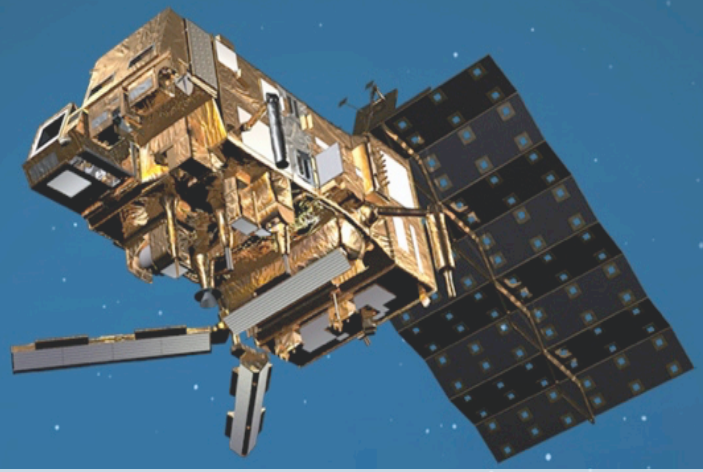


Observation satellitaire de la distribution 3D des Aérosols et de la Pollution à l'Ozone à partir d'approches innovantes de télédétection

J. Cuesta, G. Dufour, M. Eremenko,
G. Foret, A. Coman, L. Costantino,
Y. Chailleux, B. Laurent, C. Di Biagio, P. Formenti,
G. Bergametti et M. Beekmann

Collaborations: C. Flamant (LATMOS), F. Aires (LERMA), X. Liu (Harvard),
Y. Kanaya (JAMSTEC), M. Höpfner (KIT), Z. Cai (IAP), D. Zhou (NASA) …

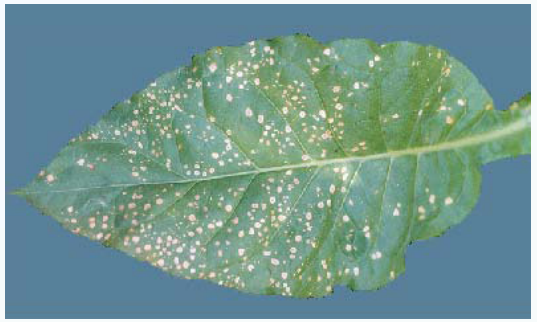
1. La pollution à l'Ozone par satellite

- Impact majeur de l'O_3 troposphérique sur la santé et les écosystèmes

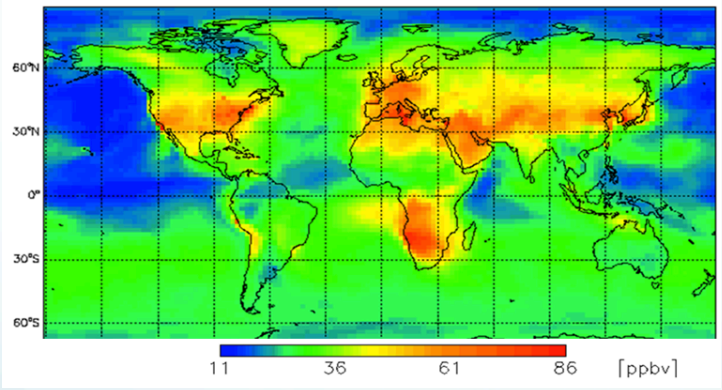
Irritation du systèmes respiratoire

Limitation de la photosynthse

Necroses des feuilles



- Préocupation societale majeure aux échelles regionale, continentale et globale



Surface O_3 from (July 2011)

Seulement les observations satellitaires couvrent ces échelles

.... Mais les méthodes actuelles utilisant une seule bande spectrale (soit l'UV ou l'IR) montrent une sensibilité à l'O3 au plus bas dans la troppposphère libre (au-dessus de 3 km d'altitude) ...

➔ Application limitée pour la qualité de l'air

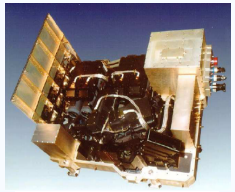
- Comment observer l'O_3 dans la **TROPOSPHERE TRES BASSE (<3 km asl)** ?

➞ Nous proposons l'approche multispectrale "**IASI+GOME2**"

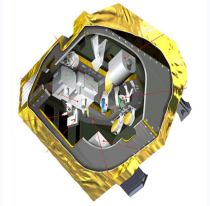
L'approche Multispectrale IASI+GOME2

Nouvelle méthode d'inversion conjointe des spectres IR et UV co-localisés

GOME-2
(Reflectance terrestre)



IASI
(Radiance thermique)



Spectres observés

UV spectrum

IR spectrum

Minimisation simultanée des résidus UV et IR

Modèles de transfert radiatif

Spectres simulés

Conditions atmosphériques et de surface

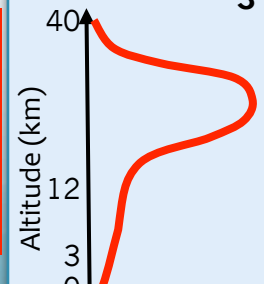
UV (VLIDORT) → Reflectance UV

IR (KOPRA) → Radiance IR

Ajustement d'un profil unique d'O_3

Iterations

Profil O_3



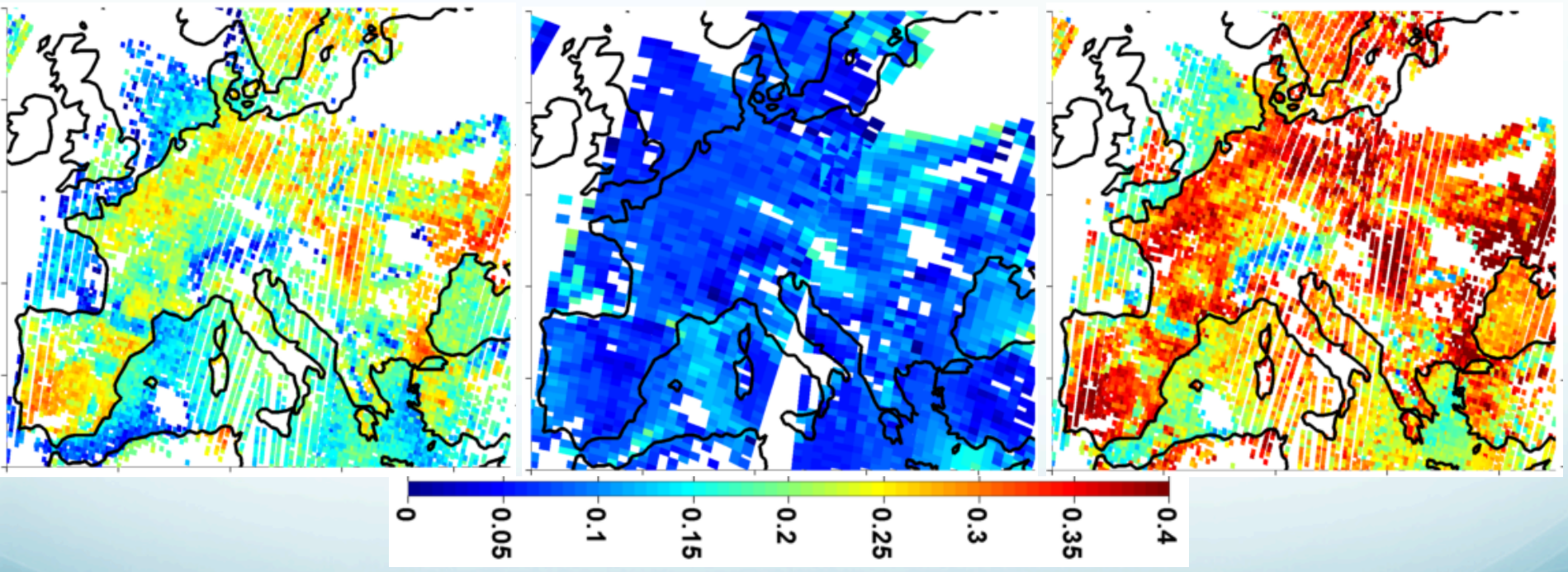
Augmentation de la sensibilité dans la très basse troposphère

Restitution multispectral pour chaque pixel satellitaire

[Cuesta et al., 2013, ACP]

Sensibilité du couplage multispectral: Dégrées de liberté dans la très basse troposphère (au-dessous de 3 km asl)

IASI (IR) | **GOME-2 (UV)** | **IASI+GOME2**



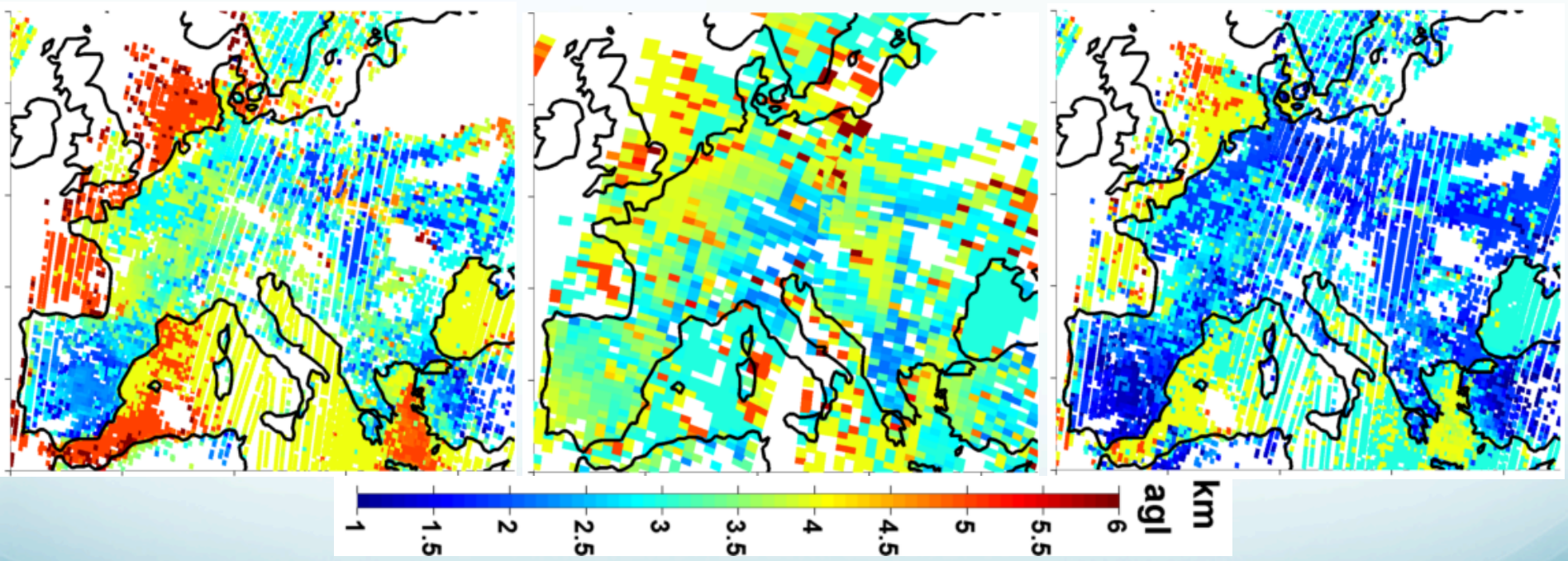
0.25 DOFs sur terre
0.15 DOFs sur mer

<0.10 DOFs

0.35 DOFs sur terre
0.25 DOFs sur mer
DOF_{IASI} + 40%

Sensibilité du couplage multispectral: Hauteur de sensibilité maximale dans la troposphère très basse (au-dessous de 3 km asl)

