LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

FAKULTÄT FÜR PHYSIK METEOROLOGIE

MIM

Hans-Ertel-Zentrum für Wetterforschung
Deutscher Wetterdienst

DWD

Assimilation of cloud-affected SEVIRI visible channels in KENDA and systematic differences between observations and model equivalents

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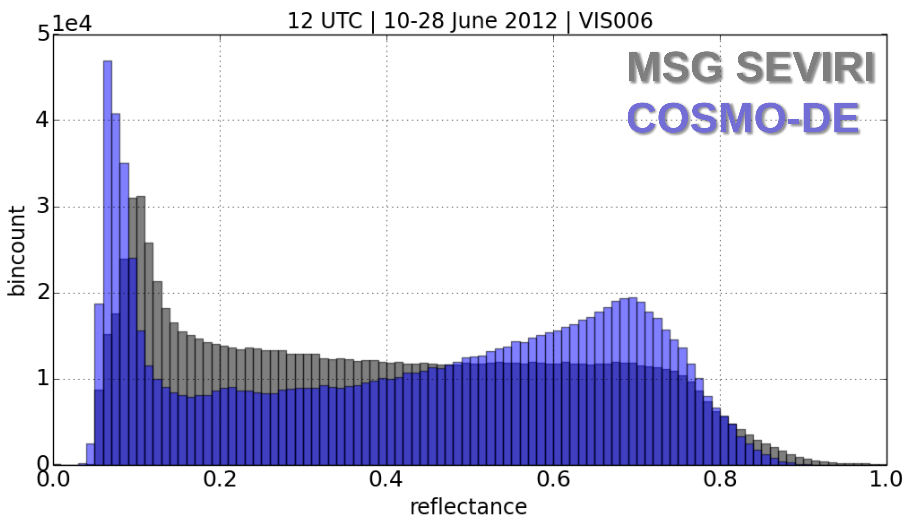
Motivation

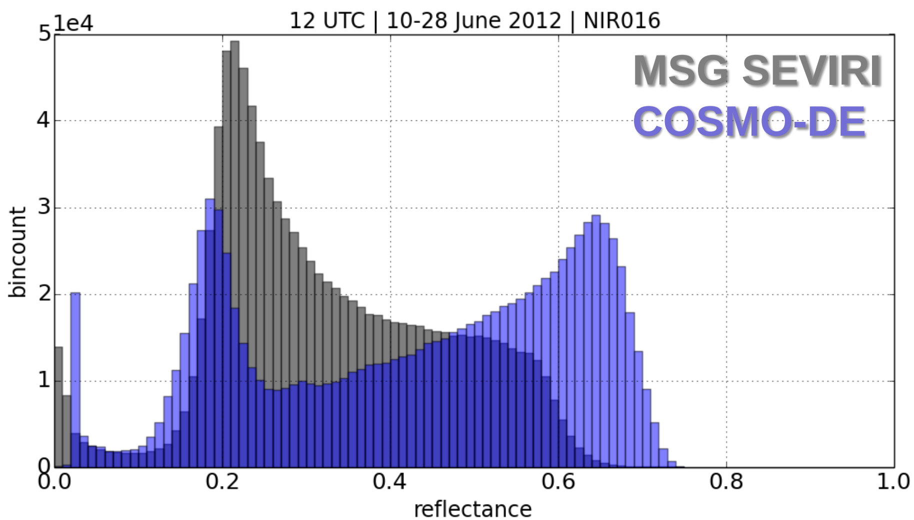
- **Convective scale NWP:**
  - Forecasts of severe weather events
  - Requires: + Optimal initial conditions
    + Suitable observations
- **Clouds** earliest signal of convection
- **Satellite observations:**
  - Dense in space and time
  - Detect clouds earlier than radar
- **Visible (VIS) & near-infrared (NIR) channels:**
  - Provide unique information on clouds
  - Already used for nowcasting
    → Potential for data assimilation (DA)
- Currently **no assimilation of VIS & NIR** channels in DA systems
- **No suitable fast forward operator** for an operational application
- **HErZ and extramural research** developed a forward operator for visible (VIS & NIR) MSG SEVIRI observations
- **DA assumes** model, operator and observations are **unbiased**:
  → **Systematic differences** pose a severe issue

Motivation

Reflectance 0.6 µm (VIS006)



Reflectance 1.6 µm (NIR016)



(10 – 28 June 2012, 12 UTC)

<u>Question:</u>

What are the reasons for (systematic) differences? E.g. …

… Model microphysics?

