

# Contrails and Their Impact on Shortwave Radiation – A Regional Model Study

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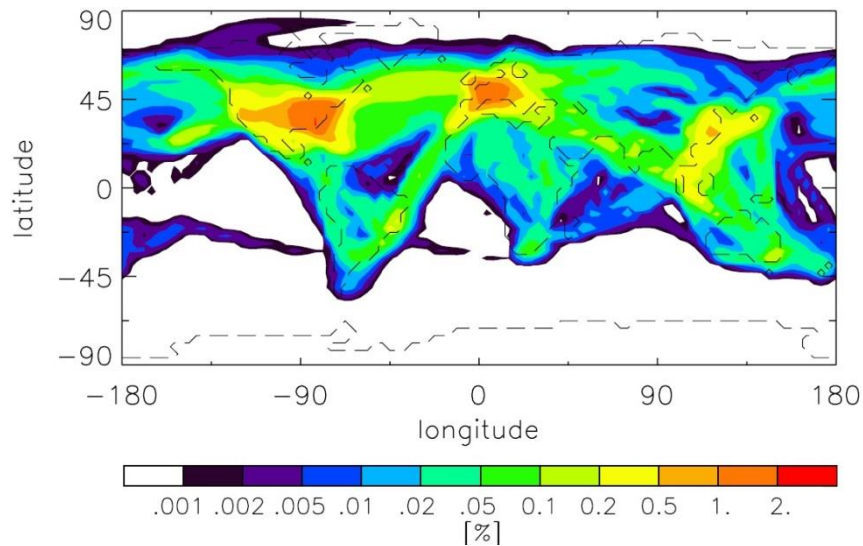
# Studying Contrails



[http://www.pv-magazine.com/fileadmin/PVI\\_website\\_pictures/Germany\\_Fuerstenwalde\\_solar\\_photovoltaic\\_project\\_Image\\_solarhybrid\\_ag.jpg](http://www.pv-magazine.com/fileadmin/PVI_website_pictures/Germany_Fuerstenwalde_solar_photovoltaic_project_Image_solarhybrid_ag.jpg)

