Priority Program SPP 1167 of the DFG

Convective and Orographically Induced Precipitation Study

Karlsruhe Institute of Technology

PRINCE: Pre-COPS measurements of a convective cluster in the northern Black Forest

P. Groenemeijer[1], Ch. Barthlott[1], A. Behrendt[2], U. Corsmeier[1], J. Handwerker[1], M. Kohler[1], Ch. Kottmeier[1], S. Pal[2], M. Radlach[2], J. Trentmann[3], A. Wieser[1], V. Wulfmeyer[2]

(1) Institut für Meteorologie und Klimaforschung, Universität Karlsruhe / Forschungszentrum Karlsruhe
(2) Institute of Physics and Meteorology, University of Hohenheim, Stuttgart
(3) Institute for Atmospheric Physics, Johannes Gutenberg University Mainz

PRINCE background and goals

The PRINCE campaign, an acronym for **PR**ediction, **I**dentification and tracki**N**g of **C**onvective c**E**lls, addressed the following questions

- *why a storm system would develop at a particular time and location,*
- *in what ways its environment influenced its development,*
- *in what ways the storm itself influenced its environment, and which effects these had on the subsequent convective evolution.*

In part as a preparation for COPS, the feasibility of a number of new measurement strategies in the direct vicinity of a storm were assessed :

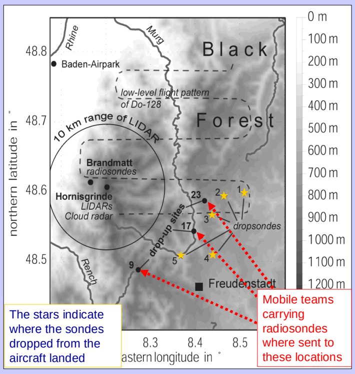
- *The operation of mobile teams equipped with "drop-up radiosondes" to be released within the area of investigation.*
- *The collocation of two lidars and a radar on the summit of a low mountain range.*
- *The equipment of a research aircraft with real-time satellite information and radar data from ground-based operational radars*

PRINCE Measurement Systems

The PRINCE field campaign area →
The sites of the sensors and radiosonde release sites are depicted by black dots.

A 10 km range ring has been drawn around the location of the lidars.

The locations of dropsonde releases from the Do-128 (labelled 1 to 5) have been plotted as stars The low-level flight pattern followed twice by the aircraft has been visualized by a dashed line.

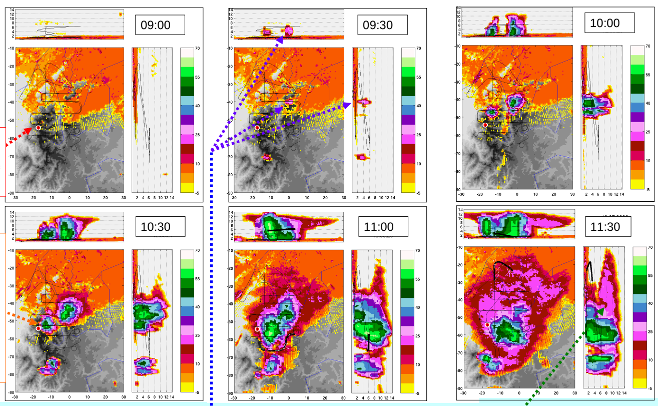


The stars indicate where the sondes dropped from the aircraft landed

Mobile teams carrying radiosondes where sent to these locations

←The Do-128 D-IBUF research aircraft carrying sensors for temperature, humidity and wind velocity.

FZK C-Band Radar



Location of the lidars at the summit of Hornisgrinde

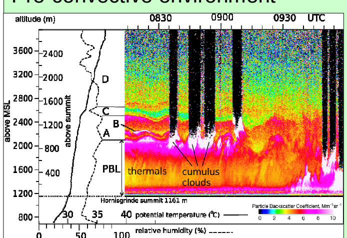
Initiation of convection near the lidar site takes place between 10:00 And 10:30 UTC

FZK C-Band radar reflectivity over the PRINCE area. Each image displays the maximum reflectivity detected above a point at the surface and the projections of the maximum reflectivity on the boundary surfaces of the data volume.

The C-Band Doppler radar in Karlsruhe detected storm initiation around 9:30 UTC over the eastern slopes of the Murg Valley (as well as a cell further south).

A large anvil cloud containing precipitation particles develops after 11:00. The research aircraft samples the air-mass below the anvil after 11:30.

Pre-convective environment



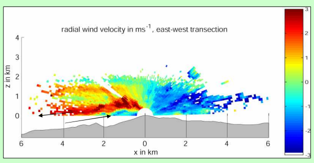
← University of Hohenheim scanning rotational Raman lidar has measured the aerosol backscatter coefficient at the summit of Hornisgrinde between 8:13 and 9:59 UTC and comparison with data of a nearby radiosonde.

It shows a complex series of aerosol layers. A comparison with the radiosonde released at nearby Brandmatt (far left) reveals that many of the layers with high backscatter correspond with layers of high relative humidity.

Thermals are visible in the lidar signal as subtle "bubbles" of slightly higher backscatter. Cumulus clouds occur after 8:40 UTC. After 9:00 the aerosol layers mix out gradually.

