SGS6833: 대기과학

12주 차 강의자료

지난시간

- 저기압의 발달

오늘의 내용

- 일기예보

일기예보 방법 #1: persistent forecast

- “내일의 날씨는 오늘과 크게 다르지 않을 것이다”

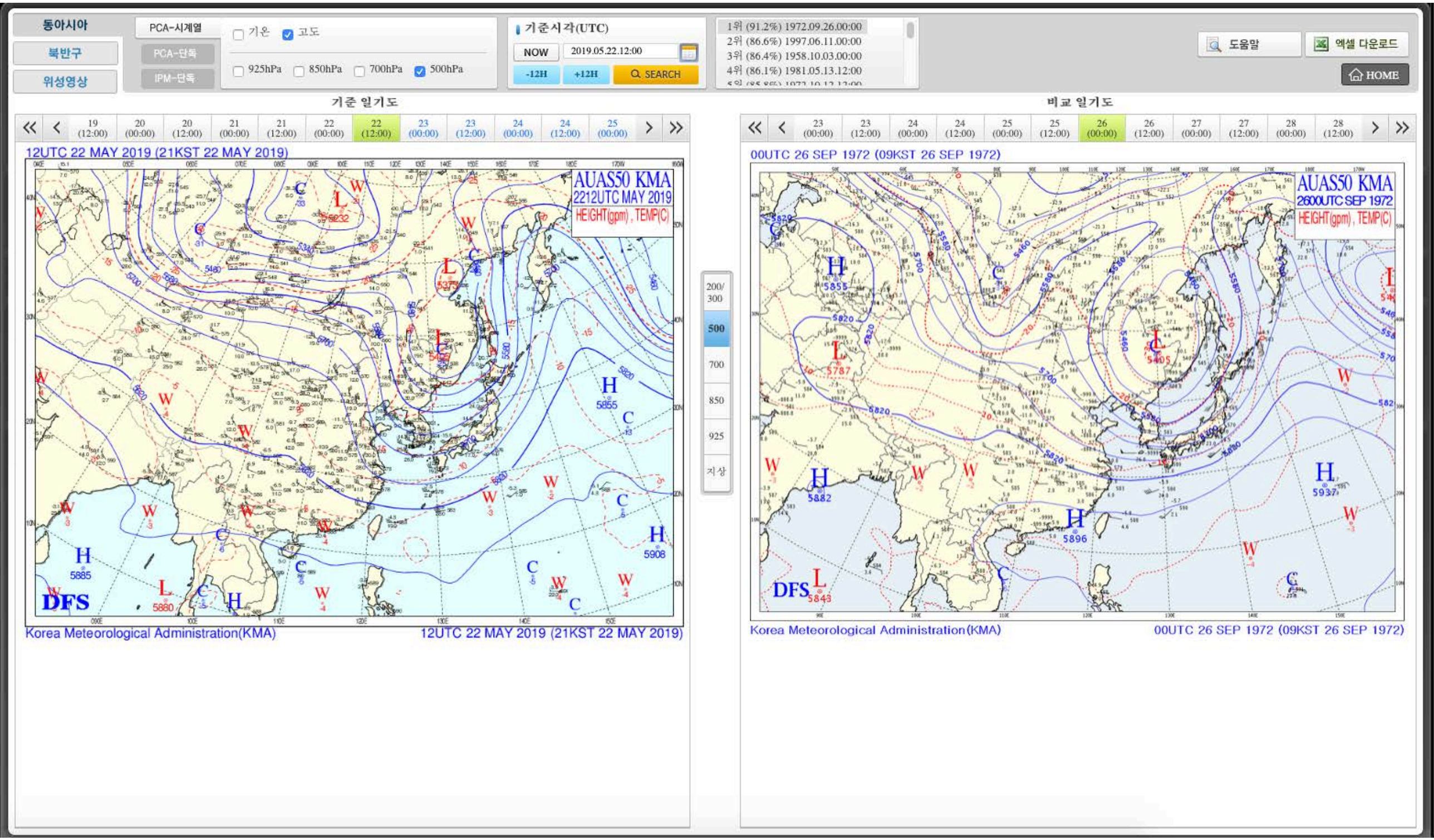
일기예보 방법 #2: Trend forecast

- “내일의 날씨는 오늘까지 보인 날씨 변동 경향의 연장일 것이다.”
- 예를 들어, 한랭전선이 동쪽으로 30 km/h의 속도로 움직이고, 지금 한랭전선이 지금 위치의 서쪽 90 km에 위치한다면, 3시간 후에 한랭전선이 도달할 것으로 예보가능

일기예보 방법 #3: analogue method

- “과거에 이런 날씨가 있었을 것이다.”
- 과거 날씨의 진행을 보며 미래의 날씨 예측
- 예: 최고온도의 예보
  - 오늘의 최고 온도가 10도였다면, 과거 30년 최고온도가 10도인 때, 최고온도와 다른 날씨 요소들 (구름량, 바람, 습도 등) 과의 상관관계를 바탕으로 현재 구름량, 바람, 습도등을 이용하여 내일의 날씨 예보
- 문제점 : “비슷” 하지만 “일치”하지는 않음

방재기상정보시스템


동아시아
북반구
위성영상
PCA-시계열
PCA-단독
IPM-단독
기온
고도
925hPa
850hPa
700hPa
500hPa
기준시각(UTC)
NOW
2019.05.22.12:00
-12H
+12H
SEARCH
1위 (91.2%) 1972.09.26.00:00
2위 (86.6%) 1997.06.11.00:00
3위 (86.4%) 1958.10.03.00:00
4위 (86.1%) 1981.05.13.12:00
도움말
엑셀 다운로드
HOME
기준 일기도
19 (12:00)
20 (00:00)
20 (12:00)
21 (00:00)
21 (12:00)
22 (00:00)
22 (12:00)
23 (00:00)
23 (12:00)
24 (00:00)
24 (12:00)
25 (00:00)
12UTC 22 MAY 2019 (21KST 22 MAY 2019)
AUAS50 KMA
2212UTC MAY 2019
HEIGHT(gpm), TEMP(C)
DFS
Korea Meteorological Administration(KMA)
12UTC 22 MAY 2019 (21KST 22 MAY 2019)
200/300
500
700
850
925
지상
비교 일기도
23 (00:00)
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27 (12:00)
28 (00:00)
28 (12:00)
00UTC 26 SEP 1972 (09KST 26 SEP 1972)
AUAS50 KMA
2600UTC SEP 1972
HEIGHT(gpm), TEMP(C)
DFS
Korea Meteorological Administration(KMA)
00UTC 26 SEP 1972 (09KST 26 SEP 1972)

일기예보 방법 #4: statistical forecast

- 통계적인 방법으로 날씨 예보
- “서울에 내일 비 올 확률 이 60%”
  - 서울 지역의 60% 면적에 비가 온다는 의미?
  - 서울 전 지역에 24시간 중 60%의 시간에 비가 온다는 의미?
  - 서울의 임의의 지역에 비가 측정 가능한 비가 올 확률이 60%
  - 현재와 같은 기상상태가 수없이 반복될 때 비가 올 확률이 60%

일기예보 방법 #5: climatological forecast

- 지역 기후를 이용한 예보
- 예: 남부 캘리포니아의 여름에는 평균 강수량이 0이므로 이번 여름에도 비가 오지 않을 것으로 예상

일기예보 방법 #5: numerical weather prediction

- 컴퓨터 모델을 이용한 예보
- 대기의 흐름을 나타내는 방정식들을 컴퓨터로 빠르게 계산하여 예보에 활용

$$\frac{u(t+\Delta t)-u(t)}{\Delta t} - fv = F_x \longrightarrow u(t+\Delta t) = u(t) + \Delta t\left(fv + F_x\right)$$

- 관심 지역을 수평/연직 격자로 나누어서 계산
- 1922: L.F. Richardson은 대기흐름을 나타내는 미분방정식을 손으로 풀어서 6시간 후 일기예보를 시도함
- 실패하였지만, 가능성은 제시

일기예보 방법 #5: numerical weather prediction

- 1950년대, Jule Charney는 수치모델이 가능할 수 있도록 미분방정식을 수정
- 컴퓨터 발달로 미분방정식 계산이 가능해짐

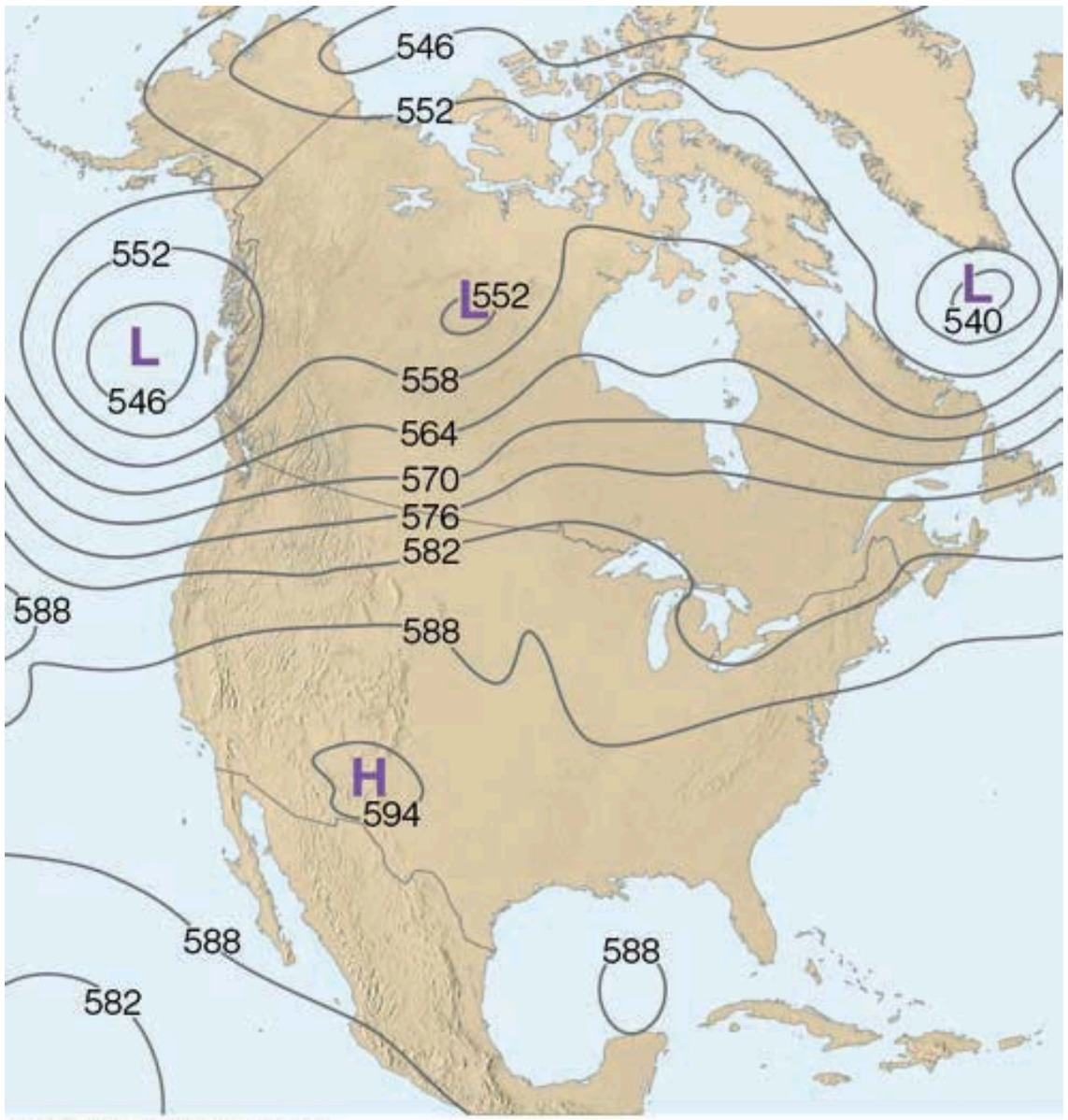
일기예보 방법 #5: numerical weather prediction

- 해상도에 따라, 미분방정식에 따라 지역적 범위에 따라 다른 성질의 모델이 존재
  - 기후모델
    - 장시간에 걸친 대류권과 성층권의 대기현상 모의
    - 기후변화 연구에도 활용
  - 현업용 종관모델
    - 날씨 예보에 사용
    - 전지구 혹은 지역 모델
    - 종관규모 일기를 묘사할 수 있는 해상도

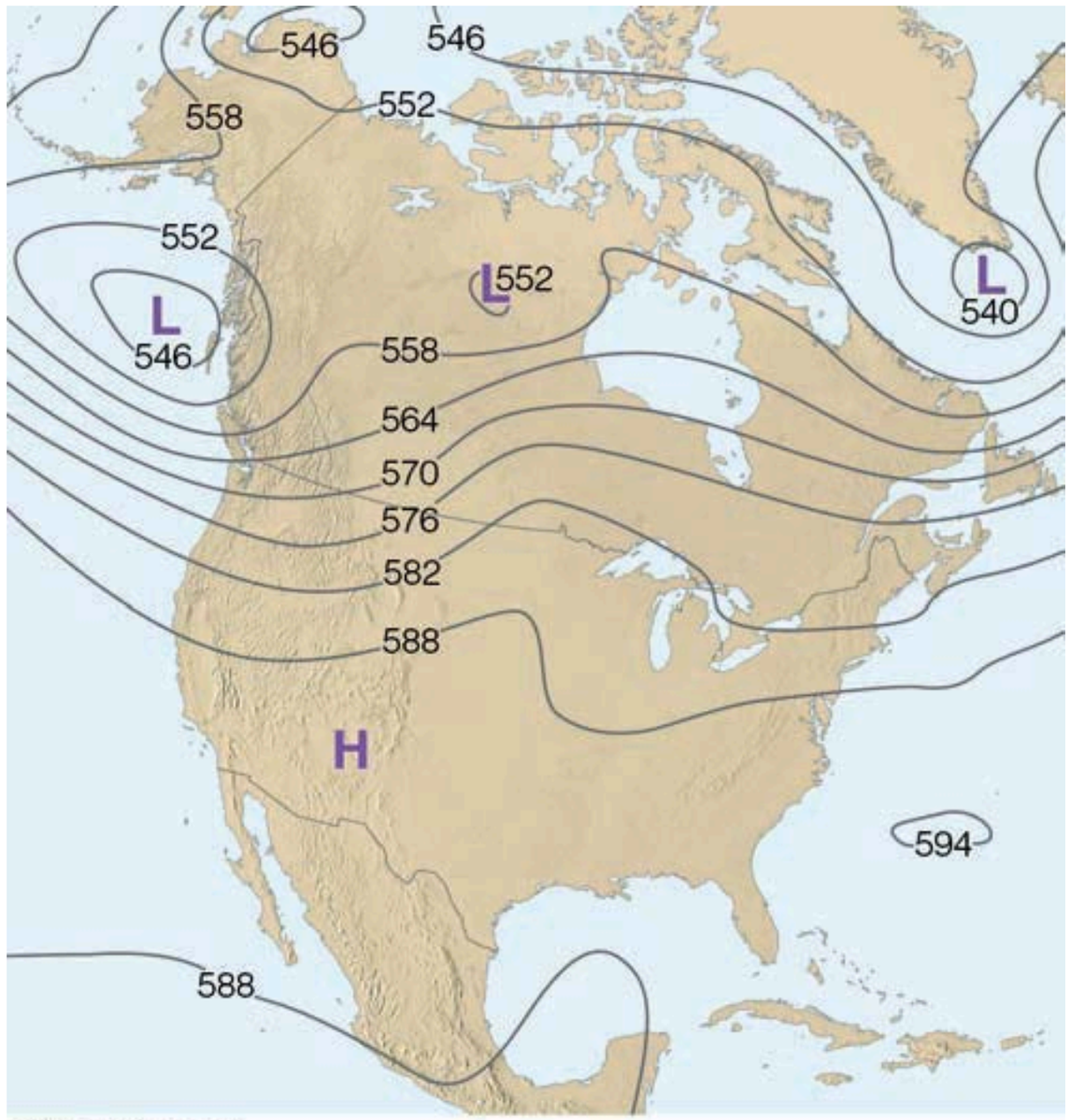
일기예보 방법 #5: numerical weather prediction

- 해상도에 따라, 미분방정식에 따라 지역적 범위에 따라 다른 성질의 모델이 존재
  - 중규모 모델
    - 국지적 날씨변동을 예측하는데 활용
    - 수평해상도가 종관모델보다 높음
  - 특화된 모델
    - 특별한 목적을 가진 모델
    - 안개, 구름 모의와 같은 물리과정을 연구하는데 활용

