The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific
and Cultural Organization

International Atomic
Energy Agency

Spring Colloquium on
'Regional Weather Predictability and Modeling'
April 11 - 22, 2005

1) Workshop **on Design and Use of Regional Weather Prediction Models,** *April 11 - 19*

2) Conference on **Current Efforts Toward Advancing the Skill of Regional Weather Prediction. Challenges and Outlook,** *April 20 - 22*

301/1652-14

An adaptive resolution study of December 3-5 2001 Mediterranean cyclone with torrential rains in Israel

S. Krichak
Tel Aviv University
Israel

An adaptive resolution study of December 3-5 2001 Mediterranean cyclone with torrential rains in Israel

Simon Krichak

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***Conference on* Current Efforts Toward Advancing the Skill of Regional Weather Prediction. Challenges and Outlook,**

April 20 – 22, Trieste Italy

<u>References</u>

Krichak, S.O., P. Alpert and M. Dayan (2004) Role of atmospheric processes associated with hurricane Olga in December 2001 flash floods in Israel. J. Hydrometeorol., vol. 5, no. 6. pp. 1259-1270

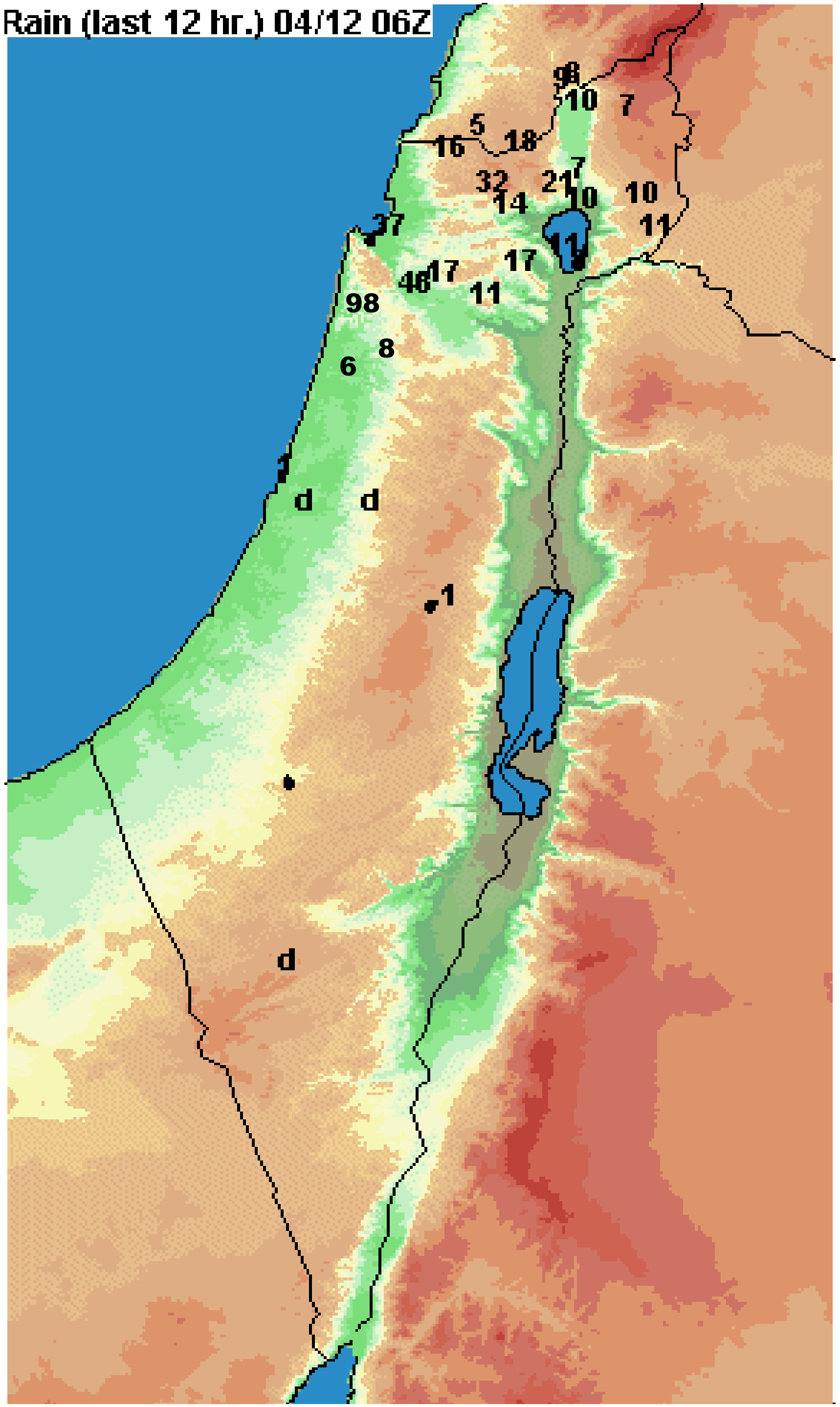
Krichak, S.O., P. Alpert and M. Dayan (2005) Effects of a PV Streamer in December 3-5 2001 Episode with Torrential Rains in Israel (submitted)

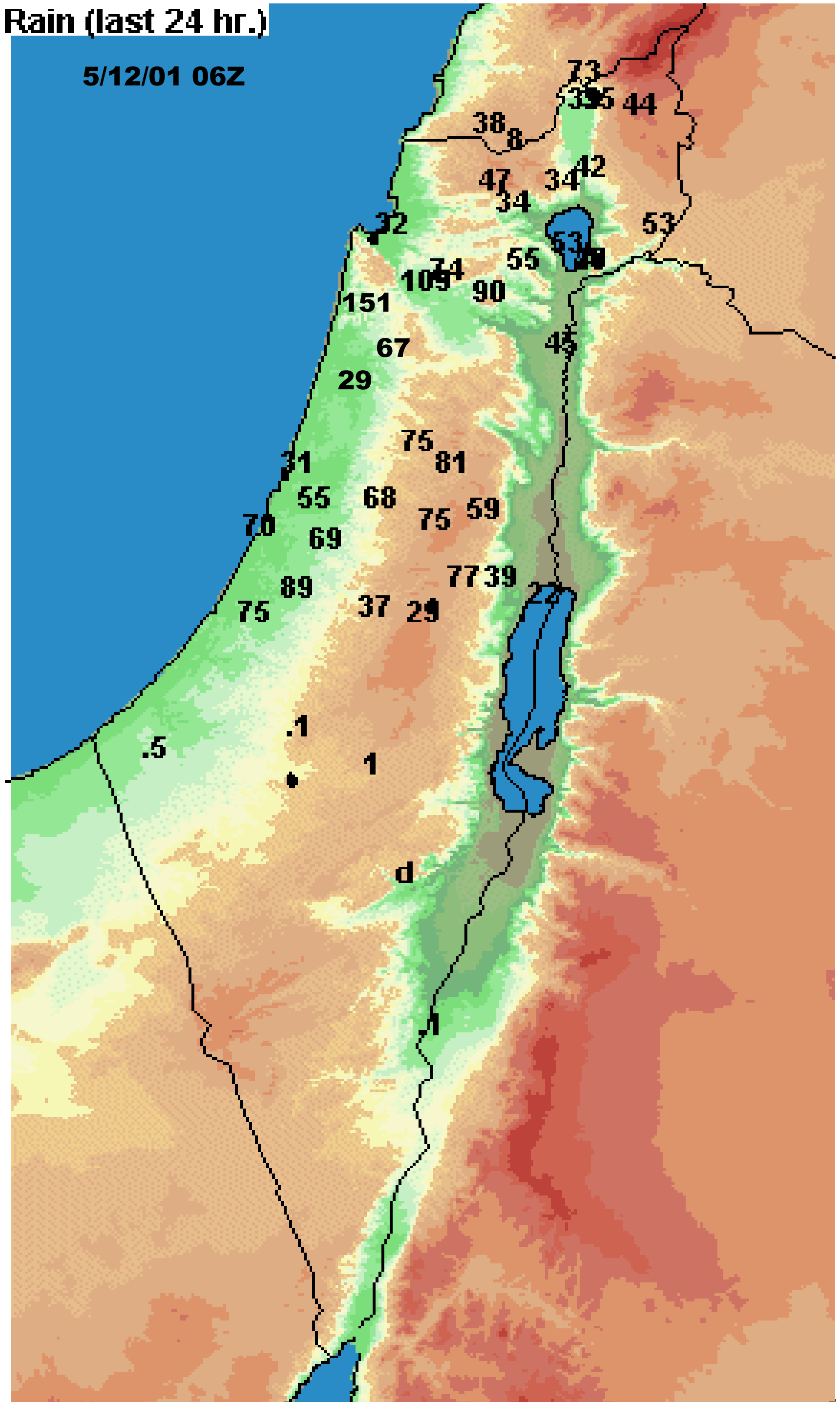
THE UNUSUALLY INTENSE

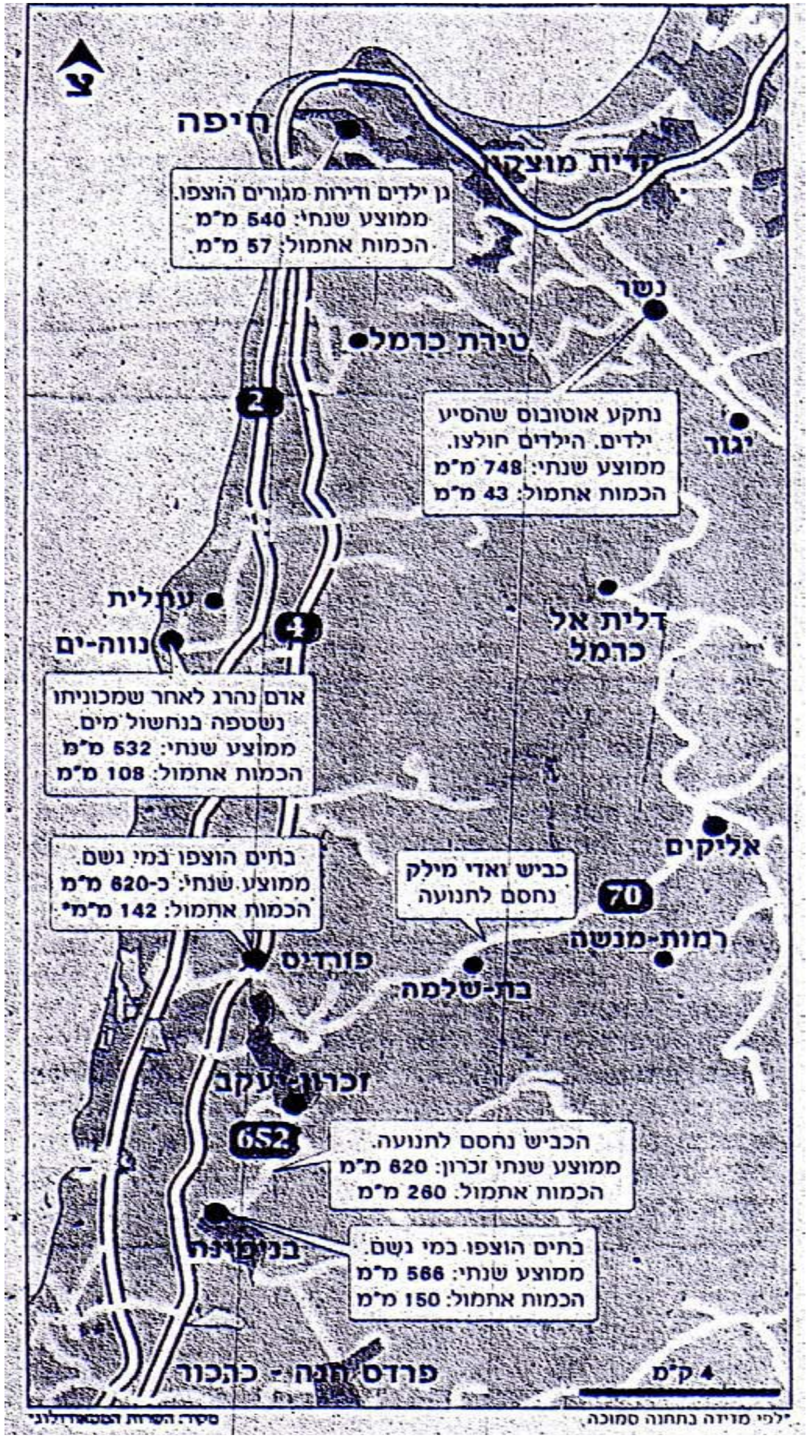
ISRAELI RAINS OF

DECEMBER 4-5 2001


Israeli floods of December
3 – 5 2001
Oren Stream


Rain (last 12 hr.) 04/12 06Z


Rain (last 24 hr.)
5/12/01 06Z



מקור: השירות המטאורולוגי

*לפי מדידה בתחנה סמוכה

260 mm of rain during about 24 hrs

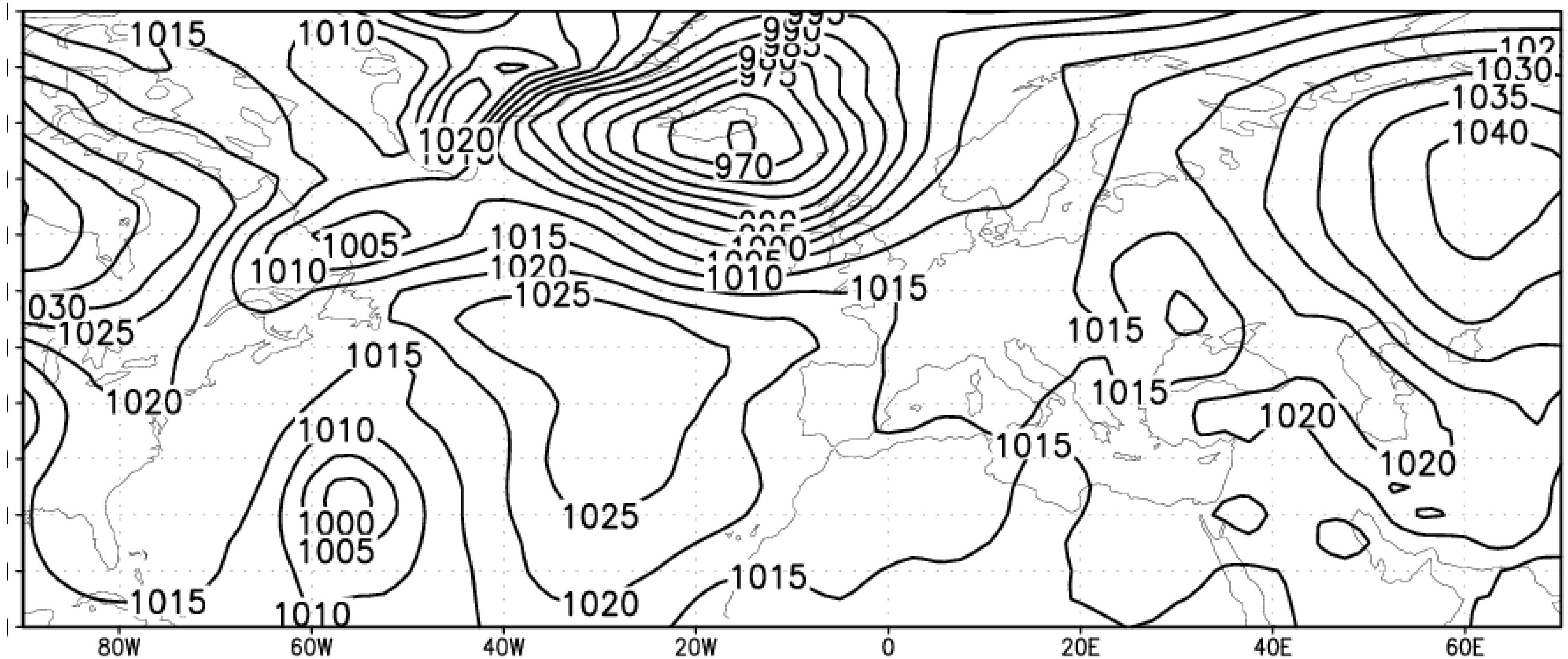
(annual precipitation ~ 650 mm)

WHY?

