Institute of Geophysics
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Analysis of the Structure and Dynamics of a Surface Frontal Zone

(A case study of cold frontal zone in Iran)

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Outline

1- Introduction

2- Previous Studies

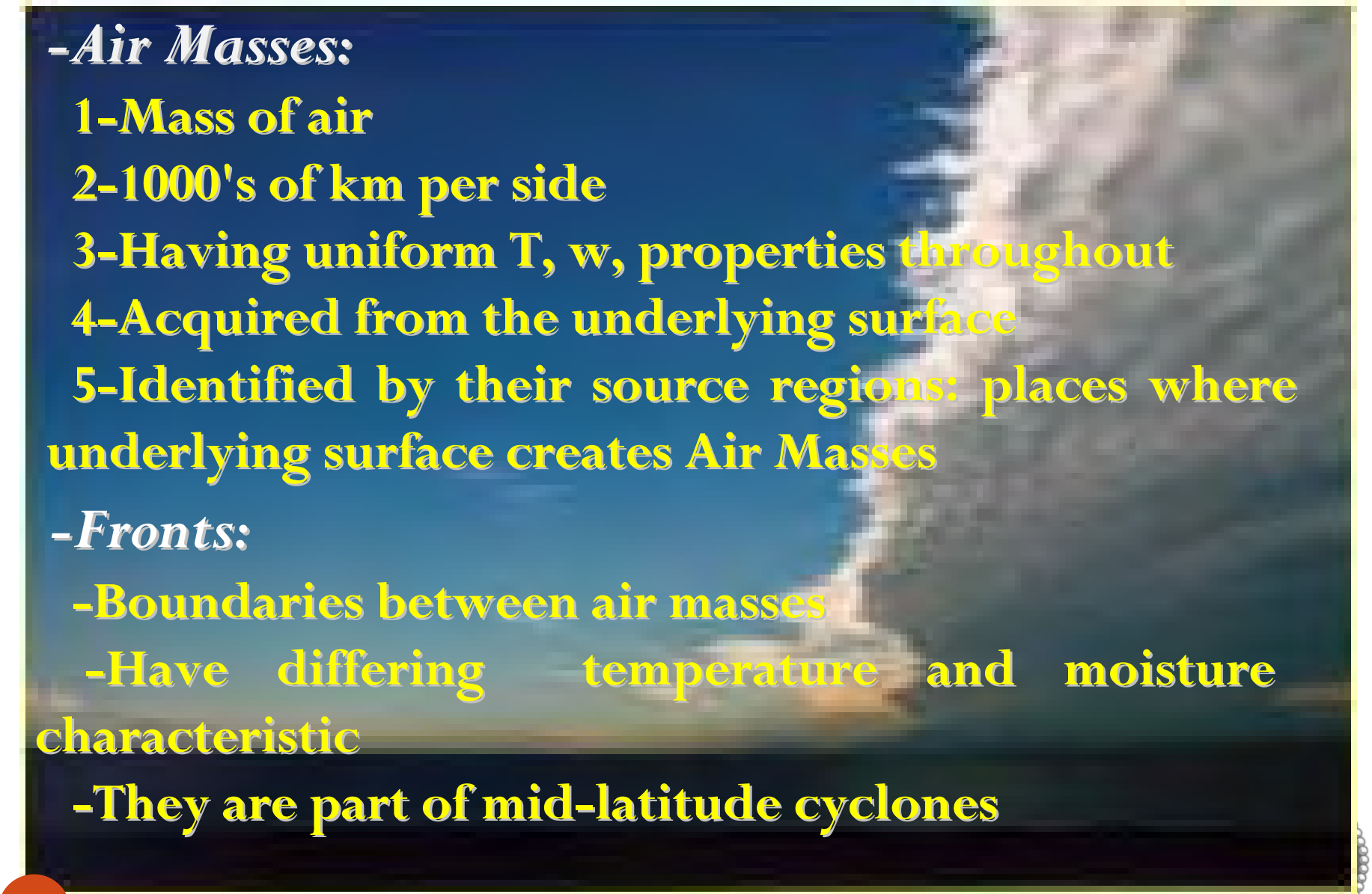
3- Sample Event

4-Methodology and Model simulation

5- Analyzing the results

6- Conclusion

Introduction



-Air Masses:

1-Mass of air

2-1000's of km per side

3-Having uniform T, w, properties throughout

4-Acquired from the underlying surface

5-Identified by their source regions: places where underlying surface creates Air Masses

-Fronts:

-Boundaries between air masses

-Have differing temperature and moisture characteristic

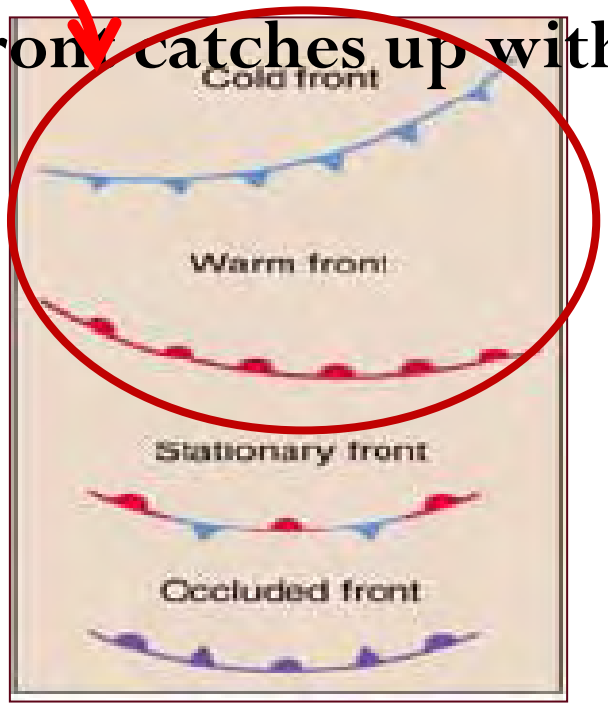
-They are part of mid-latitude cyclones

Introduction

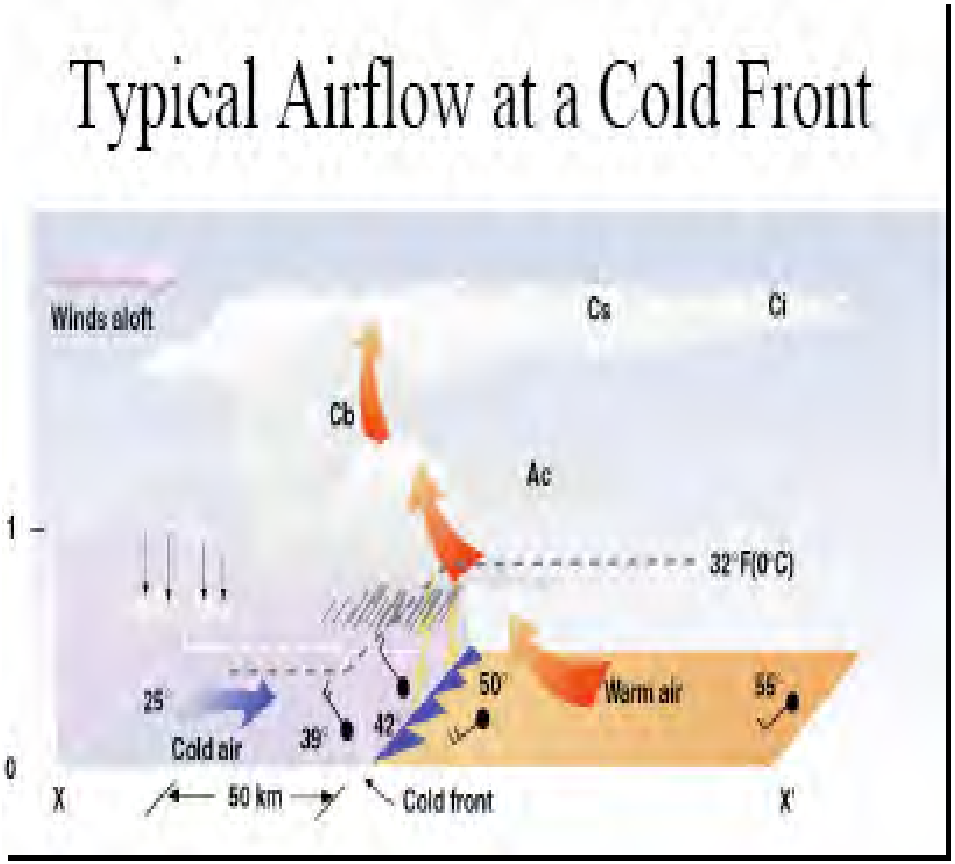
Different types of front :

1. Cold fronts: Cold air replaces warm air
2. Warm fronts: Warm air replaces cold air
3. Stationary fronts: Have not moved in last 3 or 6 hours
4. Occluded fronts: cold front catches up with warm front

