

Eigenvector-based retrieval scheme for mineral dust and volcanic ash from IASI

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Retrieval capabilities

- ⇒ stand alone TIR mineral aerosol retrieval operating in the 8-12 µm window region only
(independence from solar illumination)
- ⇒ independence from *a priori* knowledge about the atmospheric state (T,H₂O profiles)
- ⇒ independence from *a priori* knowledge about surface emissivity
- ⇒ no method differences over land, ocean and (shallow) clouds
- ⇒ accounting for particle size and composition variability
- ⇒ Bayesian probability estimates and uncertainty estimation
- ⇒ validation against AERONET
- ⇒ fast and efficient method



Linearization of the RT-problem

Simplified model of atmospheric infrared radiation (no scattering):

$$L_{TOA}(\lambda) = \int_{atm} \varepsilon_{sfc} e^{-\frac{\tau_{atm}(\lambda, z)}{\cos(\Theta_v)}} B_\lambda(T_{sfc}) + (1 - e^{-\frac{\tau_{atm}(\lambda, z)}{\cos(\Theta_v)}}) B_\lambda(T_{atm}, z) dz$$

TOA
radiance

atmosph.
extinction

surface
emission

atmospheric emission

retrieval in $830-1250 \text{ cm}^{-1}$ *window region*: no solar contributions

assume homogeneous and isothermal aerosol layer (simplifies the integration)

42 bins of 20 IASI channels each, maximum brightness temperature assumed to represent least gas absorption.

avoid strong broadband O_3 absorption \rightarrow 35 spectral bins (individual information) for aerosol retrieval



Linearization of the RT-problem

Definition of a quantity we call *equivalent optical depth* τ_{eqv} :

$$L_{\text{obs}}(\lambda) = \epsilon_{\text{sfc}} e^{-\frac{\tau_{\text{atm}}(\lambda)}{\cos(\Theta_v)}} B_\lambda(T_{\text{sfc}}) + (1 - e^{-\frac{\tau_{\text{aer}}(\lambda)}{\cos(\Theta_v)}}) B_\lambda(T_{\text{aer}})$$

observed
radiance

extinction
term

surface
emission

aerosol emission
(neglected in initial approach)

$$\rightarrow \underbrace{\ln(\epsilon_{\text{sfc}}) - \frac{\tau_{\text{gas}}(\lambda) + \tau_{\text{aer}}(\lambda)}{\cos(\Theta_v)}}_{= -\tau_{\text{eqv}}(\lambda)} = \ln\left(\frac{L_{\text{obs}}(\lambda)}{B_\lambda(T_{\text{base}})}\right)$$

observation

→ The problem of signal unmixing can be approached with *linear* methods.



Extracting the aerosol signal

Strong peak of Si-O resonance absorption around 1040 cm^{-1} .

Aerosol signal is small compared to surface emissivity, water vapour (and O_3).

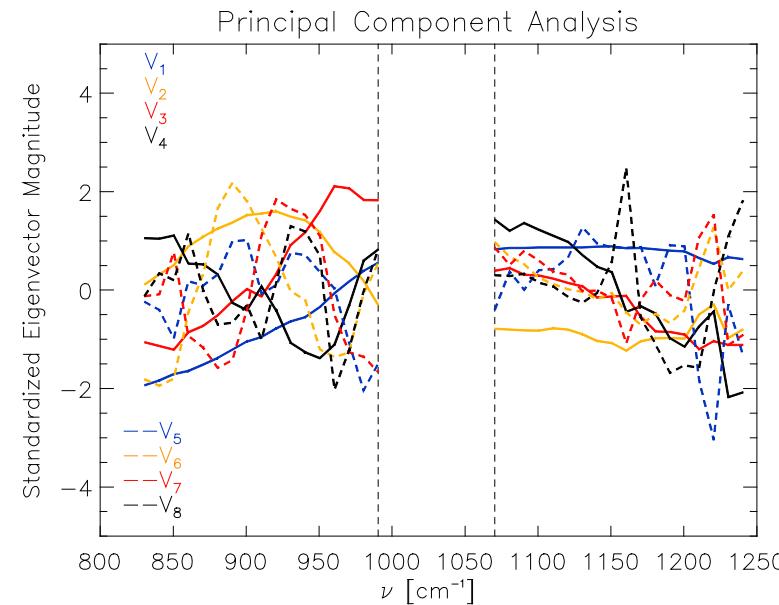
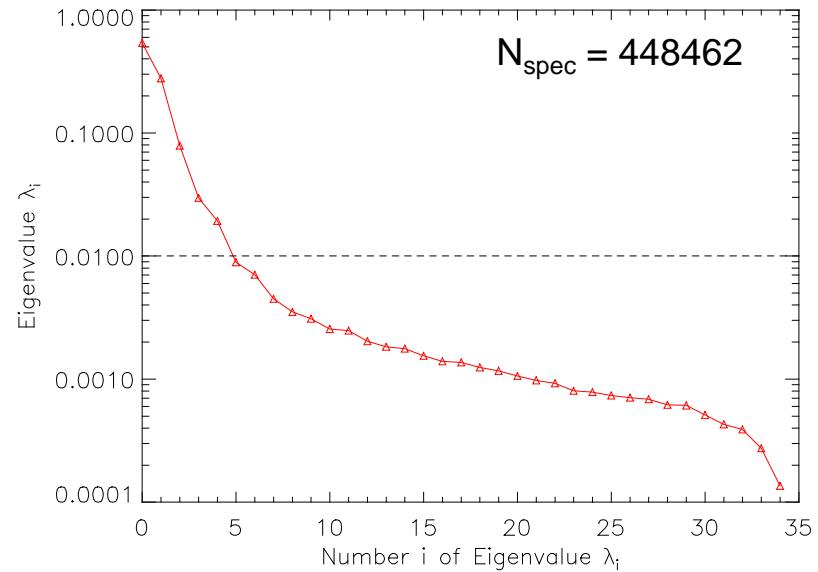
Principal Component Analysis

