# CLOUD PROPERTIES

# FROM

# COMBINED IIR AND CALIOP OBSERVATIONS

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# IIR/CALIOP Synergetic Analysis Background

- Work on single channel IR-Lidar combination to retrieve cloud properties as initiated by M.C.R PLATT in the 70's using LIRAD method

- Split Window Method in the IR for cloud property analysis (use of BTs) Inoue, 1985

- Emissivity analyses and microphysical retrievals (from emissivity Differences, C.Stubenrauch et al, 1999; ARA group), application to AIRS → stats

- Improvement of SWM using beta parameters allowing to minimize sensitivity to Cloud OD (F. Parol et al, 1991)

- Analyses of NOAA/AVHRR using beta, A. Heidinger, M. Pavolonis → PATMOS-x database

- IR–radar combined optimal analysis S. Cooper et al., 2005,
- Radar-Lidar-MODIS J. Delanöe and R. Hogan, 2010; IR-Lidar A. Sourdeval et al.,
- 2014

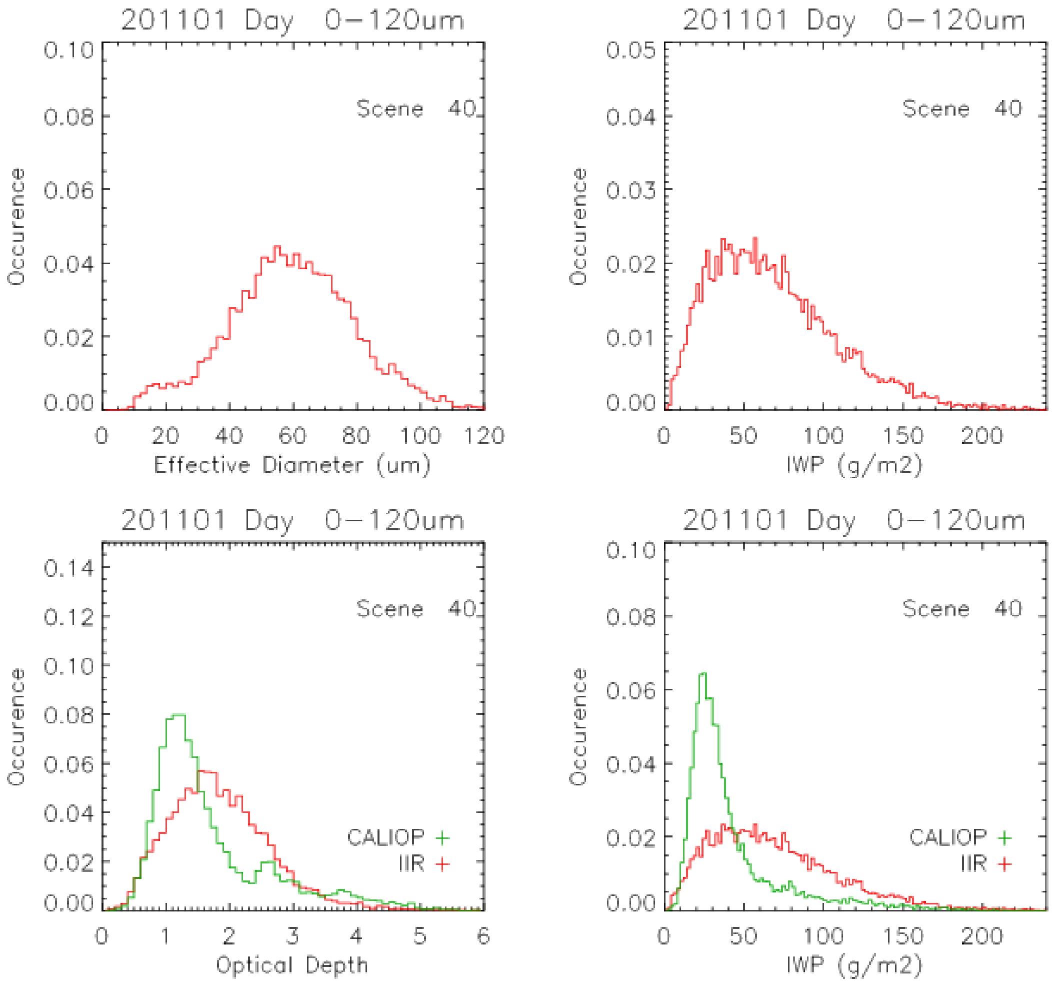
- Combined IIR-Lidar analysis using beta approach for CALIPSO (ATBD, 2006)

# Why ?

- Retrieval of Cloud Properties and radiative Feedbacks
- Infrared measurements are key parameters of numerical weather Prevision models (NWP) through data assimilation of IR clear (cloudy) radiances
- AIRS in the A-Train, and new IR operational satellites IASI/MetOp BUT …
- Remaining Challenges in NWPs :
  - Poor IWC prognostic (when available).
  - Radiances are mostly depending on cloud fraction and cloud microphysics (IWC and De), but no explicit way to account for De
  - Parametrizations of IWC(T) needed (derived from in situ and remote sensing, check agreement ?)
  - Mixed phase clouds (partition LWC-IWC, cloud feedback)

