New inferences about Cloud Structures from POLDER/PARASOL measurements in the Oxygen A Band :

Altitudes and vertical extension of cloud layers ...

… from the analysis of three years of PARASOL measurements collocated with CloudSat and CALIPSO data

Nicolas Ferlay, Marine Desmons, Frédéric Parol

(+ other LOA members)

Laboratoire d'Optique Atmosphérique
Villeneuve d'Ascq, FRANCE

Motivation and interest

- Cloud (radiative) effects : cloud forcing and feedbacks

  Globally, cloud covers tend to :

  - cool the planet :
    - $\Delta_C TOA = -20\, W.m^{-2}$

      (low cloud effects >>)
  - heat the atmospheric column :
    - $+8\, W.m^{-2}$ *Trenberth at al (2009)*
    - partition between the atmosphere and the surface

  → Cloud feedbacks

- A correct characterization of cloud properties that act on cloud forcing and feedback, and their estimation

Cloud macrophysical properties : which are relevant to cloud forcing and feedback, and their estimation ?

(Cloud fraction, horizontal inhomogeneities, altitude,vertical extension, multilayered feature)

- Multiple and diverse RT effects :
  - SW and LW
  - Fluxes and radiances
  - Direct and inverse calculations
  - Scale dependence

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Remote sensing issue

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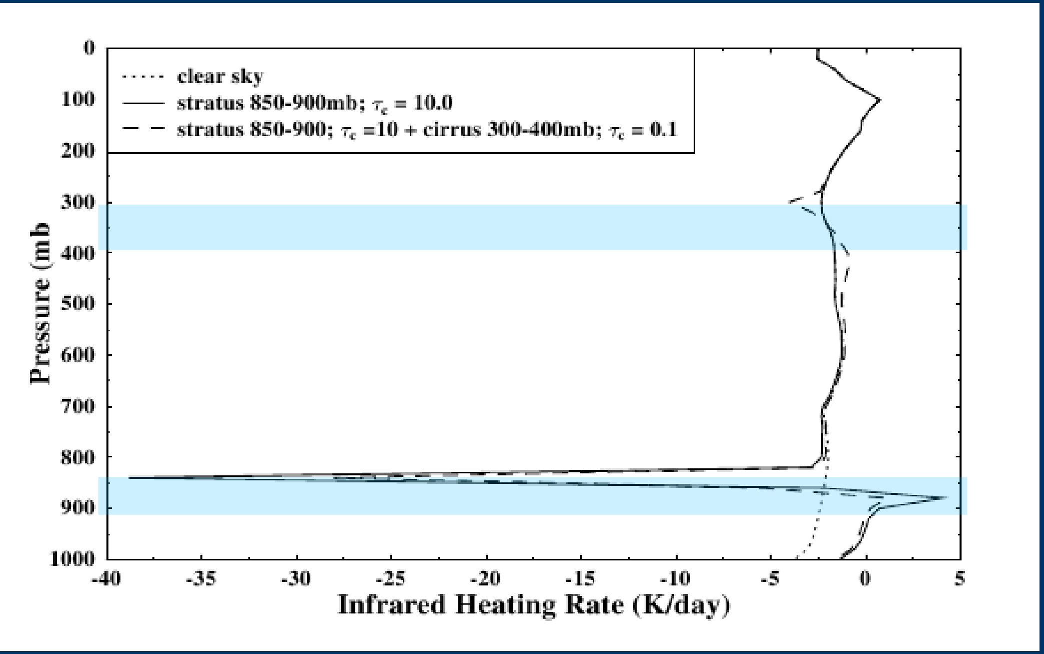
$\boxed{\text{Remote sensing issue}}$

- Linked with cloud processes (radiation/microphysics/dynamics)
  - Cooling at the top (z_{top}) of monolayer St/StCu

    → cloud maintenance
  - Rainfall = f (***H***) *Pawlowska (2003)*
  - Cancellation of aerosol indirect effect through cloud thinning is governed by z_{cb} *Wood (2007)*

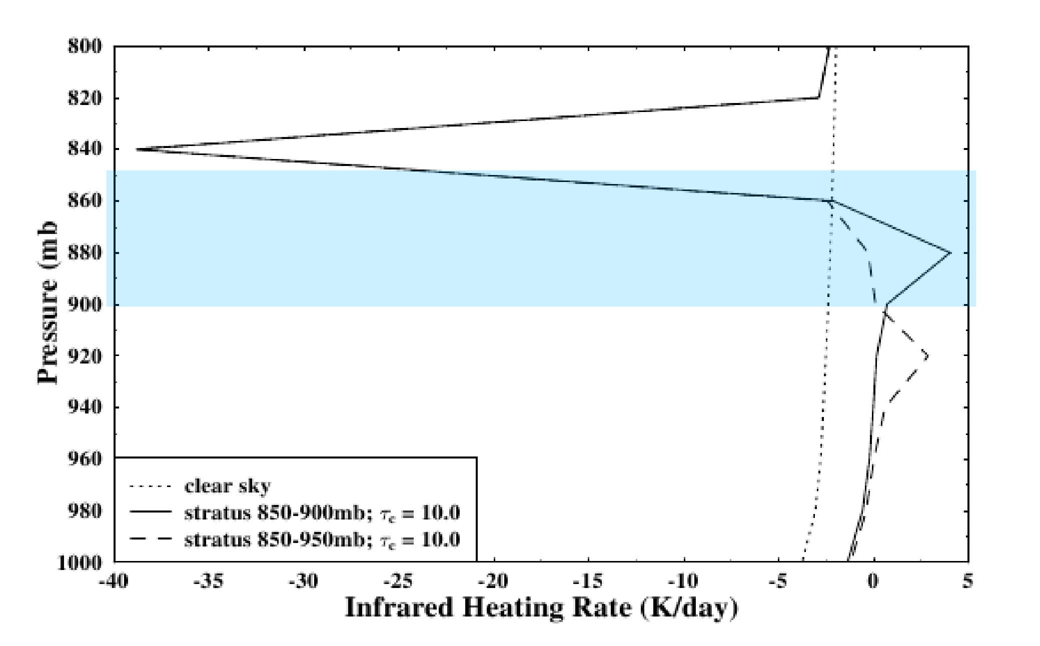
Ex. : Effects of vertical profile of cloudy atmosphere on IR quantities

