On the life time of contrail cirrus

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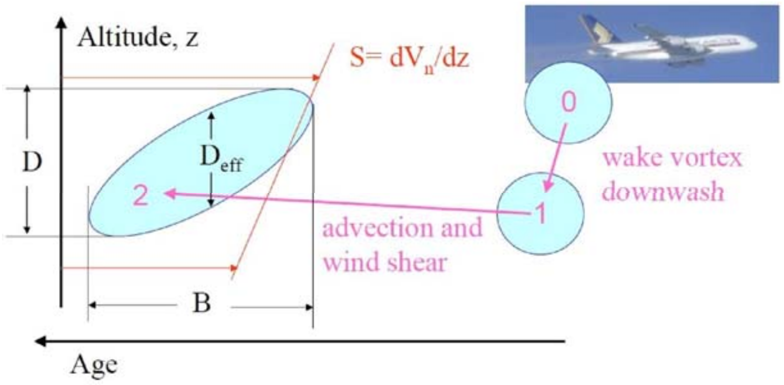
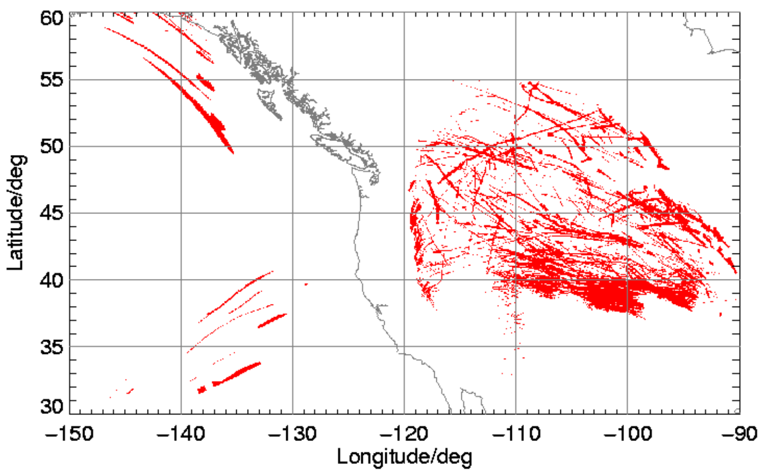
Contrail Cirrus Prediction Model (CoCiP)





Schumann (Geosci. Mod. Dev., accepted, 2012)

- Ambient meteorology from global 1-deg 3-h ECMWF IFS forecasts
- Contrails form along flight routes when Schmidt-Appleman criterion is satisfied
- Contrails form a Gaussian plume which is followed along Lagrangian trajectories
- Initial number of ice particles N equals number of soot particles emitted
- Ice water content results from deposition of humidity above saturation
- Number of ice particles per plume length stays constant expect for particle losses
- Critical: Ice particle number losses by turbulence, mesoscale gravity waves and aggregation/sedimentation
- Contrail life ends when Ice water content below zero or when N dilutes below 1/L or when optical depth below 10^{-4} or precipitates in fallstreaks below the lowest model layer

What do we know about the lifetime of contrail cirrus?

Highly variable

Most contrails visible in Meteosat images live < 1 h
(Vazquez-Navarro, 2009)

Contrail clusters are observed for 2-5 h
(Duda et al., 2001, 2004)

Some contrails have been observed for 17-18 h
(Minnis et al., 1998, Haywood et al., 2009)

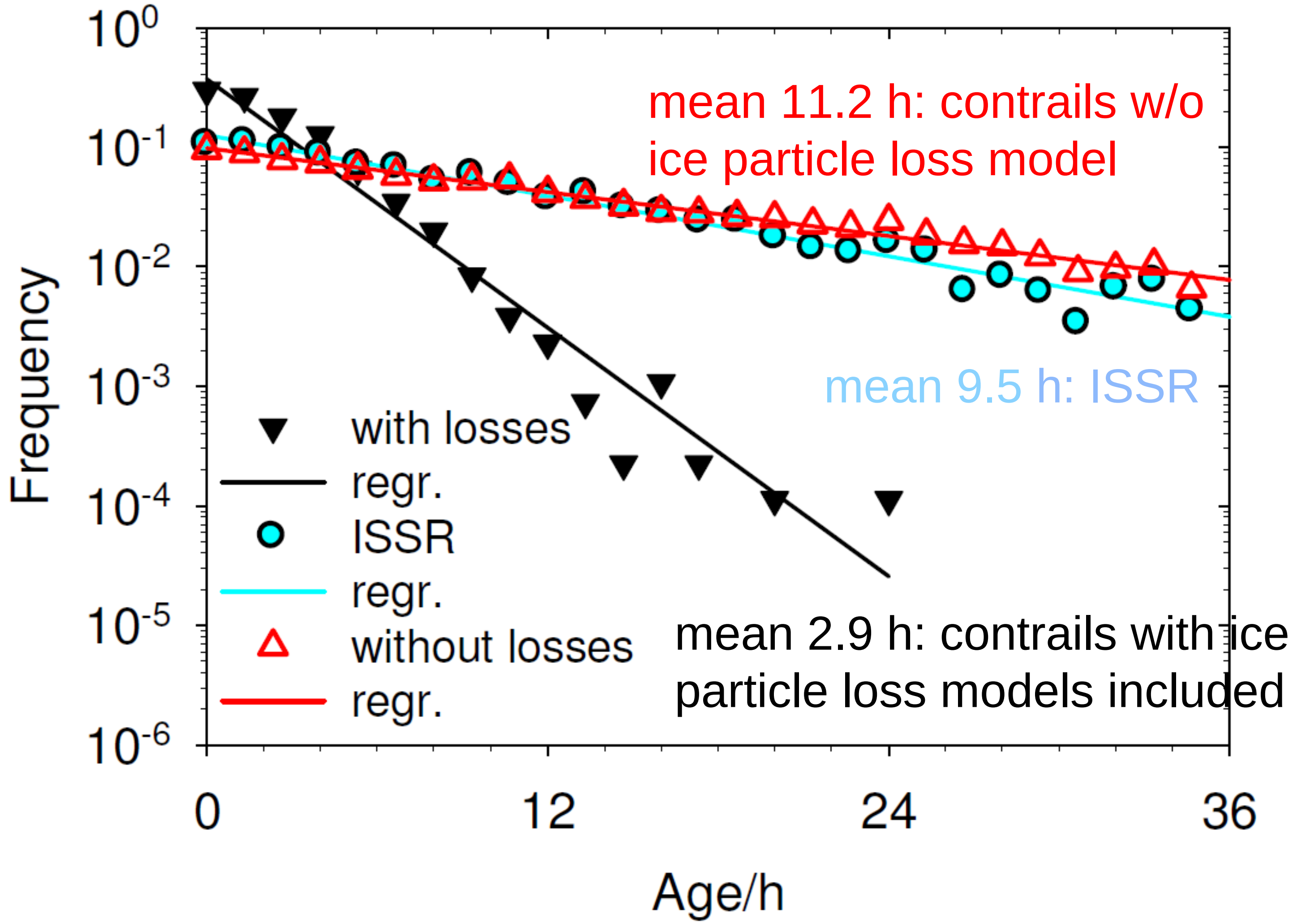
Possibly more than a day
(Bakan et al., 1994)

Ice supersaturated regions live minutes to days
(Gierens and Spichtinger 2000; Spichtinger et al., 2005a,b).

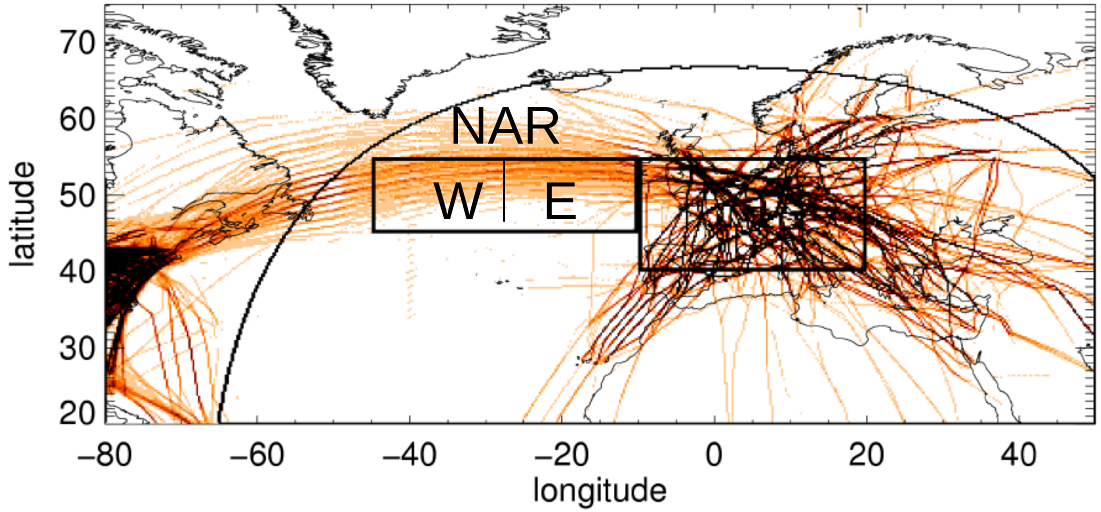
Lifetime of ISSR in ECHAM of order 9 h
(Schumann, GMD 2012)

