MASTERTHESIS – STATUS REPORT – DWD – HERZ MEETING
07. NOVEMBER 2014

ASSESSMENT OF SOURCES OF SYSTEMATIC DIFFERENCES BETWEEN SIMULATED AND OBSERVED SATELLITE IMAGES

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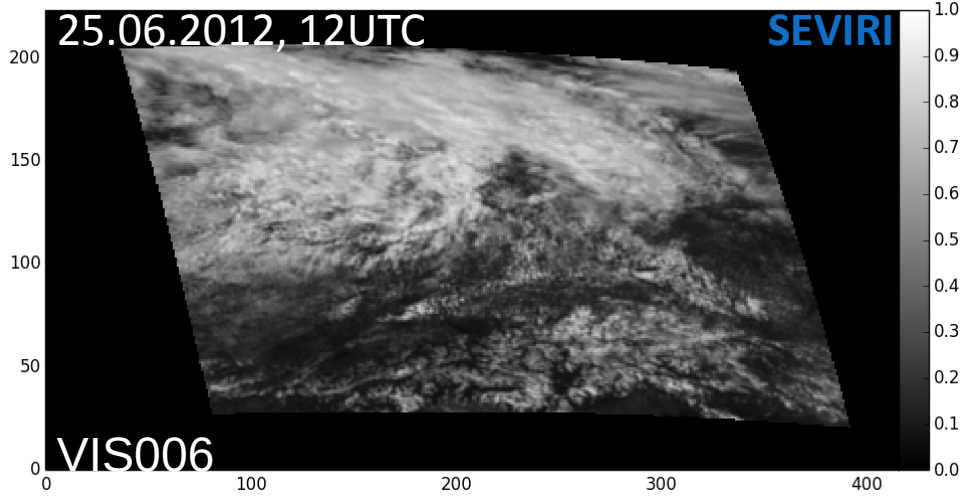
Topic

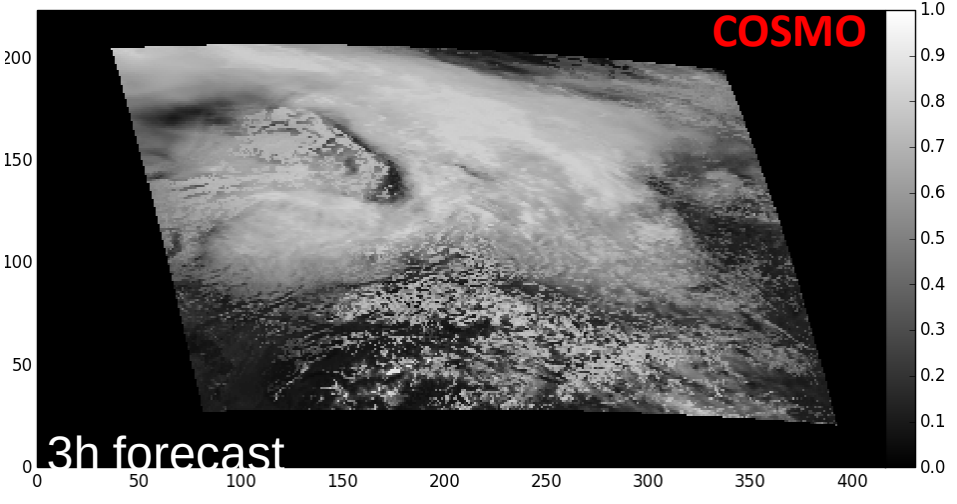
Motivation: Systematic differences pose a severe problem for data assimilation!

Question: **What are the reasons for systematic differences?**

Goal: - Quantification of systematic and random differences

- Reasons for systematic and random differences





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Data & Metrics

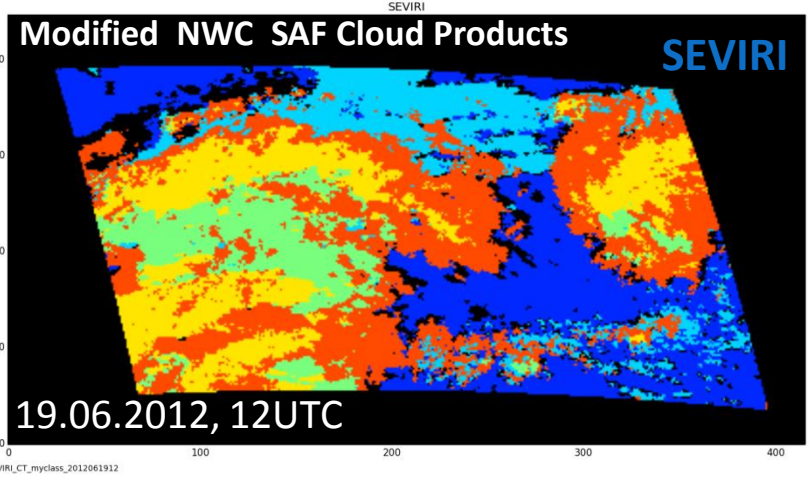
DATA

- Test period: **10 – 28 June 2012** - operational COSMO-DE forecasts (COSMO 4)
  - add. forecasts with 1-mom. micro. phys. (COSMO 5)
  - add. forecasts with 2-mom. micro. phys. (COSMO 5)
- NWC SAF: **Cloud Type (*CT*)** product for MSG SEVIRI
  Cloud Top Height (*CTH*) information for MSG SEVIRI
  (*NWC*: NoWCasting / *SAF*: Satellite Application Facility)
- EUMETSAT: **Clear Sky ReFLectance (*CSRFL*)** for MSG SEVIRI

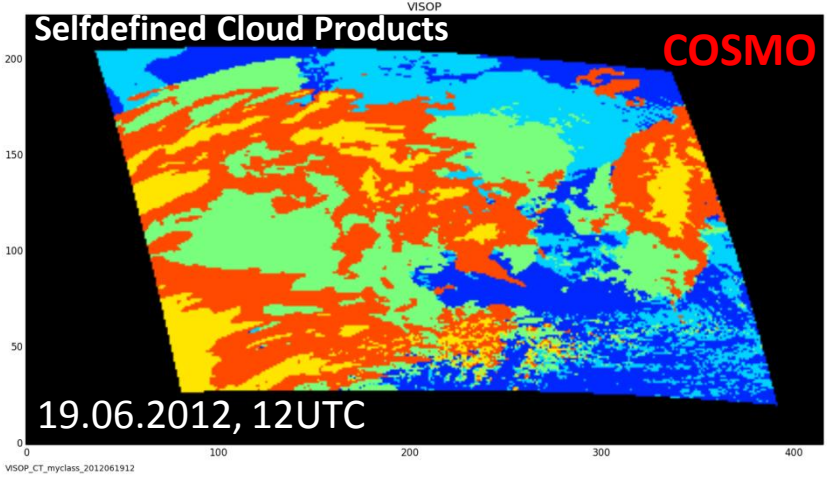
METRICS

- Reflectance histograms (with CT information)
- 2D histograms (with CTH information)
- Contingency tables (generated with CT or CSRFL)

Cloud Type Product



Fractional
Semi-trans.
High
Medium
Low
Cloud free
Off field



Height levels:

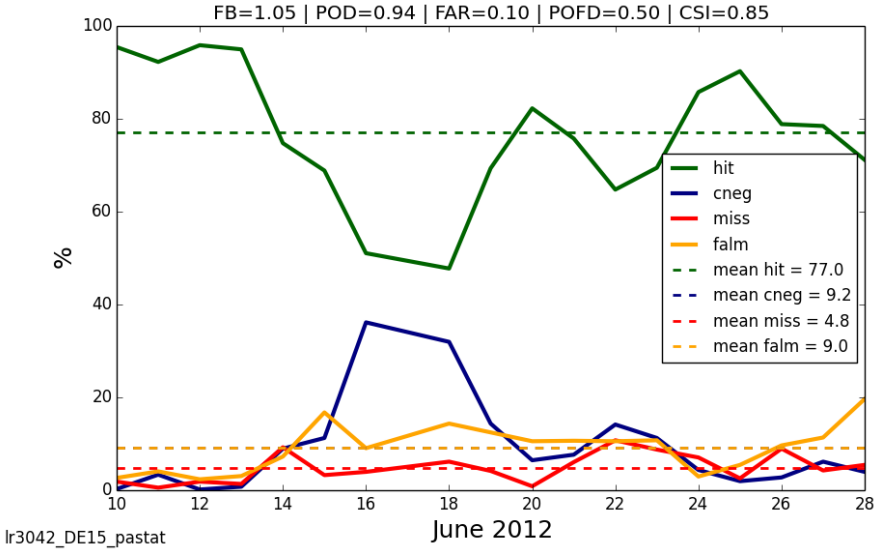
- *high* < 350hpa
- 650hpa/3.5km ≥ *medium* ≥ 350hpa/7km
- *low* > 650hpa

Optical depth:

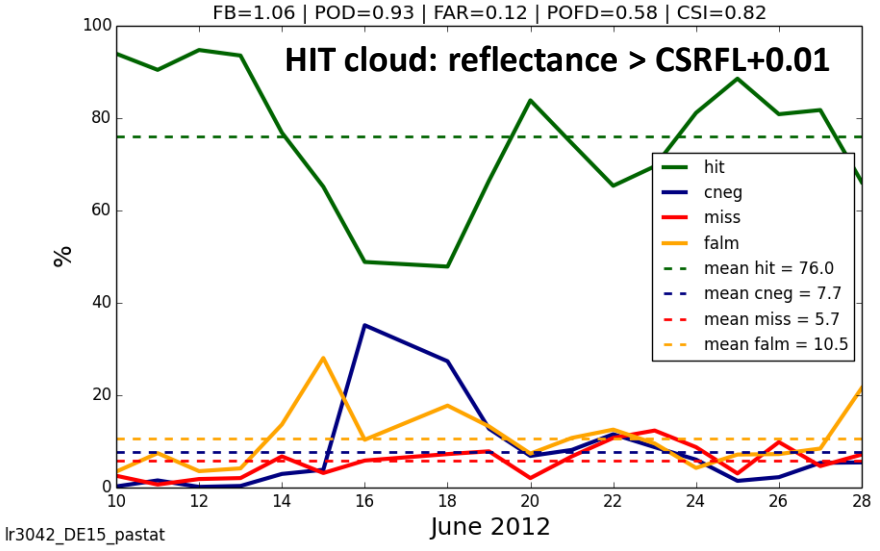
- *cloud free* < 0.1
- 0.1 ≤ *semi-transparent clouds* ≤ 1
- *opaque clouds* > 1

Contingency table for cloudiness

Cloud Type Product



Clear sky reflectance



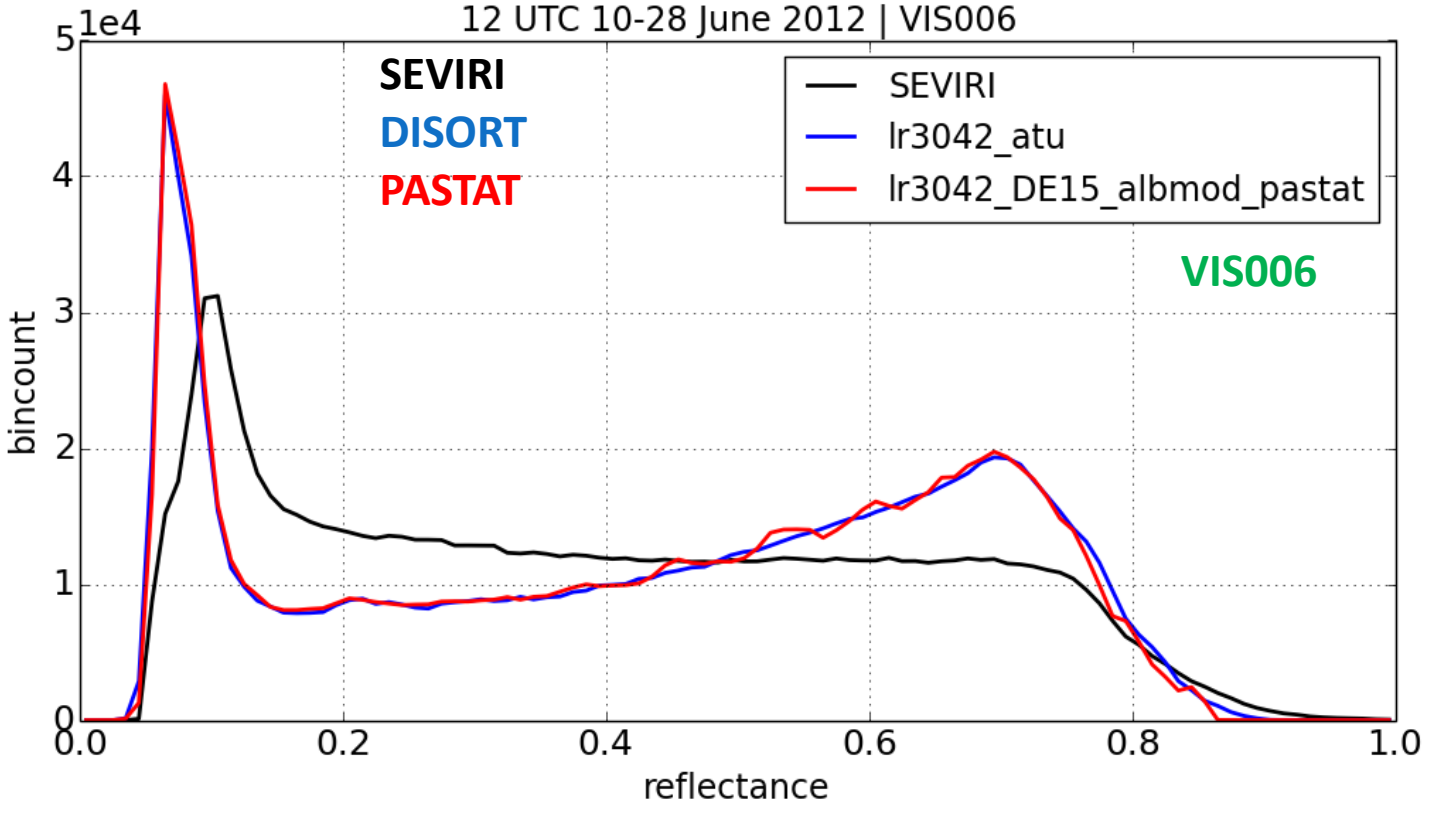
12 UTC	Cloudy *obs.*	Cloud-free *obs.*
Cloudy model	**hit** **77.0%** | **76.0%**	**false alarm** **9.0%** | **10.5%**
Cloud-free *model*	**miss** **4.8%** | **5.7%**	**correct neg.** **9.2%** | **7.7%**