- Multiple layers of clouds



From Heidinger (1998)

- Monolayer clouds :
  - same optical thickness
  - different geometrical thicknesses



Approach

Space-borned passive measurement in gas absorption bands,
here the oxygen A band

→ Information about the atmospheric scattering medium that affect photon pathlength *Van de Hulst (1980)*

Review

Yamamoto and Wark (1961)
Fisher at al (1991)
→ Cloud top pressure

Koelemeijer and Stammes (1999)

O'Brien et Mitchell (1992)
Heidinger et Stephens (2002)

high spectral resolution measurements in the A band
→ statistic of photon pathlength within cloud
→ **cloud pressure & more**

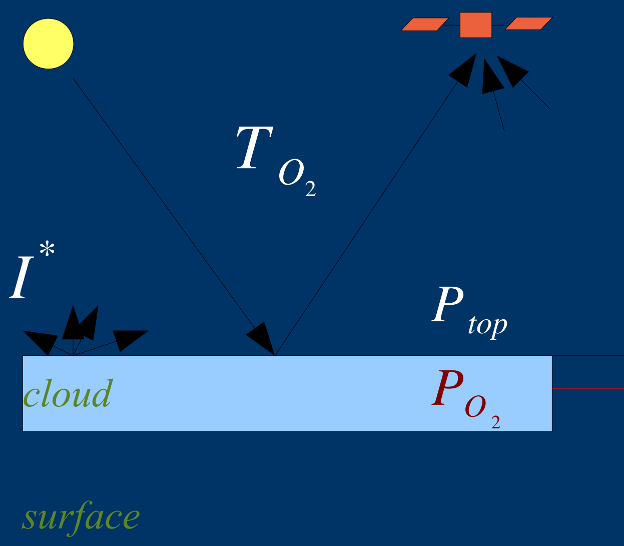
Operationally : GOME, POLDER, MERIS

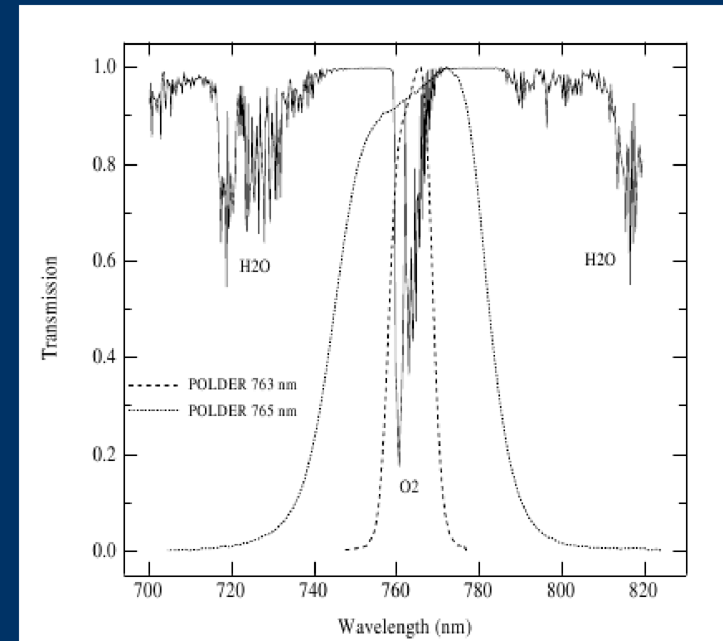
Ferlay et al (2010, JAMC) : information from POLDER about :
- Cloud geometrical thickness H,
- Middle-of-cloud pressure P_{middle}

Principle

$$r=\frac{I_{763}(\theta_v)}{I_{765}(\theta_v)}$$

$$\left(T_{O_2} \quad I^*\right)$$





P_{O_2} : angular averaging

$\sigma_{P_{O_2}}$: angular standard deviation

Vanbauce et al (2003)

- Ignores photon penetration $<Z>$ inside the cloud : $P_{O_2} \geq P_{top}$

But We analyzed theoretically that :

$$<Z> = f(\theta_v)$$

$$\overline{<Z>} \propto \frac{H}{2}, \cancel{\tau}$$

$$\Delta_\theta <Z> \propto H$$

$\propto$: depend on microphysics

hence

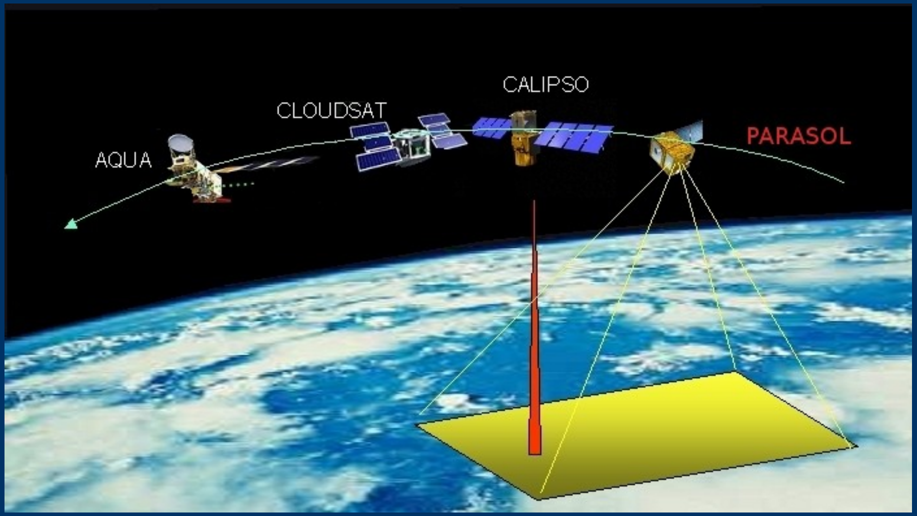
P_{O_2} close to P_{middle}

$\sigma_{P_{O_2}}$ correlated with H

To be confirmed under CALIPSO/CloudSat track ...

