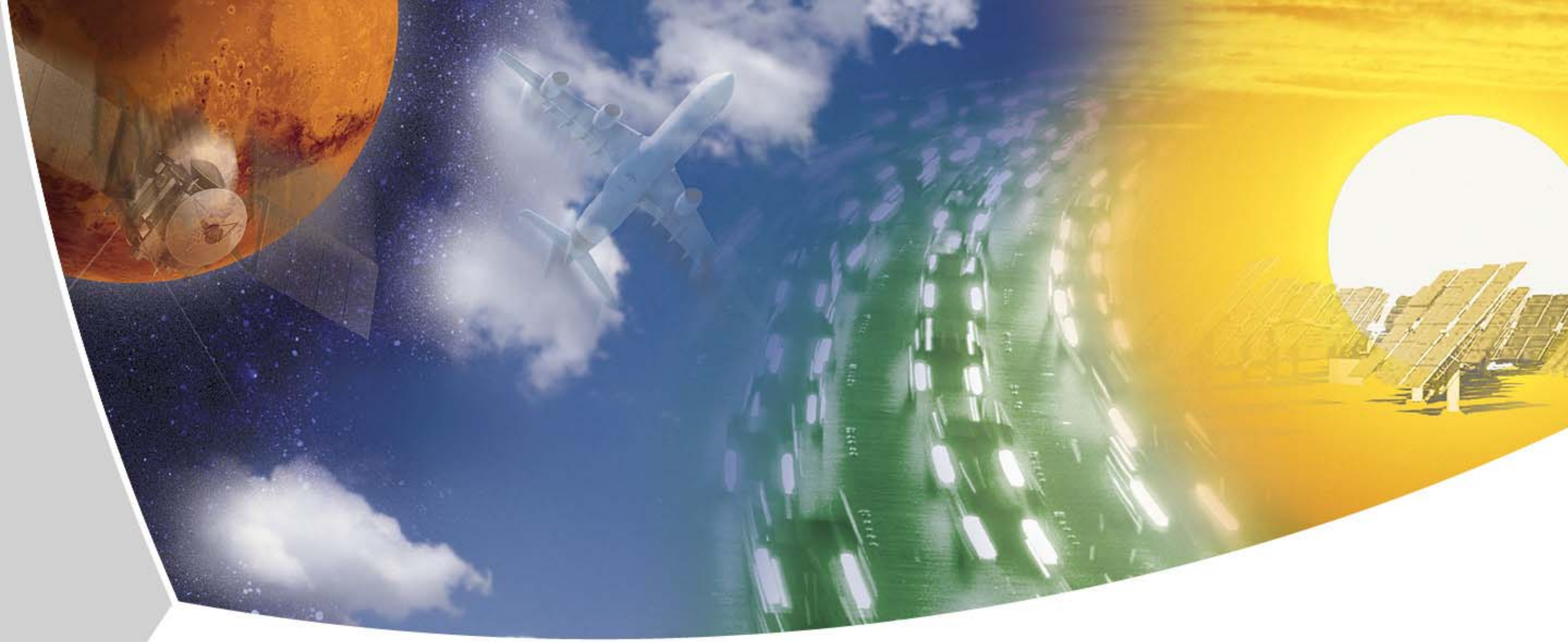


WP M2A, M2B, M2E: LES cirrus cloud and contrail cirrus simulations

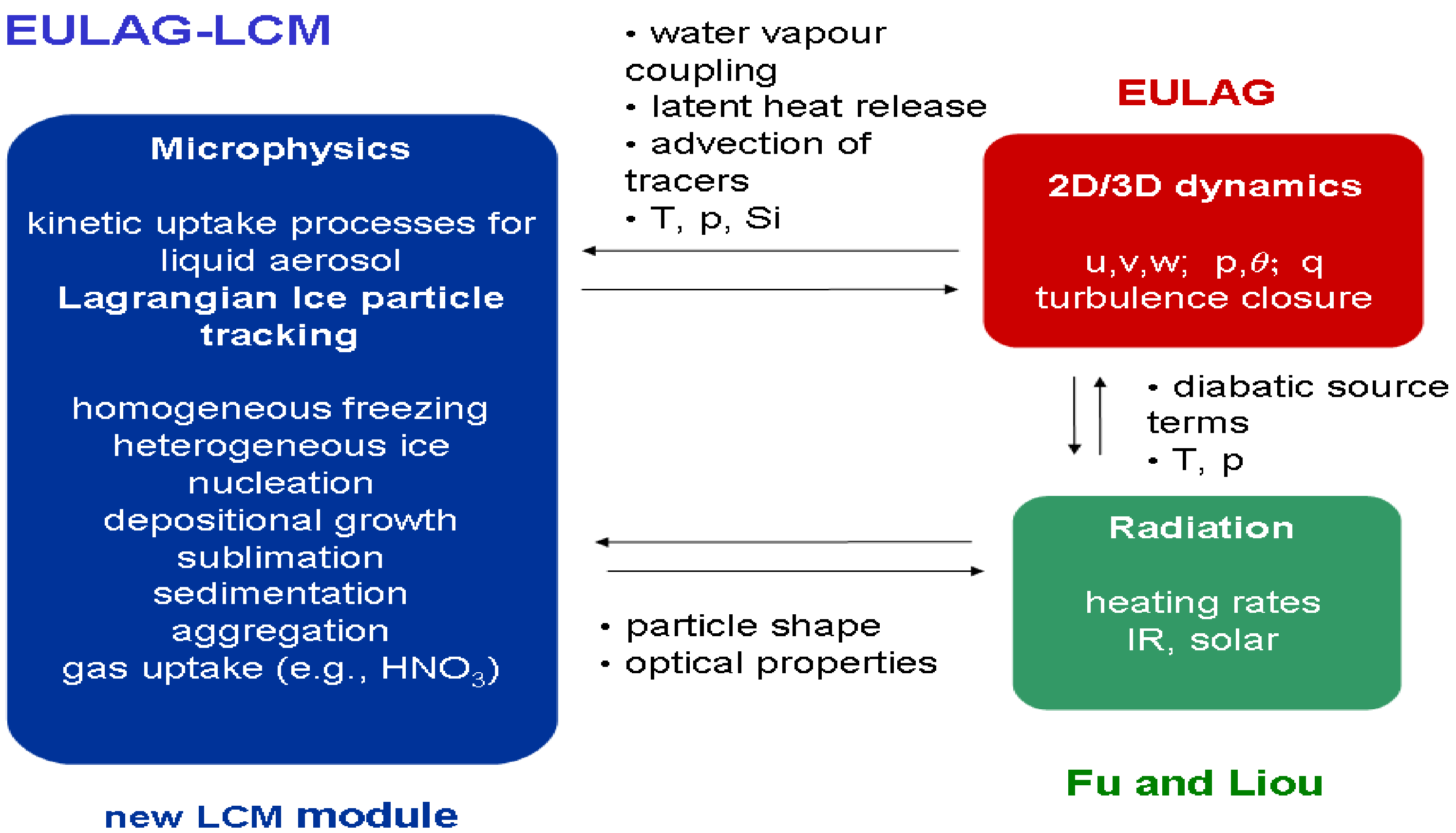
Ingo Sölch and Simon Unterstrasser

VI-ACI annual meeting

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

