Initiation and microphysical development of convective clouds observed over the Black Forest mountains during COPS

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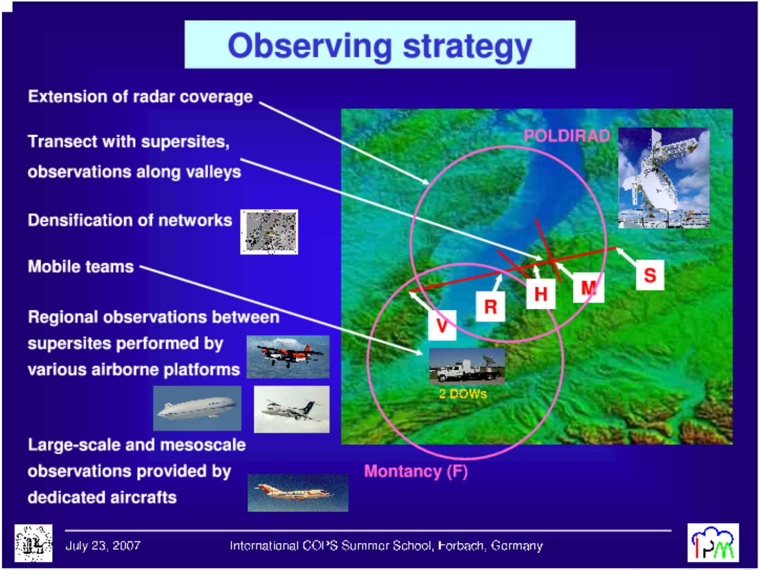
Motivation

- Low skill in forecasting convective precipitation; particularly timing, location and amount
- Major field campaigns to address summer-time convection:
  - International H20 Project (IHOP) in USA 2002
  - Convective Storm Initiation Project (CSIP) in UK 2004/5
  - Convective and Orographically-Induced Precipitation Study (COPS) in SW Germany/SE France 2007

The Convective and Orographically-induced Precipitation Study (COPS)

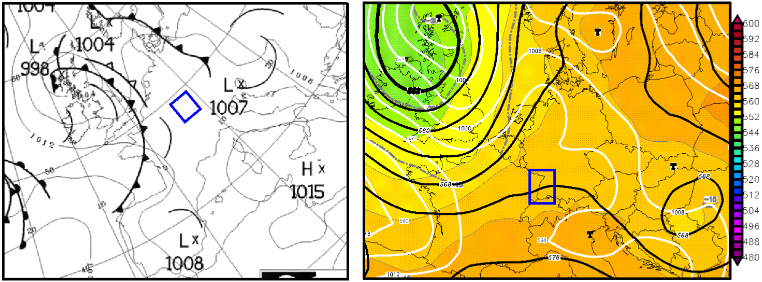
- Improve understanding of initiation and development of convection over complex terrain,
- Understand microphysics of the clouds and role of aerosols on the development of precipitation
- Two case studies: 12 August (initiation); and 15 July (microphysics and aerosols) 2007.
    - Comparison between Doppler on Wheels (DoWs) radar data with high-resolution simulations from the Weather Research and Forecasting (WRF) model on 12 August
    - Observations of aerosols (ground-based and airborne) and cloud particles during penetrations of ascending cloud on 15 July; MAC3 model runs and sensitivity studies

COPS map


Observing strategy
Extension of radar coverage
Transect with supersites,
observations along valleys
Densification of networks
Mobile teams
Regional observations between
supersites performed by
various airborne platforms
Large-scale and mesoscale
observations provided by
dedicated aircrafts
POLDIRAD
S
M
H
R
V
2 DOWs
Montancy (F)
July 23, 2007
International COPS Summer School, Forbach, Germany

