Hans-Ertel-Centre for Weather Research
DATA ASSIMLATION BRANCH

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

ASSIMILATION OF SEVIRI VISIBLE AND NEAR-INFRARED OBSERVATIONS IN KENDA/COSMO

Leonhard Scheck[1,2], Tobias Necker[1,2], Pascal Frerebeau[2], Bernhard Mayer[2], Martin Weissmann[1,2]

1) Hans-Ertel-Centre for Weather Research, Data Assimilation Branch, LMU München, Germany
2) Meteorologisches Institut, Ludwig-Maximilians-Universität München, Germany

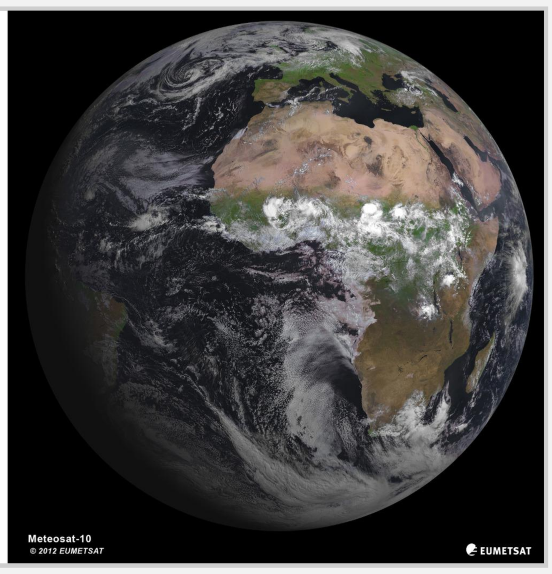
INTRODUCTION

Visible / near-infrared satellite observations:

- could provide important information about cloud properties
- are not used in operational data assimilation systems
- main problem: lack of suitable fast forward operators

Goals of this project:

- Development of fast VIS/NIR forward operator
- Improved representation of clouds by direct assimilation of visible and near-infrared SEVIRI reflectances in KENDA/COSMO.



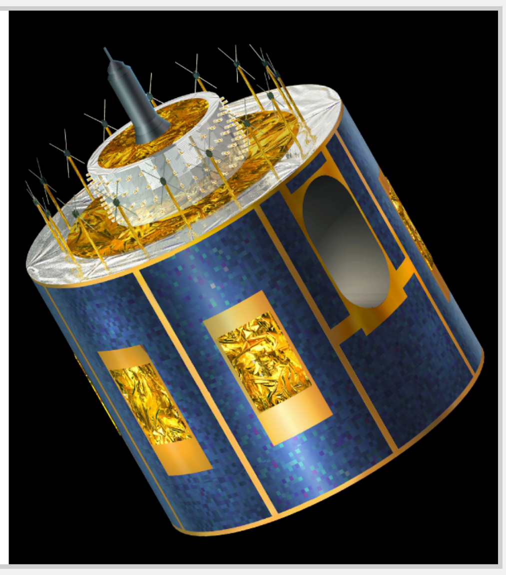
SEVIRI

Main instrument on Meteosat Second Generation (MSG)
Geostationary orbit, longitude 0.0° (MSG2)
Resolution 2-5km in Europe
New image every 15min (5min in rapid scan mode)

Visible / near-infrared channel properties:

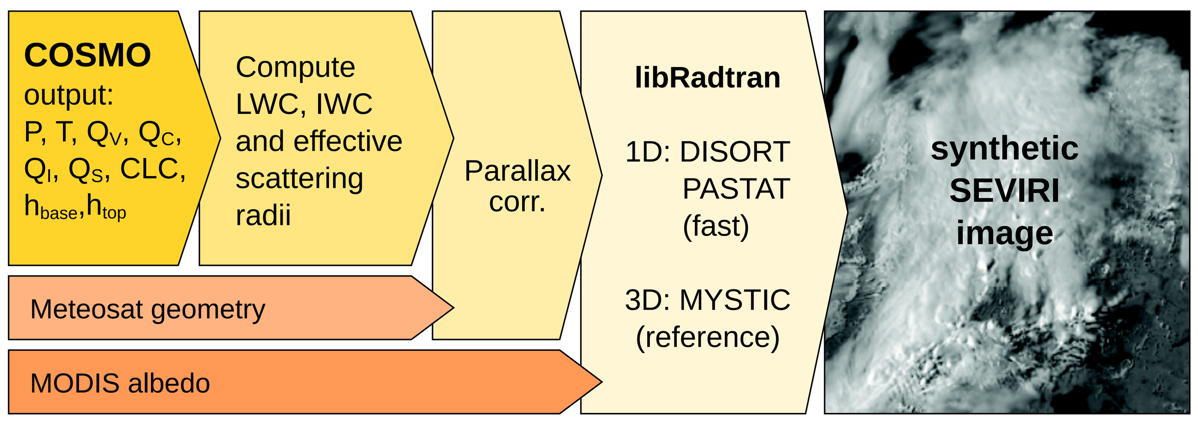
600nm, 800nm } albedos differ strongly, clouds are bright → distinguish between ground, clouds, cloud shadows

1600nm sensitive to water phase and particle sizes

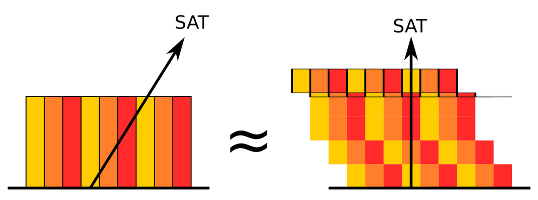


OPERATOR

BASIC DESIGN



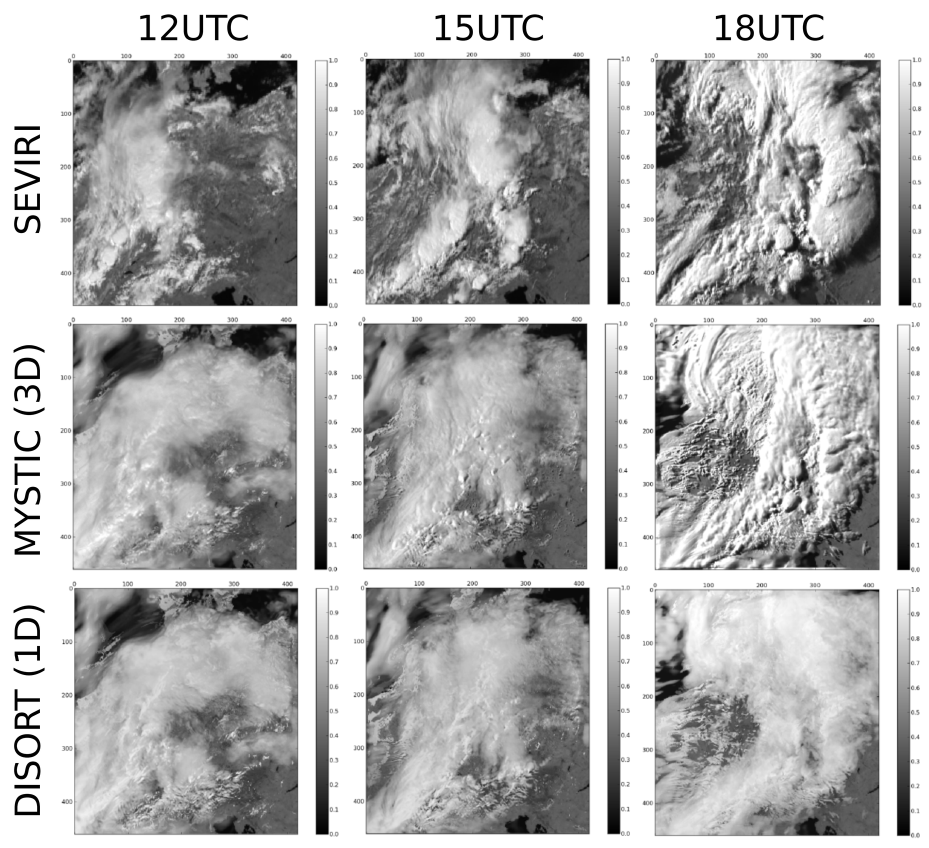
Parallax correction (first order 3D effect):



