# Assimilation of VIS/NIR Satellite Radiances

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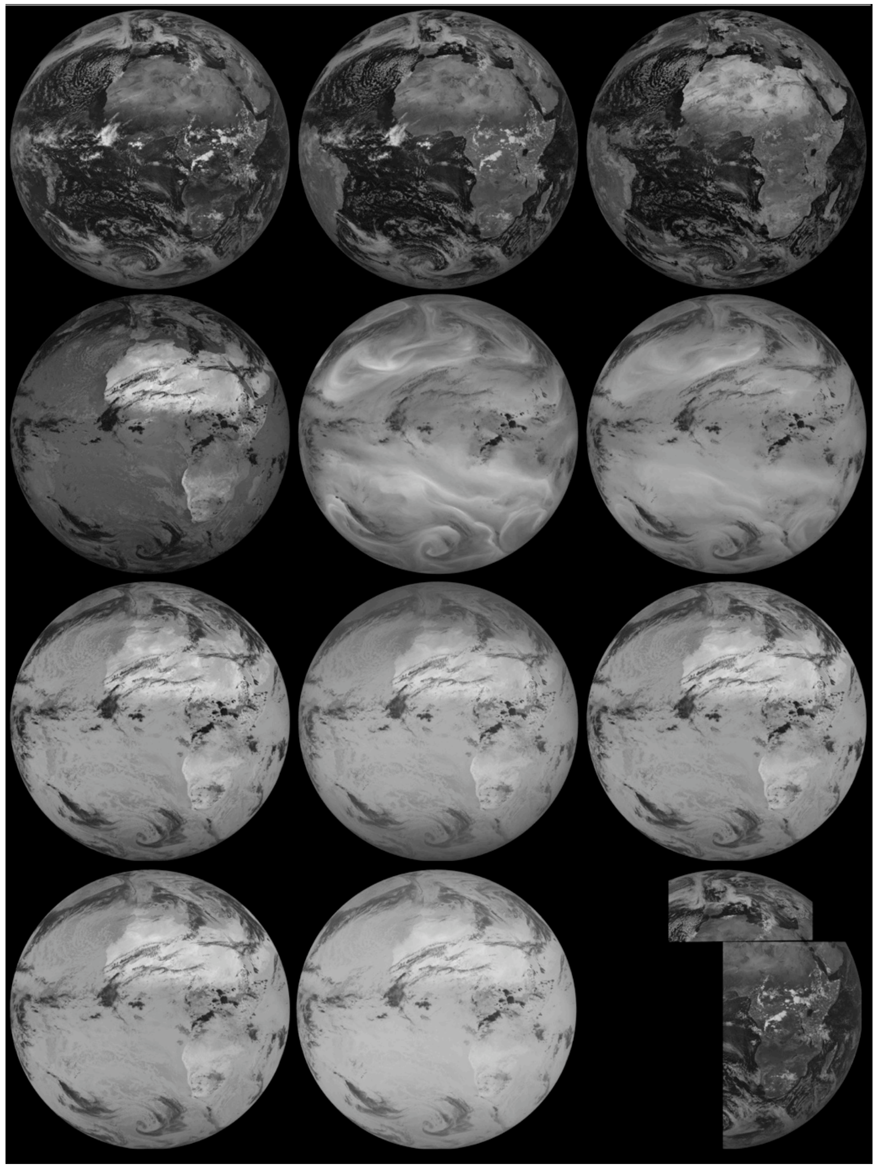
# 1. Motivation

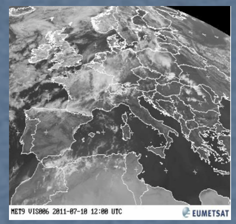


- vast increase in satellite observations, likely to continue
- direct assimilation of cloud information in satellite radiances possible with KENDA
- high spatial and temporal resolution
- MSG SEVIRI RSS provides suitable data ($\Delta x \approx 5\,\mathrm{km}$, $\Delta t = 5\,\mathrm{min}$)

# 1. Plan: Ensemble Data Assimilation

MSG SEVIRI radiances

$$\mathbf{y}_n =$$



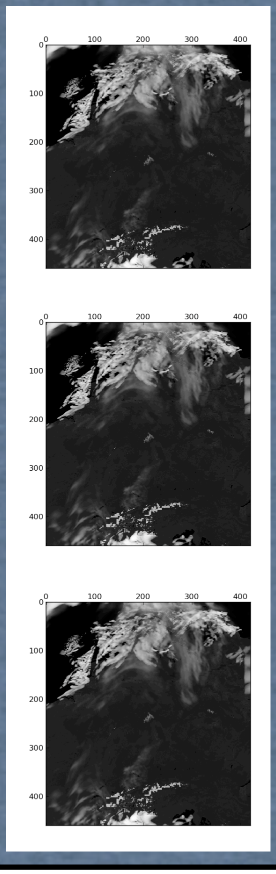
$$\begin{pmatrix} \bar{\mathbf{x}}^a \\ \mathbf{P}^a \end{pmatrix}_{n-1}$$