일기예보 방법 #5: numerical weather prediction

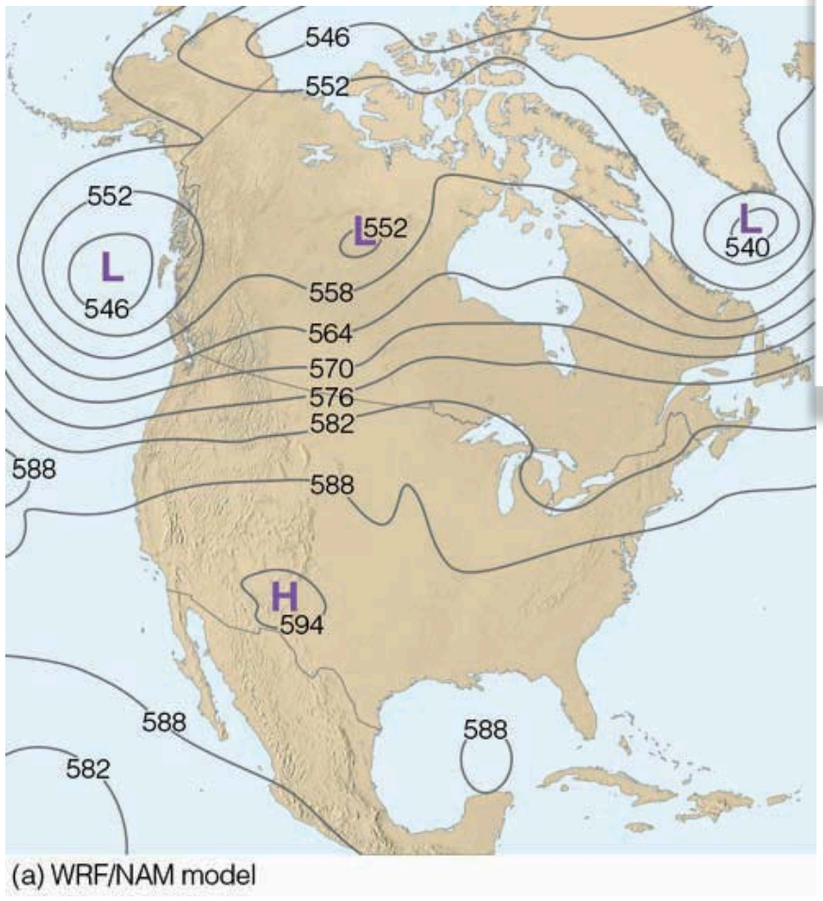


지역모델, 12km 격자

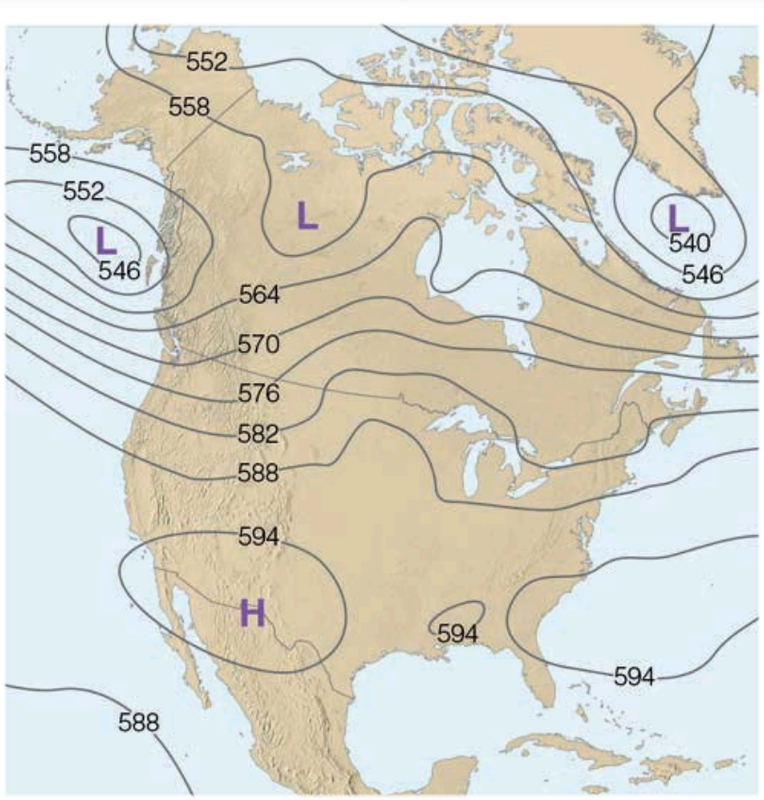


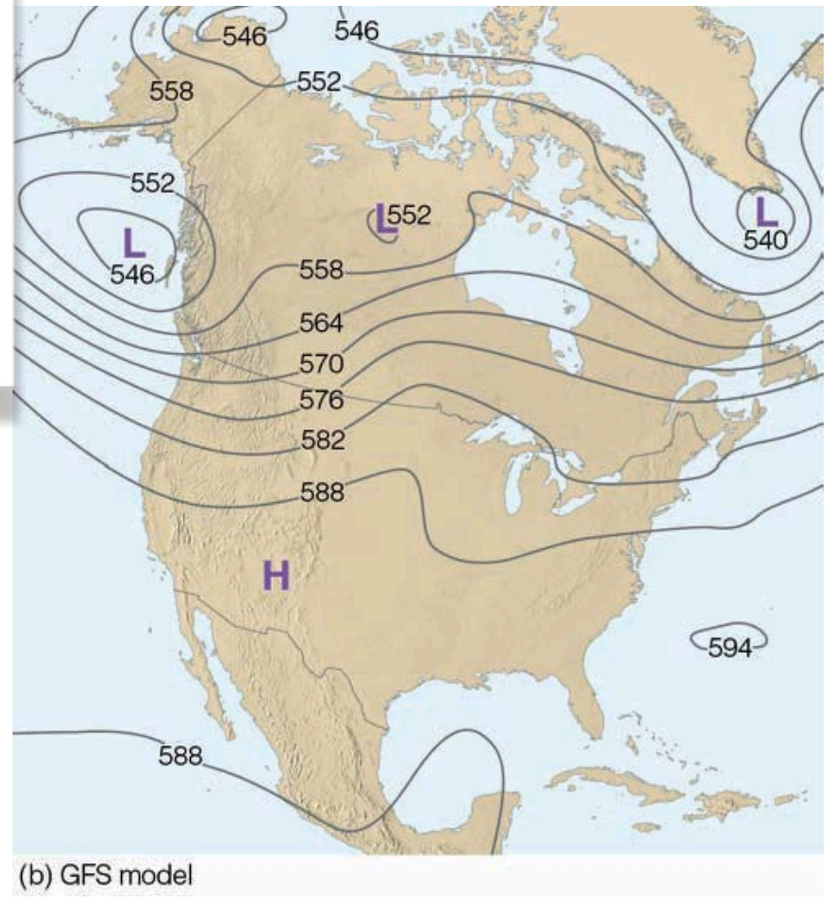
전지구모델, 60km 격자

일기예보 방법 #5: numerical weather prediction



(a) WRF/NAM model





(b) GFS model

지역모델, 12km 격자

전지구모델, 60km 격자

Unknown unknown

- Ronald Rumsfeld, 2002

> "There are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know."

일기예보 방법 #5: numerical weather prediction

- 컴퓨터모델의 한계점
  1. 여러가지 가정들: 관심있는 현상들을 잘 모의하기 위해 가정을 하여 방정식을 단순화할 수 있지만, 이로 인한 오차 발생
  2. 지역모델은 경계값들을 받아서 계산을 하는데, 경계값에 오차가 있을 수 있음. 경계값과 모델의 해상도 차이도 오차를 발생시킬 수 있음
  3. 모델의 격자보다 작은 현상을 계산할 수 없음: thunderstorm을 나타내기 어려움. 격자를 작게 만들면 계산시간이 늘어남

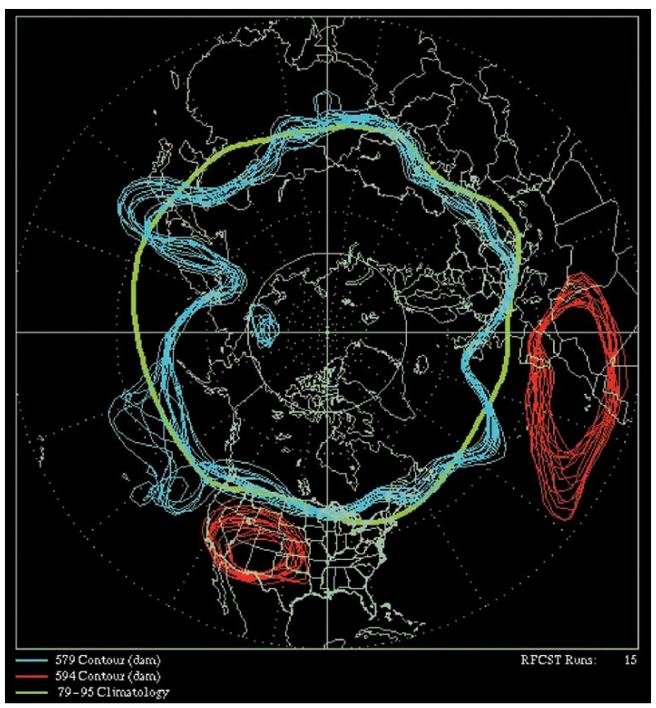
일기예보 방법 #5: numerical weather prediction

- 컴퓨터모델의 한계점
  4. 날씨에 영향을 주는 다른 요소들 (바다, 육지, 해빙 등)을 정확하게 나타낼 수 없음
  5. Chaos 이론 : 작은 오차가 비선형 시스템에서 점점 커지는 것. 초기의 오차가 시간이 지나면서 증폭됨

일기예보 방법 #5: numerical weather prediction

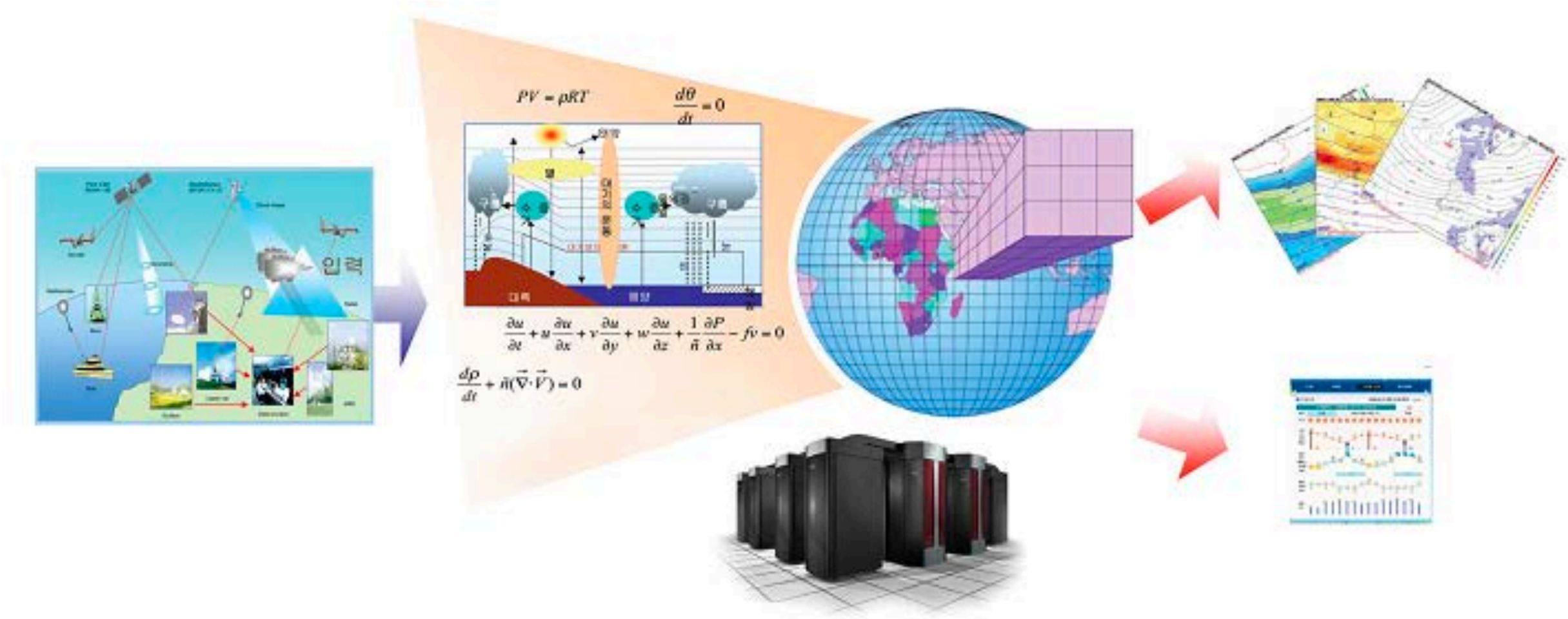
- 컴퓨터모델의 개선 방법
  - 앙상블 예보
    - 다양한 컴퓨터 시뮬레이션의 평균을 이용하여 예보
    - 초기 조건을 약간 다르게 하여 시뮬레이션 하는 방법
    - 여러 컴퓨터 모델을 써서 시뮬레이션 하는 방법

Spaghetti plot



500 mb 의 높이가 5940 m 인 선을 15개의 모델결과를 이용하여 그린 그림

일기예보 방법 #5: numerical weather prediction



[수치예보 생산과정]

일기예보의 정확도

- 12-24시간 예보 : “usually quite good”
- 2-5일 예보 : “fairly good”
- 7일 이후의 예보 : chaotic 성질로 인해 예보 정확도가 빠르게 떨어짐
- 정확도를 어떻게 평가할까?
  - Accuracy : 비가 올지 안올지, 최고 온도의 범위를 예측할 수 있는지…
  - Skill : persistent forecast와 비교해서 예보의 정확도 평가
    - 예) 여름에 비가 오지 않는 캘리포니아 남부에서 “비가 오지 않는다”라는 정확한 예보를 하여도 skill은 높지 않다.

일기예보의 Rules of Thumb

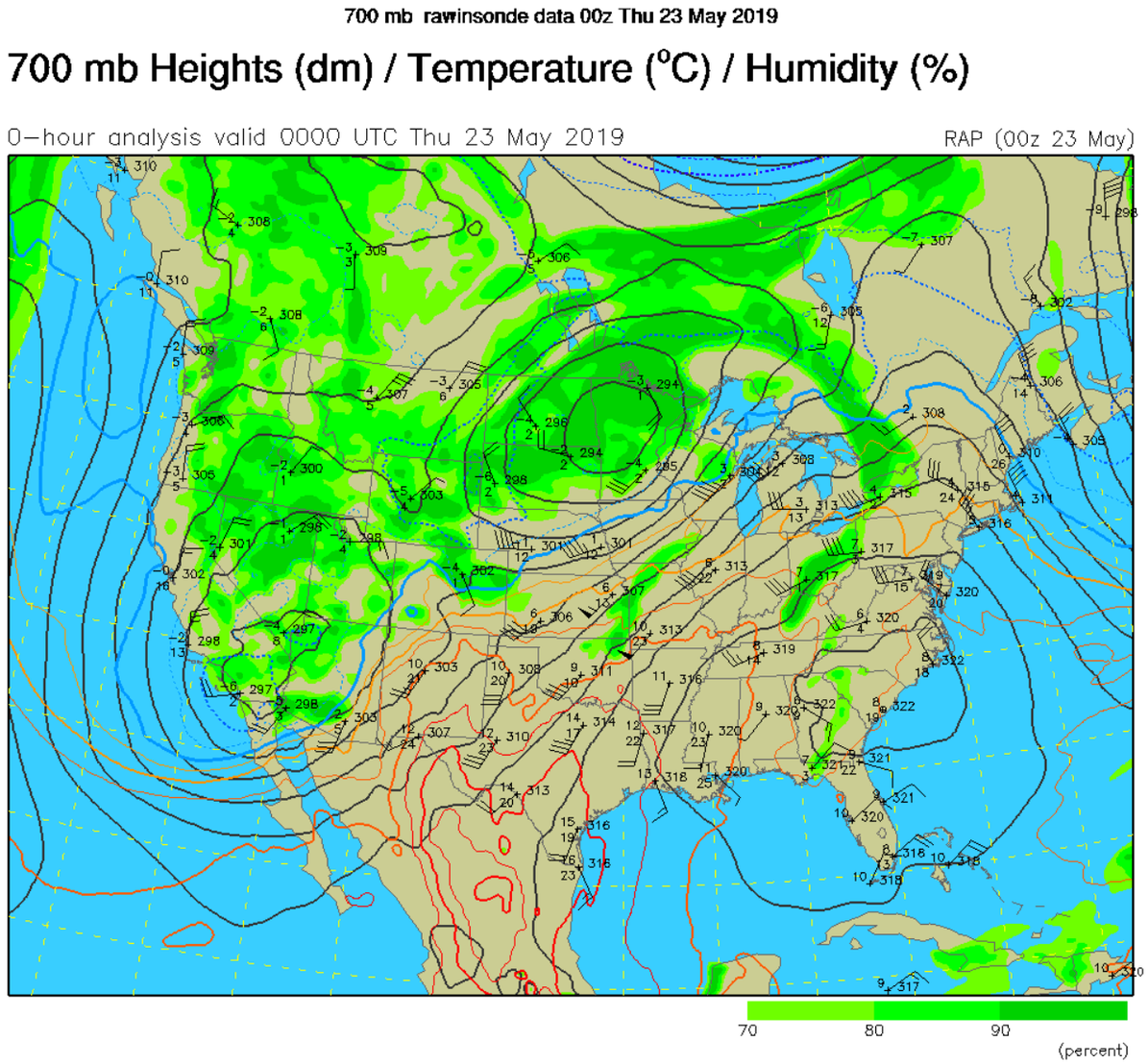
TABLE 13.1 A Few Forecasting "Rules of Thumb"*

FORECAST QUESTION	USE OF FORECAST CHART
Cloudy or clear?	On the 700-mb forecast chart, the 70 percent relative humidity line usually encloses areas that are likely to have clouds.
Will it rain?	(a) On the 700-mb forecast chart, the 90 percent relative humidity line often encloses areas where precipitation is likely. Upward air motions are present, and the chance of precipitation is enhanced. (b) Along the west coast of North America, precipitation is much more likely north of the 5640-meter height contour on the 500-mb forecast chart.
Will it rain or snow?	On the 850-mb forecast chart, snow is likely north of the −5°C (23°F) isotherm, whereas rain is likely south of this line. On the 1000-mb to 500-mb thickness chart, the 5400-meter thickness line is widely used (east of the Rockies) as the dividing line between rain and snow.
Will the surface low intensify?	For the storm to intensify (deepen), an area of upper-level divergence must be over the surface cyclonic storm. On a 500-mb forecast chart that shows vorticity, look for a vorticity maximum (vort max) and remember from Chapter 12, p. 332, that to the east of an area of positive vorticity we usually find upper-level divergence, upward air motions, and cyclonic storm development.

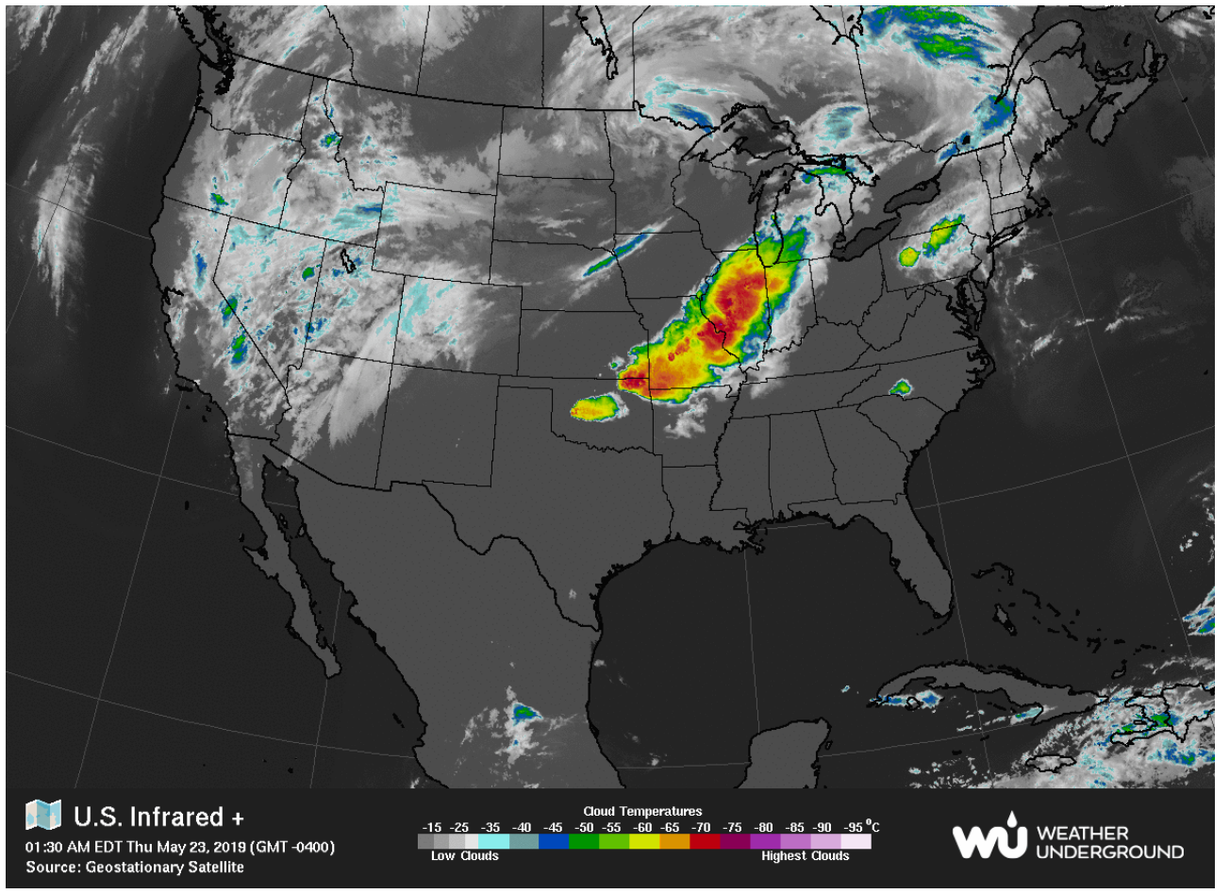
*The forecast charts (progs) found in this table can be obtained from the World Wide Web.

