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MODIS Collection 6 Cloud Thermodynamic Phase Discrimination and Comparisons with MODIS Collection 5, CALIOP and PARASOL

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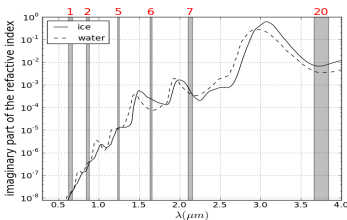
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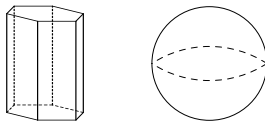
Conclusions

MODIS Cloud Phase Discrimination (Introduction) :

Why is it important to continue improving the cloud phase discrimination ?



Imaginary part of the refractive index for liquid and ice particles



Spherical vs. non spherical particles

- cloud and climate modelling
- cloud remote sensing.

Why is it important for cloud remote sensing ?

⇐ (fig) different optical properties between ice and liquid particles

⇒ Strong impact on the MOD06 product.

⇒ Cloud Phase is an important first step for the MODIS cloud optical product.

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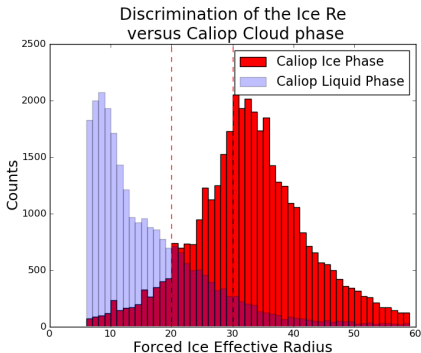
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How cloud phase pixel classification works in C6 :

New Cloud Phase Discrimination Algorithm (No longer use cloud mask tests)

MODIS C6 cloud phase algorithm is based on

- C6 1km Cloud Top Temperature,
- C6 1km Cloud Phase Infrared [*Baum et al. (2012)*] ,
- a $1.38 \mu m$ reflectance test,
- and 3 Cloud Effective Radius tests.



- Re retrieval at $1.6 \mu m$
- Re retrieval at $2.1 \mu m$
- Re retrieval at $3.7 \mu m$

⇐ (fig) C5 SWIR reflectance ratio tests are replaced by Re tests (using the new Ice LUT model). (see also : Bob Holz et al. talk)

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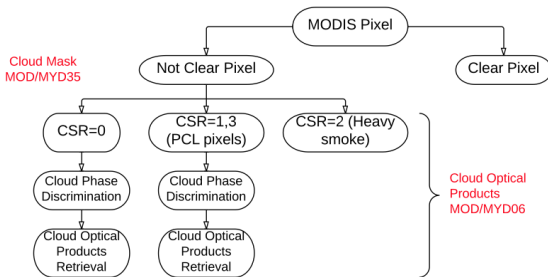
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Cloudy Pixel Populations Differences (C6 vs C5) :

Is the cloud phase reported for the same pixel population as C5 ?



- C5 : cloud phase discrimination are reported only when CSR = 0
- C6 : cloud phase discrimination are reported when CSR = 0,1,3
- CSR (Clear Sky Restoral) algorithm has been improved for C6 (see Kerry Meyer's presentation on Thursday)

⇒ What are the differences between MODIS C5 and C6 at a granule level ?

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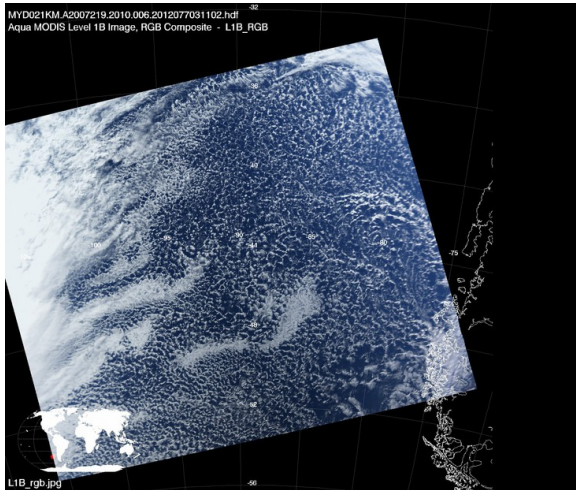
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Broken Clouds : RGB image (2007-2010)



⇒ Example of Broken Clouds (What is the differences between MODIS C5 and C6 Cloud Phase?)

