HD(CP)²

Towards representing the impact of convection on cirrus in ICON-GCM

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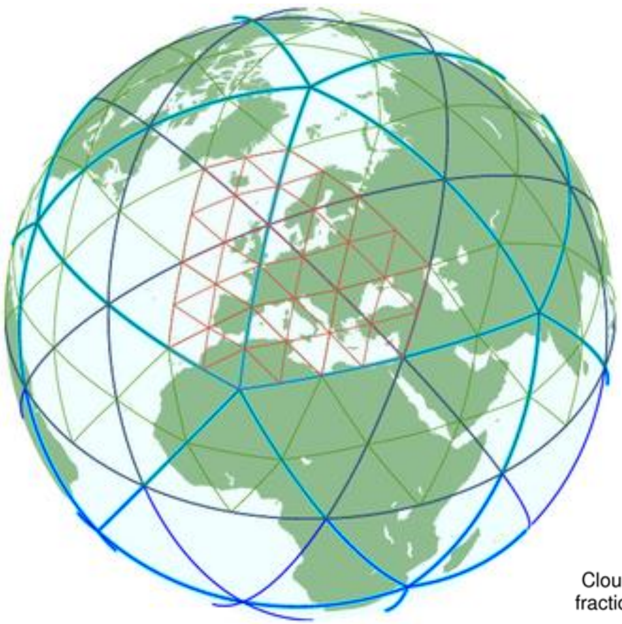
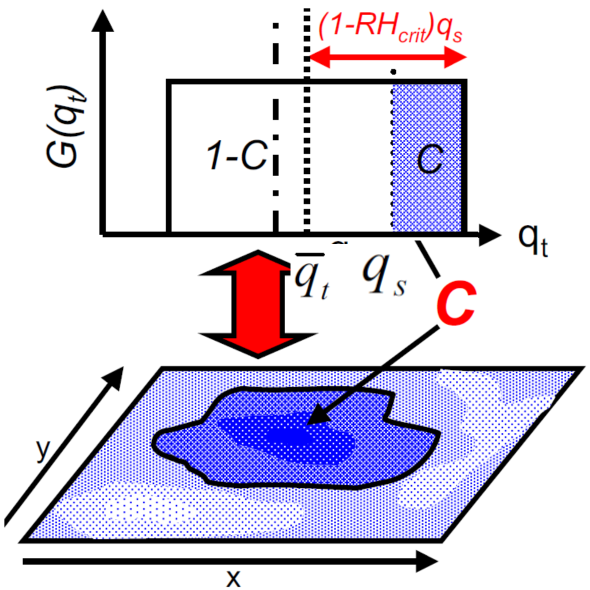
NY, 29 March 2017

ICON GCM – Cloud Scheme

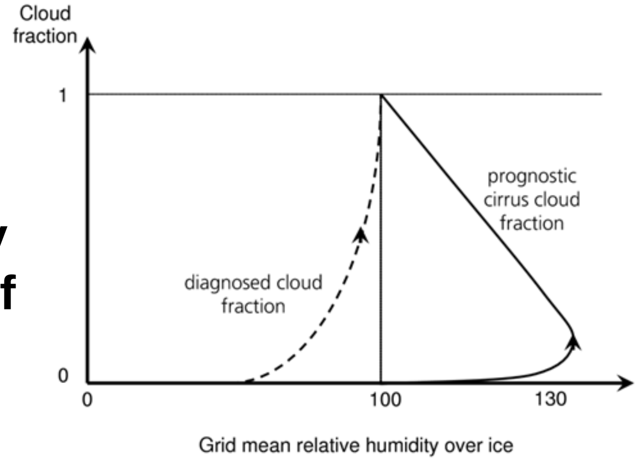


ICON-GCM coupled to ECHAM6 physics.

Resolution – R2B4 (~140km)
Time step – 10 minutes



Ice cloud cover scheme requires additional prognostic variable. Only homogeneous freezing of ice crystals considered.



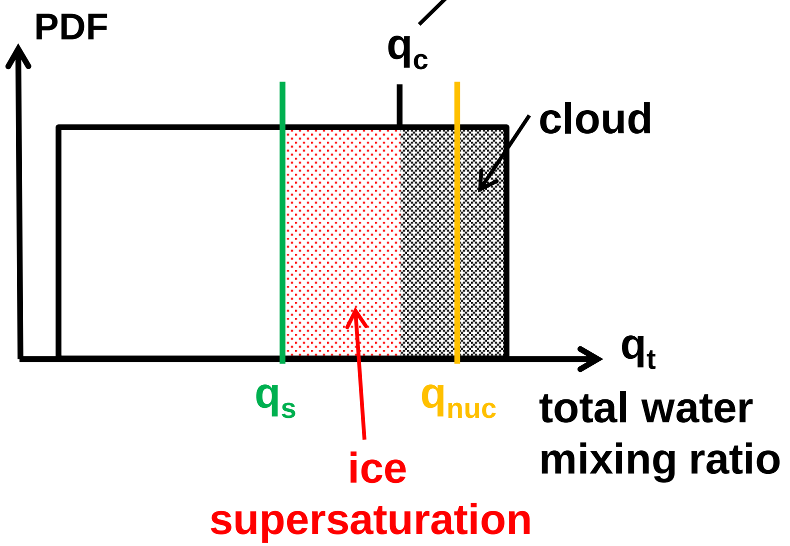
Sundqvist cloud scheme homogeneous PDF of subgrid variability of total water with fixed variance. Microphysical 1-Moment scheme (water mass) with saturation adjustment within a cloud.

AIM: Coupling convection with large scale clouds

Ice cloud scheme – in situ formation

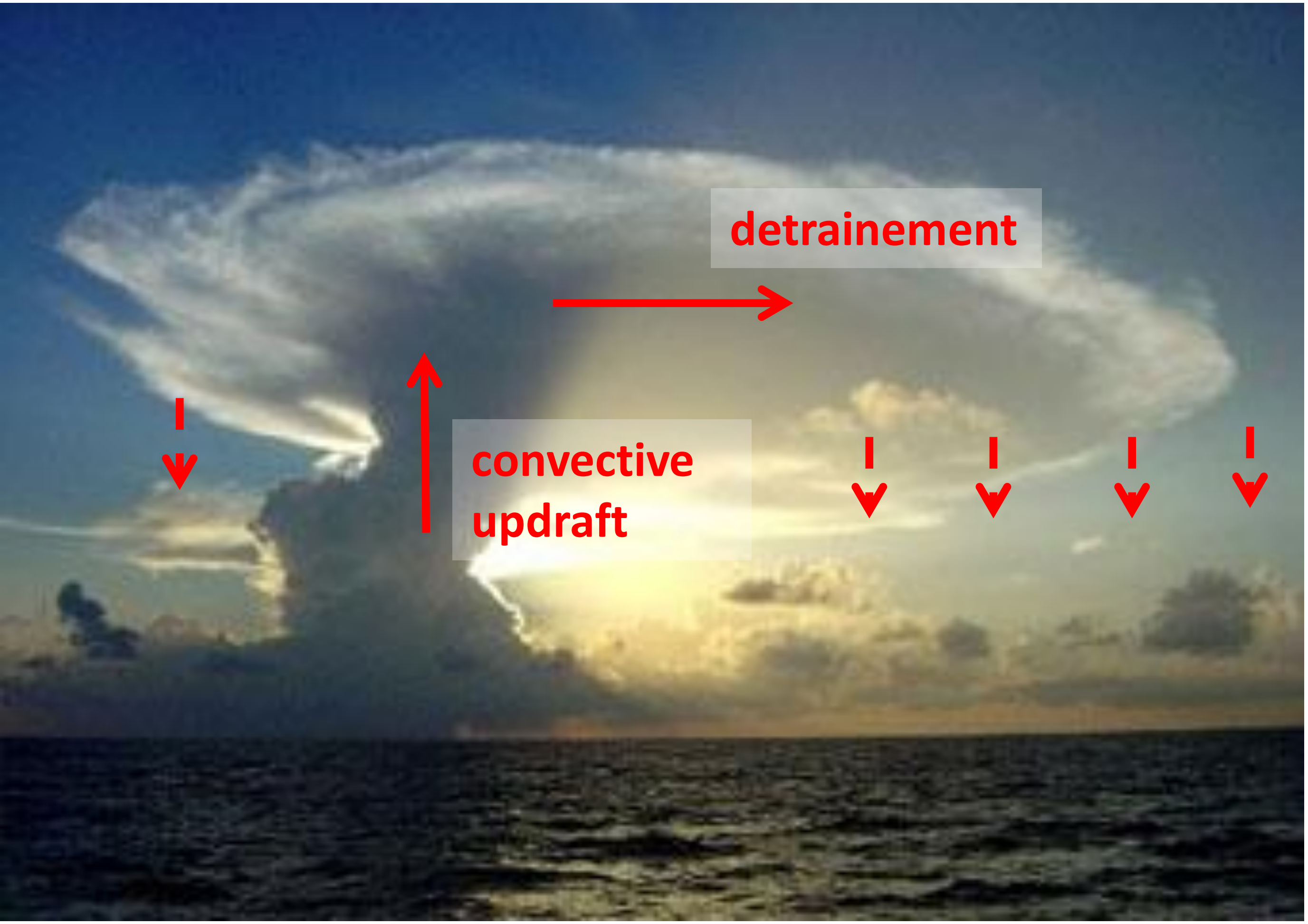
$$\frac{dC}{dt} = \Delta C_{hom} + \Delta C_{conv} + \Delta C_{sed} + \Delta C_{fm} + \Delta C_{sub}$$