is used for extracting *uncorrelated* pieces of information.

\mathbf{K} -matrix has been calculated with *Spearman* rank-correlation of spectra from 20 days over 4 seasons over the Sahara, Arabia and adjacent oceans.

Eight eigenvectors account for almost all variability (96%) in the τ_{eqv} spectra.

V_3 - V_8 are used for aerosol retrieval.



Extracting the aerosol signal

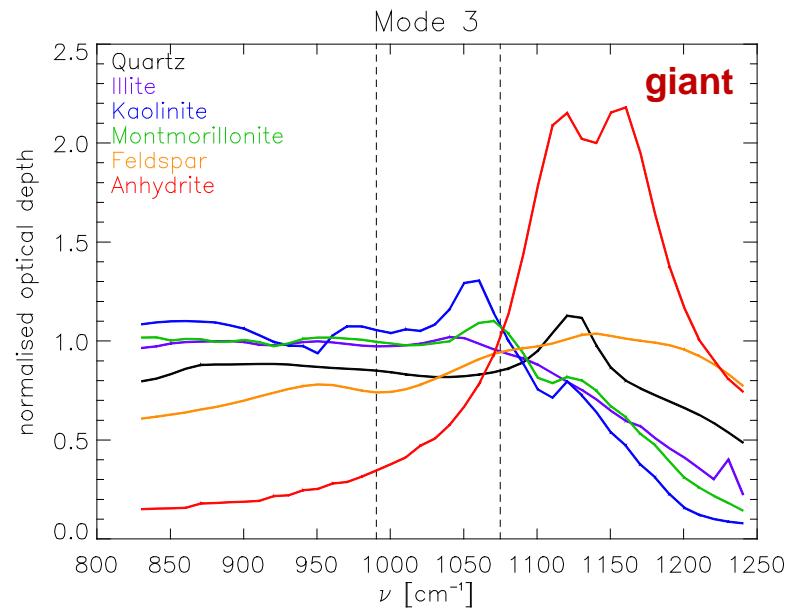
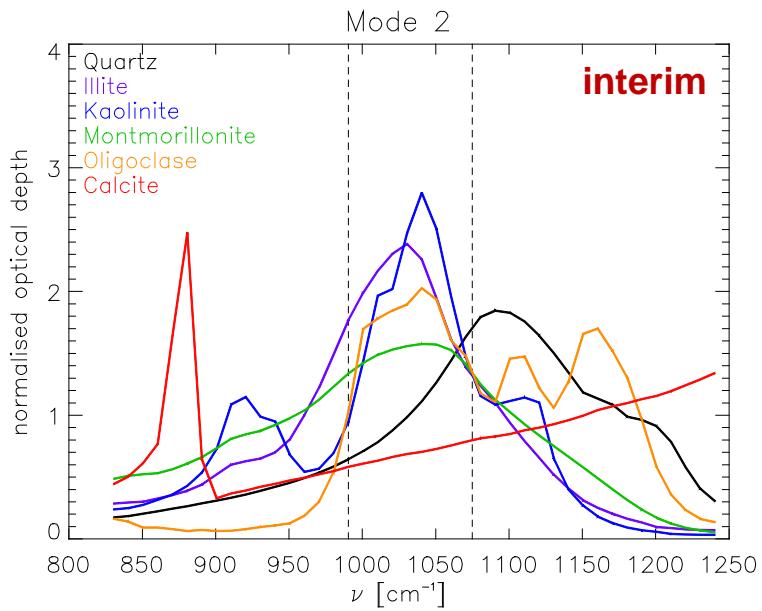
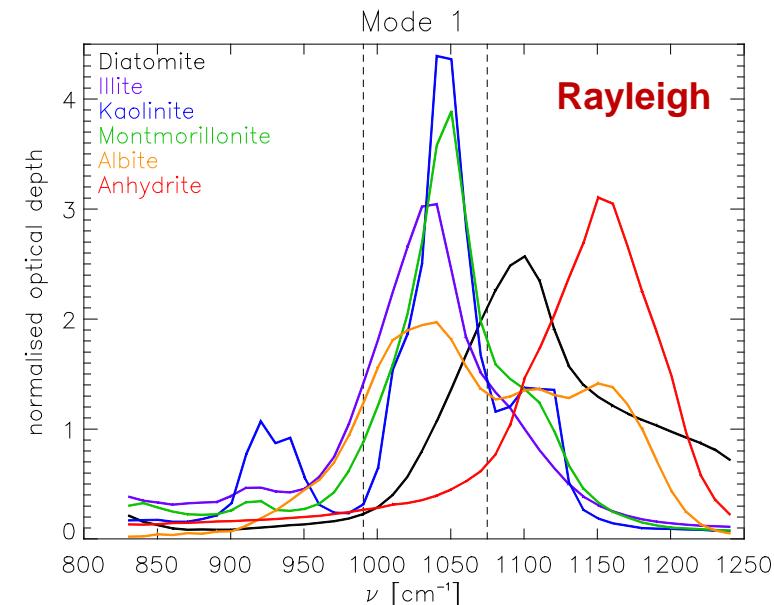
6 components

