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JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Ice formation pathways in Warm Conveyor Belts

ICCARUS Seminar 2019

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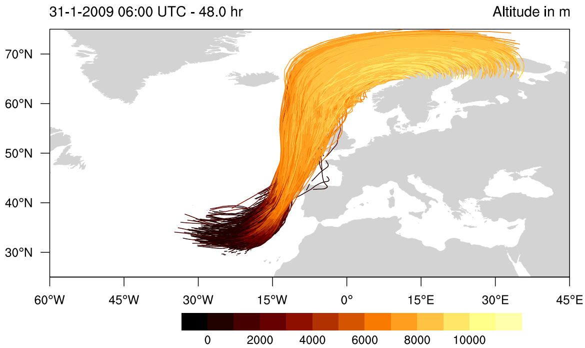
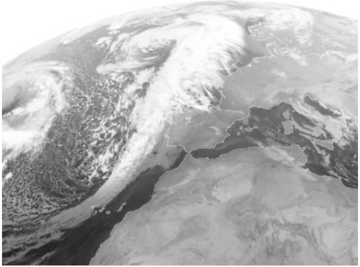
Warm Conveyor Belts (WCB)

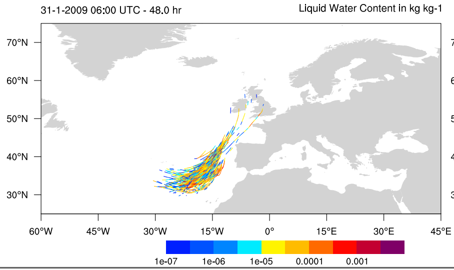


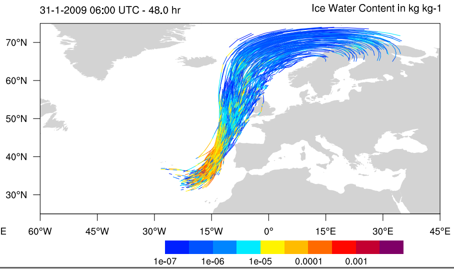
- Warm Conveyor Belts (WCB) are air streams associated with frontal systems and cyclone activity
- WCBs transport moisture and cloud particles from the boundary layer into the upper troposphere
- Form a cloud band and vast Cirrus with long persistence in outflow region

Warm Conveyor Belts (WCB)

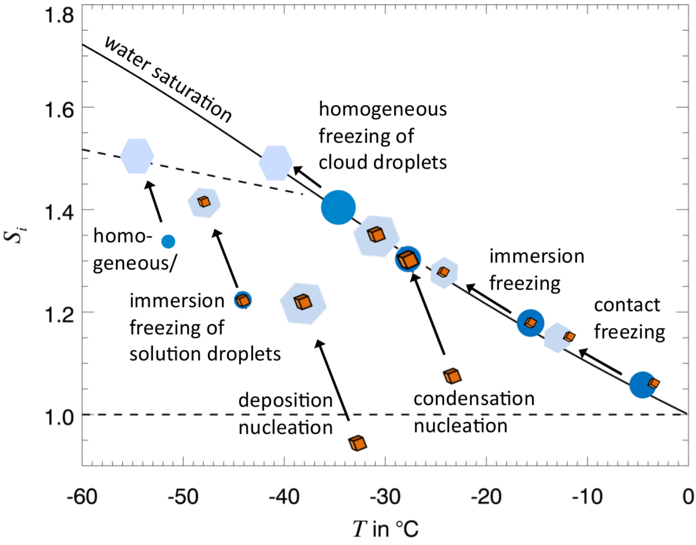


Meteosat SEVIRI infrared satellite image for 30-01-2009 06:00 UTC (Joos and Wernli, 2012)



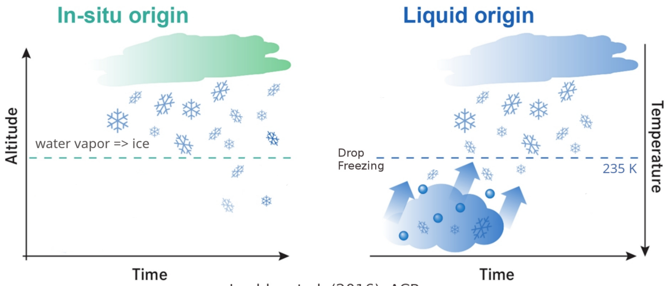


Introduction: ice particle formation

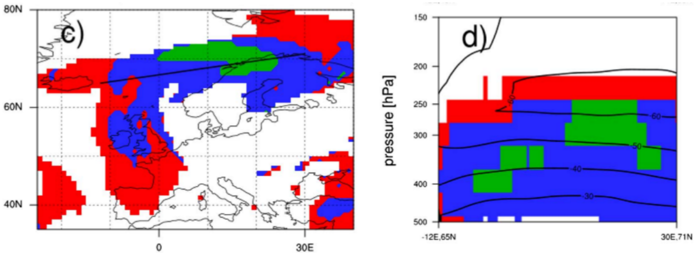


Hoose and Möhler (2012)