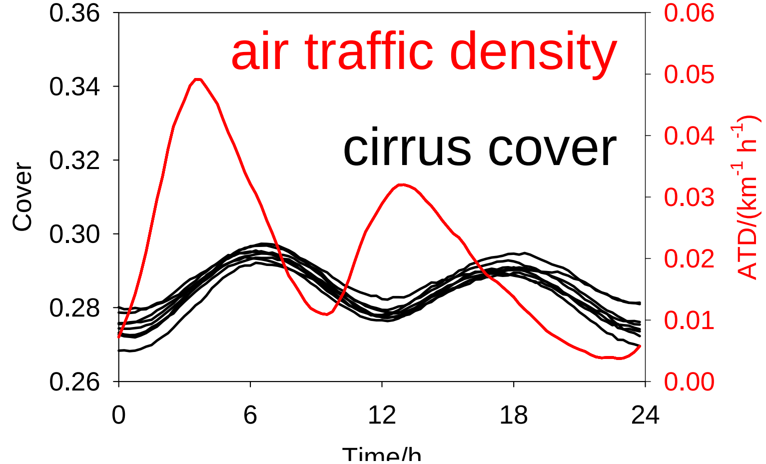
Lifetime very important for climate impact

Frequency distributions of life times of ISSR and contrails computed with ECMWF/CoCiP

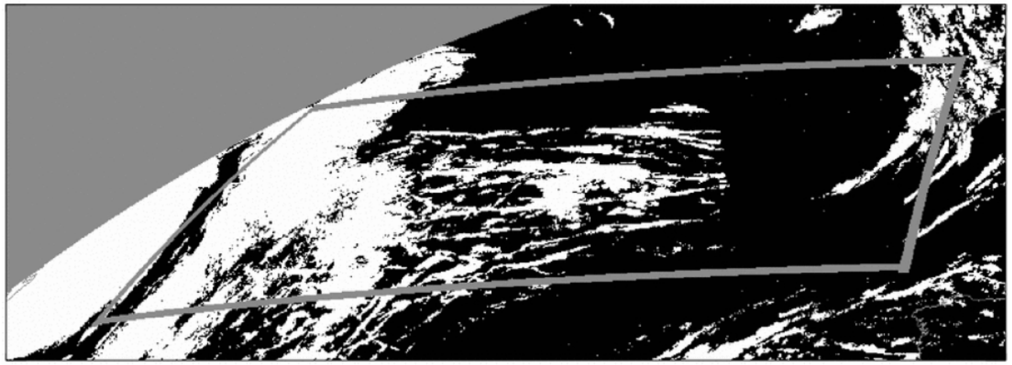


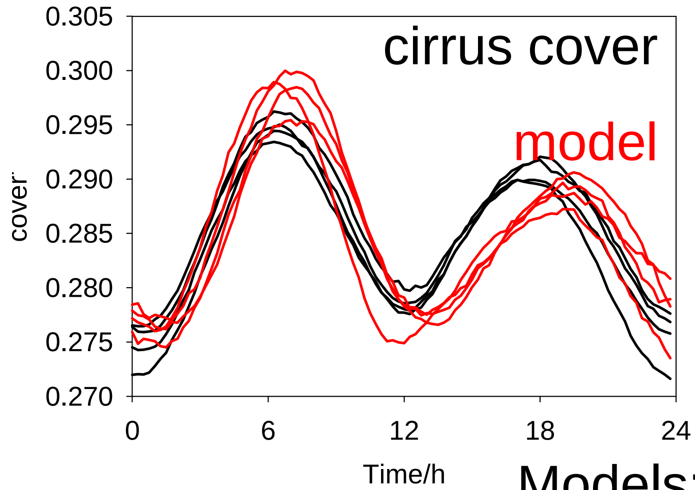
Determination of lifetime of contrail cirrus from mean diurnal cycle of cirrus cover/OLR over NAR and models