Reference: Kostka et al. „Observation Operator for Visible and Near-Infrared Satellite Reflectances", JTAC, submitted

Radiative transfer solvers	RMSE reflectance	comp. effort for COSMO-DE scene
MYSTIC (3D monte carlo)	reference	O(CPU days)
DISORT (1D discrete ordinate method)	< 6%	O(CPU hours)
NEW: PASTAT (1D look-up table based)	< 10%	< 1 CPU minute

RESULTS: SEVIRI vs. 3D vs. 1D



Obs. vs. Model: Realistic structures, differences in location of clouds (discrepancy btw. model and reality).

1D vs. 3D: Agreement good for 6-15 UTC (RMSE<6%), worse for larger sun zenith angles (→ cloud shadows)

PASTAT: A Look-up table based 1D radiative transfer solver

(PhD thesis Pascal Frerebeau)

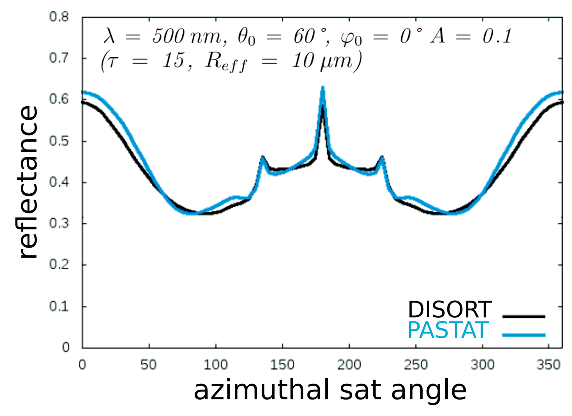
Method: fit function for radiance, coefficients from look-up tables

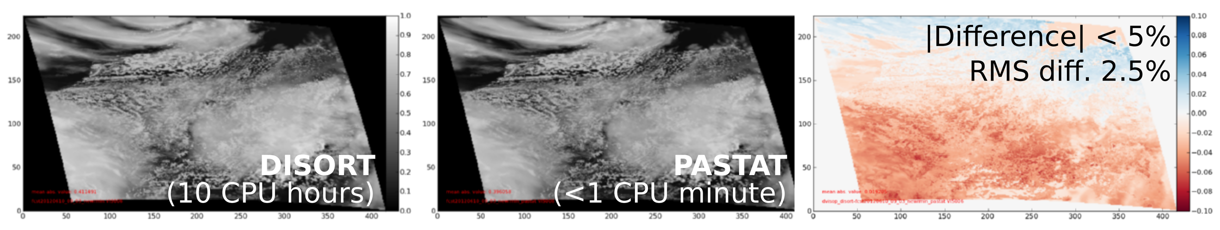
$$I_{\mathrm{toa}}(\overbrace{\mu,\phi}^{\text{sat angles}},\overbrace{\mu_0,\phi_0}^{\text{sun angles}},\mathbf{p}) = \sum_{k=0}^{3}\mu^k I_k(\mathbf{p})\left[1+(1-\mu)\underbrace{\sum_{l=1}^{4} c_{k,l}(\mathbf{p})}_{\text{coefficients}}\cos\left(l(\phi-\phi_0)\right)\right]$$

20 coefficients, 6 parameters **p** (wavelength, albedo, water & ice optical depths, max. effective scattering radius, solar zenith angle)
→ 20 six-dim. tables (computed by least-squares fit to DISORT)

Potential advantage: Developing adjoint should be relatively easy...