700 mb 차트 에서 상대습도가 70%보다 높은 지역은 보통 구름이 많다.

일기예보의 Rules of Thumb



http://www.meteo.psu.edu/~wfr1/w4/wxupper.htm



https://www.wunderground.com/maps/satellite/regional-infrared

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Will it rain?	(a) On the 700-mb forecast chart, the 90 percent relative humidity line often encloses areas where precipitation is likely. If upward velocities are present, the chance of measurable precipitation is enhanced. (b) Along the west coast of North America, precipitation is much more likely north of the 5640-meter height contour on the 500-mb forecast chart.
Will it rain or snow?	On the 850-mb forecast chart, the 0°C isotherm is usually found near the 5000-meter height line. Rain is likely south of this line. On the 1000-mb to 500-mb thickness chart, the 5400-meter thickness line is widely used (east of the Rockies) as the dividing line between rain and snow.
Will the surface low intensify?	For the storm to intensify (deepen), an area of upper-level divergence must be over the surface cyclonic storm. On a 500-mb forecast chart that shows vorticity, look for a vorticity maximum (vort max) and remember from Chapter 12, p. 332, that to the east of an area of positive vorticity we usually find upper-level divergence, upward air motions, and cyclonic storm development.

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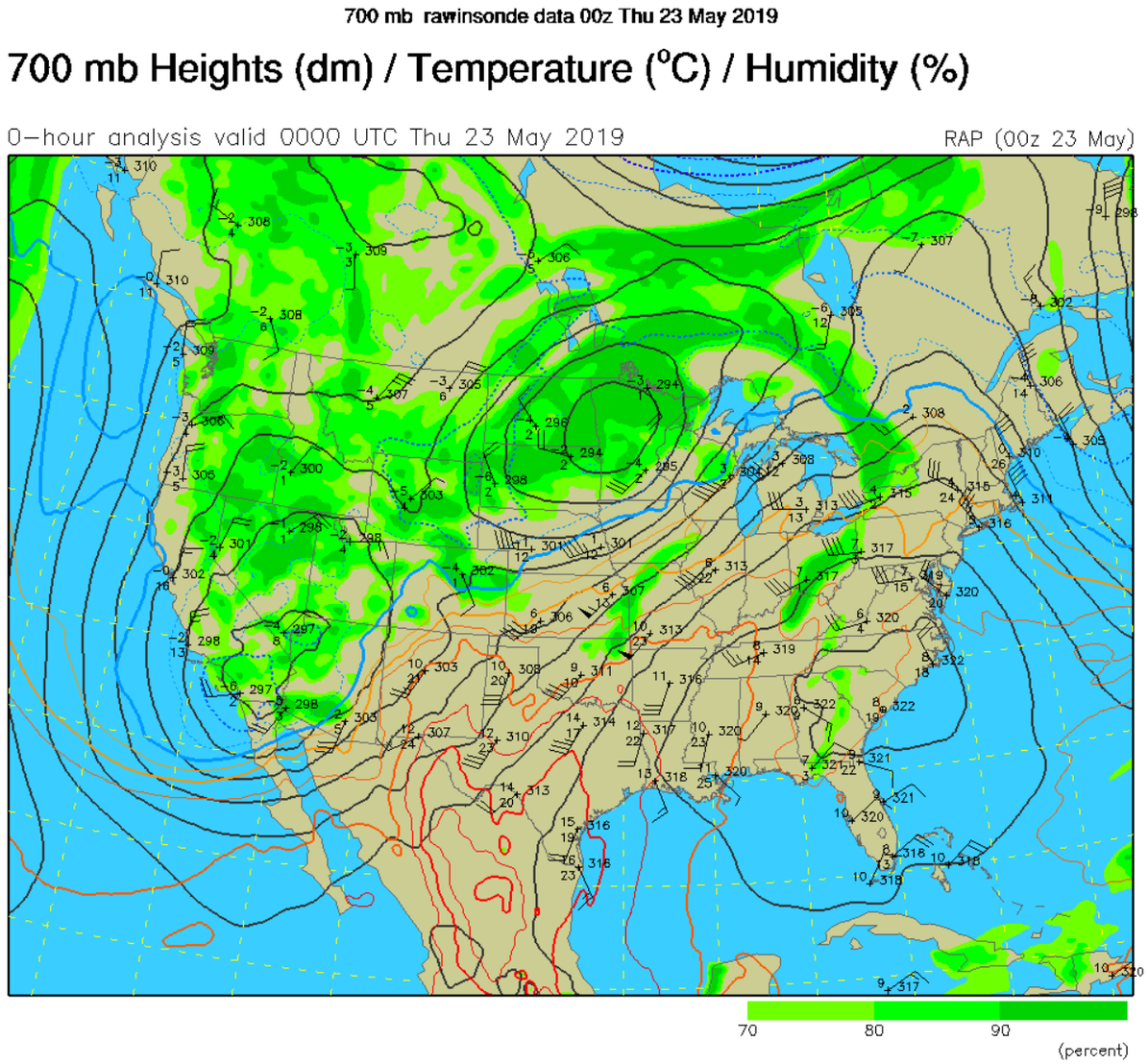
700 mb 차트 에서 상대습도가 90%보다 높은 지역은 비가 내릴 수 있다.
상승기류가 있으면 비가 올 확률이 높아진다.

일기예보의 Rules of Thumb



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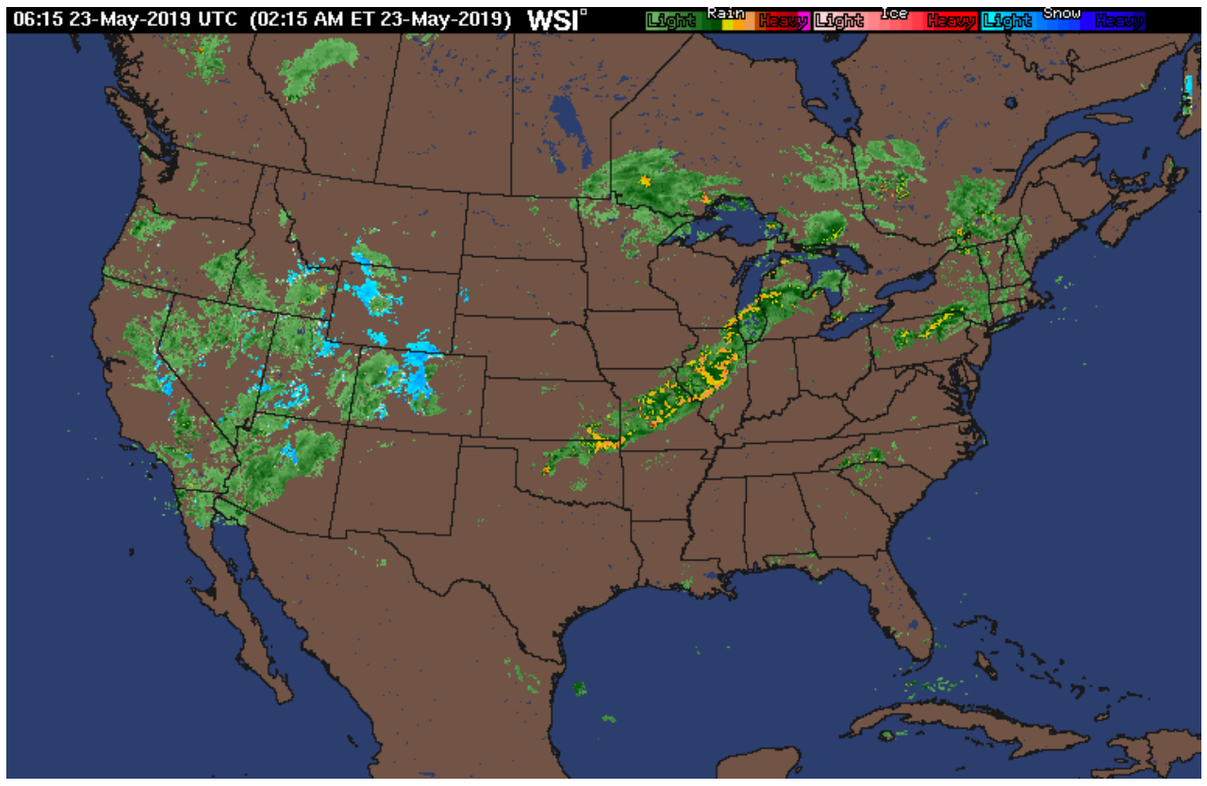

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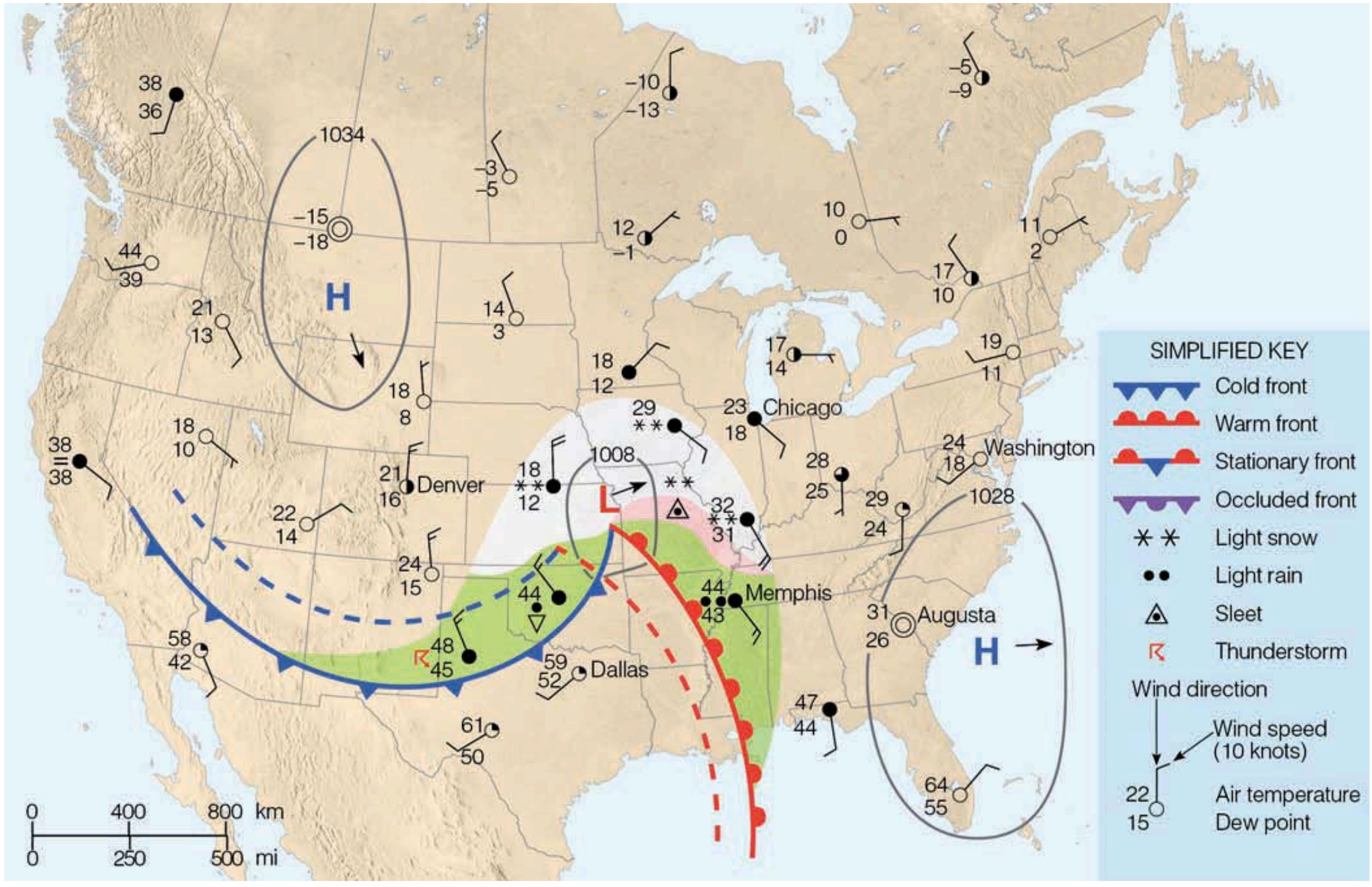
850 mb 차트 에서 온도가 -5도 선의 북쪽에는 눈이오고 남쪽에는 비가 온다.

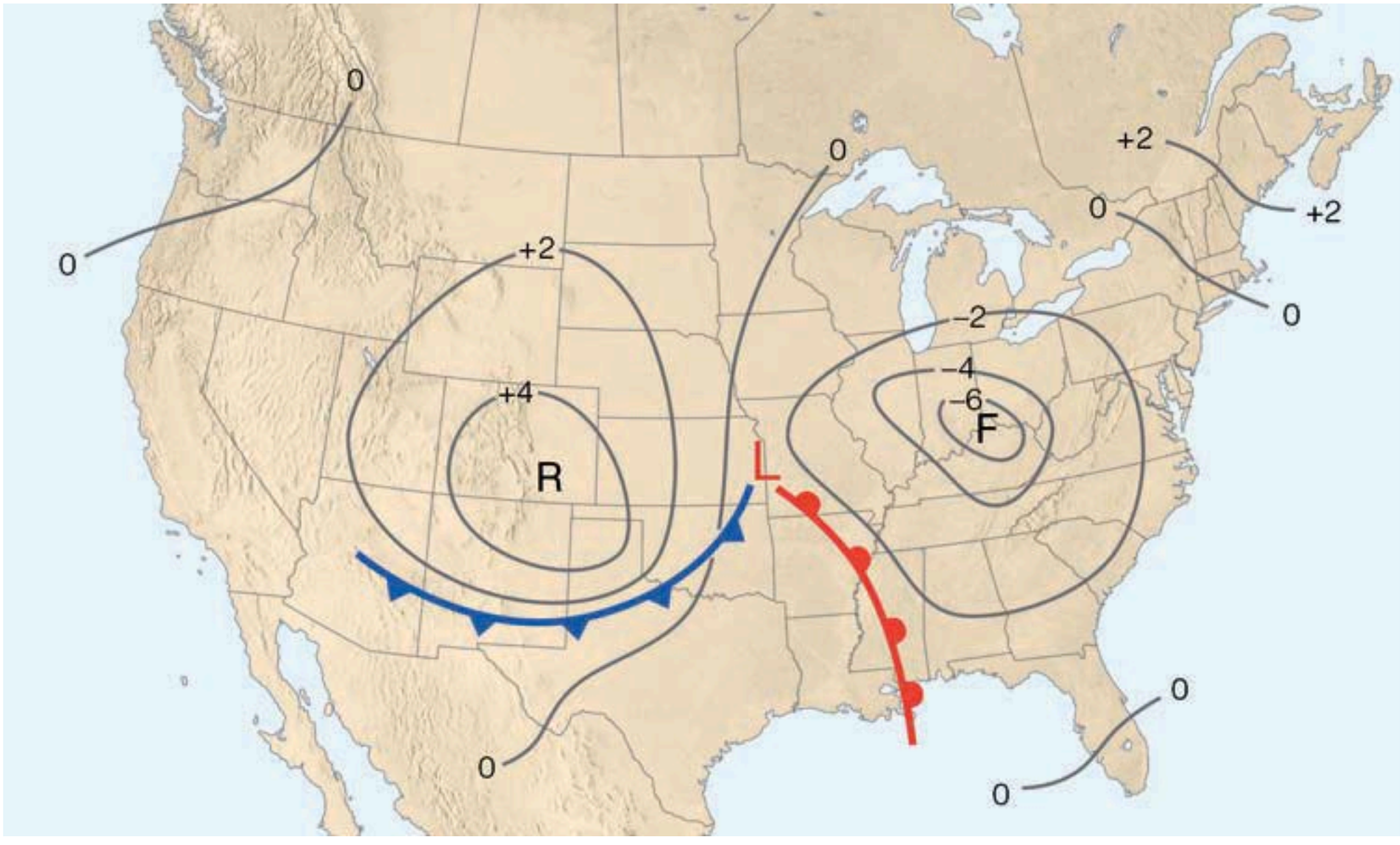
지상일기도를 이용한 일기예보

- Rule of thumbs
  - 중위도 저기압은 지난 6시간동안 움직인 것 처럼 움직인다.
  - 저기압의 위치는 따뜻한 지역의 등압선을 따라 움직인다.
  - 저기압은 압력이 제일 많이 낮아지는 쪽으로 이동한다.
  - 고기압은 압력이 제일 많이 높아지는 쪽으로 이동한다.
  - 저기압/고기압은 500 mb층의 바람 방향으로 이동한다.

