LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN | FAKULTÄT FÜR PHYSIK METEOROLOGIE | MIM

Hans-Ertel-Zentrum für Wetterforschung
Deutscher Wetterdienst
DWD

A Forward Operator for SEVIRI VIS/NIR Satellite Radiances

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COSMO/CLM User Seminar, 06.03.2012

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN
FAKULTÄT FÜR PHYSIK
METEOROLOGIE

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Hans-Ertel-Zentrum für Wetterforschung
Deutscher Wetterdienst
DWD

Hans-Ertel-Centre for Data Assimilation

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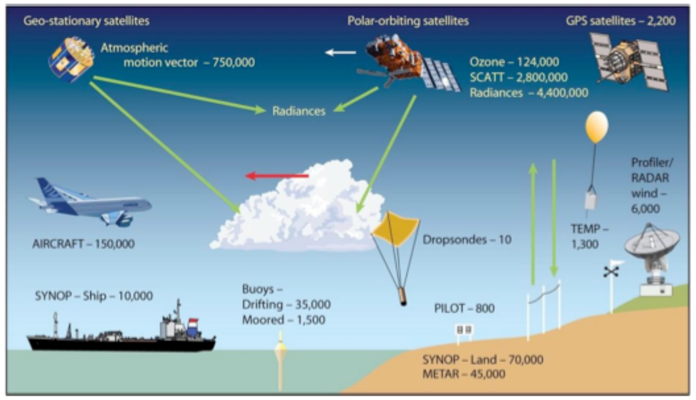
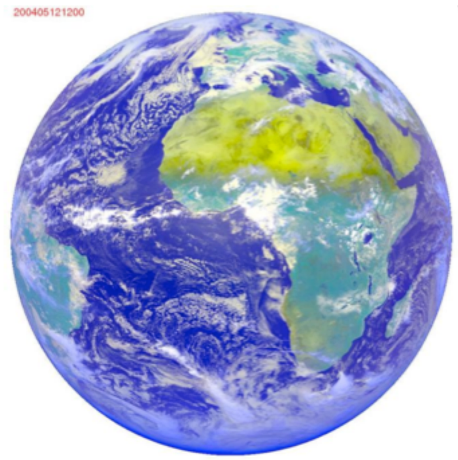
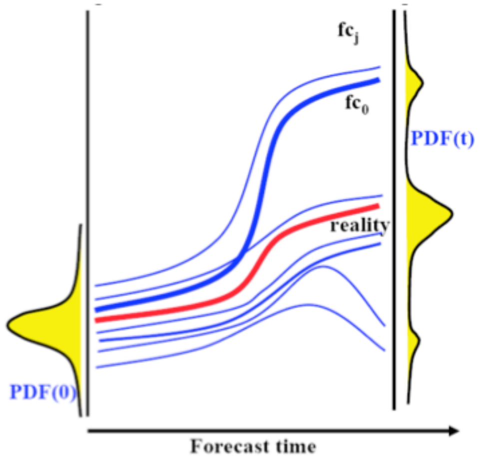
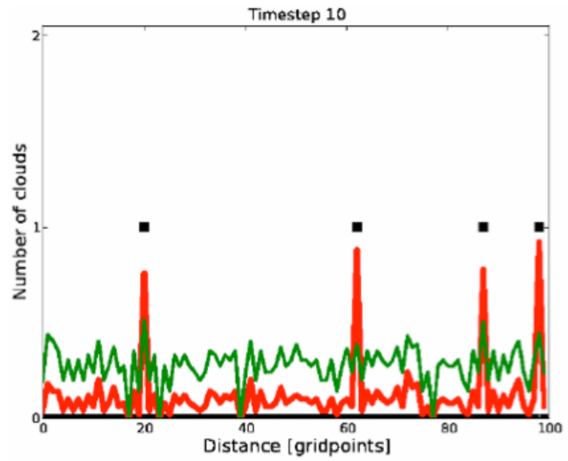
P. Kostka, C. Kühnlein, B. Mayer, M. Sommer, M. Würsch









Observation impact

Tools to quantify the analysis and forecast impact of observations in EnDA

Monitoring of observations

Optimized use of observations

Satellite observations

Direct assimilation of MSG SEVIRI VIS+NIR radiances in KENDA

AMV height correction with lidar observations

(Lightning)
(ADM-Aeolus)

Ensemble forecasts
(talk C. Kühnlein, 16:30)