$$\Delta C_{HOM} = \begin{cases} \int_{q_{nuc}}^{q_c} PDF\, dq \text{ if } q_c > q_{nuc} \\ -\int_{q_c}^{q_{sat}} PDF\, dq \text{ if } q_c < q_{sat} \end{cases}$$



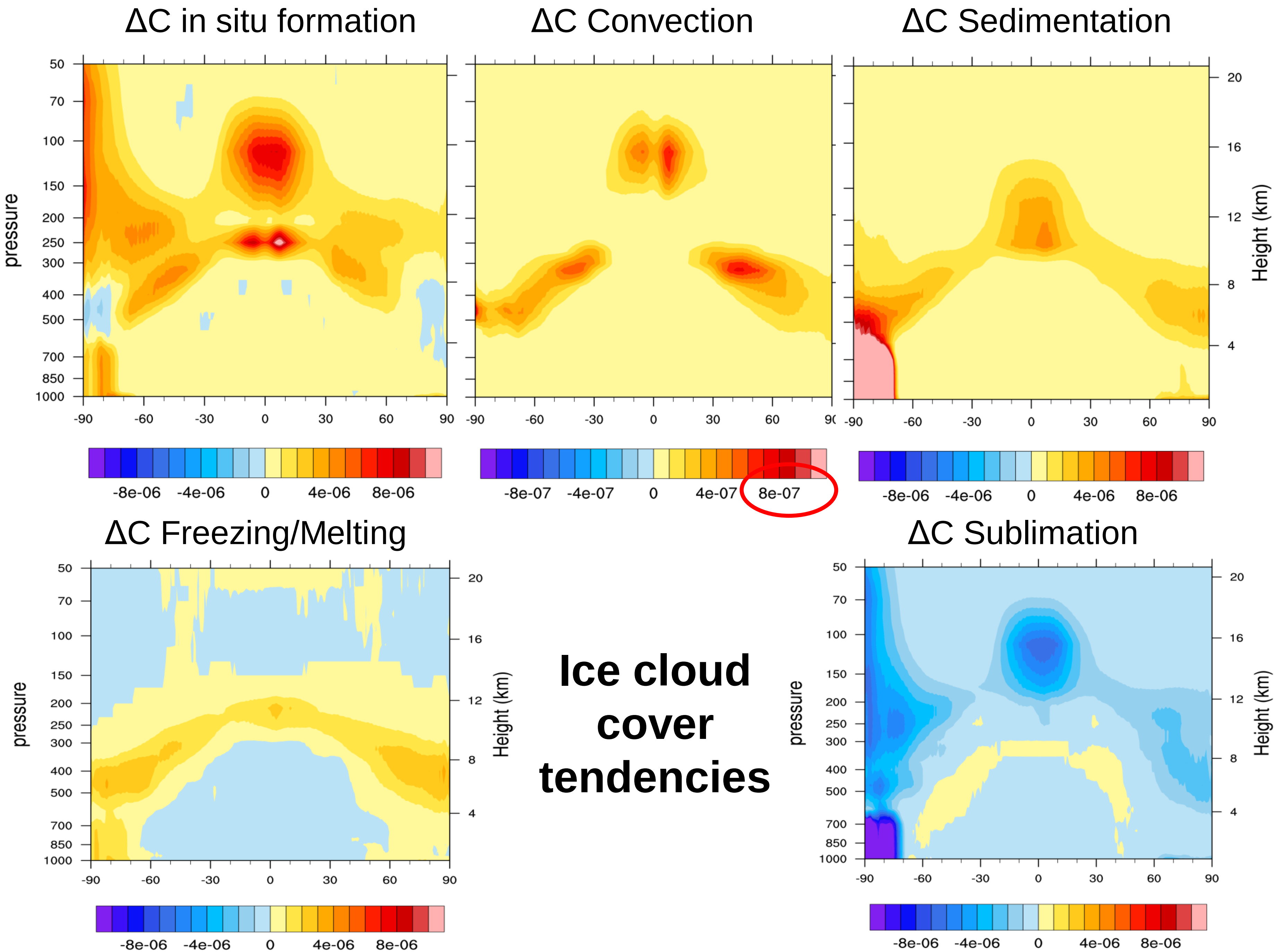
Ice cloud scheme – Convective source term

$$\frac{dC}{dt} = \Delta C_{hom} + \Delta C_{conv} + \Delta C_{sed} + \Delta C_{fm} + \Delta C_{sub}$$