Contingency table for cloudiness

12 UTC	3h forecast	VISOP	Cloud type	Clear sky reflectance
Correctly classified	**86.2 %**	**83.7 %**
FBI / ***frequency bias*** *(overforecasted if greater 1)*	**1.05**	**1.06**
POD / ***probability of detection*** *(perfect score if 1)*	**0.94**	**0.93**
FAR / ***false alarm ratio*** *(pefect model if 0)*	**0.10**	**0.12**

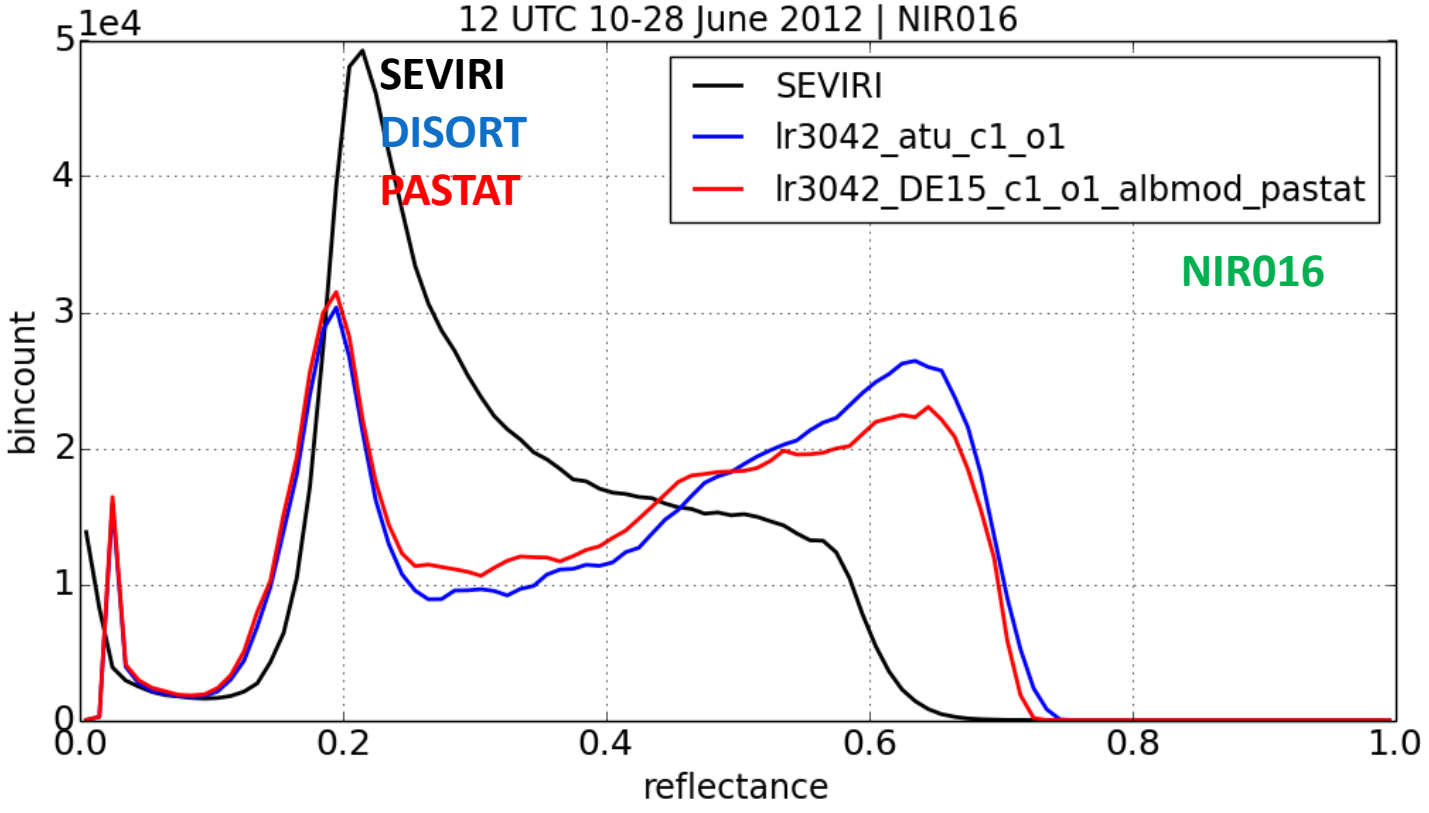
More **false alarm´s** than misses → **too many clouds in the model**

DISORT vs. PASTAT



Reflectance histogram peak curve

DISORT vs. PASTAT



Reflectance histogram peak curve

- For the NIR channel bigger differences between DISORT and PASTAT as for the VIS channels

Sensitivity study

Sensitivity studies performed to determine sources for systematic differences

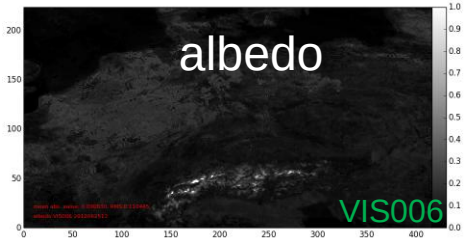
MODEL: (COSMO 4.28/5.0)

1. Lead time
2. Different microphysics schemes
   a. 1-moment scheme
   b. 2-moment scheme

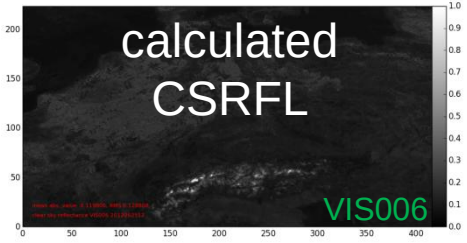
OPERATOR: (DISORT/PASTAT)

1. Albedo
2. Sub-grid water
3. Atmosphere
4. Aerosol
5. LibRatran version
6. No ice/water

SEVIRI albedo calculated with the SEVIRI CSRFL



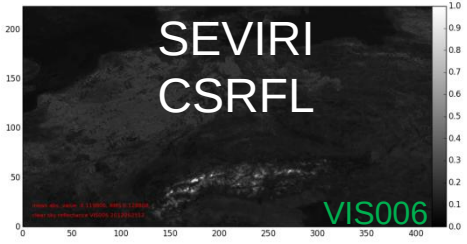
OPERATOR
with clouds
turned off



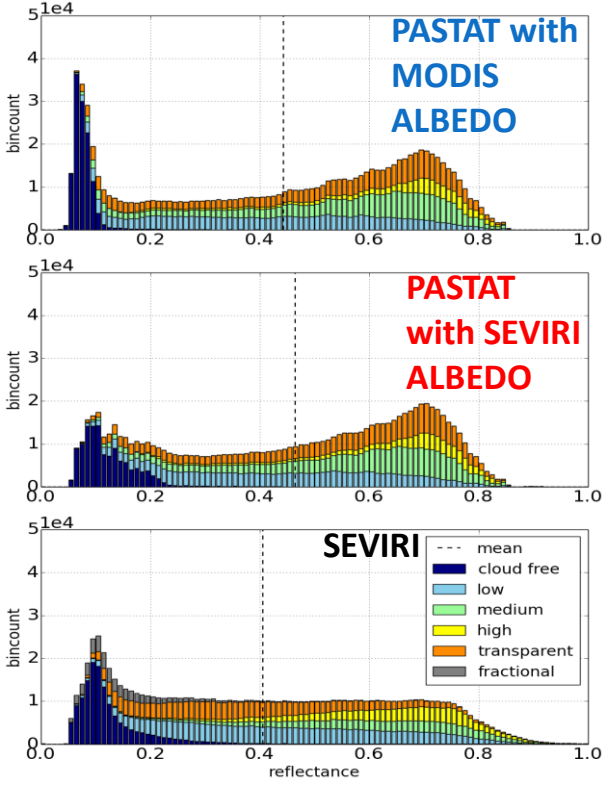
Change albedo

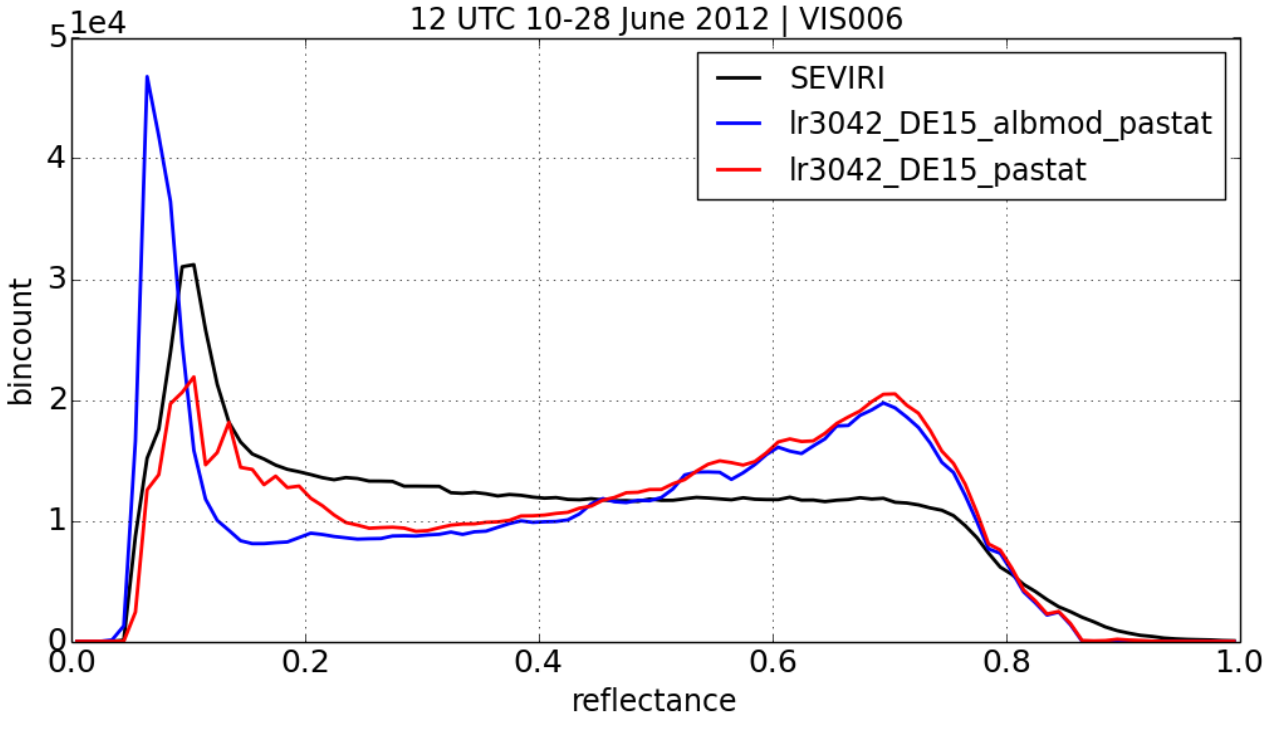
≠ | = ☺

Change the albedo iteratively till the calcualted CSRFL is the same as the SEVIRI CSRFL



