

Sensitivity Studies of LM vs. LM_Z for Greece

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GREECE**

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BTZ Langen 5-7March 2007***


PRESENTATION OUTLINE

- ◆ LM_z vs LM_tf (main feature difference)
- ◆ Domain Geographic Characteristics
- ◆ Test Cases Synoptic Description
- ◆ Comparative Presentation of:
 - ◆ Cloud Cover
 - ◆ 12hr Accumulated Precipitation (06-18UTC)
- ◆ Numerical Validation of Coordinate transformation LM_z↔LM_tf
- ◆ Conclusions

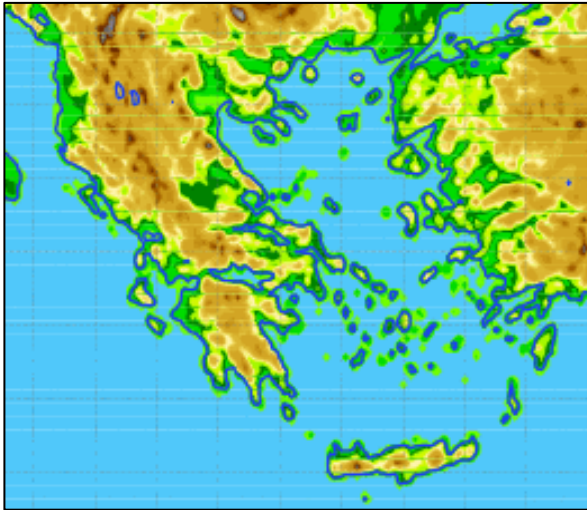
LM_z vs LM_tf (main feature difference)

LM_z uses model levels parallel to surface and consequently intersecting orography while LM_tf uses terrain following coordinates.

Technical details (References-Acknowledgments):

1. J. Steppeler, H. W. Bitzer, M. Minotte, and L. Bonaventura, “*Nonhydrostatic atmospheric modelling using a z-coordinate representation*”, Mon. Wea. Rev. 2002, 130, 2143-2149.
 2. H. W. Bitzer and Steppeler J., “*Documentation of the dynamical core of LM*” COSMO Technical Report No.6, April 2004, <http://www.cosmo-model.org/public/technicalReports.htm>
 3. Steppeler, H. W. Bitzer, Z. Zanjic, U. Schättler, P. Prohl, U. Gjertsen, L. Torrisi, J Parfinievich, E. Avgoustoglou, and U. Damrath, “*Prediction of clouds and Rain Using a z-Coordinate Nonhydrostatic Model*”, Mon. Wea. Rev. 2006, 134, 3625-3643.
-  Tirli V., Tzeferi T., Senior Meteorologists of HNMS, Contributions to the Synoptic Evaluation of the Test Cases.

Domain Geographic Characteristics



grid size: ~7km
of horizontal grid points: 189X225
of model levels :35

- ◆ **Complex Orography mainly developed from North to South over the Mainland Greece as well as West to East over the Northern Part of the Country.**
- ◆ **Almost equally partitioned land-sea mask.**
- ◆ **Large number of mountainous islands.**
- ◆ **The North to South orographic structure of Western Greece was expected to effect cloud formation and precipitation in a way that might demonstrate differences between the terrain following coordinates version of LM and LM_Z.**

Test Case #1

Synoptic Description

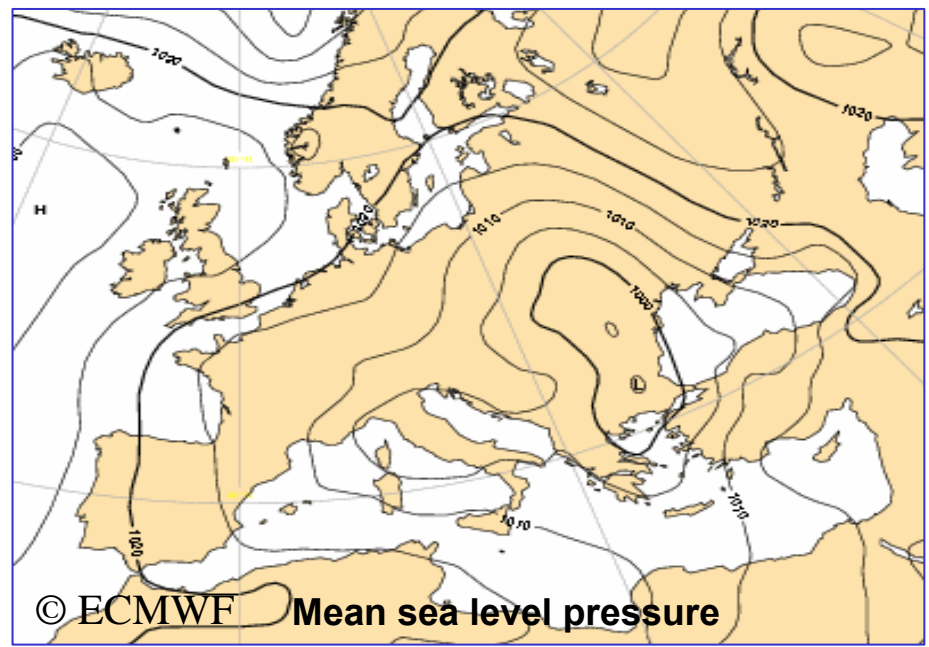
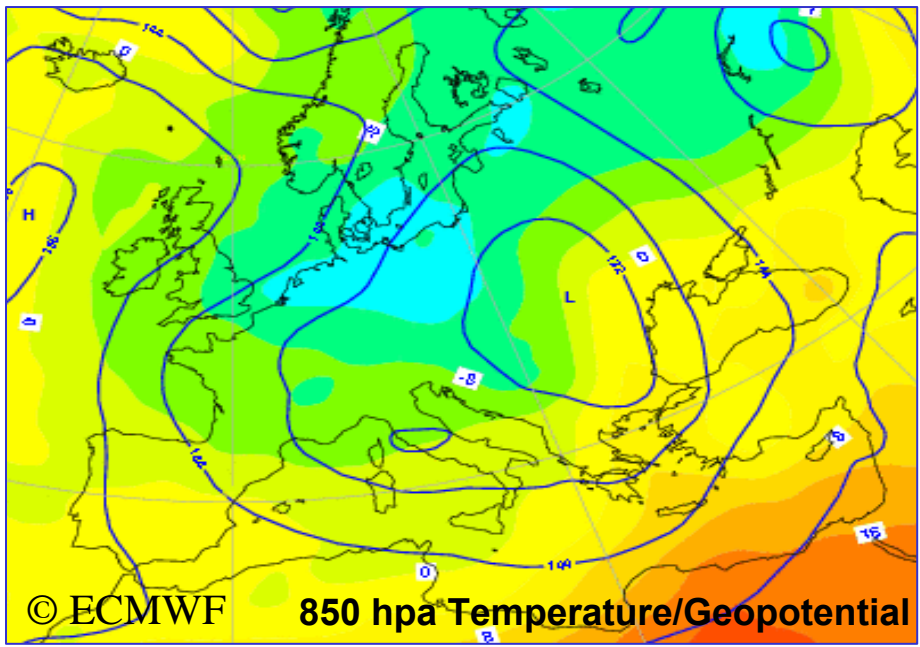
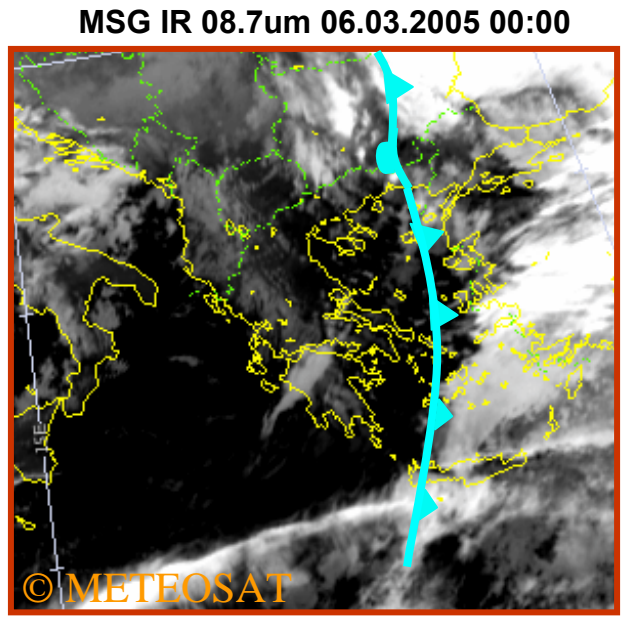
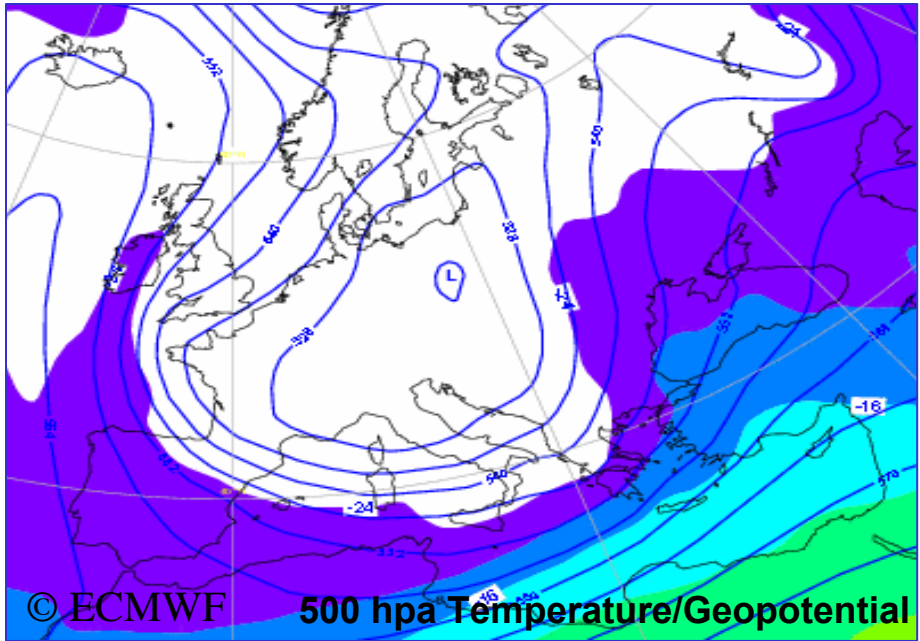
- ◆ We investigate the weather development over Greece during the three day period of 6, 7 and 8 March 2005.

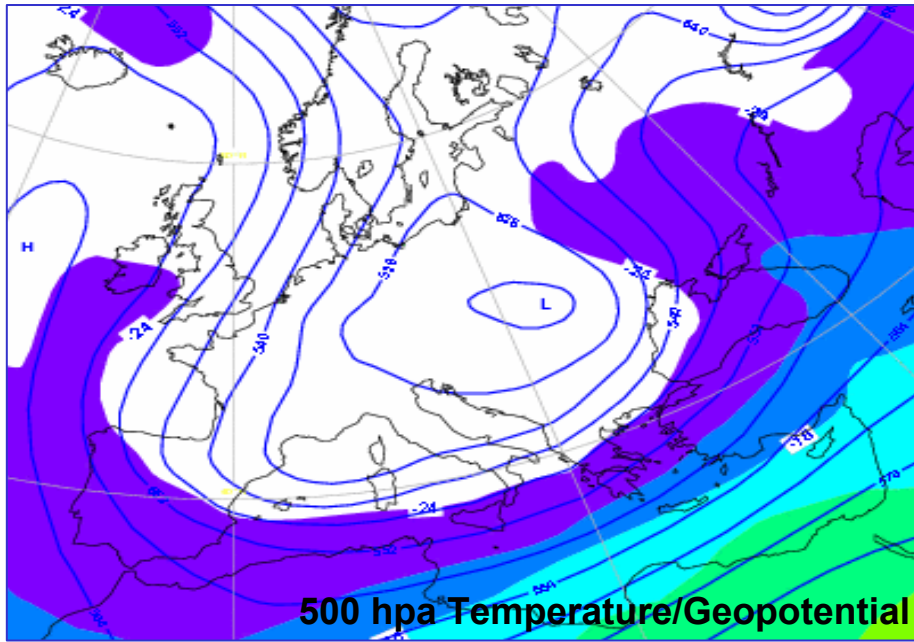
- March 6:

A deep Low Pressure system over E. Balkans associated with frontal activity extended to East Aegean moving E/NE.

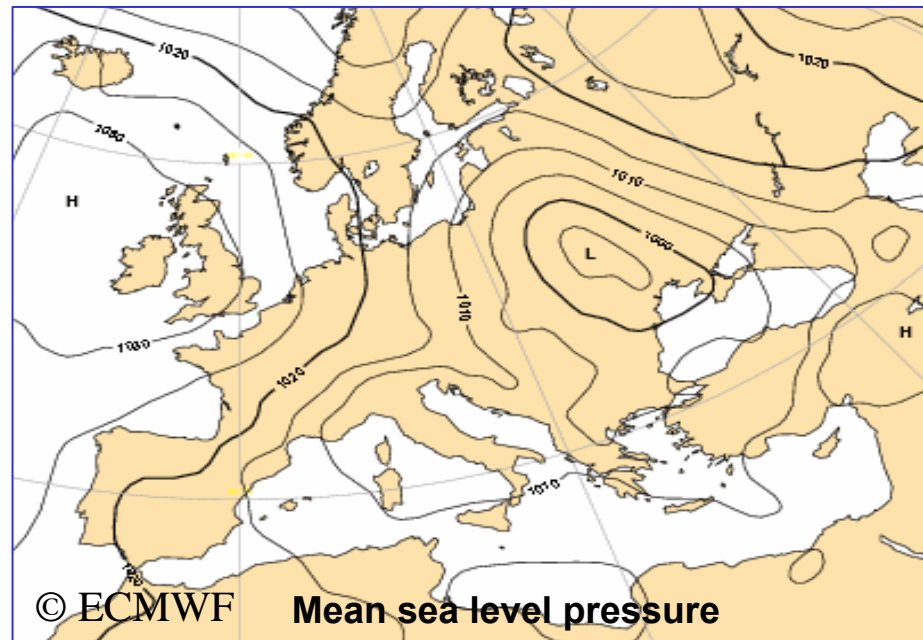
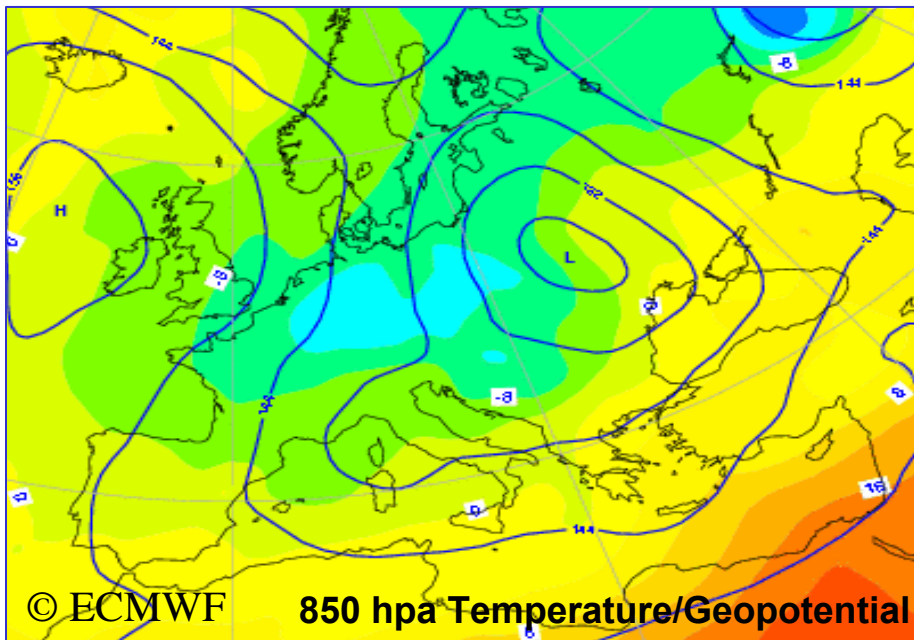
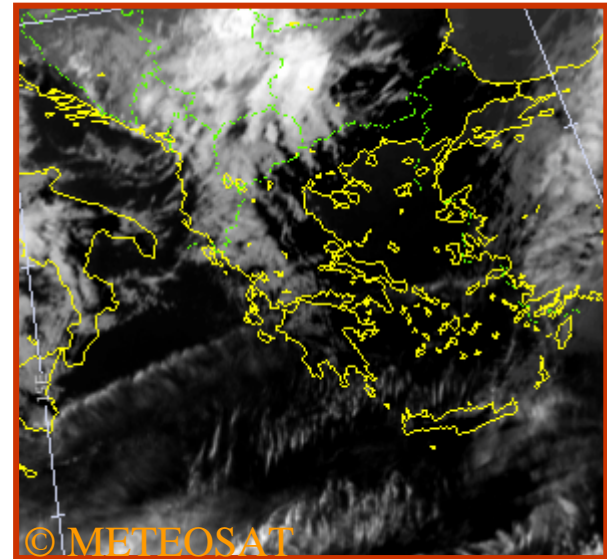
- March 7 & 8:

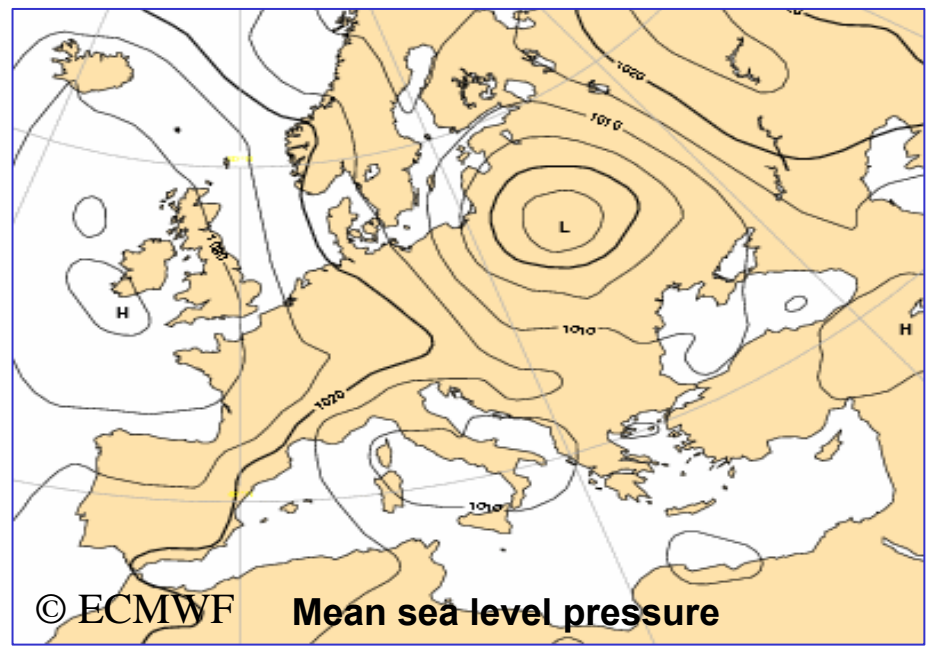
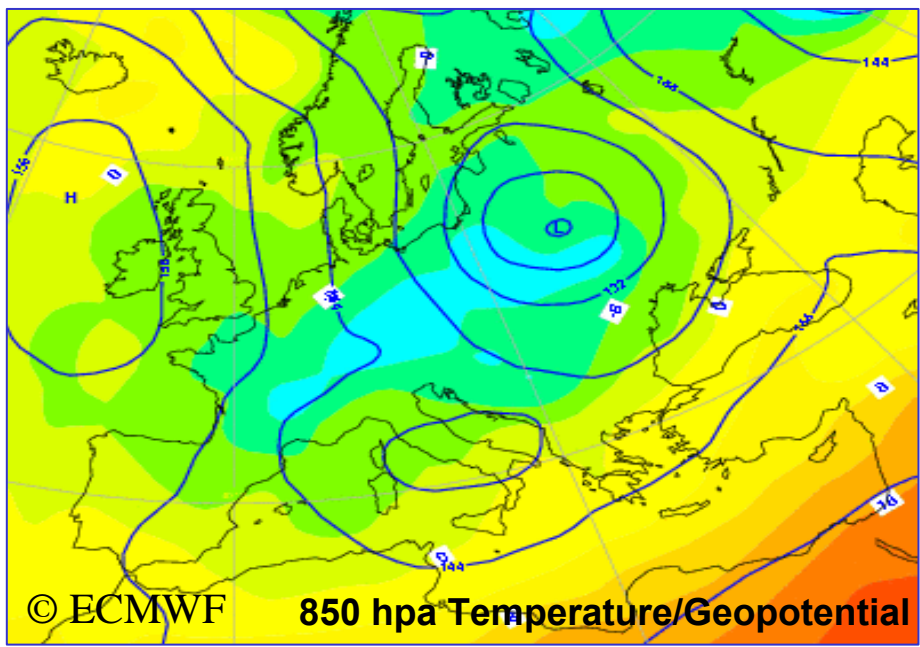
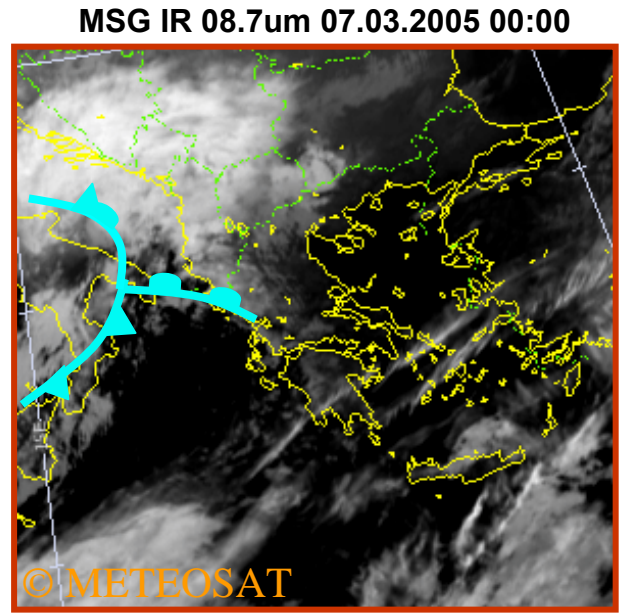
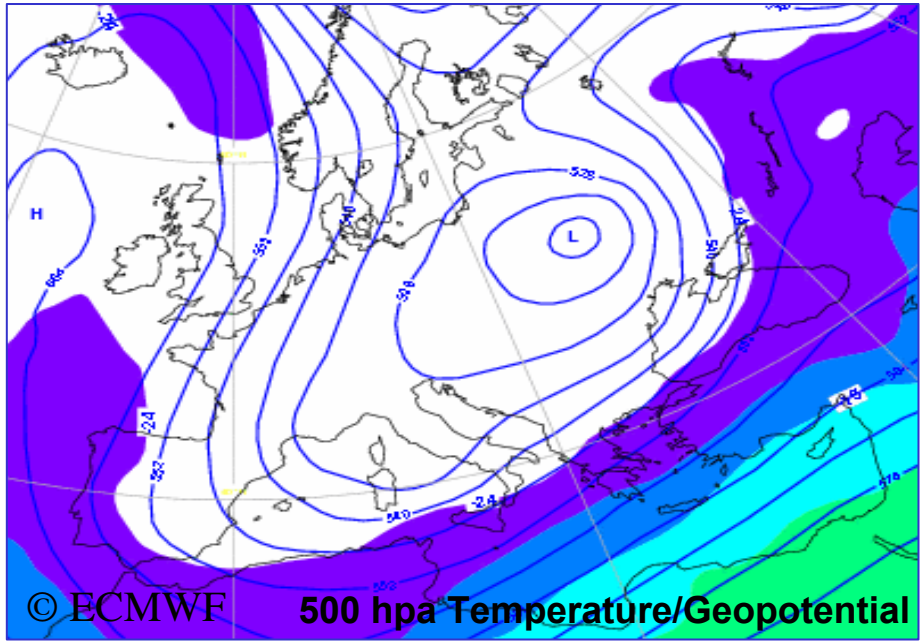
Moderate frontal development over S. Italy moving East and combined with a strong SW wind field in middle troposphere.

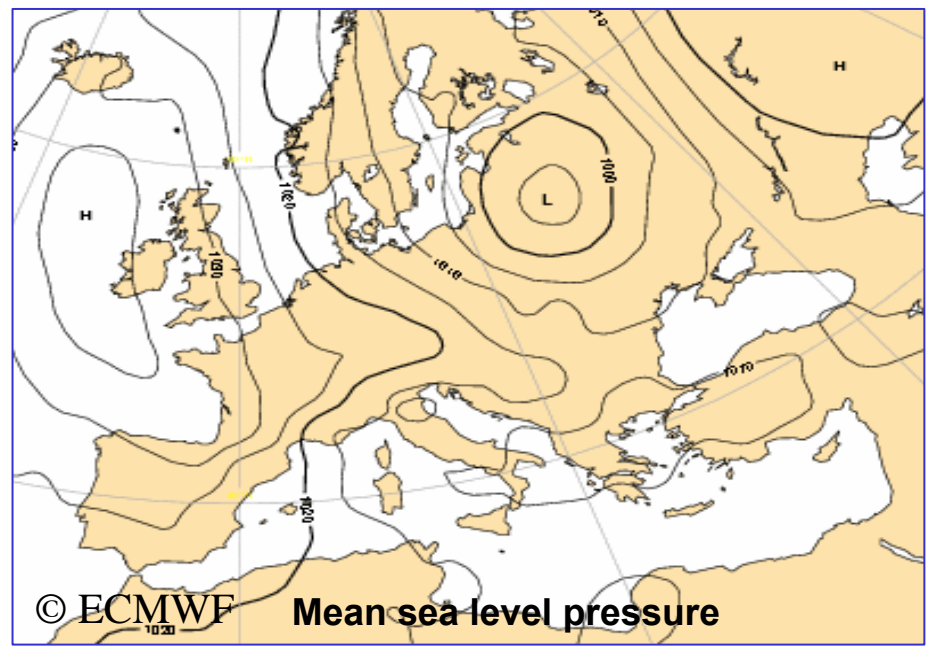
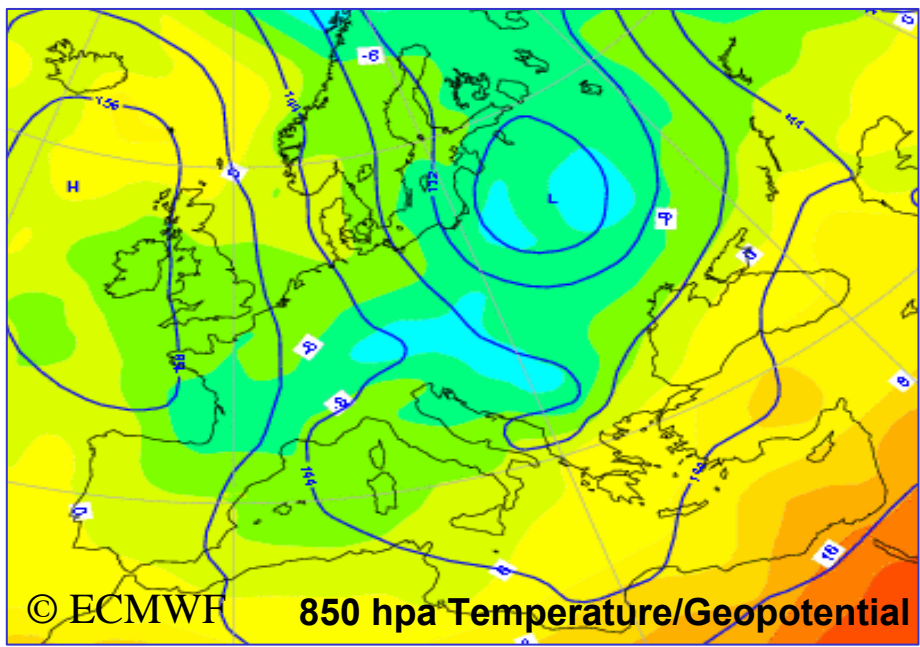
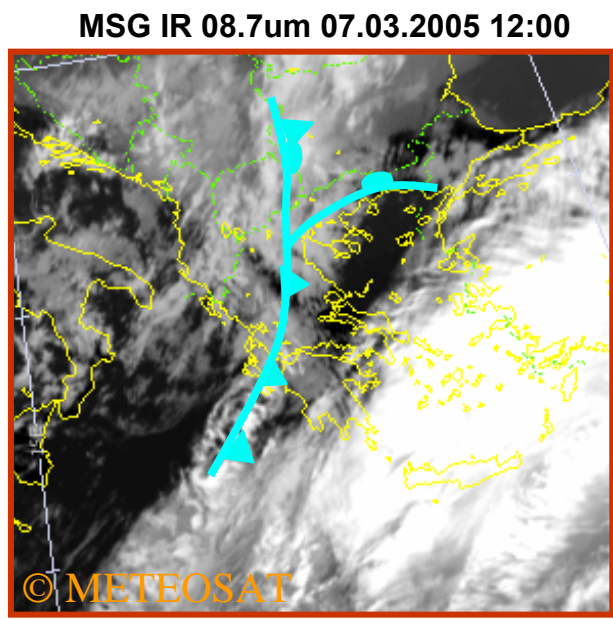
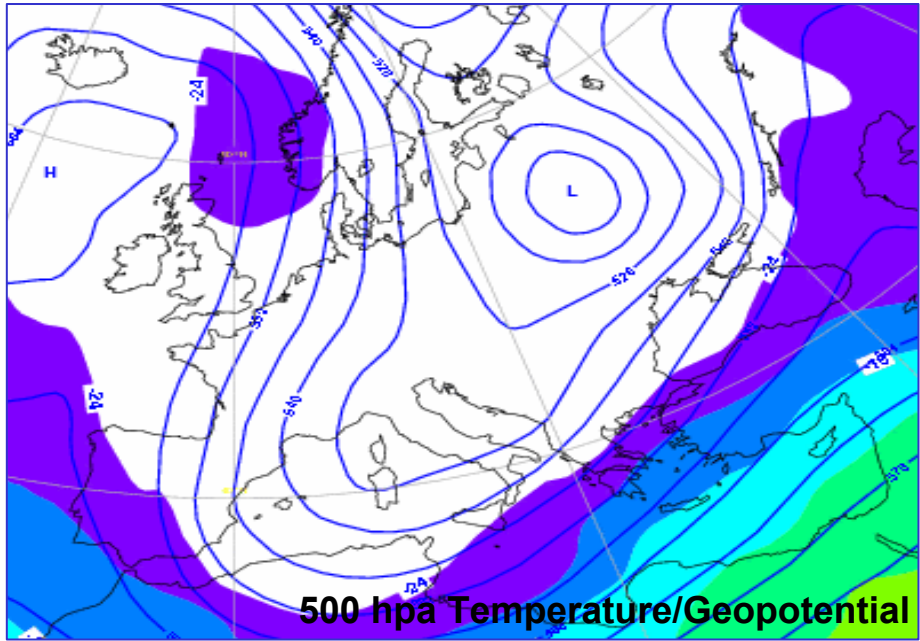