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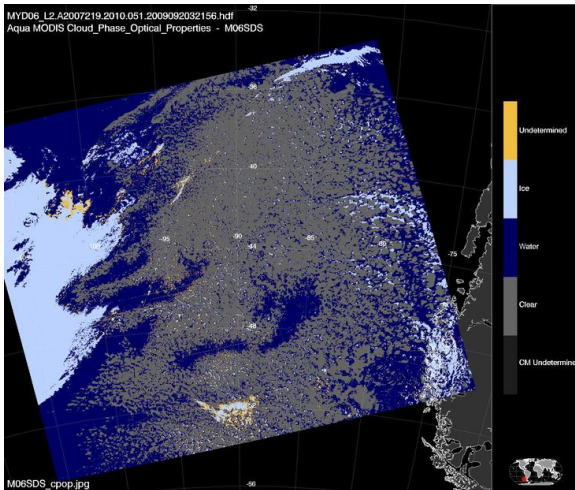
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Broken Clouds : MODIS C5



Colorscale :

- Dark Blue : Liquid Clouds
- Light Blue : Ice Clouds
- Yellow : Undet. Clouds
- Light Grey : Clear Sky or CSR=1,2,3

⇒ MODIS C5 Shortcomings : False Ice cloud phase discrimination for broken clouds.

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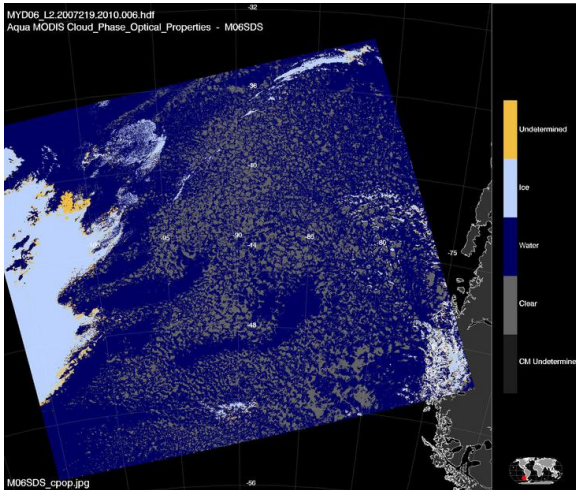
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Broken Clouds : MODIS C6



Colorscale :

- Dark Blue : Liquid Clouds
- Light Blue : Ice Clouds
- Yellow : Undet. Clouds
- Light Grey : Clear Sky or CSR=2

⇒ MODIS C6 : globally a better cloud phase discrimination for broken clouds

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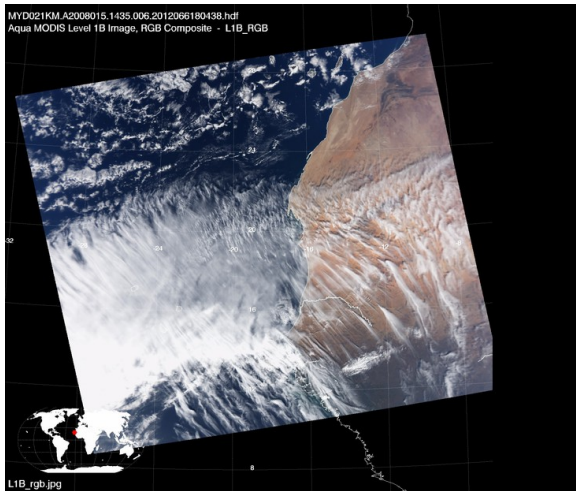
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Ice Clouds : RGB image (2008-015-1435)



⇒ Example for Ice Clouds (What is the differences between MODIS C5 and C6 Cloud Phase ?)

