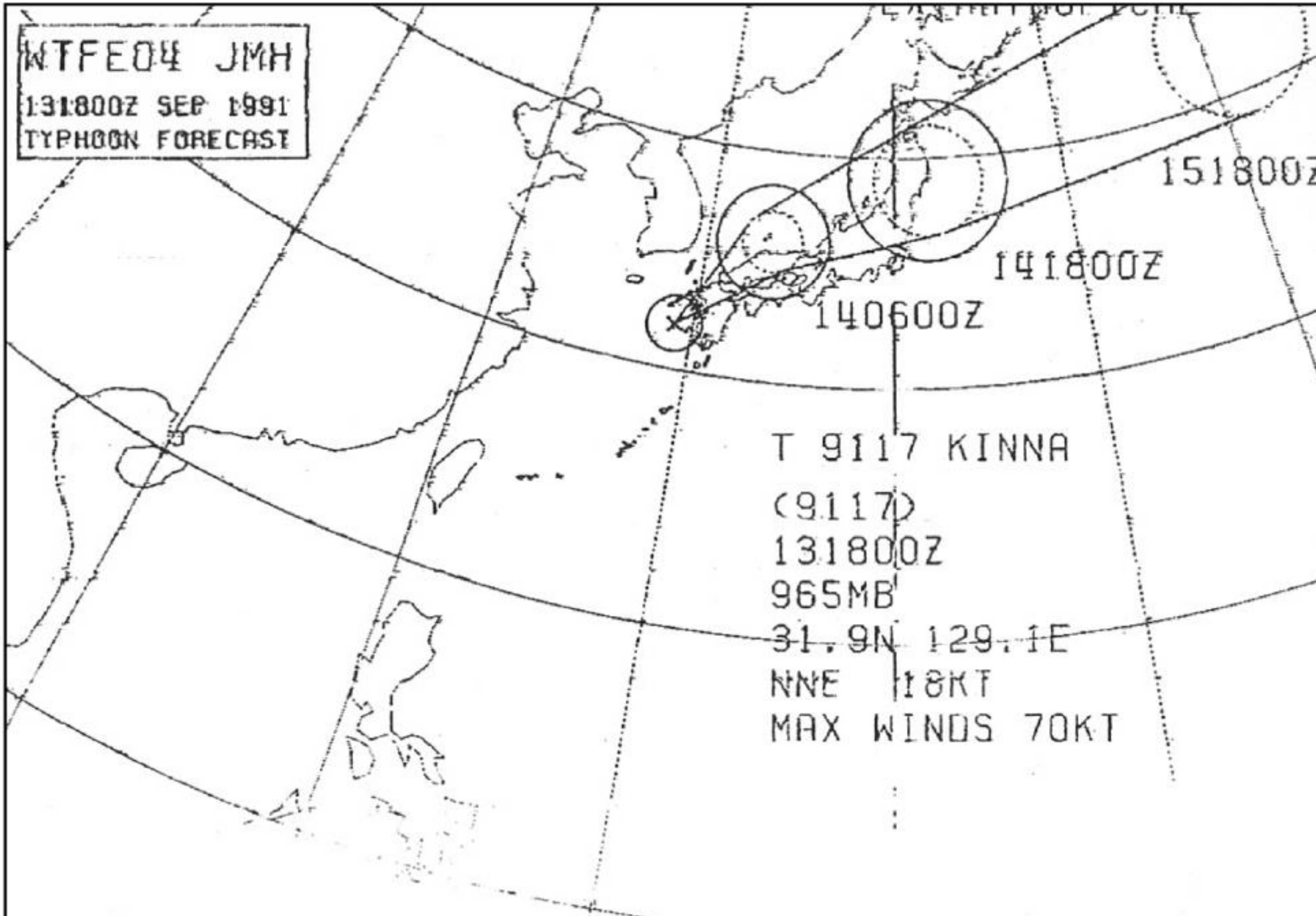

WTFE02 JMH
130300Z SEP 1991
TYPHOON FORECAST
140300Z
131500Z
T 9117 KINNA
(9117)
130300Z
955MB
27.6N 127.8E
NORTH 13KT
MAX WINDS 80KT