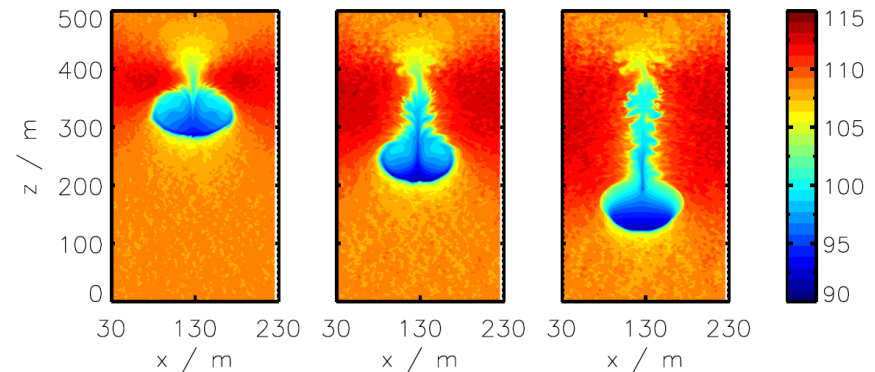
# Studying Contrails

- global scale: parameterizations, averages



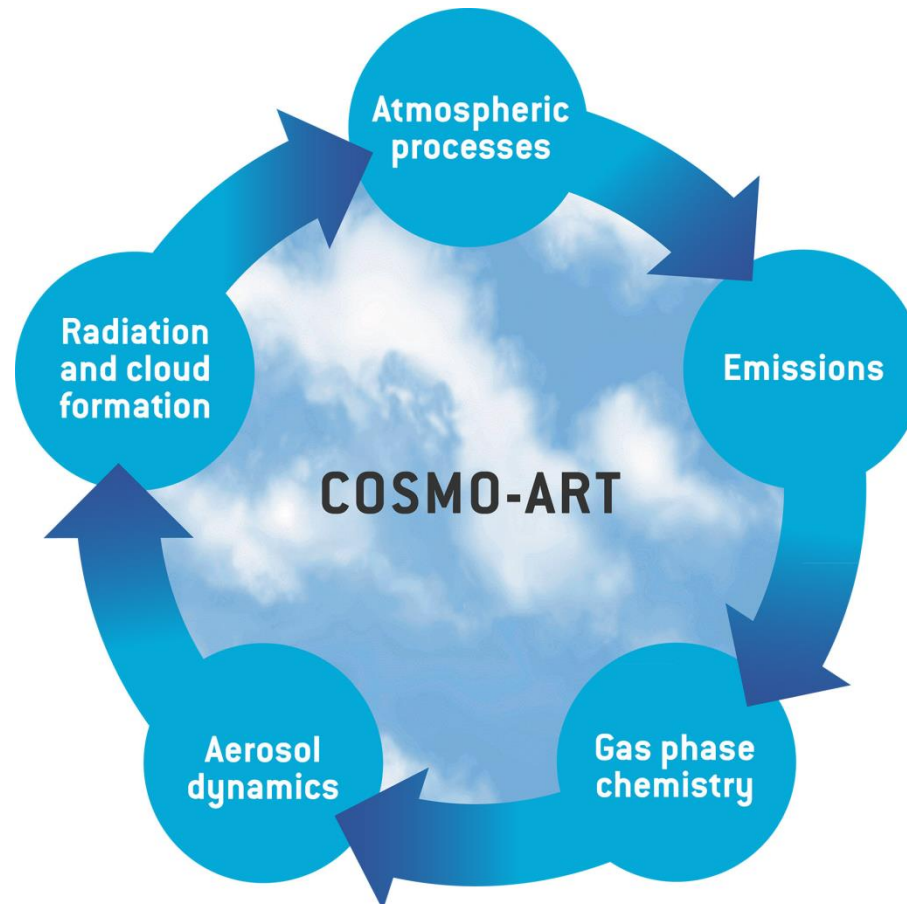
Burkhardt and Kärcher, 2011

- LES: exact, but not applicable on larger scale



Unterstrasser, 2008

# The Model System COSMO-ART



Vogel et al., 2009  
Bangert et al., 2012

# Cloud Microphysics

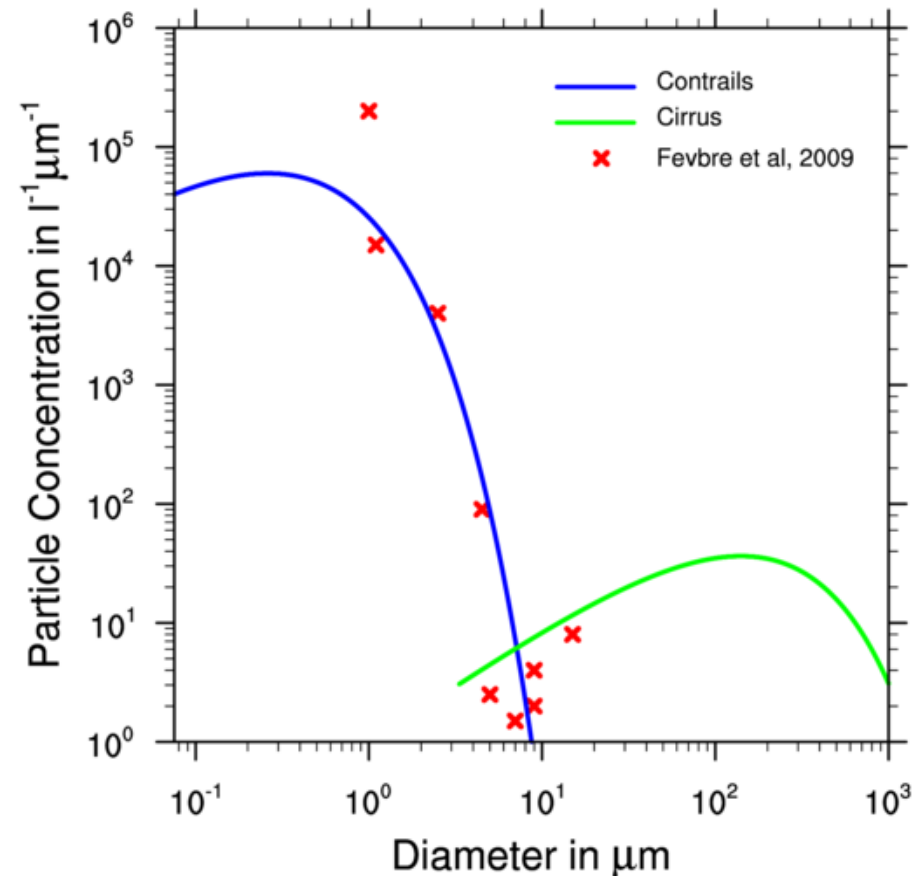
- two moment cloud microphysics (Seifert and Beheng, 2006)
  - number and mass concentration of all hydrometeors
  
- six hydrometeor classes
  - water droplets
  - ice crystals
  - rain droplets
  - snow flakes
  - graupel
  - hail

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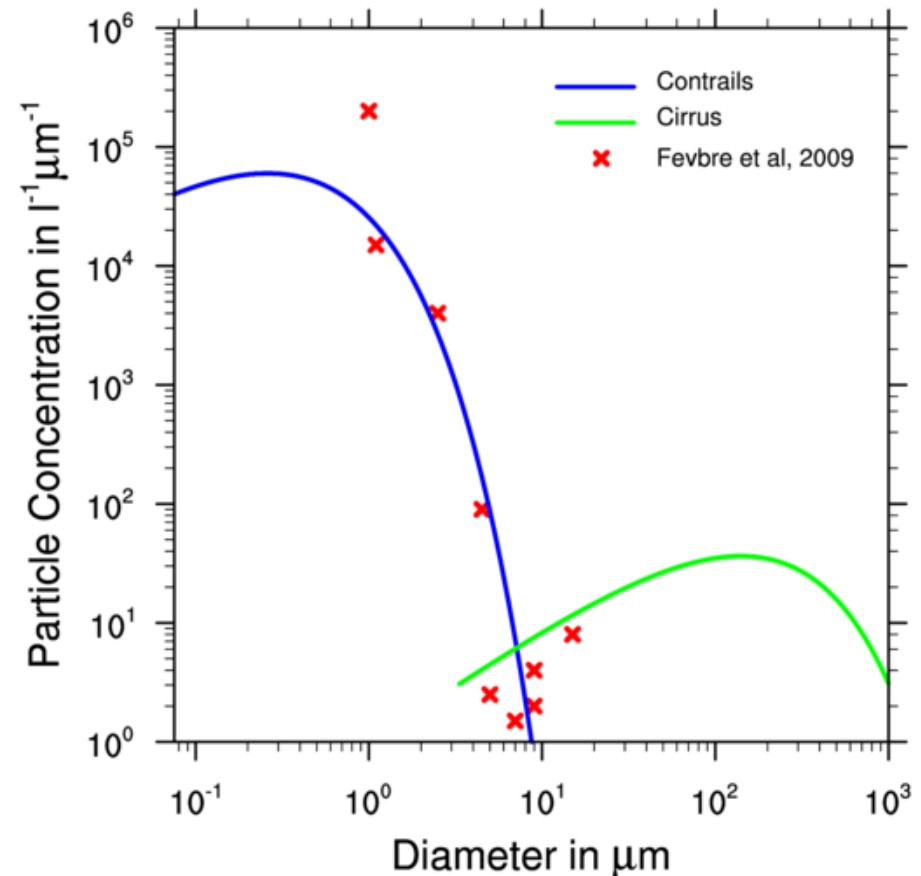


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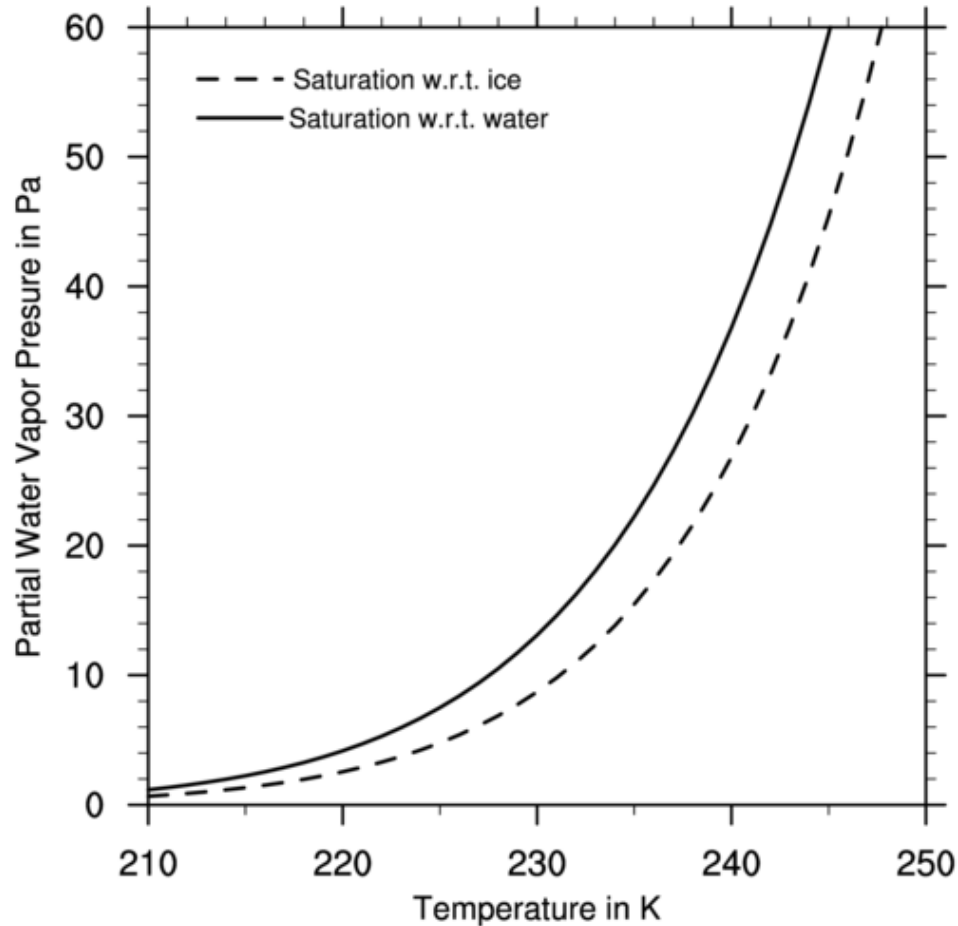
- six hydrometeor classes