IASI (IR) | **GOME-2 (UV)** | **IASI+GOME2**



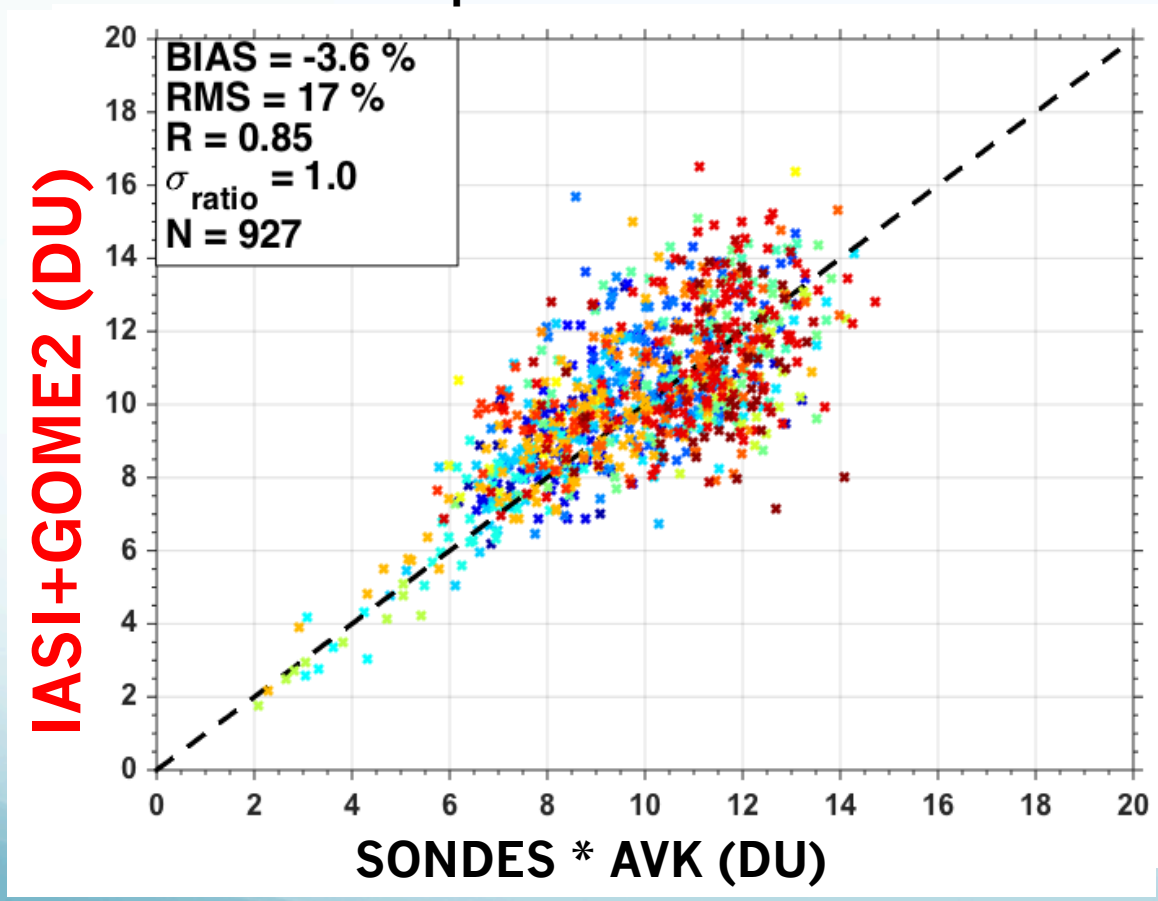
3 km agl sur terre
4.3 km agl sur mer

3.7 km agl

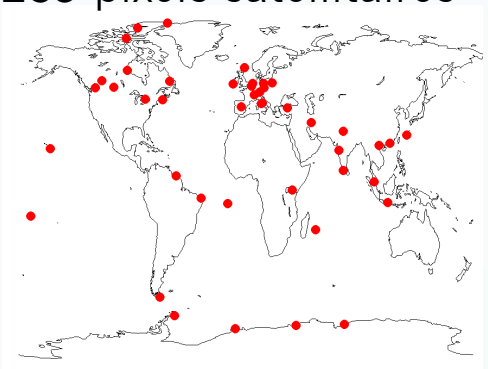
2.2 km agl sur terre
3.5 km agl sur mer
H_{IASI} *- 800 m*

Validation du couplage IASI+GOME2 : IASI+GOME2 vs. **Ozonesondes**

Très basse troposphère :
Colonnes partielles surface-3 km asl



- ✓ 927 sondages (en ciel clair)
- ✓ 44 stations atour du monde
- ✓ Période: 2009 et 2010
- ✓ 9239 pixels satellitaires

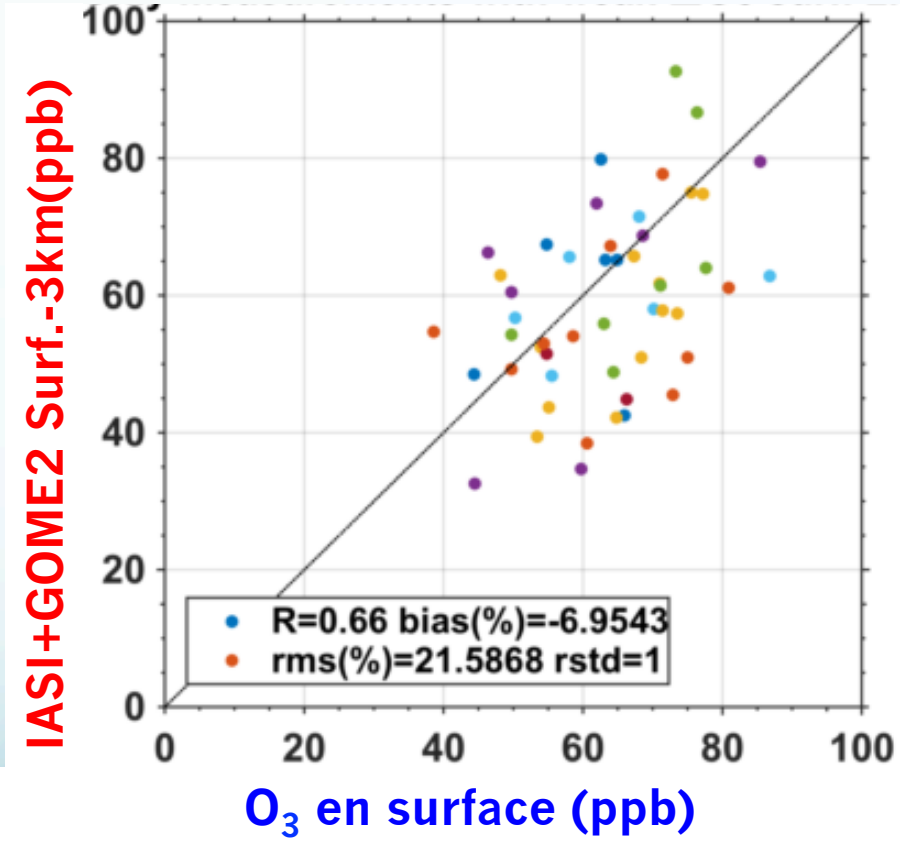


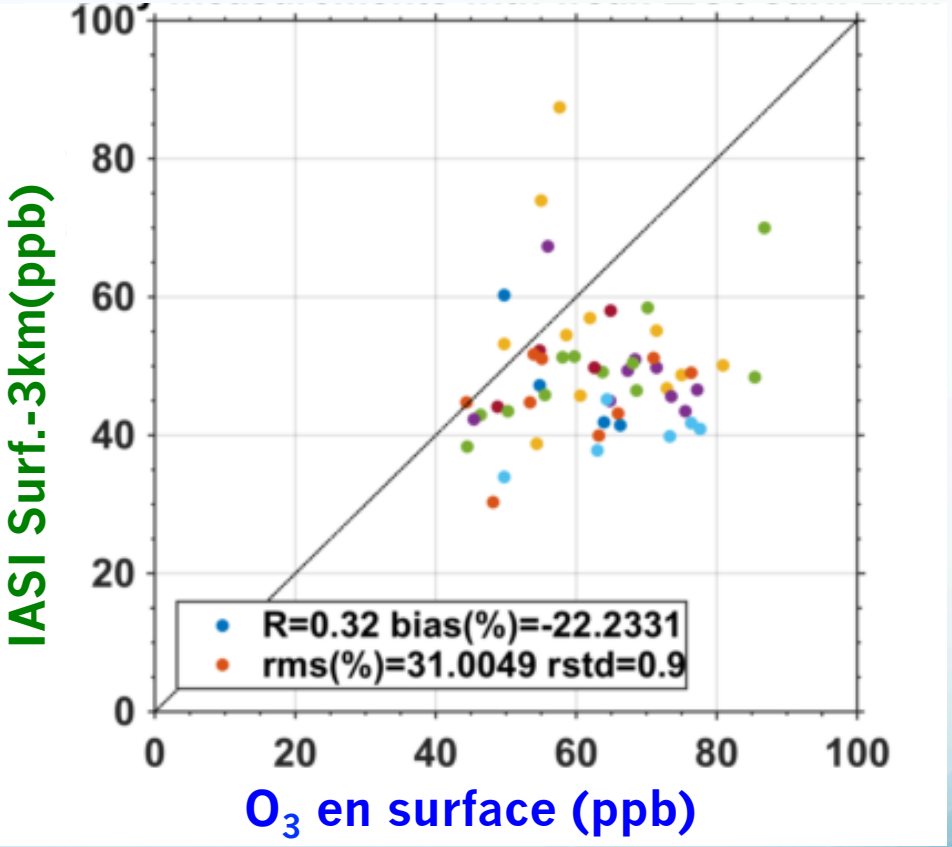
Bon accord avec les sondes:

- ✓ Faible biais moyen: -3,6 %
- ✓ Très bonne corrélation: 0,85
- ✓ Bonne précision (RMS): 17%
- ✓ Bonne variabilité

Validation du couplage IASI+GOME2 : IASI+GOME2 vs. **Mesures In situ à la surface**

2 épisodes de pollution en Asie de l'est: 4-9 Avril et 4-9 Mai 2009
Cas avec un gradient entre la surface et 2 km < 20 ppb (selon CHASER)





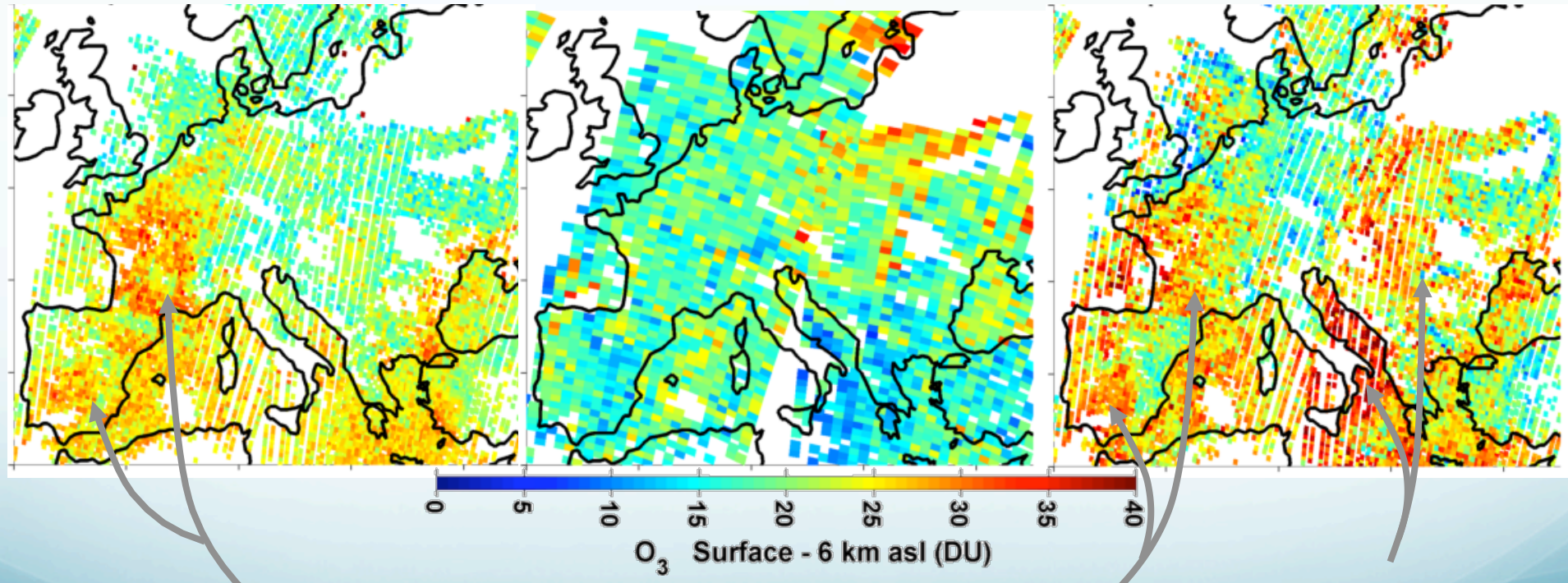
- ✓ **Bonne correlation : Unique actuellement**
- ✓ Faible biais moyen
- ✓ Précision proche de l'erreur de IASI+GOME2

La variabilité à la surface n'est pas observée avec IASI seul

Observations satellitaires de la pollution O_3 : IASI+GOME2 vs. approche à une bande spectrale

19 Août 2009

IASI (IR) **GOME-2 (UV)** **IASI+GOME2**



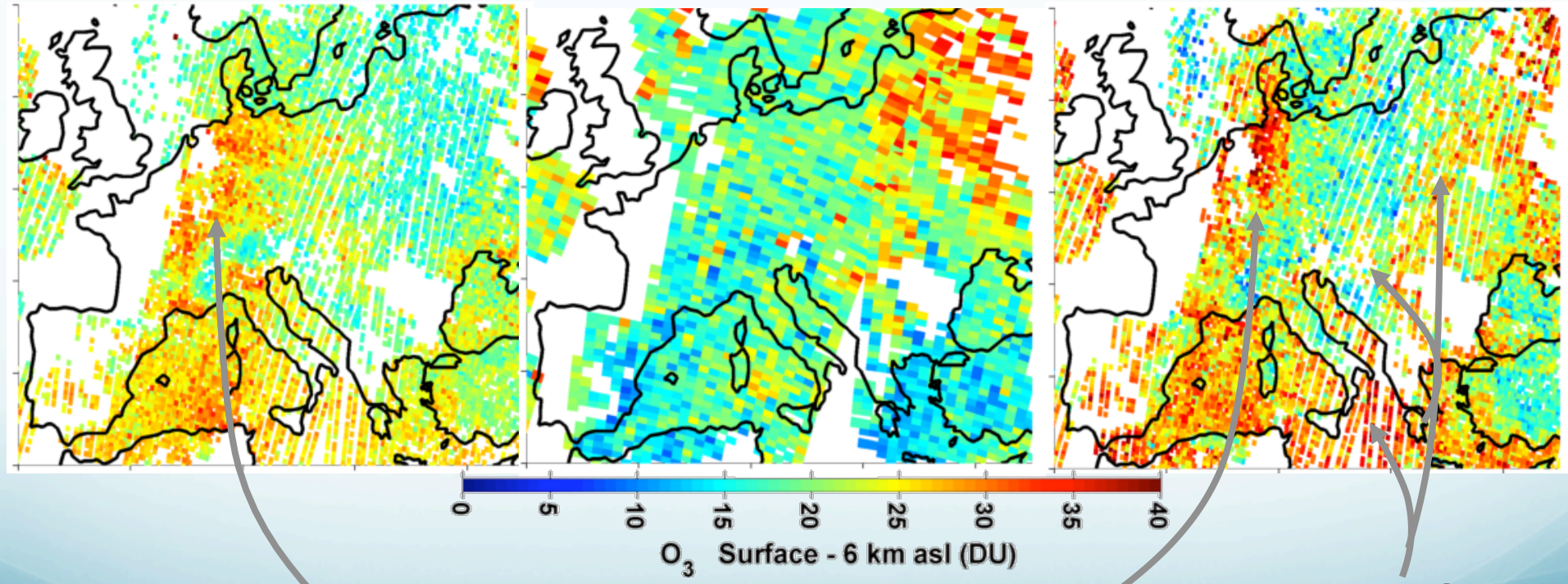
Panaches d'O_3 à l'ouest montrés par IASI et IASI+GOME2 → jusqu'à 4-5 km asl

Panaches d'O_3 à l'est et sur mer seulement observés par IASI+GOME2

Observations satellitaires de la pollution O_3 : IASI+GOME2 vs. approche à une bande spectrale

20 Août 2009

IASI (IR) **GOME-2 (UV)** **IASI+GOME2**



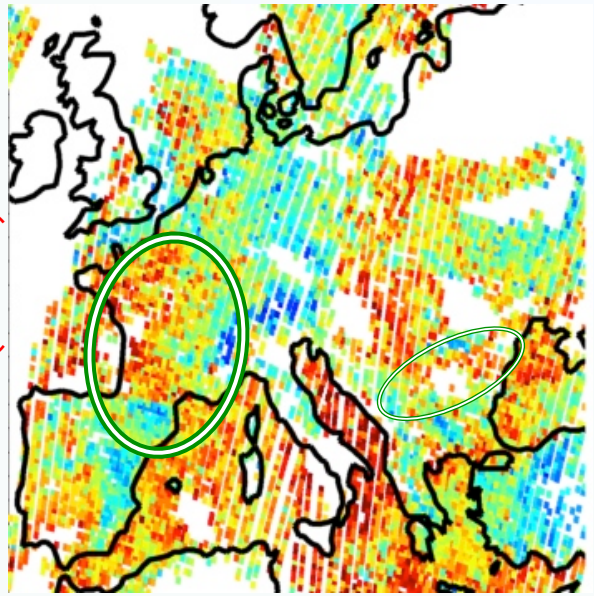
Panaches d'O_3 à l'ouest montrés par IASI et IASI+GOME2 → jusqu'à 4-5 km asl

Panaches d'O_3 à l'est et sur mer seulement observés par IASI+GOME2

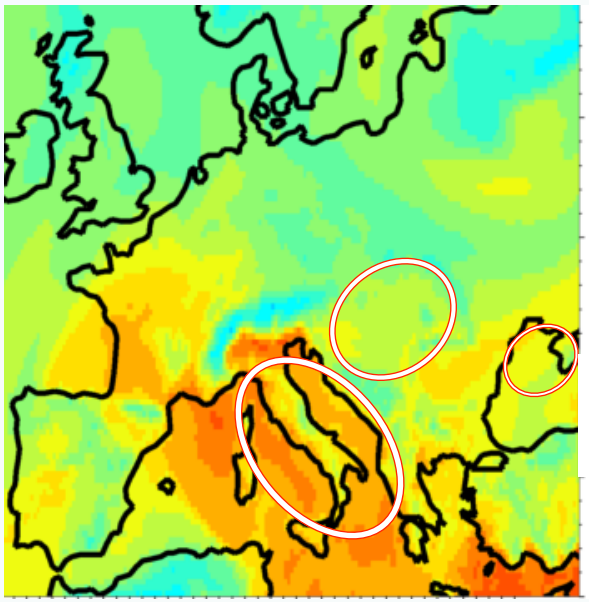
IASI+GOME2 vs. CHIMERE :

19 August 2009

IASI+GOME2
Très basse Tropo
(<3km)