M2A: Lagrangian ice crystal tracking module (finished)

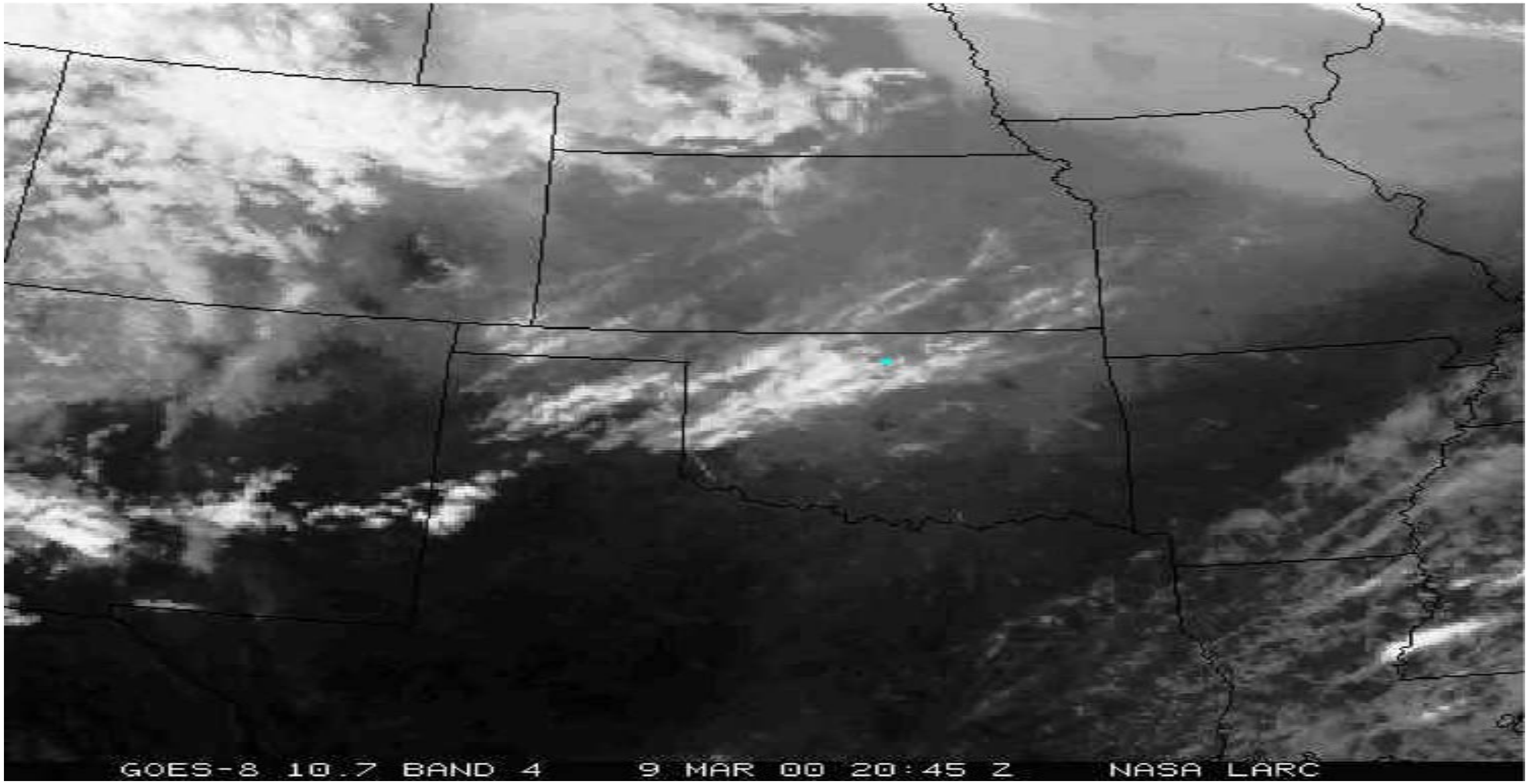
The EULAG-LCM (Lagrangian Cirrus Module) is a cirrus-cloud resolving Large Eddy simulation model to study the formation and persistence of cirrus clouds that form below 235 K.