# Ice Cloud microphysics

## CALIPSO V3



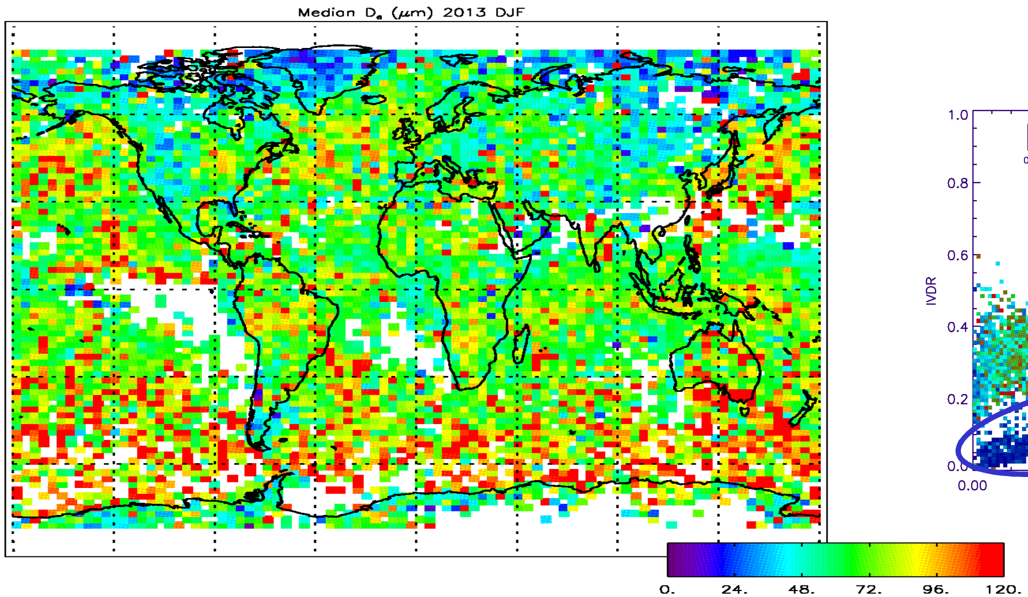

**IIR (categorized cloud types)**

**IIR – CALIOP V3**

**Larger CALIOP IWC in V4**

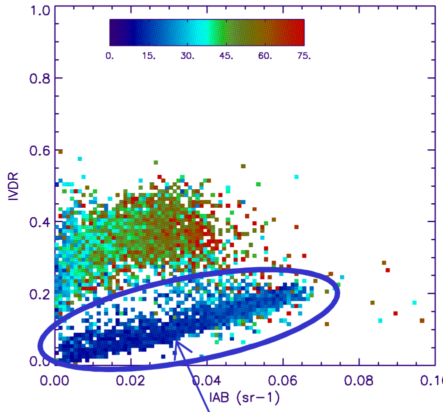
# CLOUD MICROPHYSICS

## GLOBAL EFFECTIVE DIAMETER IN UPPER LEVEL CLOUDS and IDENTIFICATION OF PHASE




IIR DJF for high
ST and opaque clouds

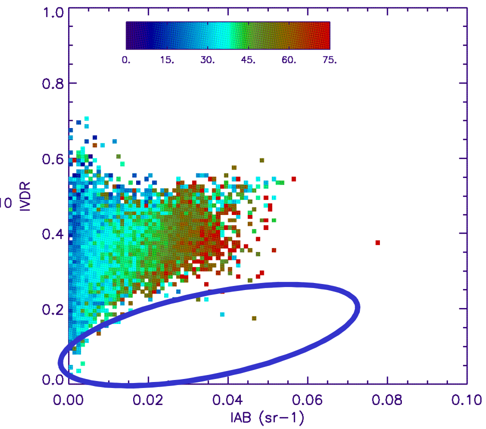
T > 233 K




Water clouds

De (color scale)