MeCiDA cirrus classification, 26.04.2004, 04:45 UTC

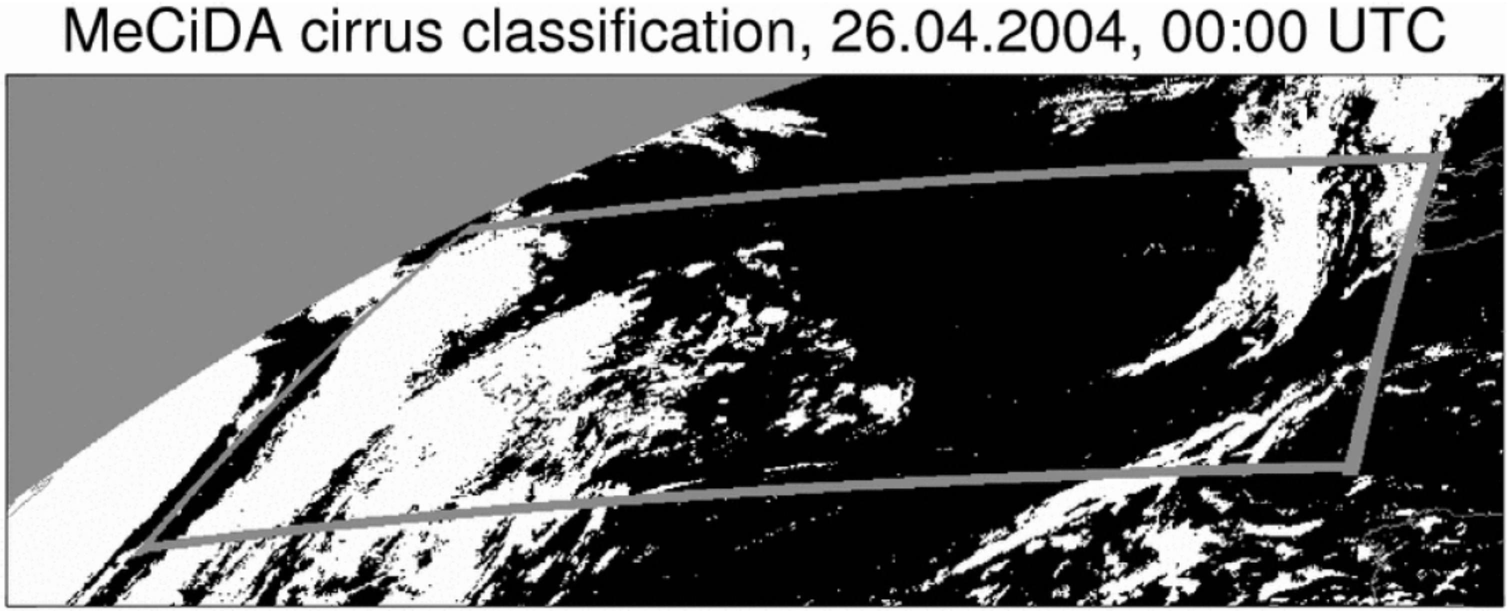


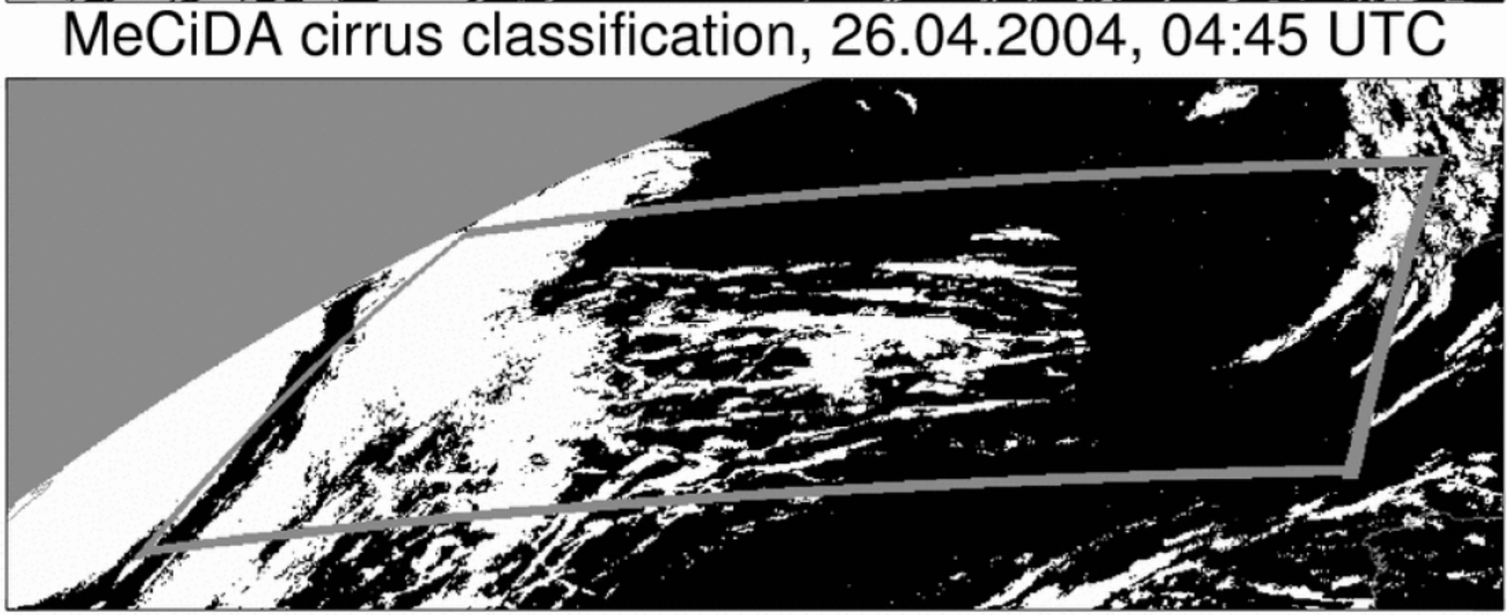


Cirrus cover: MeCiDa-2 (Ewald et al., 2012)

Outgoing LW radiation **OLR** (Vazquez-Navarro et al., 2012)

Models:
a) linear,
b) CoCiP





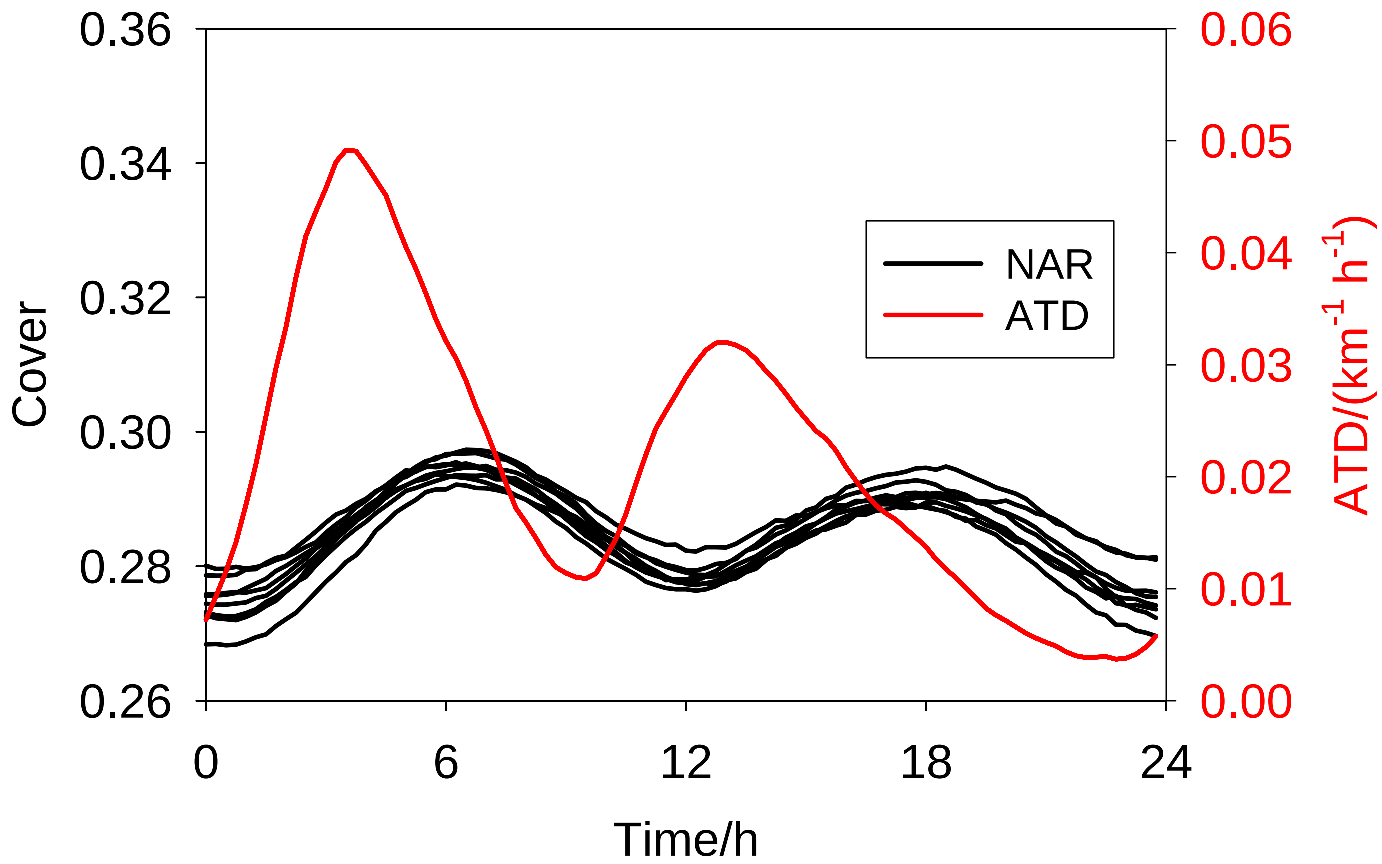
cirrus cover

shortly before

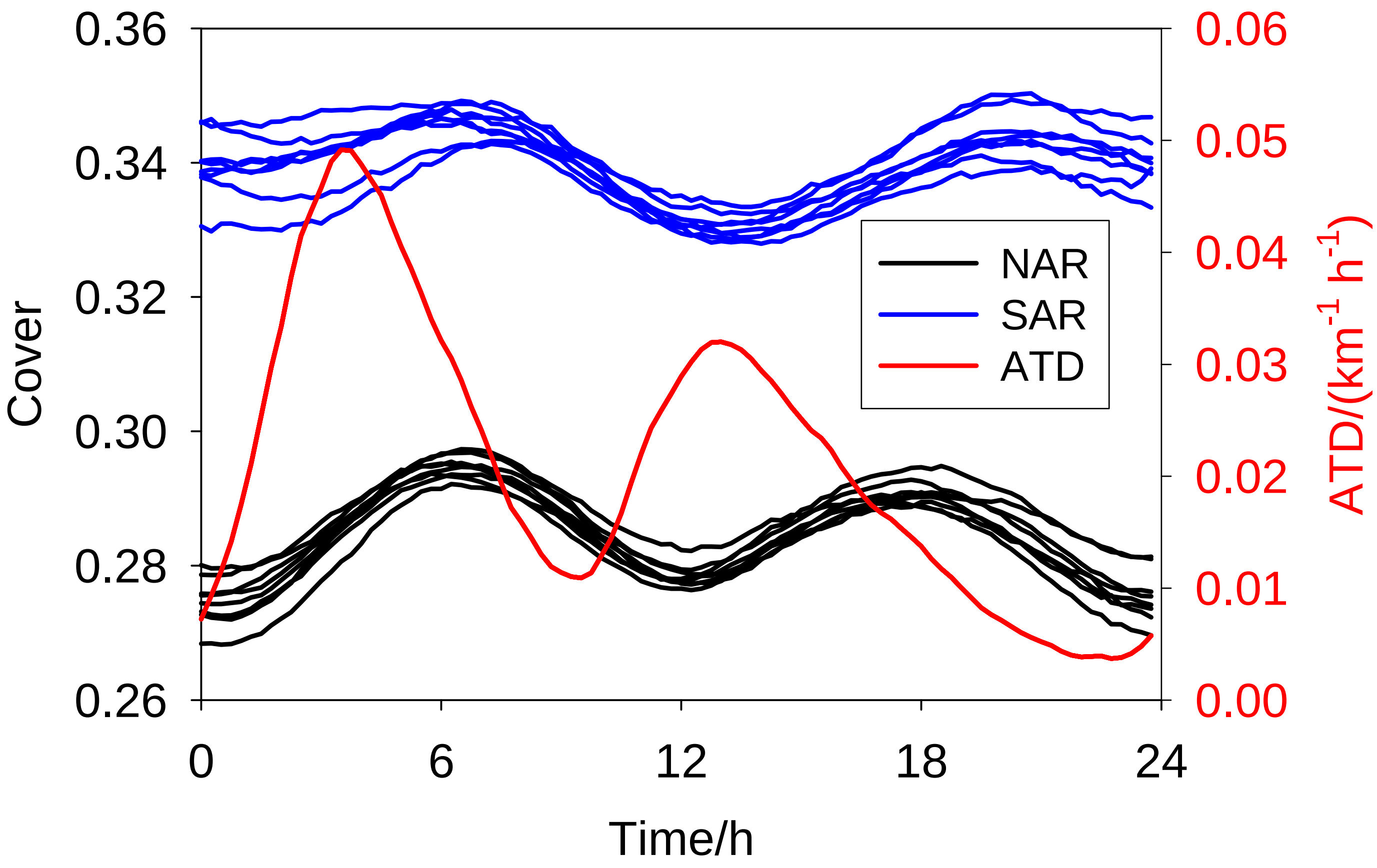
and after

morning traffic peak

Annual mean cirrus cover (8 years of Meteosat-IR data) follows air traffic density (ATD) with a delay of 3-4 h