Warm & cold fronts are typical synoptic event atmosphere



Introduction

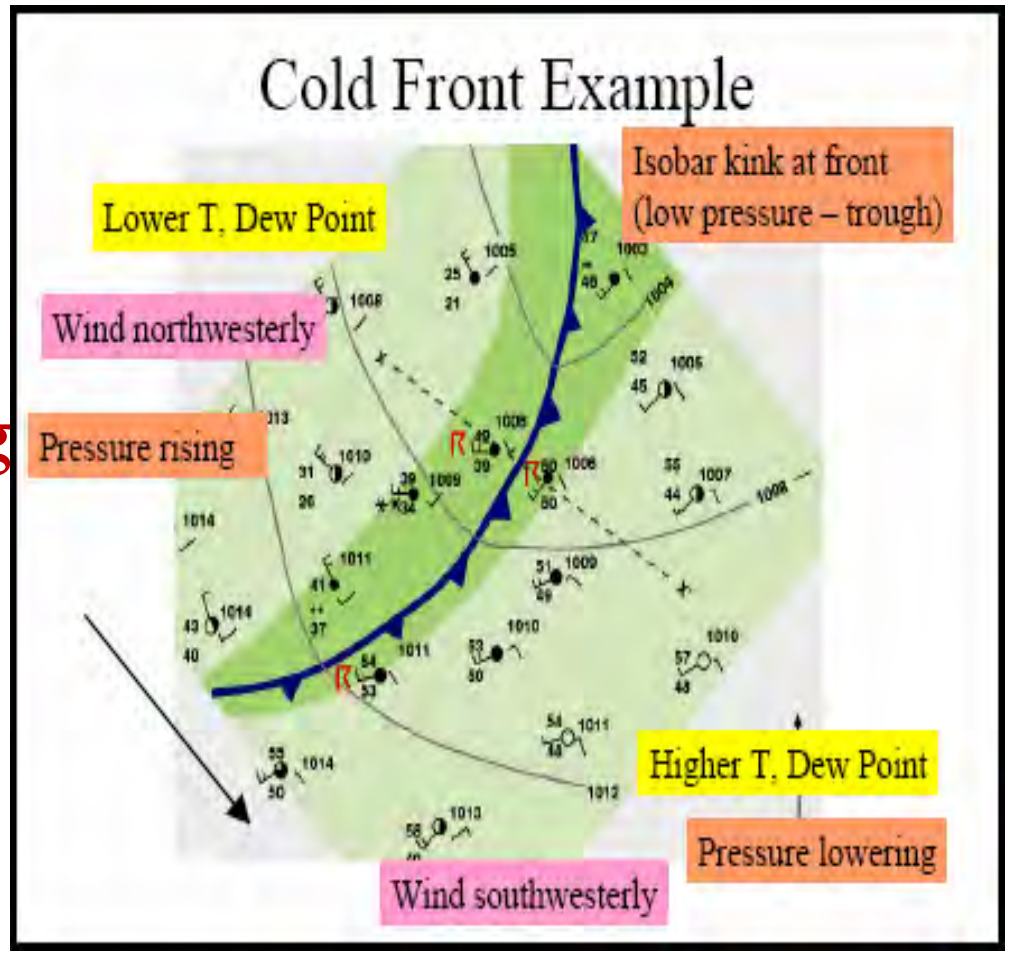


Cold Fronts:

- ✓Occur where cold air replace warm air
- ✓Relatively steep due to dense air
- ✓fast moving 30-50 mph
- ✓Produce forced uplift, convective thunderstorms

Frontal Passage:

- ✓ **Heavy rainfall or snow, combined with rapid temperature drops.**
- ✓ **Convective precipitation from rapid vertical lifting on steep frontal profile.**
- ✓ **Cold front catches up with warm front**



Frontogenesis:

Frontogenesis:

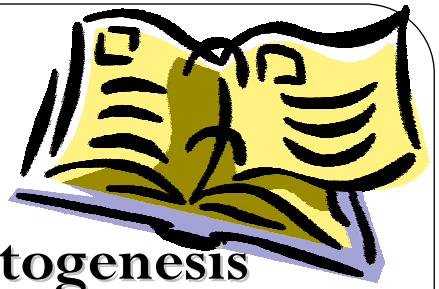
-Refers to the change in the magnitude and orientation of the temperature gradient at a level or layer (e.g. 850 – 700 mb) due to the directional and speed changes in the wind field (e.g. convergence and divergence).

- ***Increase*** in the horizontal thermal gradient with time.

Frontolysis:

-Simply defined as a ***decrease*** in the horizontal thermal gradient with time.

Previous studies



❖**Petterssen (1936):** Quantifying the amount of Frontogenesis Function as change in potential temperature gradient by the horizontal wind.

❖**Miller (1948):** Generalized Frontogenetical Function without diabatic heating.

❖**Sanders (1955):** Frontogenetical Function and the role of vertical motion in frontogenesis process.

❖**Schultz and Sanders (2002):** Relation between frontogenesis and temperature advection pattern

❖**Schultz (2006):** Analyses of Sanders function by Model simulation.

INTHE PRESENT STUDY :

- Appropriate form of frontogenesis used by Schultz (2006).
- Refined form of vorticity equation used by Sanders(1955).

Methodology

-Frontogenesis Function: ***The Lagrangian rate of change of the magnitude of the horizontal potential temperature gradient because of the three-dimensional wind.***

$$F = \underbrace{-\frac{1}{|\nabla_H \theta|}\left\{\frac{\partial \theta}{\partial x}\left(-\frac{\partial u}{\partial x}\frac{\partial \theta}{\partial x}-\frac{\partial v}{\partial x}\frac{\partial \theta}{\partial y}\right)+\frac{\partial \theta}{\partial y}\left(-\frac{\partial u}{\partial y}\frac{\partial \theta}{\partial x}-\frac{\partial v}{\partial y}\frac{\partial \theta}{\partial y}\right)\right\}}_{\text{Deformation term}} \underbrace{-\frac{1}{|\nabla_H \theta|}\left\{\frac{\partial \theta}{\partial z}\left(-\frac{\partial w}{\partial x}\frac{\partial \theta}{\partial x}-\frac{\partial w}{\partial y}\frac{\partial \theta}{\partial y}\right)\right\}}_{\text{Tilting term}}$$

Deformation term: horizontal processes intensifying the horizontal potential temperature gradient

Tilting term: role of the vertical motion wind altering the horizontal potential temperature gradient

Methodology

Vorticity Equation: *The development and dissipation of the strong cyclonic shear, (characteristic of the frontal zone), for frictionless flow*

$$-\frac{d}{dt}\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)=\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)+\left(\frac{\partial w}{\partial x}\frac{\partial v}{\partial z}-\frac{\partial w}{\partial y}\frac{\partial u}{\partial z}\right)+f\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)+\frac{df}{dt}$$

Effect of confluence term in changing the horizontal shear.

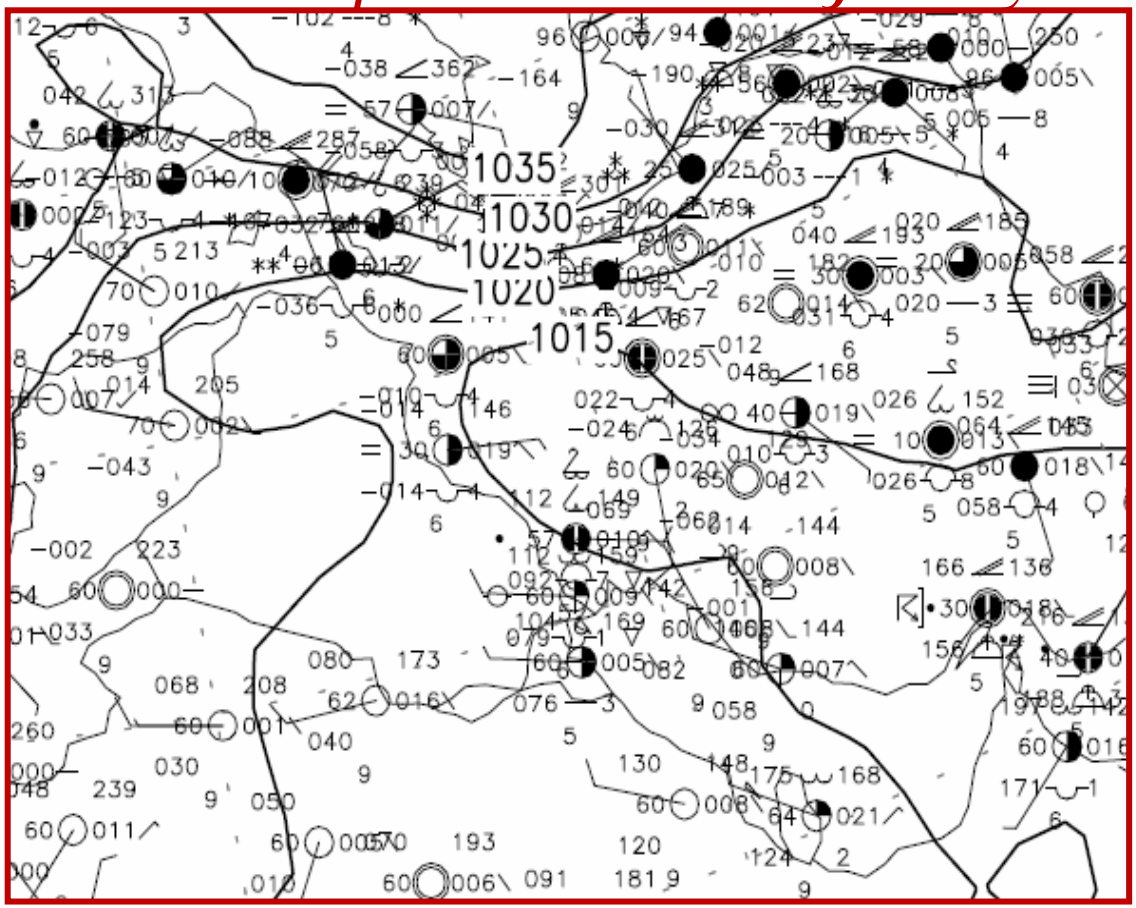
Changing vertical component of vorticity with time