Fig. 15.2g Surface Forecast, Kinna, Day Three



15.3 Example Three: Tropical Cyclone Gary

Fig. 15.3a

500 Mb Chart, Gary, Day One

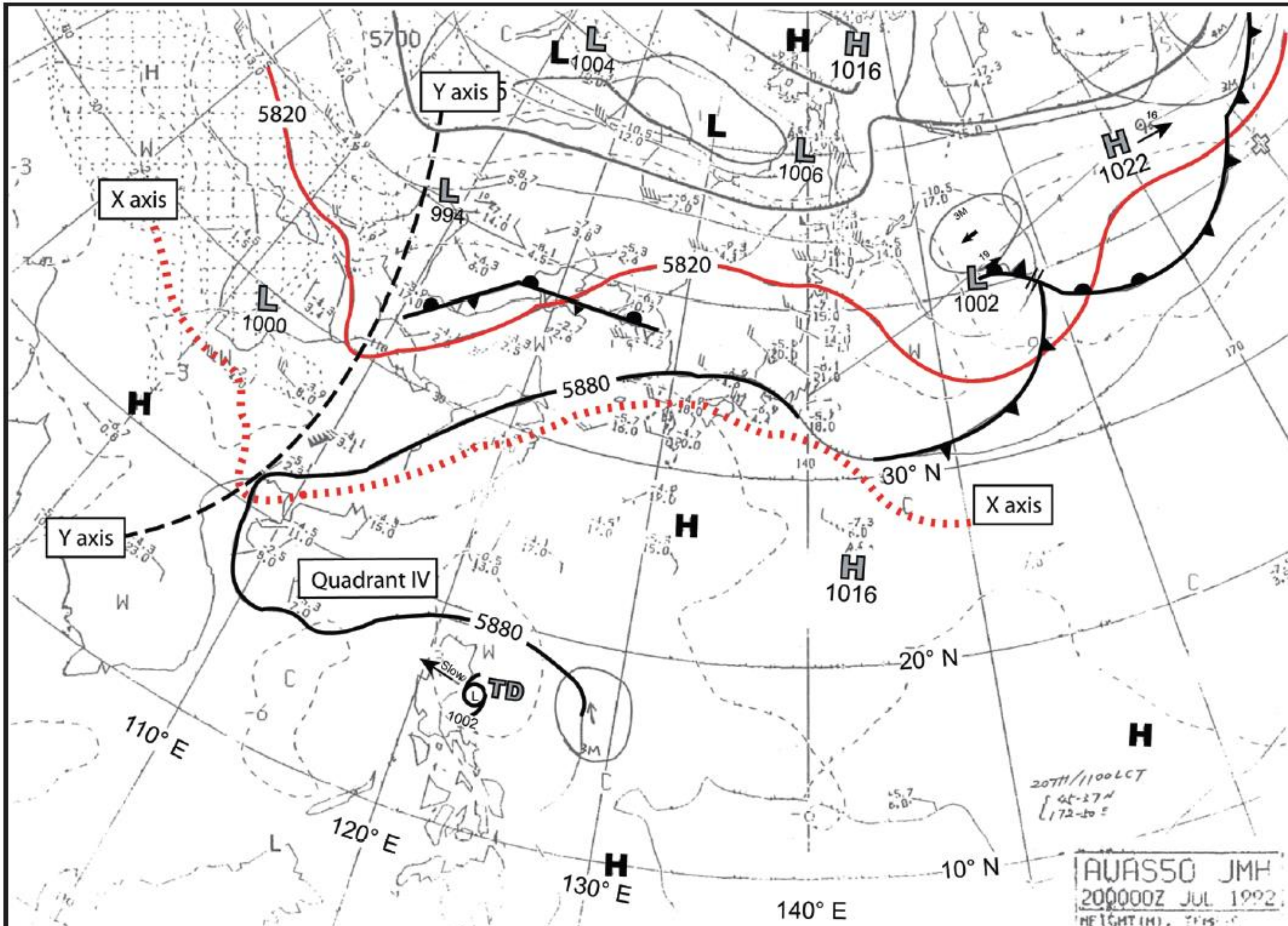


Fig. 15.3b

500 Mb Chart, Gary, Day Two

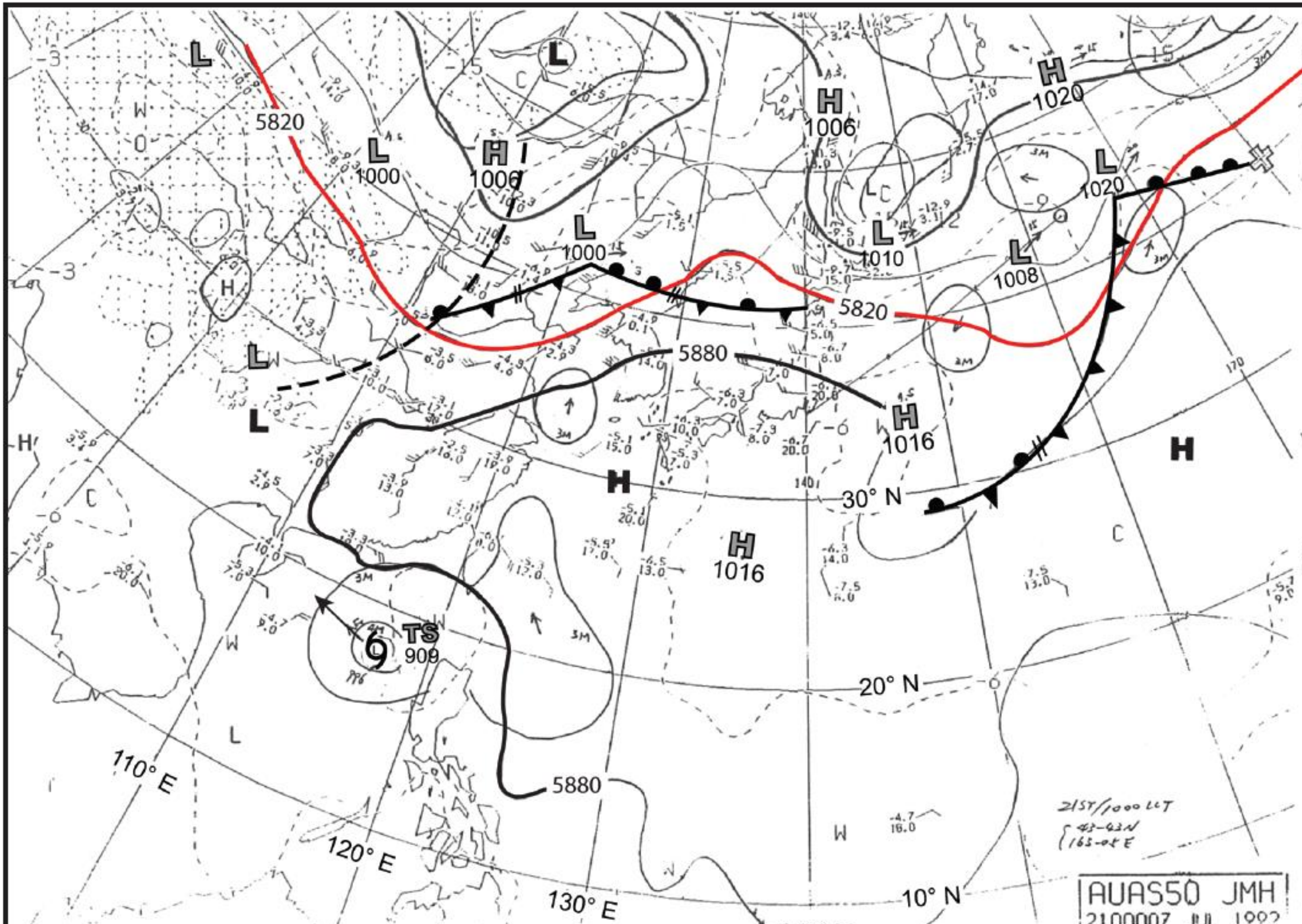
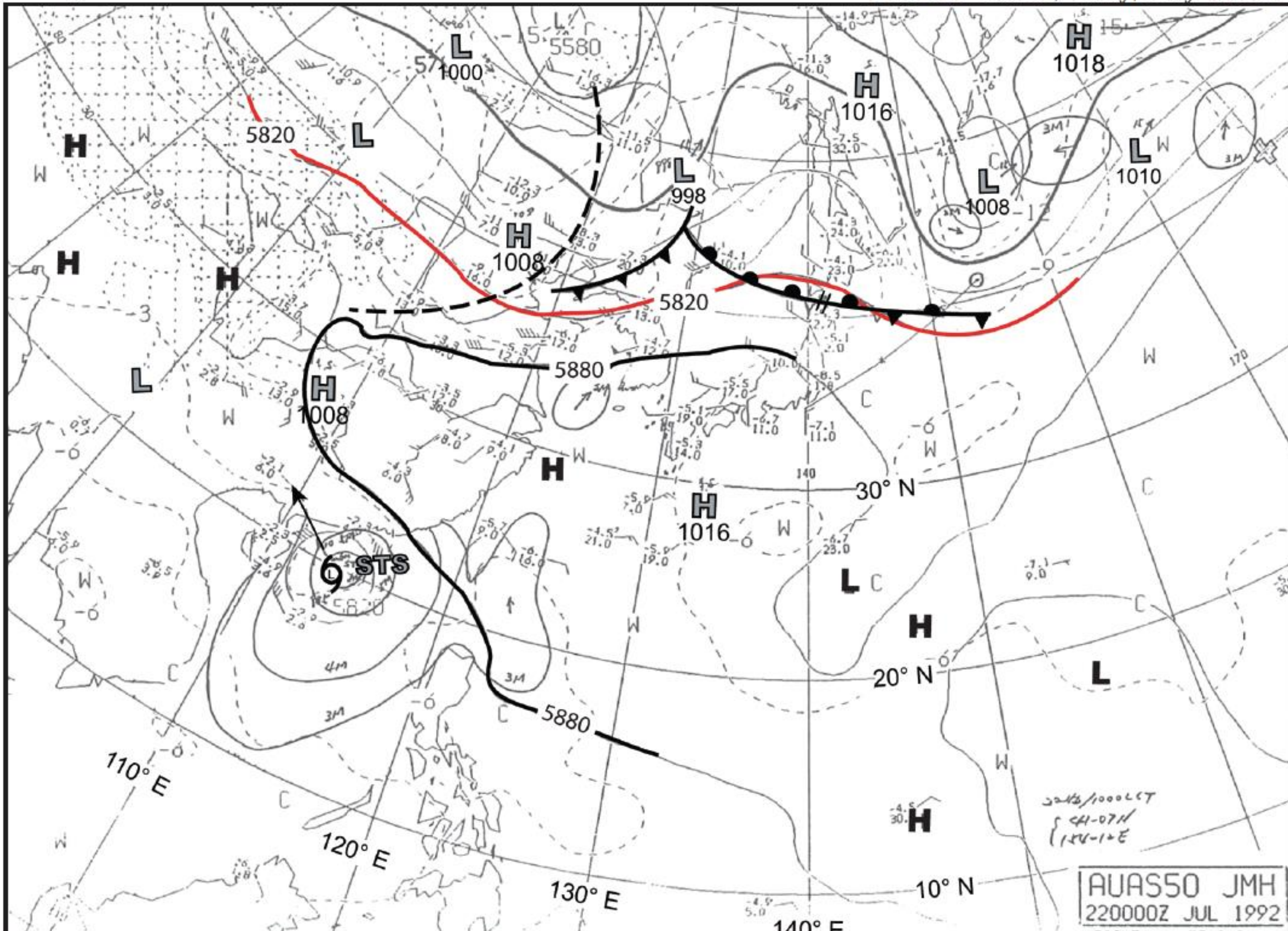