- water droplets
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- graupel
- hail
- **young contrail ice crystals**



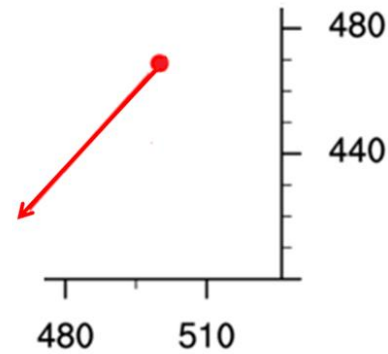
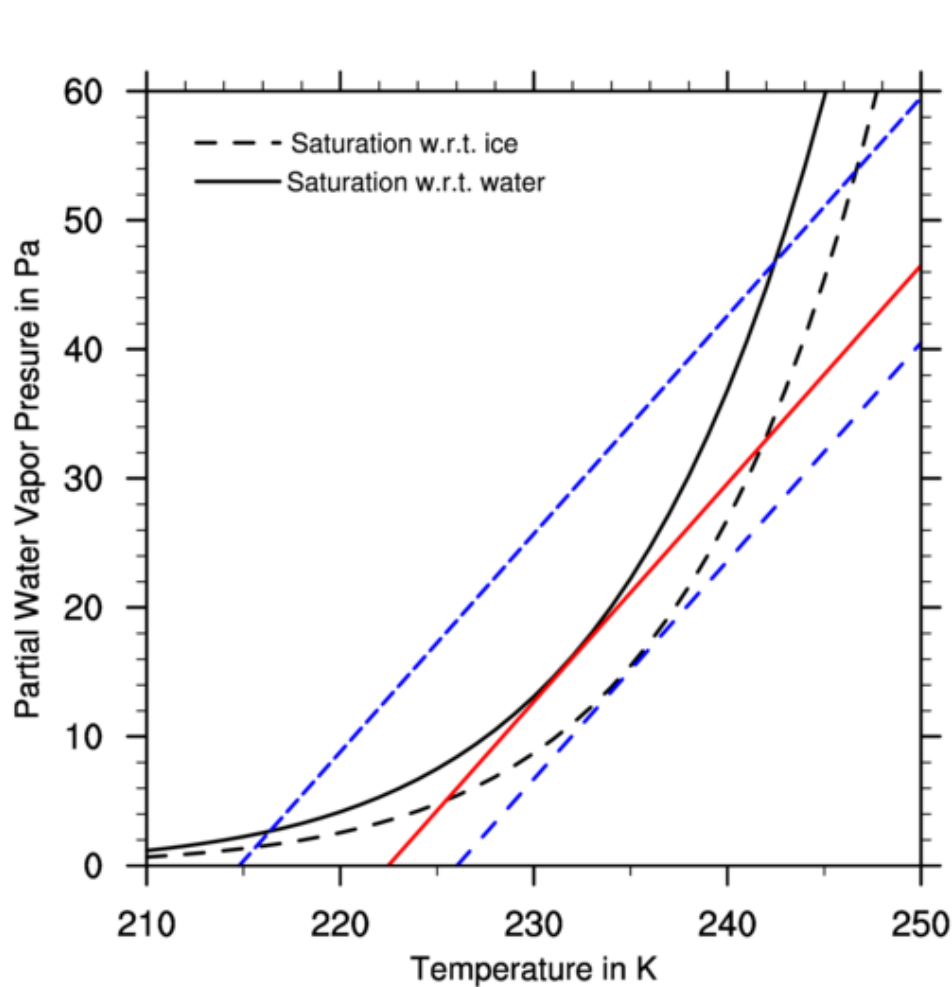


# Schmidt-Appleman-Criterion (Schumann, 1996)

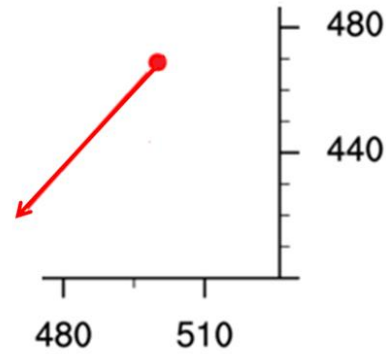
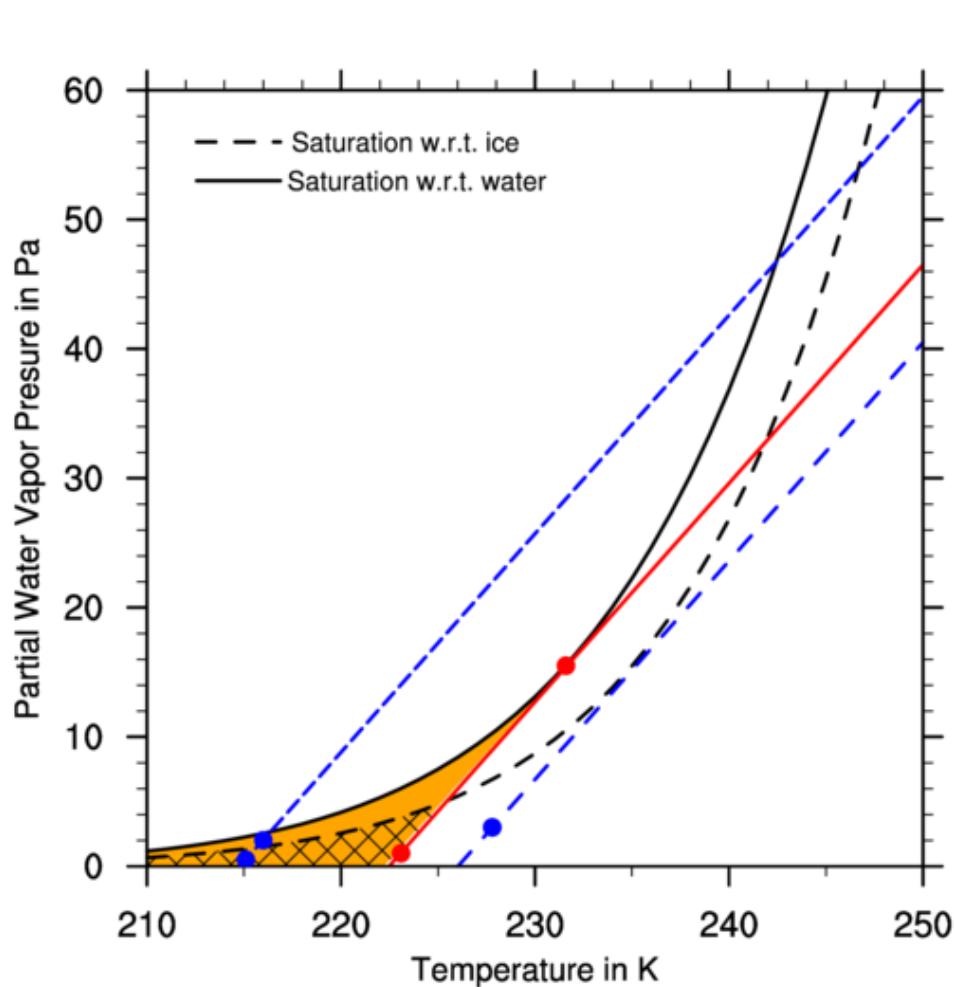