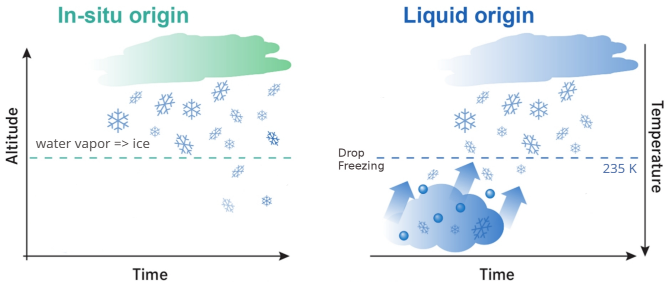
In-situ and liquid origin



Luebke et al. (2016), ACP



Case study 30-01-2009. Red: in-situ; Blue/Green: liquid origin (Heini Wernli et al., 2016)



Luebke et al. (2016), ACP

- Which ice formation processes are dominant for WCBs?
- In-situ vs liquid origin
- Simulations of WCBs in ICON NWP
- Investigation of ice formation pathways with ice modes microphysics scheme

Microphysics: Seifert and Beheng (2006)

- Modified version of ICON standard two-moment scheme
- Multiple ice classes: 'ice modes'
- Ice modes have their own size distributions
- Governed by same parametrizations except for particle formation process

Distinction between 5 ice modes:

- Ice from hom. freezing solution droplets: n_{hom}, q_{hom}
- Ice from deposition nucleation: n_{dep}, q_{dep}
- Ice from immersion freezing: n_{het}, q_{het}
- Ice from hom. freezing cloud droplets: n_{frz}, q_{frz}
- Secondary ice production from rime splintering: n_{sec}, q_{sec}

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In-situ origin
Liquid origin

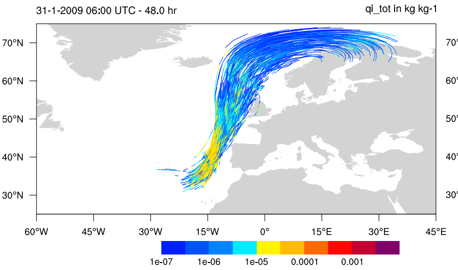
10 cloud particle classes:

- Ice from hom. freezing solution droplets: n_{hom}, q_{hom}
- Ice from deposition nucleation: n_{dep}, q_{dep}
- Ice from immersion freezing cloud droplets: n_{het}, q_{het}
- Ice from hom. freezing cloud droplets: n_{frz}, q_{frz}
- Secondary ice production from rime splintering: n_{sec}, q_{sec}
- Cloud droplets: n_c, q_c
- Rain: n_r, q_r
- Snow: n_s, q_s
- Graupel: n_g, q_g
- Hail: n_h, q_h

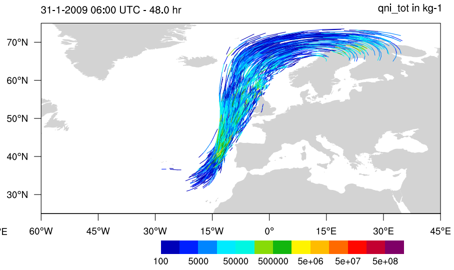
Warm Conveyor Belt: 30-01-2009

- Well documented case (Joos and Wernli, 2012)
- Simulation of North Atlantic/Europe at 2.5 km resolution
- Initialisation and boundary conditions with IFS