Fig. 15.3c 500 Mb Chart, Gary, Day Three

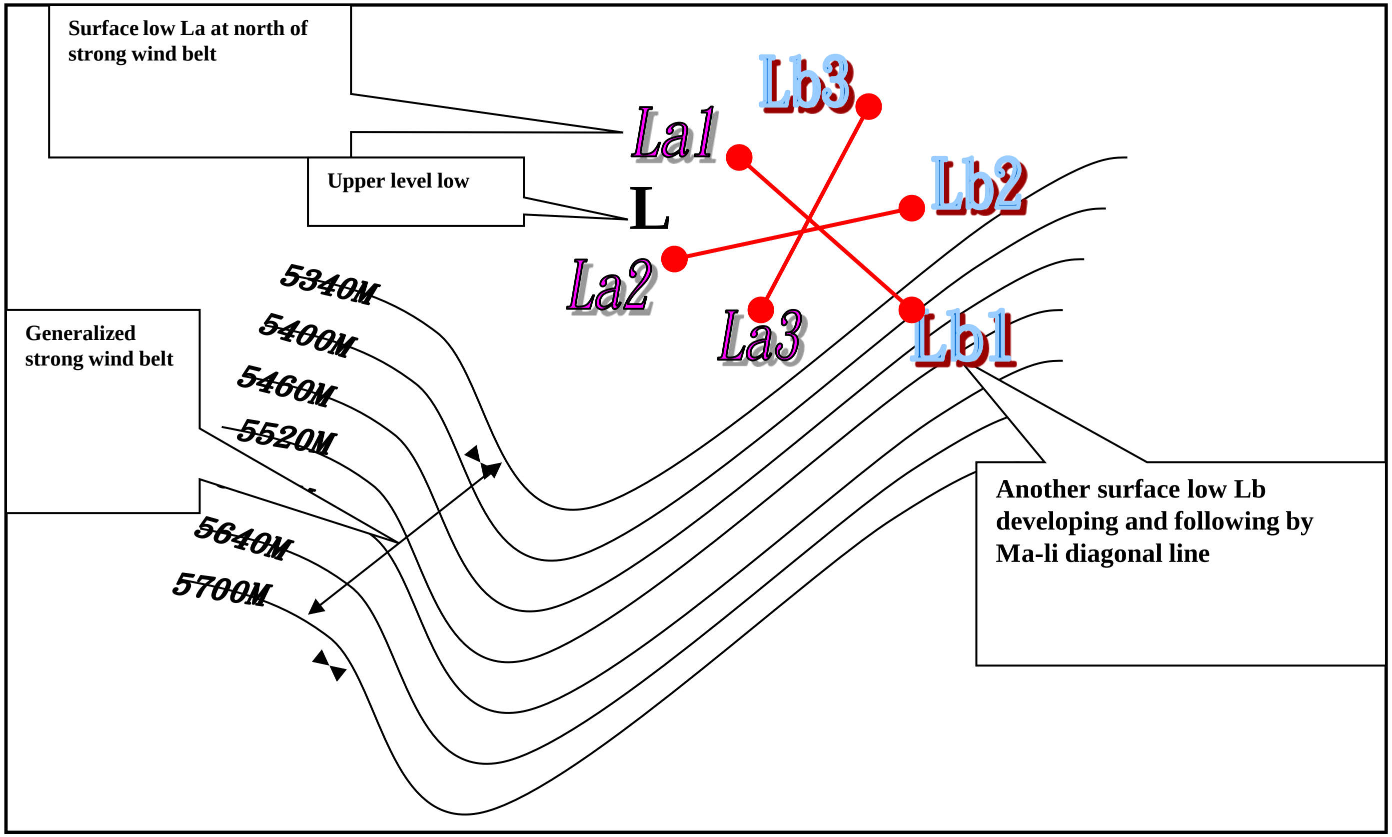


兩個溫帶氣旋互相接近時的變性探討

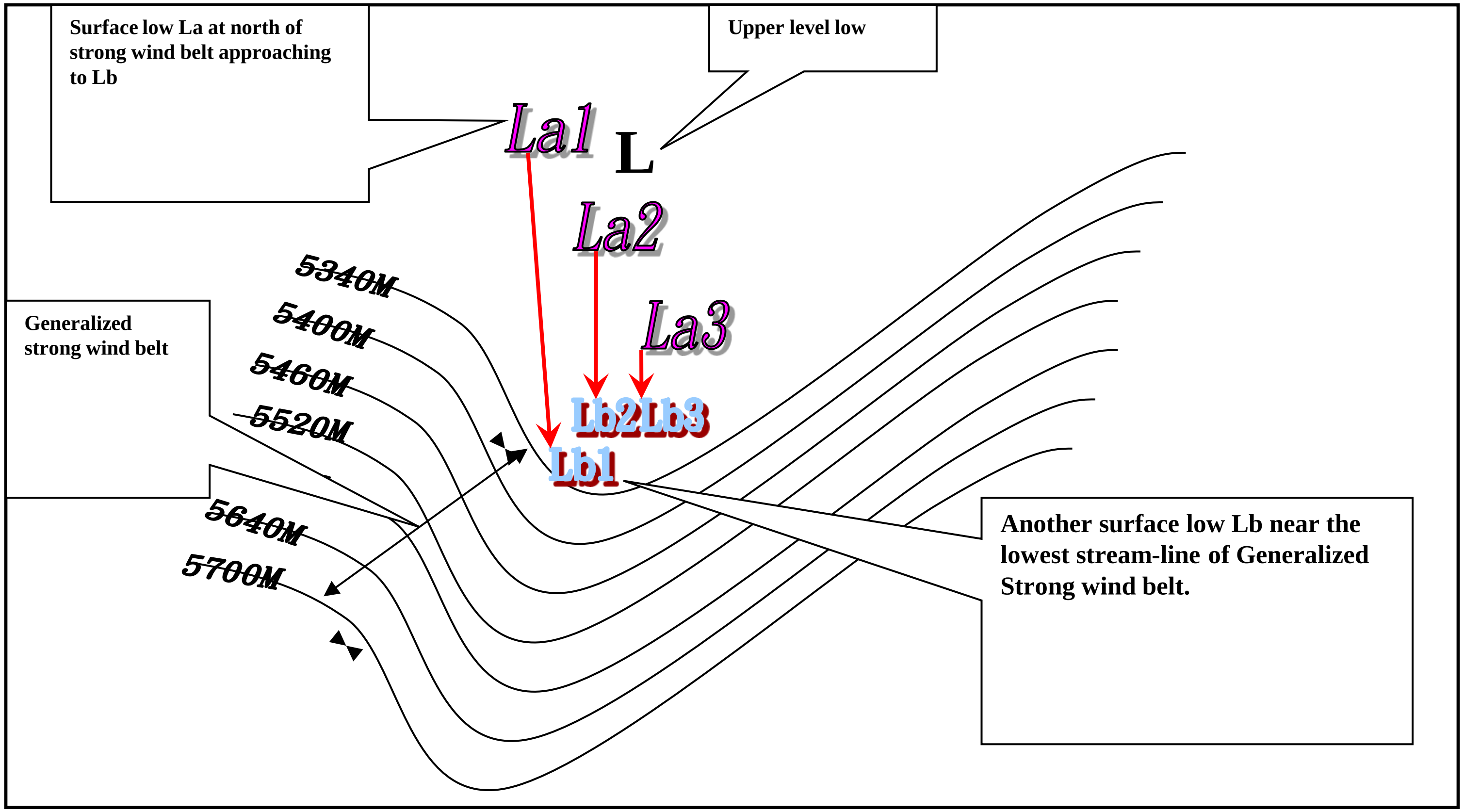
１·ＤＵＭＢＥＬＬ　ＥＦＦＥＣＴ　當貝爾效應（或稱啞鈴效應）

２·ＡＳＳＩＭＩＬＡＴＥ　ＥＦＦＥＣＴ　同化效應（或稱吞併效應）

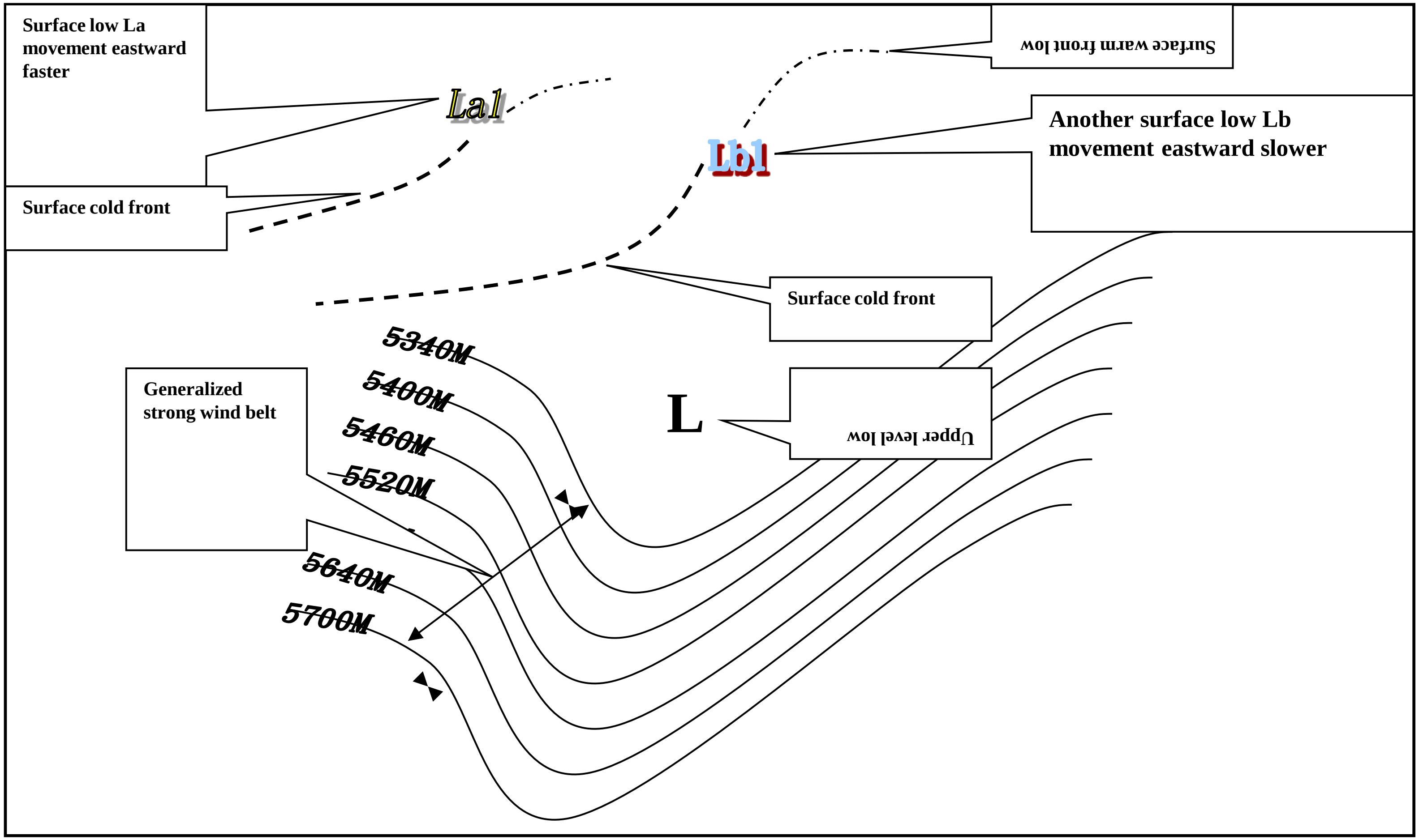
３·ＢＯＭＢ　ＥＦＦＥＣＴ　爆彈效應（或稱雙冷鋒效應）



Illustrates transformation of two surface low systems with "Dumbbell Effect", La is
surface low at north of the strong wind belt, Lb is another surface low under the
strong wind belt will going into C zone usually, their motion shown in three steps
above by mark 1,2 and 3 (i.e. La1/Lb1, La2/Lb2, La3/Lb3), the combined motion of