Data used

Sensor	Data
POLDER3	Under CALIPSO/CloudSat : P_{O_2} and $\sigma_{P_{O_2}}$ Cloud cover *cc* Surface index Cloud phase Solar zenithal angle
CALIOP/CLOUDSAT	2B GEOPROF LIDAR : Number of cloud layers *n* ALTOP, ALTBASE → H
MODIS	Cloud phase



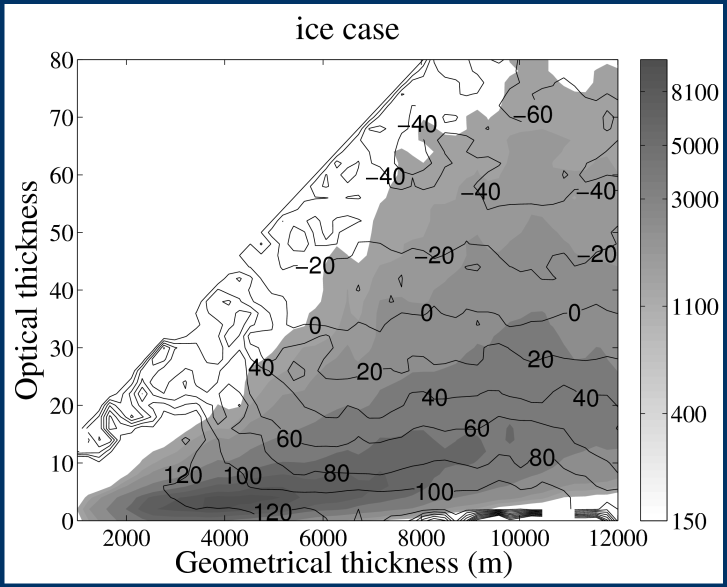
Cases

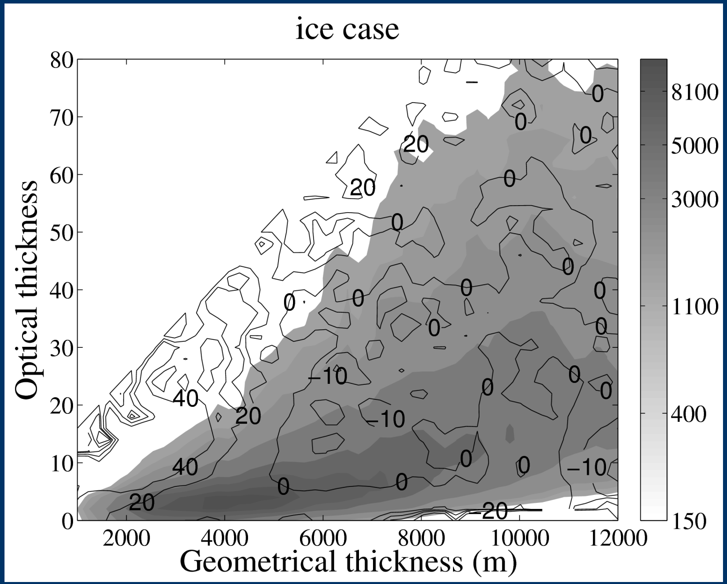
- Years : 2007, 2008, 2009
- Monolayer clouds ($n=1$)
- $cc \geq 0{,}95$
- Liquid and ice clouds
- $n_{\text{liquid}} = 1.263.026$, $n_{\text{ice}} = 737.220$ in 2008

POLDER oxygen pressure (1)

$P_{O_2} - P_{\text{middle}}$ (in hPa) for monolayer ice clouds, on average in 2008