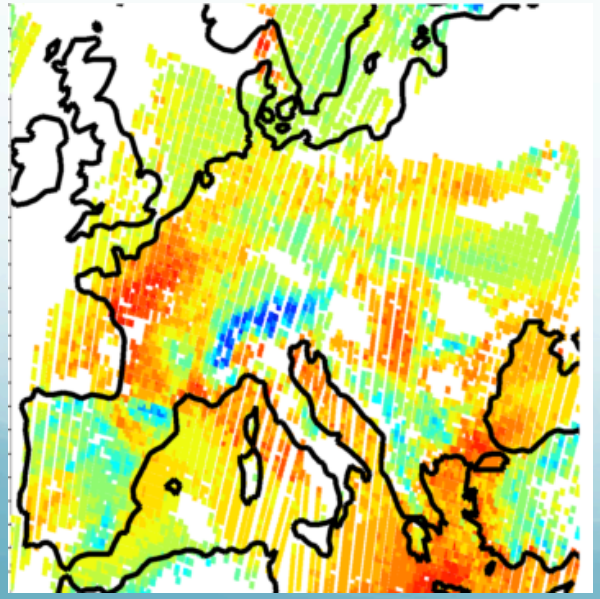
CHIMERE raw
Très basse tropo



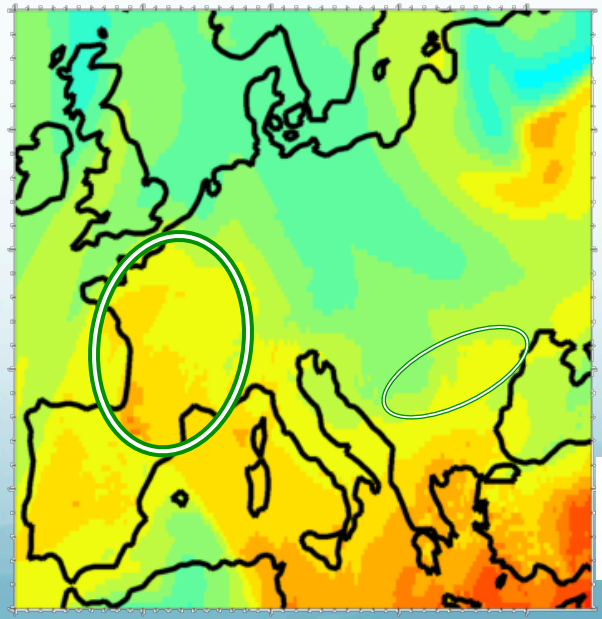
Plumes below 3 km asl

Only seen by IASI+GOME2

CHIMERE*avk
Très basse tropo



CHIMERE raw
3 – 6 km asl



Also above

Also observed by IASI over land

O_3
LMT
(DU)

2. Desert dust distribution by satellite

3D distribution of desert dust

Life cycle of dust:
uplift, transport and deposition

Environmental impacts:
Air quality, radiative budget, atmospheric dynamics, etc.

➔Satellite observations are key for observing desert dust distribution, but standard products only provide a 2D distribution (horizontal and transects) or a mean altitude of dust layers.

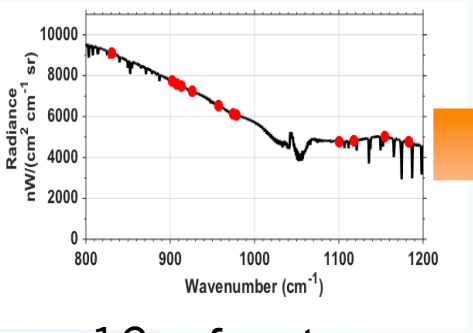
➔We propose to describe the full 3D distribution of dust with

AEROIASI

AEROIASI:

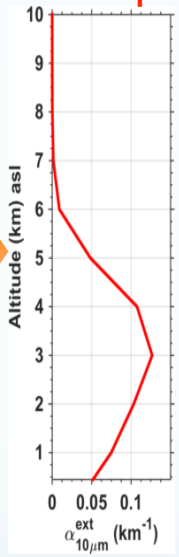
Retrieval of the 3D distribution of desert dust for each IASI overpass