(quartz, illite, kaolinite, montmorillonite, feldspar, $\text{CaSO}_4/\text{CaCO}_3$)

3 size modes

(small Rayleigh mode, interim mode, giant Mie mode)

Rayleigh and interim modes: $\tau(\nu)$ of different size distributions measured by FTIR (Univ. Iowa)
 giant mode: Mie calculations

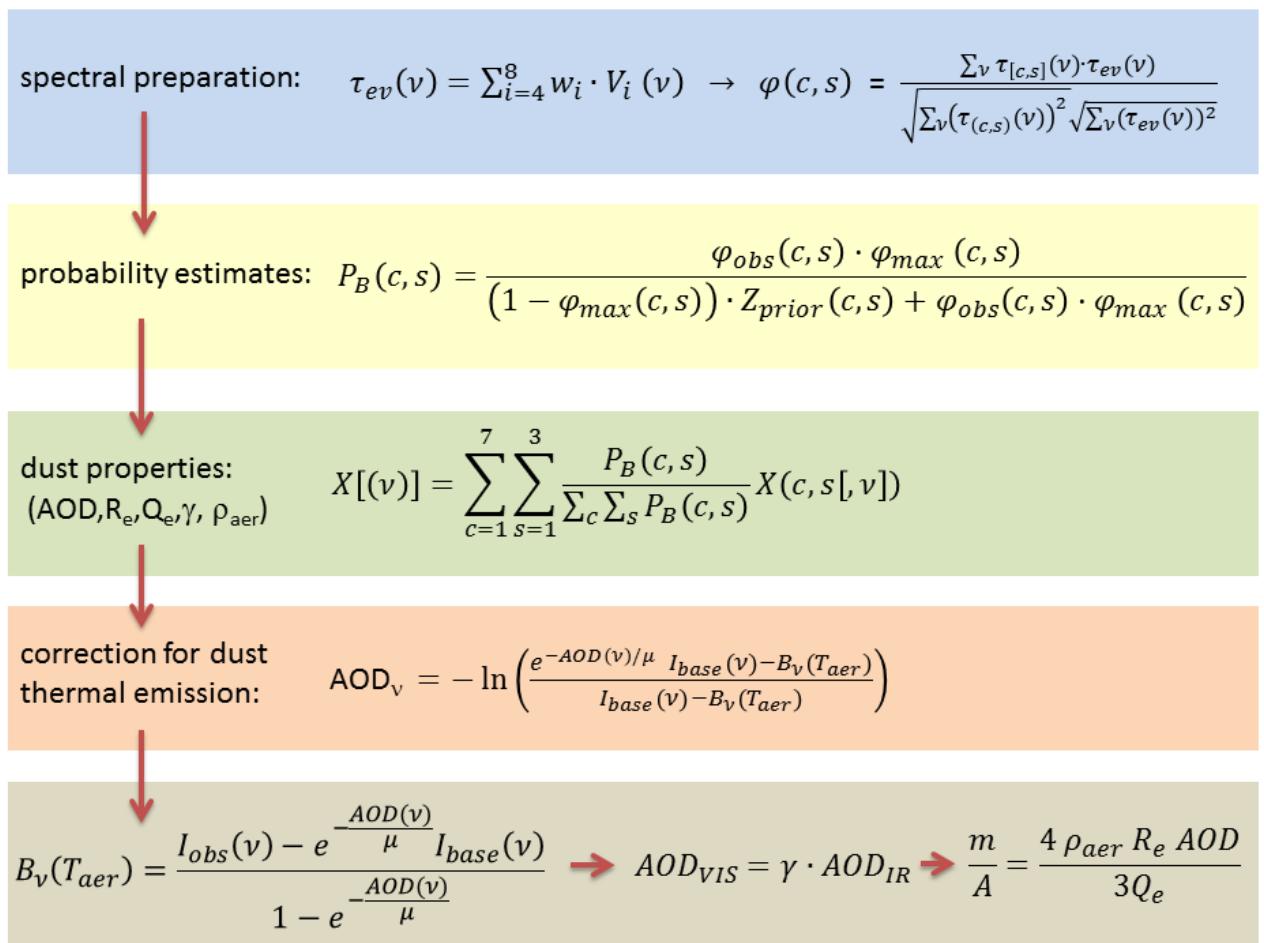