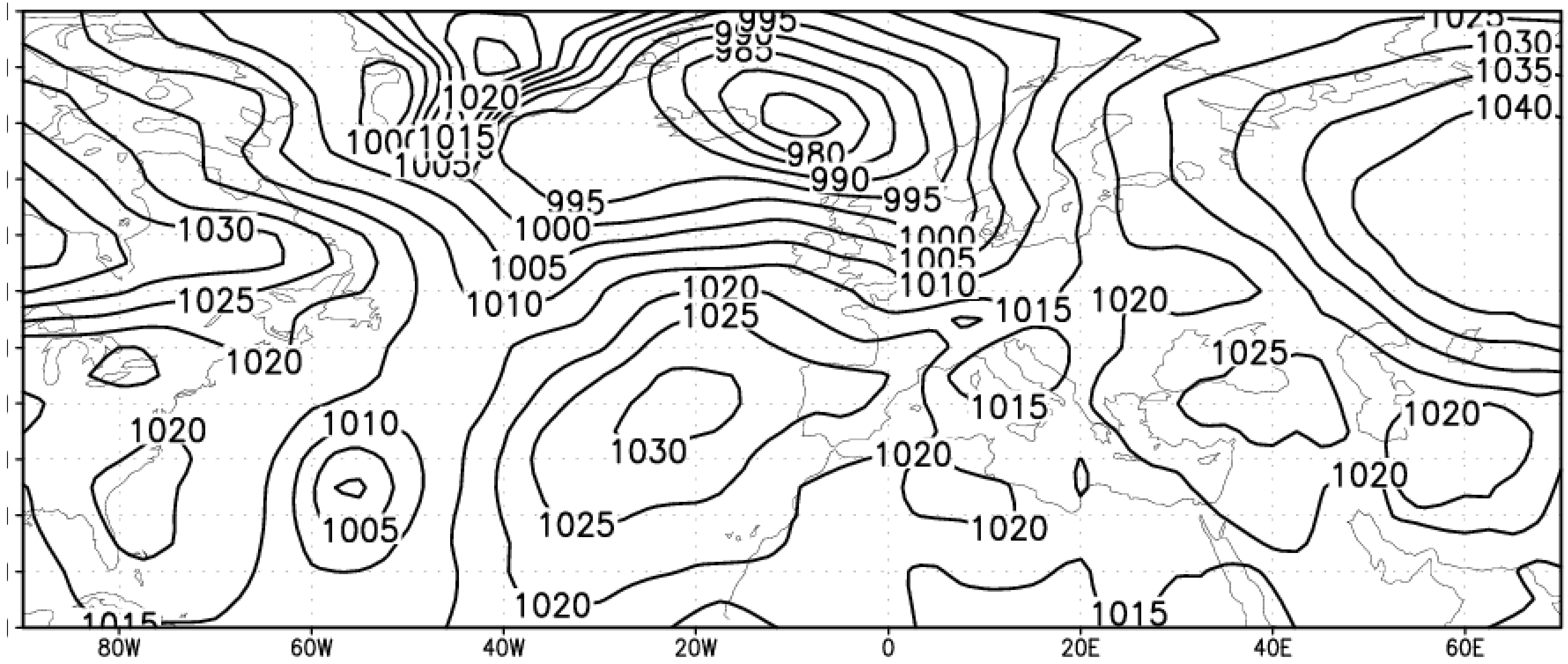
NNRP data

SLP

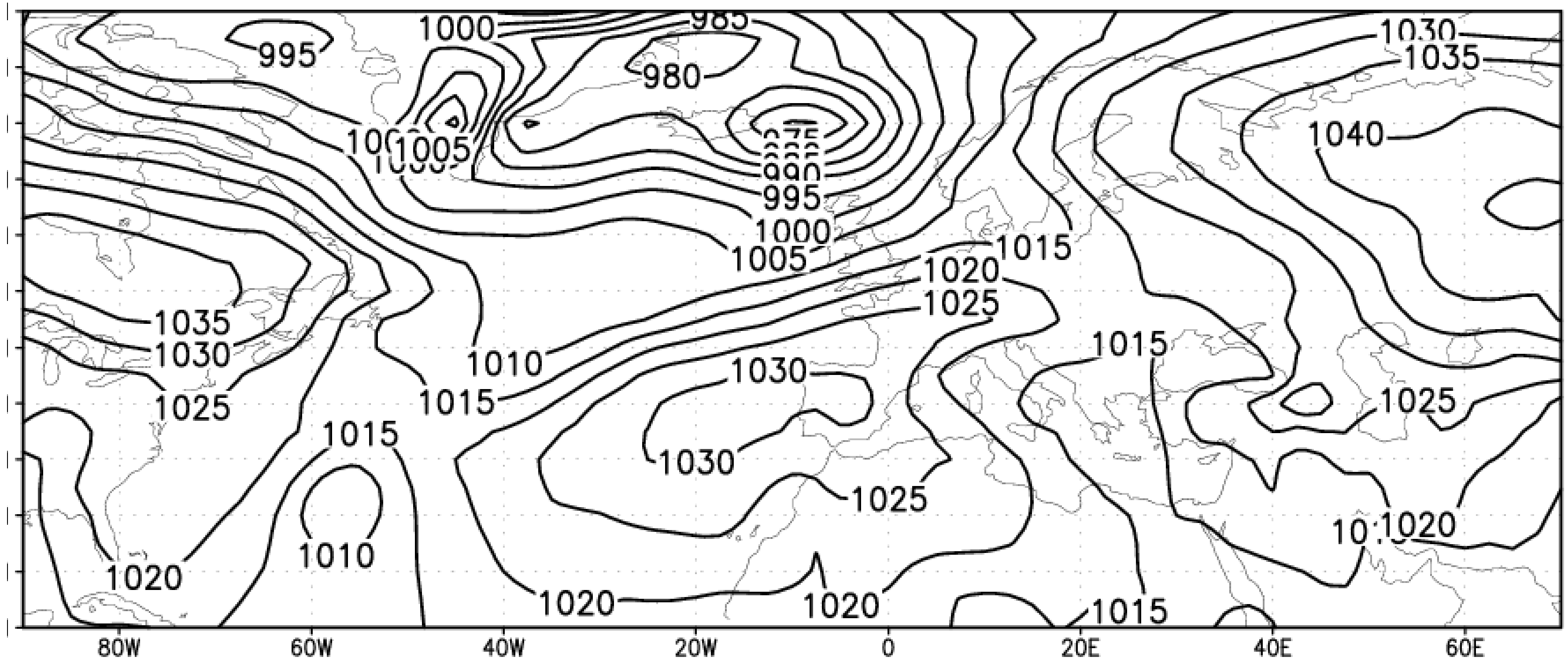
(a) SLP NNRP 00271101



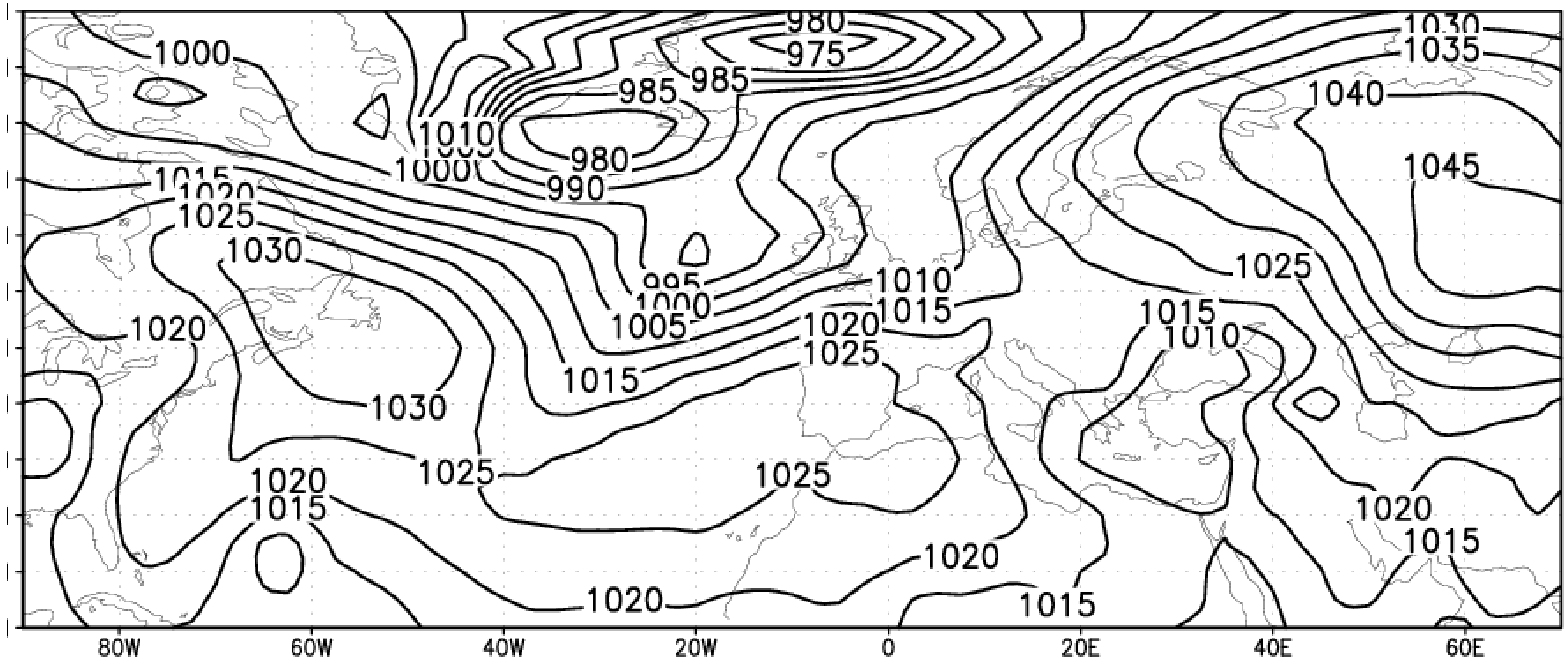
(b) SLP NNRP 00281101

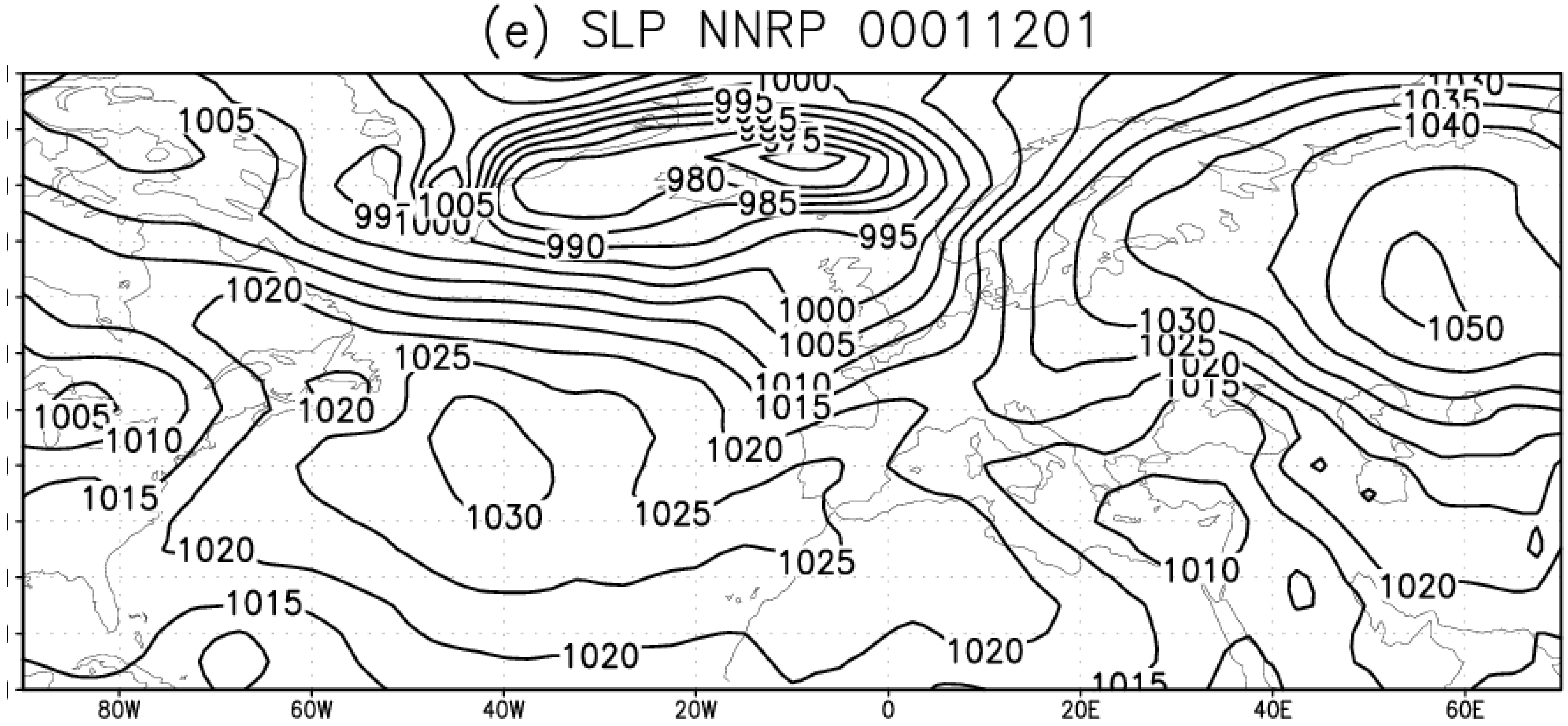


(c) SLP NNRP 00291101



(d) SLP NNRP 00301101





(e) SLP NNRP 00011201
1005
995
975
980
985
990
1005
1000
995
1000
1005
1010
1015
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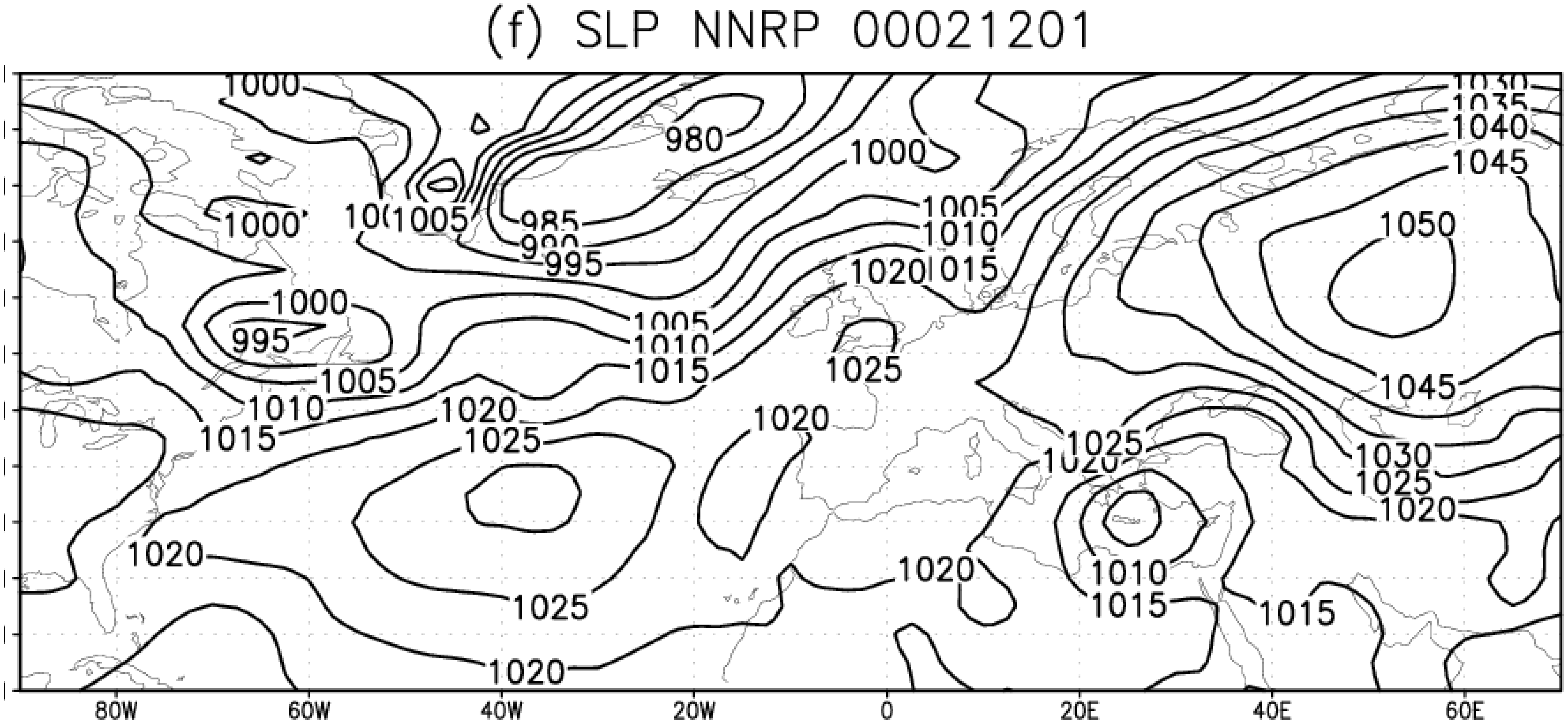
1020
1025
1020
1030
1025
1005
1010
1015
1020
1025
1030
1035
1040
1050
1030
1025
1020
1015
1010
1020
1025
1020
1015
1020
1020
1015
80W
60W
40W
20W
0
20E
40E
60E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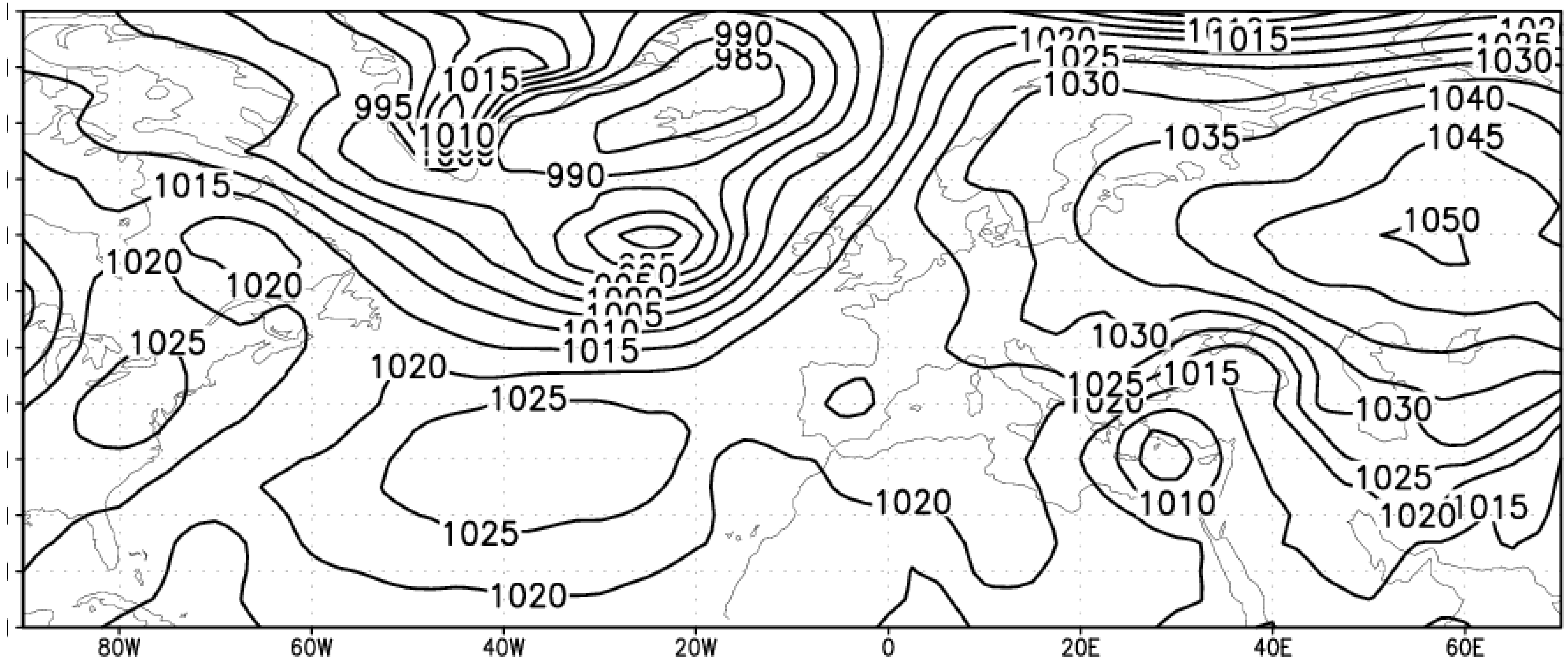
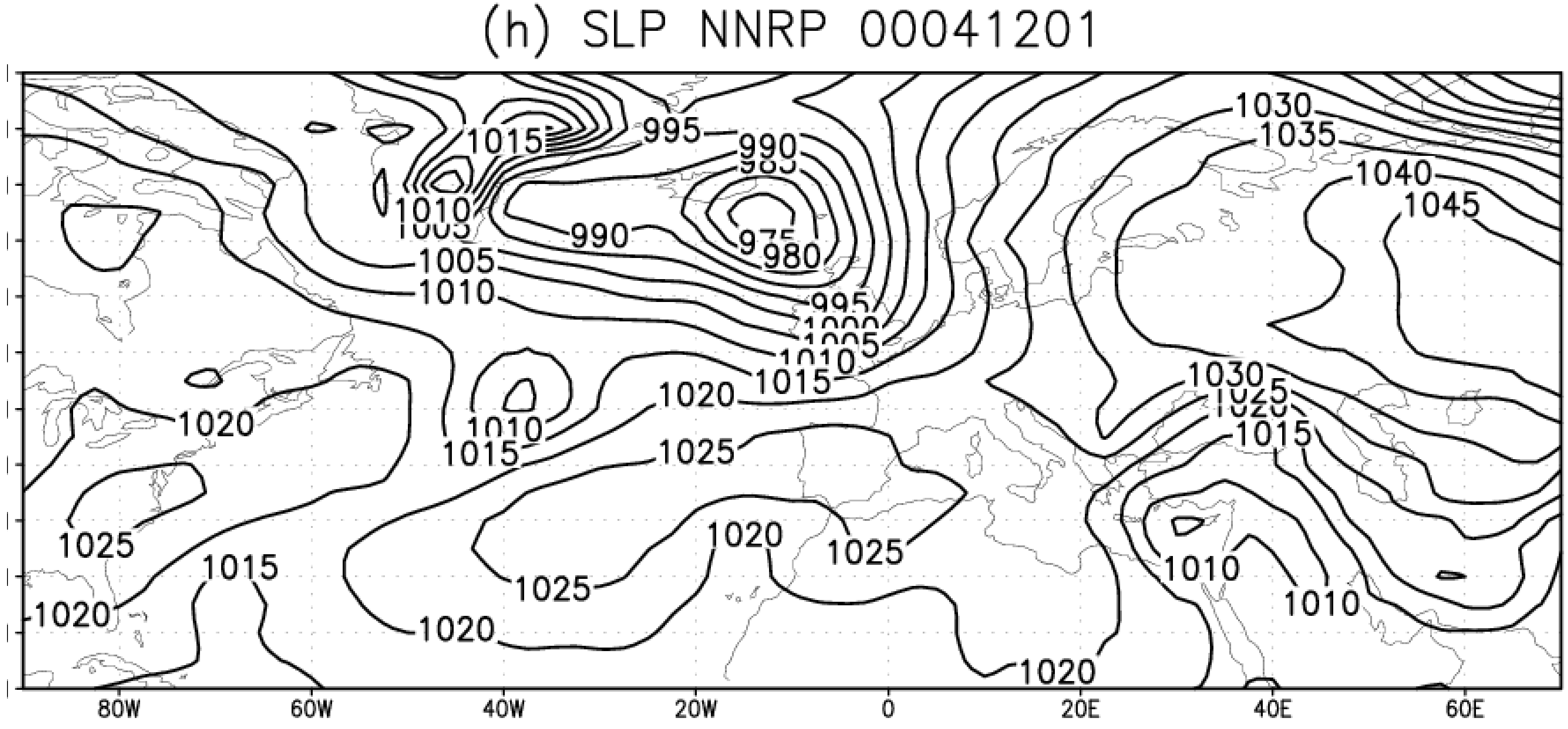
20W
0
20E
40E
60E

(g) SLP NNRP 00031201

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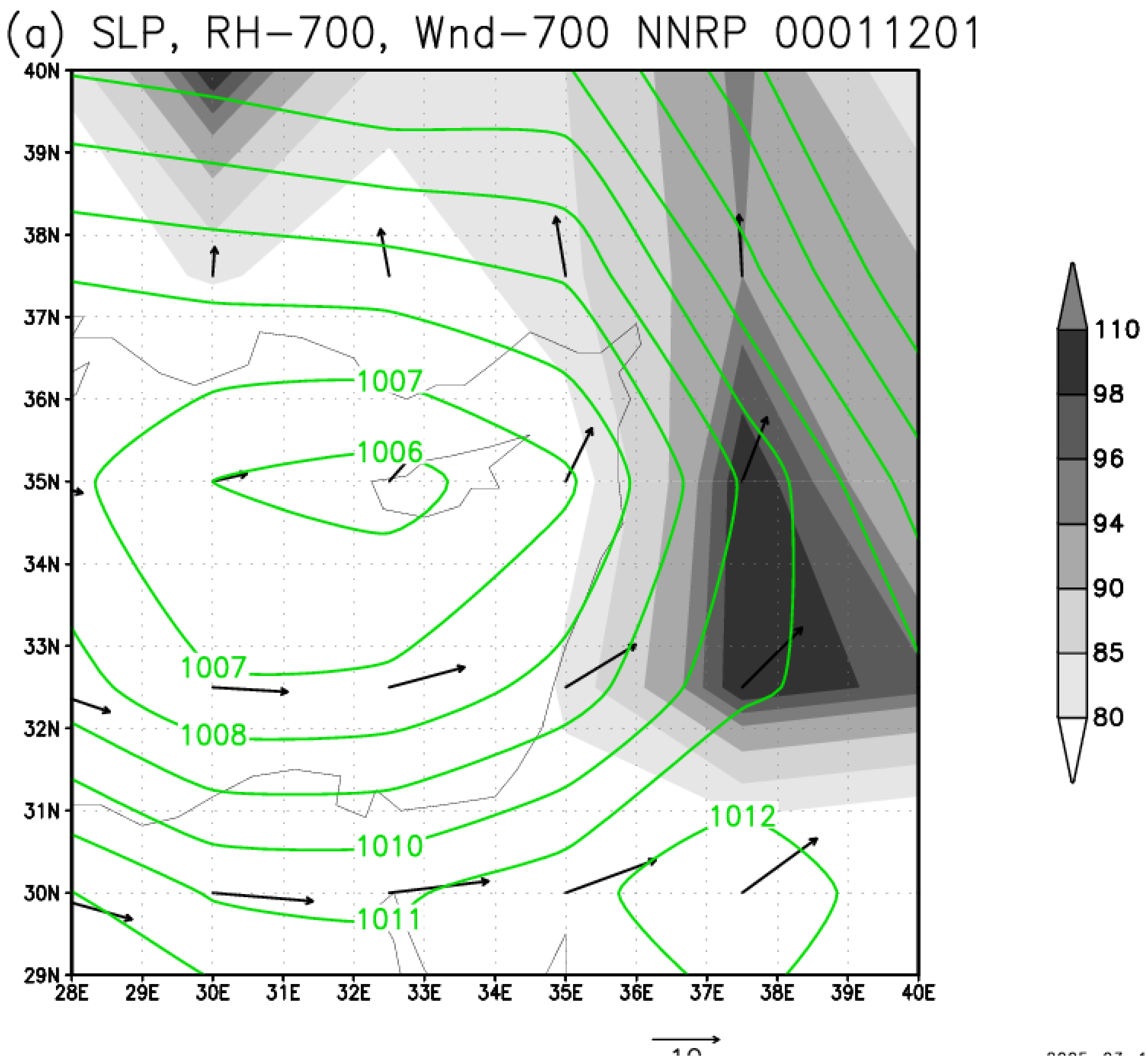
40W
20W
0
20E
40E
60E


(a) SLP, RH-700, Wnd-700 NNRP 00011201
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36N
35N
34N
33N
32N
31N
30N
29N
28E
29E
30E
31E
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33E
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35E
36E
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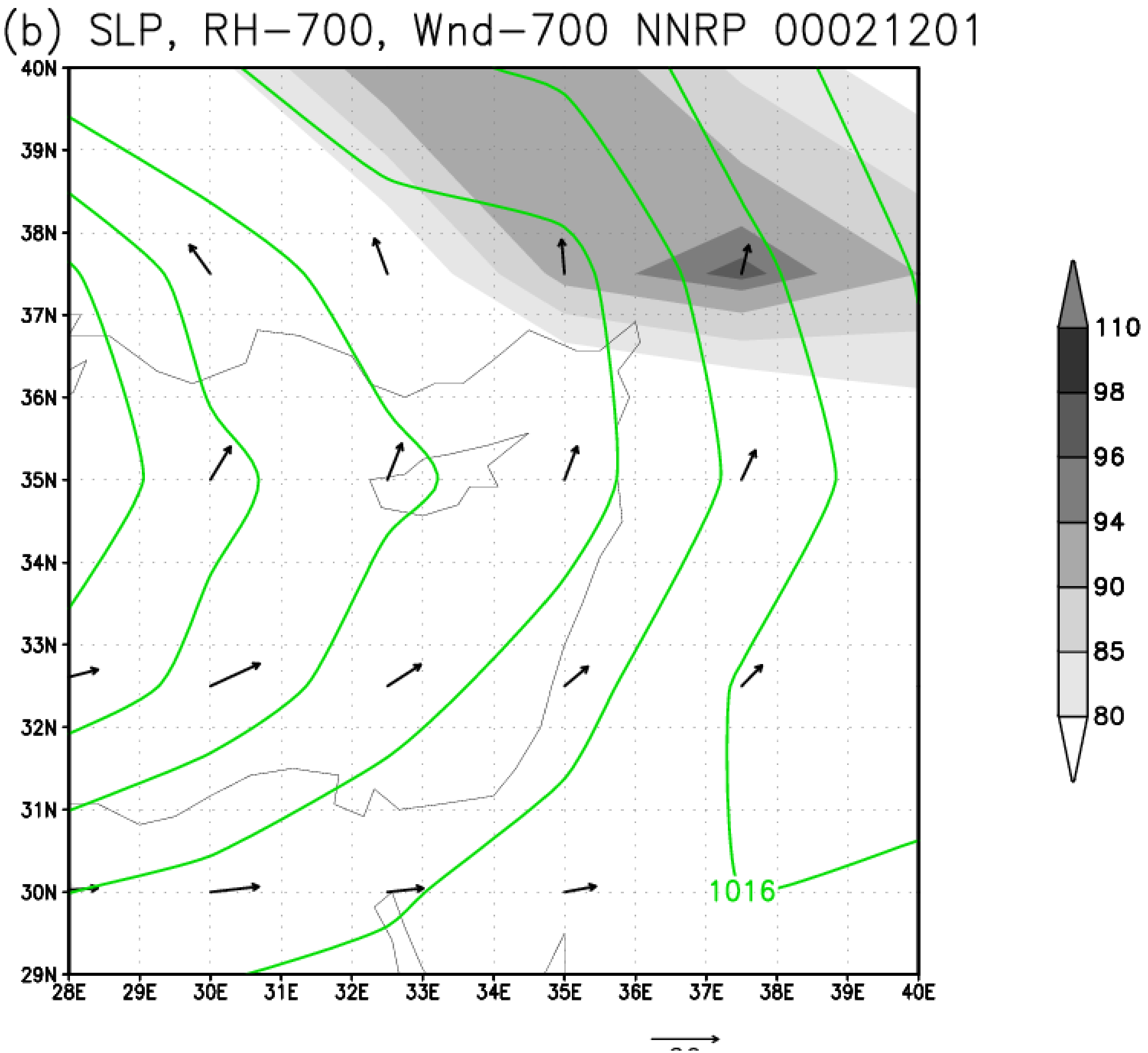

(b) SLP, RH-700, Wnd-700 NNRP 00021201
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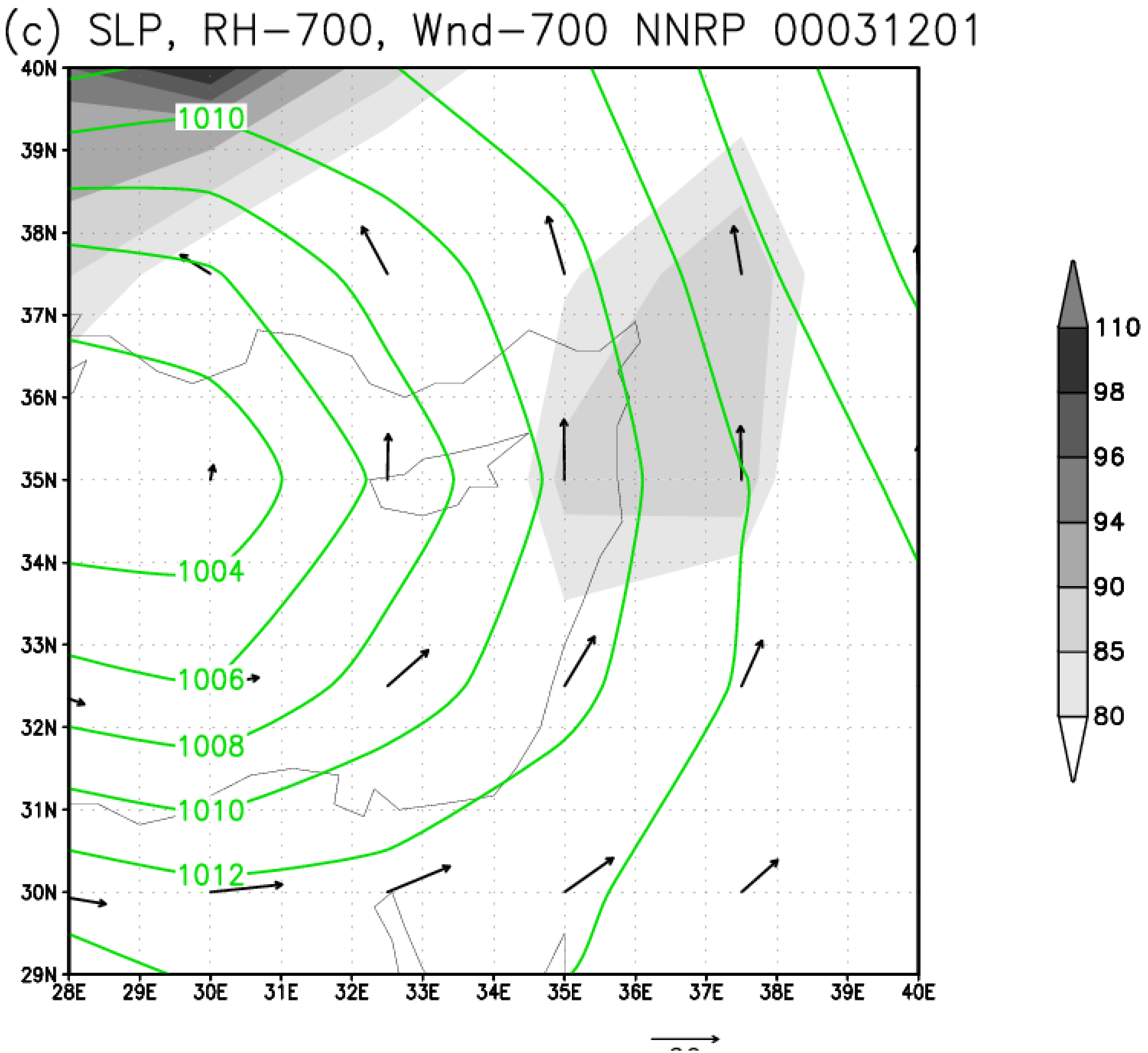

(c) SLP, RH-700, Wnd-700 NNRP 00031201
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29E
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37E
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40E
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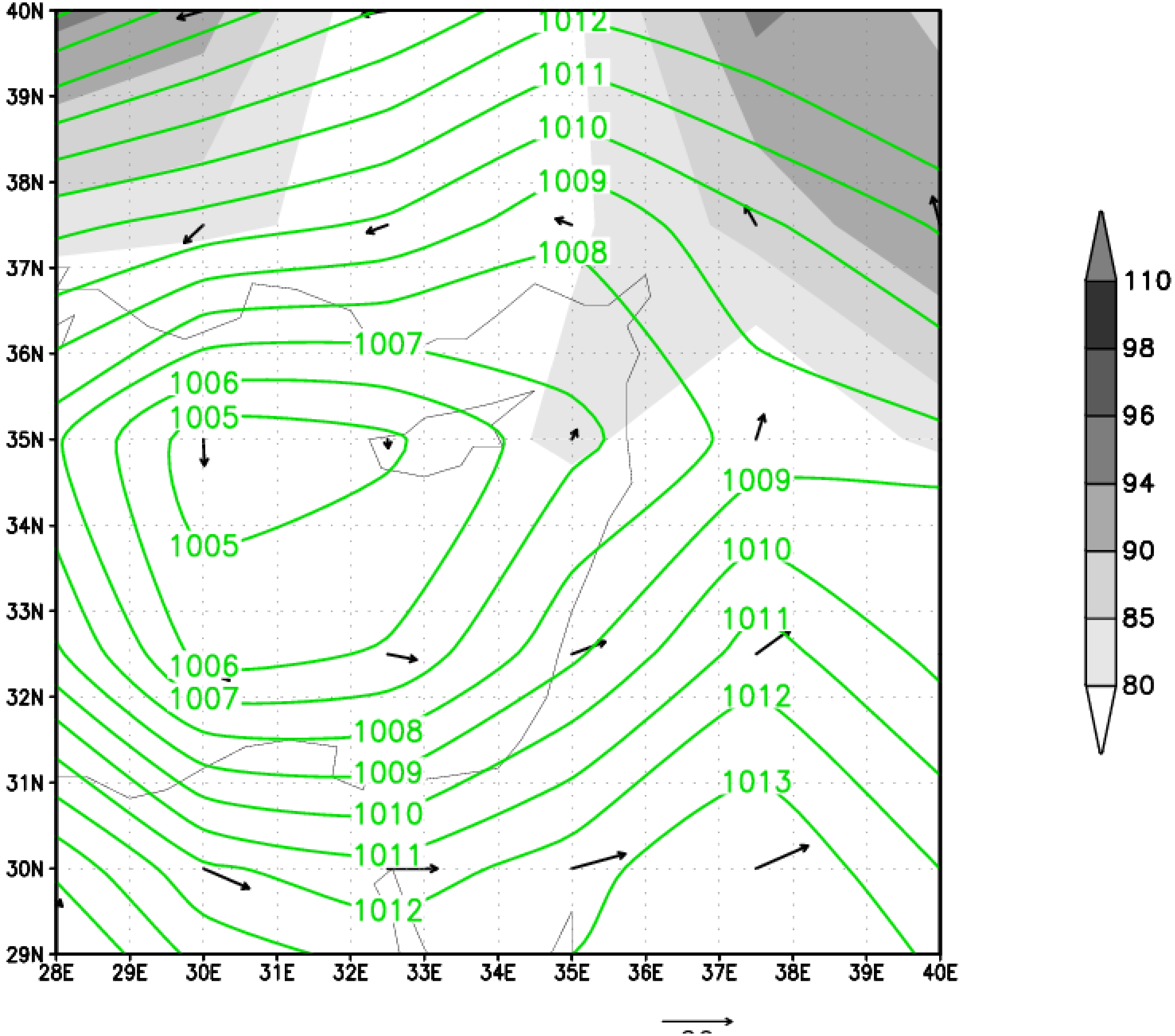
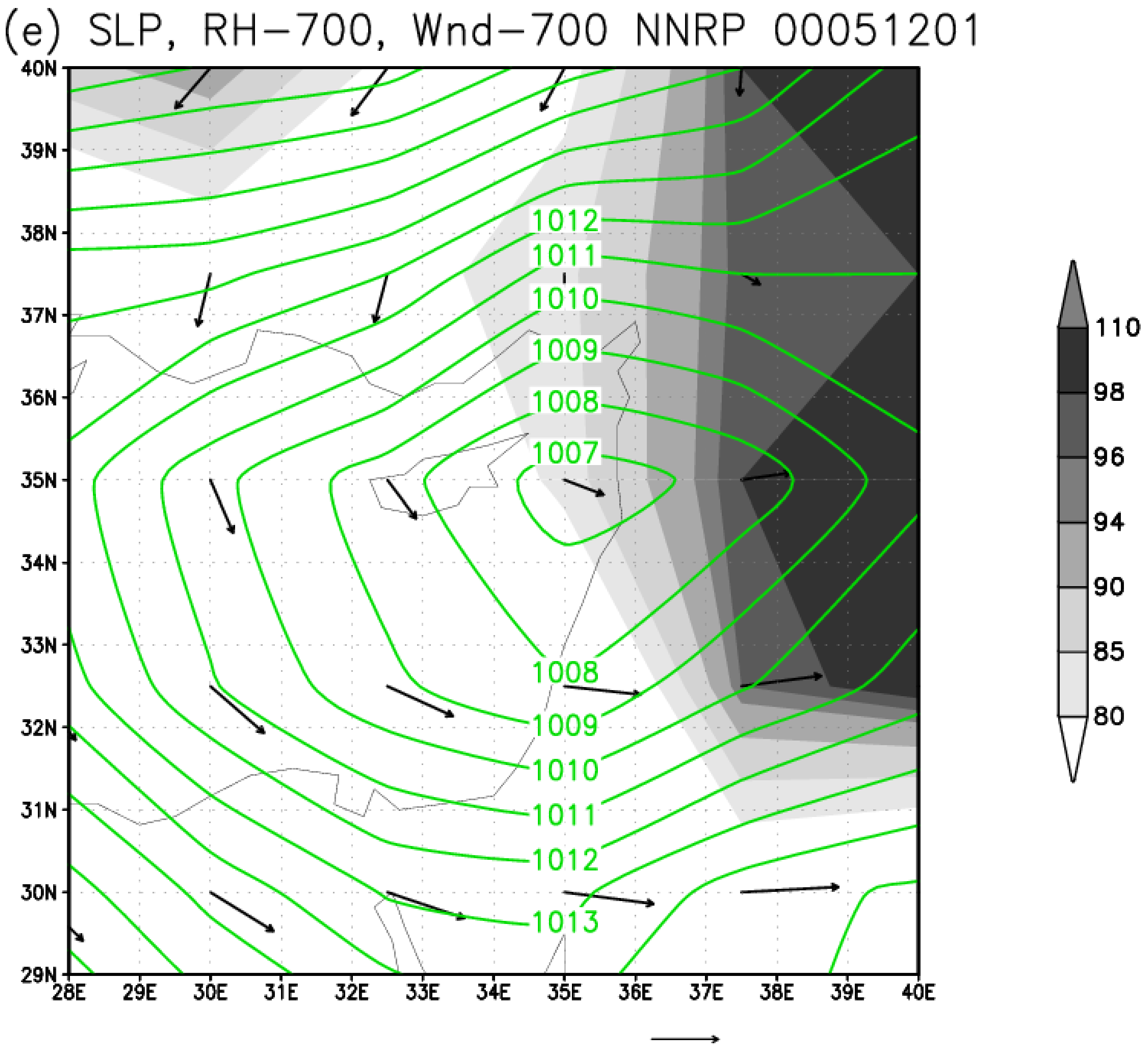
(d) SLP, RH−700, Wnd−700 NNRP 00041201