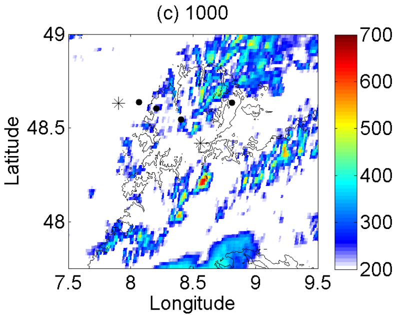
IOP 15a: 12 August, 2007

Synoptic Conditions

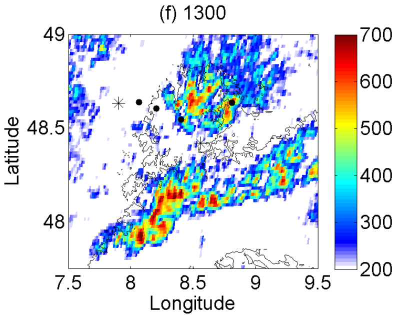


- Well-defined trough over the UK and surface low centred over northwest Scotland
- Weak upper level ridge positioned over central Europe and weak surface high
- Diffluent flow at 500mb over E France and SW Germany

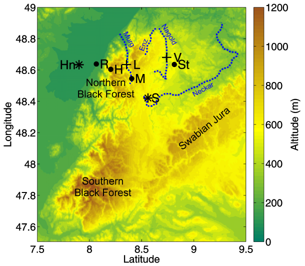
Satellite Observations

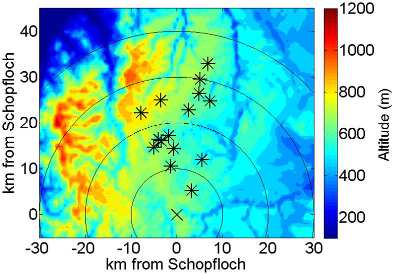


Satellite Observations



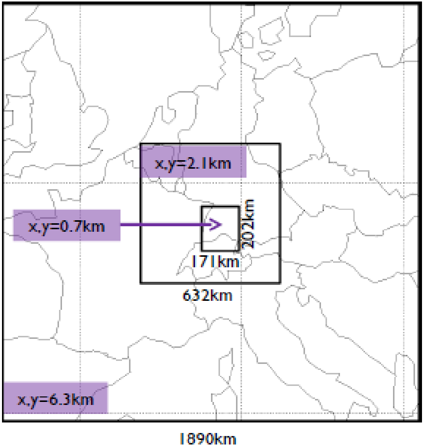
Doppler on Wheels (DoW) Radar Observations





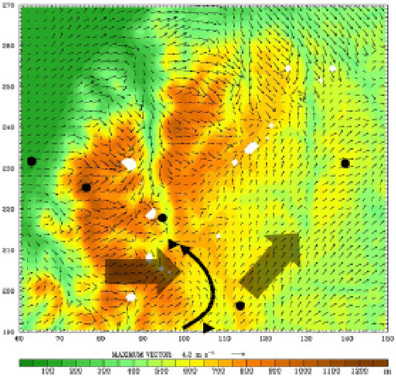
Location of 1st precip (11-14 UTC)