Algorithm outline

a priori probability estimates for mineral dust:

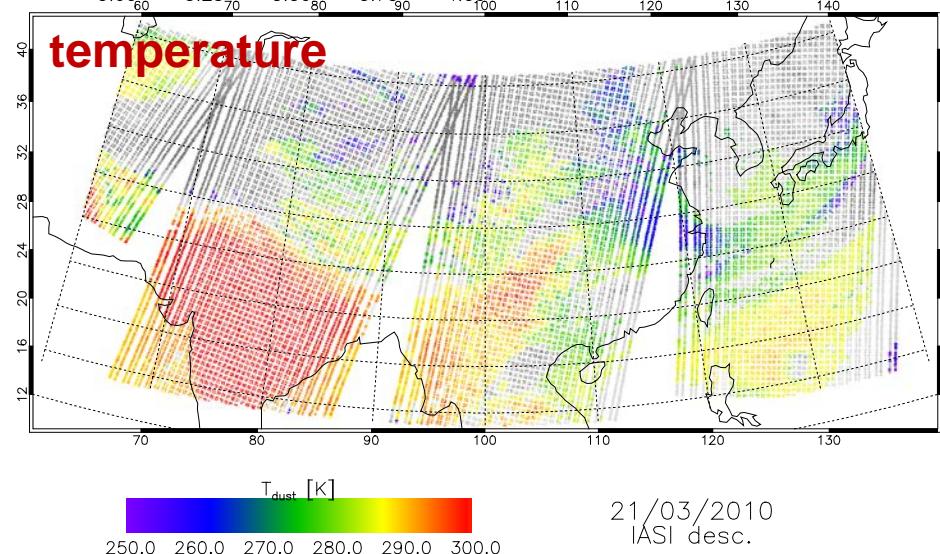
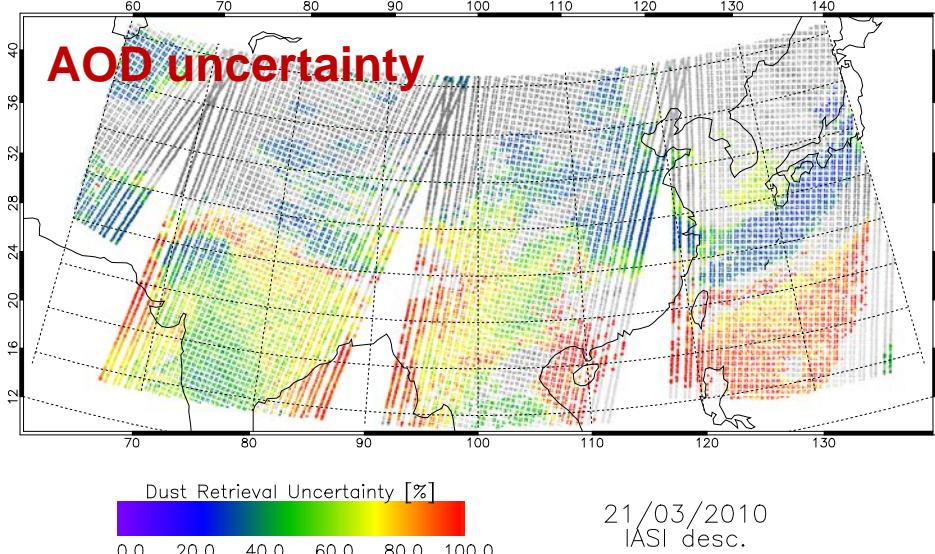
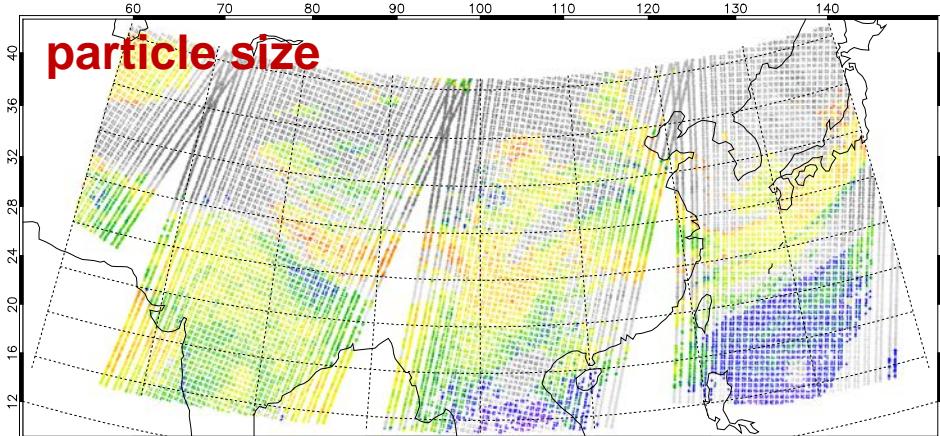
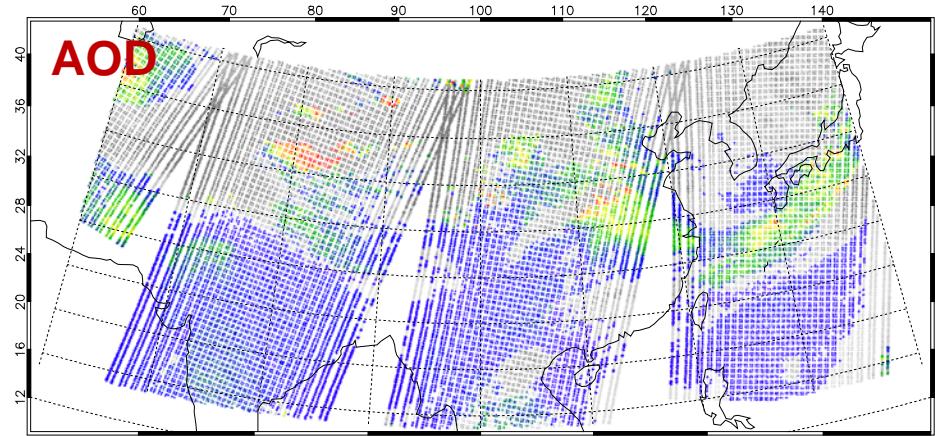
3 size modes:
according to
GERBILS obs.
(Johnson &
Osborne, 2011)

