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Slantwise circulations and convection in pre-frontal environment over central Italy: a numerical study

Maurizio Fantini, Piero Malguzzi and Andrea Buzzi

Institute of Atmospheric Sciences and Climate
ISAC-CNR

Bologna, Italy

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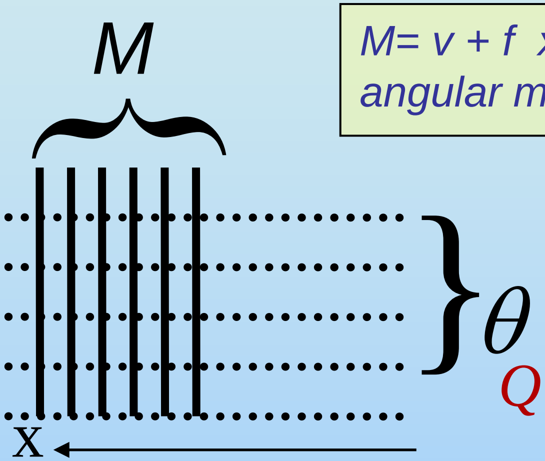
Outline →

- Quasi 2-D processes: symmetric instability and Delta-M (Δ-M) adjustment (Morcrette and Browning, QJRMS, 2006). Relevant to mesoscale precipitating systems ?

- Model experiments performed with and without orography.

- Analysis of evolutions of regions of dry and moist symmetric instability.

(Fantini et al, QJRMS, 2011, subm.).



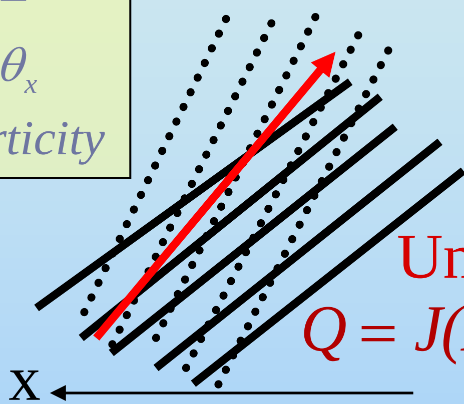
M= v + f x: pseudo-angular momentum

$$Q = J(M,\theta) = = M_x\theta_z - M_z\theta_x$$

potential vorticity

Stable

$$Q = J(M,\theta) > 0$$



Unstable

$$Q = J(M,\theta) < 0$$

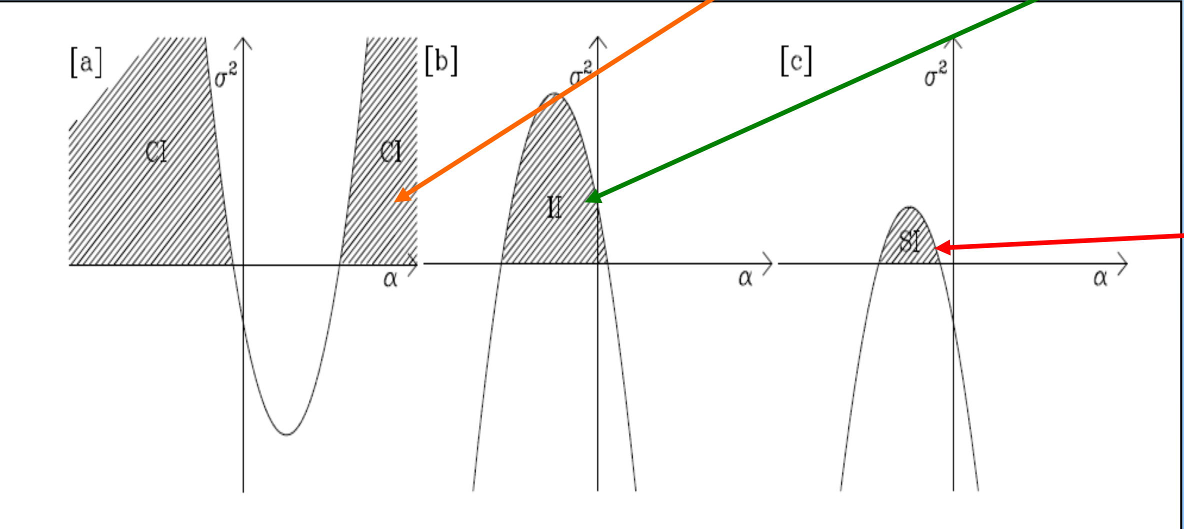
With normal modes: ~ $exp\ (\sigma t + i(kx+mz))$:

$\alpha = -k/m$ is the slope of the wavefront, i.e. trajectory slope.

($\alpha = 0$: horizontal traject.; $\alpha = \pm\infty$: vertical traject.).

$\sigma^2 = -\alpha N^2 - 2S^2\alpha - F^2$ is a growth rate (in geostrophic and hydrostatic balance).

$N^2 = g\,\theta_z/\theta_0$, $S^2 = f\,v_z$, $F^2 = f\,(f + v_x)$, $Q = F^2 N^2 - S^4$



DRY CASE:

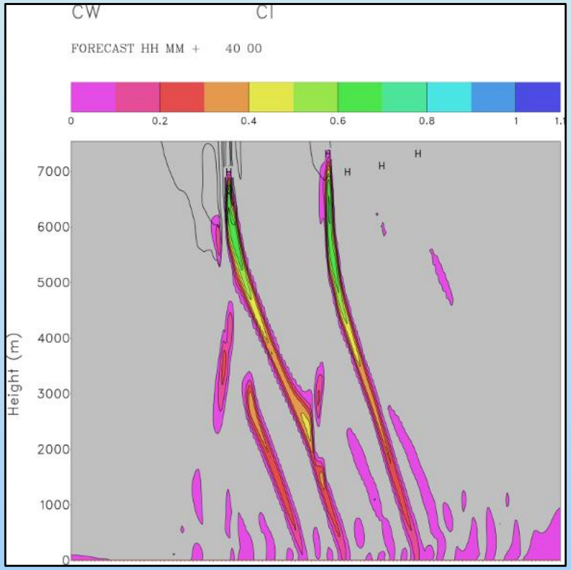
- C. I. - Convective Instability: $N^2<0$.
- I. I. - Inertial instability: $N^2>0$, $F^2<0$ ($Q<0$), $\sigma^2_{max}=-Q/N^2$.
- S. I. - Symmetric Instability: $N^2>0$, $F^2>0$, $Q<0$, $\sigma^2_{max}=-Q/N^2$.