Cloud-free IASI spectra



12 µ-fenetres entre 8-12 µm

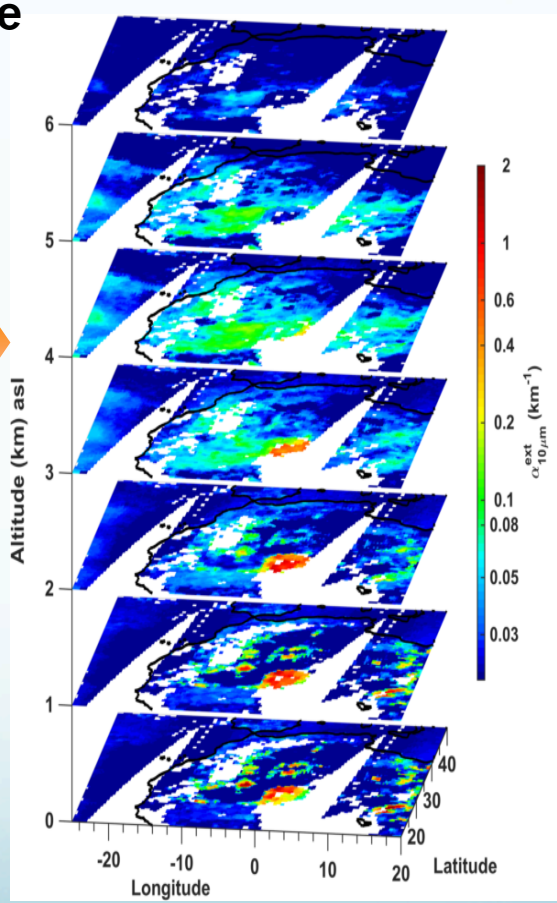
Dust extinction profile à 10 µm



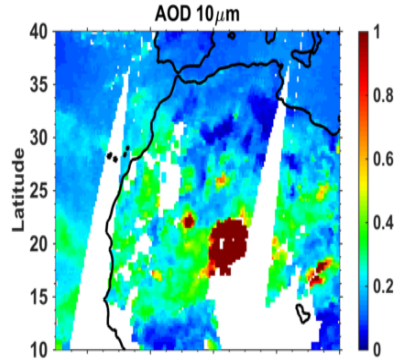
T_{surf} & $N_{AERO}(z)$

Auto-adaptive Tikhonov-Philips regularization

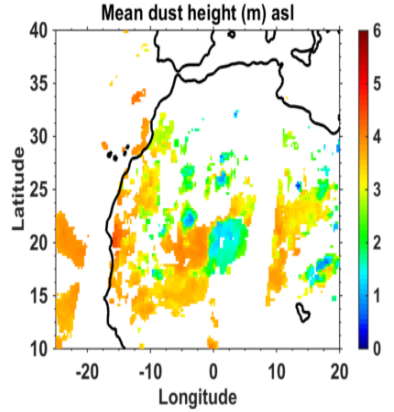
3D distribution of dust



AOD at 10 µm

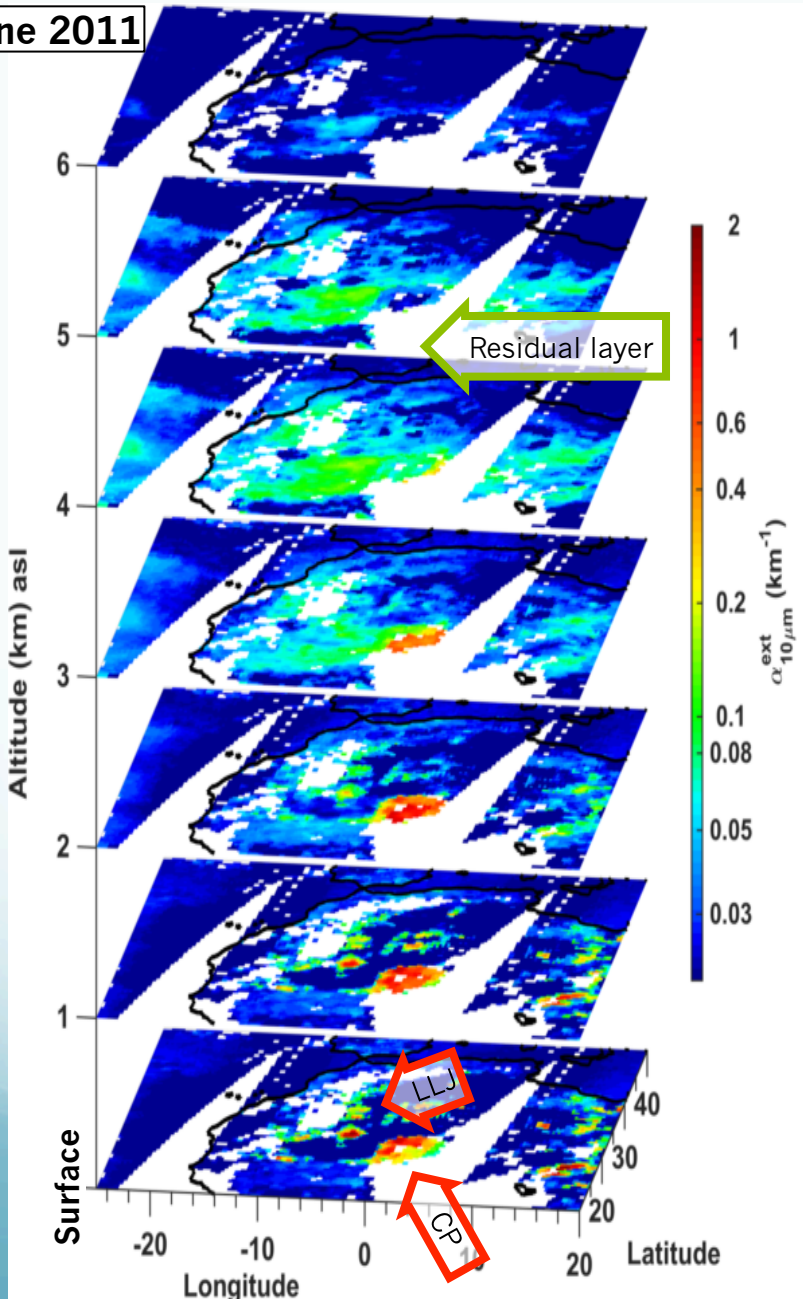


Altitude of dust

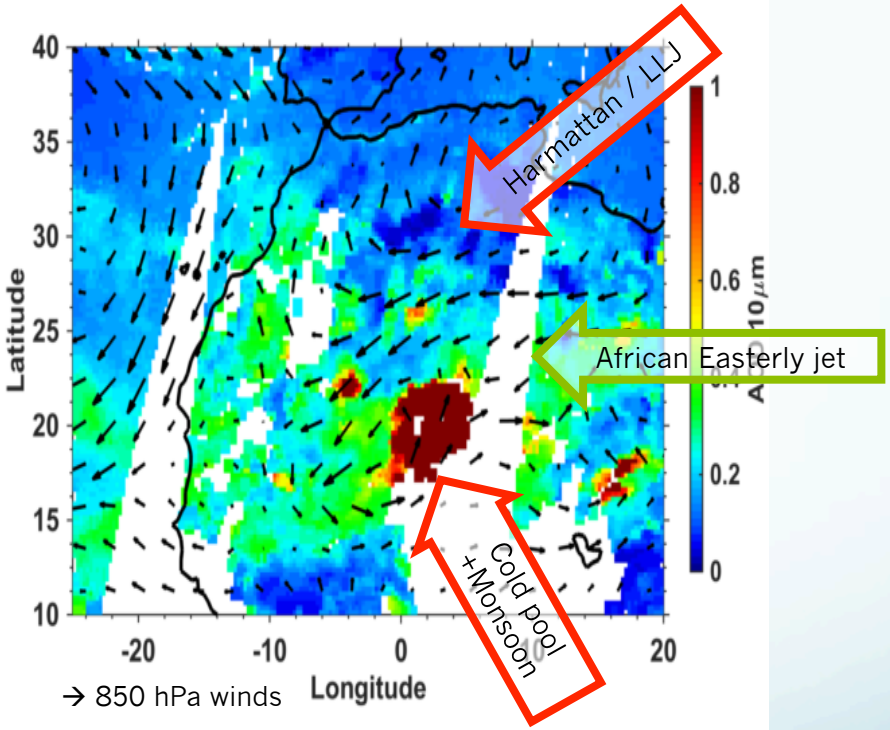


Saharan dust in 3D from AEROIASI

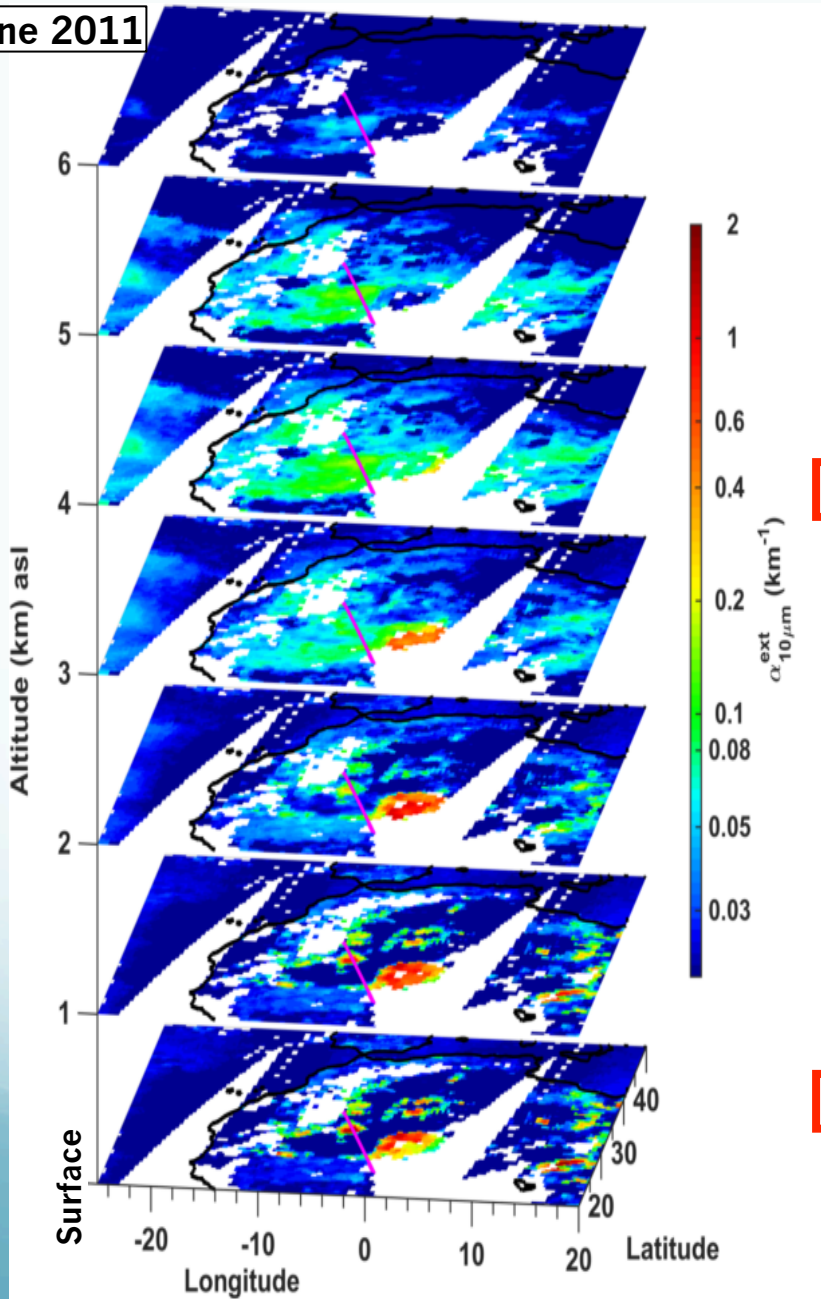
17 June 2011

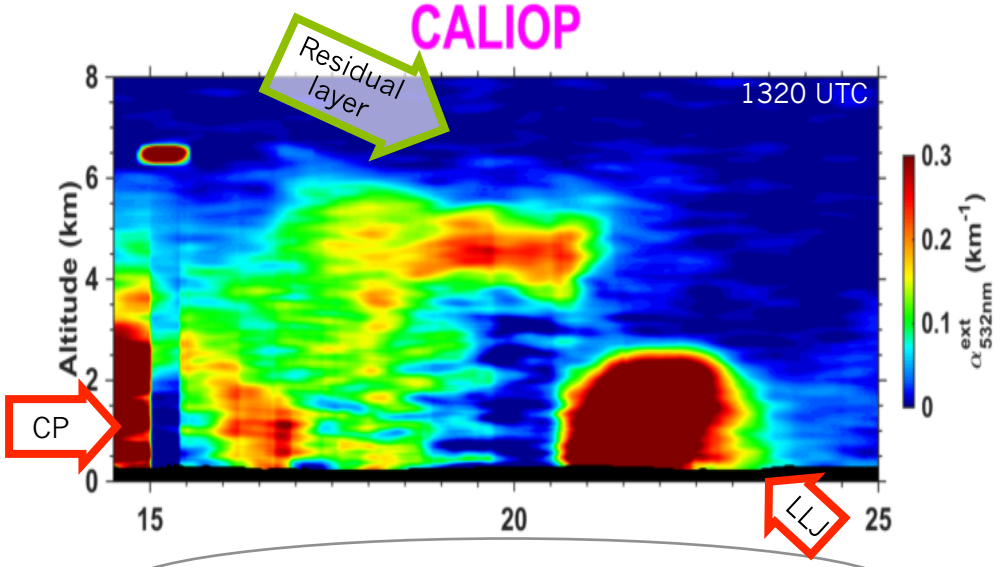


Dust uplift and transport

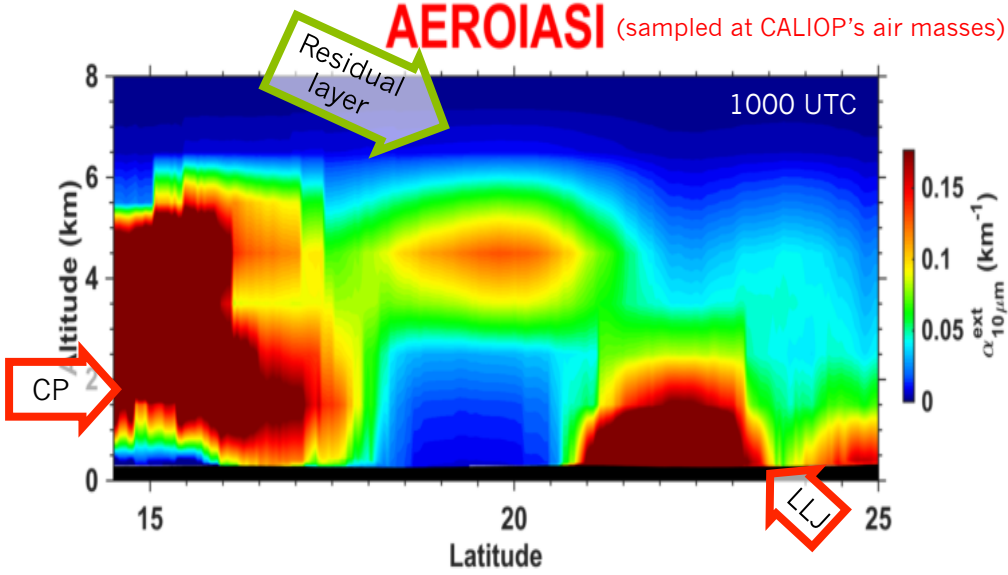


Saharan dust in 3D from AEROIASI

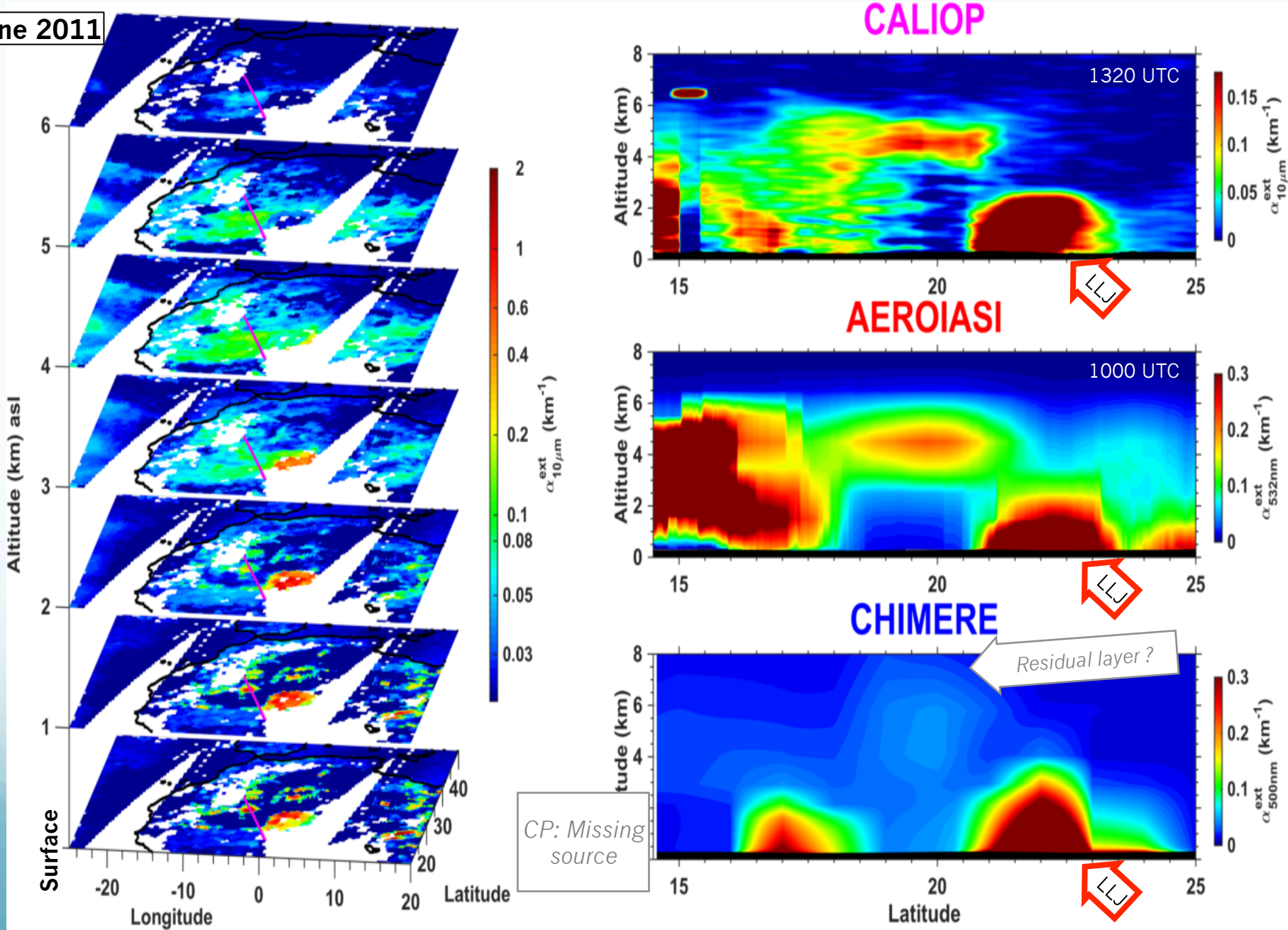




Remarkable agreement



Saharan dust in 3D from AEROIASI



Summary

Two new and currently unique satellite approaches for:

✓ IASI+GOME2: depicting lowermost tropospheric ozone (Cuesta et al., 2013)

- → Based on the simultaneous fit of UV and IR spectra
- → Validated against in situ measurements (sondes and at the surface)
- → Describe the daily distribution of ozone plumes below 3 km.