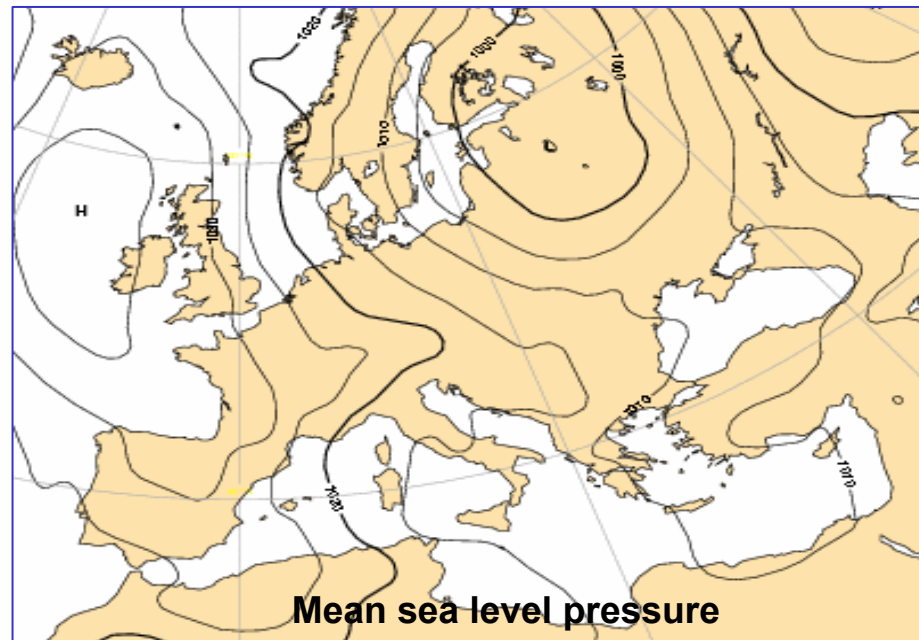
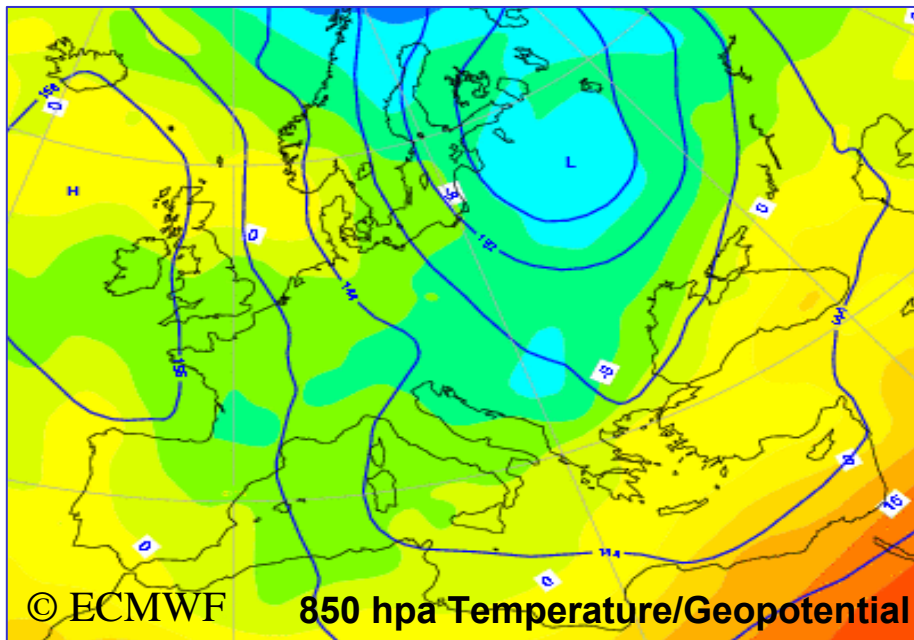
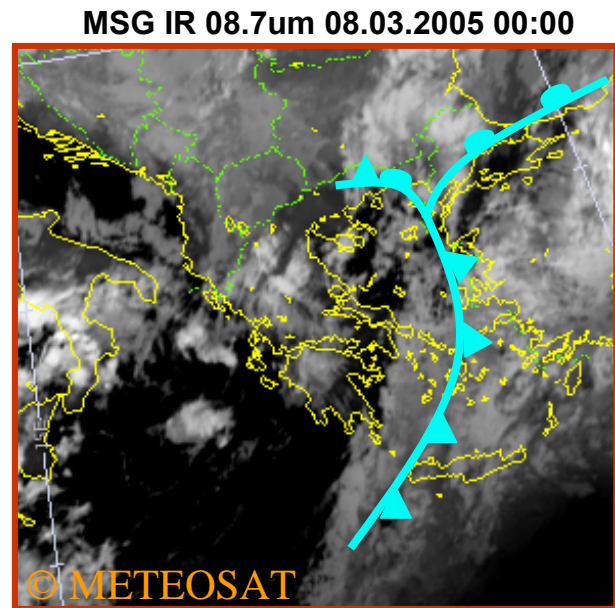
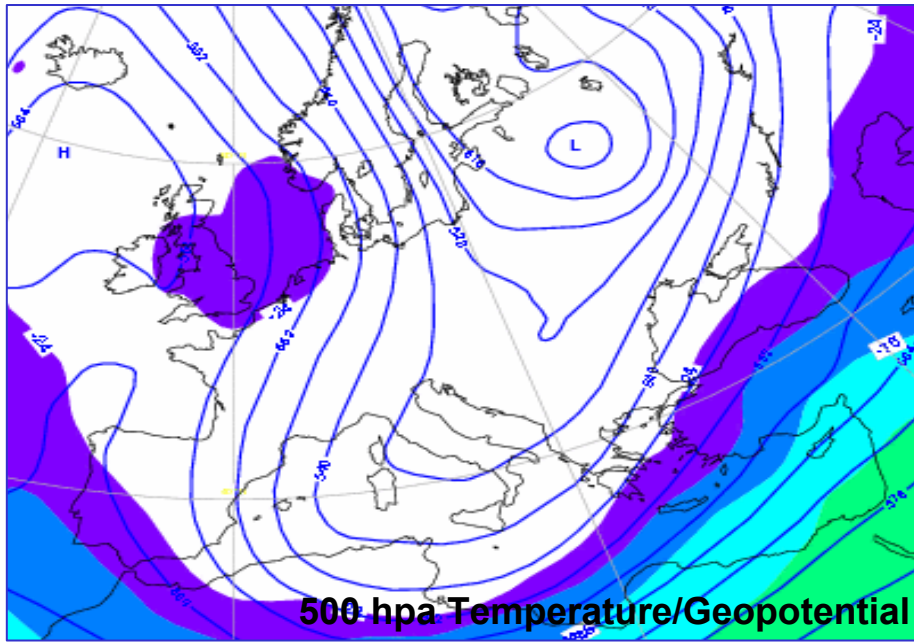


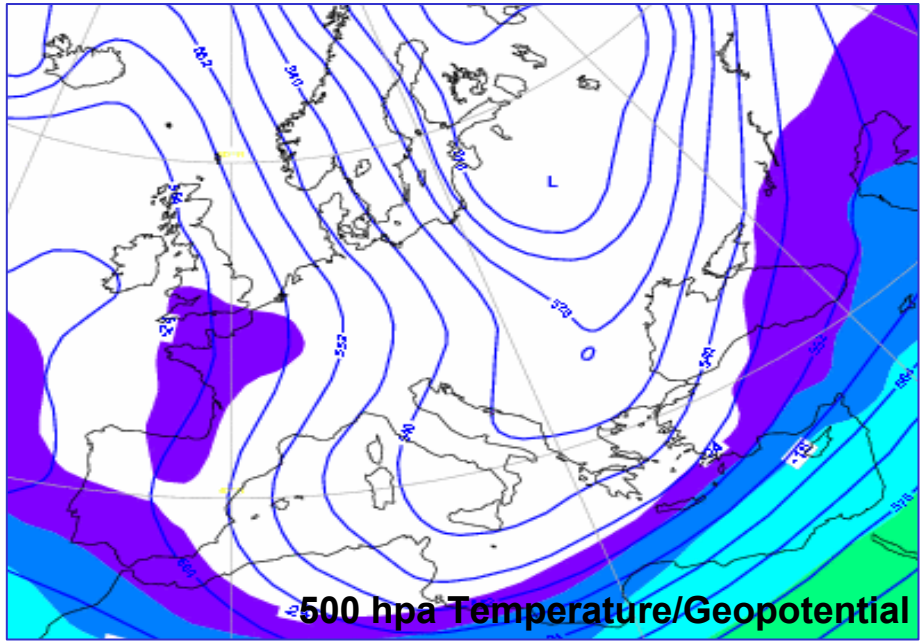
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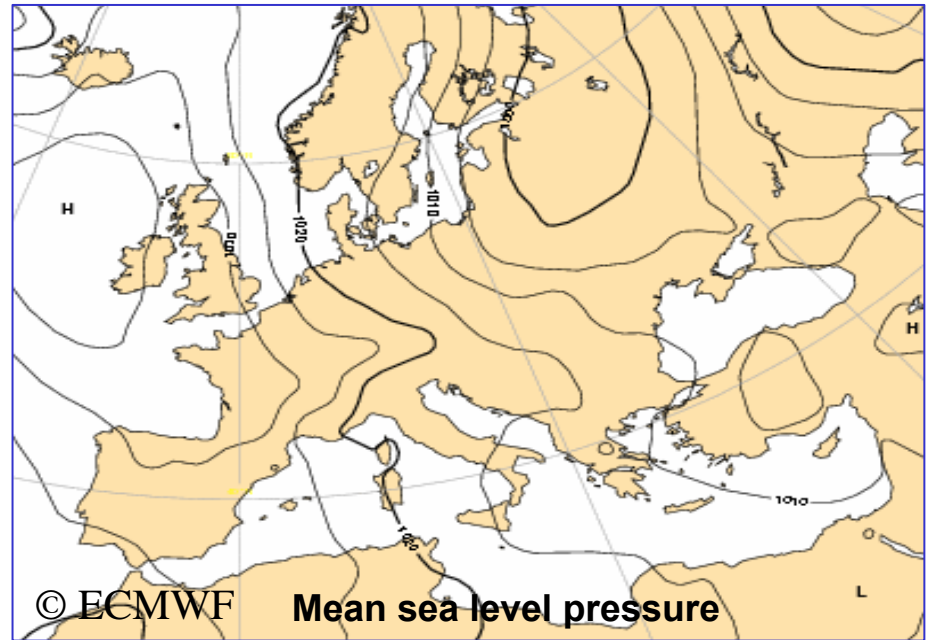
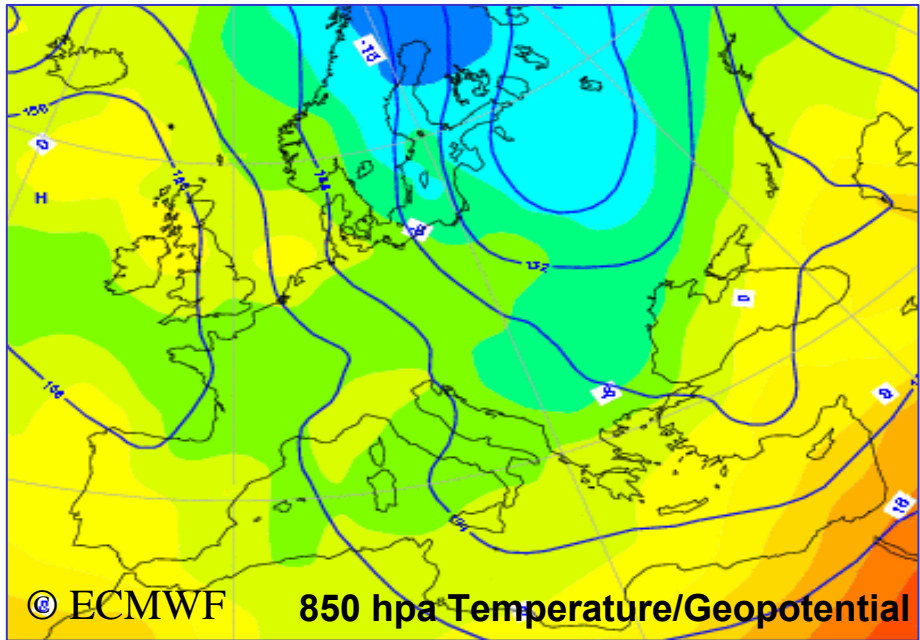
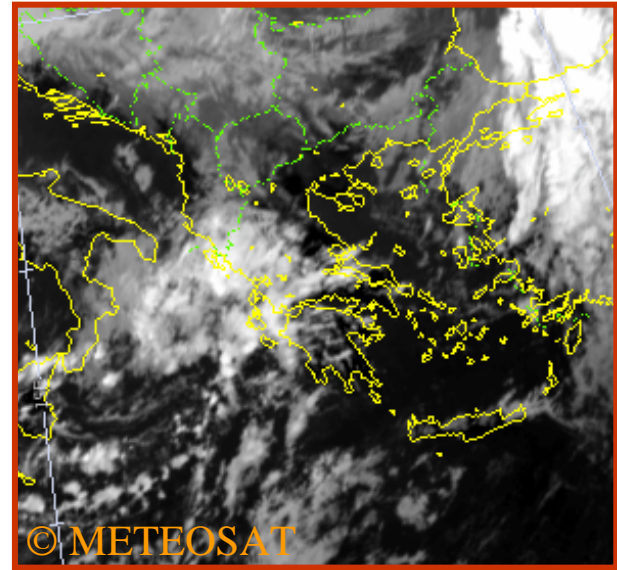






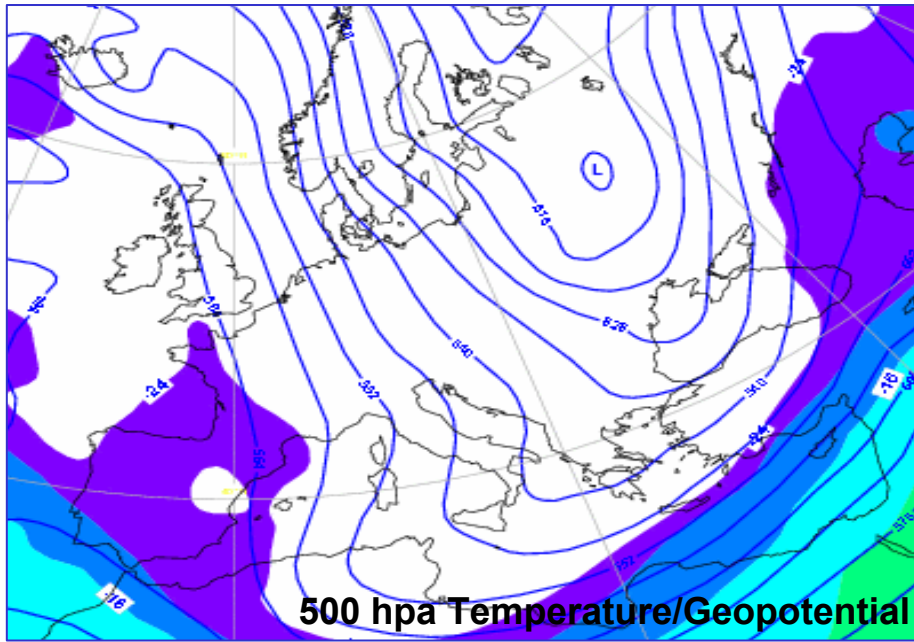


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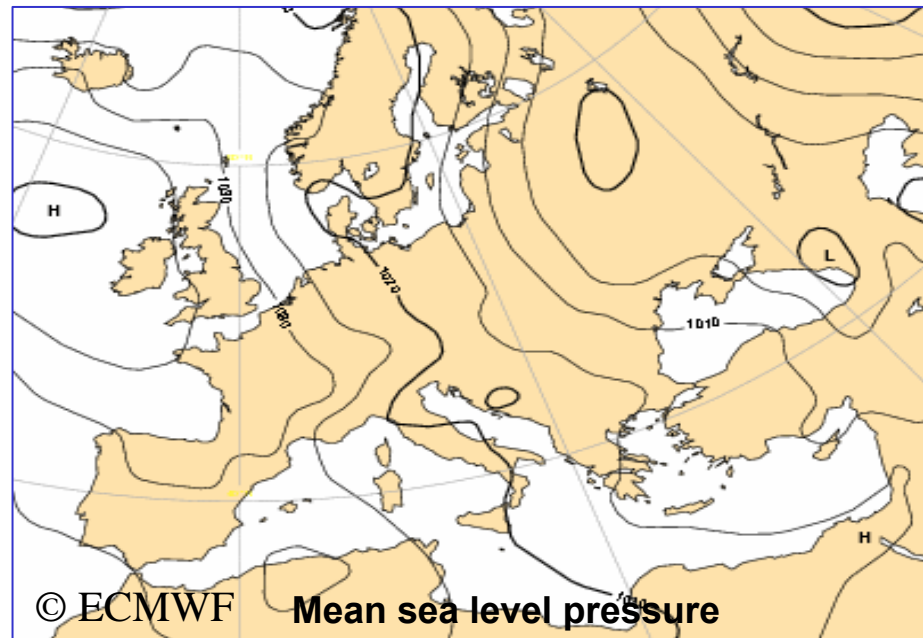
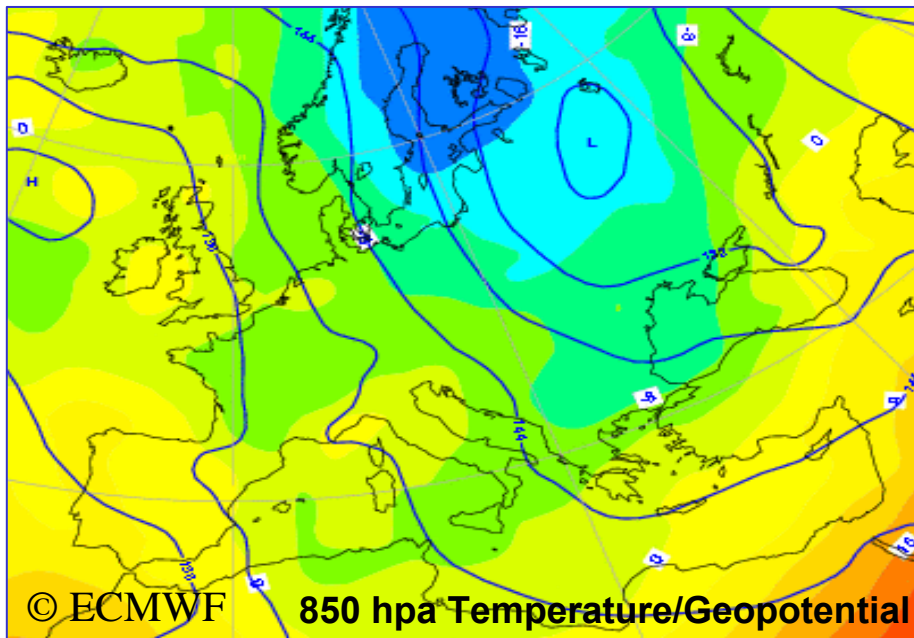
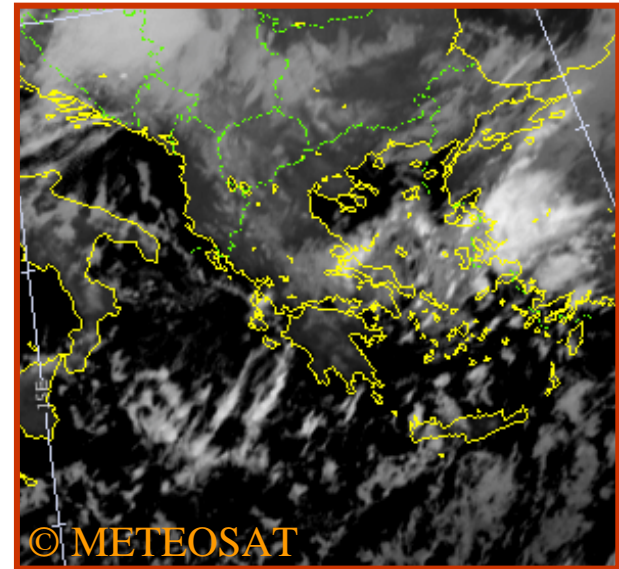


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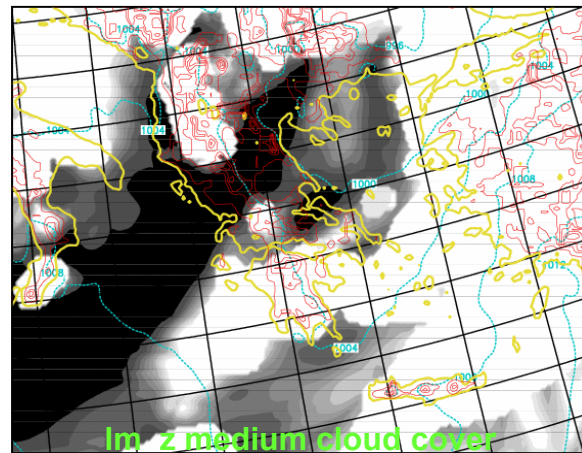
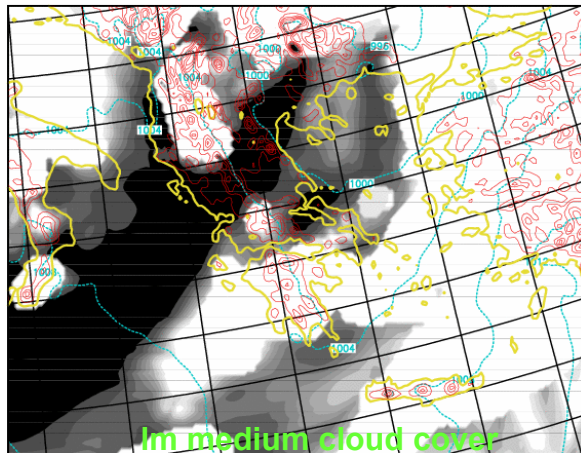


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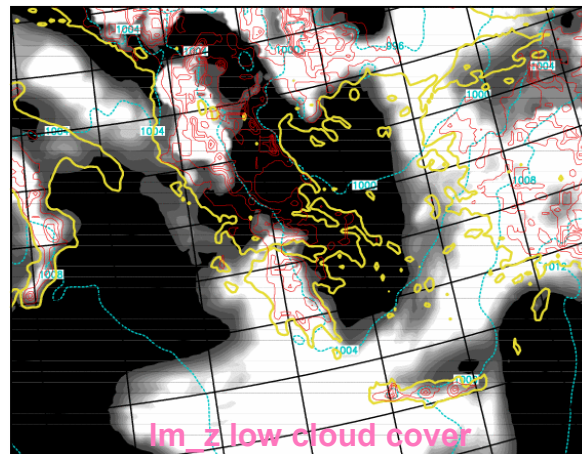
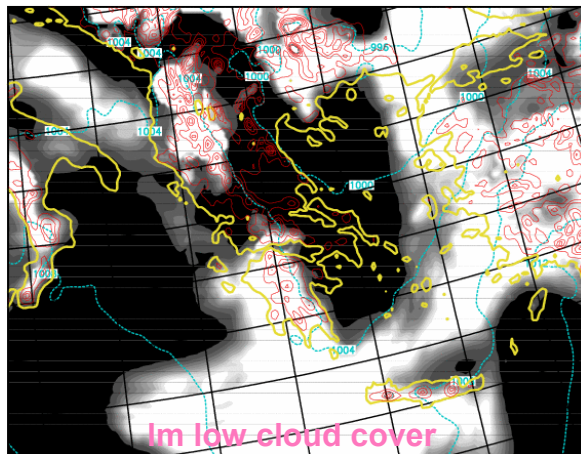
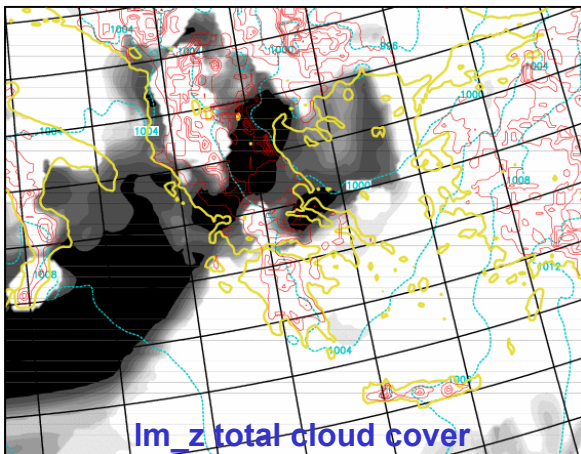
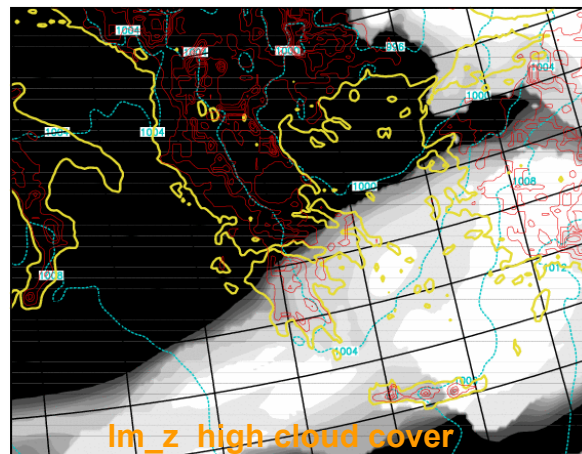
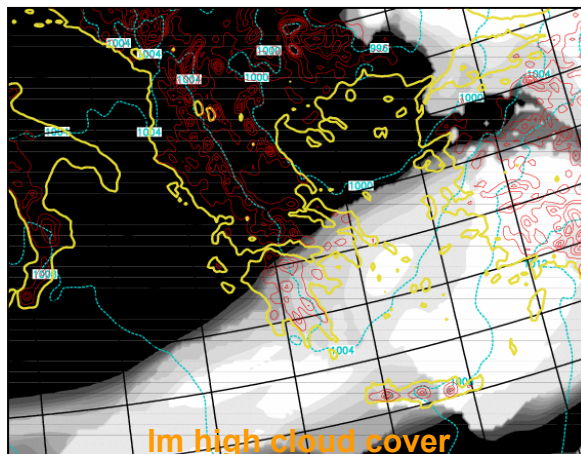
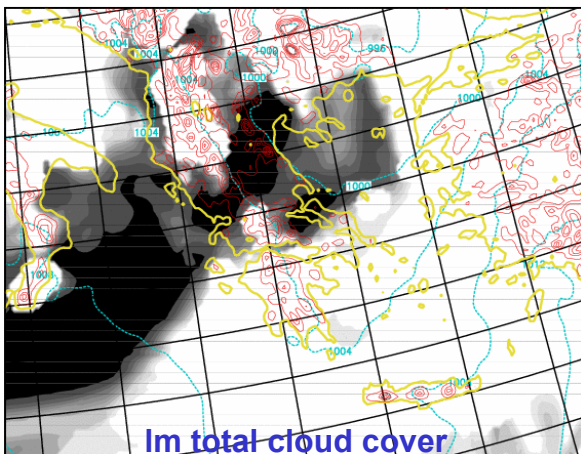
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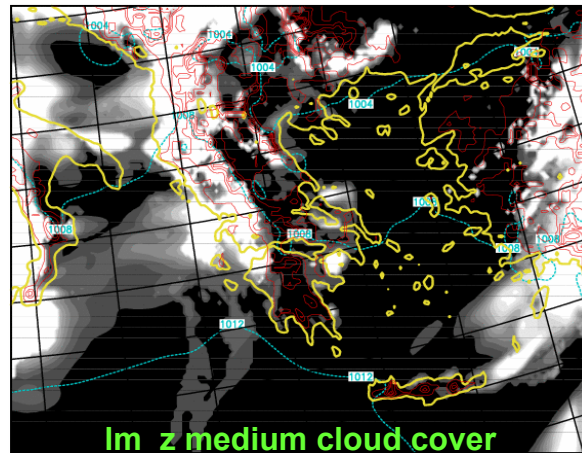
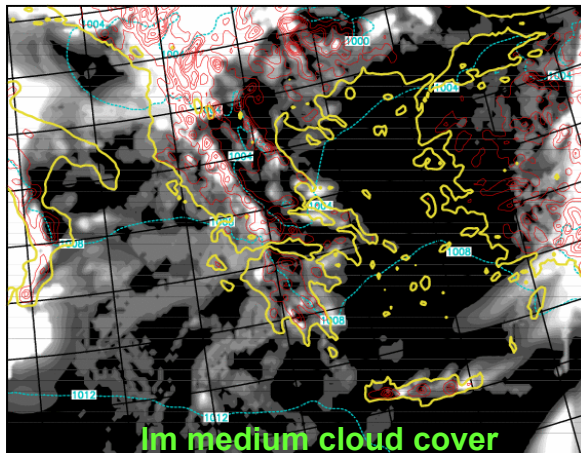
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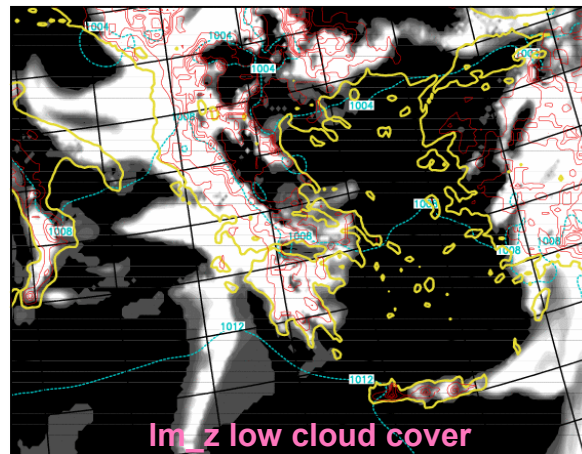
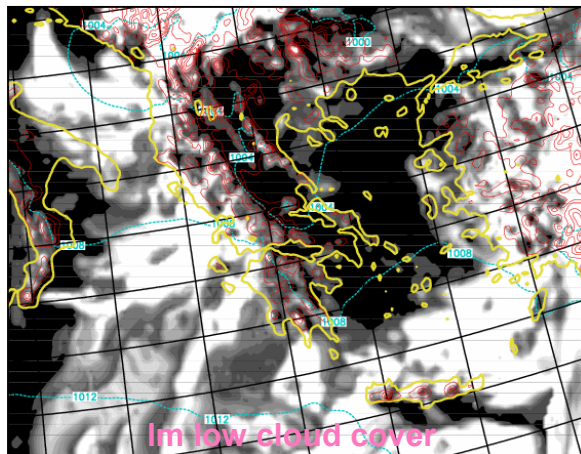
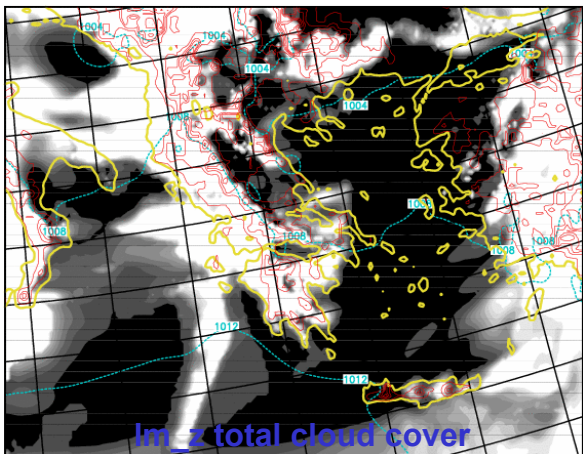
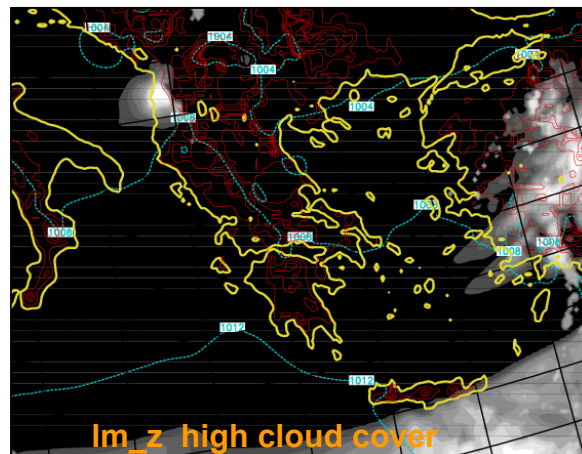
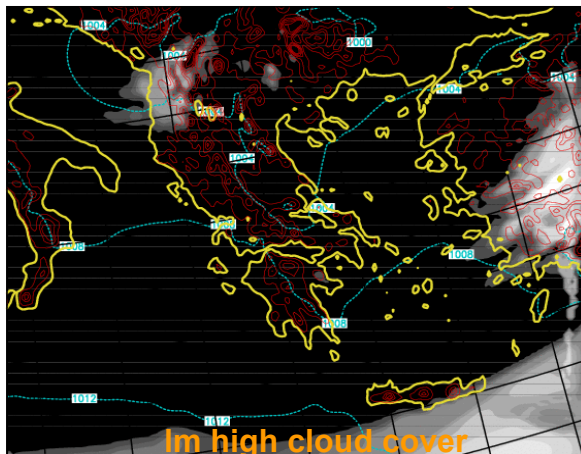
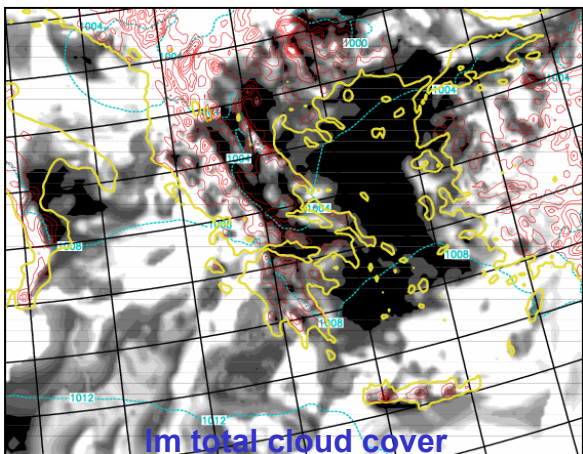
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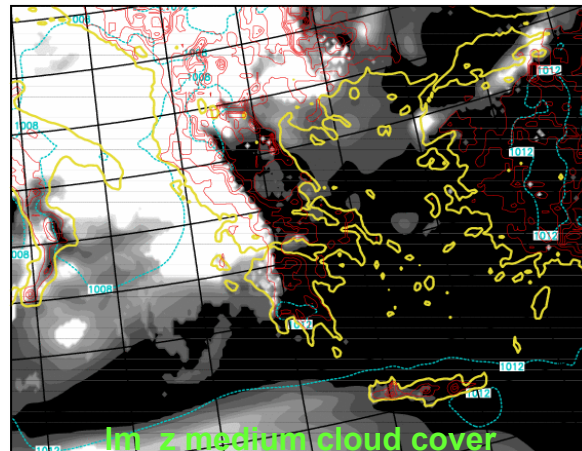
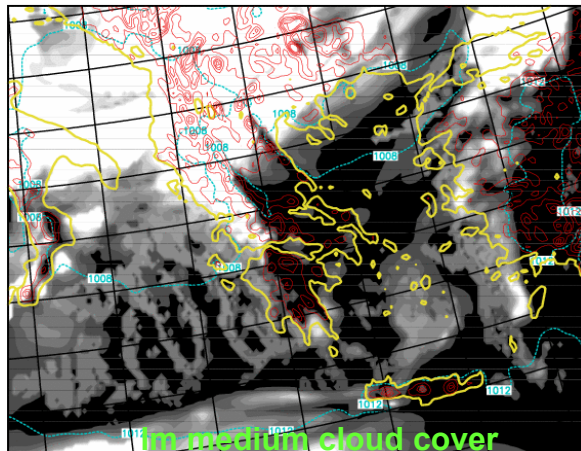
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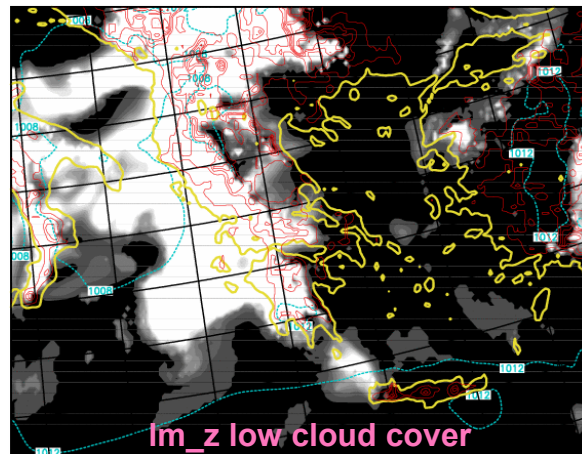
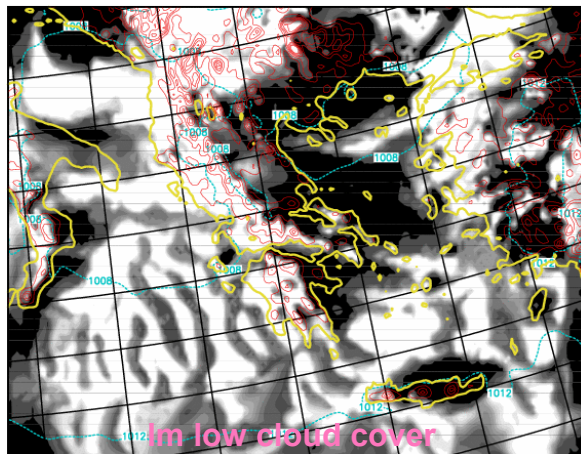
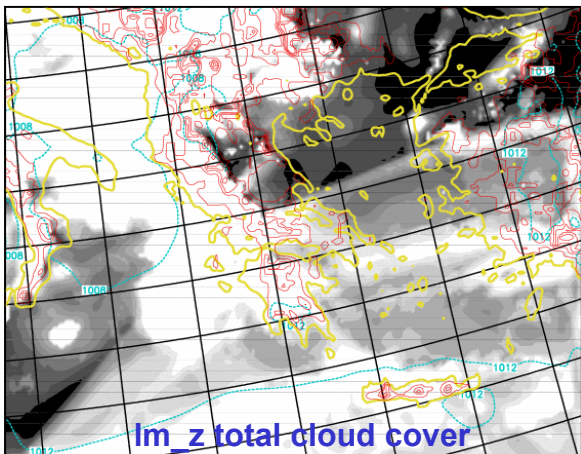
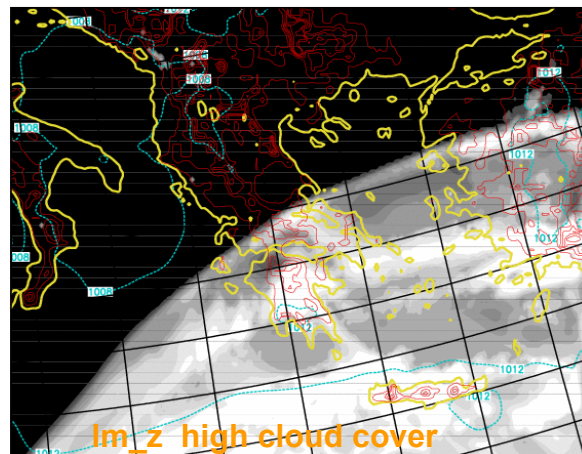
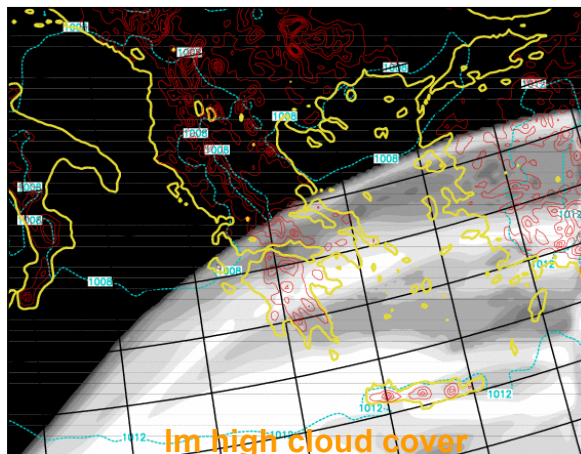
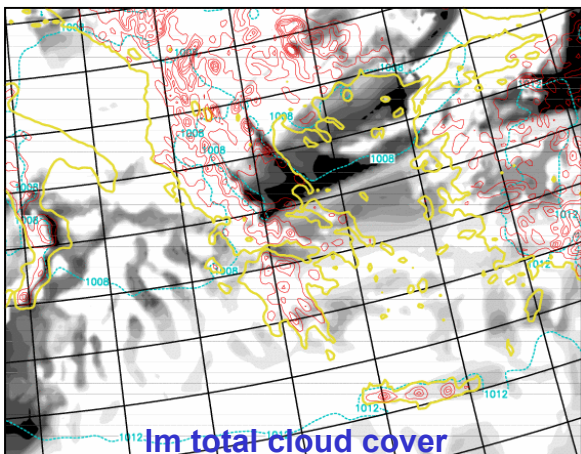
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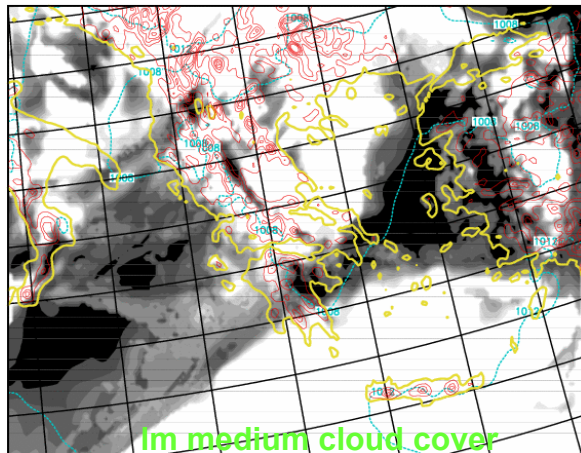
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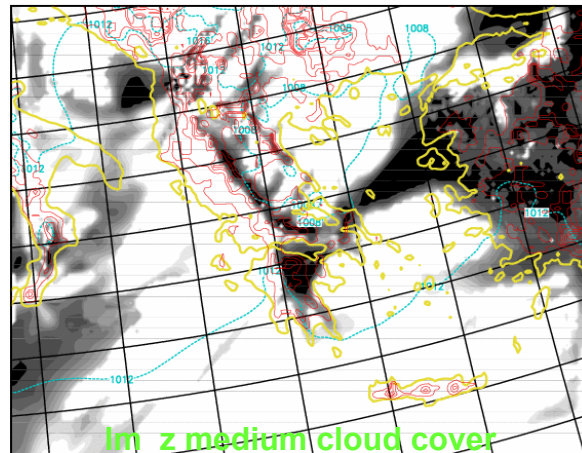