Results: Extremely fast, only small errors, compared to DISORT, directional dependency of radiance well reproduced



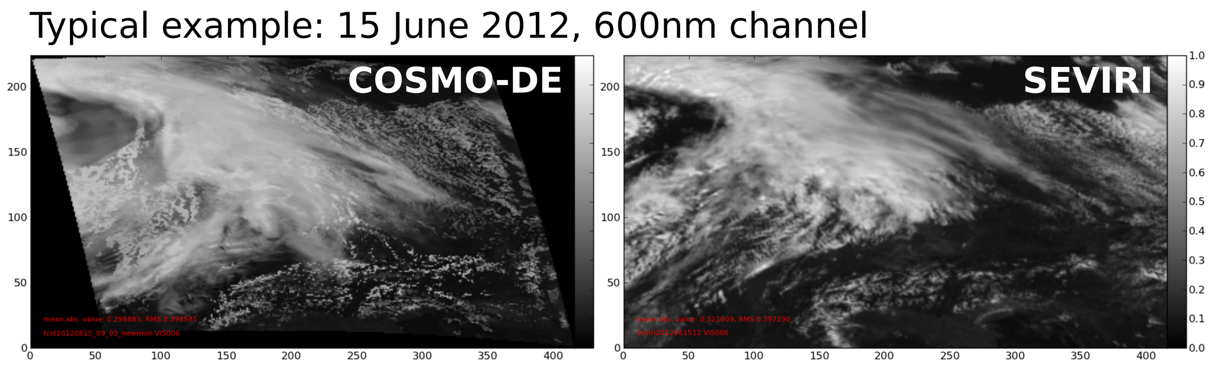


SYSTEMATIC DIFFERENCES BETWEEN OBSERVATIONS AND MODEL

The fast forward operator is used to quantify systematic differences between SEVIRI observations and operational COSMO-DE forecasts (master thesis Tobias Necker).

Goal: Identification of model and operator deficiencies

Typical example: 15 June 2012, 600nm channel



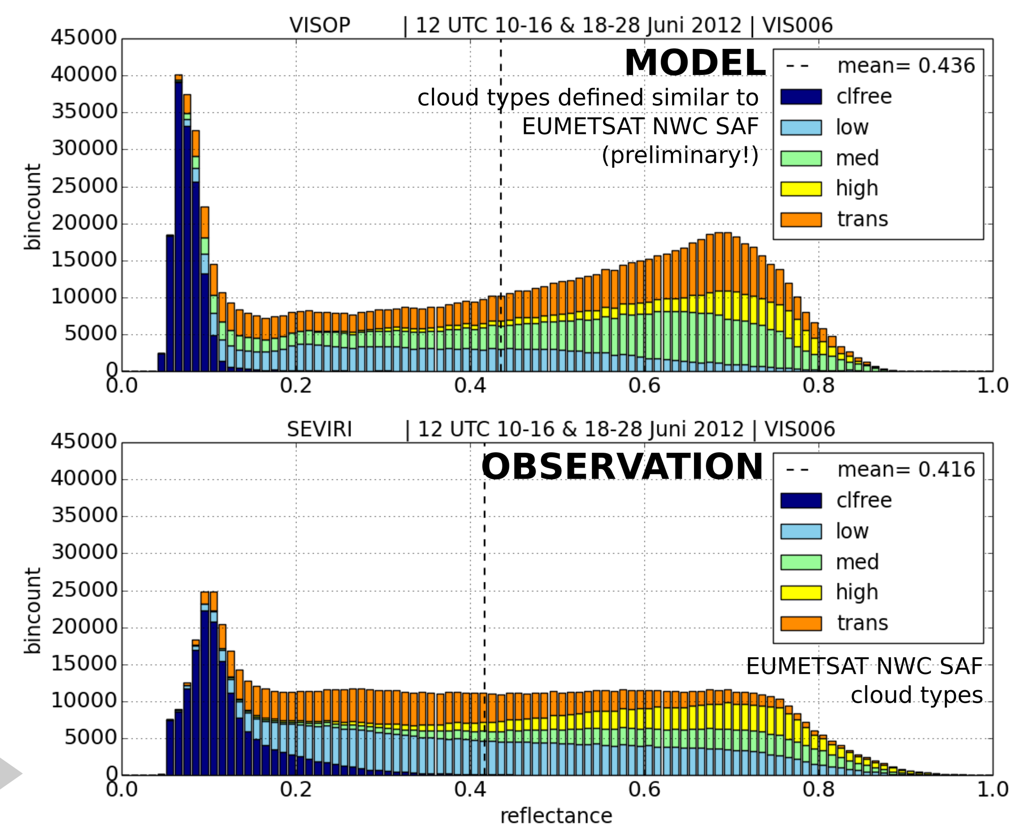
Agreement not bad, but **too many clouds in the model.** Confirmed by contingency table and reflectance histograms. → microphysics problem?