M2E: Cloud resolving model runs: Case study (GEWEX)

Synoptically generated mid-latitude cirrus cloud field on 9 March 2000 over Oklahoma (US)

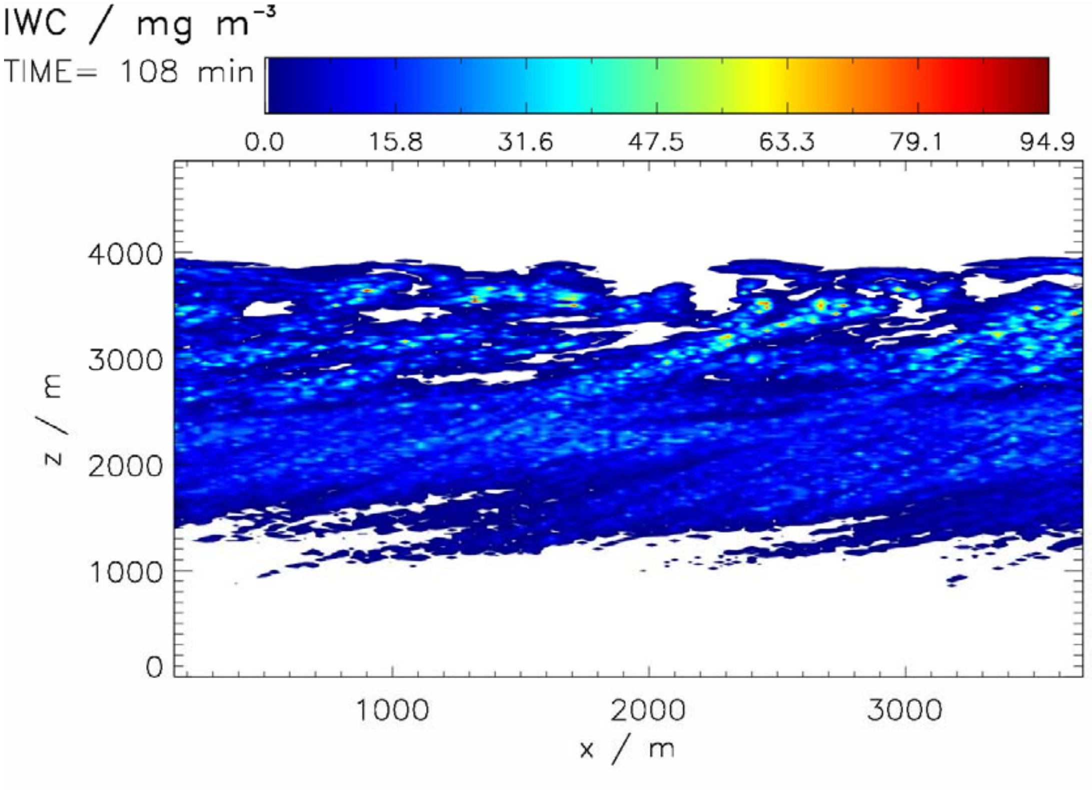
Comprehensive data from ground-based and aircraft-based measurements

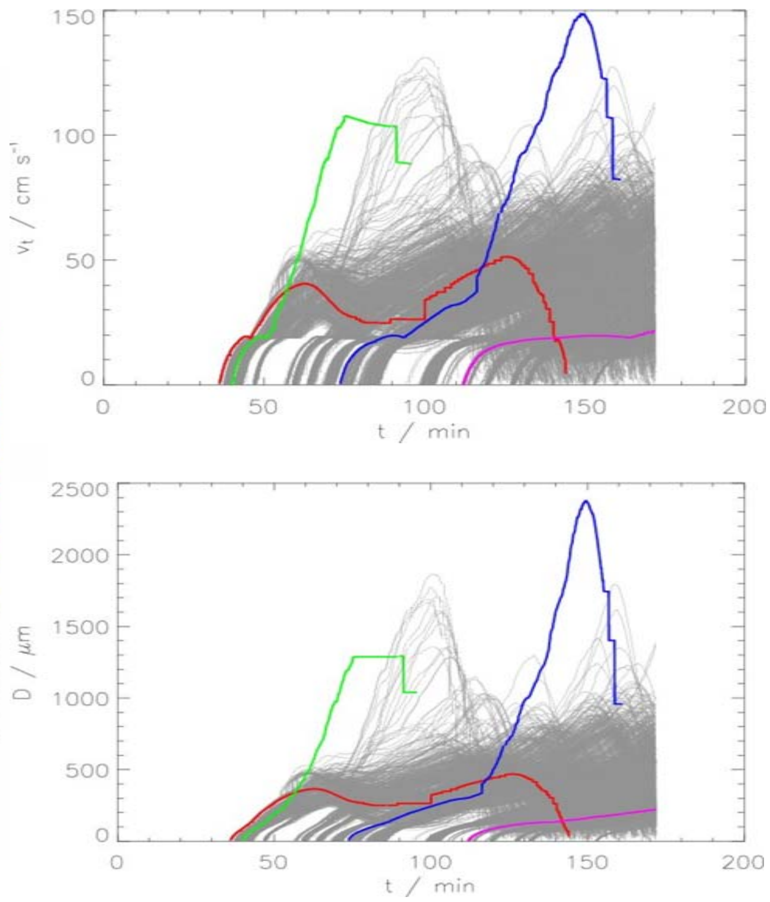


M2E: Cloud resolving model runs: Case study (GEWEX)