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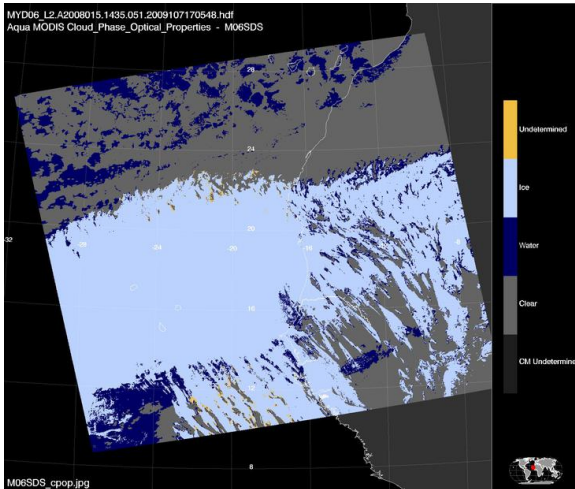
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Ice Clouds : MODIS C5



Colorscale :

- Dark Blue : Liquid Clouds
- Light Blue : Ice Clouds
- Yellow : Undet. Clouds
- Light Grey : Clear Sky or CSR=1,2,3

⇒ MODIS C5 Shortcomings : False liquid cloud phase discrimination at ice cloud edges.

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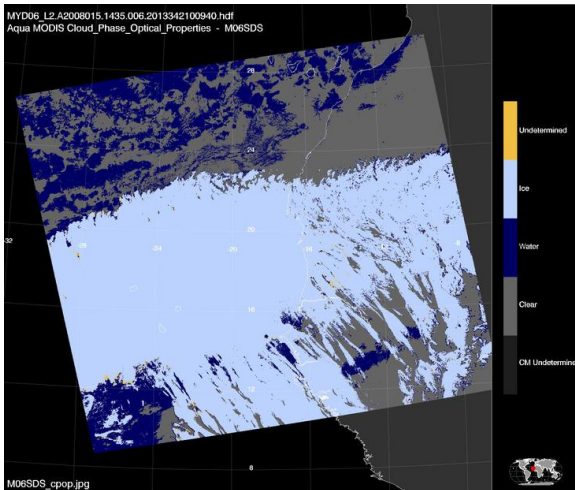
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Ice Clouds : MODIS C6



Colorscale :

- Dark Blue : Liquid Clouds
- Light Blue : Ice Clouds
- Yellow : Undet. Clouds
- Light Grey : Clear Sky or CSR= 2

⇒ Better cloud phase discrimination for ice cloud edges.

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Comparisons Caliop-Modis : Data Screening (1/2)

What data screening has been used for these comparisons ?

- Calipso/Caliop 1km & 5km product version 3 and Aqua/MODIS
- Caliop and Modis data from January and July 2008
- Caliop Version 3 of Cloud thermodynamic Phase :
 - Liquid Cloud
 - Ice Cloud (ROI Randomly Oriented Ice)



- Caliop : only one cloud layer found
- Surface flags (Modis)
- (Opt.) Opacity flags (Caliop)
- (Opt.) with/without snow/ice surface flags (Modis)

⇒ about 45 different data screenings

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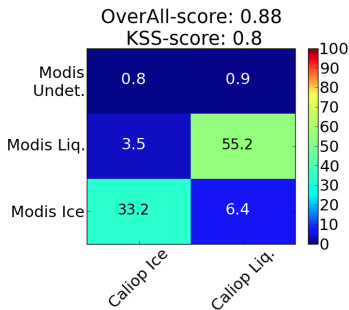
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Comparisons Caliop-Modis : Data Screening (2/2)

Which methodology has been used to compare Modis and Caliop ?