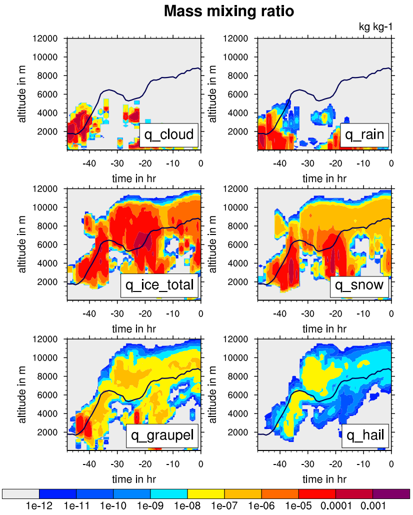
Total ice mass

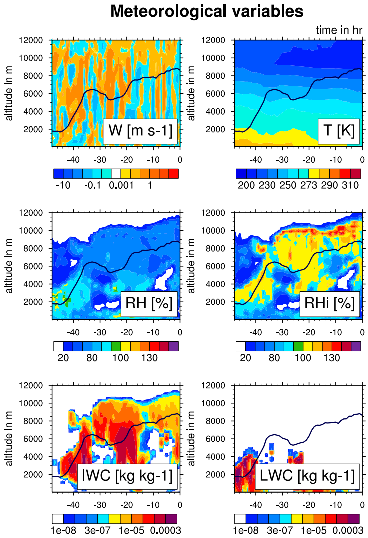


Total ice number

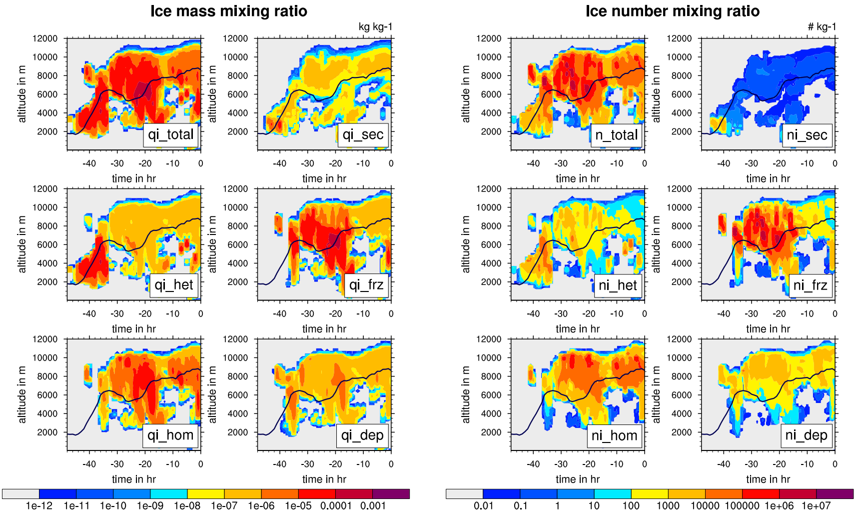


Vertical slice



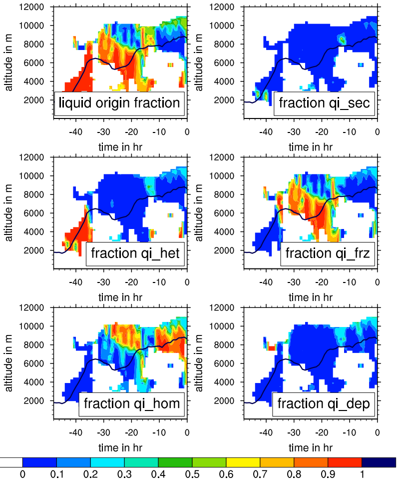


Vertical slice: ice modes

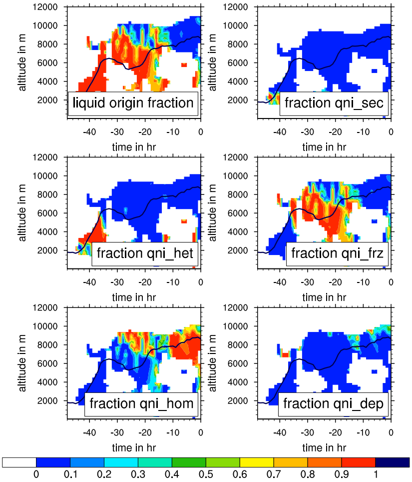


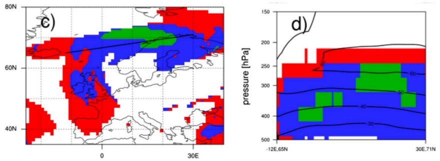
Vertical slice: ice mode fractions

Ice mode mass fractions

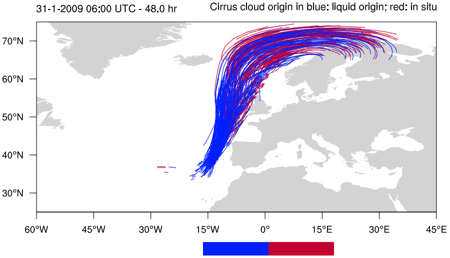


Ice mode number fractions





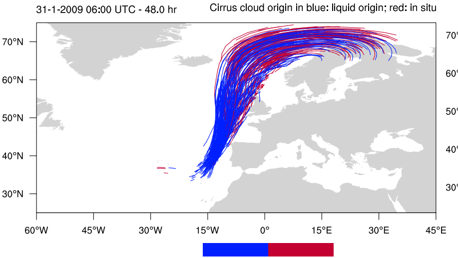
Red: in-situ; Blue/Green: liquid origin (Heini Wernli et al., 2016)