WRF Model Setup

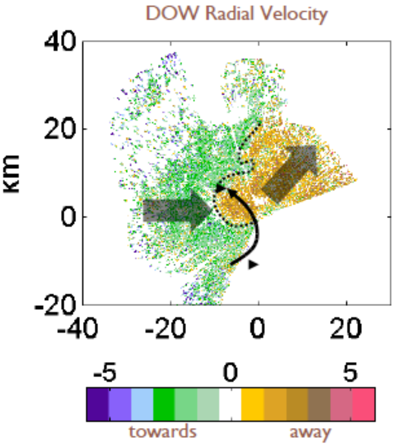


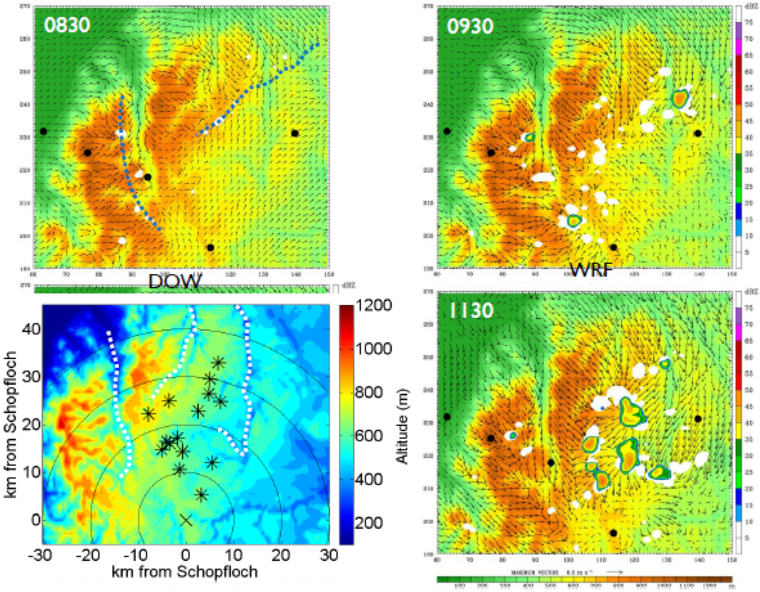
- Version 3.1
- 121 vertical levels
- Initialised by GFS analyses at 0000 UTC used as boundary conditions on outer domain
- Model output every 5mins for d3, 60mins for d1 and d2

WRF Results and Comparison with Obs

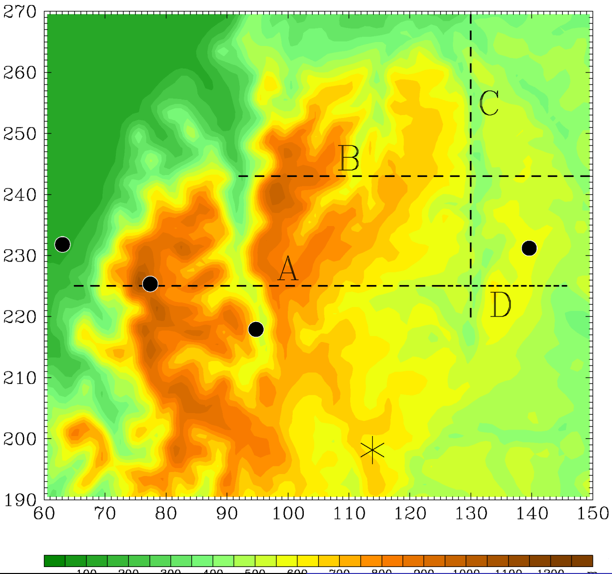


WRF

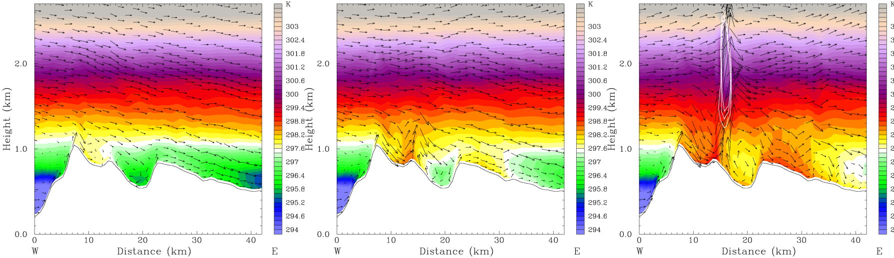


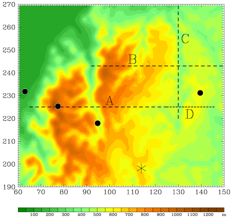

0830
0930
WRF
DOW
1130
40
30
20
10
0
-30 -20 -10 0 10 20 30
km from Schopfloch
km from Schopfloch
1200
1000
800
600
400
200
Altitude (m)