(e) SLP, RH-700, Wnd-700 NNRP 00051201
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40E
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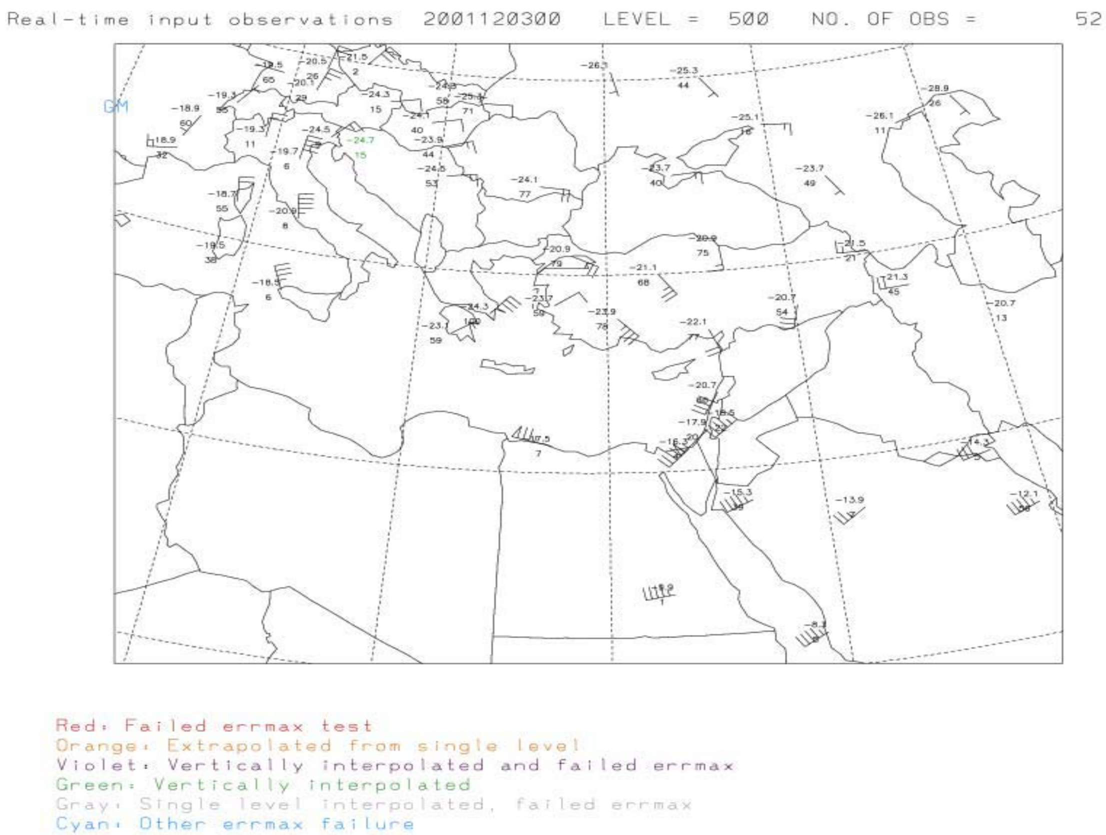
Resolution of the data is too coarse for the purpose

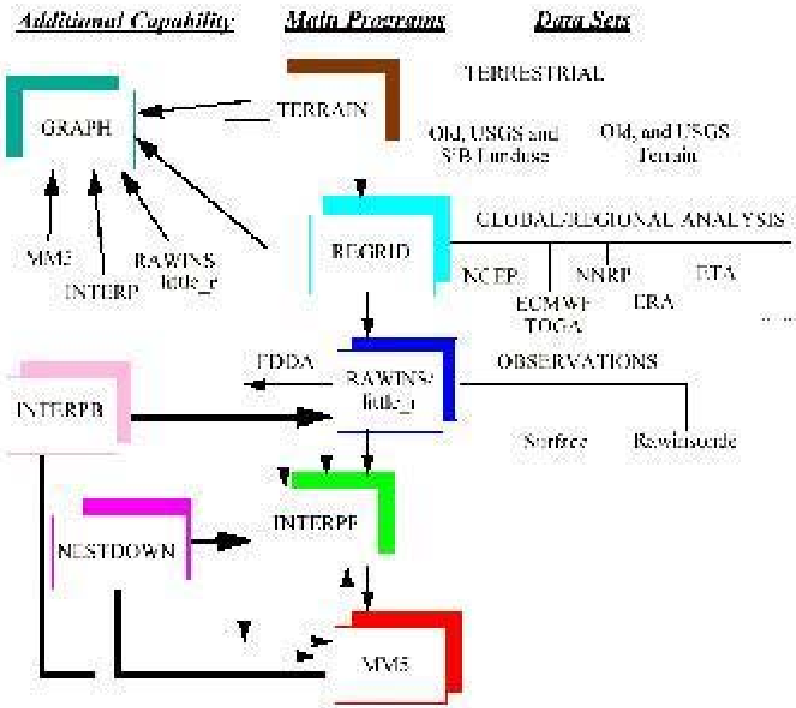
Not enough observation data as well is available



Will use atmospheric model simulation to create a higher resolution data set for the analysis of the event

MM5

MM5 Modeling System Flow Chart

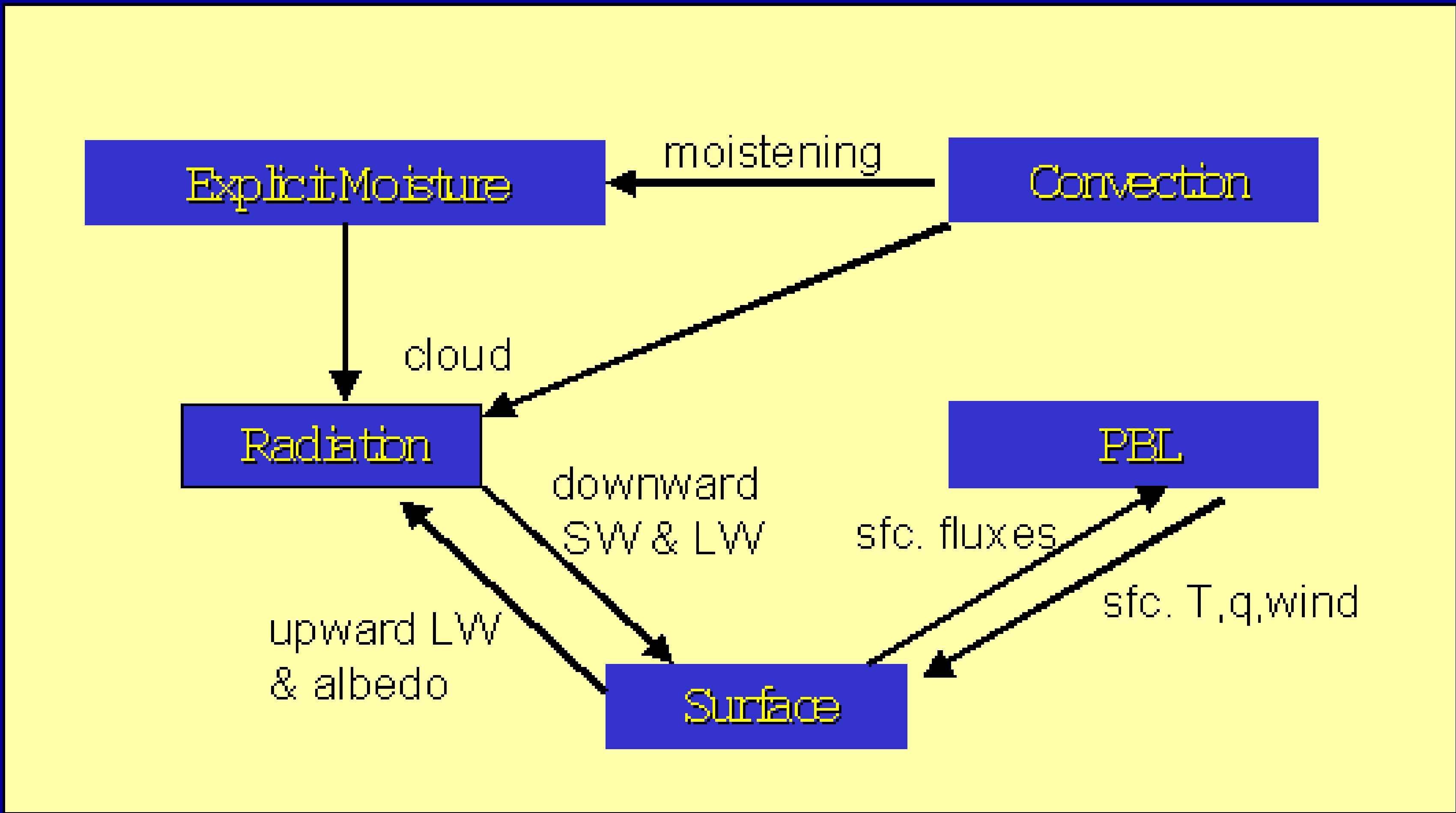


MM5 Model

- The forecast component of the MM5 System
- Dynamics
  - Compressible, nonhydrostatic with terrain-following coordinate, map-factors, full Coriolis
- Numerics
  - Second order time-split leapfrog time scheme
  - Second-order centered space scheme
- Physics
  - Full physics for NWP applications
  - Many options for each physics component

MM5 details

Scheme Couplings

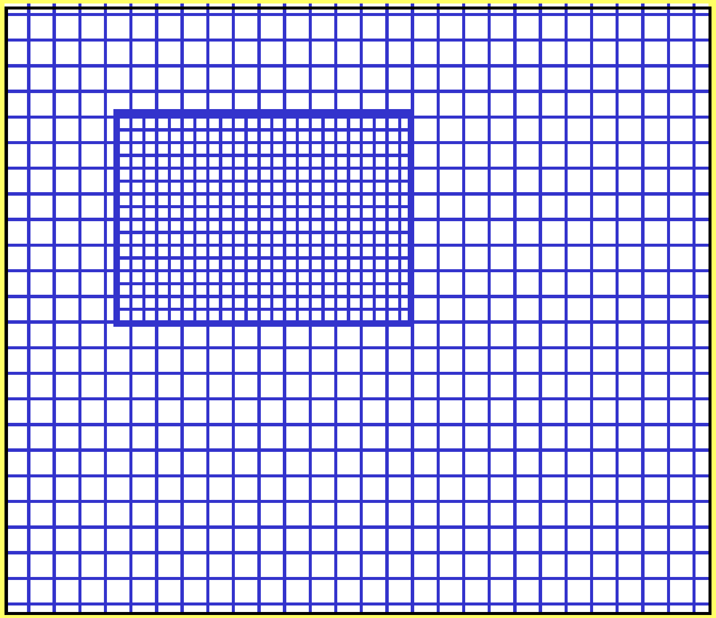


MM5 Modeling System

Other Features:
- **Nonhydrostatic**

$$\frac{dw}{dt} - \frac{u^2 + v^2}{a} = -\frac{1}{\rho}\frac{\partial p}{\partial z} + 2\Omega u \cos\phi - g + F_{rz}$$

- **Grid nesting**



USUAL STRATEGY FOR OPERATIONAL APPLICATION

Nesting

- One-way nesting
  - Run model, then use NESTDOWN to create nest initial and boundary conditions, then run nest
  - Sequential runs
  - No feedback
  - Any integer ratio

A more attractive approach

NOT USED IN OPERATIONAL APPLICATIONS

Nesting

- Two-way nesting
  - Multiple domains at same time
  - 3:1 grid size ratio
  - 3 nest time-steps per parent step
  - Parent forces nest at its boundaries
  - Nest feeds back to parent in interior
  - Generally more expensive than 1-way

**TWO-WAY NESTING:
NUMERICALLY AND
METEOROLOGICALLY
IS MORE CONSISTENT**

THOUGH

**NOT RECOMMENDED FOR
OPERATIONAL APPLICATIONS**

SINCE IT IS NOT LOGICAL TO GIVE A HIGHER PRIORITY TO THE PROCESSES OVER THE HIGH-RESOLUTION DOMAIN

WHEN THEY ARE THE LARGE-SCALE ONES

- METEOROLOGICAL OBSERVATIONS AND INITIAL DATA PROBLEM

- NOT ACCURATE INITIAL / LATERAL BOUNDARY DATA ESPECIALLY IN THE AREA WITH SMALL SCALE PROCESSES

ADDITIONAL GEOPHYSICAL DATA

- SYSTEMATIC EFFORS OVER SPECIFIC AREAS

ACCURACY AND STASBILITY OF NUMERICAL APPROXIMATIONS

- SOLUTION MAY BE LESS STABLE IN THE AREAS WITH HIGH GRADIENTS, UNSTABLE STRATIFICATION, SPECIFIC TYPES OF THE FLOW

MODEL RESOLUTION

- TRUNCATION ERRORS - DYNAMICALLY IMPORTANT SCALES BECOME SUB-GRID ONES WHEN RESOLUTION IS LOWER THAN NEEDED IN A PARTICULAR PROCESS

ROLE OF TERRAIN

- ERRORS IN THE AREAS WITH STEEP TERRAN

PARAMETERIZATION OF PHYSICAL PROCESSES

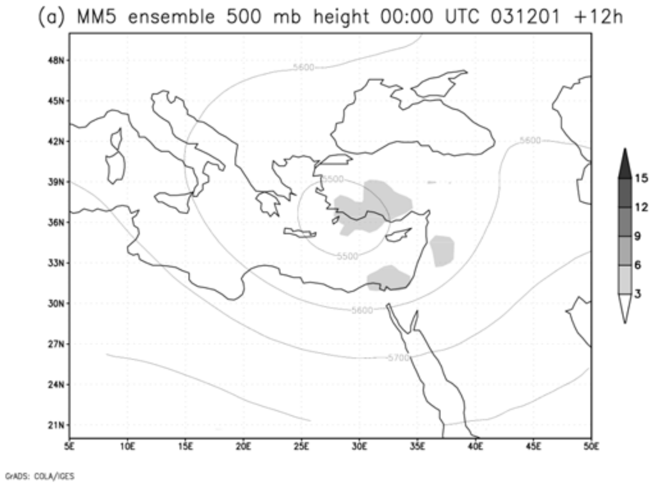
- PHYSICAL PARAMETRIZATION APPROACHES ARE BASED ON ASSUMPTIONS WHICH ARE ONLY ON THE AVERAGE VALID FOR PARTICULAR REGIONS

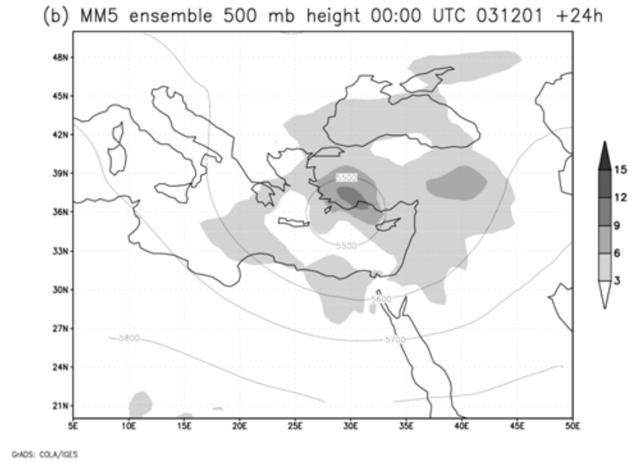
SUGGESTED SOLUTION

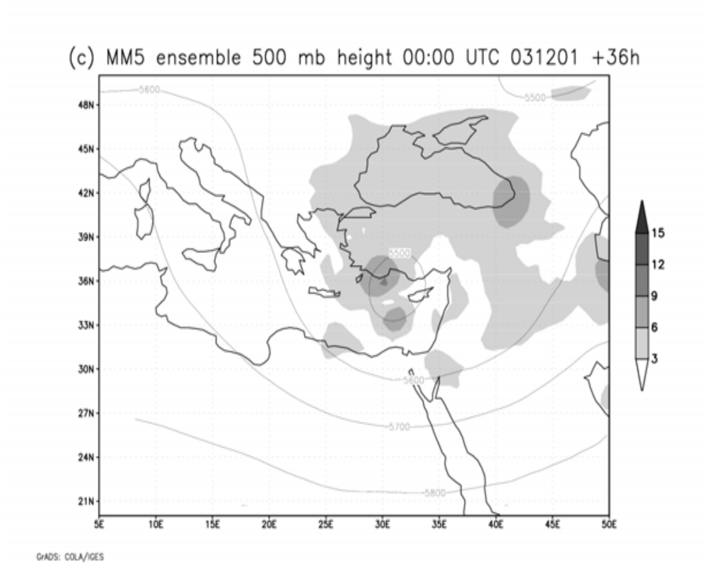
VARIABLE (ADAPTIVE) RESOLUTION

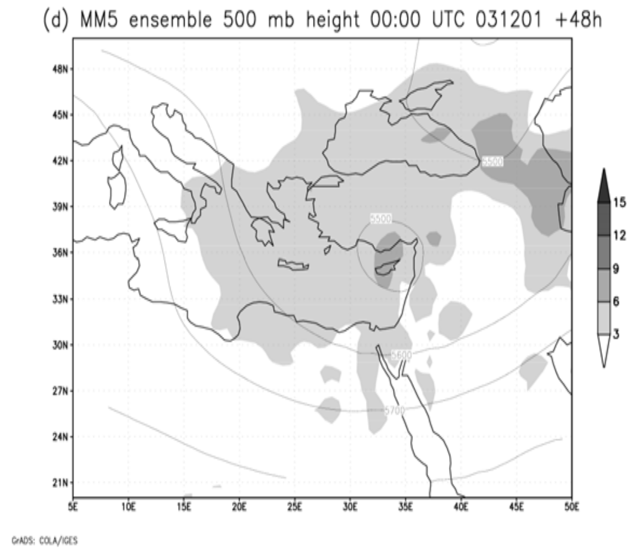
ENSEMBLE APPROACH FOR DETERMINATING AREAS WITH INCREASED ROLE OF SMALL-SCALE EFFECTS

Dec 3-5 2001: ENSEMBLE SIMULATION









ENSEMBLE – BASED DOMAIN CONFIGURATION ADAPTED

Table1. MM5 configuration

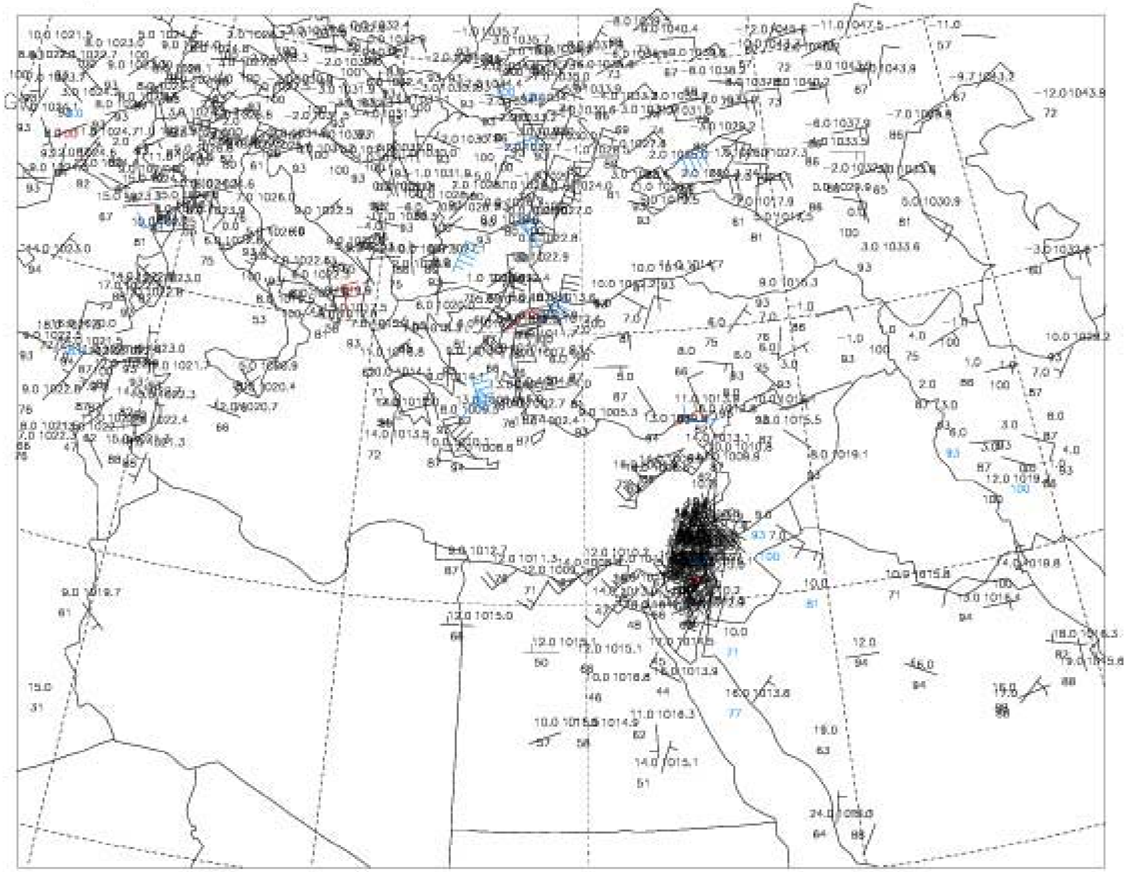
Number of points	73 x 73	85 x 67	127 x 100
Resolution (km)	45	15	5
Number of layers	37	37	37
MPHYS	Simple ice	Simple ice	Simple ice
ICUPA	Betts-Miller	Grell	Grell
BLTYP	Eta Mel-Yam	MRF	MRF
FRAD	RRTM	0	0
ISOIL	Multi-layer	Multi-layer	Multi-layer

TARGETTED VERIFICATION

MM5 SUCCESSIVE CORRECTION (Cressman) OA

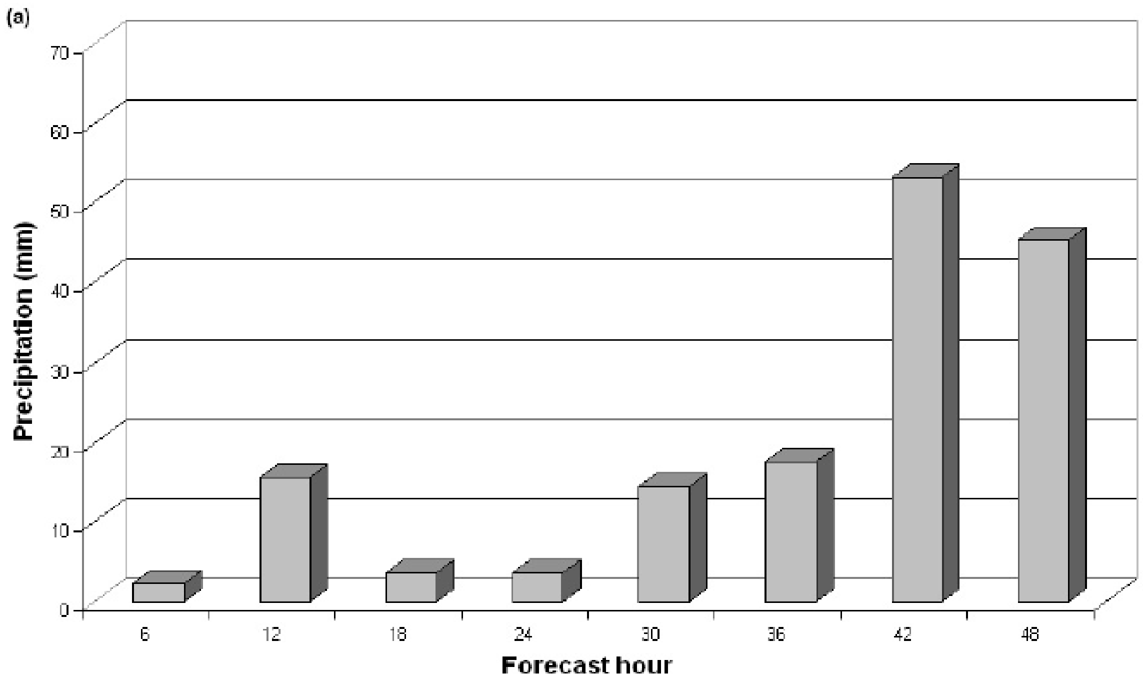
OF SURFACE OBSERVATION DATA IN ISRAEL

Real-time input observations 2001120300 LEVEL = 1001 NO. OF OBS = 397



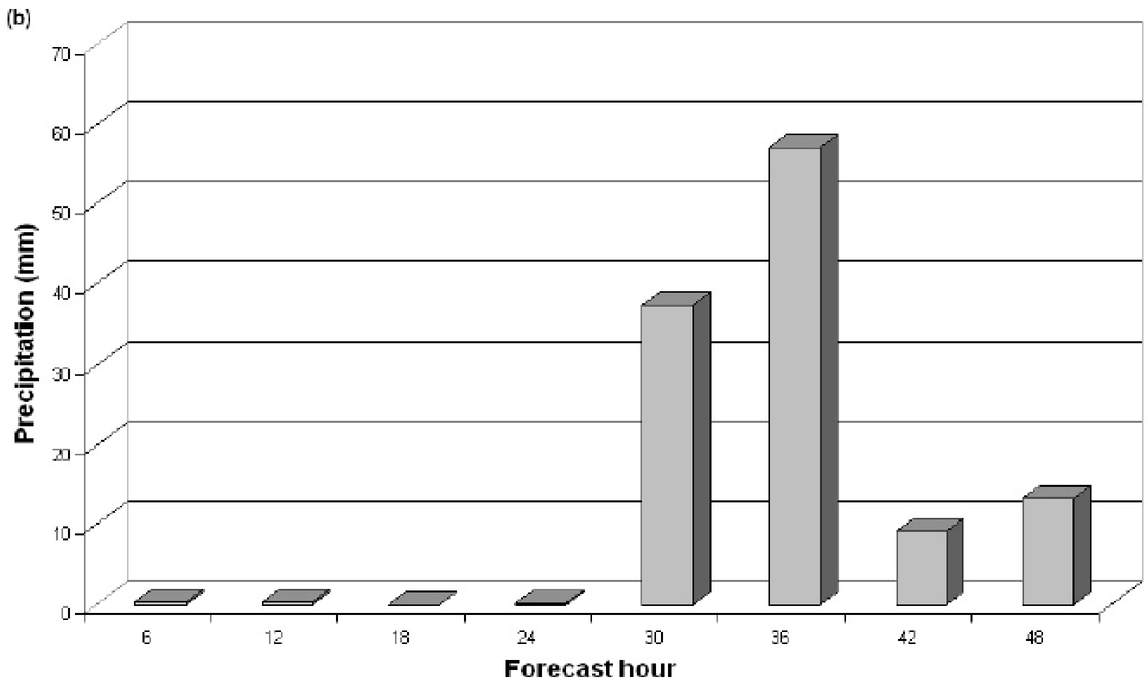
Red: Failed errmax test
Orange: Extrapolated from single level
Violet: Vertically interpolated and failed errmax
Green: Vertically interpolated
Gray: Single level interpolated, failed errmax
Cyan: Other errmax failure