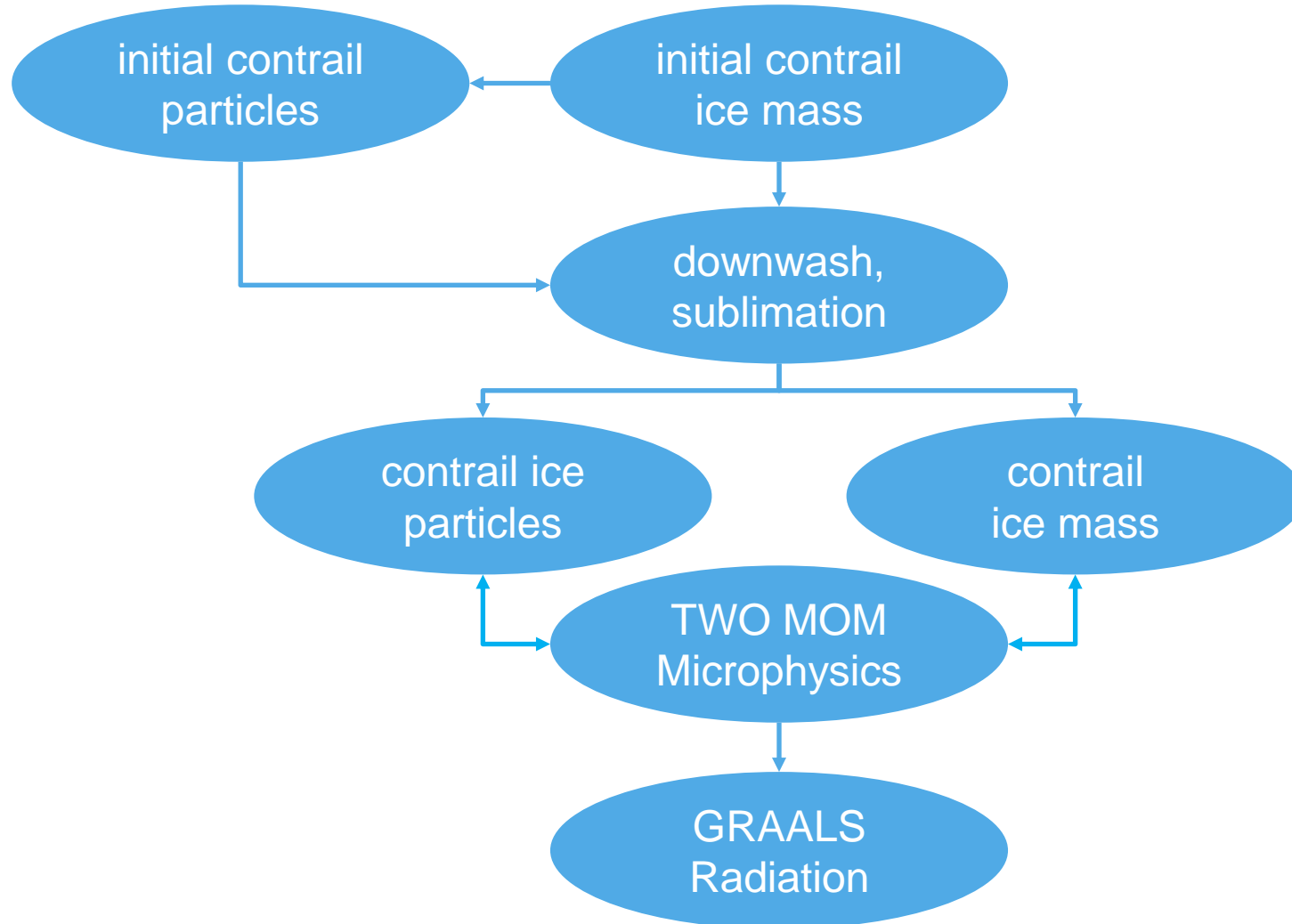
# Schmidt-Appleman-Criterion (Schumann, 1996)



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# A Parameterization for Contrails



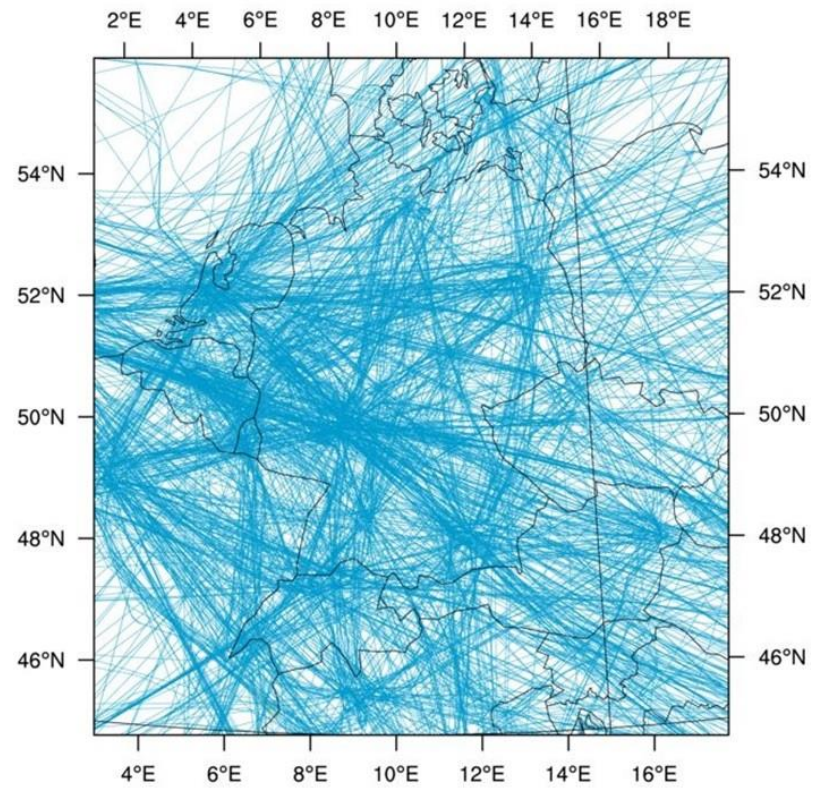
# Data Set

- Provided by Institute of Air Transport and Airport Research, DLR

- Data Feed:

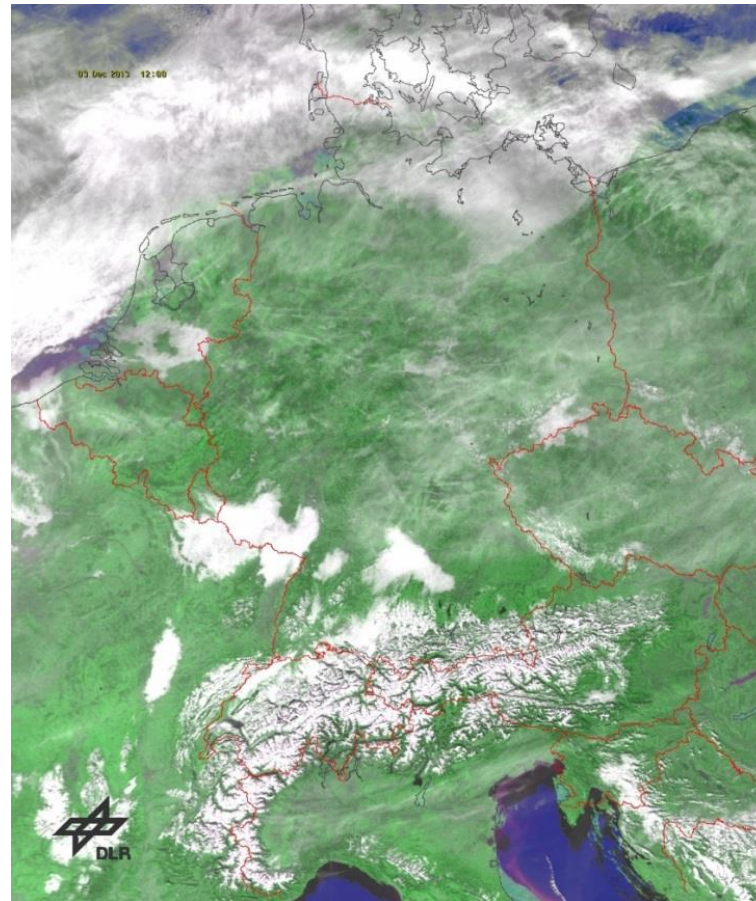


- Flight tracks, 2013/12/03 08-16 UTC



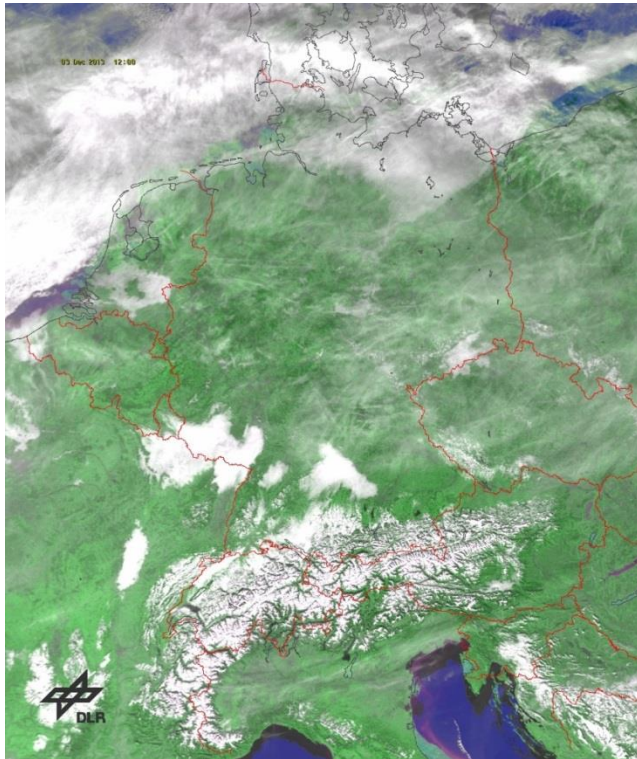


# Case Study, 2013/12/03

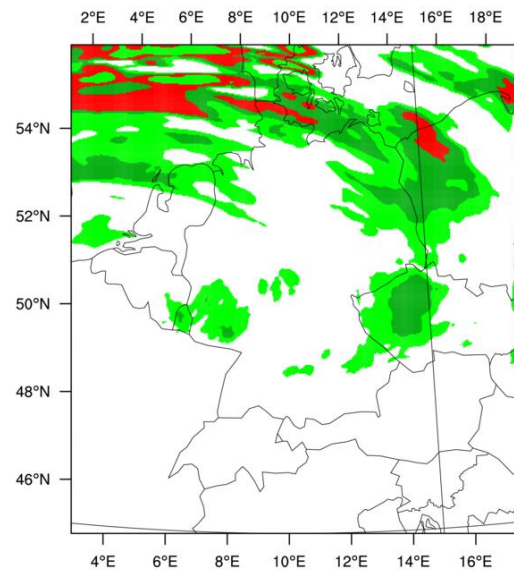


# Comparison Reference and Contrails

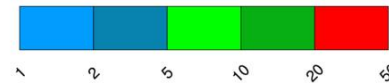
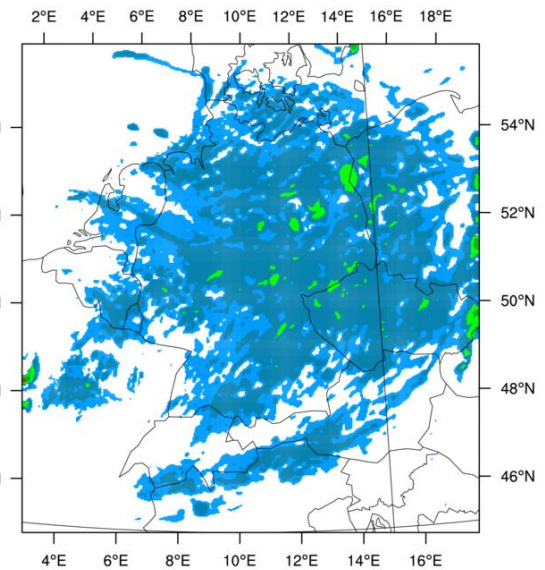
■ 2013/12/03 12 UTC