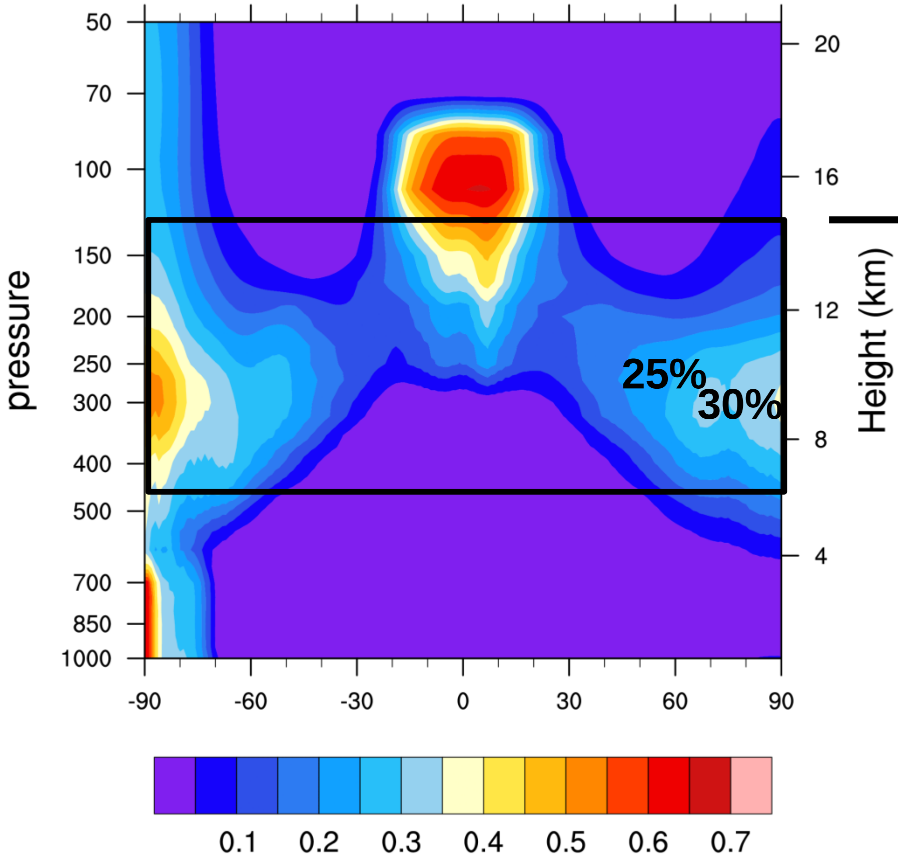


$$\Delta C_{CONV} = \frac{D_{up}}{\rho}$$

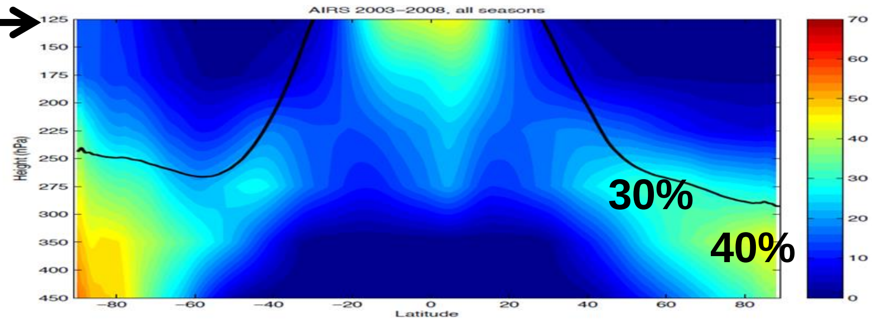
D_{up} – detrained mass


ΔC in situ formation
ΔC Convection
ΔC Sedimentation
ΔC Freezing/Melting
ΔC Sublimation
Ice cloud cover tendencies
pressure
Height (km)
50
70
100
150
200
250
300
400
500
700
850
1000
20
16
12
8
4
-90
-60
-30
0
30
60
90
-8e-06
-4e-06
0
4e-06
8e-06
-8e-07
-4e-07
0
4e-07
8e-07

Ice supersaturation frequency



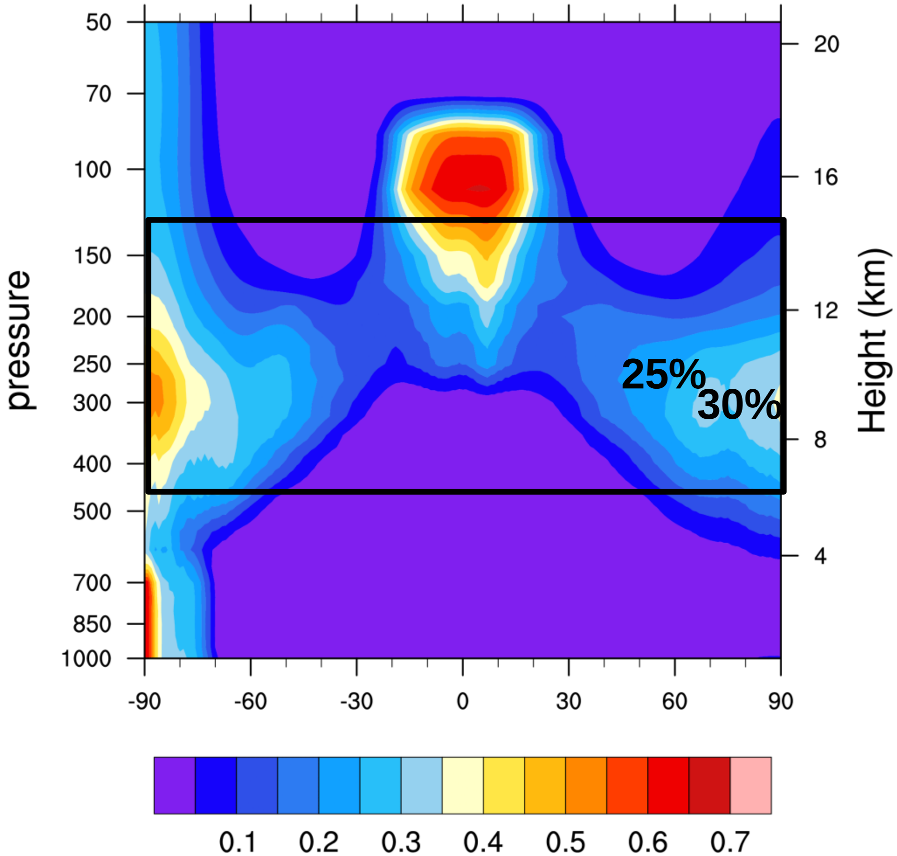
AIRS-observations of ISS frequency, scaled with MOZAIC measurements

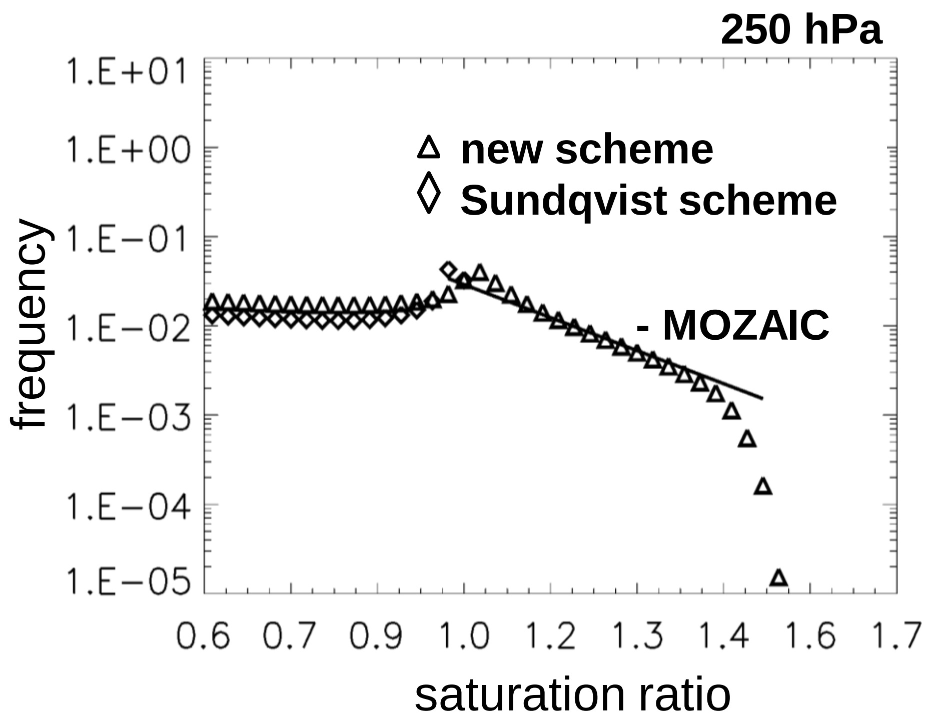


Lamquin et al., 2012

Slight underestimation in northern high and mid latitudes
Polar maxima too high – too high polar tropopause

