# Assimilation of visible and near-infrared satellite observations in KENDA-COSMO

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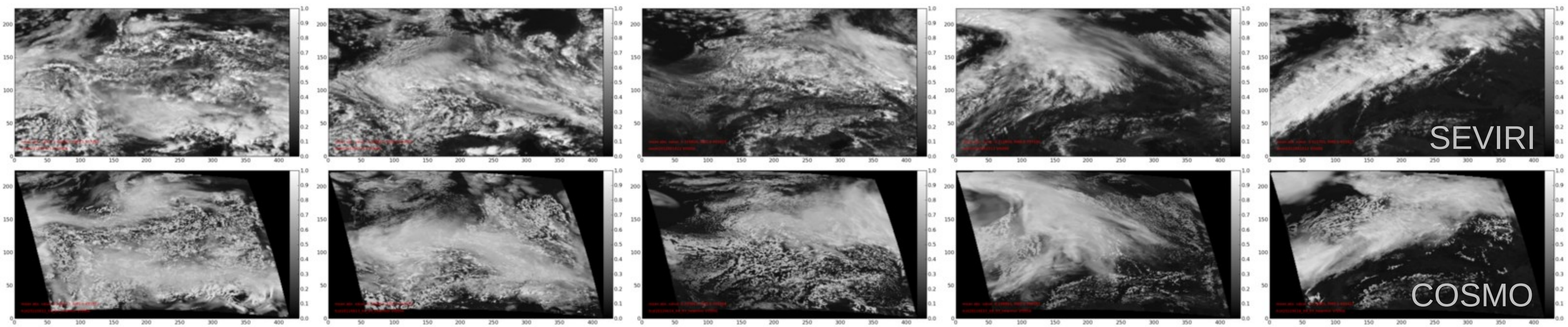
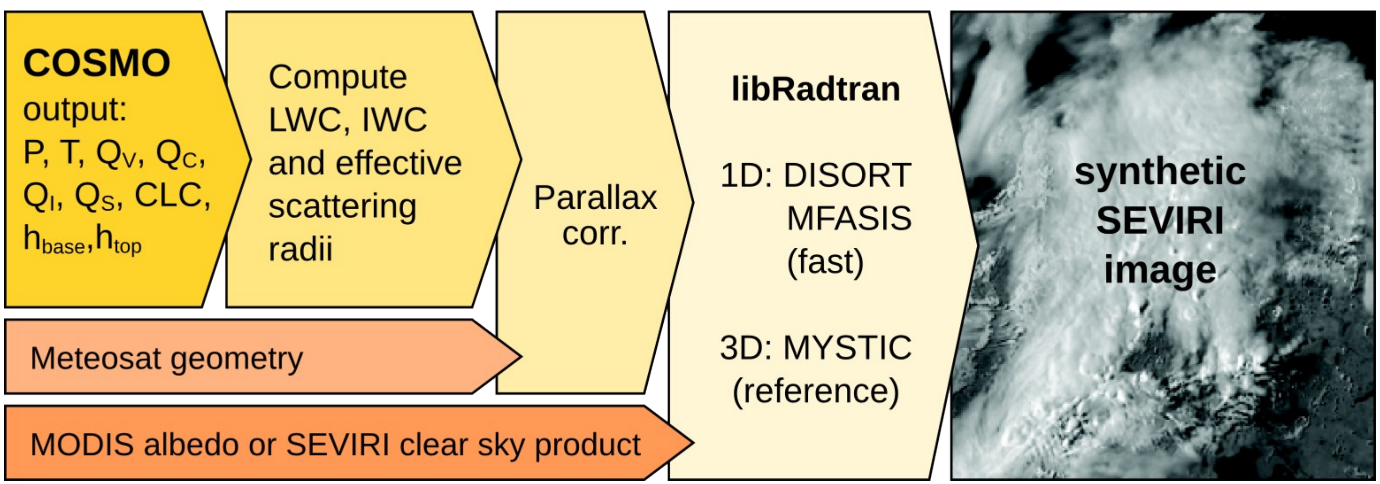