WRF Cross-Sections

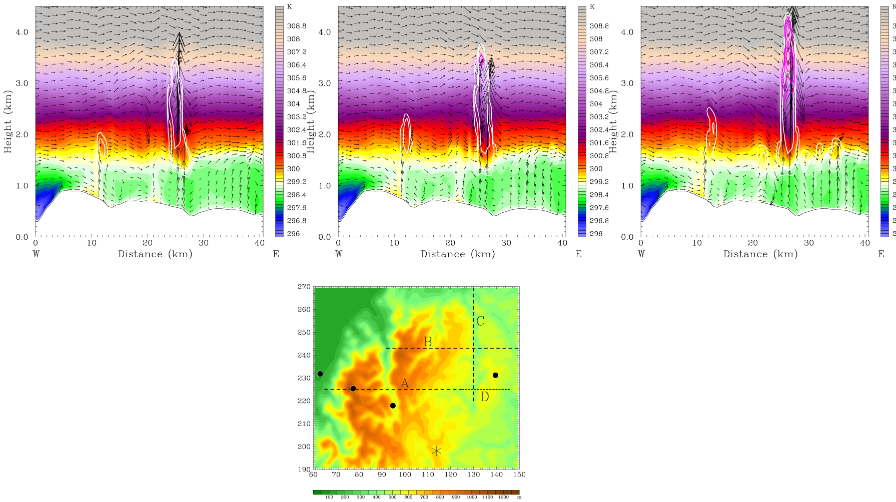


Cross-Section A

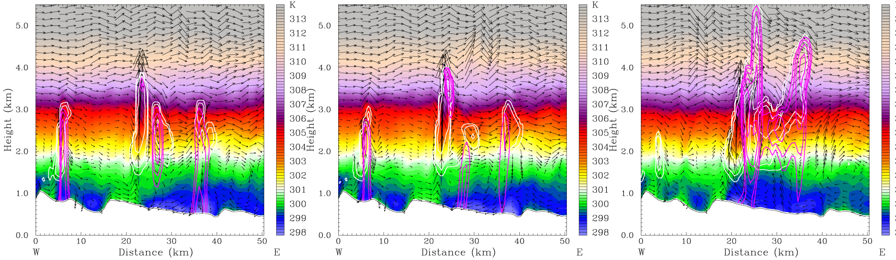


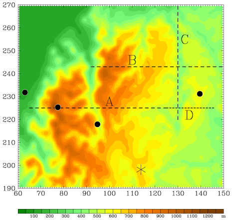


Cross-Section B



Cross-Section D





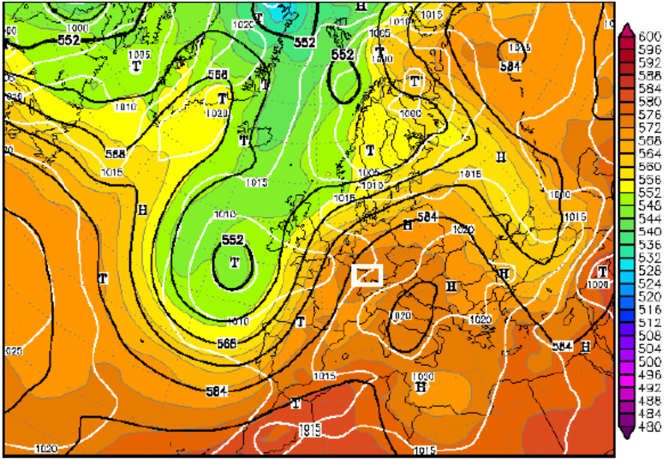
Summary of this case

- DOW radar observations showed that precipitating clouds only developed between the north-south orientated Murg and Nagold Valleys
- WRF model used to investigate processes responsible for initiating convection
- Simulated thermodynamics, clouds and precipitation compared well with observations
- Physical processes
  - elevated heating formed warm and moist cores
  - convergence lines controlled location of convection within cores
  - cold-pool outflows generated secondary convection