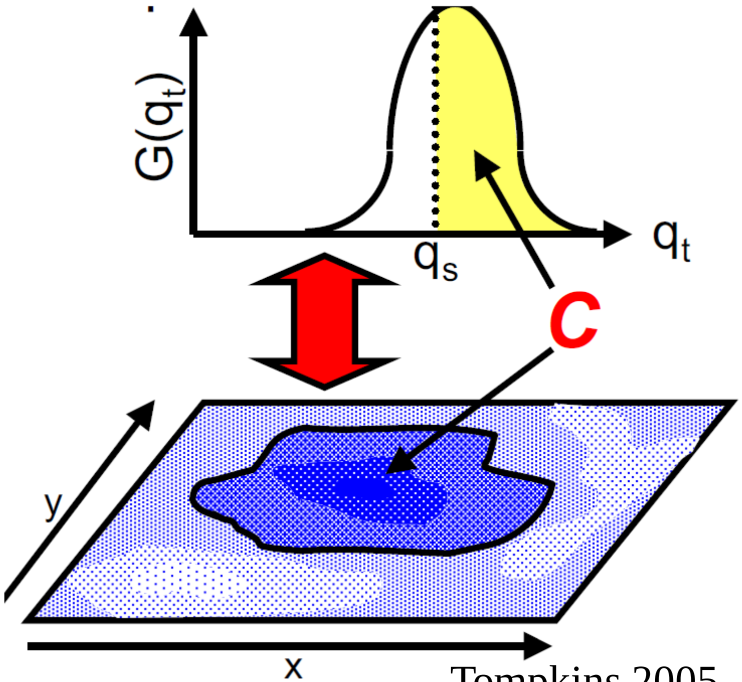
Ice supersaturation frequency





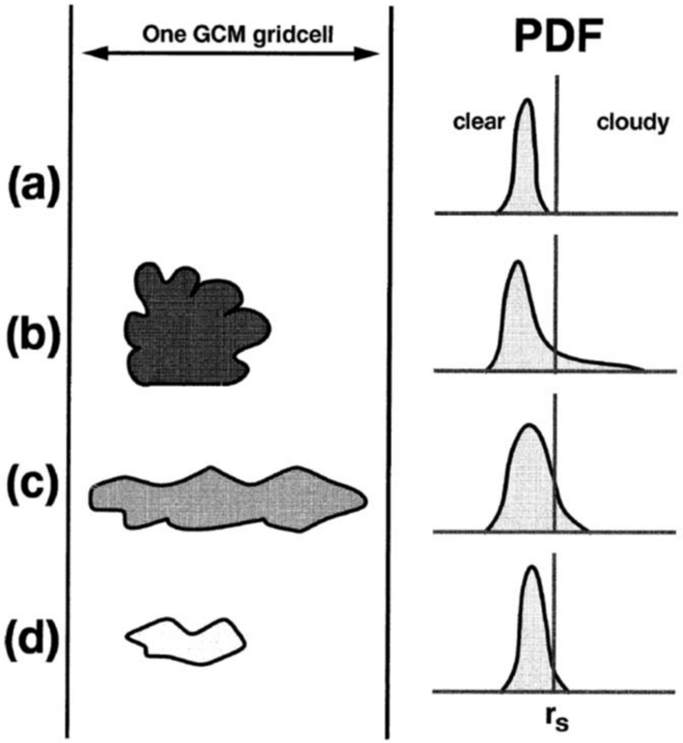
Distribution and spectrum of ice supersaturation in good agreement with data. Modification of simple scheme generally works well and there is good agreement with observational data.

Connection Clouds – Dynamics: PDF cloud scheme



Tompkins 2005

Basis for cirrus scheme is a PDF cloud scheme.
Total water variability described by PDF.



Tompkins 2002

PDF moments change due to dynamical and microphysical processes.

Representation of PDF of subgrid scale variability can be used in order to calculate: microphysical processes, radiative transfer.

HD(CP)^2

Explosive afternoon convection over northern Germany 4th – 5th July 2015

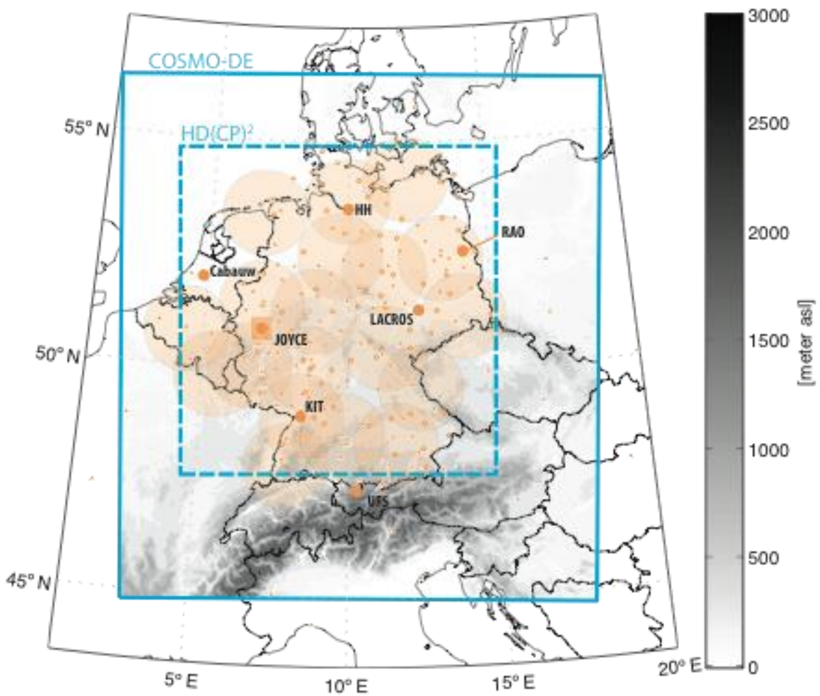
Ulrike Burkhardt[1], Harald Rybka[2], Martin Köhler[2], Axel Seifert[2], Johan Strandgren[1], Luca Bugliaro[1], Jens Reichardt[2], Janina Stäudle[2], Akos Horvath[3], Stefan Bühler[3], Odran Sourdeval[4], Johannes Quaas[4]

1 DLR, 2 DWD, 3 Uni Hamburg, 4 Uni Leipzig

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

CCNY, 27 March 2017

Learning from high resolution modeling HD(CP)2



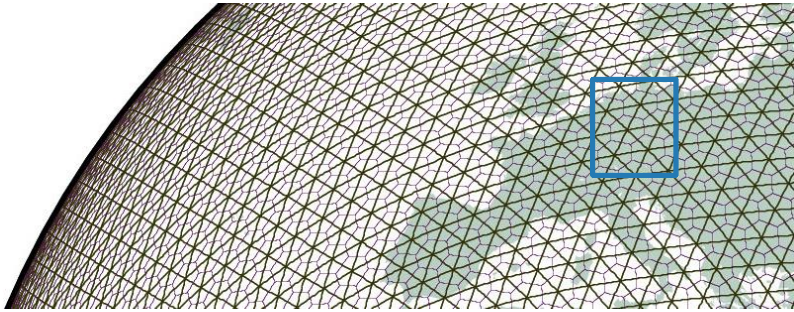
High resolution (~100m) modeling

Dense observational network over Germany

Improvement in the representation of clouds in order to improve climate forecasts

HD(CP)2 – project ‚Anvil cirrus + stratiform convective outflow'

Impact of convection on upper tropospheric water budget - change of UT water budget due to convection in a changing climate



climate change

↓

more water transport into UT

↓

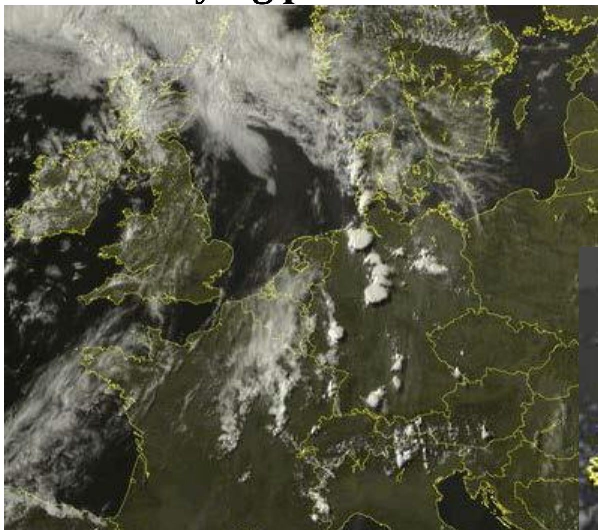
change in precipitation efficiency?