# Visible / near-infrared satellite observations

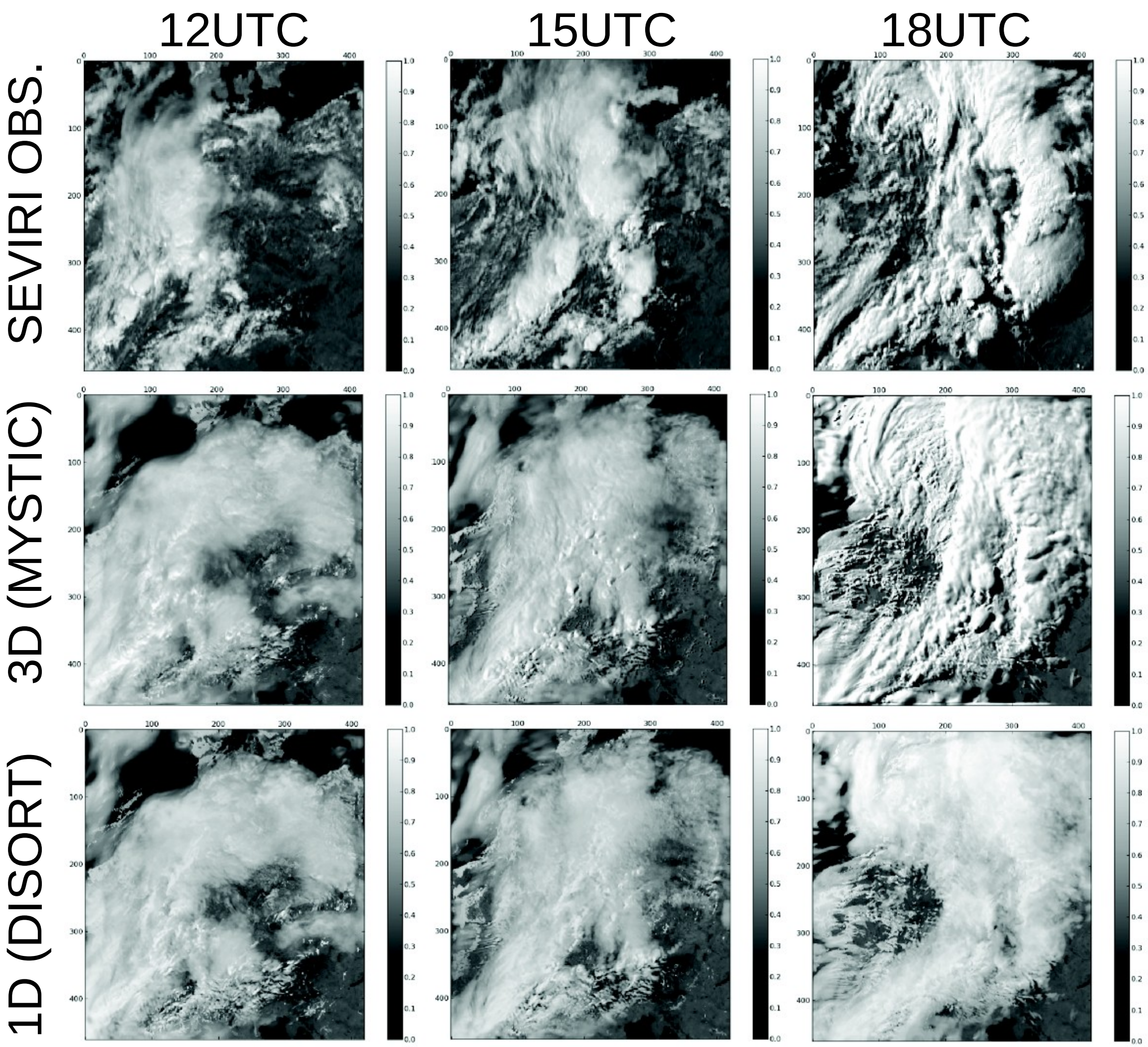
- are very interesting for **convective scale data assimilation**: high spatial and temporal resolution, excellent coverage
- provide complementary information on **cloud distribution** (detects convection earlier than radar, low clouds) **and cloud properties** (particle size, water phase)
- are not used in operational data assimilation systems, mainly because suitable **fast forward operators do not exist** (scattering makes radiative transfer complex)

# VISOP: A fast forward operator for VIS/NIR satellite images




geostationary
0.6µm, 0.8µm, 1.6µm
3km nadir resolution
full disc every 15min

Kostka et al. „Observation Operator for Visible and Near-Infrared Satellite Reflectances“, J. Atmos. Oceanic Technol., 2014




22 June 2011

## Operator results

**Obs. vs. Model (3D RT):**
Realistic structures.
Significant differences, mainly due to discrepancy between forecast and reality

**1D RT vs. 3D RT:**
Agreement quite good for 06-15 UTC (mean rel. error < 5% with parallax correction)

**Computational effort:**
3D: several **CPU-days**
1D: several **CPU-hours**

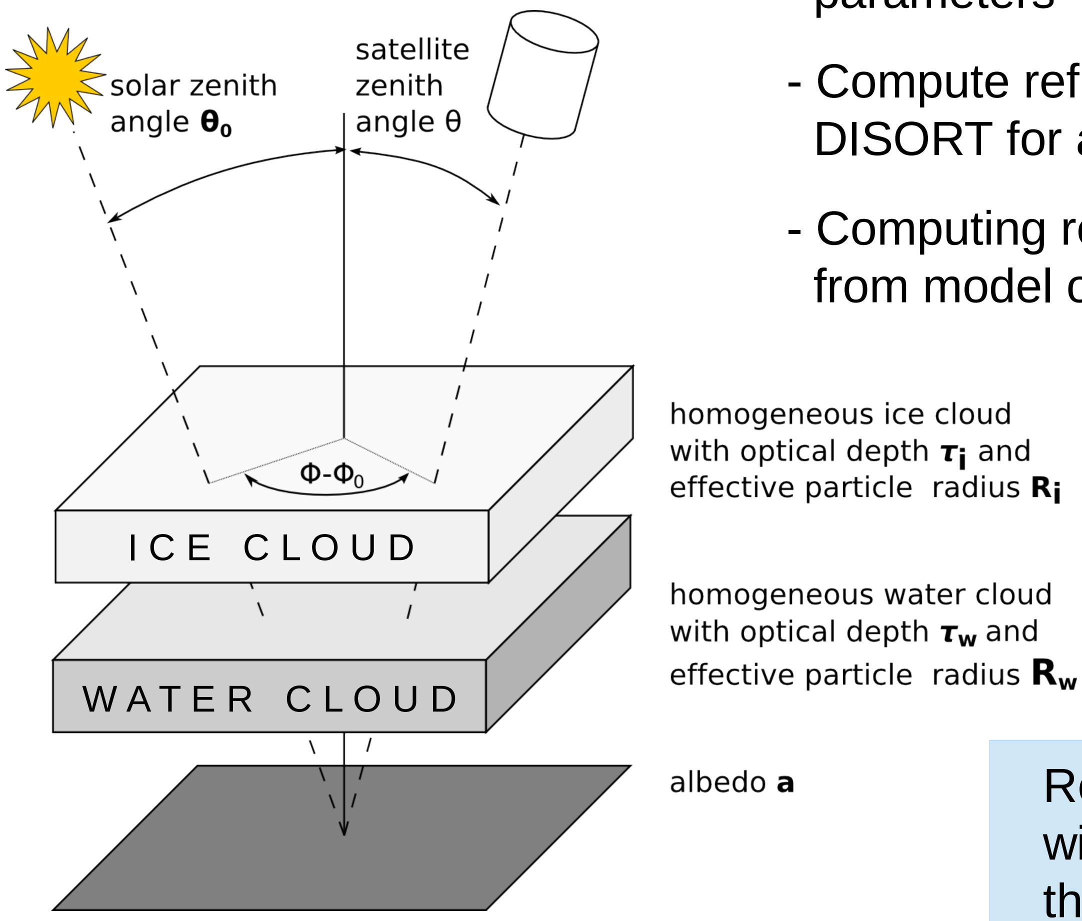
Operational requirement:
**< 1 CPU-minute...**