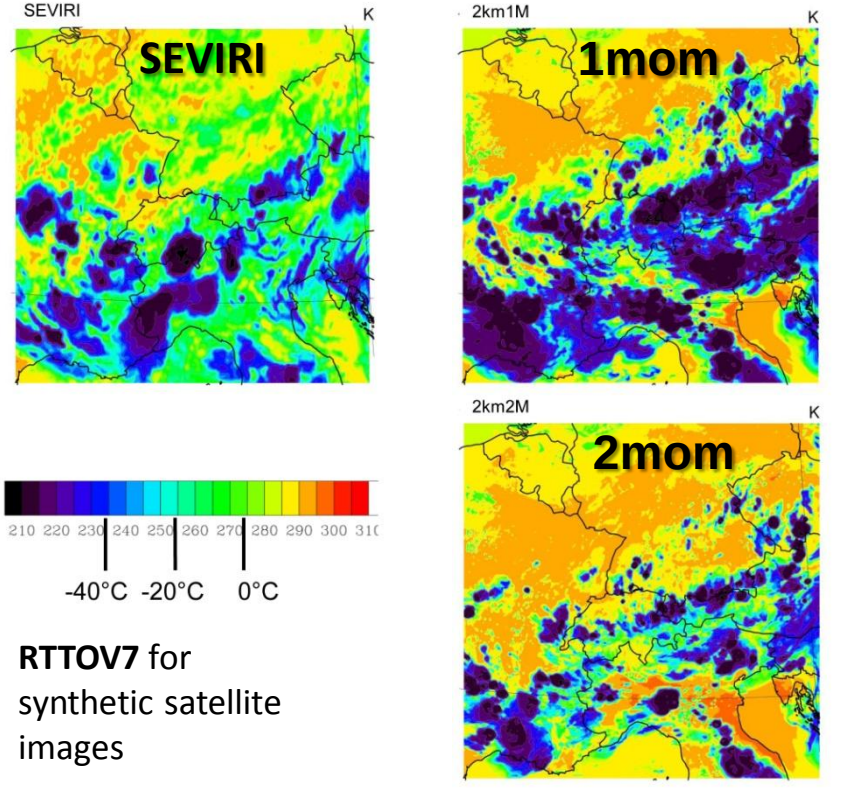
Sensitivity to albedo





- **Reflectance of cloud free pixel** depends strongly on the **albedo**

Sensitivity to microphysics - Motivation



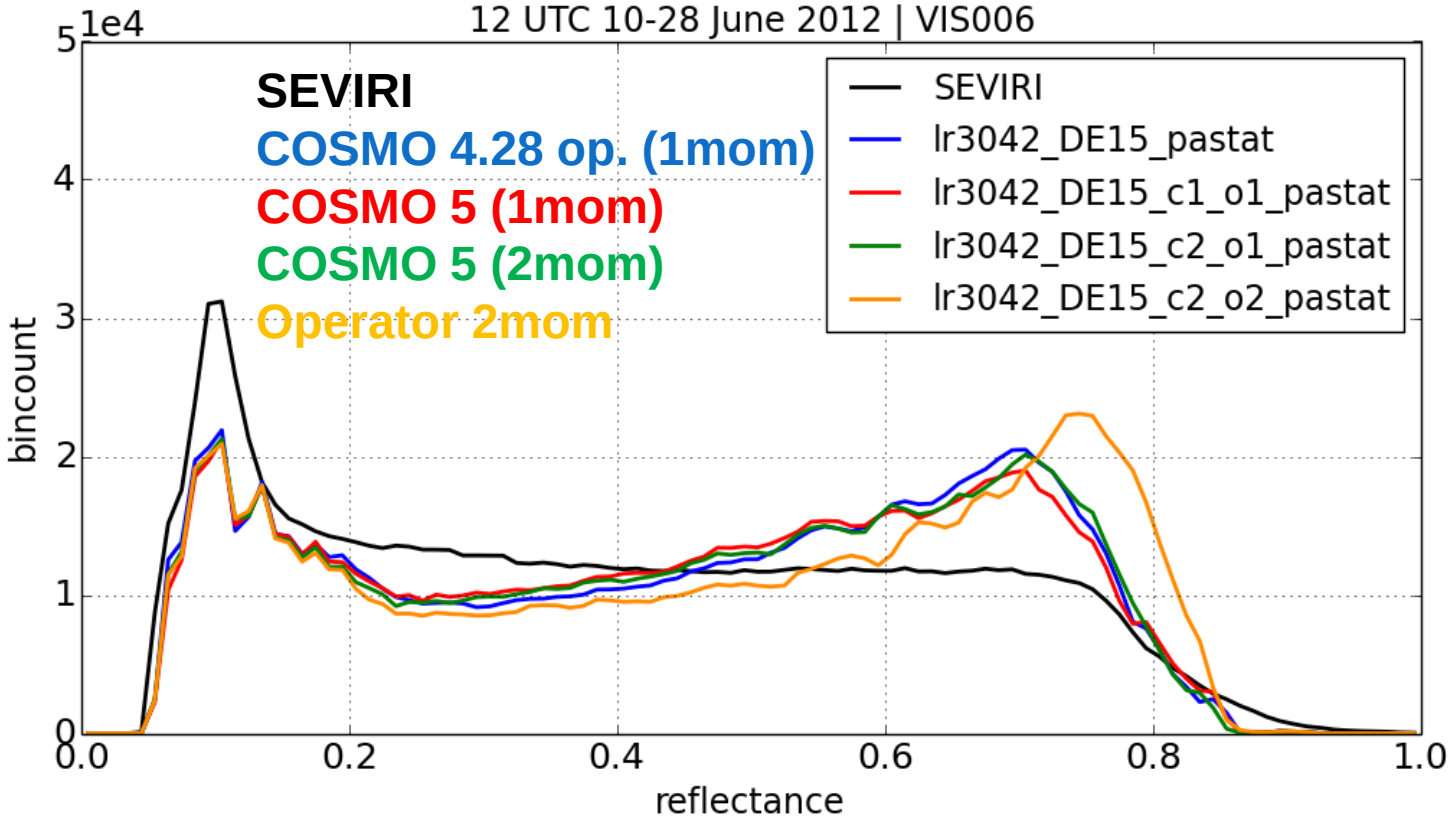
RTTOV7 for synthetic satellite images

By Michael Keller (ETH Zürich - March 2014)

➢ Too much high cloud cover in COSMO with one-moment microphysics scheme
=> Substantial improvement with ice sedimentation

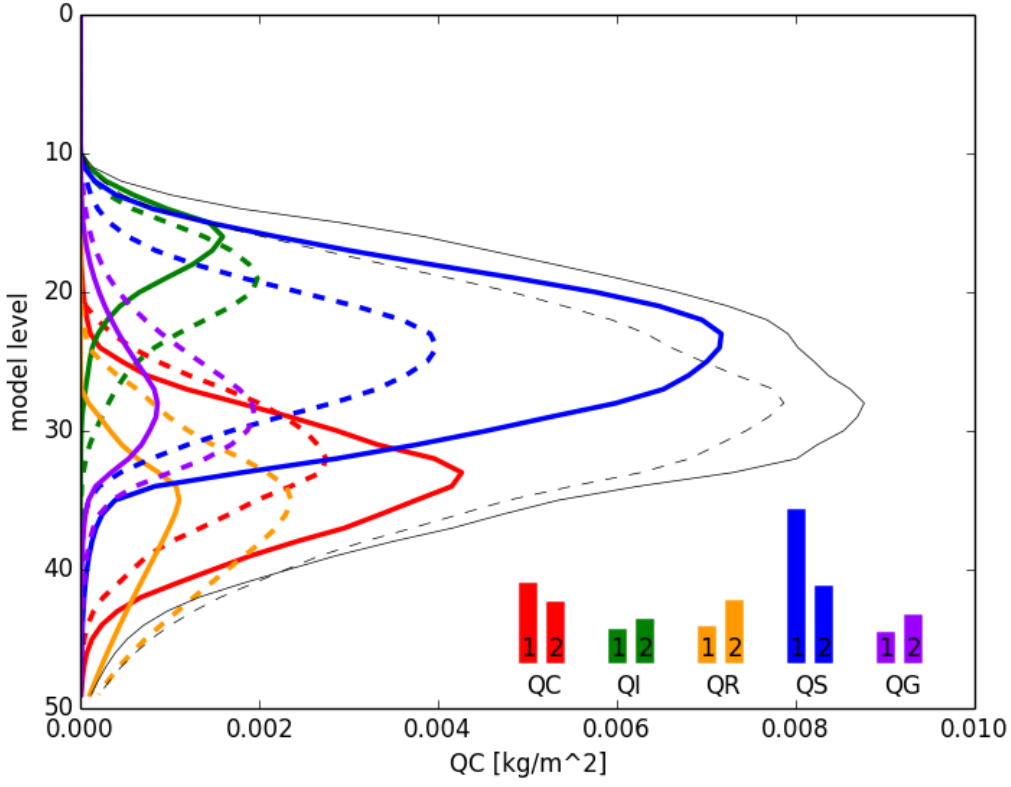
S. Reiter (Uni Köln – Dec. 2013)
➢ Less cold TBs with two-moment cloud ice scheme
➢ Cloud ice sedimentation reduces cloud ice at cloud top

Sensitivity to microphysics – Reflectance Histogram



- 2mom does not reduce clouds with high reflectances

Sensitivity to microphysics – Vertical Profiles



Reduce with 2mom:

QC: specific cloud water content

QS: specific snow content

Increase with 2mom:

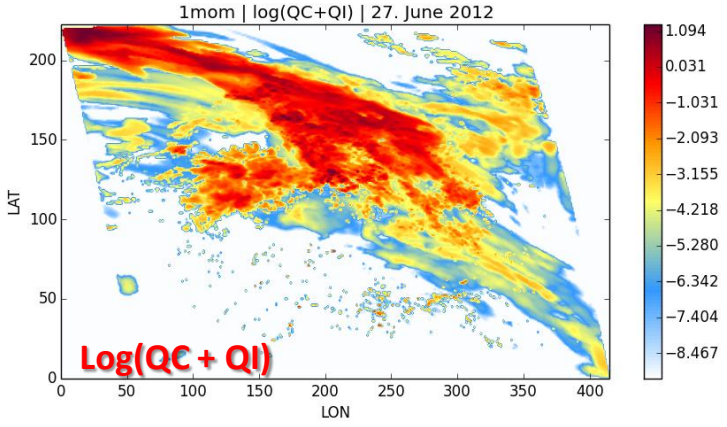
QI: specific cloud ice content

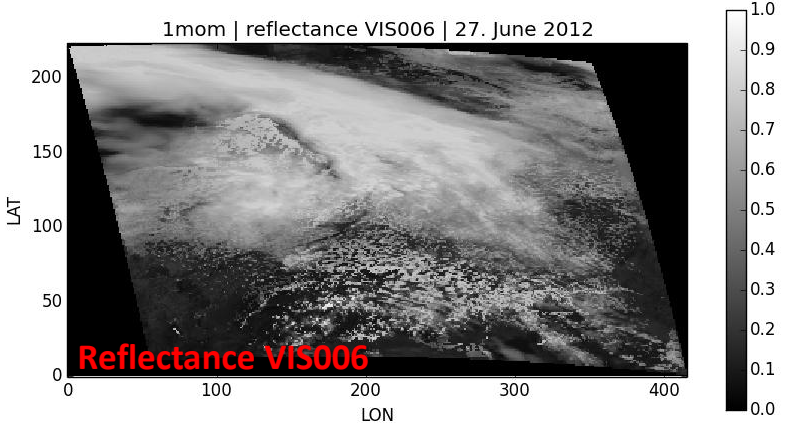
QR: specific rain content

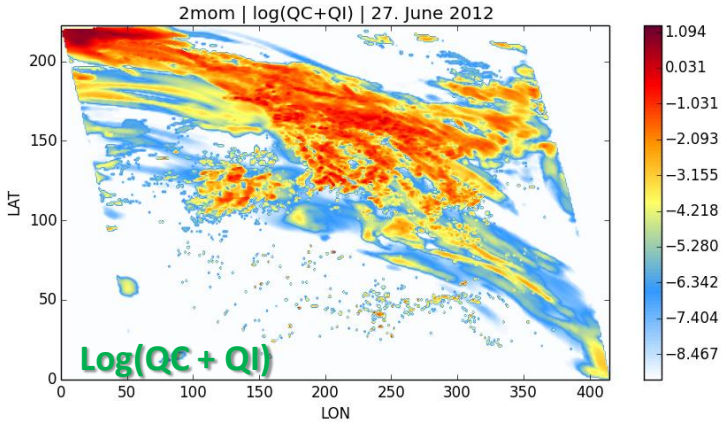
QG: specific graupel content

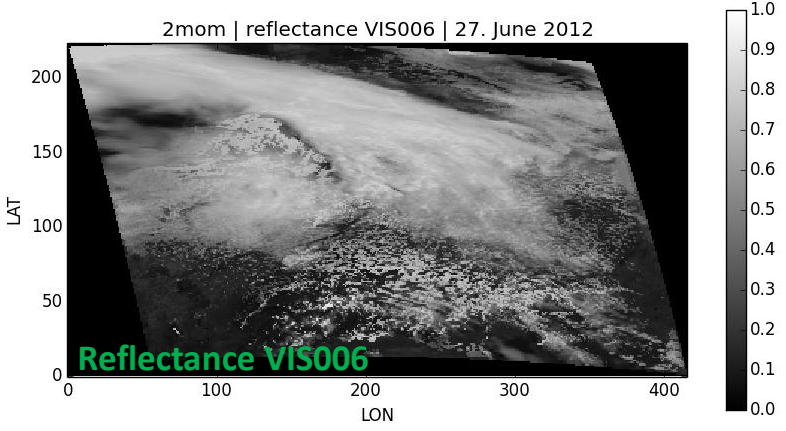
Total Q reduces with 2mom

Sensitivity to microphysics -







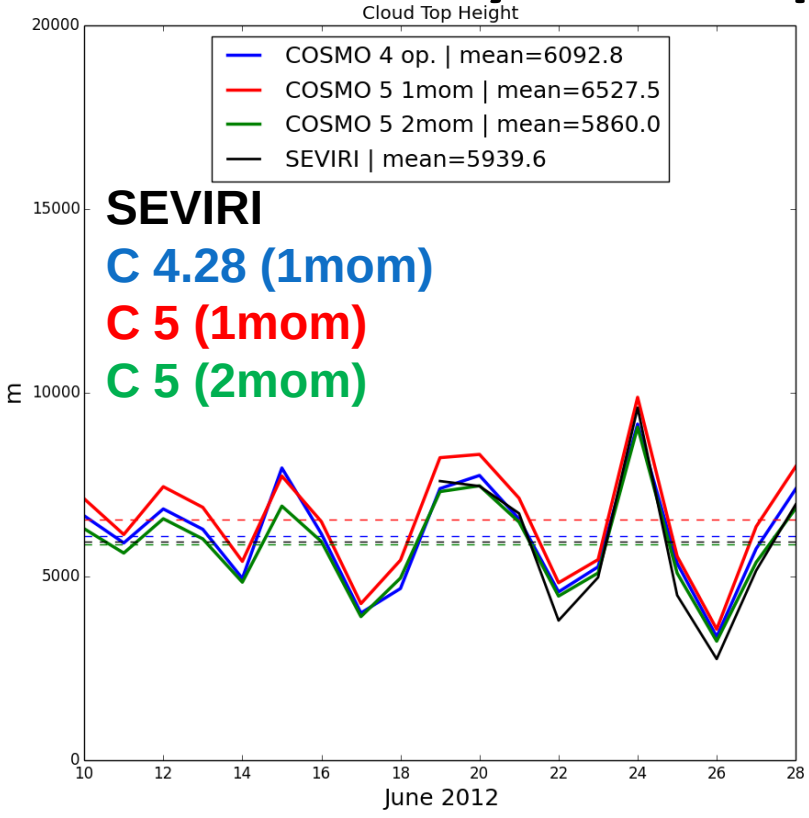


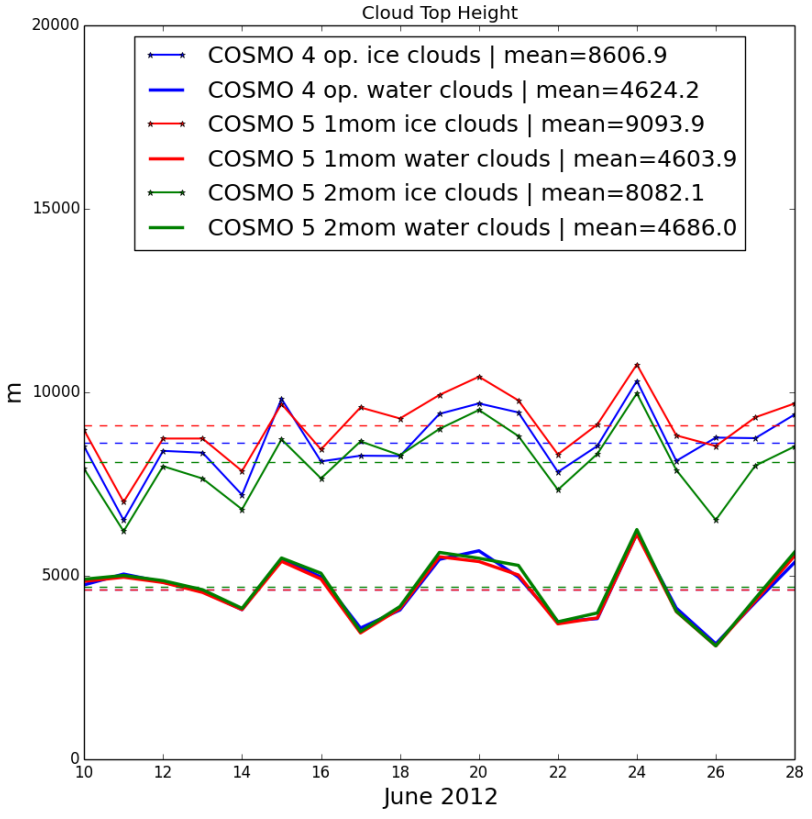
12 UTC
27.06.2012

1mom

2mom

Sensitivity to microphysics – Cloud Top Height



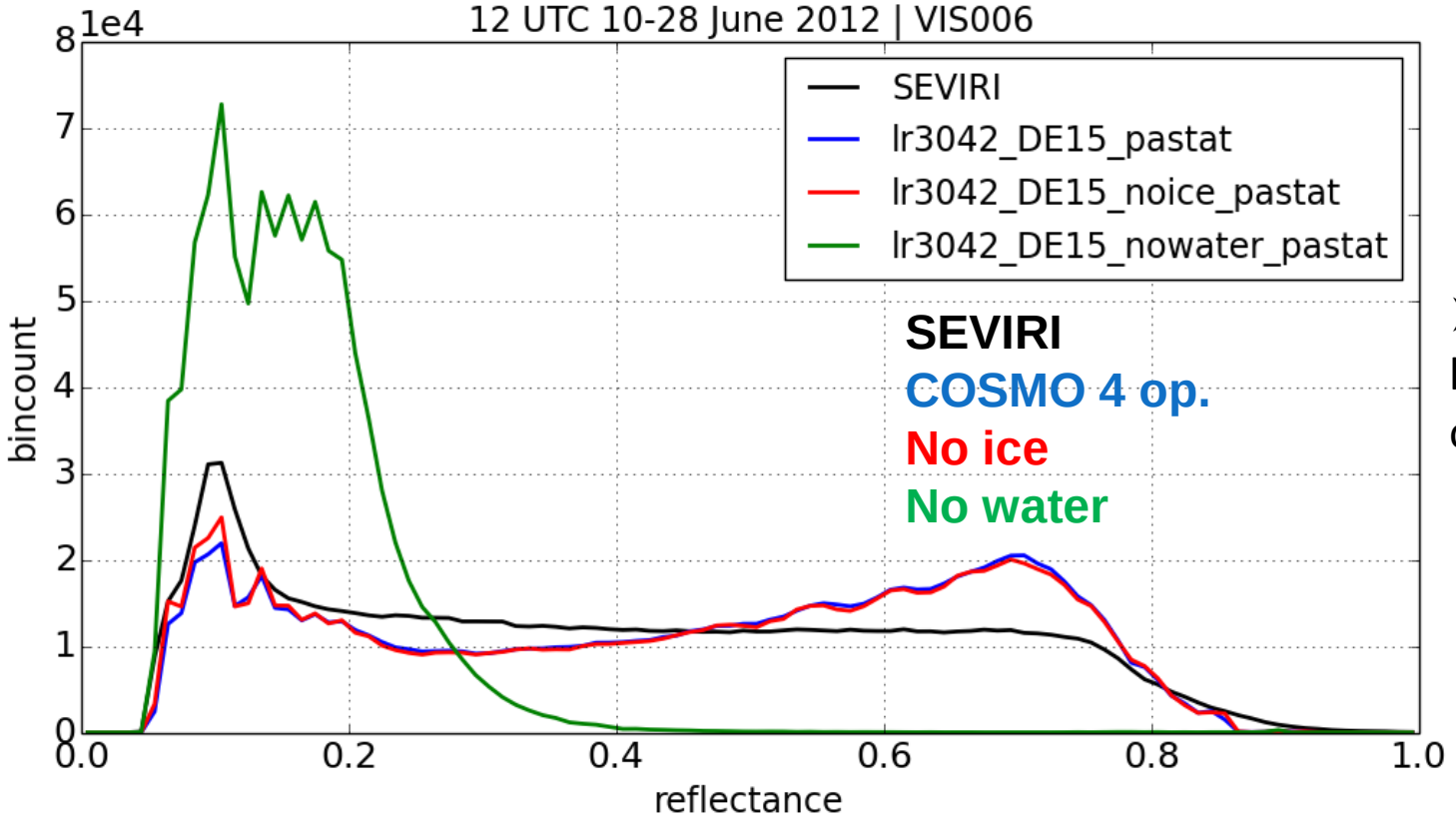


<- ice

<- water

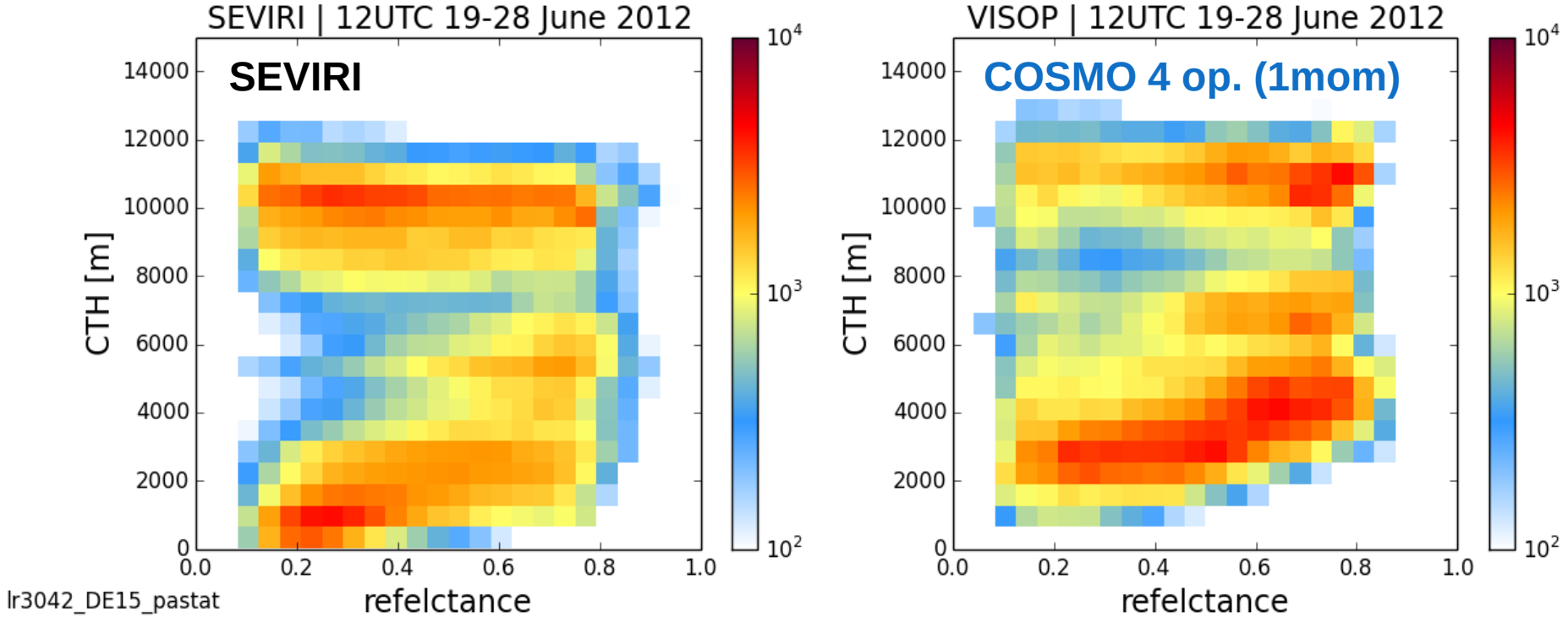
➢ **Ice clouds approx. 1 km lower for 2 mom**