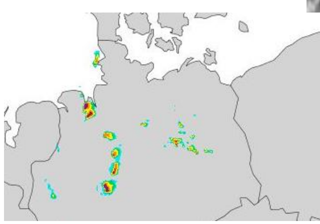
↓

properties and life cycle of anvils

Convective case study 4th - 5th July 2015

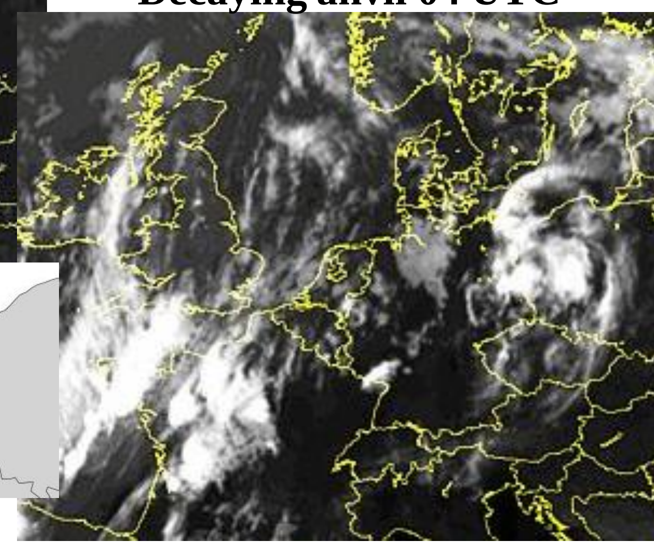
Intensifying phase 16 UTC



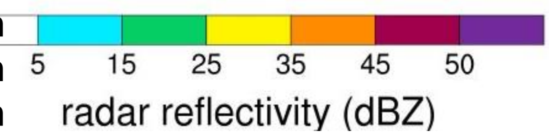


Developed anvil 22 UTC

Decaying anvil 04 UTC

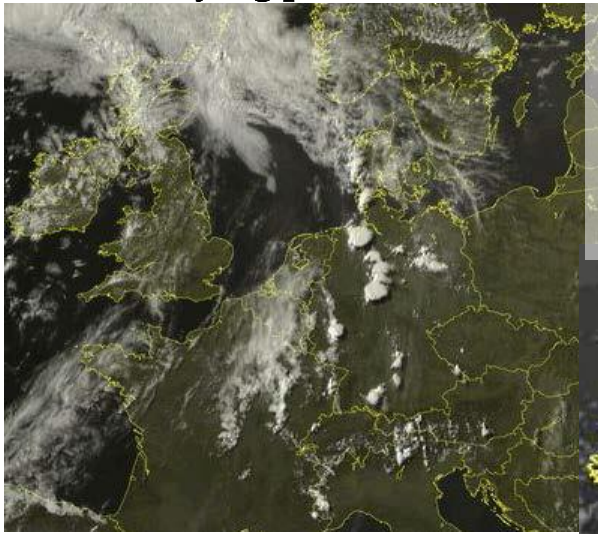


5 dBZ ~ .04 mm/h
15 dBZ ~ 0.3 mm/h
25 dBZ ~ 1.3 mm/h
35 dBZ ~ 5.6 mm/h
45 dBZ ~ 24 mm/h



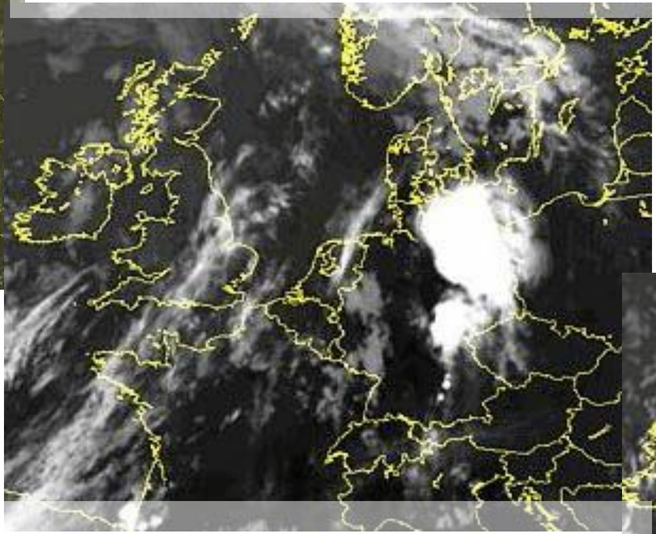
Convective case study 4th -5th July

Intensifying phase 16 UTC

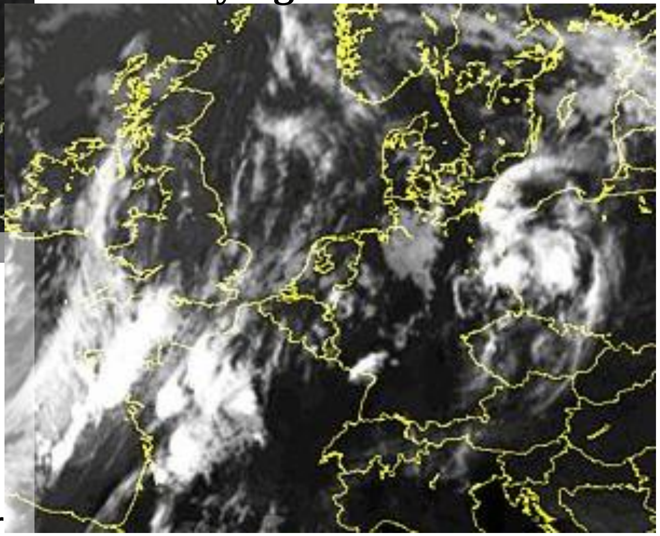


Observations:

SPARE-ICE: IR(AVHRR) + MW(MHS) trained on 2C-ICE radar/lidar
CIPS : IR(METEOSAT) trained on lidar(Calipso)
DARDAR : lidar / radar (Calipso, Cloudsat)
RAMSES : Raman lidar in Lindenberg (Germany)



Decaying anvil 04 UTC



ICON model simulations:

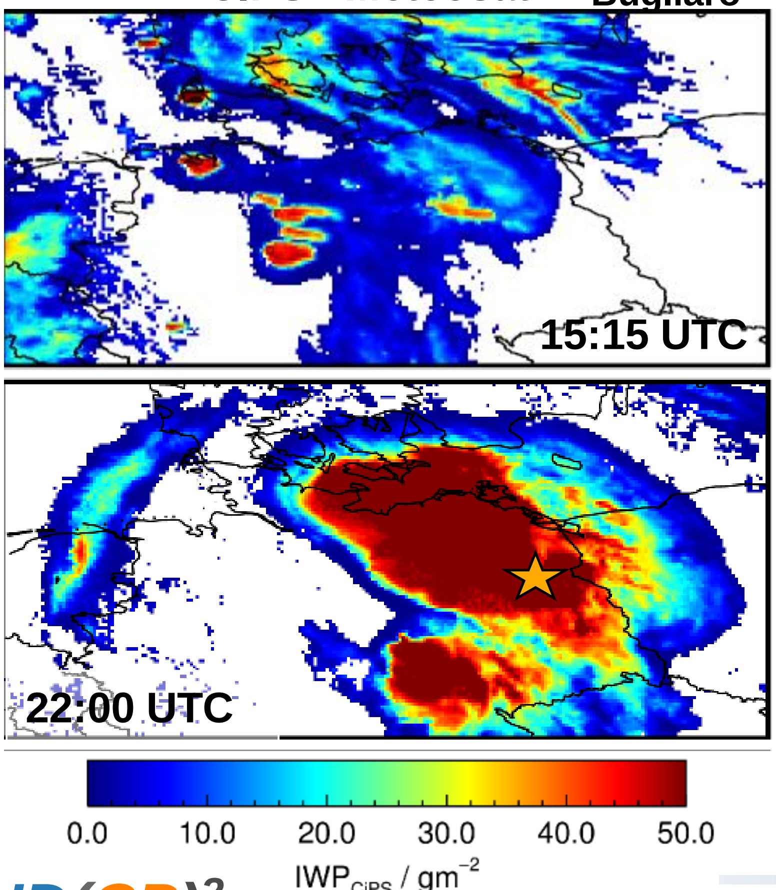
ICON-LEM : ~150 m resolution
ICON-NWP : ~ 30 km resolution, Tiedtke-Bechtold convection, Seifert-Beheng cloud scheme
ICON-GCM : ~140 km resolution, Tiedtke-Nordeng convection, Lohmann-Röckner microphysics, Sundqvist cover