T< 233 K

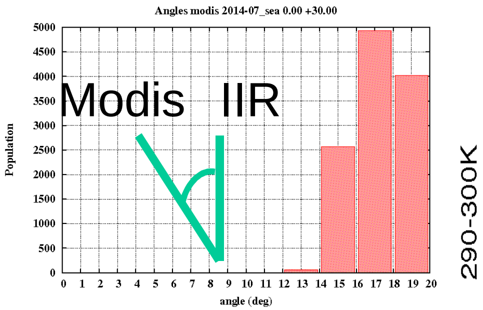


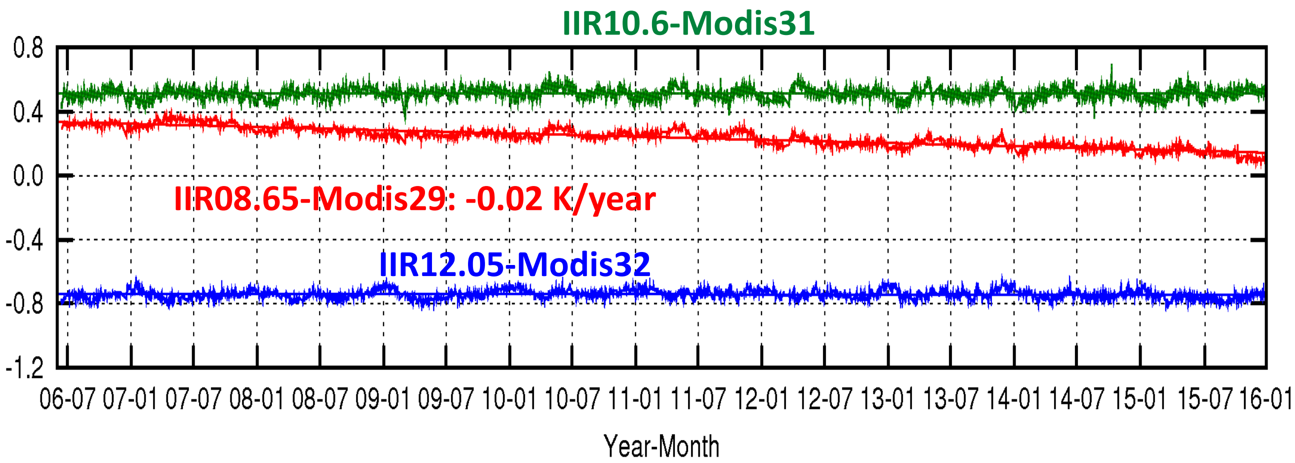

Ice Clouds only

**IIR resolution is 1 km, linked to CALIOP layer product benefiting from each-other**

# IIR – MODIS/AQUA Trends

**Tropics 290-300 K MODIS viewing angles: 12-20° (max: 16-18°) (Coll. 5)**




Nb pts: 3.7+e6

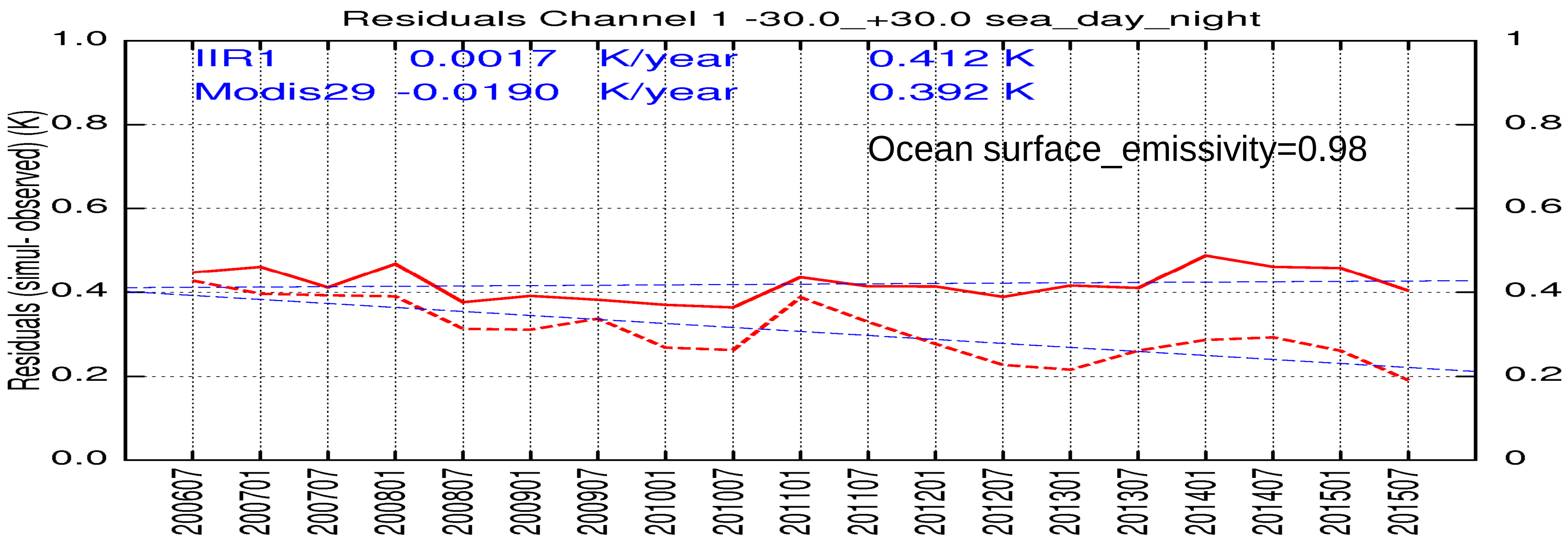
Std Dev: 0.48
0.63
0.48

| IIR/ MODIS | Observations 30S-30N 290-300 K | TIGR – Tropical air masses Clear sky simulations |
|---|---|---|
| IIR 08.65 – Modis 29 | 0.34 K (-0.02K/y) | 0° : 0.16 K ± 0.07 K<br>12°: 0.25 K **20°: 0.39 K** |
| IIR 10.60 – Modis 31 | 0.51 K | 0°: 0.23 K ± 0.25 K<br>12°: 0.30 K **20°: 0.40 K** |
| IIR 12.05 – Modis 32 | -0.74 K | 0°: -1.16 K ± 0.35 K<br>12°: -1.08 K **20°: -0.96 K** |

Overall, Agreement within **0.25 K**

# IIR - MODIS/AQUA BTDs

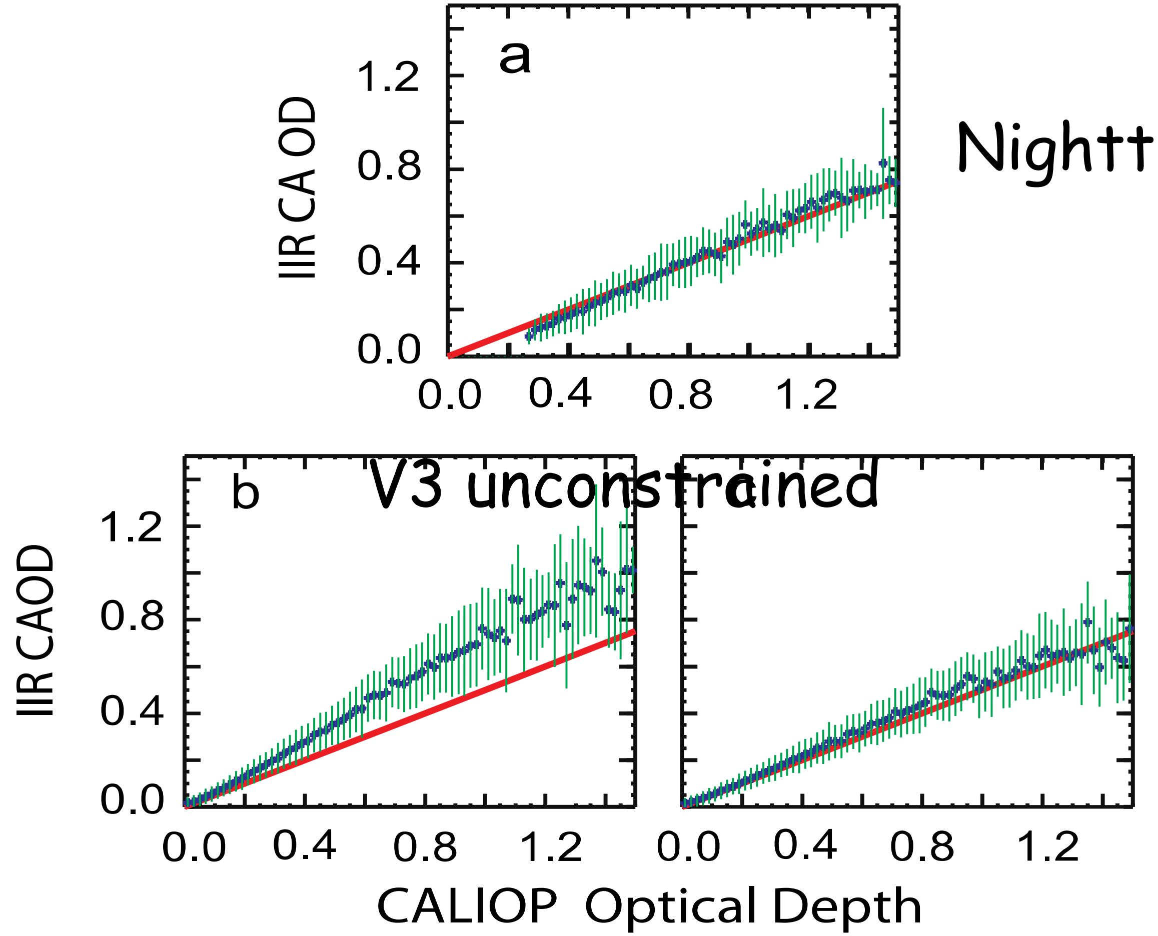
**4A RTM Simulations – clear sky observations over ocean**
**IIR 08.65µm (solid) & MODIS 29 (dashed) (ARA/LMD/IPSL; N. Scott and coll.)**




- Excellent stability and agreement of IIR w.r.t. MODIS/AQUA similar channels
- **No detectable trend of IIR calibration since CALIPSO launch.**