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Im medium cloud cover



Im_z medium cloud cover

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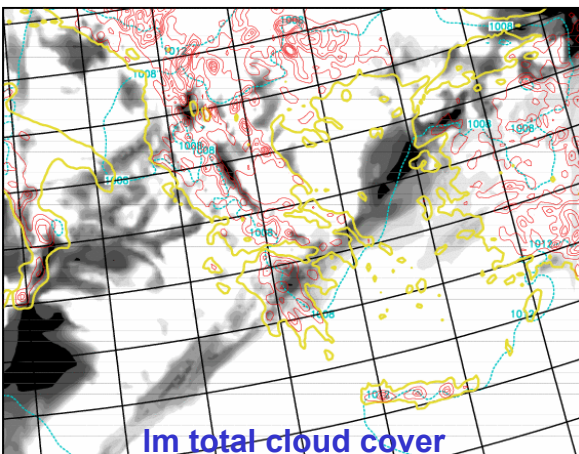
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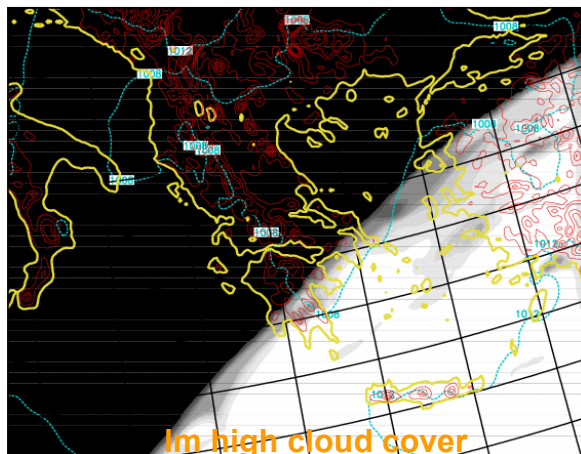
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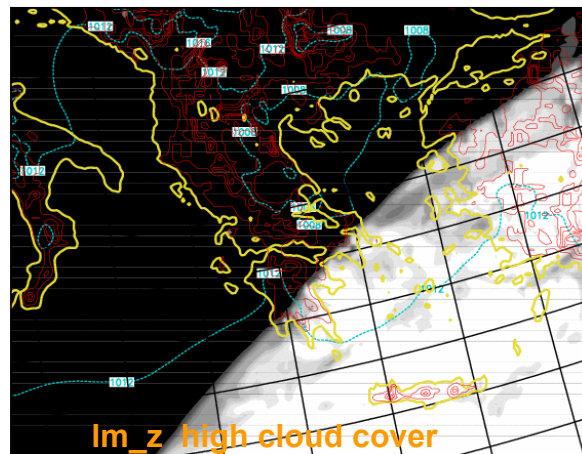
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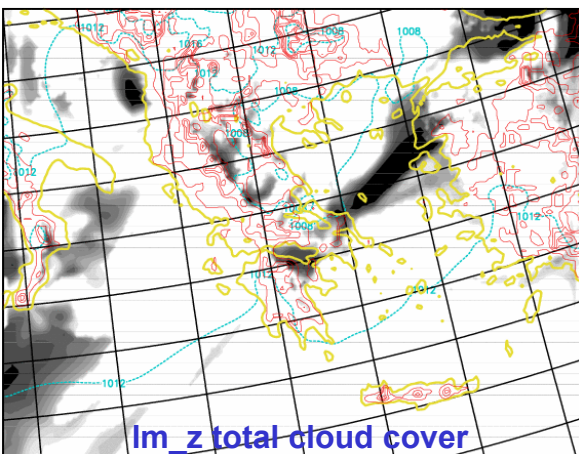
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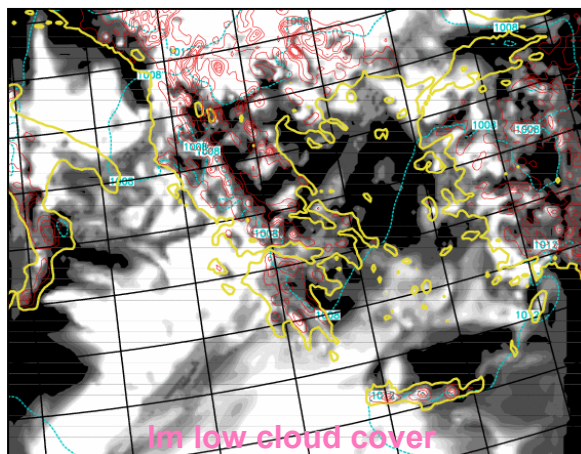
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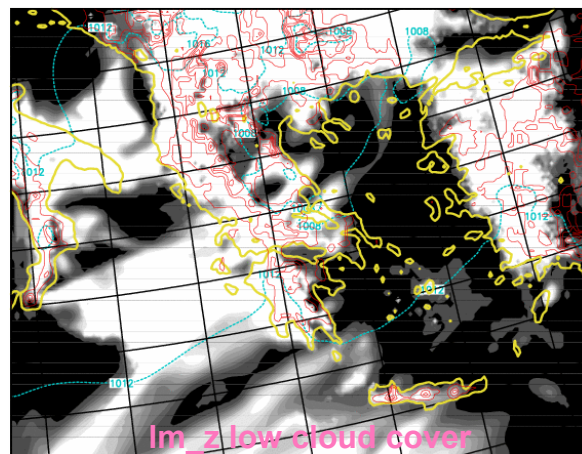
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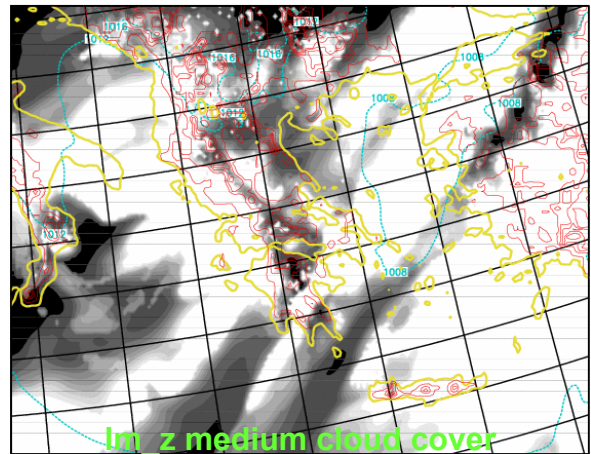
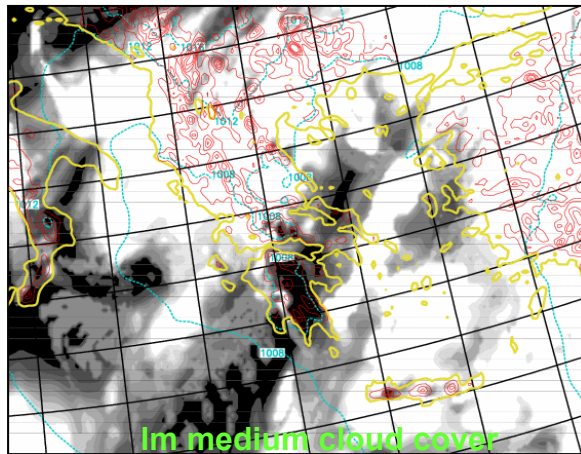
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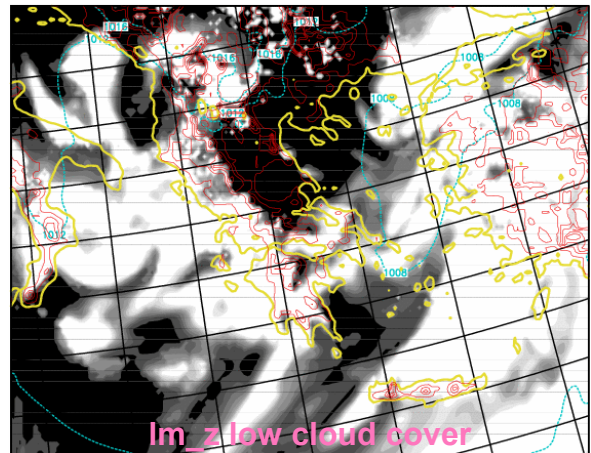
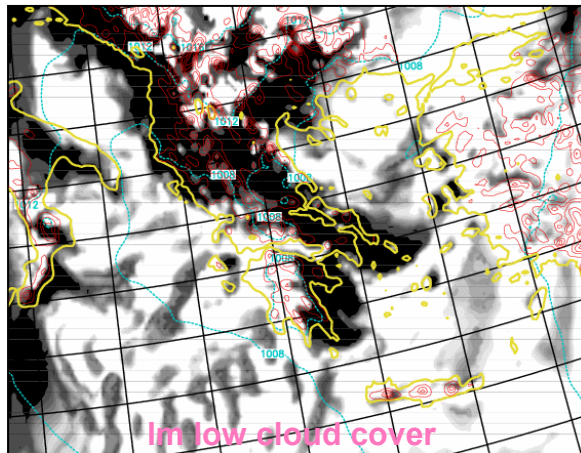
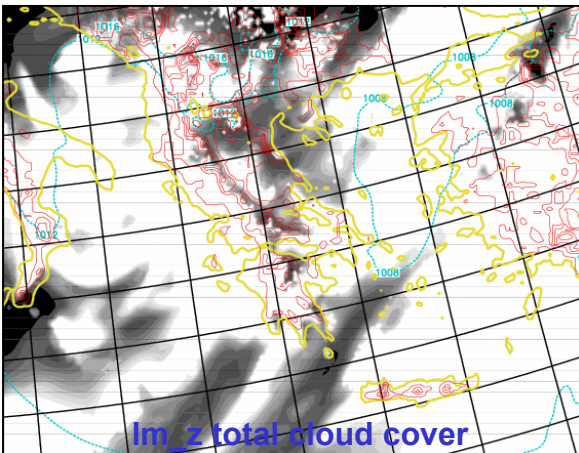
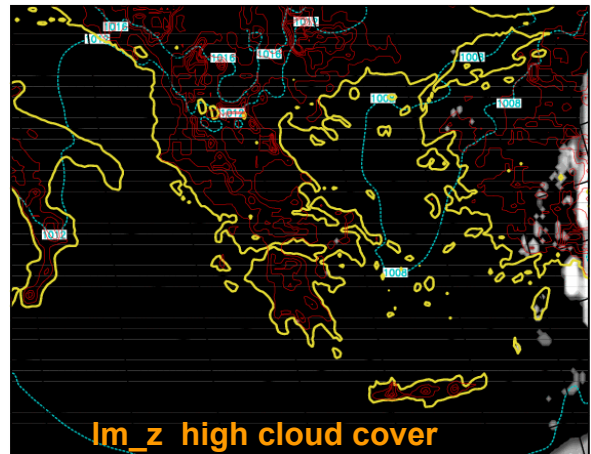
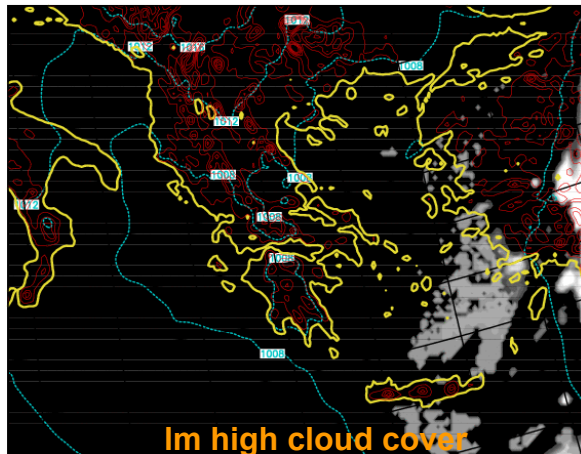
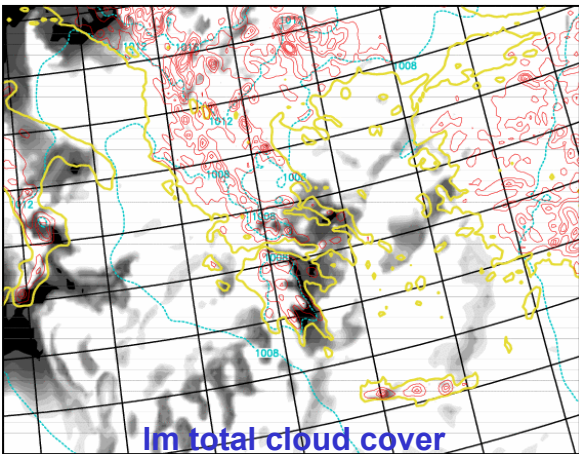
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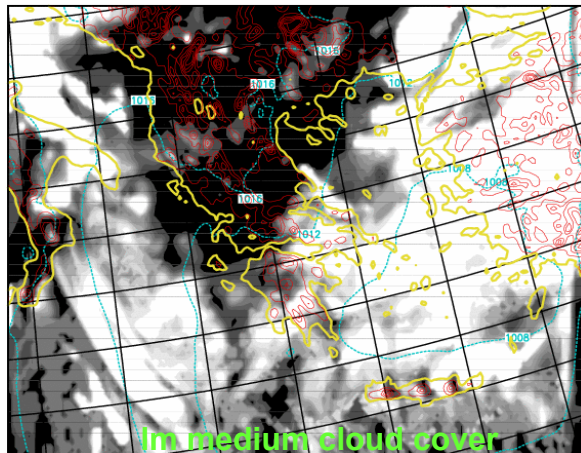
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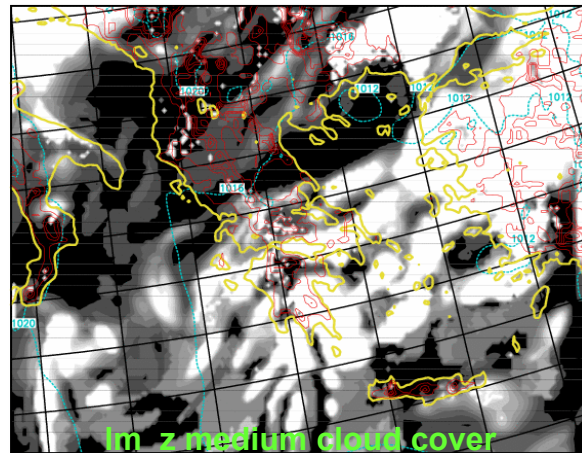


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Im medium cloud cover



Im_z medium cloud cover

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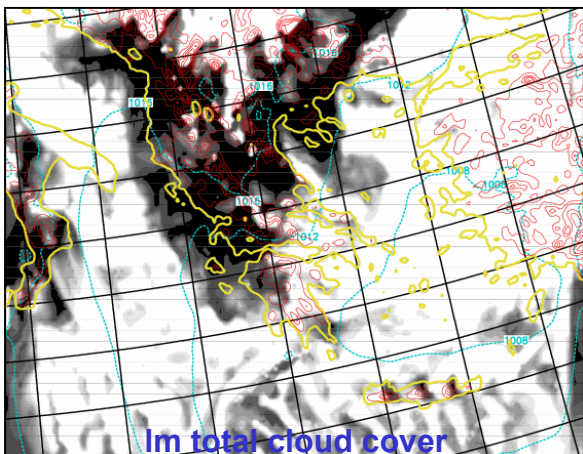
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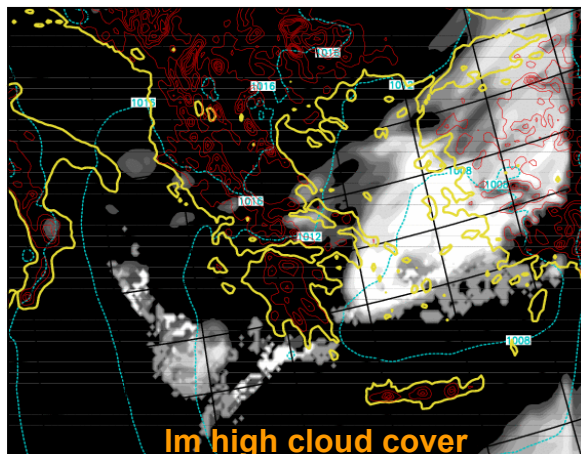
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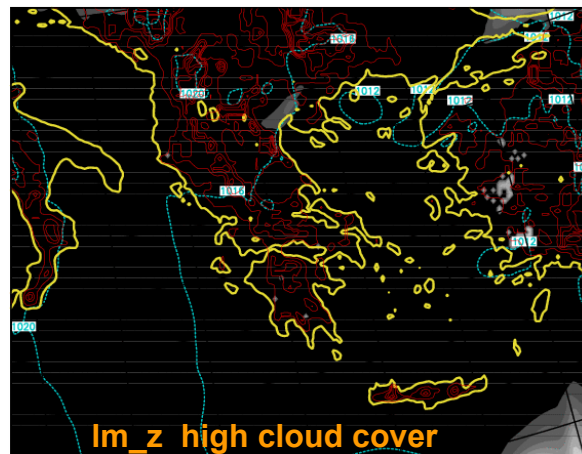
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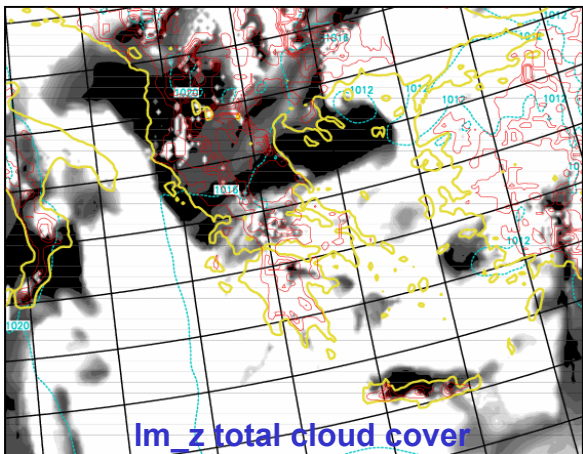
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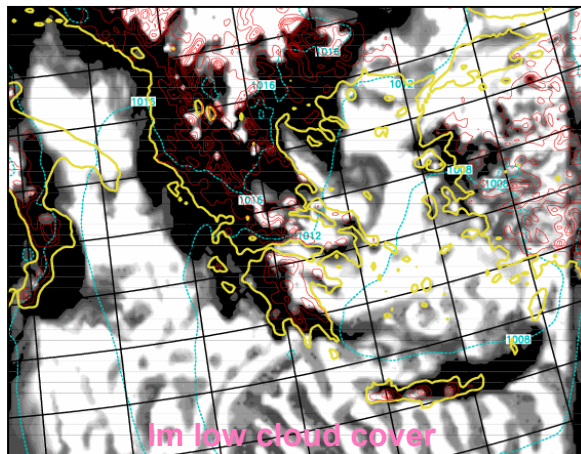
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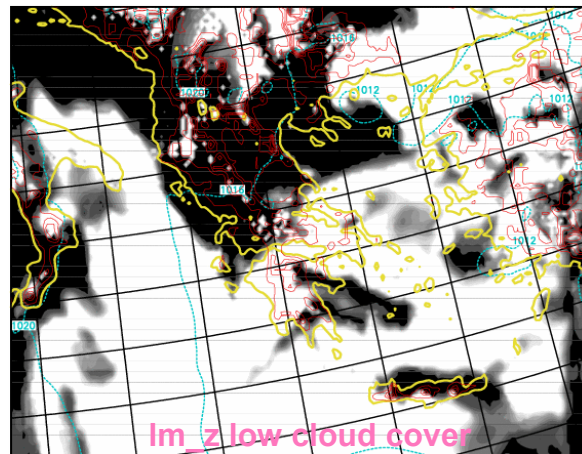
Im_z high cloud cover



Im_z total cloud cover



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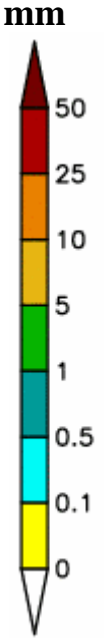
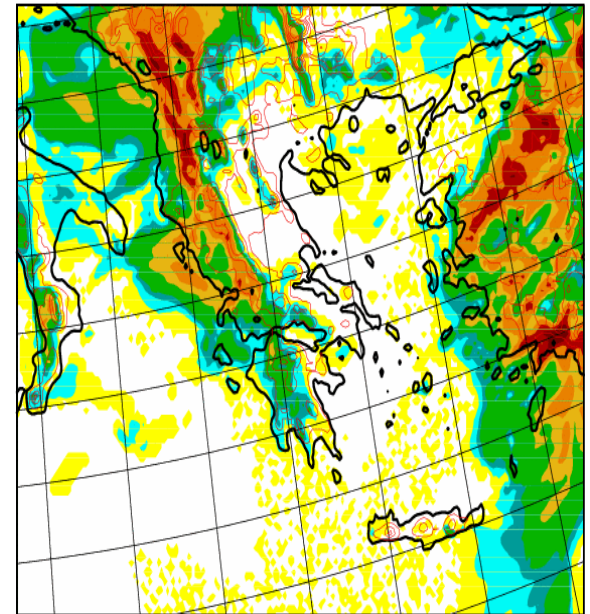
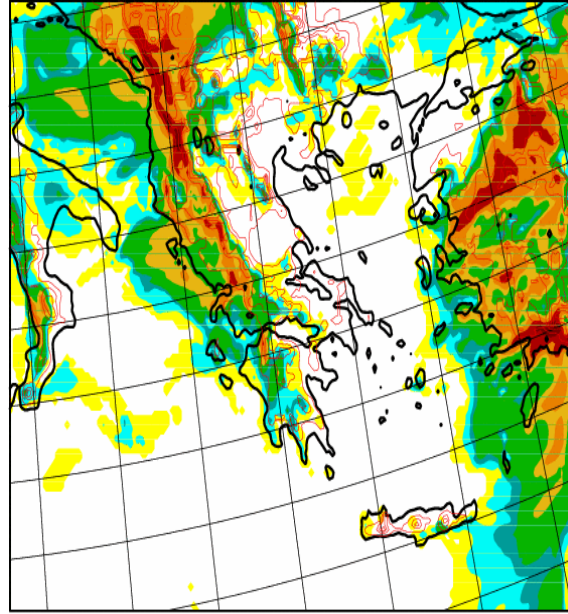
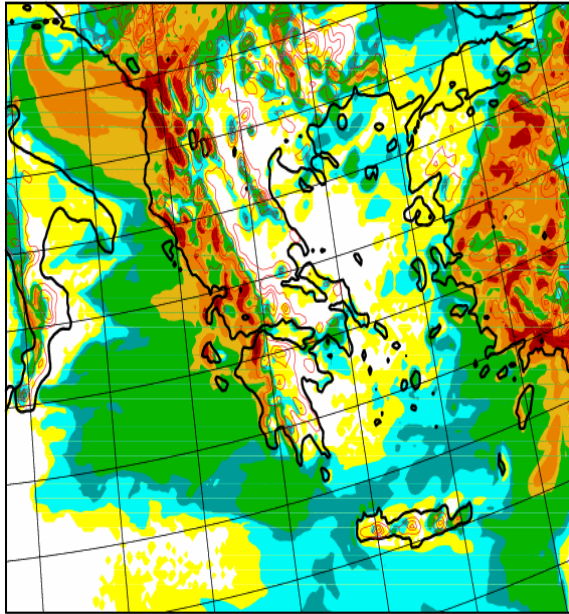


Im_z low cloud cover

LM_TF
Version 3.15

LM_Z
Version 1.4

LM_Z
Version 1.5

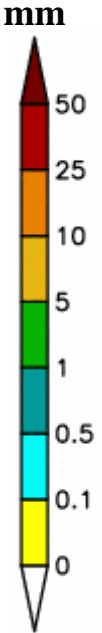
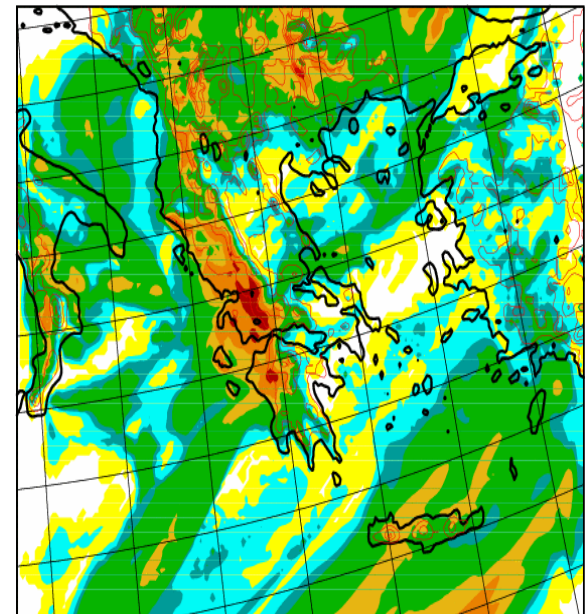
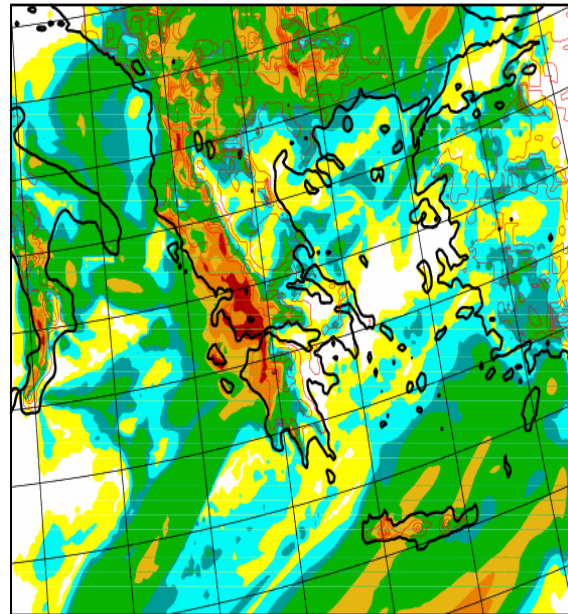
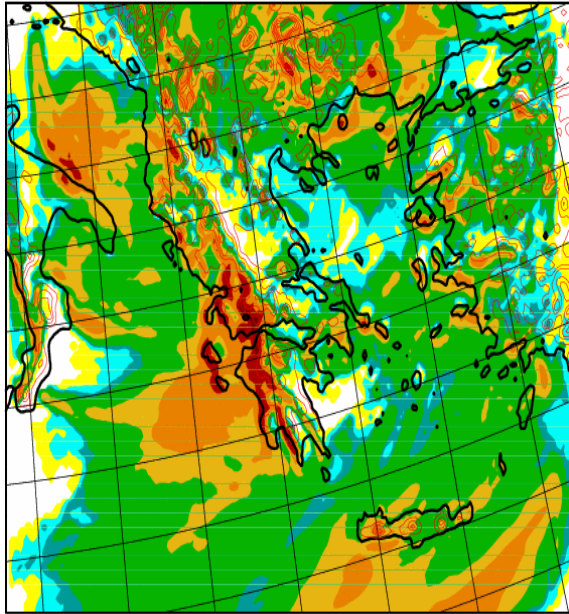


12h Accumulated Precipitation (in mm) for March 6 2005 06 to 18 UTC. The initial conditions are from the Global Model of DWD (00 UTC analysis, 24hr forecast).