horizontal gradient of vertical motion

horizontal shear due to the Coriolis force

Sample event

Mean sea level pressure 00 UTC 6 January 2008



29.4 N- 41.8N

44.8 E -56.5 E

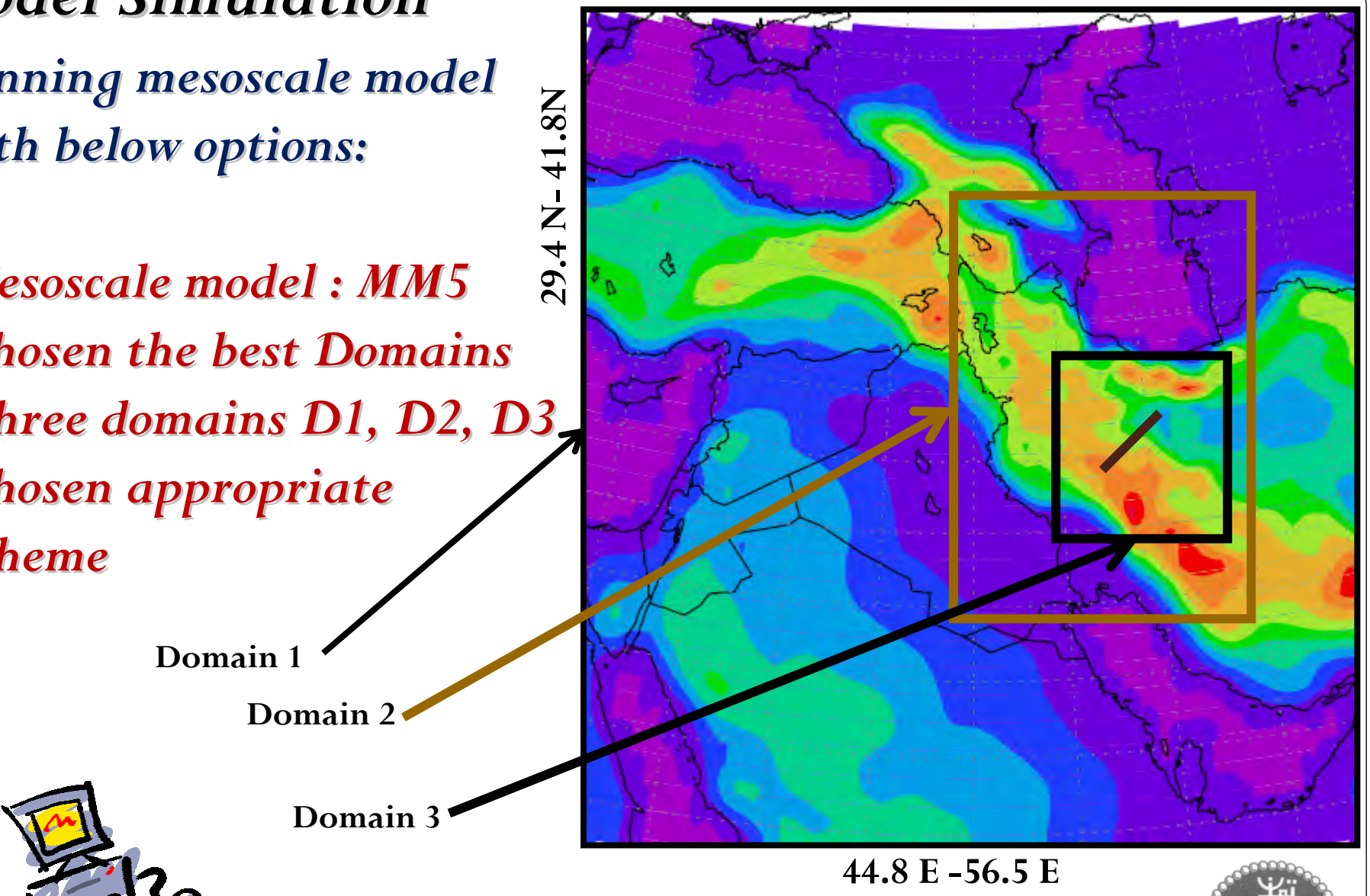
-Arose on 5-6 January 2008 and made a lot of difficulties in life planning because of its precipitation.

-Intensified at 00- 12 UTC 6 January 2008 and then weakened.

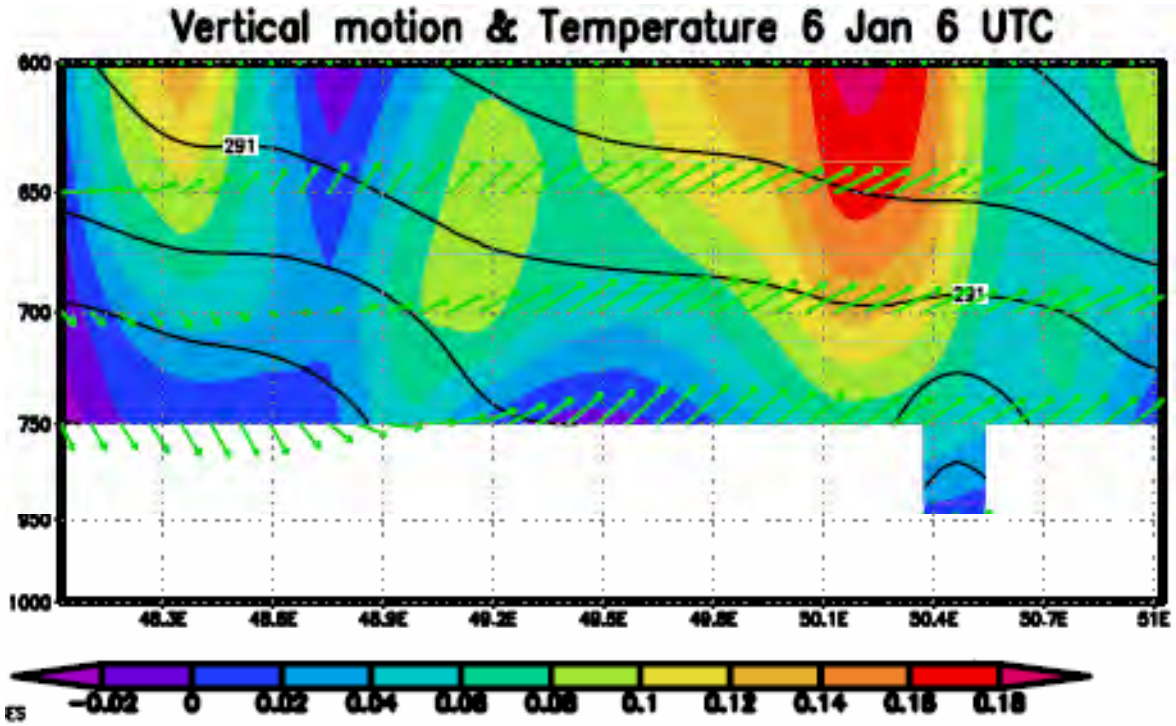
Model Simulation

Running mesoscale model with below options:

- Mesoscale model : MM5
- Chosen the best Domains
- Three domains D1, D2, D3
- Chosen appropriate scheme



Analyzing Outputs



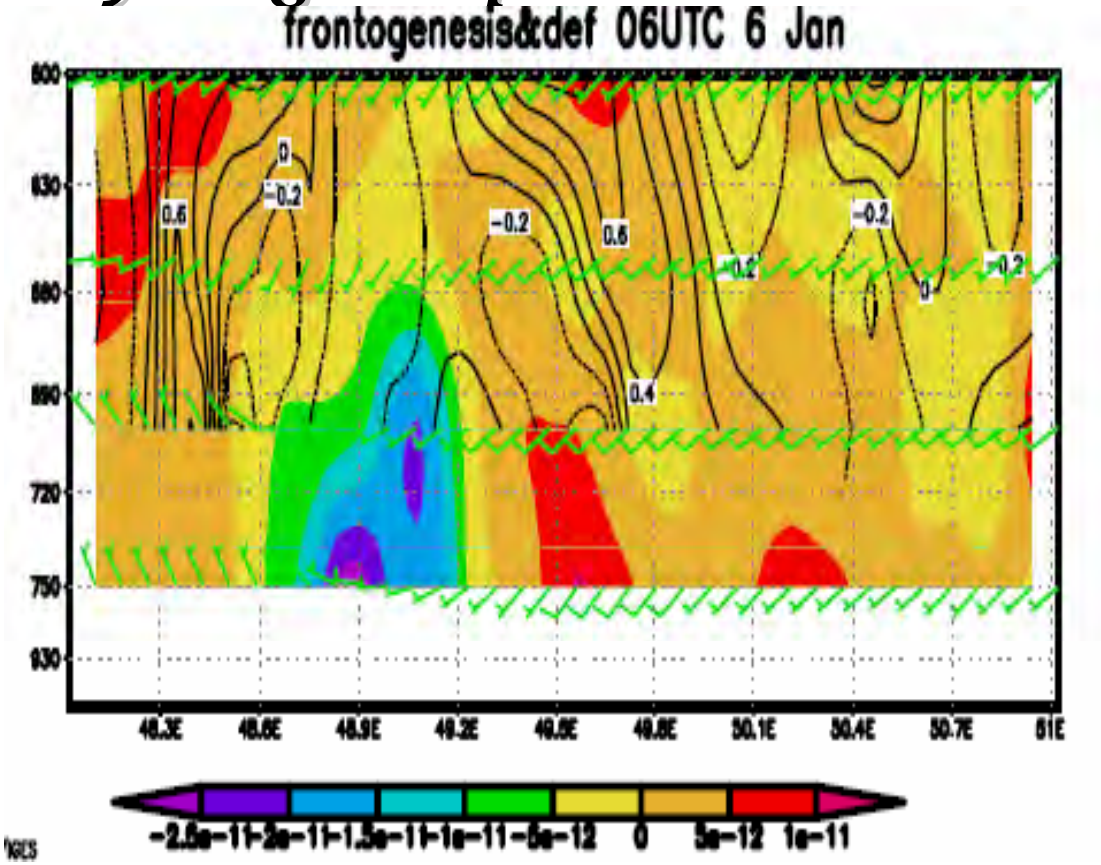
-Nearly vertical Isentropes at the leading edge of the front.