Cirrus cover in South Atlantic region (SAR) provides proxy for cirrus without aviation (varies because of solar tide)



Fit cover NAR-SAR

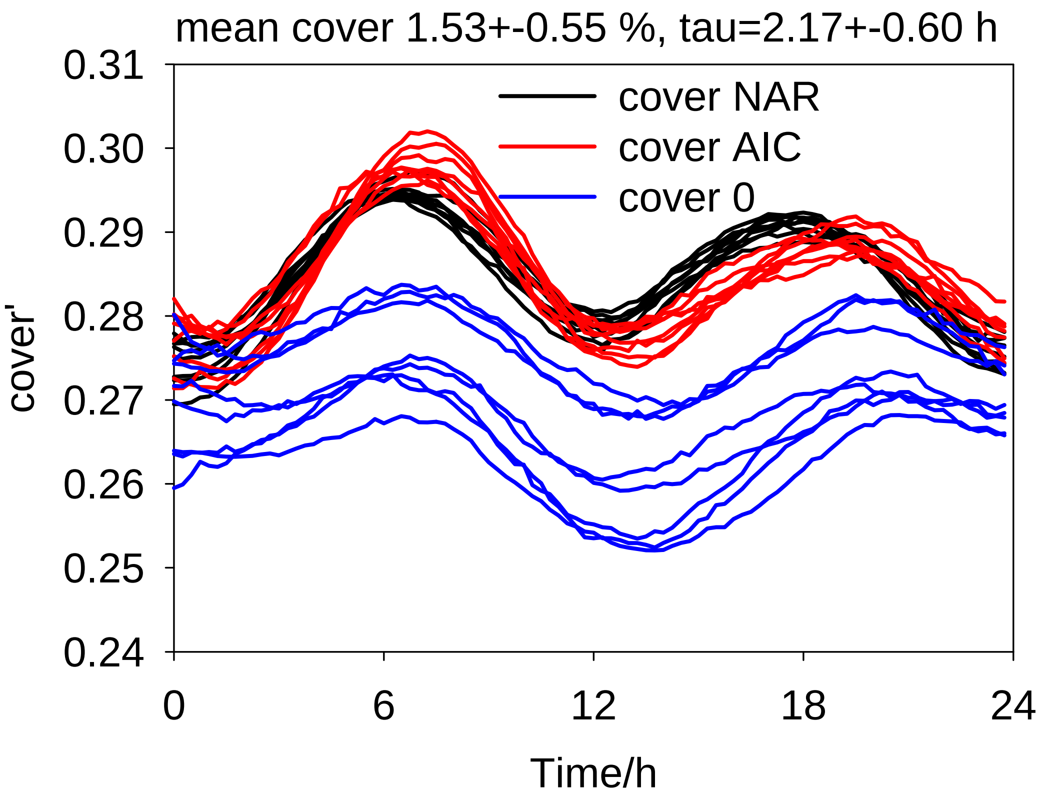
$$C(t) \approx C_{model}$$

$$C_{model} = c_0 + c_{AIC}$$

$$C_{model} = \langle c_0 \rangle + c_0'(t) + A c_R(t/\tau)$$

$$c_R(t) = \int_{-\infty}^{t} a(t')r(t-t')dt'$$

$$r(t) = (t/\tau)\exp(-t/\tau)$$

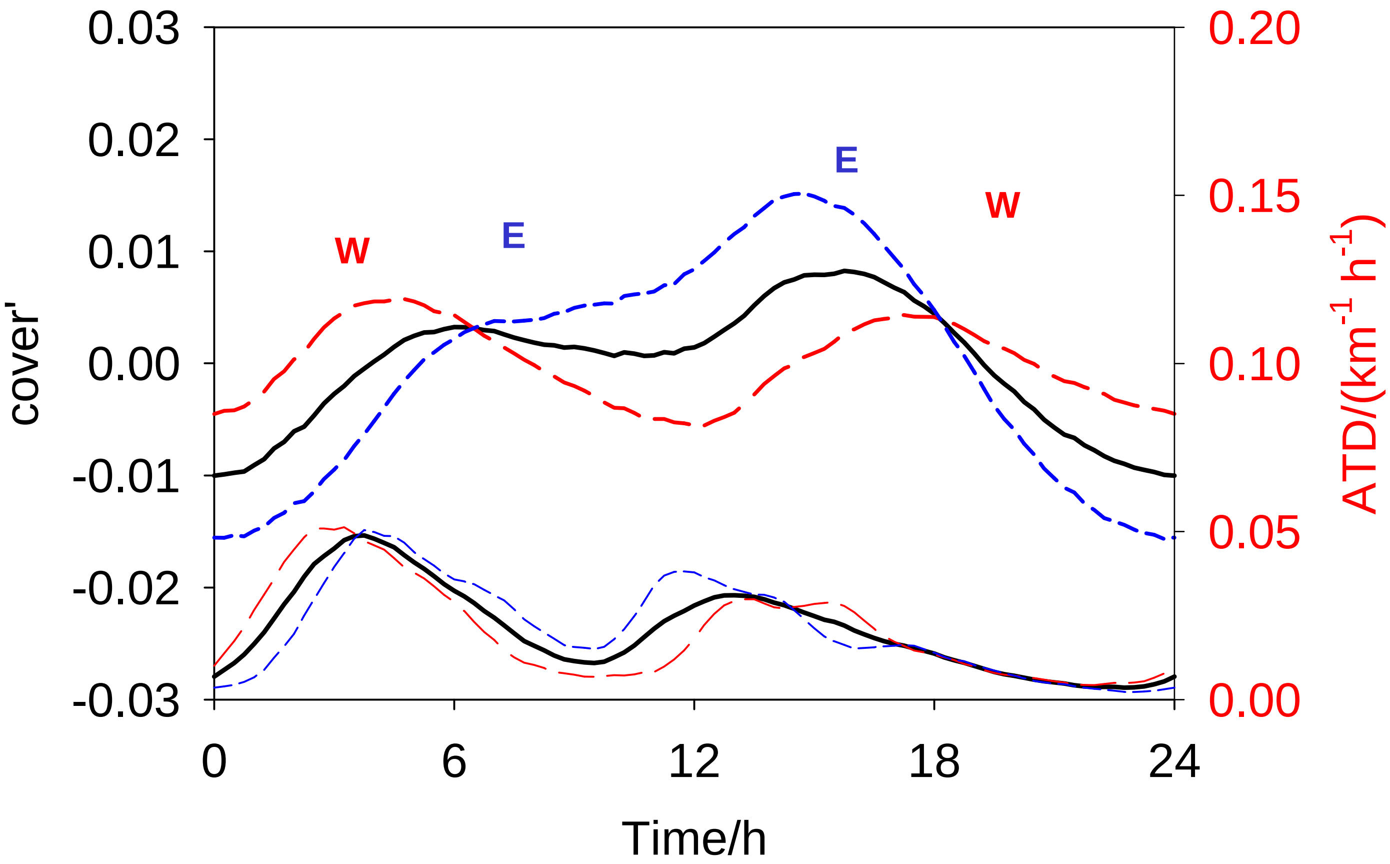