Clean Simulation



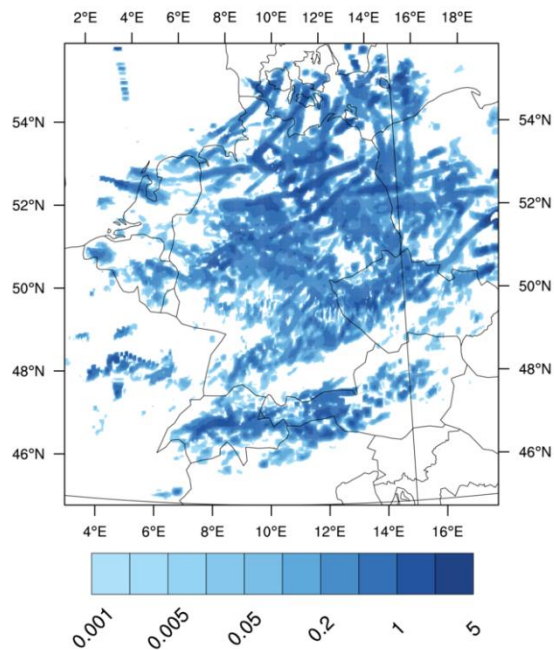
Contrails and Contrail Cirrus



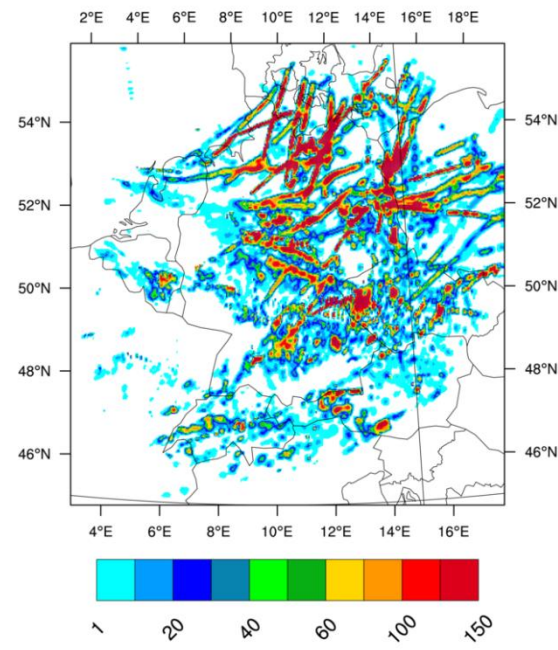
IWP [g / m<sup>2</sup>]

# Contrail Microphysical Properties

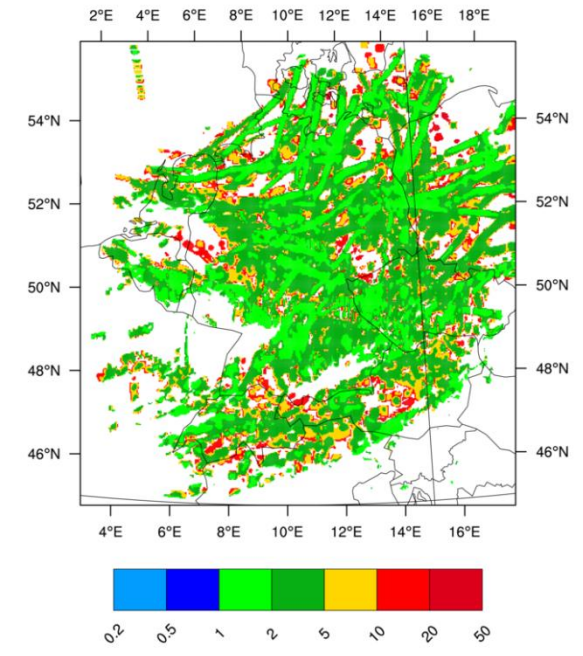
- 2013/12/03 10 UTC, 10 000 m
- max. contrail age: 2 h



IWC [mg / m<sup>3</sup>]



N [1 / cm<sup>3</sup>]

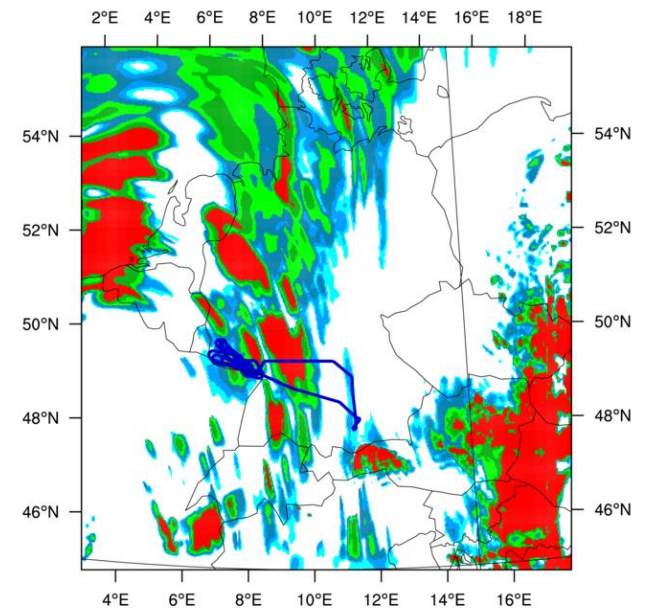
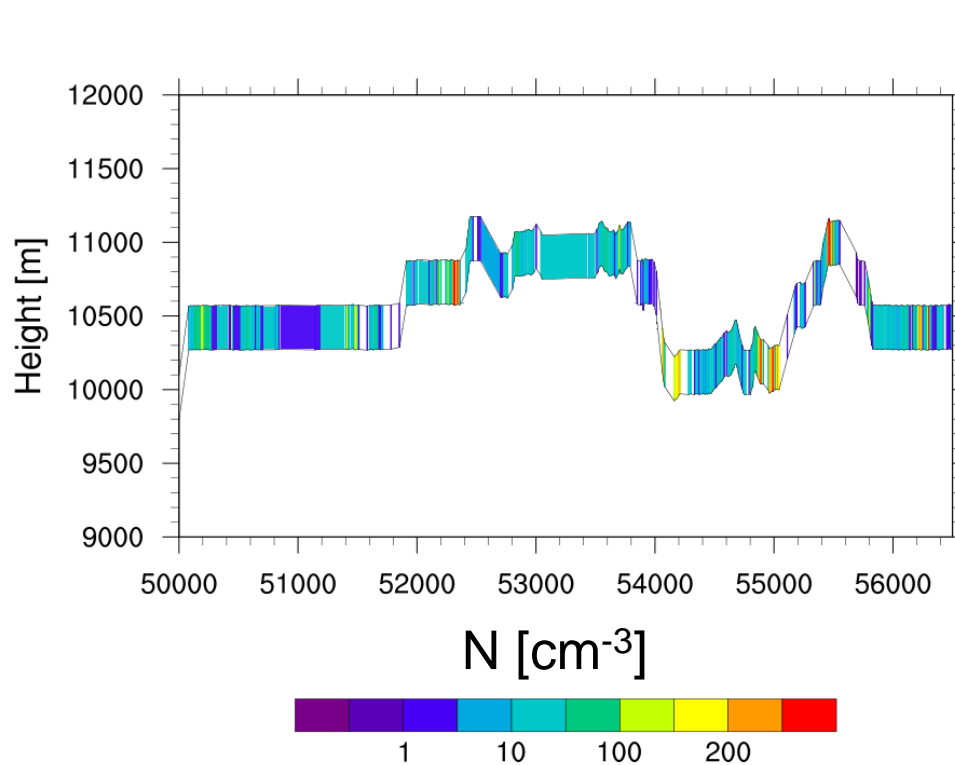


r [μm]