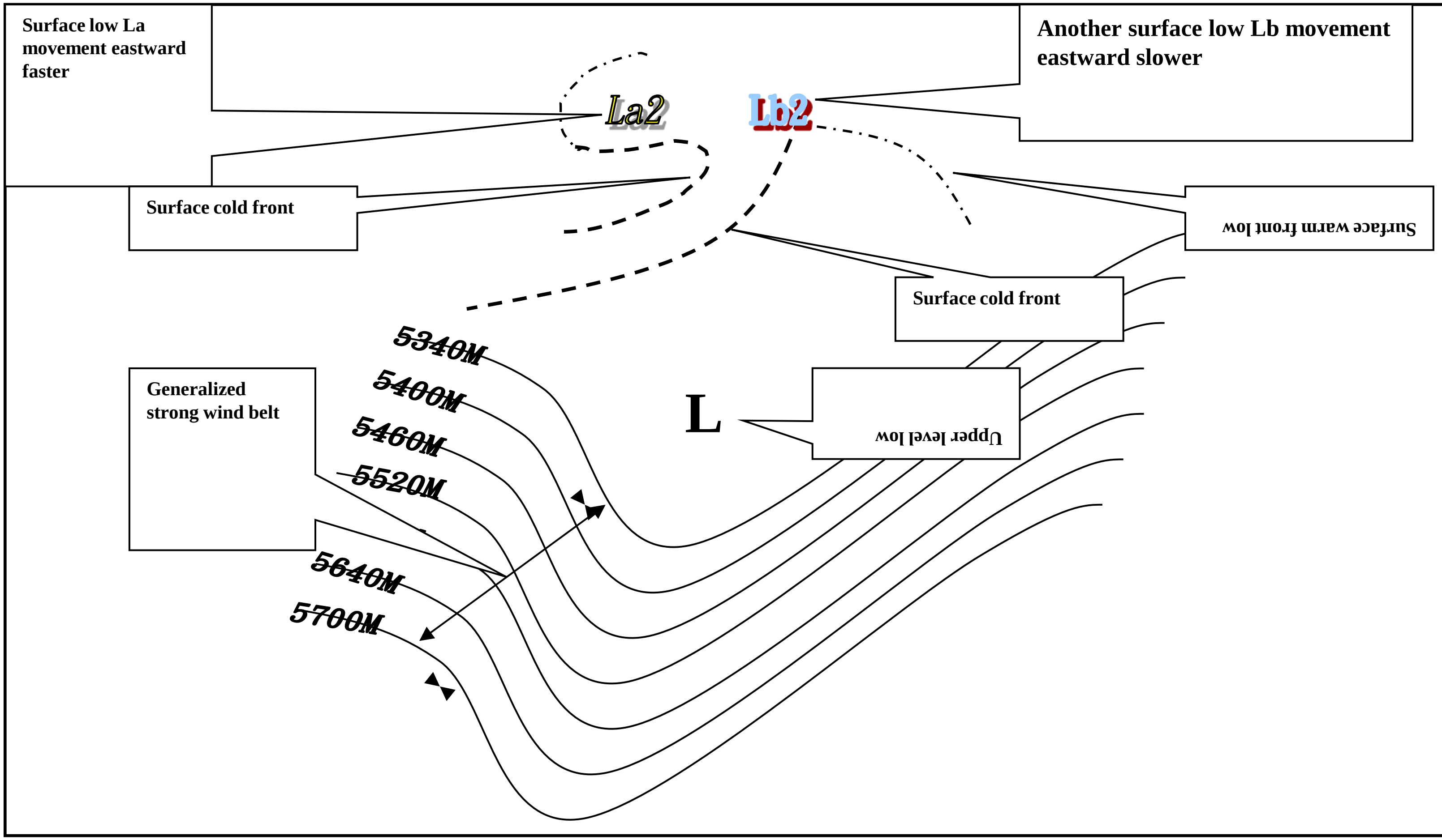
Illustrates transformation of two surface low systems with “Absorption Effect”, La
is surface low at north of the generalized strong wind belt, Lb is another surface low
near the lowest stream-line of generalized strong wind belt, La will assimilated by
Lb, their motion shown in three steps above by mark 1, 2 and 3 (i.e. La1/Lb1



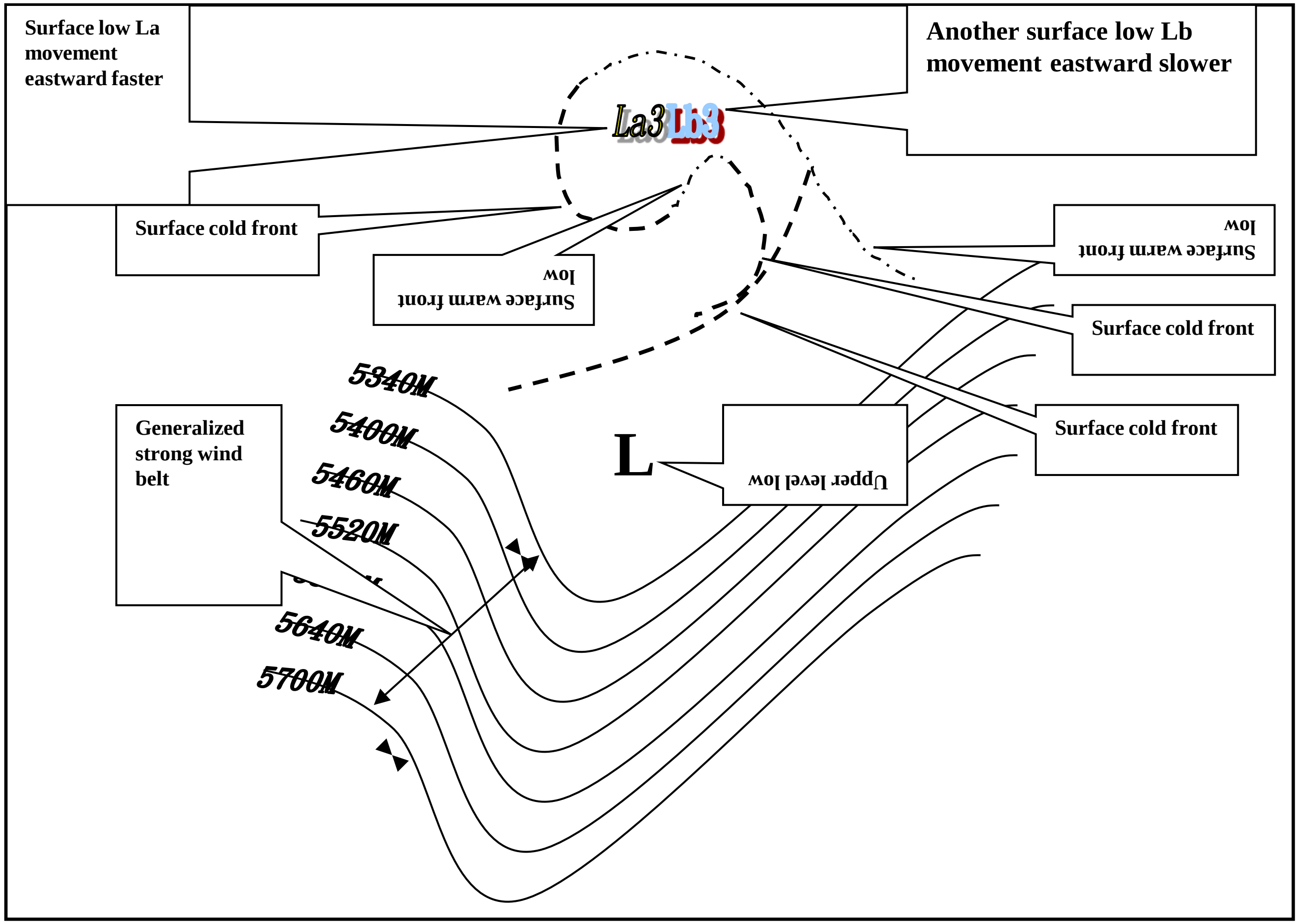
Illustrates transformation of two surface low systems with "Meteorological Bomb Effect", La and Lb are surface lows at north of the generalized strong wind belt,