$c_0'(t)$ as observed over SAR

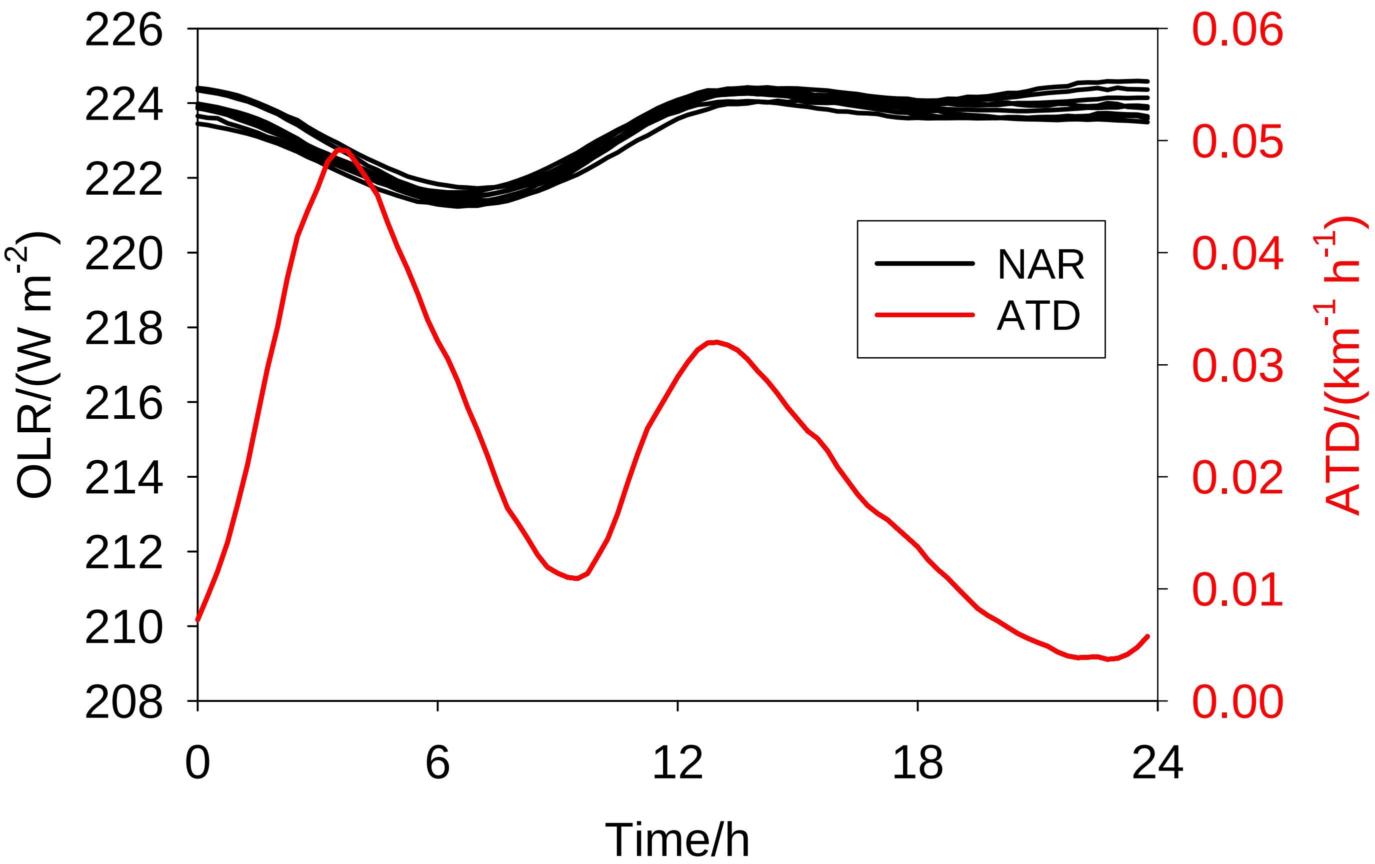
Model parameters $\langle c_0 \rangle$, A, τ from

$$S = \langle (C(t) - C_{model})^2 \rangle = \min$$

West and east part mean values of cirrus cover' cycles in (NAR-SAR) clearly reflect air traffic cycles

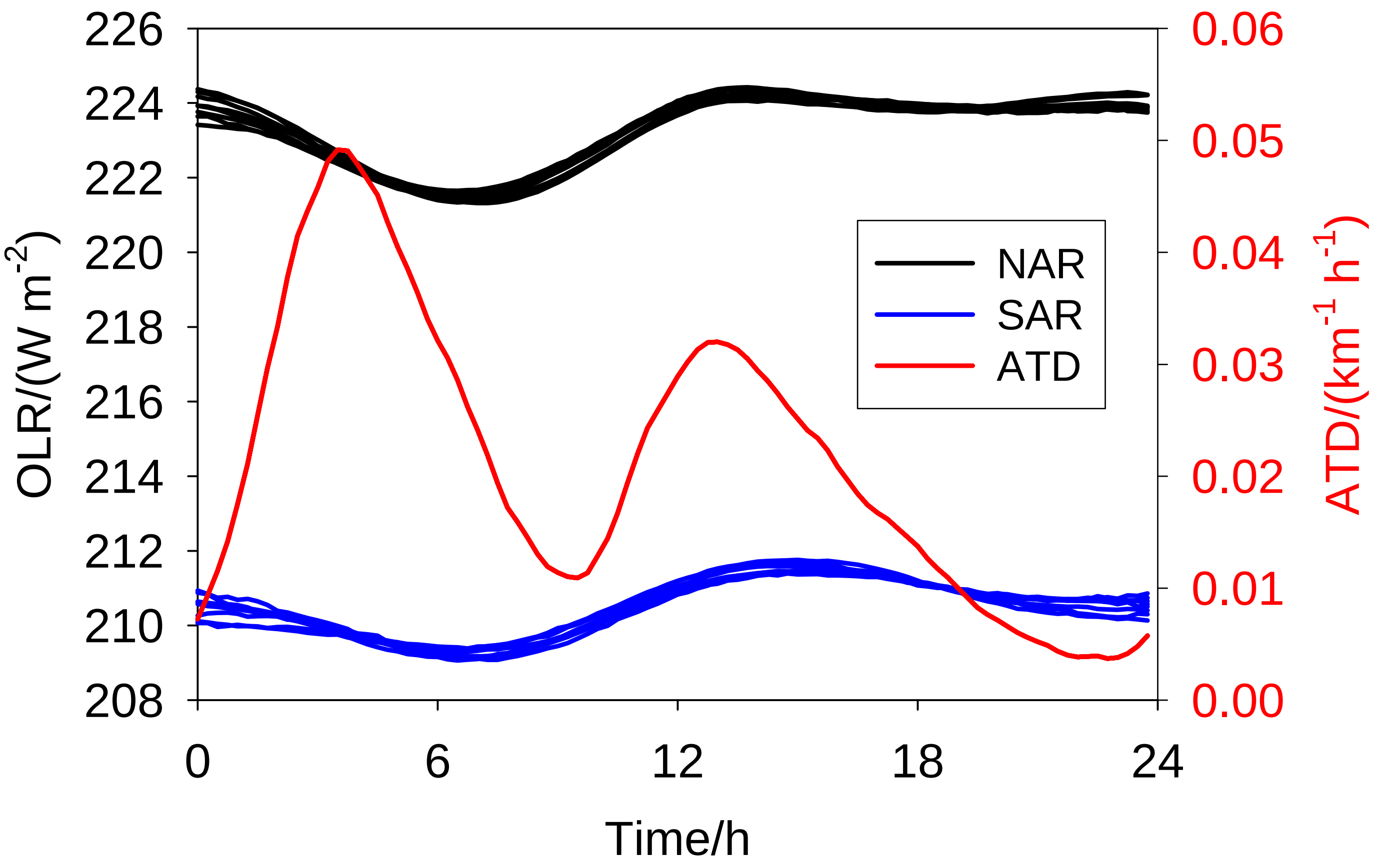


Annual mean outgoing longwave radiation (OLR from 8 years of Meteosat IR data) and air traffic density (ATD)

