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ASSIMILATION OF VISIBLE AND NEAR-INFRARED SATELLITE REFLECTANCE IN KENDA/COSMO

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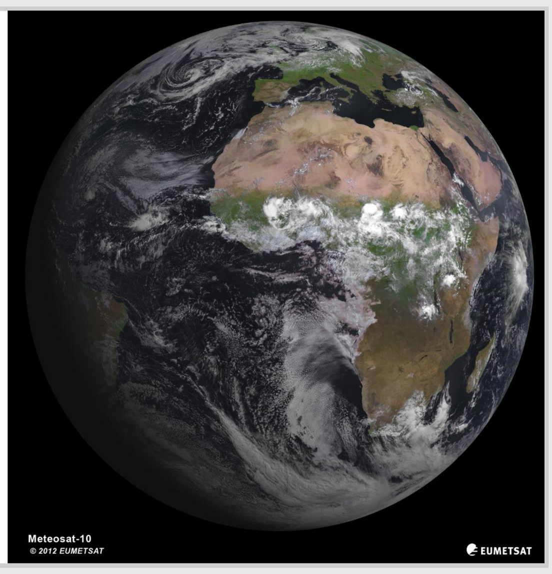
INTRODUCTION

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.



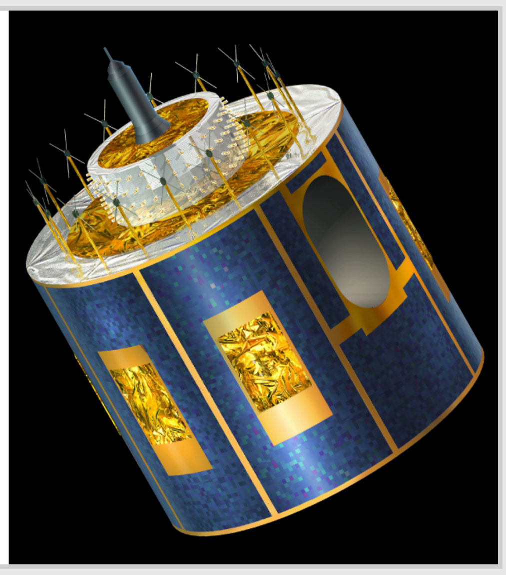
SEVIRI

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:

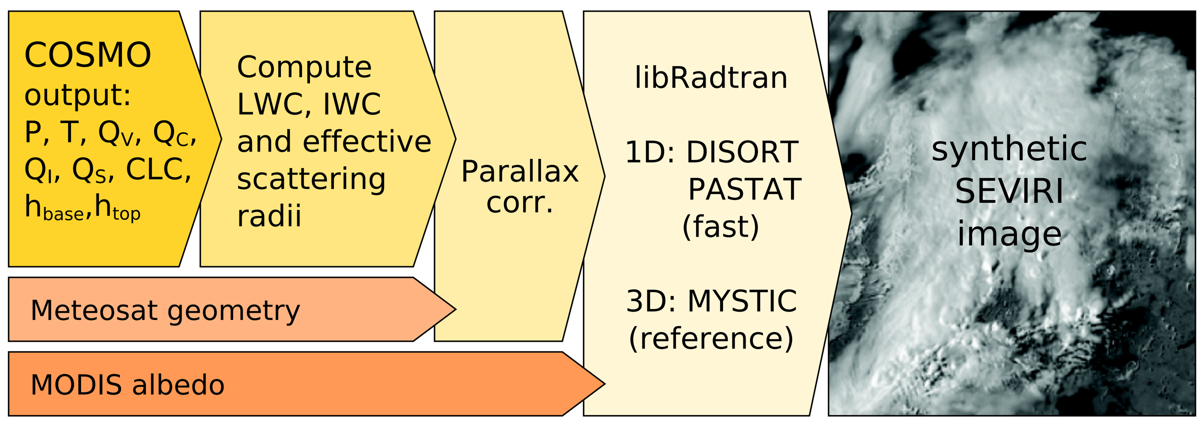
600nm, 800nm } albedos differ strongly, clouds are bright → distinguish between ground, clouds, cloud shadows