(some) References

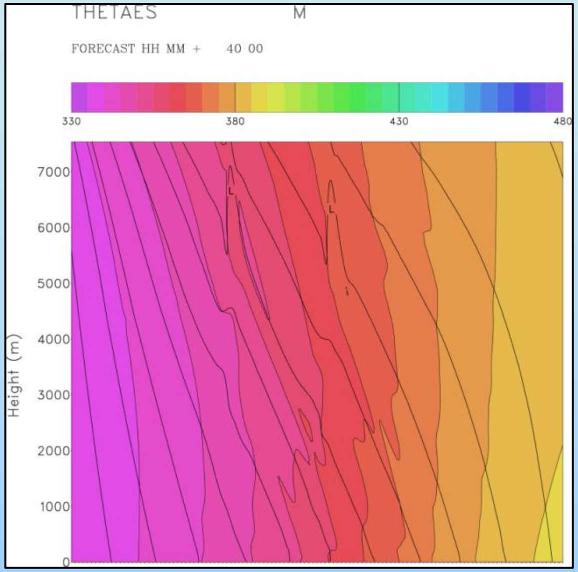
- Bennetts, Hoskins 1979 QJRMS
- Fischer, Lalaurette 1995 QJRMS
- Gray, Dacre 2008 QJRMS
- Holt, Thorpe 2001 QJRMS
- Hoskins 1974 QJRMS
- Jones, Thorpe 1992 QJRMS
- Morcrette, Browning 2006 QJRMS
- Ooyama 1966 JAS
- Persson, Warner 1995 JAS
- Schultz, Knox 2007 MWR
- Schumacher, Schultz, Knox 2010 MWR
- Thorpe, Rotunno 1989 JAS
- Xu 1986 QJRMS
- Xu, Clark1985 JAS

Symmetric instability (S. I.) has been related to the formation of slantwise ascent and descent and rainbands in strong baroclinic regions.

Co-existing convective and S. I. in model experiments and initiation of convection by S.I. (Fantini & Malguzzi, *Adv. in Geosci.*, 2008):



cloud water and cloud ice (0.1g/Kg)

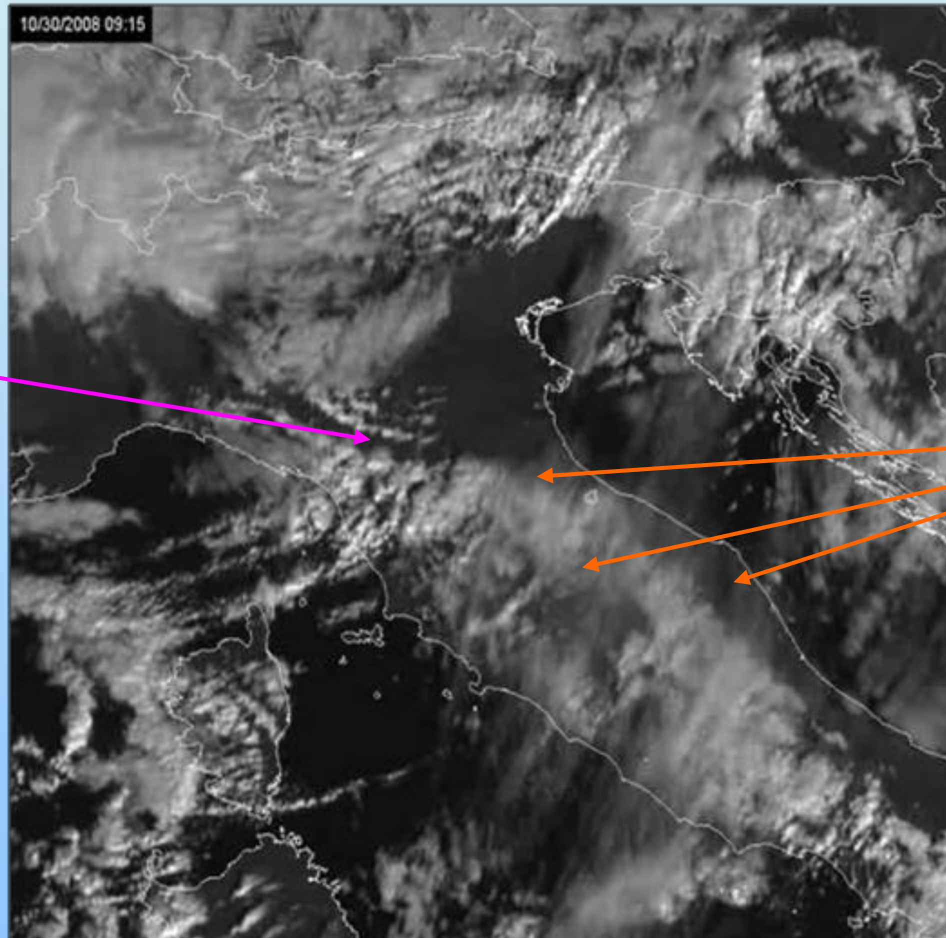


M (10 m/s) and thetaes (K)

Slantwise and upright convection are observed to co-exist

“Down-scale” event (Xu,1986)

A case over Italy: MSG images (vis.), 30 Oct. 2008, 0915 UTC North - Central Italy