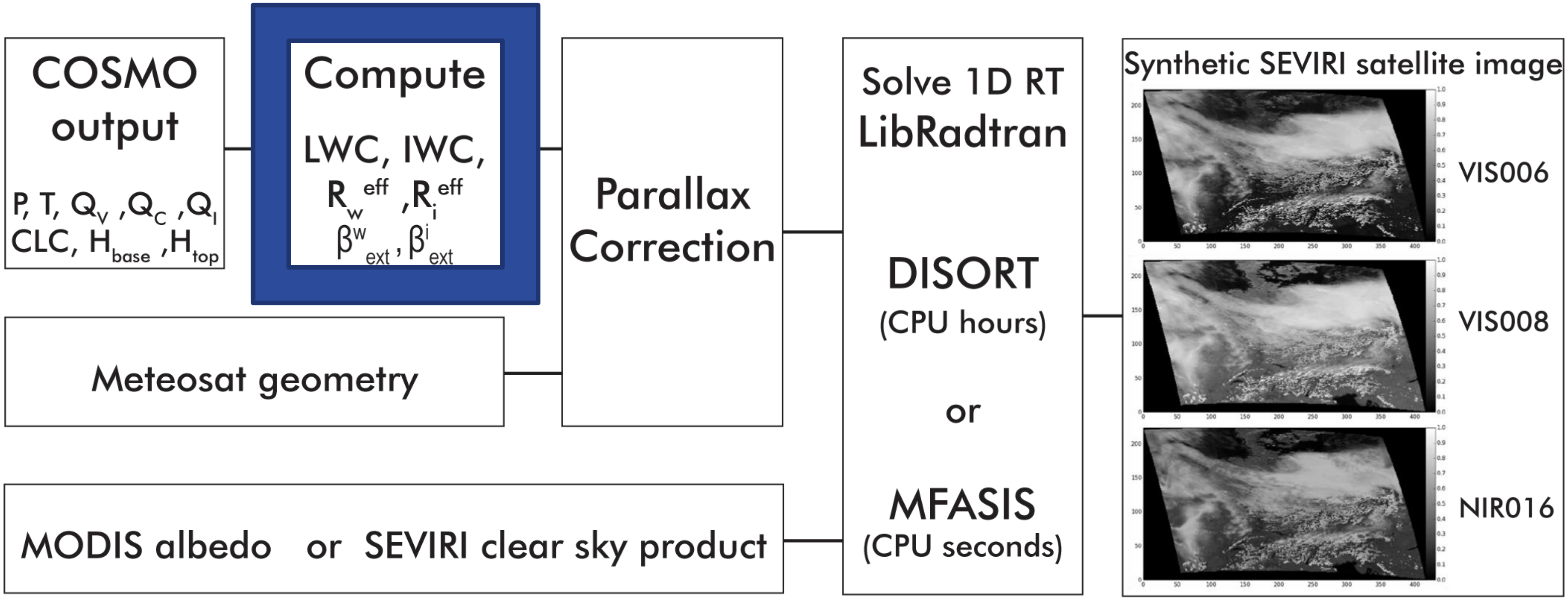
… Operator assumptions?

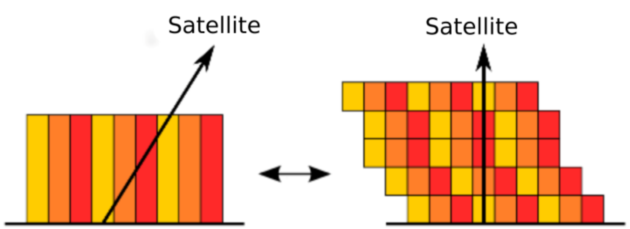
… Other?

<u>Goal:</u>

- Reduction of **systematic differences**

Schematic view of the operator





Parallax Correction

DISORT: DIScret Ordinate Radiative Transfer

MFASIS: Method for FAst Satellite Image Simulations

Kostka, P., M. Weissmann, R. Buras, B. Mayer, and O. Stiller, 2014: Observation Operator for Visible and Near-Infrared Satellite Reflectances. *J. Atmos. Oceanic Technol.*, **31** (**6**), 1216–1233, doi:10.1175/JTECH-D-13-00116.1.

Frerebeau, P., L. Scheck, R. Buras, and B. Mayer, 2015: A fast radiative transfer model for the simulation of visible satellite imagery, in preparation.

Parameterizations and assumptions

Resolved processes:
(gridscale clouds)

- Deep convection explicitly resolved at dx = 2.8 km
- Grid scale cloud related variables: Q_C , Q_I , Q_R ,$Q_{S,}$ Q_G

Unresolved processes:
(subgrid clouds / parameterized)