Without any correction

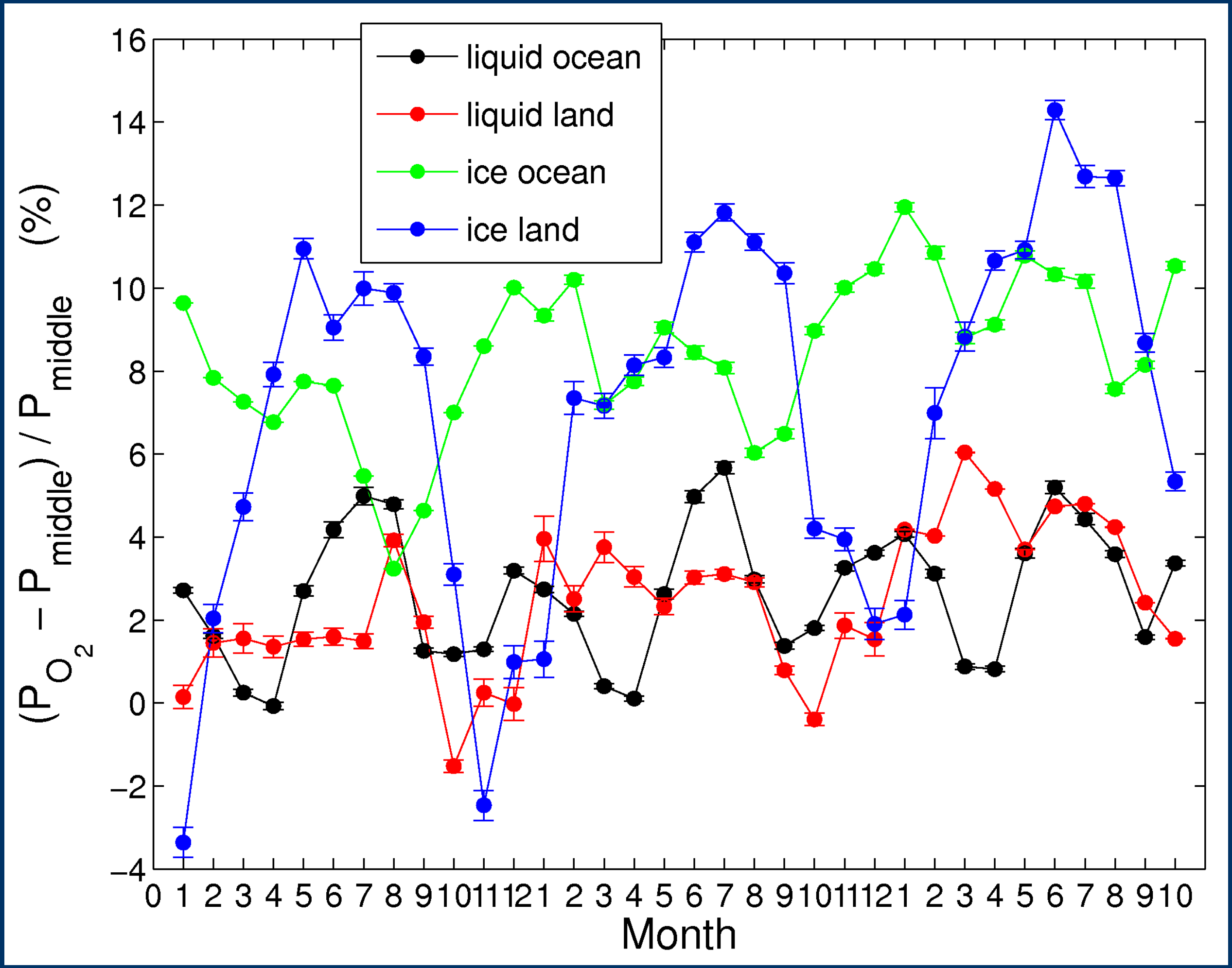




After a τ-based correction

POLDER oxygen pressure (2)

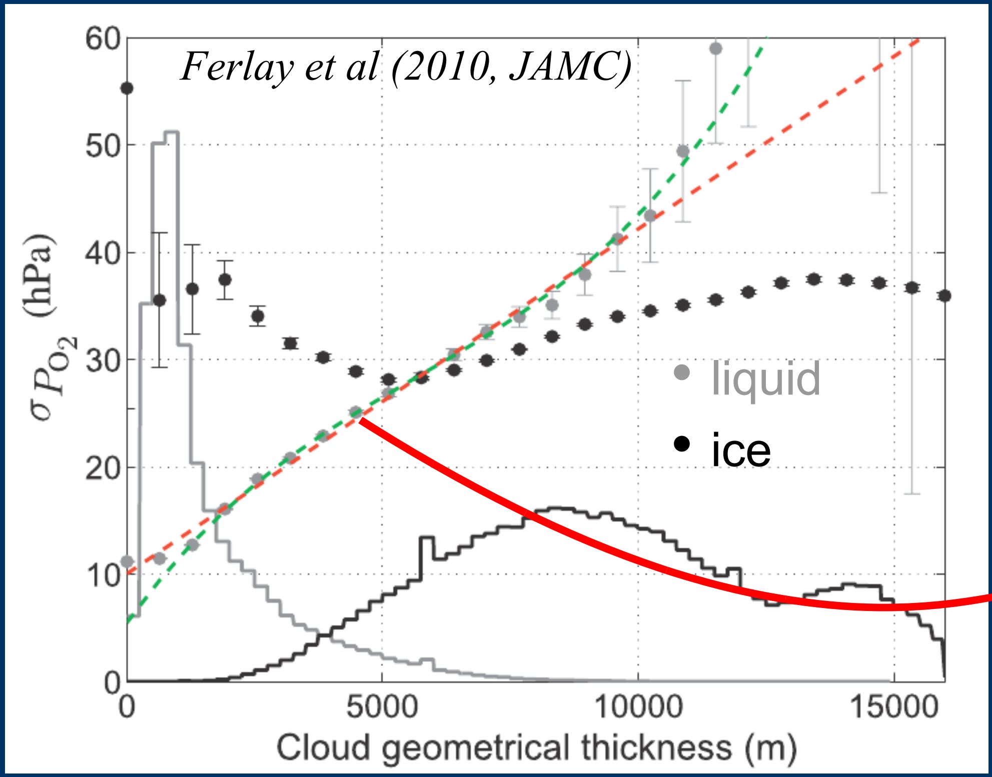
$$\frac{P_{O_2} - P_{\text{middle}}}{P_{\text{middle}}}$$ for monolayer clouds on monthly average over 2007-2009



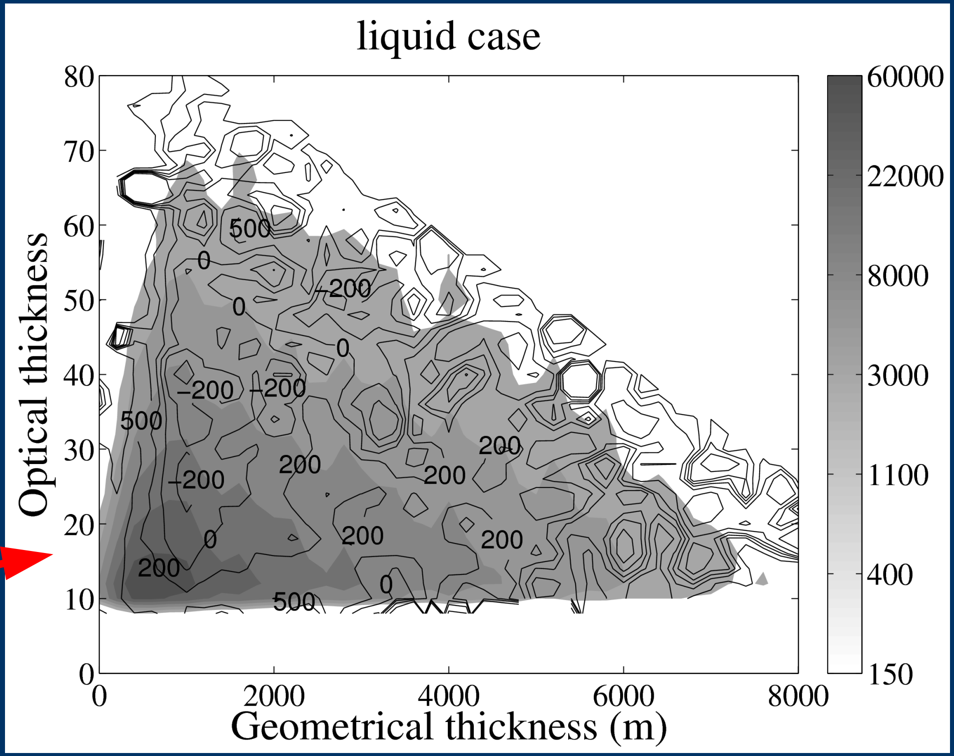
Climatology, drift ?