LM_TF
Version 3.15

LM_Z
Version 1.4

LM_Z
Version 1.5

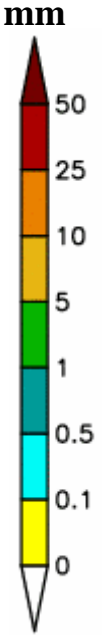
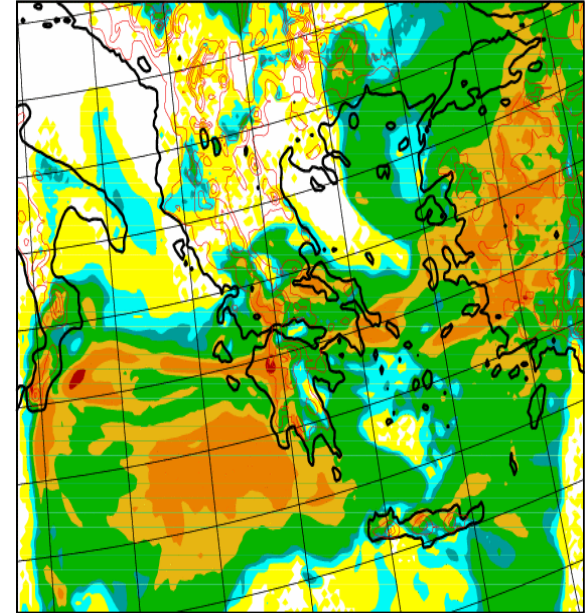
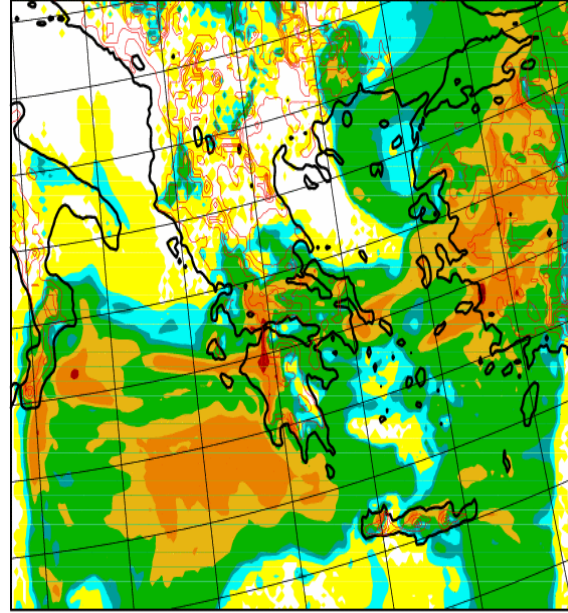
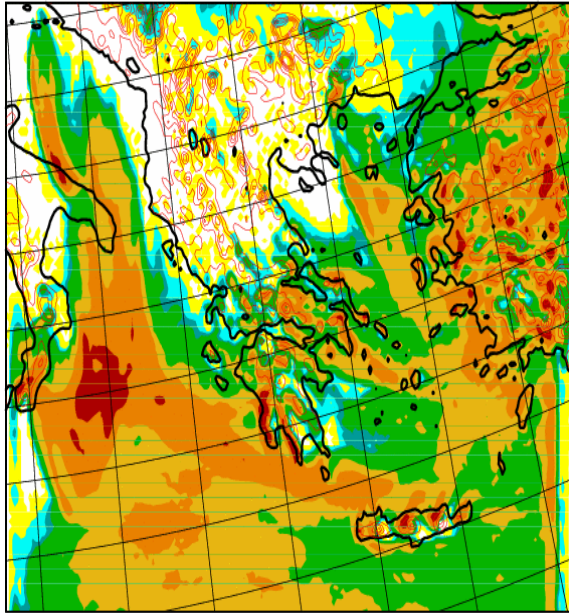


12h Accumulated Precipitation (in mm) for March 7 2005 06 to 18 UTC. The initial conditions are from the Global Model of DWD (00 UTC analysis, 24hr forecast).

LM_TF
Version 3.15

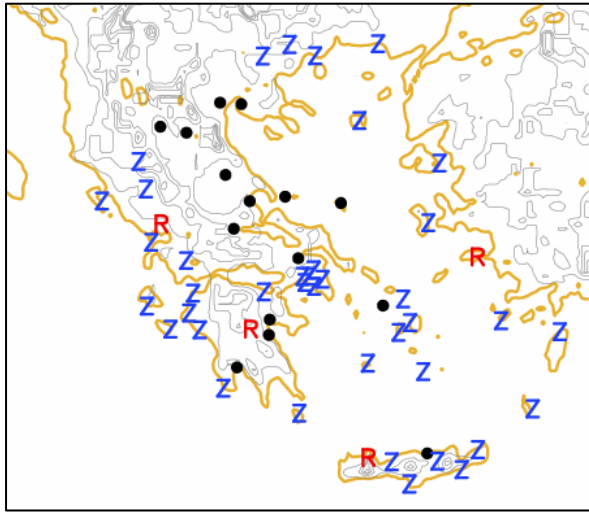
LM_Z
Version 1.4

LM_Z
Version 1.5

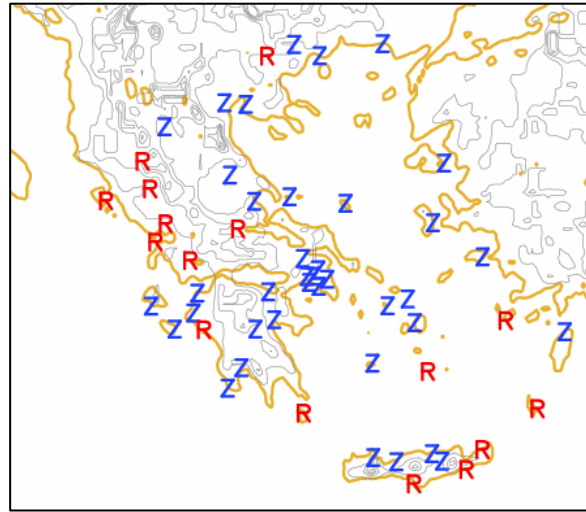


12h Accumulated Precipitation (in mm) for March 8 2005 06 to 18 UTC. The initial conditions are from the Global Model of DWD (00 UTC analysis, 24hr forecast).

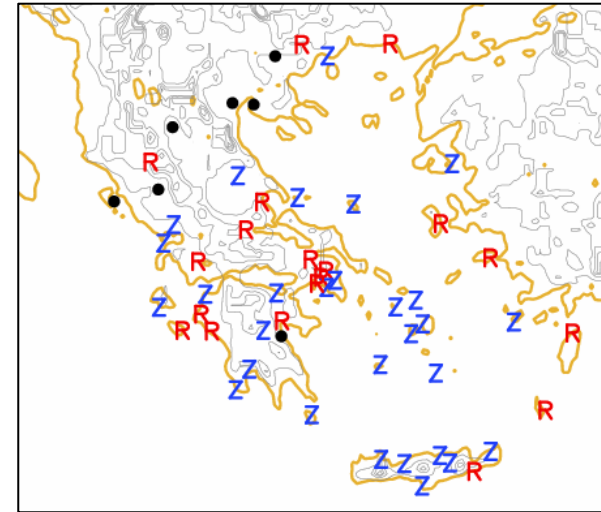
March 6 2005



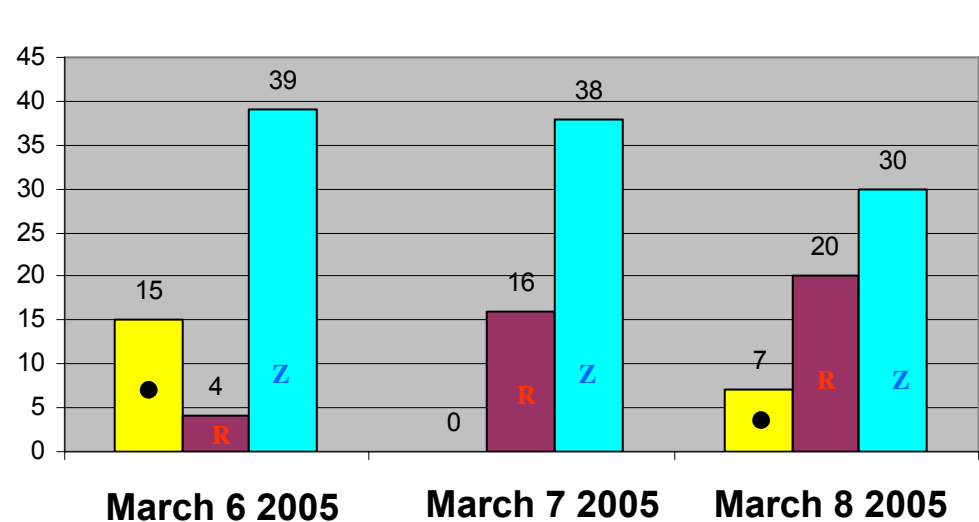
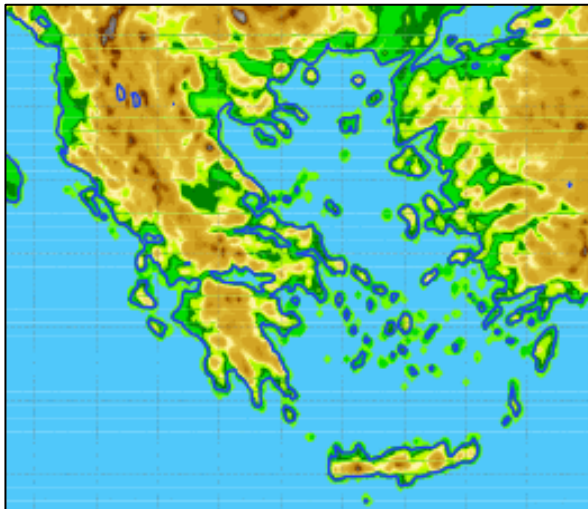
March 7 2005



March 8 2005



R: 12h forecasted accumulated precipitation from “Regular” LM is closer to observation
Z: 12h forecasted accumulated precipitation from LM_Z is closer to observation



Total, Average, Minimum and Maximum
observed and forecasted precipitation height (mm)

	March 06 (58 Stations)	March 07 (54 Stations)	March 08 (57 Stations)
Observed: Total	10.52	152.00	78.01
Average	0.18	2.82	1.37
Max	5	18	8
Min	0	0	0
LM_TF: Total	145.99	304.56	266.06
V_3.15 Average	2.52	5.64	4.67
Max	23.80	41.61	27.8
Min	0	0	0
LM_Z: Total	36.87	167.82	155.57
V_1.4 Average	0.64	3.11	2.73
Max	7.59	25.54	15,8
Min	0	0	0
LM_Z: Total	48.05	152.21 (!!)	171.80
V_1.5 Average	0.83	2.82 (!!)	3.01
Max	16.24	19.10	15.65
Min	0	0	0

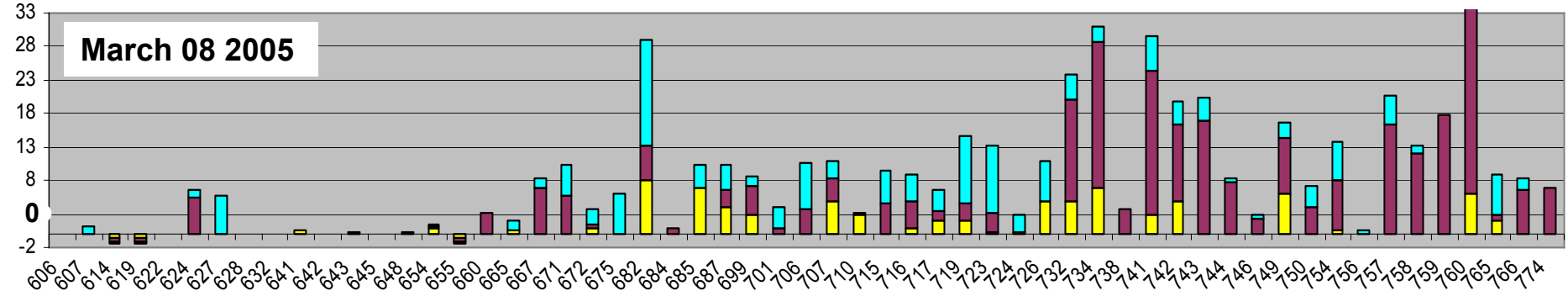
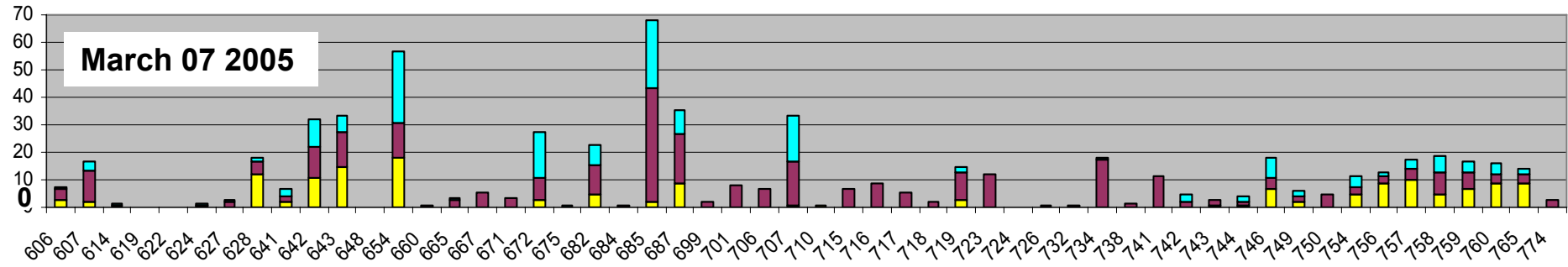
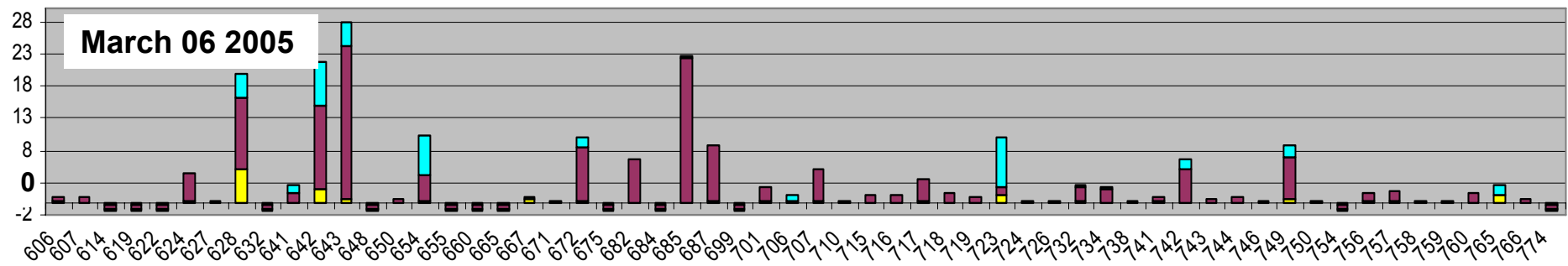
Threat Scores (TS)

Precipitation Threshold (mm)	March 06			March 07			March 08		
	LM_TF V_3.15	LM_Z V_1.4	LM_Z V_1.5	LM_TF V_3.15	LM_Z V_1.4	LM_Z V_1.5	LM_TF V_3.15	LM_Z V_1.4	LM_Z V_1.5
1 (Hits,Obs,False)	13 (3,4,20)	40 (4,4,6)	38 (3,4,4)	56 (23,23,18)	80 (20,23,2)	81 (22,23,4)	39 (14,18,18)	43 (16,18,19)	44 (16,18,18)
2 (Hits,Obs,False)	13 (2,2,14)	40 (2,2,3)	40 (2,2,4)	57 (21,21,16)	74 (17,21,2)	72 (18,21,4)	31 (11,16,19)	47 (14,16,14)	41 (14,16,18)
3 (Hits,Obs,False)	8 (1,1,12)	20 (1,1,4)	20 (1,1,4)	45 (14,17,14)	63 (12,17,2)	60 (12,17,3)	30 (9,13,17)	29 (8,13,15)	30 (9,13,17)
4 (Hits,Obs,False)	8 (1,1,11)	0 (0,1,3)	20 (1,1,4)	28 (8,14,15)	53 (9,14,3)	41 (7,14,3)	25 (6,10,14)	14 (3,10,11)	20 (5,10,15)
5 (Hits,Obs,False)	10 (1,1,9)	0 (0,1,3)	20 (1,1,4)	25 (7,14,14)	41 (7,14,3)	35 (6,14,3)	29 (6,9,12)	17 (3,9,9)	17 (3,9,9)

$$TS = \frac{\text{Hits}}{\text{Observations} + \text{False Alarms}} \times 100$$

Hits: Cases where Obs and Fcast values \geq Threshold
 Observations: Cases where Obs values \geq Threshold
 False Alarms: Cases where Obs values $<$ Threshold and
 Fcast values $>$ Threshold

mm



Station #

- LM_z
- LM_tf
- OBS

- Observed and Forecasted Precipitation Heights (06-18 UTC) from LM_Z and LM.
- Columns below 0th horizontal correspond to no observed or forecasted precipitation.
- Stations with no precipitation shown correspond to traces of observed but no forecasted precipitation.

Test Case #2

Synoptic Description

- ◆ We investigate the weather development over Greece during the three day period of 17, 18 and 19 November 2005.

17 November 2005

500 hpa:

- W/SW stream over Greece becoming gradually SW associated with geopotential and temperature fall in the NW/SE direction.
- A first “trough” already affecting the NW parts of Greece.
- A second “trough”, located over the Central Mediterranean, is moving in the E/NE direction passing over S parts of Greece.

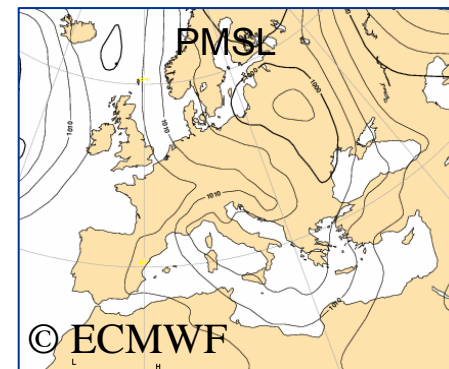
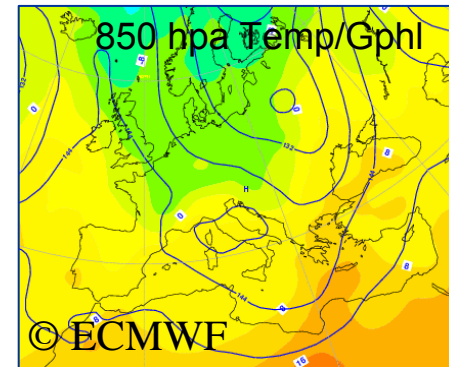
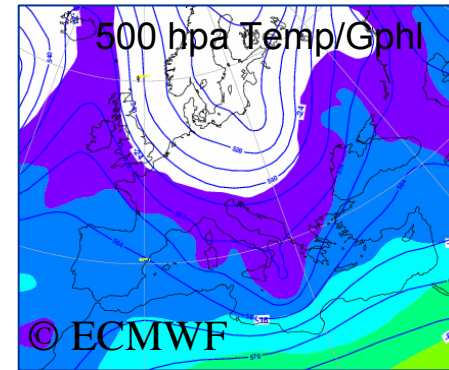
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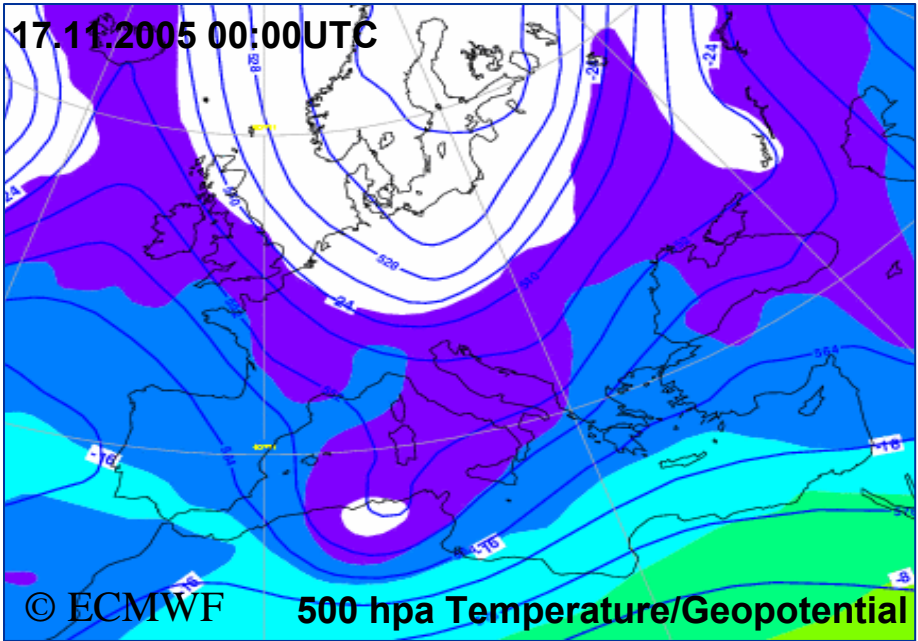
- Thermal “ridge” over E parts of Greece.
- Cold advection from NW to SE with consequent temperature fall, mainly in the second part of the day.

Surface:

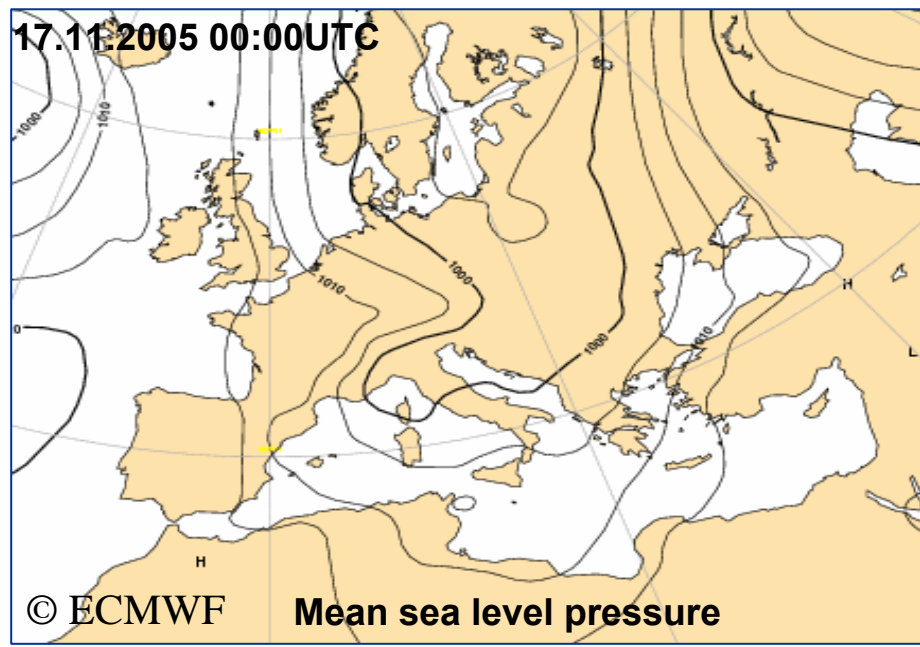
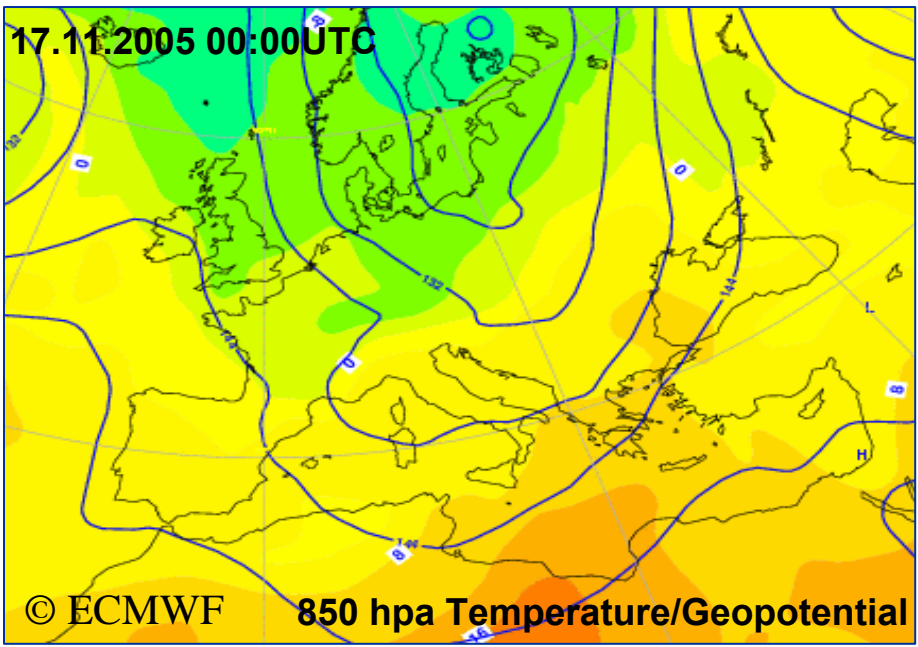
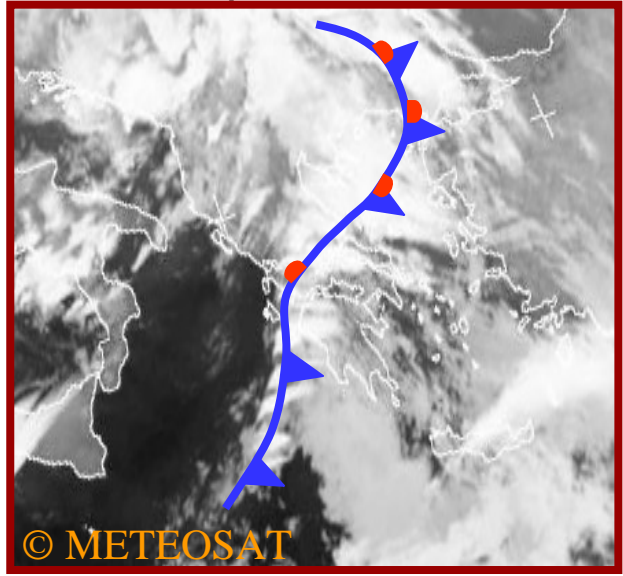
- Low barometric pressures in the Adriatic and N Balkans extended S are associated with relatively high pressures in Turkey.
- Strong to gale winds over E Greece.
- Cold front over W Greece moving E.
- A barometric low developed over the Ionian is moving E.

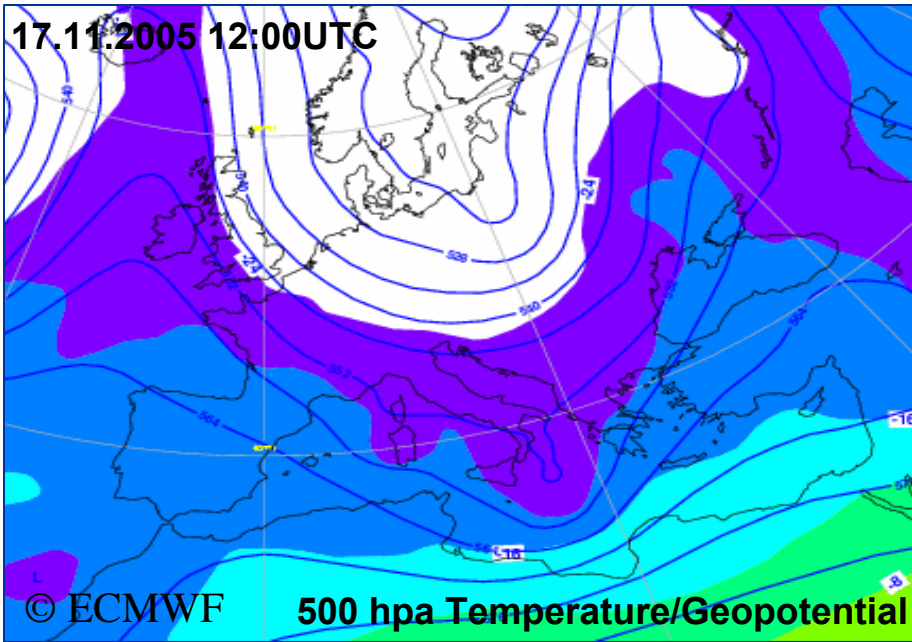
12UTC



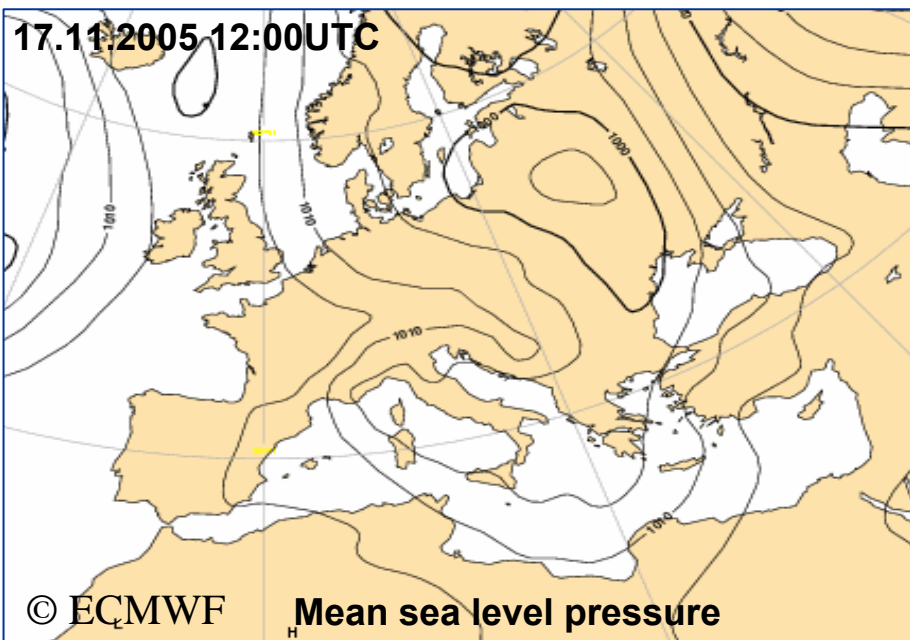
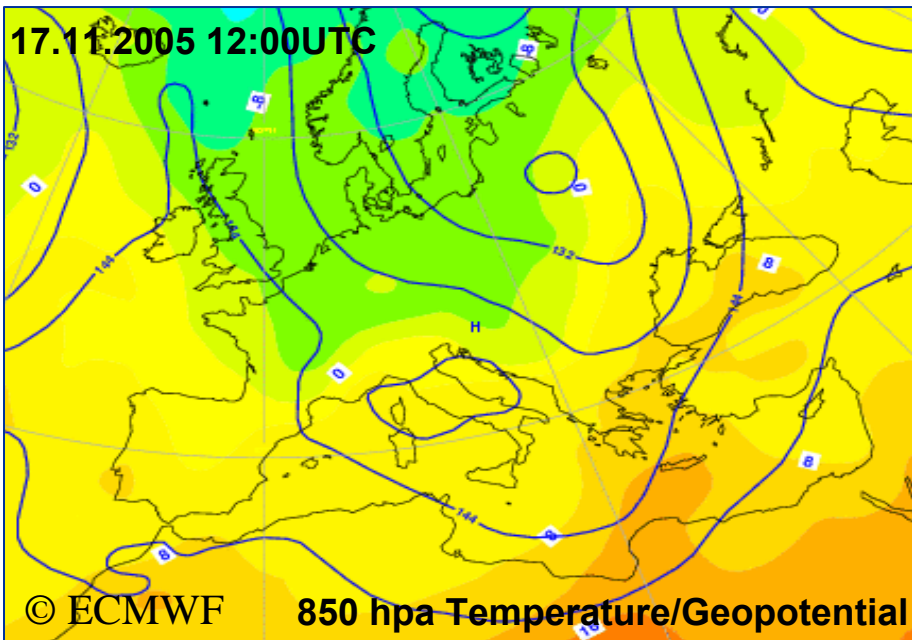
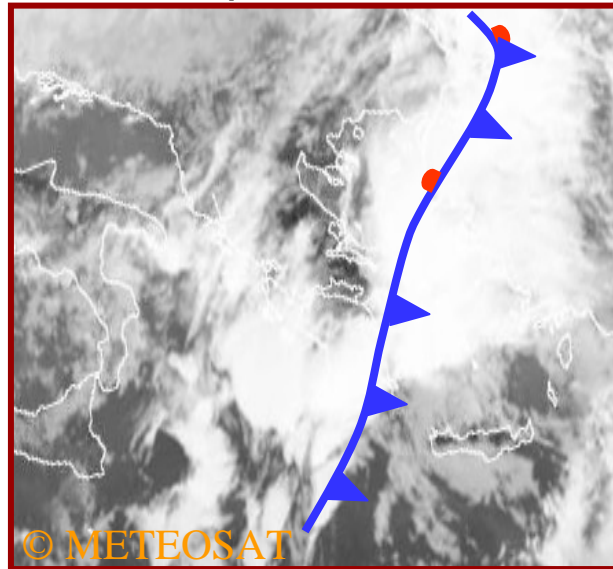


MSG IR 10.8 μm 17.11.2005 00:00UTC





MSG IR 10.8 μm 17.11.2005 12:00UTC



18 November 2005

500 hpa:

- There is a “trough” over SE Greece moving E fast.
- Prevailing NW winds.
- Progressive anticyclonic circulation.
- Geopotential and temperature are rising.