Improved representation of forecast uncertainty

KENDA initial perturbations

Flow-dependence and impact time of perturbations

DA methods

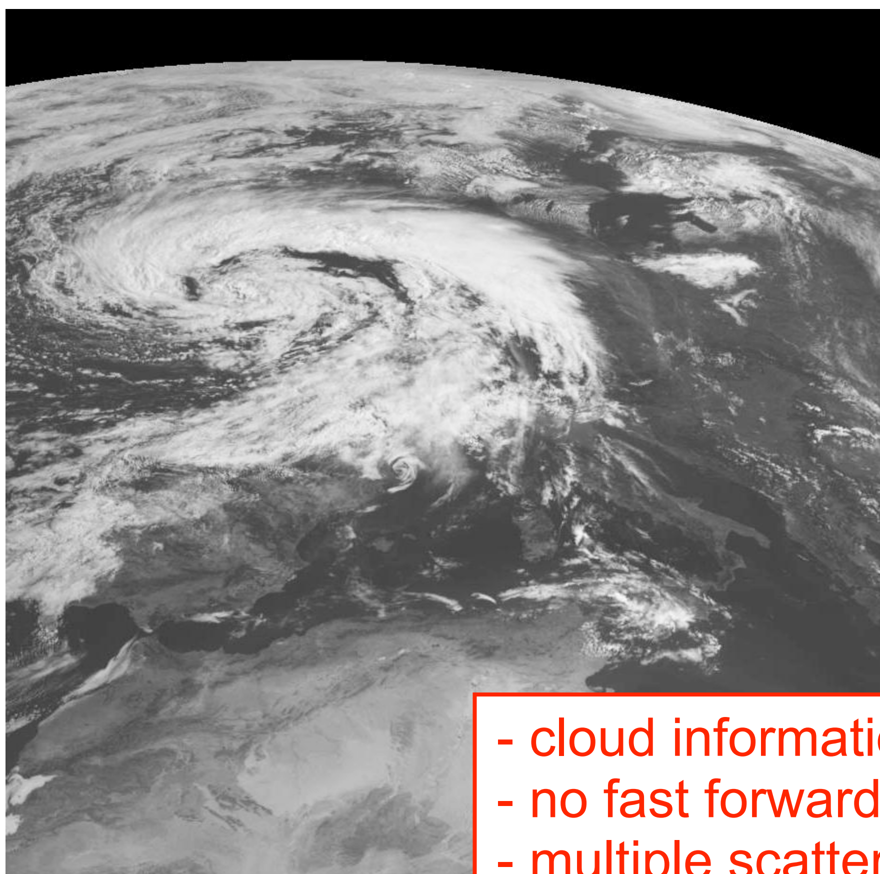
Methods for convective-scale DA

Idealized tests with non-Gaussian error statistics (toy models)

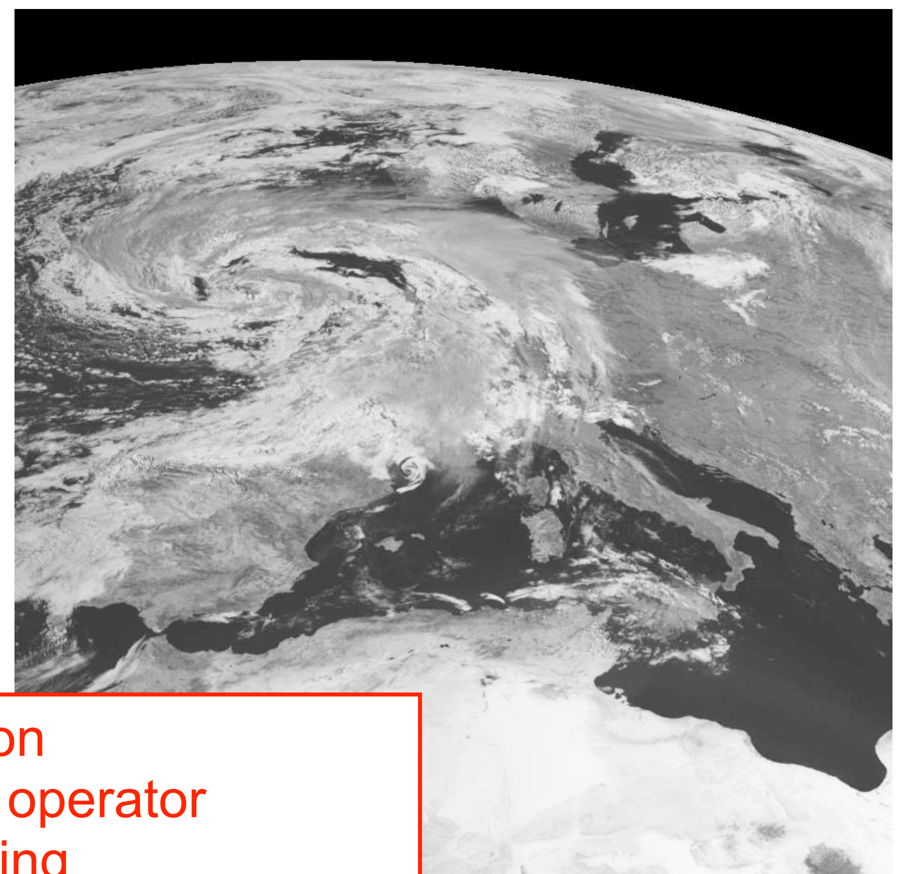
Robust methods for highly non-linear systems

Assimilation of VIS/NIR Radiances

VIS (0.6 μm)