-Strongest horizontal temperature gradient at lower levels.

-Strong vertical motion at the leading edge of the front.

-Increasing wind shear with height, means large vertical gradient of the horizontal wind vector.

Analyzing Outputs

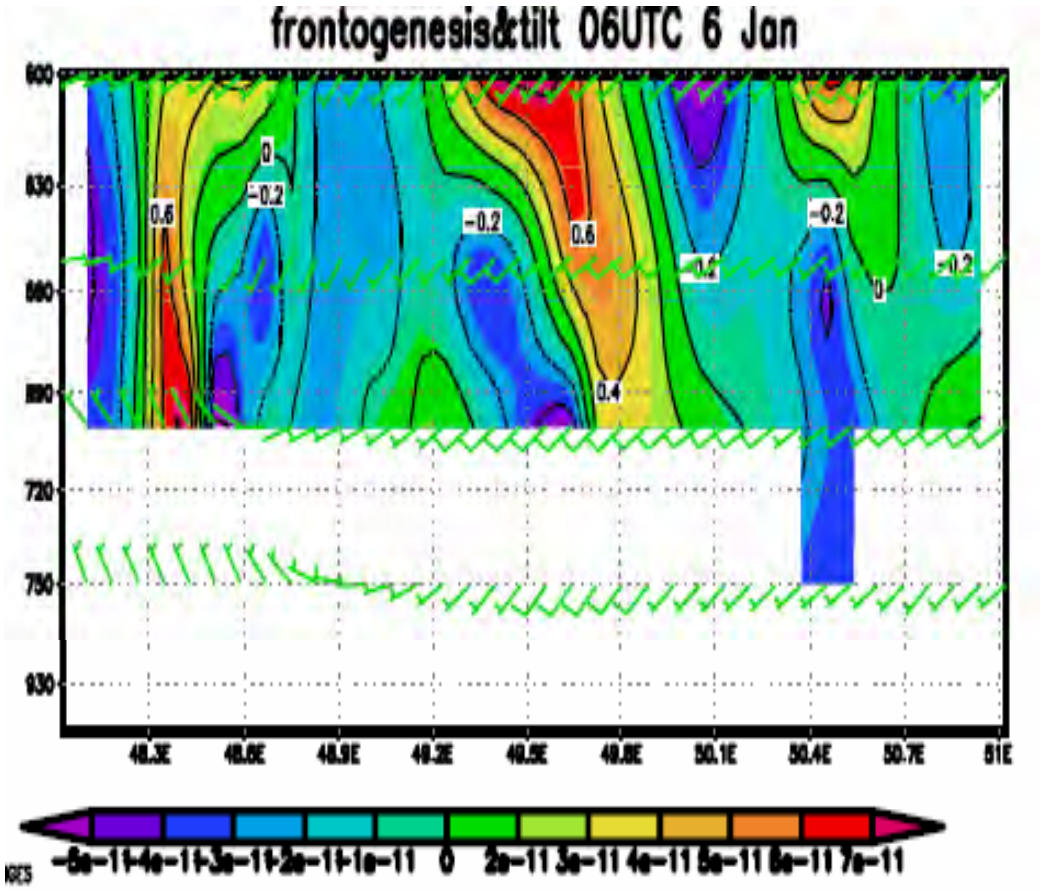


-Steeply tilting isentropes above the front produced a vertically oriented maximum of deformation term.

-Deformation term is concentrated within the frontal zone with its maximum value near the surface, where the horizontal temperature gradient and wind shift are strongest and coincident.

-Above the leading edge of the front, the deformation term dominates the total frontogenesis.

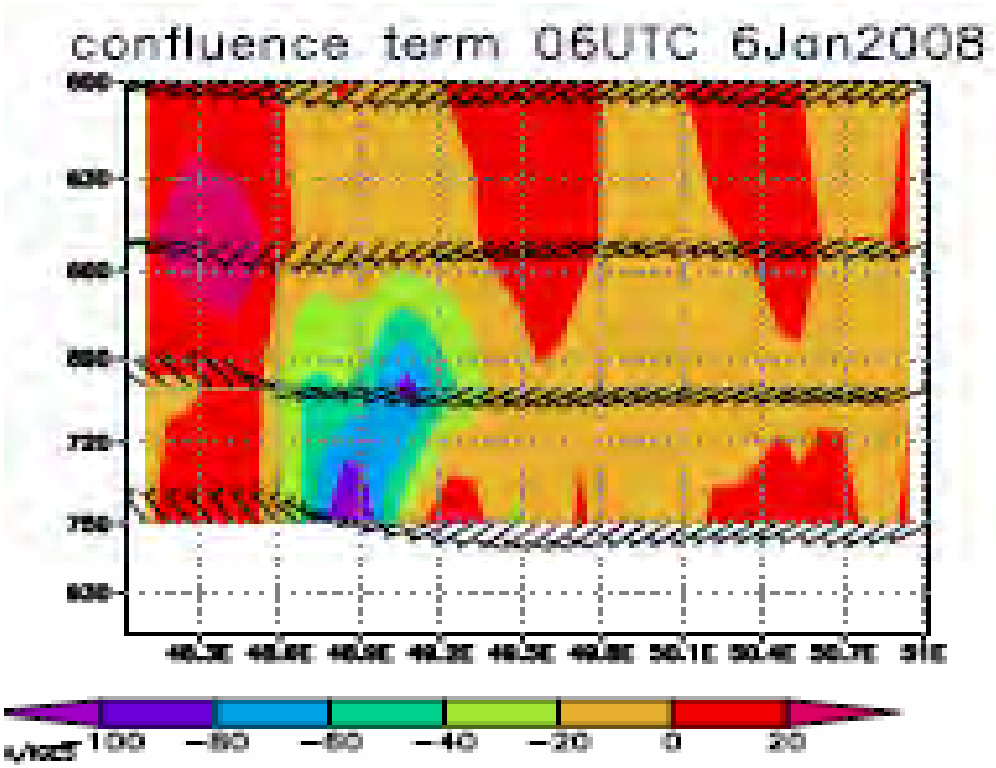
Analyzing Outputs

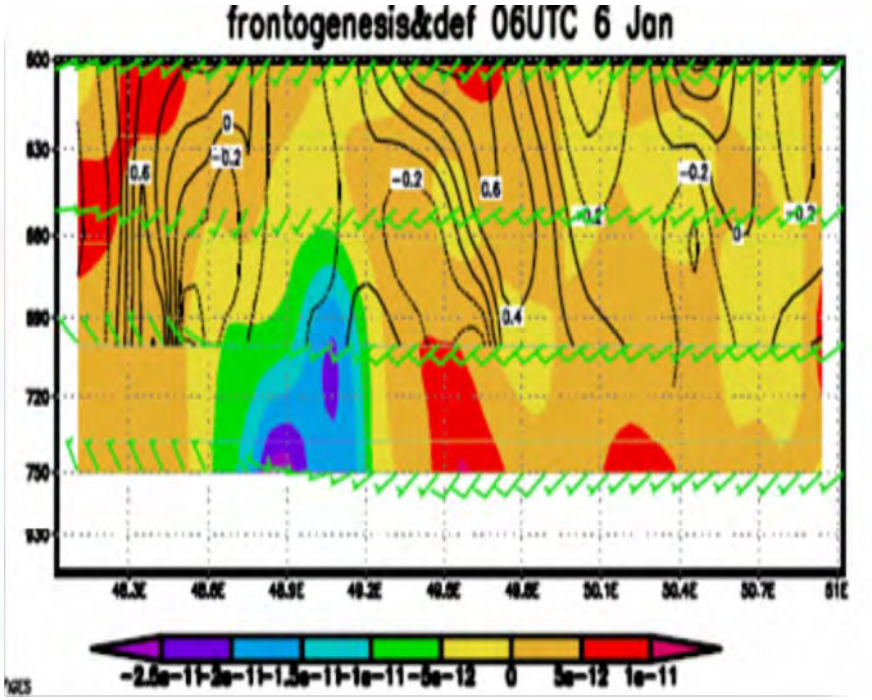


-The effect of tilting is strongly frontogenetical in the warm air near the position of frontal zone at the ground, because of the intensified horizontal gradient of vertical motion.

- The tilting term in the model simulation does not play a substantial role in frontolysis within the frontal zone although it is frontogenetical at the leading edge of the front.