Correlation between $\sigma_{P_{O_2}}$ and cloud geometrical thickness H (1)

For monolayer clouds in 2008



$H_{inv} - H_{true}$ (m) on average



➡ One-to-one relation (close to linear) for liquid clouds

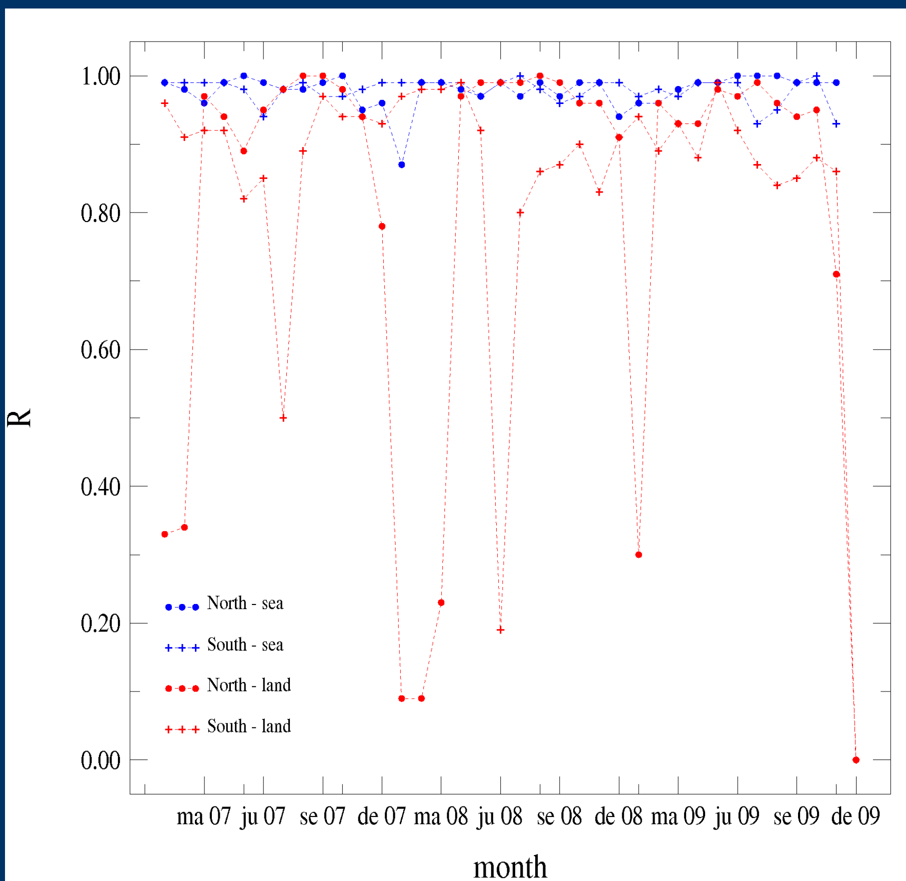
➡ Inversion of *H*

Correlation between $\sigma_{P_{O_2}}$ and cloud geometrical thickness H (2)