mineralogical composition:
abundance of
6 components
compiled by
Sokolik & Toon
(1999)

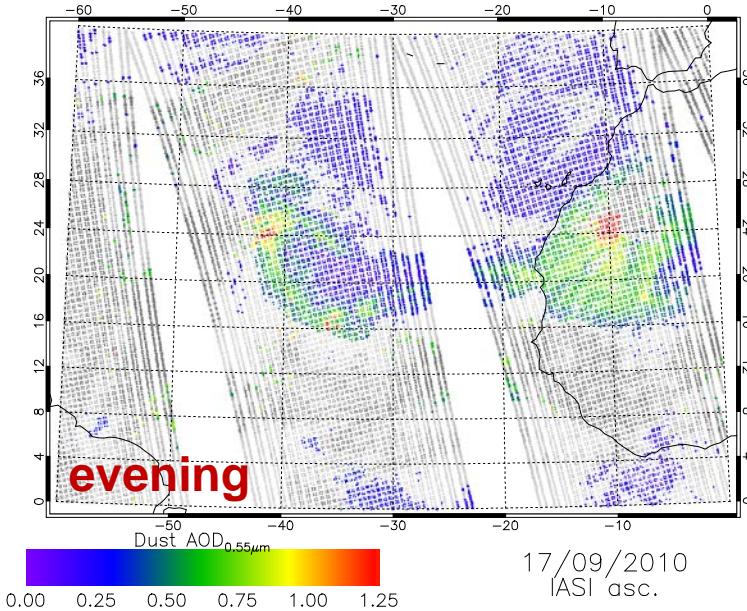
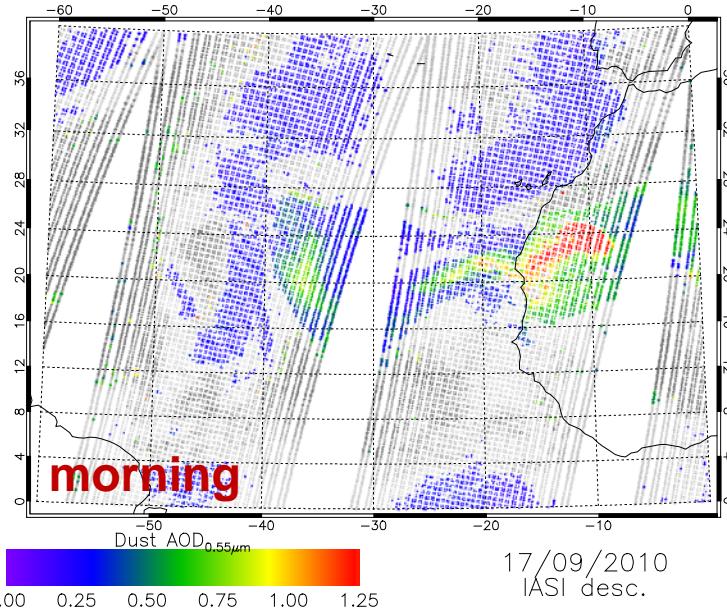
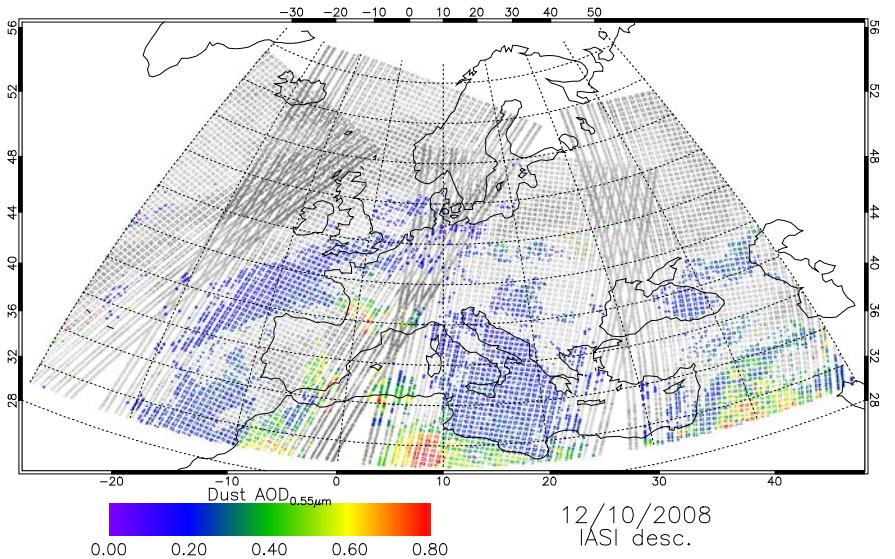