⇒ Development of contingency tables (3×2)

⇒ Definition of skill scores (for the analysis of association)



Two skill scores :

- OverAll Score $[0, 1]$

$$score = \frac{a_{31} + a_{22}}{\sum_{i=1}^3 \sum_{j=1}^2 a_{i,j}}$$

- KSS Score $[-1, 1]$
(Hanssen-Kuiper Skill Score)

$$score = \frac{(a_{21} * a_{32} - a_{22} * a_{31})}{(a_{21} + a_{31})(a_{22} + a_{32})}$$

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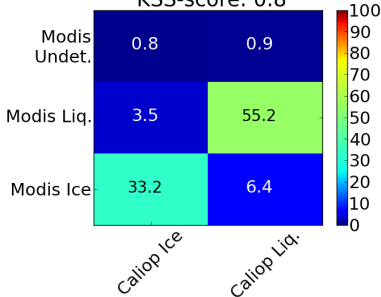
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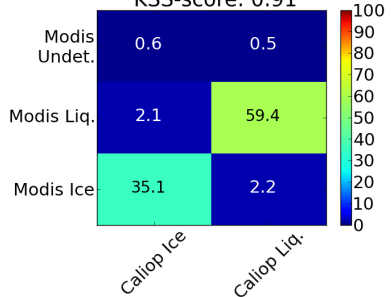
Comparisons Modis-Caliop : Over Open Ocean, All Clouds

Cloud Thermodynamic Phase retrieval comparisons between MODIS C5 and C6 overcast clouds versus CALIOP v3 :

MODIS C5 Cloud Phase
 No-Opaque-Clouds Flag,Ocean
 Without Snow/ice surface,
 OverAll-score: 0.88
 KSS-score: 0.8



MODIS C6 Cloud Phase
 No-Opaque-Clouds Flag,Ocean
 Without Snow/ice surface,
 OverAll-score: 0.95
 KSS-score: 0.91



⇒ better agreement between MODIS C6 and CALIOP over Ocean

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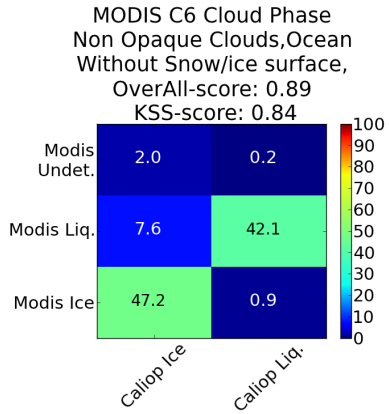
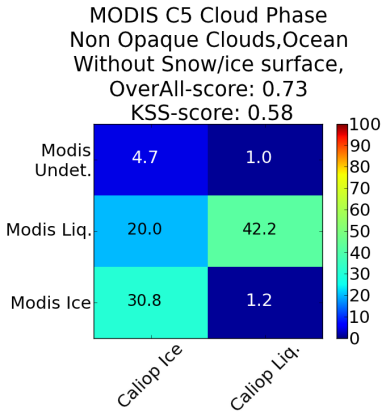
Over Snow/Ice Desert

MODIS-PARASOL

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Comparisons Modis-Caliop : Over Ocean, Caliop Non Opaque

Cloud Thermodynamic Phase retrieval comparisons between MODIS C5 and C6 overcast clouds versus CALIOP v3 :



⇒ better agreement between MODIS C6 and CALIOP over Ocean Non Opaque

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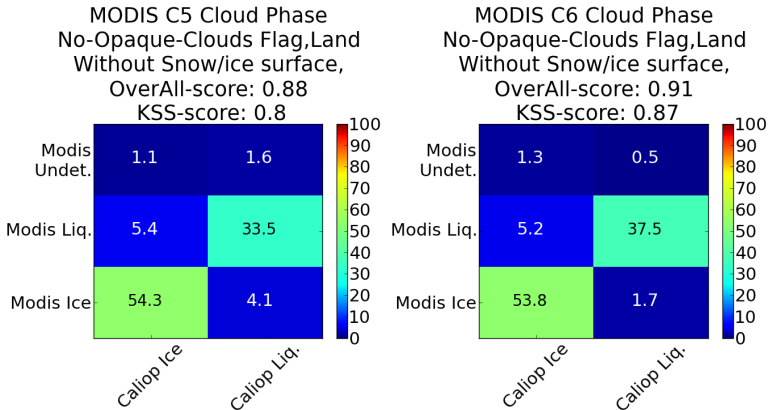
Over Snow/Ice Desert