CIPS – SPAREICE - A-Train – RAMAN Lidar

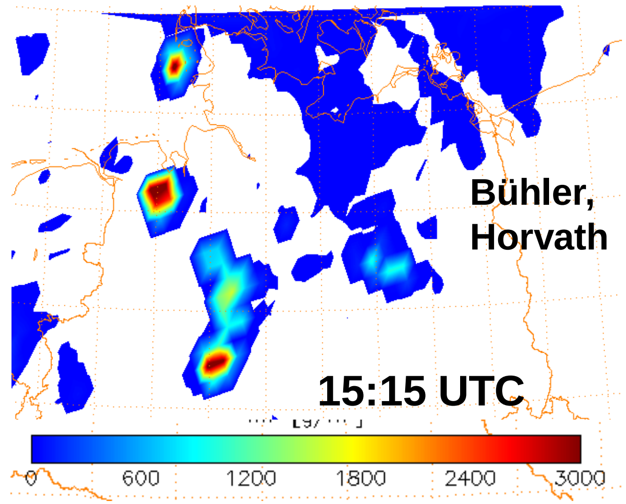
CIPS (thin cirrus): extend of convective anvil + IWP thin anvil
SPARE-ICE: ice water content of convective system

CIPS - Meteosat

Strandgren, Bugliaro



SPAREICE – NOAA18/19

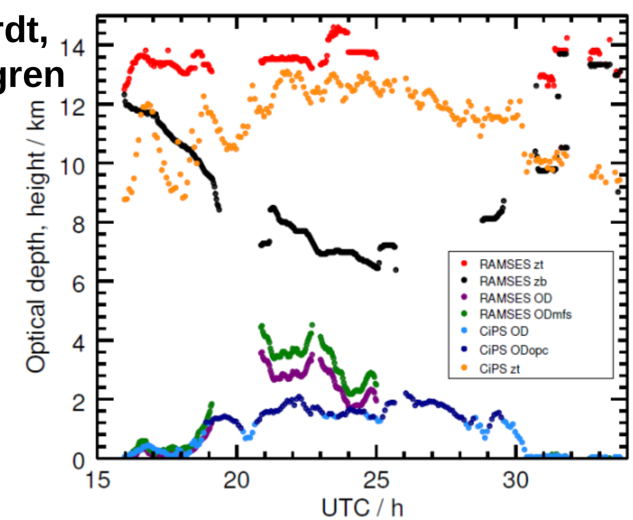


For thin cirrus DARDAR, SPAREICE and CIPS agree well, for thick cirrus CIPS underestimates IWP

RAMSES- Raman Lidar / CIPS

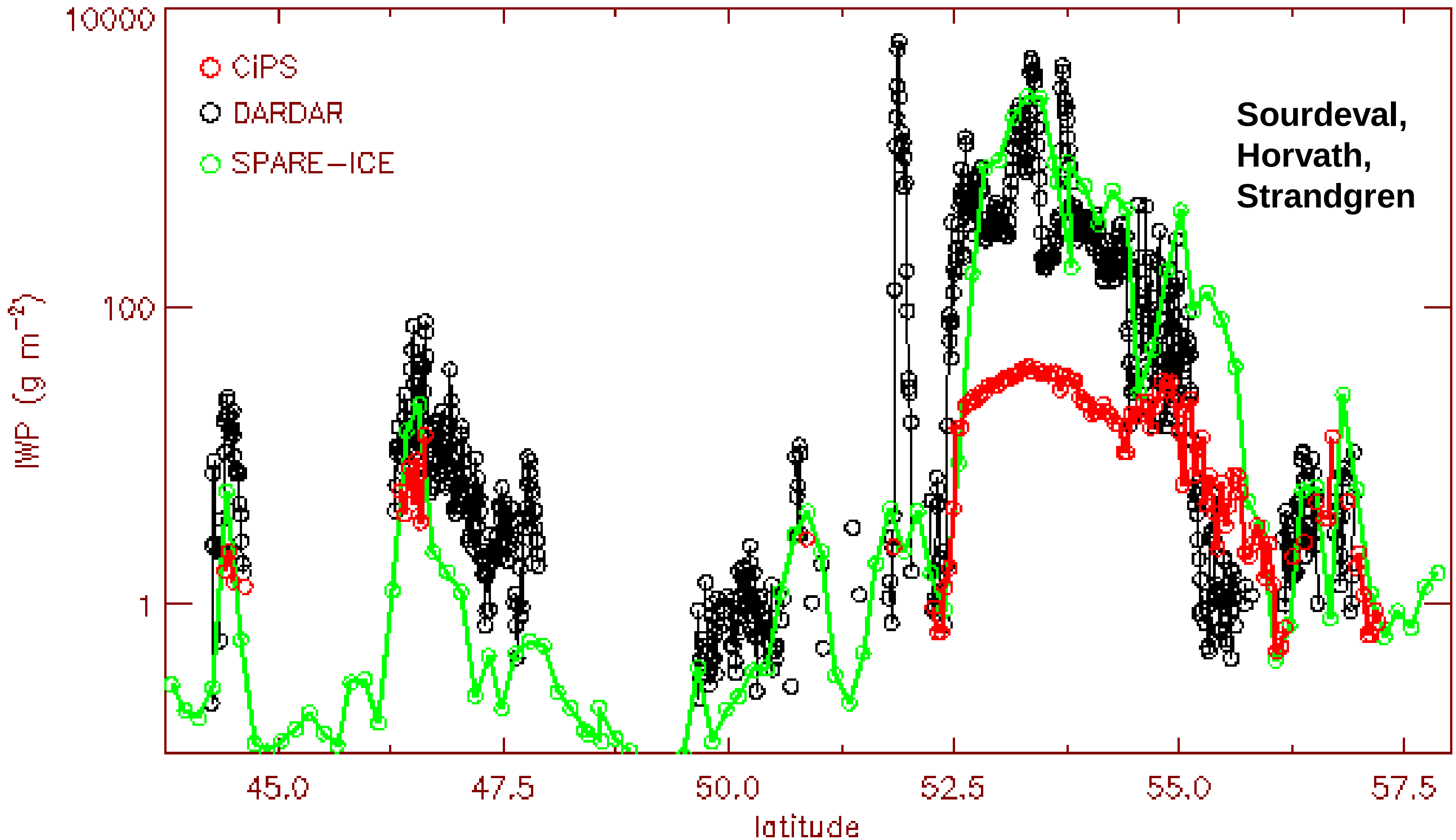
Reichardt, Strandgren

temporal evolution of convective anvil over Lindenberg: CIPS (trained for thin cirrus) – RAMSES Raman lidar