- → New insights on the evolution of **photo-chemical production of ozone** during transport in synergism with CO measurements.

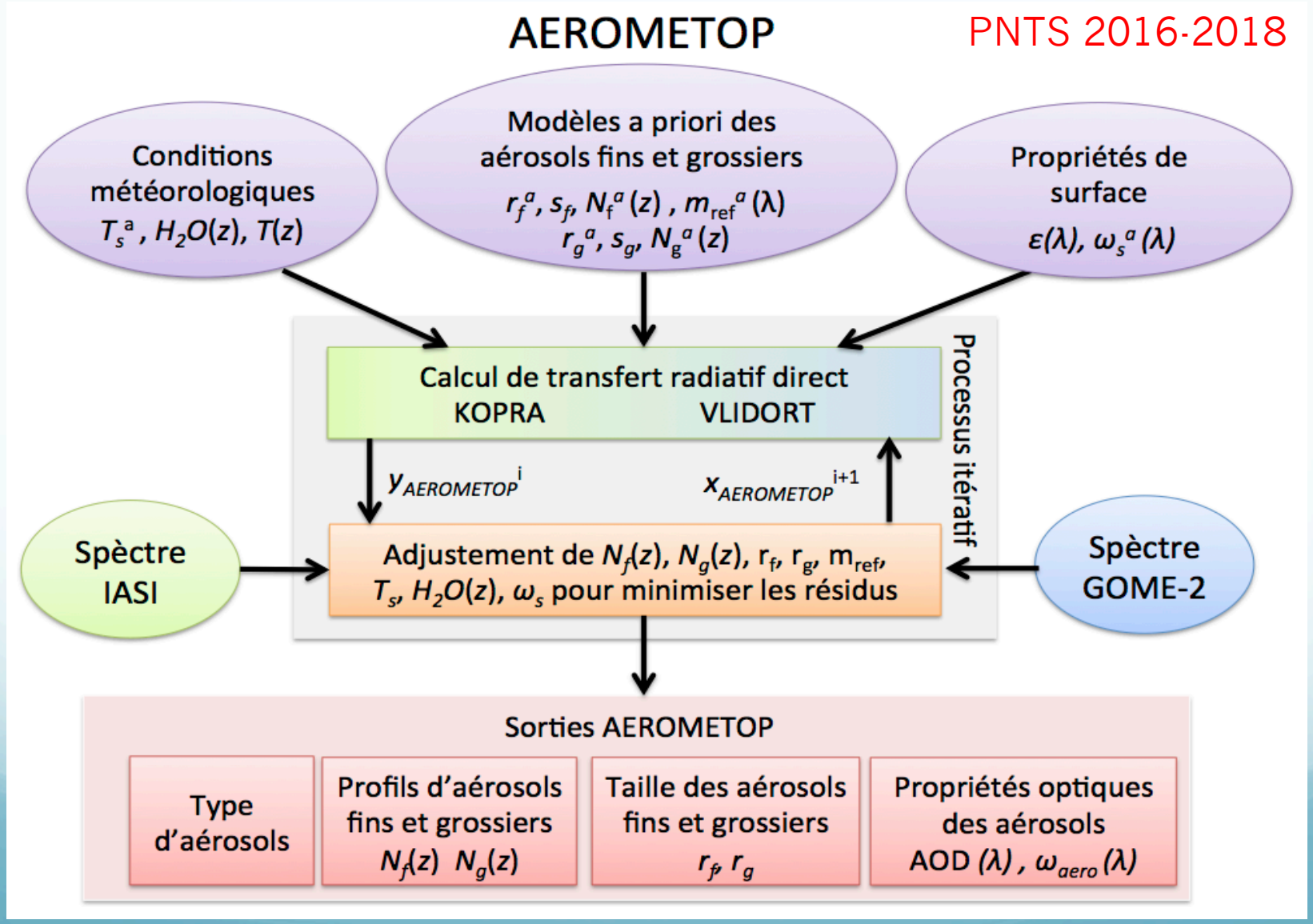
✓ AEROIASI: observing the 3D distribution of coarse aerosols (Cuesta et al., 2015)

- → Auto-adaptive fit of IR spectra
- → Validated against CALIOP lidar transects (vertical structure of dust plumes) and other satellite products for the horizontal distribution
- → New insights on **dust emission mechanisms and 3D transport pathways of dust in link with mixing mechanisms**

➢ On-going & upcoming:

- ➢ Comparisons with chemistry-transport models (CHIMERE, WRF-Chem) and other state-of-the-art satellite observations
- ➢ Massive production and **dissemination of IASI+GOME2 observations** by the French national datacentre AERIS

New development: AEROMETOP Multispectral retrieval of aerosols



Acknowledgements

Principle for observing dust vertical distribution with IASI

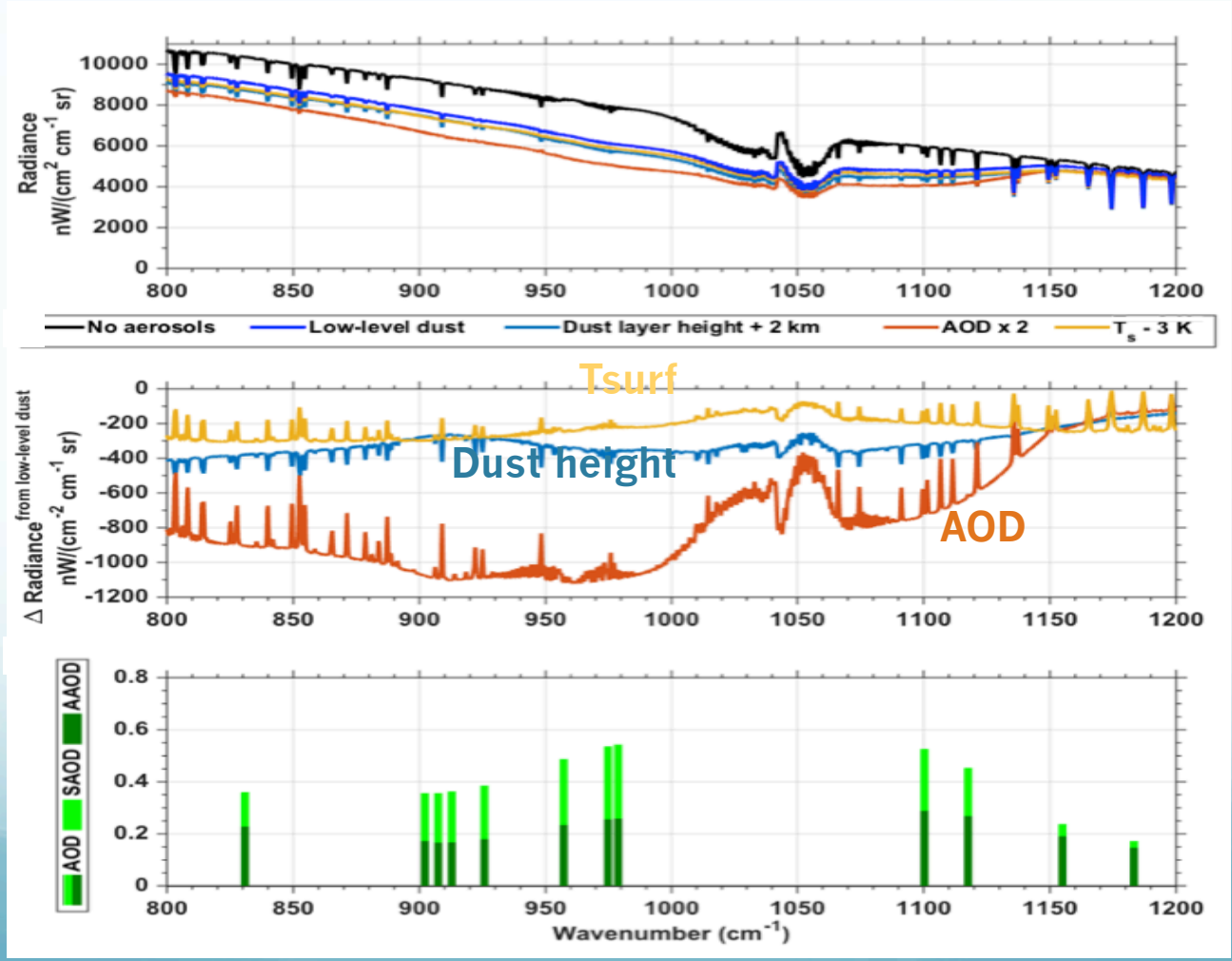
Aerosols in the thermal infrared

- Absorption (AAOD)
- Scattering (SAOD=AOD·AAOD)
- Emission (T_{layer})