LETKF

forecast step

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

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



synthetic satellite pictures

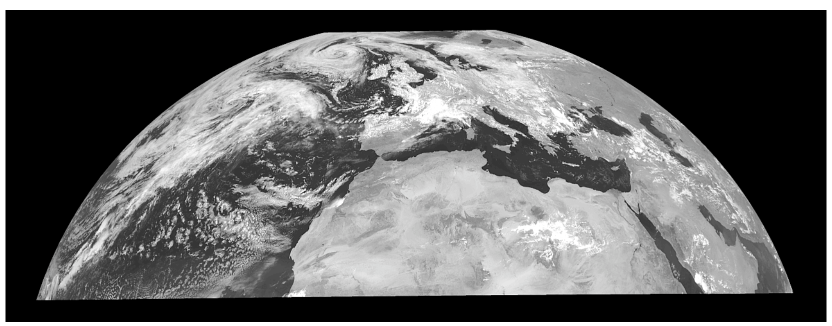
LETKF

analysis step

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

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

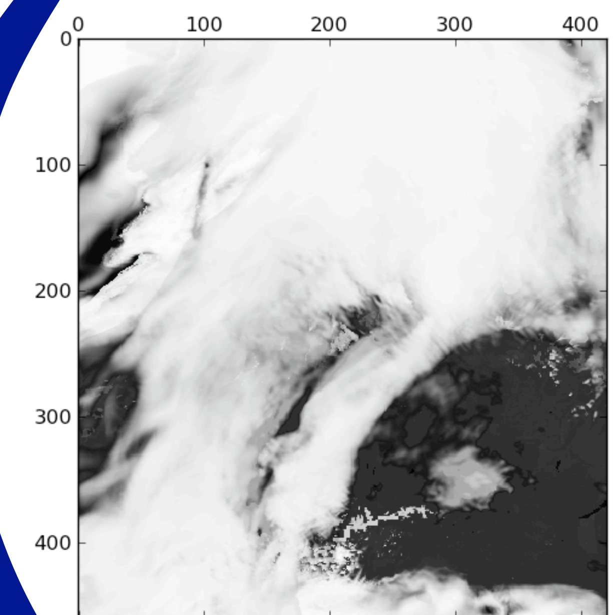
# 2. First Step: Observation Operator



Meteosat-8 RSS radiances

$$I_\nu(\mathbf{r}, \mathbf{\Omega}, t) = c\, h\, \nu\, f_\nu(\mathbf{r}, \mathbf{\Omega}, t)$$