La move to eastward is faster than Lb, La's cold front will catch Lb's, then cause

"Bomb Effect", above shown the first condition of this two lows

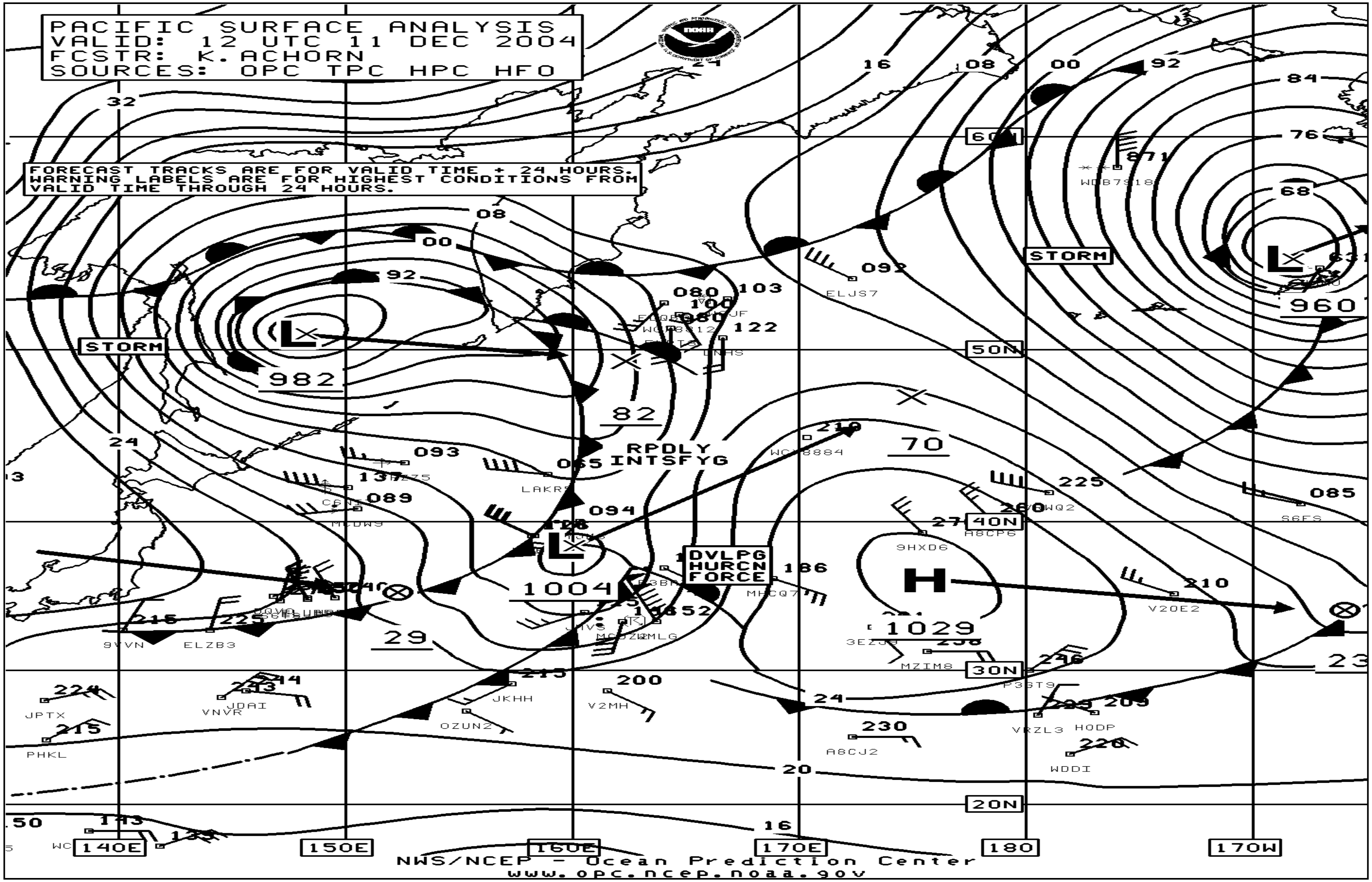


Illustrates transformation of two surface low systems with “Meteorological Bomb Effect”, when La closed to Lb, La’s cold front will accelerate and cause its rotates in a counterclockwise motion, above shown the second condition of this two lows.



Illustrates transformation of two surface low systems with “Meteorological Bomb Effect”, when La combined with Lb, La’s “S” shape front completes a 90 degree spiral, the two lows merging process is quick, which often leads to a hurricane-force new cyclone, above shown the third condition of this two lows.