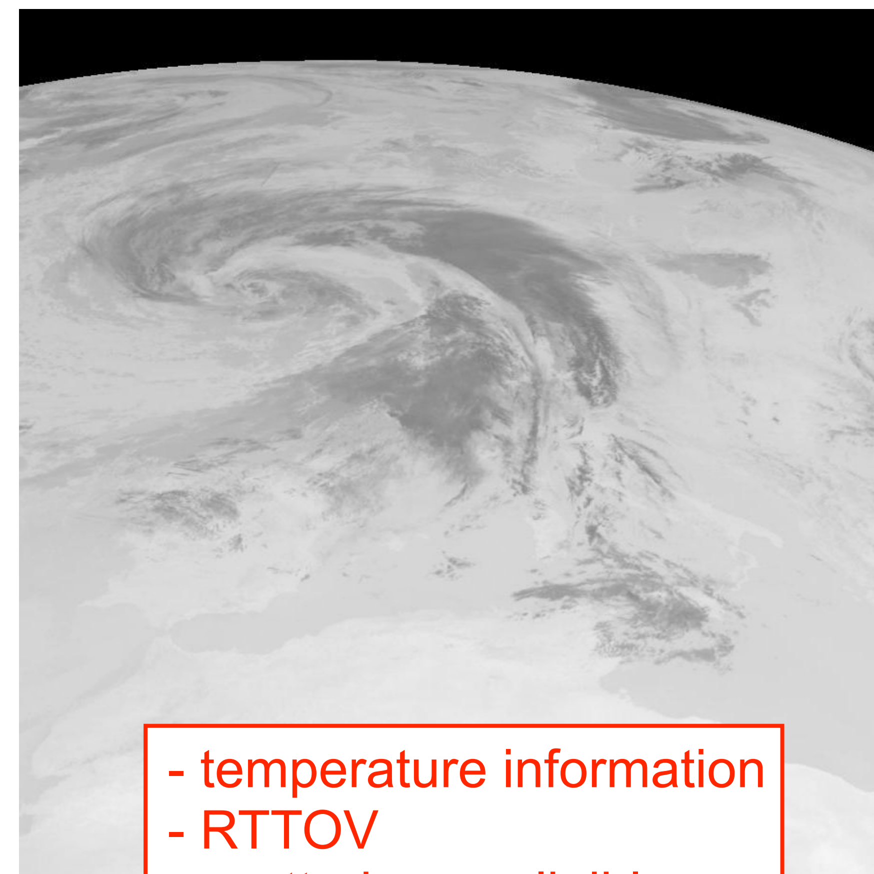


NIR (1.6 μm)



- cloud information
- no fast forward operator
- multiple scattering
- only forward operator in EnDA

IR (10.8 μm)



- temperature information
- RTTOV
- scattering negligible

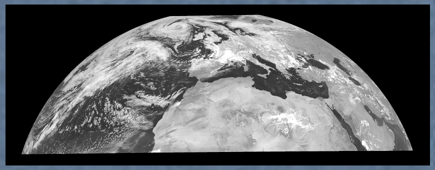
23 June 2004, 08 UTC, MSG-1, EUMETSAT

Project: Ensemble Data Assimilation (LETKF)

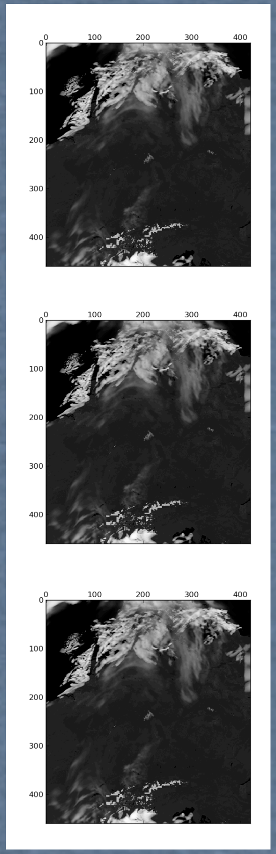
[Hunt et al. 2006]

MSG-SEVIRI radiances

$\mathbf{y}_n =$



$H_n\left(\mathbf{x}_n^{b(i)}\right) =$



synthetic satellite images

$$\begin{pmatrix}\bar{\mathbf{x}}^a \\ \mathbf{P}^a\end{pmatrix}_{n-1}$$

COSMO

forecast step

$$\mathbf{x}_n^{b(i)} = M_{n-1,n}\left(\mathbf{x}_{n-1}^{a(i)}\right)$$

KENDA

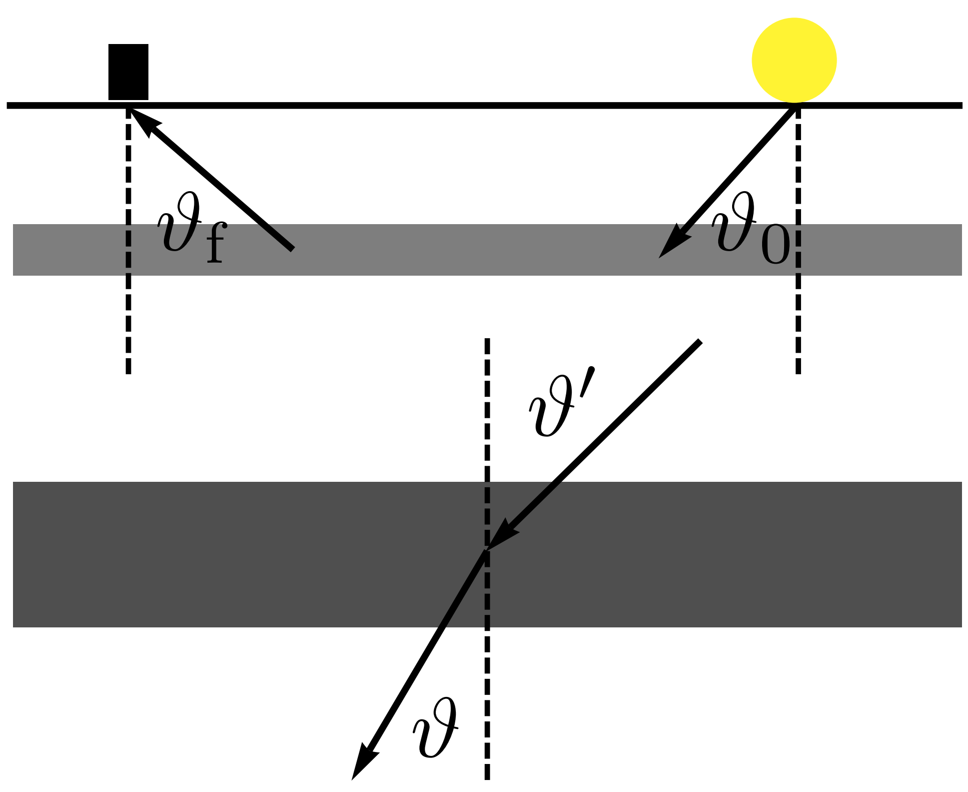
analysis step

$$\bar{\mathbf{x}}^a = \bar{\mathbf{x}}^b + \mathbf{K}\left[\mathbf{y} - H(\bar{\mathbf{x}}^b)\right]$$