# Cirrus OD comparisons

**(IIR vs CALIOP)**



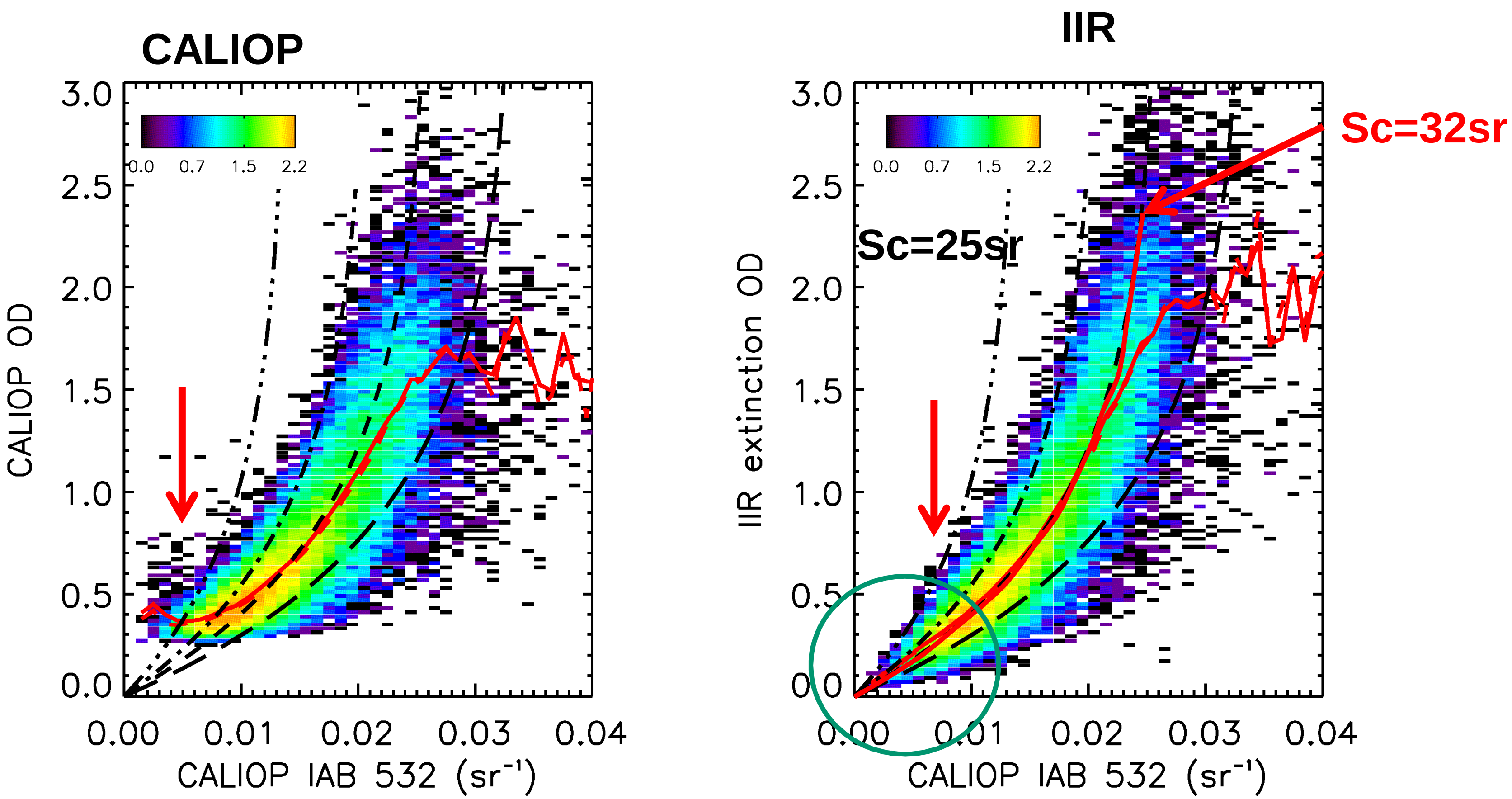

Nighttime
constrained

Garnier et al.,
ILRC, 2012
JAOT, 2012

→ IIR analyses showed that V3 CALIOP operational Lidar ratio equal to 25 sr was underestimated and that 32 sr was more appropriate

# Cirrus OD comparisons

**V3 constrained retrievals, single-layered, ROIs, ocean, Dec 2007 to Nov 2008**

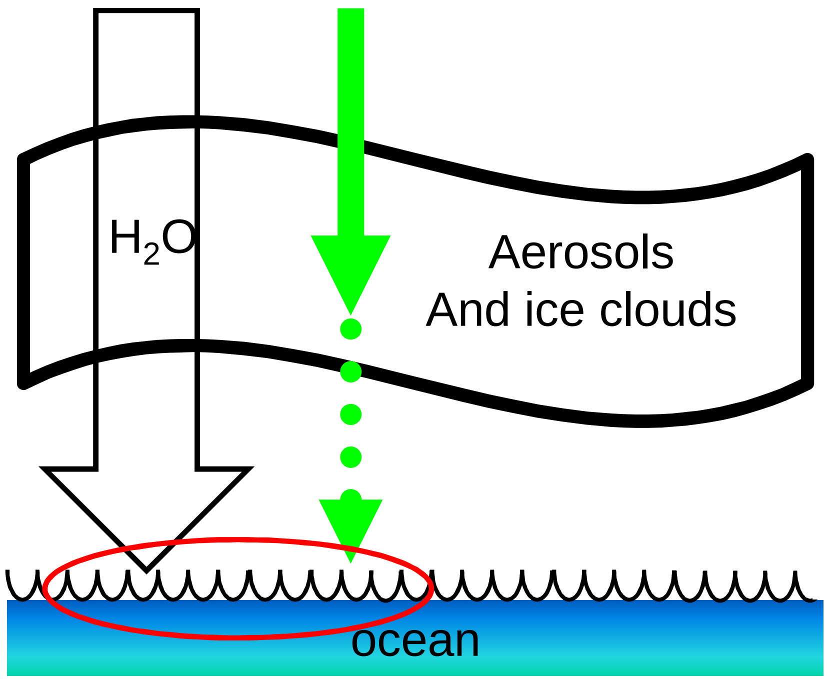



→ High sensitivituy of IIR / CALIOP Bias at low ODs corrected in V4

# Cirrus OD comparisons

**Taking advantage of A-Train synergies**

CLOUDSAT Beam (Reference) + CALIPSO Beam (Deviations) → **SODA-ICE**




An empirical relationship between CALIPSO ISB vs CLOUDSAT (σ) surface is well defined in clear sky conditions. It is used to retrieve **Total column optical depths.**

SODA data available on ICARE website

Josset et al., 2012

# Cirrus OD comparisons

Use of layer-integrated attenuated backscatter ($sr^{-1}$), Platt, JAS, 1973

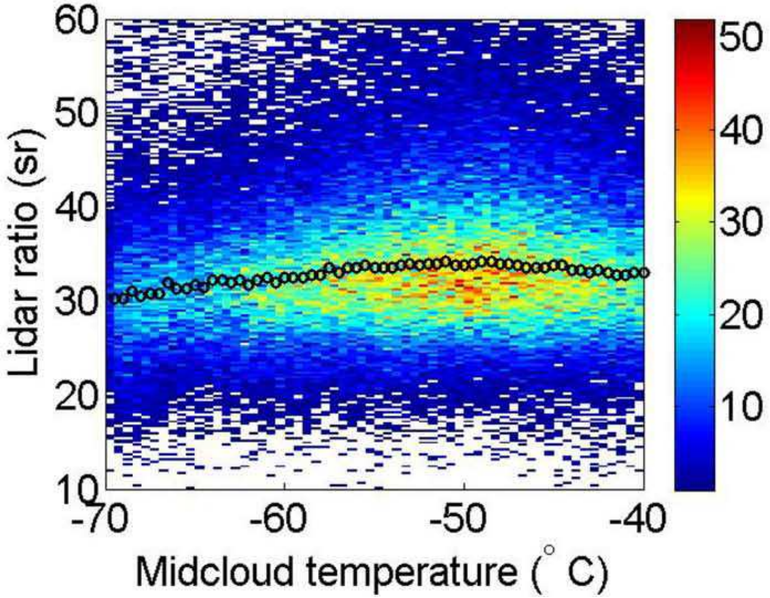
$$S^* = \eta \cdot S_{cal} = \eta_T \cdot S_{calt}$$