The Doppler-lidar shows a weak, but well-developed mountain-valley breeze system along the western slope of the Hornisgrinde (the Rhine-Valley side).

FZK Doppler-lidar → radial velocity at 09:33 UTC RHI scan (azimuth 270°)



Red colors are velocities away from the lidar, while blue colours are velocities towards the lidar. Both the uphill flow as well as the return flow can be seen.

Convective initiation

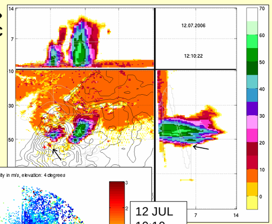
The C-Band radar detects the first precipitation particles in a developing convective cell about 4 kilometres to the ENE of the Hornisgrinde summit at 10:10 UTC.

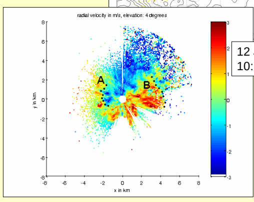
Two minutes earlier, the Doppler lidar detects two lines of radial wind convergence (labelled A and B).

Zone A is located to the west of the lidar and corresponds with the location where the emitted beam crosses the interface between the uphill and downhill branches of the mountain/valley breeze system.

The location of zone B corresponds with that above which the radar indicates the first precipitation particles. It appears that the radial convergence in this case has been caused by the convective updraft that a few minutes later started to produce precipitation.

FZK C-Band radar → reflectivity at 10:10 UTC





← Doppler-lidar radial velocity from the Hornisgrinde summit at 10:08 UTC.

PPI scan at 4 degrees elevation.

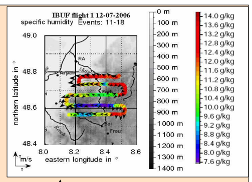
Convective feedback

The research aircraft Do-128 has measured the air under the storm system's anvil cloud starting at 11:39 UTC

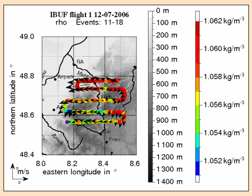
While flying legs at 1100 m above MSL it measured a divergent wind field, a local minimum of moisture, a local maximum of potential temperature and slightly lower density.

The single possible source of the drier is the air previously present at higher altitudes and the air must have subsided.

The fact that the air is less dense than its mesoscale environment (and positively buoyant) suggests that the forcing for the downward motion originates elsewhere.



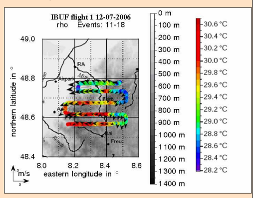
Specific humidity

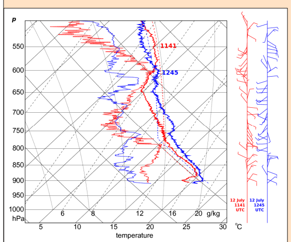


Density

Observations by the Do-128 research aircraft while flying at 1100 m above mean sea level between 11:39 and 12:12 UTC

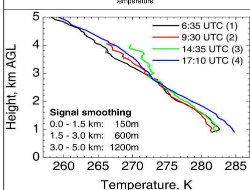
Potential Temperature





← Skew-T,log-p diagram of two sondes at mobile station 9.

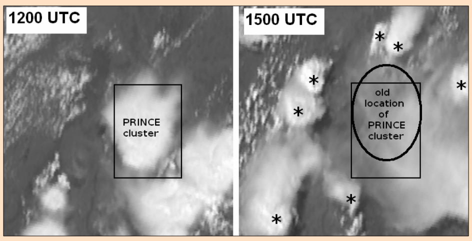
Indications for subsidence under the anvil cloud are seen in radiosonde data taken at station 9 on the southwestern flank of the storm system. As it matures and decays, the air below the 600 hPa-level warms. Lidar measurements on Hornisgrinde confirm indicate a strong temperature increase above 3 km AGL between 9:30 and 14:35. After that time, this layer cools a bit, but the near-surface air warms more.



← Temperature profiles measured with the temperature LIDAR of the University of Hohenheim on the Hornisgrinde

Soundings taken after the storm systems decay show a pronounced reduction of boundary-layer moisture, leading to profiles that exhibit very little CAPE.

METEOSAT Satellite image (VIS) of the storm system (1200 UTC) and new convective storms (1500 UTC). Source: EUMETSAT/FZK



Satellite pictures show that new convective development is inhibited within a radius around the location of the original storm cluster.

Conclusions

References are available upon request from the authors (pieter.groenemeijer@imk.fzk.de).

The study has revealed the development of a warm, dry downdraft on the flanks of a mature storm system. This feature has had profound implications for the subsequent development of convection: in vicinity of the original storm system, it resulted in a drying of the lower troposphere and an increased stability that prevented new storms to form.

The PRINCE measurement campaign has been successful in resolving various aspects of the convective evolution on July 12th. Especially the positioning of a Doppler and backscatter lidar on the summit of the Hornisgrinde has been very useful, because delivered simultaneous data of the quasi-horizontal wind field and the vertical structure of aerosol layers. Within COPS, lidars have again been collocated on the Hornisgrinde and drop-up radiosonde teams have again been deployed successfully.

Acknowledgement

This work has been carried out within the Virtual Institute COSI-TRACKS, which is funded by the Helmholtz Association.