Convection Initiation over Complex Terrain: Lessons Learned from TRACT, VERTIKATOR, PRINCE, COPS and CSIP

compiled by

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Contents

TRACT	VERTIKATOR	CSIP	PRINCE	COPS	NEPTUN-HyMeX
1992	2002	2005	2006	2007	2012

Data resolution and CI identification

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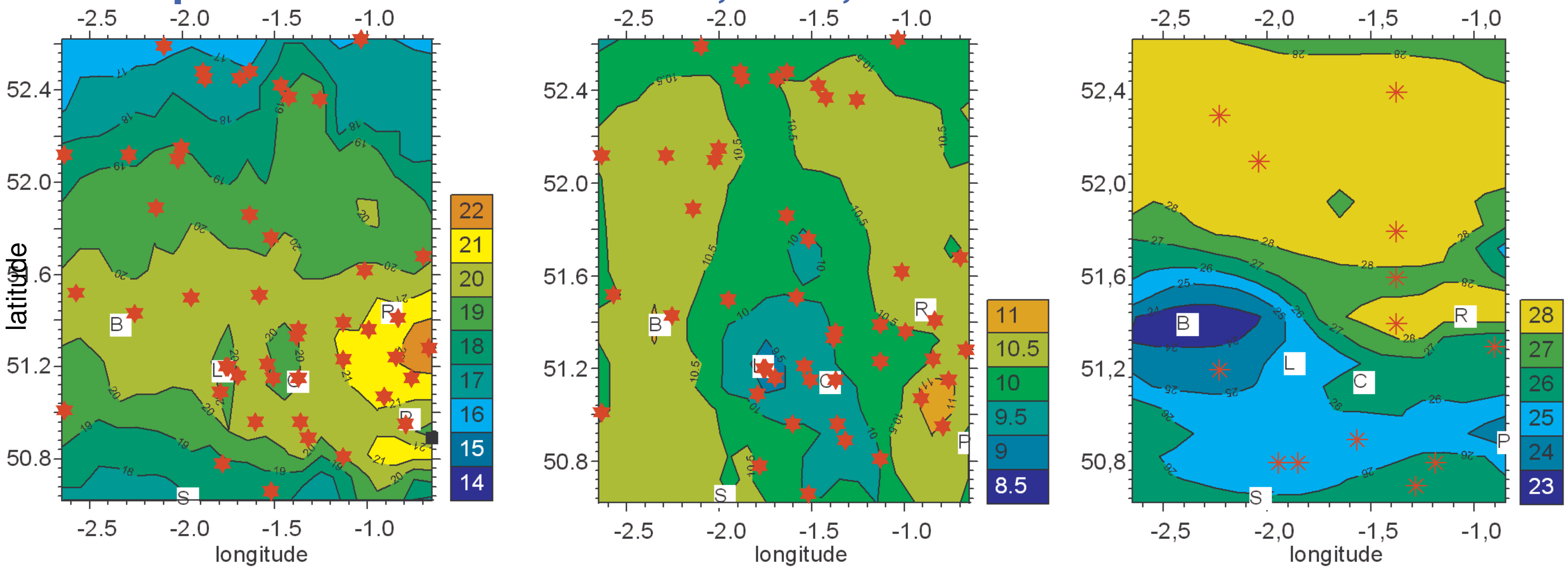
The impact of increased spatial data resolution on the detection of the initiation of convection

„Adjustment method“ algorithm relates GPS IWV data to radiosonde profiles (S. Khodayar)

Example: 1200 UTC on 29 June, 2005, CSIP domain

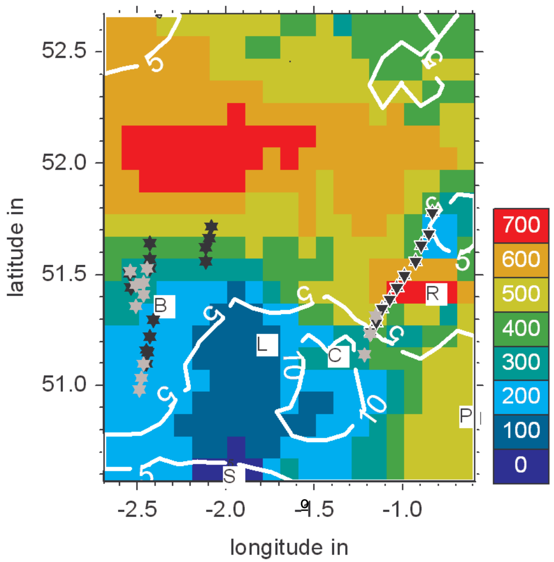


Temperature | **Mixing ratio** | **Interpolated IWV (GPS, sondes)**

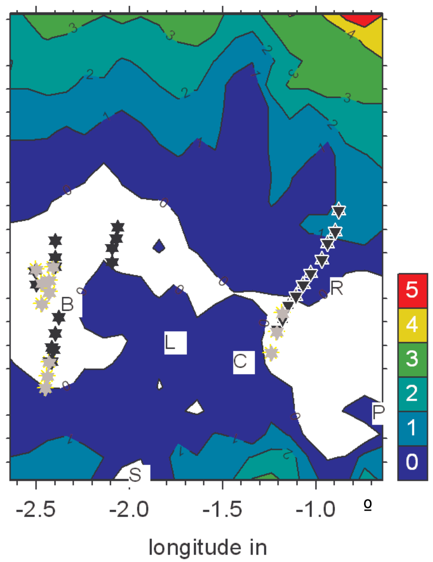
There is more fine scale information within the humidity field when “assimilating” the GPS and radiosonde data.

Data resolution and CI identification

The method allows better estimates for the likelihood and location of deep convection when using it to calculate convection-related indices, parameters quantifying stability, convection inhibition and triggering of convection.



CAPE [J kg^{-1}] (colour scale)
CIN [J kg^{-1}] (isolines)

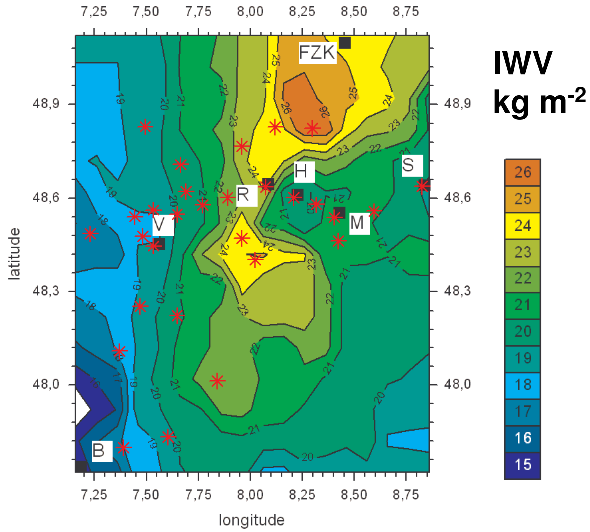


T_c - T_s [K]

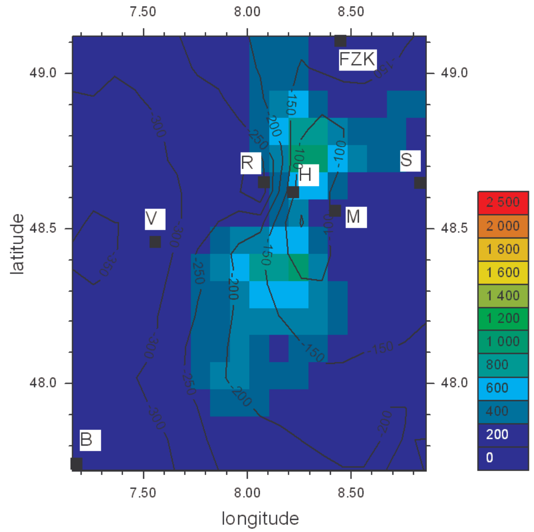
Cloud and precipitation tracks are found where CIN is lowest and trigger temperature is reached.

Data resolution and CI identification

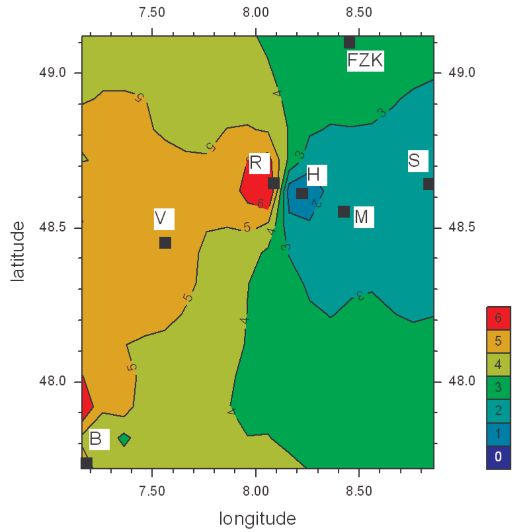
Validity of the method over mountainous terrain



Interpolated humidity



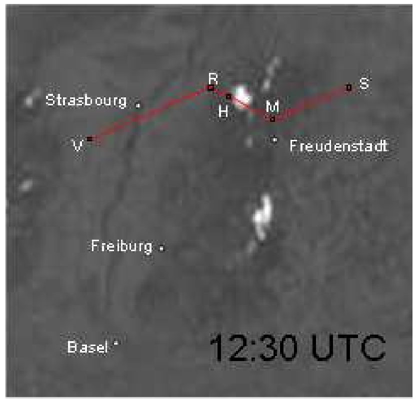
CAPE in J kg^{-1}(colour scale)
CIN in J kg^{-1} (isolines)