$$\begin{pmatrix}\bar{\mathbf{x}}^a \\ \mathbf{P}^a\end{pmatrix}_{n}$$

Observation Operator based on libRadtran

[Mayer, Kylling 2005]



- COSMO-DE model fields:
  qv, qc, qi, qs, clc, htop/hbas_sc, (ps, t)
- MODIS albedo and satellite geometry
- discrete ordinate method [Stamnes et al. 1988]
- mapping to observation space

absorption | scattering | incoming | emission

$$\mu \frac{\mathrm{d}I}{\mathrm{d}\tau} = -I + \frac{\omega}{4\pi} \int \mathrm{d}\varphi' \mathrm{d}\mu' \, \mathcal{P}(\ldots) \, I(\ldots) + \frac{\omega}{4\pi} \mathcal{P}_0(\ldots) \, S_0 \, \mathrm{e}^{-\tau/\mu_0} + (1-\omega) \; B(\tau)$$

Cloud Microphysics

- **liquid clouds:** [Zinner et al. 2008]

$$1\,\mu\mathrm{m} < R_{\mathrm{eff}} < 25\,\mu\mathrm{m}$$

- **ice clouds:** [Wyser 1998]

$$20\,\mu\mathrm{m} < R_{\mathrm{eff}} < 90\,\mu\mathrm{m}$$

- **model snow:** [Seifert, private comm.]
  about factor 10 larger than ice

$$q_{\mathrm{ice}} = q_{\mathrm{i}} + 0.1\,q_{\mathrm{s}}$$

Sub-gridscale Clouds in COSMO

stratiform clouds:
0.5% of saturation mass fraction are condensed water

shallow convective clouds:
1.0% of saturation mass fraction or at least 0.2g/kg are condensed water where Tiedtke scheme operative [Tiedtke 1989]

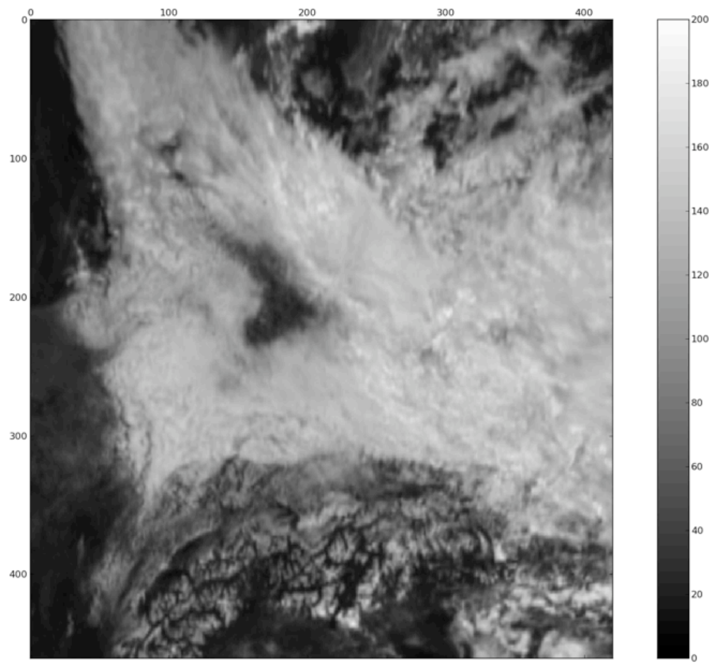
total cloud water/ice:

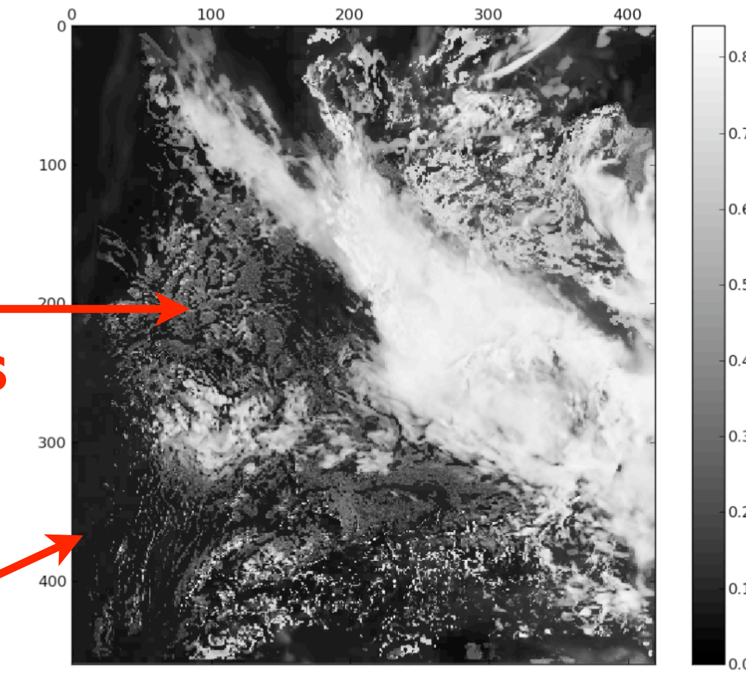
$$q_{\mathrm{tot}} = q_{\mathrm{con}}\,\mathcal{N}_{\mathrm{con}} + q_{\mathrm{strat}}\,\mathcal{N}_{\mathrm{strat}}\,(1 - \mathcal{N}_{\mathrm{con}})$$

SEVIRI observation

Operator simulation (5-10 min.)