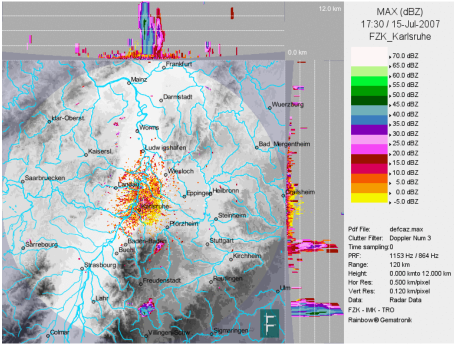
IOP 8a: 15 July, 2007

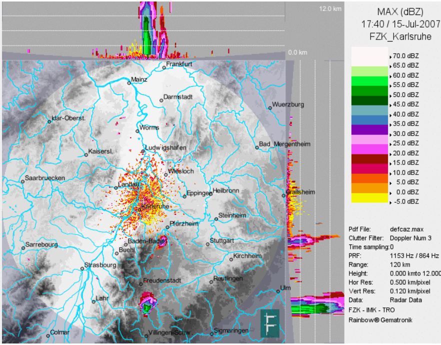
Microphysical Development and Role of Aerosols

Synoptic Conditions

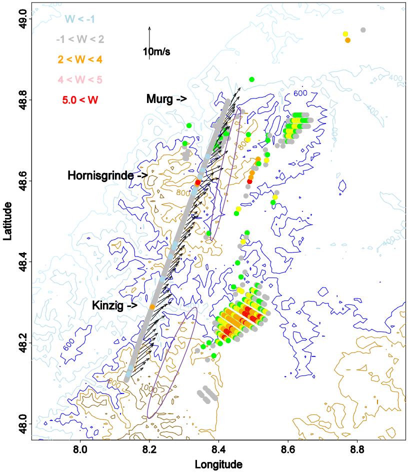


IMK Radar showing N and S clouds

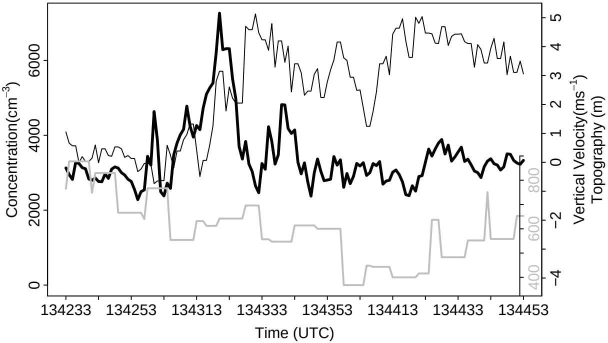




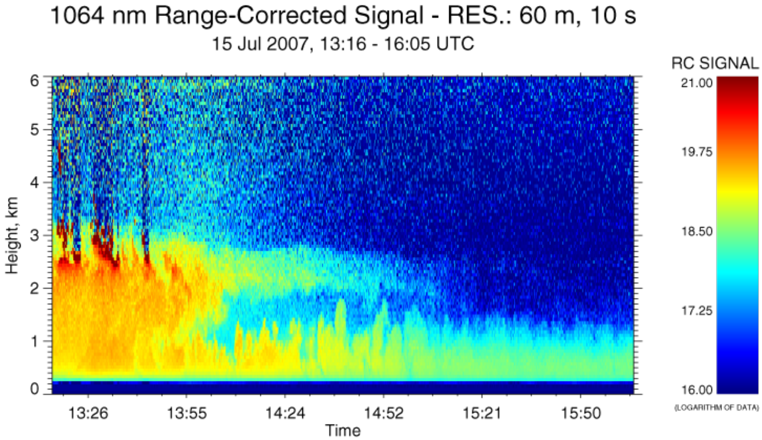
Track of a/c; position of clouds



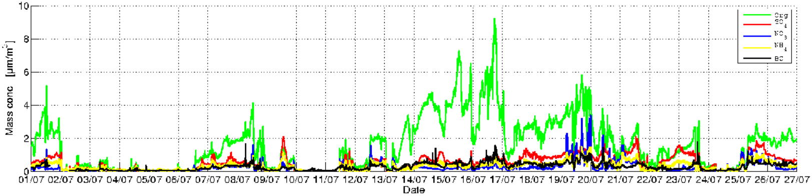
Vertical velocity and conc from CPC



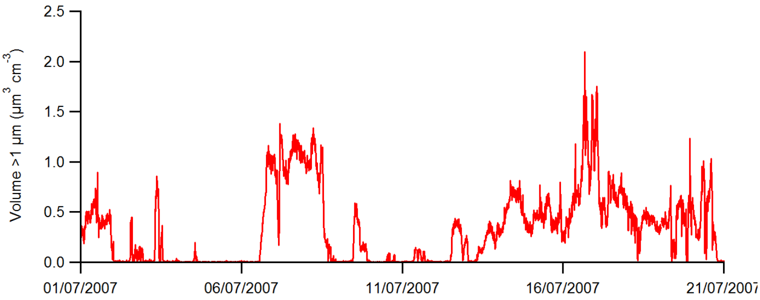