T_c - T_v in ºC

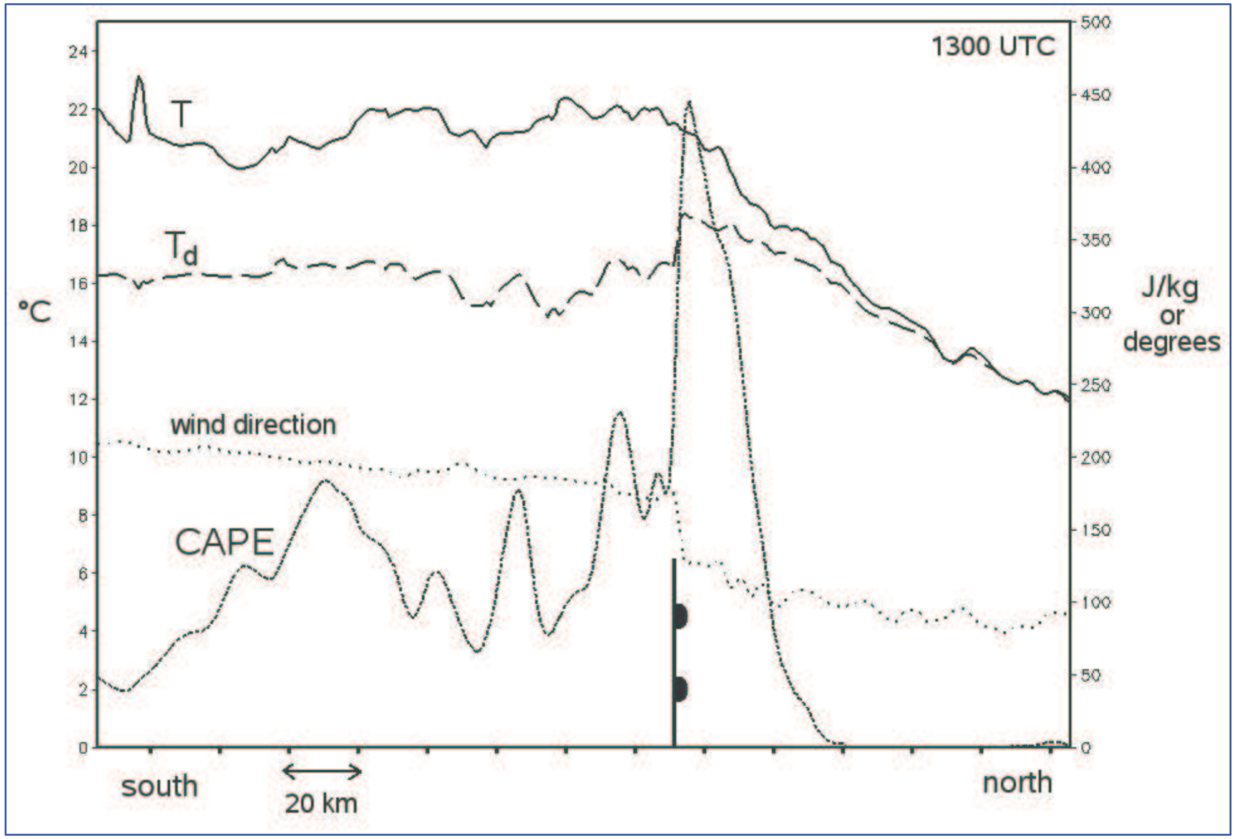
Detection of CI in complex terrain during COPS IOP 8b

15 July 2007; 11:00-12:30 UTC



Prerequisites for CI

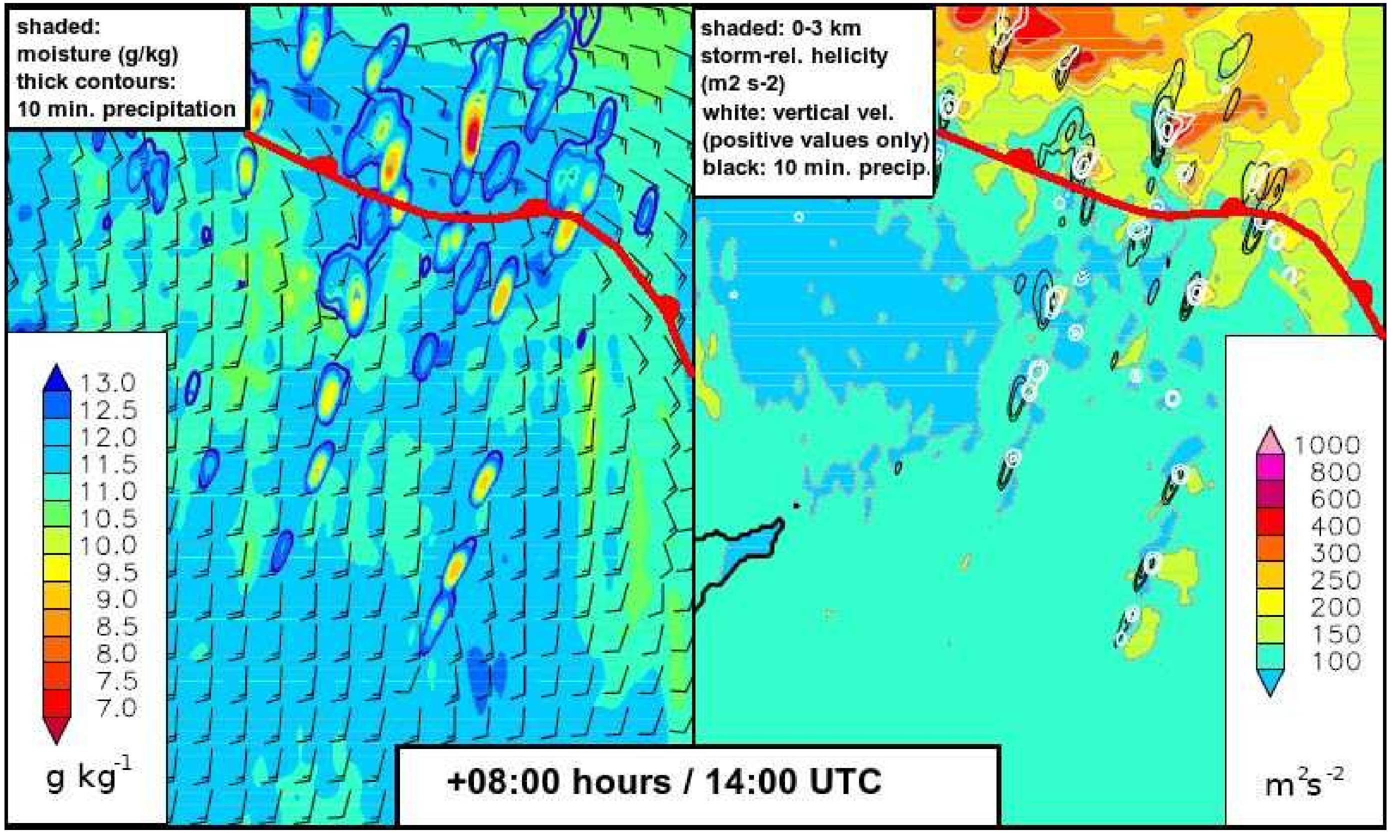
Cross section calculated from interpolated surface measurements at the time the Birmingham tornado develops during CSIP.



Wind shear and CAPE are most pronounced north of the warm front

Birmingham tornado: Instability and shear necessary for rotating upsdrafts

COSMO results



COSMO results

High wind shear and high helicity north of the front

Convective cells are activated when passing the front northward

Vertical motion and humidity (fluxes)

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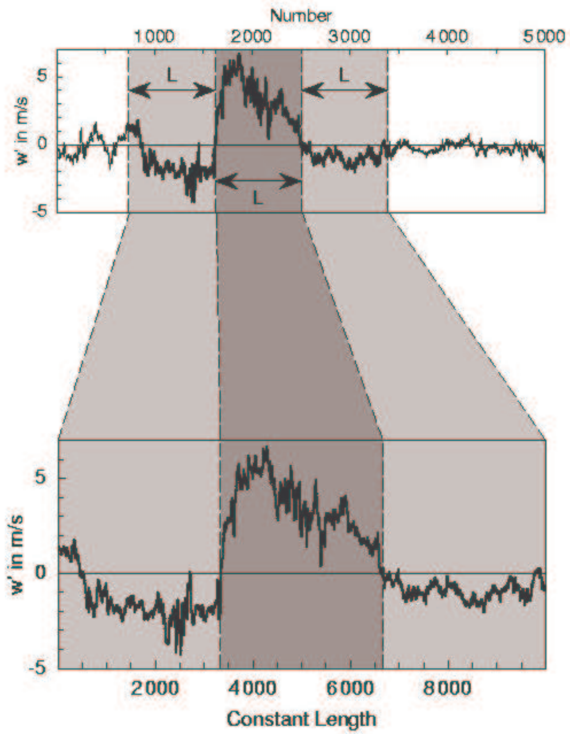
Which kind of vertical transport structures dominate within the PBL?

Classification of thermal updrafts and downdrafts from aircraft transects from VERTIKATOR

Method



Results

2000 m MSL

Updraft dry 121	Updraft moist 128
Downdraft dry 112	Downdraft moist 110

1000 m MSL

Updraft dry 68	Updraft moist 133
Downdraft dry 124	Downdraft moist 55

Total numbers of updrafts and downdrafts during fully developed CBL

Humid downdrafts and dry updrafts dominate in the middle of the CBL

similar frequencies of all types in upper CBL

Vertical motion and humidity (fluxes)

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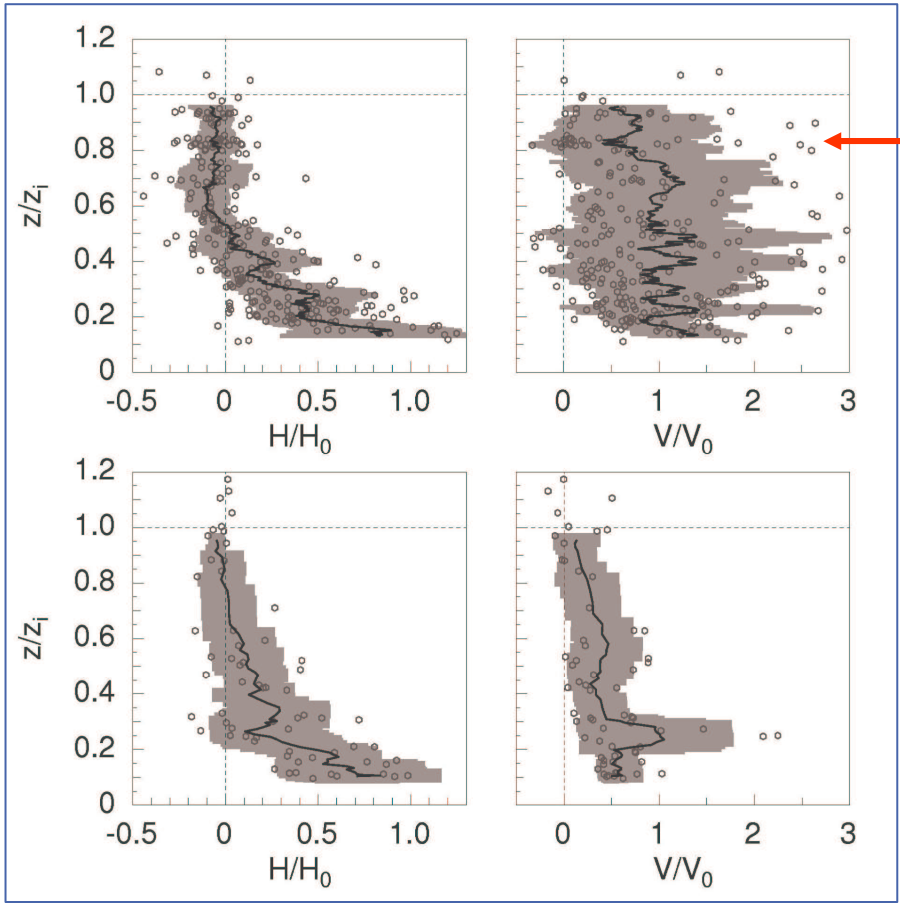
Vertical profiles of variances and covariances (fluxes) within the PBL over complex terrain during VERTIKATOR.