$\longleftrightarrow$ $H_n\left( \right.$



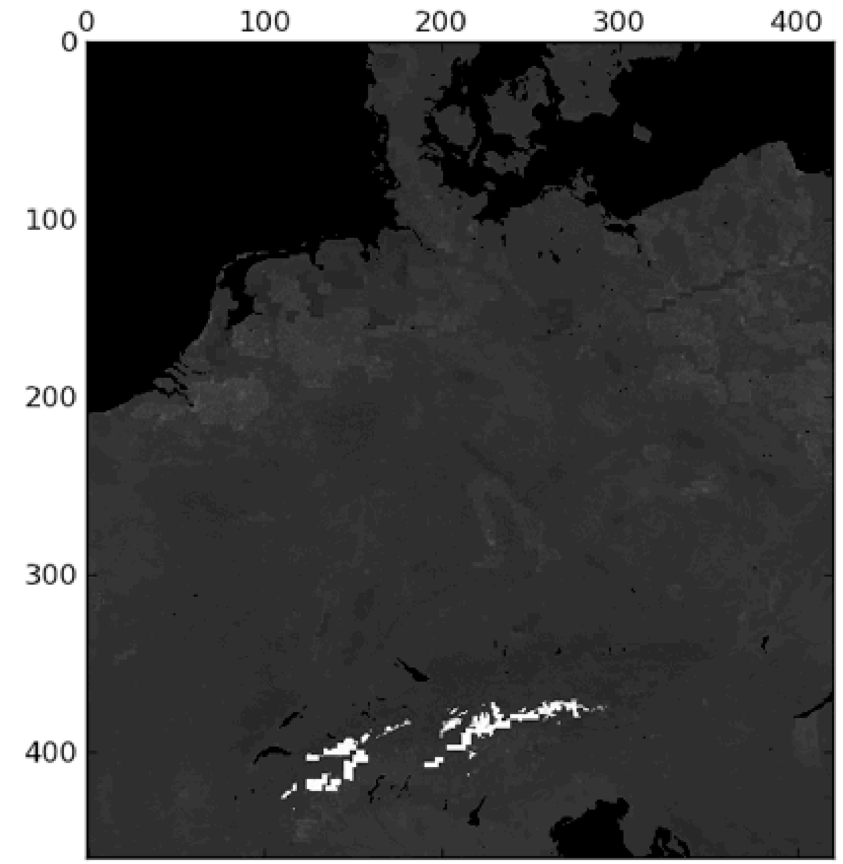

$\left. \right)$

COSMO-DE model

- operator maps model onto obs. space
- comparison possible in analysis step

# 2. Slow Operator: cosmo_disort.py

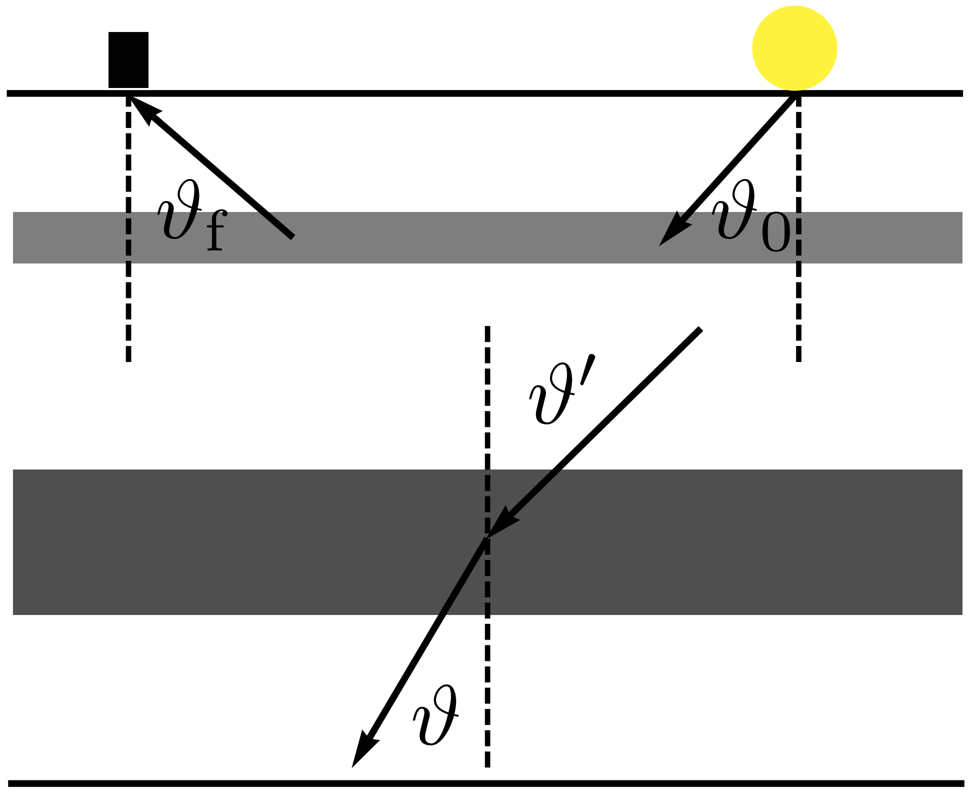
- COSMO-DE grib file output
- extract model fields: wgrib
- for each pixel (j,i):
  build up vertical column containing
  cloud information LWC, IWC, Reff
- calculate radiances with libRadtran




$$\mathrm{A}_{ji},\ \mathrm{lon}_{ji},\ \mathrm{lat}_{ji},$$
$$\mathrm{z}_k,\ \mathrm{p}_{jik},\ \mathrm{T}_{jik},$$
$$\mathrm{Q_C}_{jik},\ \mathrm{Q_I}_{jik}$$

# 3. Radiative Transfer Solver DISORT

[Stamnes et al. 1988]




- infinite plane-parallel atmosphere with homogeneous model layers
- optical properties from input parameters LWC, IWC, Reff
- discretize into streams $\mu_i = \cos\vartheta_i$

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

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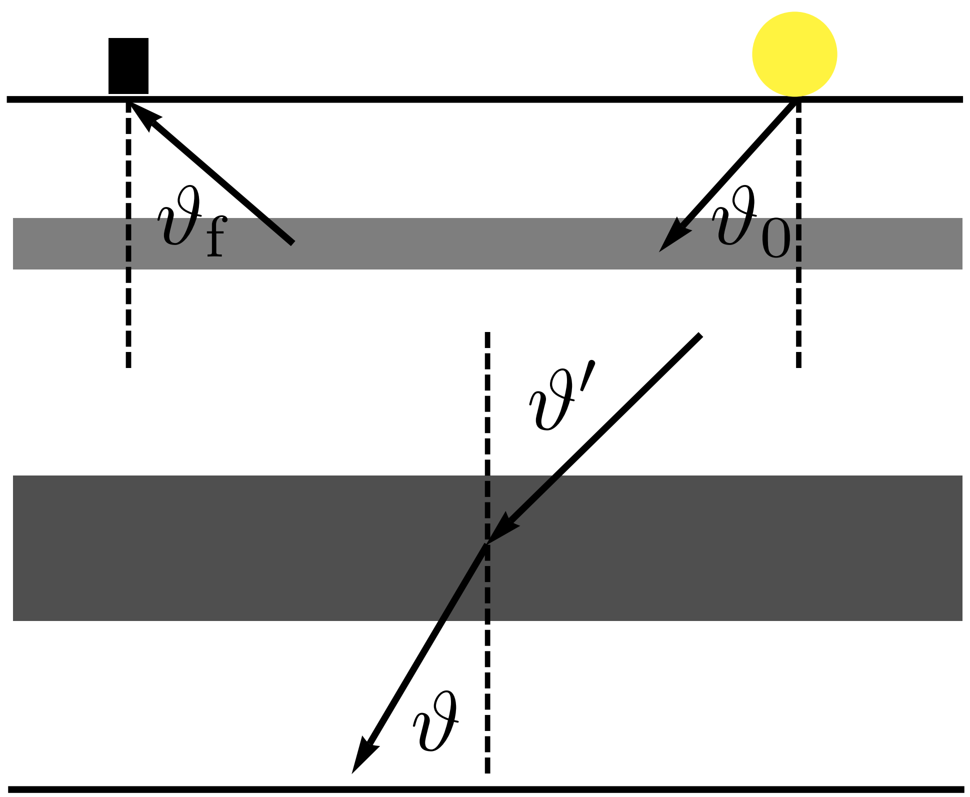