지상차트를 이용한 일기예보



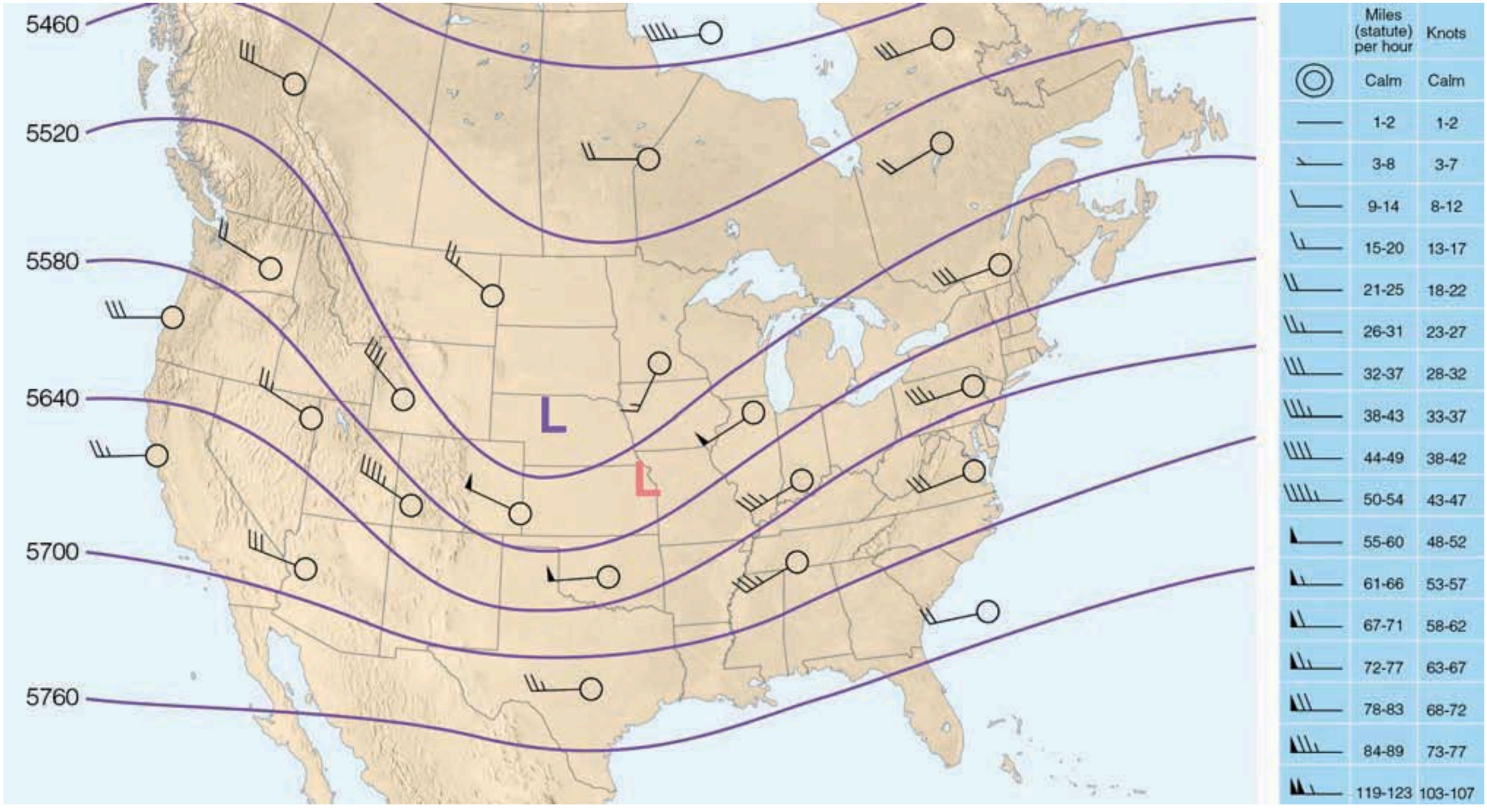
지상차트를 이용한 일기예보



지상 기압의 6시간 동안의 변화

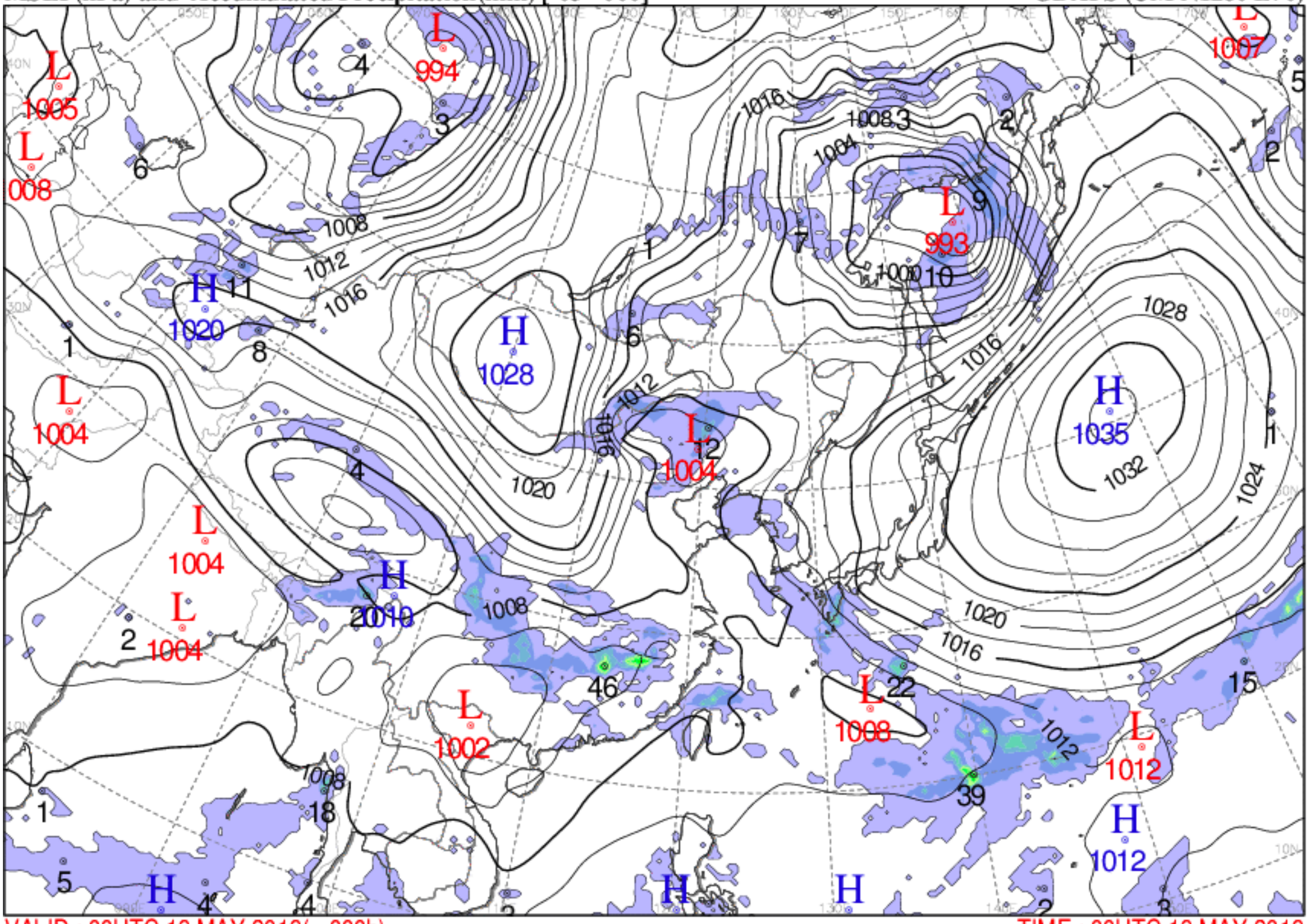
저기압의 이동방향 뿐만 아니라 강도의 변화도 예상할 수 있다.

지상차트를 이용한 일기예보



MSLP(hPa) and Accumulated Precipitation(mm) [-03 - 000]

GDAPS (UM N1280 L70)

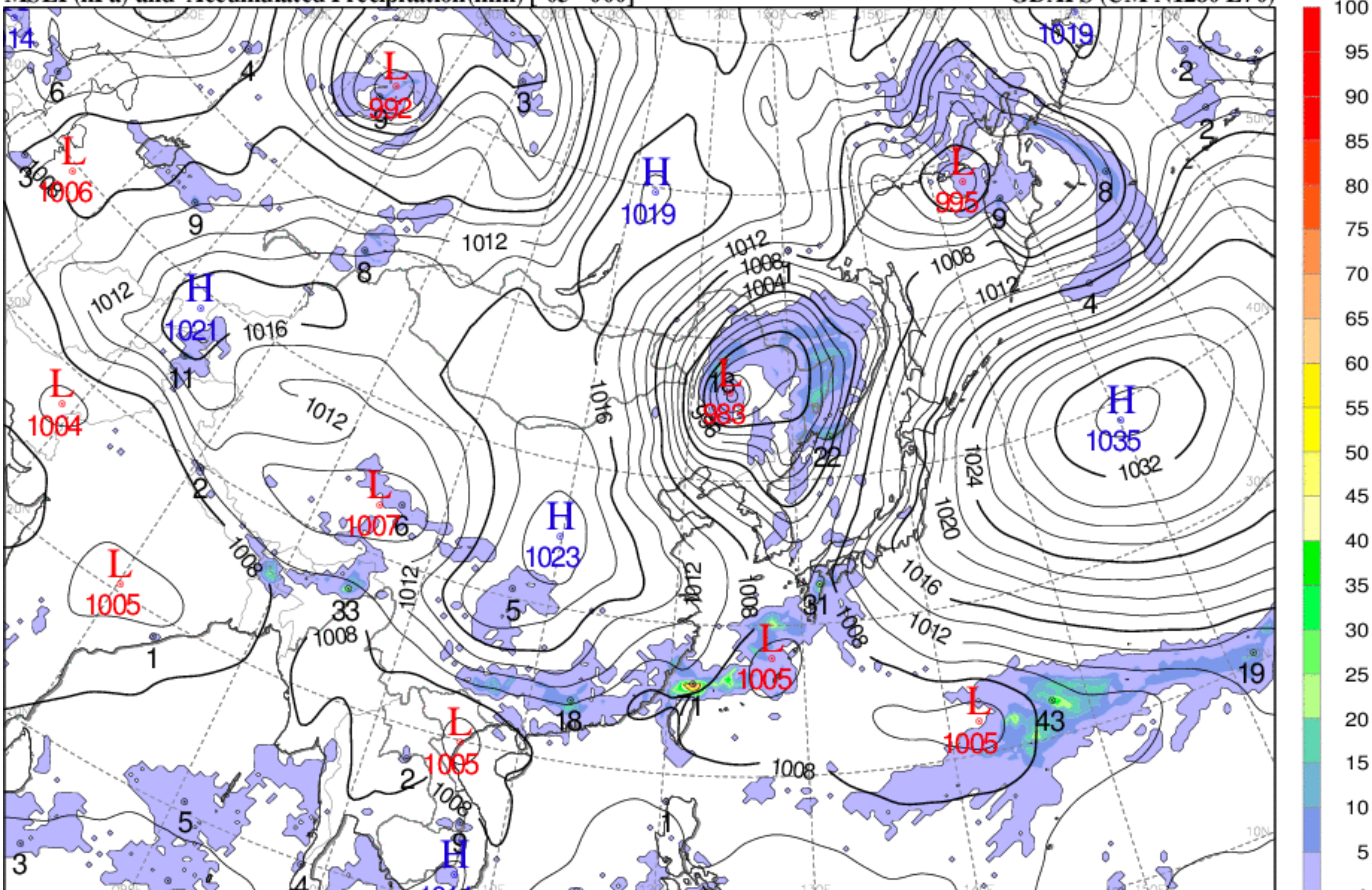


100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0

VALID : 00UTC 19 MAY 2019(+ 000h)
09KST 19 MAY 2019(+ 000h)

TIME : 00UTC 19 MAY 2019
09KST 19 MAY 2019

MSLP(hPa) and Accumulated Precipitation(mm) [-03 - 000] GDAPS (UM N1280 L70)

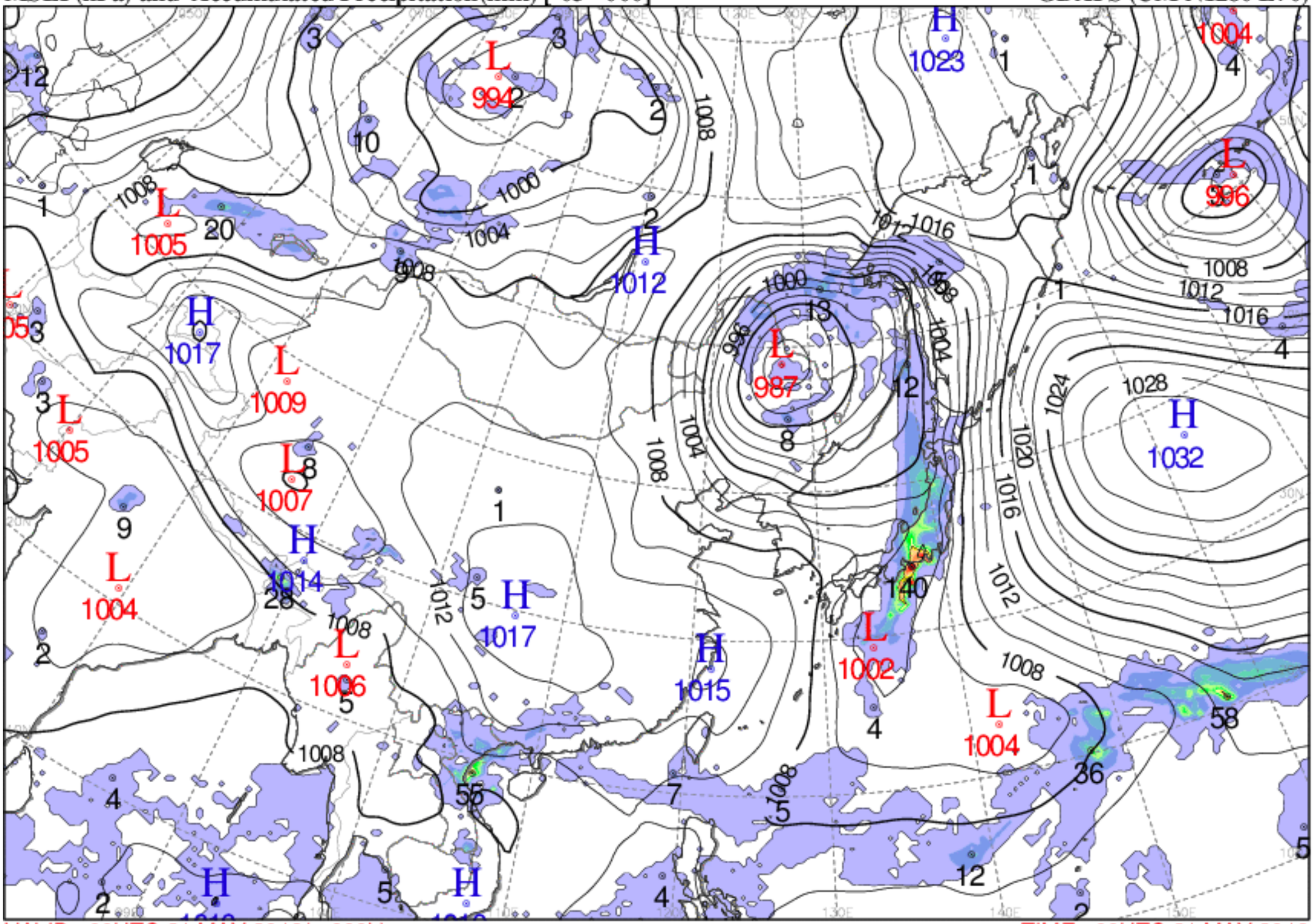


VALID : 00UTC 20 MAY 2019(+ 000h)
09KST 20 MAY 2019(+ 000h)

TIME : 00UTC 20 MAY 2019
09KST 20 MAY 2019

MSLP(hPa) and Accumulated Precipitation(mm) [-03 - 000]

GDAPS (UM N1280 L70)



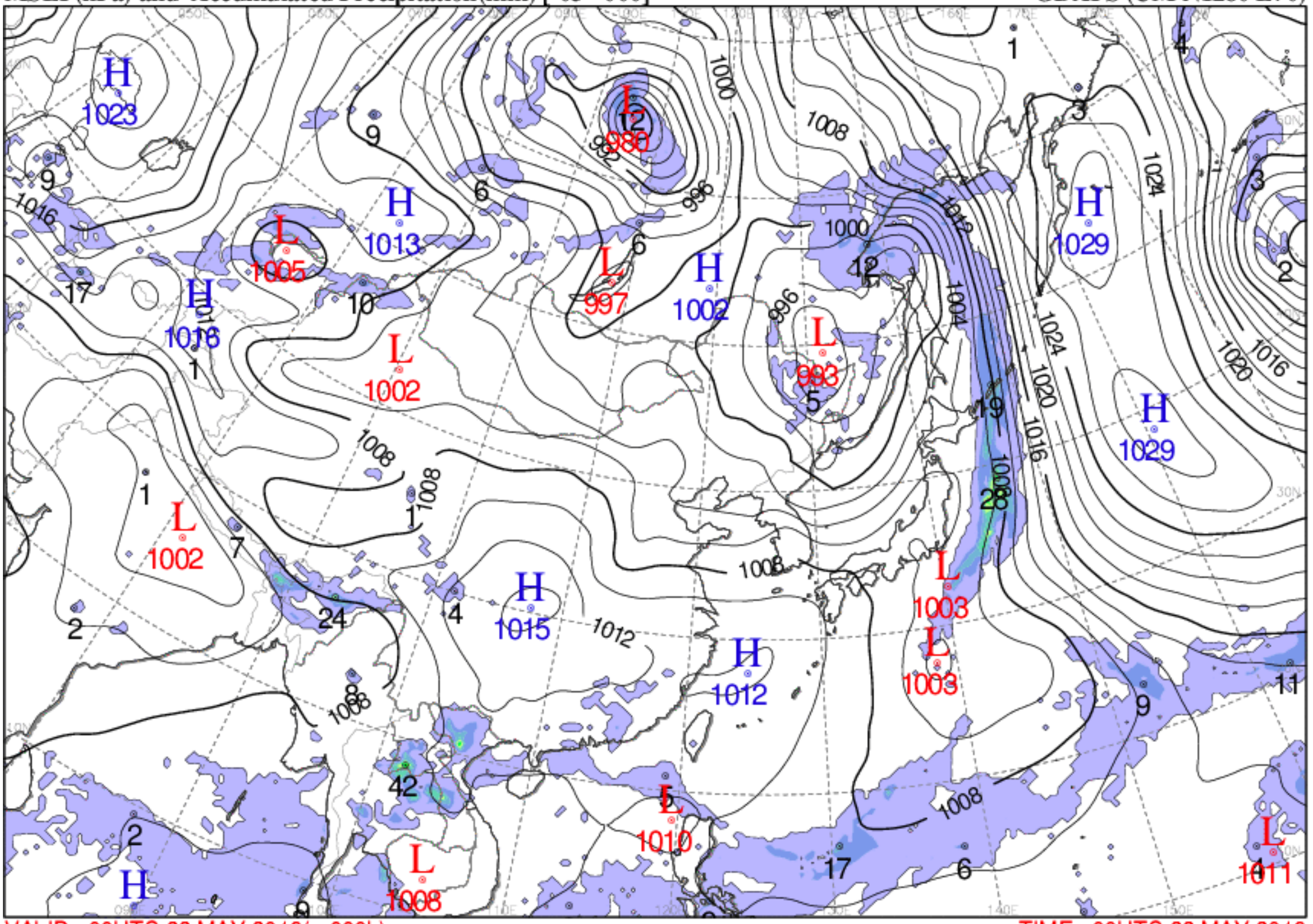
100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0