Black Forest

Single temporary very high fluxes of latent heat give reason for local CI

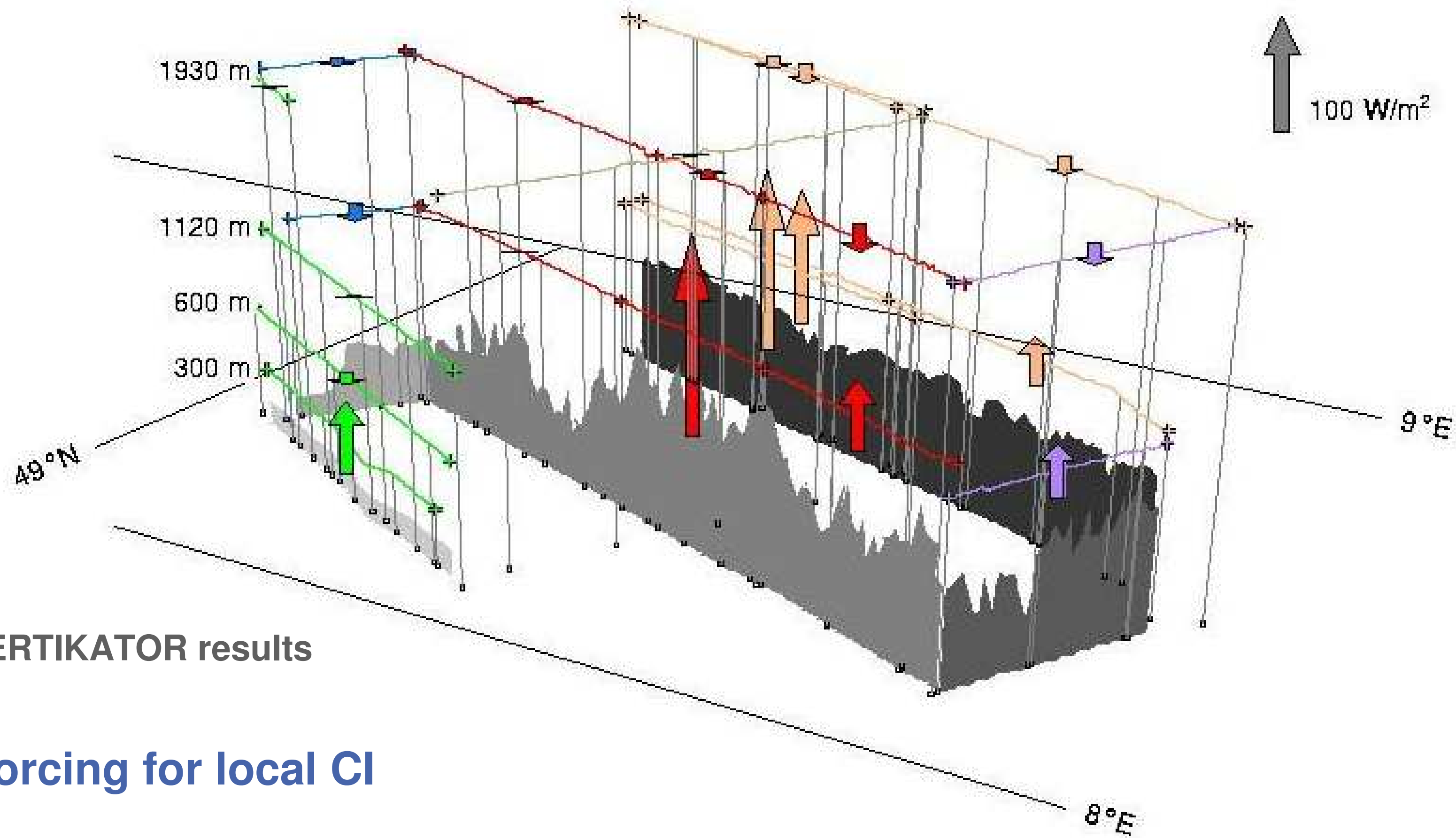
The black line shows the mean fluxes, the grey shading the standard deviation.

Rhine valley

sensible heat latent heat

Vertical motion and humidity (fluxes)

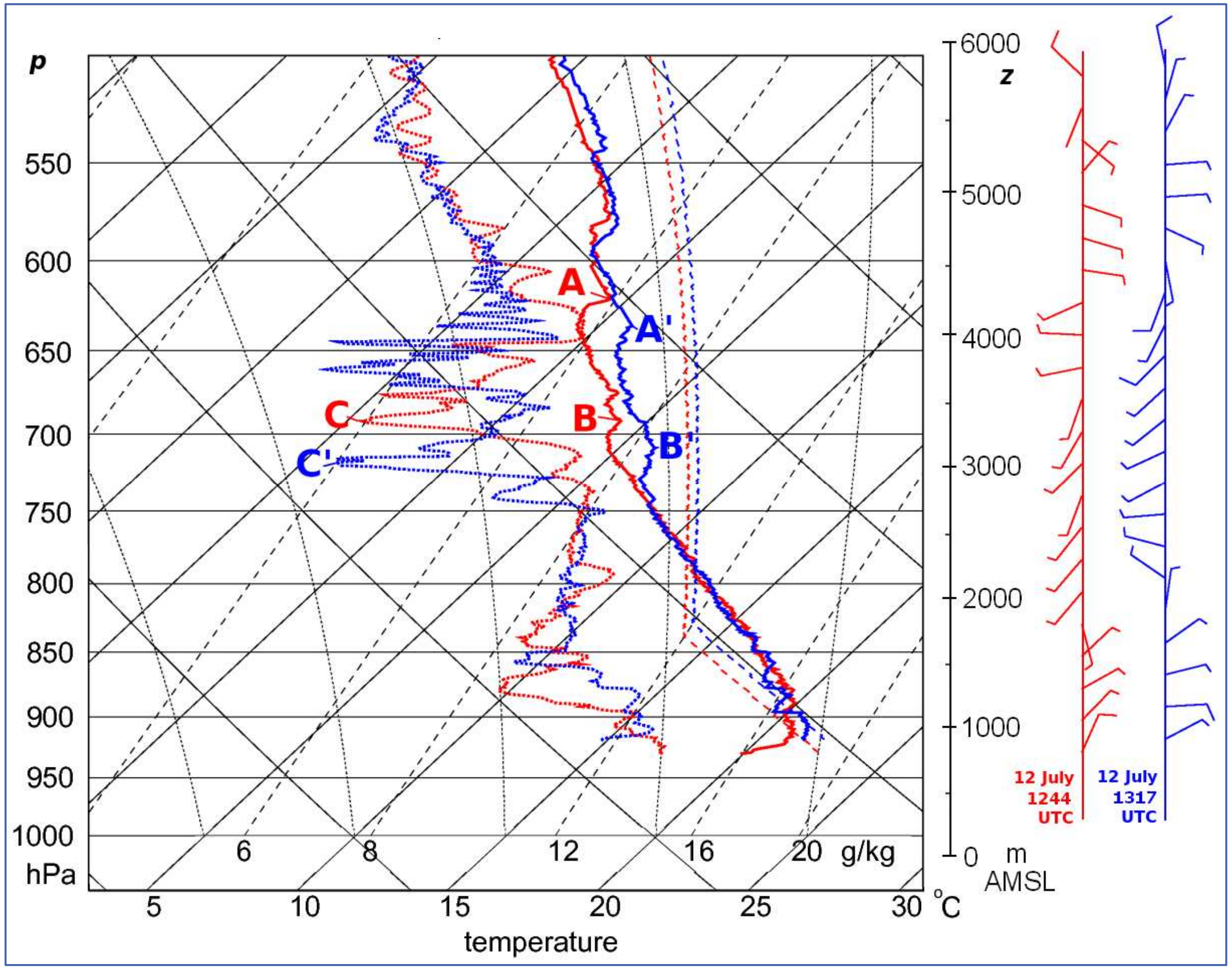
Variability of turbulent heat fluxes above flight sections over the Black Forest and the Rhine valley at different heights.