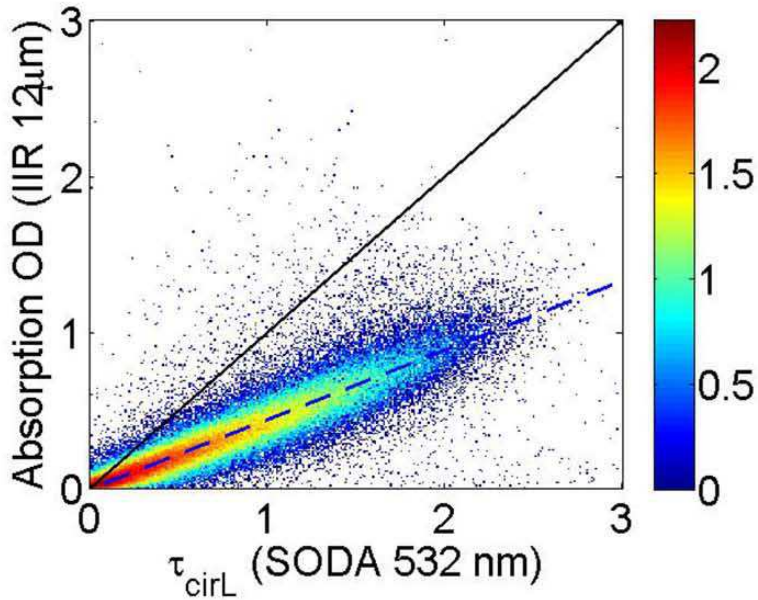
$$S^* = \frac{1 - T^2_{apparent}}{2\gamma'}$$