VIS 006

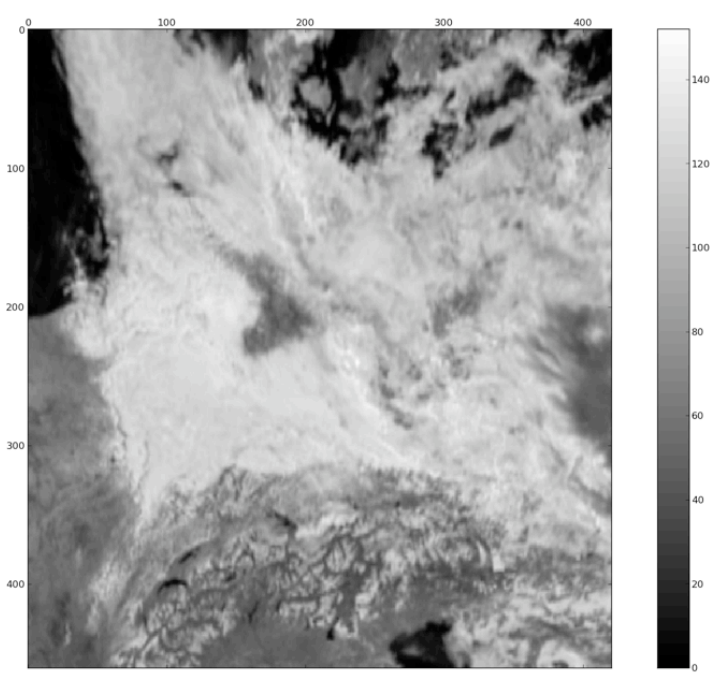


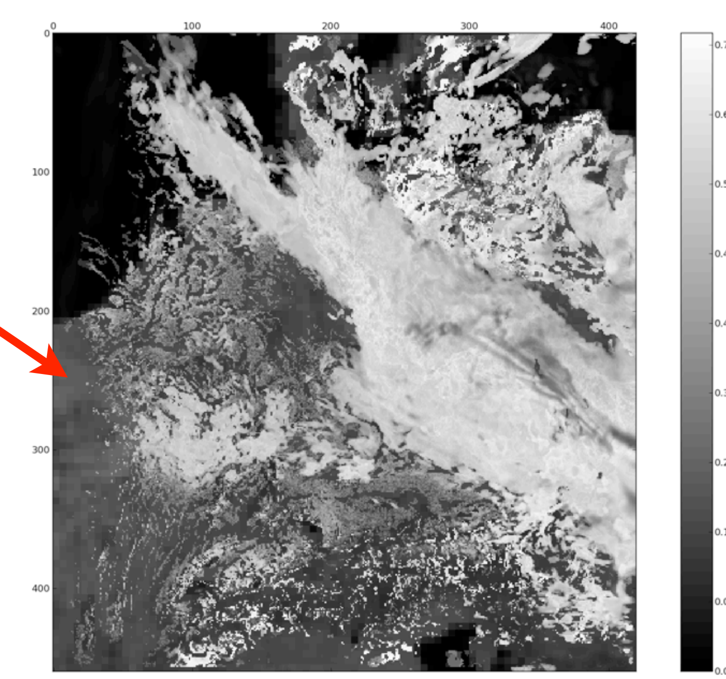


sub-gridscale shallow convective clouds

albedo wavelength-dependent

NIR 016



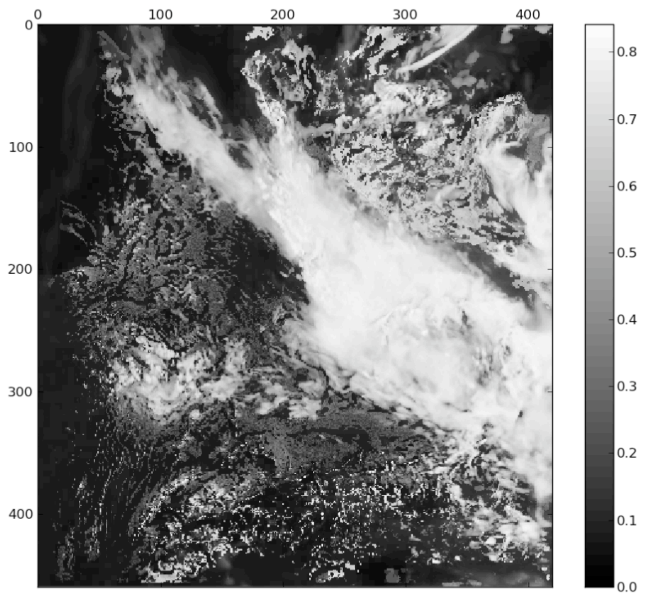


use operator to study possible model errors?