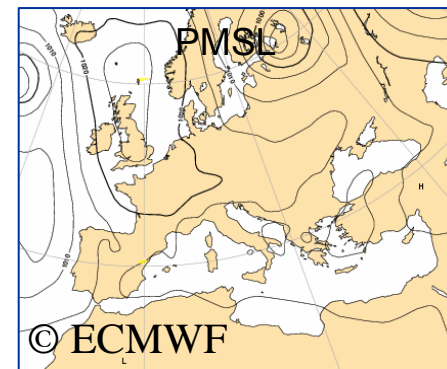
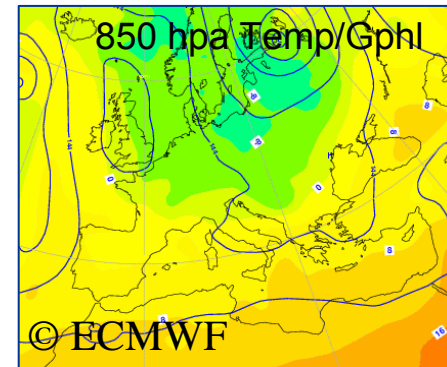
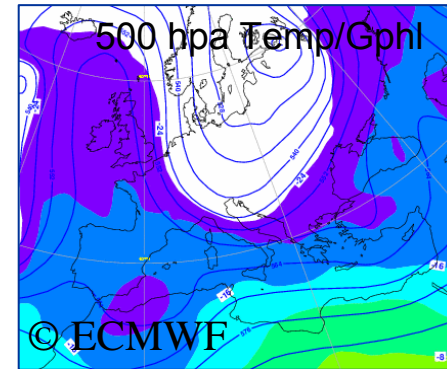
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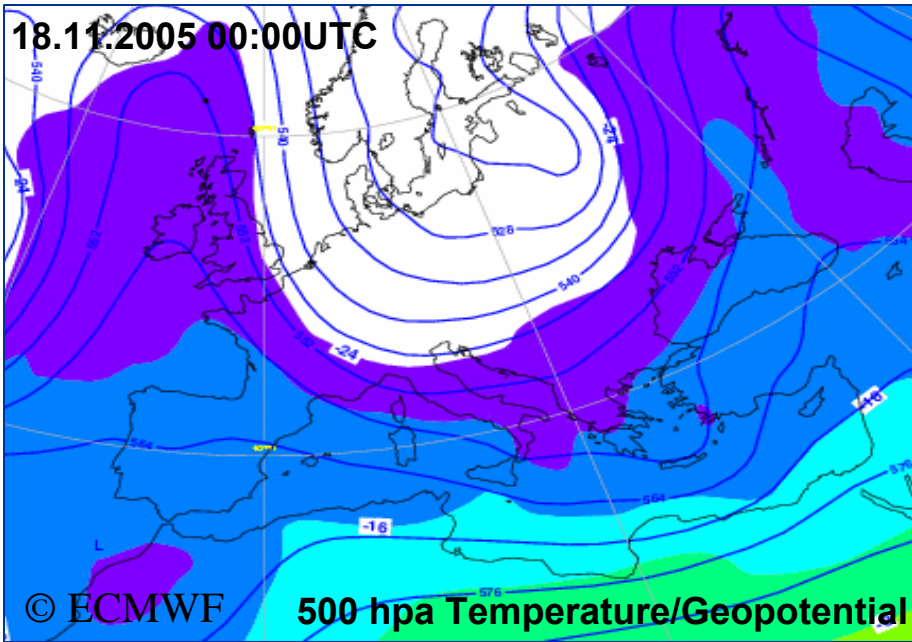
- Relatively warm air masses over Greece and cold over N Balkans and N Italy.

Surface:

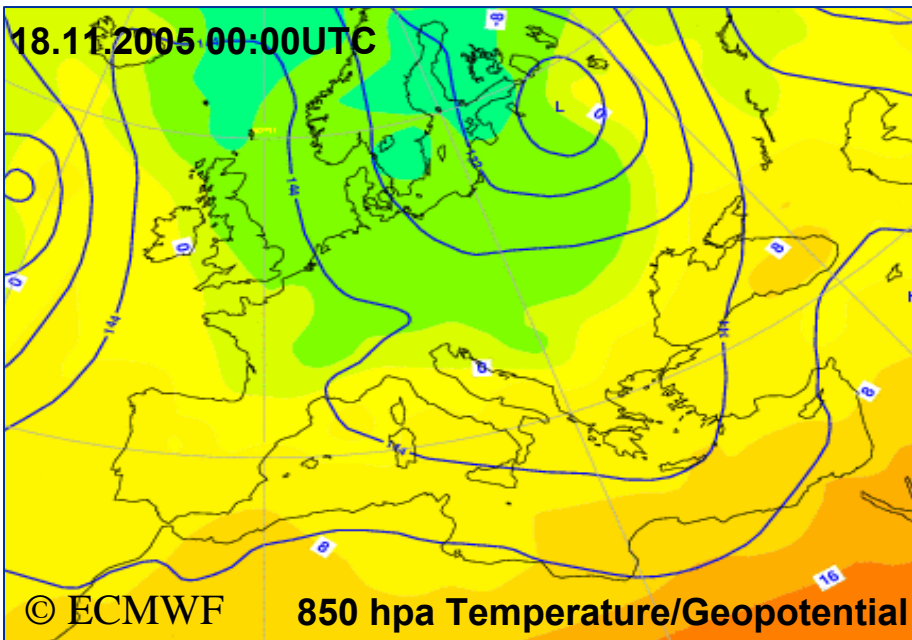
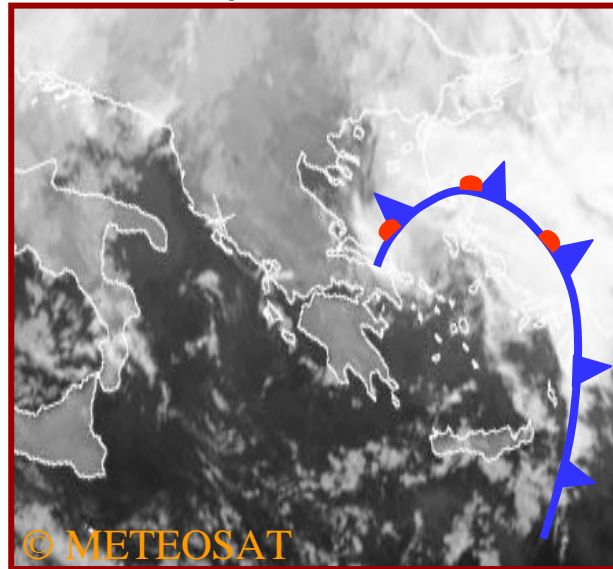
- The barometric lows over N Aegean and S Italy are filling up.

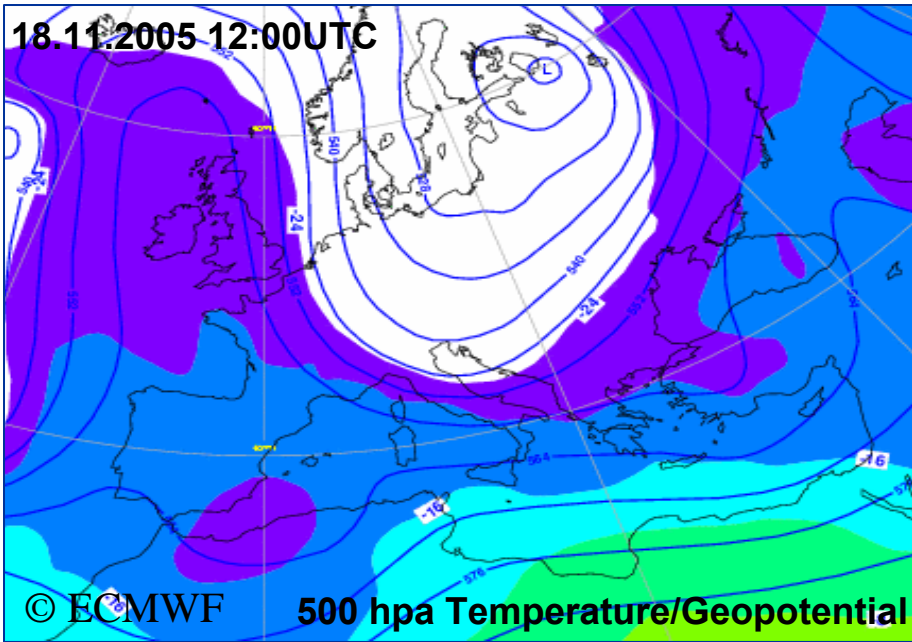
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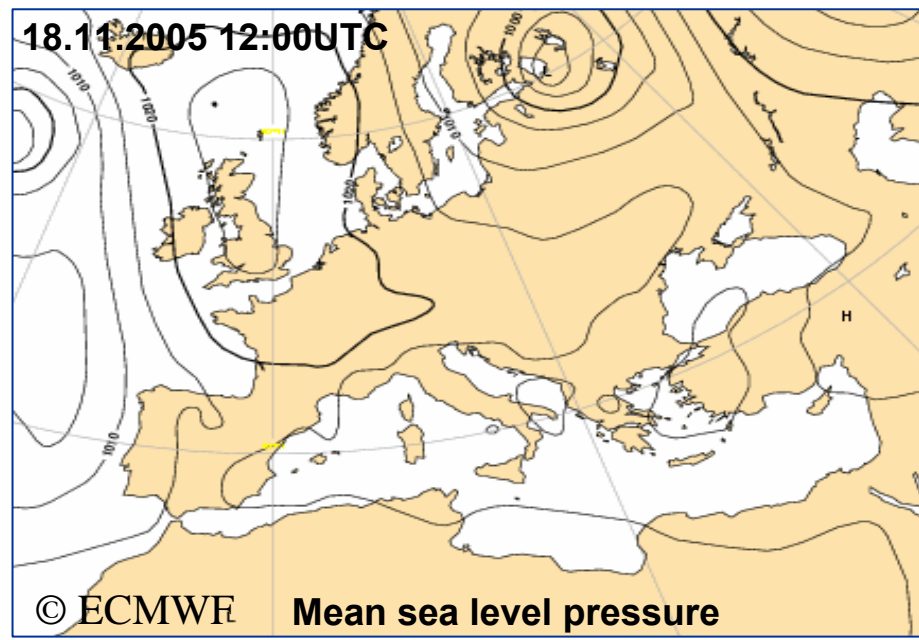
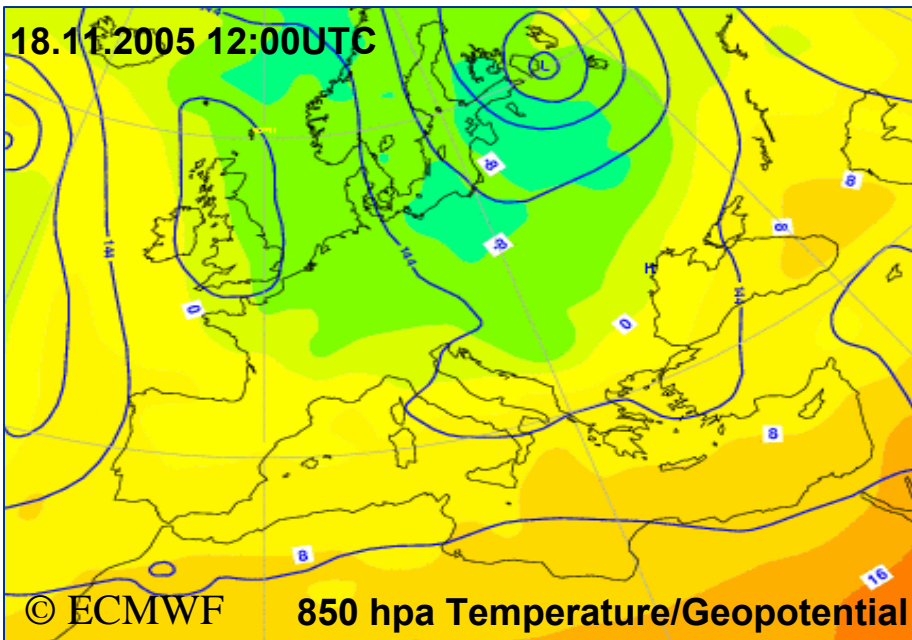
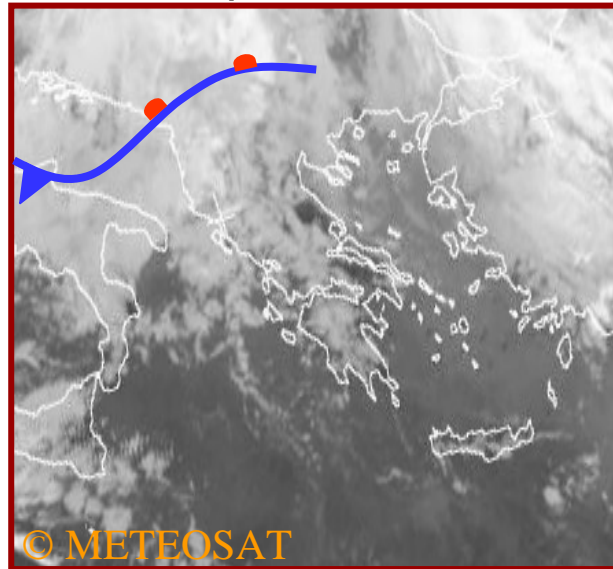


MSG IR 10.8 μm 18.11.2005 00:00UTC





MSG IR 10.8 μm 18.11.2005 12:00UTC



19 November 2005

500 hpa:

- Cold air masses from N and C Europe are moving S towards the Balkans.
- Geopotential and temperature fall over Greece.
- Cyclonic circulation.

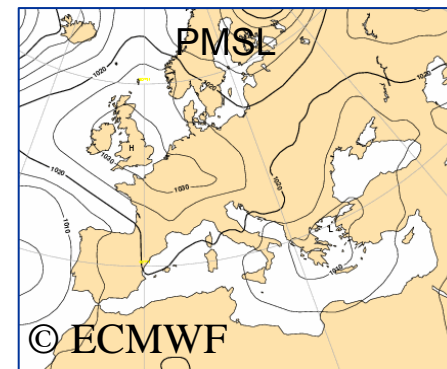
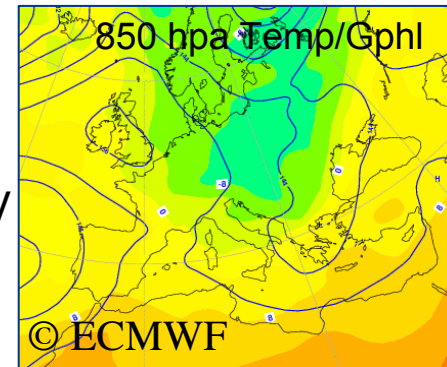
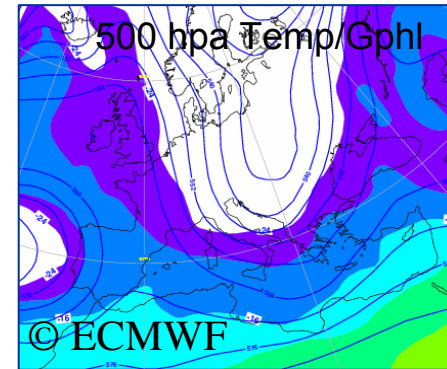
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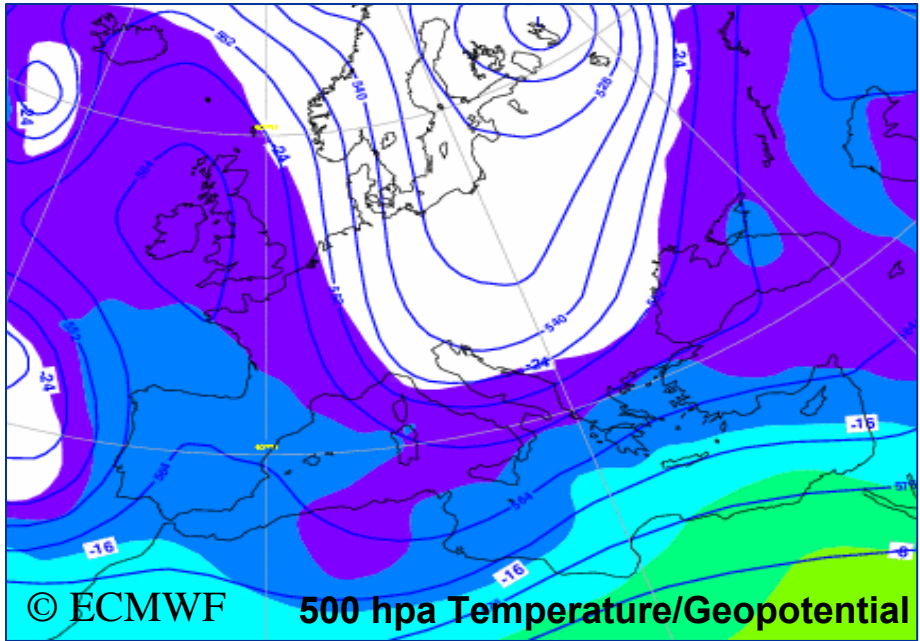
- Initially, temperature rising over E and N Greece.
- Cold advection over NW Greece.
- Significant temperature fall over N Greece progressing gradually over the country.

Surface:

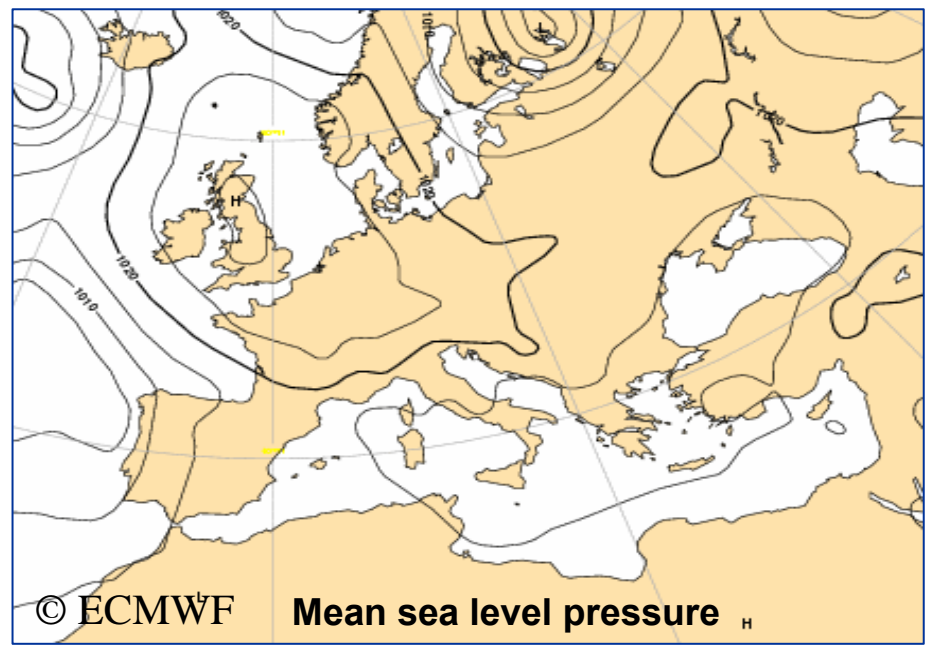
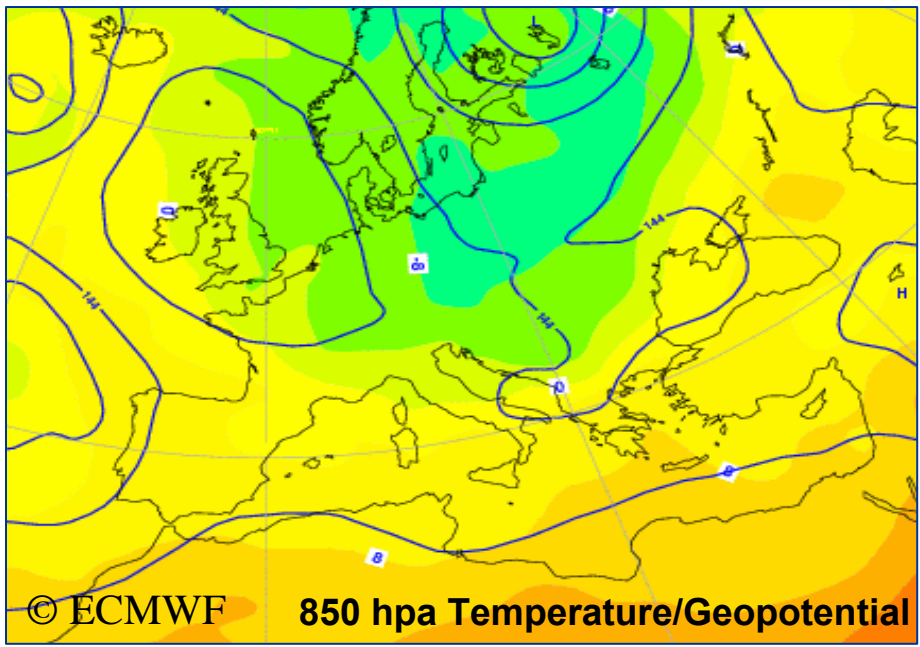
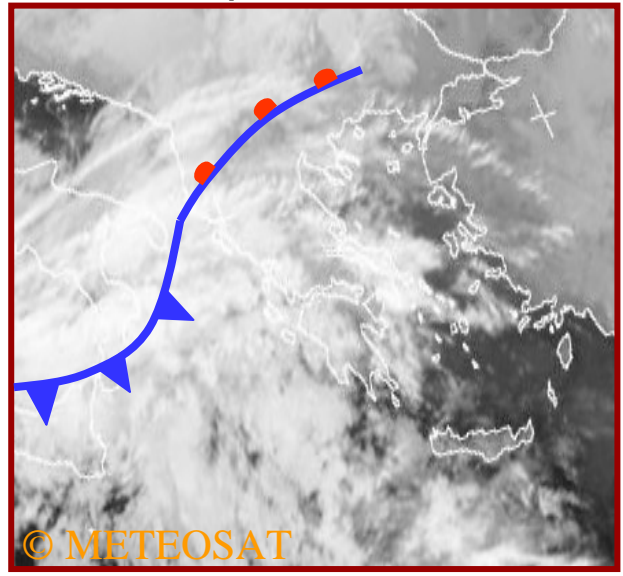
- Low barometric pressures over N Aegean and N Italy with frontal activity moving E affecting Greece.

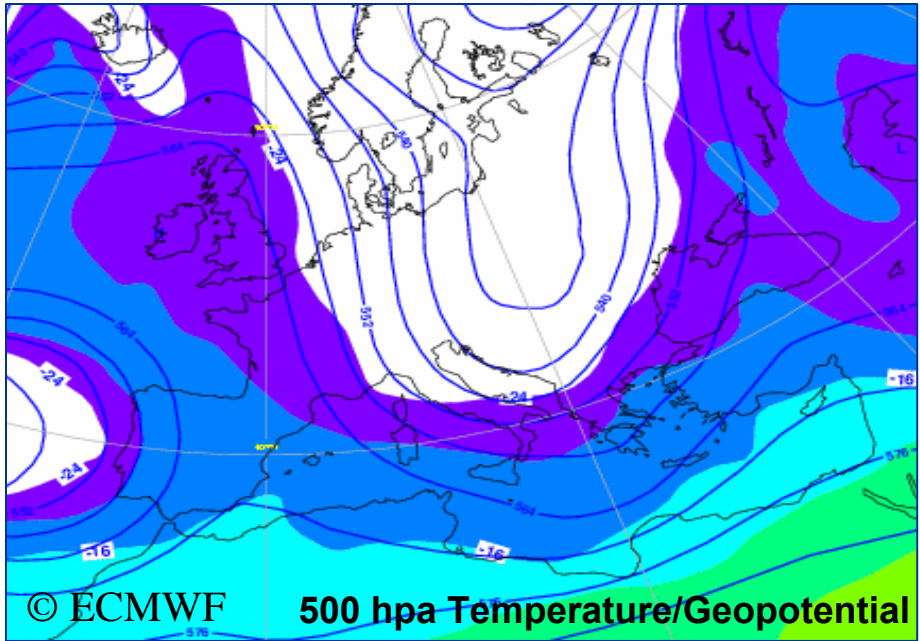
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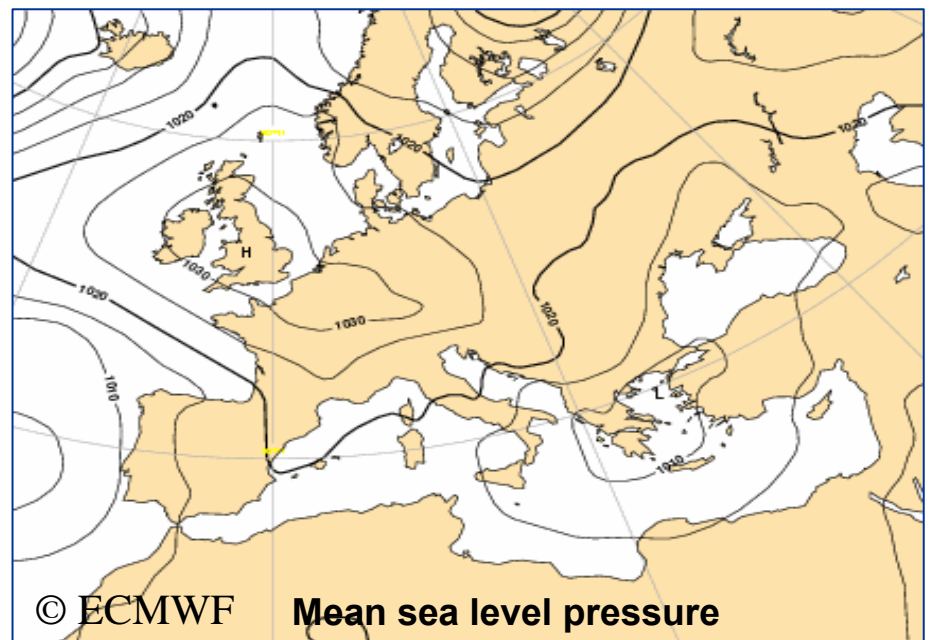
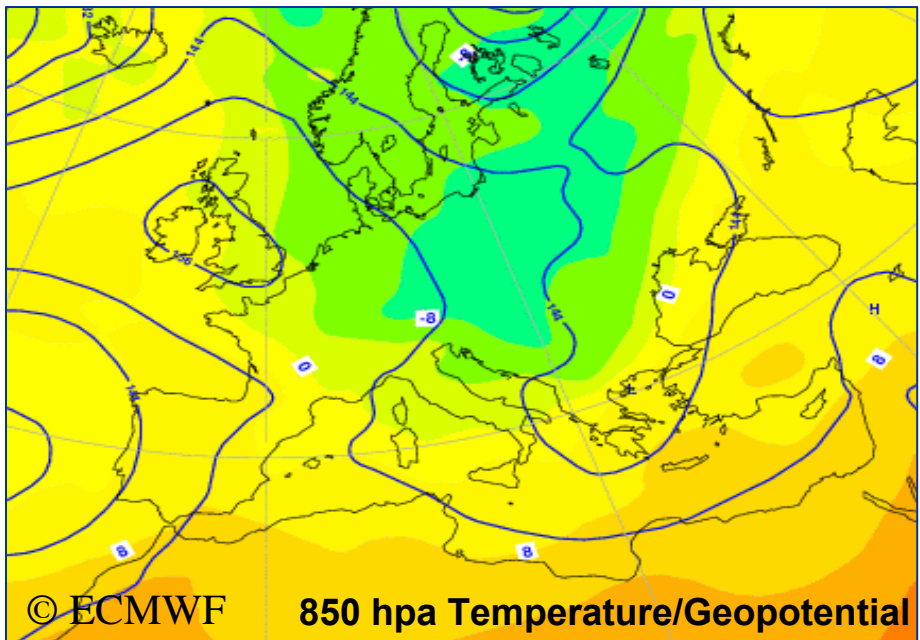
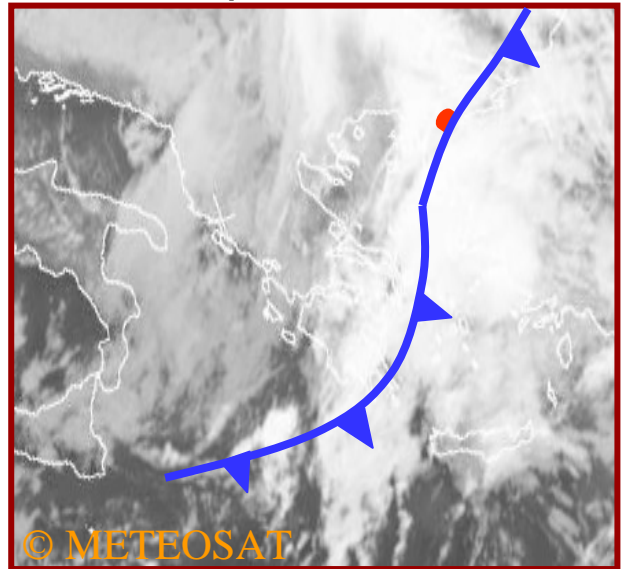


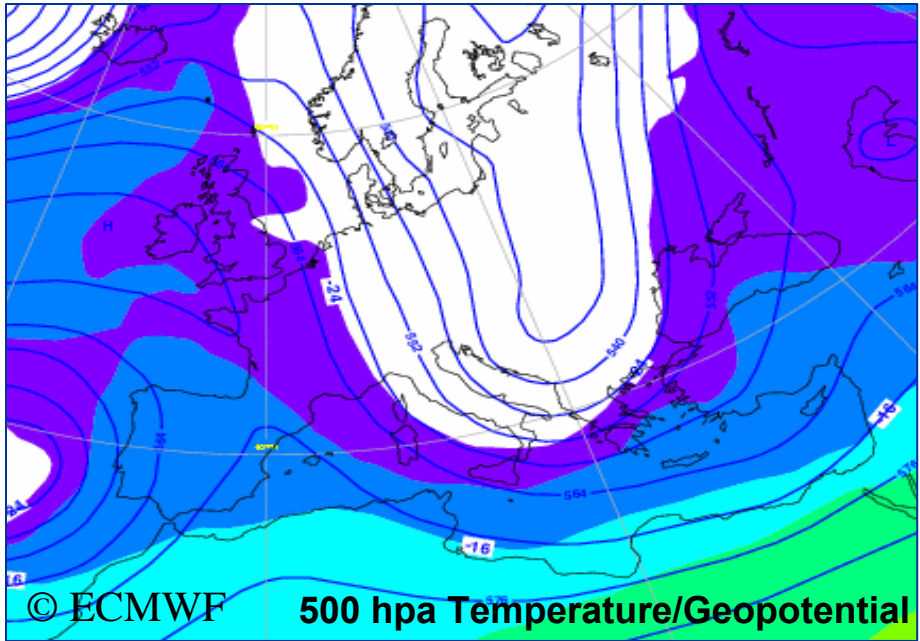
MSG IR 10.8 μm 19.11.2005 00:00UTC



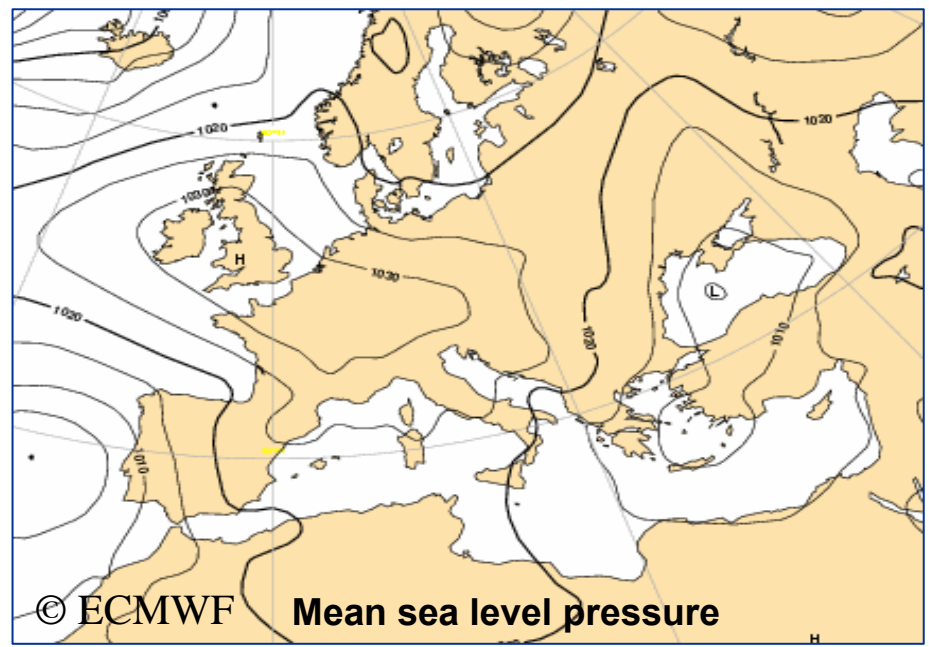
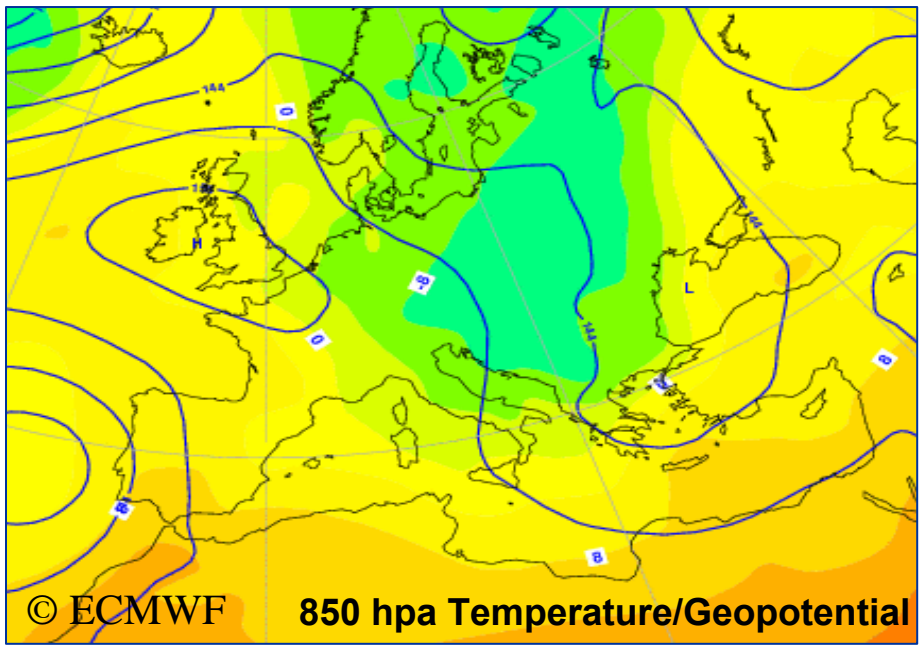
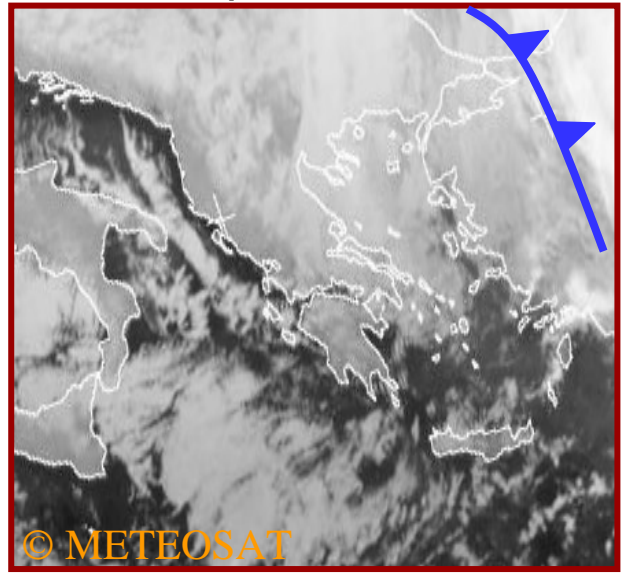