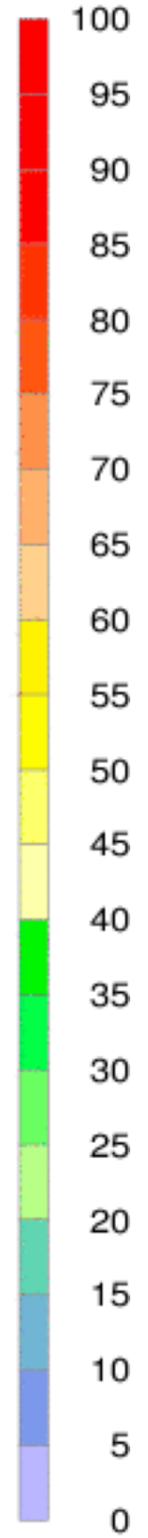
VALID : 00UTC 21 MAY 2019(+ 000h)
09KST 21 MAY 2019(+ 000h)

TIME : 00UTC 21 MAY 2019
09KST 21 MAY 2019

MSLP(hPa) and Accumulated Precipitation(mm) [-03 - 000]

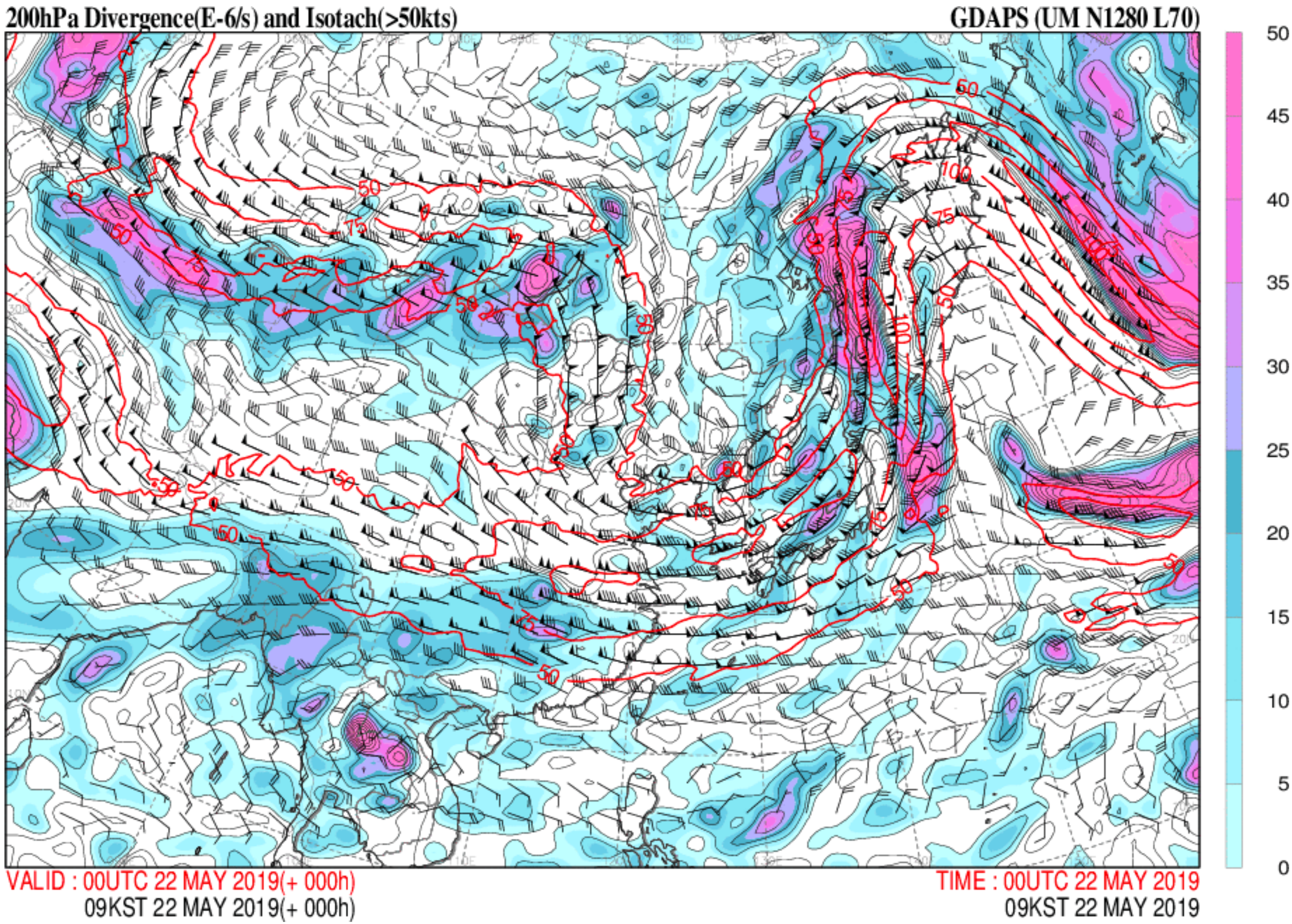
GDAPS (UM N1280 L70)





VALID : 00UTC 22 MAY 2019(+ 000h)
09KST 22 MAY 2019(+ 000h)

TIME : 00UTC 22 MAY 2019
09KST 22 MAY 2019


200hPa Divergence(E-6/s) and Isotach(>50kts)
GDAPS (UM N1280 L70)
50
45
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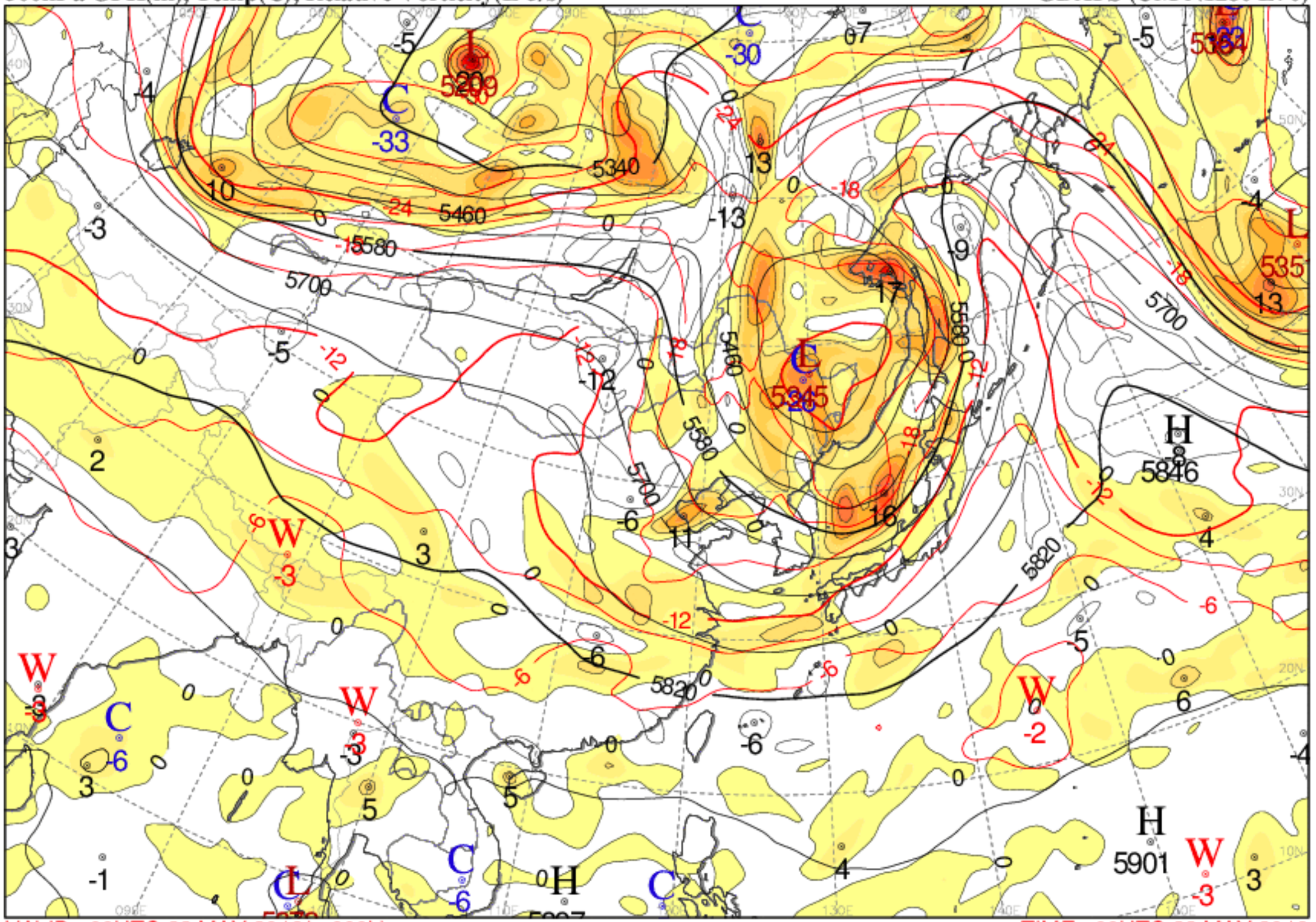
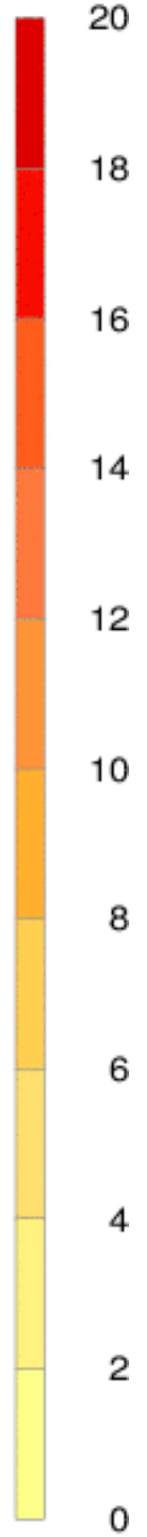
VALID : 00UTC 22 MAY 2019(+ 000h)
09KST 22 MAY 2019(+ 000h)
TIME : 00UTC 22 MAY 2019
09KST 22 MAY 2019

500hPa GPH(m), Temp(C), Relative Vorticity(E-5/s)

GDAPS (UM N1280 L70)



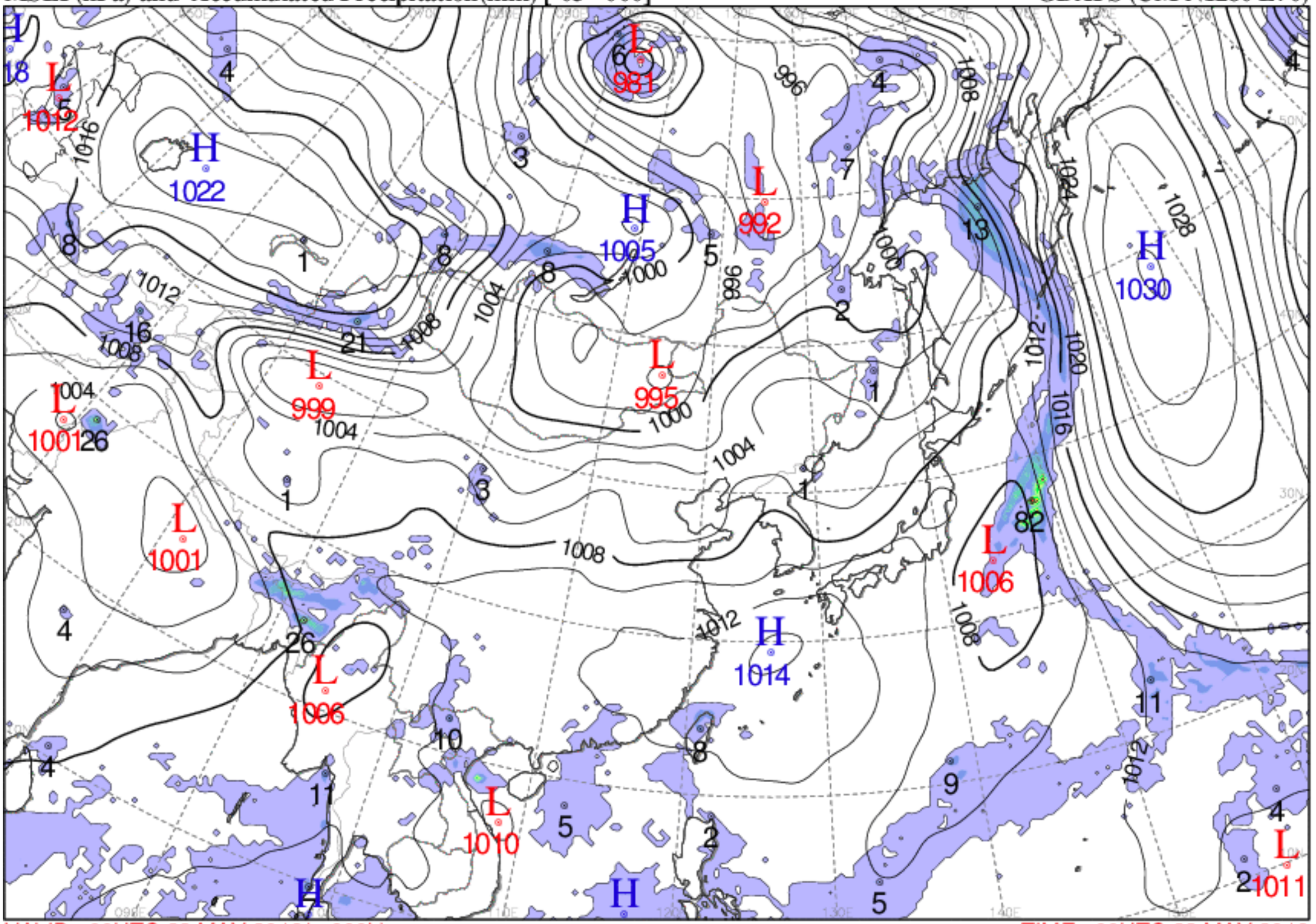


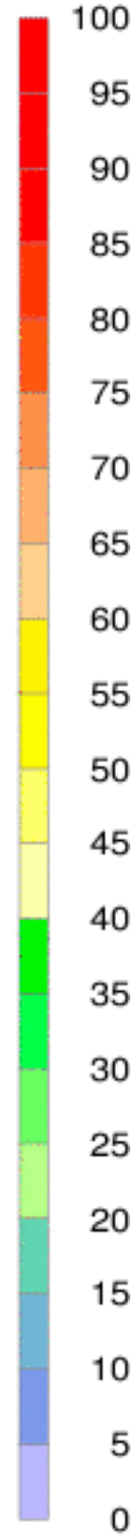
VALID : 00UTC 22 MAY 2019(+ 000h)
09KST 22 MAY 2019(+ 000h)

TIME : 00UTC 22 MAY 2019
09KST 22 MAY 2019

MSLP(hPa) and Accumulated Precipitation(mm) [-03 - 000]

GDAPS (UM N1280 L70)



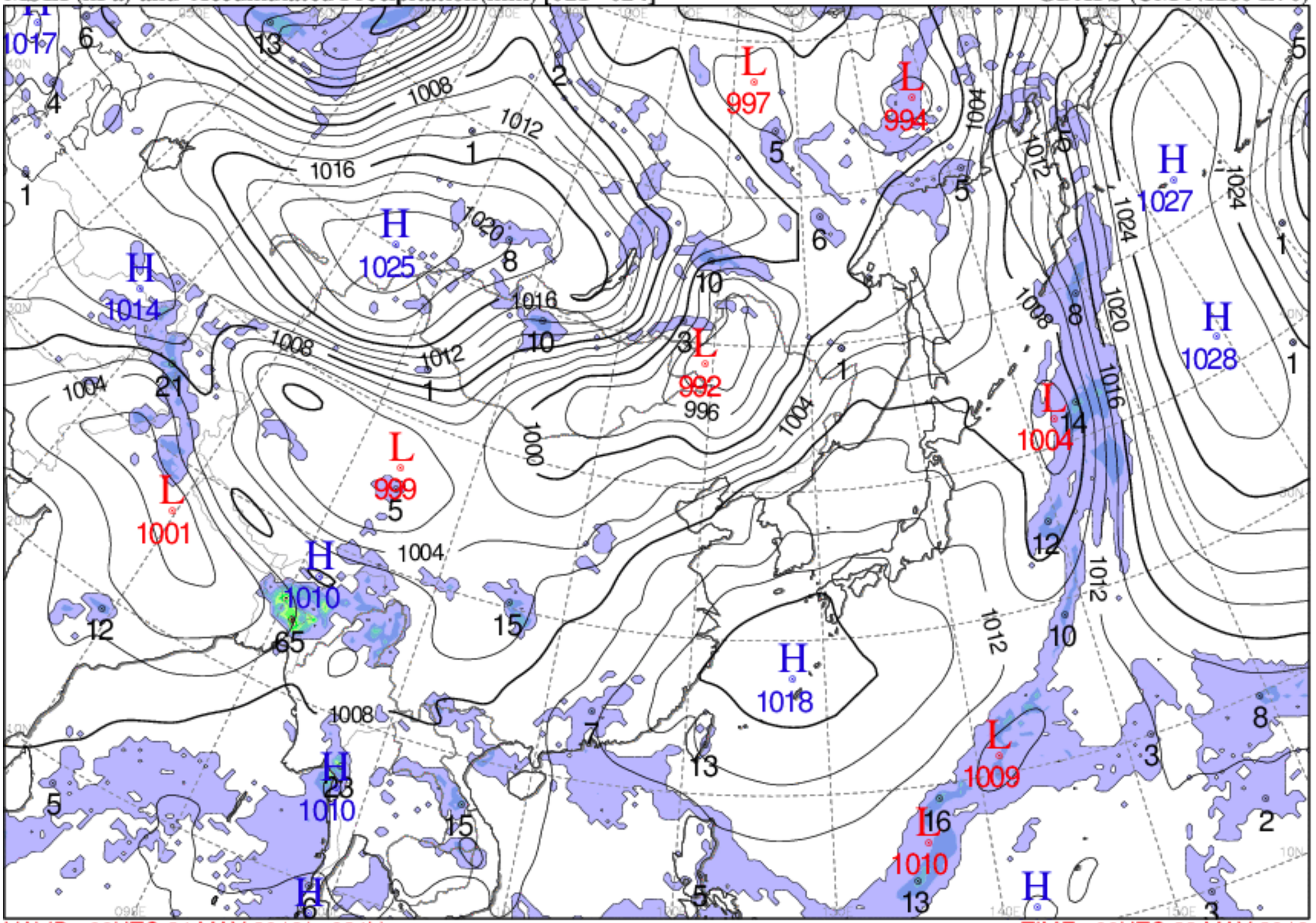


VALID : 00UTC 23 MAY 2019(+ 000h)
09KST 23 MAY 2019(+ 000h)