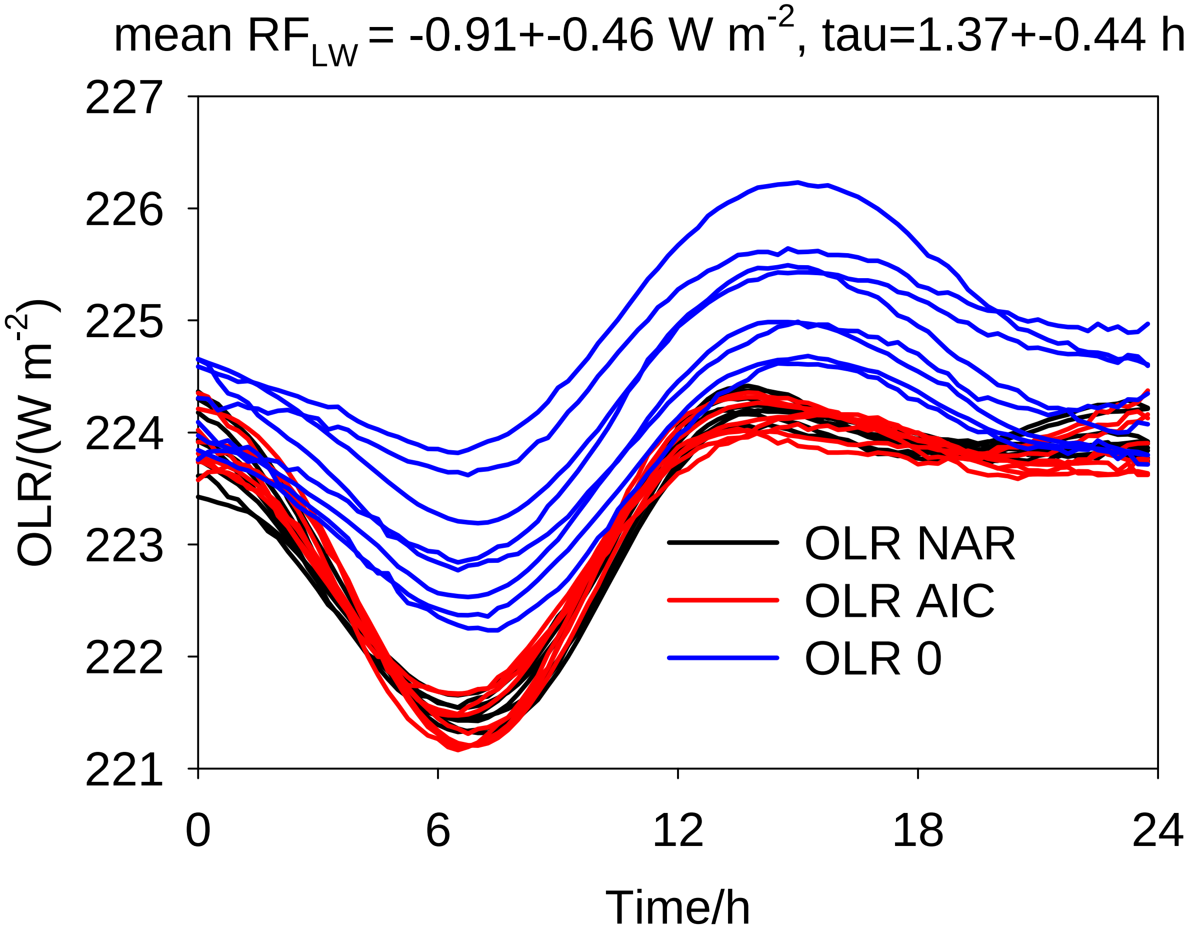


OLR: reflects diurnal solar and air traffic cycles

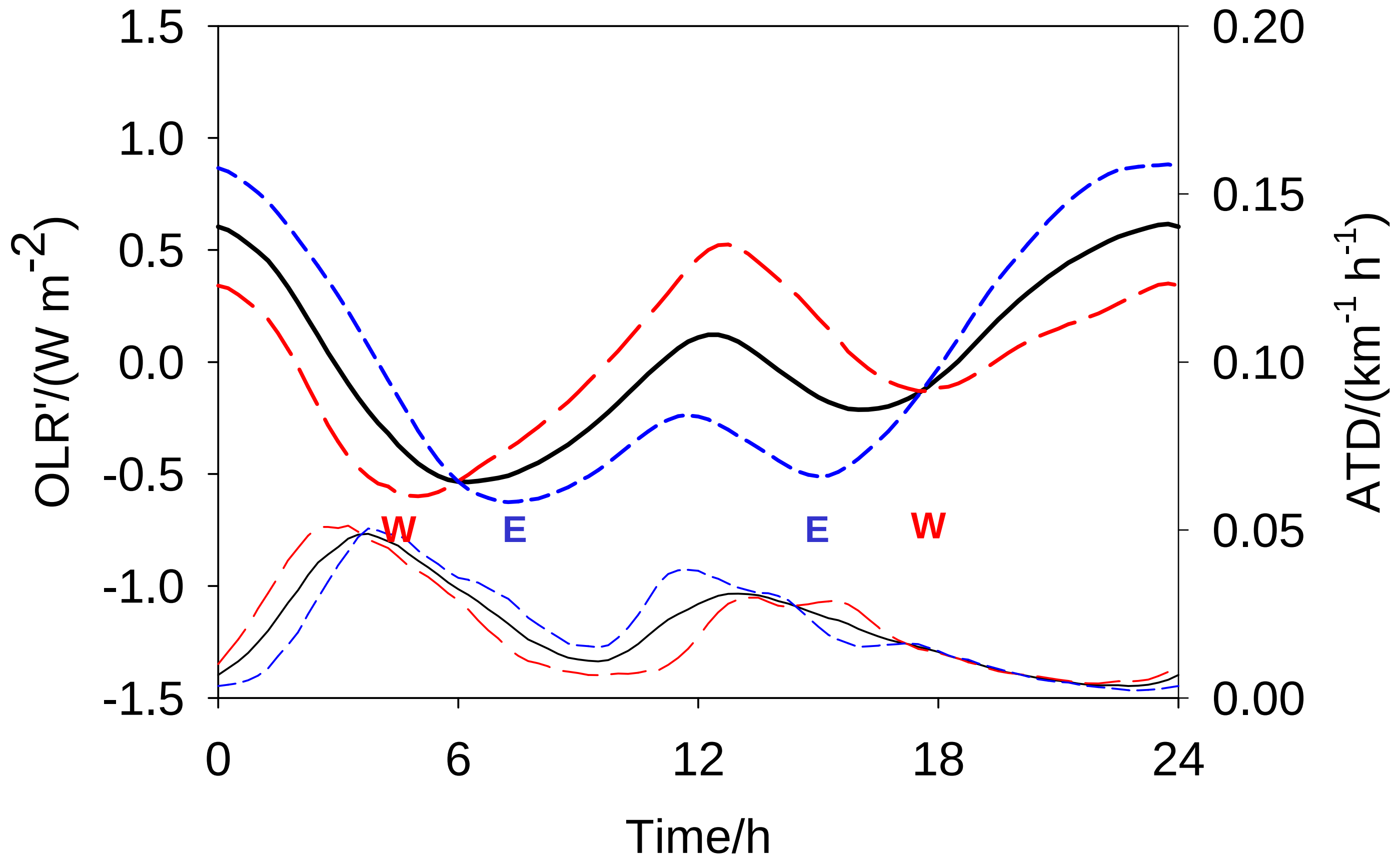
Diurnal cycle in SAR identifies daily solar cycle



Fit OLR NAR-SAR



West and east part mean values of OLR' cycles in (NAR-SAR) clearly reflect air traffic cycles