1600nm sensitive to water phase and particle sizes

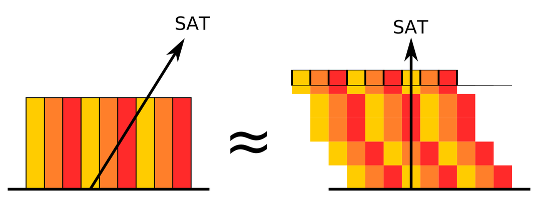


OPERATOR

BASIC DESIGN

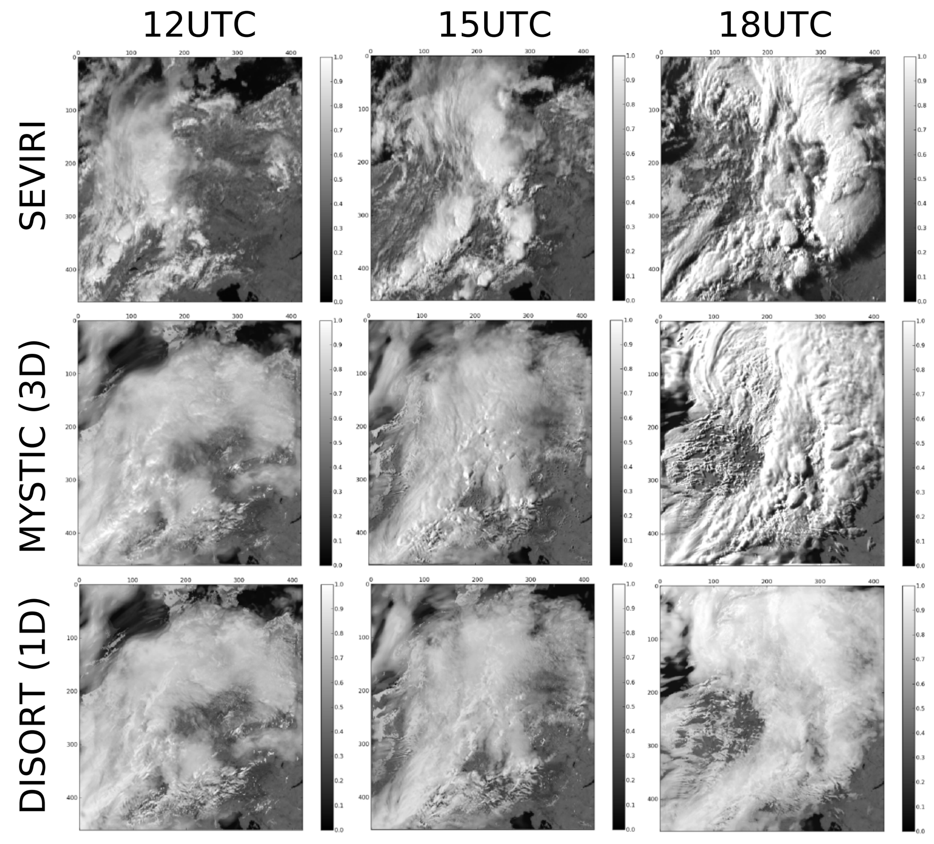


Parallax correction
(first order 3D effect):



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

RESULTS: SEVIRI vs. 3D vs. 1D



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

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

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

(coefficients)

20 coefficients, 6 parameters p (albedo, water & ice optical depths, max. eff. scatt. radius for water & ice particles, solar zenith angle)
→ 20 six-dim. tables (computed by least-squares fit to DISORT)
Results: Extremely fast, only small errors, compared to DISORT

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)