IASI spectra

Differences in IASI spectra

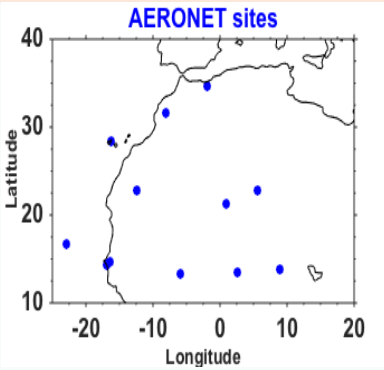
Optical properties of dust

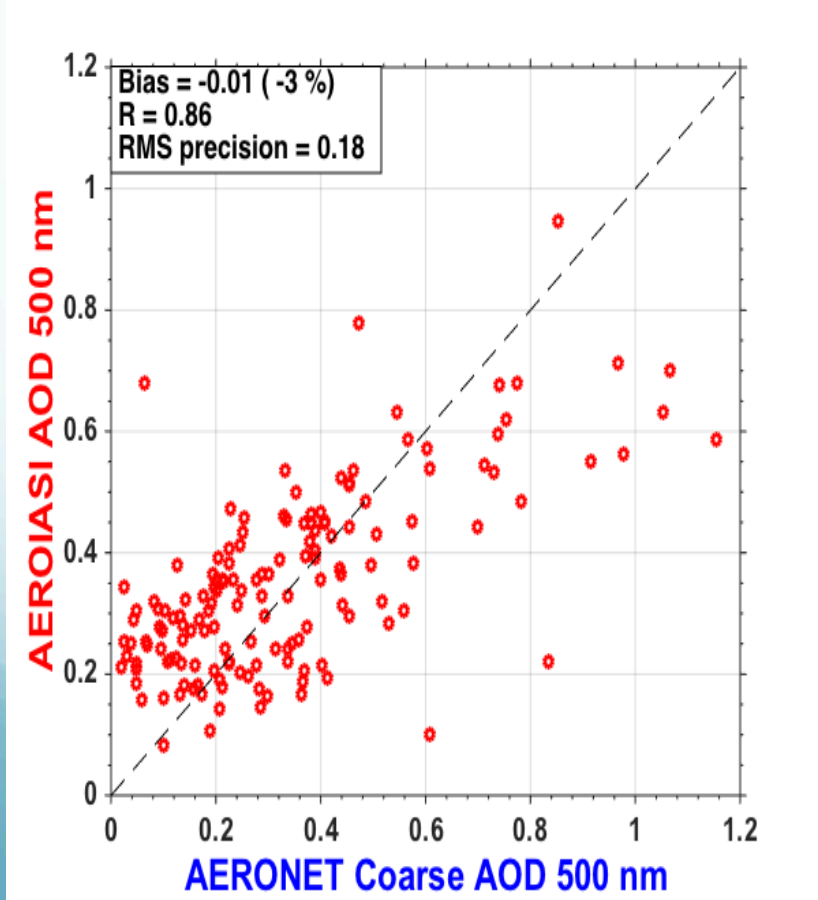


AOD from AEROIASI vs AERONET

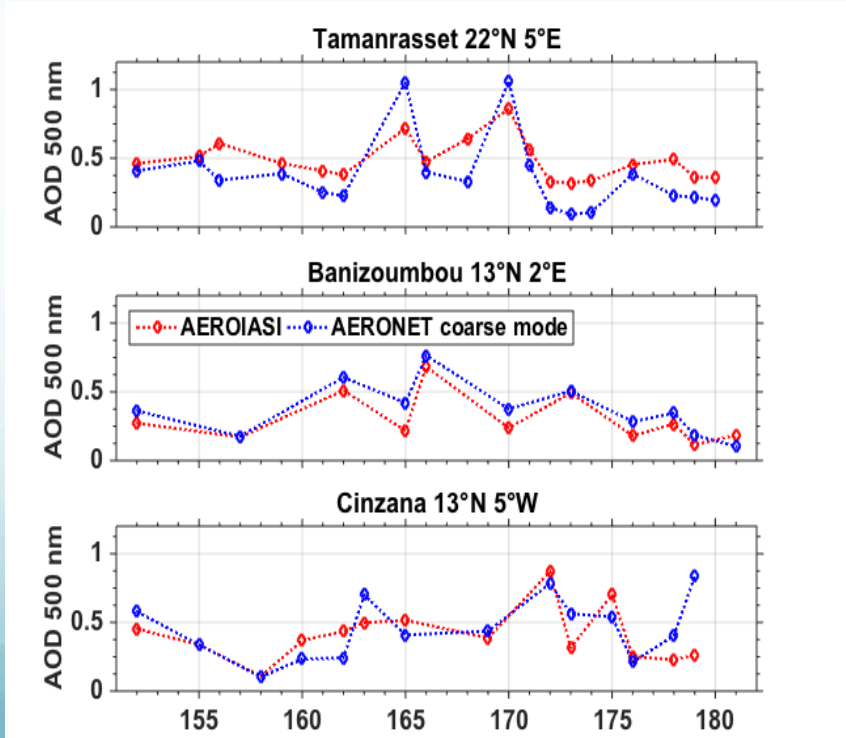
Daily comparison of AEROIASI with AOD^{Coarse} from 12 AERONET sites in June 2011

- ✓ Low mean bias : <3%
- ✓ Good correlation: R=0.86
- ✓ Precision : 0.18
- ✓ From this comparison we estimate $\frac{AOD^{Total}_{500nm}}{AOD_{10\mu m}} \approx 1.7$





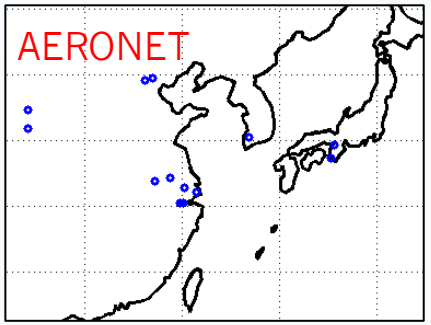
- ✓ Good tracking of dust content evolution