# A fast replacement for DISORT: MFASIS (PhD thesis Pascal Frerebeau)

**Strategy:** - Describe atmosphere and geometry by a few parameters

- Compute reflectance look-up tables with DISORT for all parameter combinations

- Computing reflectance = calculate parameters from model output, interpolate in look-up tables




**Parameters:**
satellite angles, SZA, water & ice optical depths, eff. radii for water and ice particles, albedo

Reflectance varies more strongly with the satellite angles than with the other parameters

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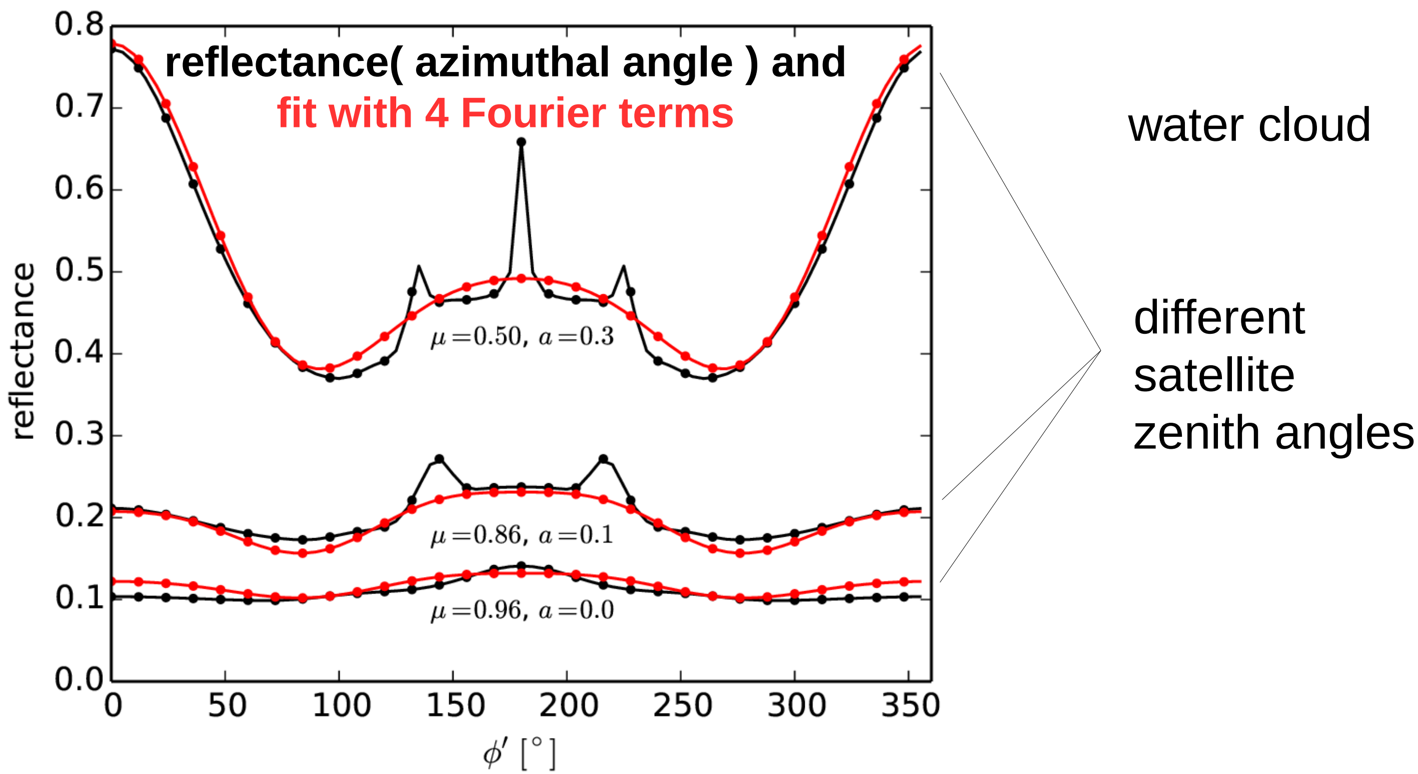


**Idea:** Instead of tabulating reflectance directly for many satellite angles, use cosine / power series expansion of the reflectance in the satellite angles and tabulate only a few coefficients