VERTIKATOR results

Forcing for local CI

Downdraft of WARM and DRY air outside the core a convective cell



A PRINCE case, 2006

Convective clusters

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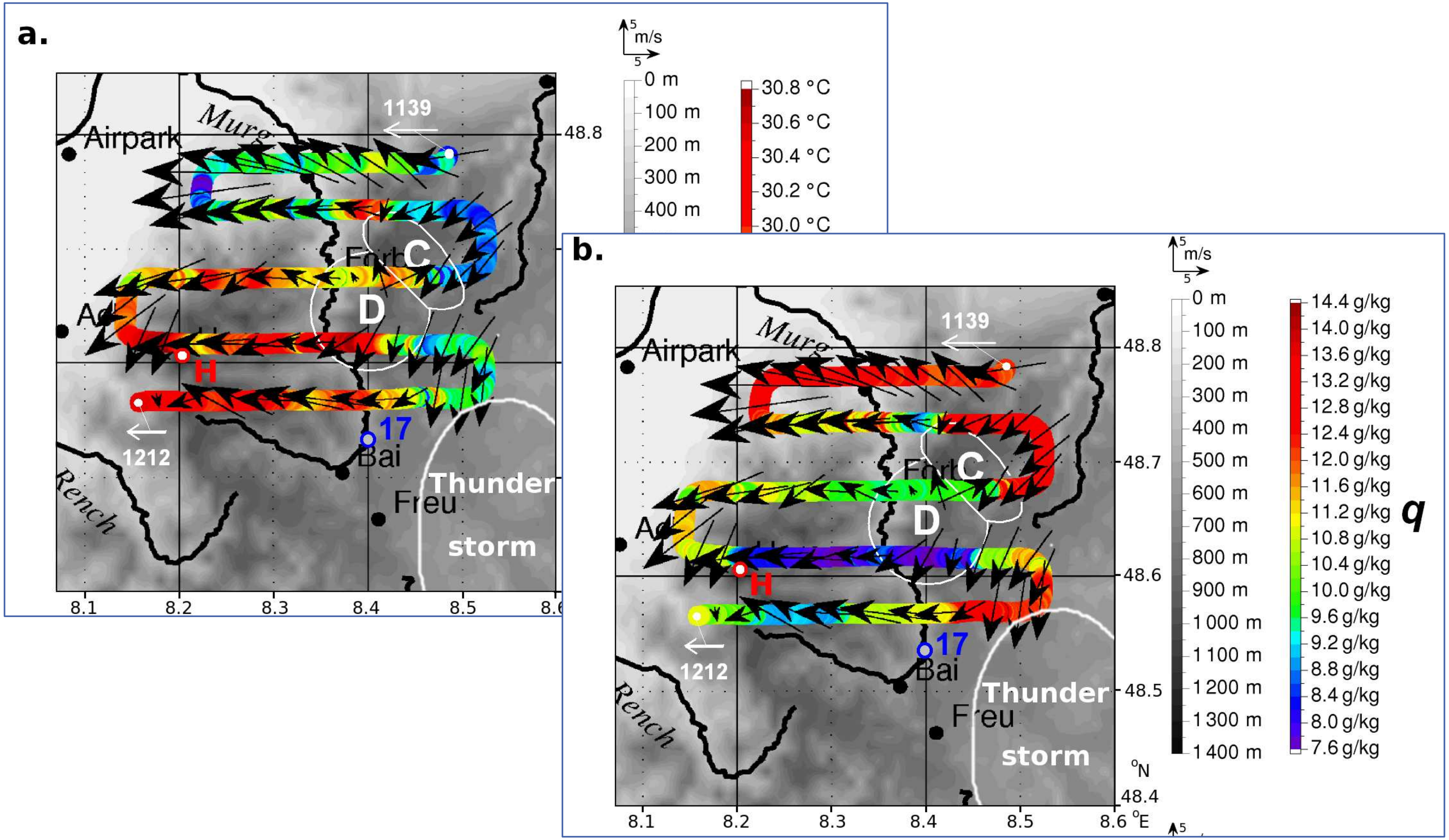
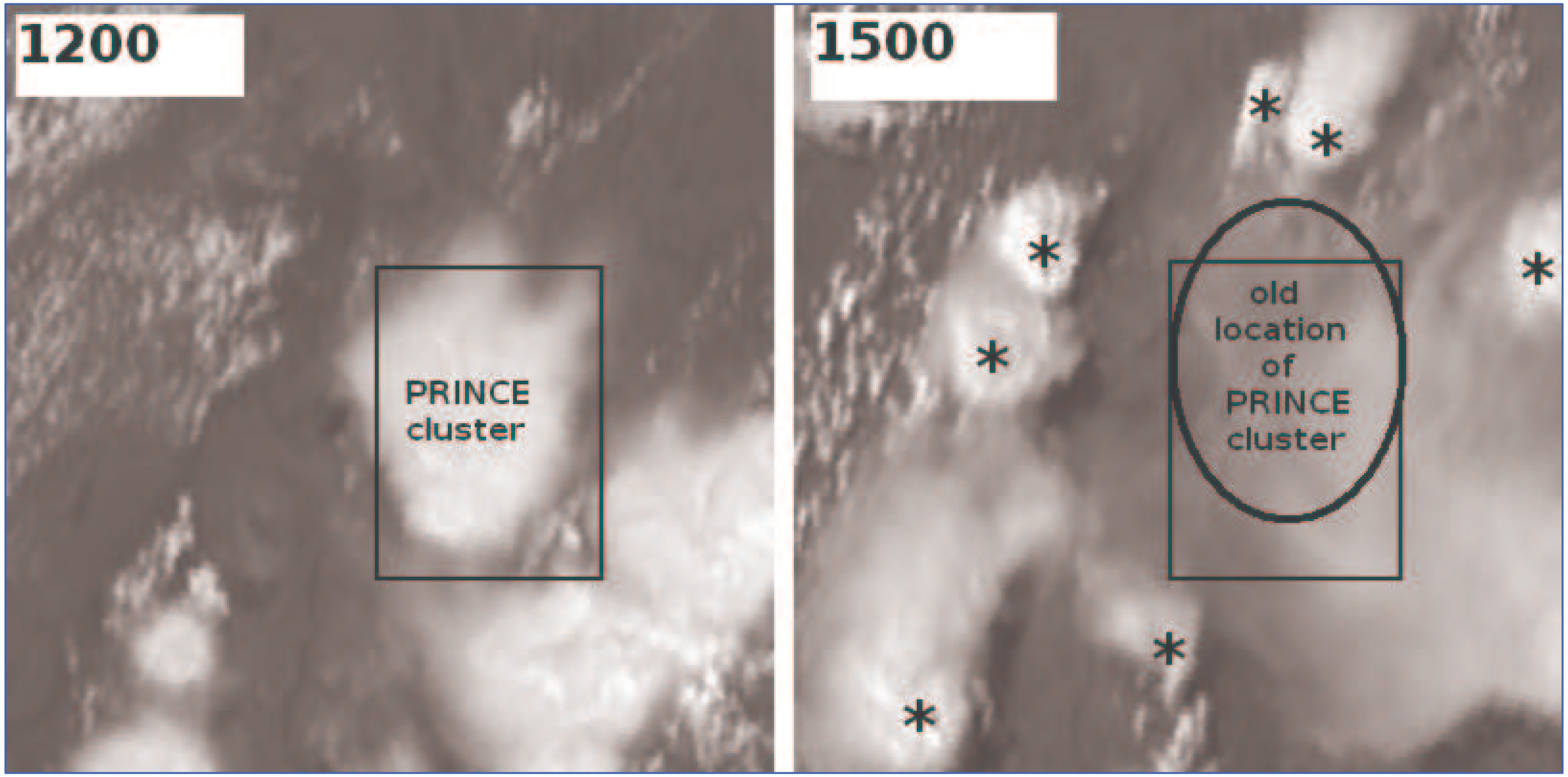
Downdraft of WARM and DRY air outside the core a convective cell

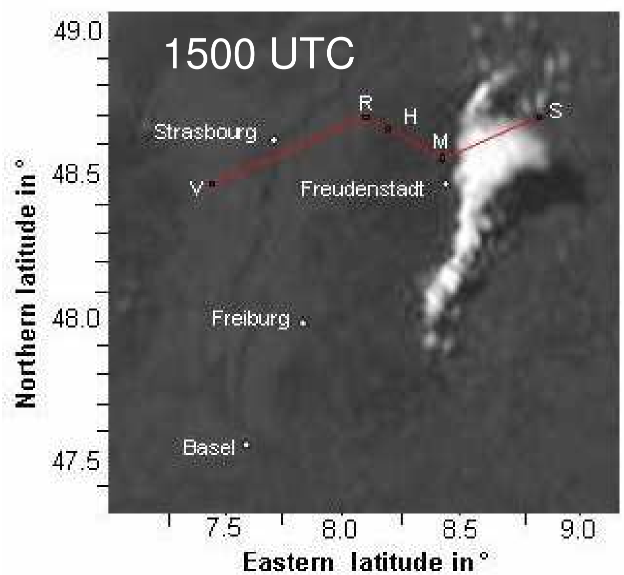


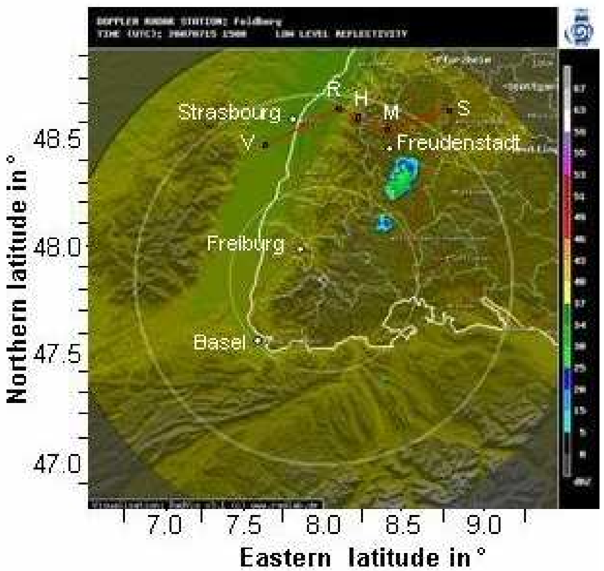
Convective clusters

Secondary convection initiated far away from the subsiding warm and dry air



About convergence zones, moisture convergence, scale interaction and scale superposition: The COPS cases IOP 8b and 9c





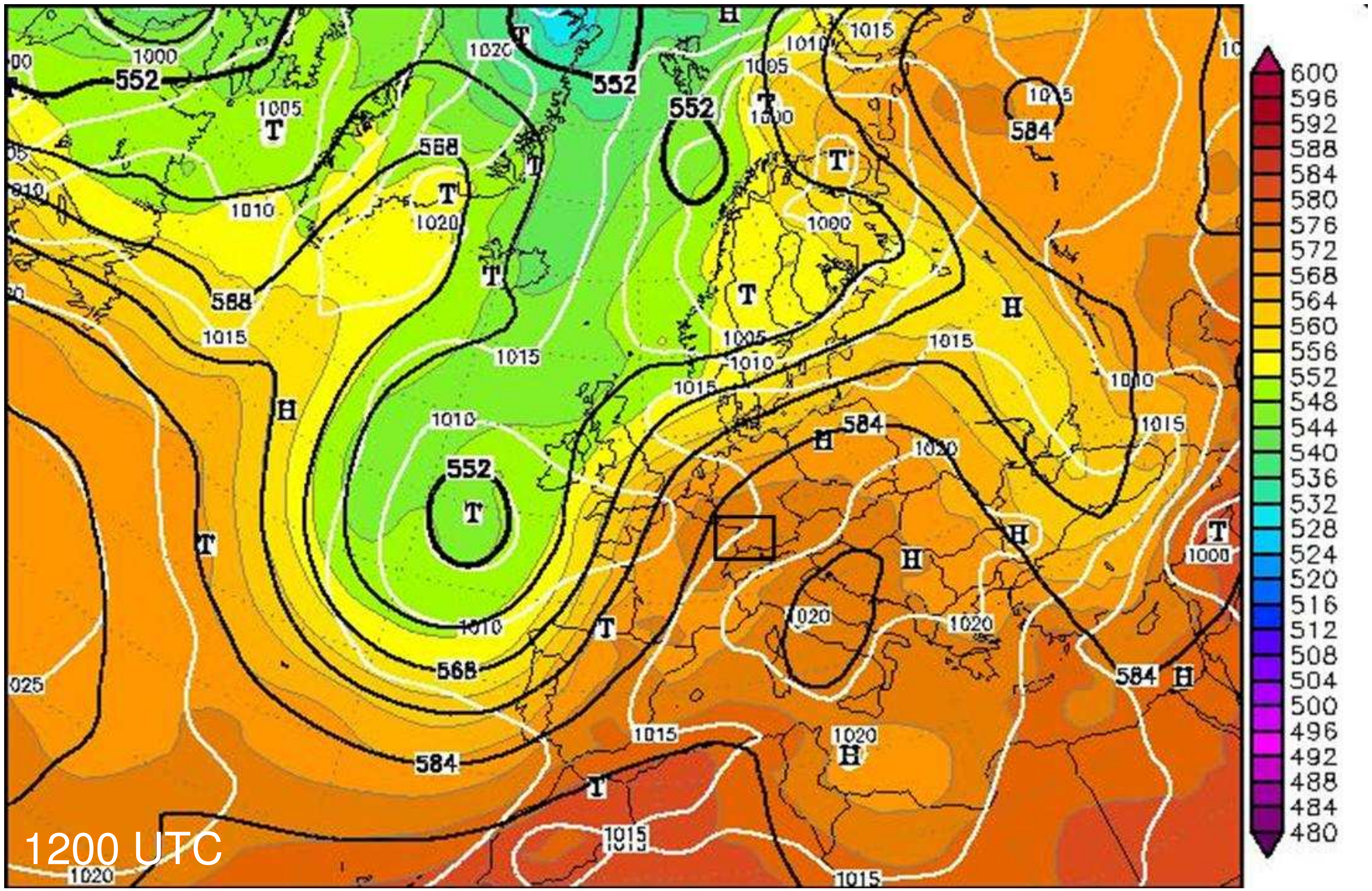
Deep convection southeast of Freudenstadt with rain rate 21-35 mm h^{-1}

But conditions were not favourable for deep convection: Trigger needed!