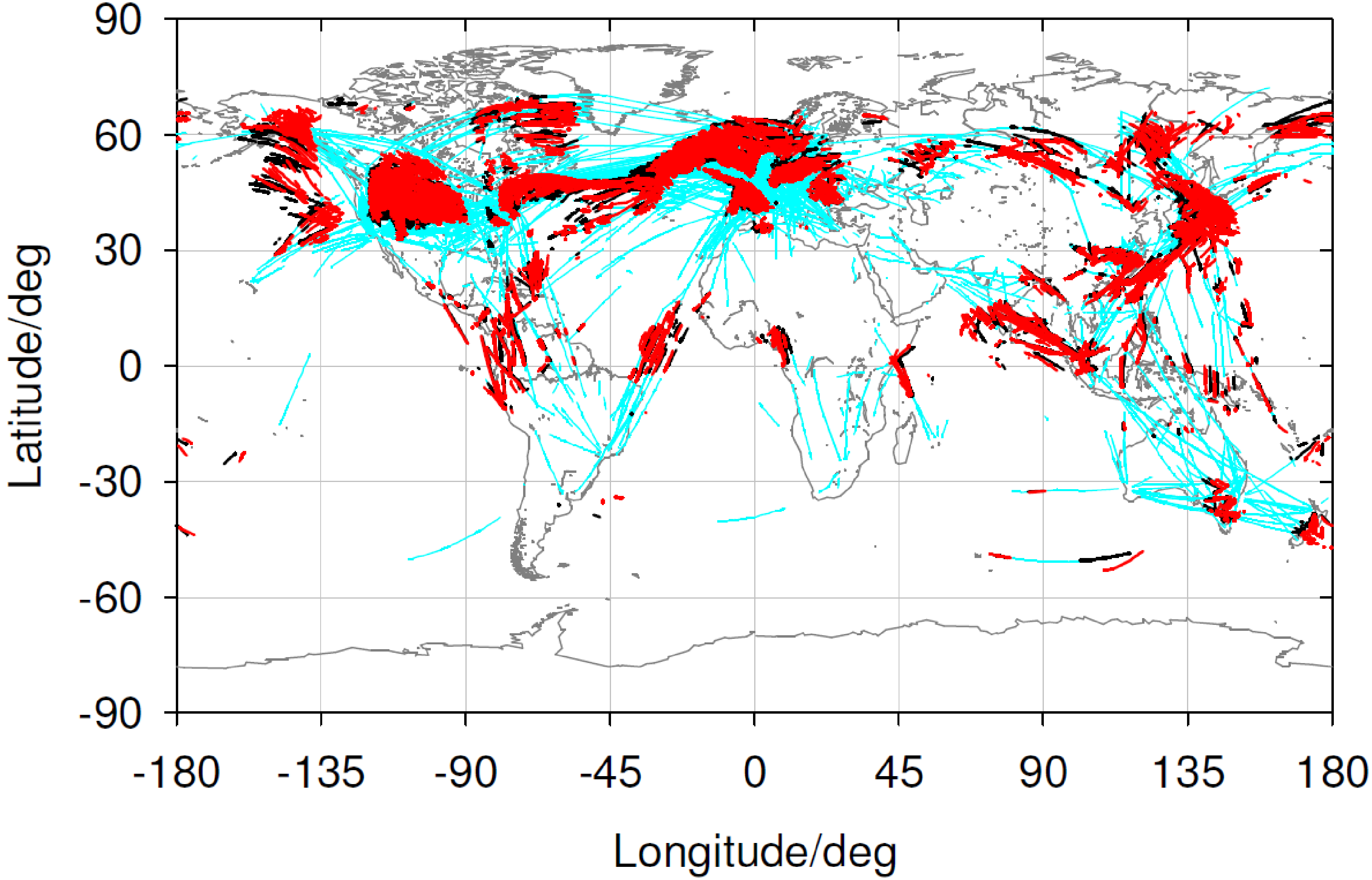
mean: OLR effect of order 1 W m^{-2}

Contrail Cirrus Prediction – Example: 0600 UTC in June 2006

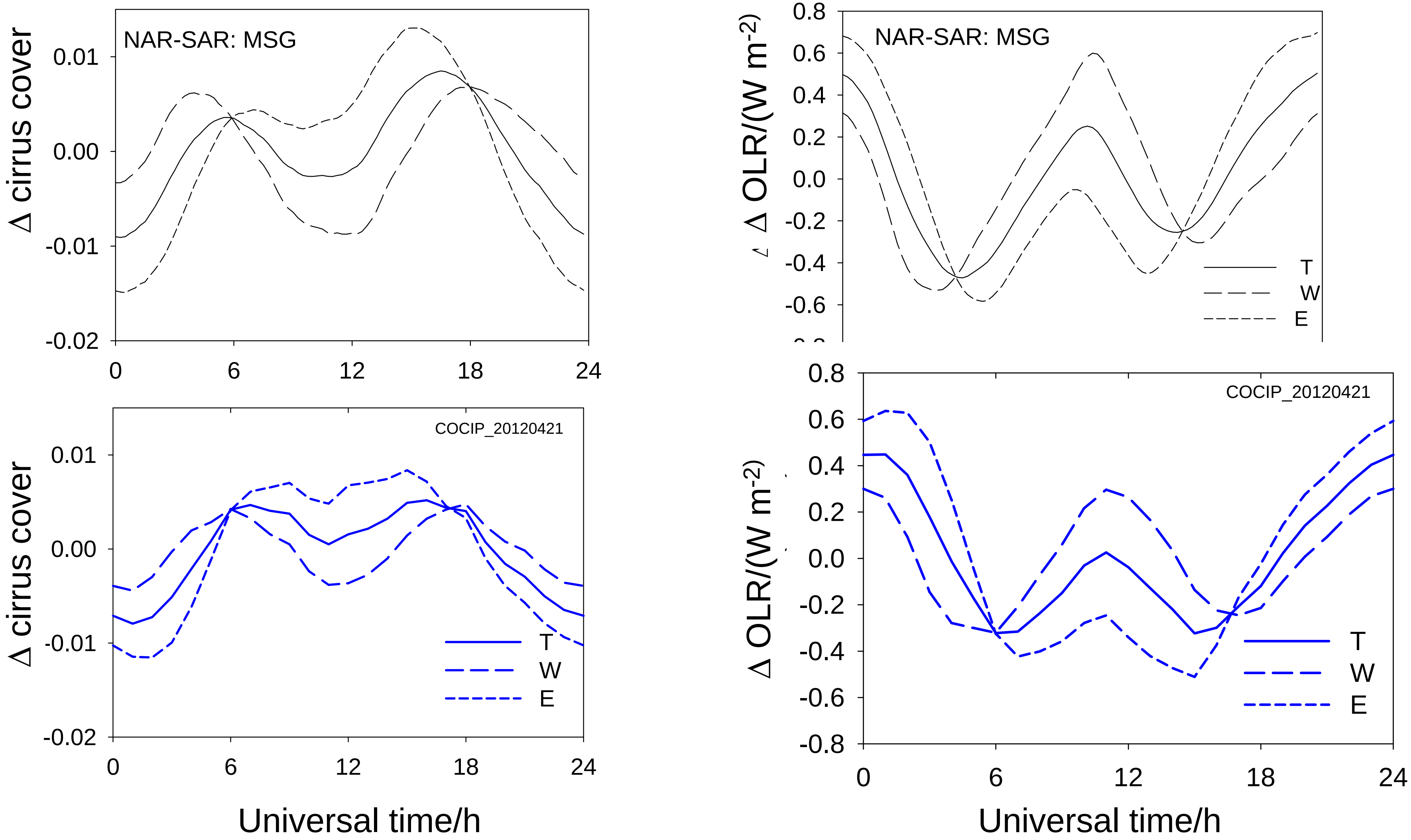
flight path causing contrail (Schmidt-Appleman satisfied)