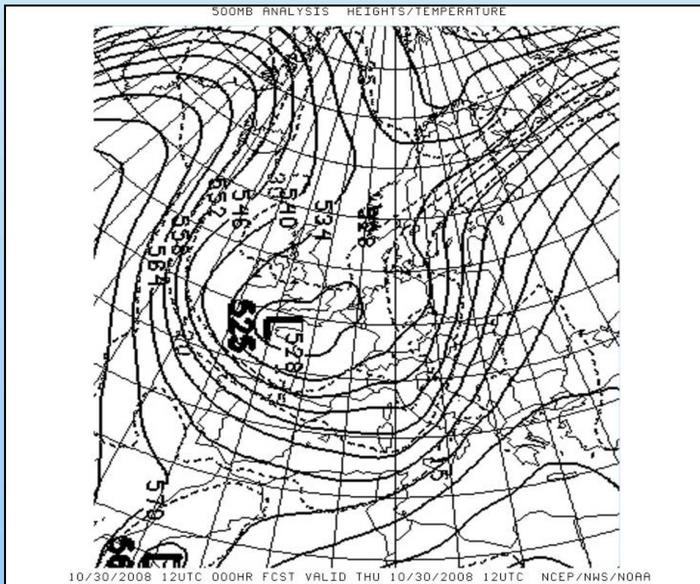


non-stationary lee waves

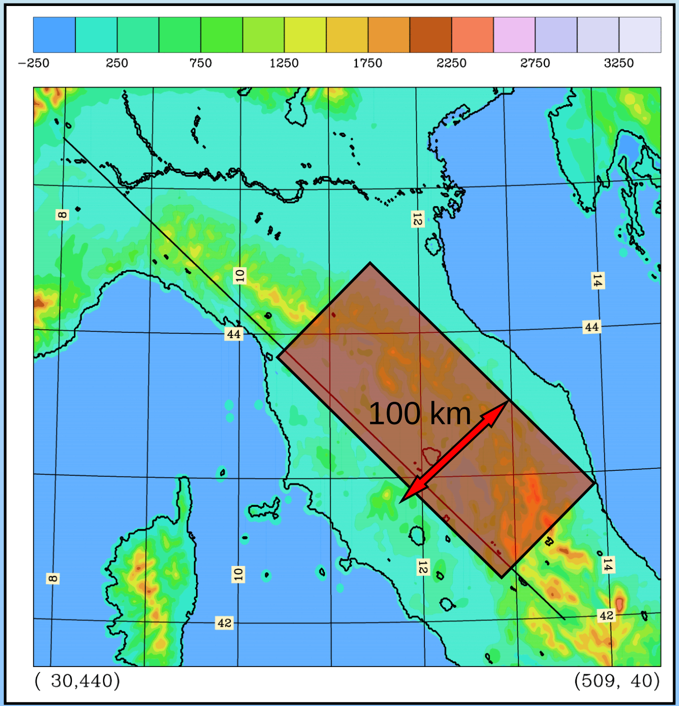
rain-bands

Numerical experiments:

NH model MOLOCH, 0.9 km grid, 50 levels - 12 h simulations, from 01:00 UTC of 30/10/2008, nested in BOLAM and starting from NCEP analysis and boundary data.

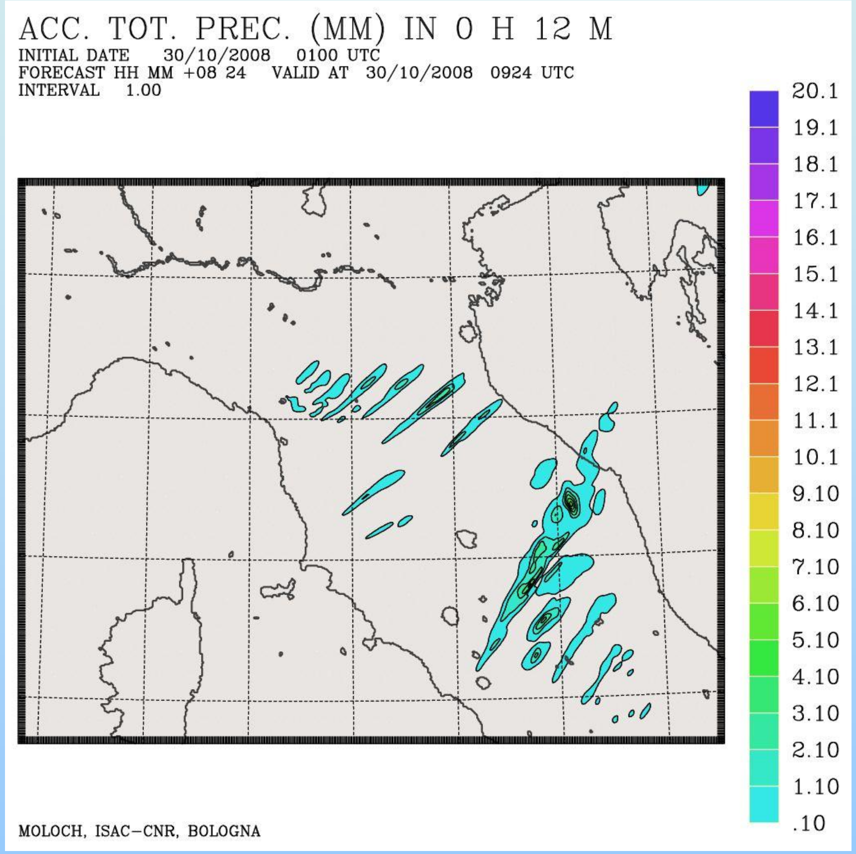


500 hPa analysis (GPH and T) at 12:00 UTC, 30 Oct 2008
(modified from: NWS DIFAX weather map archive at archive.atmos.colostate.edu)