- infinite plane-parallel atmosphere with homogeneous model layers
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- discretize into streams $\mu_i = \cos\vartheta_i$

absorption

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

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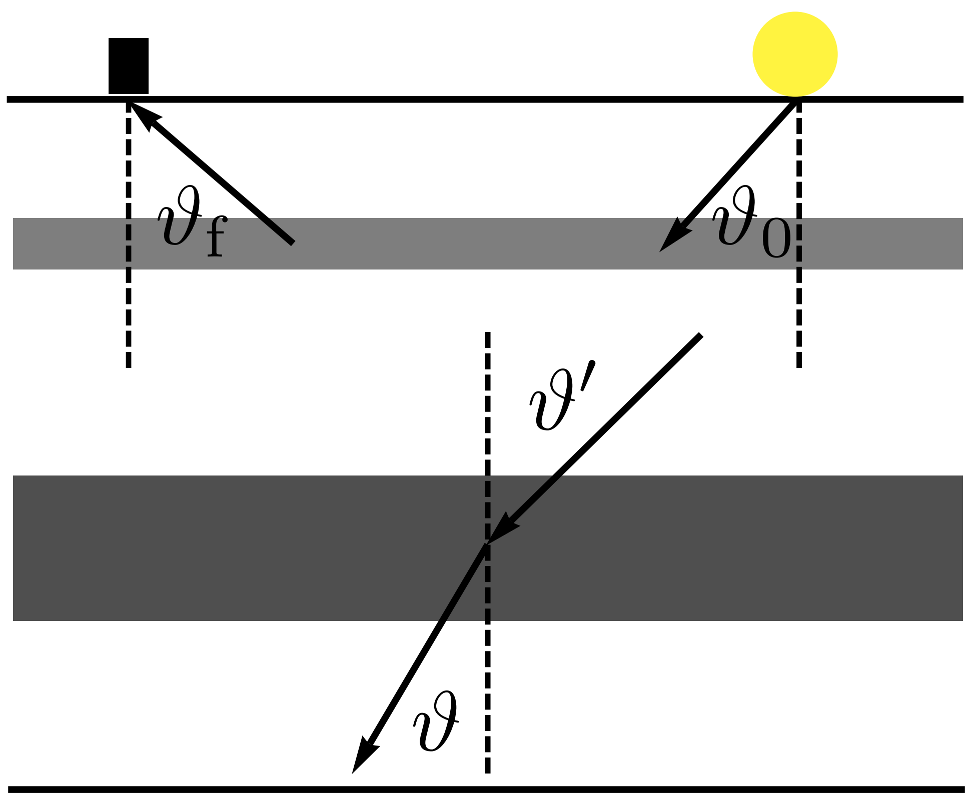


- infinite plane-parallel atmosphere with homogeneous model layers
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scattering

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

# 3. Radiative Transfer Solver DISORT

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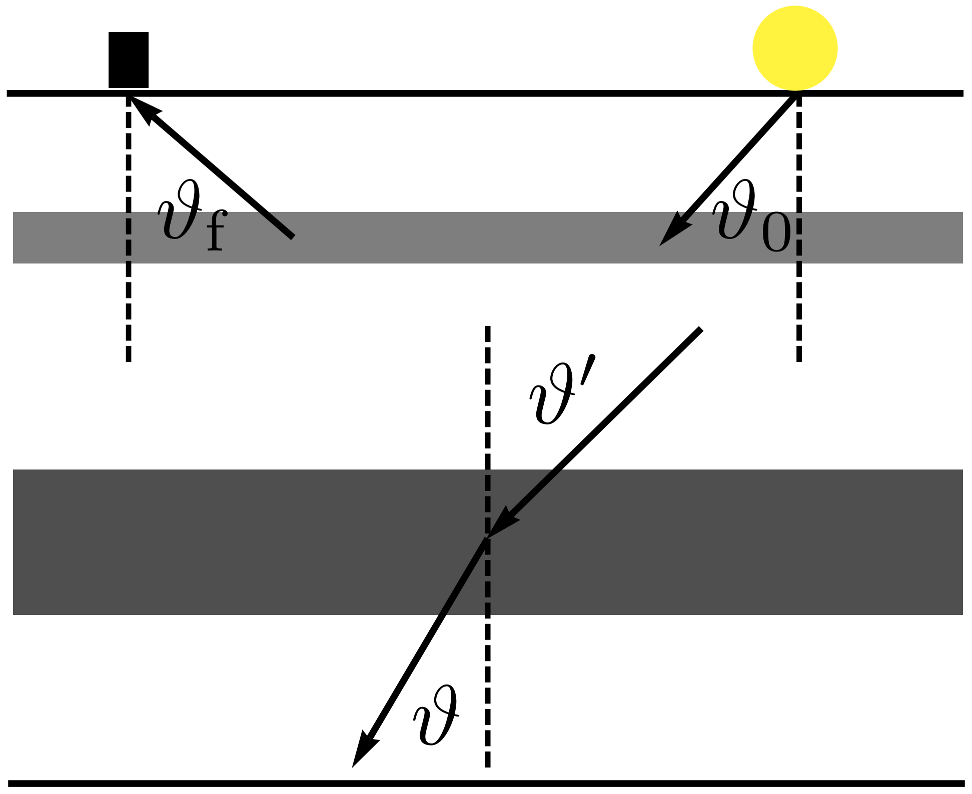