1. Subgrid scheme (SGS)

   Subgrid clouds for grid scale relative humidity < 100 %

2. Shallow convection scheme (CON)

   Shallow conv. implies unresolved clouds

Cloud fractions (N): N_{sgs} N_{con}

Mixing ratios (Q): Q_{sgs} Q_{con}

↓

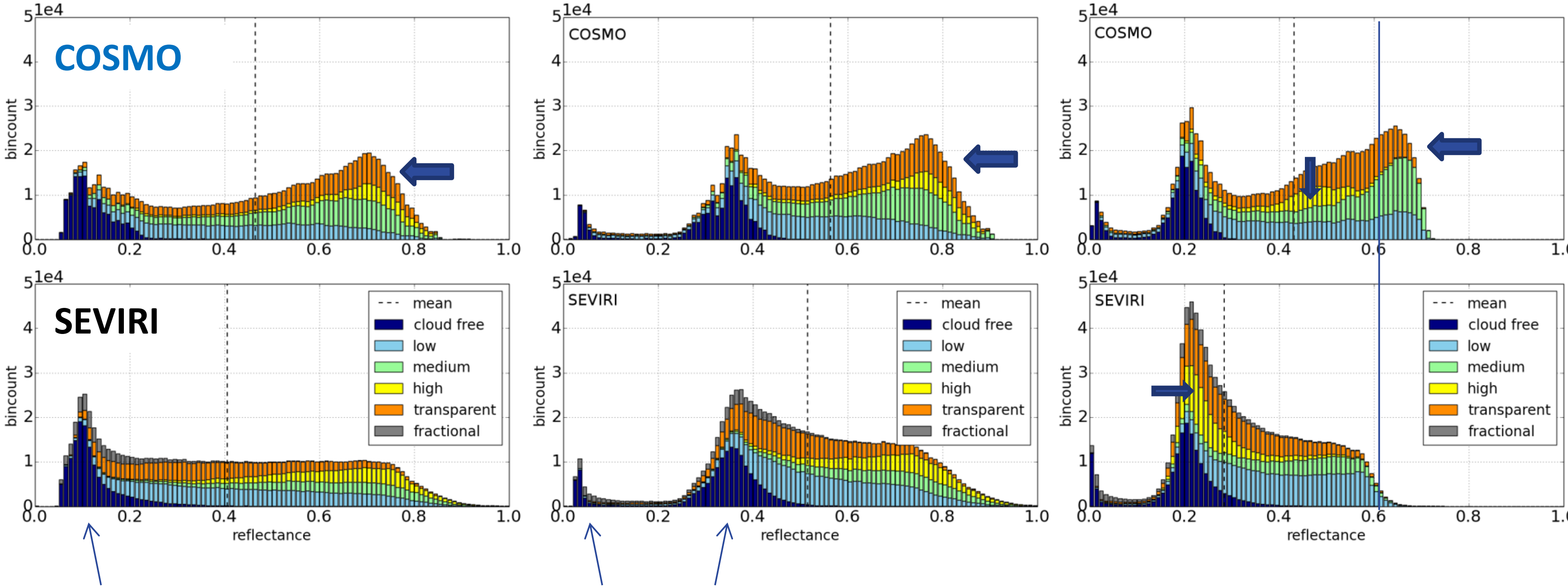
Radiatively active total mixing ratios

↓

LWC & IWC

Histogram with CT information

VIS006 | VIS008 | NIR016



sea & land
(depending on the albedo)

sea   land

10 – 28 June 2012,
operational 3h forecast,
12 UTC

Subgrid cloud fraction

$$\mathcal{N}_{\mathrm{sgs}} = \max\left(0, \min\left[1, \left(\frac{Q_{\mathrm{tot}}}{Q_{\mathrm{sat}}} - \alpha_{\mathrm{sgs}}\right)(1-\alpha_{\mathrm{sgs}})^{-1}\right]\right)$$

$$\alpha_{\mathrm{sgs}} = \alpha_1 - \alpha_2\sigma(1-\sigma)(1+\sqrt{3}(\sigma-0.5))^2$$

$\alpha_1 = 0.95$ **$\alpha_2 = 0.80$**

$\alpha_2 = 0.40$

N_{sgs} : subgrid cloud fraction

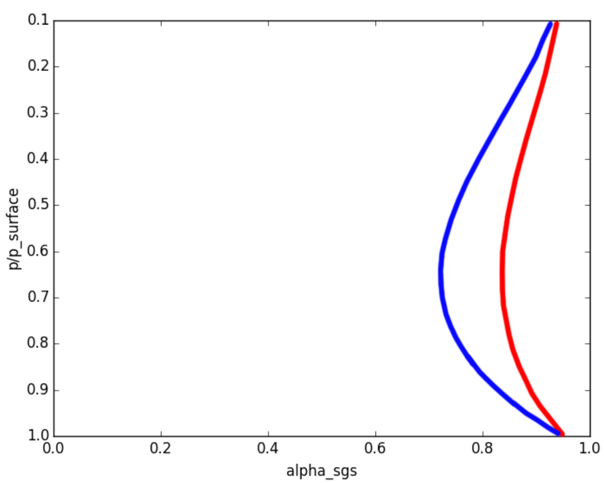
Q_{tot} : total humidity mixing ratio (Q_C+ Q_I+ Q_V)