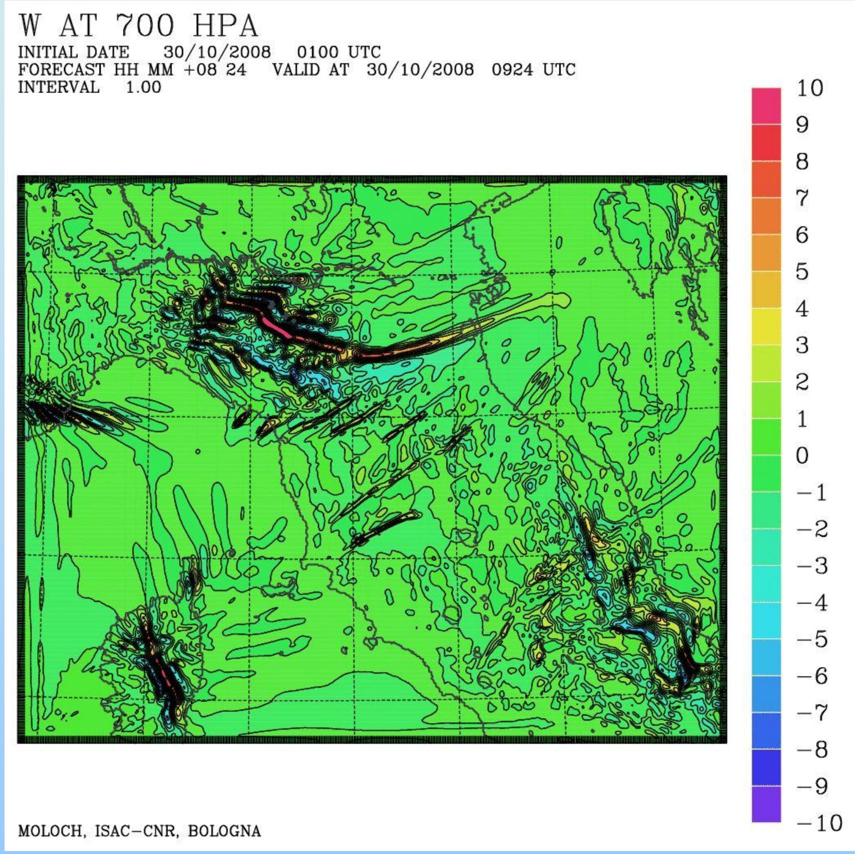


MOLOCH model domain and cross-sections

Experiment with full topography

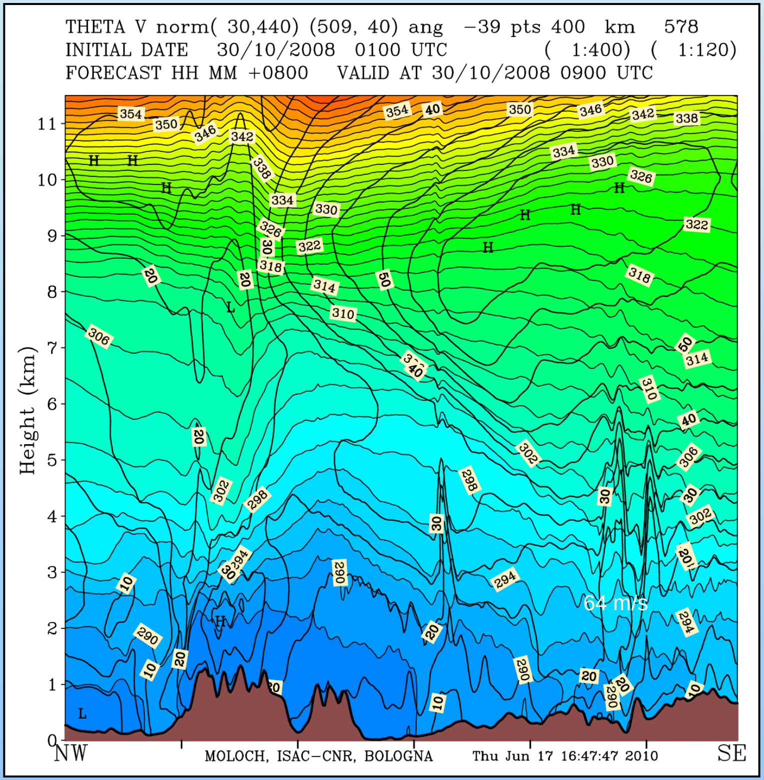


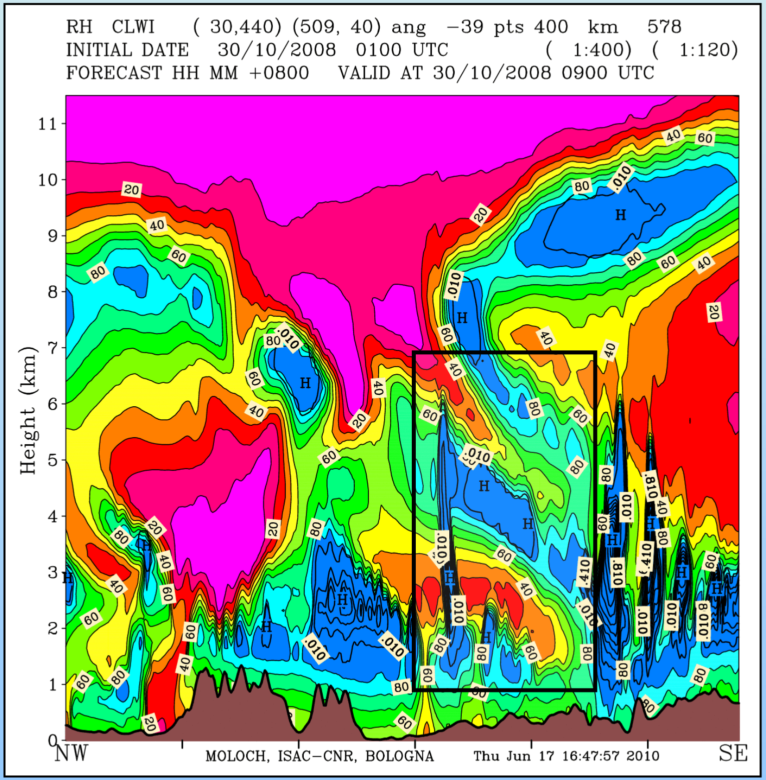
Model accumulated precipitation at 0924 UTC