Precipitation prediction



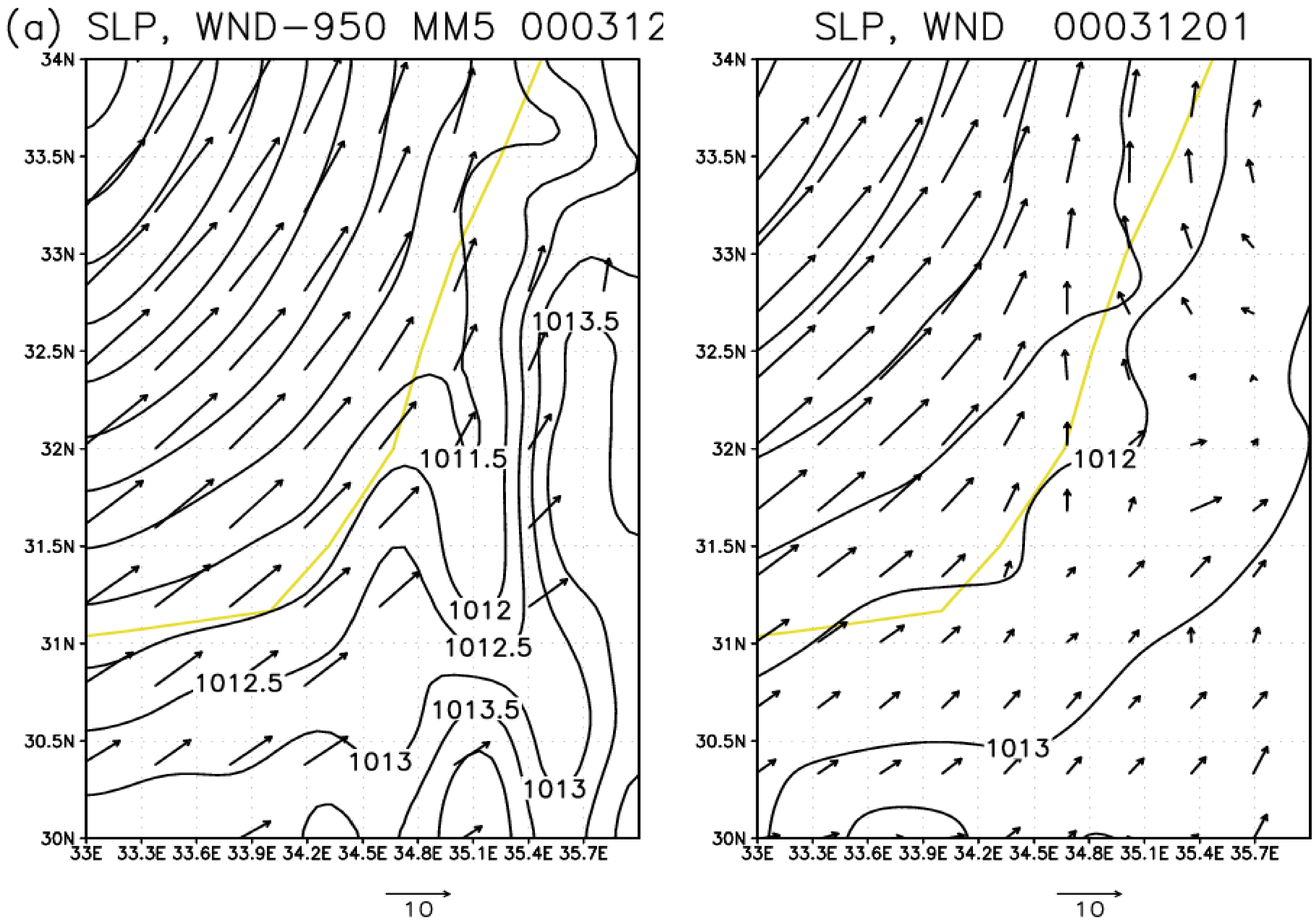
FCST

LAT: 32.66 oN
LON:34.80 oE

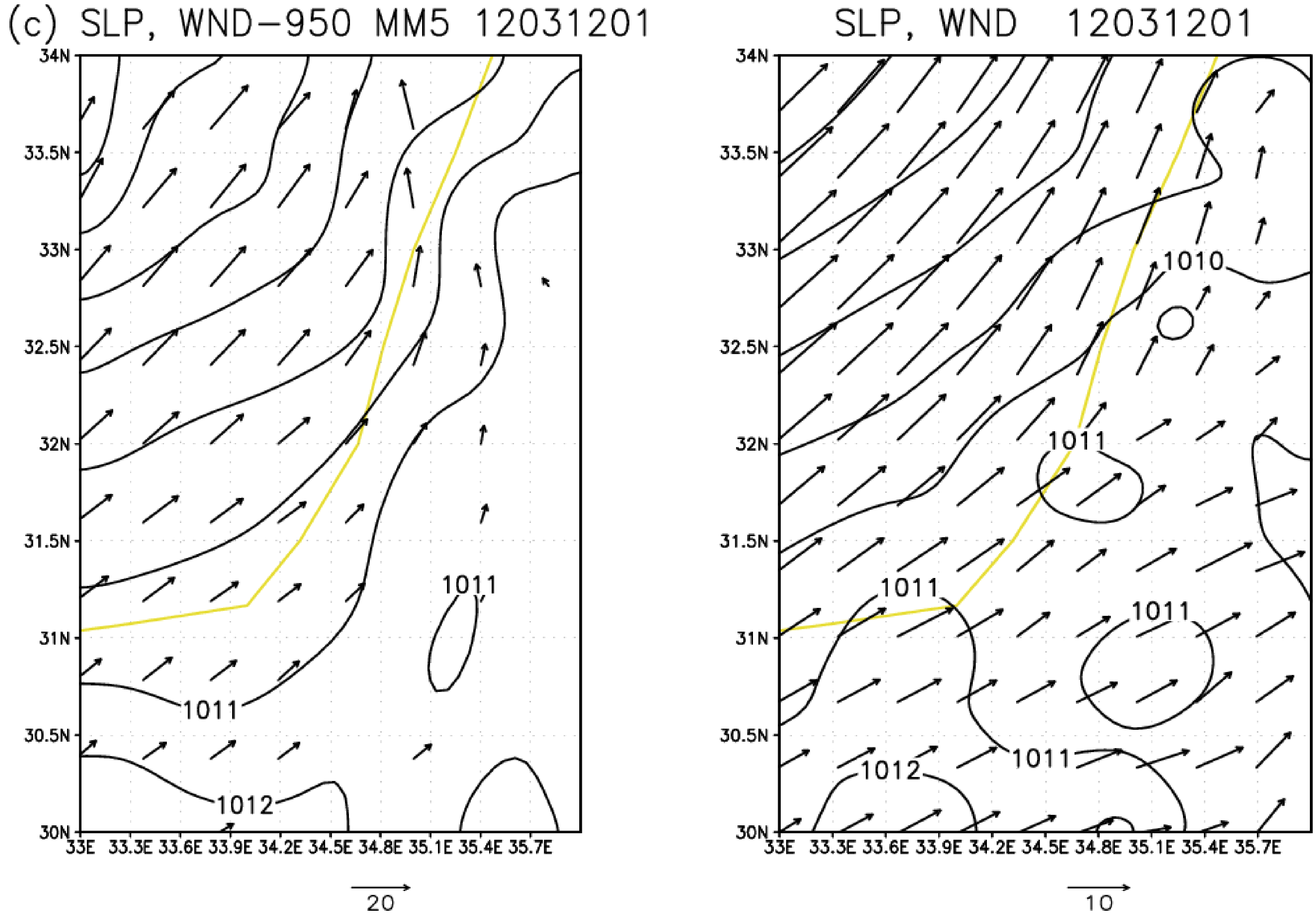


OBS

SLP/Wind prediction



(a) SLP, WND-950 MM5 000312
SLP, WND 00031201
34N
33.5N
33N
32.5N
32N
31.5N
31N
30.5N
30N
33E 33.3E 33.6E 33.9E 34.2E 34.5E 34.8E 35.1E 35.4E 35.7E
1011.5
1012
1012.5
1013
1013.5
10


(c) SLP, WND-950 MM5 12031201
SLP, WND 12031201
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33.5N
33N
32.5N
32N
31.5N
31N
30.5N
30N
33E 33.3E 33.6E 33.9E 34.2E 34.5E 34.8E 35.1E 35.4E 35.7E
1010
1011
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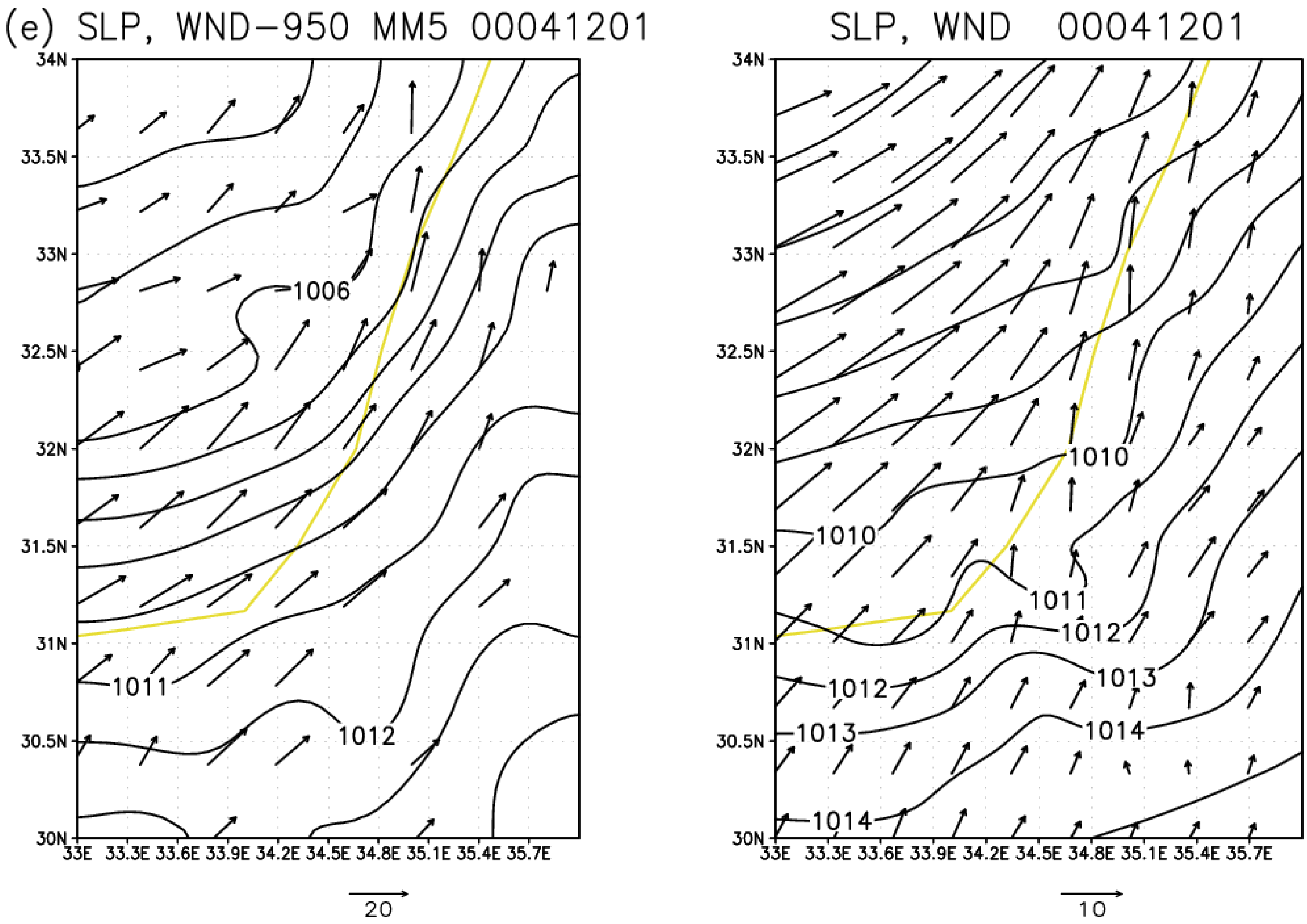
20
10


(e) SLP, WND-950 MM5 00041201
SLP, WND 00041201
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32.5N
32N
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30.5N
30N
33E
33.3E
33.6E
33.9E
34.2E
34.5E
34.8E
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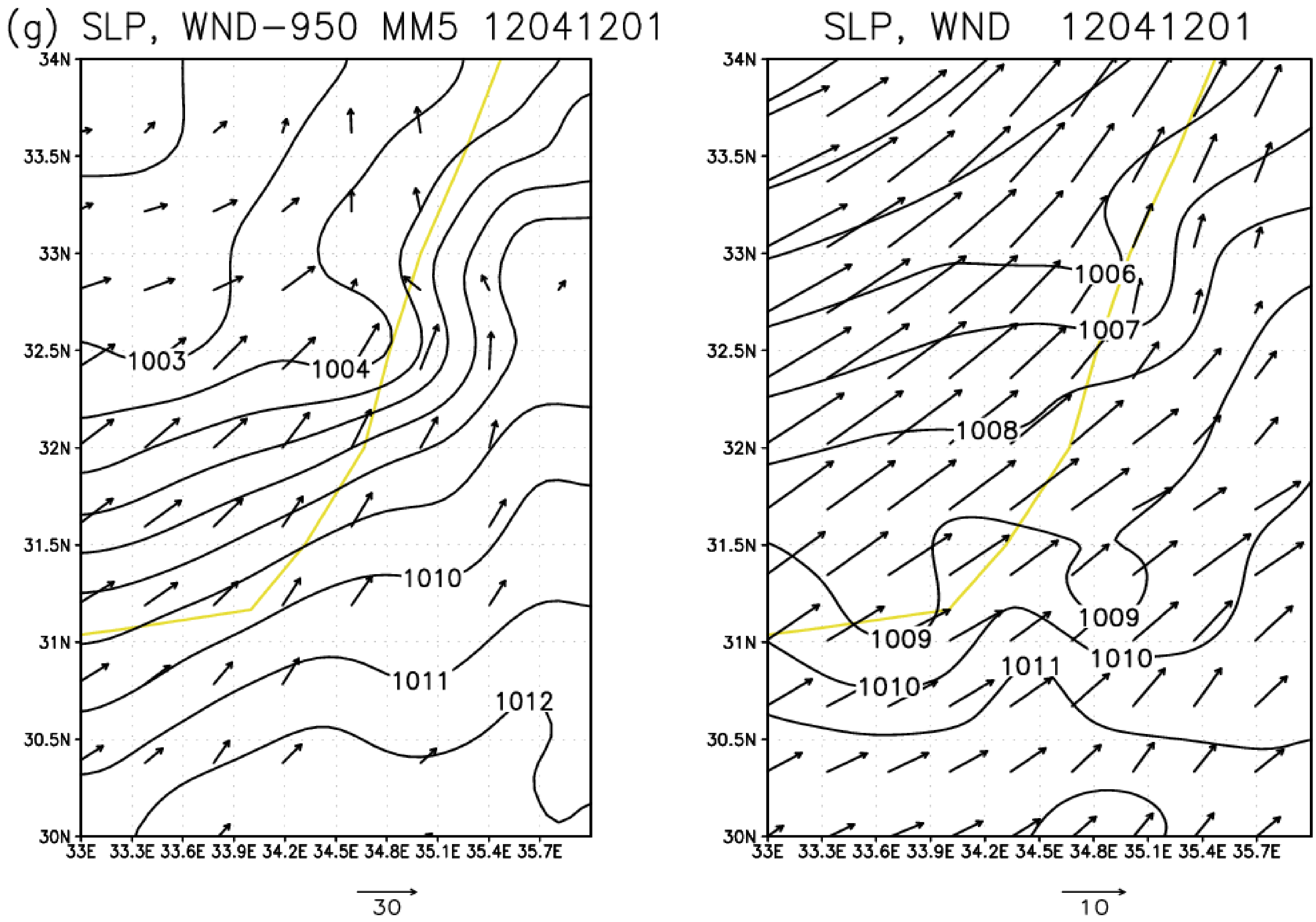

(g) SLP, WND-950 MM5 12041201
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33.3E
33.6E
33.9E
34.2E
34.5E
34.8E
35.1E
35.4E
35.7E
1003
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SLP, WND 12041201
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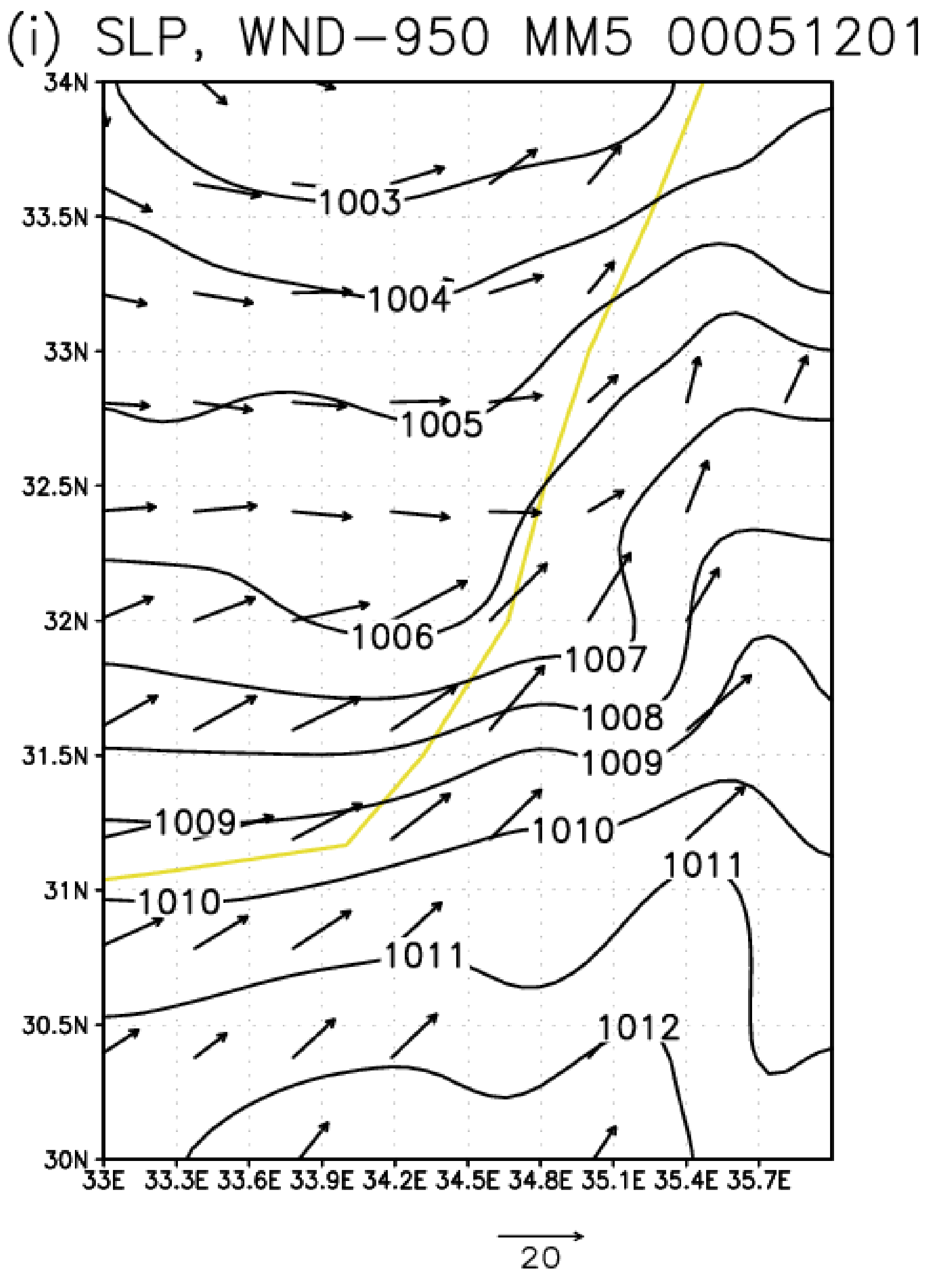

(i) SLP, WND-950 MM5 00051201
34N
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30N
33E 33.3E 33.6E 33.9E 34.2E 34.5E 34.8E 35.1E 35.4E 35.7E
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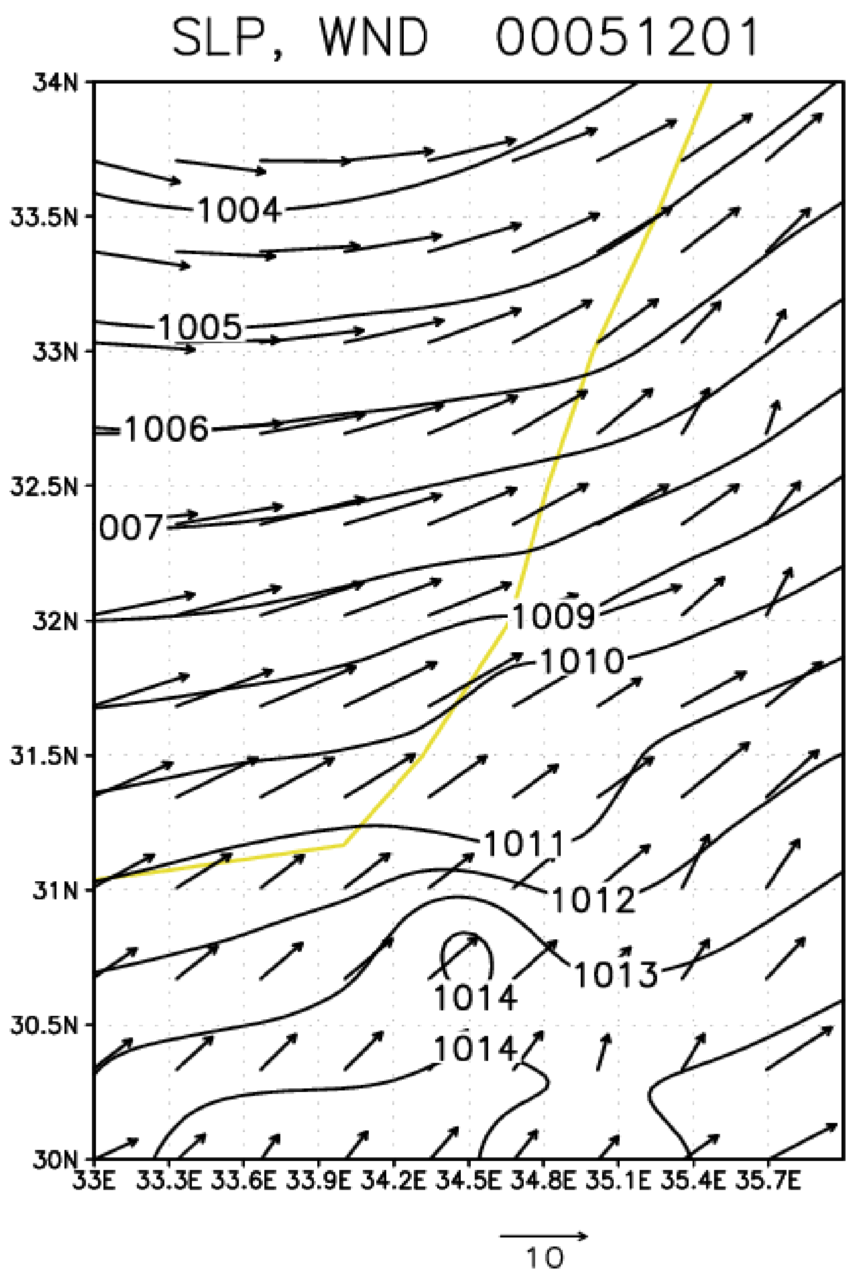

SLP, WND 00051201
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33.5N
33N
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30.5N
30N
33E 33.3E 33.6E 33.9E 34.2E 34.5E 34.8E 35.1E 35.4E 35.7E
1004
1005
1006
007
1009
1010
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1013
1014
1014
10

Conclusion

SIMULATION RESULTS
ARE IN AGREEMENT WITH THE
OBSERVATIONS OVER THE
TARGET VERIFICATION AREA

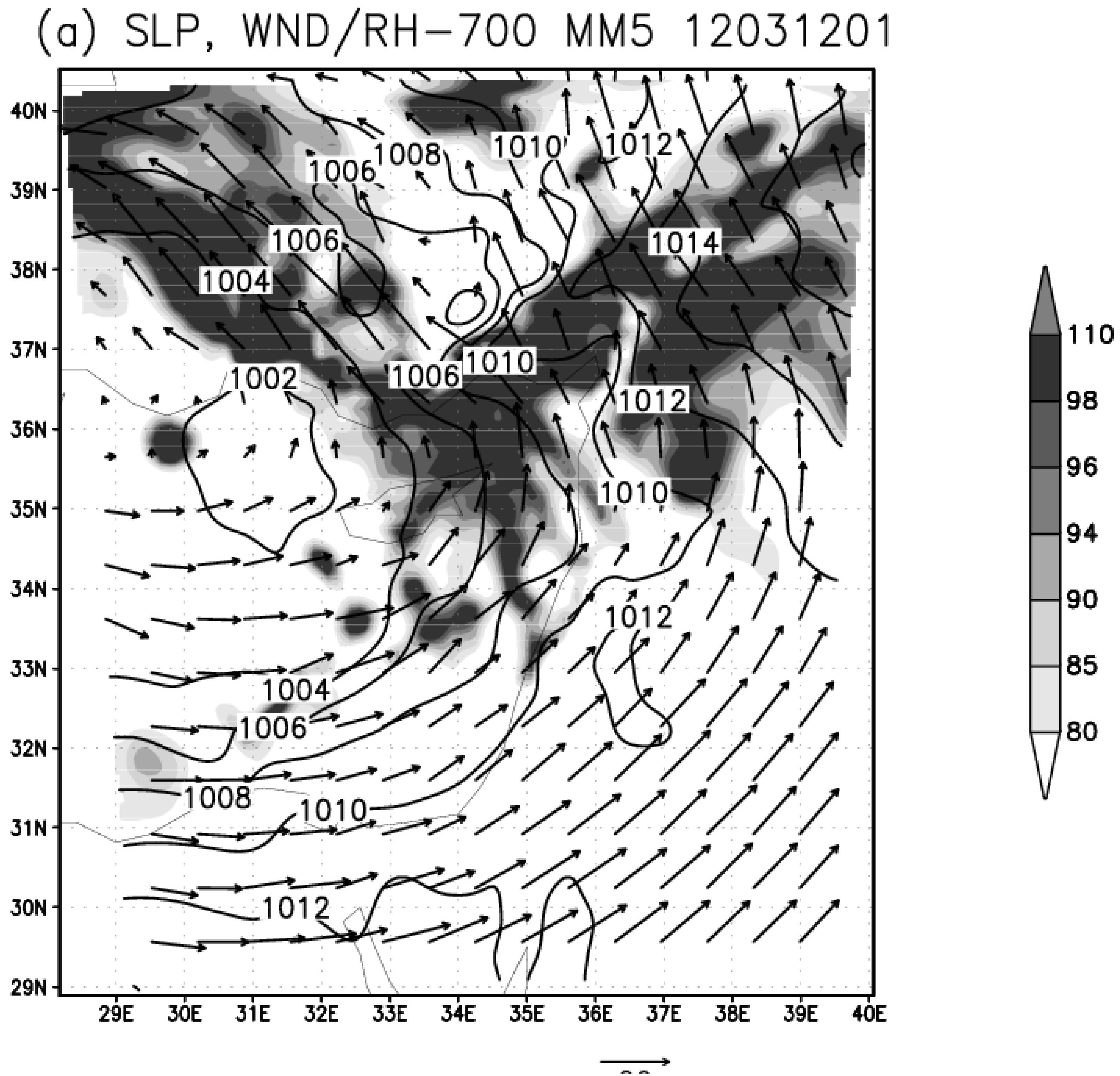
Conclusion

THE HIGH-RESOLUTION DATA SET MAY BE USED FOR INVESTIGATING THE EVENT

CONVENTIONAL SYNOPTIC ANALYSIS

SLP/Wind

Splitting of a wet air mass system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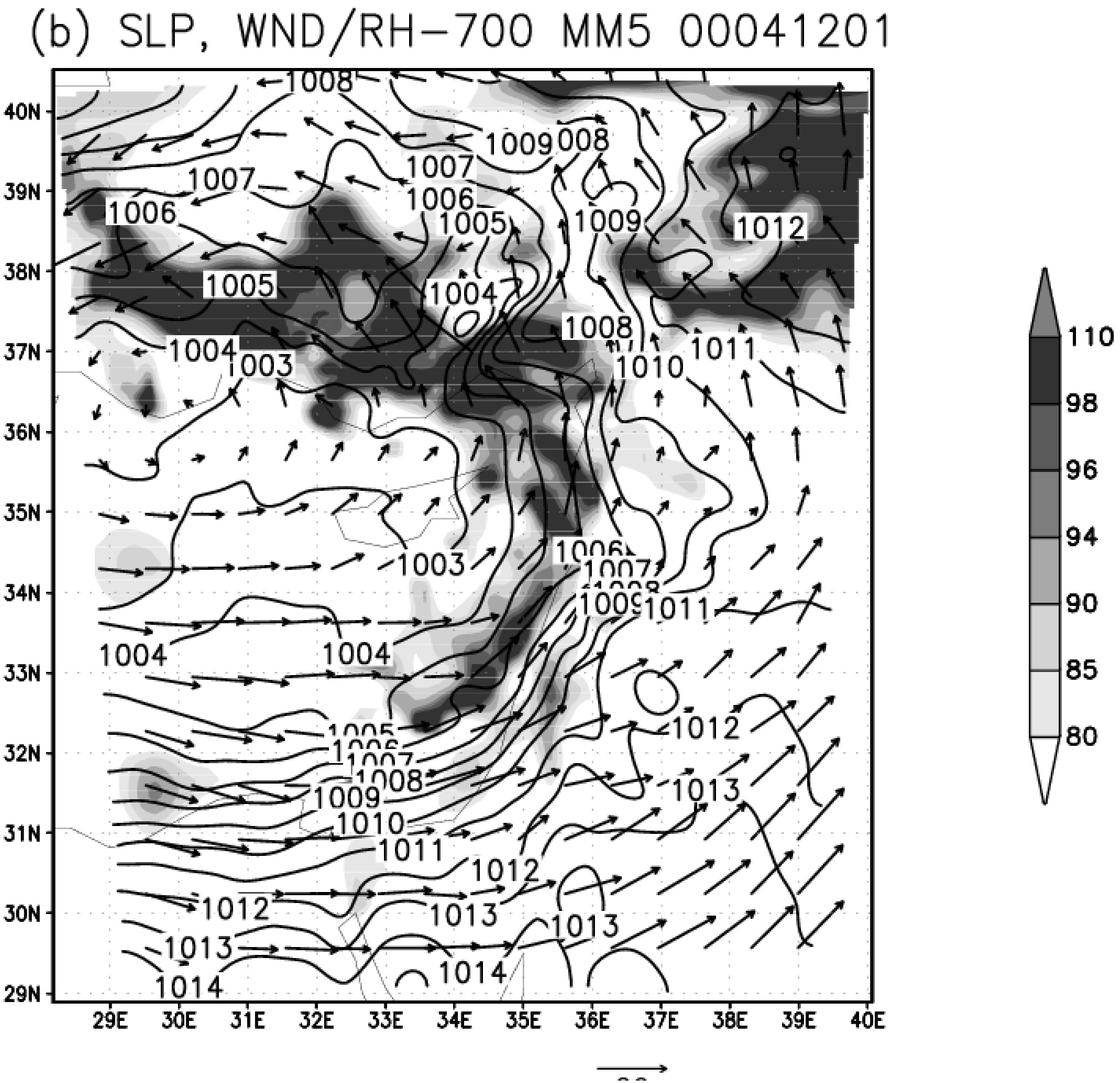