Aerosol lidar backscatter: Murg Valley



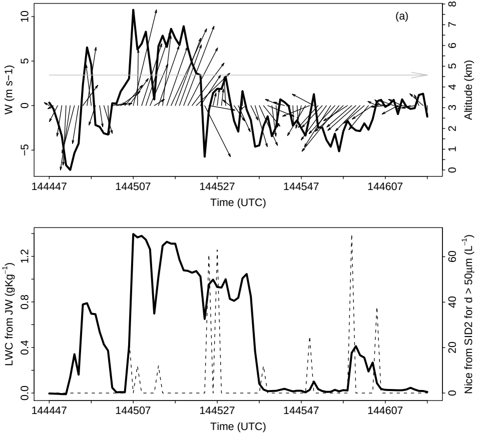
Aerodyne Time-of-Flight Aerosol Mass Spectrometer, Hornisgrinde



Coarse-mode aerosol: Grimm OPC behind 4μm filter

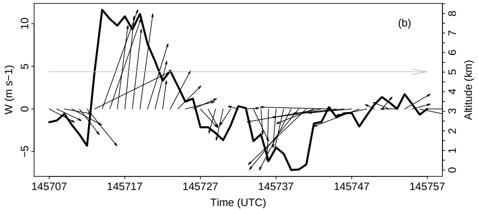


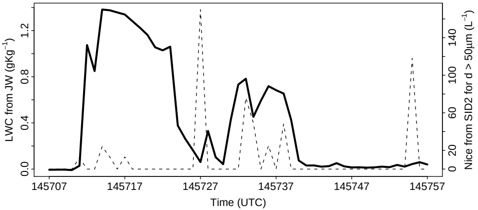
Aircraft penetrations: VW, LWC, SID-2 ($d > 50\mu$m)



1445 UTC, 4.6 km MSL; $T \approx$ -4°C

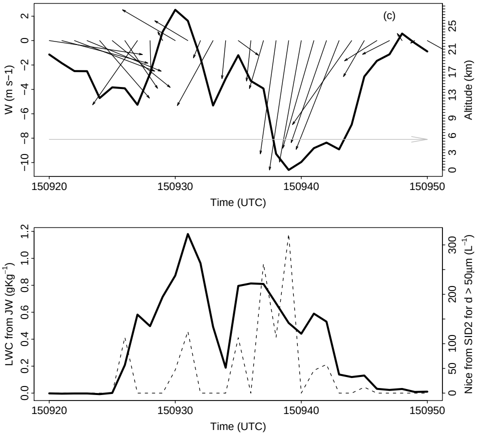
Aircraft penetrations: VW, LWC, SID-2 ($d > 50\mu$m)