Model vertical velocity w at 700 hPa 0924 UTC

Experiment with full topography



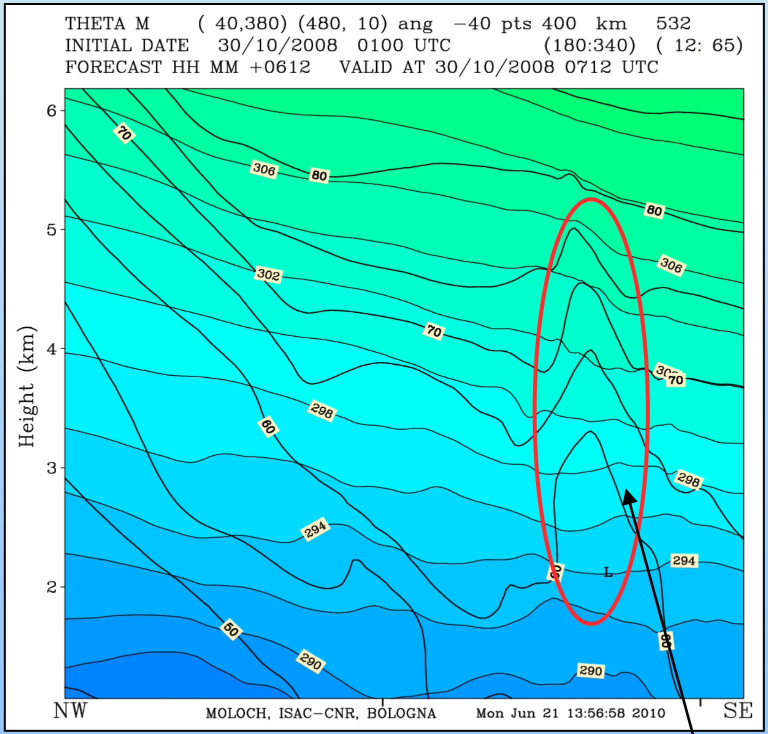


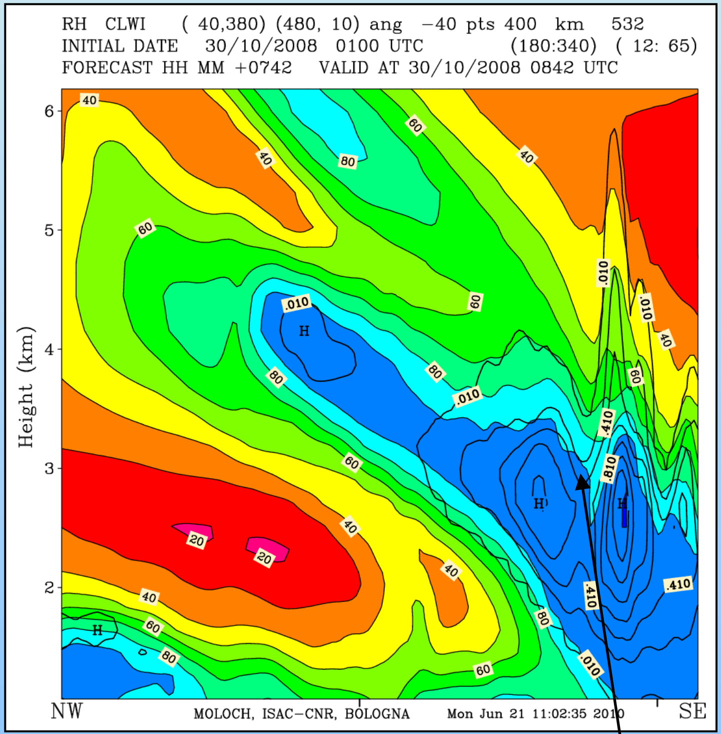
normal wind and dry potential temperature 09:00 UTC	relative. humidity and cloud condensate 09:00 UTC

Experiment with flattened topography,

Average cross-section of pseudo-momentum M and dry potential temperature θ, 07:12 UTC

Average cross-section: relative humidity (colour) and cloud condensate (liquid water + ice, thick lines), 08:42 UTC





Convection-generated "buckle" of M

Symmetrically unstable (dry or moist?)

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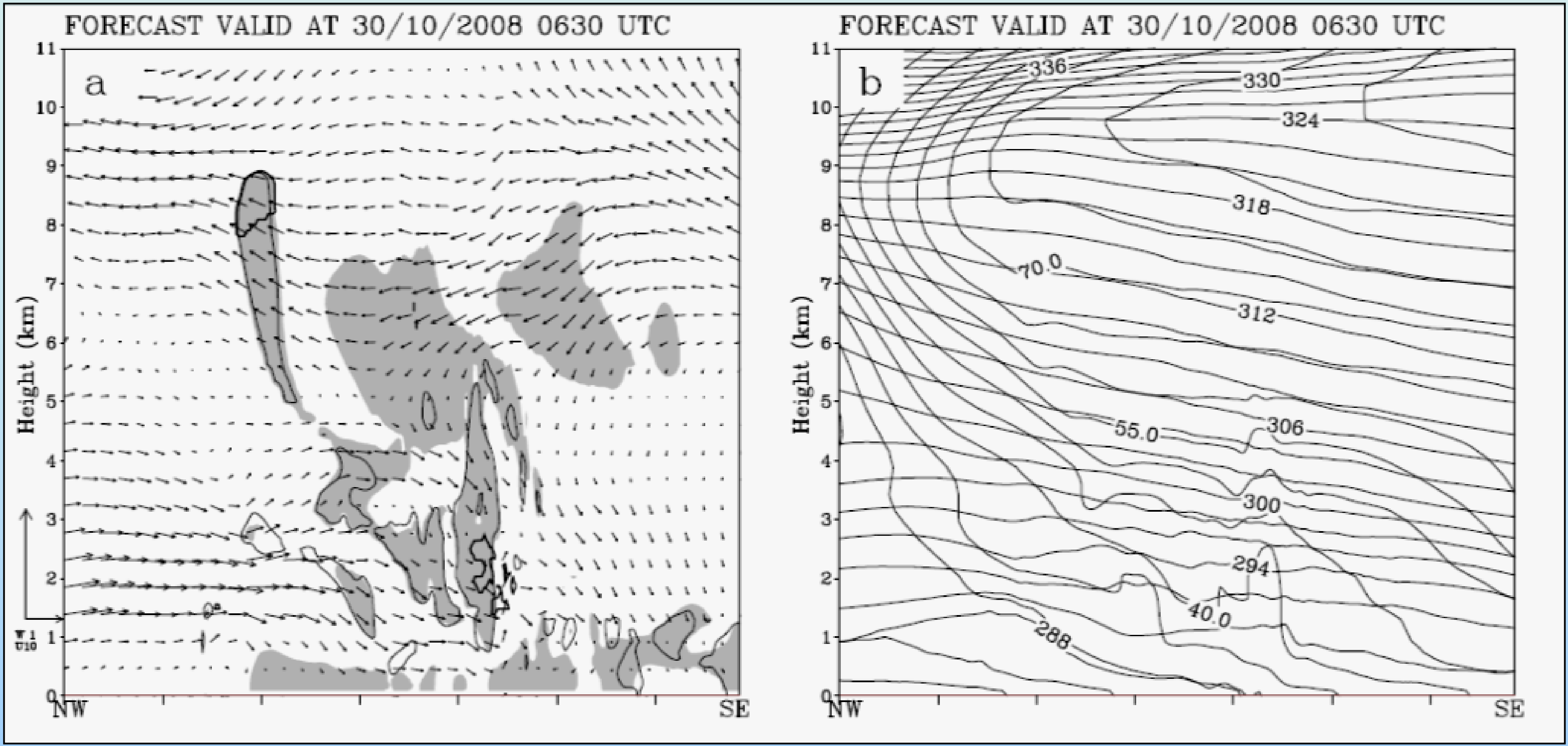
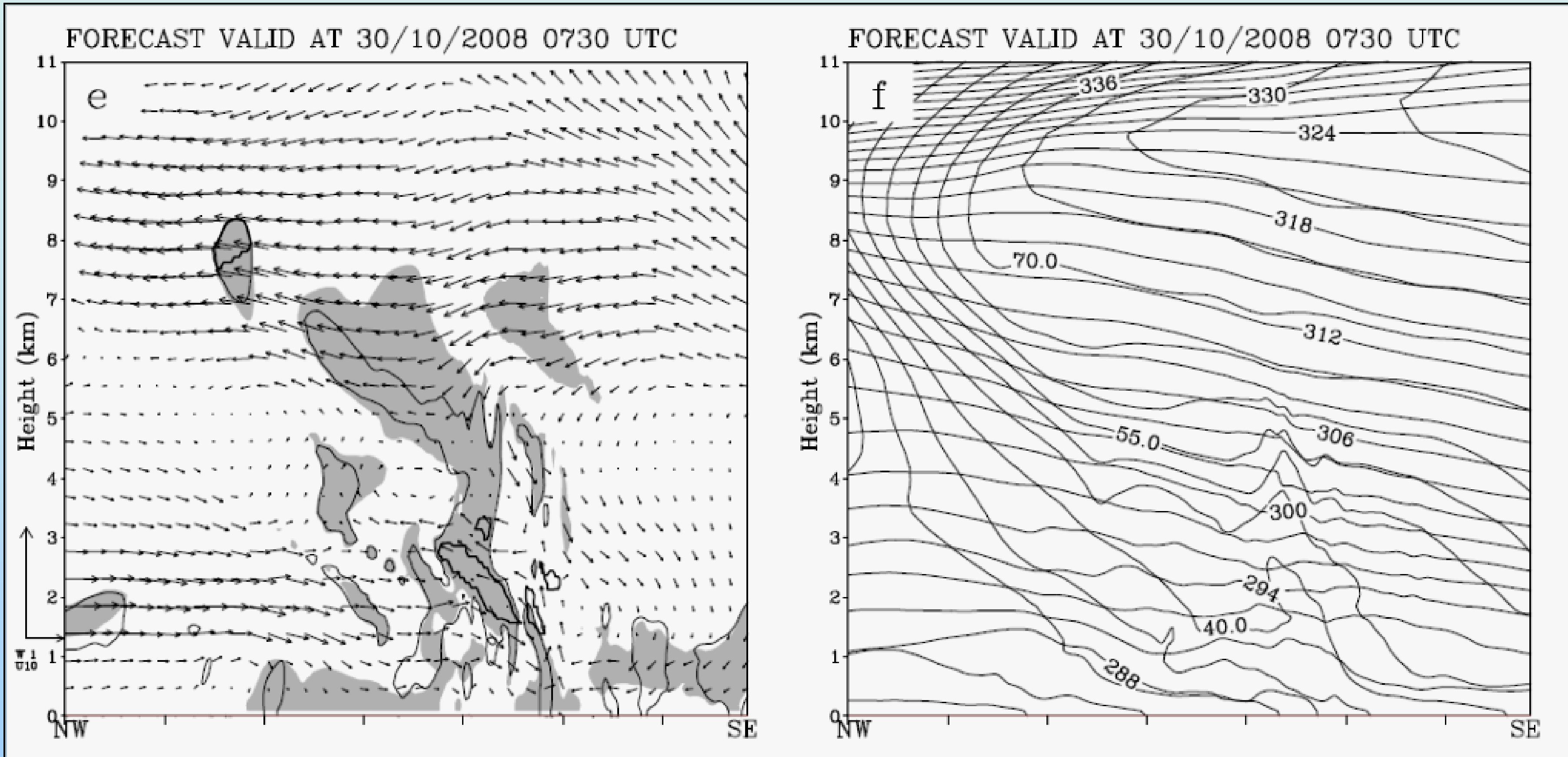
Averaged cross-sections