(b) SLP, WND/RH-700 MM5 00041201
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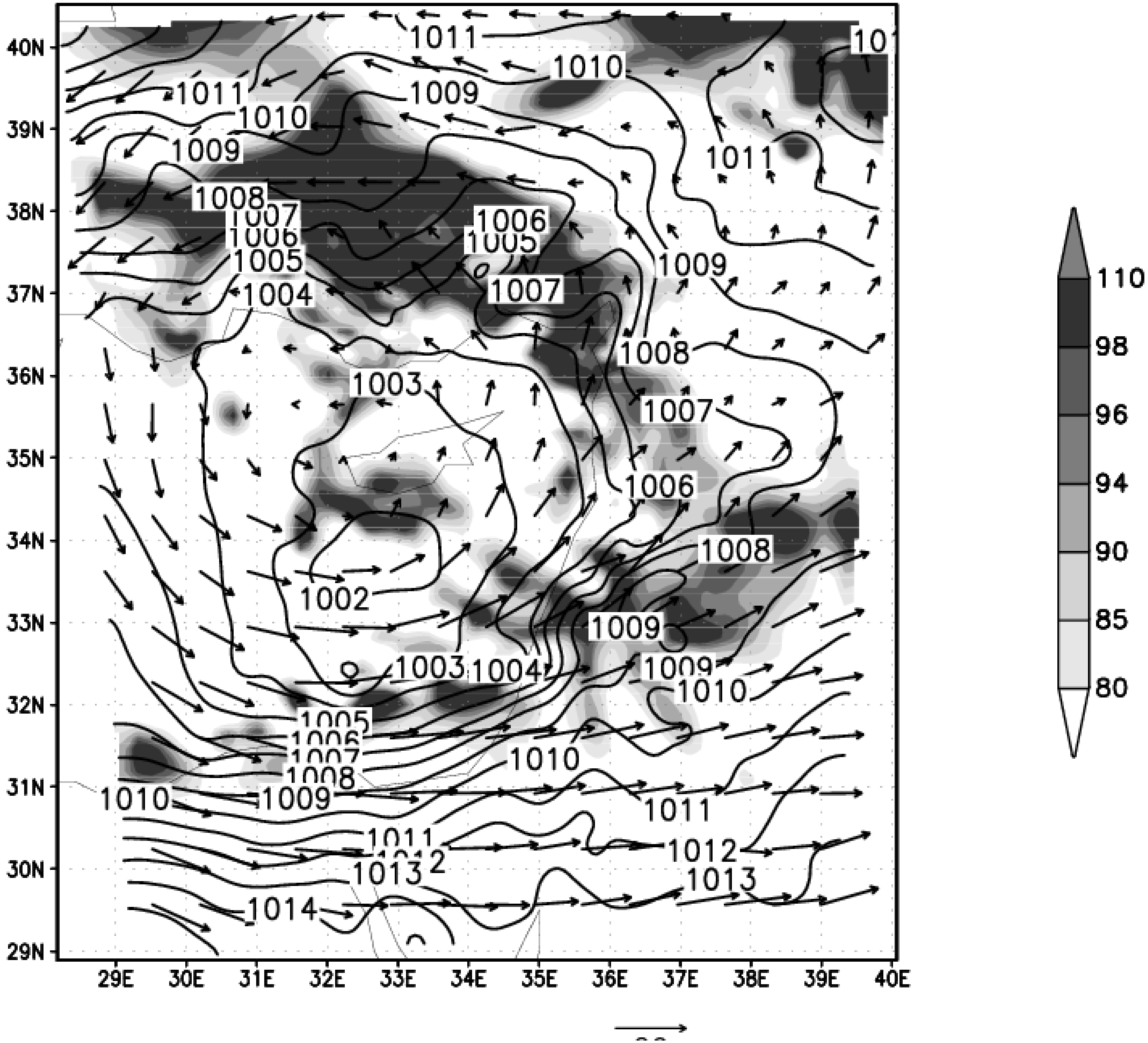
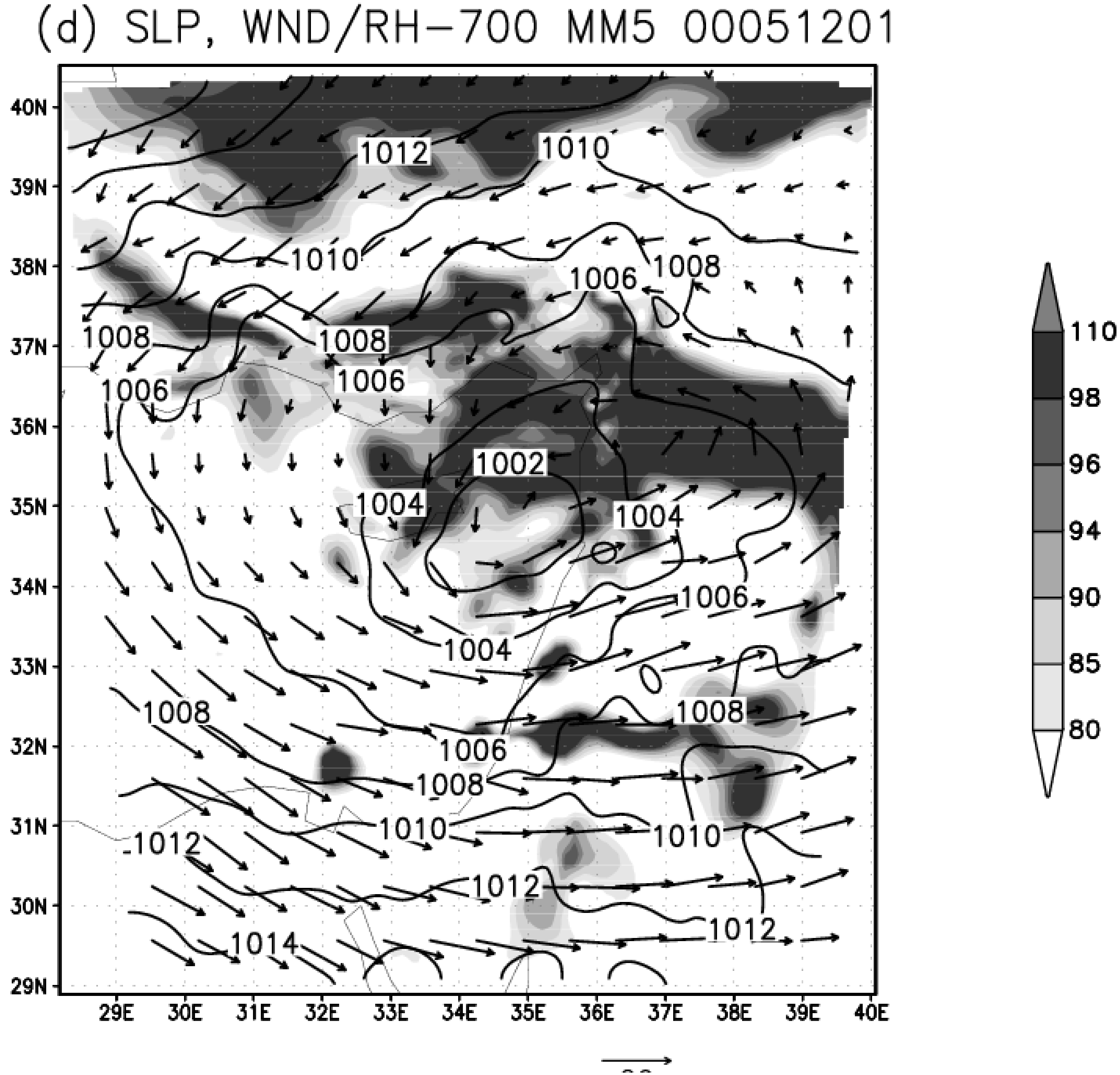
(c) SLP, WND/RH-700 MM5 12041201

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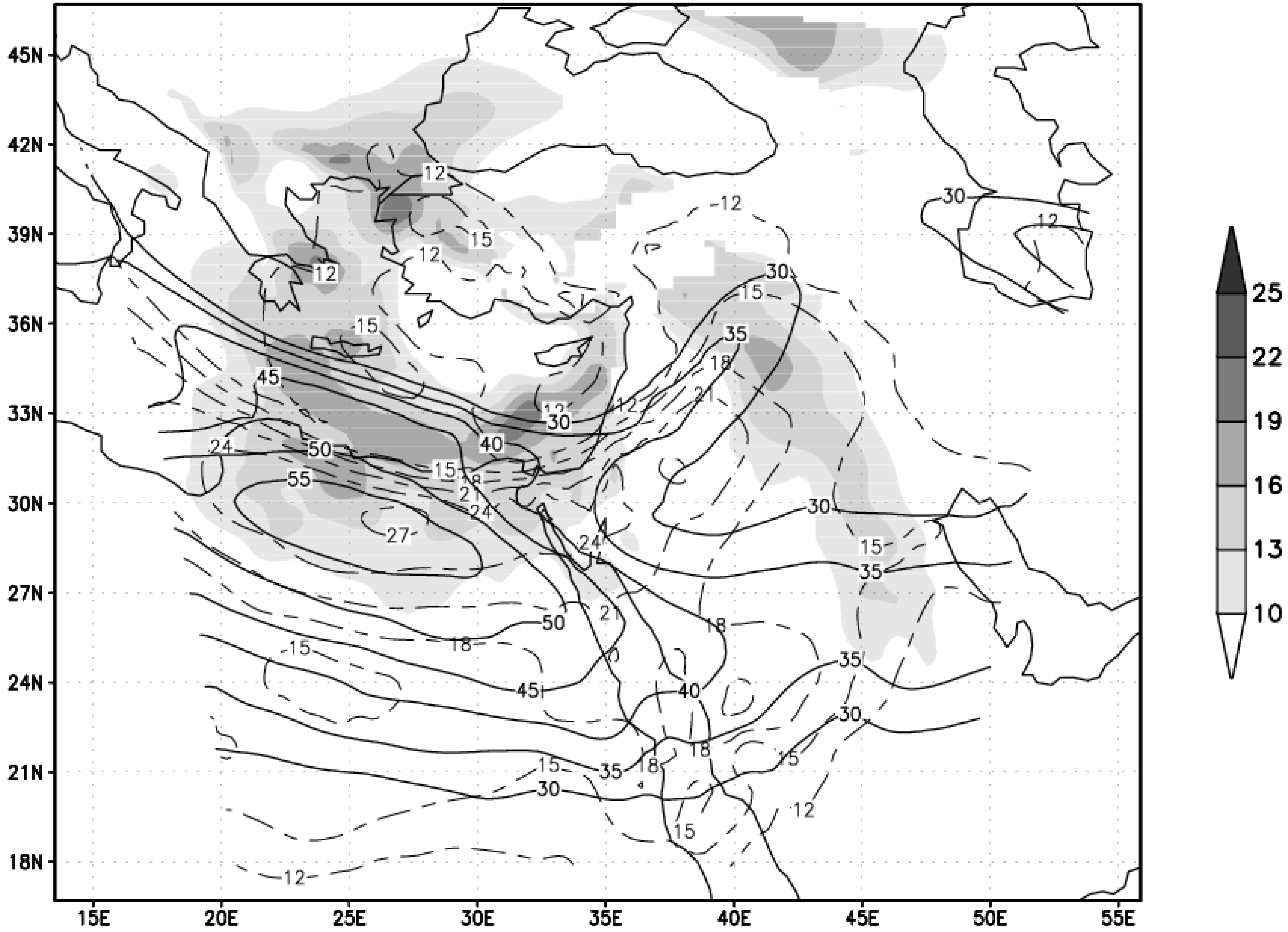
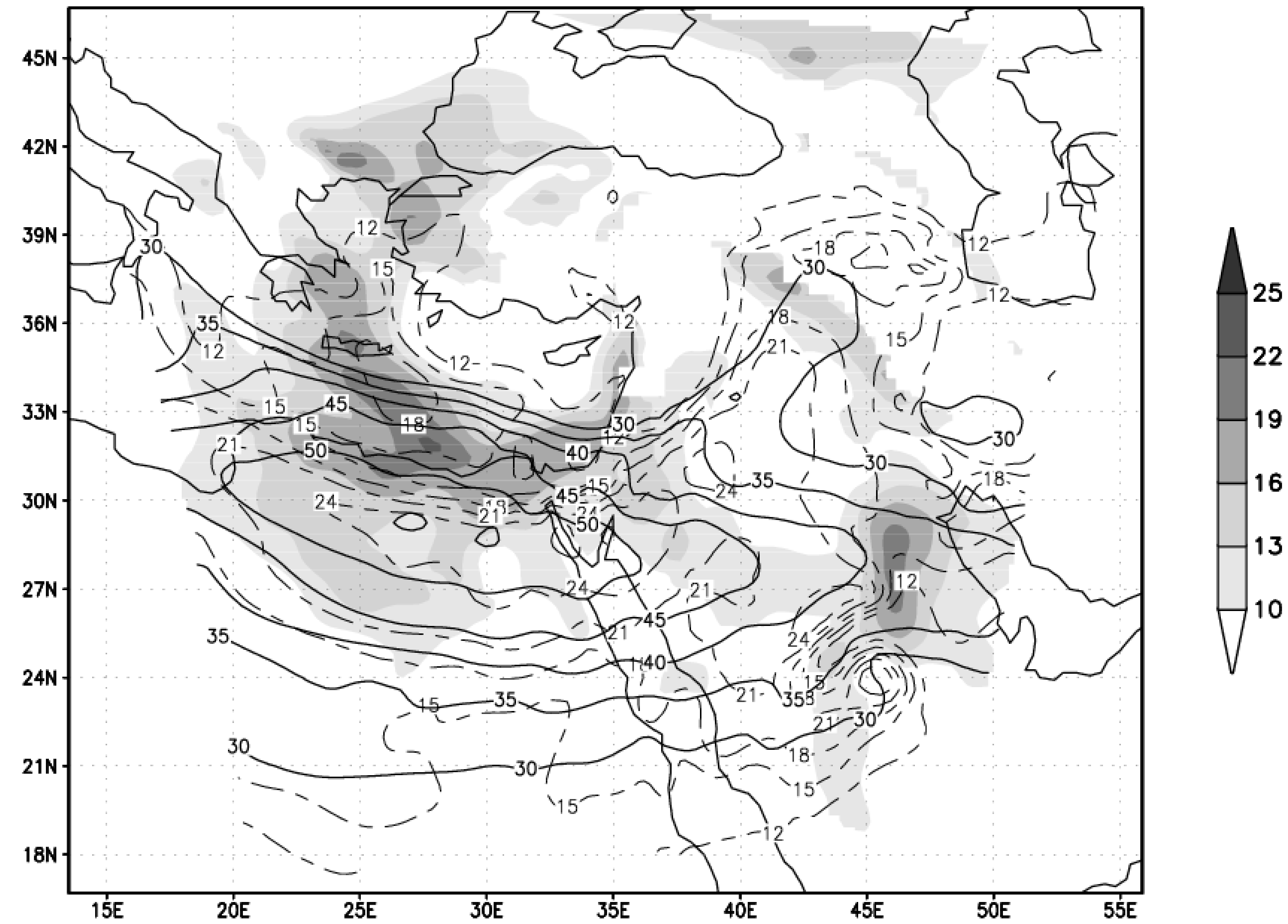
1010
1008
1006
1008
1008
1006
1006
1002
1004
1004
1006
1004
1008
1008
1006
1008
1010
1010
1012
1012
1012
1014
110
98
96
94
90
85
80

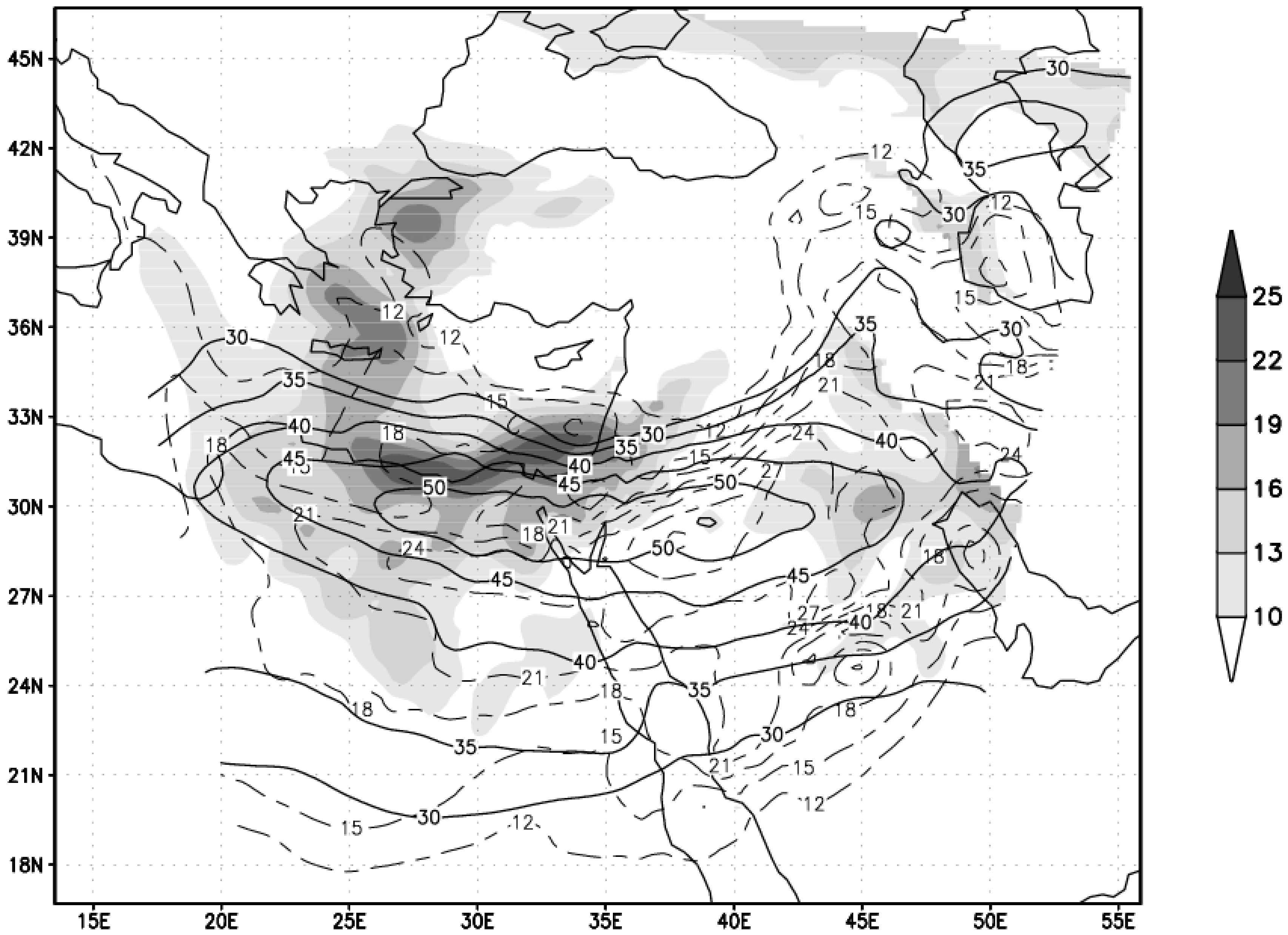
Wind

a) MM5 Wnd magn 850(sh),600(d),300(s) hPa 00.03.12.01+12



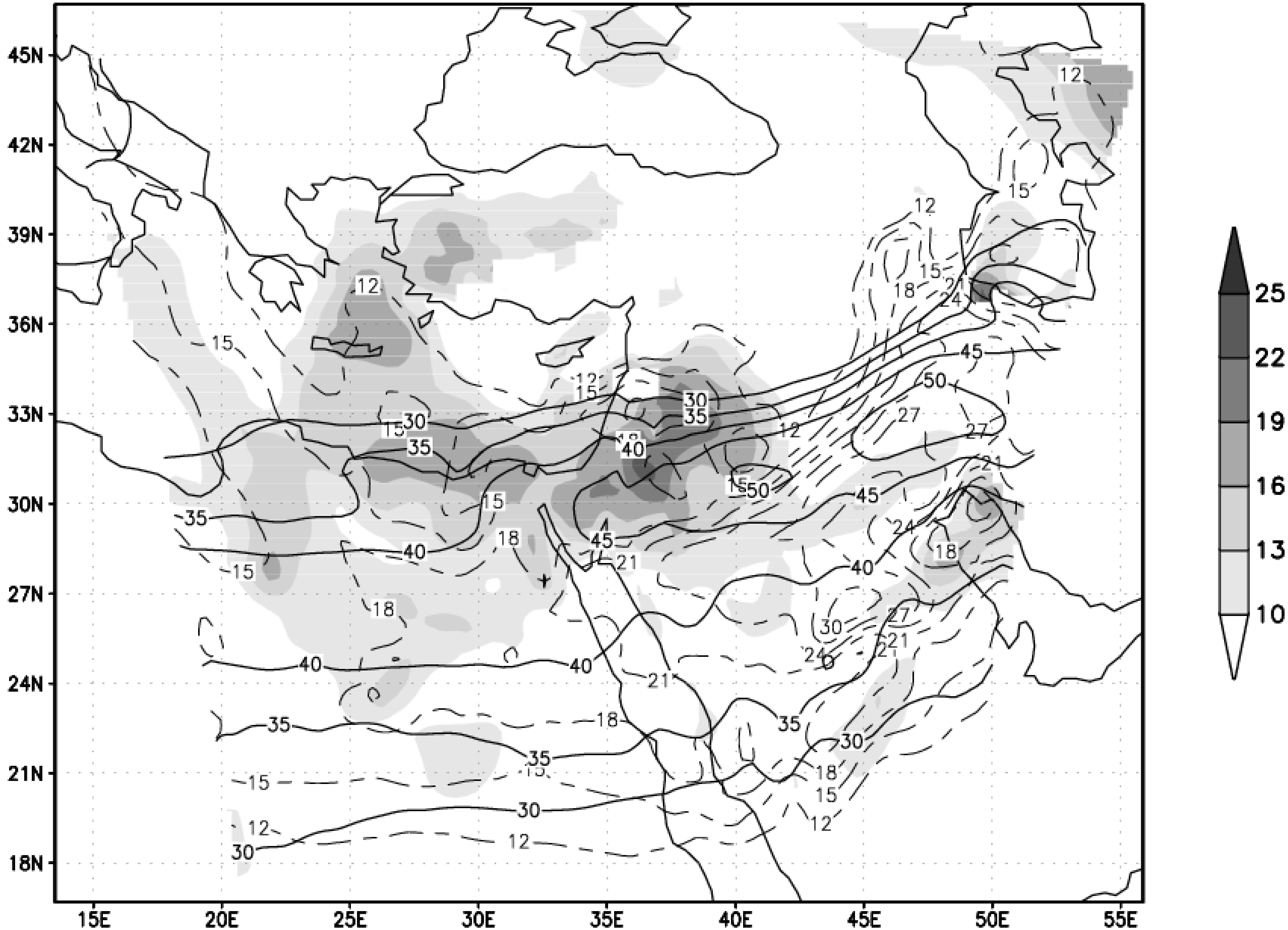
b) MM5 Wnd magn 850(sh),600(d),300(s) hPa 00.03.12.01+24





c) MM5 Wnd magn 850(sh),600(d),300(s) hPa 00.03.12.01+36

d) MM5 Wnd magn 850(sh),600(d),300(s) hPa 00:03.12.01+48



Upper-level jet from Alpine region

Low-level jet over the north-EM

A POTENTIAL VORTICITY PERSPECTIVE

Mathematical Definition of PV

Ertel:

$$P = -g(f + \zeta_\theta)\left(\frac{\partial\theta}{\partial p}\right) \approx \frac{(f + \zeta_\theta)}{-\left(\Delta p / \Delta\theta\right)/g}$$

Vorticity times static stability

ξ is the relative vorticity on isentropic surface, *g* – gravity acceleration, *f* – Coriolis parameters and theta - potential temperature. ***PV*** is usually determined in *pvu* (potential vorticity units), where 1 *pvu* = 10 K $m^2 kg^{-1} s^{-1}$

Units of Potential Vorticity

1 PVU equals…

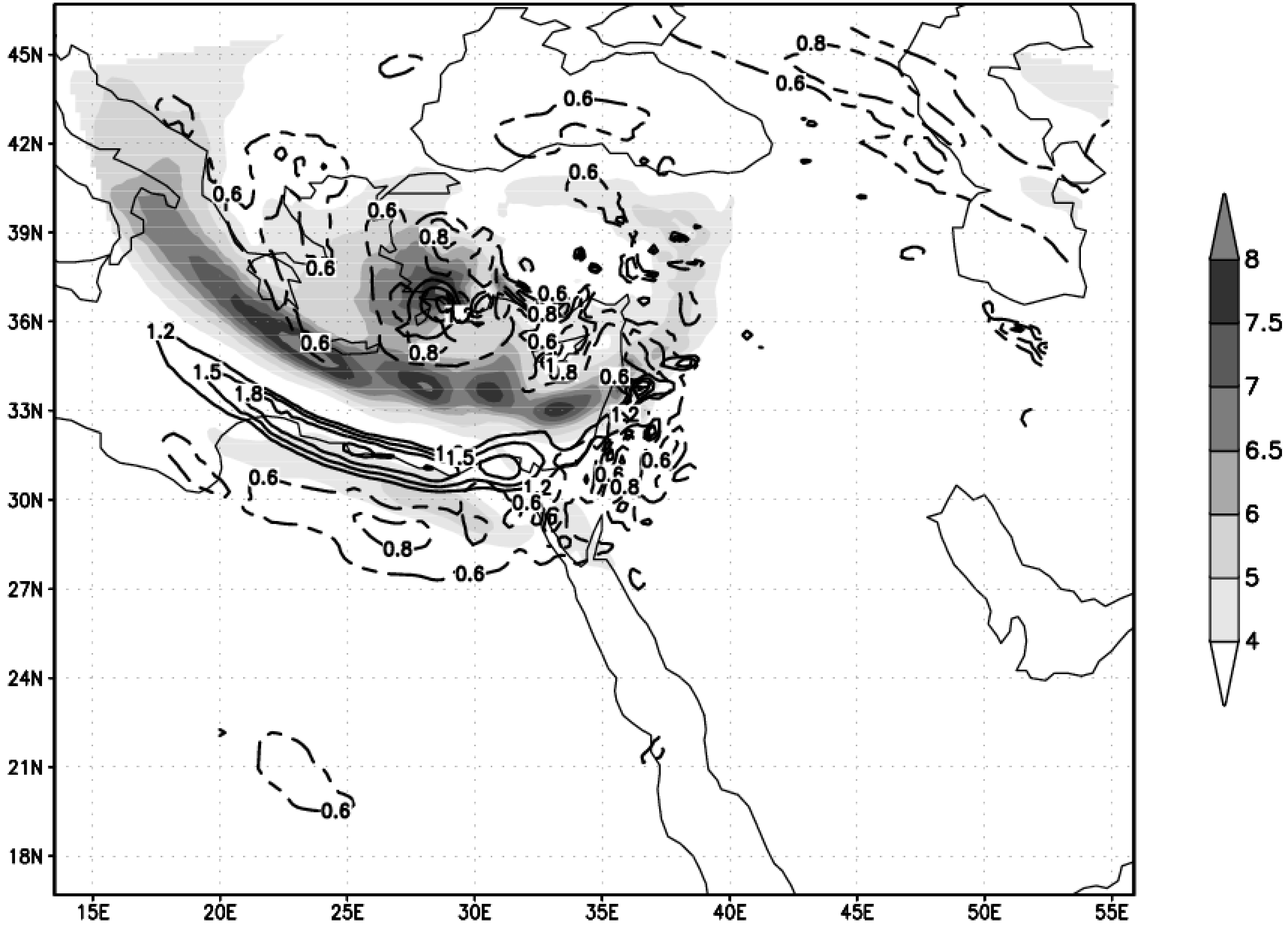
Midlatitude Troposphere: -0.2 to 3.0 PVU