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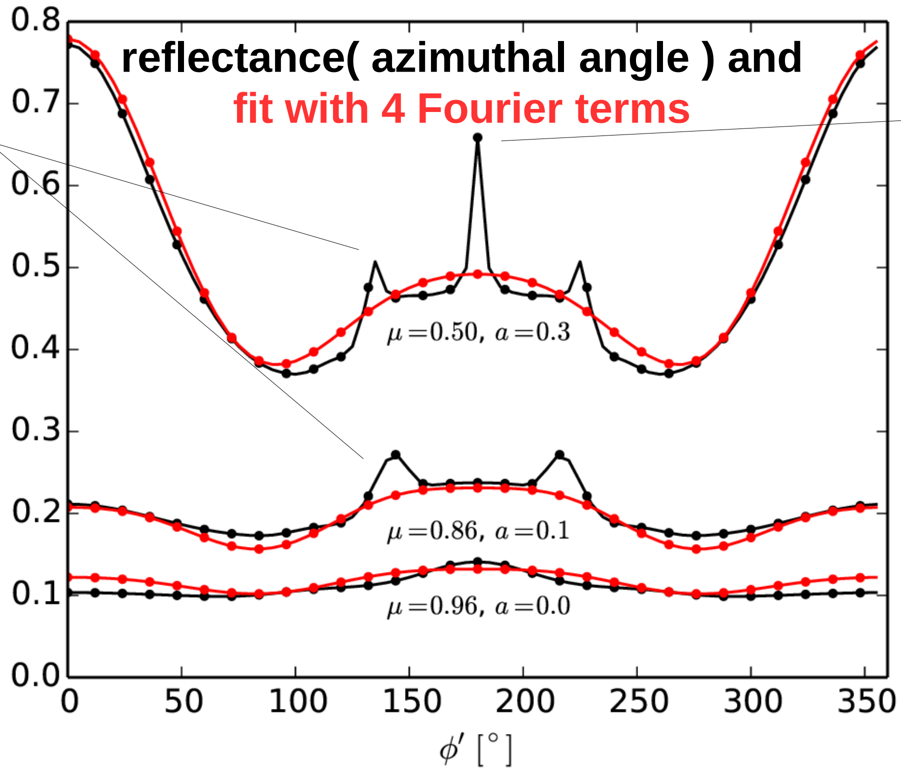



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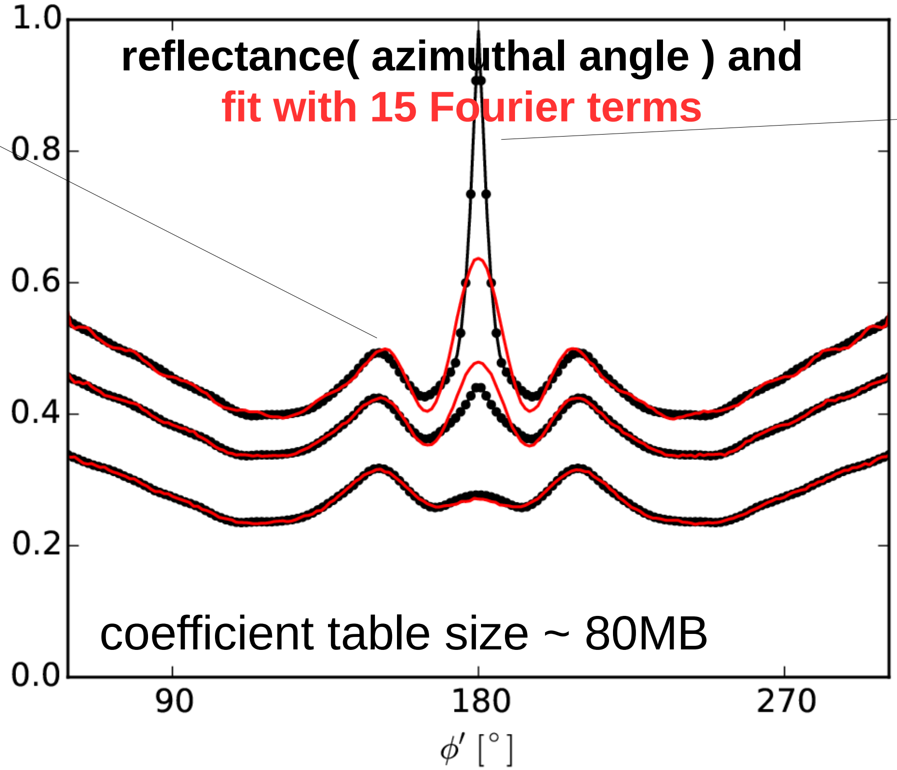
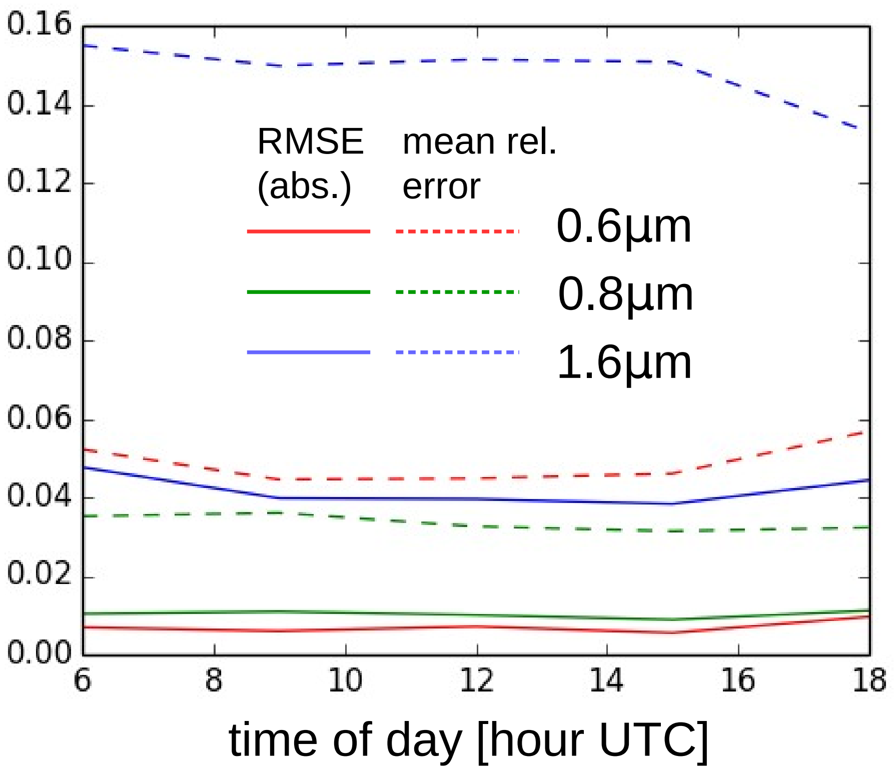