- infinite plane-parallel atmosphere with homogeneous model layers
- optical properties from input parameters LWC, IWC, Reff
- discretize into streams $\mu_i = \cos\vartheta_i$

incoming

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

# 3. Radiative Transfer Solver DISORT

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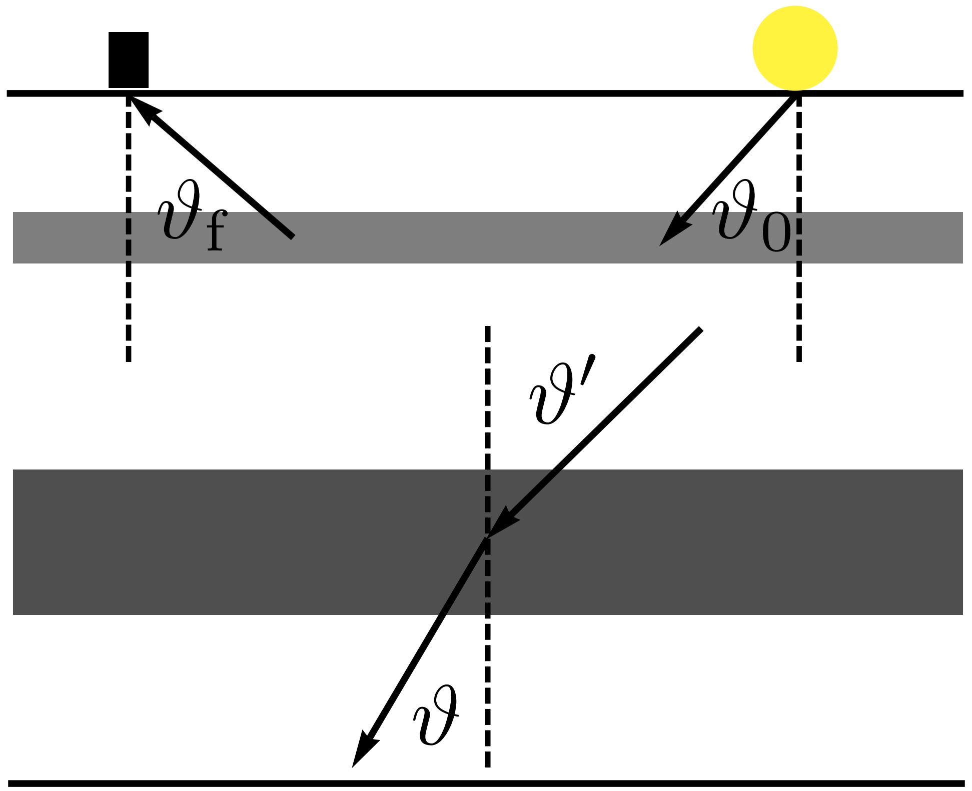


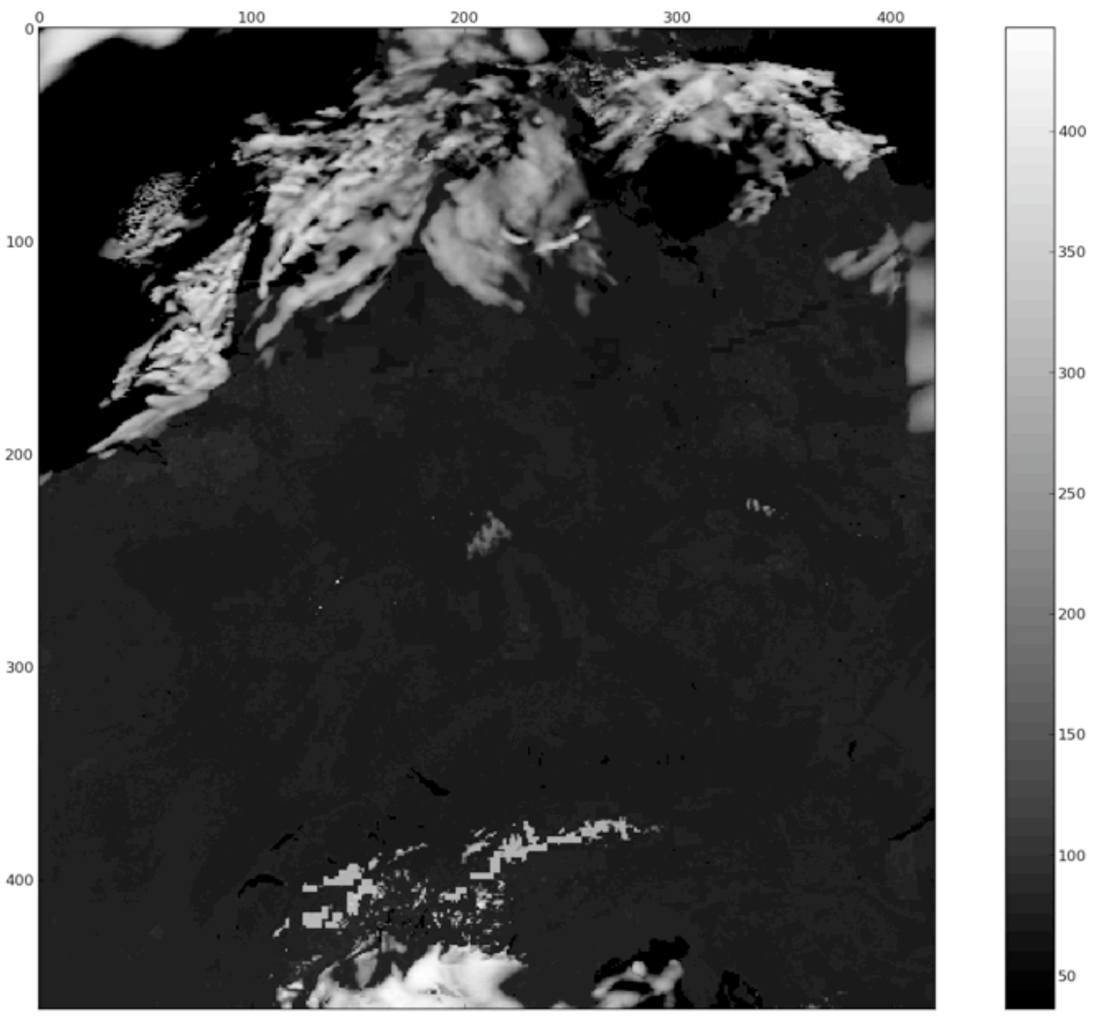

- infinite plane-parallel atmosphere with homogeneous model layers
- optical properties from input parameters LWC, IWC, Reff
- discretize into streams $\mu_i = \cos\vartheta_i$