Contingency table: Distinguish only between cloudy and cloud-free

Contingency table (for June 10 – 28, 2012, only at 12UTC)		observation: cloudy	observation: cloud-free
model	cloudy	a hit 76.9%	b false alarm 9.1%
model	cloud-free	c miss 4.7%	d correct negative 9.2%

Probability of detection	a/(a+c)	94%
Frequency bias	(a+b)/(a+c)	+5.3%
False alarm ratio	b/(a+b)	10.6%

Reflectance histograms: "False alarm clouds" for 0.5 < r < 0.8 probably mainly related to high and transparent clouds in COSMO



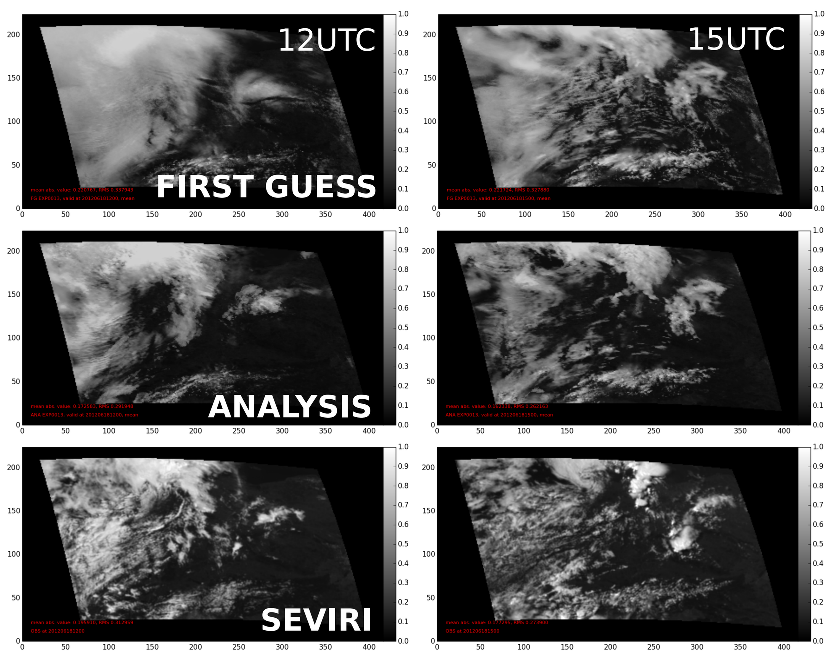
DATA ASSIMILATION EXPERIMENTS

KENDA setup for SEVIRI assimilation experiments:

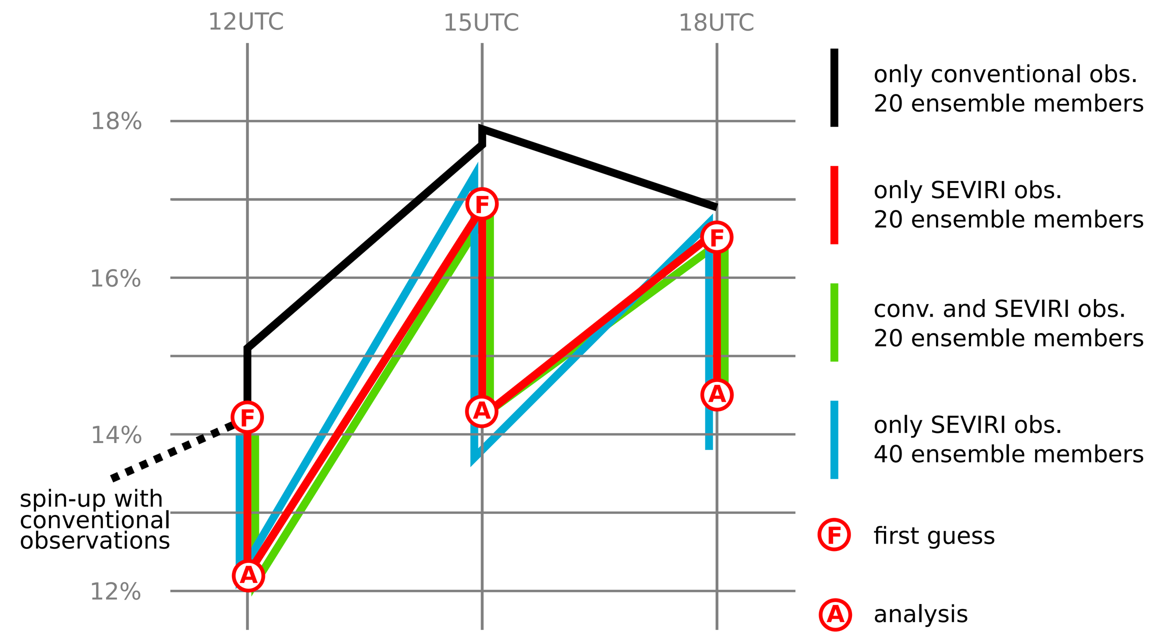
- 3-hourly LETKF assimilation, analysis ensemble with 20 or 40 members
- 20 member ECMWF EPS boundary conditions (time-lagged → 40 BCs)
- Spin-up phase: several cycles with conventional observations only
- First experiments: Assimilation of 600nm SEVIRI observations, observation error assumed to be 10%, no vertical localization

Preliminary results:

- Ensemble mean is drawn towards SEVIRI observations: More structure and less clouds than first guess, lower RMSE in reflectance
- Larger ensemble (40 instead of 20 members) leads to reduced RMSE: better chance to find ensemble member with cloud at the right position
- conventional observations are not able to reduce reflectance error
- conventional + SEVIRI obsesrvations: Very similar to SEVIRI only (assumed observation error probably too low)



First guess, analysis and observed reflectance for the "only SEVIRI observations" 20 member run.



Evolution of the RMS reflectance error of the ensemble mean for different assimilation experiments started at 18 June 2012, 12UTC.

OUTLOOK

OPERATOR
- Optimization and evaluation of PASTAT
- More 3D effects (e.g. cloud shadows) will be modelled in HD(CP)2-O3

SYSTEMATIC DIFFERENCES
- Further characterization of "false alarm clouds"
- Variation of model and operator parameters → separation of their error contributions

DATA ASSIMILATION
- Verification with other observations
- Assessment of forecast impact, single Observation studies
- Sensitivity experiments (obs. error, localization, obs. freq., ensemble size, assim. interval)
- Linearity improvements (double penalty problem): Smoothing? Warping?
- Assimilation of several wavelengths and complementary observations (radar, GPS)
- Detection and exclusion of problematic cases from assimilation (e.g. cloud shadows)