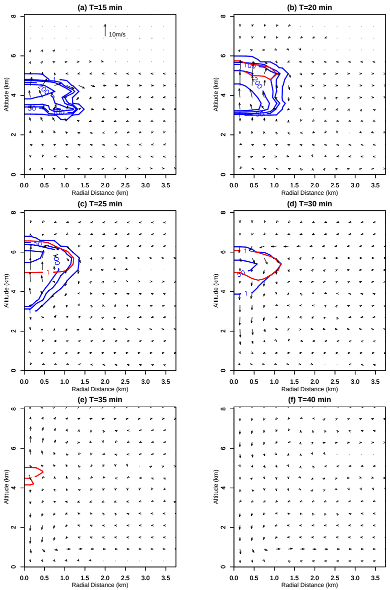


1457 UTC, 5 km MSL, $T \approx$ -7°C

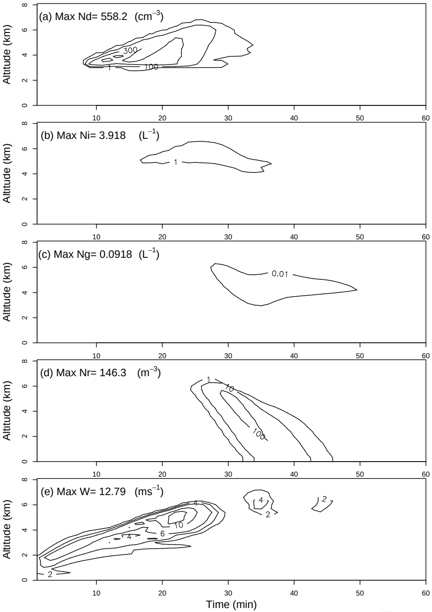
Aircraft penetrations: VW, LWC, SID-2 ($d > 50\mu$m)