TIME : 00UTC 23 MAY 2019
09KST 23 MAY 2019

MSLP(hPa) and Accumulated Precipitation(mm) [021 - 024]

GDAPS (UM N1280 L70)

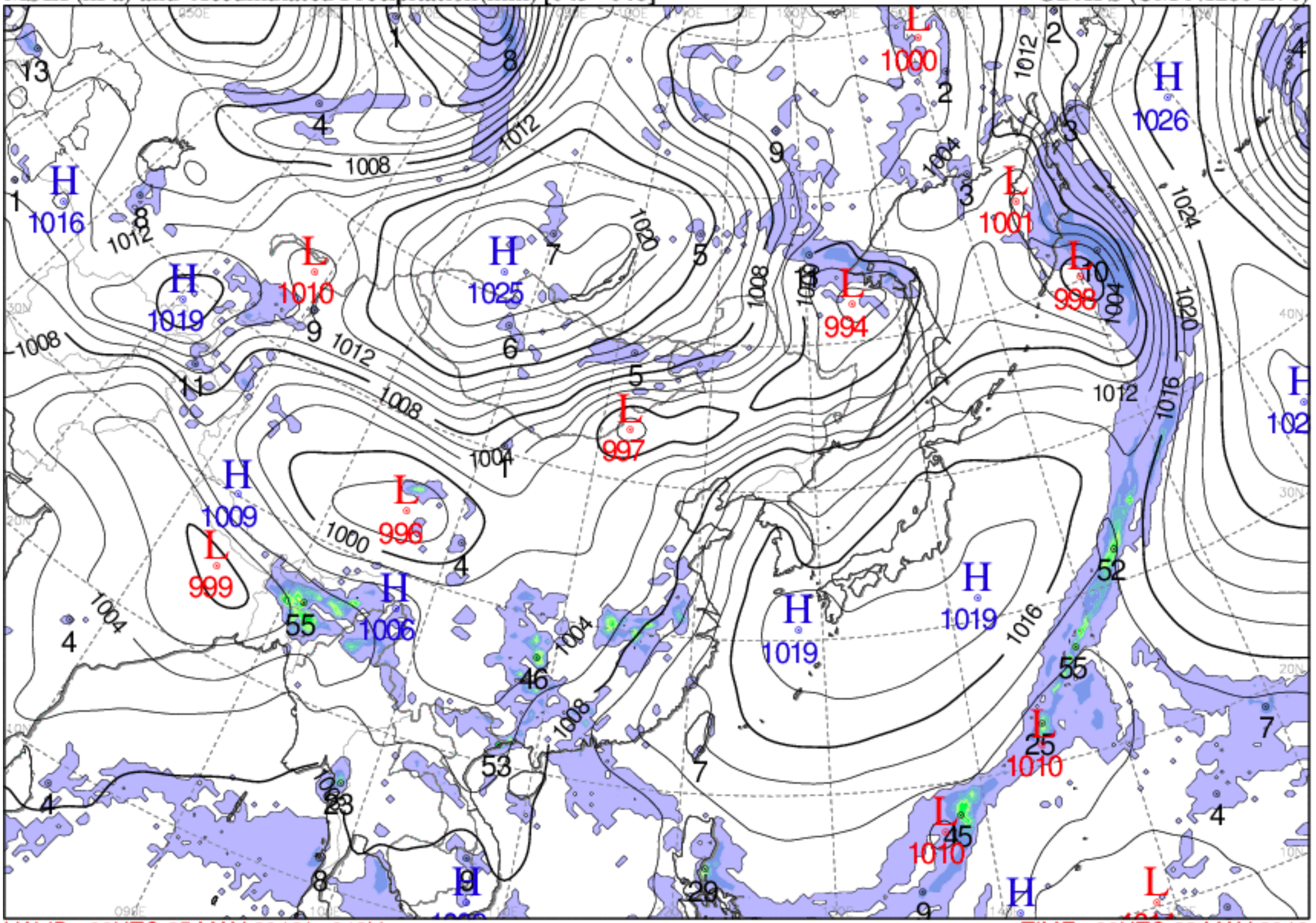


VALID : 00UTC 24 MAY 2019(+ 024h)
09KST 24 MAY 2019(+ 024h)

TIME : 00UTC 23 MAY 2019
09KST 23 MAY 2019

MSLP(hPa) and Accumulated Precipitation(mm) [045 - 048]

GDAPS (UM N1280 L70)



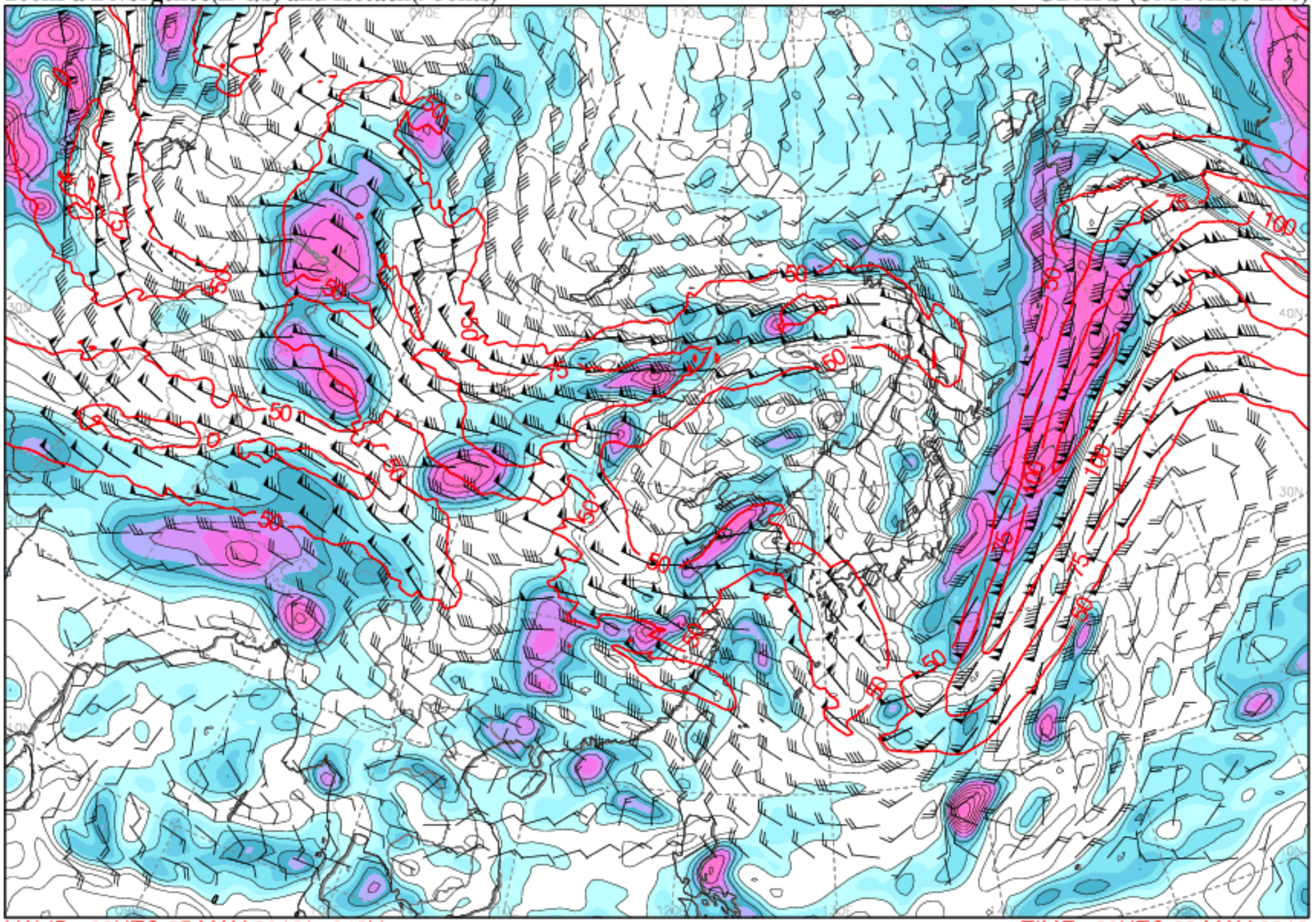
100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0

VALID : 00UTC 25 MAY 2019(+ 048h)
09KST 25 MAY 2019(+ 048h)

TIME : 00UTC 23 MAY 2019
09KST 23 MAY 2019

200hPa Divergence(E-6/s) and Isotach(>50kts)

GDAPS (UM N1280 L70)

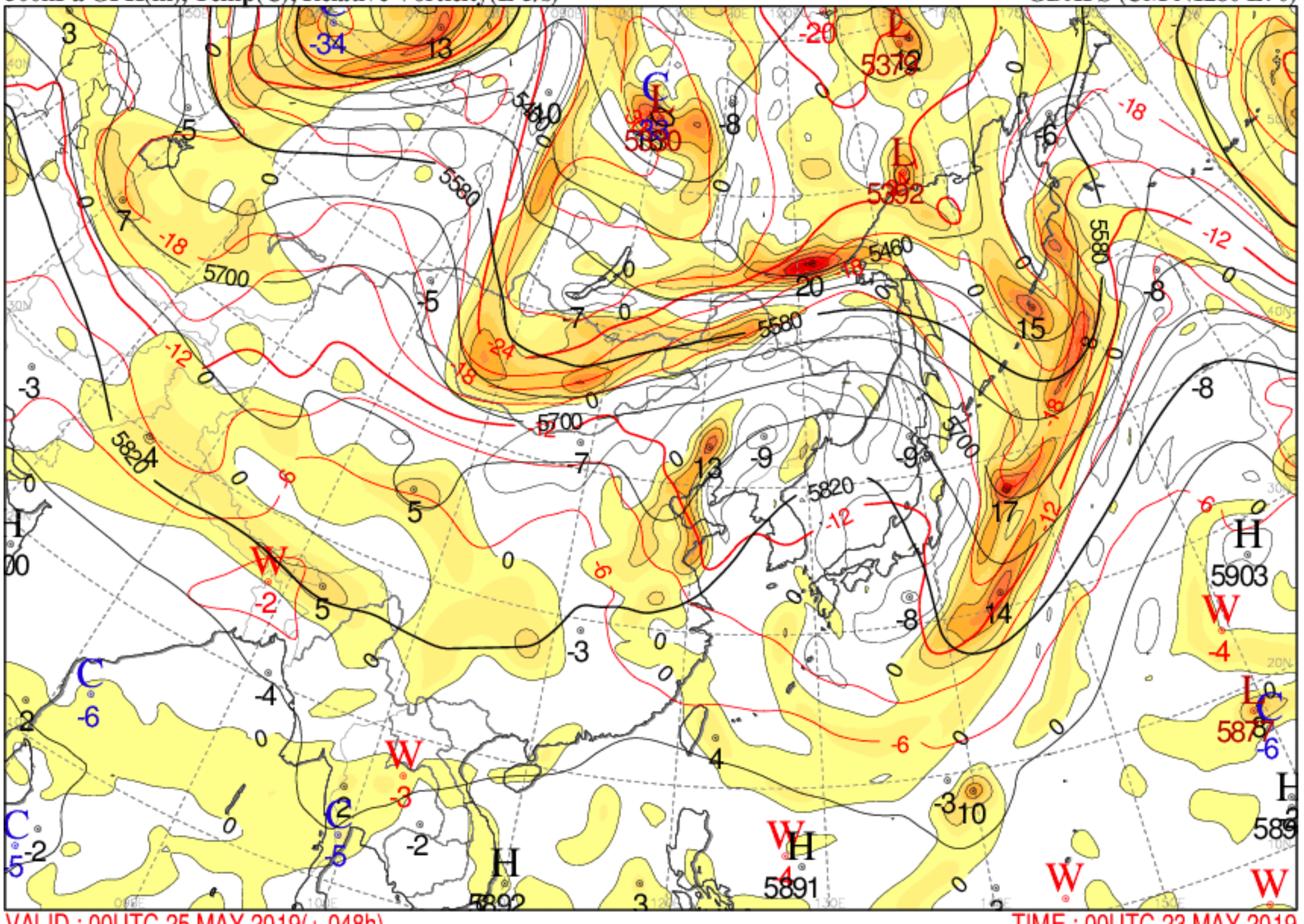


VALID : 00UTC 25 MAY 2019(+ 048h)
09KST 25 MAY 2019(+ 048h)

TIME : 00UTC 23 MAY 2019
09KST 23 MAY 2019

500hPa GPH(m), Temp(C), Relative Vorticity(E-5/s)

GDAPS (UM N1280 L70)

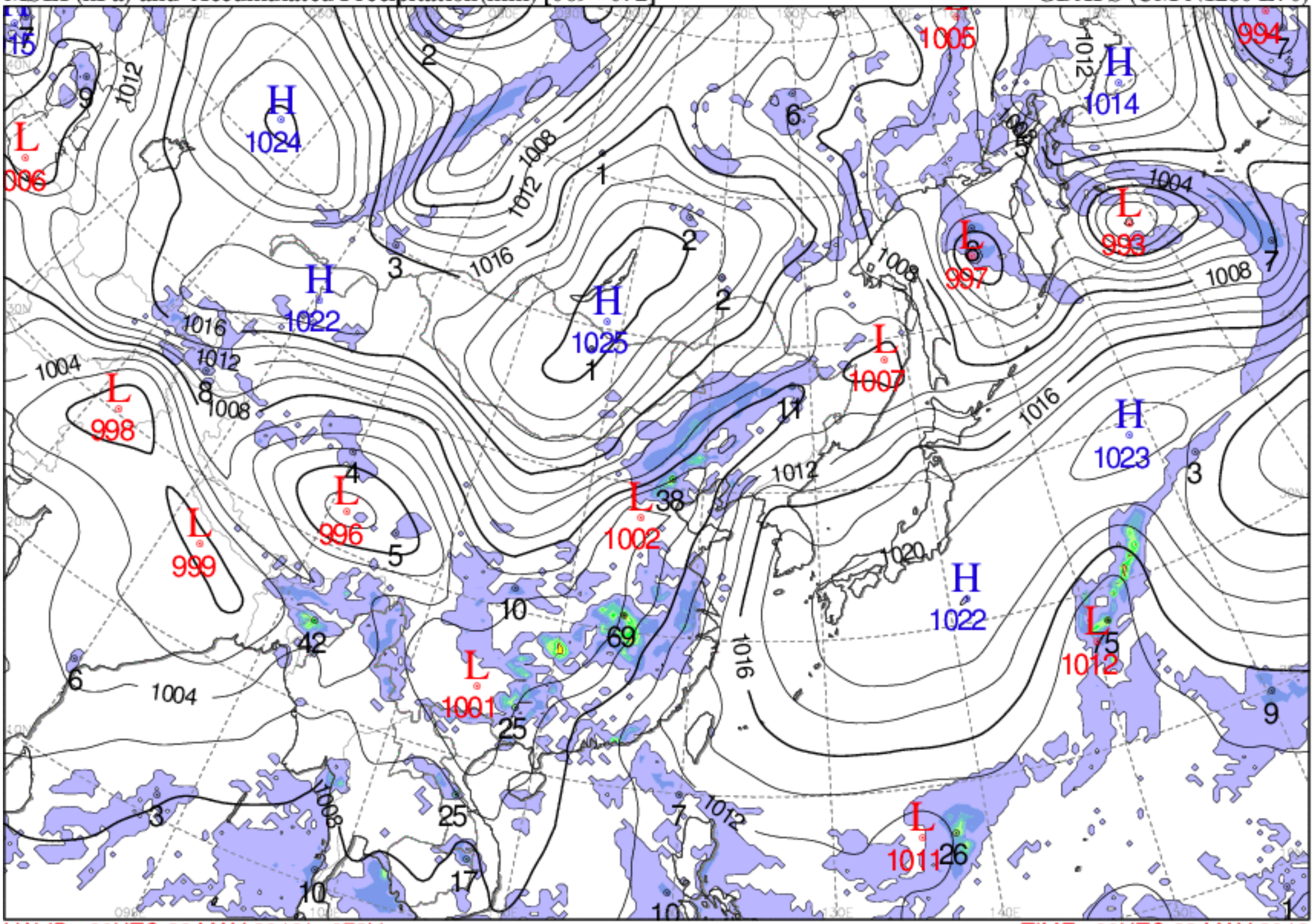


VALID : 00UTC 25 MAY 2019(+ 048h)
09KST 25 MAY 2019(+ 048h)

TIME : 00UTC 23 MAY 2019
09KST 23 MAY 2019

MSLP(hPa) and Accumulated Precipitation(mm) [069 - 072]

GDAPS (UM N1280 L70)



VALID : 00UTC 26 MAY 2019(+ 072h)