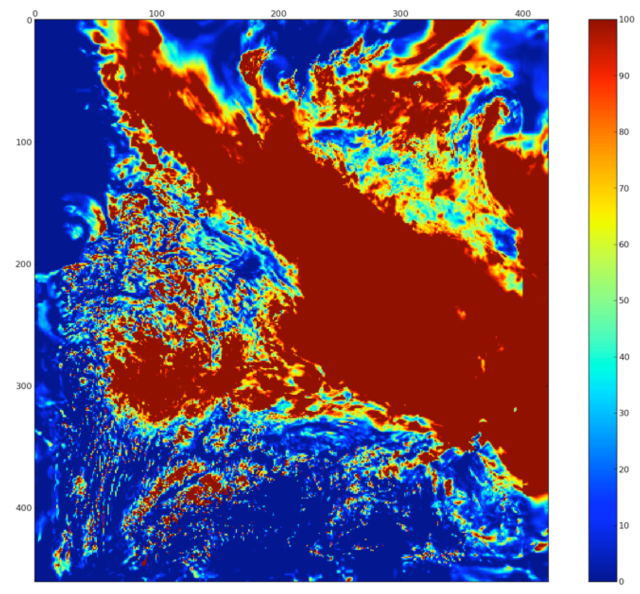
Comparison to Infrared Channel

(31.07.2011, 12:00 UTC)

water clouds

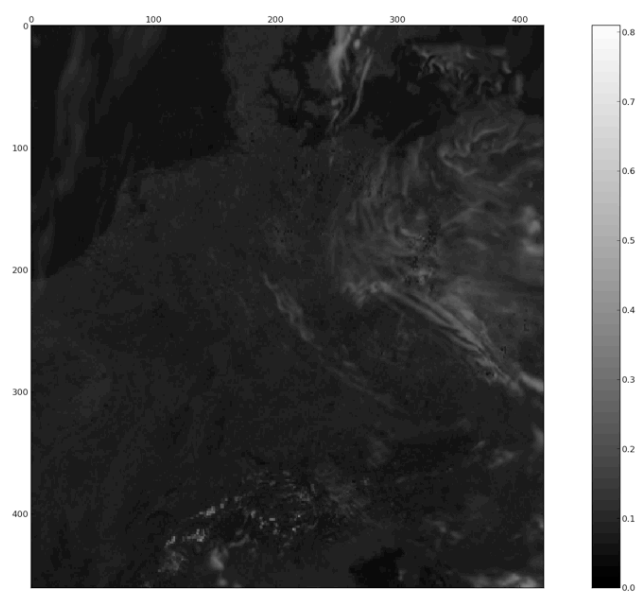


VIS operator

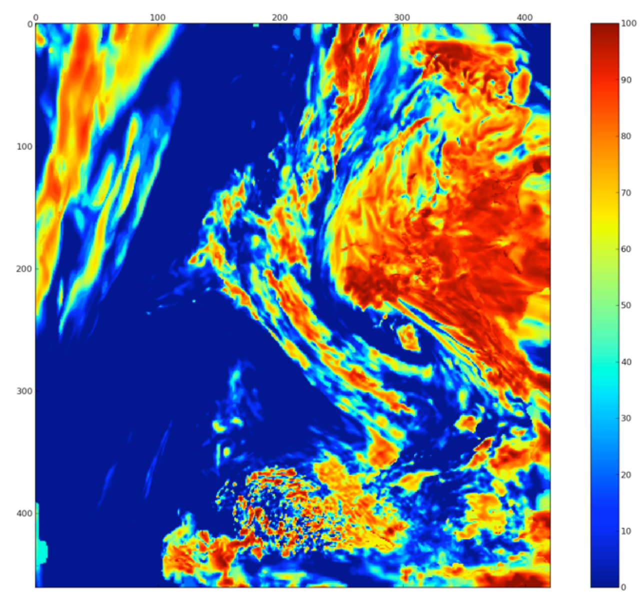


low clc (> 800 hPa)

ice clouds



VIS operator

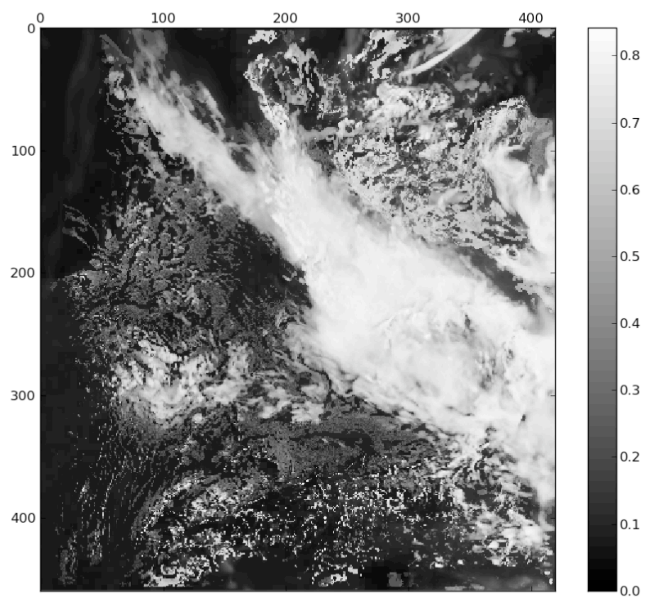


high clc (< 400 hPa)