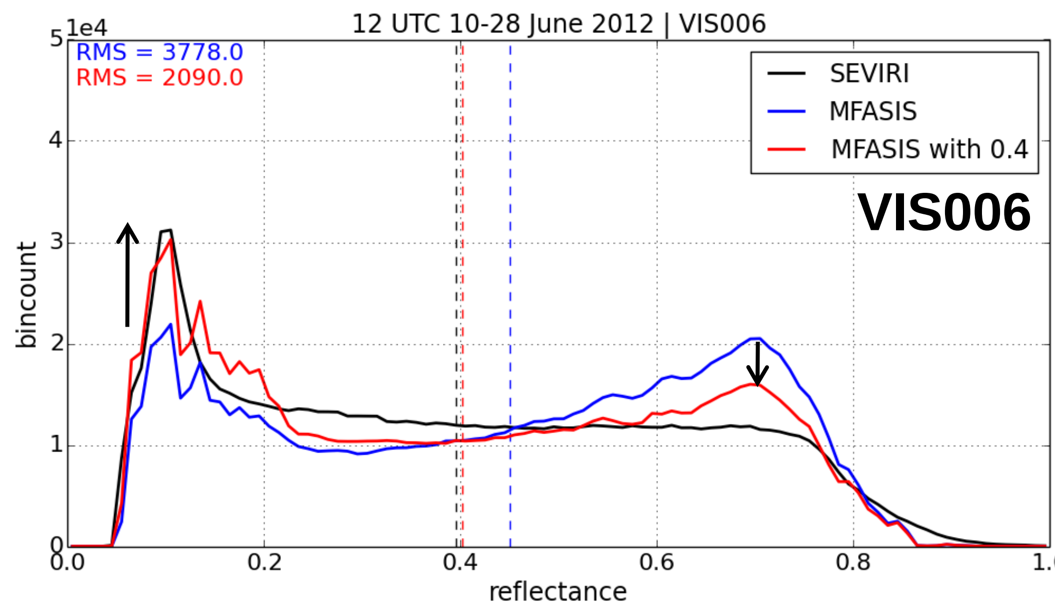
Q_{sat} : total saturation mixing ratio

α_{sgs} : critical relative humidtiy

σ : $p/p_{surface}$

→ Cloud cover modification





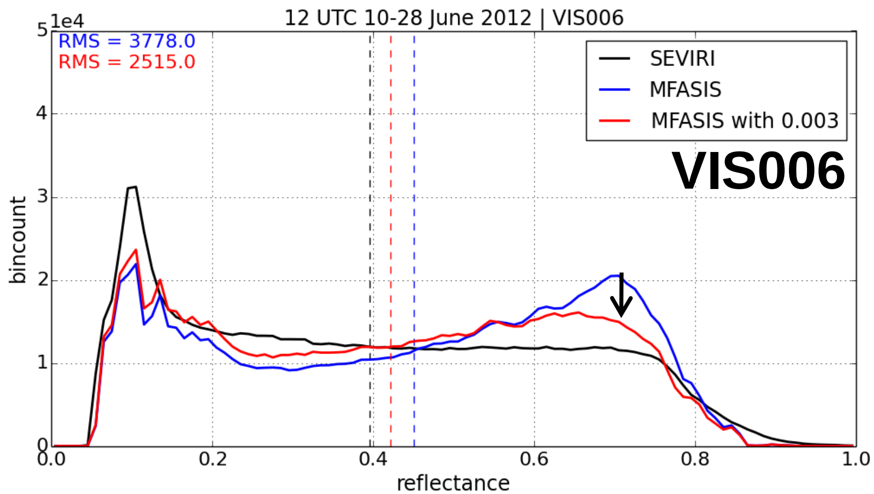
Cloud water content

Subgrid scheme:

$$Q_{\text{sgs}} = \nu_{\text{sgs}}\, Q_{\text{sat}}$$

ν_{sgs} = 0.005
ν_{sgs} = 0.003

→ Subgrid cloud brightness

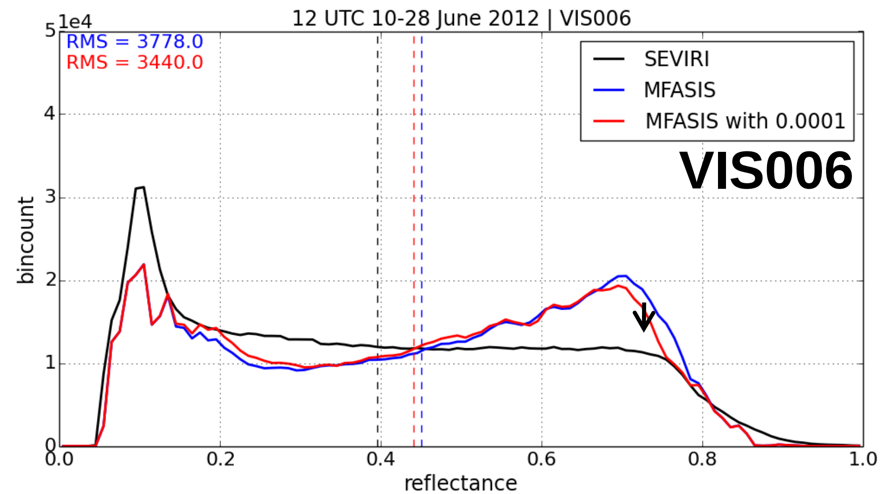


Shallow convection scheme:

$$Q_{\text{con}} = \nu_{\text{con}}\, Q_{\text{sat}}$$

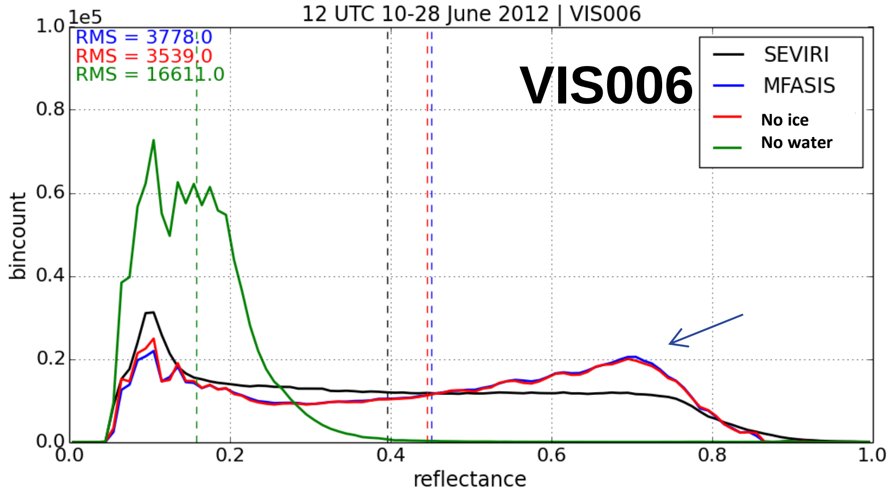
ν_{con} = 0.01
ν_{con} = 0.0001

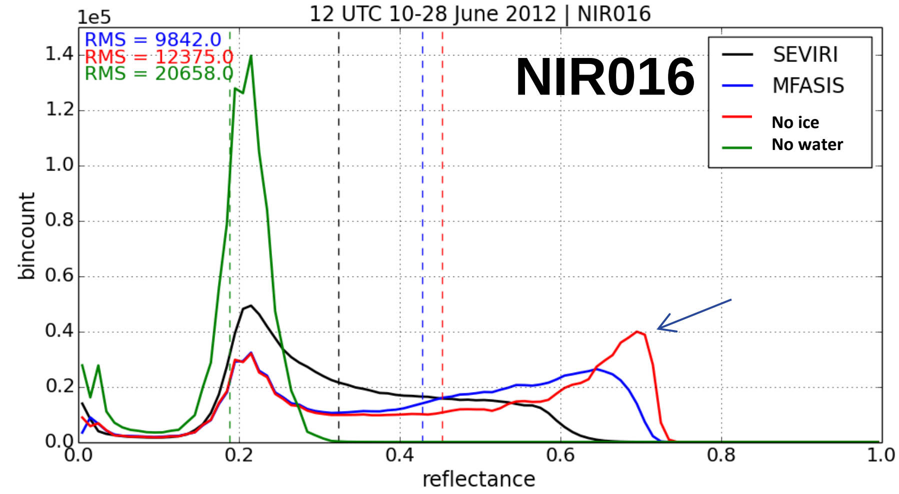
→ Brightness of shallow conv. clouds

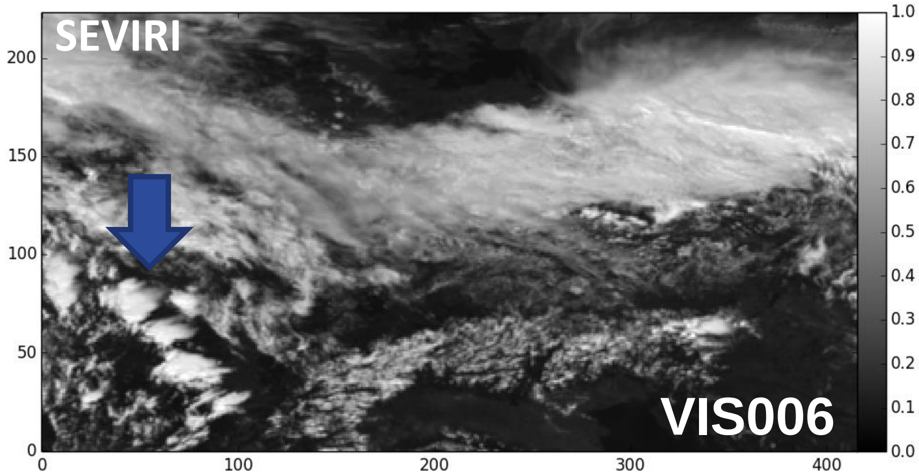


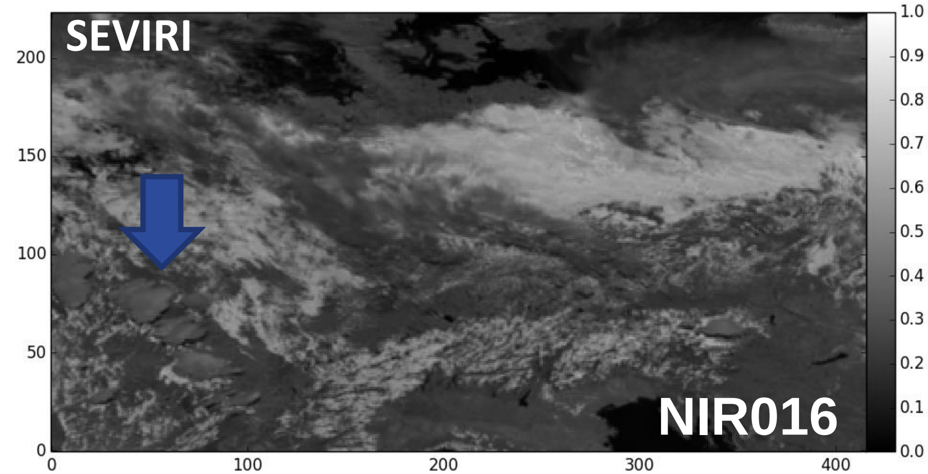
Q_{sat} : total saturation mixing ratio (liquid and frozen water)
Q_{sgs} : total subgrid mixing ratio
Q_{con} : total shallow conv. mixing ratio