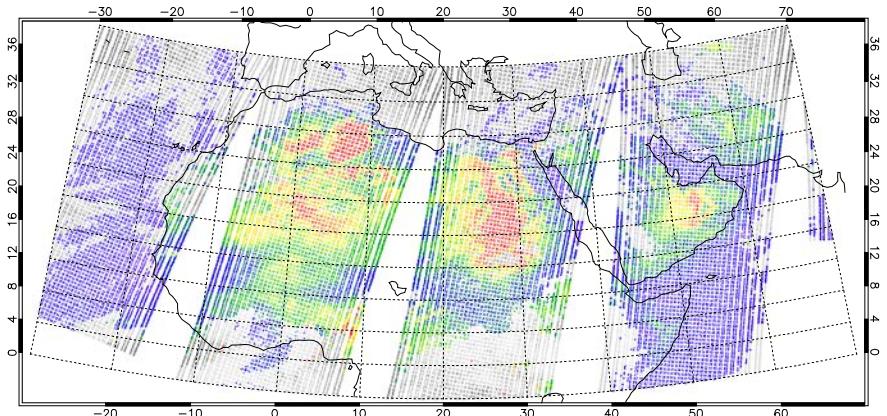


Example episode: Asian dust

$P_{dust} > P_{crr}$

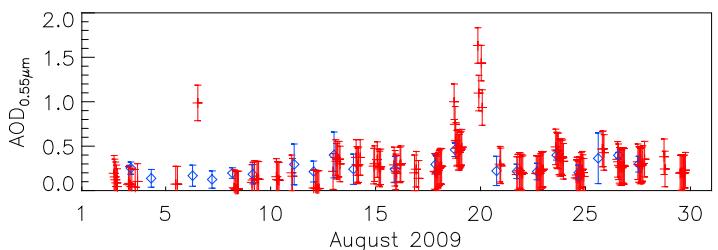
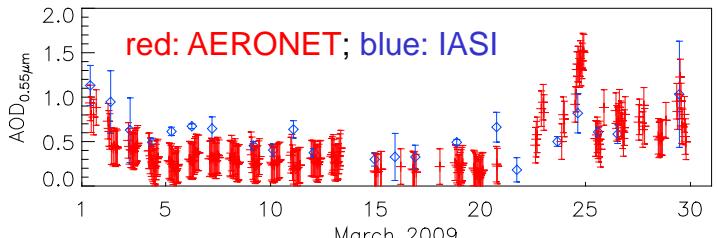