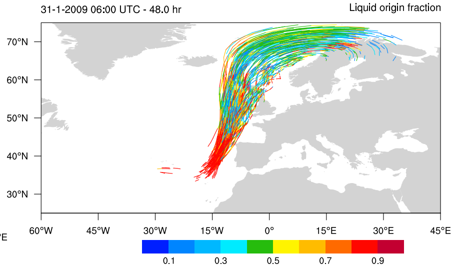
Cirrus origin classification

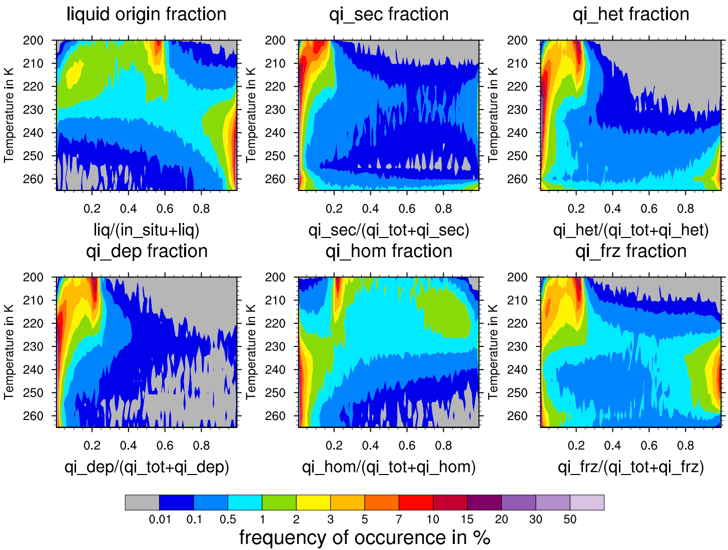
- Heini Wernli et al. (2016)
- Calculate backwards trajectories of cirrus clouds
- If liquid water was present then classification as liquid origin, otherwise as in-situ cloud
- Liquid origin fraction: 69 %, In-situ fraction: 31 %

Cirrus origin classification



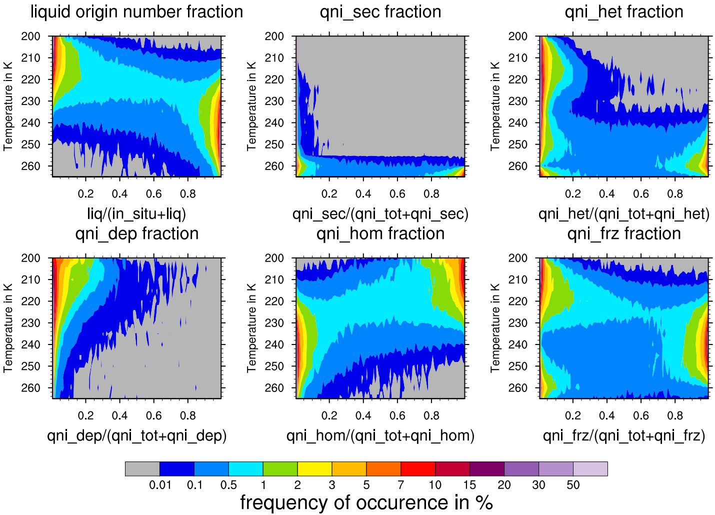
Ice modes classification





liquid origin fraction
qi_sec fraction
qi_het fraction
Temperature in K
200
210
220
230
240
250
260
0.2
0.4
0.6
0.8
liq/(in_situ+liq)
qi_sec/(qi_tot+qi_sec)
qi_het/(qi_tot+qi_het)
qi_dep fraction
qi_hom fraction
qi_frz fraction
qi_dep/(qi_tot+qi_dep)
qi_hom/(qi_tot+qi_hom)
qi_frz/(qi_tot+qi_frz)
0.01
0.1
0.5
1
2
3
5
7
10
15
20
30
50
frequency of occurence in %

In-situ vs liquid origin: number fractions



Summary

- Strong and distinct WCB
- Long lasting and vast cirrus cloud field
- Liquid origin dominates during WCB ascend
- Liquid origin fraction in WCB outflow pushed below 55 %
- Deposition nucleation weak

- Deposition and immersion freezing depend on ice nucleating particles (INPs)
  - ..and hence representation of INPs and their activation spectra
- Homogeneous nucleation depends on strength of vertical updraft...
  - ..and hence grid resolution
- Hande et al. (2015) favors deposition nucleation and homogeneous freezing of cloud droplets
- Phillips et al. (2008) favors homogeneous nucleation and immersion freezing

Research questions

- In-situ vs liquid origin: clear distinction?
- Radiative, micro- and macrophysical properties?

Short-term plans

- Analysis of ice mode contributions to optical depth
- Implement and test other nucleation and freezing parametrizations
- Write a model paper

References

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