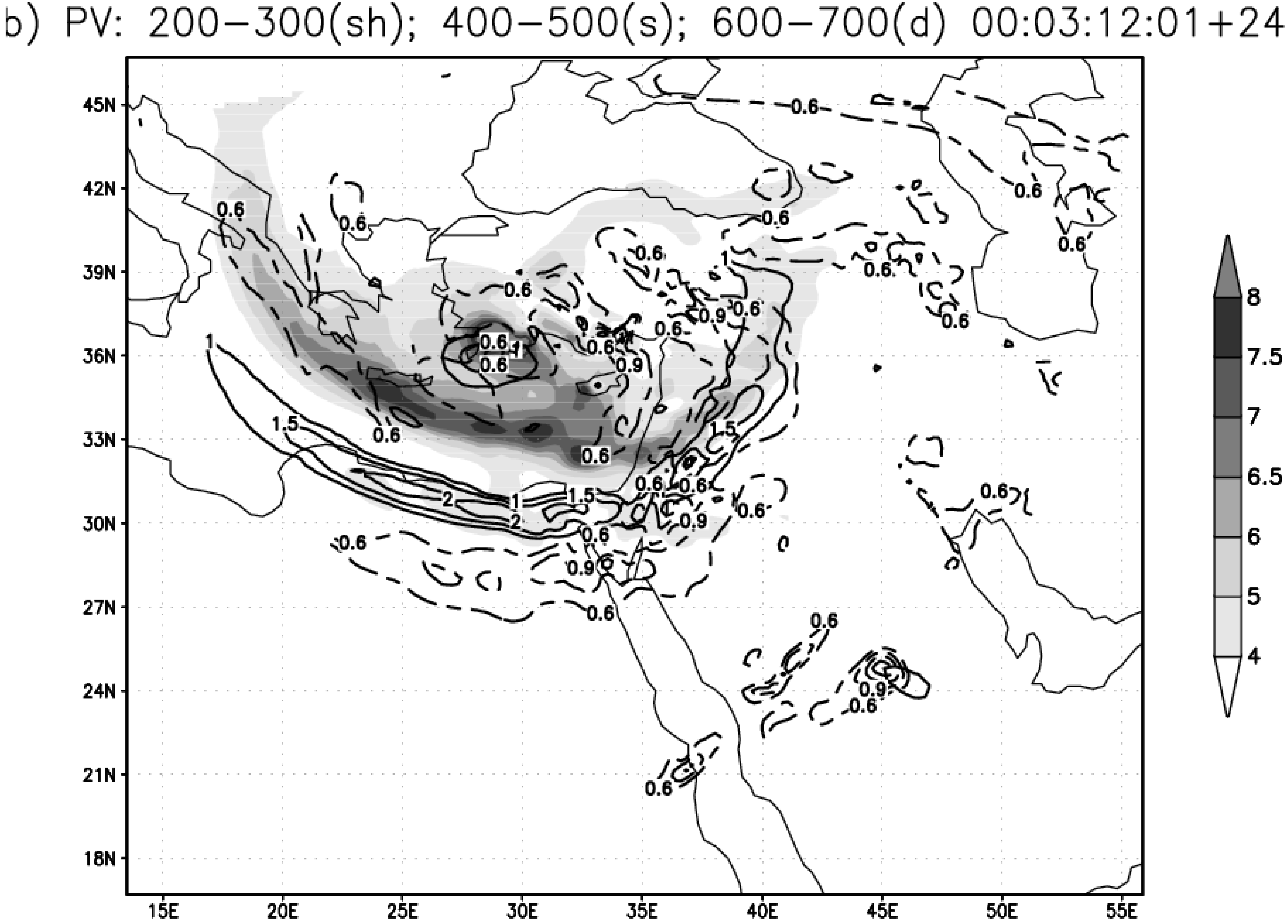
Typical value: 0.6 PVU

Midlatitude Stratosphere: 1.5 to 10.0 PVU

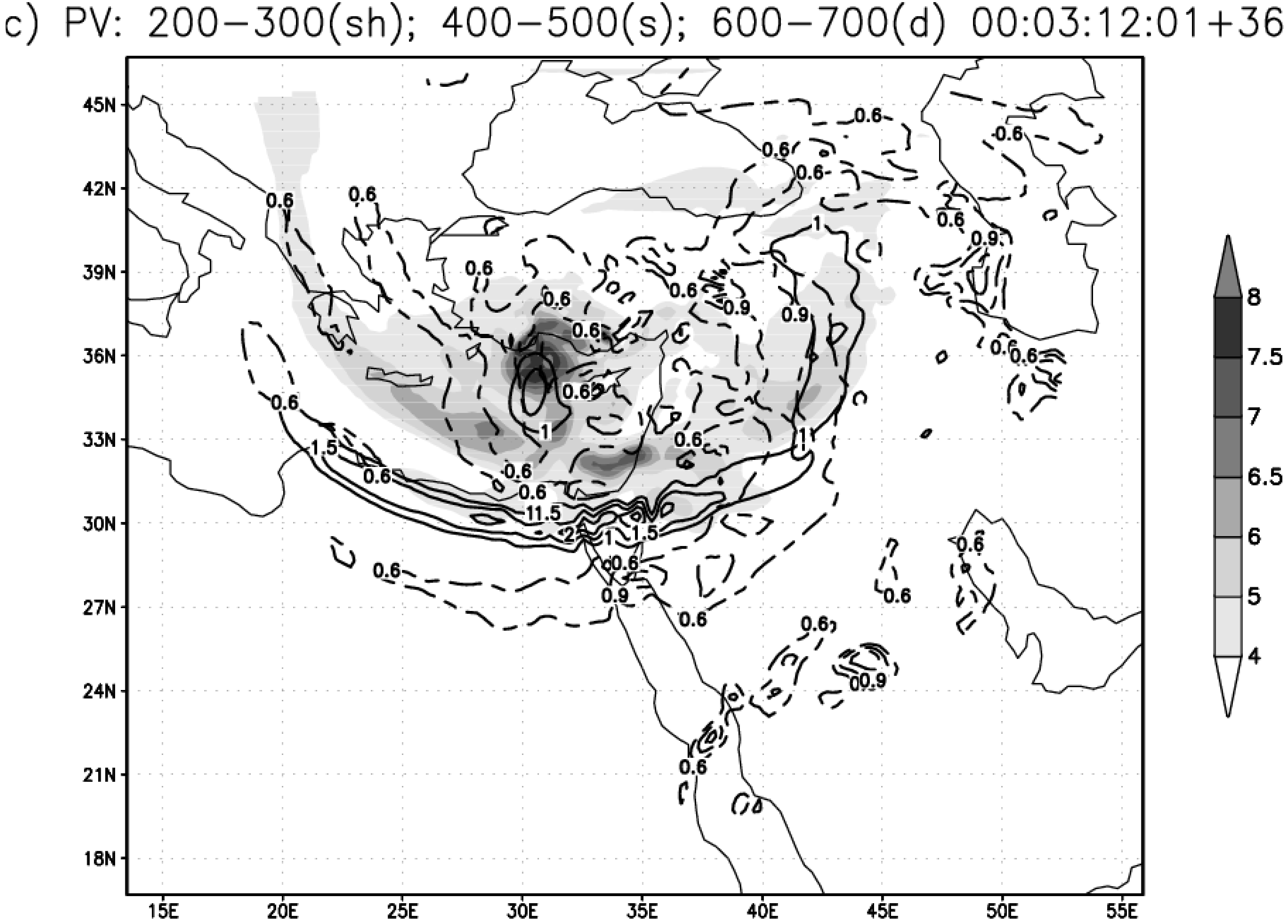
Typical value: 5.0 PVU

a) PV: 200−300(sh); 400−500(s); 600−700(d) 00:03:12:01+12



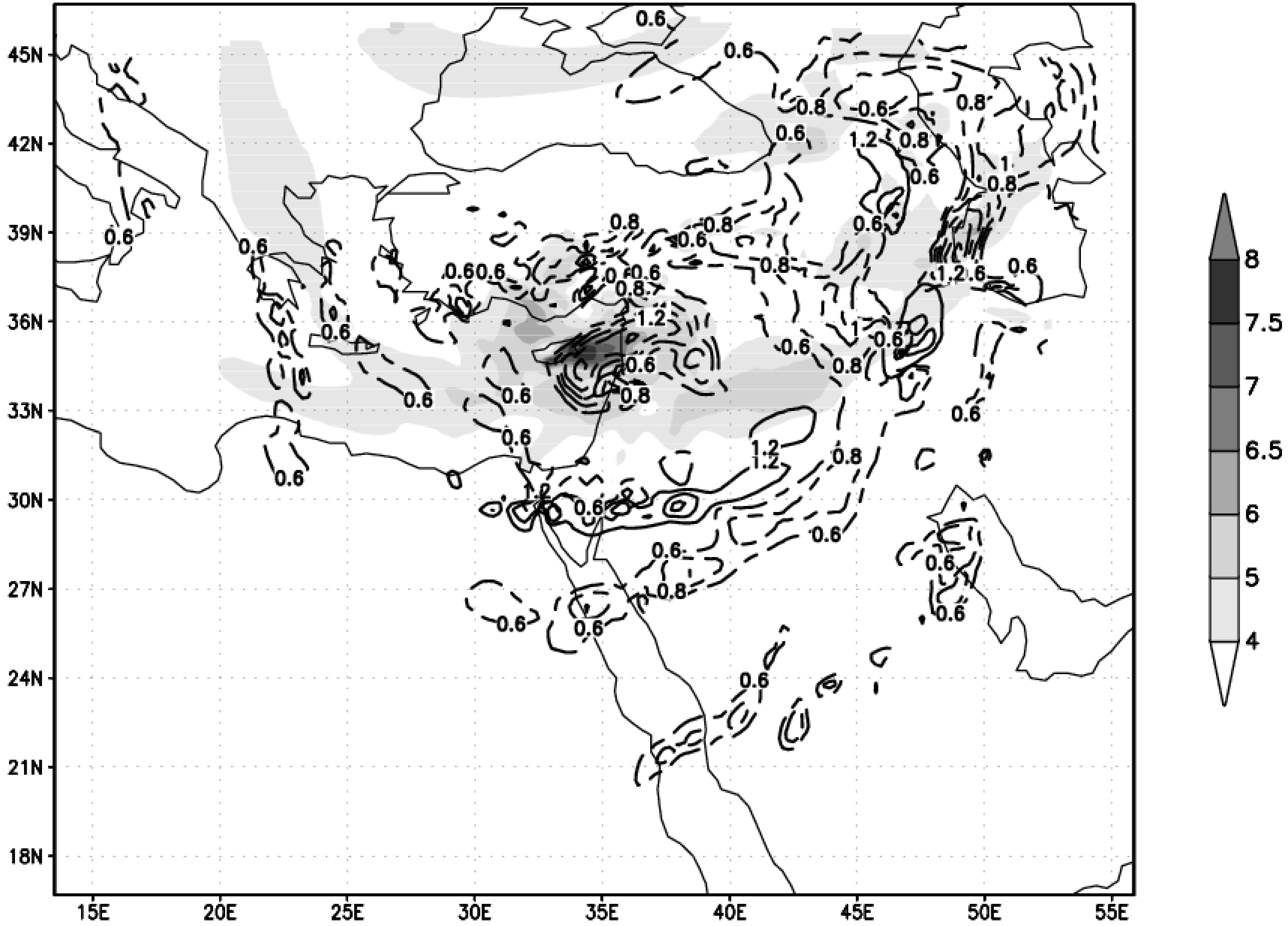


b) PV: 200-300(sh); 400-500(s); 600-700(d) 00:03:12:01+24
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15E
20E
25E
30E
35E
40E
45E
50E
55E
8
7.5
7
6.5
6
5
4

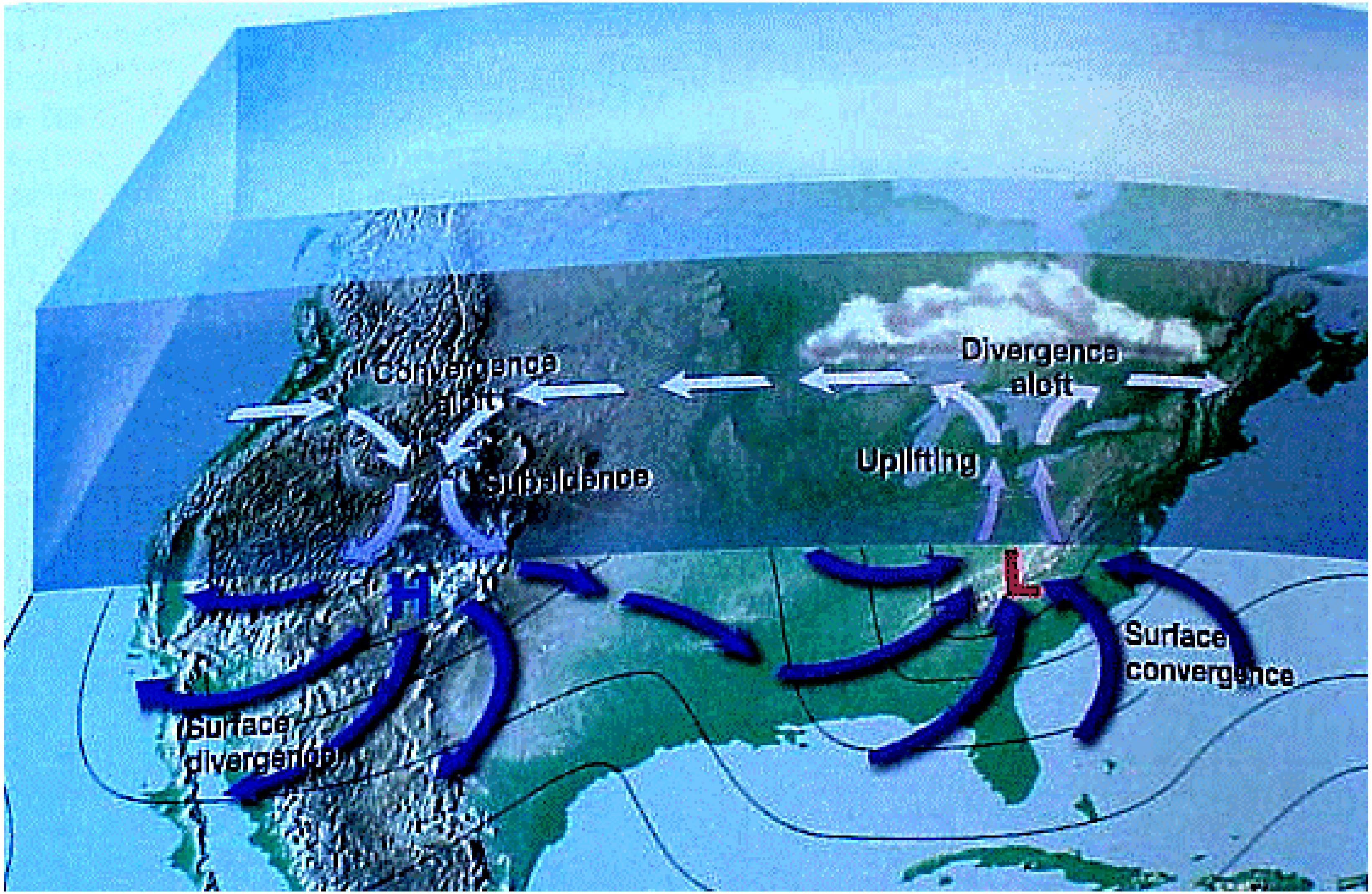


c) PV: 200–300(sh); 400–500(s); 600–700(d) 00:03:12:01+36
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15E
20E
25E
30E
35E
40E
45E
50E
55E
8
7.5
7
6.5
6
5
4

d) PV: 200−300(sh); 400−500(s); 600−700(d) 00:03:12:01+48



A tilted three-dimensional PV structure

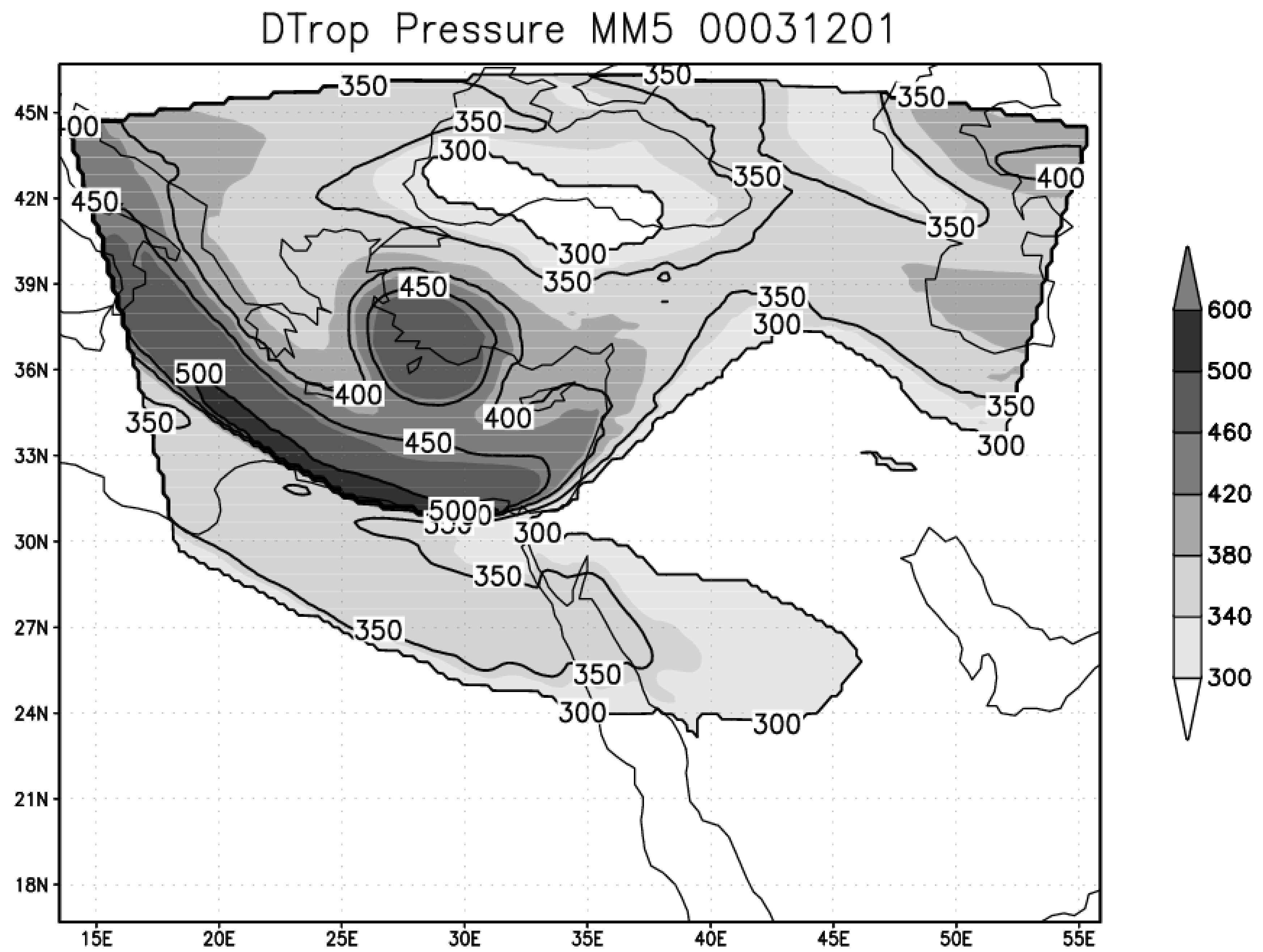

Convergence
aloft
Subsidence
Divergence
aloft
Uplifting
Surface
divergence
Surface
convergence
H
L

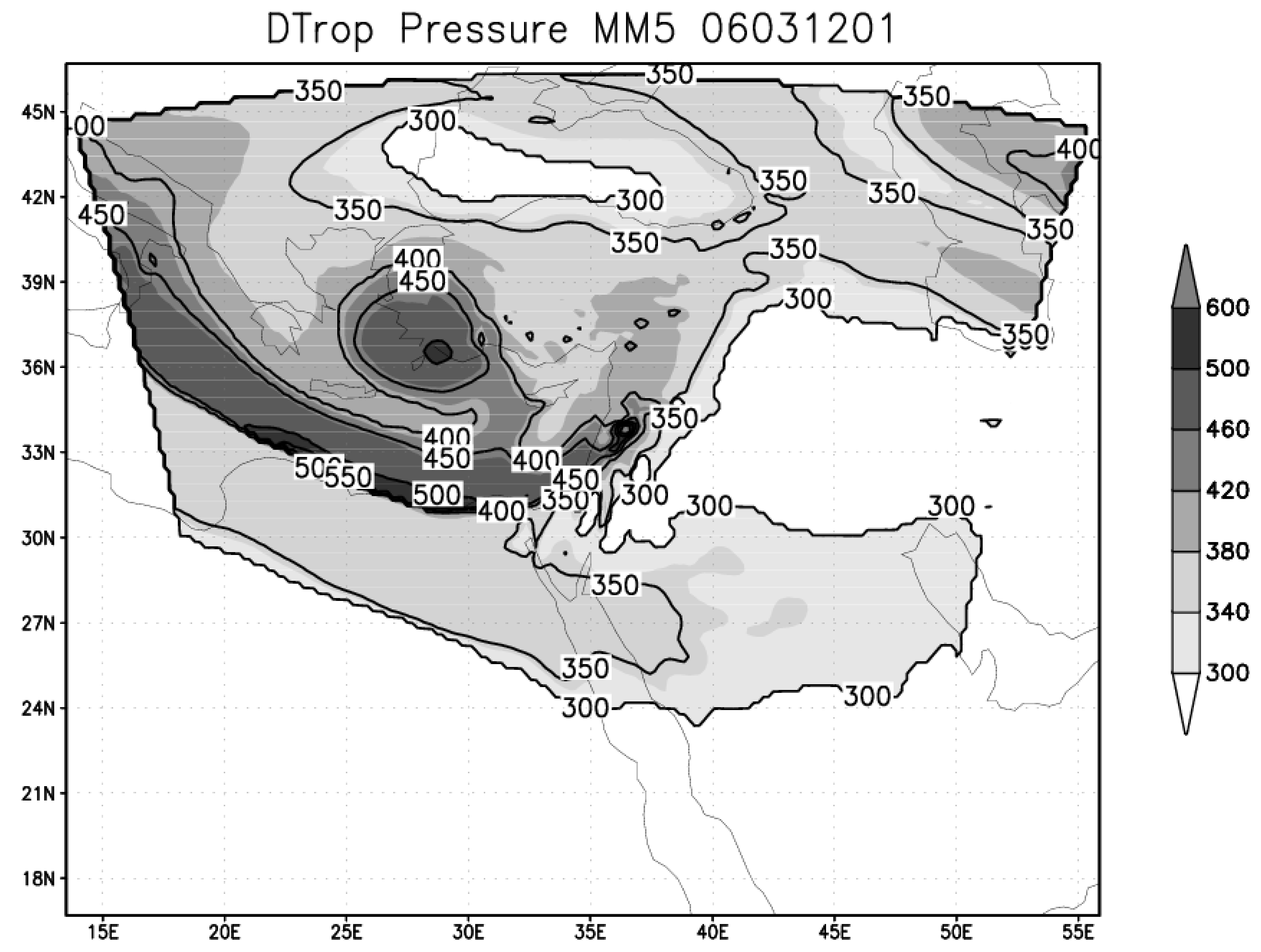
Dynamic Tropopause Maps

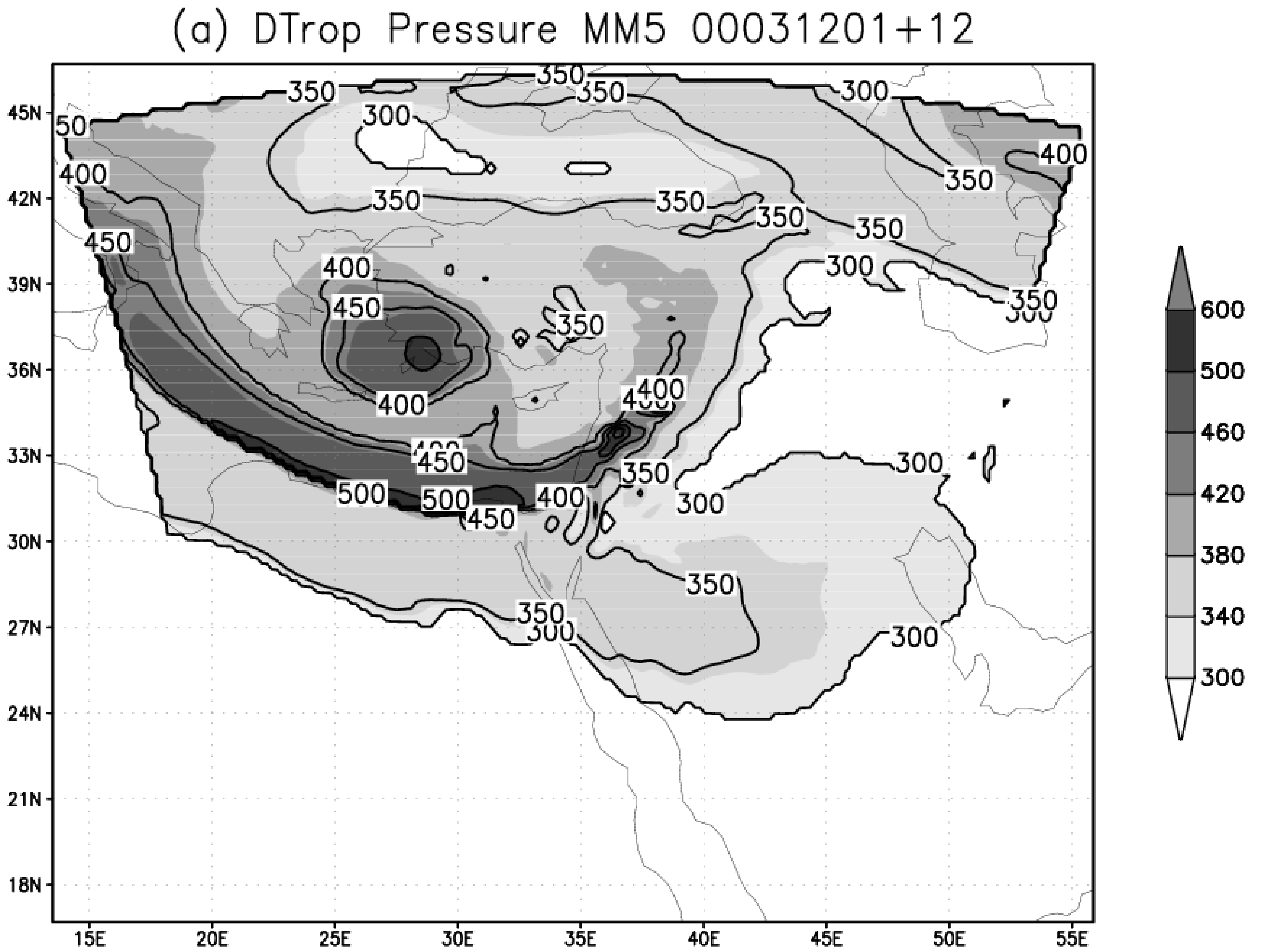
The dynamic tropopause is defined as the 1.5 PVU surface