Heselbach, 15 July 2007, 1130 UTC: CAPE 360 J kg^{-1}, CIN 80 J kg^{-1}

Convergence zones and CI

A mesoscale surface low moves over the COPS area from SW to NE resulting in convergent flow



Convergence zones and CI

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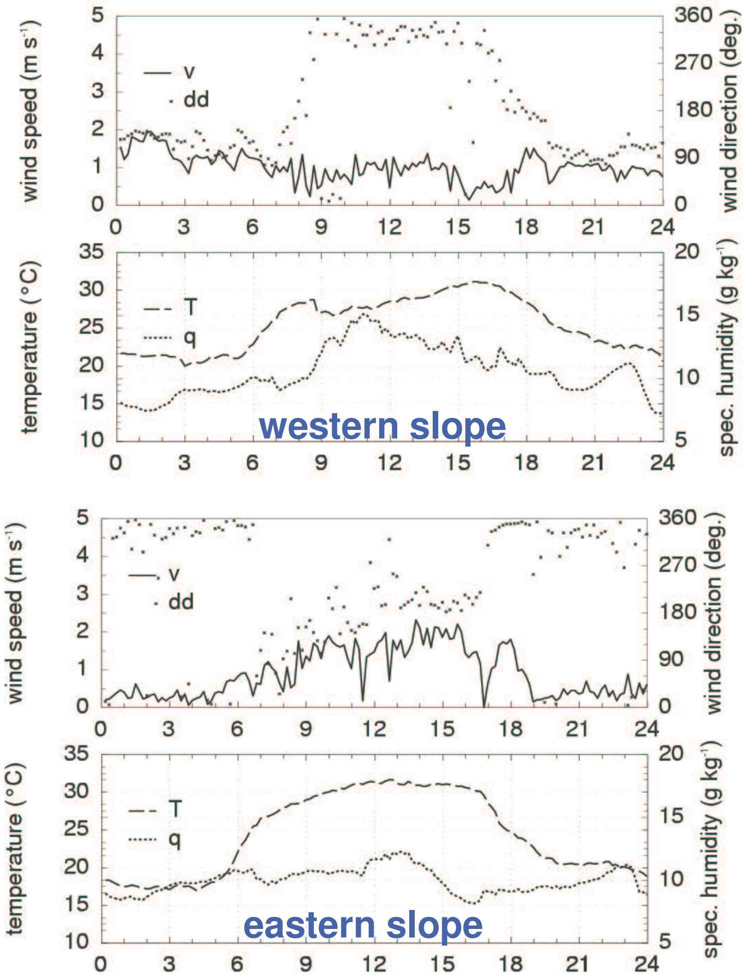
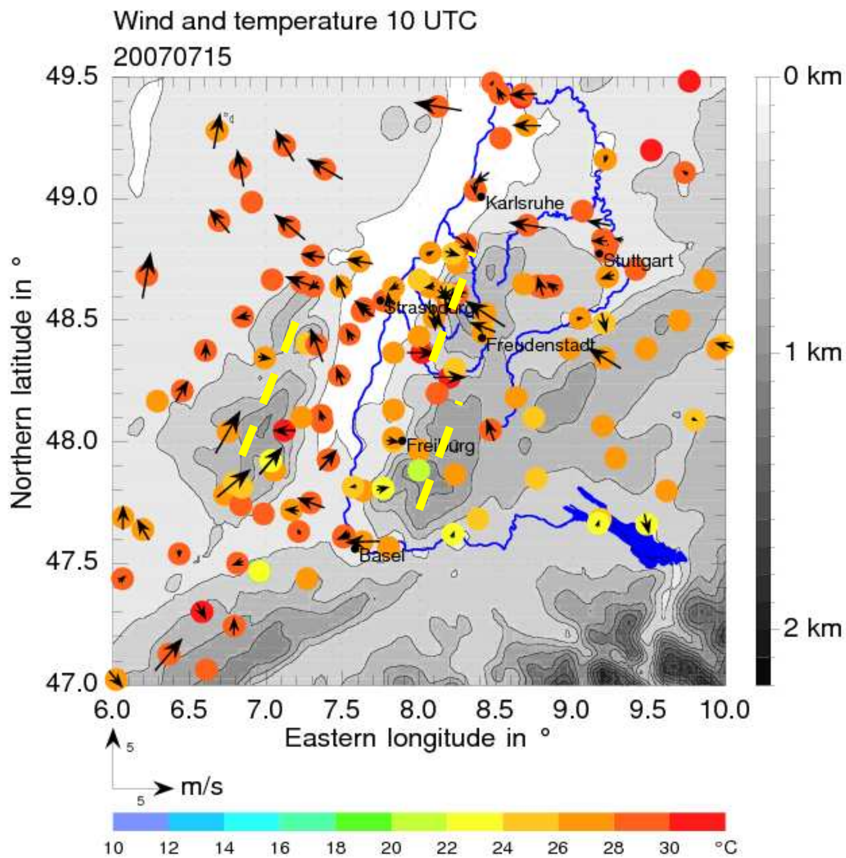
Mountain scale convergence

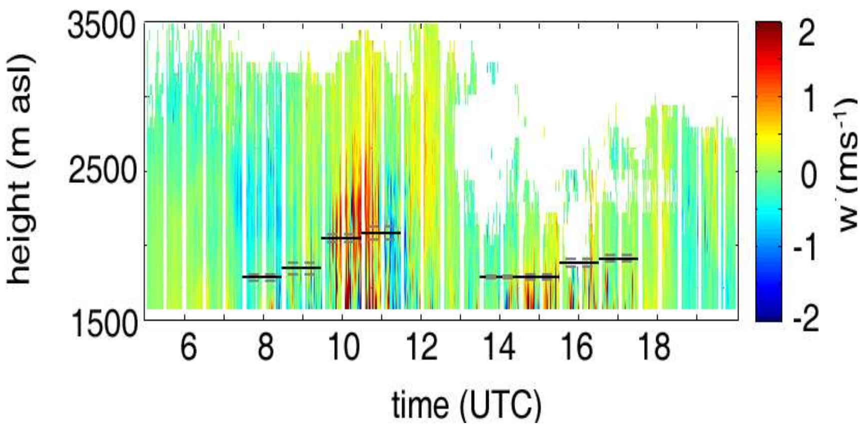


Synoptic scale convergence

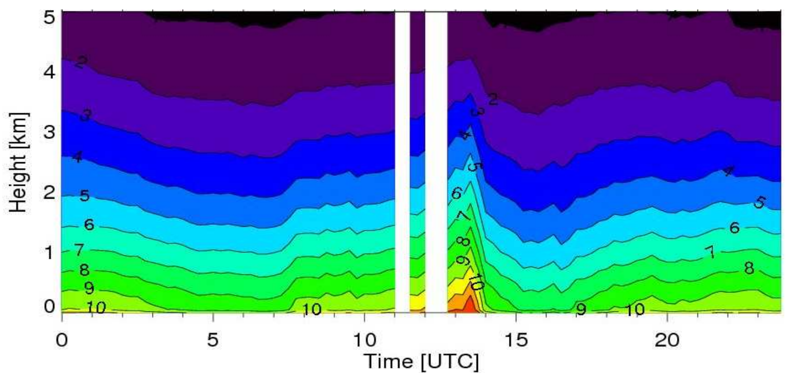


The convergence zone indicated by increasing vertical wind and increasing surface near humidity moves slowly eastward over the Black Forest