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

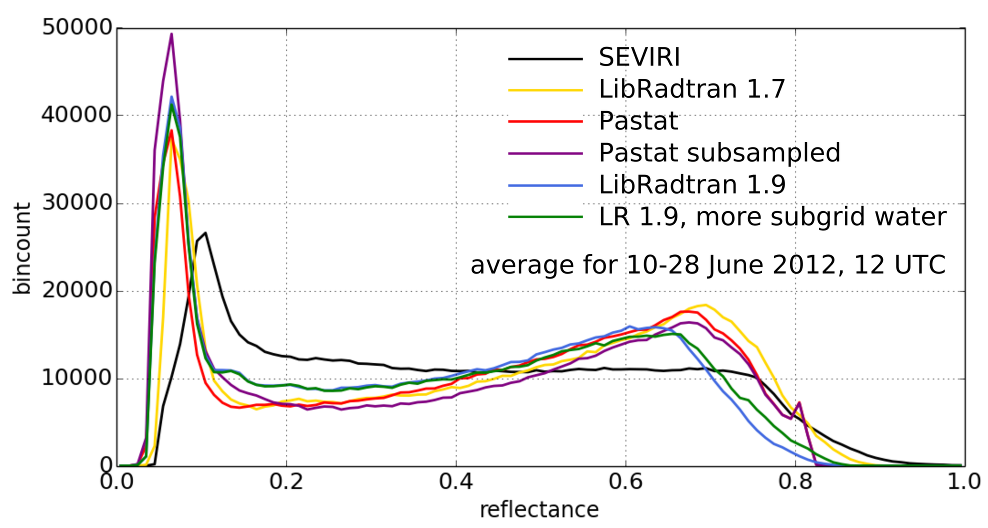
Contingency table: Cloudy v.s. cloud-free

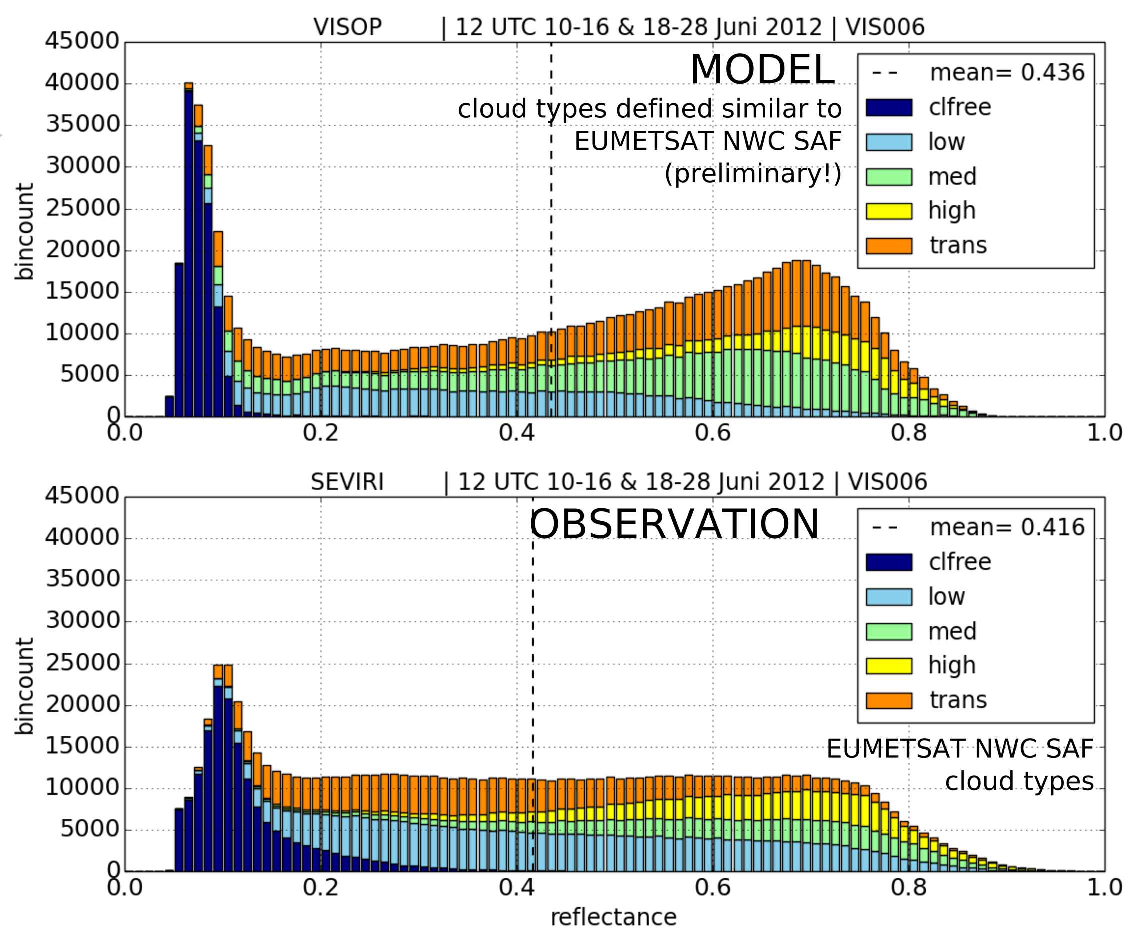
Contingency table for June 10 – 28, 2012, only at 12UTC		observation: cloudy	observation: cloud-free
model	cloudy	a hit 76.9%	b false alarm 9.1%
model	cloud-free	c miss 4.7%	d correct negative 9.2%

