Measurements of Small Ice Crystals during TWP-ICE

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Motivation

At microphysical level, ice water content (IWC) & crystal shapes & sizes determine radiative impacts of cirrus

Contradictory conclusions on the role of small crystals (max. dimension D < 50 μm) for extinction/mass properties of cirrus have been reached:

- Studies using probes detecting forward scattering of light suggest small crystals contribute significantly to IWC & extinction
- Other studies have hypothesized the shattering of large ice crystals (D >~ 100 μm) on protruding components of forward scattering probes artificially increase small crystal #

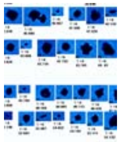

FIG 1: Small crystals imaged by CPI 27 Jan. 2006 during TWP-ICE

Goal: determine if measurements of small ice crystals from Cloud and Aerosol Spectrometer (CAS) probe during TWP-ICE were artificially inflated due to crystal shattering

Measurements

Use data from flights on 27 January and 29 January in aged cirrus, and from flight on 2 February in a fresh anvil from the probes depicted below

FIG 2: Cloud Aerosol and Spectrometer Probe (CAS) that sizes between 0.5 and 50 μm, and Cloud Imaging Probe (CIP) that nominally sizes between 25 and 1550 μm.

FIG 3: Cloud Droplet Probe (CDP) that sizes between 2 and 50 μm, and Counterflow Virtual Impactor (CVI) that provides bulk measures of mass.

Data from a Nevzorov probe detecting presence of liquid water and high resolution images of ice crystals with 15 < D < 1500 μm obtained by SPEC Inc. Cloud Particle Imager (CPI) were also used in this study

How/Why Compare CAS and CDP?

- CAS and CDP, both manufactured by DMT, have similar optical systems to detect forward scattered light
- CAS has inlet and shroud, whereas CDP has open path design → comparison of CAS/CDP concentrations of crystals with D > 3 μm, $N_{>3}$, is a good test of whether shattering amplified CAS concentrations
- During Costa-Rica Aura Validation Experiment (CR-AVE), coincident data with CAS, CIP and CDP also obtained in cirrus: however, CAS did not have shroud during→ comparison of TWP-ICE/CR-AVE good test of how much shroud contributes to potential shattering

FIG 4: Picture of CAS as installed on WB-f7 during CR-AVE, January 2006. Inlet, but not shroud, present.

Comparison of CAS/CDP Data

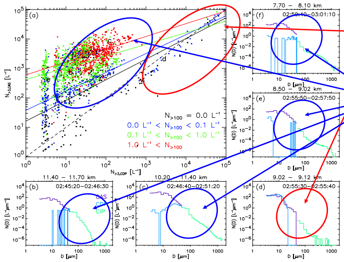

FIG 5: a) $N_{>3,CAS}$ against $N_{>3,CDP}$ for varying $N_{>100}$ measured by CIP during TWP-ICE; lines give best fit to data. b) to f) give N(D) for 5 times during a spiral descent of Proteus on Feb. 2.

$N_{>3}$ for CAS & CDP agreed within 2% for liquid periods (T > 0°C or liquid detected by Nevzorov probe)

$N_{>3,CAS}$ 91±127 times greater than $N_{>3,CDP}$ in ice

- Includes times in aged cirrus and fresh anvils, and at top and bottom of cirrus layers where size sorting occurring
- Ratio of $N_{>x,CAS}/N_{>x,CDP}$ statistically significant function of $N_{>100}$ (FIG. 6) for x < 25 μm → crystals < 25 μm responsible for discrepancy & most produced by shattering

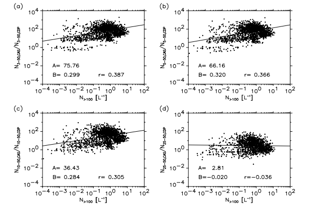

FIG 6: $R = N_{x-50,CAS}/N_{x-50,CDP}$ against $N_{>100}$ for a) x=2, b) x=3, c) x=5 and d) x =25 μm. Lines give best fit to $R = A N_{>100}{}^{B}$; A, B and regression coefficients indicated.

During CR-AVE (FIG. 7), N_{5-10} and N_{10-15} order of magnitude less than during TWP-ICE (but not N_{15-20} or N_{20-25}) → shroud responsible for most shattering?

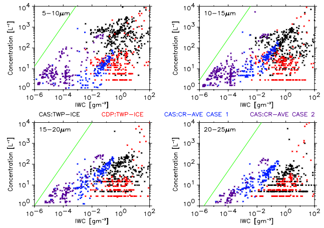

FIG 7: Concentration measured by CAS & CDP against IWC for TWP-ICE and CR-AVE case 1 (CIP activity) and case 2 (cold thin cirrus). Green lines correspond to derived relationships assuming maximum shattering on CAS shroud and inlet.

What causes CDP/CAS ratio to vary in ice clouds?

Look at distributions of shapes/sizes for Jan. 27 (TWP-ICE) to understand differences between CAS and CDP

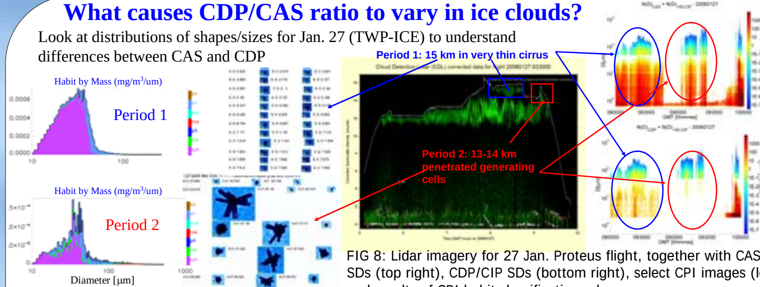

FIG 8: Lidar imagery for 27 Jan. Proteus flight, together with CAS/CIP SDs (top right), CDP/CIP SDs (bottom right), select CPI images (left) and results of CPI habit classification schemes

Few particles with D < 25 μm from CDP in Period 2 when recently generated larger pristine particles occur; their occurrence in Period 1 suggests CDP is able to detect them when present

Few particles with D > 200 μm in Period 1, but $N_{>3,CAS} > N_{>3,CDP}$?; shattering should not be as significant

Laboratory tests indicated differences in shapes between periods could not explain varying response of probes

Significance of Results

Differences in CAS/CDP response consistent with shattering/bouncing occurring on inlet and especially shroud of CAS.

If shattering explains discrepancy, N could be overestimated by 300%, extinction 106% and IWC 49% using CAS.

More observations in variety of meteorological conditions and using variety of probes (CAS, CDP and FSSP) required.

Acknowledgment: This research was supported by the Office of Science (BER), U.S. DOE Atmospheric Radiation Measurement (ARM) Program Grant Numbers DE-FG02-02ER63337 and DE-FG02-07ER64378.