2D model runs -> Tracking the evolution of the cloud advected with the wind

Particle tracking gives new analysis methods and insight into cloud evolution

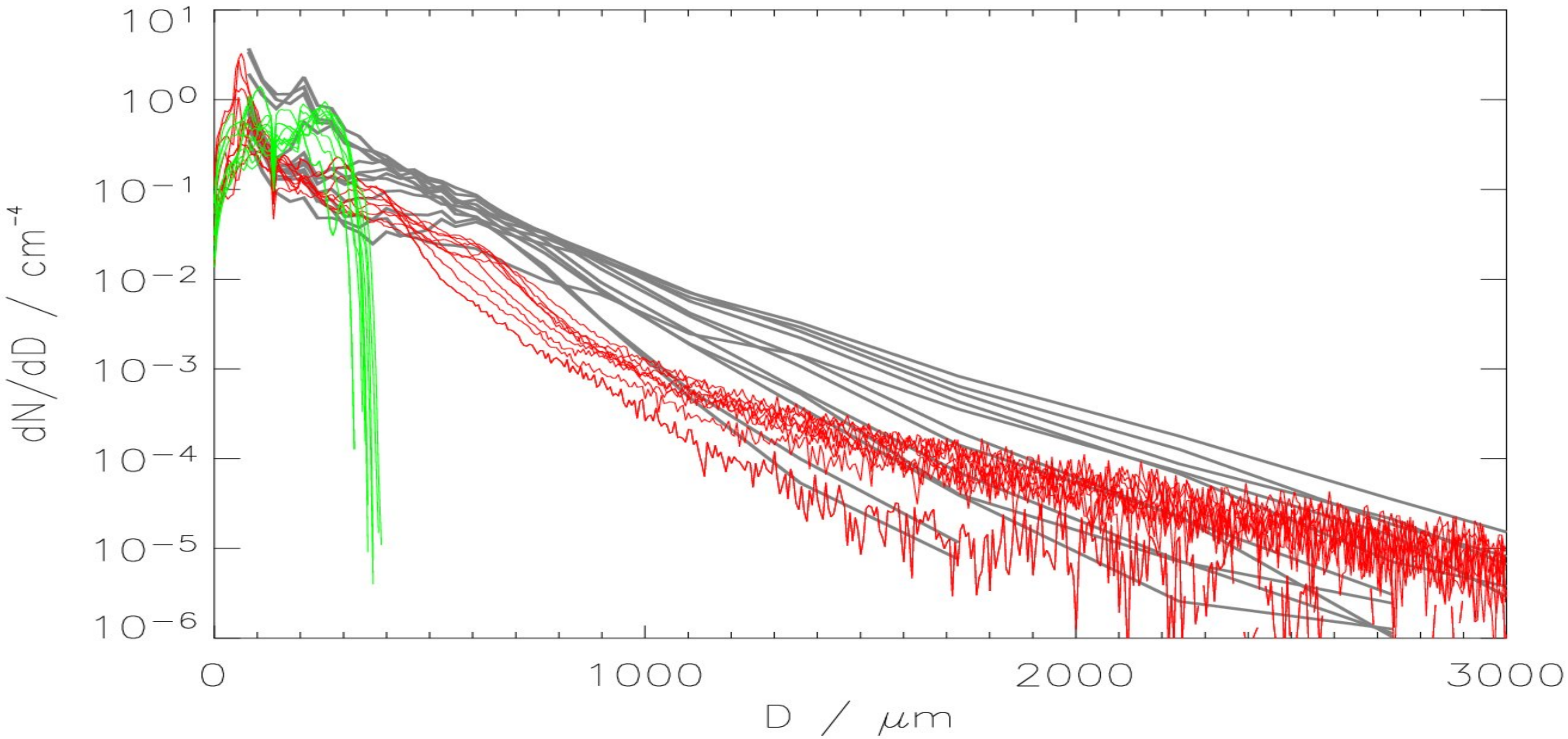




M2E: Cloud resolving model runs: Case study (GEWEX)

Comparison of model results with vertical profiles obtained during airborne measurements during spiral descents in the cloud deck

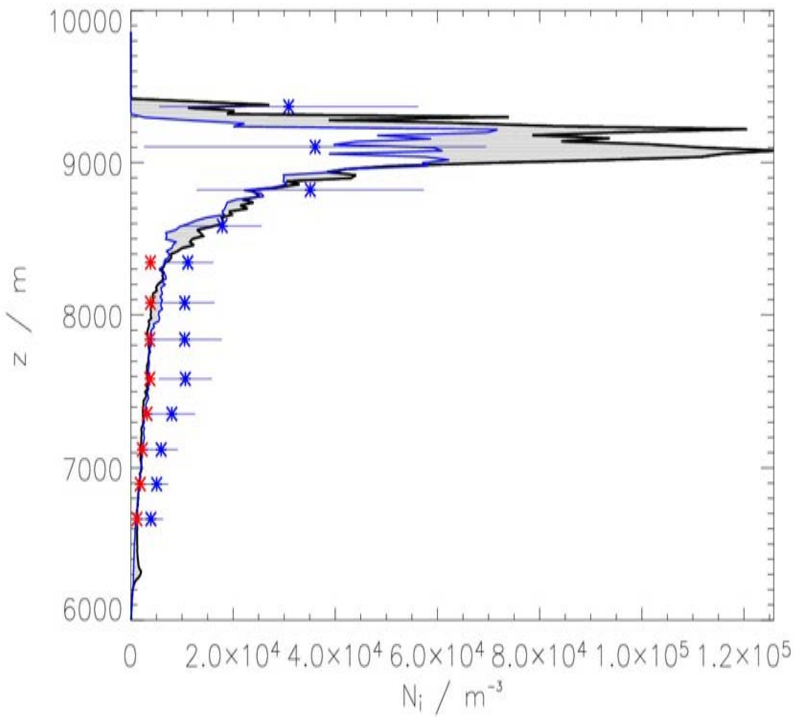
Great influence of ice crystal aggregation