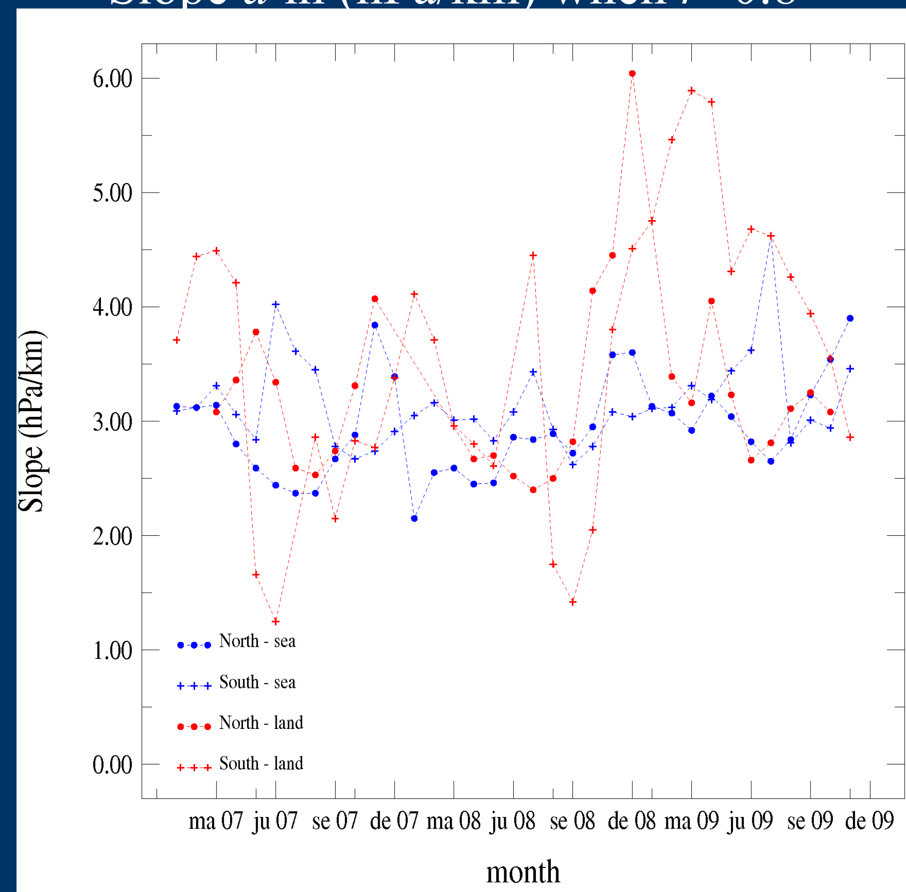
$$\sigma_{P_{O_2}} = aH + b$$

Correlation for liquid clouds over 2007-2009

Correlation factor *r*



Slope *a* in (hPa/km) when *r*>0.8



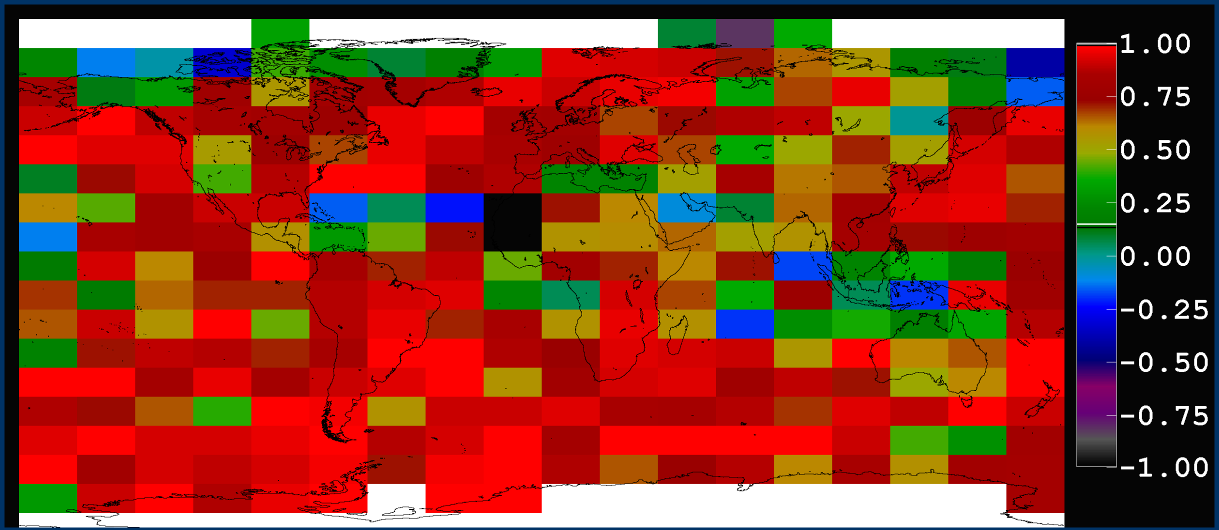
Solid correlation; weak variability over ocean

Correlation between $\sigma_{P_{O_2}}$ and cloud geometrical thickness H (3)

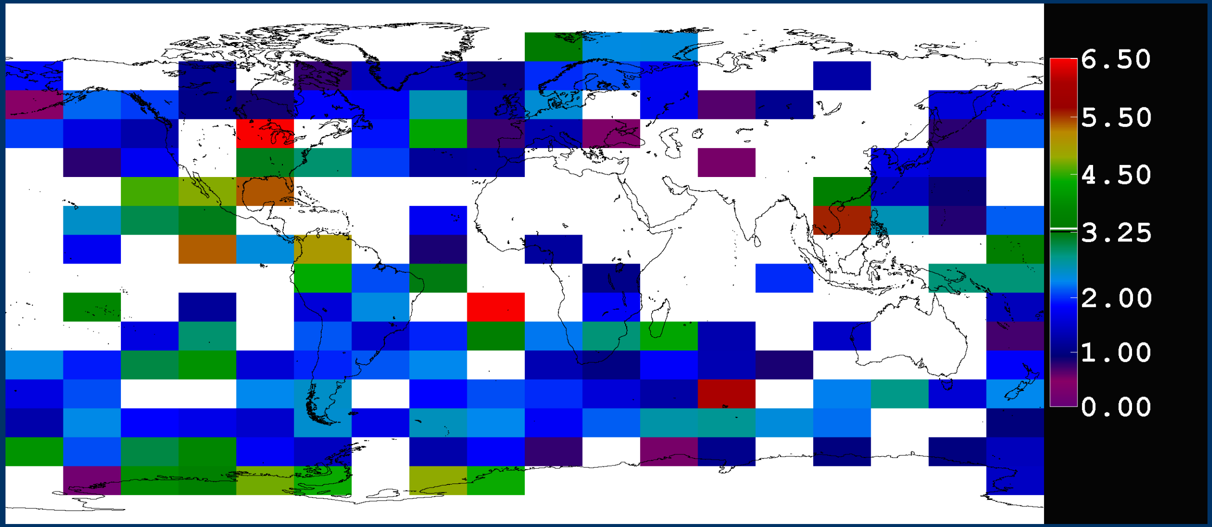
$$\sigma_{P_{O_2}} = aH + b$$

Correlation everywhere for liquid clouds in 2008 ?