Sensitivity to ice / water



➢ Water clouds have a big effect on the reflectance

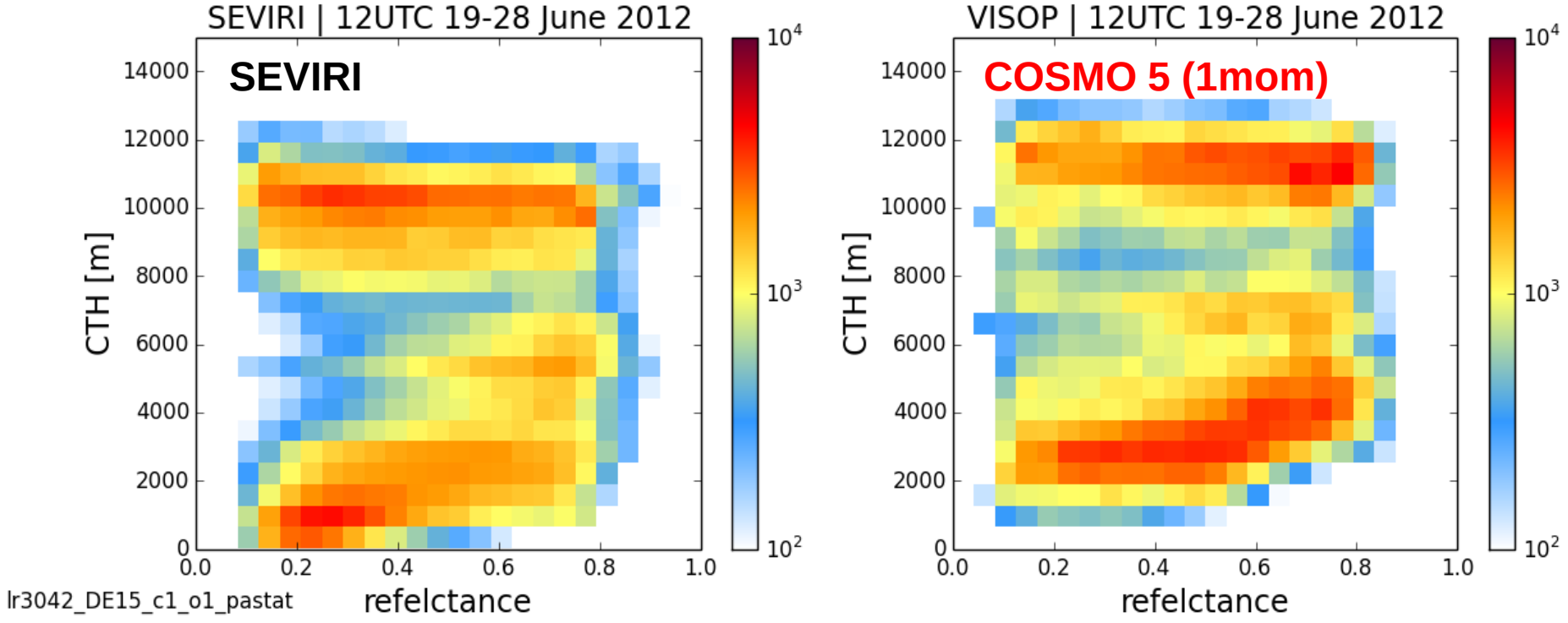
Sensitivity to microphysics



lr3042_DE15_pastat

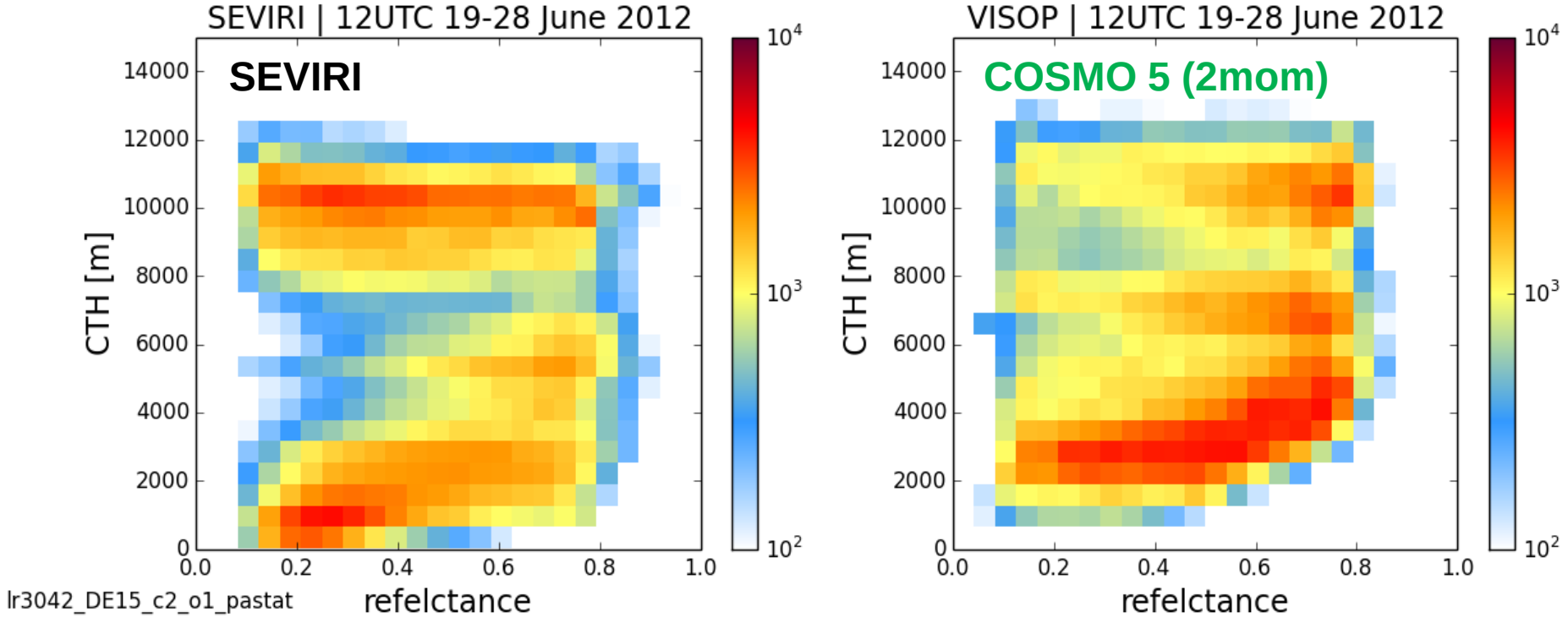
➢**COSMO and SEVIRI show a similar correlation**

Sensitivity to microphysics



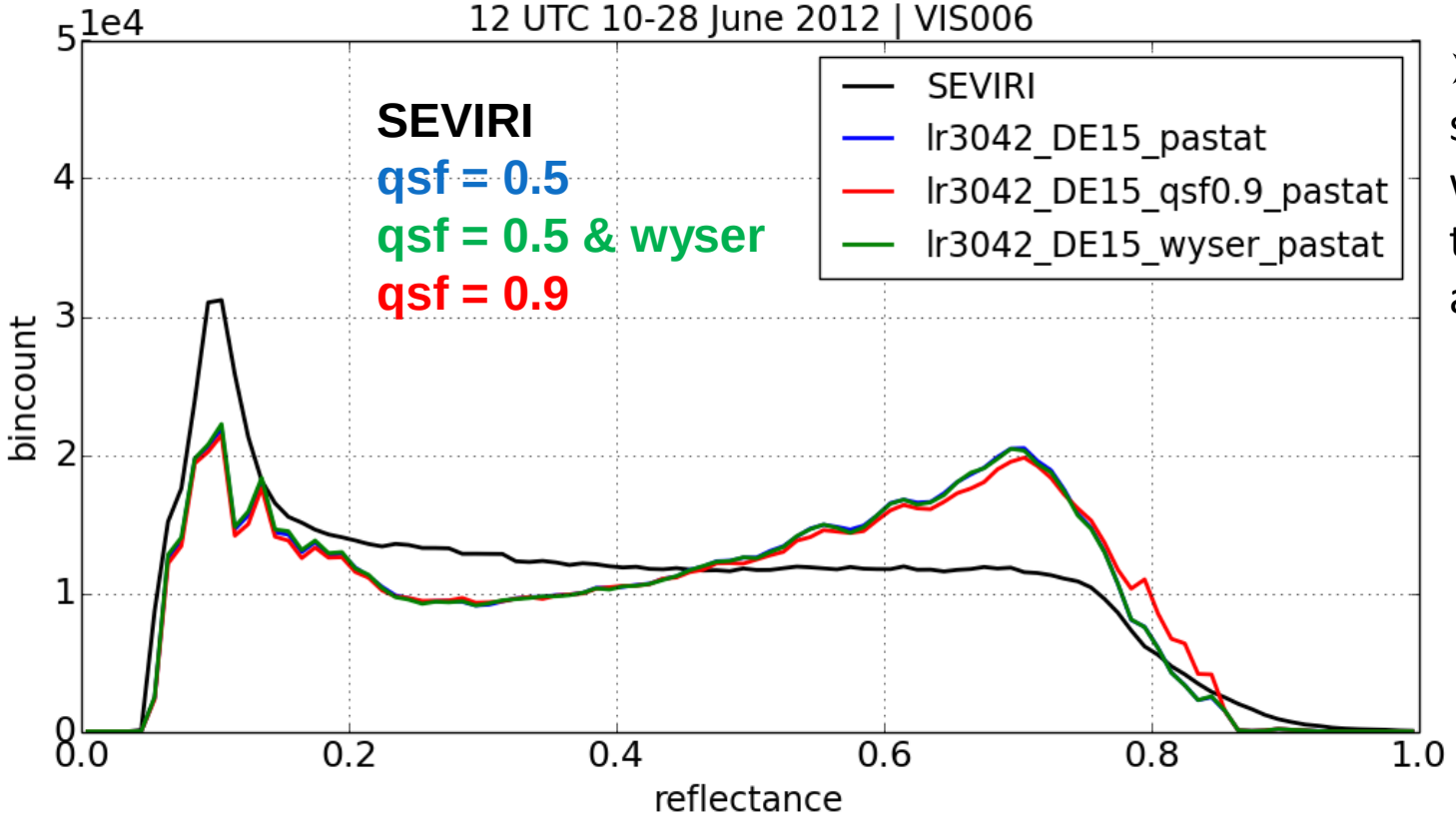
➢ **Too many low clouds with high reflectances (>0.5) in COSMO**

Sensitivity to microphysics



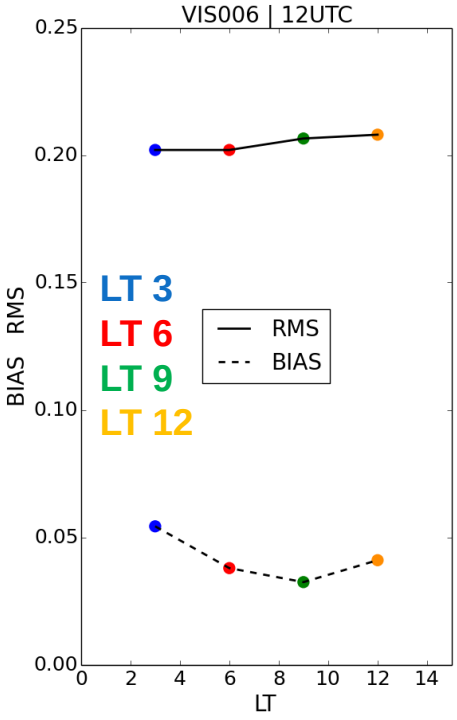
➢ **2 mom reduces high clouds but not clouds with high reflectances**

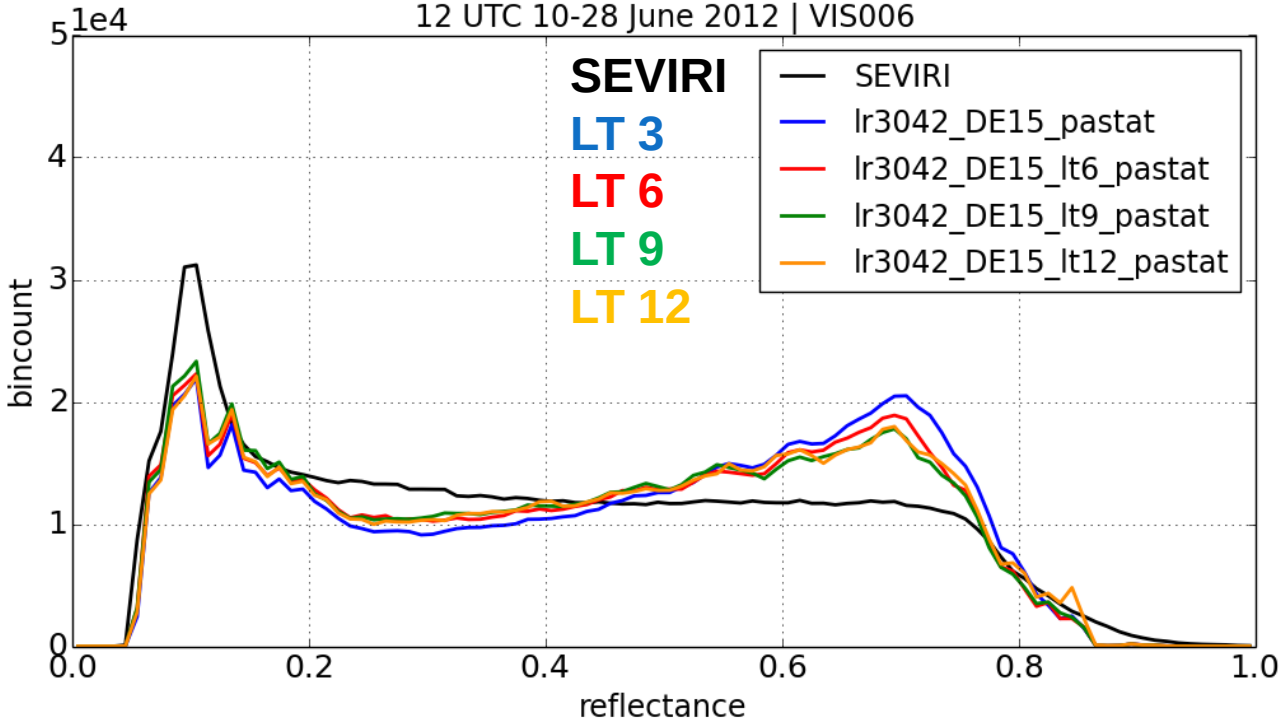
Sensitivity to sub-grid water



- Assumptions about sub-grid-scale water content in the operator have an effect

Sensitivity to the lead time (LT)





➢ **Longer LT better than short LT**

Summary

➢ The **calculated albedo** from the SEVIRI CSRFL reduces the systematic differences
⇒ **expect positive impact on assimilation**

➢ **2 moment microphysics scheme:**
- does not reduce cloudiness
- does not reduce systematic differences for visible reflectances (in contrast to infrared case)

➢ Two different methods showed that there are **too many clouds** in the model/operator