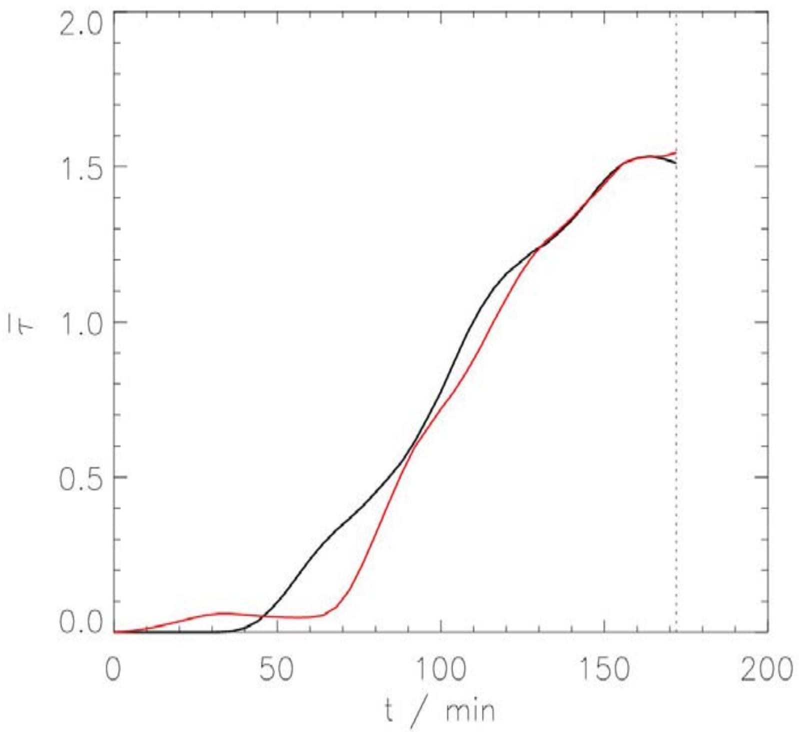


M2E: Sensitivity to nucleation pathway (Ongoing work)

Standard run with homogeneous nucleation of H_2SO_4/H_2O aerosol particles

Sensitivity to inclusion of IN ($2\ l^{-1}$) with parameterisation of Möhler et. al (2006)





Sensitivity small relative to updraft speed or supersaturation in the current case

Outlook

- Further parametrisations for different types of IN needed (atmospheric measurements difficult)
- Are there any hints on particle aggregation in the AIDA chamber (prefered shape of aggregates, size dependence) ?
- Diversity of particle shapes nucleated from the same sort of aerosol?

M2B: Simulations of contrail-to-cirrus transition (finished)

2D Model similar to EULAG-LCM. Use 2-moment bulk microphysics scheme (Spichtinger&Gierens).

Extensive parameter studies are completed. We have investigated the impact of relative humidity, temperature, wind shear, stratification, radiation on microphysical, optical and geometric properties of contrails.

M2E: Potential of re-nucleation induced by contrail dynamics

A large fraction of crystals can sublimate during the contrail vortex phase.

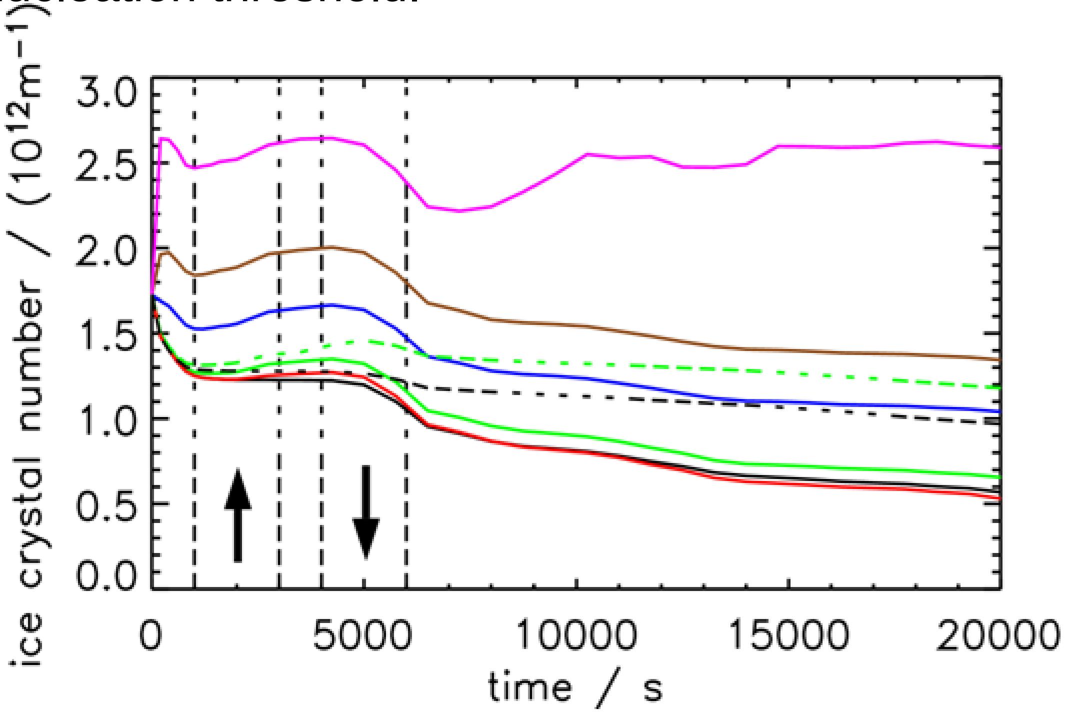
Does re-nucleation possibly occur during contrail-to-cirrus transition ?

