Correlations between microphysical properties of large-scale semi-transparent cirrus (from TOVS) and the state of the atmosphere (from ECMWF ERA-40)

Gaby Rädel
Claudia Stubenrauch, Fadoua Eddounia

Laboratoire de Météorologie Dynamique
Ecole Polytechnique, France
Effective ice crystal size ($D_e$) and IWP retrieval of semi-transparent cirrus

based on: spectral difference of cirrus emissivities at 11-8 µm

**Observations:**

- NOAA10 1987 - 1991, 60°N - 60°S, $\theta_v < 25°$
- large-scale cirrus: 1°x1° overcast, $p_{clld} < 440$ hPa
- $T_{clld} < 263K, T_B^{meas}(8\mu m), T_B^{meas}(11\mu m), T_{clld}, T_{surf}$
- $\varepsilon_{surf}(SARB)$, closest TIGR $H_2O/T$ profiles

**Method:** simulate $\varepsilon(\lambda, D_e, IWP, \theta)$

- hom. cloud, $\beta_{abs}(D_e), <\omega_0(D_e), <g(D_e)>
- planar polycrystals (mod. ADA)
- bimodal size distribution

$$\varepsilon(\lambda, \Theta_\nu) = \frac{B(T_B^m(\lambda, \Theta_\nu)) - B(T_{surf}(\lambda, \Theta_\nu))}{B(T_{clld}(\lambda, \Theta_\nu)) - B(T_{surf}(\lambda, \Theta_\nu))}$$

**Radiative transfer**

- Streamer (J.Key)

**Variable:** $D_e, IWP$
produce look-up tables: \( D_e = f(\varepsilon_{8\mu m}, \varepsilon_{11\mu m}) \), \( IWP = f(D_e, \varepsilon_{11\mu m}) \)

For \( 0.3 < \varepsilon_{11\mu m} < 0.85 \) and \( 0.7 < \tau_{VIS} < 3.8 \), sensitivity up to \( D_e \leq 80\mu m \).
Sensitivity study on ice crystal size retrieval


NOAA10 global average: \( \langle D_e \rangle = 55 \mu m \)
\( \langle IWP \rangle = 30 \text{ g/m}^2 \)

Possible errors:

**Overestimation of** \( D_e \): thin Ci with underlying water cloud

- partial cover of thick Ci
- different crystal shapes, e.g.
  - hexagonal columns instead of polycrystals

**Underestimation of** \( D_e \): vertical heterogeneity, i.e.:

- increasing \( D_e \) with cloud depth
- broader size distribution
Evaluation of TOVS cloud height with LITE
(newest LITE inversion by L. Sauvage)

796 TOVS low clouds
560 LITE single- 236 multi-layer

495 TOVS high clouds
161 LITE single- 334 multi-layer

P_{cl}(TOVS) \approx P_{cl}(mid-cloud)
better agreement for low large-scale cirrus clouds

LITE:
- low clouds
- high clouds

z_{top} - z_{base}:
- 1.3 km
- 2.7 km

very thin LITE high clouds
heterogenous scenes

\Delta z < 1 \text{ km}: 70\%
peak at 0

\Delta z < 2 \text{ km}: 60\%
peak at -0.5 \text{ km}
Regional and seasonal variations of $D_e$ and IWP

TOVS  NOAA10 3-year averages

$N_\varepsilon (SHm) > N_\varepsilon (NHm) > N_\varepsilon (trop)$

NH land: $N_\varepsilon (sum) < N_\varepsilon (win)$

$IWP(trop) > IWP(NHm) > IWP(SHm)$

land: $IWP(midsum) > IWP(midwin)$

$D_e(trop) > D_e(NHm) > D_e(SHm)$

land: $D_e(midsum) > D_e(midwin)$
Large-scale semi-transparent cirrus 60°N – 60°S

cold cirrus: $D_e$ depends more on IWP than on $T_{cld}$
IWP increases with $T_{cld}$
## Regional dependence for thin and thick Cirrus