Rapidly Intensifying low

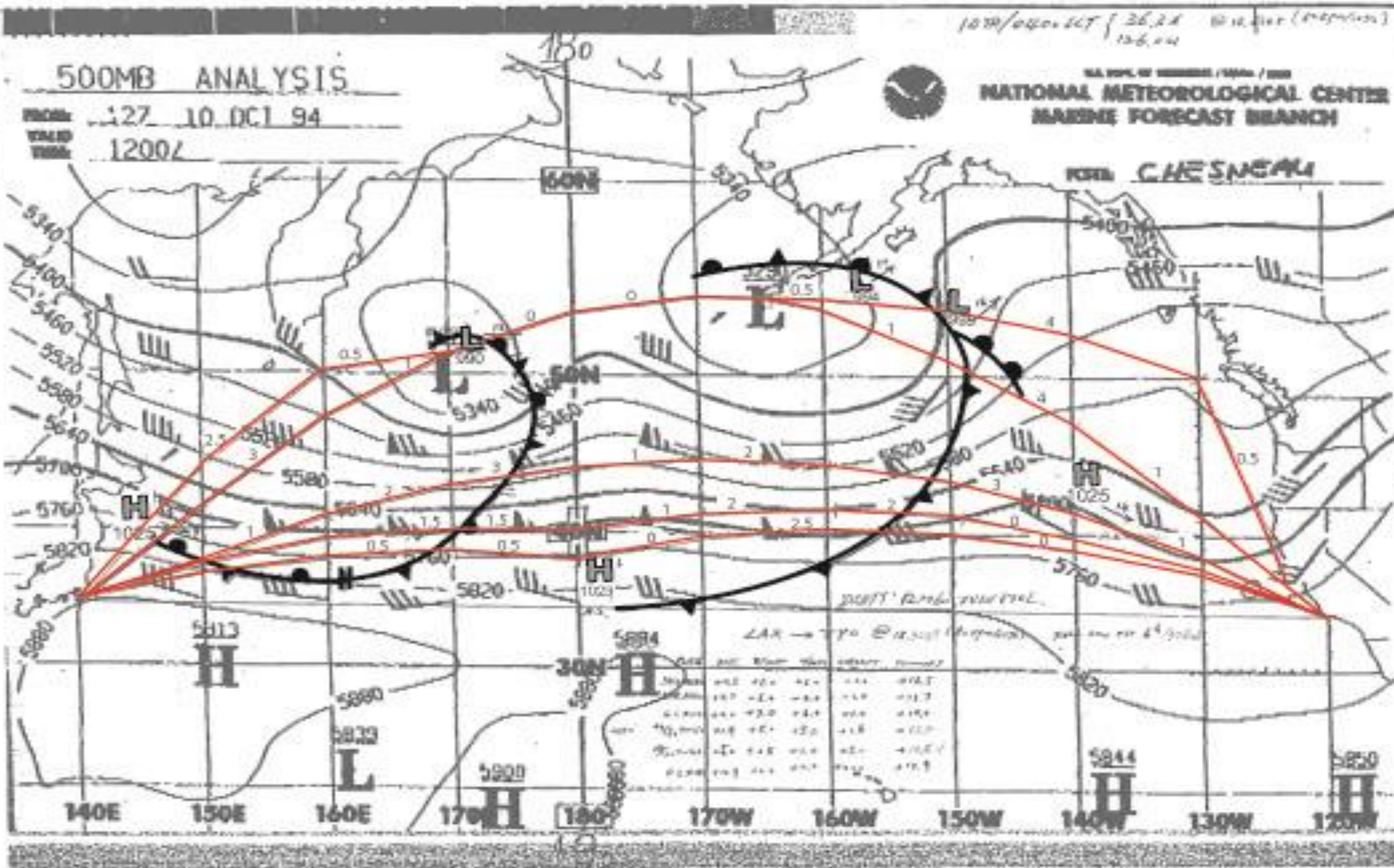


Rapidly Intensifying Low

- Definition…“a synoptic scale cyclone”that deepens 1 Bergeron (24 Mbs per day, + or a - latitude adjustment factor). Near latitude 45N(or S) the adjustment is 18 Mbs per day, near 60N the adjustment is by definition 24 Mbs per day. Note that many cyclones deepen that magnitude in less than 12 hours.
- The following are guidelines for identifying meteorological rapidly intensifying low:
- Abundant moisture in the warm sector of a wave cyclone is indicative of rapid wave cyclone intensification or cyclogenesis.

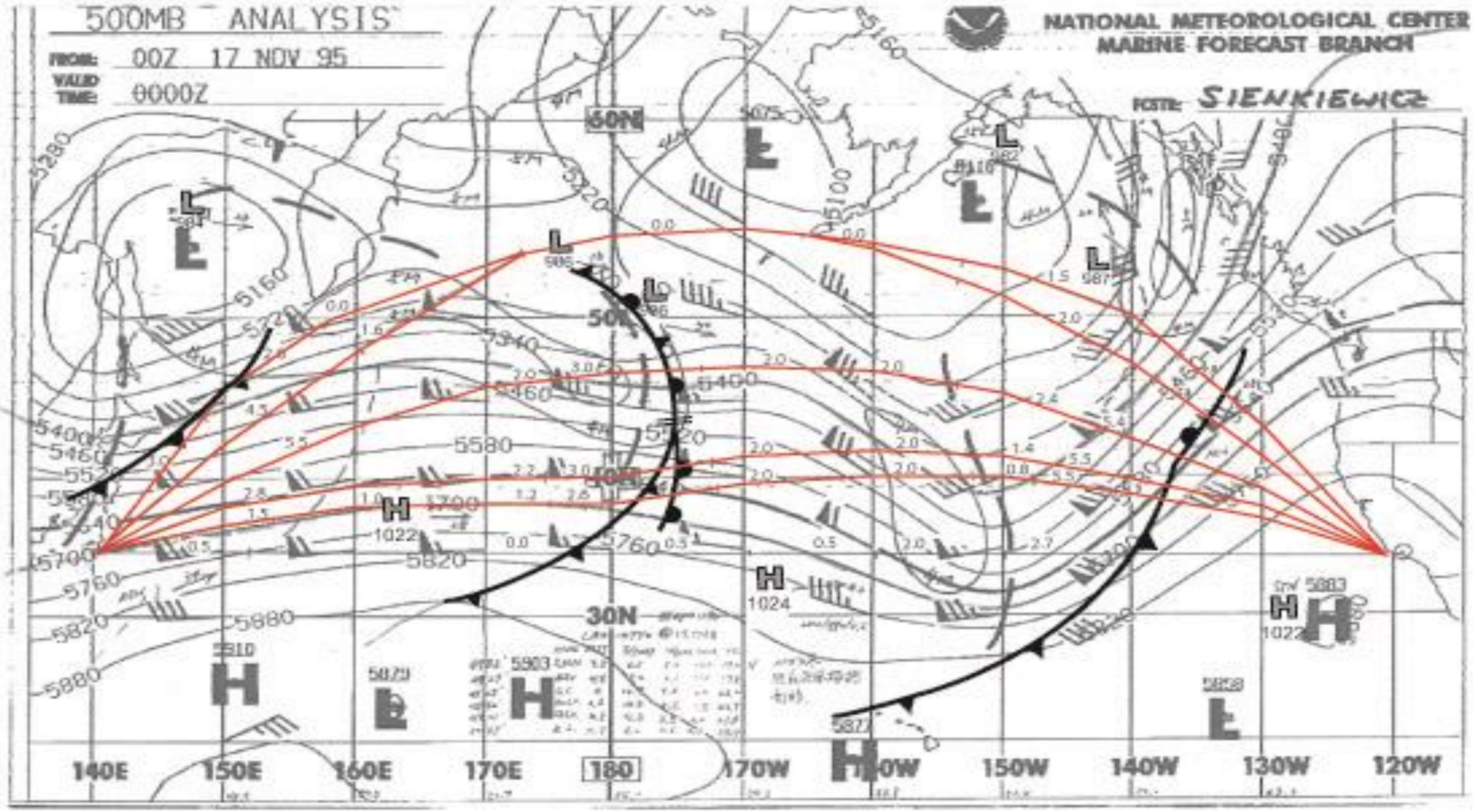
- Warm air is a prime trigger for meteorological rapidly intensifying low.
- Impressive warm frontal zones on a frontal wave, particularly at low latitudes, is indicative of advection (transport) of warm air.
- Low Stability or “static stability”
- Strong upper level jet stream of a zonal nature with winds in excess of 100 knots is indicative of a tight frontal boundary.
- Fast Movement…Contrary to higher latitude wave cyclones which tend to be slower moving systems, lower latitude cyclones, especially those that develop into meteorological rapidly intensifying low usually move quite rapidly under a zonal jet stream(35 knots or more).