Use different heterogeneous nucleation threshold.

T=217K, RHi= 120%
Updraft + Downdraft
(w=10cm/s, w=-10cm/s)

Rh_{het}=
130% (red)
120% (green)
110% (blue)
105% (brown)
101% (magenta)
—— (black)

Overall $3*10^{12}$ particles



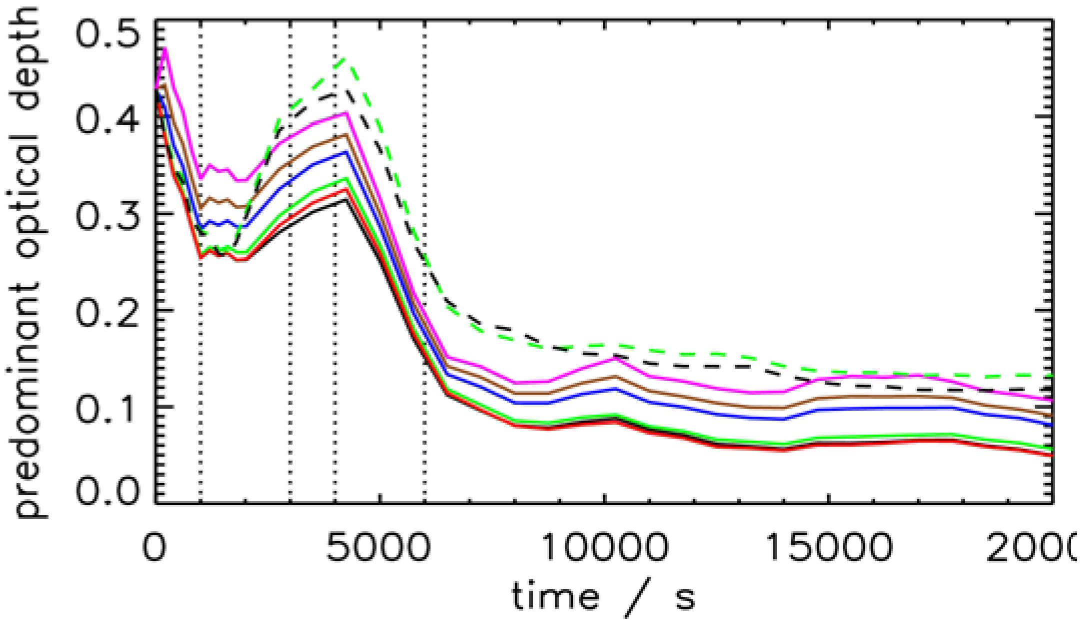
M2E: Potential of re-nucleation induced by contrail dynamics

Impact on optical depth of contrail is zero to moderate (depending strongly on the nucleation threshold). IN stay close to contrail where the relative humidtity is approx at saturation. No additional water vapour uptake of newly formed particles.

T=217K, RHi= 120%
Updraft + Downdraft
(w=10cm/s, w=-10cm/s)

Rh_{het}=
130% (red)
120% (green)
110% (blue)
105% (brown)
101% (magenta)
—— (black)

Overall $3*10^{12}$ particles



Nucleation thresholds of preactivated soot cores are needed, to assess the potential of re-nucleation reliably.

END

Appendix B: Ice particle trajectories

$$\frac{d\mathbf{x}_i}{dt} = \mathbf{u} + \left(\tilde{\mathbf{u}}_i + \mathbf{v}_{t,i}\right)$$

$$\tilde{\mathbf{u}}_i(t) = R_L \mathbf{u}_i(t - \Delta t_{MIC}) + \mathbf{u}_i^*(t)$$

$$\mathbf{u}_i^*(t) = \sqrt{1 - R_L^2}\sigma_u \Omega$$

Lagrangian autocorrelation $R_L = \exp(-\frac{\Delta t_{MIC}}{\tau_L})$

Lagrangian timescale $\tau_L = K_m / E$

$$\sigma_u = \sqrt{E},$$

Appendix C: EULAG model equations

$$\frac{d\mathbf{u}}{dt} + f\mathbf{k} \times \mathbf{u}' = -\nabla\left(\frac{p'}{\bar{\rho}}\right) + \mathbf{g}\frac{\theta'_d}{\bar{\theta}} + \mathbf{D_u}$$