Analyzing Outputs

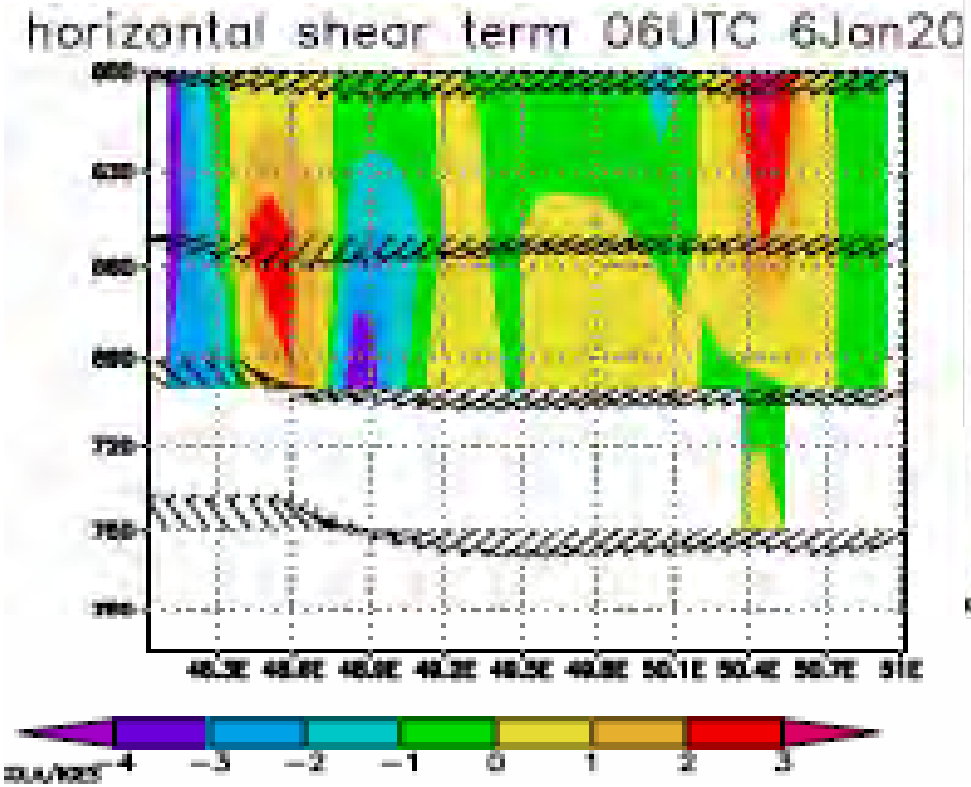


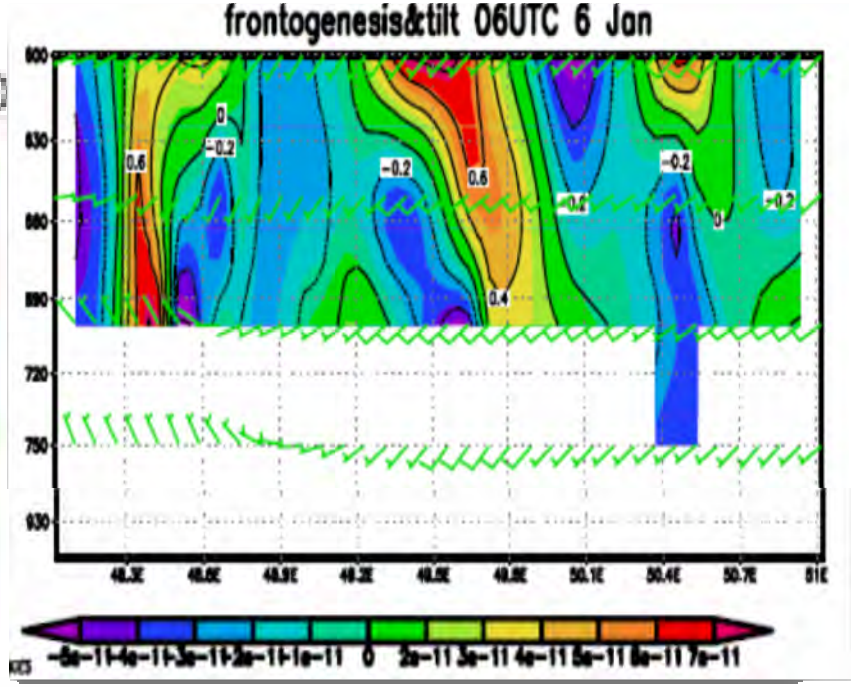


-Pattern is similar to the deformation field of frontogenesis.

-This effect is strongly frontogenetical within the lower portion of the frontal zone (because of the coincidence of confluence and strong horizontal shear).

Analyzing Outputs

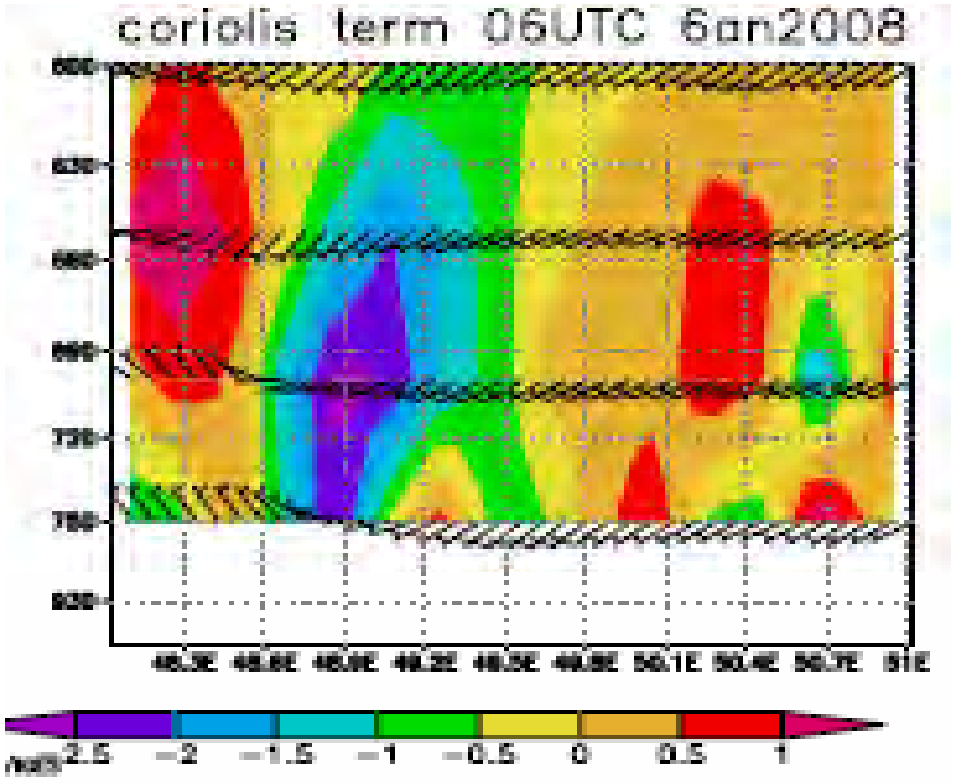




-In the lower levels of the zone, the effect is frontolytical due to the negative gradients of vertical motion and vertical wind shear

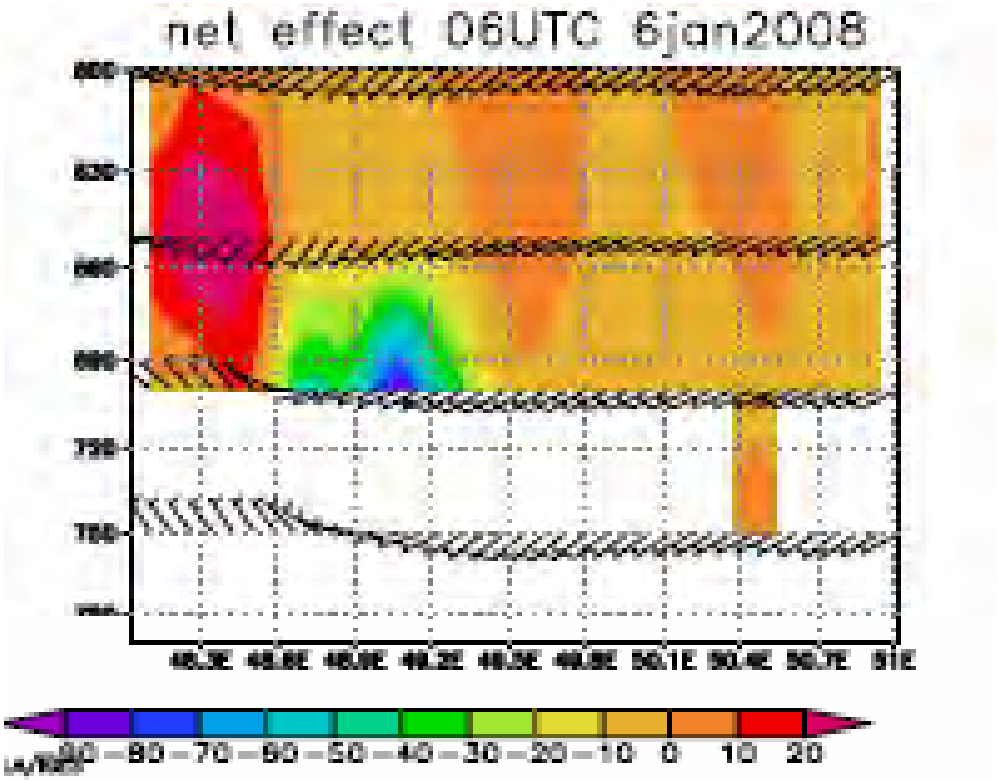
-The patterns of horizontal shear and vertical wind shear are in agreement.