Correlation factor r



Slope a in (hPa/km) when r>0.8



<u>Over ocean :</u>

- good correlation
- some variability

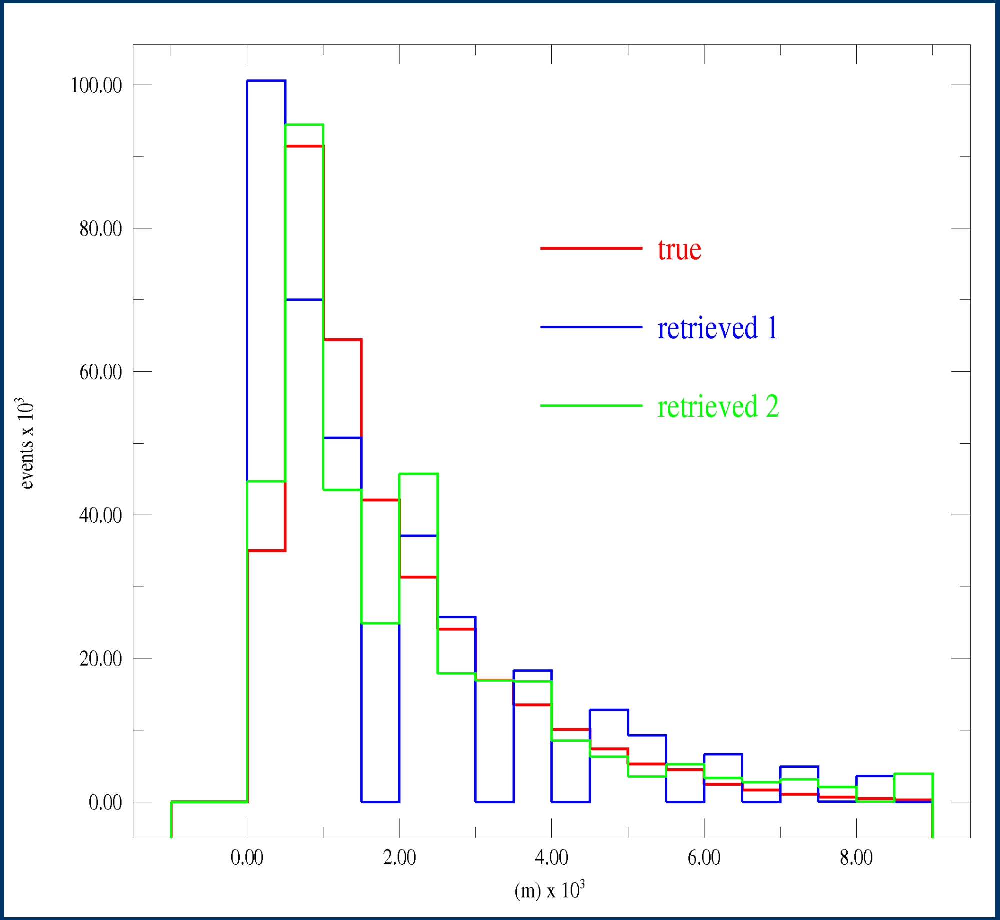
<u>Over land :</u>

weaker correlation

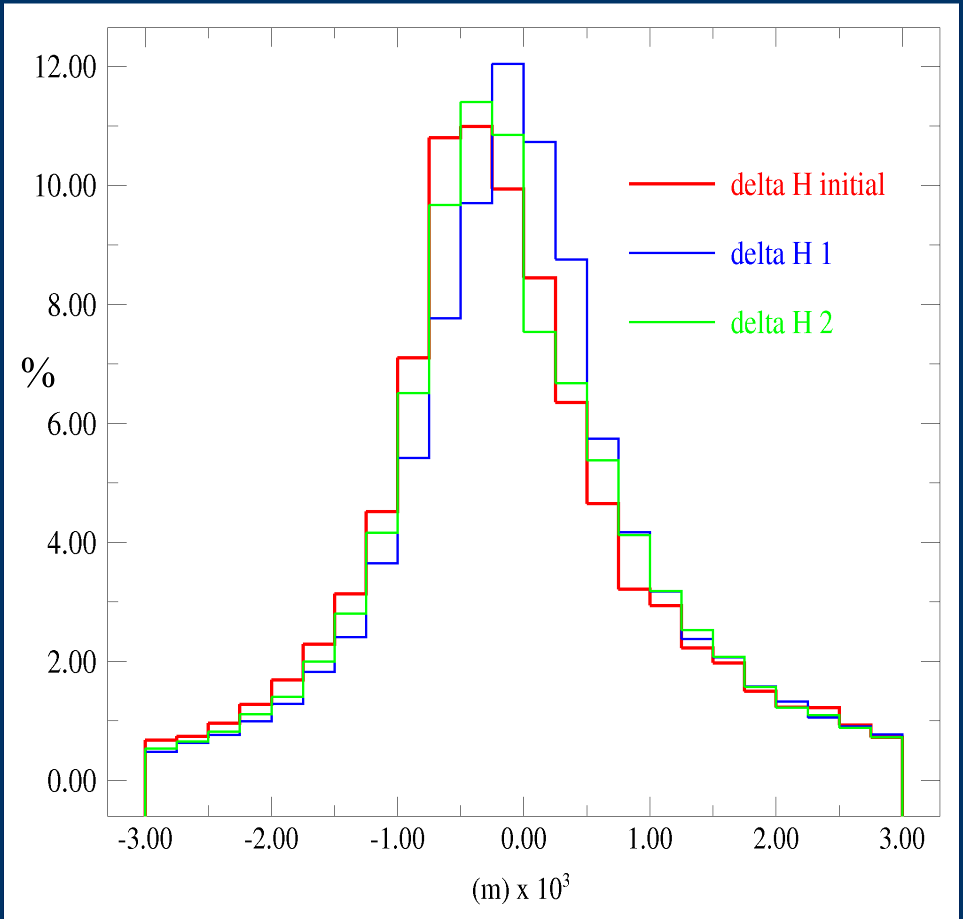
Correlation between $\sigma_{P_{O_2}}$ and cloud geometrical thickness H (4)

Improvement of the relation $H = f(\sigma_{P_{O_2}})$: account for θ_s, τ

Histogram of H



Histogram of ΔH



Conclusion :

- $P_{O_2} \simeq P_{\text{middle}}$
- Solid statistical correlation between $\sigma_{P_{O_2}}$ and H for liquid clouds
- Work in progress
- Potential for a climatology of cloud vertical occurrence from passive instruments

Important question :

- Necessity for active measurements to get $H = f(\sigma_{P_{O_2}})$?

  or can we parameterize it only from passive instruments ?