emission

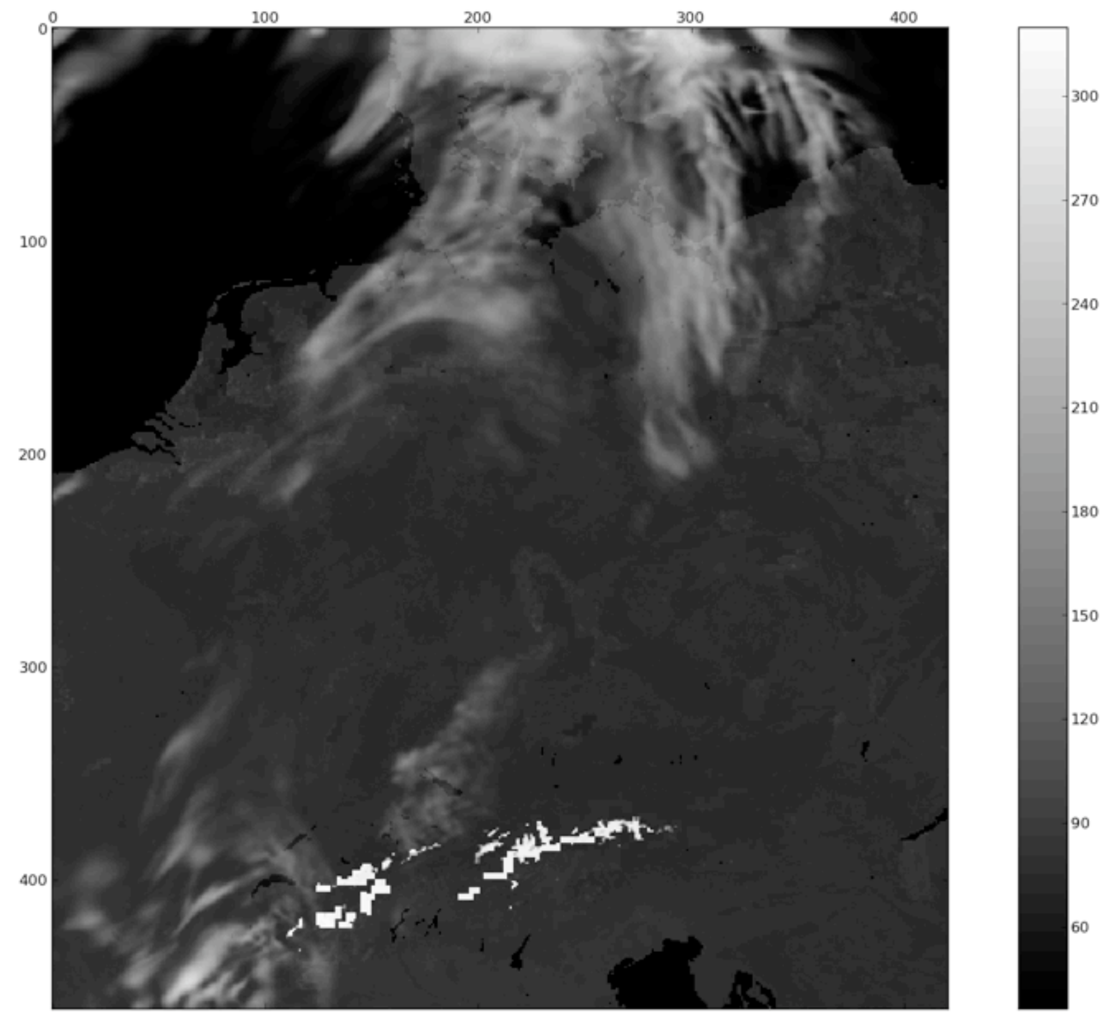
$$\mu \frac{\mathrm{d}I}{\mathrm{d}\tau} = -I + \frac{\omega}{4\pi} \int \mathrm{d}\varphi' \mathrm{d}\mu' \, \mathcal{P}(\ldots)\, I(\ldots) + \frac{\omega}{4\pi} \mathcal{P}_0(\ldots)\, S_0 \, \mathrm{e}^{-\tau/\mu_0} + (1-\omega)\; B(\tau)$$

# 4. Results: VIS 600nm

(18.10.2008, 12h UTC)