No ice / no water

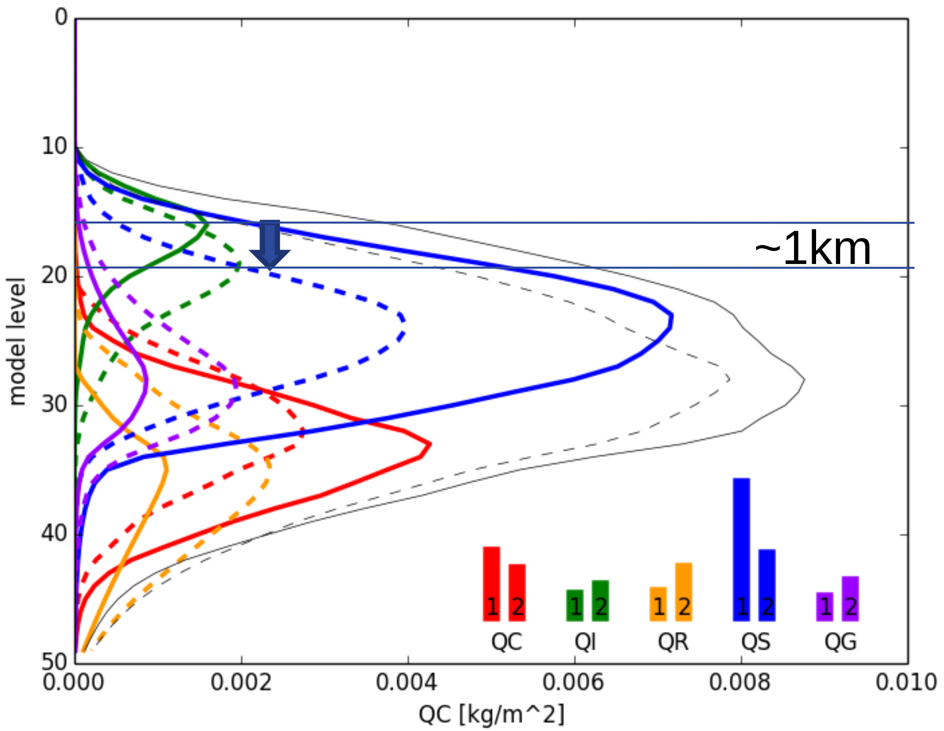








Vertical profiles



Reduced with 2mom:

QC: specific **cloud water** content

QS: specific **snow** content

Increased with 2mom:

QI: specific **cloud ice** content

QR: specific **rain** content

QG: specific **graupel** content

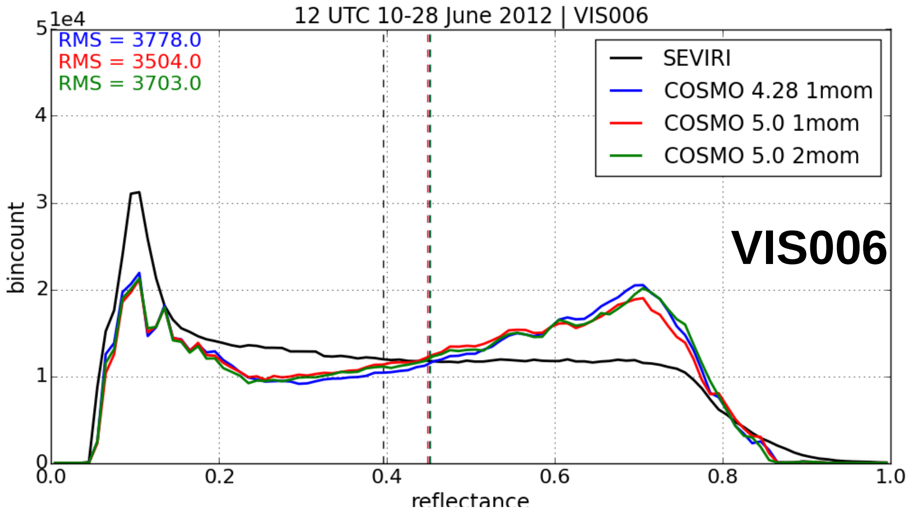
Total Q reduces with 2mom

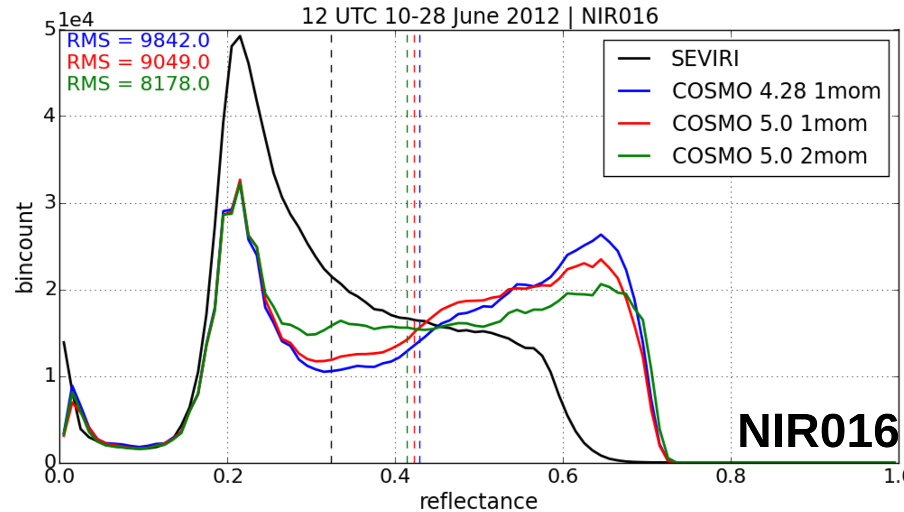
1-moment scheme: - predicts mass fraction of cloud variables