Josset et al. 2010
(η=0.6)
Sc=30 to 32 sr

**η = 0.6**

**SODA and CALIPSO/IIR**

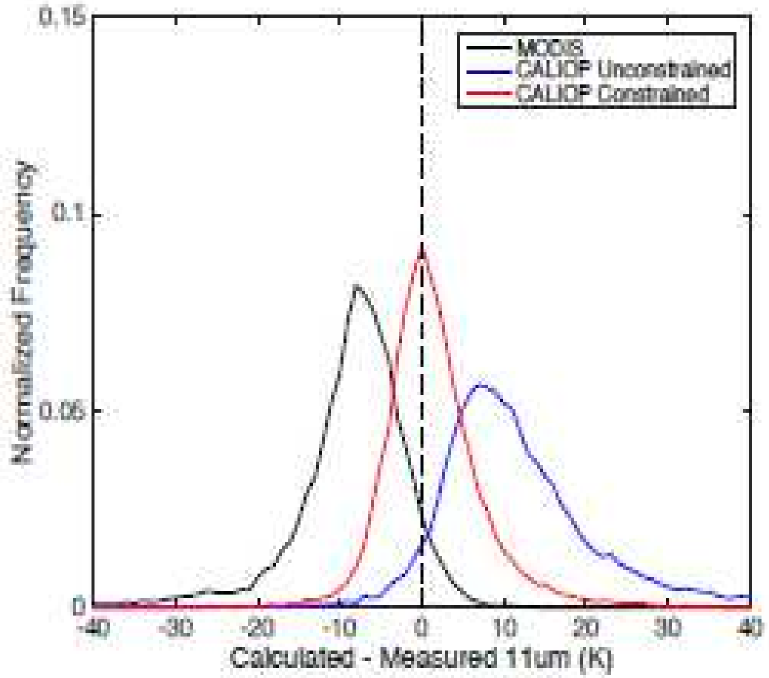


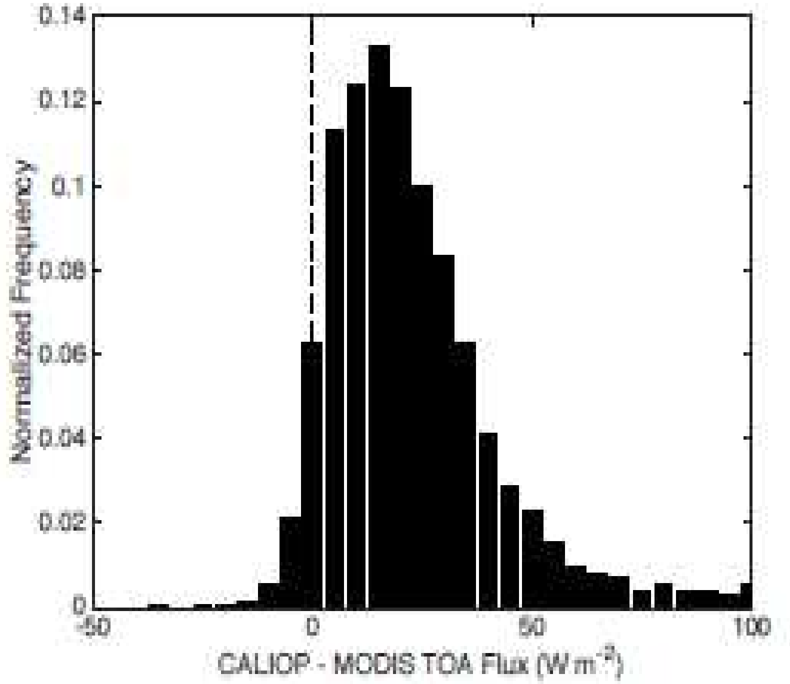




Convergence of results with IIR/CALIOP Garnier et al., JAOT, 2012

# Cirrus OD comparisons

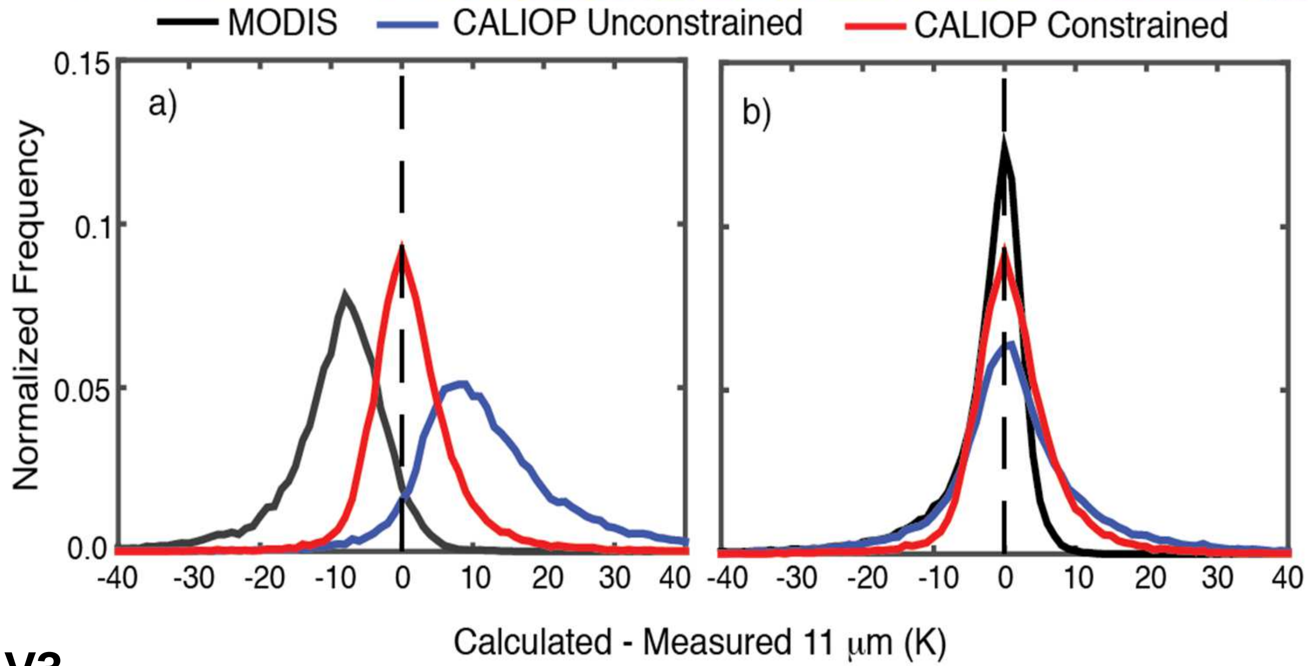
## CALIOP V3




Holz et al., ACP, 2015

# Cirrus OD comparisons

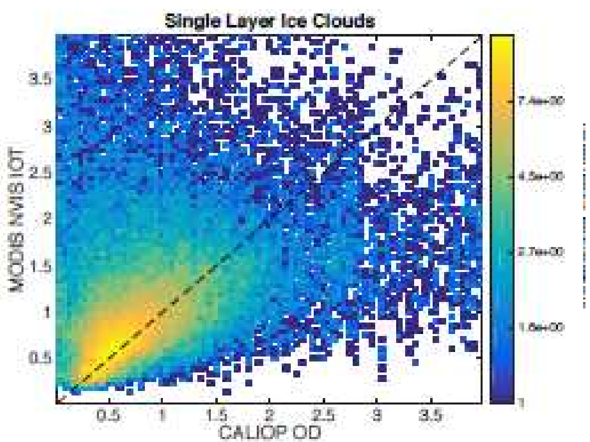



**CALIOP V3**

First discussions CCSTM in Madison, 2009

Conclusion CCSTM Newport News, 2016

DONE !!

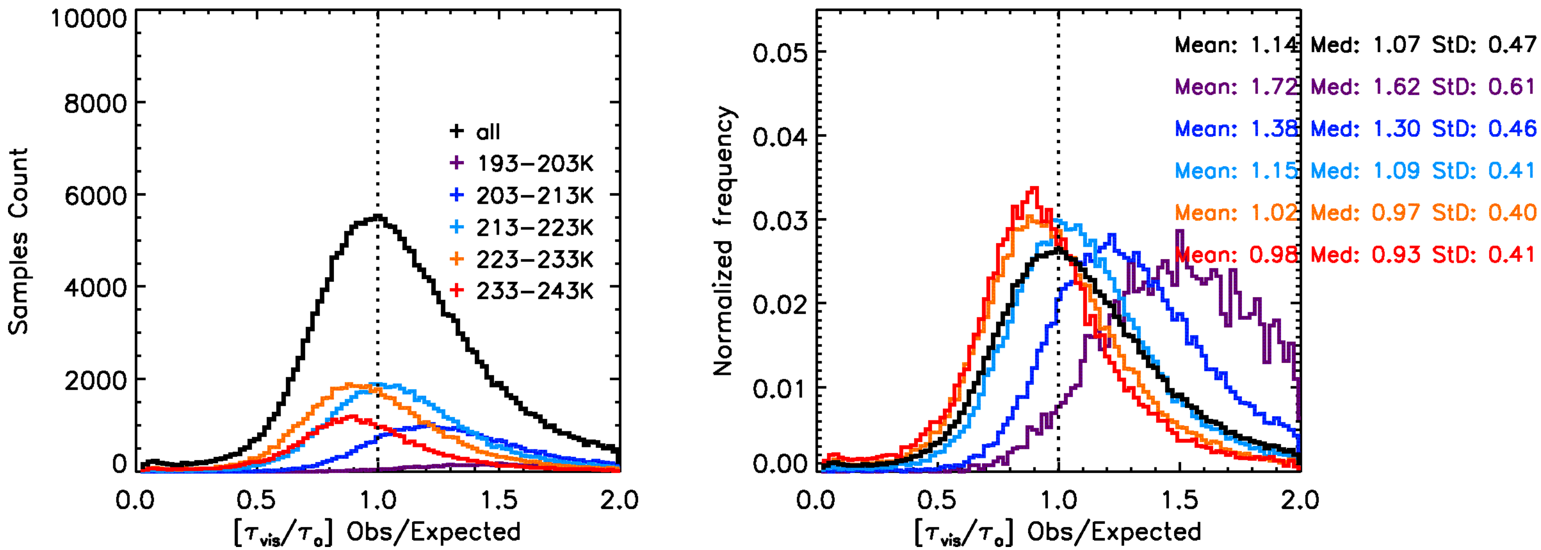



$S_c$=32 sr
+ MODIS coll. 6

Holz et al., ACP, 2015

# Cirrus OD comparisons

CALIOP constrained retrievals




In fact : Comparing CALIOP and IIR ODs
shows that average value is OK …

but looking to temperature

Distributions evidence **dependence WITH TEMPERATURE**

# Cirrus cloud Lidar ratios

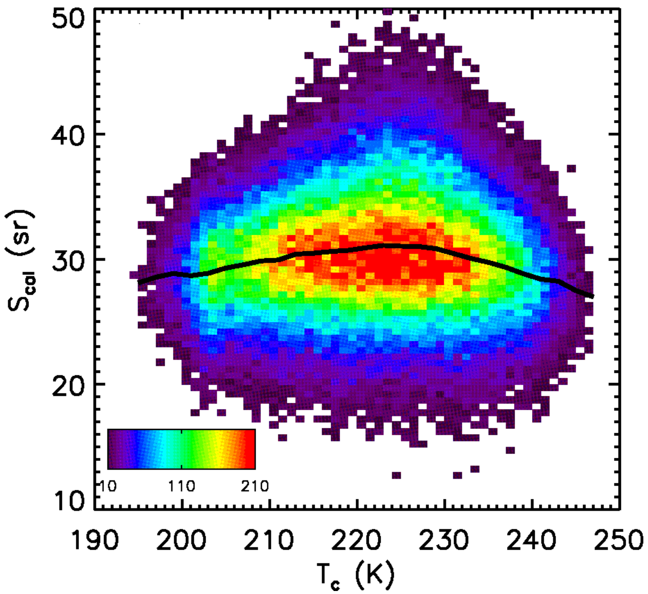
Use of layer-integrated attenuated backscatter ($sr^{-1}$), Platt, JAS, 1973