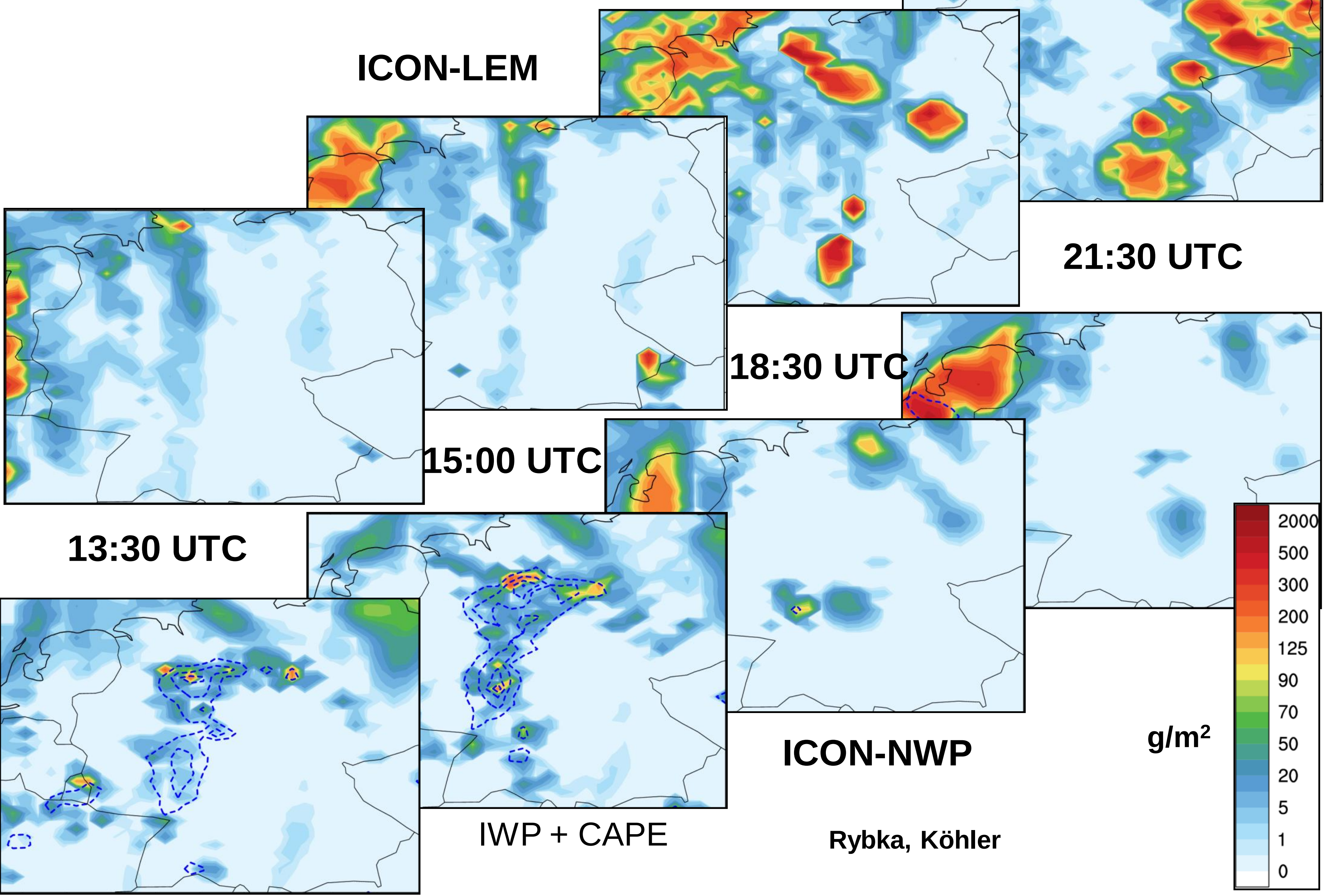
5th July ~12:30 UTC: DARDAR – SPARE-ICE – CIPS

(12:22 UTC) (12:42 UTC) (12:25 UTC)