flight path causing persistent contrail

contrail position



CoCiP model also covers W-E differences in cover and OLR

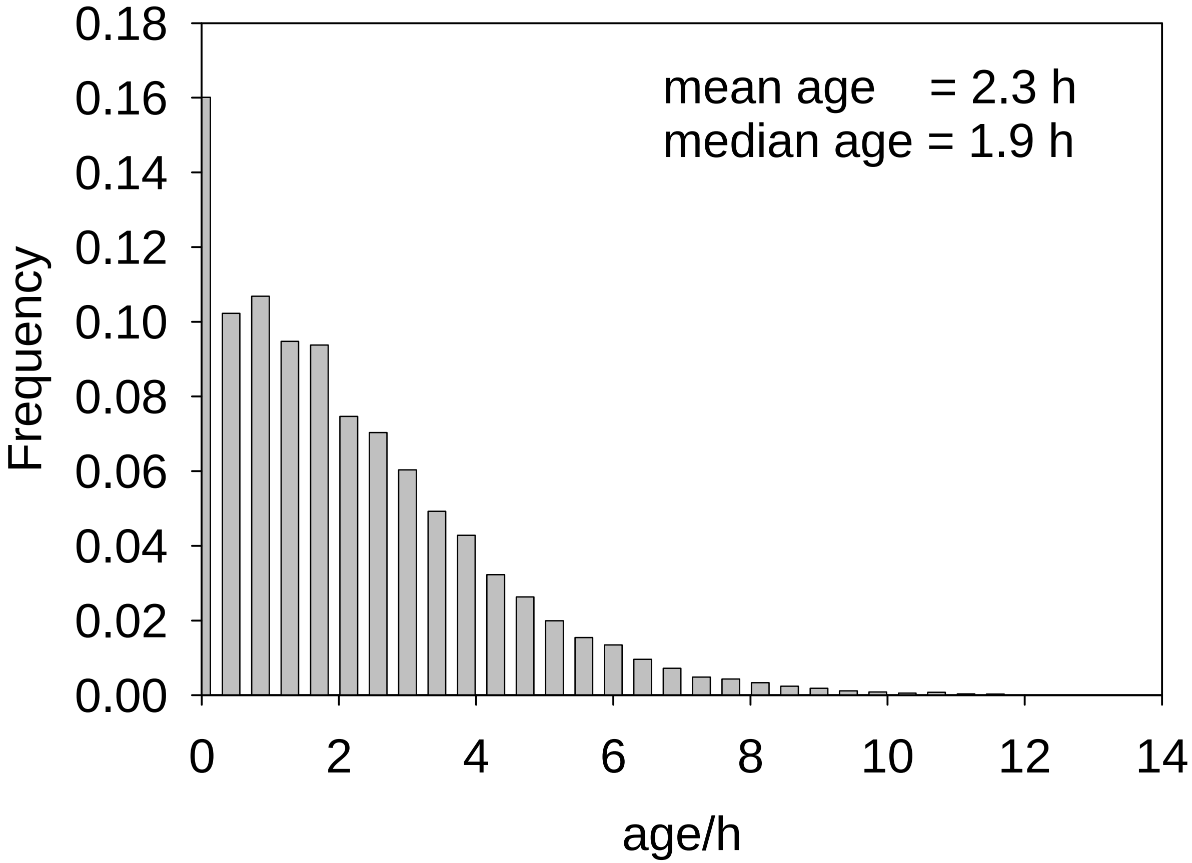


Best with enhanced vertical mixing,
partly by differential radiative heating

OZK, icase1747,

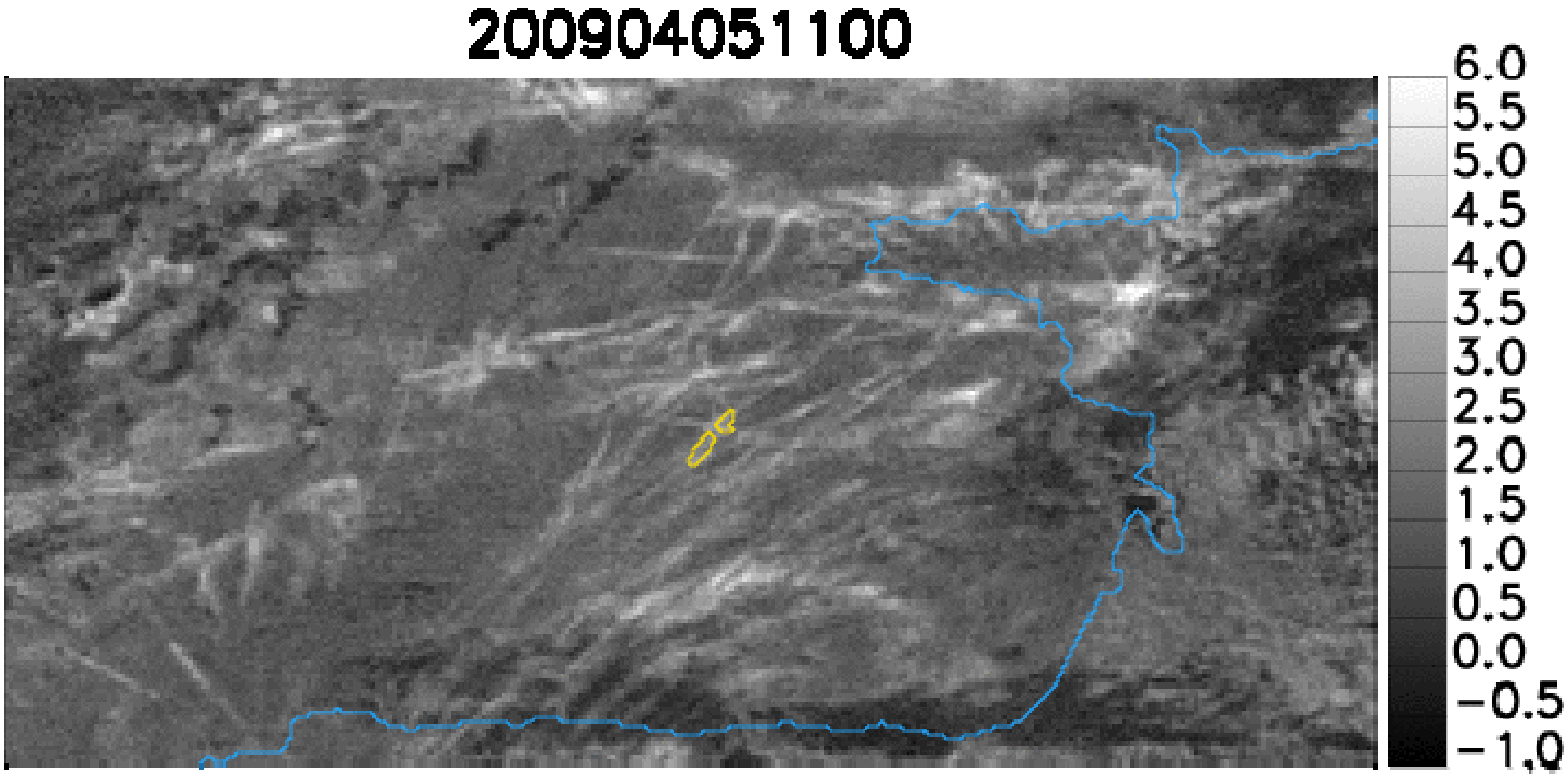
NE_global= 49.2 mW/m^2

Age frequency distribution of contrails derived from CoCiP results on average over all analysis times



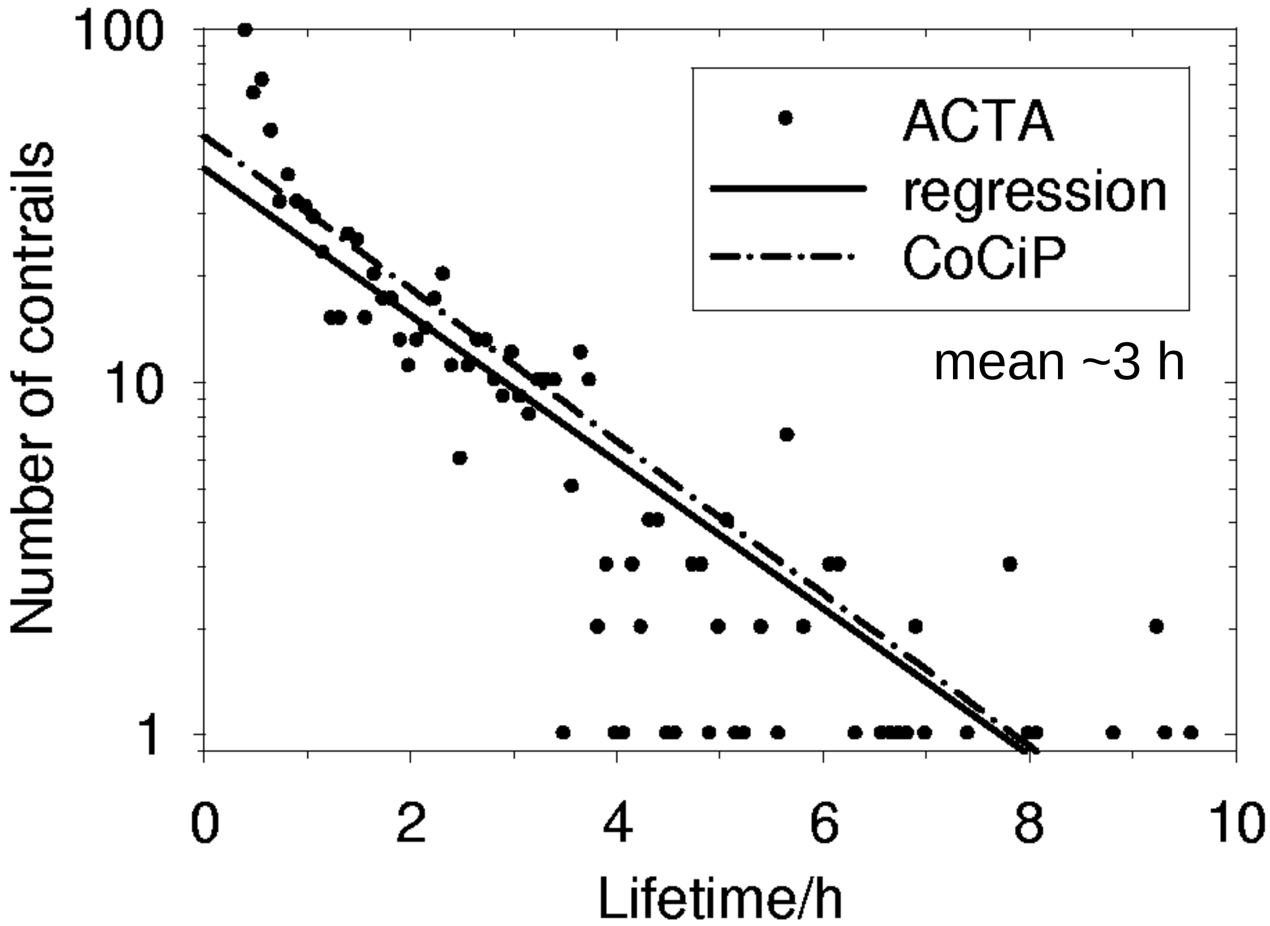
this is an Eulerian time scale (the Lagrangian time scale is larger)

Contrails tracked in Meteosat images by ACTA



ACTA: An automatic contrail tracking algorithm,
Vazquez-Navarro et al., AMT (2010)

Typical contrail life time: shorter than ISSR life time? Pdf of cirrus and contrail ages



ACTA data from M. Vazquez-Navarro

Conclusions

Time scales of contrail cirrus derived from comparison of 8 years of Meteosat cirrus/OLR observations and 2 models (linear + CoCiP)

Typical mean contrail cirrus lifetime values: 2 - 4 h

Mean life time of Ice supersaturated regions is far larger

What are the mechanisms that limit the life time?

- dispersion? turbulent particle losses? particle size dispersion? aggregation? – probably all of them

Ongoing work:

Global RF of aviation induced cirrus (preliminary: ~ 50 -- 100 mW/m^2)