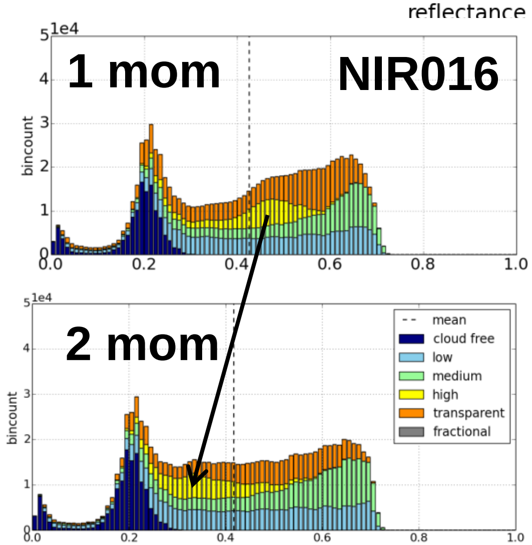
2-moment scheme: - predicts mass fraction & number concentration of cloud variables

- improved ice sedimentation, heteorogeneous & homogeneous ice nucleation

Microphysics







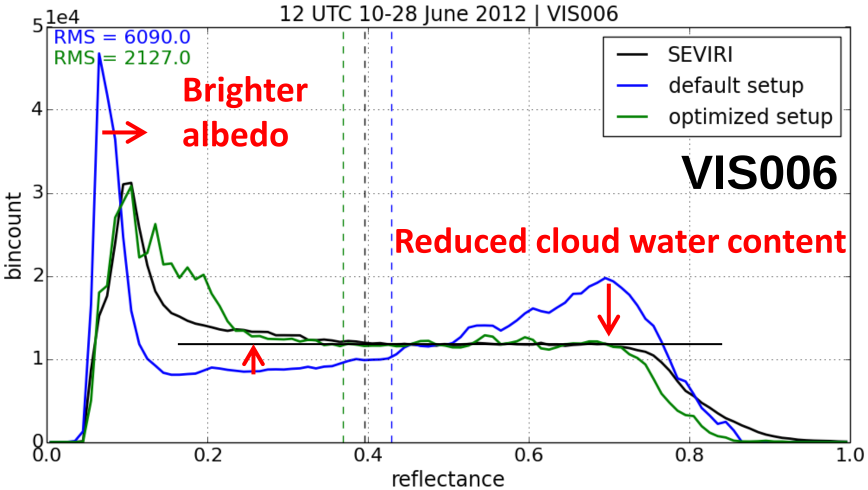
➢ Much **smaller impact than for IR channels**, because reflectances do not depend on cloud top height (depends on ice sedimentation)

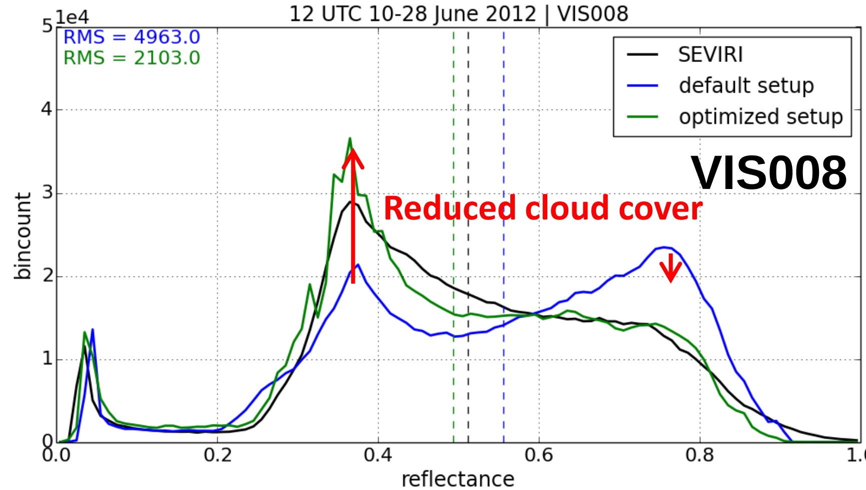
➢ Some influence due to changed particle radii (depends on 2-moment scheme settings)