Perspectives :

- Ice cloud cases
- Multilayer cloud covers
- To obtain new POLDER products
- To find the adequate characteristics of future sensors

Thanks

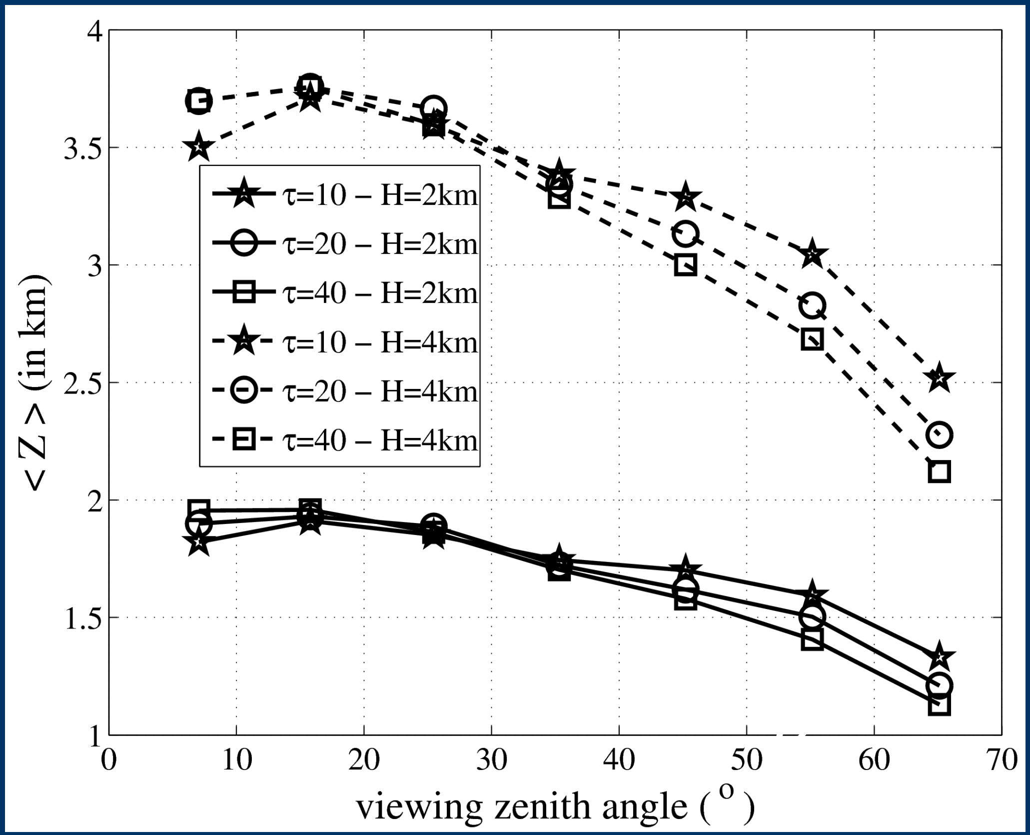
- For your attention
- To ICARE thematic center for providing the (MULTI_SENSOR) data
- To the CNRS PNTS financement program

Monte Carlo simulation of photon pathlength within cloud layer

↓

Equivalent vertical penetration of photons within cloud layer

Example of liquid clouds, C1 phase function, $\theta_{sun} = 0°$



$$\langle Z\rangle = \frac{\langle L\rangle}{\frac{1}{\mu_0} + \frac{1}{\mu}} \propto \mu_0\, \mu H$$

Van de Hulst (1980)

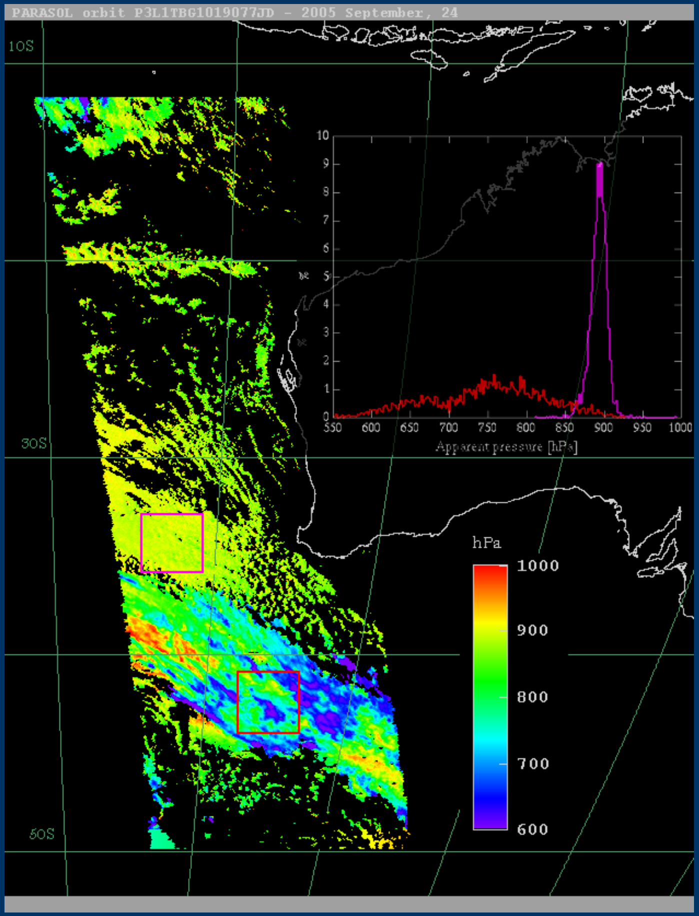
$$\langle Z\rangle \propto H, \cancel{\tau}\ ?$$

Davis et al (2007)

$$\Delta_\theta \langle Z\rangle \propto H$$

PARASOL data : September 24th, 2005

P_{O_2}



$\sigma_{P_{O_2}}$