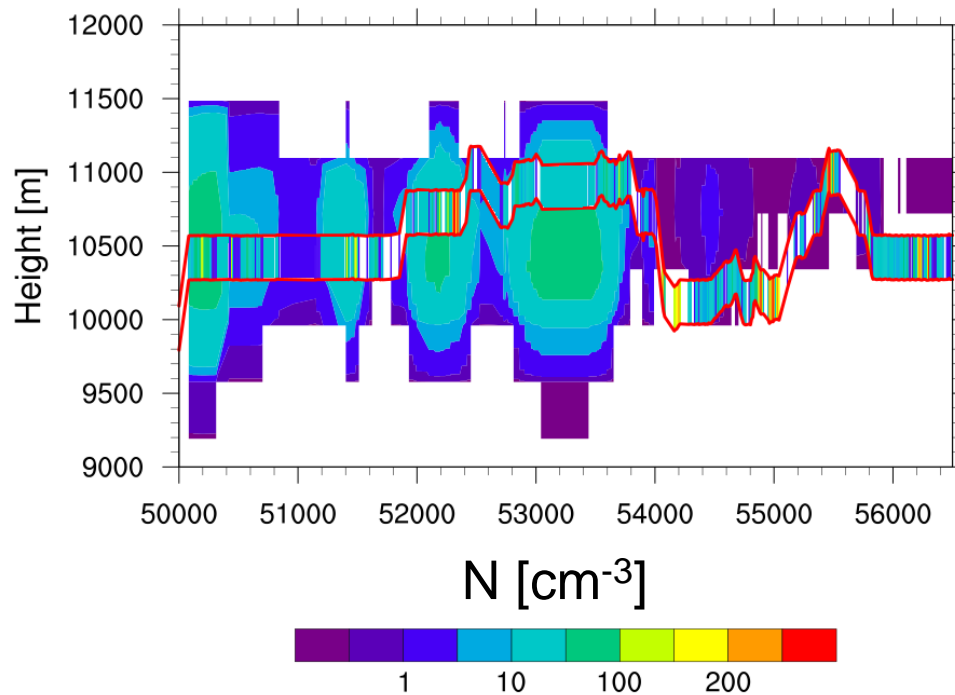
# Comparison with Measurement (ML-Cirrus)