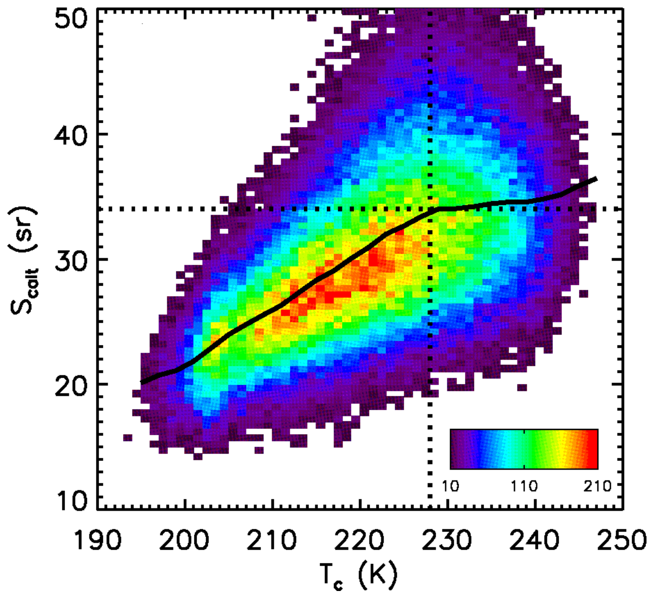
$$S^* = \eta \cdot S_{cal} = \eta_T \cdot S_{calt}$$

$$S^* = \frac{1 - T^2_{apparent}}{2\gamma'}$$

**η = 0.6 V3**

**η = f(T) V4**



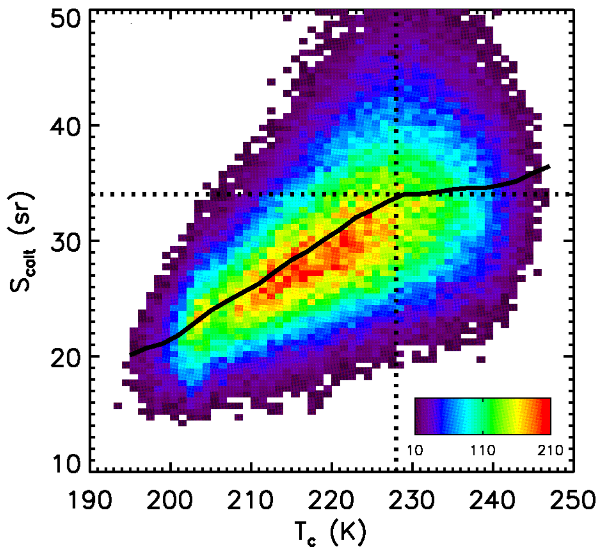

Same average value but different distribution

Garnier et al., AMT, 2015

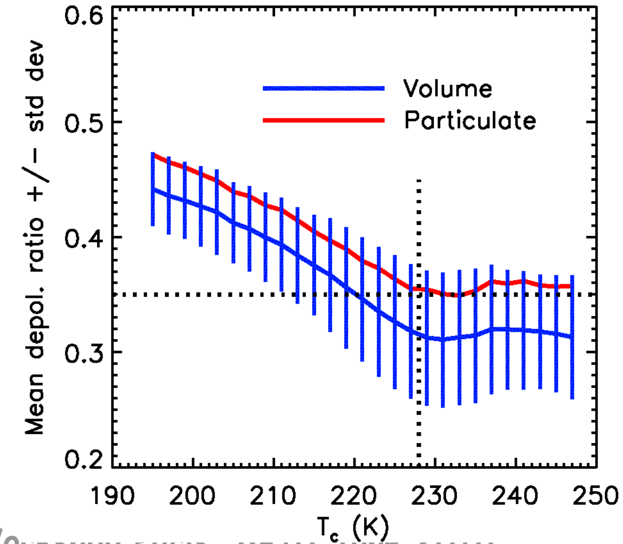
# Links with Cirrus cloud microphysics

The change in lidar ratio is corresponding to a change in microphysical properties derived from IIR (**more solid columns below 230 K**).

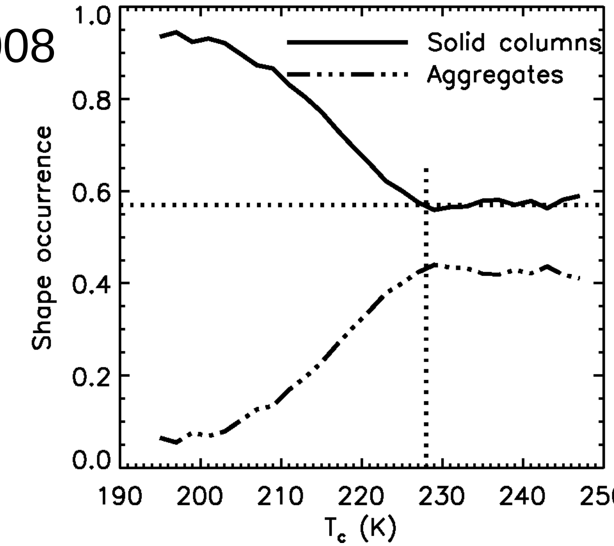
CALIOP depolarization is showing the same change in behavior most probably linked to a change in dominating particle shape