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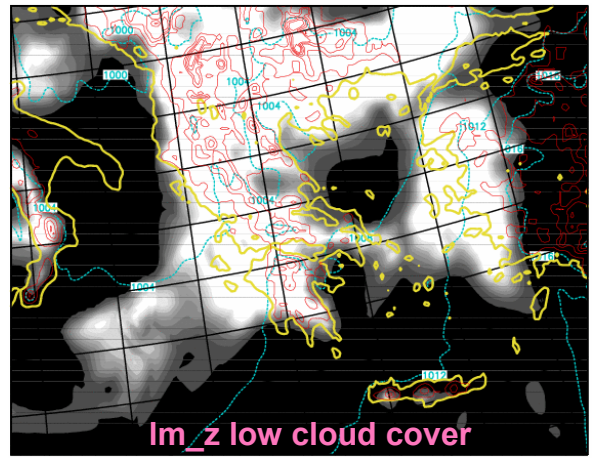
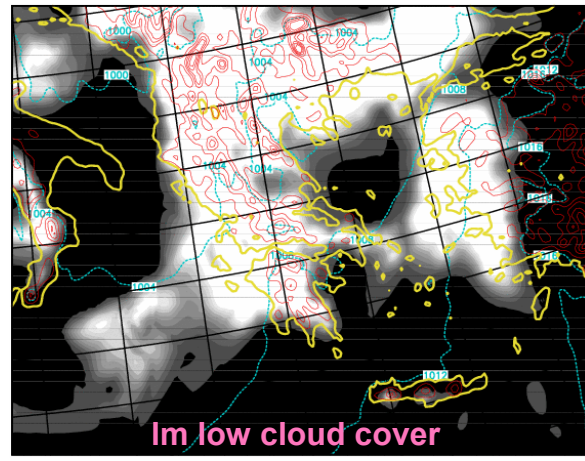
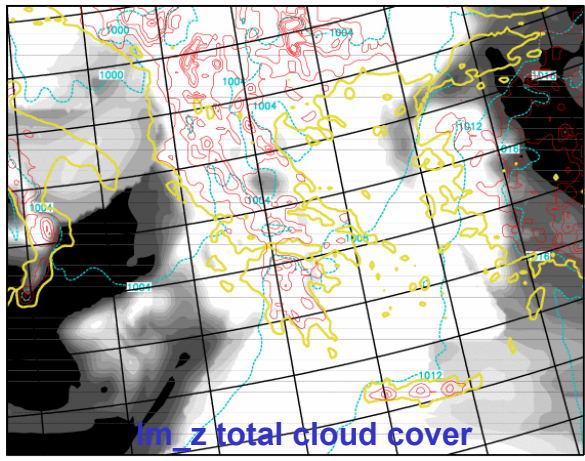
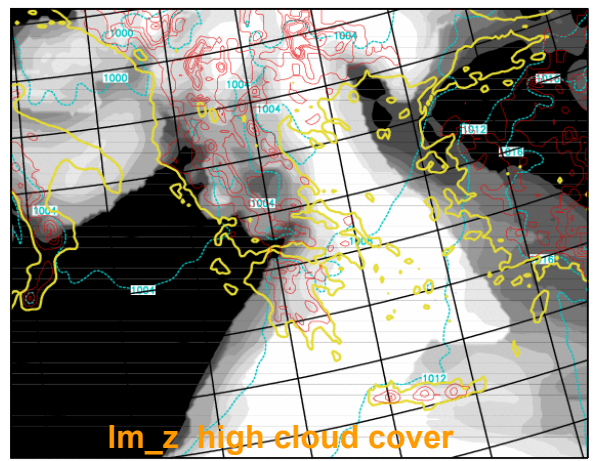
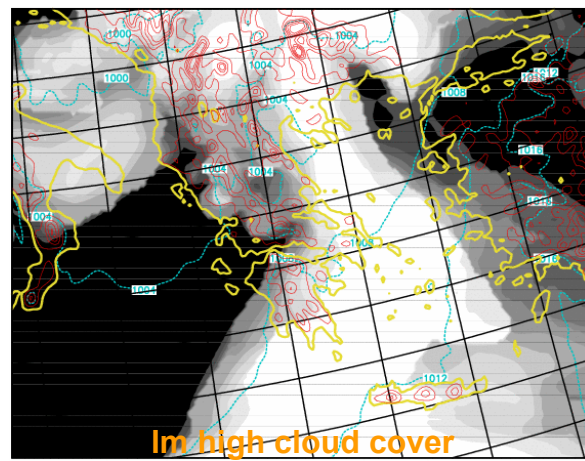
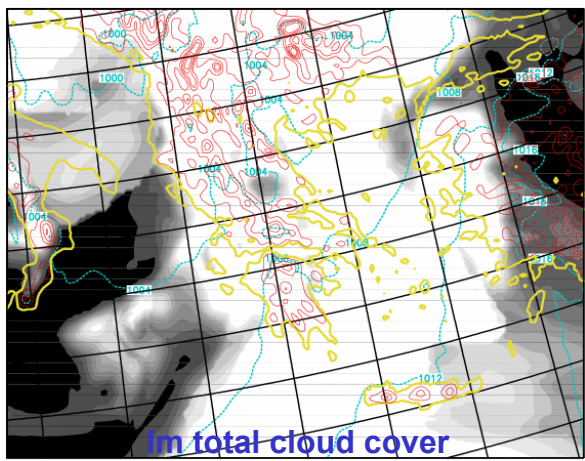
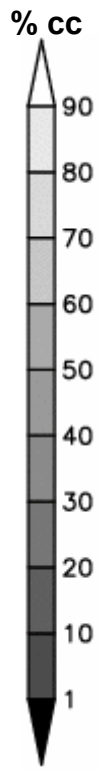
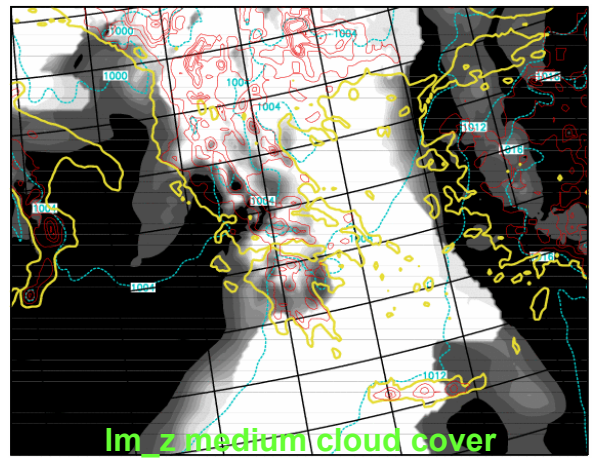
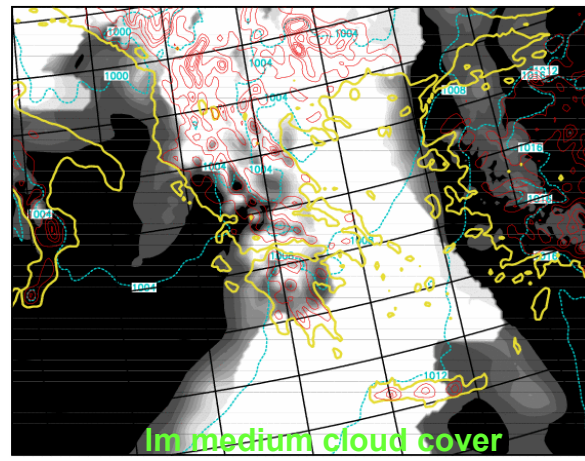


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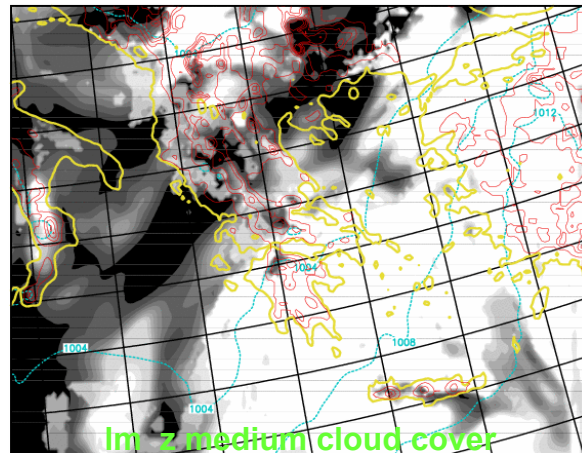
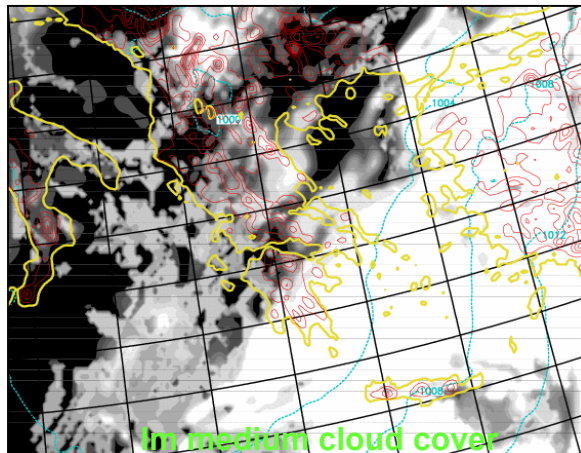
MSG IR 10.8 μm 17.11.2005 00:00

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MSG IR 10.8 μm 17.11.2005 12:00

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% CC

90

80

70

60

50

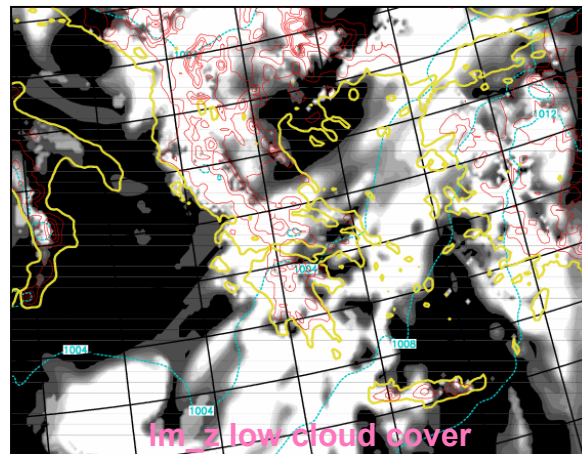
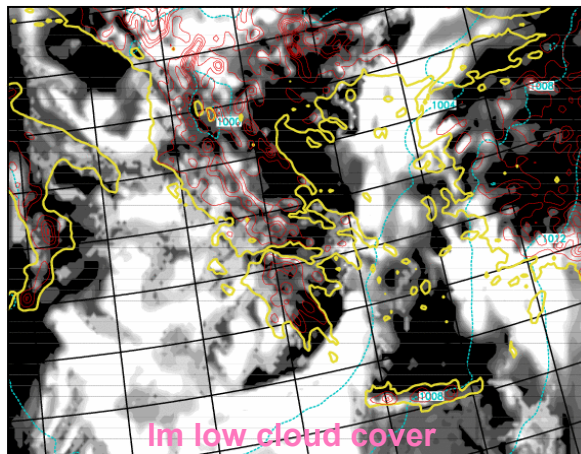
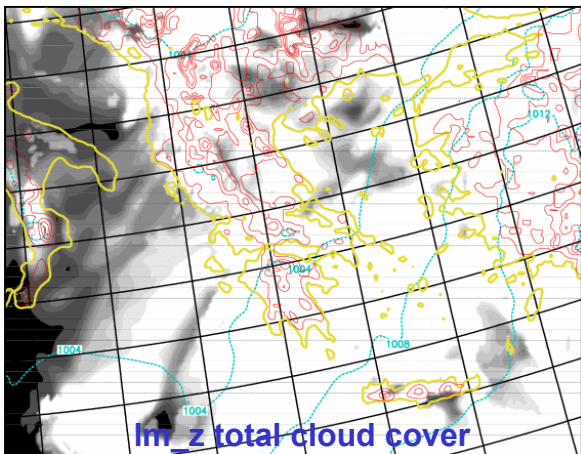
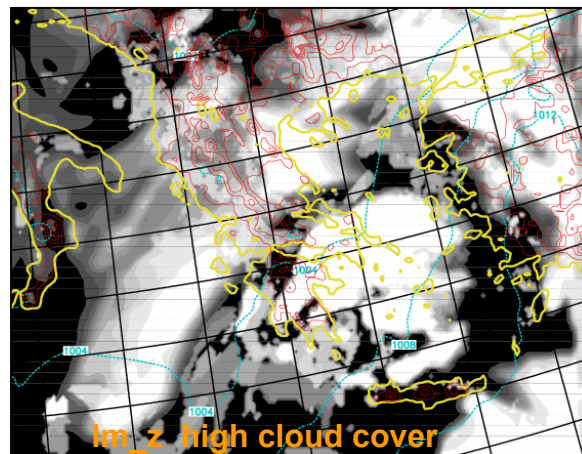
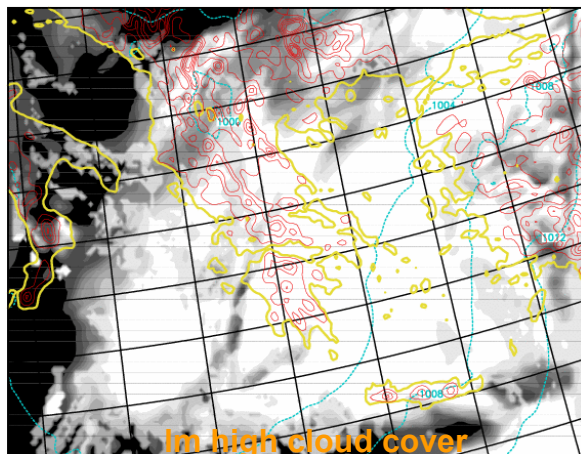
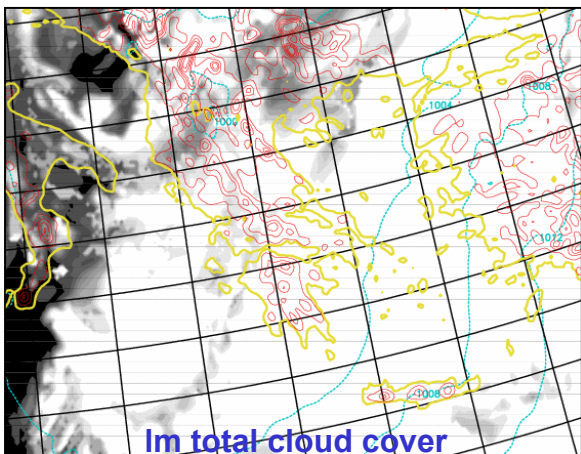
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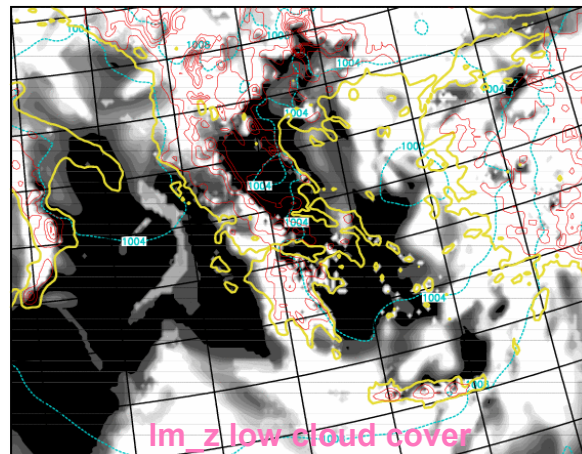
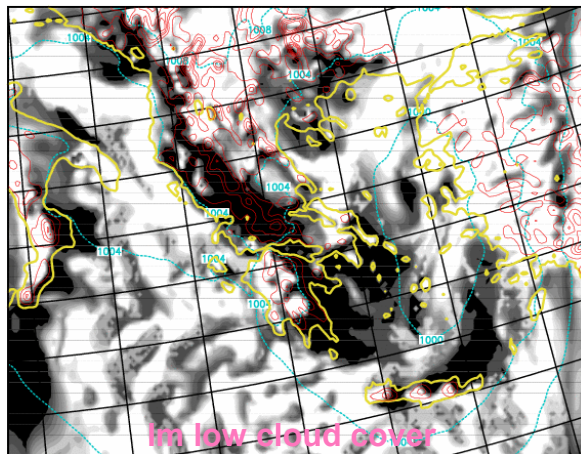
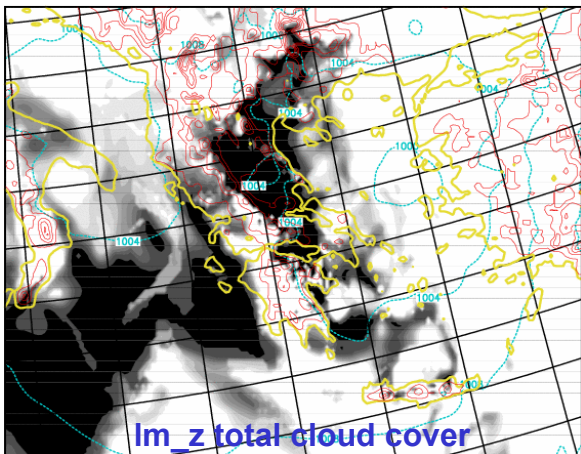
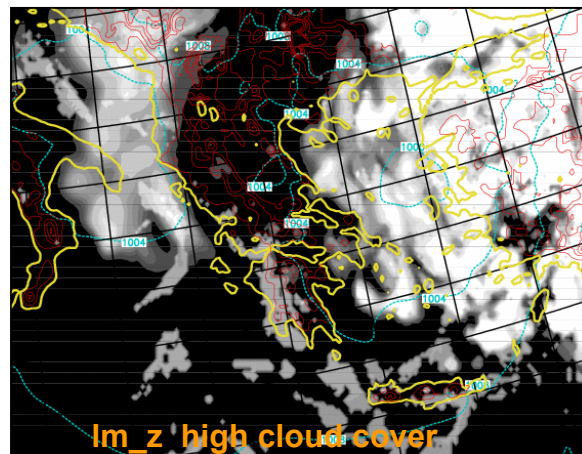
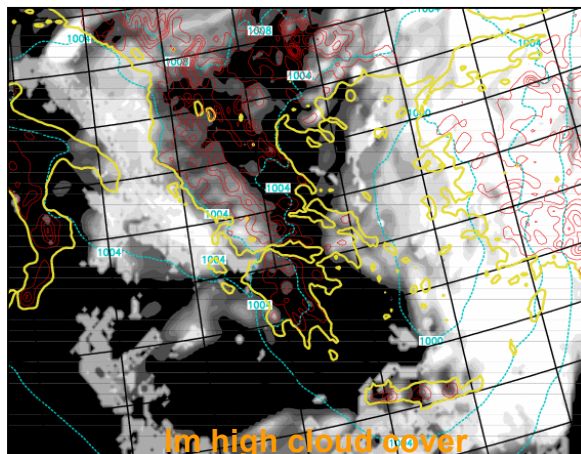
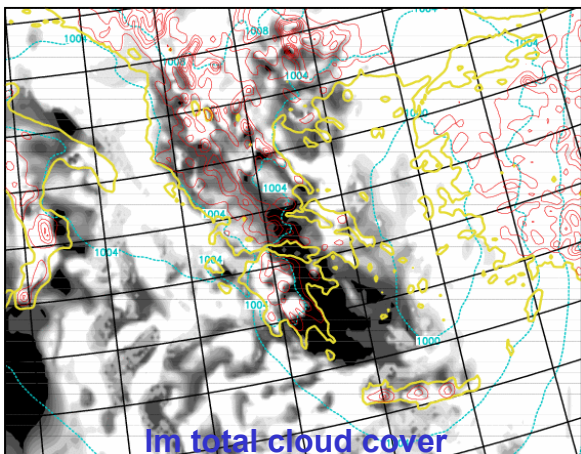
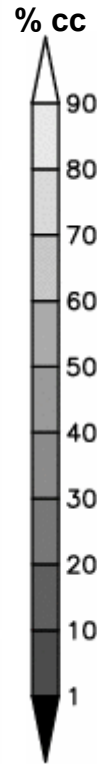
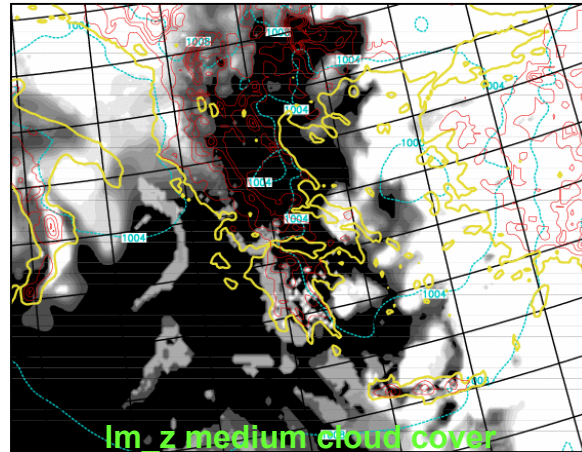
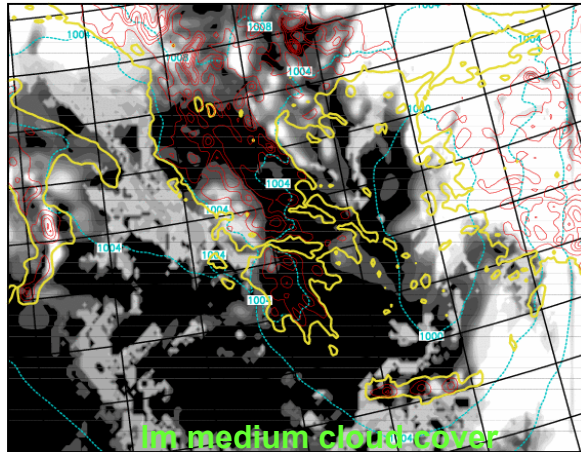
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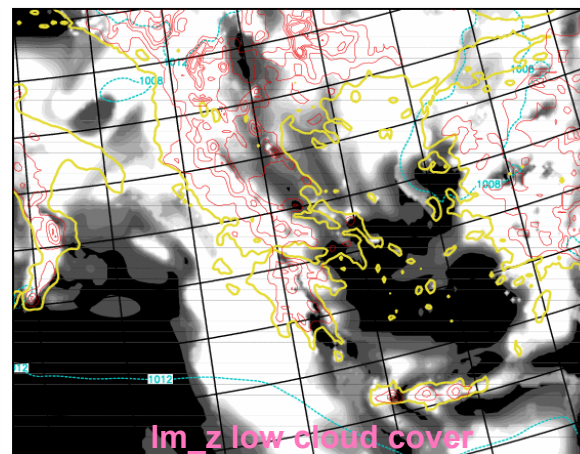
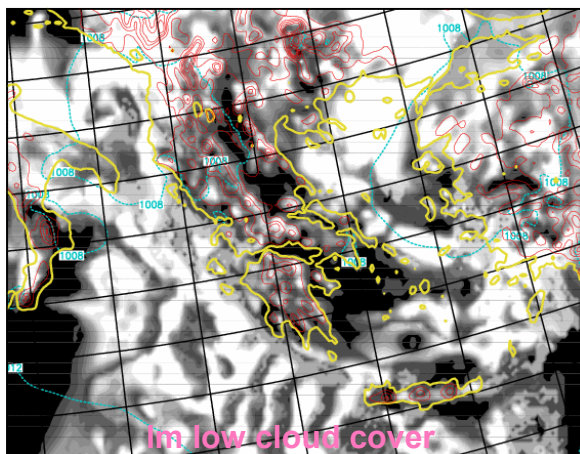
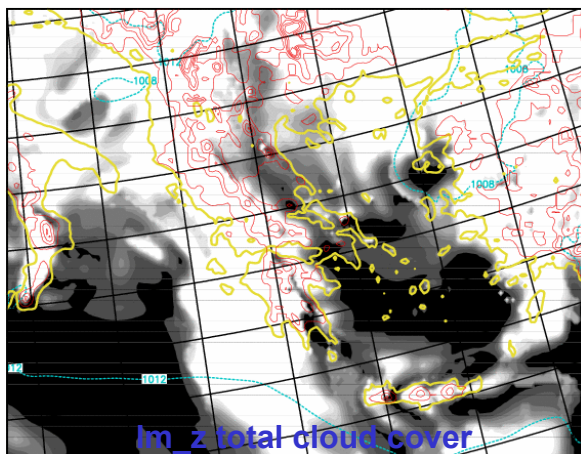
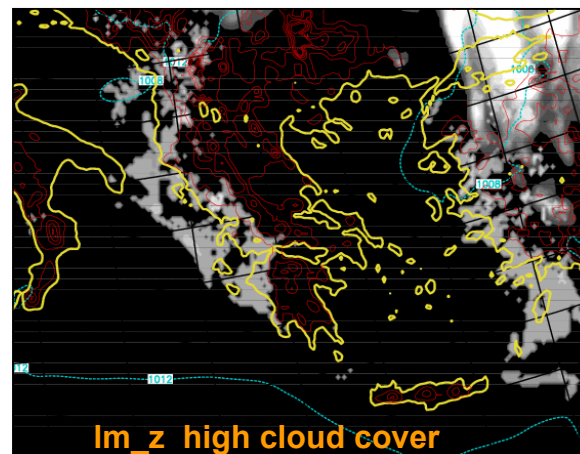
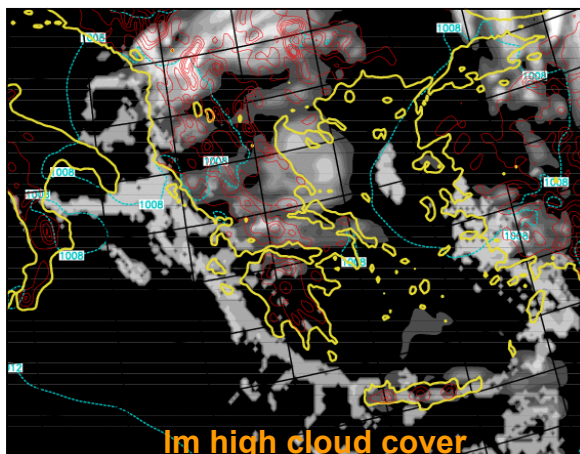
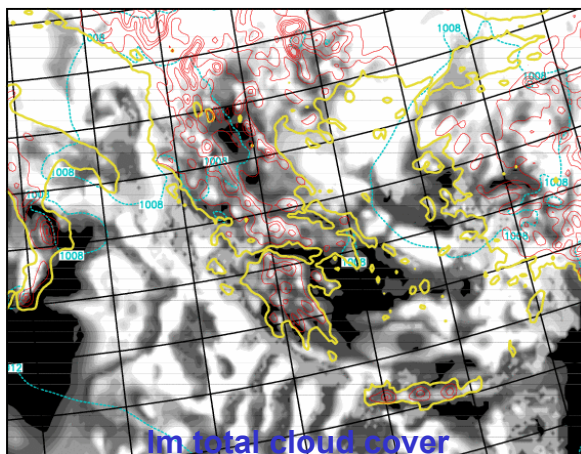
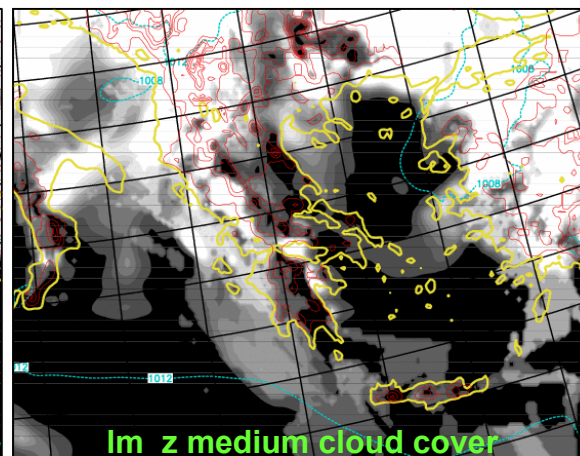
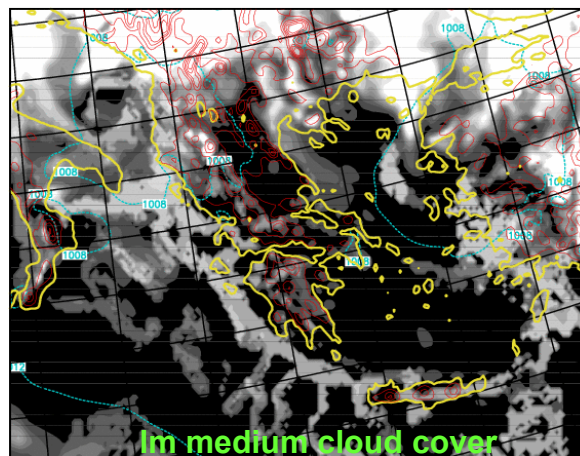
MSG IR 10.8 μm 18.11.2005 00:00