Hornisgrinde 11 UTC

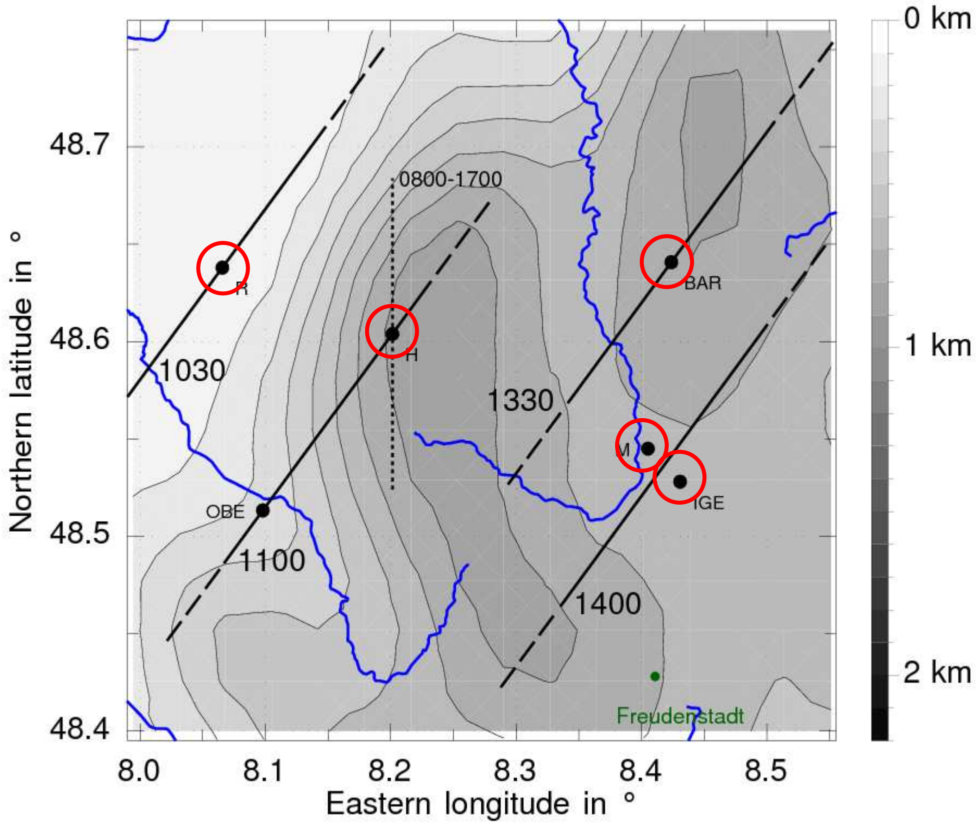


Heselbach humidity 14 UTC

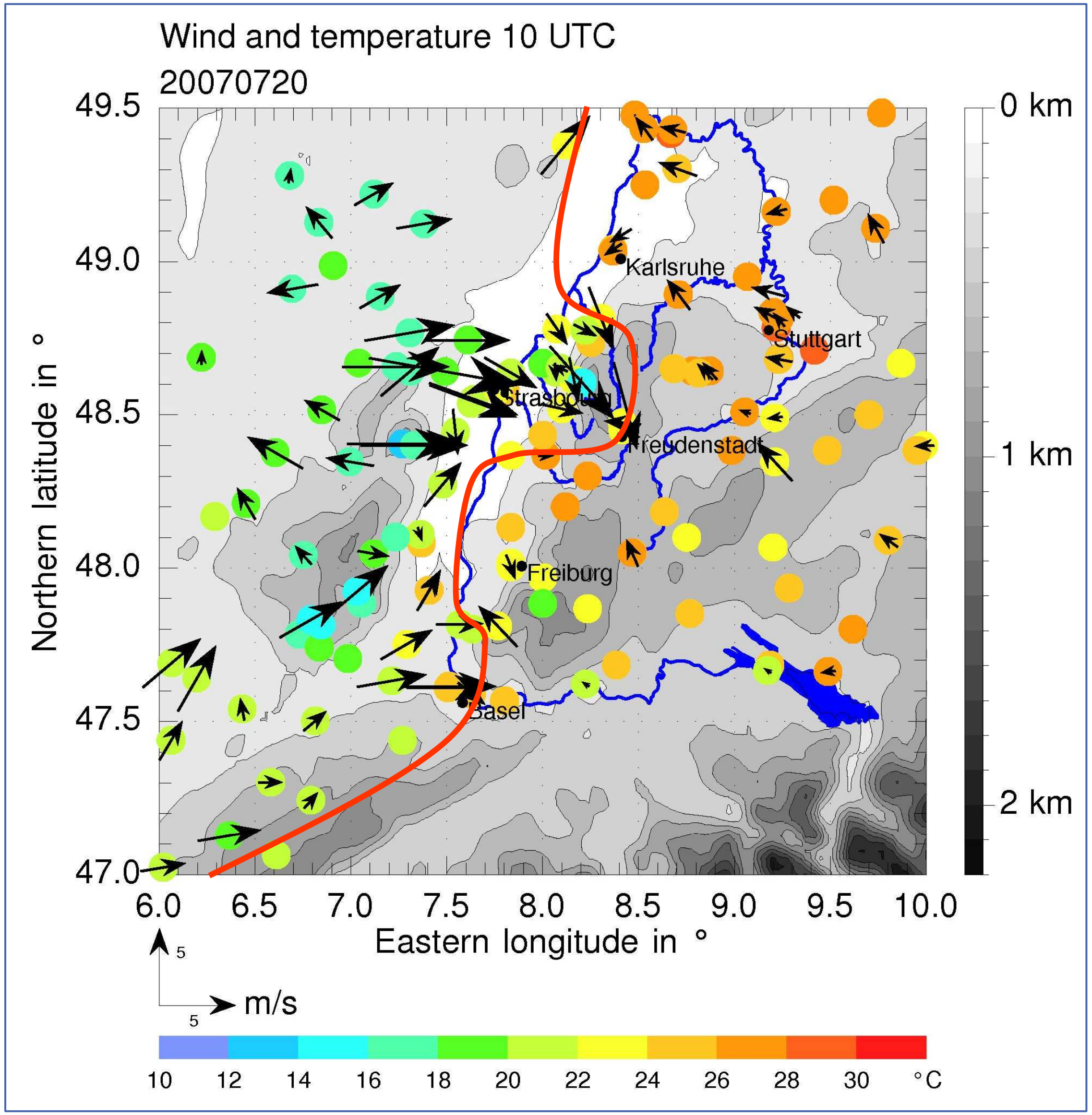


Convergence zones and CI

The convergence zone is generated by superposition of mesoscale and mountain scale convergence and indicated by increasing vertical wind and increasing surface near humidity. It moves slowly eastward over the Black Forest.



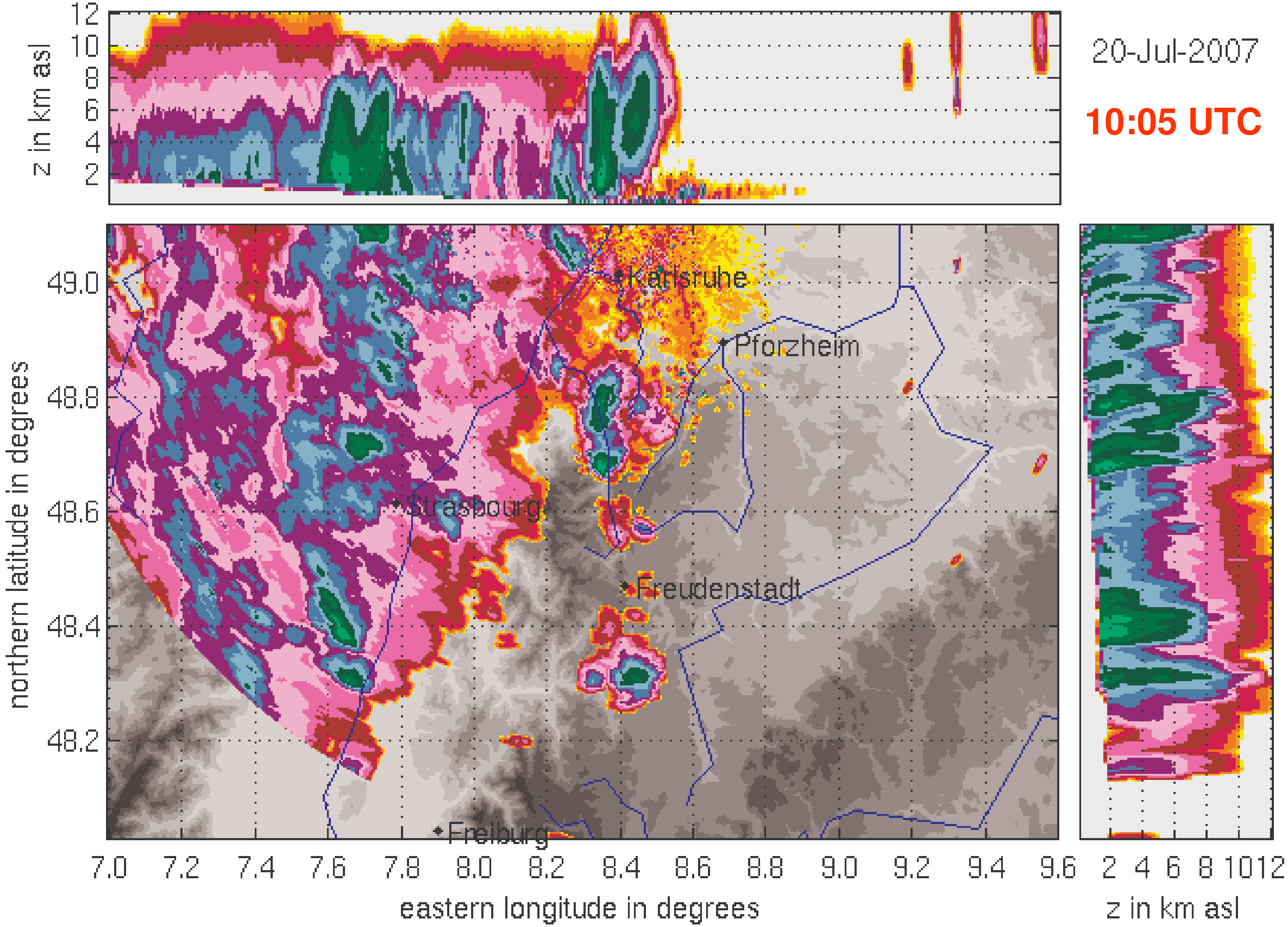
Convergence zones and CI



About convergence zones, moisture convergence, scale interaction and scale superposition:

The COPS cases IOP 8b and IOP 9c

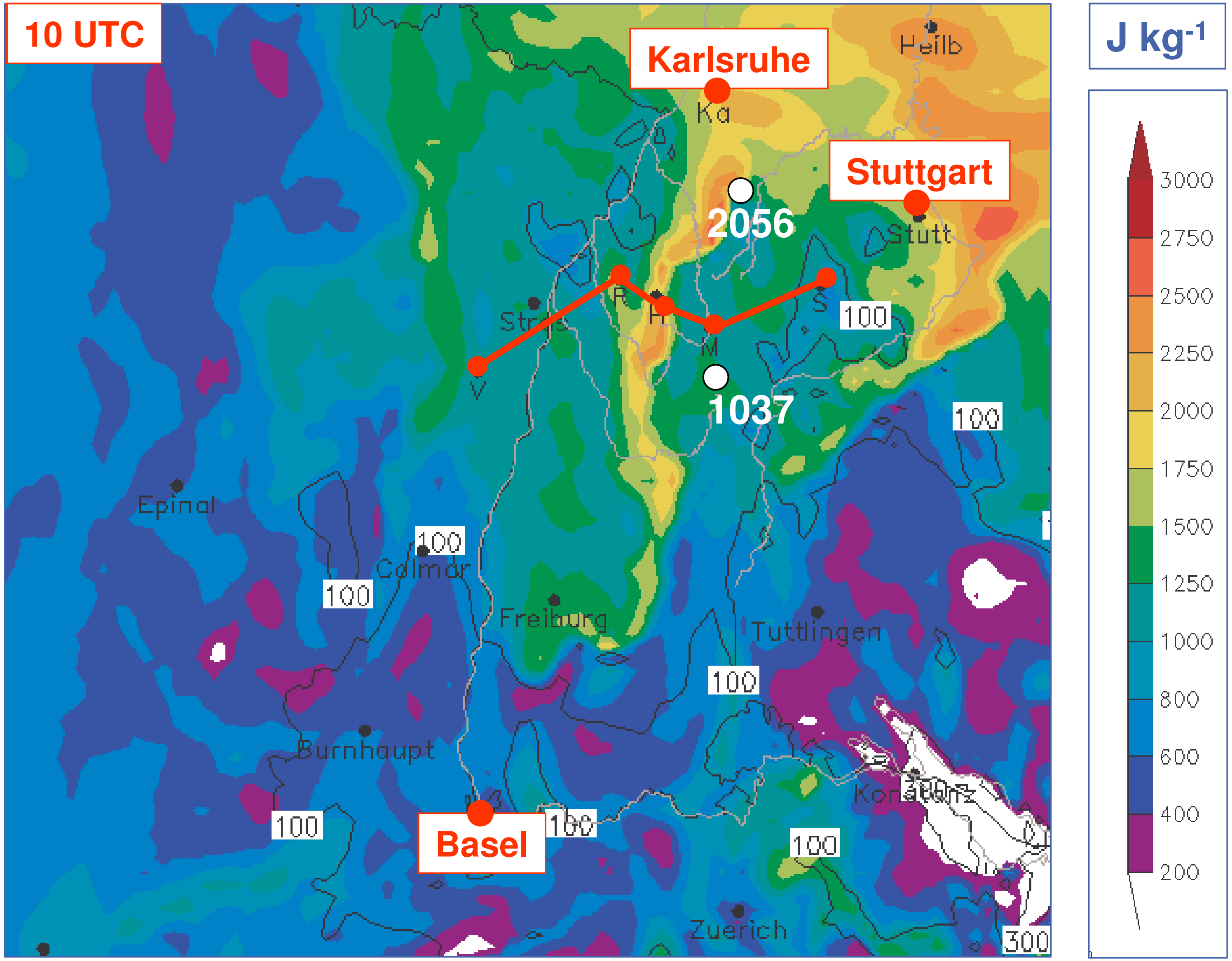
Convergence zones and CI



IMK-Radar

Courtesy: Jan Handwerker, IMK, KIT

Convergence zones and CI



CAPE and CIN simulations IOP 9c

CAPE: colourcode

CIN: Isolines

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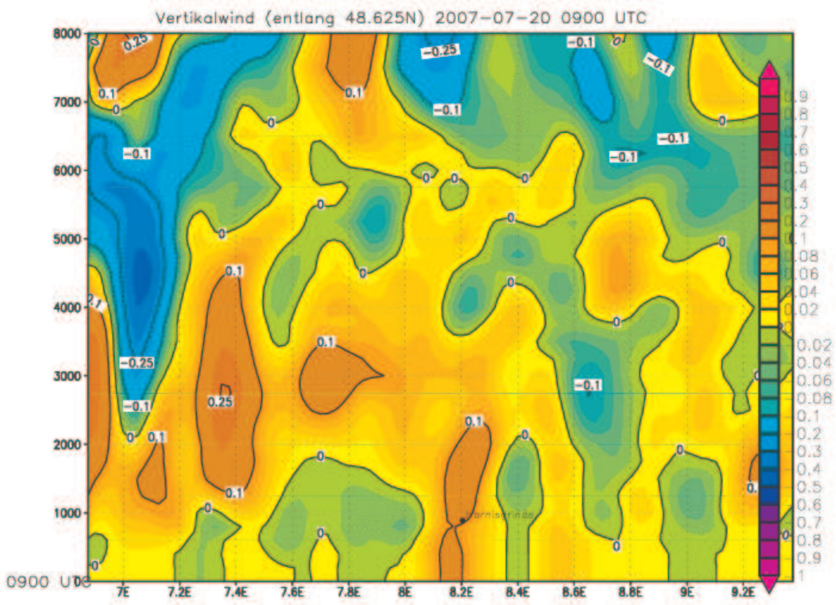
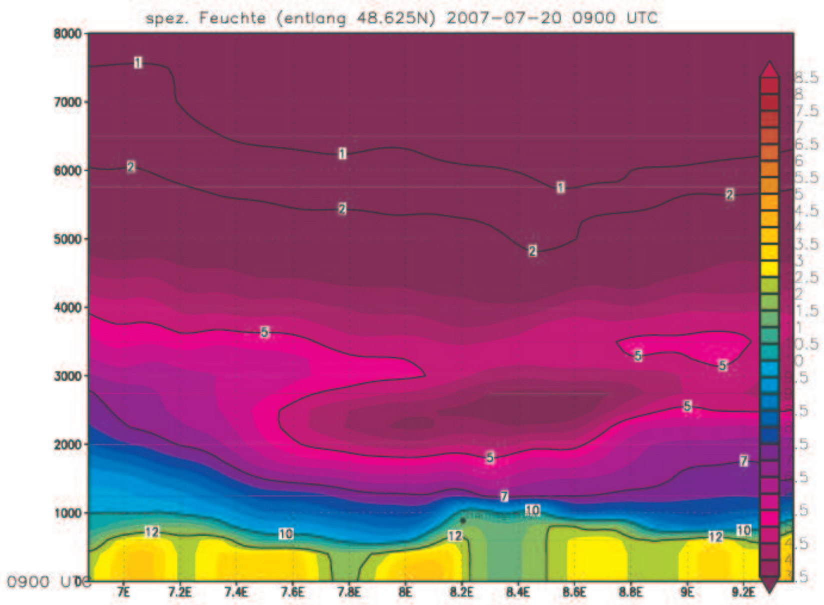
Vertical cross section at Hornisgrinde latitude at 09 UTC
Surface near humidity maximum and lifting area moving east



Vertical wind speed



Specific humidity

Convergence zones and CI

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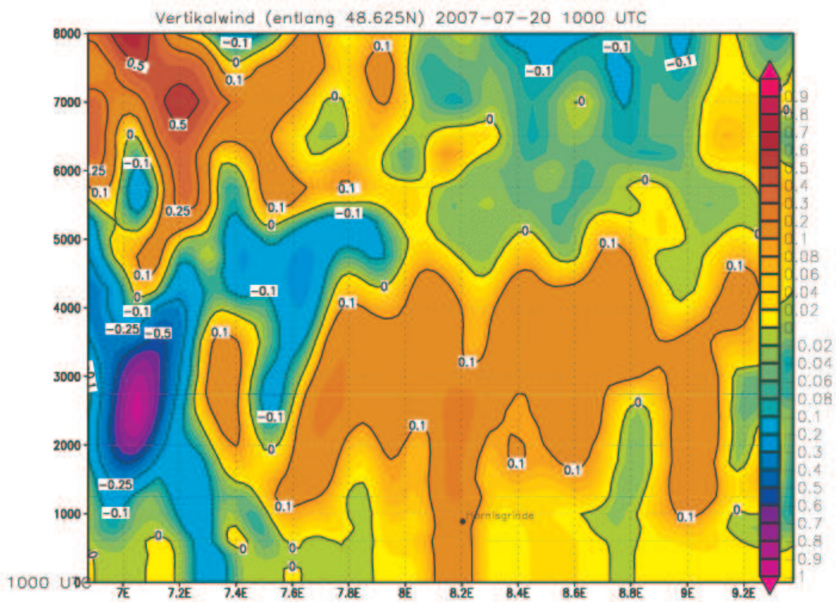
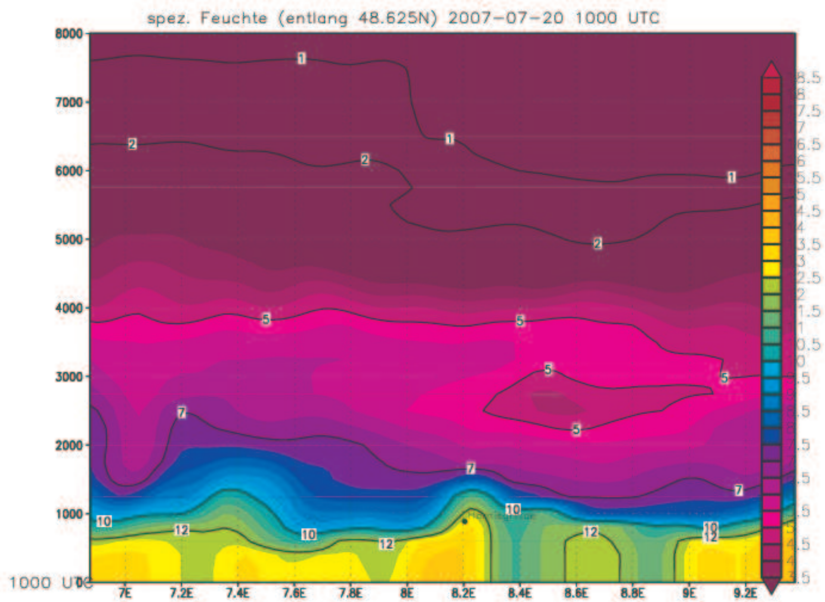
Vertical cross section at Hornisgrinde latitude at 10 UTC
Surface near humidity maximum and lifting area moving east



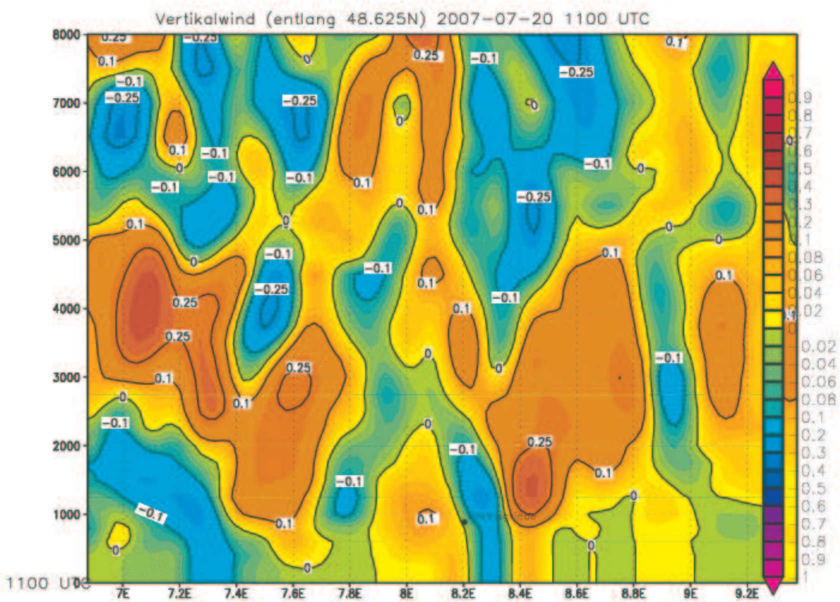
Vertical wind speed



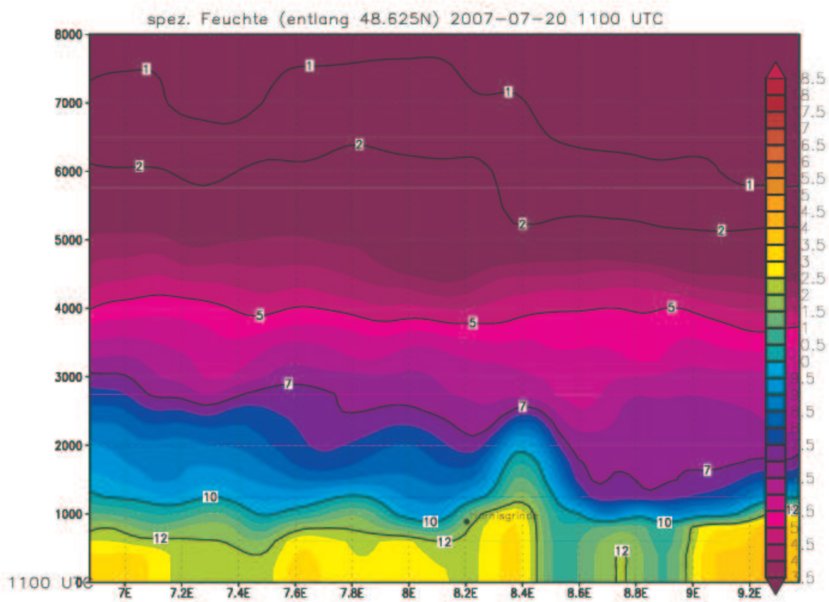
Specific humidity

Convergence zones and CI

Vertical cross section at Hornisgrinde latitude at 11 UTC
Surface near humidity maximum and lifting area moving east