**Thin Cirrus**

- **Midlatitudes**
  - Dₑ vs. Tₑd
  - IWP vs. Tₑd

- **Tropics**
  - Dₑ vs. Tₑd
  - IWP vs. Tₑd

**Thick Cirrus**

- **Midlatitudes**
  - Dₑ vs. Tₑd
  - IWP vs. Tₑd

- **Tropics**
  - Dₑ vs. Tₑd
  - IWP vs. Tₑd

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**Different behaviour in midlatitudes and tropics**

- Thick Ci in tropics: Dₑ and IWP do not depend strongly on Tₑ, almost no scatter due to different IWP or Dₑ.
Atmospheric properties accompanying large-scale cirrus

**ERA-40 ECMWF reanalyses:**
- humidity, U, V and W for 23 pressure levels
- Every 6 hours, 1.125° x 1.125° spatial resolution

**Co-location with TOVS observations:** (1989, 1990)

<table>
<thead>
<tr>
<th></th>
<th>Water vapour (cm)</th>
<th>Horizontal wind (m/s)</th>
<th>Frequency of situations with strong updraft</th>
<th>no wind</th>
<th>strong downdraft</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>RMS</td>
<td>mean</td>
<td>RMS</td>
<td>9%</td>
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<tr>
<td>NH midlatitude summer</td>
<td>3.0</td>
<td>1.2</td>
<td>14.5</td>
<td>10.9</td>
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<td>NH midlatitude winter</td>
<td>1.4</td>
<td>0.8</td>
<td>26.1</td>
<td>15.8</td>
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<tr>
<td>Tropics</td>
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<td>0.9</td>
<td>7.6</td>
<td>6.0</td>
<td>7%</td>
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<tr>
<td>SH midlatitude summer</td>
<td>2.3</td>
<td>1.0</td>
<td>23.4</td>
<td>13.8</td>
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<tr>
<td>SH midlatitude winter</td>
<td>1.5</td>
<td>0.8</td>
<td>22.3</td>
<td>15.2</td>
<td>10%</td>
</tr>
</tbody>
</table>

**tropics:** largest water vapour, smallest winds  
**midlat. winter:** strongest winds  
**SH:** horizontal winds always strong  
**most large-scale semi-transparent cirrus in situations with no vertical wind**
$D_e$ and IWP as function of humidity and wind

Large-scale semi-transparent cirrus 60 N – 60 S, $T_{clld} < 233K$

De and IWP increase with water vapour

$D_e$ 12 µm smaller in case of strong winds

IWP 10 gm$^{-2}$ larger in case of strong vertical updraft

Regional distributions of $D_e$ and IWP as function of humidity and wind

- $D_e$ larger in case with no winds than strong winds
- Humid tropics: IWP larger in case of strong $w$ than strong $u+v$
Cirrus horizontal extent

determine horizontal extent of cirrus clouds ($\varepsilon > 0.3$):

a. empty boxes are filled with 'most likely' information on cirrus type
b. simple clustering algorithm groups adjacent boxes containing
depth convection ($\varepsilon > 0.95$), cirrus ($0.95 > \varepsilon > 0.5$)
or thin cirrus ($0.5 > \varepsilon > 0.3$)

Examples: 18/07/1989 and 30/12/1989 7h30 PM
Cirrus horizontal extent

Cirrus clusters: largest in tropics
smallest in ML summer

D_e as fct. of distance to convective centre:
D_e small if very close to convective centre
and in smaller clusters → dynamics?

Graphs showing the dependence of D_e on distance for different regions:
- Tropics
- Midlat. winter
- Midlat. summer

Gaby Rädel
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Conclusions and Outlook

- Large-scale semi-transparent cirrus: \( \langle D_e \rangle = 55 \mu m \) \( \langle IWP \rangle = 30 g/m^2 \)
- \( IWP \) increases with \( T_{cld} \)
- TOVS Path-B & ECMWF reanalyses \( \Rightarrow \)  
  \( D_e \) and \( IWP \) increase with atmospheric water vapour, 
  increase depends on vertical updraft, hor. wind, 
  formation processes?
- Study \( D_e \) as function of cirrus size and location to convective center for different dynamic situations
- Find parameterizations \( IWP = f(q,w,T) \), \( D_e = f(IWP,q,w,u+v,T) \) using also cluster information