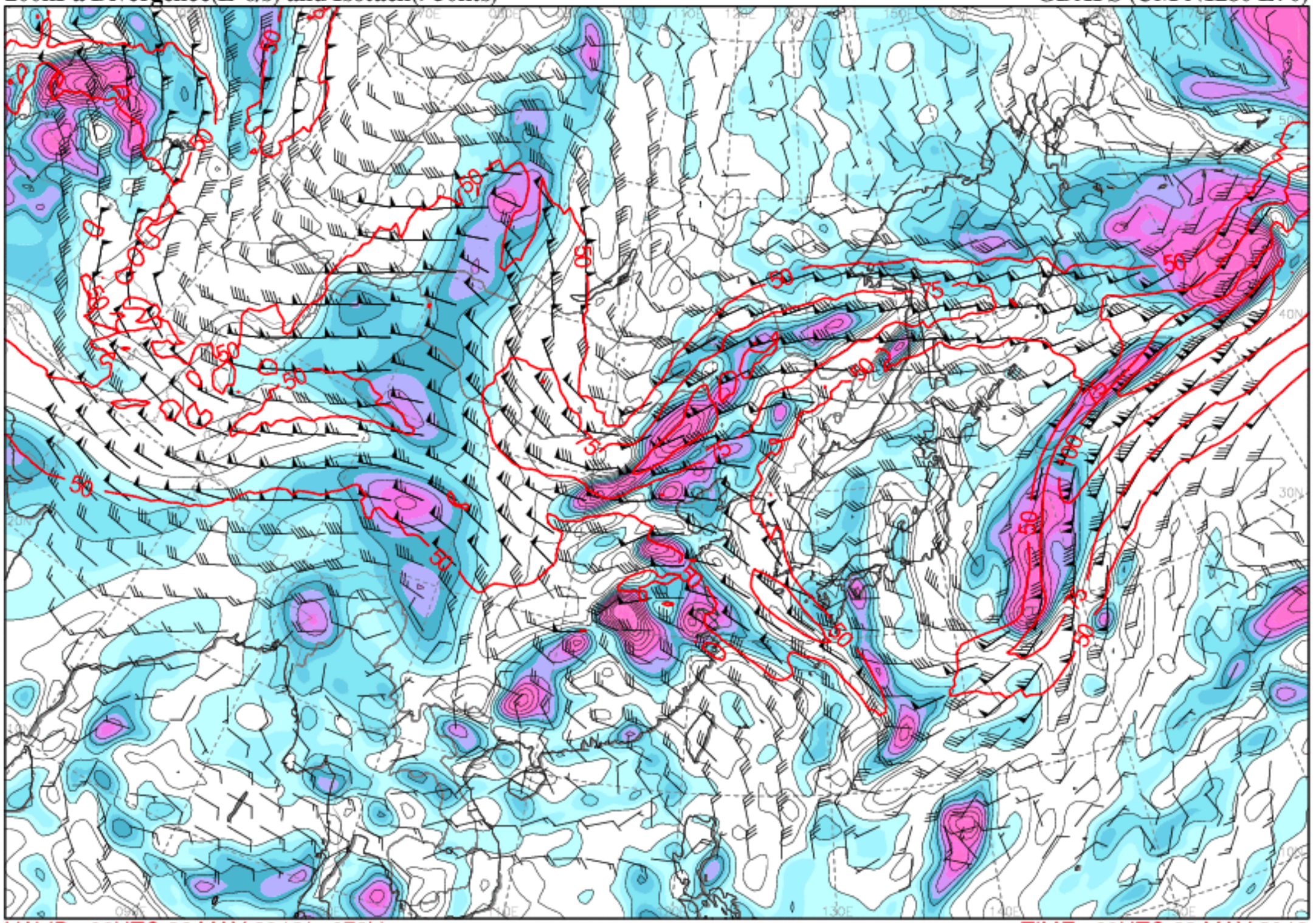
09KST 26 MAY 2019(+ 072h)

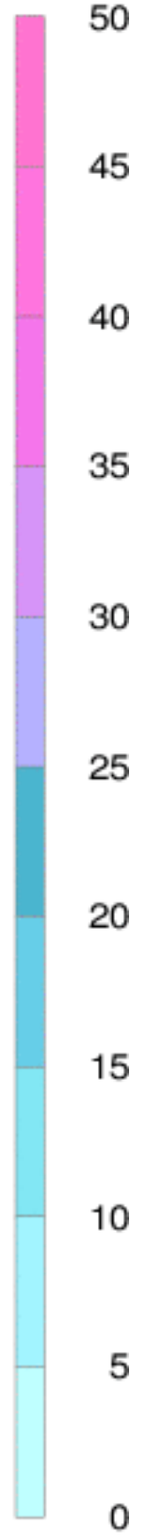
TIME : 00UTC 23 MAY 2019

09KST 23 MAY 2019

200hPa Divergence(E-6/s) and Isotach(>50kts)

GDAPS (UM N1280 L70)



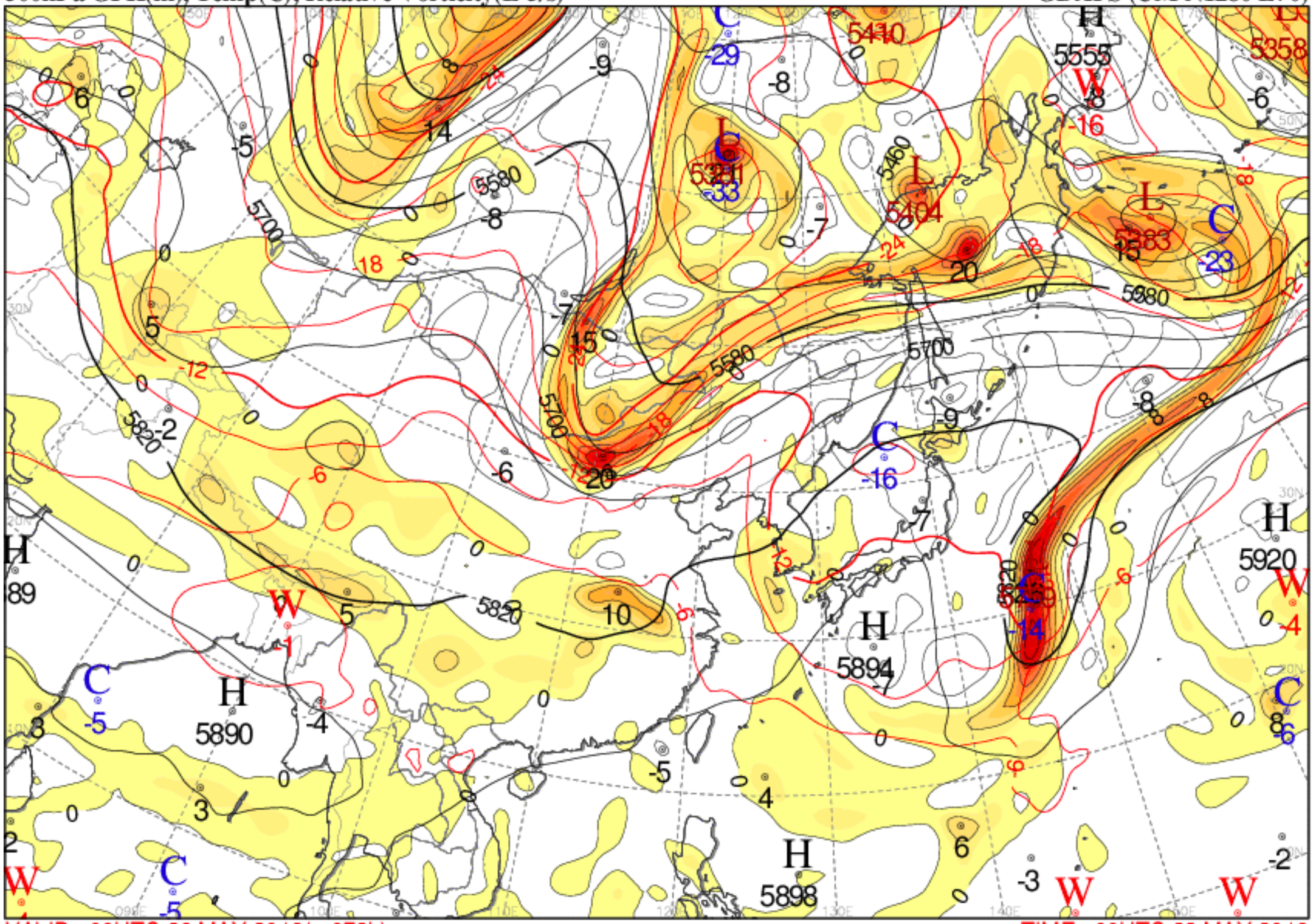


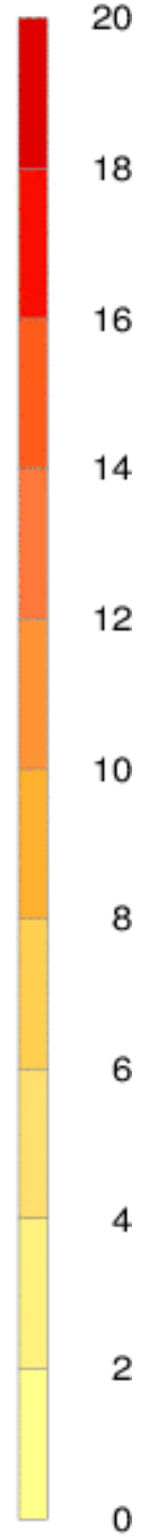
VALID : 00UTC 26 MAY 2019(+ 072h)
09KST 26 MAY 2019(+ 072h)

TIME : 00UTC 23 MAY 2019
09KST 23 MAY 2019

500hPa GPH(m), Temp(C), Relative Vorticity(E-5/s)

GDAPS (UM N1280 L70)



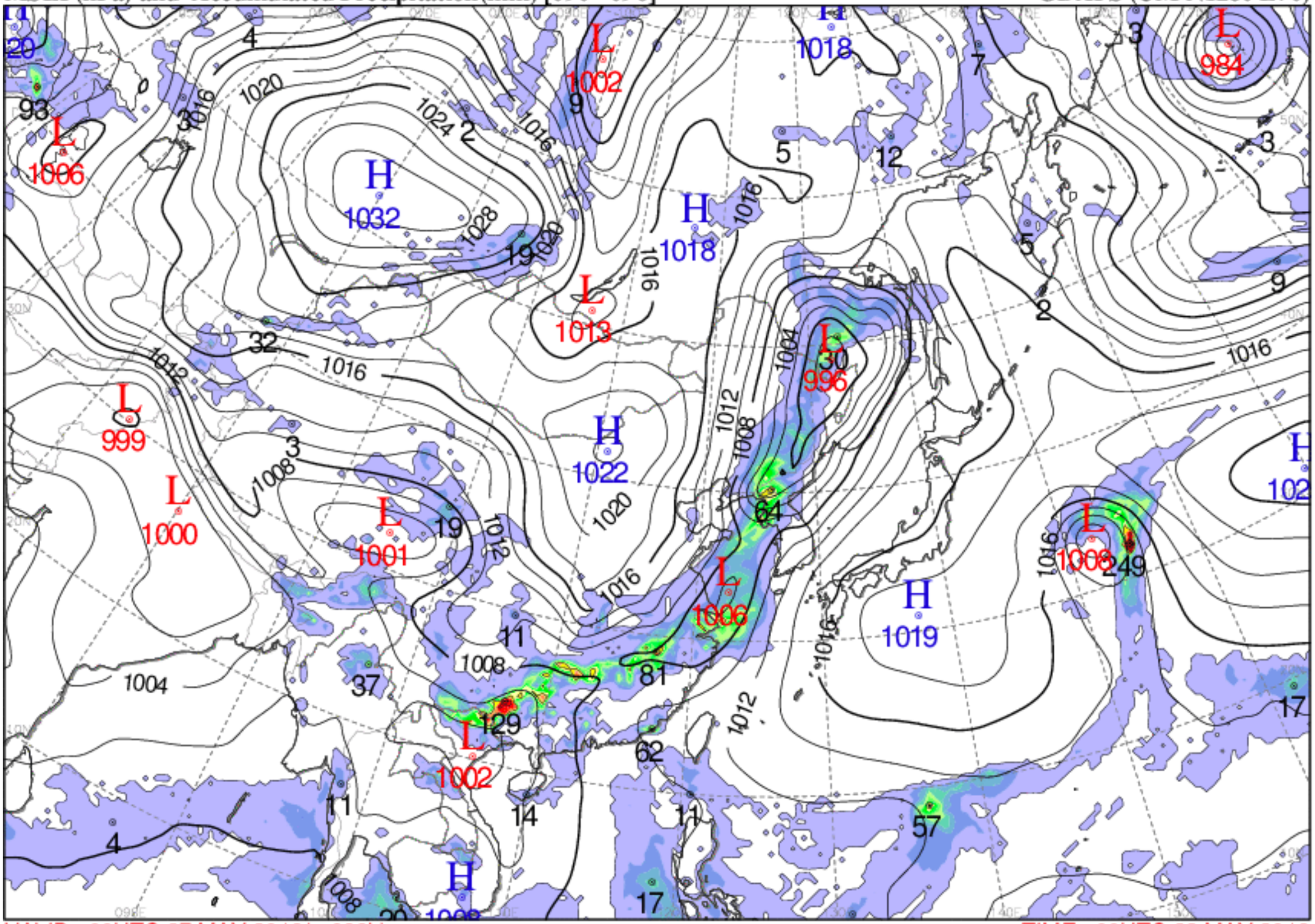


VALID : 00UTC 26 MAY 2019(+ 072h)
09KST 26 MAY 2019(+ 072h)

TIME : 00UTC 23 MAY 2019
09KST 23 MAY 2019

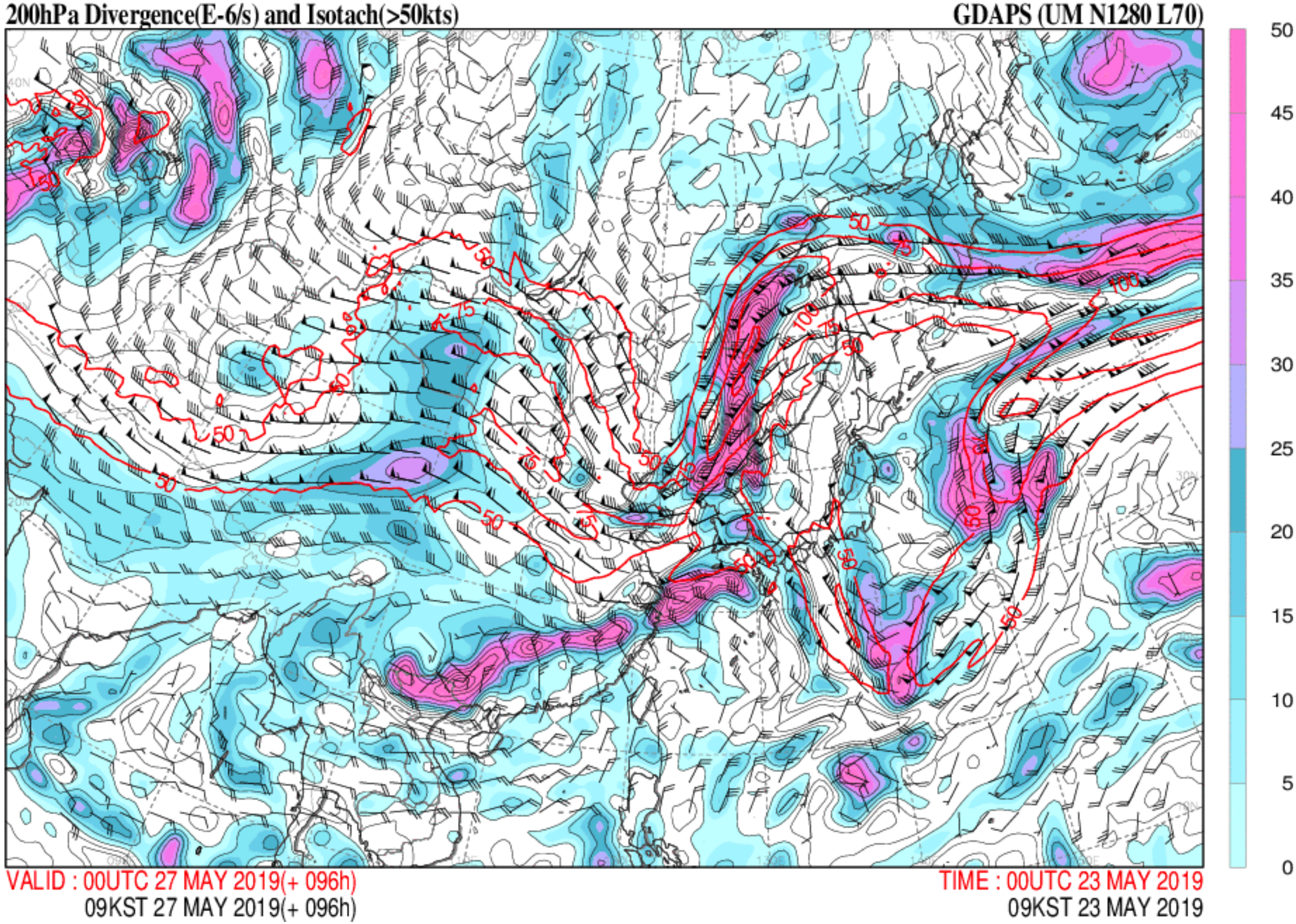
MSLP(hPa) and Accumulated Precipitation(mm) [090 - 096]

GDAPS (UM N1280 L70)



VALID : 00UTC 27 MAY 2019(+ 096h)
09KST 27 MAY 2019(+ 096h)

TIME : 00UTC 23 MAY 2019
09KST 23 MAY 2019


200hPa Divergence(E-6/s) and Isotach(>50kts)
GDAPS (UM N1280 L70)
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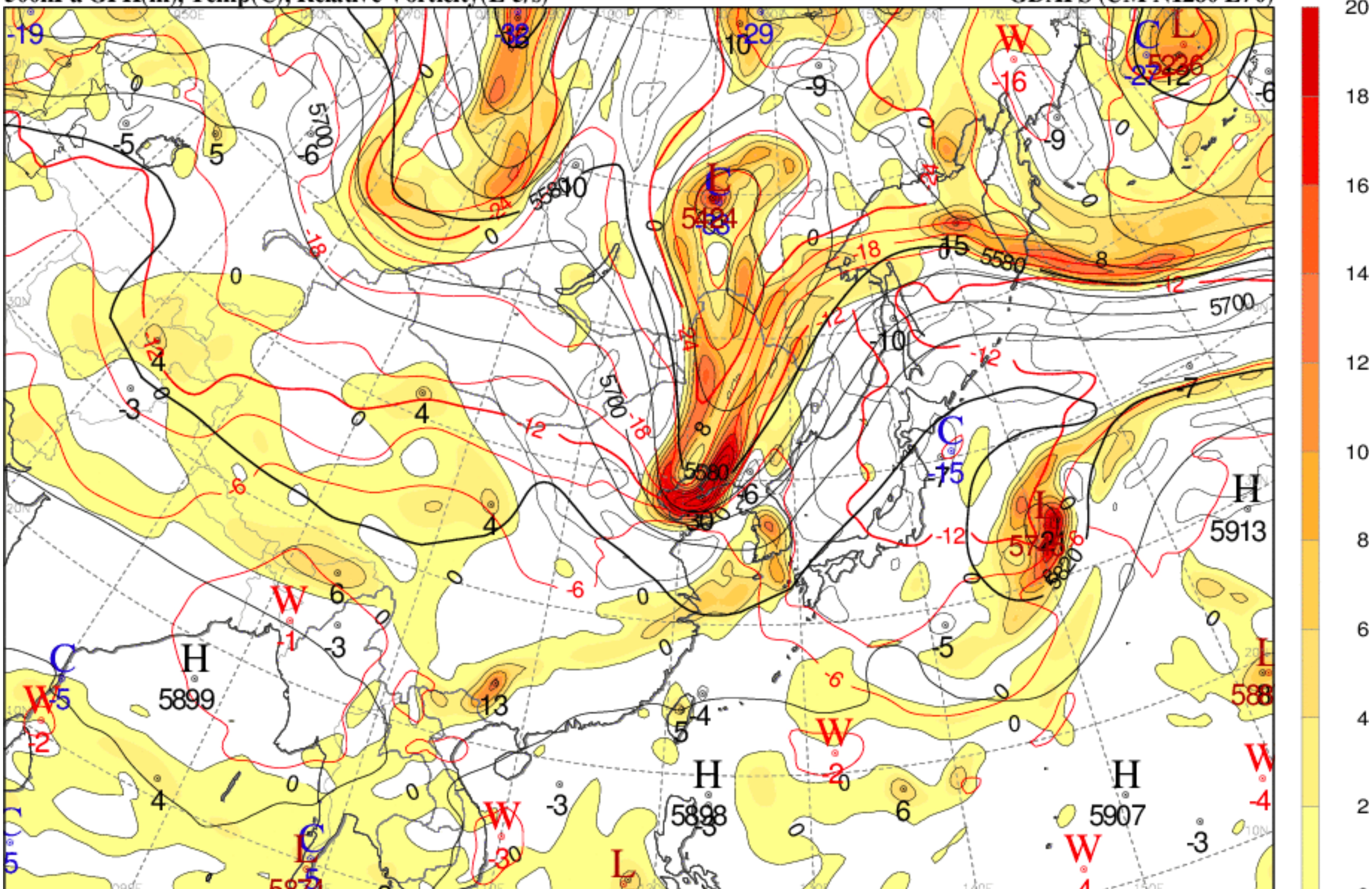
VALID : 00UTC 27 MAY 2019(+ 096h)
09KST 27 MAY 2019(+ 096h)
TIME : 00UTC 23 MAY 2019
09KST 23 MAY 2019