■ 2014/04/10



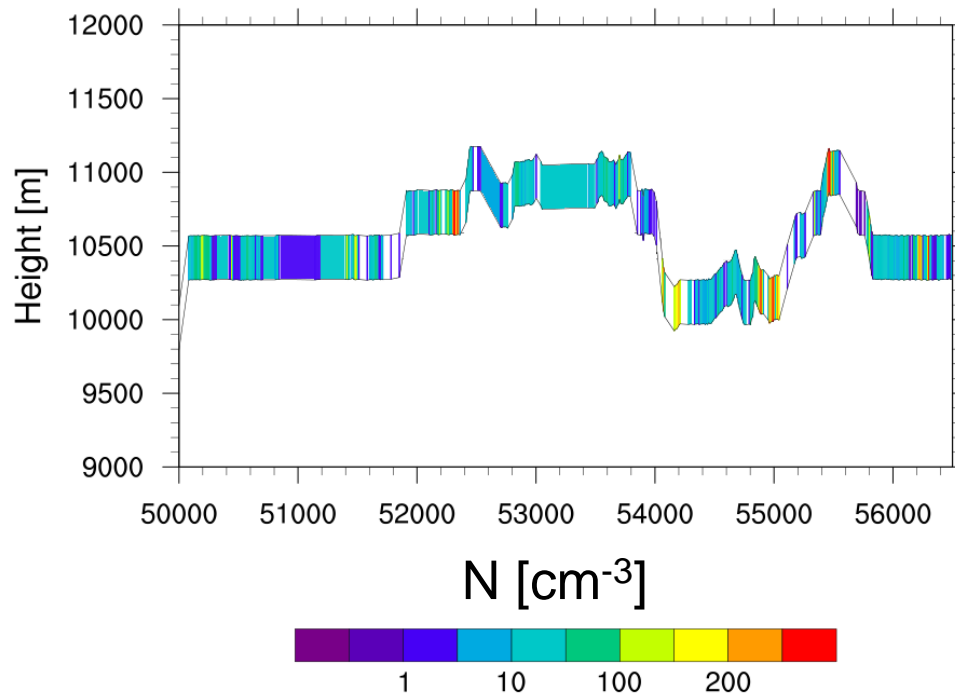
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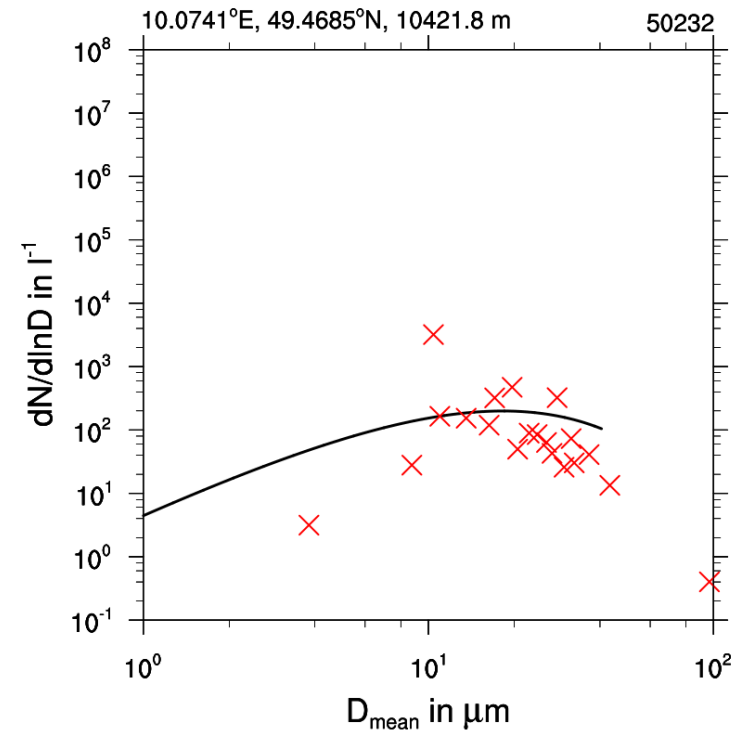
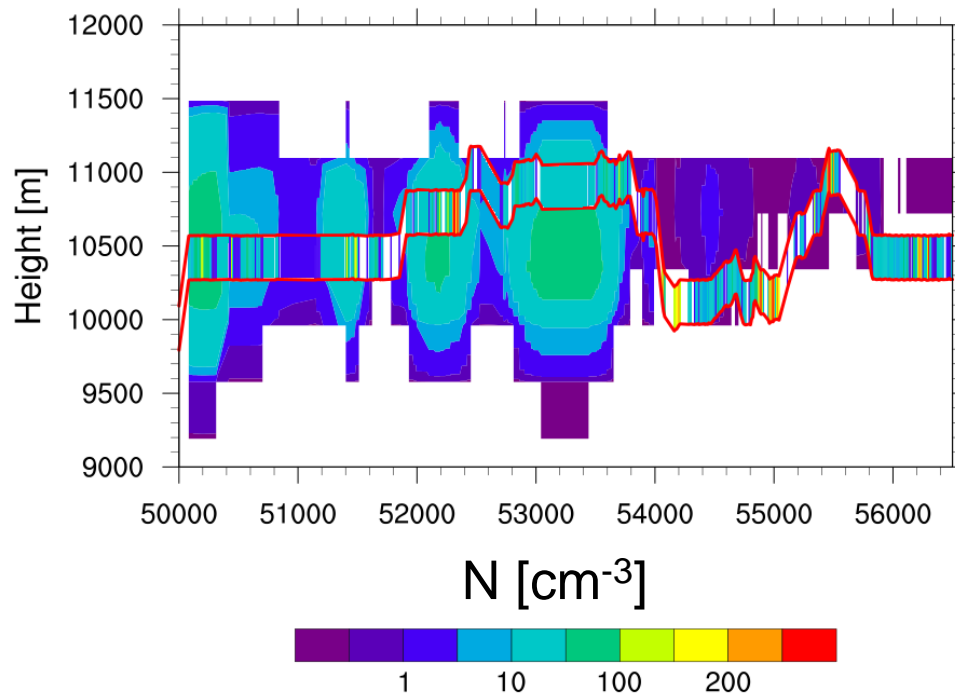
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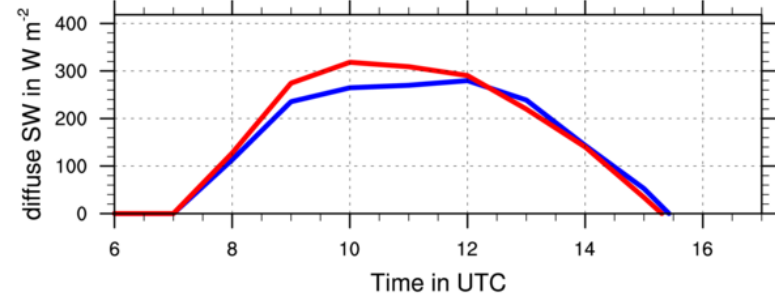
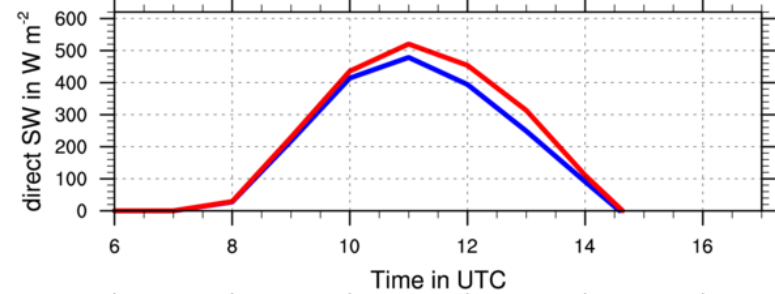
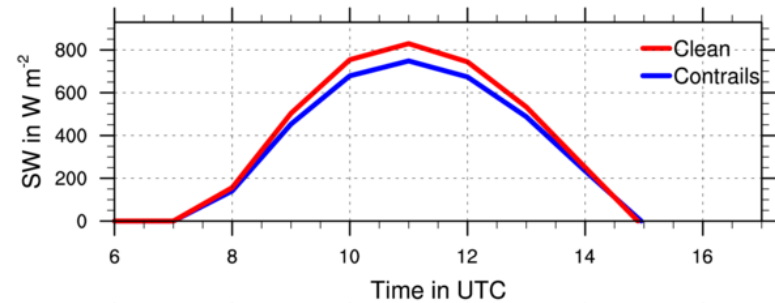
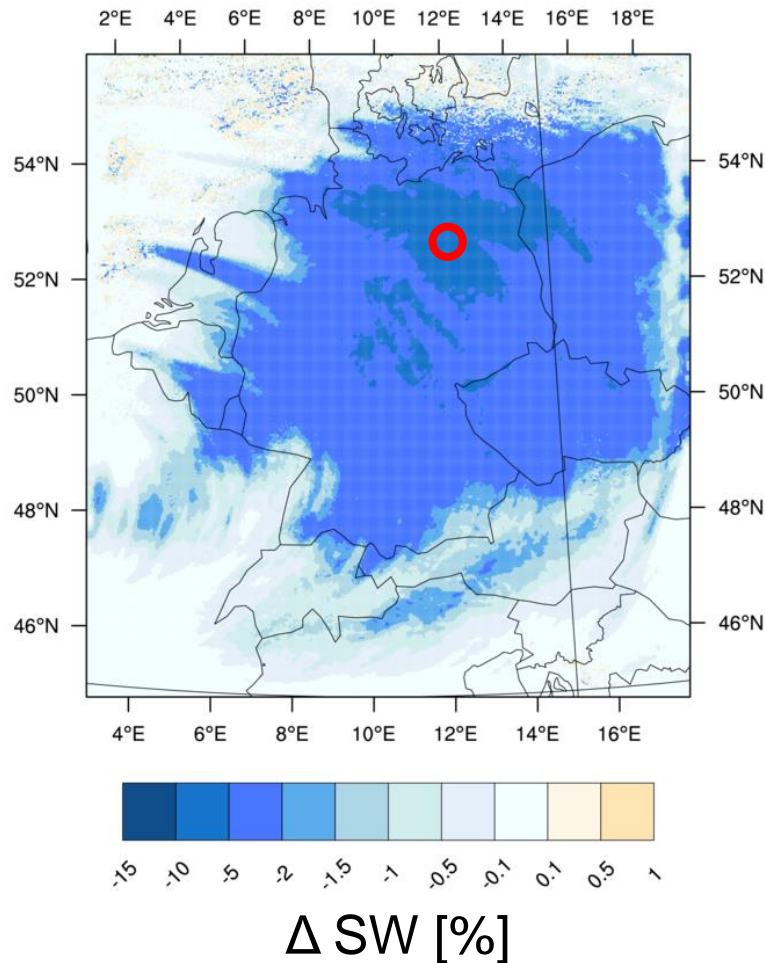
# Comparison with Measurement (ML-Cirrus)

■ 2014/04/10



# Contrail Effect on Short Wave Radiation

■ 2013/12/03



# Summary

- unique, high resolved data set of real time based flight tracks
- parameterization of contrail formation vortex dynamics
- new contrail ice class in a two moment microphysics scheme
- simulations of contrail life cycle and contrail cirrus
- validation with measurement: microphysics in reasonable agreement
- impact on sw-radiation budget (local reductions up to 10%)

# Effect on Natural Cirrus

- 2013/12/03, 12 UTC: Additional ice mass due to contrails