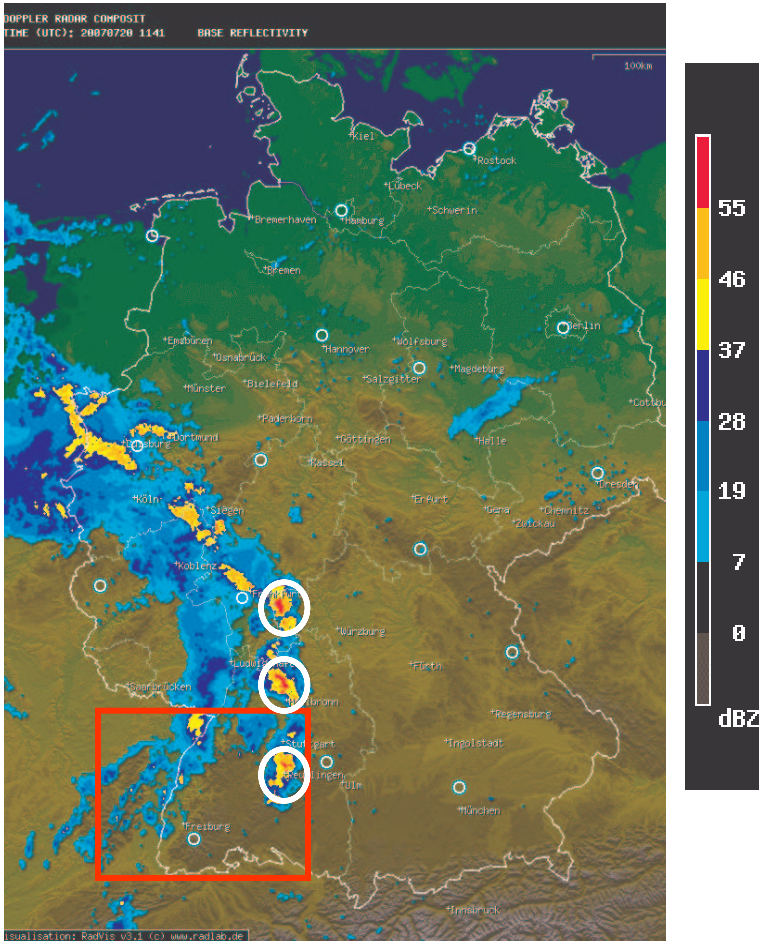
Vertical wind speed

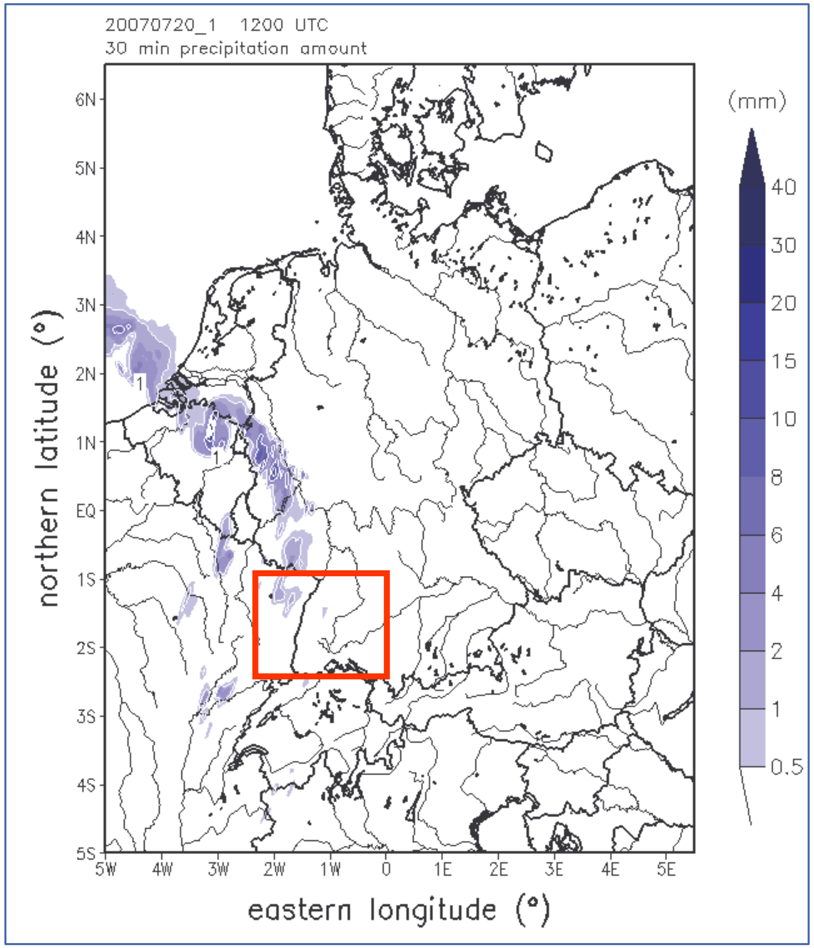


Specific humidity

Convergence zones and CI

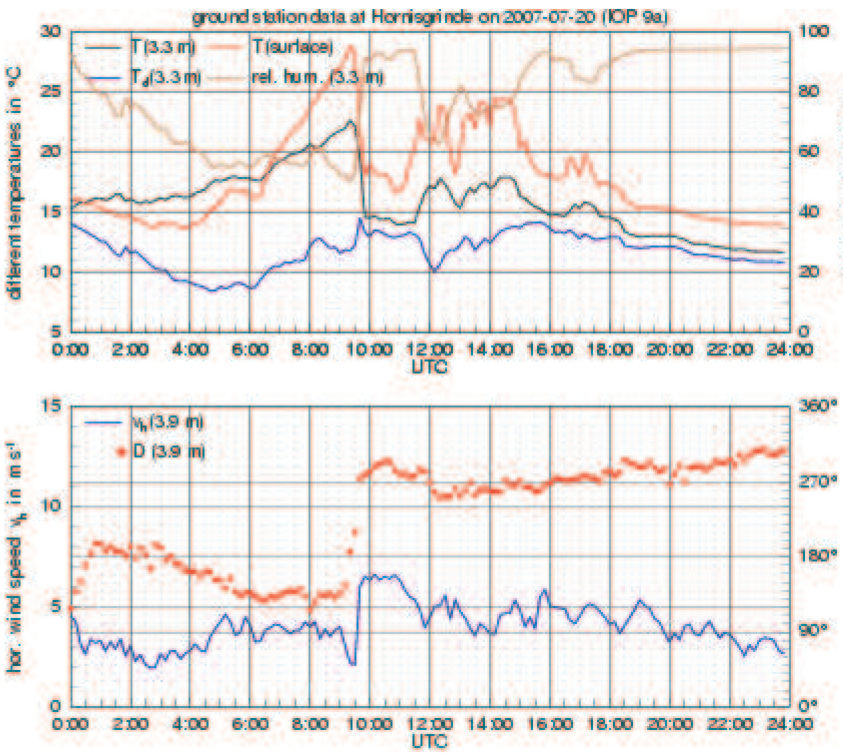
COSMO-DE does not simulate any CI and precipitation in this case



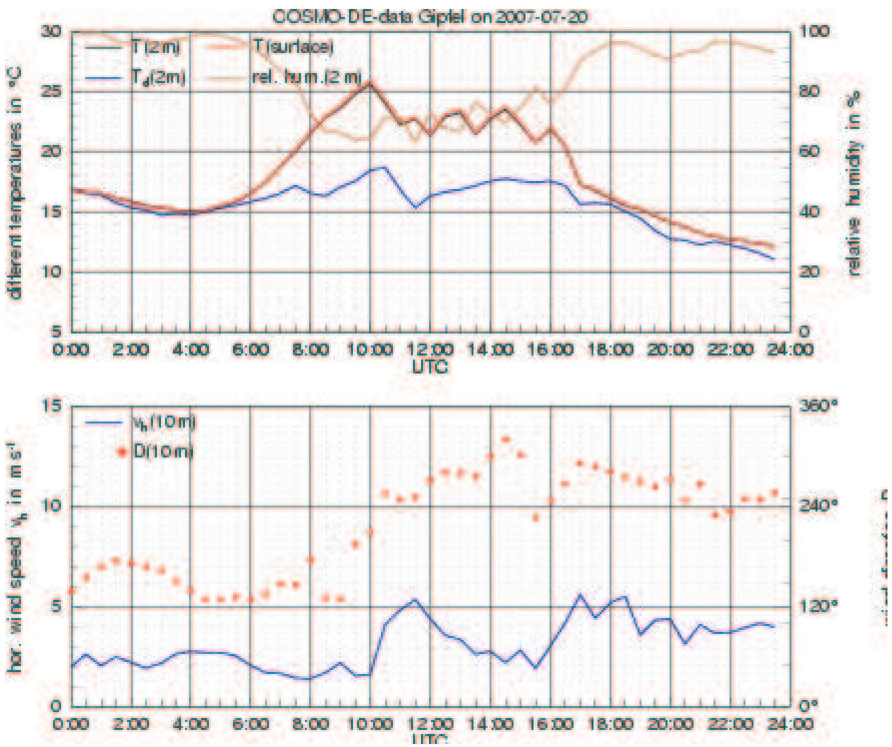


Convergence zones and CI

Why is there no CI in the model?



Measured time series



COSMO-DE model results

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The chain of processes leading to convection initiation over complex terrain

Differential heating of slopes within the mountain range

Generation of slope and valley winds

Forming of convergence zones over the ridges (moisture convergence)

Eventually interaction with larger scale convergence
  (gust fronts, MSCs, synoptic scale convergence)

Strong locally lifting over the ridges

Exceeding the trigger temperature

Lifting to the LFC

Deep convection

…

Ongoing transport of humid air from the lower PBL via valley paths

CI over Complex Terrain: Lessons Learned

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With contributions of…

Pieter Groenemeijer
Samiro Khodayar
Norbert Kalthoff
Christian Barthlott
Holger Mahlke
Christoph Kottmeier
Markus Hasel
…and many others

Thank you!