500hPa GPH(m), Temp(C), Relative Vorticity(E-5/s) GDAPS (UM N1280 L70)

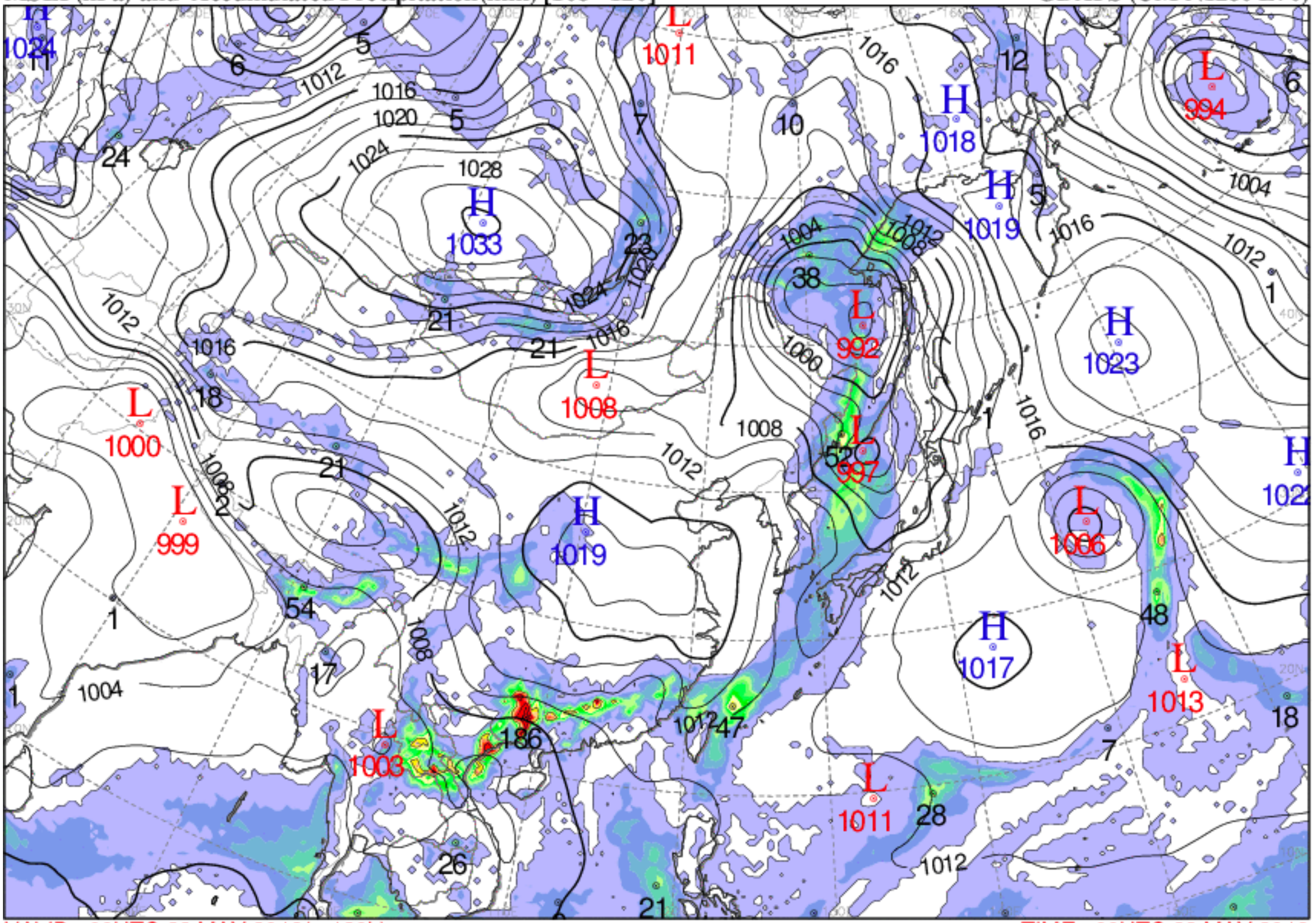


VALID : 00UTC 27 MAY 2019(+ 096h)
09KST 27 MAY 2019(+ 096h)

TIME : 00UTC 23 MAY 2019
09KST 23 MAY 2019

MSLP(hPa) and Accumulated Precipitation(mm) [108 - 120]

GDAPS (UM N1280 L70)

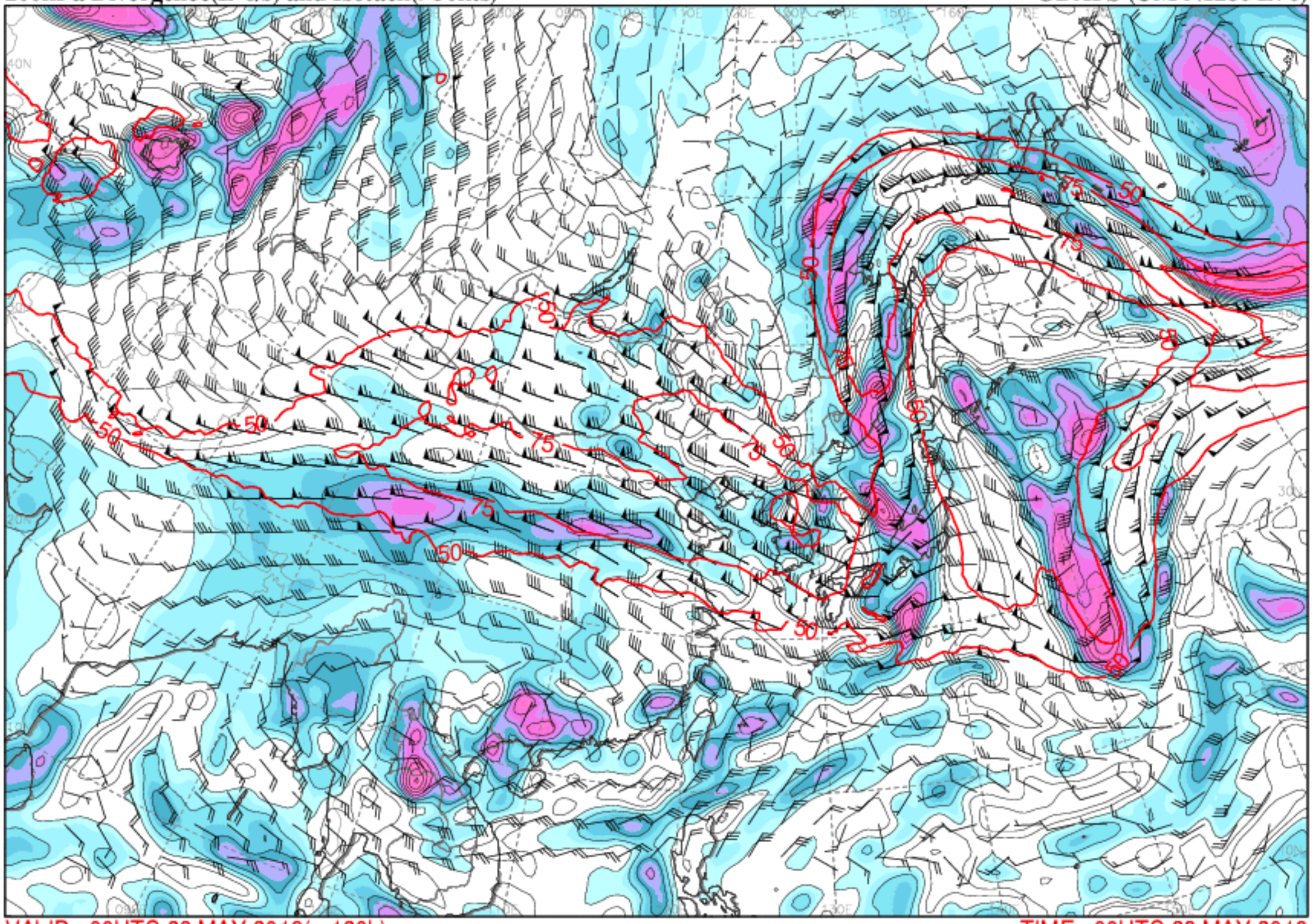


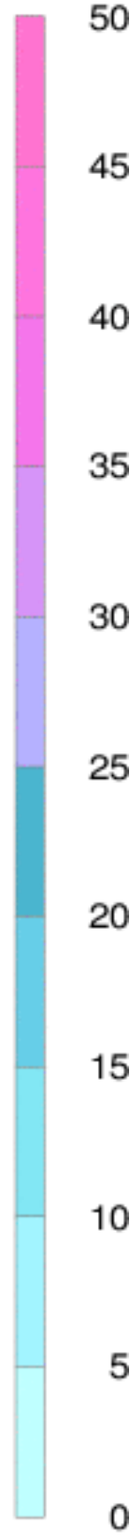
VALID : 00UTC 28 MAY 2019(+ 120h)
09KST 28 MAY 2019(+ 120h)

TIME : 00UTC 23 MAY 2019
09KST 23 MAY 2019

200hPa Divergence(E-6/s) and Isotach(>50kts)

GDAPS (UM N1280 L70)





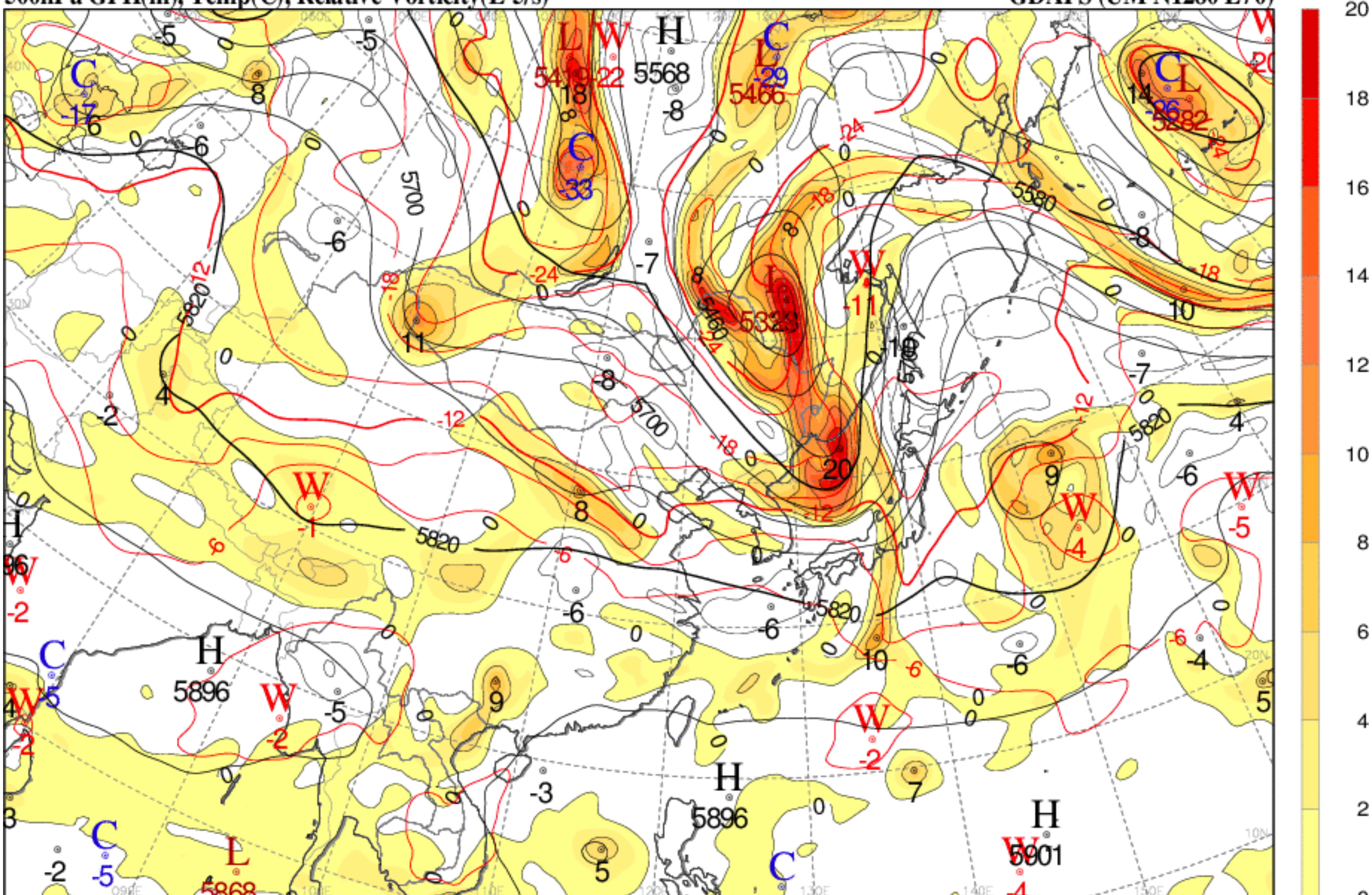
VALID : 00UTC 28 MAY 2019(+ 120h)

09KST 28 MAY 2019(+ 120h)

TIME : 00UTC 23 MAY 2019

09KST 23 MAY 2019

500hPa GPH(m), Temp(C), Relative Vorticity(E-5/s) GDAPS (UM N1280 L70)

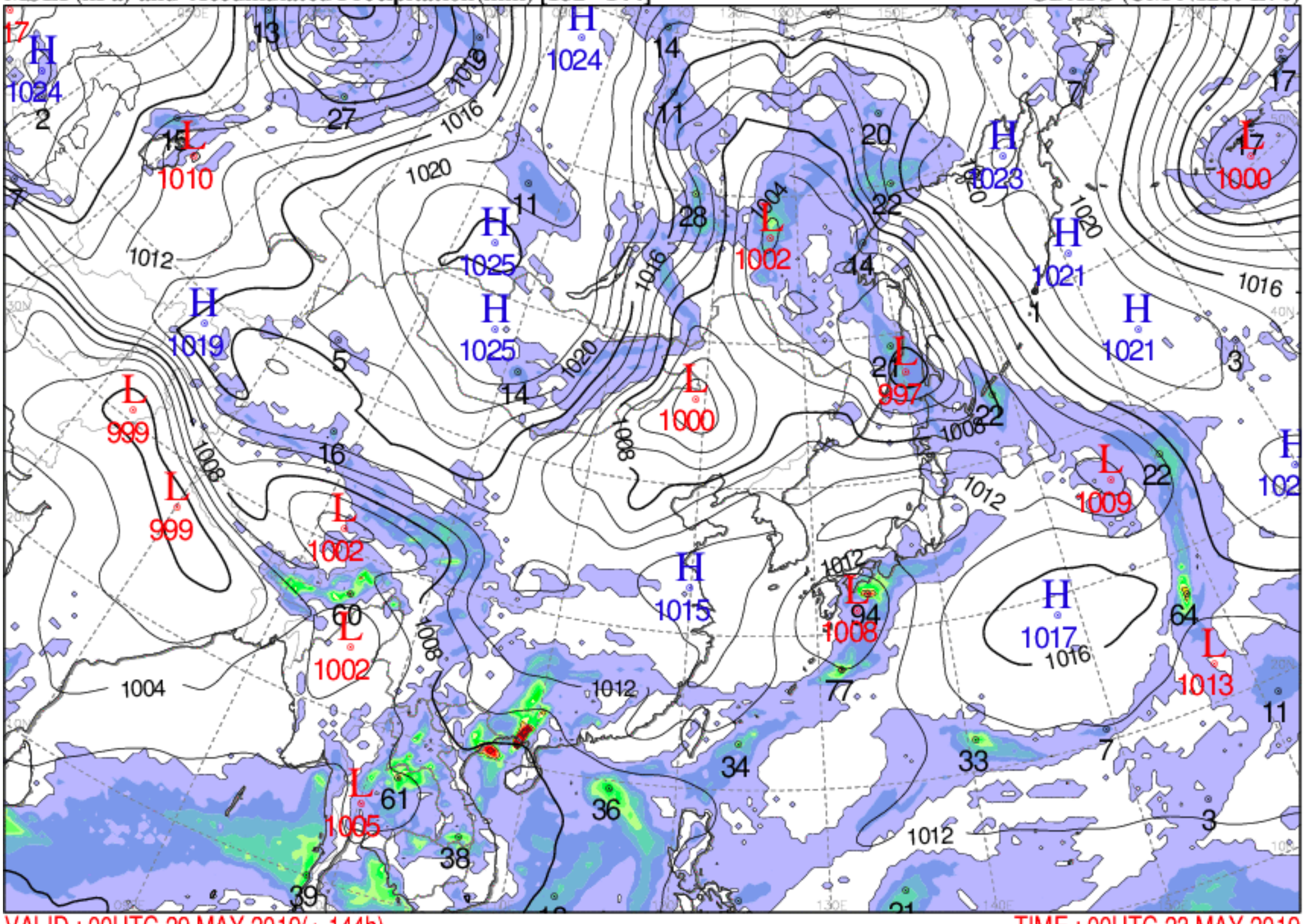


VALID : 00UTC 28 MAY 2019(+ 120h)
09KST 28 MAY 2019(+ 120h)

TIME : 00UTC 23 MAY 2019
09KST 23 MAY 2019

MSLP(hPa) and Accumulated Precipitation(mm) [132 - 144]

GDAPS (UM N1280 L70)



100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0

VALID : 00UTC 29 MAY 2019(+ 144h)

09KST 29 MAY 2019(+ 144h)

TIME : 00UTC 23 MAY 2019

09KST 23 MAY 2019