**Idea:** Instead of tabulating reflectance directly for many satellite angles, use cosine series or power series expansion of the reflectance in the satellite angles and tabulate only a few coefficients

# Comparison with DISORT for a COSMO/SEVIRI scene in June

Data: 3-hourly operational COSMO-DE forecasts for June 15-22, 2012




**Visible channels:** RMSE ~ 0.01, mean relative error 3.5%-5% wrt. DISORT

Mean relative error relative to MYSTIC 3D results for 0.8µm:
DISORT: 4%-6% (for not too large SZA)
MFASIS: 5%-7% (estimated, assuming independent errors)

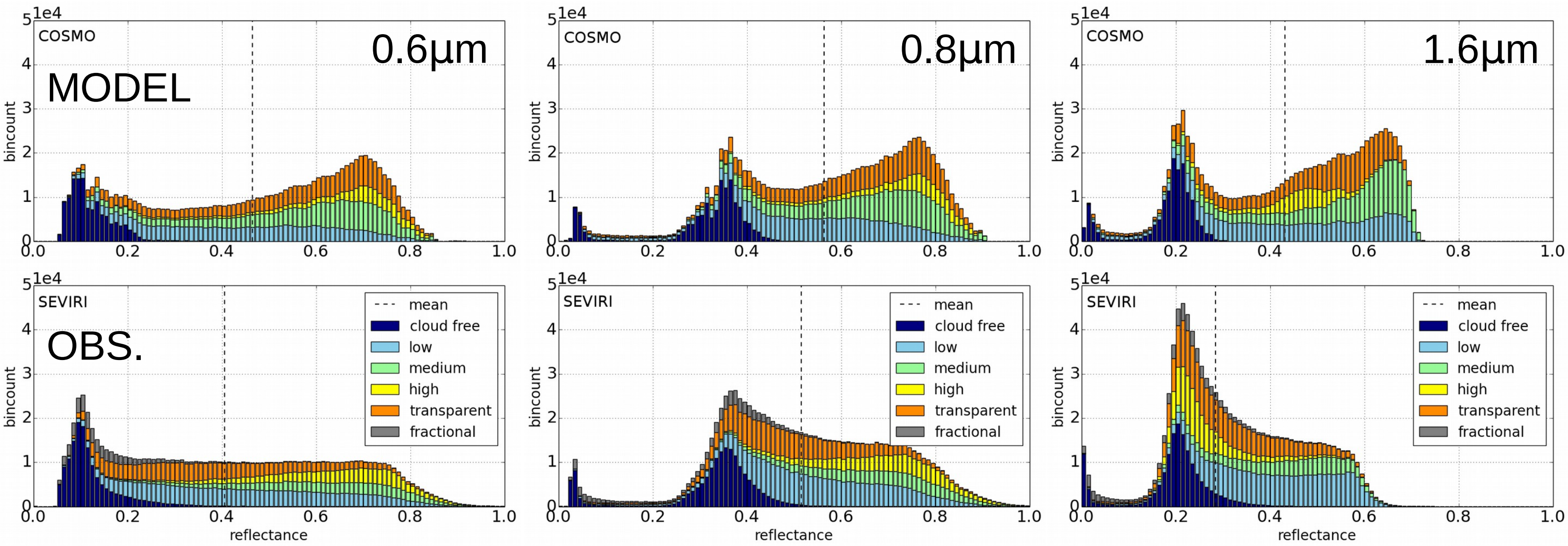
→ **MFASIS is sufficiently accurate to be used as faster (3 orders of magnitude) replacement for DISORT**

Near-infrared: very sensitive to particle radius, which needs to be determined better
Feb./March + Oct./Nov.: Glory → Error around noon increased by factor ~3

# Comparison synthetic vs. real SEVIRI observations

Even if the RT was perfect, approximations & parameterizations in the model and the operator can cause **systematic differences**

**Test**: 18-day period in June 2012, VISOP / COSMO-DE vs. METEOSAT SEVIRI




**Reflectance histograms: Too many pixels with high reflectance**

Cause: Mainly **too many clouds**, for NIR also a systematic error in cloud brightness.

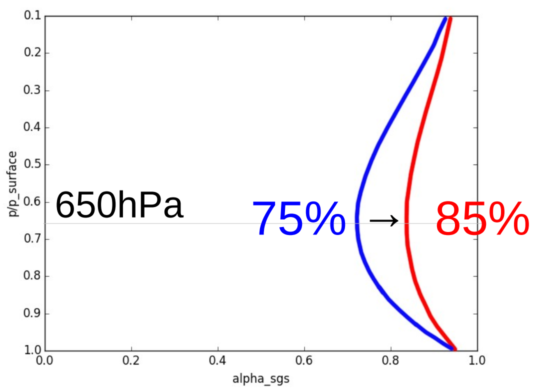
NWC SAF cloud type product + model equivalents: **Too many medium clouds.**

# Comparison synthetic vs. real SEVIRI observations

Biases should be understood and removed / corrected before assimilation
→ **sensitivity analysis** for tuning parameters in operator and model

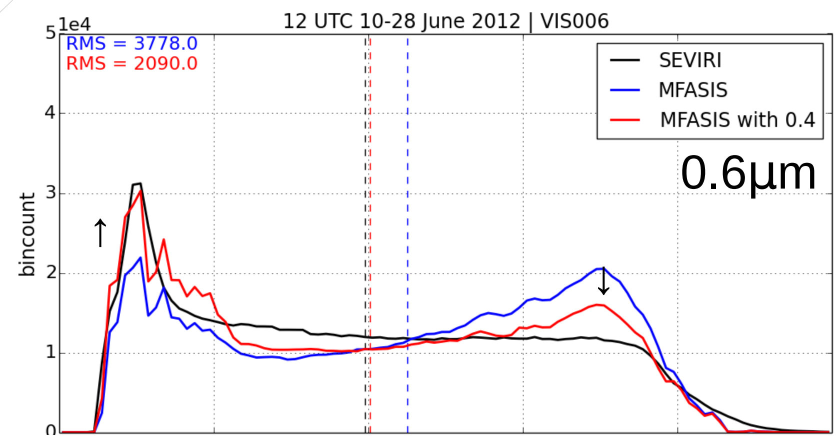
Strongest impact on bias: Changes in **subgrid contribution to LWC**