1 PVU = $10^{-6} m^2 s^{-1} K\ kg^{-1}$

Dynamic tropopause pressure

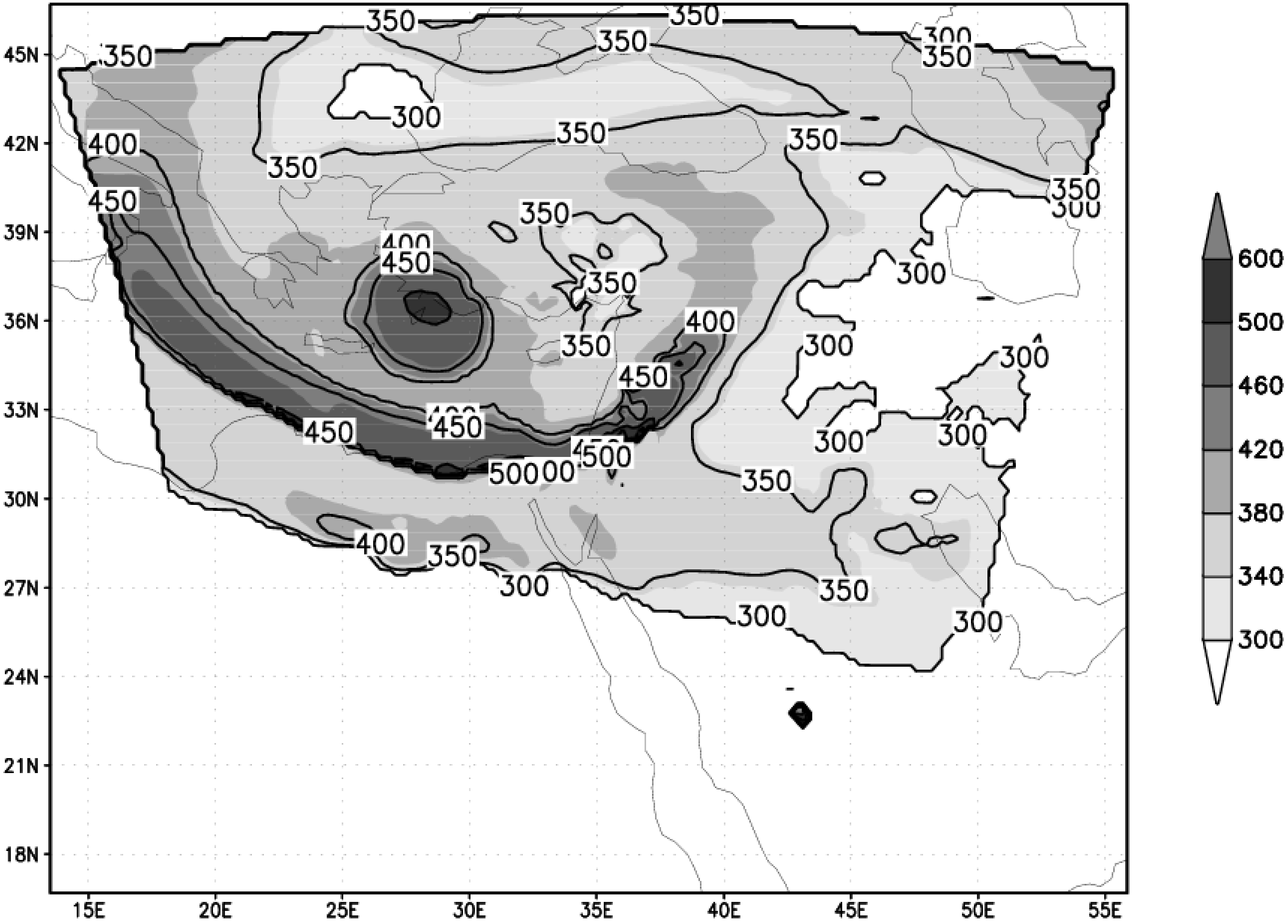

DTrop Pressure MM5 00031201
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15E
20E
25E
30E
35E
40E
45E
50E
55E
600
500
460
420
380
340
300

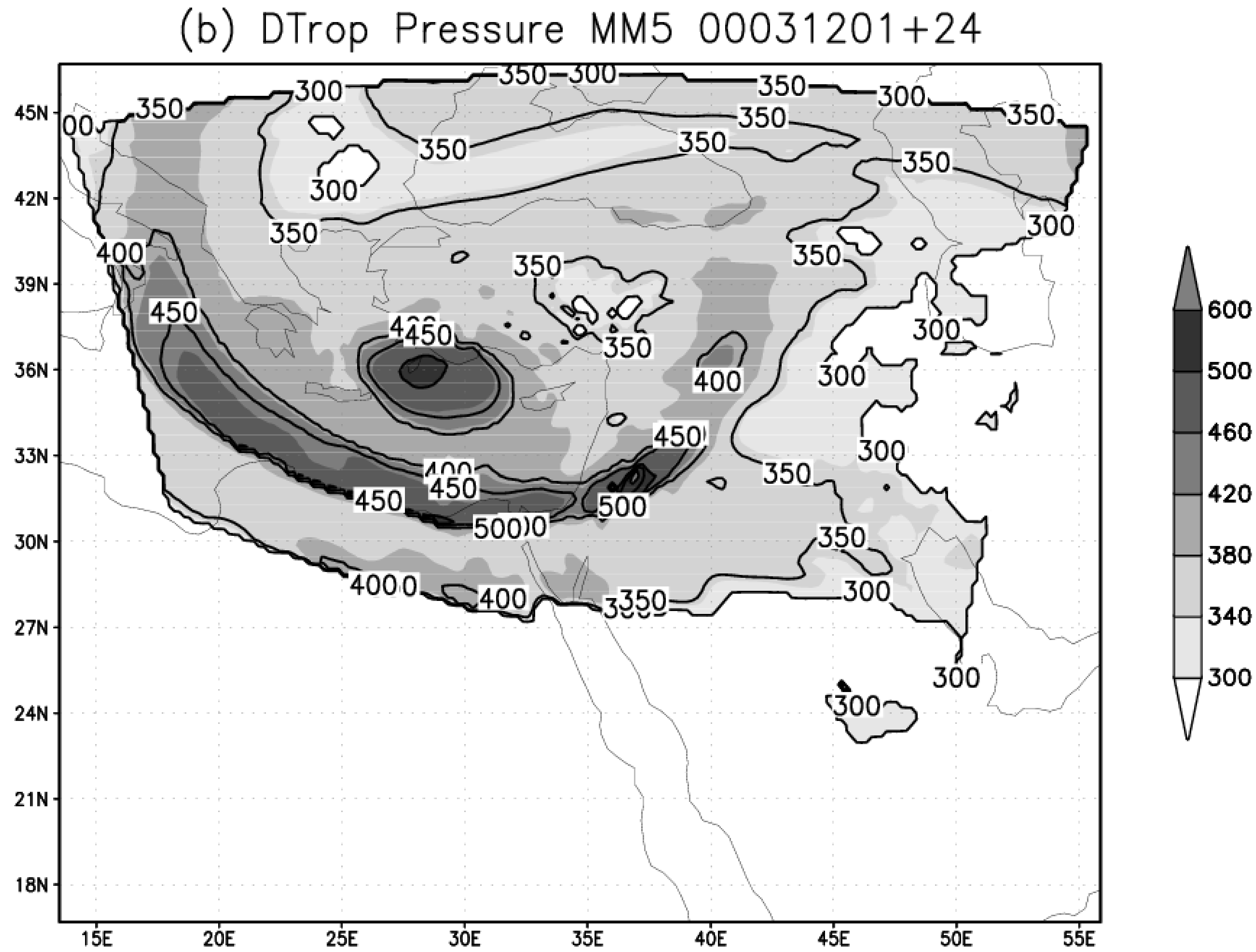

DTrop Pressure MM5 06031201
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15E
20E
25E
30E
35E
40E
45E
50E
55E
600
500
460
420
380
340
300
350
300
400
450
500
550



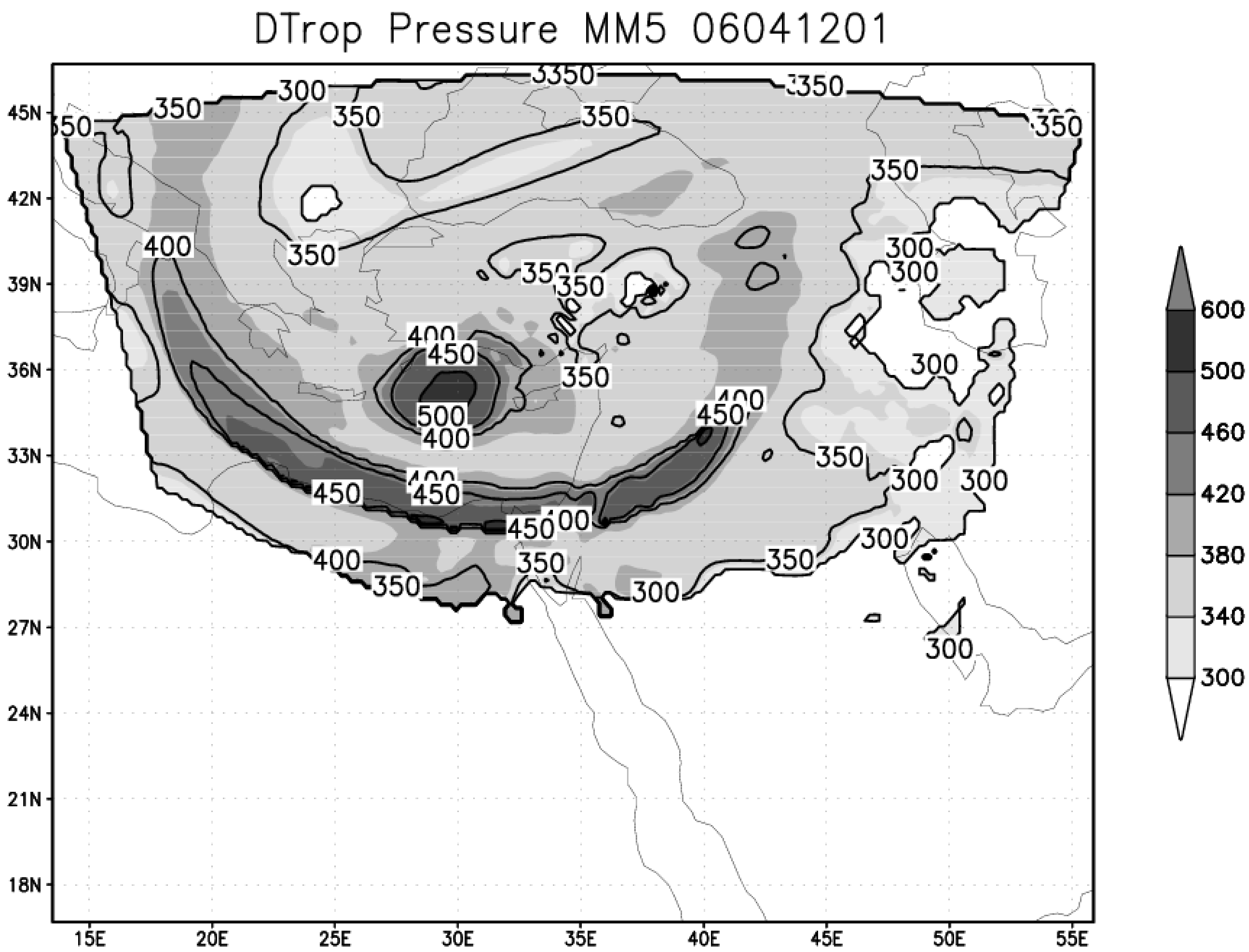
(a) DTrop Pressure MM5 00031201+12
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15E
20E
25E
30E
35E
40E
45E
50E
55E
600
500
460
420
380
340
300

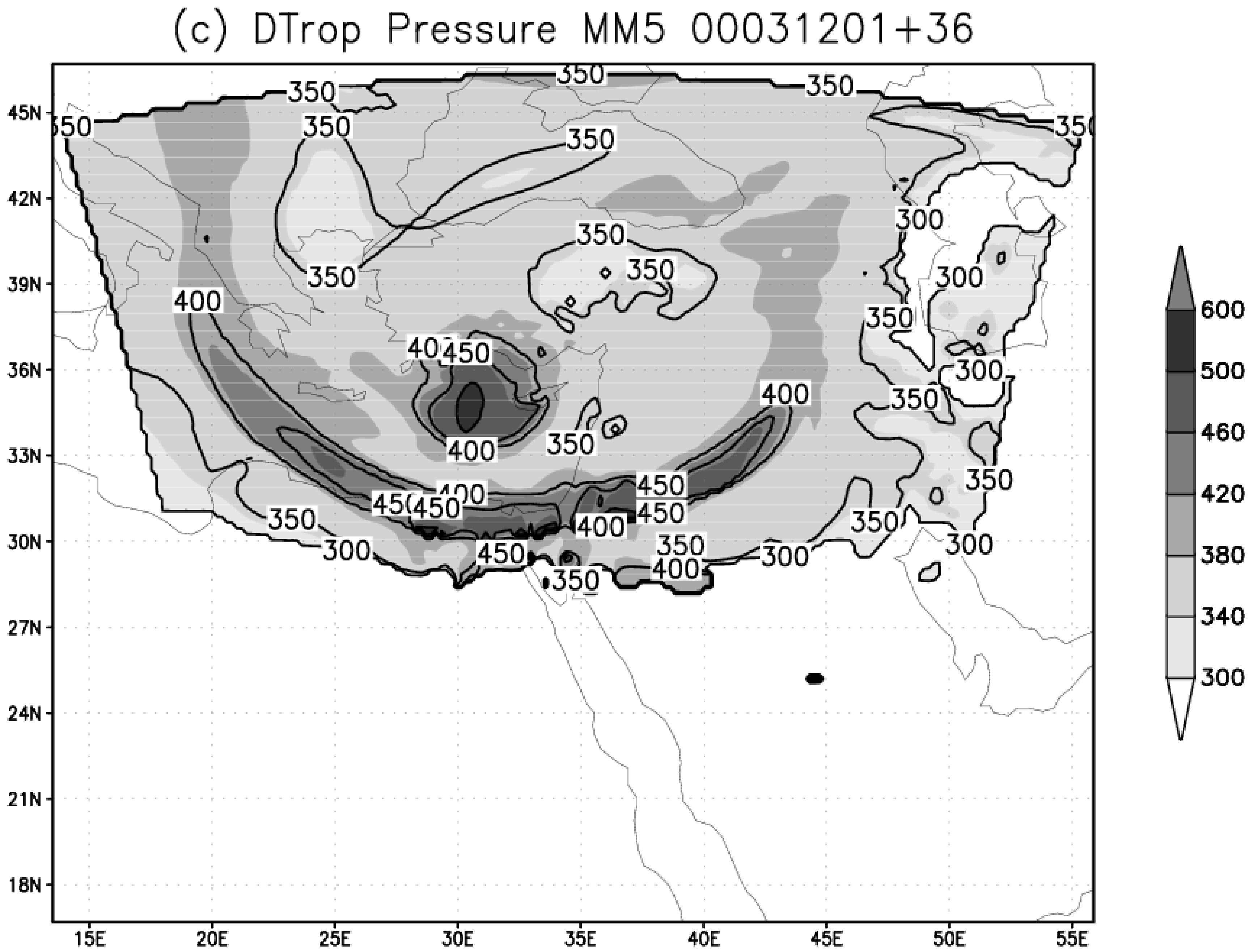
DTrop Pressure MM5 18031201



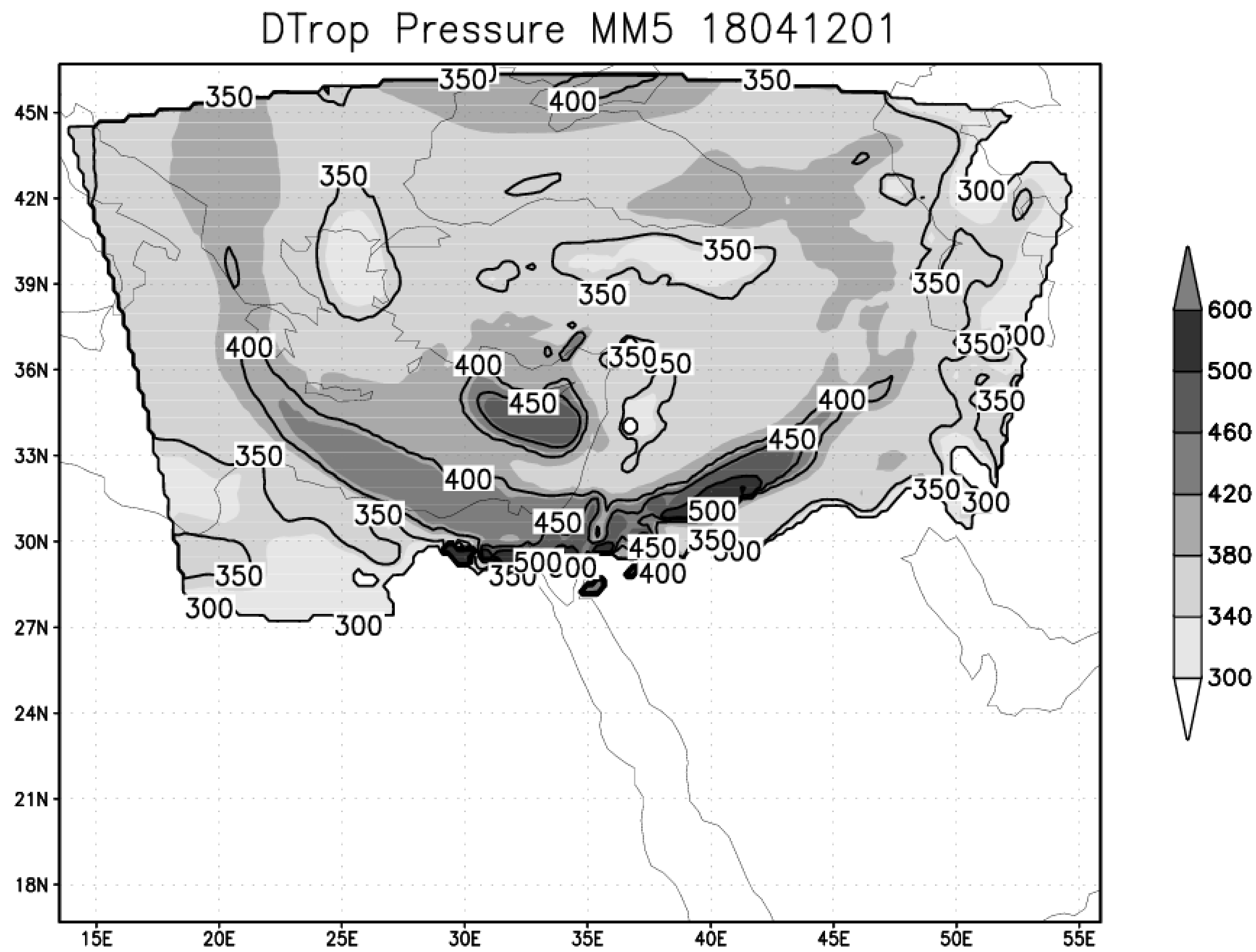


(b) DTrop Pressure MM5 00031201+24
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15E
20E
25E
30E
35E
40E
45E
50E
55E
600
500
460
420
380
340
300
300

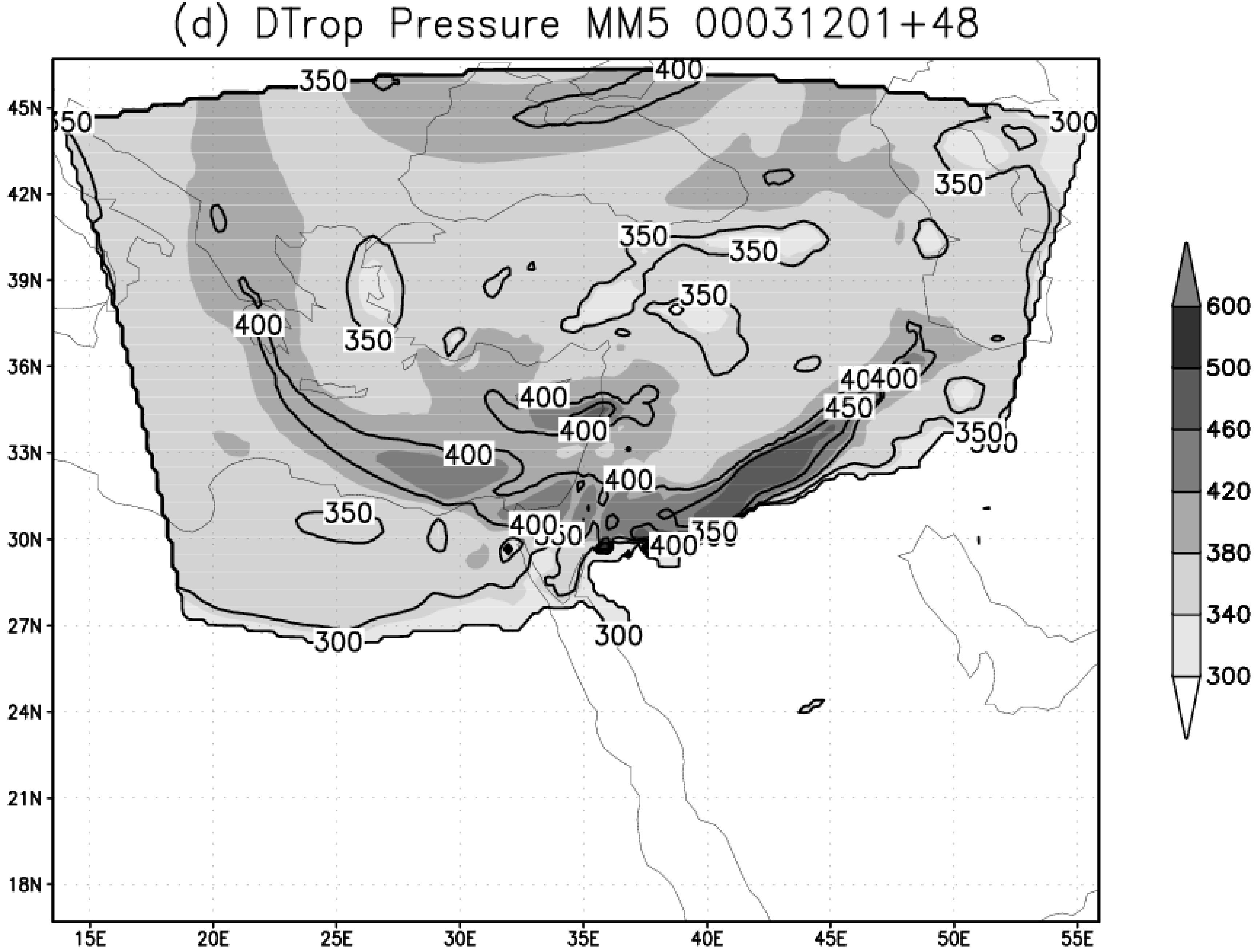

DTrop Pressure MM5 06041201
600
500
460
420
380
340
300
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15E
20E
25E
30E
35E
40E
45E
50E
55E



(c) DTrop Pressure MM5 00031201+36
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15E
20E
25E
30E
35E
40E
45E
50E
55E
600
500
460
420
380
340
300
300



DTrop Pressure MM5 18041201
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15E
20E
25E
30E
35E
40E
45E
50E
55E
600
500
460
420
380
340
300


(d) DTrop Pressure MM5 00031201+48
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15E
20E
25E
30E
35E
40E
45E
50E
55E
600
500
460
420
380
340
300
300
350
400
450

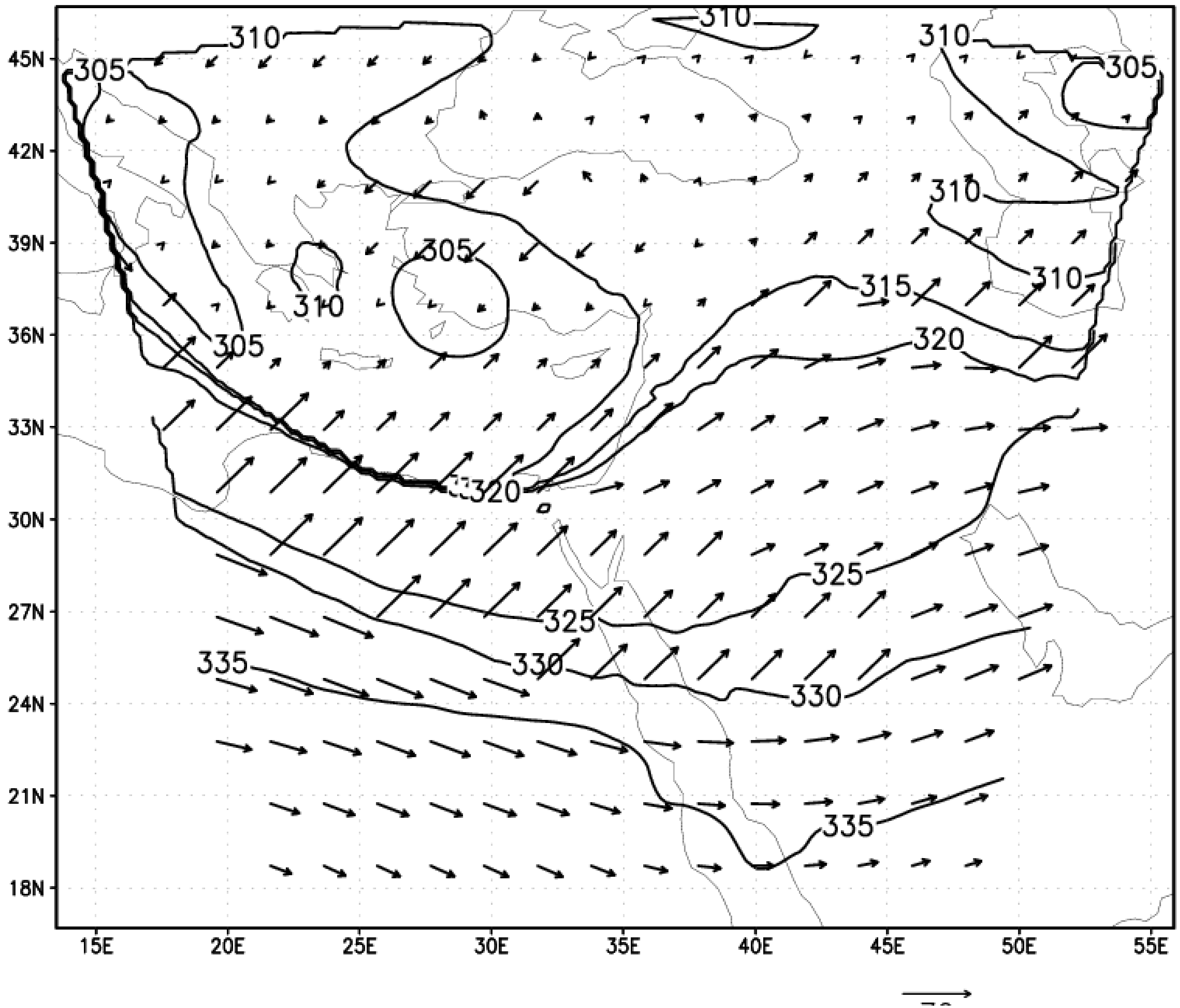
The streamer and associated with it tropopause fold led to intensification of the cyclone, formation of a low-level jet and dragging-in wet air masses possibly but not necessary of the Olga origin over the region.

A reasonable guess:

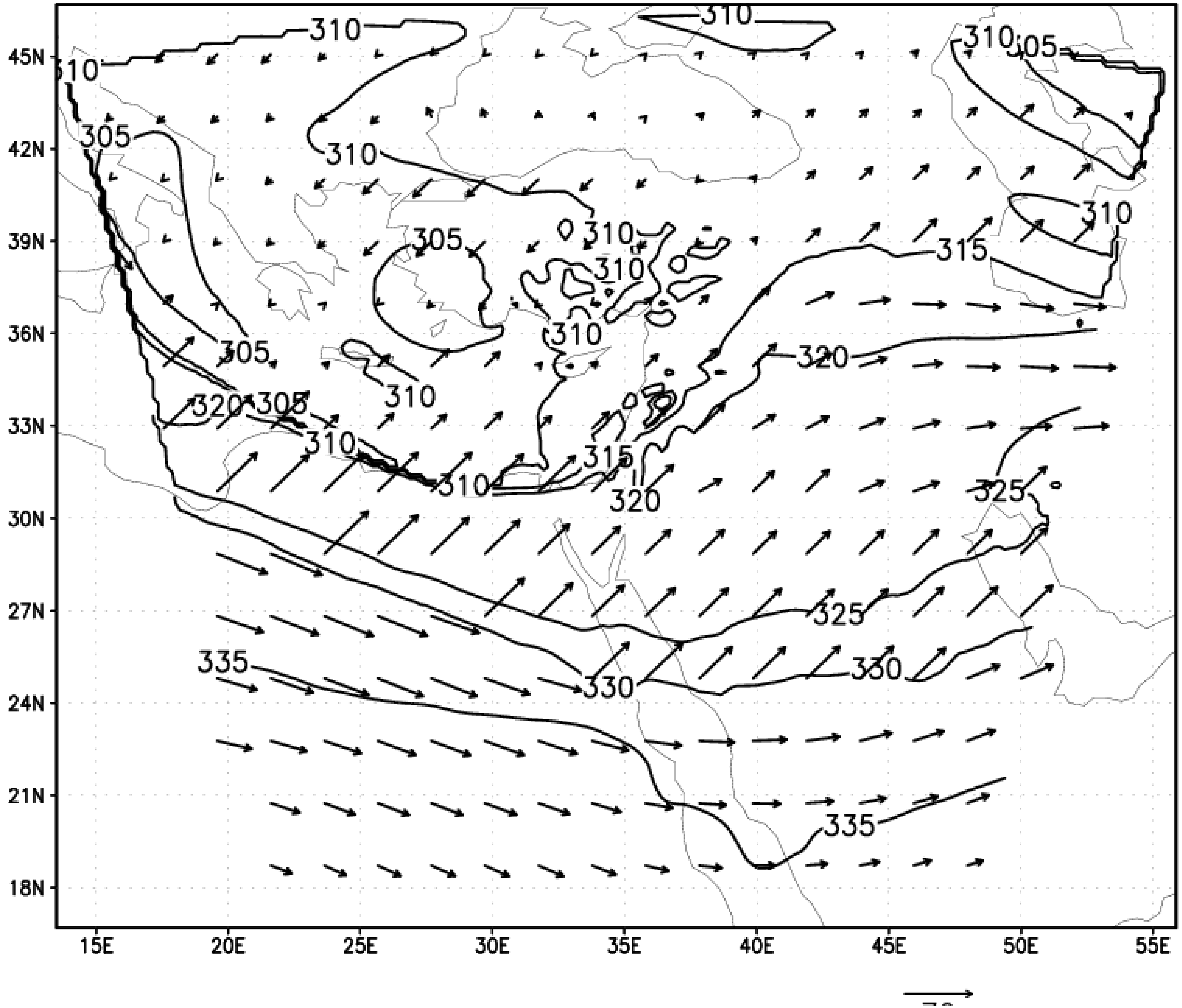
At the beginning of the process the EM area was strongly capped by an inversion inhibiting convection outside the storm area.