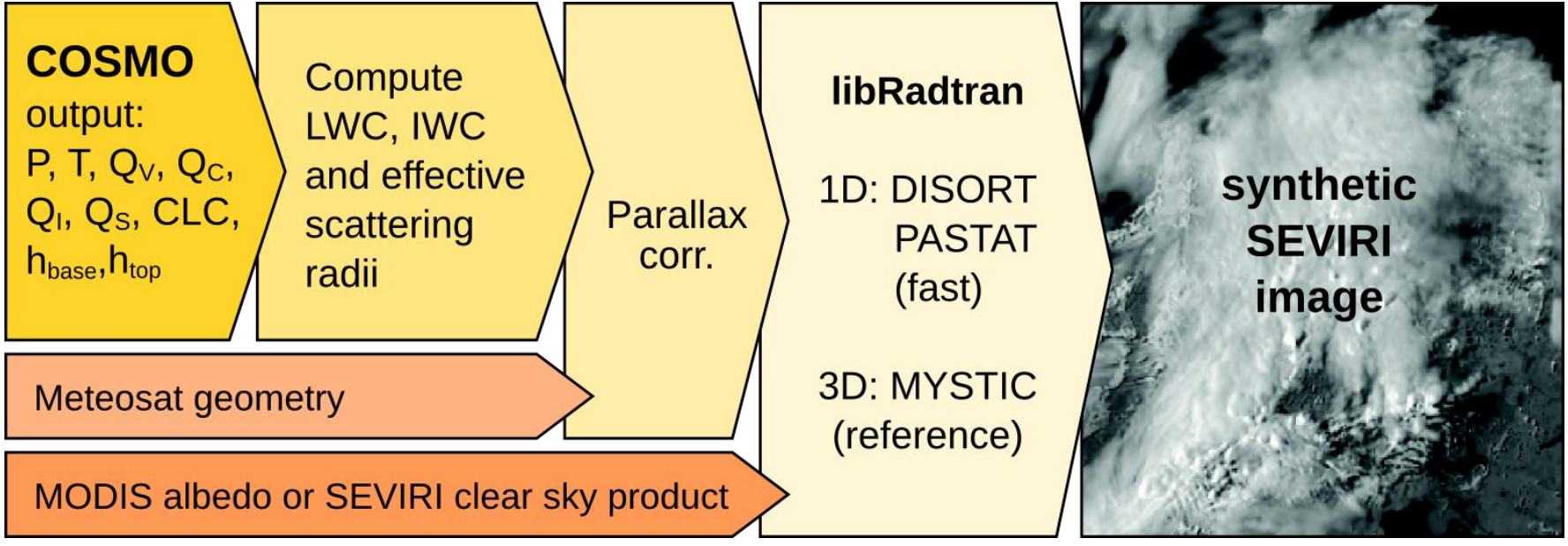
➢ Longer lead times better than shorter lead times

➢ **Sub-grid scale settings** have an effect on the operator

Outlook

- Detect and exclude cloud shadows in SEVIRI (cannot be reproduced with 1D transport)
- Subsampling

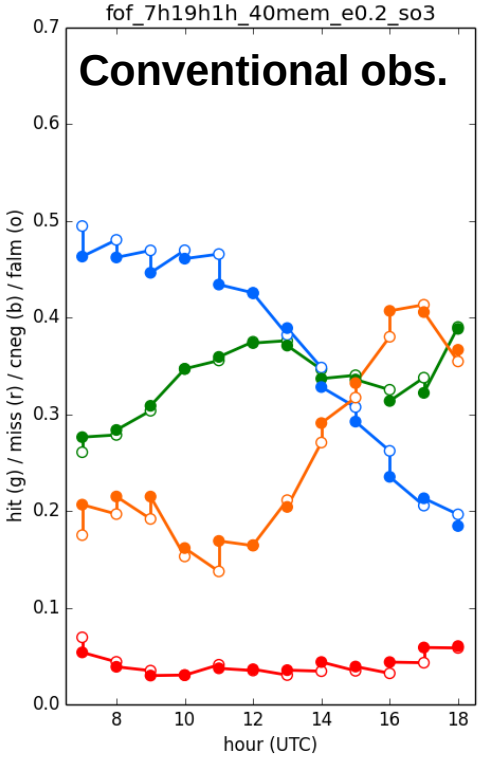
Operator

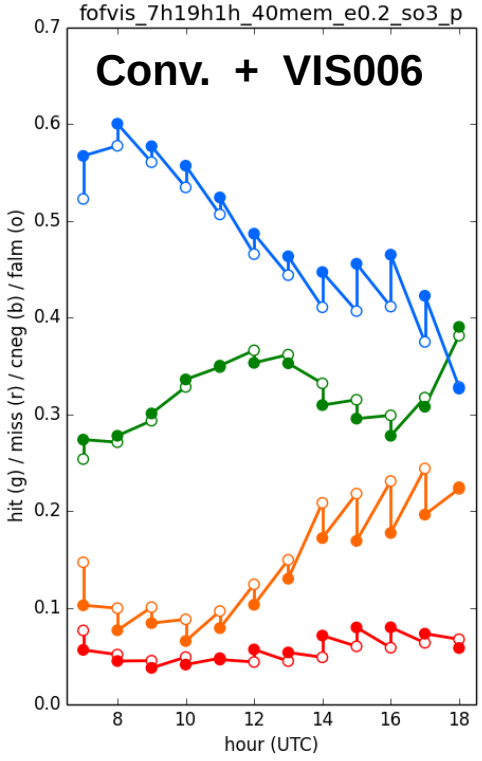


Motivation

- **Clouds:** earliest signal of convection (earlier visible in satellite than in radar data)
- **VIS/NIR channels:**
  - Cloud information
  - Used for nowcasting
    -> potential for DA
- Currently **no assimilation of VIS & NIR reflectances** in DA systems
- **No suitable** fast **forward operator** for an **operational application**
- **HErZ** developed a forward operator for visible (VIS & NIR) MSG SEVIRI observations (*VISOP)*
- **Forward operator** calculates synthetic satellite images (*VISOP for COSMO-DE*)
- For **Ensemble DA** only forward operator required
- **Systematic differences** pose a severe problem for data assimilaion

Motivation





- **Assimilation of VIS/NIR observations**

Diurnal variation
(KENDA , 40 members)

HIT / Cloud :
reflectance > 0.3

HIT
COR. NEG.
FALSE ALA.
MISS

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Work plan

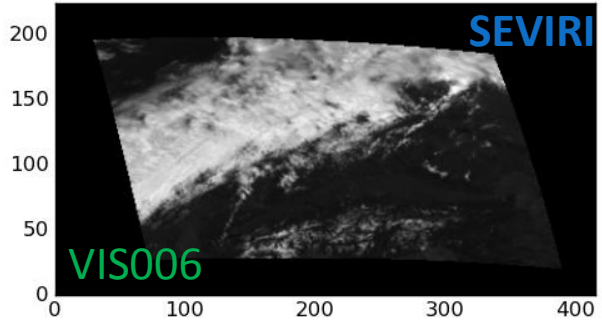
1. Investigate systematic differences between simulated and observed satellite images:
   - **Mean, BIAS, RMS, histograms and contingency tables**
   - Use **Cloud products and Cloud Top Height information** for comparison:
     - ***detect* pixel** with low/medium/high clouds or cloudfree pixels
       -> Get information which clouds are false
     - ***differences* and *errors*** for the different cloud types
       -> Discover systematic differences between SEVIRI & COSMO

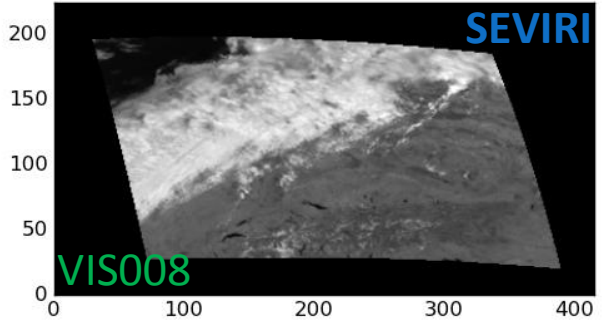
2. Test the **sensitivity** of differences to **settings of the forward operator** and possibly different COSMO **microphysics schemes**.

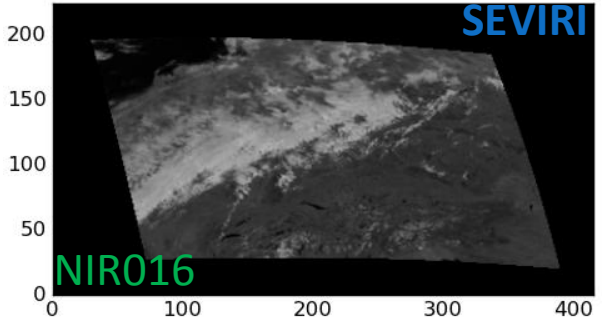
SEVIRI

- **SEVIRI** = Spinning Enhanced Visible and InfraRed Imager
- 12 channels: **VIS** + **NIR** (4 channel) 0,4 – 1,6 µm & (6 channel) 3,8 - 13,4 µm
- **Geostationary orbit** in 36000 km; 1 image every 15min
- **SEVIRI field**: full disc 3712 x 3712
  used field/ grid points 224 x 416
  horizontal grid spacing ~ 3 km
- **Used channels**: VIS006 | VIS008 | NIR016

16.06.2012, 12UTC







Forward Operator for VIS/NIR

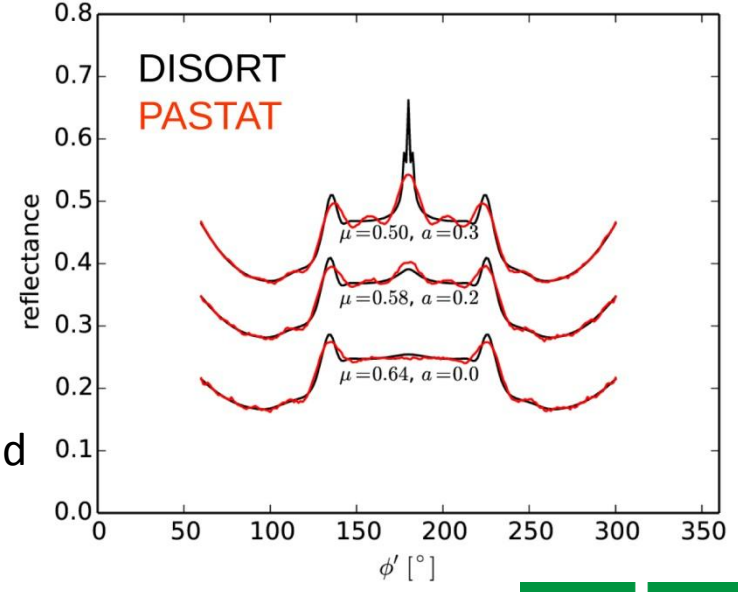
• **COSMO –DE**:	horizontal grid spacing	2.8 km
domain	horizontal grid points	421 x 461
	vertical layers	50

DISORT

- Solves 1D radiative transfer with the libRadtran library and uses the DISORT method
- Run time ≈ hours

PASTAT

- Uses look up tables calculated with the DISORT method
- Faster than VISOP due to look up tables
- Run time ≈ minutes