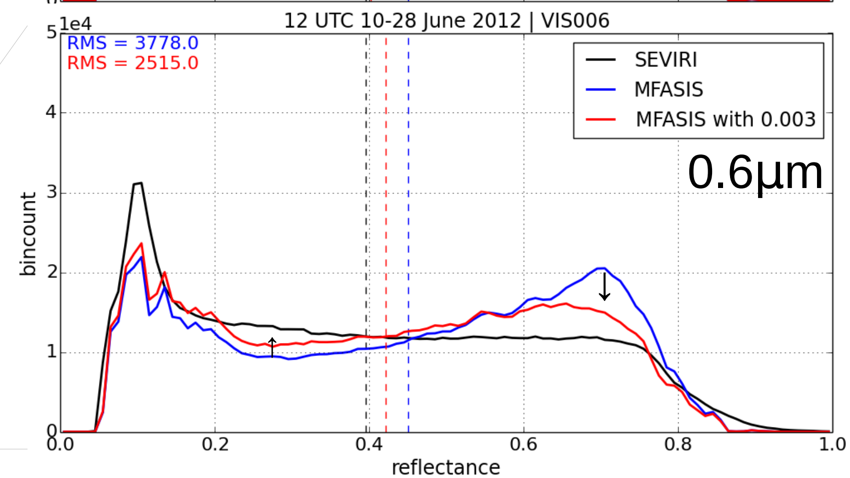
Subgrid cloud cover in COSMO:
RH > $RH_{crit}$( z, parameters ) → sg. clouds




Subgrid cloud water content in COSMO:

$Q_c^{sg} = f * Q_{sat}$,  f = 0.5% → 0.3%
→ average optical depth of clouds



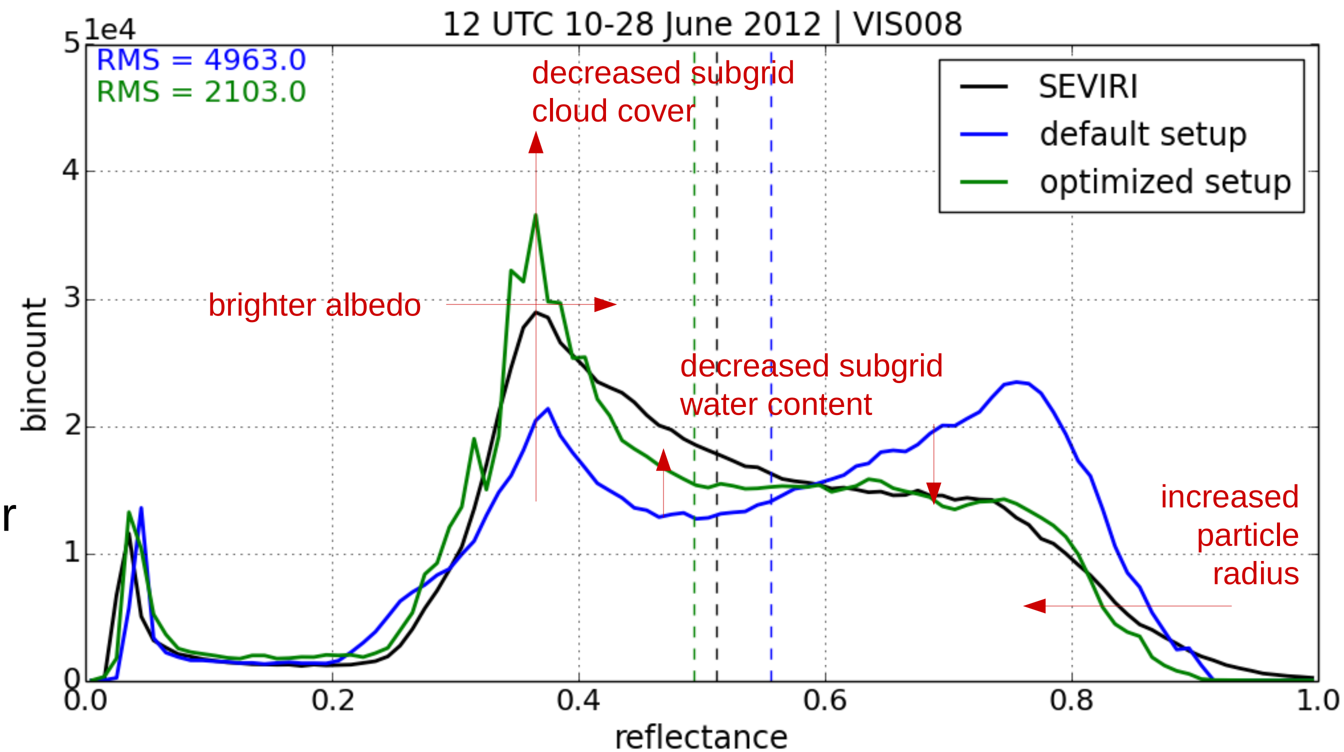



# Comparison synthetic vs. real SEVIRI observations

**Other important tuning parameters / operator improvements**
- particle radii (→ cloud cond. nuclei): parameterized or from 2-moment scheme
- interpreting snow as cloud ice (changing radius of discrimination)
- improved albedo (derived from SEVIRI clear sky product instead of MODIS)