Temperature and winds at dynamic tropopause

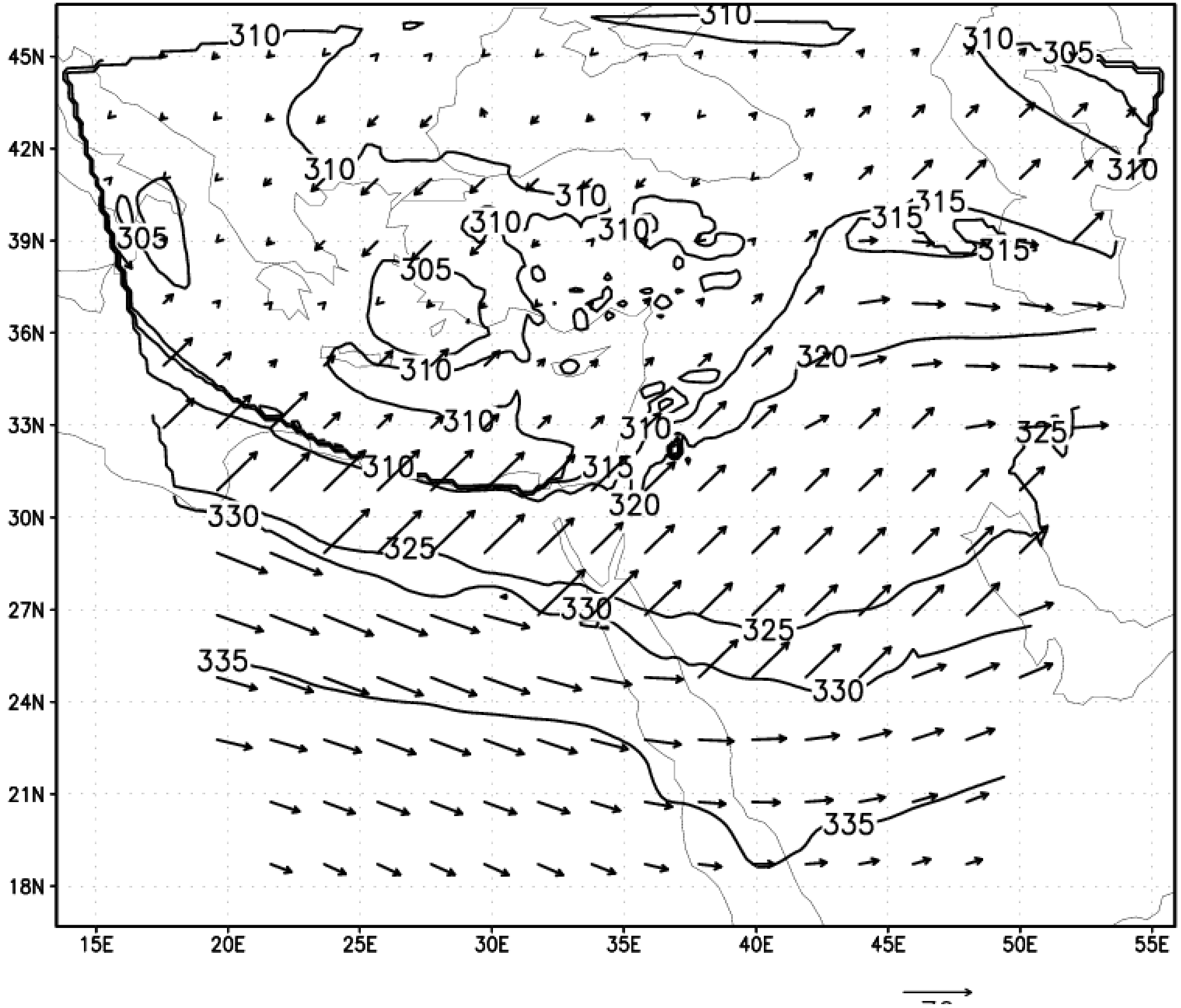
DTROP THETA/WND 00031201



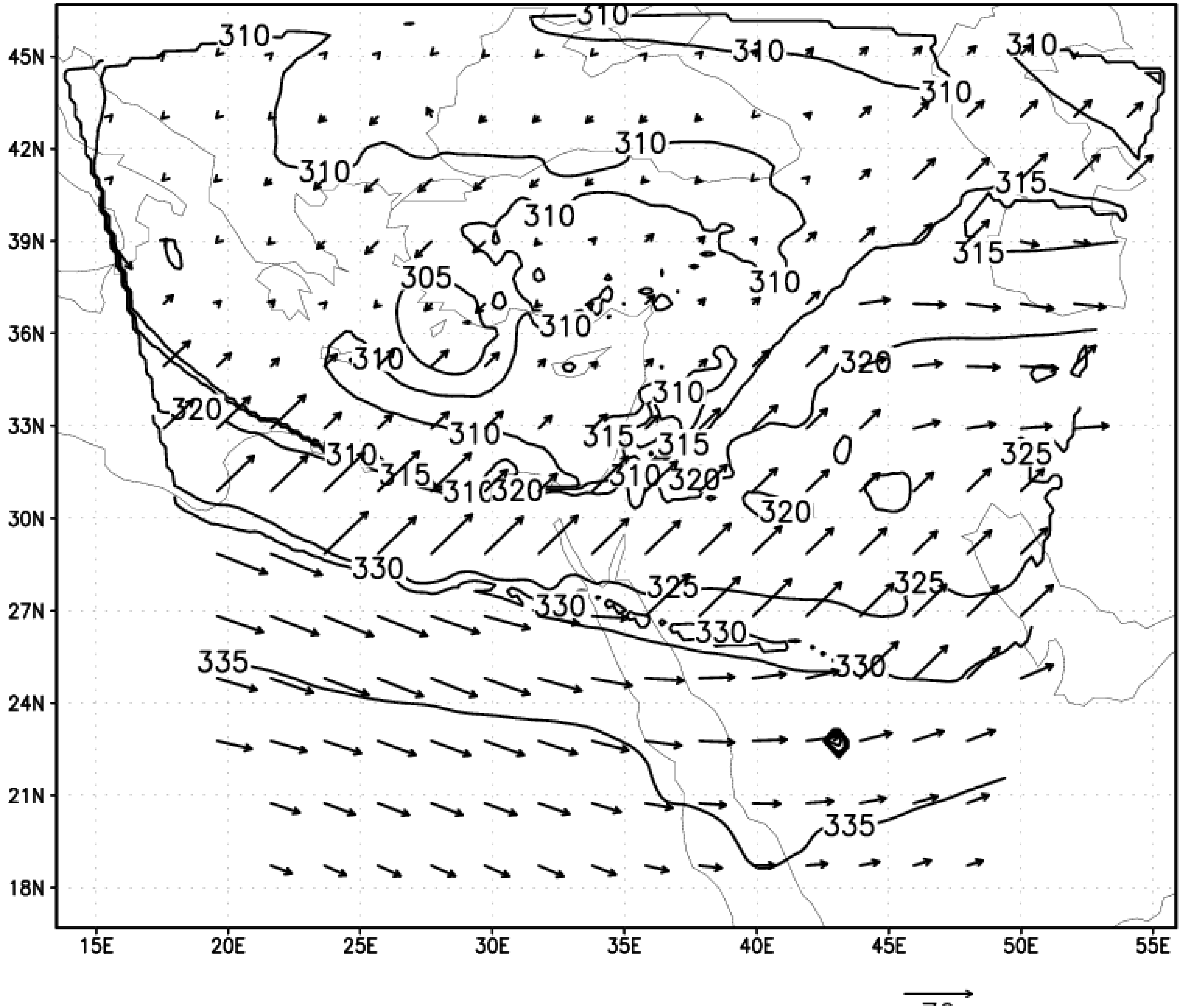
DTROP THETA/WND 06031201



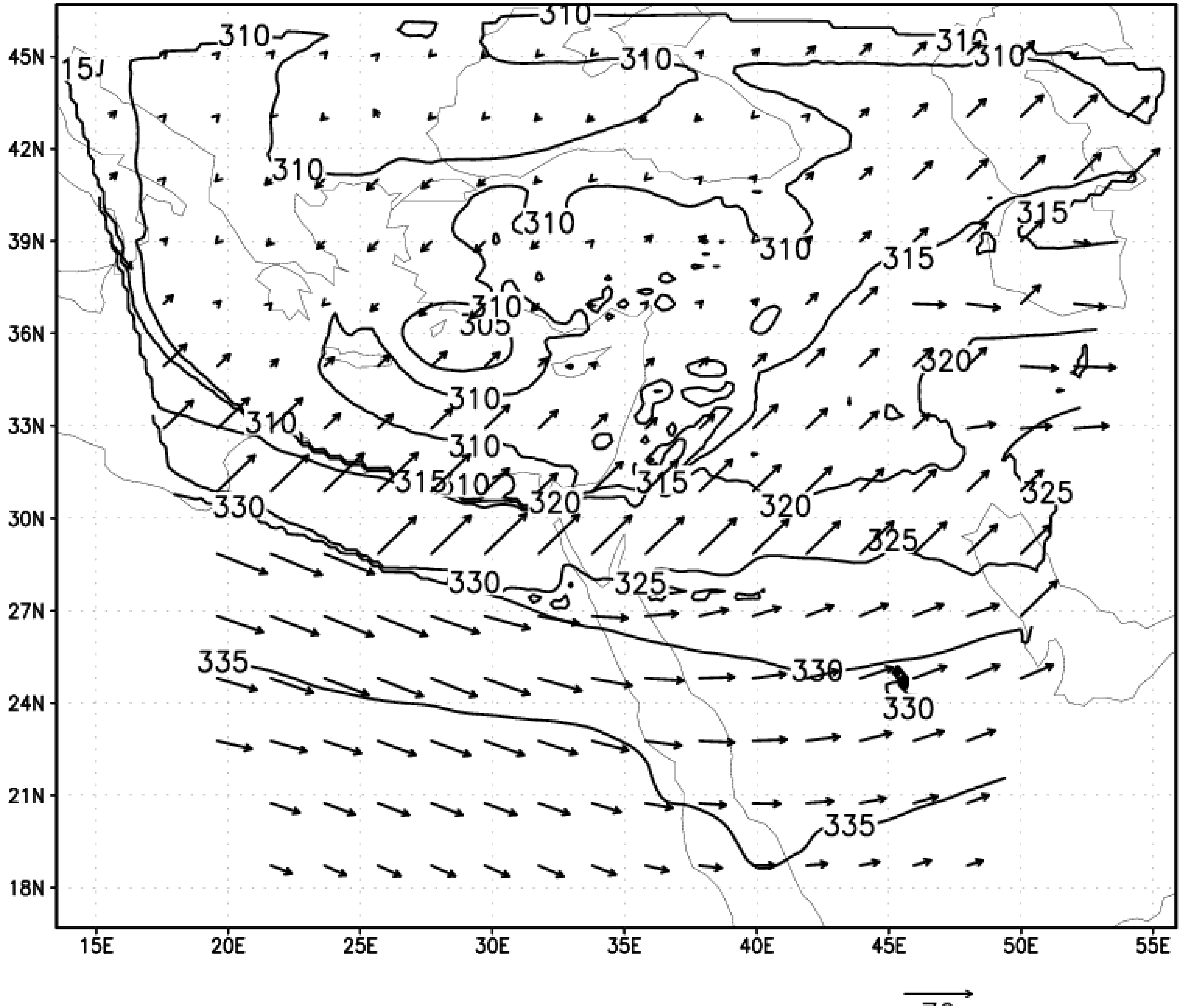
(a) DTROP THETA/WND 00031201+12



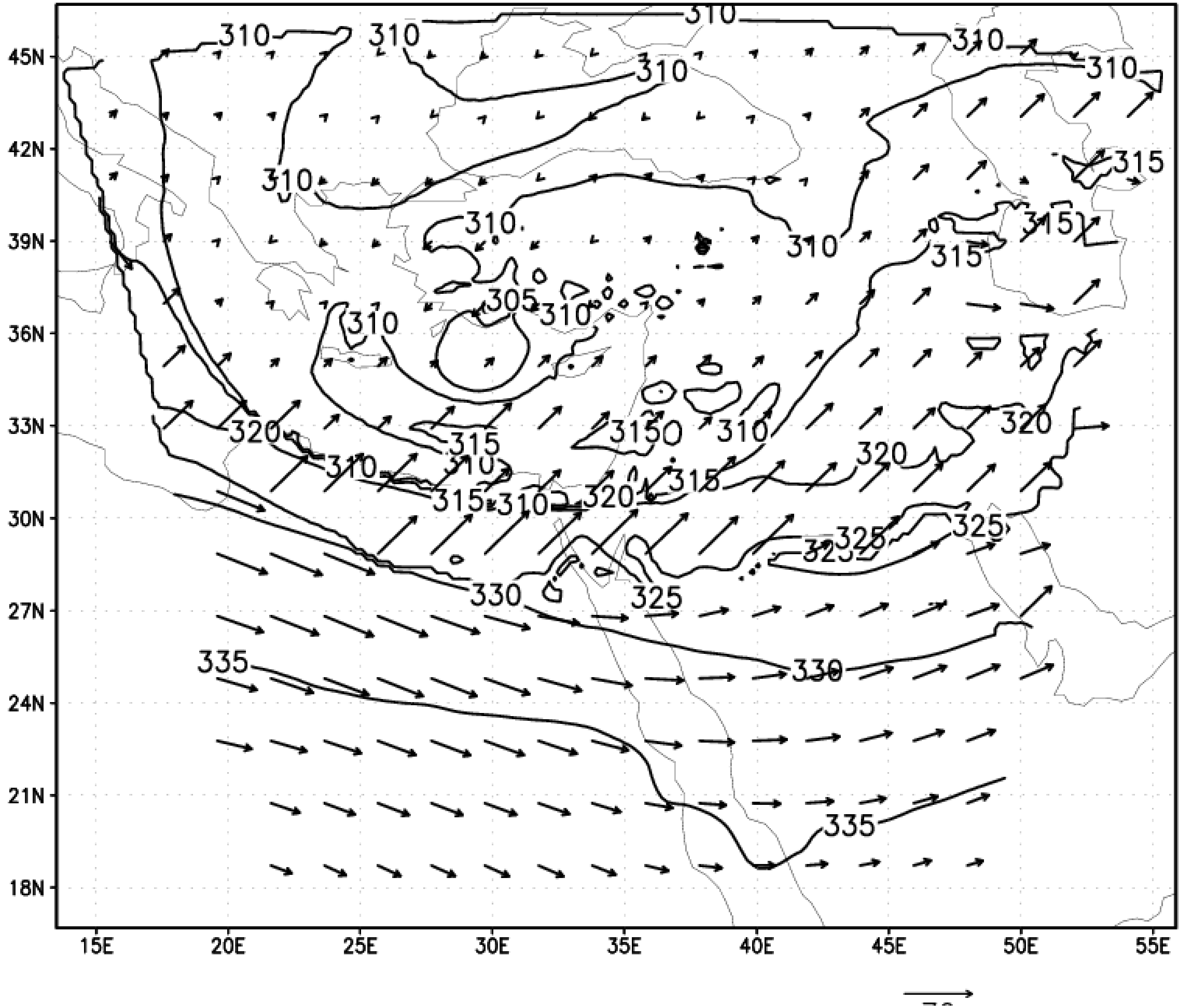
DTROP THETA/WND 18031201



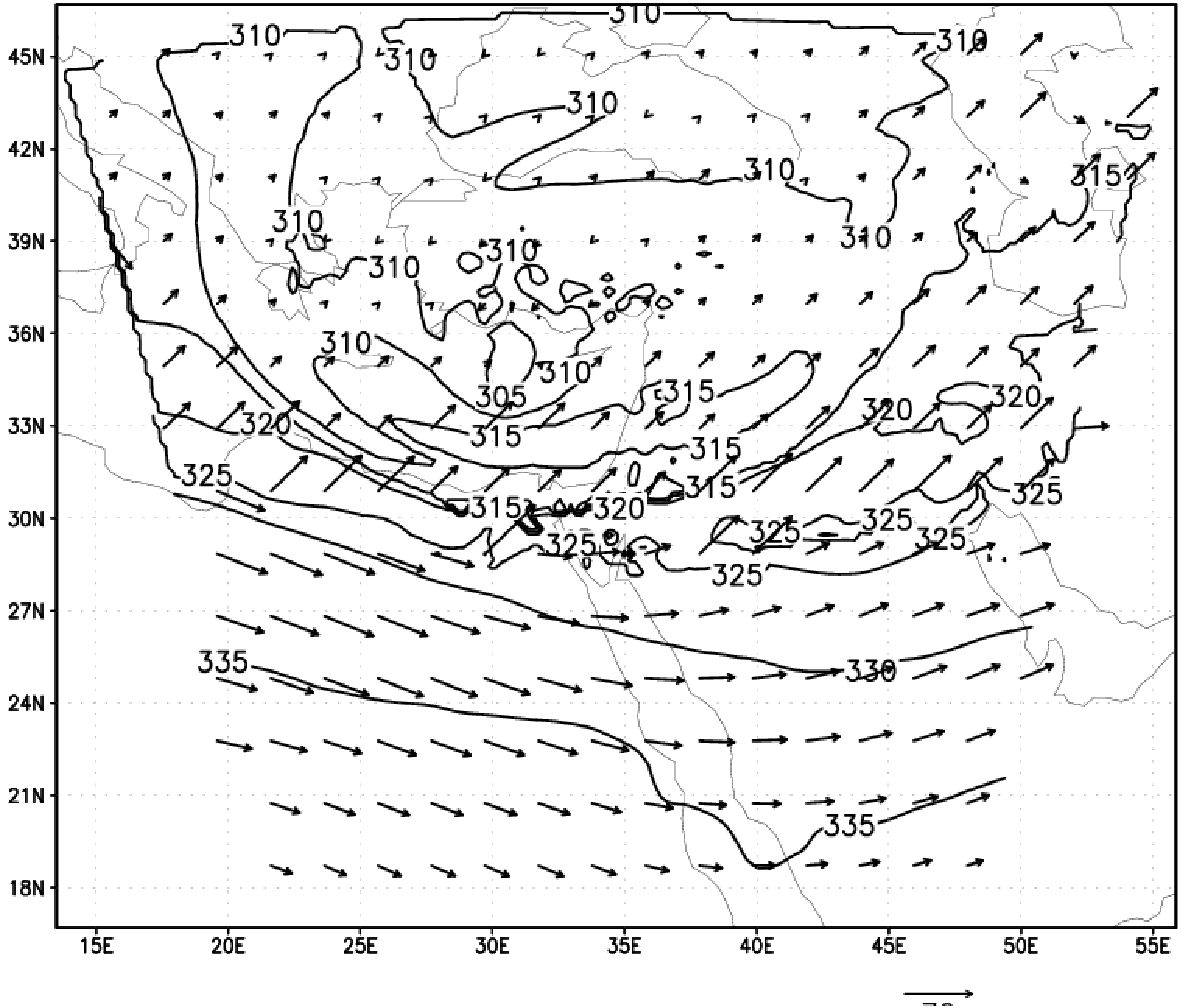
(b) DTROP THETA/WND 00031201+24



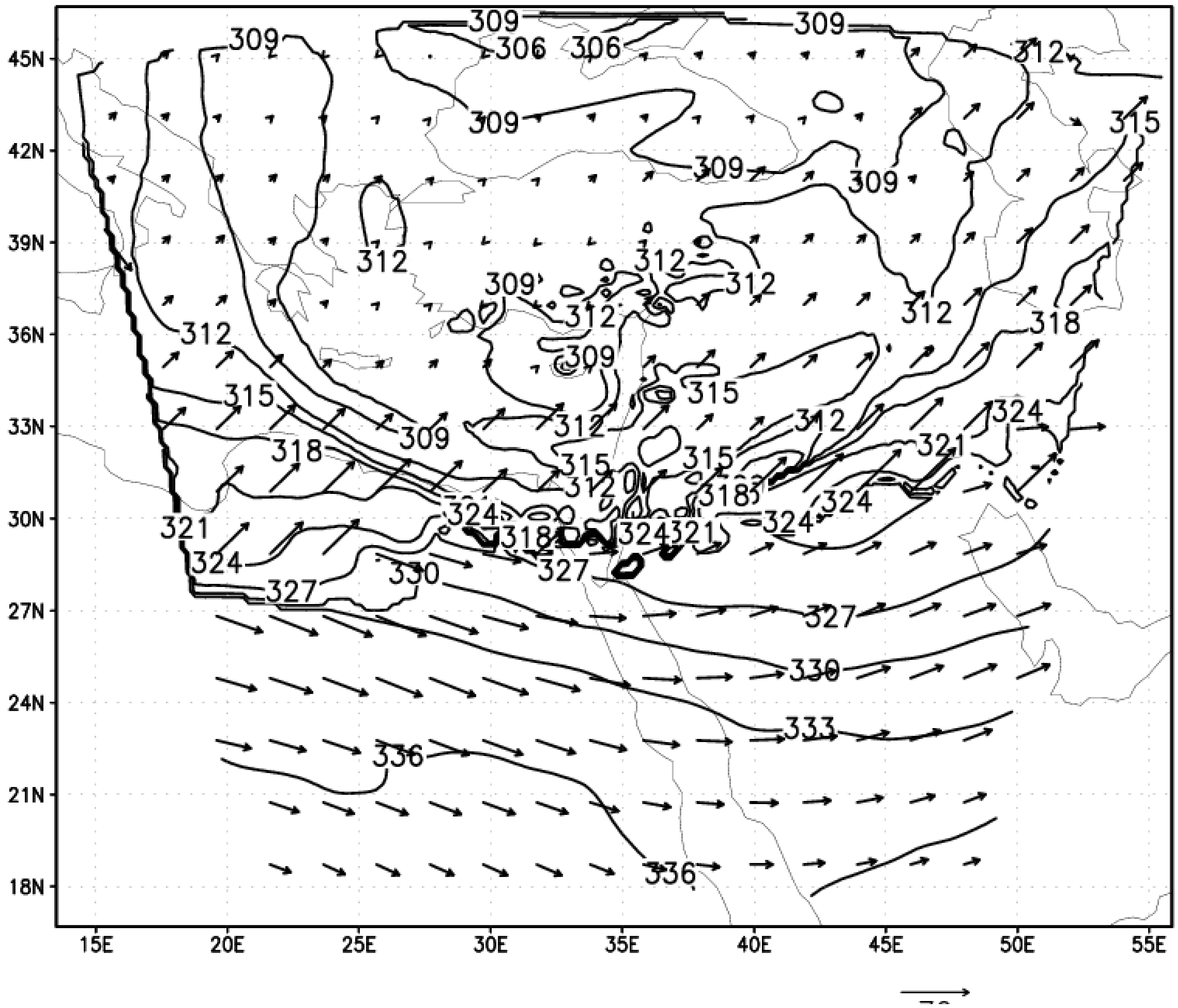
DTROP THETA/WND 06041201



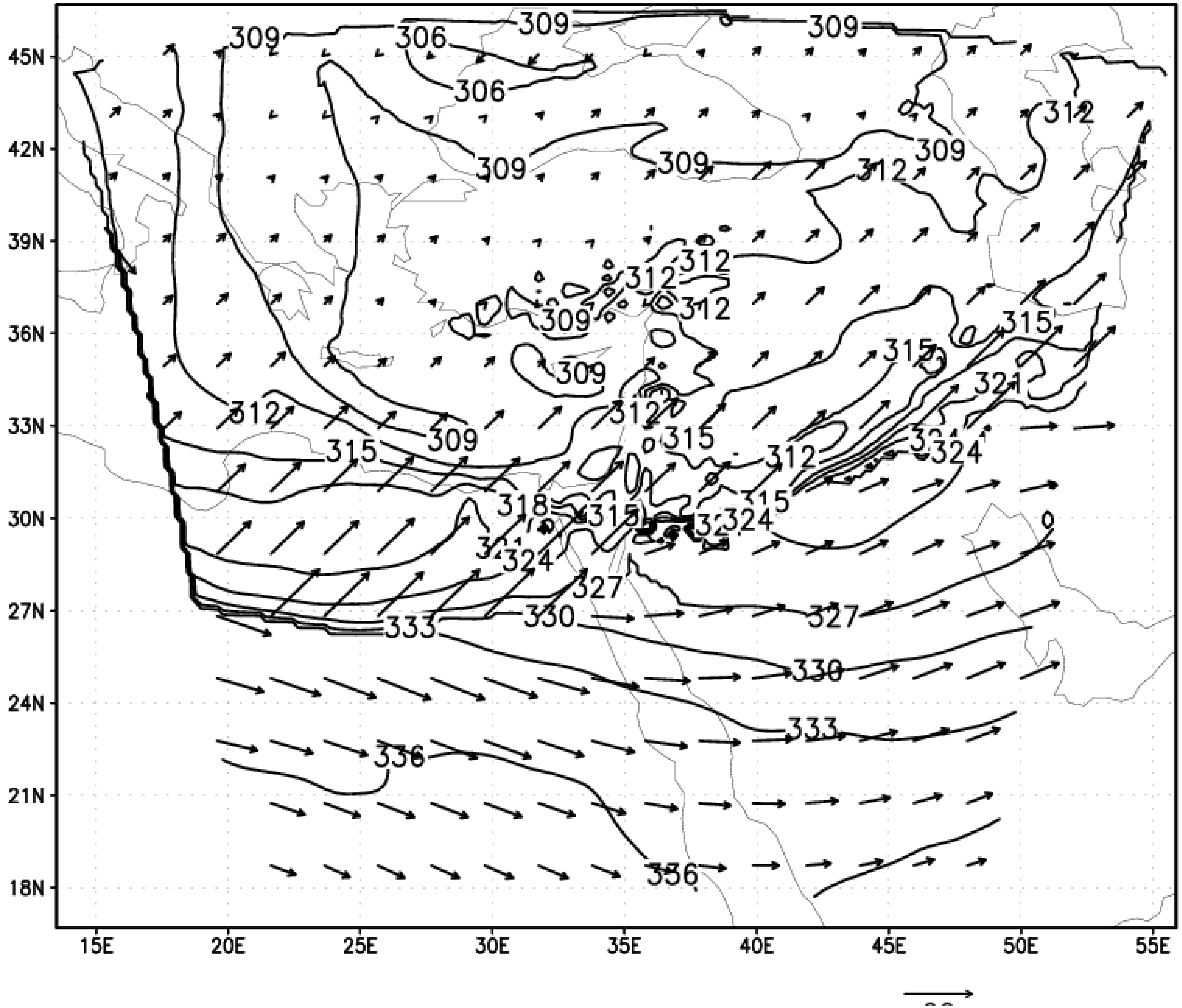
(c) DTROP THETA/WND 00031201+36



DTROP THETA/WND 18041201



(d) DTROP THETA/WND 00031201+48



The persistent coherent PV anomaly streamer existed over the area during 36-48 hrs.

Such conditions are especially advantageous for the development of mesoscale convective systems and torrential rains.

The hazardous weather conditions in Israel of December 3-5 2001 resulted from the development of a persisting coherent three-dimensional PV streamer structure characterized by localized wind speed maxima (jet streak) along upper troposphere jet over the southern part of the Mediterranean Sea region. Another important feature of the process was a pre-existing cyclone over the northern EM.

The upper-level jet streak were responsible for organizing the mesoscale storm environment to enhance the amount of low-level moisture that is processed. The processes determined the intensity of the MCS developed also due to the PV streamer effects and finally the torrential rains in Israel.

Predictability aspects:

Olga

PV anomaly over Newfoundland

Tropopause disturbance

Iceland Low/Siberian High dipole

PV streamer over Alpine region

Tropopause fold over the SE Mediterranean

Meso-scale Convective System

Adaptive resolution modeling