- Shaded: dry statically stable, dry PV<0 → dry Symmetric Instability.
- Thick lines: moist PV<0, saturated and moist statically stable → moist Symmetric Instability.
- Thin lines: areas of absolute vorticity < 0 → Inertial Instability.

Potential temperature θ and and pseudo momentum M.

Averaged cross-sections



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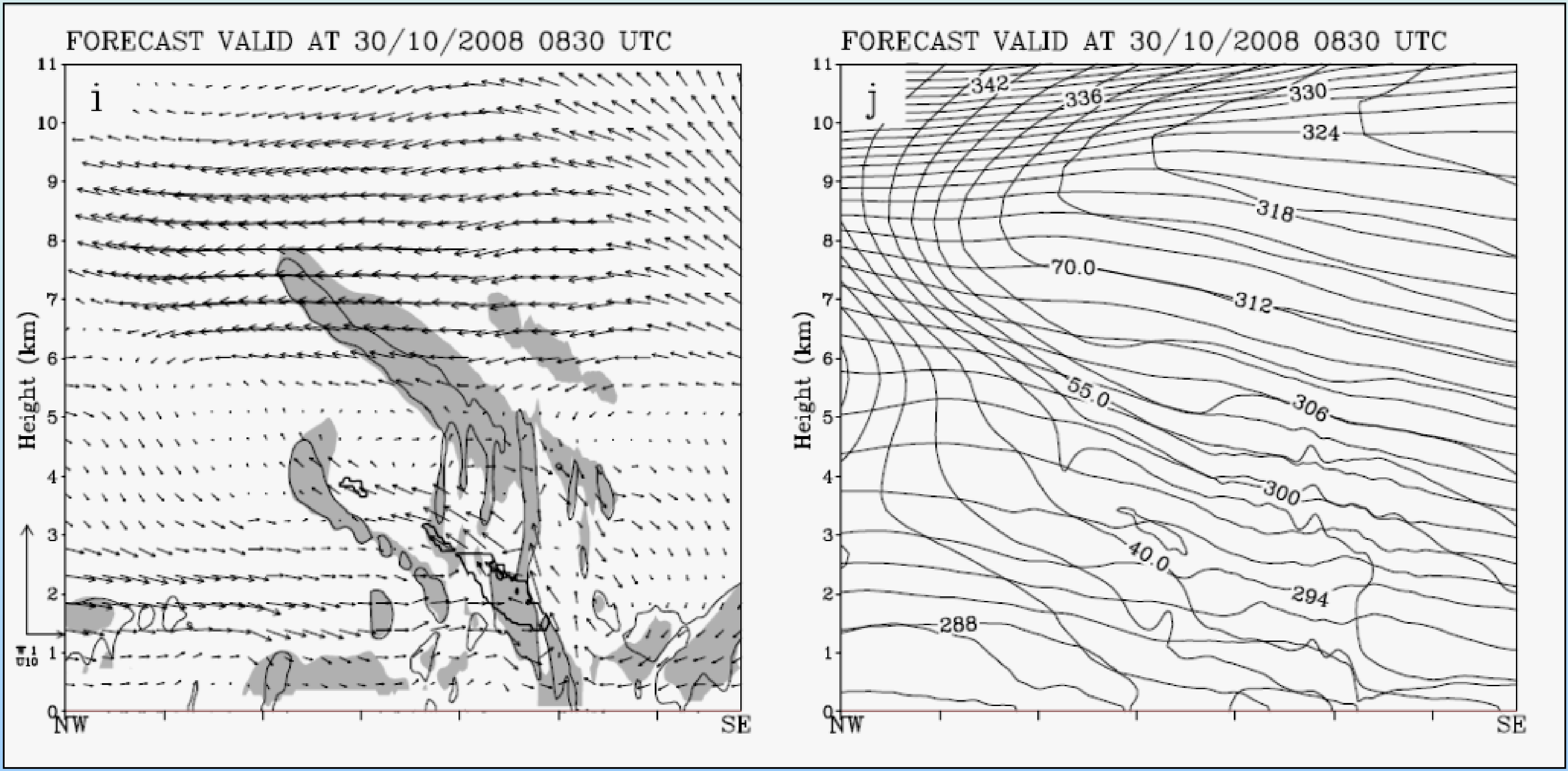