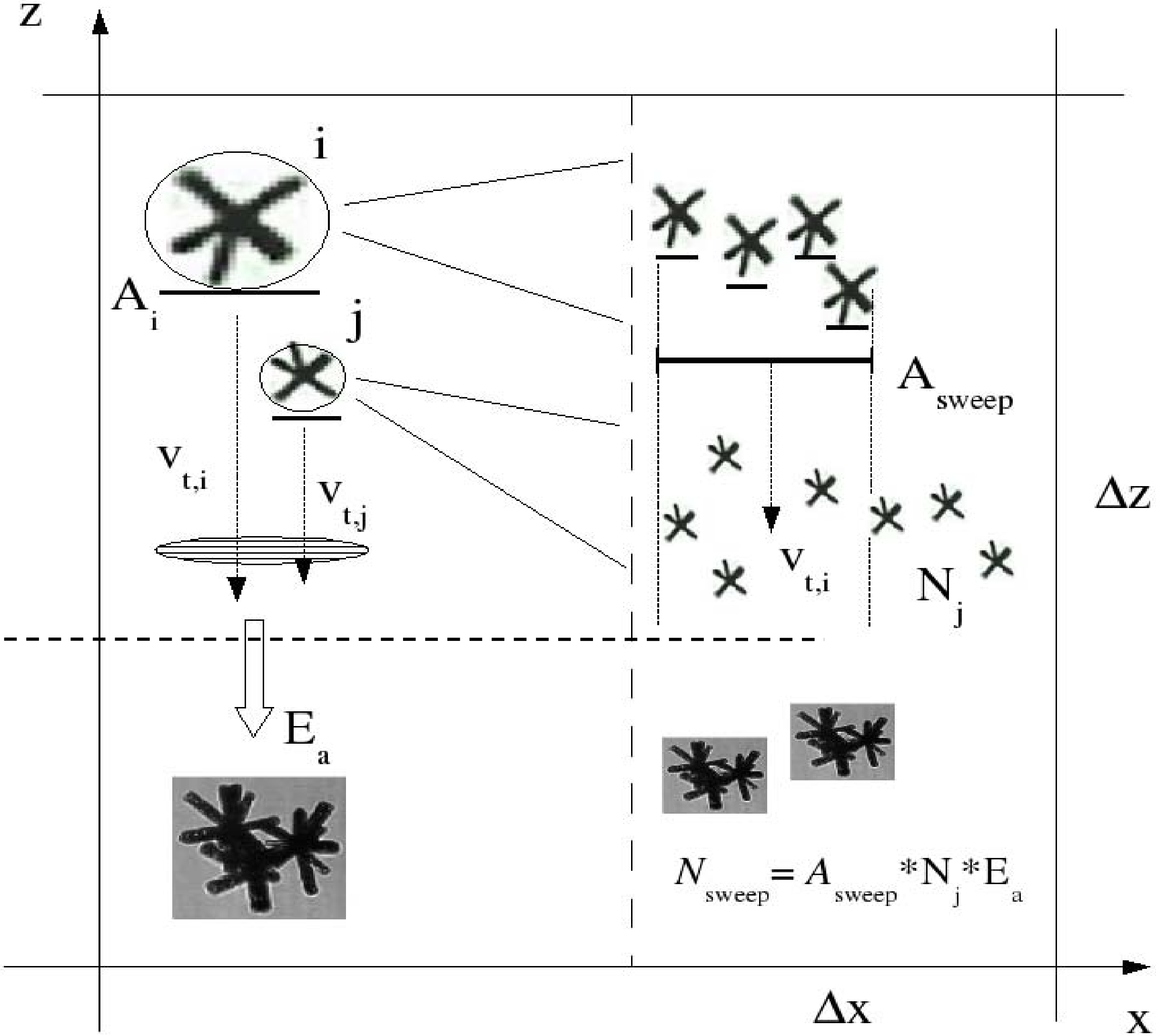
$$\frac{d\theta'}{dt} = -\mathbf{u}\cdot\nabla\theta_e + \mathbf{D}_\theta + Q_R + Q_H.$$