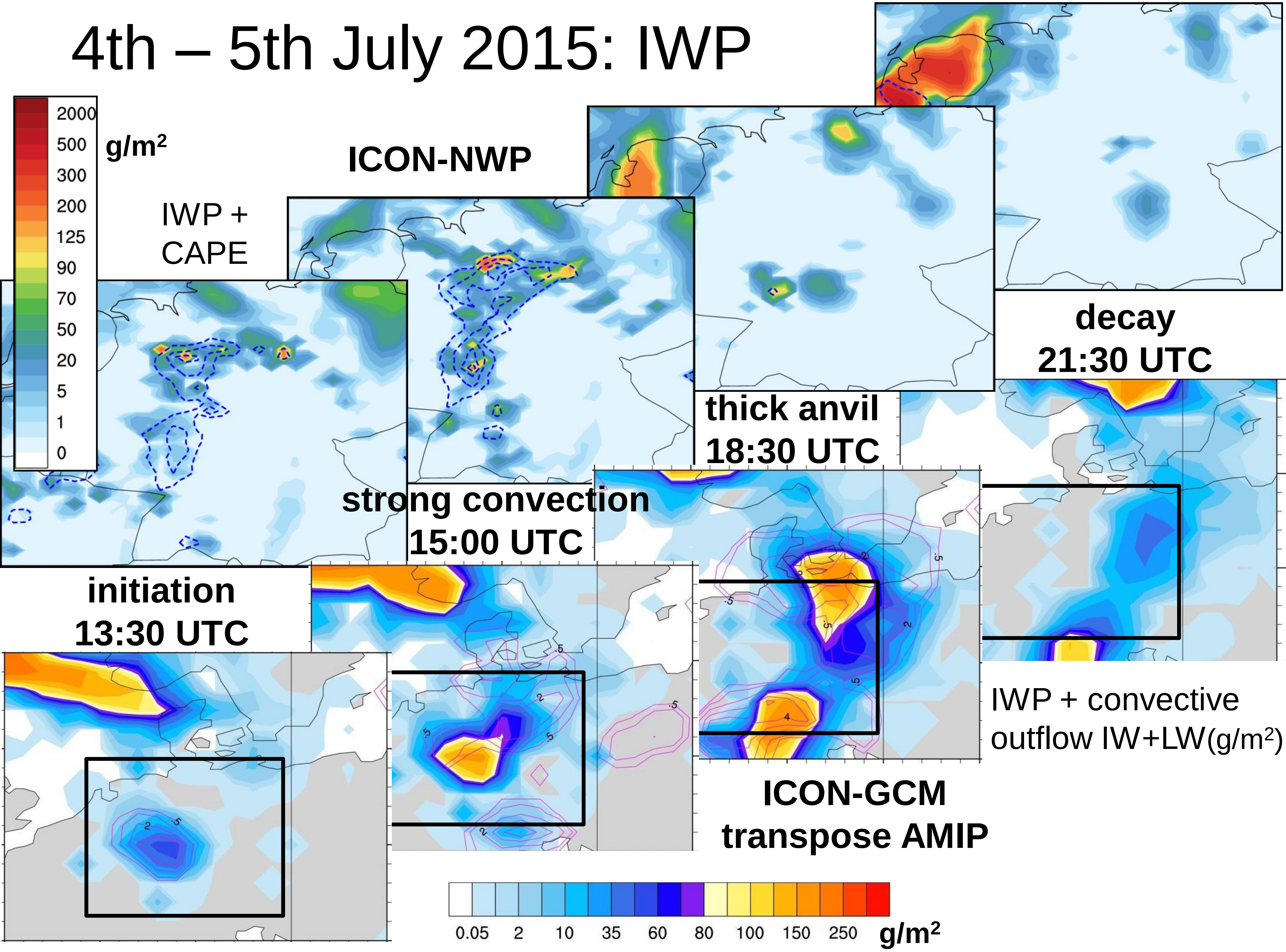
Sourdeval, Horvath, Strandgren

4th – 5th July 2015: IWP

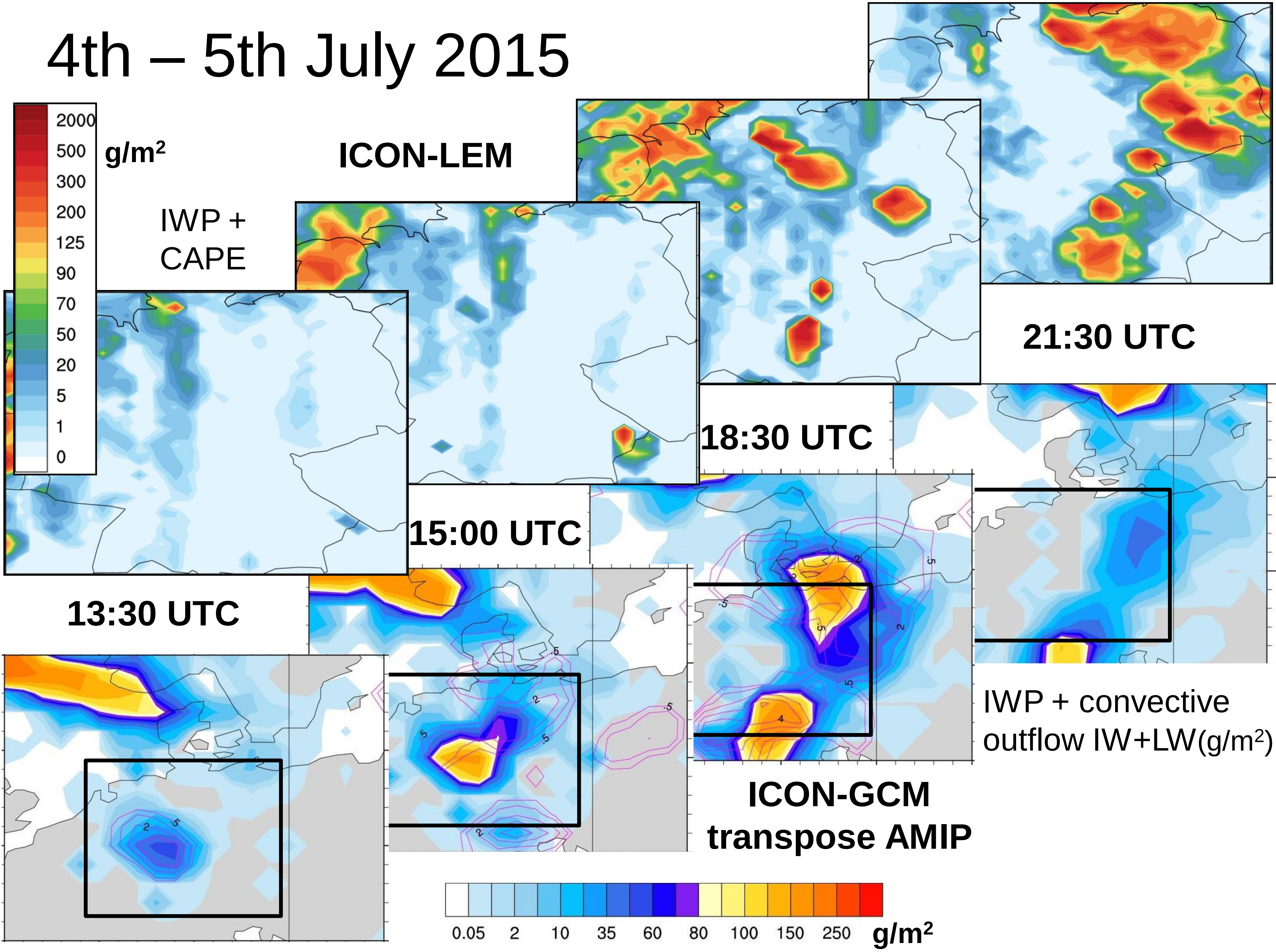


Rybka, Köhler

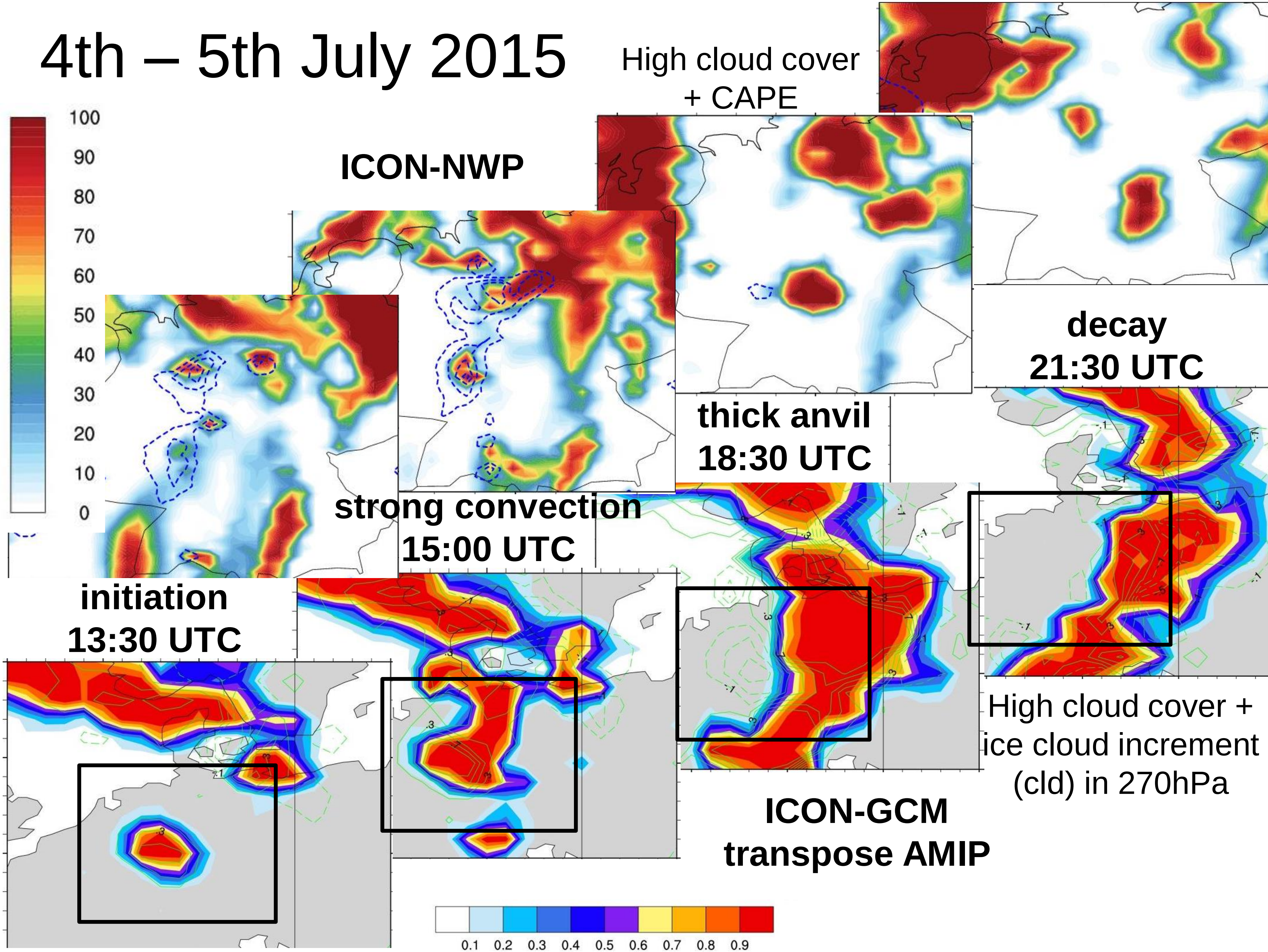
4th – 5th July 2015: IWP



4th – 5th July 2015



4th – 5th July 2015



Summary

- **Extension of Sundqvist large scale cloud scheme to resolve ice cloud macrophysics**
  - Captures observed frequency of ISS
  - Links ice cloud cover to atmospheric + microphysical processes
  - Reduces cirrus cloudiness and increases upper tropospheric RH (as expected)
- In Work: Extension of Tompkins cloud scheme for ice clouds (Tompkins‘ scheme allows a better link between clouds and dynamics)
- **Case study 4th – 5th July 2015:**
  - Remote sensing methods: IWP, anvil area, anvil top height, anvil life cycle
  - LEM simulations simulating many small events – not clear if realistic – but IWP looks good + timing good
  - Low resolution simulations vary regarding onset of convection (too early), overall convective mass flux or detrained water (too little), life time of anvil (too short particularly in NWP)
  - Longer lasting anvil in ICON-GCM seems to be connected with convective mass fluxes lasting until 18:30h (later than in NWP) and maybe due to larger cloud cover?
  - Overall convective strength varies depending on start date of simulation (NWP)

Future

- Evaluate high resolution simulation regarding representation of microphysics, precipitation formation and the life cycle of the anvil
- Study and improve convective mass fluxes, microphysics in convective parameterization and interaction convection-large scale clouds in ICON-NWP and ICON-GCM learning from high resolution simulations
- Study anvil properties for varying surface temperatures
- Analysis using feature tracking and trajectories
- NARVAL – simulations?

Ice water path 4th – 5th July 2015 (ICON –LEM)