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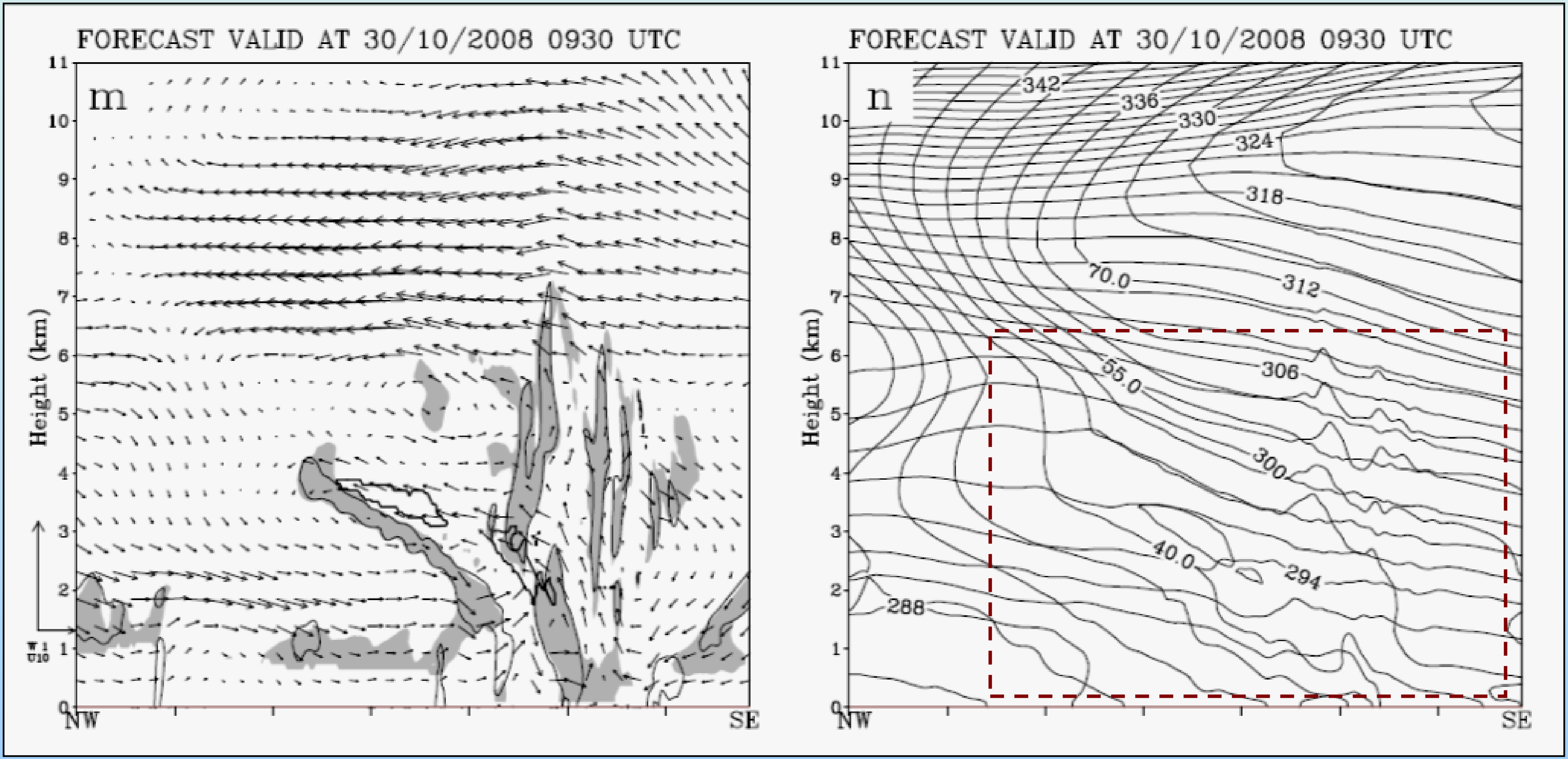

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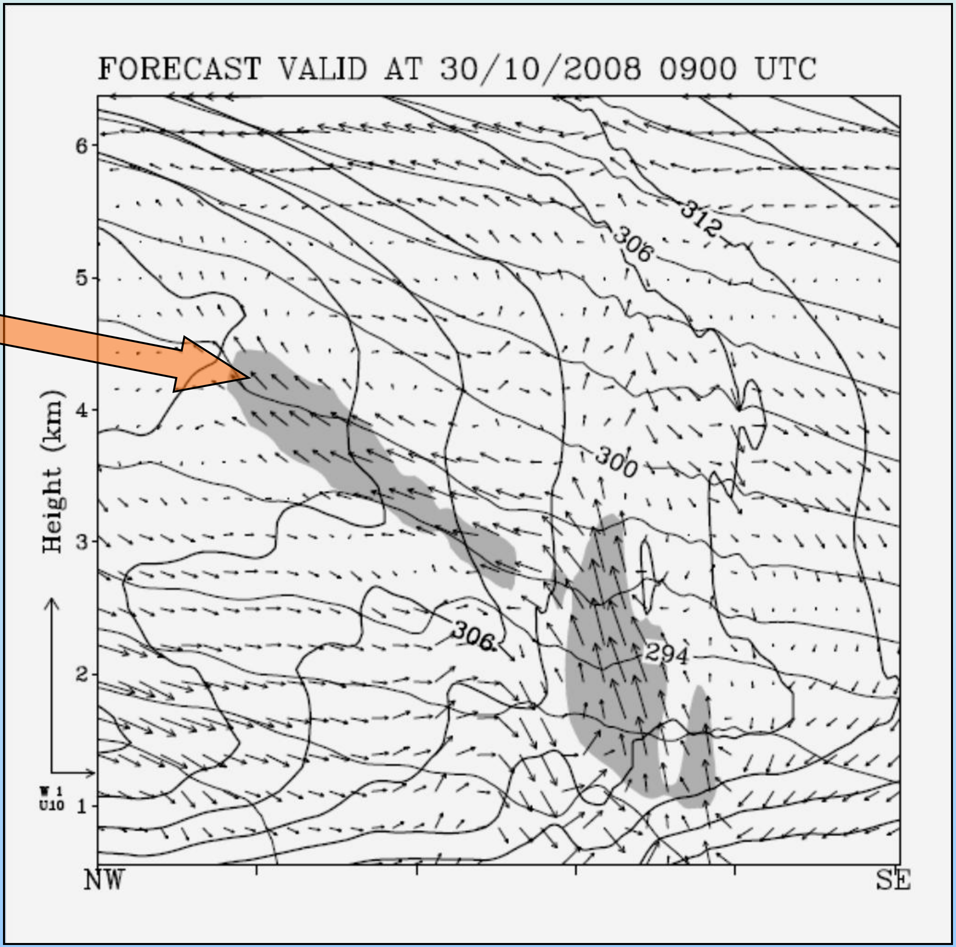
Potential temperature θ and and pseudo momentum M.