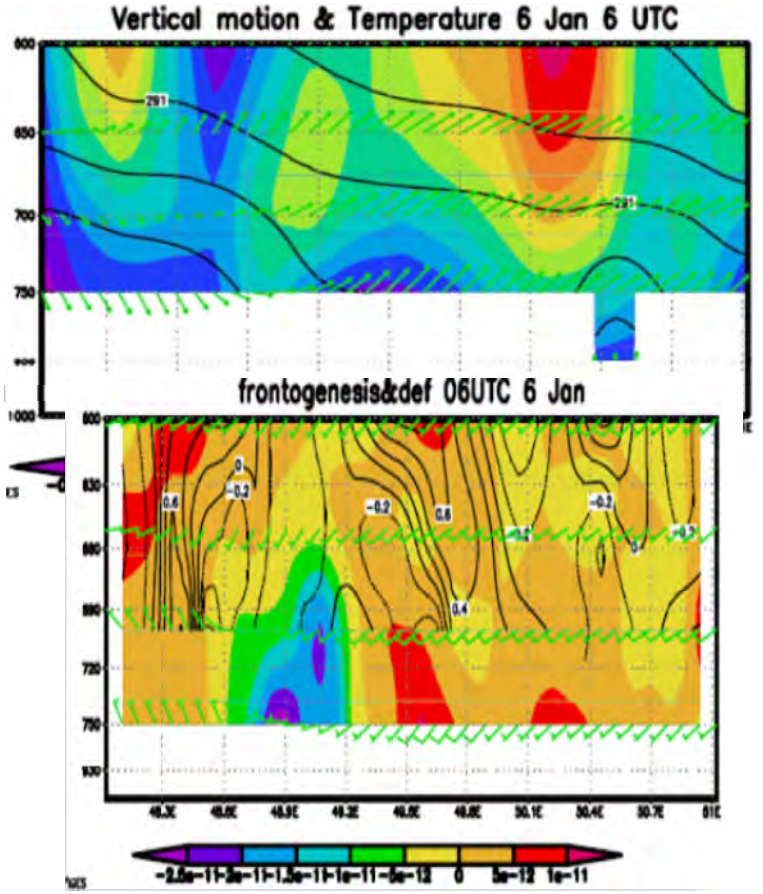
Analyzing Outputs



-Smaller effect than both confluence and tilting terms, its small frontogenetical effect in the lowest portion of the zone is obvious.

Analyzing Outputs

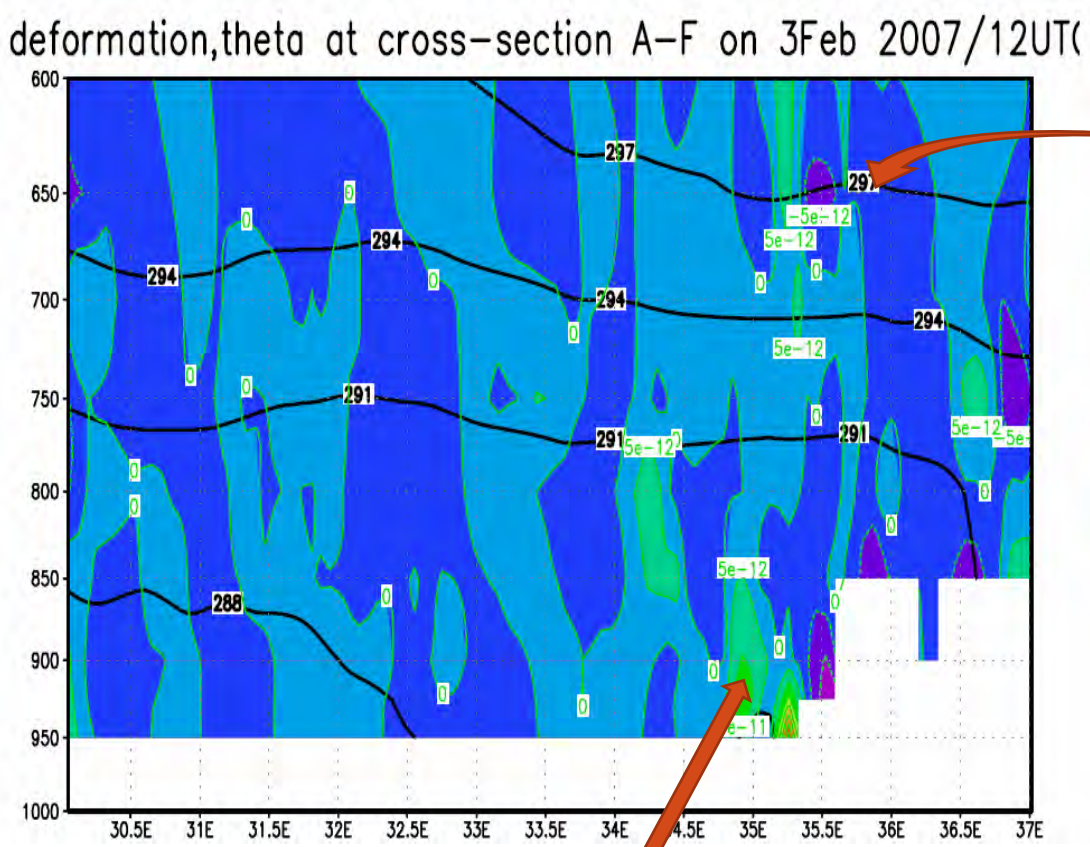




It can be seen that, similar to temperature and net frontogenesis fields in frontal zone, the effect of shear vorticity is frontogenetical and outer the frontal zone is frontolytical.

Conclusion

1- The intense frontal zone reaches its maximum strength near the ground and weakens with height.
2- The isentropes at the leading edge of the front are nearly vertical.
3- The effect of vertical horizontal gradient of vertical motion on differing vertical isentropes results in very different fields for tilting.
4- The pattern of vorticity is similar to that of temperature and deformation field in frontogenetical or frontolytical effects in the frontal zone.

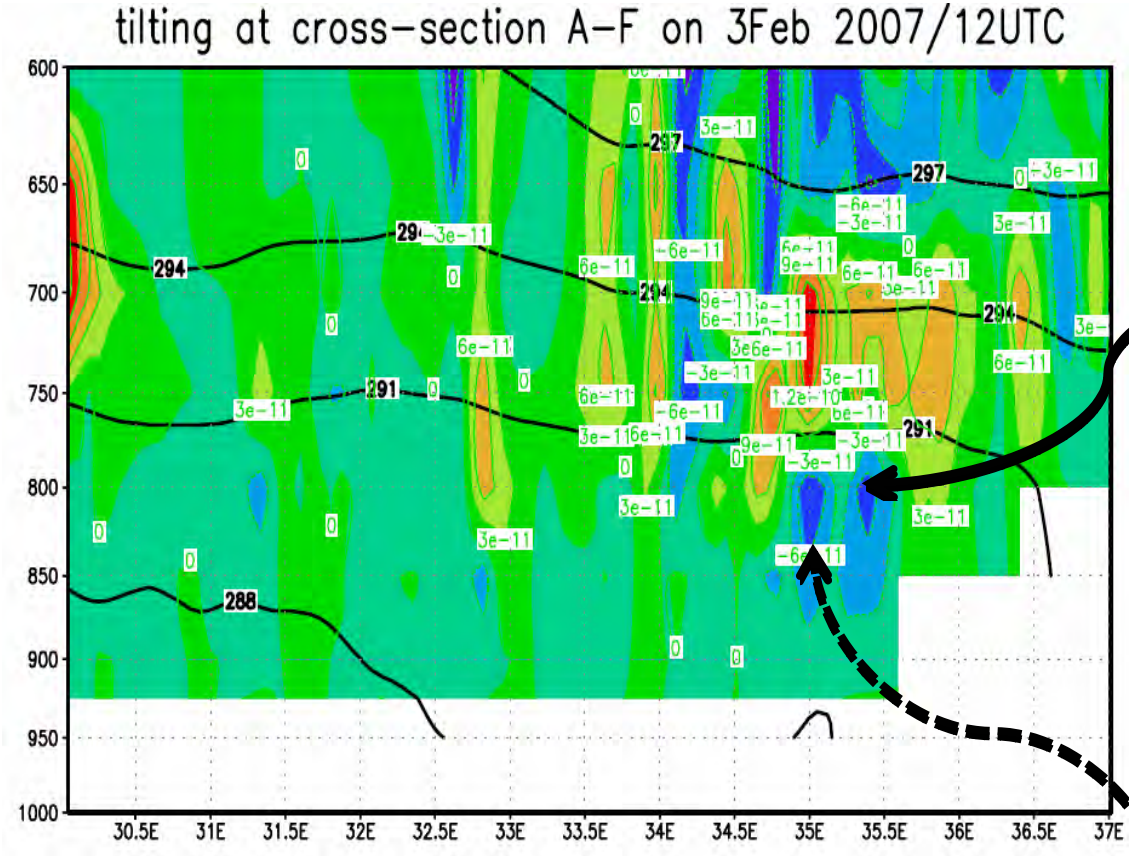


در خارج از منطقه جبهه ای اثر جمله تغییر شکل کمتر است؛ در سمت راستِ مقدار بیشینه، یعني در قسمت گرم جبهه، مقادیر منفي جمله تغییر شکل دیده میشود.

بیشینه مقدار جمله تغییر شکل حوالي طول جغرافیایي 36-35 درجه شرقي در نزدیکی سطح زمین (به علت انطباق گرادیان دماي پتانسیلي و جملات هم شاري)

14

مقادير مثبت و بزرگ جمله كج‌شدگي در هواي گرم مجاور مرز جبهه، مربوط به گراديان شديد مثبت حركات قائم در اين مكان است.



در مكان بيشينة جمله تغييرشكل، جمله كج‌شدگي داراي مقادير اندكي است.