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

Impact of radiative transfer method and microphysics assumptions: Improved RT, higher subgrid water content and subsampling (calling RT twice for cloudy and clear part of column) improve shape of reflectance histogram:

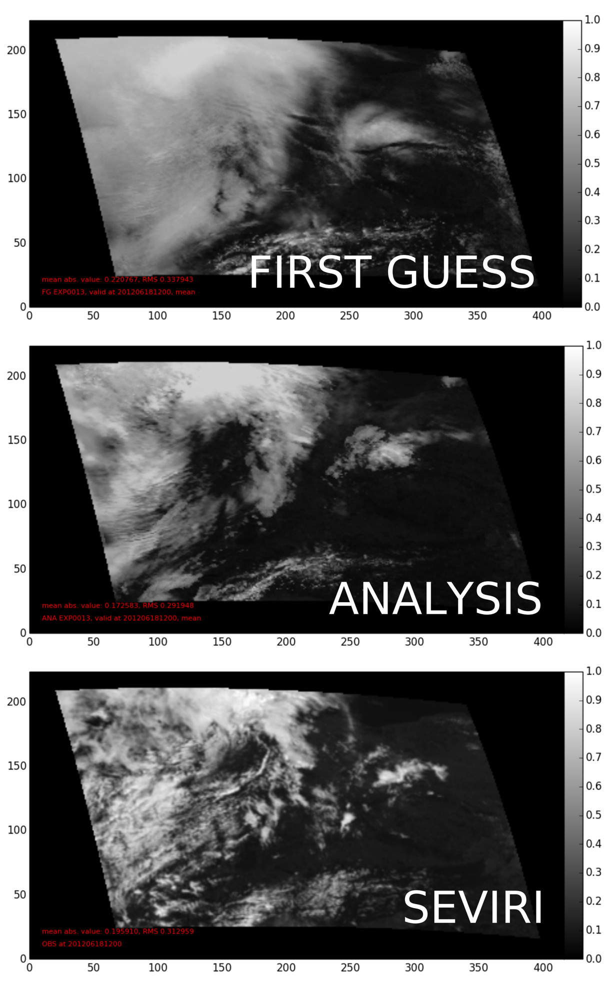


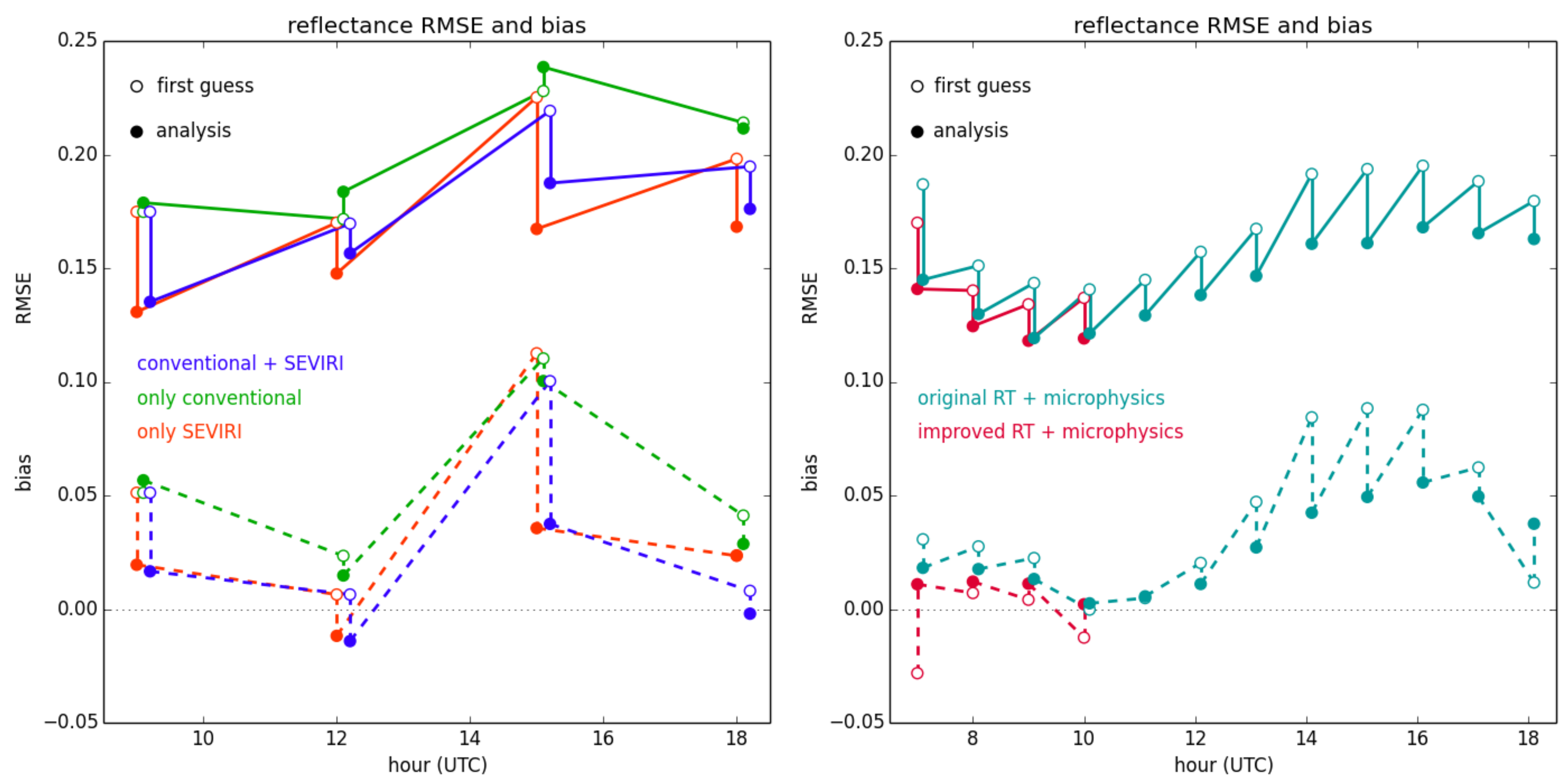


DATA ASSIMILATION EXPERIMENTS

KENDA setup for SEVIRI assimilation experiments:
- LETKF assimilation
- 40 ensemble members
- assimilation interval: 1h or 3h
- 20 member ECMWF EPS boundary conditions (+12h time-lagged versions → 40 BCs)
- Spin-up phase: several cycles with conventional observations
- First experiments: Assimilation of 600nm SEVIRI observations, observation error assumed to be 20%, no vertical localization, horiz. localization radius 100km, superobbing over 9km radius

Preliminary results:
- Ensemble mean is drawn towards SEVIRI observations: More structure and less clouds than first guess, lower RMSE and bias in reflectance
- conventional observations: not able to reduce reflectance error
- 1h instead of 3h assimilation interval: RMSE and bias reduced
- Operator improvements in radiative transfer and microphysics assumptions: further reduction in RMSE and bias, RMSE of first guess runs increases slower





Evolution of the reflectance RMSE and bias of the ensemble mean for different assimilation experiments started at 18 June 2012, 12UTC. Left: Runs with SEVIRI and/or conventional observation and an assimilation interval of 3 hours. Right: Runs with original and improved RT and microphysics settings and an assimilation interval of 1 hours.

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)