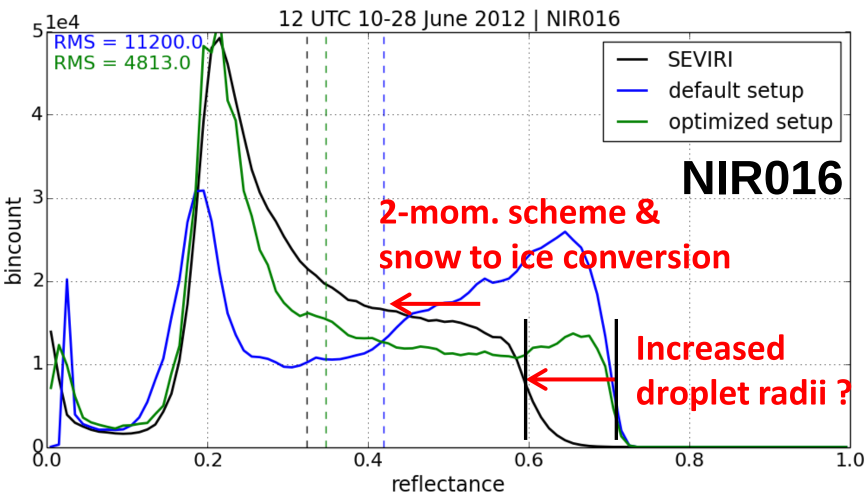
SEVIRI **COSMO 5 (1 mom)**

COSMO 4.28 opera. (1 mom) **COSMO 5 (2 mom)**

Optimized configuration







Default setup <-> **Optimized setup**

MODIS albedo → SEVIRI albedo

Subgrid mixing ratio → Reduced

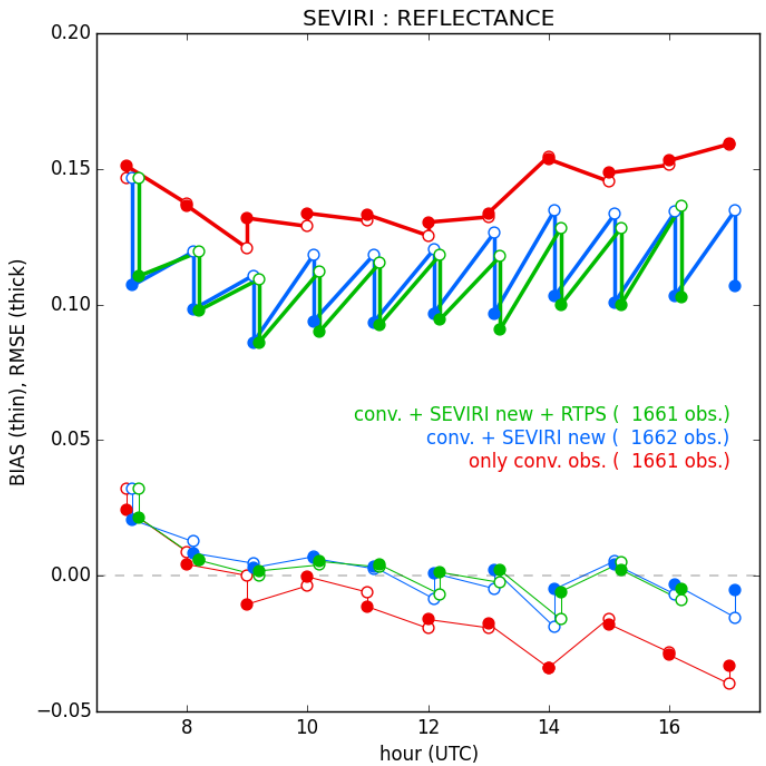
Subgrid cloud fraction → Reduced

Snow to ice conversion 0% → 10%

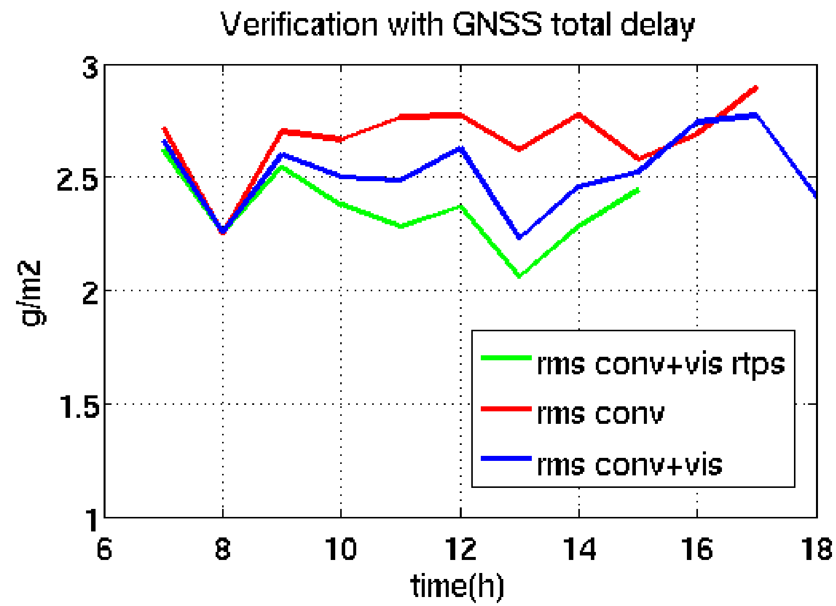
1-mom. scheme → 2-mom. scheme

Assimilation of SEVIRI VIS006

COSMO-DE 2.8 km, KENDA LETKF data assimilation, 40 members, 18 June 2012



The assimilation draws towards the observations



Verification with independent observations of integrated water vapor derived from GNSS delay observations:
→ The assimilation of cloud information has a beneficial effect on the distribution of humidity

Summary

- **Systematic differences**:
  - Too many water clouds in COSMO
  - Too bright clouds in COSMO
- **Fairly realistic clouds by modified:**
  - Subgrid cloud fraction
  - Subgrid cloud water content
- **2-moment microphysics scheme:**
  - Does not reduce cloudiness
  - Reduces systematic differences of ice cloud (heights)
  - Negligible impact in VIS spectrum
- **Assimilation experiments indicate:**
  - Better cloud distribution
  - Improved humidity fields

Outlook

- **Verify results with different period or observations:**
  - Impact of ice clouds
  - Seasonal effects (sun angle, fog) (HOPE period: April/March 2013)
- Further sensitivity studies, in particular to address differences in the **NIR channel:**
  -> Droplet/particle size
- **Consistency** between model and operator (in cooperation with U. Blahak)
- **Further assimilation experiments ongoing**