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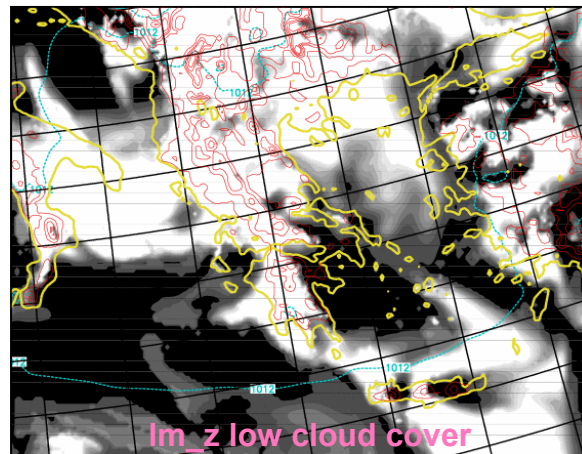
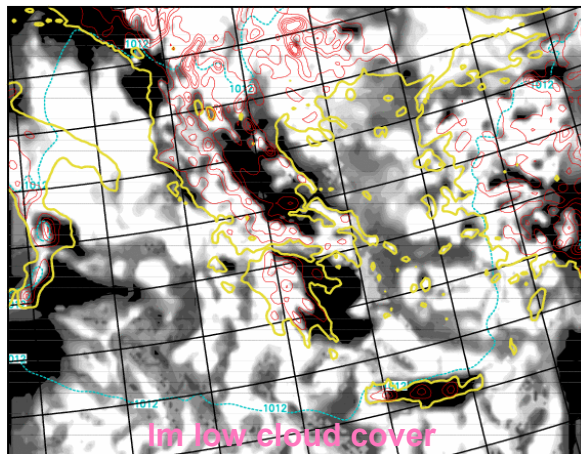
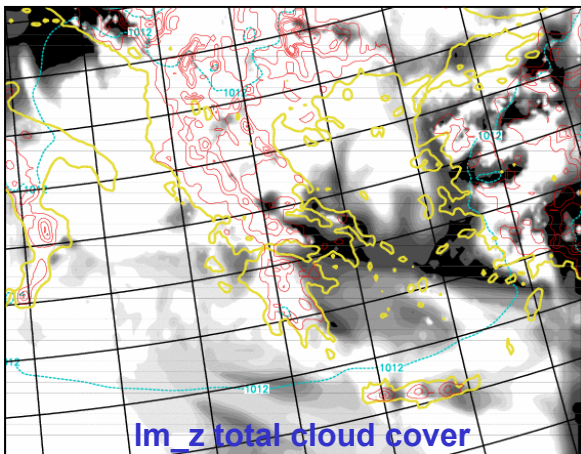
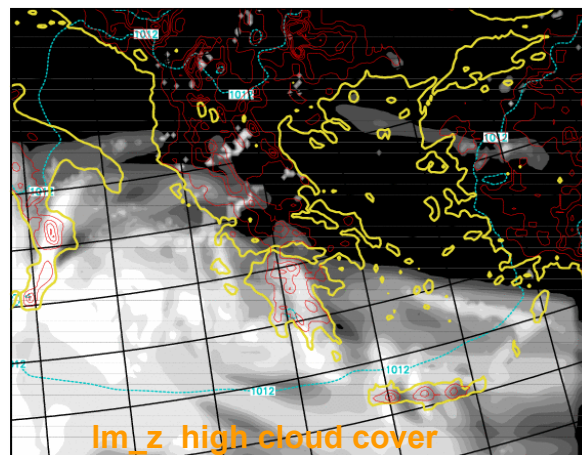
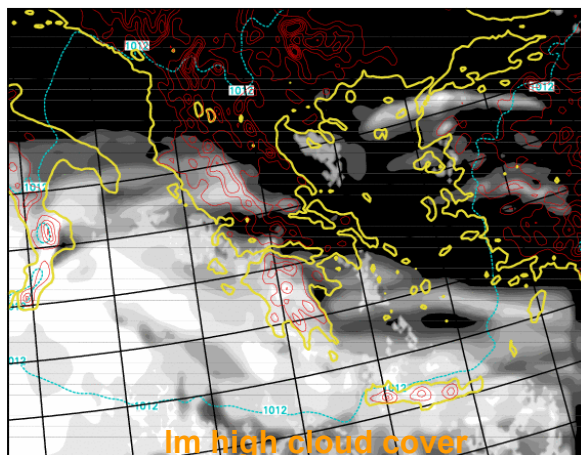
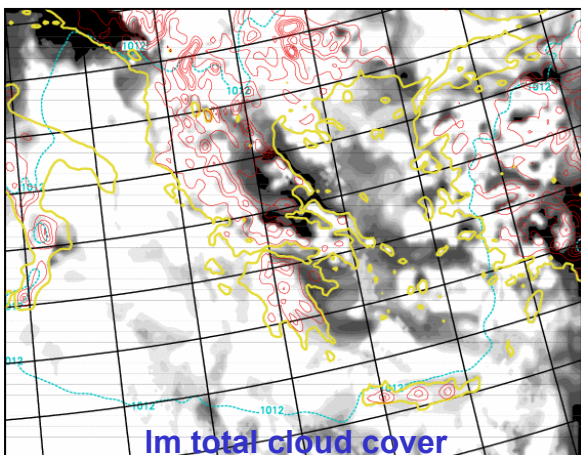
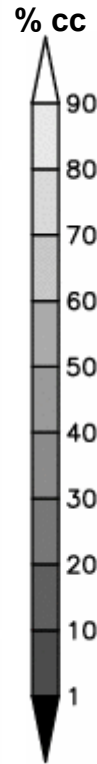
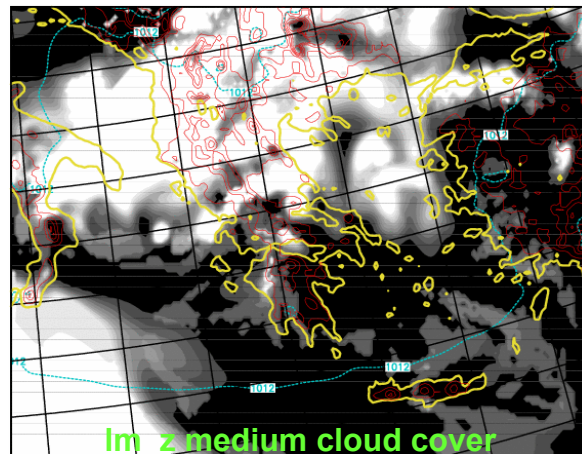
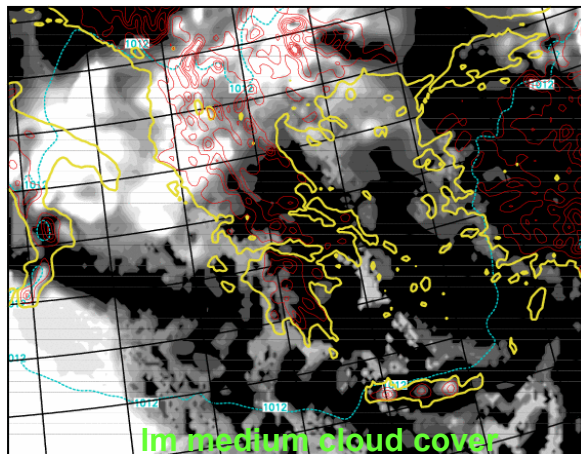
MSG IR 10.8 μm 18.11.2005 12:00

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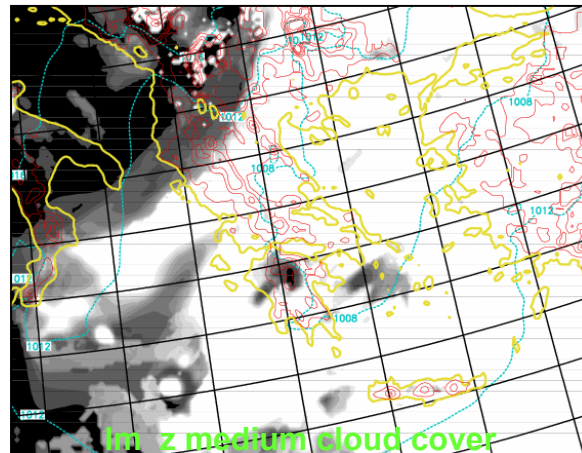
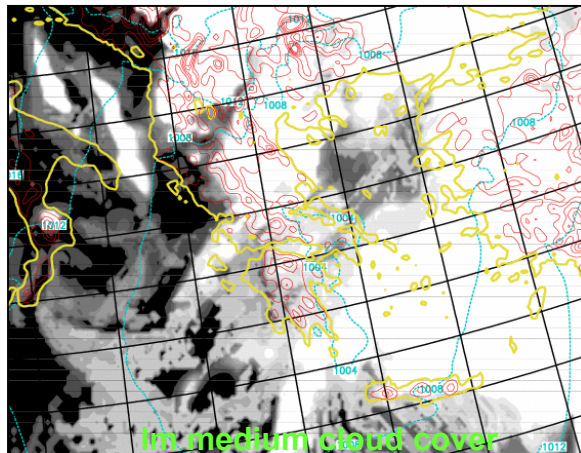
MSG IR 10.8 μm 19.11.2005 00:00

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MSG IR 10.8 μm 19.11.2005 12:00

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% CC

90

80

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60

50

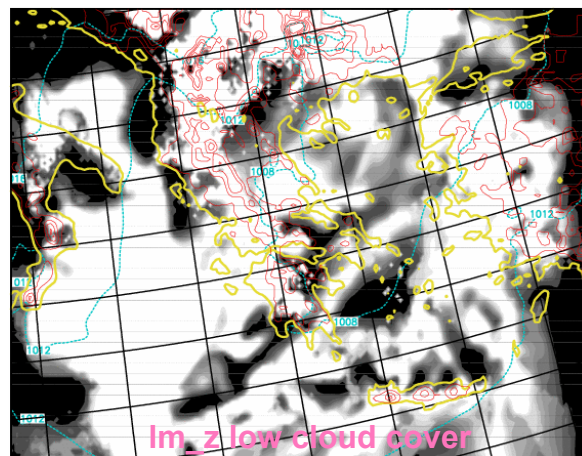
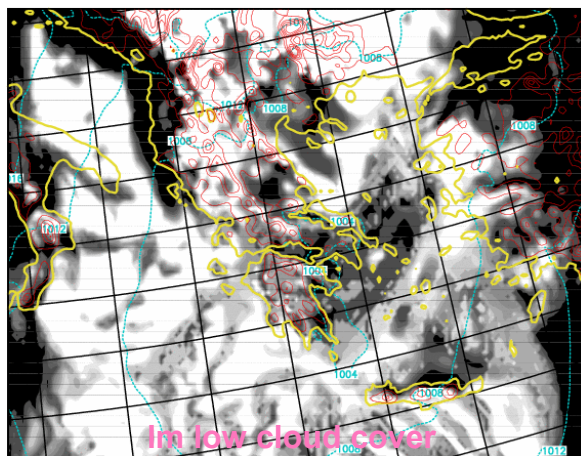
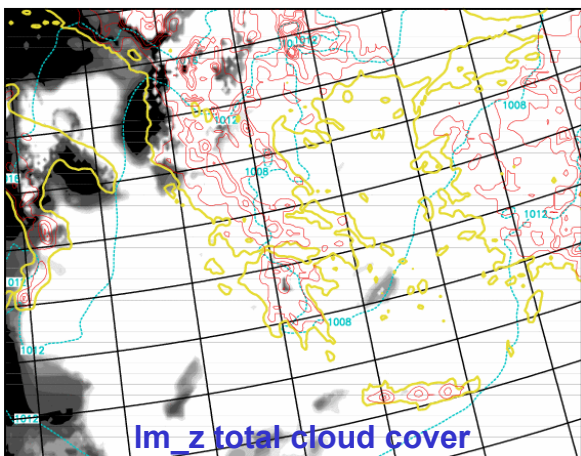
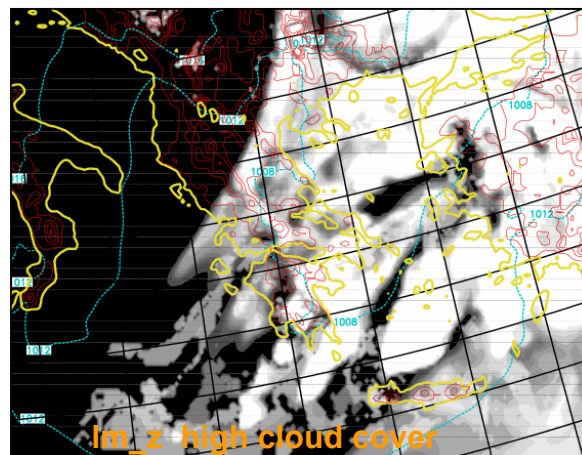
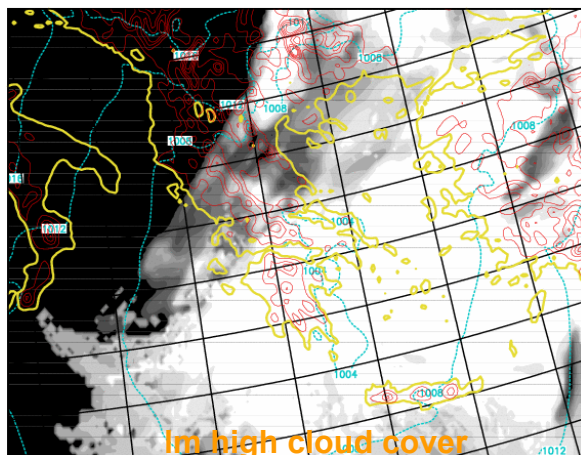
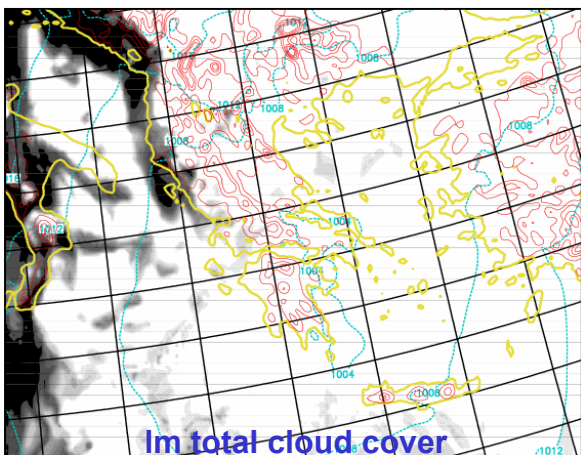
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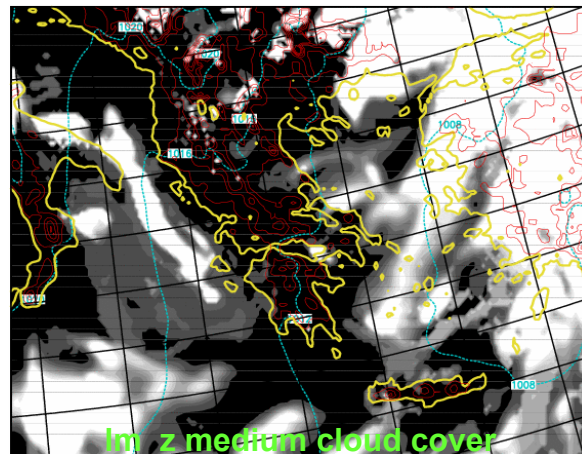
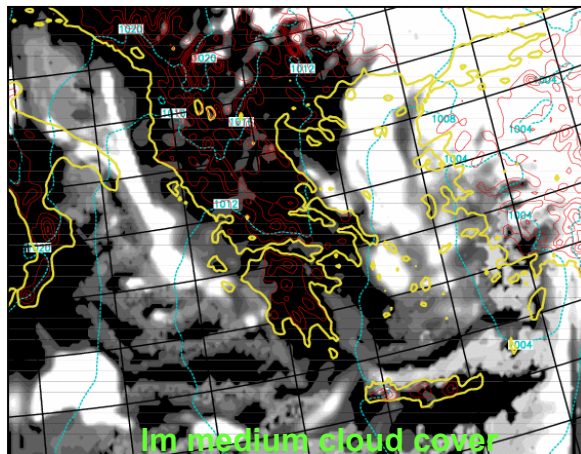
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MSG IR 10.8 μm 20.11.2005 00:00

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% CC

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80

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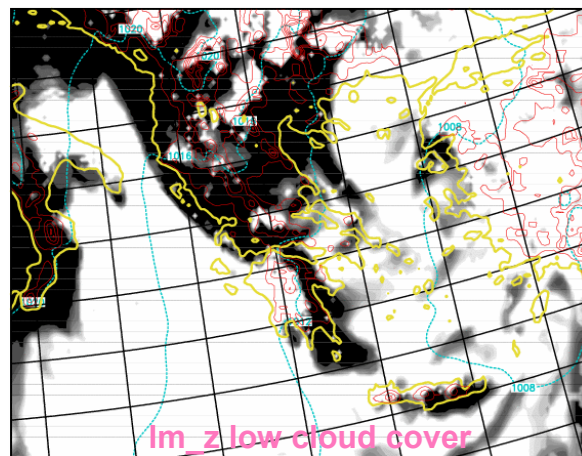
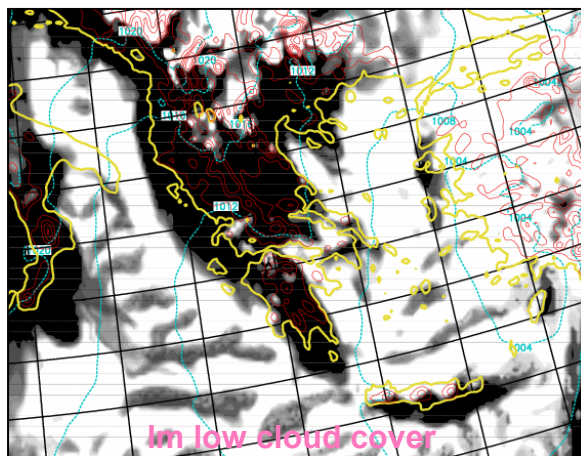
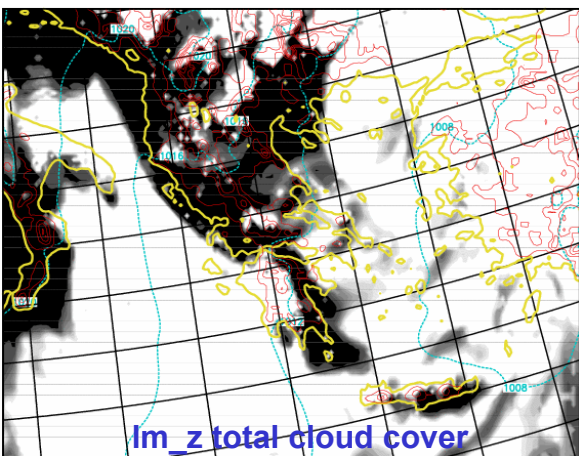
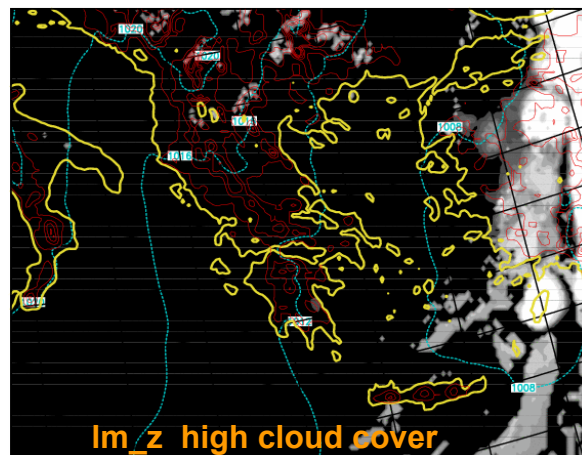
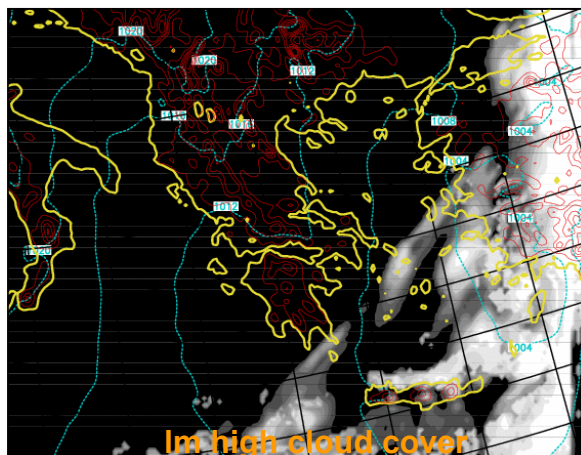
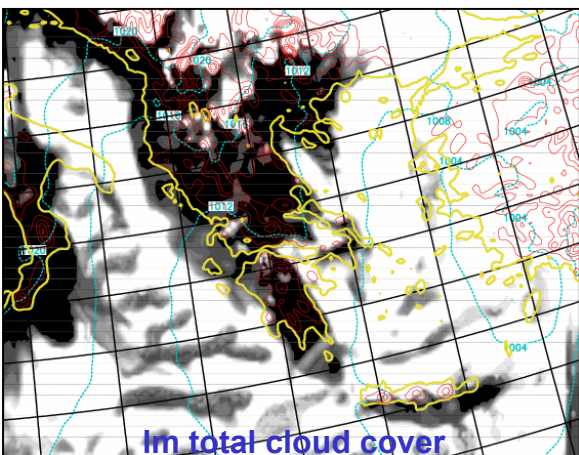
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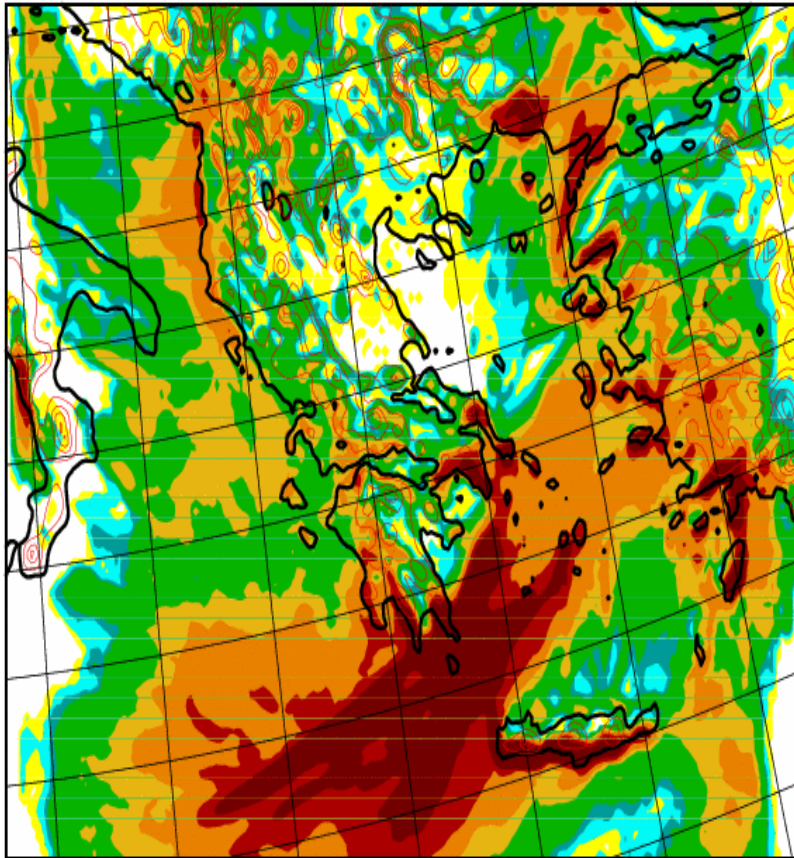
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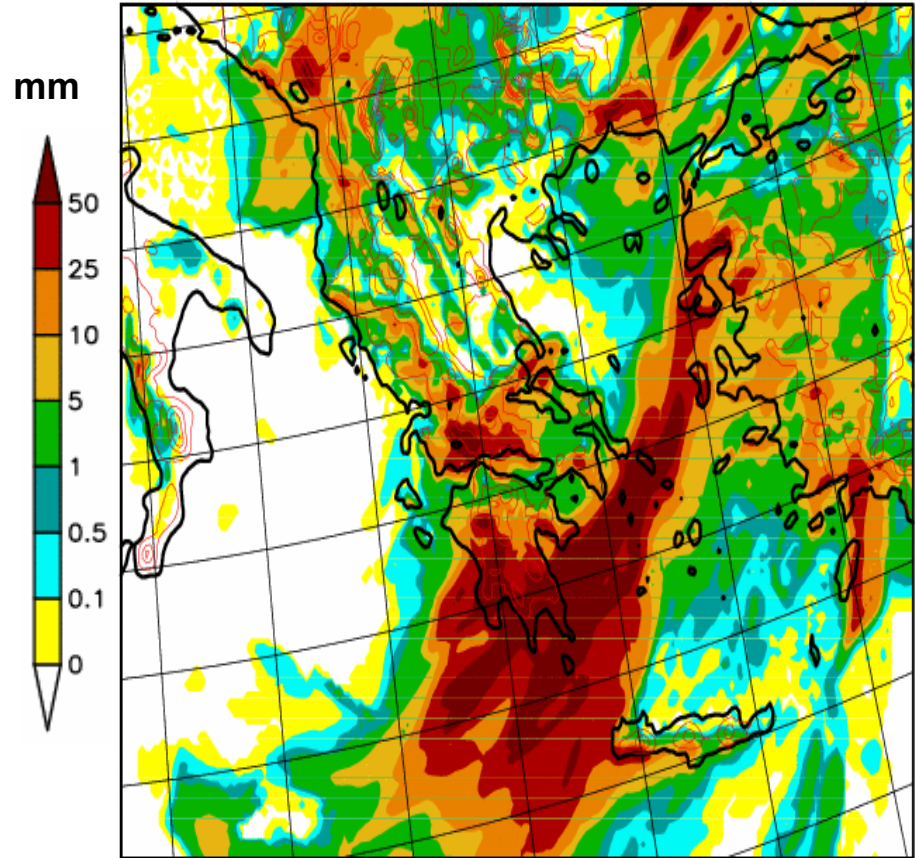
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LM_TF
Version 3.15

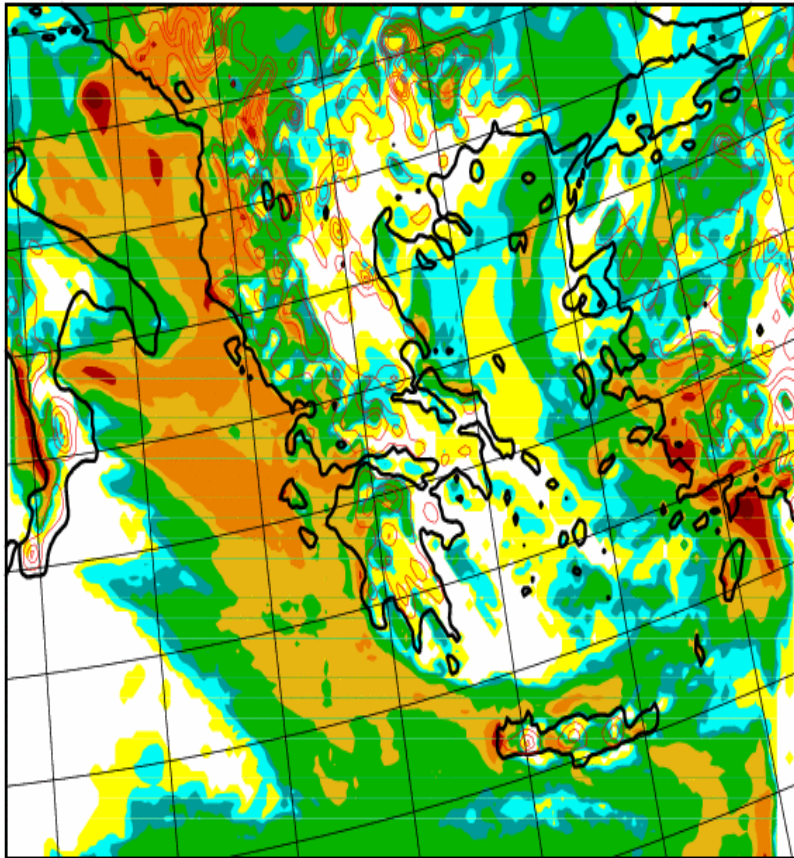


LM_Z
Version 1.5

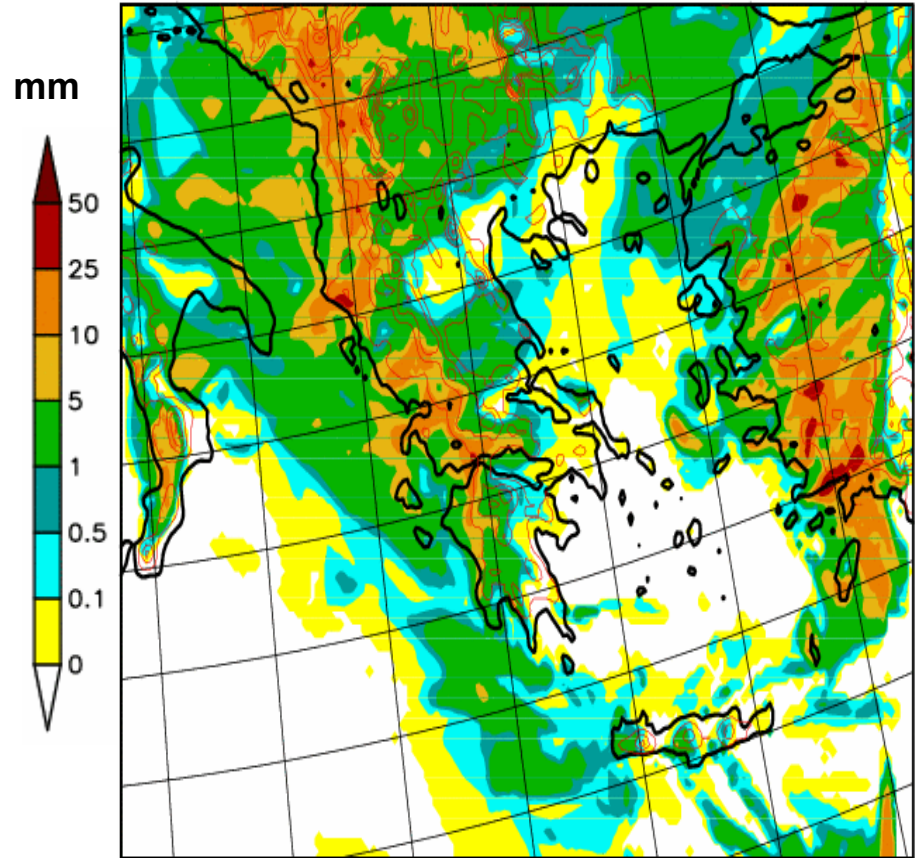


12h Accumulated Precipitation for November 17 2005 06 to 18 UTC. The initial conditions are from the Global Model of DWD (00 UTC analysis, 24hr forecast).

LM_TF
Version 3.15

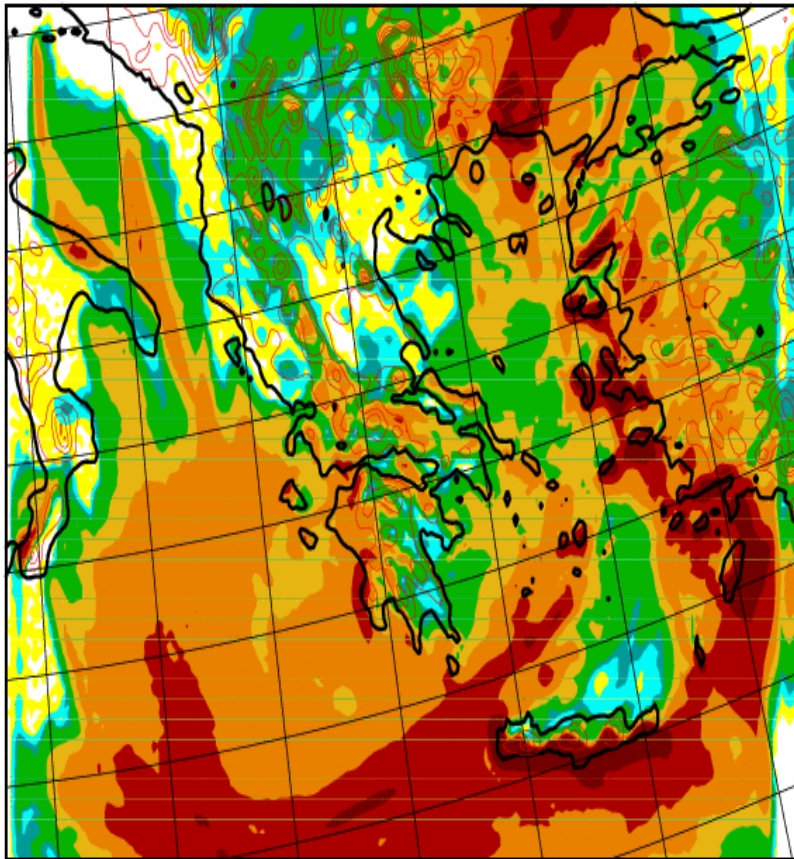


LM_Z
Version 1.5

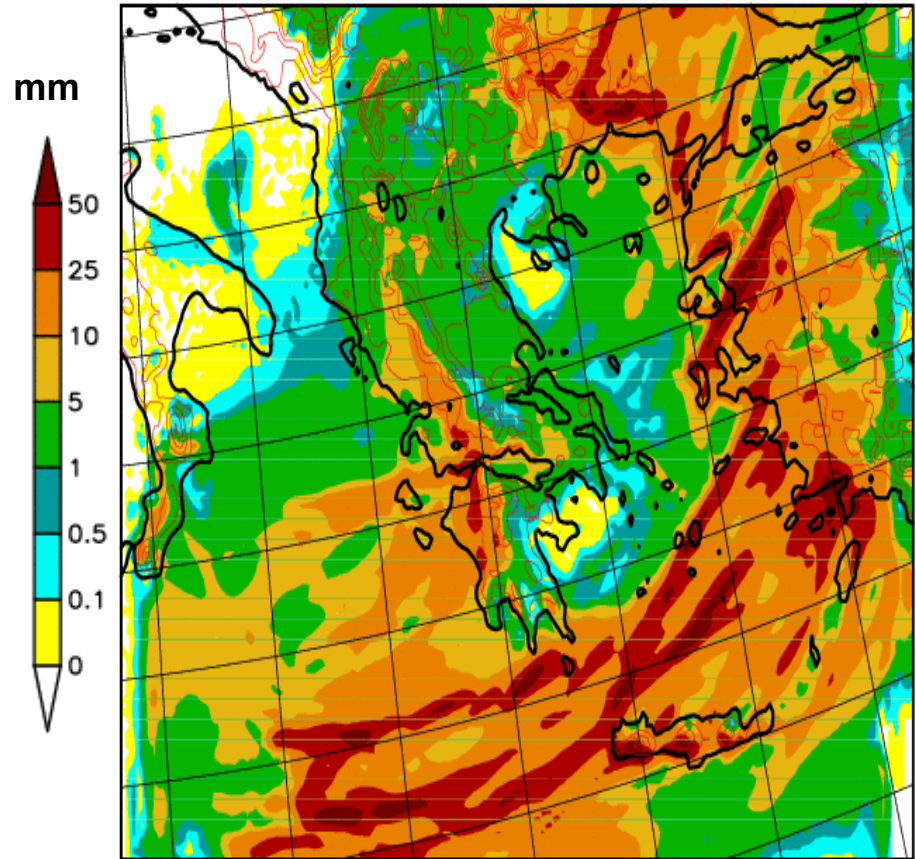


12h Accumulated Precipitation for November 18 2005 06 to 18 UTC. The initial conditions are from the Global Model of DWD (00 UTC analysis, 24hr forecast).