$$\left[\frac{\mathrm{mW}}{\mathrm{m}^2\,\mathrm{nm}\,\mathrm{sr}}\right]$$

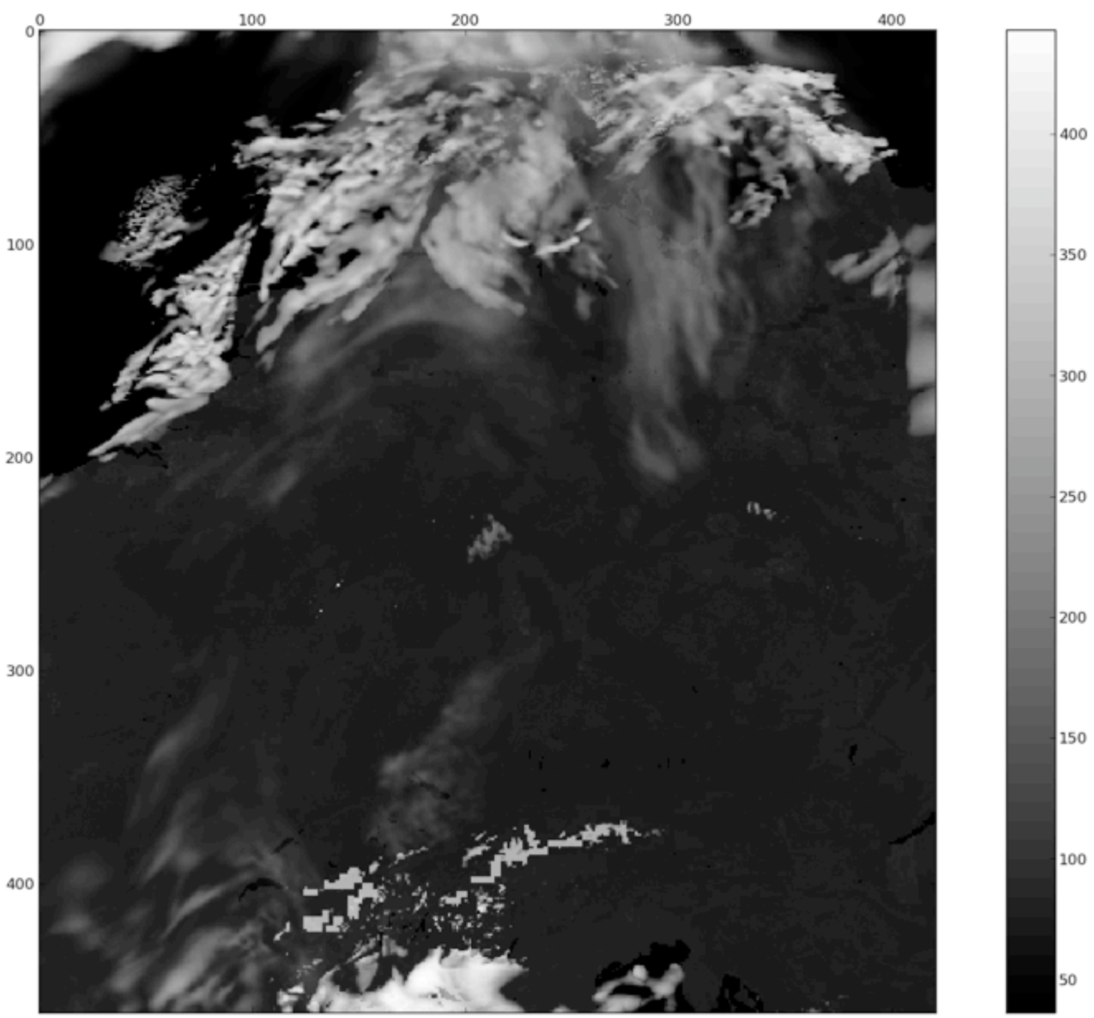



water clouds only

ice clouds only

# 4. Results:

(18.10.2008, 12h UTC)

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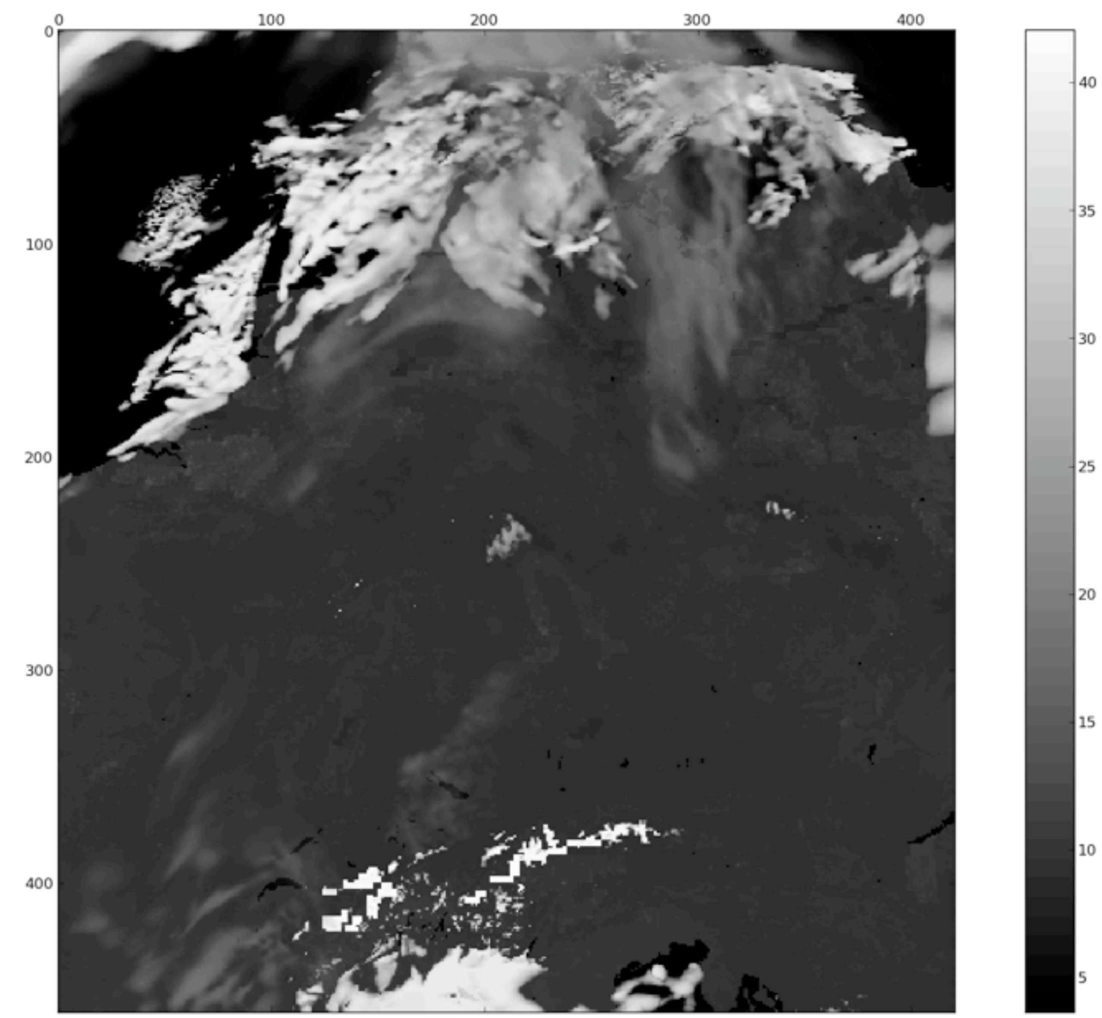