$\eta_T$ from G2015 study




2008



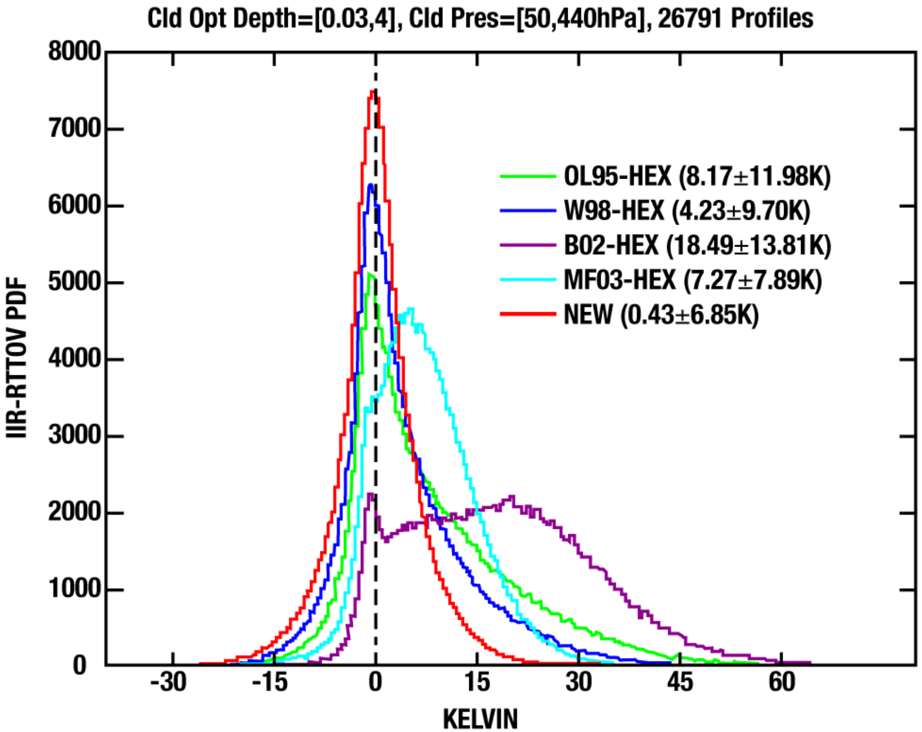
# Parametrizations

- Several data bases for IWC, De, PSD, shape f(T) to link in situ and remote sensing for ex. (not limitative)
  - Baran et al., 2011, 2014 (in situ)
  - Heymsfield et al., 2014 (in situ)
  - Garnier et al., 2012, 2014, 2015 (IIR)
  - Delanoë et al., 2010 … (Dardar)
  - …
- A-Train multiple observations foster combined analyses

# Cloud Parametrizations

All clouds
Final
B00257RW

(best with
small
and large
CODs)



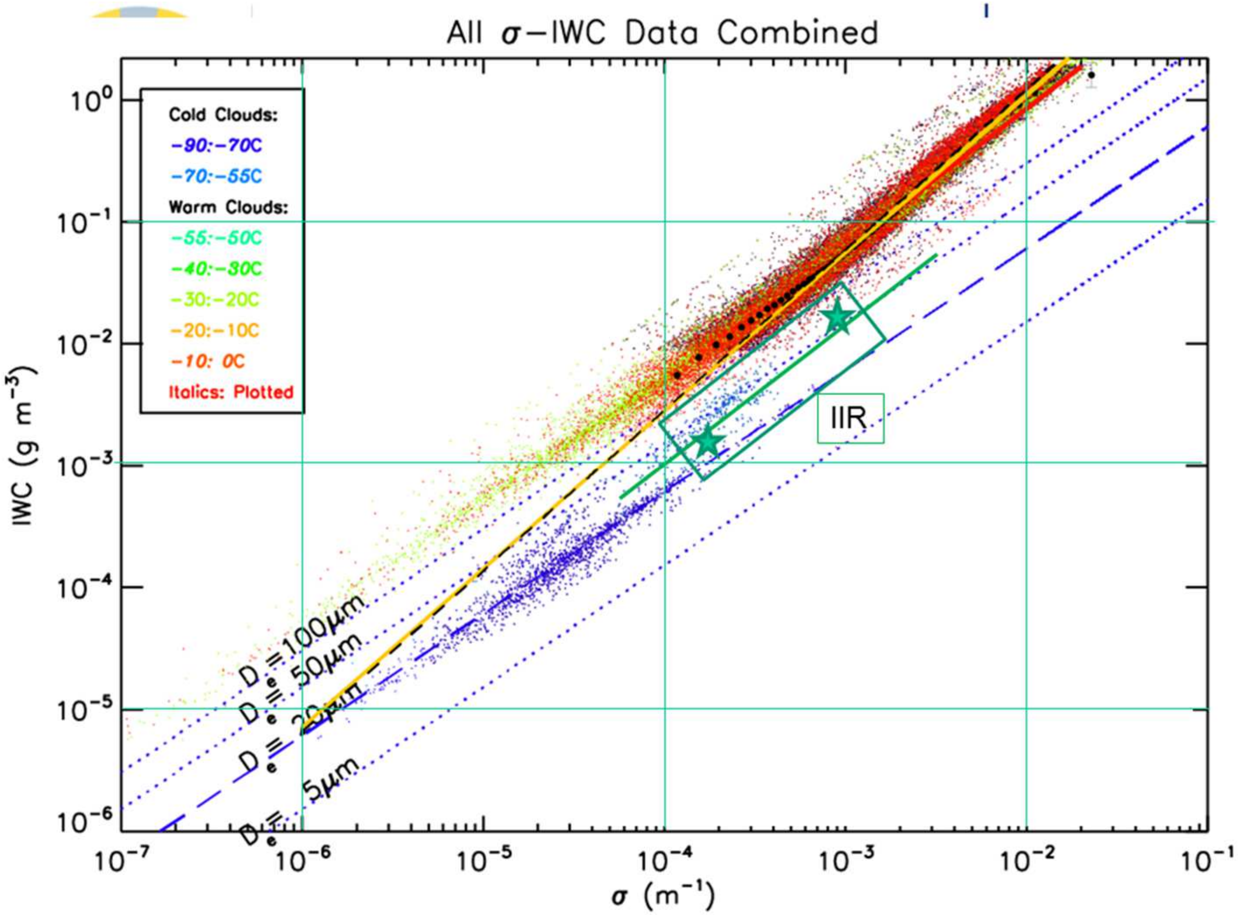

Distribution of TOA brightness temperature differences between IIR measurements and RRTOV simulations at 12 µm
Minimized over the whole database
-- > Final B02 shows very reduced bias resulting from the new parametrization → implementation in NWP

Look for optimized
Optical parameters
Relationship with
IWC, T

Using IIR and
Dardar/2C-ice
Inputs for TOA BT
Analysis :
RTTOV op RTM
NWP-SAF
study at CMS

**Vidot et al., JGR, 2015**

# Ice Particle Size : De, IWC, T




IWC-s
From
Heymsfield et al.
2014

IIR obs :
20 to 80 µm
Domain

+
Garnier et al.
2013

## Other uses of IIR data :

- **Cloud dynamics in convective systems using MODIS and IIR (J. Luo)**
- **Ice cloud formation analysis (D. Mitchell)**
- **Desert dust (uptake and radiative impact over China) (B. Chen)**
- **Mineral particles from Volcanic eruption (J. P. Vernier)**
- **…**

# SUMMARY

IIR/CALIOP are high value measurements for Clouds (and Aerosols) : global analysis of microphysics /IIR cloud type.

Combined approach was very successful within V3 and V4 preparation.

Analysis of clouds and aerosols forcings requires more focus on water/ice clouds and mixed phase clouds : Improving microphysics of Ice/Water/mixed clouds is a further step in V4 (+ new L3).

IIR and CALIOP are highly beneficial to each other. Strong need to keep this link in forthcoming missions.