**Optimized settings:**
Systematic errors strongly reduced, marked positive frequency bias for cloudiness is gone...

**To do:**
Consistent settings for all channels and for operator and model (radiation feedback?)



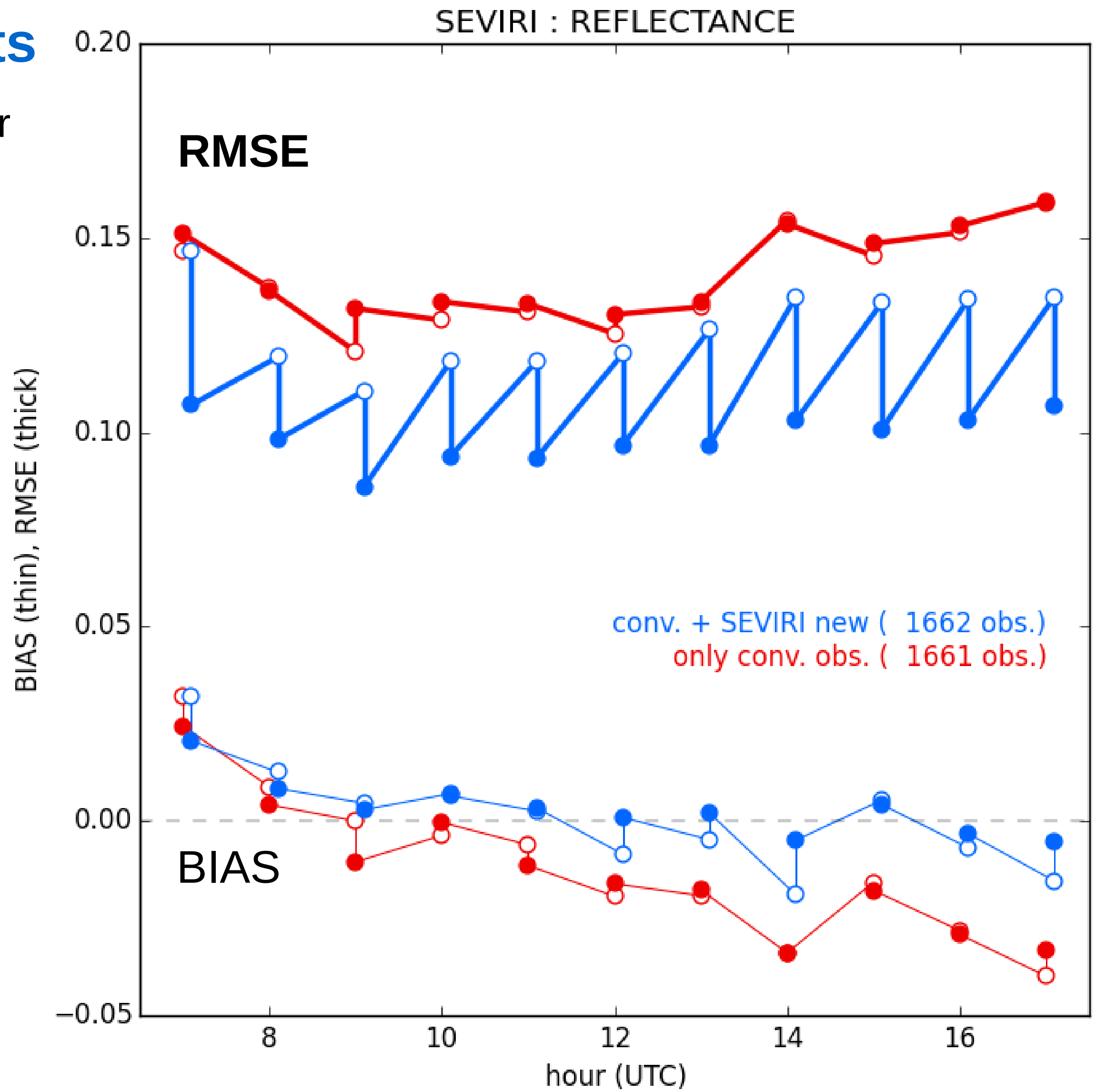
# First assimilation results

Assimilation of conventional and/or SEVIRI obs. in COSMO/KENDA

**Setup:**
40 member LETKF
1h assimilation interval
600nm observations
Observation error 0.2
Superobbing (radius 3 pixels)
Horiz. localization 100km
No vertical localization

Assimilation of SEVIRI observations:
**lower reflectance RMSE and bias**

Independent GPS humidity observations: reduced error



# Getting ready for „Big Data Assimilation“

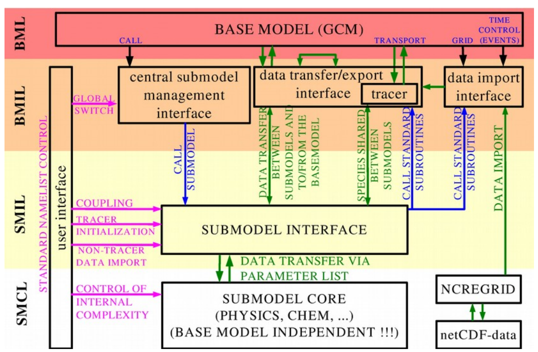
**High resolution of models and observations**

**Massively parallel architectures must be used**

**3D effects cannot be neglected**

I/O restrictions

Operator must run online to reduce output




→ **VISOP online version using MESSy (**standard. interface for code components)

MYSTIC Monte Carlo RT calculation (**10 CPU-days**) of 50m PALM LES model output (Carolin Klinger, LMU)