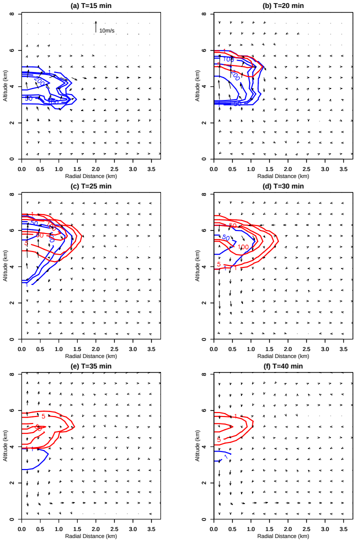


1509 UTC, 5.3 km MSL, $T \approx$ -9°C

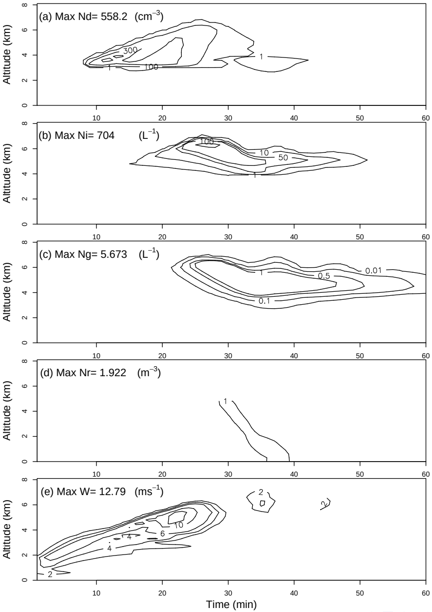


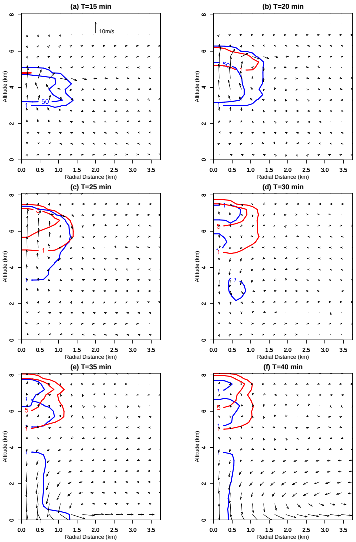
MAC3 model: reference run


(a) Max Nd= 558.2 (cm−3)
300
100
1
(b) Max Ni= 3.918 (L−1)
1
(c) Max Ng= 0.0918 (L−1)
0.01
(d) Max Nr= 146.3 (m−3)
1
10
100
(e) Max W= 12.79 (ms−1)
4
10
6
2
Altitude (km)
Time (min)

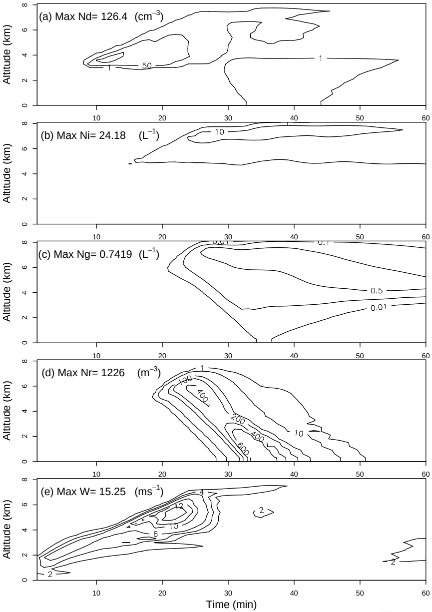


Biological ice nuclei


(a) Max Nd= 558.2 (cm−3)
(b) Max Ni= 704 (L−1)
(c) Max Ng= 5.673 (L−1)
(d) Max Nr= 1.922 (m−3)
(e) Max W= 12.79 (ms−1)
Altitude (km)
Time (min)

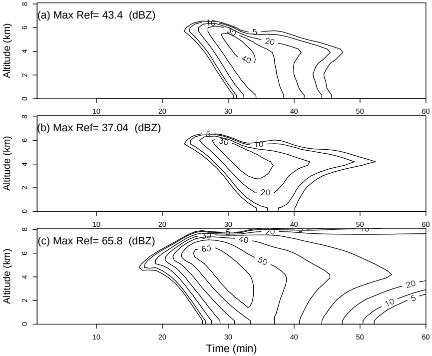

(a) T=15 min
(b) T=20 min
(c) T=25 min
(d) T=30 min
(e) T=35 min
(f) T=40 min
10m/s
Altitude (km)
Radial Distance (km)

Low aerosol



(a) Max Nd= 126.4 (cm^{-3})
(b) Max Ni= 24.18 (L^{-1})
(c) Max Ng= 0.7419 (L^{-1})
(d) Max Nr= 1226 (m^{-3})
(e) Max W= 15.25 (ms^{-1})
Altitude (km)
Time (min)

Reflectivity from: Reference; biological IN; low aerosol



Summary of this case

- High concentrations of relatively small ice particles
- Conditions not suitable for HM
- Biological nuclei, oxidised aerosol particles in vented polluted air and desert dust – all possible candidates.
- Model results: standard Meyers – hardly any ice particles; biological ice nucleus scheme – high concentration of ice particles.
- Increased emissions of biogenic VOC oxidation products from the trees
- Venting of pollutants from valleys in BF mts can influence microphysics and dynamics:
  - oxidised aerosol particles – more efficient ice nuclei?
  - greater number of CCN causes cloud to be shallower and produce less rain – cleaner cloud was more vigorous
- Convection initiated by orographically-influenced flows may be modified by differences in aerosol loadings that are generated within the flows.