در منطقه جبهه‌اي جملة كج‌شدگي به خصوص در ترازهاي پائين به صورت جبهه‌زدايي عمل مي‌كند كه به علت مجموع اثر گراديان منفي حركات قائم و پايداري ايستايي جو است

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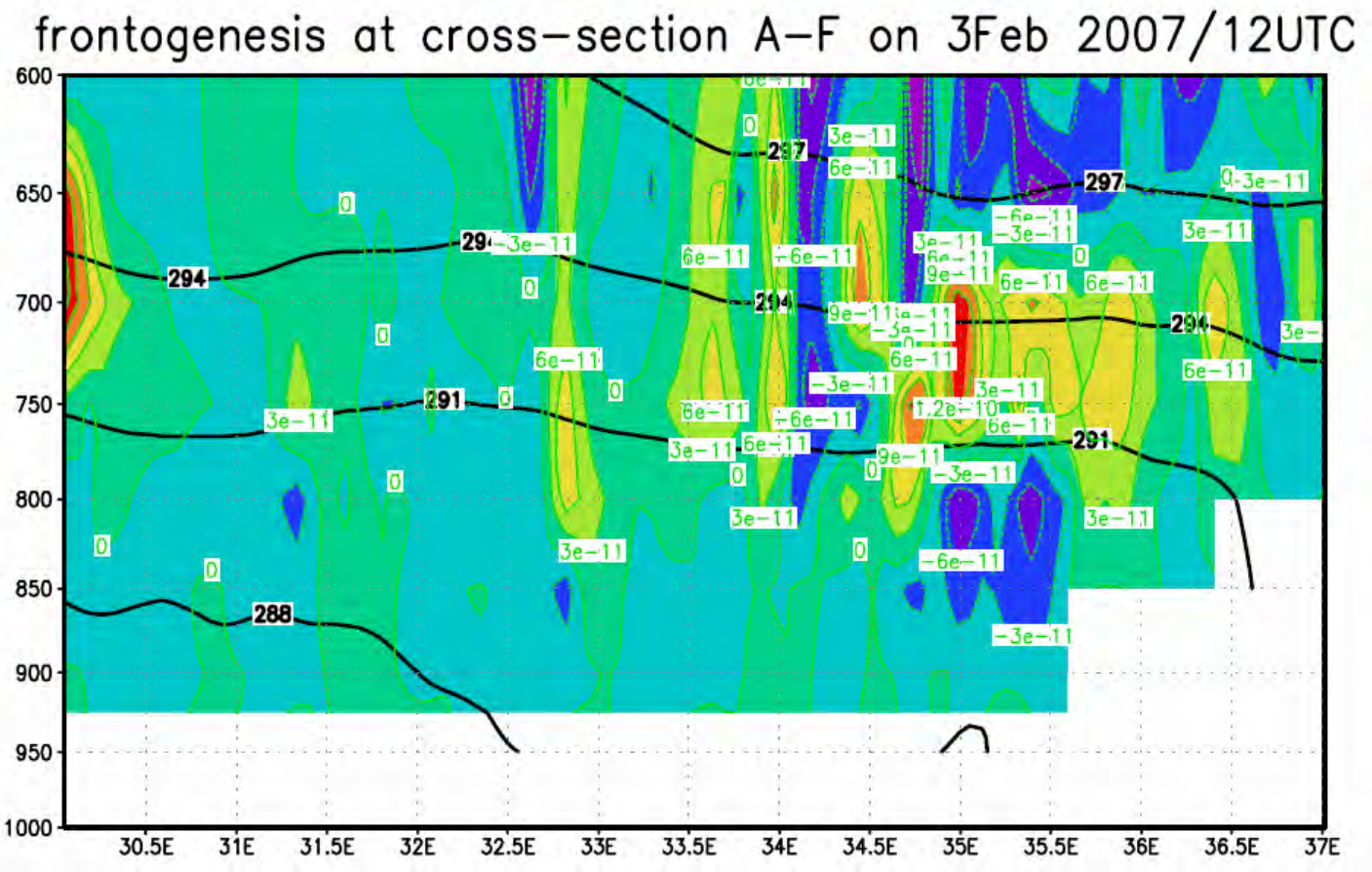
frontogenesis at cross-section A-F on 3Feb 2007/12UTC
600
650
700
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850
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30.5E
31E
31.5E
32E
32.5E
33E
33.5E
34E
34.5E
35E
35.5E
36E
36.5E
37E
294
297
291
288
3e-11
6e-11
9e-11
1.2e-10
-3e-11
-6e-11
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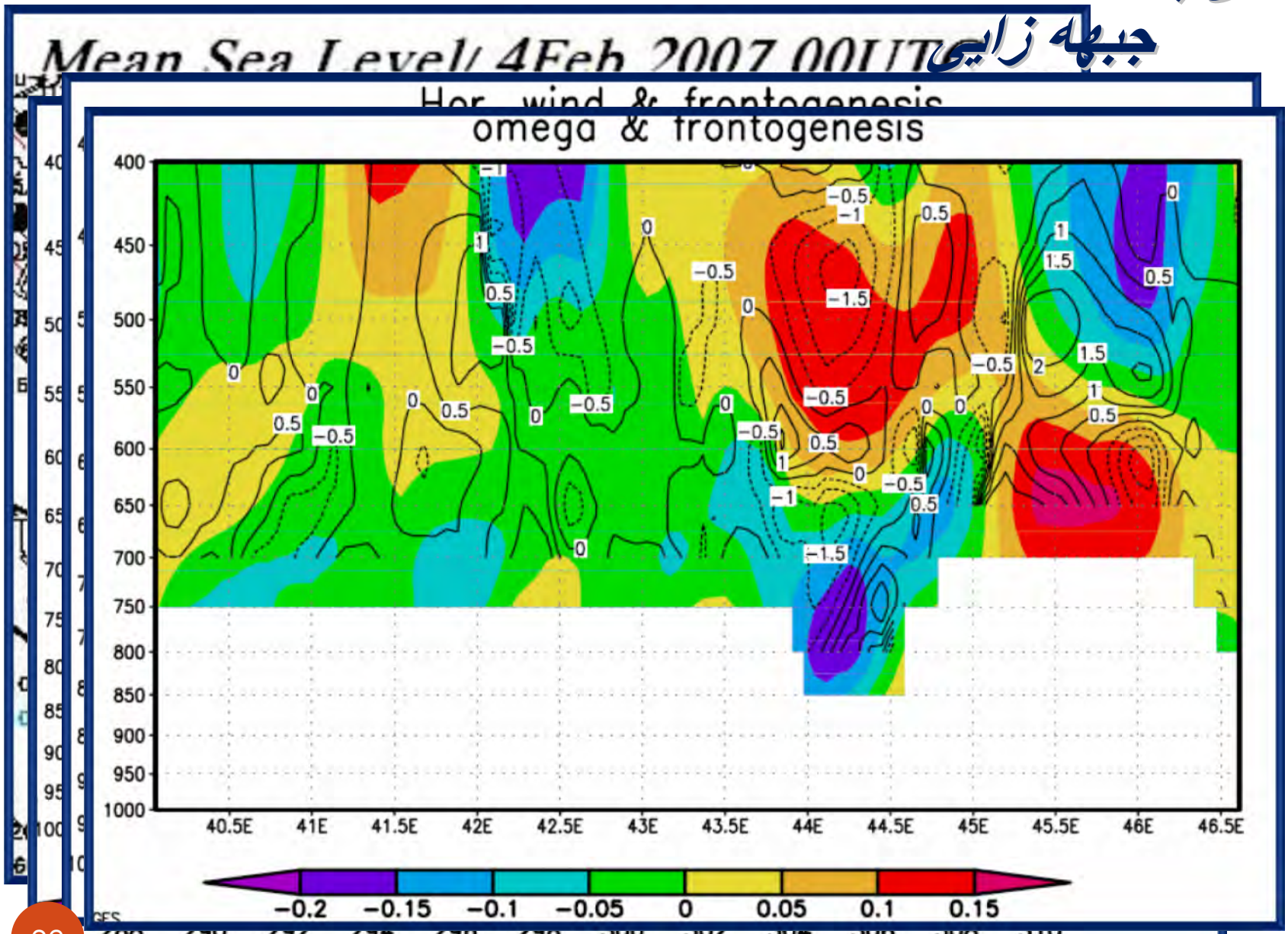
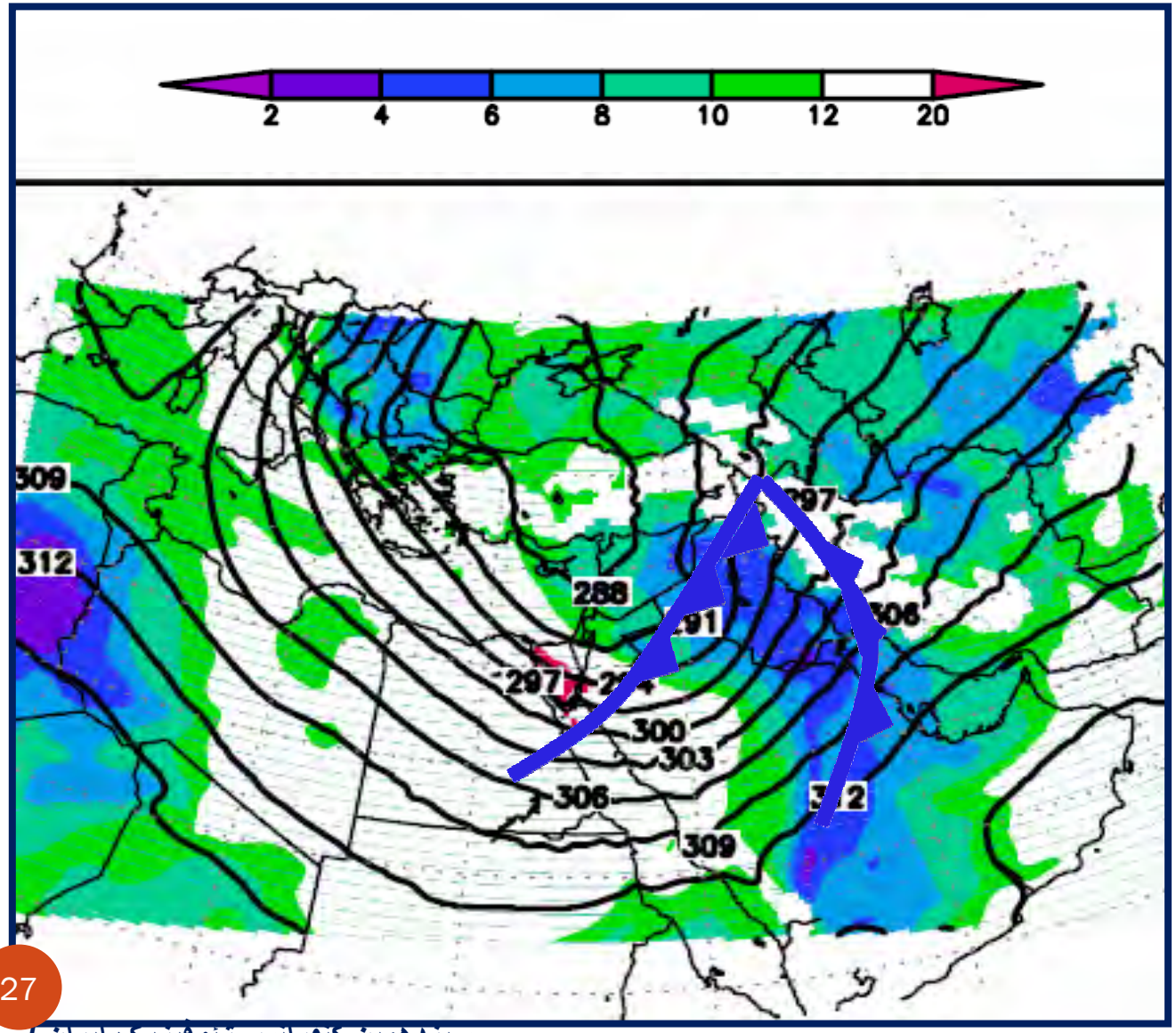
بررسی پارامترهای مختلف در جبهه زایی