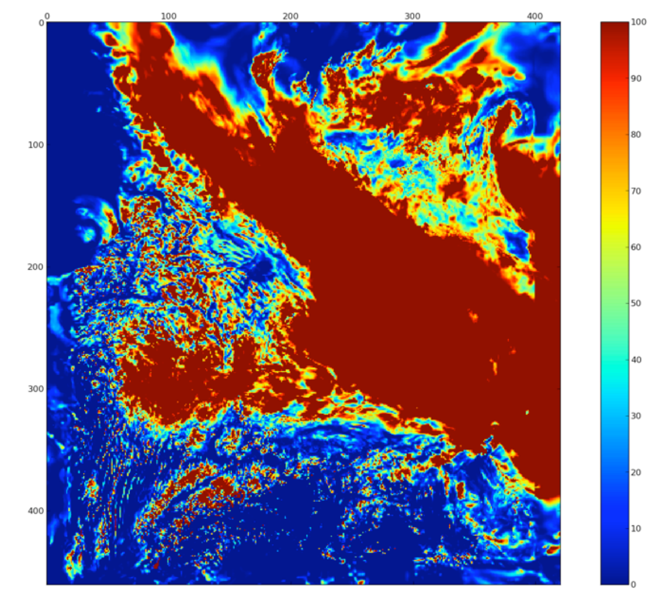
Comparison to Infrared Channel

(31.07.2011, 12:00 UTC)

water clouds



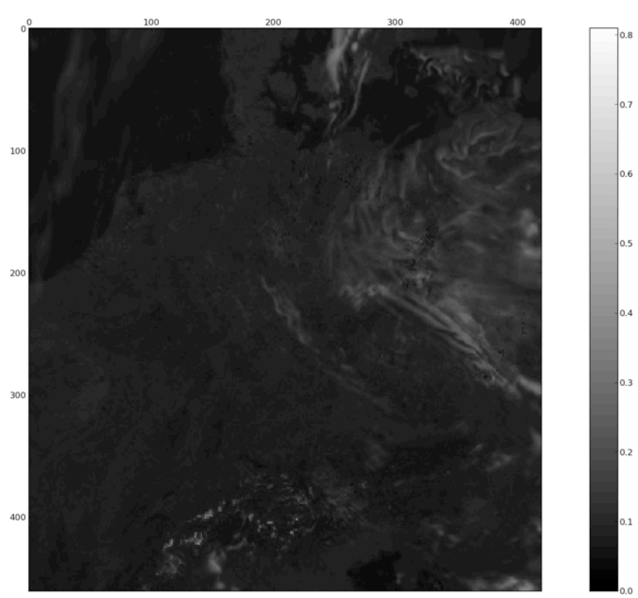
VIS operator



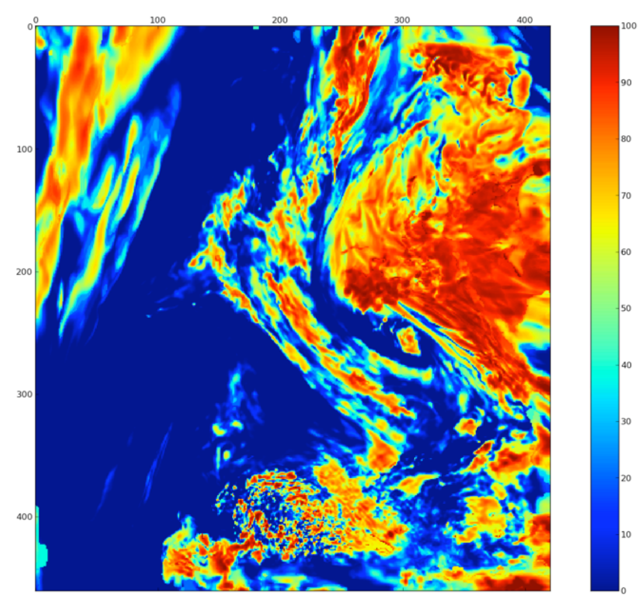
low clc (> 800 hPa)

