Representing the Ice Fall Speed in Climate Models: Results from SPARTICUS

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Global Climate Models (GCMs) are highly sensitive to the representation of clouds and their feedbacks. According to a study by Sanderson et al. (2008), the ice fall velocity ($V_i$) is the second most important factor affecting the global feedback parameter in GCMs.

In spite of its importance, $V_i$ in climate models is highly uncertain due in part to its dependence on the ice particle size distribution (PSD), which has been plagued with measurement uncertainties from small ice particles produced by shattering. However, data processing techniques used in conjunction with new probes in recent field campaigns appear to have significantly reduced the artifact concentration of small ice particles.
Selected Case Studies

<table>
<thead>
<tr>
<th>Synoptic Cirrus (117 segments)</th>
<th>Anvil Cirrus (122 segments)</th>
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<tbody>
<tr>
<td>- Jan 19\textsuperscript{th}</td>
<td>- April 22\textsuperscript{nd}</td>
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<tr>
<td>- Jan 20\textsuperscript{th}</td>
<td>- April 28\textsuperscript{th}</td>
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<td>- March 23\textsuperscript{rd}</td>
<td>- June 12\textsuperscript{th}</td>
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<td>- March 26\textsuperscript{th}</td>
<td>- June 14\textsuperscript{th}</td>
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<td>- April 1\textsuperscript{st}</td>
<td>- June 15\textsuperscript{th}</td>
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<td>- June 17\textsuperscript{th}</td>
<td>- June 24\textsuperscript{th}</td>
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Cloud segments are identified for each case by making sure that

- they contain no liquid water,
- they have good sampling statistics and utilize a good fraction of the data
- they are sampled under relatively steady microphysical conditions
Satellite Images Help Determine Cloud Type (Anvil/Synoptic Cirrus)

Source: P. Minnis (NASA Langley)
http://www.angler.larc.nasa.gov/cgi-bin/site/showdoc?mnemonic=ARM-SPARTICUS
General Approach

- The size resolved 2D-S measurements of number, projected area and mass concentration appear reasonable.
  - Ice artifacts from shattering greatly reduced
  - Good agreement between 2D-S and CVI IWC during TC4

This study uses 2D-S data from SPARTICUS, a recent field campaign sampling mid-latitude cirrus. The treatment of $D_e$ (effective diameter) is general for liquid, mixed phase and ice clouds and is expressed as:

$$D_e = \frac{3}{2}(\frac{IWC}{\rho_iA_t})$$

$V_i$ (ice particle fall speed) is calculated by using two different methods, namely the Mitchell-Heymsfield (2005) method (MH) and the Heymsfield-Westbrook (2010) method (HW). $V_i$ is generally expressed as:

$$V_i = \alpha D^\beta$$

Applying this definition to 2DS measurements, $D_e$ and $V_m$ (the PSD mass weighted fall-speed) were expressed as:

$$V_m = \Sigma V_i(D) m(D) N(D) \Delta D / \Sigma m(D) N(D) \Delta D$$

$$D_e = \frac{3}{2} \Sigma m(D) N(D) \Delta D / (\rho_i \Sigma A(D) N(D) \Delta D)$$
Synoptic Cirrus PSDs from 2DS
Fall Speed Related To $D_e$ Using:

\[ V_{HW} = 0.004D_{eff}^2 + 0.191D_{eff} - 5.64 \]
\[ R^2 = 0.992 \]

\[ V_{MH} = 0.006D_{eff}^2 - 0.161D_{eff} + 5.034 \]
\[ R^2 = 0.993 \]
Area Ratios of SPARTICUS Synoptic Cirrus

PSD Area Ratio for SPARTICUS

N = 60
Sparticus Synoptic Cirrus

Normalized Frequency

PSD Mean Area Ratio

0 0.25 0.5 0.75 1

0.4 0.5 0.6 0.7 0.8 0.9 1 1.1
Area Ratios From Other Field Campaigns

TC4 Anvil Cirrus
N = 25

TC4 Aged Anvil Cirrus
N = 23

In Situ Cirrus NAMMA & TC4
N = 12

Arctic (ISDAC) Cirrus
N = 162
SPARTICUS SYNOPTIC CIRRUS:  
$V_m$ vs. $T$ and $V_m$ vs. IWC

$v_H = 116.617 + 1.734T$
$R^2 = 0.7846$

$V_{HW} = 0.902 + 30.667 \log(IWC)$
$R^2 = 0.619$
SPARTICUS SYNOPTIC CIRRUS:
\( D_e \) vs. \( T \) and \( D_e \) vs. IWC
$V_m$ And $D_e$ Related To IWC And T

- Predicted $V_m$ (HW) vs. Observed $V_m$
  - $V_m = 105.595 + 1.55T + 0.05$ IWC
  - $R^2 = 0.831$

- Predicted $D_e$ vs. Observed $D_e$
  - $D_e = 160.27 + 1.8T + 0.04$ IWC
  - $R^2 = 0.769$
Model consistency achieved by predicting $V_m$ from $D_e$.
THANK YOU!

INPUTS AND COMMENTS?