MODIS-PARASOL

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Comparisons Modis-Caliop : Over Land, All Clouds

Cloud Thermodynamic Phase retrieval comparisons between MODIS Collection 5 (C5) and Collection 6 (C6) versus CALIOP v3 over Land :



⇒ better agreement between MODIS C6 and CALIOP over Land

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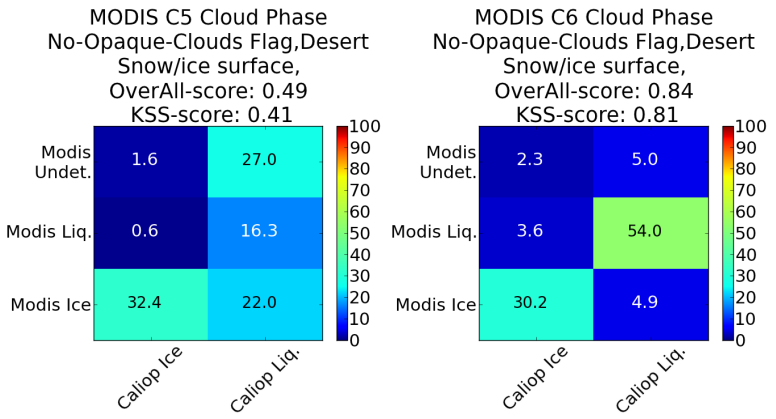
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Comparisons Modis-Caliop : Over Snow/Ice Desert, All Clouds

Cloud Thermodynamic Phase retrieval comparisons between MODIS Collection 5 (C5) and Collection 6 (C6) versus CALIOP v3 (Snow or Ice) & Desert :



⇒ better agreement between MODIS C6 and CALIOP over Snow/ice Desert

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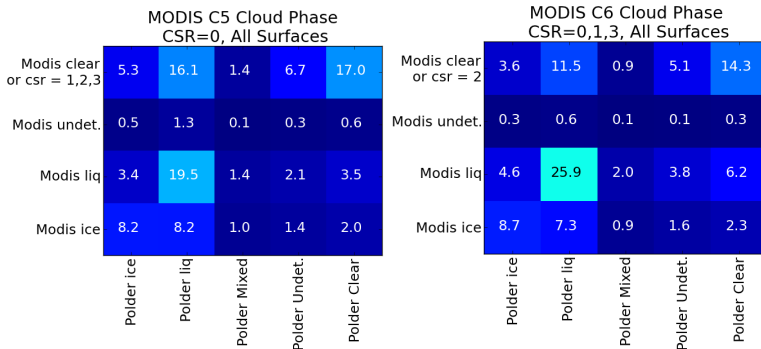
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MODIS-PARASOL

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Comparisons Modis-Polder : Global overview

Cloud Thermodynamic Phase retrieval comparisons between MODIS Collection 5 (C5) and Collection 6 (C6) versus PARASOL/POLDER :



⇒ MODIS Liq. - POLDER Ice : Broken Clouds ?

⇒ MODIS Ice. - POLDER Liq. : Multilayer Clouds ?

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Conclusions :

MODIS C6 CloudThermodynamic Phase :

- New Cloud Phase Discrimination Algorithm Logic
(No longer use cloud mask tests)
Based on the new C6 Ice LUT model.
- Comparisons MODIS C6 vs C5
 - ⇒ Better cloud phase discrimination for Broken clouds.
 - ⇒ Better cloud phase discrimination for Ice cloud Edges.
- Comparisons MODIS C6 vs CALIOP
 - ⇒ Globally a better agreement between MODIS and CALIOP
 - ⇒ Substantial improvement over Desert/ Snow Ice Surfaces.
- Comparisons MODIS C6 vs POLDER