Example episodes: Saharan dust

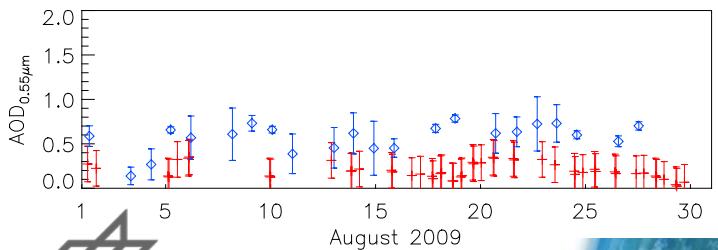
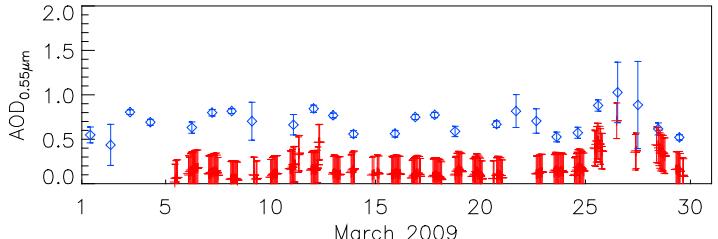


AERONET validation

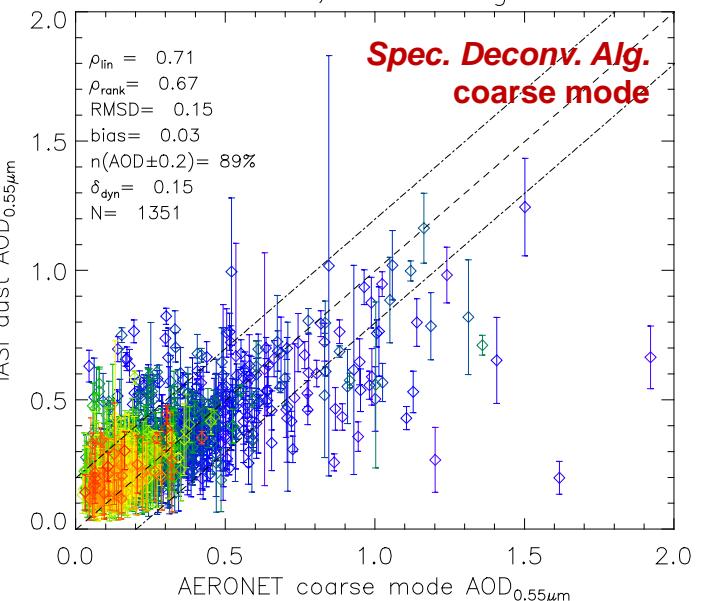
IER_Cinzana



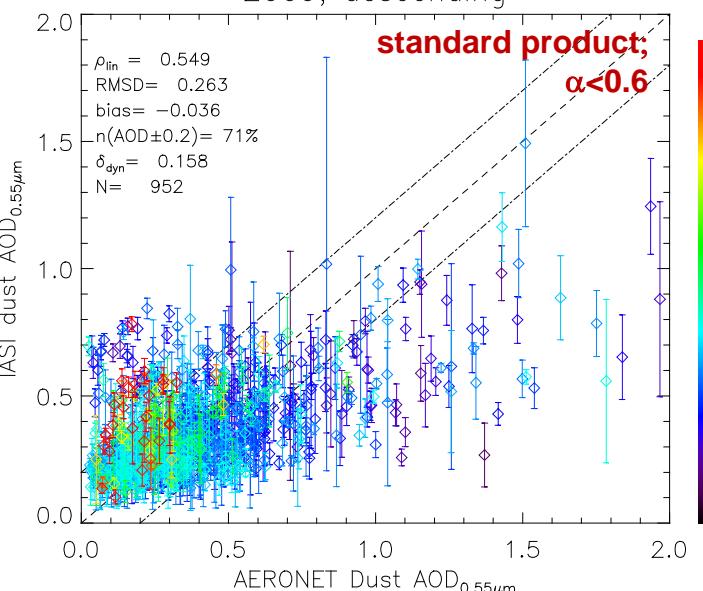
Tamanrasset_NM



2009, descending

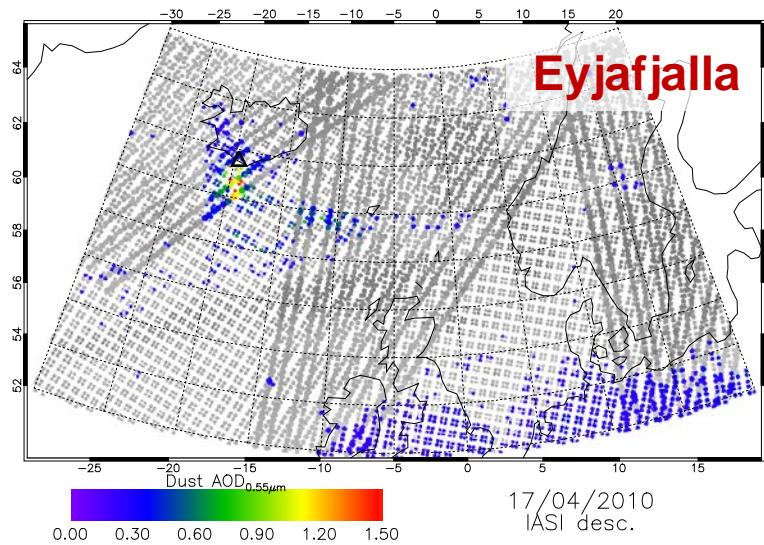
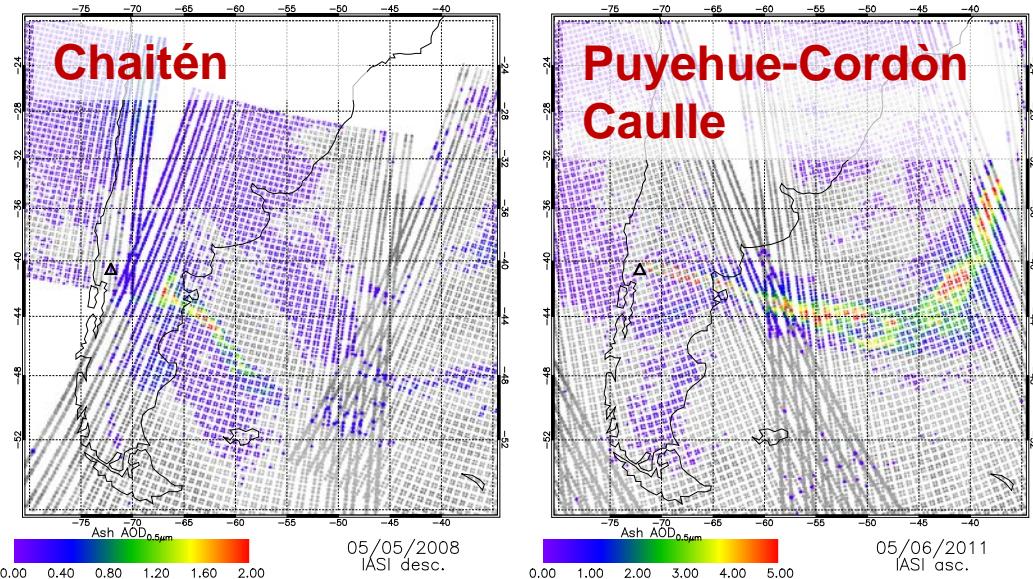
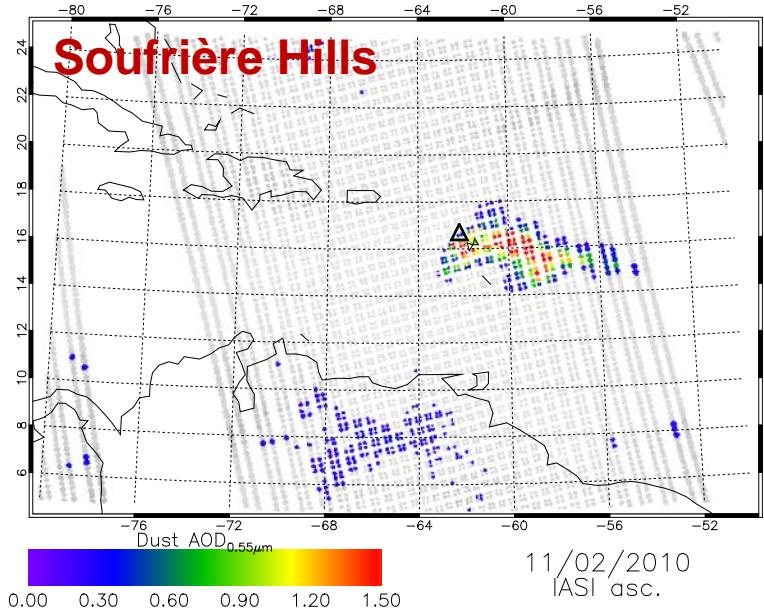


2009, descending

 $\eta_{AERONET}$  $\eta_{AERONET}$ 

Observation of volcanic ash

- volcanic ash observations (this version) with the dust setup [3 clays, Z_{prior}]
- Modelled ash spectra (purely absorbing or Mie) yield completely different AOD
- discrimination between desert dust and volcanic ash remains challenging



Summary

- fast and efficient standalone TIR mineral aerosol retrieval for IASI
- no *a priori* knowledge about atmospheric state or surface emissivity
- not sensitive to biomass burning or industrial aerosol
- retrieval of AOD, particle size, emission temperature, dust mass , dust probability , AOD uncertainty, dust composition
- Validation against AERONET coarse mode AOD (1351 coinc.):
 $\rho=0.71$, $\text{RMSD}=0.15$, bias = 0.03, $\delta_{\text{dyn}}=0.15$ 89% in $\text{AOD}\pm0.2$
- giant mode extinction spectra from Mie simulations (not FTIR)
- discrimination between desert dust and volcanic so far needs external auxiliary methods (e.g. Lagrangian modelling)