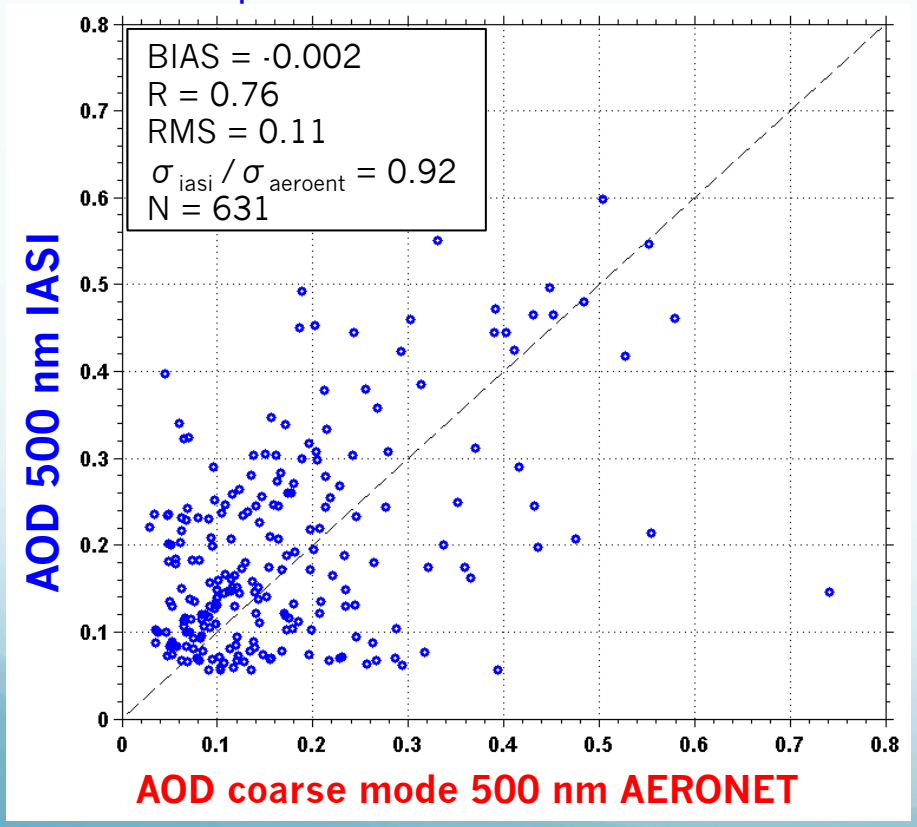


Validation of new aerosol observations
Dust aerosols from IASI vs. AERONET

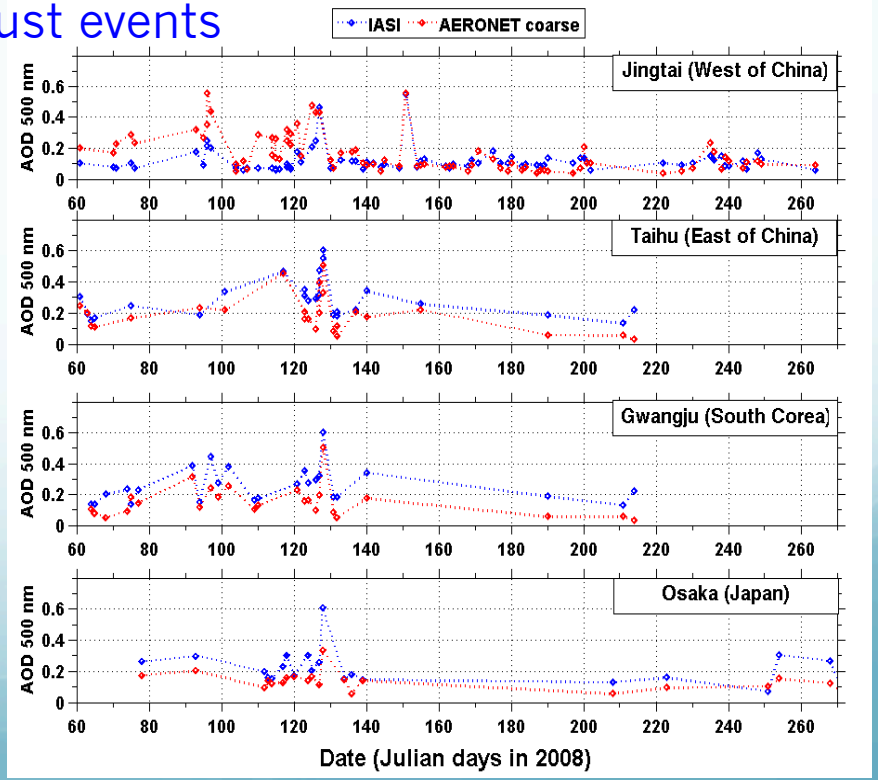
Daily comparison of IASI with AOD_{coarse} from 13 sites between March-September 2008 (period with dust outbreaks)

- ✓ Negligible mean bias : <1%
- ✓ Good correlation: R=0.76
- ✓ IASI reproduces well the AOD variability seen by AERONET





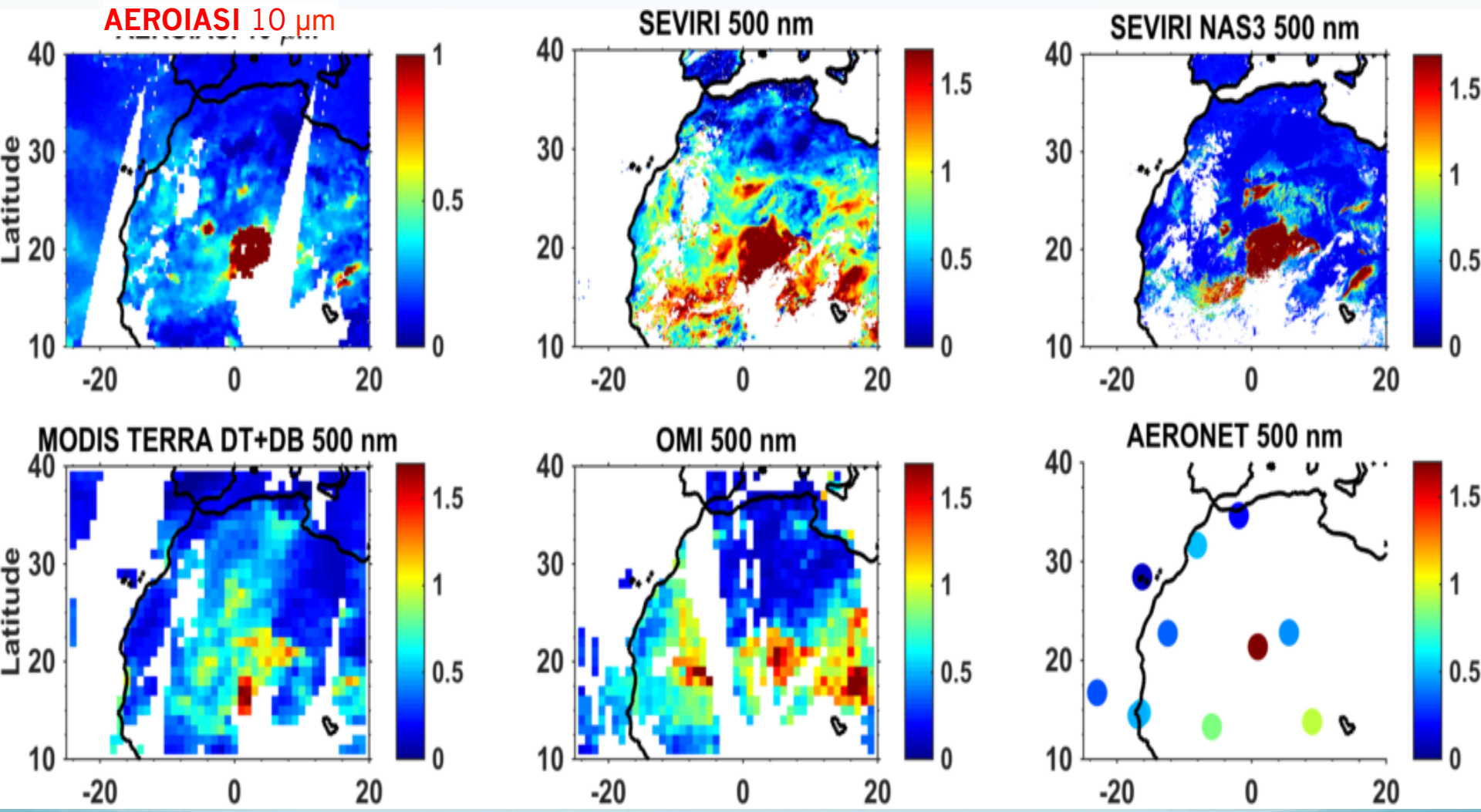
- ✓ Good detection & quantification of daily dust events



AOD: Aerosol Optical Depth

Dust horizontal distribution: AEROIASI vs other products

17 June 2011

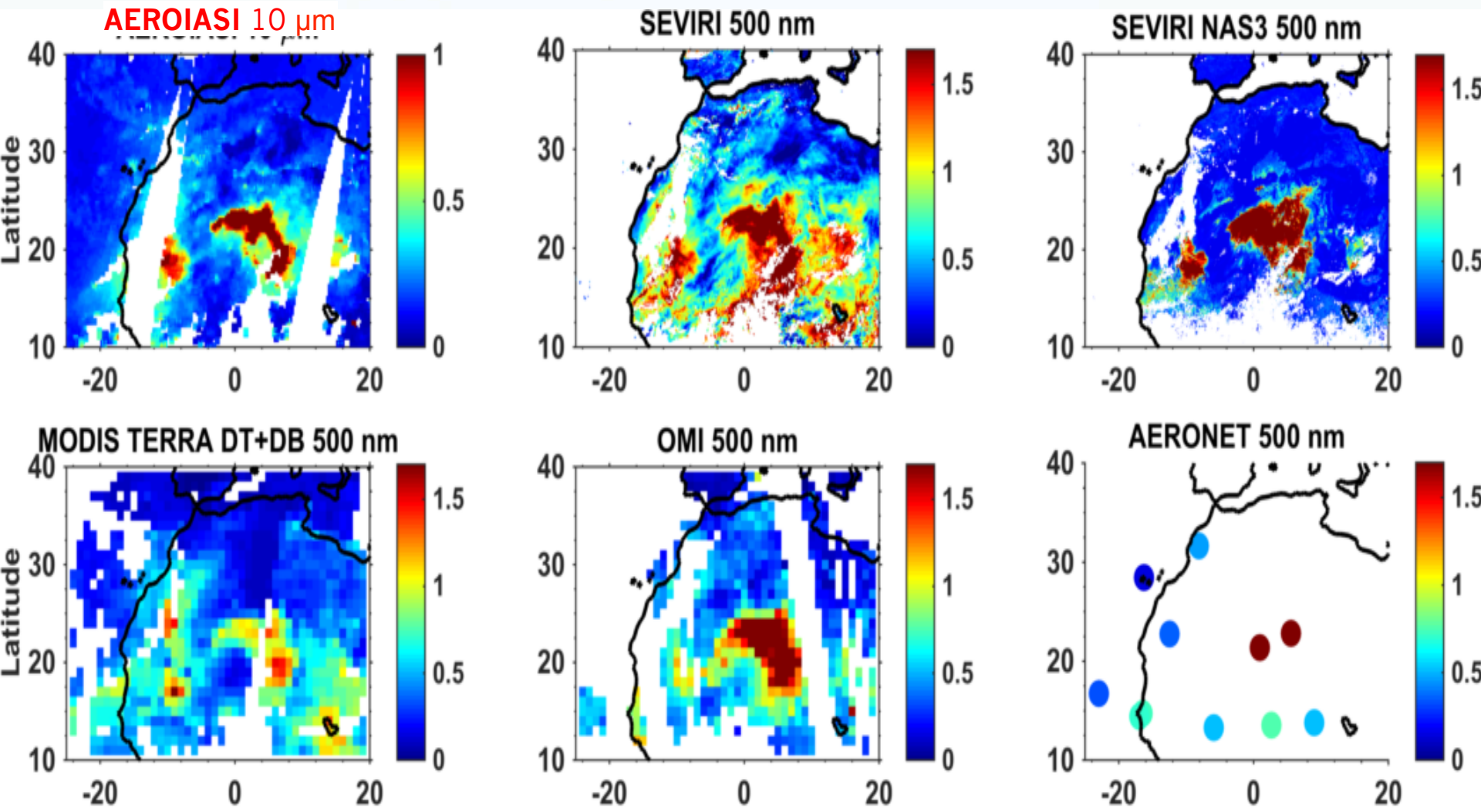


➔ *AEROIASI: dust structures in close agreement with SEVIRI and quantitative agreement with AERONET*

➔ *Underestimation for MODIS and OMI with respect to other products and AERONET*

Dust horizontal distribution: AEROIASI vs other products

18 June 2011



➔ *AEROIASI: dust structures in close agreement with SEVIRI and quantitative agreement with AERONET*

➔ *Underestimation for MODIS over the Sahara with respect to other products and AERONET*

➔ *Agreement of AEROIASI and MODIS over the Atlantic*

Saharan dust in 3D from AEROIASI