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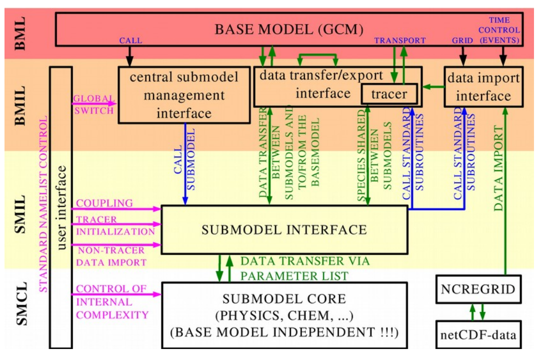
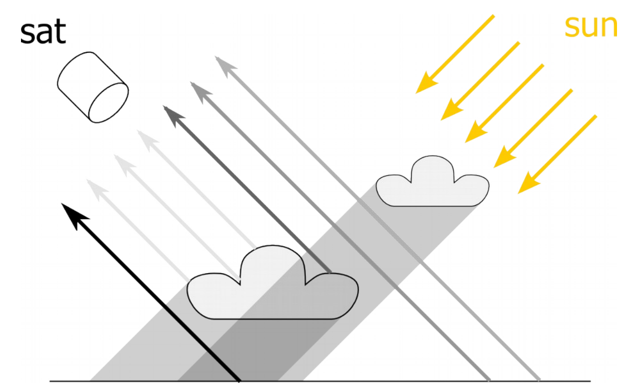


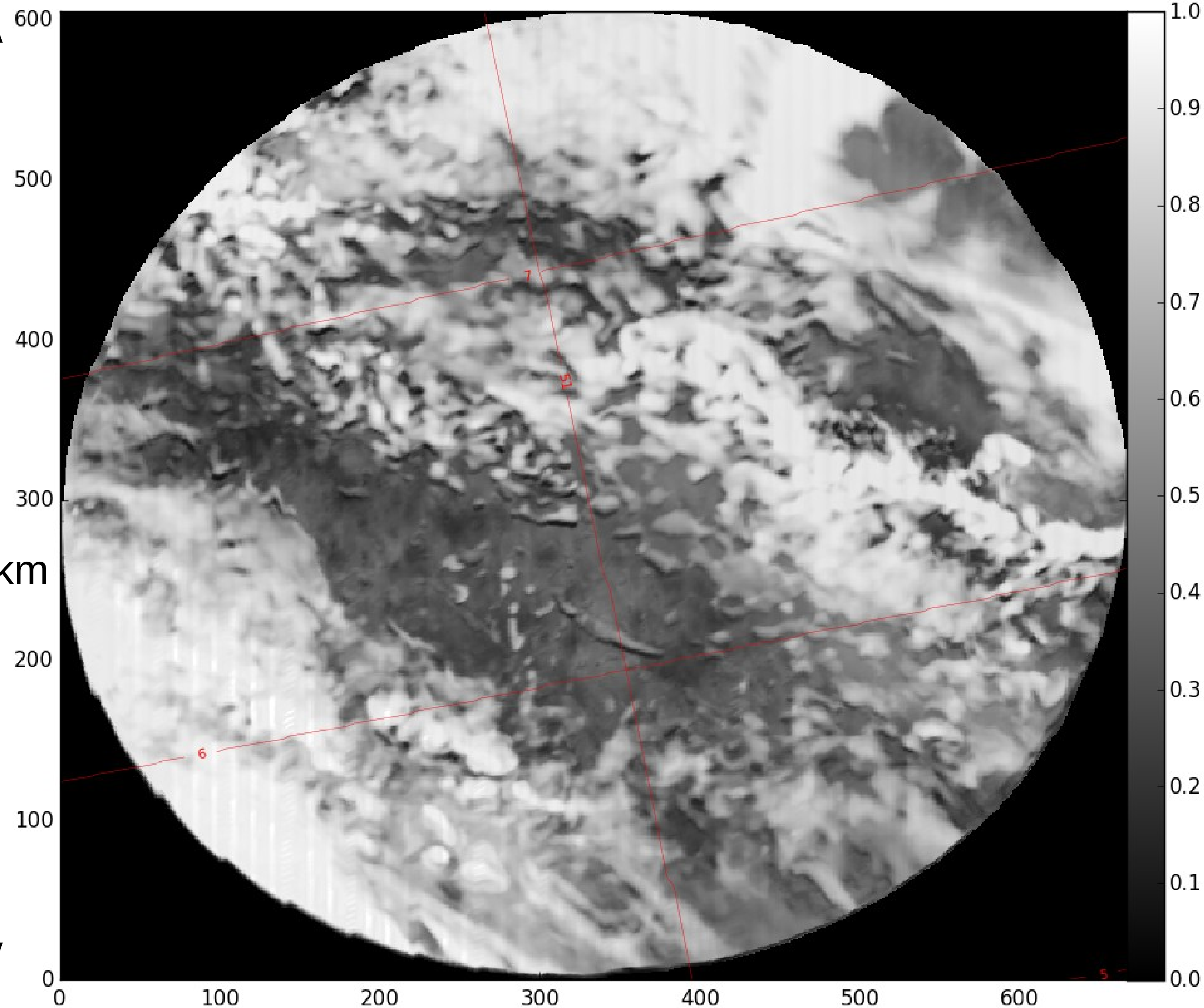

→ **VISOP online version using MESSy (**standardized code component interface)

→ **3D version** (shadows, parallax corr.) based on MFASIS is in development

Both issues are investigated in the framework of the HD(CP)2 project, in which 100m resolution ICON runs on domain covering Germany are performed

Simulated MODIS 0.8µm image (250m Pixel size) generated from ICON-LES model output with 300m resolution

166 km




Computational effort for RT: O(CPU sec.)

## SUMMARY

- We developed a 1D RT method to synthesize visible satellite images that is sufficienty accurate for DA and O(1000) faster than DISORT

- Near-infrared + glory affected visible radiances: Larger errors, improvements requires to better account for high sensitivity to particle radii

- Systematic differences between model/operator and observations:
  Most important sensitivities are understood, optimization of settings is under way

- First assimilation results are promising

- Big Data Assimilation:
  Online operator version is ready, 3D extensions are in development