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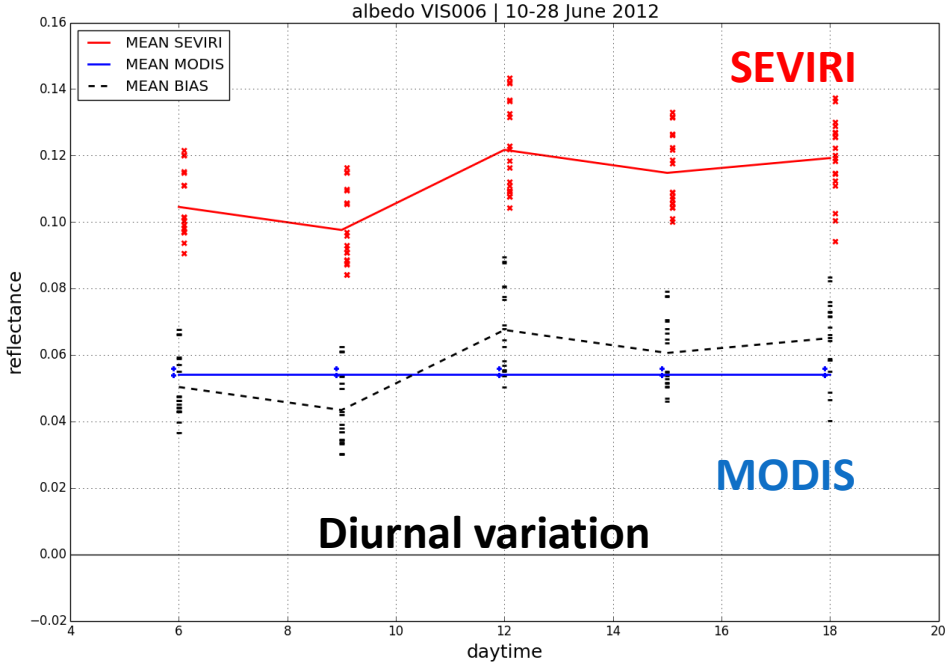
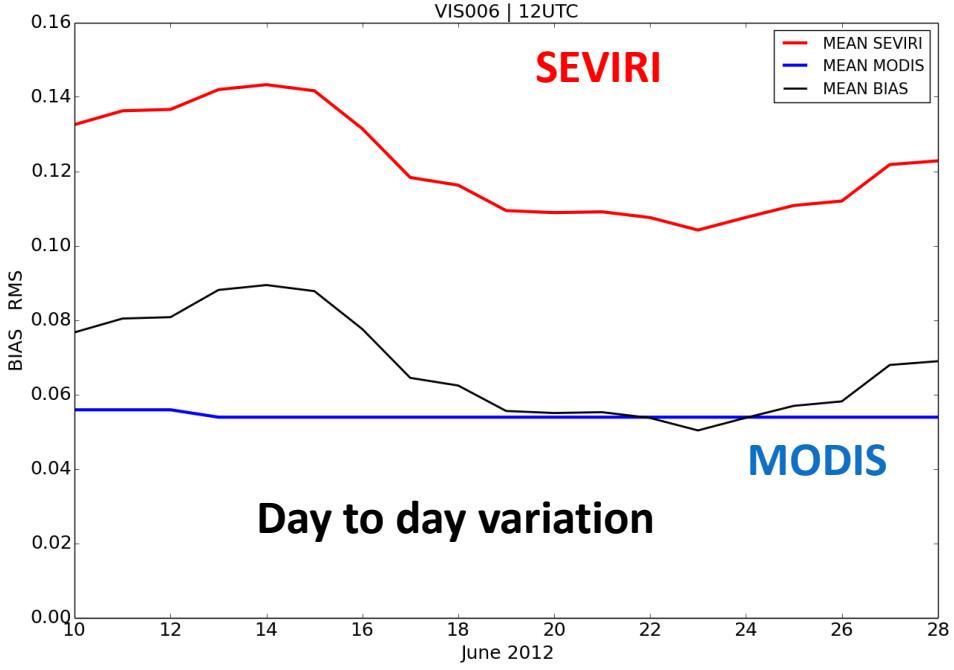
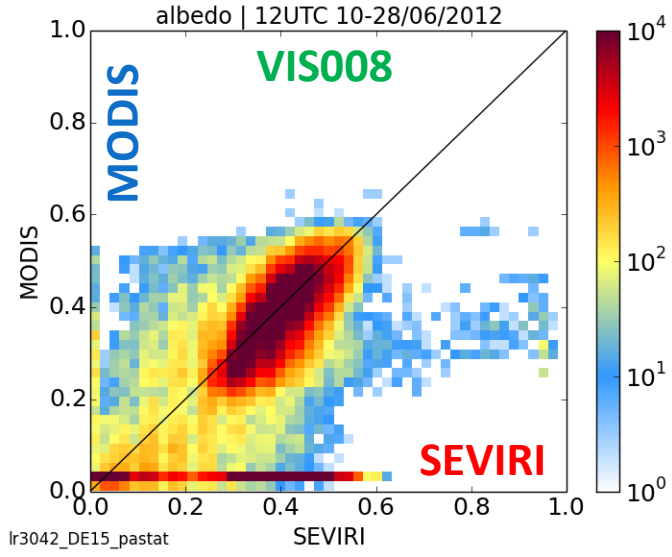
MODIS vs SEVIRI albedo

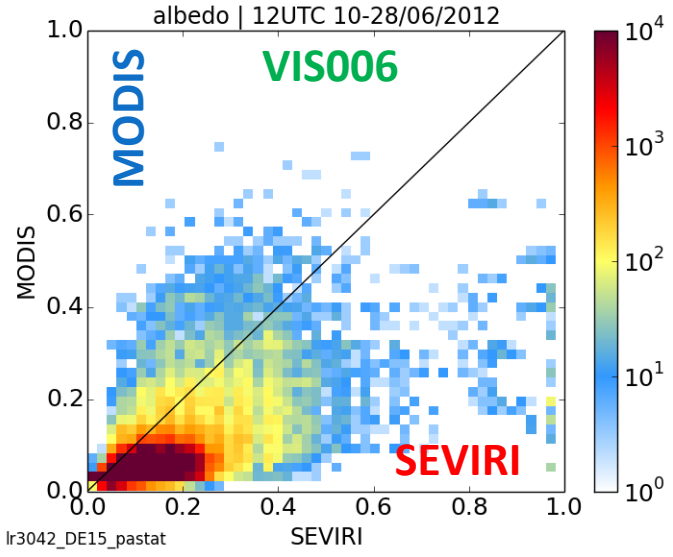


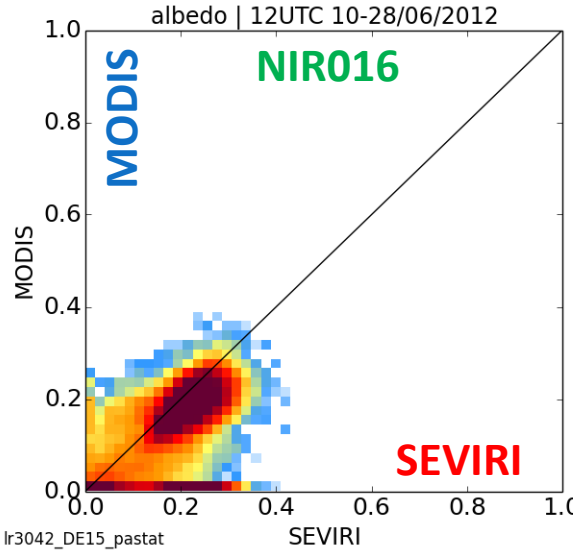


- **MODIS albedo**: Sixteen-day period & only midday
- **SEVIRI CSRFL**: Daily at midday & weekly wednesday for 6/8/10/12/14/16/18UTC

Albedo


albedo | 12UTC 10-28/06/2012
VIS008
MODIS
SEVIRI
MODIS
SEVIRI
lr3042_DE15_pastat


albedo | 12UTC 10-28/06/2012
VIS006
MODIS
SEVIRI
MODIS
SEVIRI
lr3042_DE15_pastat

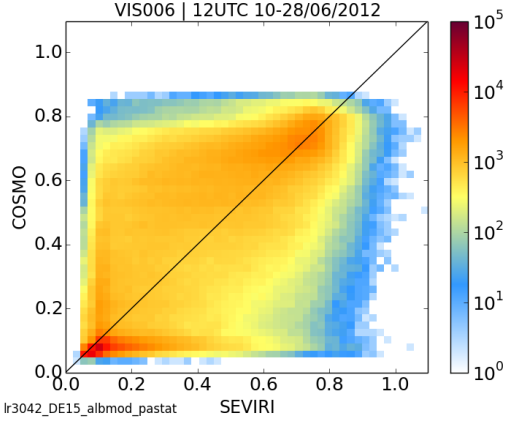

albedo | 12UTC 10-28/06/2012
NIR016
MODIS
SEVIRI
MODIS
SEVIRI
lr3042_DE15_pastat

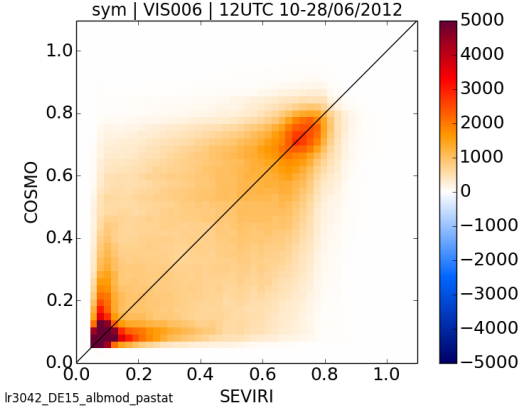
Hist 2D field (H)

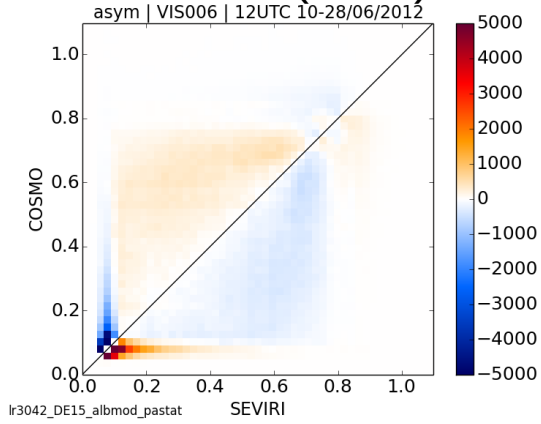
SYM ½(H+H^T)

ASYM ½(H-H^T)

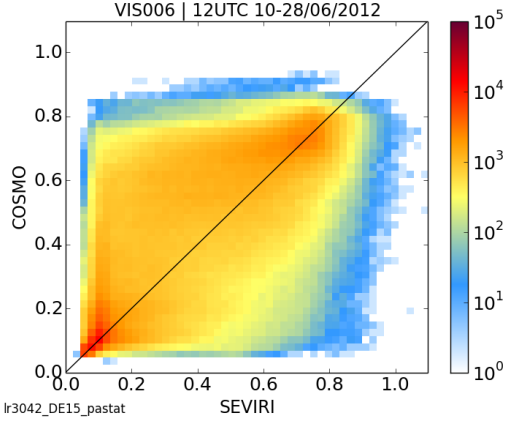
2d reflectance histograms

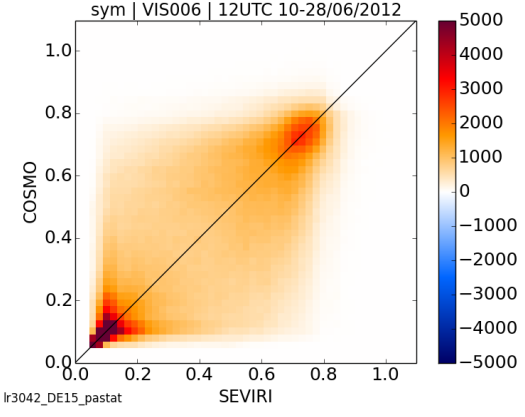


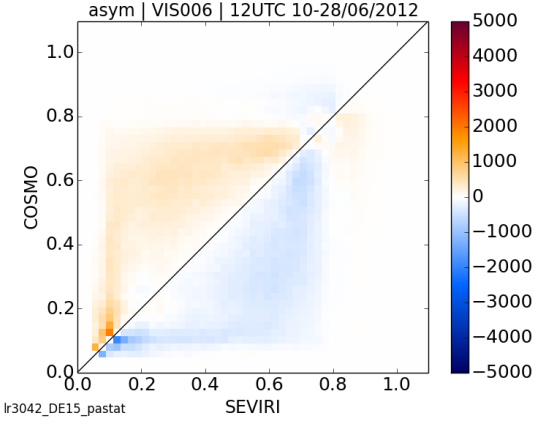




PASTAT with MODIS ALBEDO







PASTAT with SEVIRI ALBEDO

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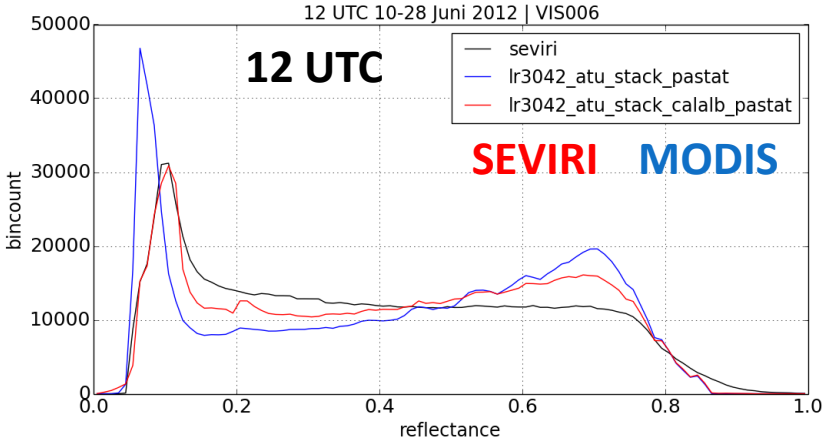
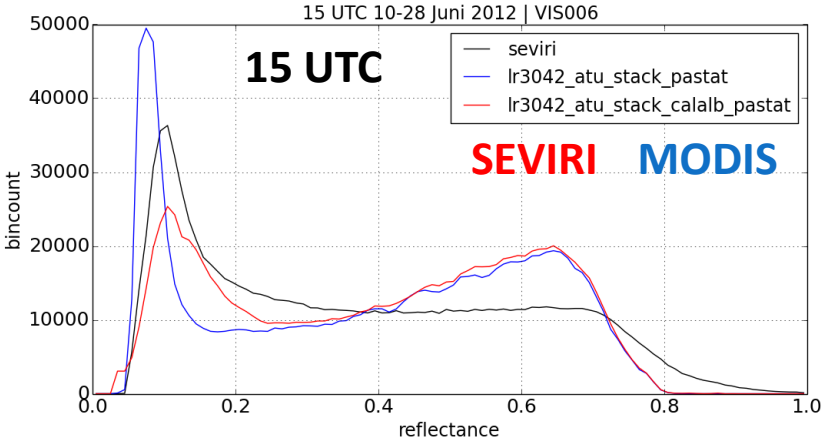
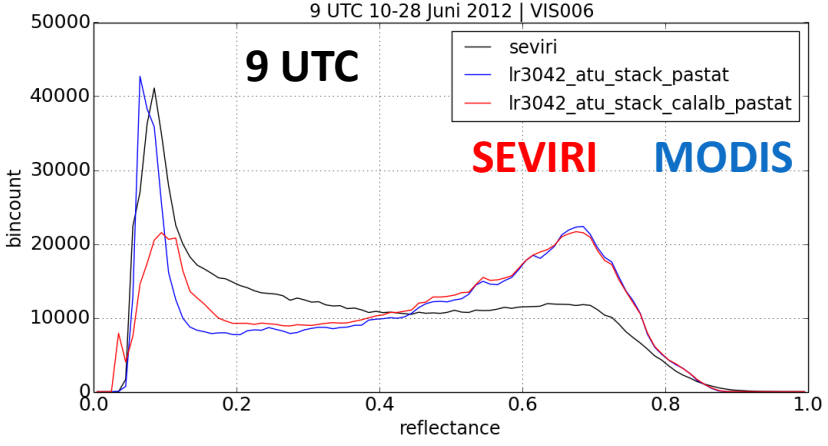