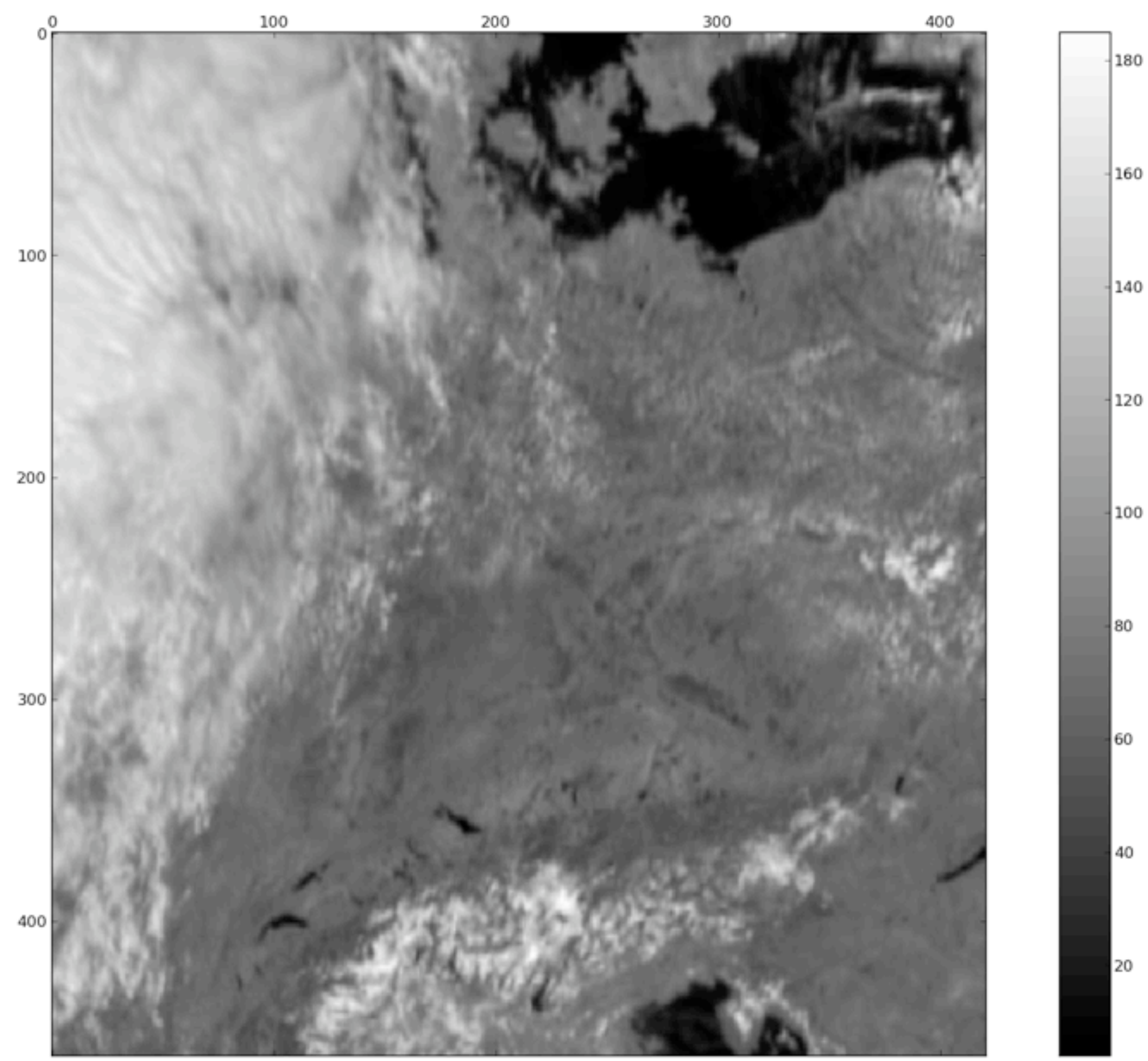

VIS 600nm

NIR 1600nm

# 4. Outlook

- improve satellite geom./albedo map for slow operator (6h)
- test accuracy against 3D operator MYSTIC
- SEVIRI radiances on COSMO grid
- run ensembles once KENDA installed
- accelerate slow to fast operator

# Backup Slide




- resolution of observed radiances only about 5-6 km over Germany
- sensible to have highly resolved observation operator?