Averaged cross-section

In this area the motion follows dry isentropes although the air is saturated.

Possible effects of condensate on buoyancy?

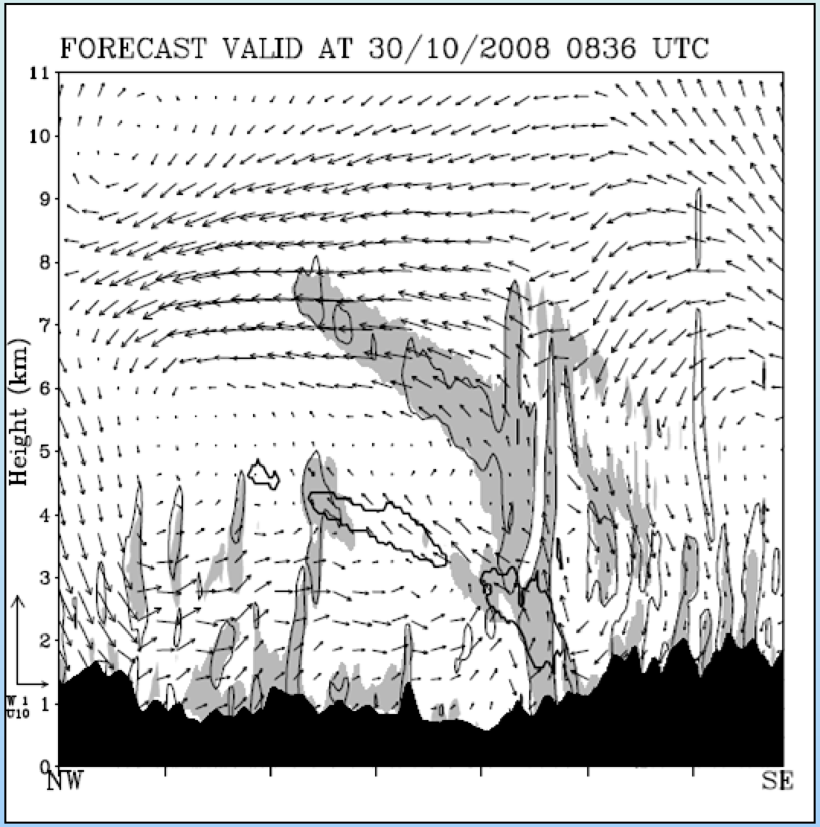


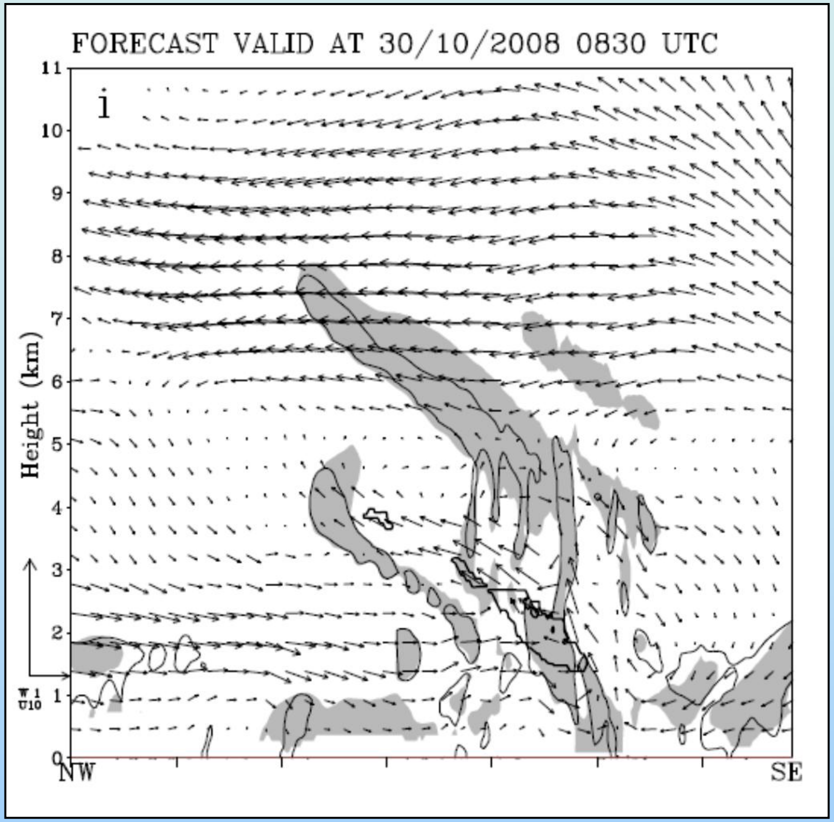
Thin: dry pot. temp. θ.

Thick: saturated equivalent pot. temp. θ_{es}.

Shaded: saturated areas /r.h.> 95%).

Averaged cross-sections





Comparison of cross-sections with (left) and withouth orography (right).

Summary

- **Numerical simulations starting from a real situation show occurrence of S. I.**

- **S. I. is mixed with upright convective cells (“up-scale” development; Δ-M adjustment).**

- **Slanted circulation is slower than the upright convection, but develops coherently along a distance of 100 km**

-**Slanted motion appears locally dry/moist; dry trajectories even in saturated areas - possible role of condensate loading in reducing moist instability.**