inverted COSMO RTTOV IR108

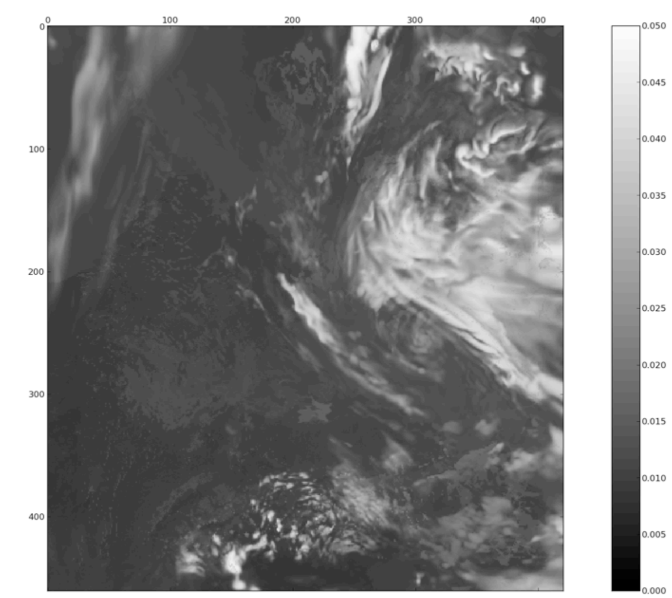
ice clouds



VIS operator

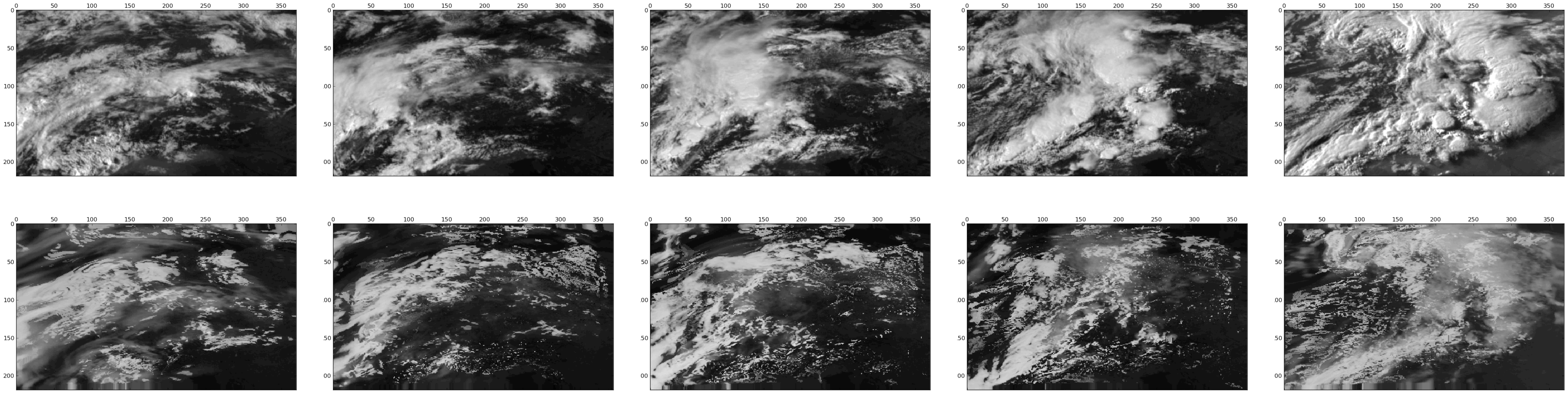


high clc (< 400 hPa)



Time Series: Observation vs. 3h-Forecasts

(22.06.2011, VIS006)



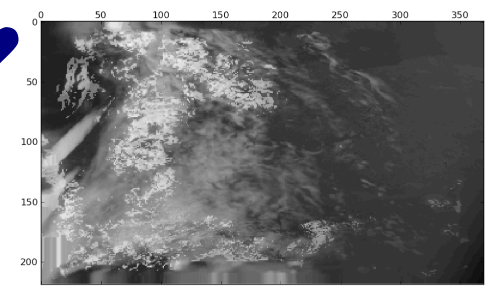
06 09 12 15 18 UTC

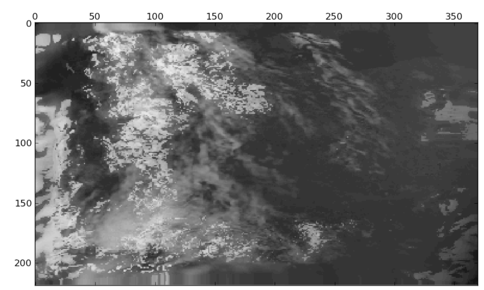
- overall cloud structures well represented by operator
- clouds are not always well represented by model

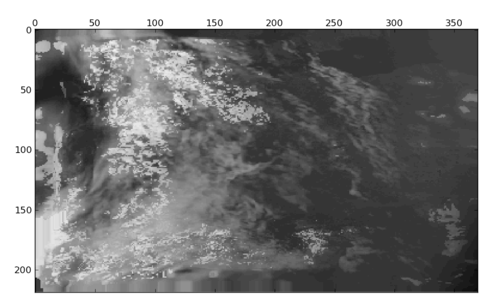
First KENDA-Run in Munich

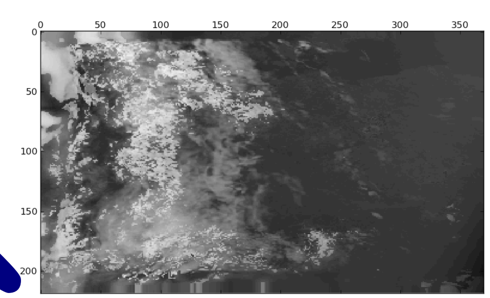
(KENDA test period 07.08.2009, 18:00 UTC)

$$H\left(\mathrm{x}^{b(i)}\right) =$$

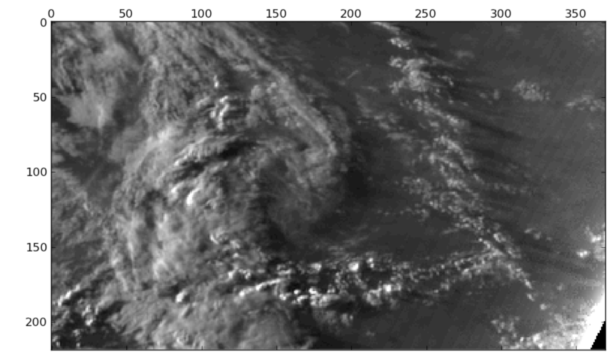








$$\mathrm{y} =$$



- KENDA+VIS works technically
- first test experiment running
- to demonstrate fc-improvement:
    - correct error covariance
    - bias correction (?)
    - adaption of KENDA (?)
    - long period, fast operator, ...

Future Plans

- apply operator to selected set of test-cases in summer 2011
- assessment of operator accuracy with 3D simulation (MYSTIC)
- assimilate VIS/NIR radiances in KENDA for a longer period
- study observation impact of assimilating additional radiances
- implement and test operationally feasible operator