$$\nabla\cdot(\bar{\rho}\mathbf{u}) = 0.$$

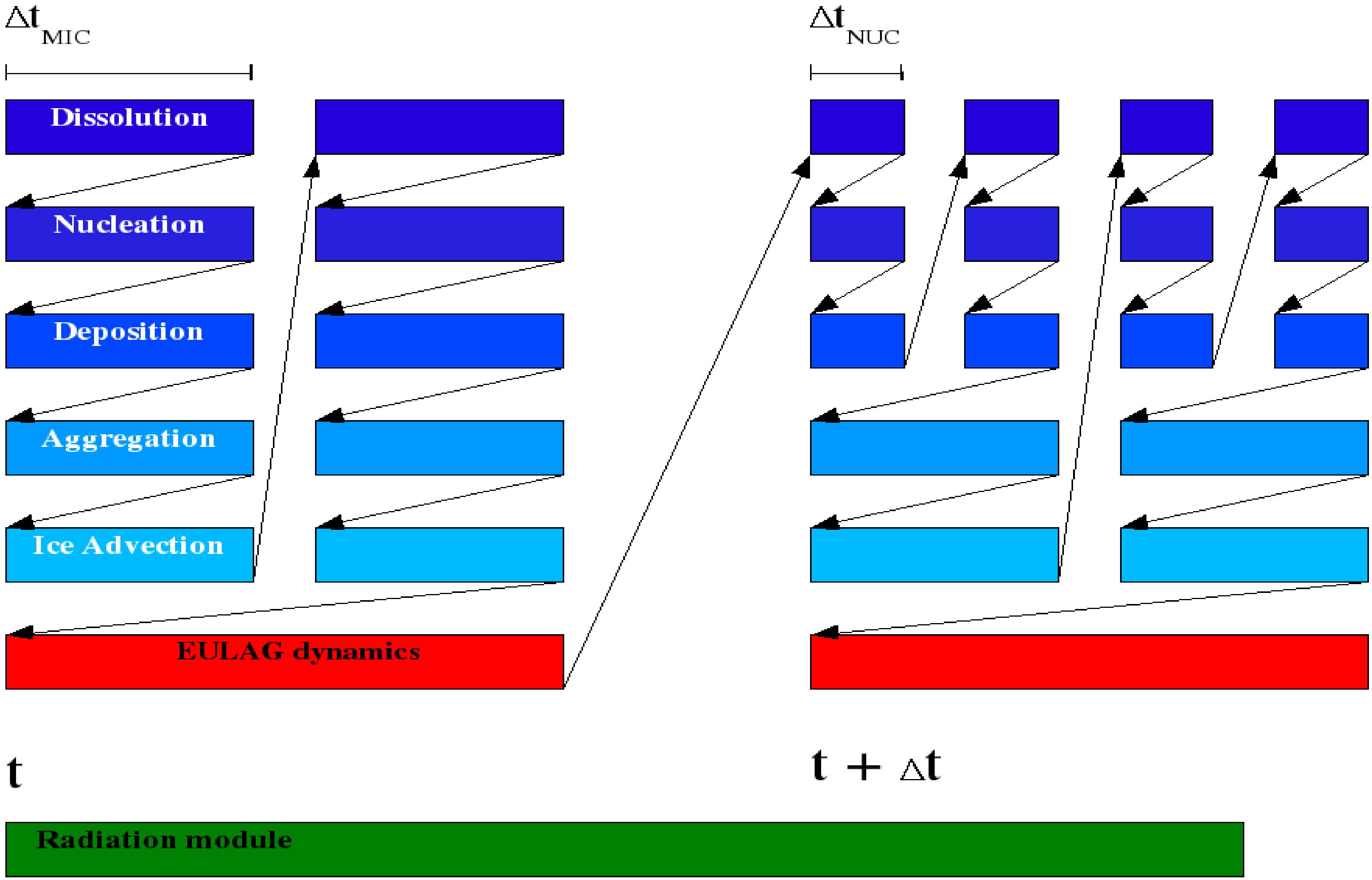
$$\theta' = \theta - \theta_e.$$

$$\frac{dq_v}{dt} = \mathbf{D}_{q_v} - Q_{DEP} - Q_{DIS}$$

Appendix D: Cluster—cluster aggregation algorithm



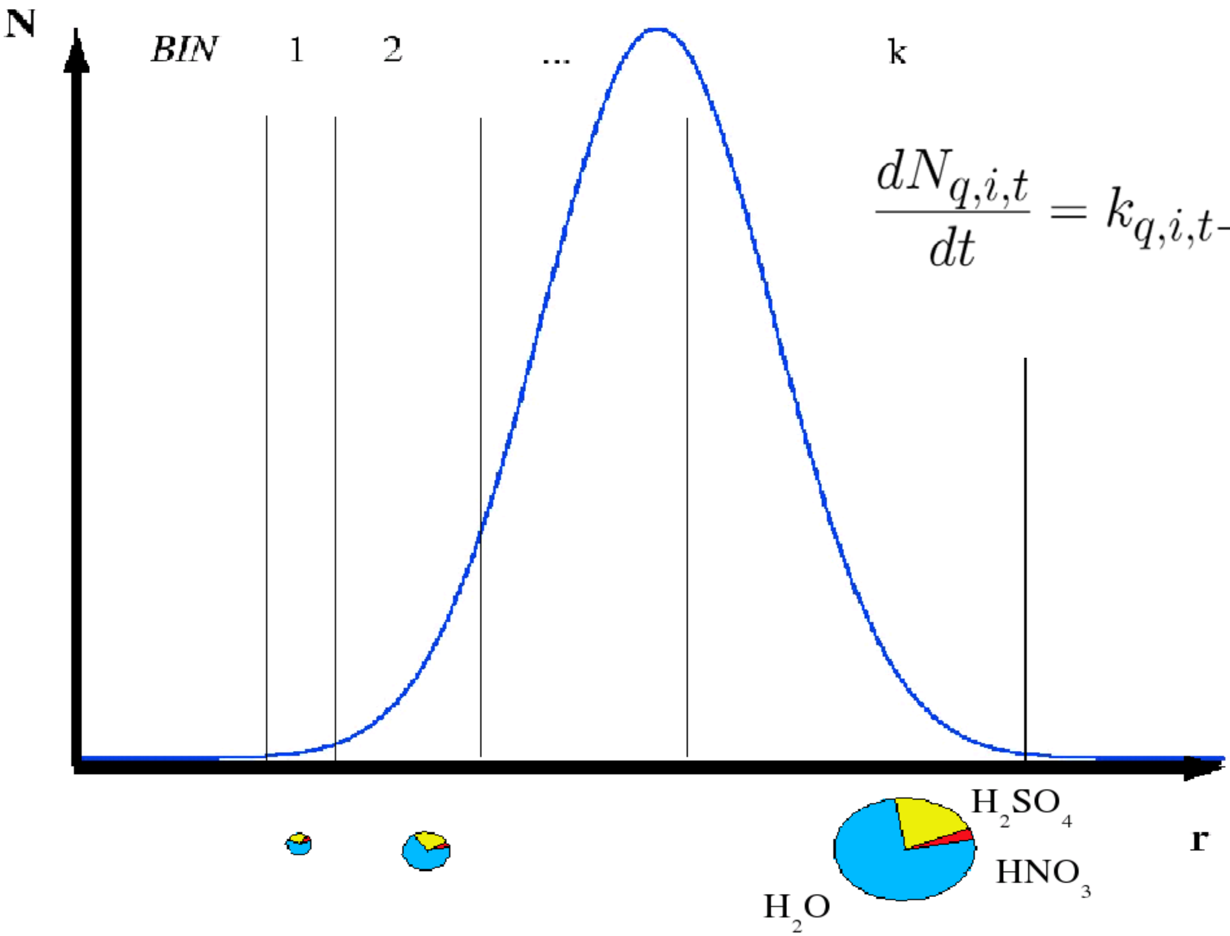
Appendix E: Operator splitting scheme



Appendix F: Kinetic uptake of H_2O and HNO_3 on liquid aerosol particles ($H_2SO_4/H_2O/HNO_3$)

Size-resolved uptake on typical aerosol component of UTLS

Solving dissolution equations for the number concentrations $N_{q,i,t}$ of the molecules of each trace gas species residing in aerosol particles in every size bin.



$$\frac{dN_{q,i,t}}{dt} = k_{q,i,t-h}\left(N_{q,t} - S'_{q,i,t-h}\frac{N_{q,i,t}}{H'_{q,i,t-h}}\right)$$

Appendix G: Scales in cirrus cloud processes