LM_TF
Version 3.15

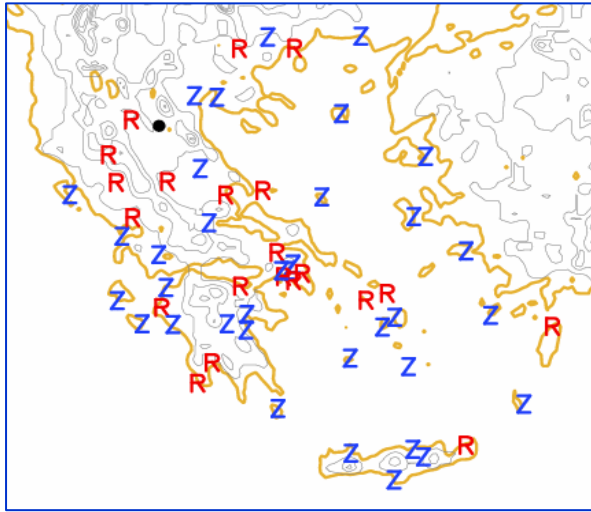


LM_Z
Version 1.5

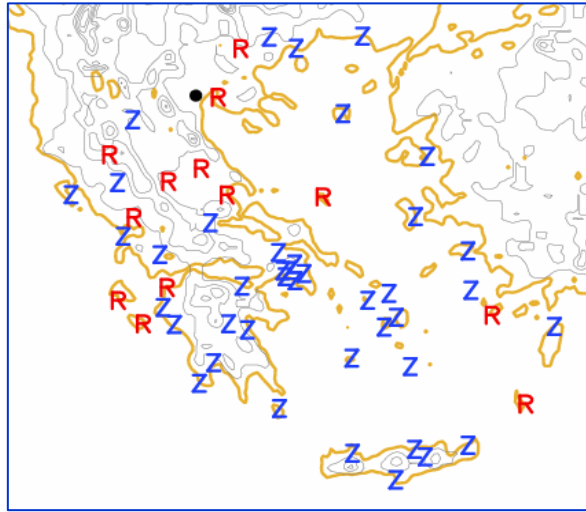


12h Accumulated Precipitation for November 19 2005 06 to 18 UTC. The initial conditions are from the Global Model of DWD (00 UTC analysis, 24hr forecast).

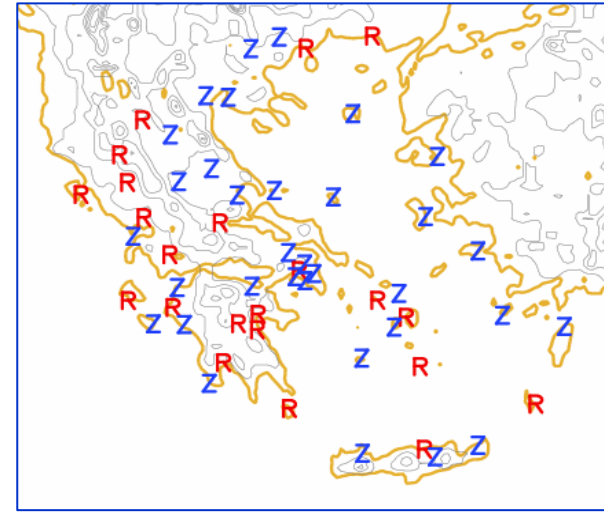
November 17 2005



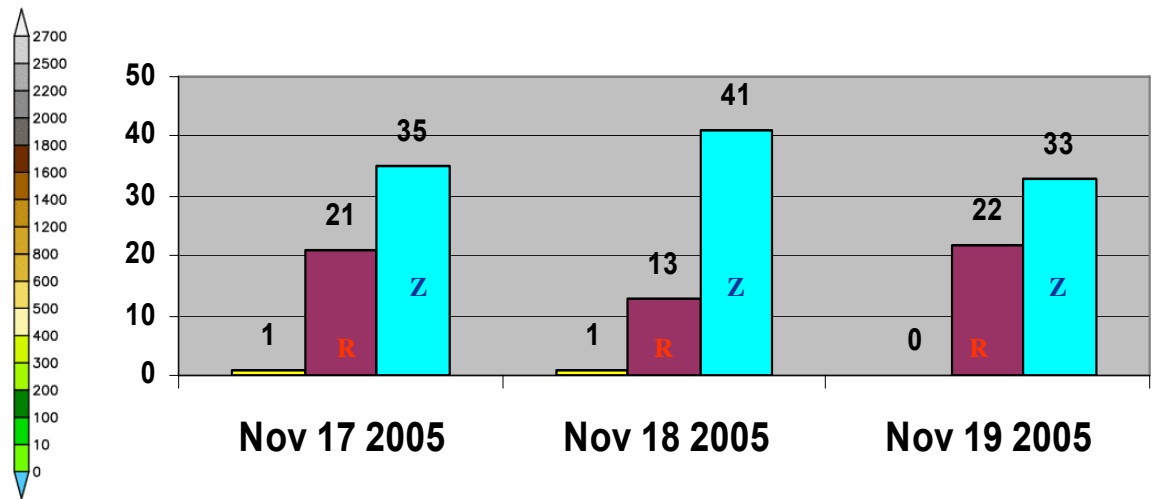
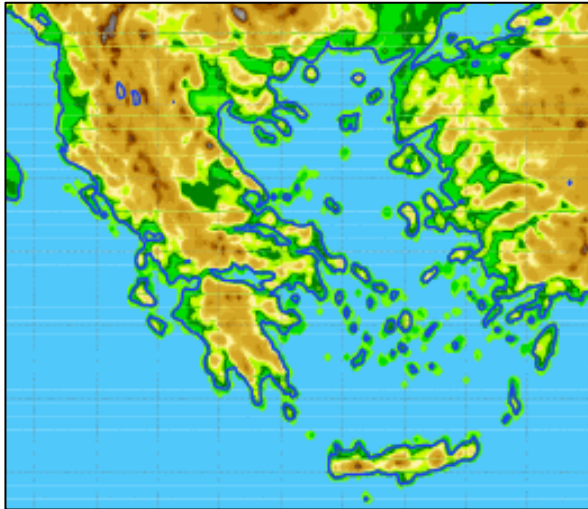
November 18 2005



November 19 2005



R: 12h forecasted accumulated precipitation from “Regular” LM is closer to observation
Z: 12h forecasted accumulated precipitation from LM_Z is closer to observation



Total, Average, Minimum and Maximum
observed and forecasted precipitation height (mm)

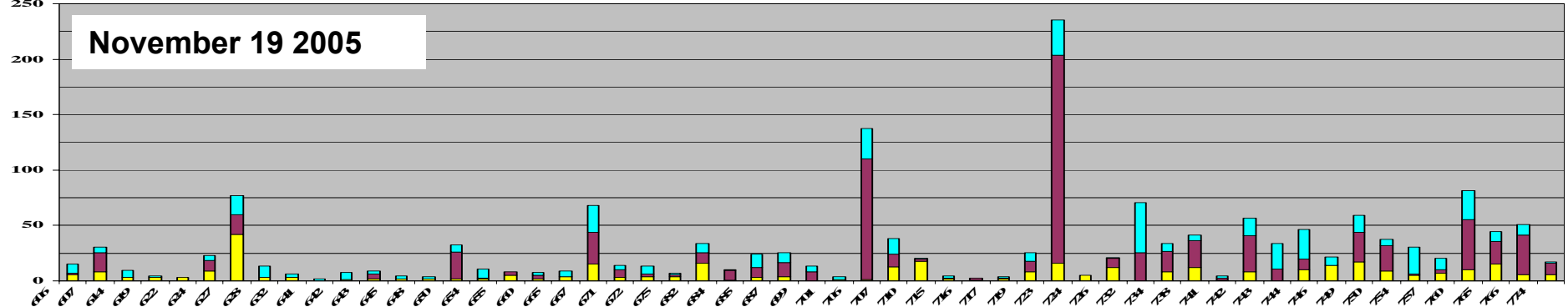
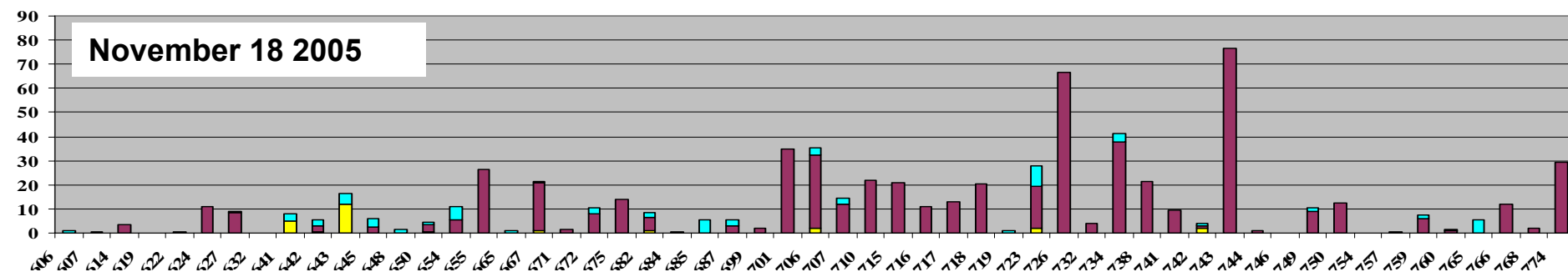
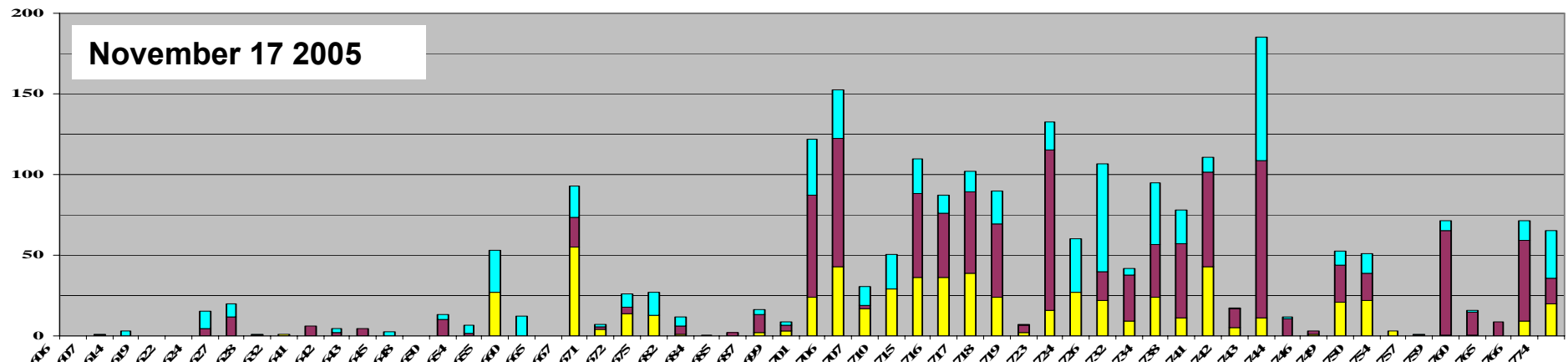
		Nov. 17 57 Stations	Nov. 18 55 Stations	Nov. 19 55 Stations
Observed :	Total	615.4	26.0	358.1
	Average	10.80	0.47	6.51
	Max	55.0	12	42
	Min	0	0	0
LM_tf: V_3.15	Total	1024.5	588.5	788.8
	Average	17.97	10.7	14.34
	Max	99.4	76.8	187.6
	Min	0	0	0
LM_Z: V_1.5	Total	632.5	65.6	487.8
	Average	11.10	1.19	8.87
	Max	76.8	8.4	44.9
	Min	0	0	0.1

Threat Scores (TS)

Precipitation Threshold (mm)	November 17		November 18		November 19	
	LM_TF V_3.15	LM_Z V_1.5	LM_TF V_3.15	LM_Z V_1.5	LM_TF V_3.15	LM_Z V_1.5
1 (Hits,Obs,False)	60 (27,33,12)	65 (28,33,10)	10 (4,7,33)	27 (6,7,15)	59 (32,48,6)	79 (42,48,5)
2 (Hits,Obs,False)	57 (24,30,12)	62 (25,30,10)	6 (2,5,31)	28 (4,5,9)	54 (28,45,6)	67 (34,45,6)
3 (Hits,Obs,False)	52 (21,28,12)	68 (24,28,7)	0 (0,2,29)	12 (1,2,6)	51 (23,37,8)	66 (29,37,7)
4 (Hits,Obs,False)	52 (20,16,12)	75 (24,26,6)	0 (0,2,28)	17 (1,2,4)	51 (20,30,9)	60 (24,30,10)
5 (Hits,Obs,False)	55 (19,25,9)	74 (23,25,6)	0 (0,2,27)	0 (0,2,4)	54 (19,26,9)	54 (20,26,11)

$$TS = \frac{\text{Hits}}{\text{Observations} + \text{False Alarms}} \times 100$$

Hits: Cases where Obs and Fcast values \geq Threshold
 Observations: Cases where Obs values \geq Threshold
 False Alarms: Cases where Obs values $<$ Threshold and
 Fcast values $>$ Threshold



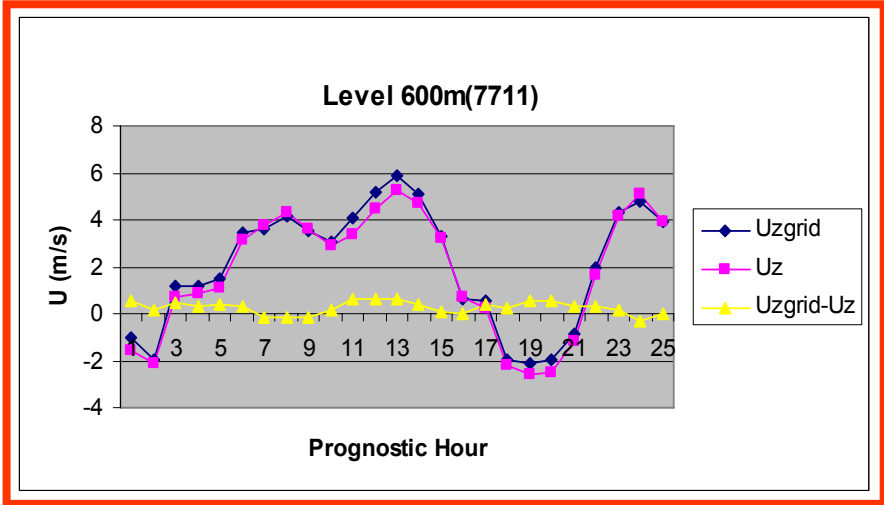
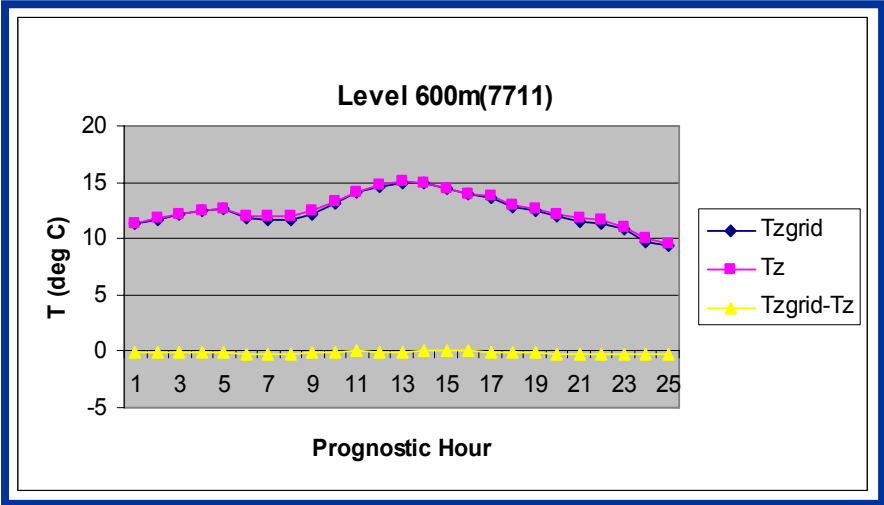
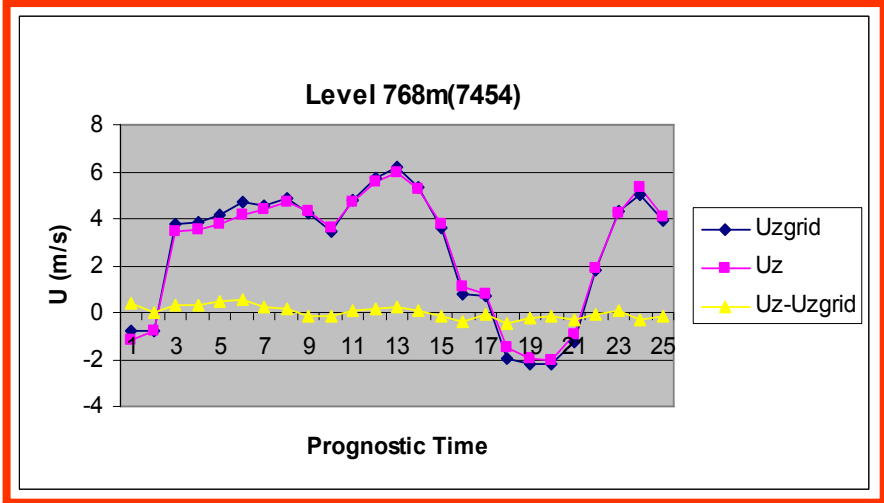
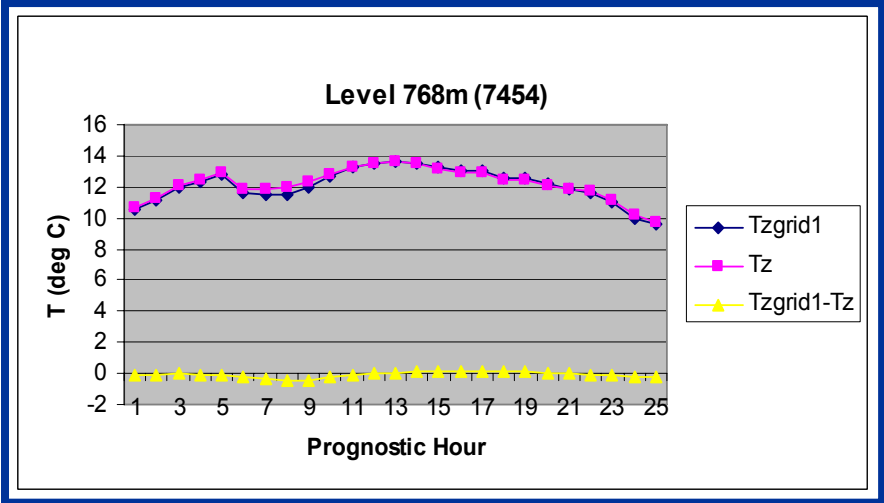
■ LM_z
■ LM_tf
■ OBS

◆ Observed and Forecasted Precipitation Heights (06-18 UTC) from LM_Z and LM.
◆ Stations with no precipitation shown correspond to traces of observed but no forecasted precipitation.

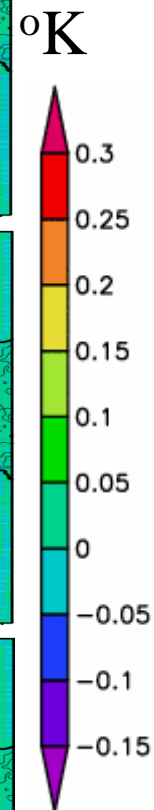
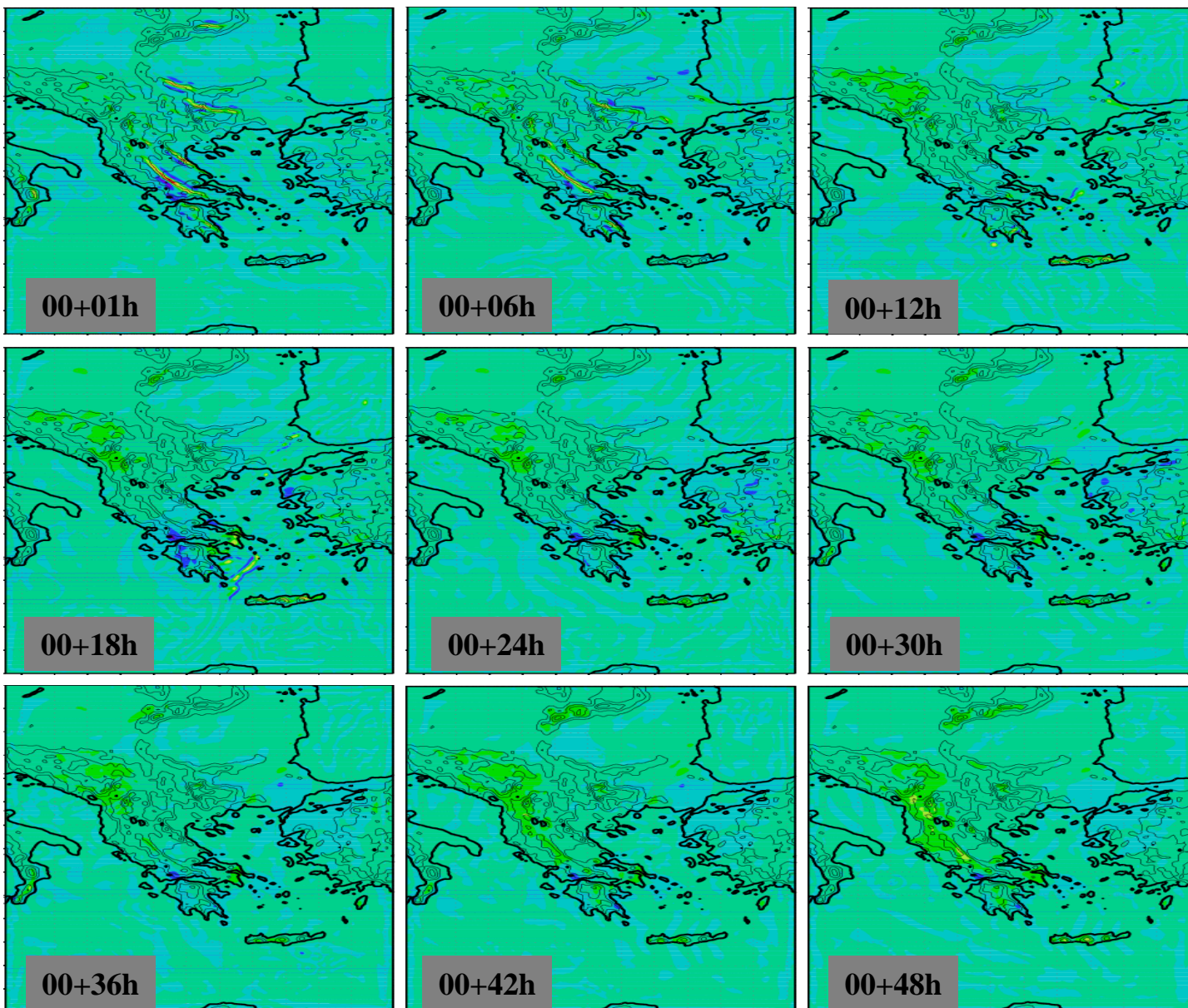
Numerical Validation of Coordinate transformation $LM_z \leftrightarrow LM_{tf}$

- ✚ The Parameterization of the Physical Processes is done using the parameterization package of the LM_{tf}
(Steppeler, J., H. W. Bitzer, A. Gassmann, U. Damrath, and G. Gregoric “ *Mesogamma scale forecasts by non-hydrostatic model LM*”, Meteor. Atmos. Phys., 82, 75-96, 2002)
- ✚ Transformations I and I^{-1} are defined through cubic spline interpolation to convert fields (f) between LM_{tf} (f^p) and LM_z (f^z) representations i.e, $f^p = I f^z$ and $f^z = I^{-1} f^p$
(Steppeler et al, Ref. 3)
- ✚ Due to transformations between spaces of different dimensions I and I^{-1} are not inverse to each other.
- ✚ An interpolation error is accumulated every time step

**Lat:-15.75, Lon:10.6, Surface Height 460 m
Im_z_1.5 for 17-11-2005**

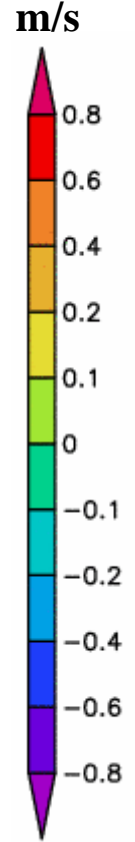
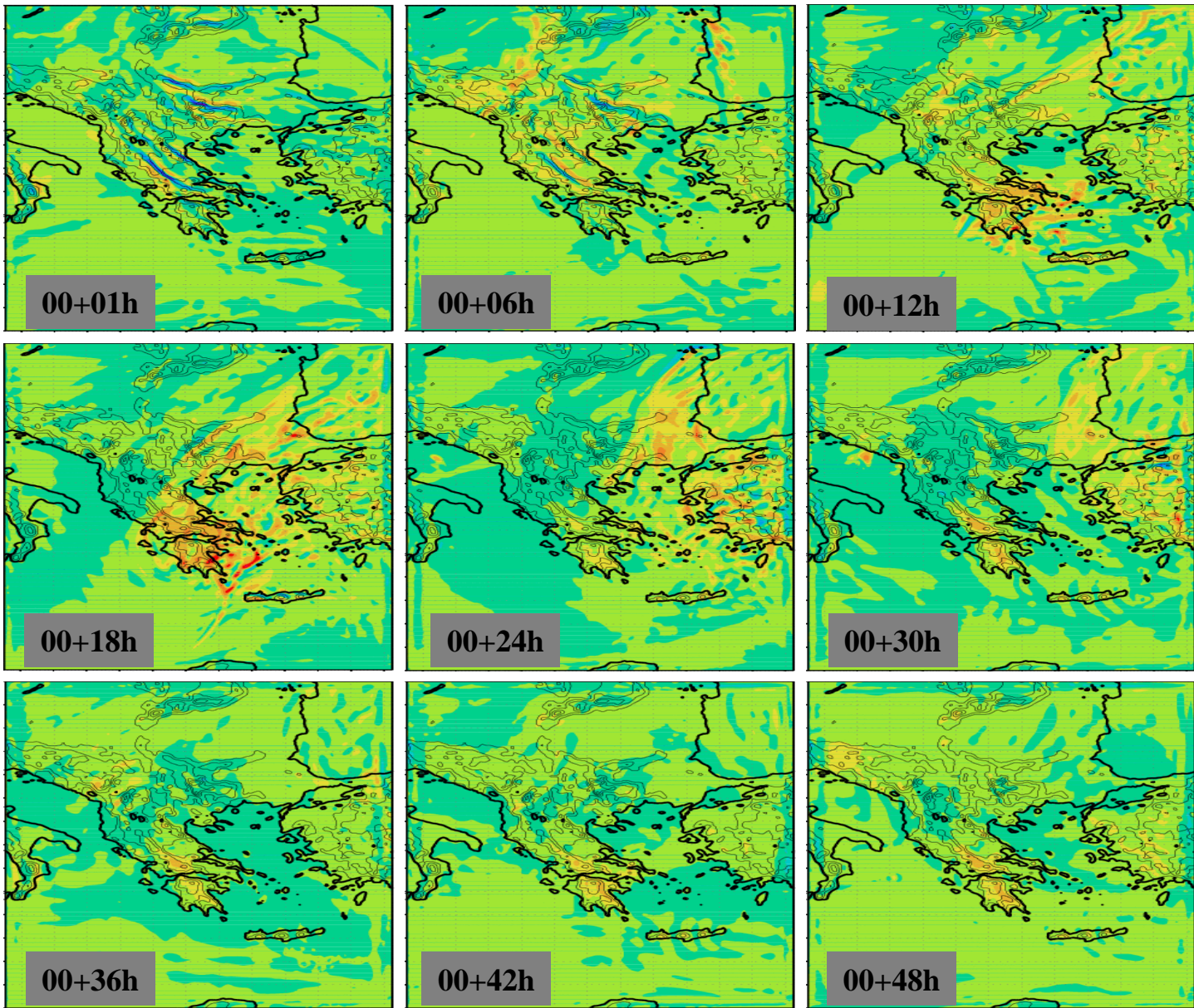


$\langle T_{zgrid} \rangle - \langle T_z \rangle$ **lm_z_1.5 for 17-11-2005**



21 Upper Levels (m)
22184
19620
17514
15770
14302
13055
11982
11024
10141
9320
8540
7796
7101
6457
5856
5293
4764
4263
3787
3341
2927

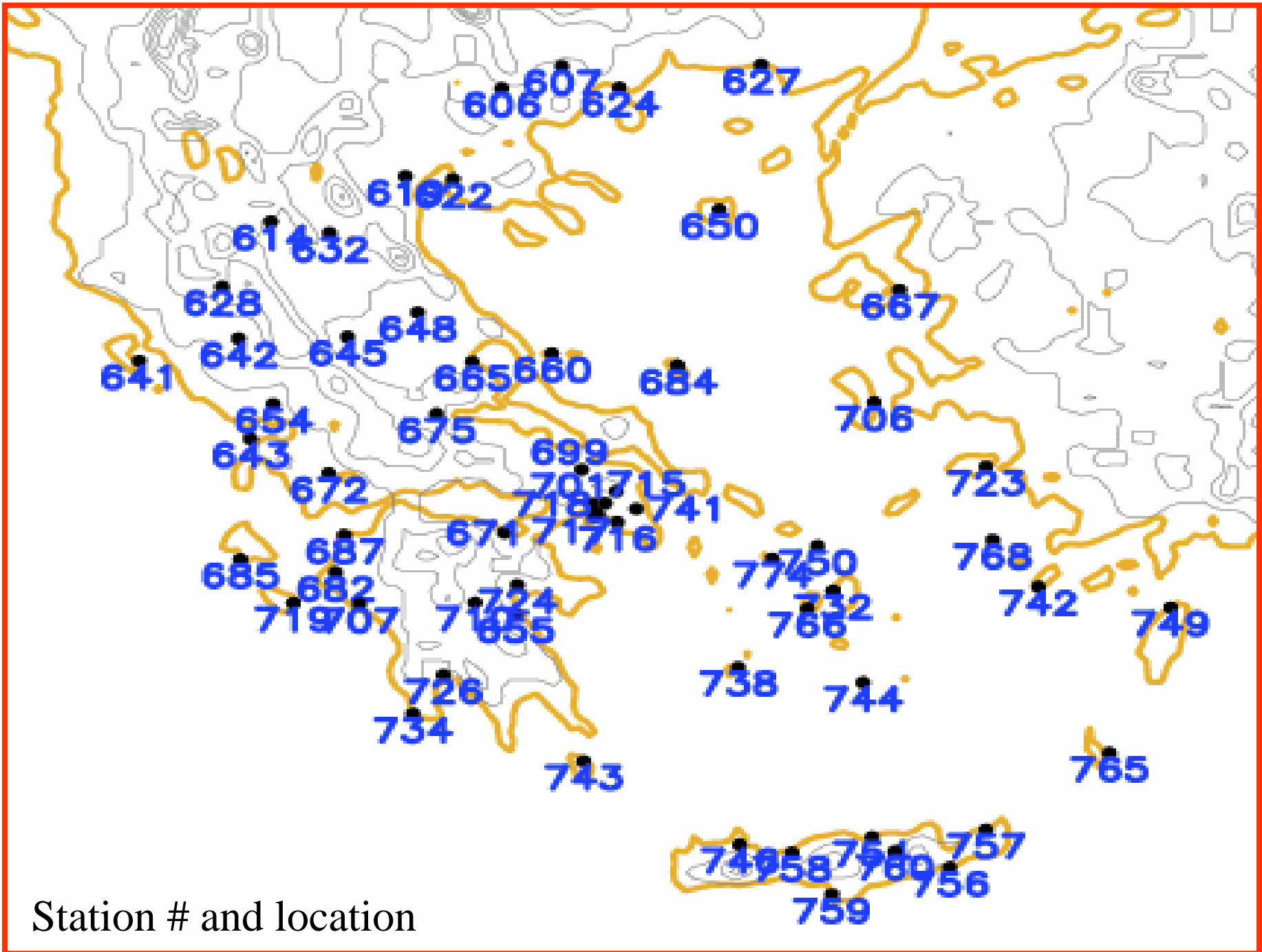
$$\sqrt{\langle U_{zgrid}^2 + V_{zgrid}^2 \rangle} - \sqrt{\langle U_z^2 + V_z^2 \rangle} \quad \text{lm_z_1.5 for 17-11-2005}$$



21 Upper Levels (m)
22184
19621
17514
15770
14302
13055
11982
11024
10141
9320
8540
7796
7101
6457
5856
5293
4764
4263
3787
3341
2927

Conclusion and Remarks

- ✚ For the test cases under consideration, LM_Z forecast showed relative preponderance over LM both for 12h accumulated precipitation in connection to a change of precipitation maxima.
- ✚ More systematic investigation is necessary for large and continuous time periods as well as towards different grid sizes.
- ✚ The presented results, although optimistic towards LM-z, should be reevaluated through later versions of LM_z.



Station # and location