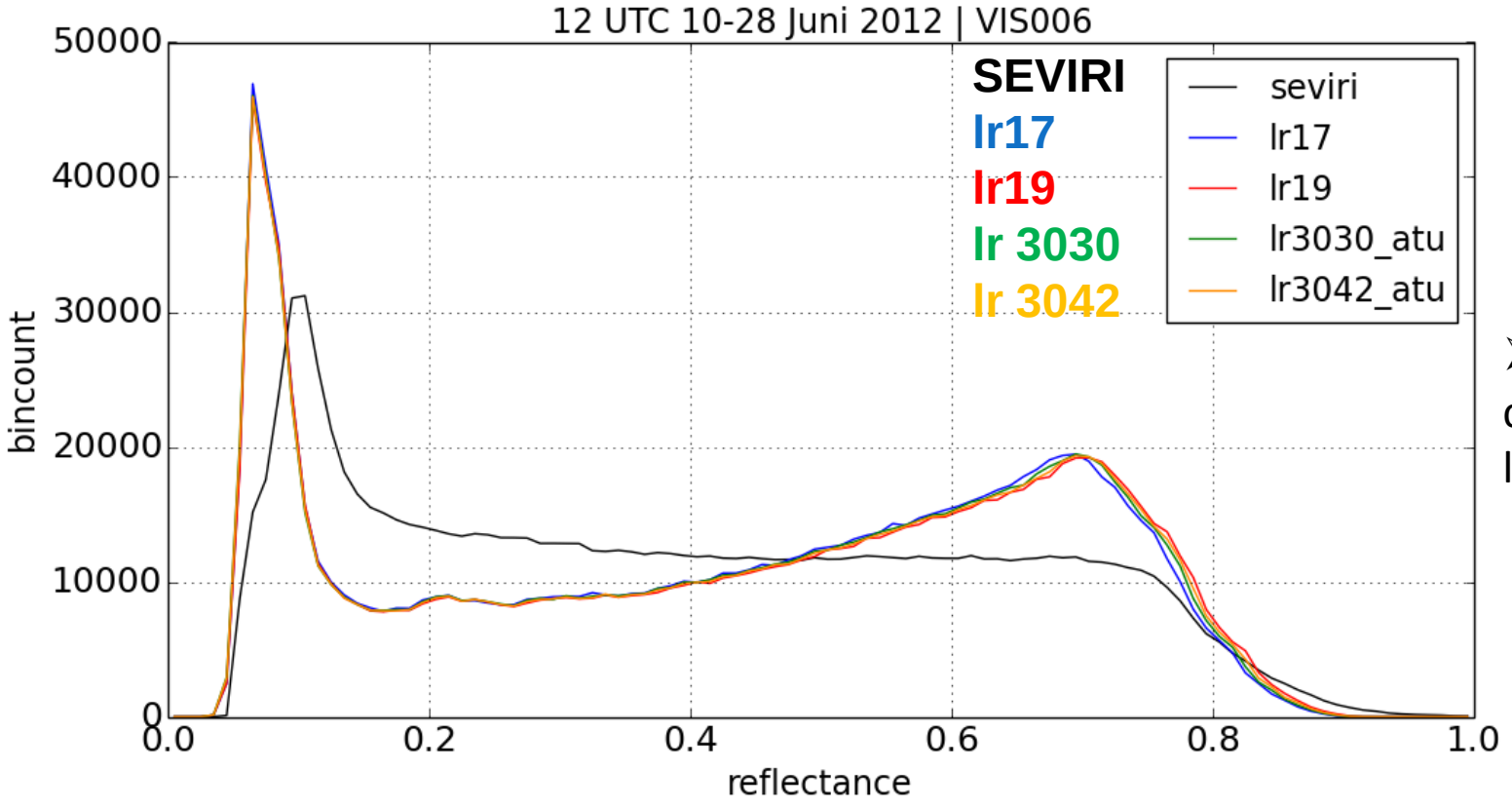




Reflectance histograms

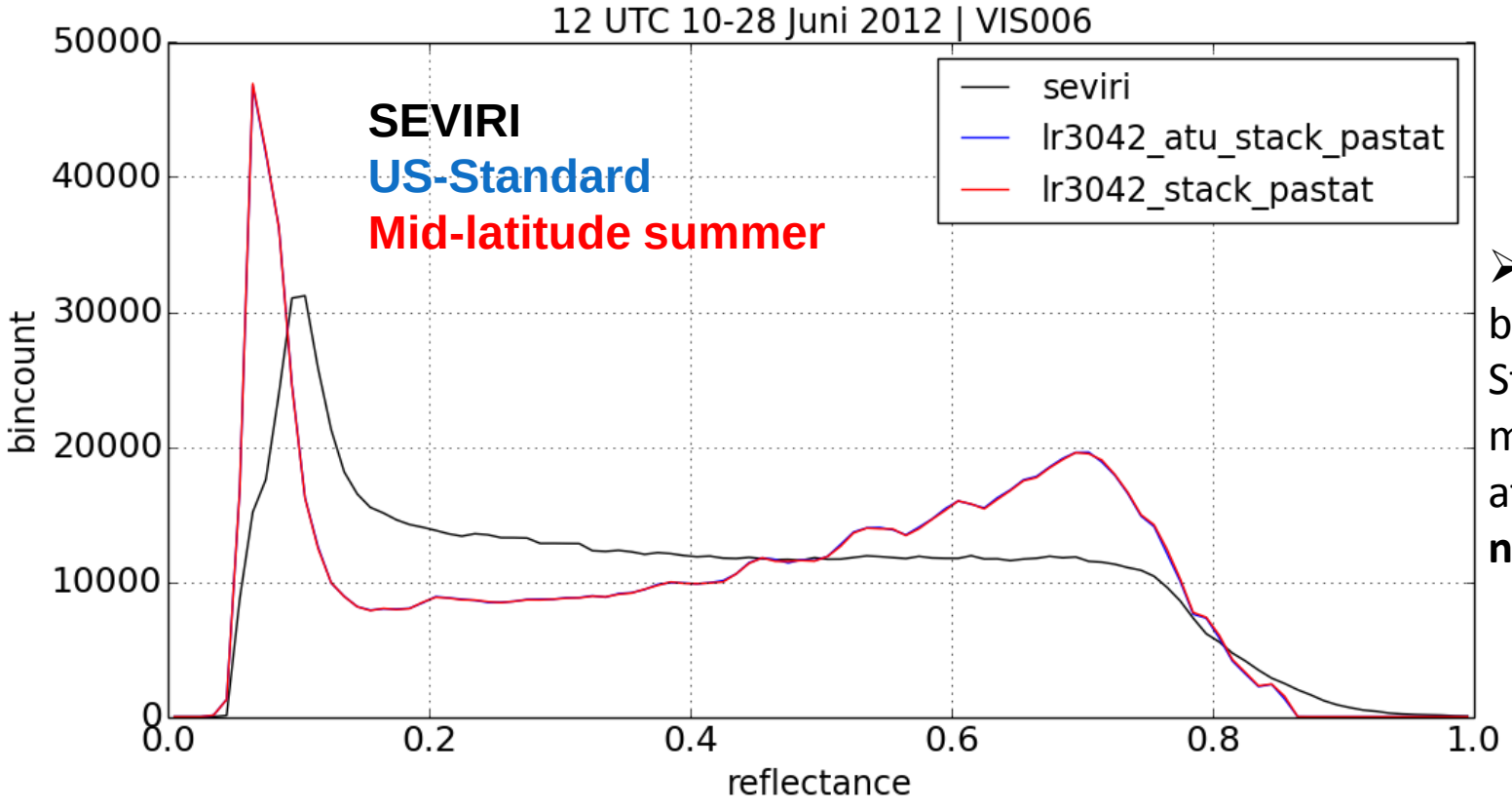
- **Position of left peak** correct for SEVIRI albedo
- **Height of left peak** mostly smaller due to too much clouds in the model

Impact of bug fixes and improvements in libRadtran



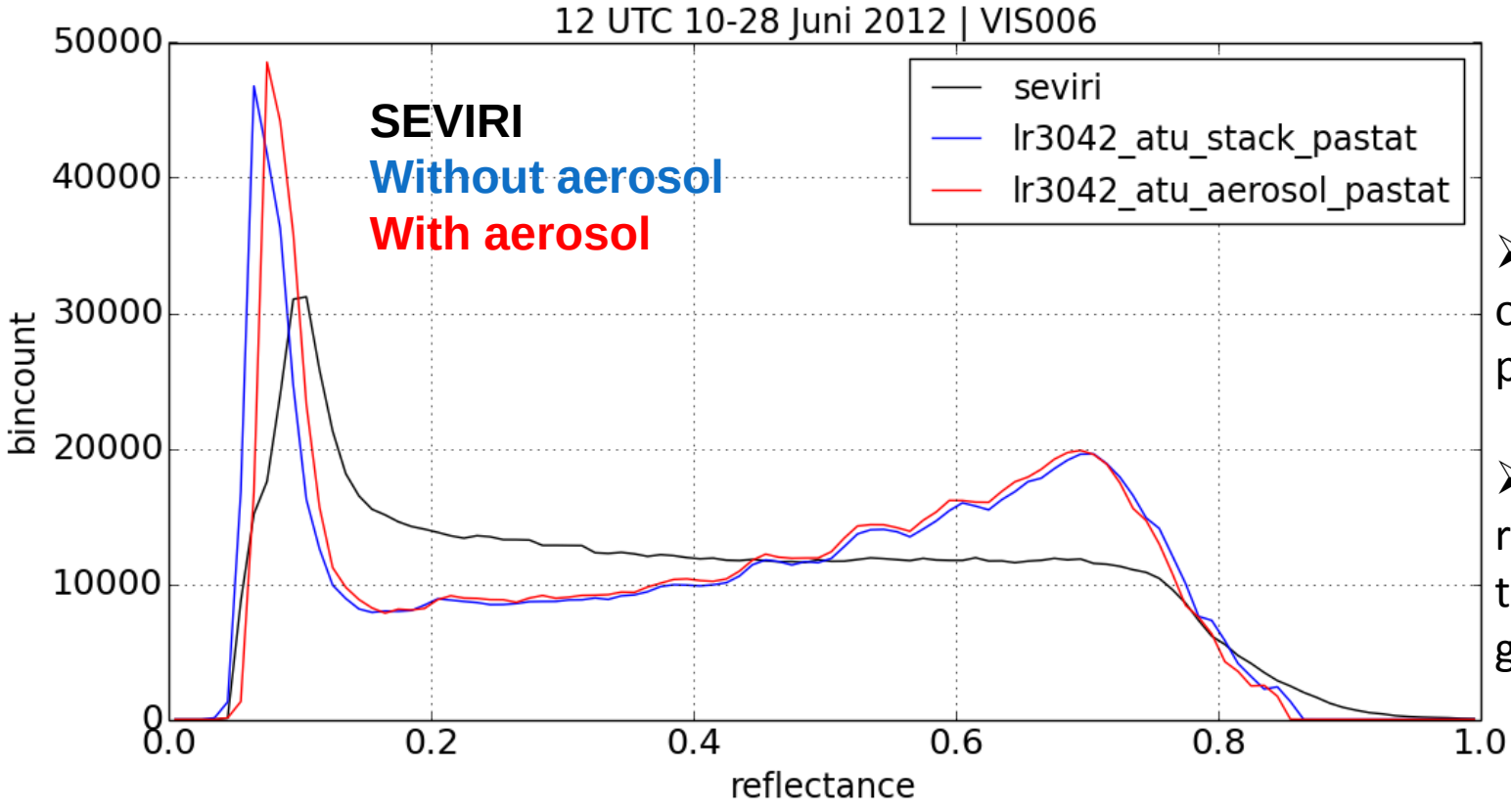
- Only small changes from lr17 to lr3042

Sensitivity to the atmosphere



➢ **Differences** between US-Standard and mid-latitude atmosphere **negligible**

Sensitivity to aerosol



- Positive effect on cloud free pixel
- RMSE reduced due to the shift of the ground peak

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