- **Sea Surface Temperatures... Wave cyclones develop over water temperatures of 15 or 16 degrees Celsius, Some wave cyclones will develop over areas of strong thermal gradients (Gulf Stream & Kurishio)**
- **Strong Positive Vorticity Advection (PVA) associated with a rapidly moving and amplifying short wave in the final developing stages.**
- **The mature wave cyclone has characteristic comma head shape cloud pattern with wrap around cloud bands with the center of circulation quite apparent on meteorological satellite imagery.**



Los Angeles—Tokyo
Draft/ 12M60 Even keel
Wind force/ Beaufort force no.4
Wave height/ 2 Meters
Speed 82RPM/11.6%/18.3239 Kts
Full Low estimate (Weather loss rate) of D area/ 978mb/ 6 Hours
The IV quadrant of C zone/ 2 Hours

Route	Distance	East Part	West Part	Current	Summary
Coastal Aleu.	+10.5	+5.0	+3.0	-2.0	+16.5
Traditional Aleu.	+4.7	+6.0	+4.0	-1.0	+13.7
Single G.C.	+0.0	+7.0	+6.0	1.0	+14.0
40/180 Two G.C.	+2.9	+5.0	+3.0	+1.5	+12.4
38/180 Two G.C.	+5.0	+2.5	+1.0	+2.0	+10.5
R.L.	+12.9	+0.0	+0.0	+0.0	+12.9



Los Angeles—Tokyo
Draft/ 12M53 Even keel
Wind force/ Beaufort force no.4
Wave height/ 2 Meters
Speed 88RPM/7.0%/20.66 Kts
Full Low estimate (Weather loss rate) of D area/ 980mb/5.5 Hours
The IV quadrant of C zone/ 4.0 Hours

Route	Distance	East Part	West Part	Current	Summary
Coastal Aleu.	+7.5	+6.5	+5.0	-2.0	+17.0
Traditional Aleu	+4.8	+7.2	+6.1	-1.0	+17.1
Single G.C.	+0.0	+14.8	+7.5	+1.0	+23.3
40/180 Two G.C.	+2.6	+13.5	+4.8	+1.5	+22.4
38/180 Two G.C.	+4.5	+12.9	+3.5	+2.0	+22.9
R.L.	+11.7	+6.2	+0.5	+0.0	+18.4

航海學始終無解的解答

500mb氣象圖越洋最佳航路設計新解

(內容介紹)

- 本書第一章簡介中，討論傳統的穿越大洋航路設計，格於中長期天氣的難以預測，始終無法提供所謂的「理想航路」，既使在「鮑氏航海學」的航路篇中，也無法提供有效又合理可行的航路設計。近代的氣象預測能力已經增進，對於中長期天氣的預測，已經有相當程度的準確性，再結合電腦模擬的程式功能，許多收費氣象服務公司，已經能夠提供所謂的「最理想航路Optimum Route」，雖然不能做到完美的絕對有效，至少已經能夠保證合理程度的效果。

- 第三章討論狹義強風帶的移動特性，詳細說明利用500MB圖做航路設計時，應該注意的狹義強風帶的變化，使得航路設計更加有效。
- 要運用電腦程式在船舶上，並沒有技術上的困難，但是中長期天氣預測的資料，必須付費才能取得，所以必然增加了航行之成本，加以中長期天氣的資料，是以預測形式提供的，與實際的狀況難免有所差異，全然依賴氣象服務公司的遙控導航，往往失去了現場應變的先機，更無法逃避電腦運算程式中，邏輯設計的瑕疵，從航海安全的觀點來看，是屬於冒險的行為，也違背了船長主導航行的原則。
- 本書第二章討論航路設計與狹義強風帶的關係，每一節分別說明地形、港口地理位置、航向航速與長短波等單一項目與狹義強風帶的關係，並且分成太平洋與大西洋兩部份獨立探討。

- 第四章討論各種航路的形狀與地理位置，航路的形狀與狹義強風帶的關係，特別針對限制緯度的決定，提出個人研究心得，使得航路的限制緯度，符合實務航海的需求，使得最理想的航路可以完成。
- 第五到八章分別討論A,B,C,D各區的航路設計觀念，以及與該區相關的利用。
- 在第九章中，分別說明在各種型態狹義強風帶之下，如何有效決定理想航路的基本原則。
- 第十章提出決定理想航路的標準評估程序---分段評估法，提供實務案例，用實務作業的方式，說明評估程序。

- 第十一章列舉其他方法的評估程序---剔除法、觀察法等等，並提供實務案例，用實務作業的方式，說明評估程序。
- 第十二章討論印度洋的理想航路設計。
- 第十二章專題說明在印度洋的理想航路設計，印度洋位在熱帶與亞熱帶區，全區只受到季風的控制，最佳航路的選擇不多，但是也能使航行更安全與舒適。

印度洋季風期的浪高判斷（節錄參考）

- 從理論上探討，印度洋季風期的湧浪，是因為長時間的季風吹襲所形成的，而季風的形成，則歸因於地面高低壓中心之間所產生的梯度風。當夏季時，位在非洲大陸的高氣壓逐漸增強，而位在印度大陸的低氣壓也逐漸增強，此兩者之間的氣壓梯度差很明顯的增加，於是產生了強烈的梯度風，由是發展成季風。

- 根據統計，印度大陸的低氣壓與非洲大陸的高氣壓，其氣壓梯度若維持大於25 mb，則能夠在印度洋上造成的最大湧浪高度為6米；其氣壓梯度若維持介於26～27 mb，則能夠在印度洋上造成的最大湧浪高度為7米；其氣壓梯度若維持介於28～29 mb，則能夠在印度洋上造成的最大湧浪高度為8米。在此同時，如果搭配500 mb高空圖分析，可以得到更確定的判斷如下：
- 當高空低壓槽線進入阿拉伯半島時(註:平均動量約每日五度, 但進入印度洋區後, 逐漸增至每日十度)，或5820流線的切離低壓在印度洋上從小圈逐漸擴大，印度洋上的湧浪開始大於6米；當高空低壓槽線正對印度洋中心時，或5820流線的切離低壓在印度洋上從擴大到與繞極的5820流線相接（合併），湧浪的高度達到最高；當高空低壓槽線東移出馬來西亞半島時(此時印度洋上可能有高空切離低壓)，印度洋上的湧浪開始減弱。

- 當切離的高空高壓向東移動進入阿拉伯半島時，若此切離高空高壓覆蓋阿拉伯半島的面積達三分之一，則印度洋上湧浪的高度，應從氣壓梯度推斷的浪高扣除一米；若此切離高空高壓覆蓋阿拉伯半島的面積達二分之一，則印度洋上湧浪的高度，應從氣壓梯度推斷的浪高扣除二米；若此切離高空高壓覆蓋阿拉伯半島的面積達四分之三，則印度洋上湧浪的高度，應從氣壓梯度推斷的浪高扣除三米。