بررسی پایداری ایستایی در سطح 700hPa



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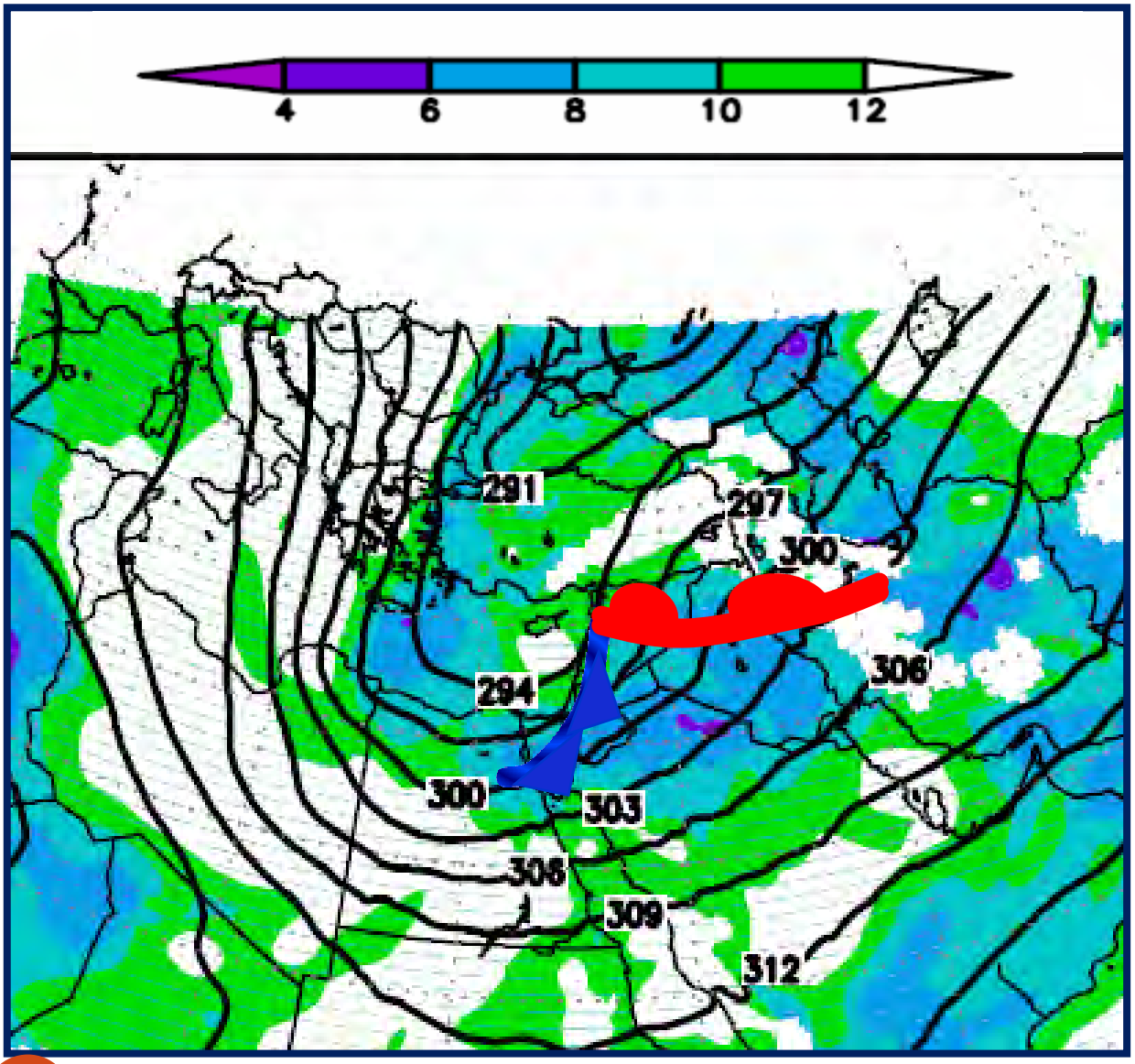
بررسی پایداری ایستایی در سطح 700hPa



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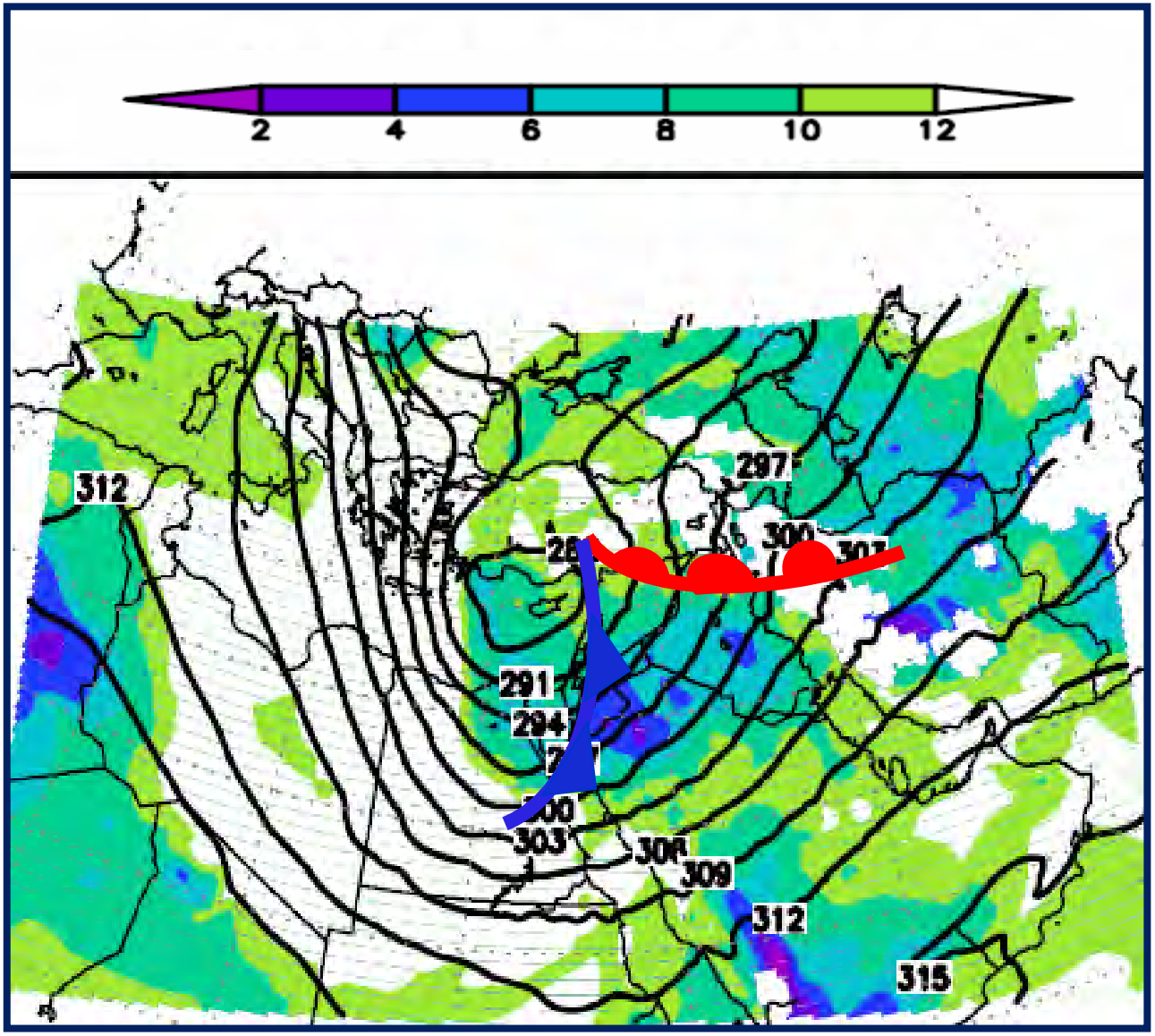
بررسی پایداری ایستایی در سطح 700hPa



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