Pointing parameters and CO_2 vertical profile retrieval

From ACE-FTS limb occultation measurements

Recent paper published on ACP about feasibility of retrieving CO_2 using N_2 continuum absorption (Foucher et al.)

ACE meeting, May 2009

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Introduction

Objectives

- Determination of ACE-FTS pointing parameters independent from CO_2 a priori data using **N_2 collision-induced absorption continuum at 4µm**
- Retrieving averaged CO2 vertical profiles with a **2ppm accuracy and a 2km vertical resolution**

Interests

- CO_2 is a very good atmospheric air tracer (inert in almost all atmosphere)
- Tropo/strato transport and interaction : Models improvement
- Carbon cycle fluxes
- Biomass fire and plume detection

Methodology

ACE v2.2 ***pTz*** ***CO_2 dependent***

1st step

N2 continuum :

Model + sensitivities

pTz new retrieval

Estimation of retrieval accuracy

pTz *free from CO_2 a priori*

2nd step

4A/OP (RTM)

CO_2 spectral mw selection

Regularization

CO_2 retrieval

Estimation of retrieval error and vertical resolution

CO2 profiles

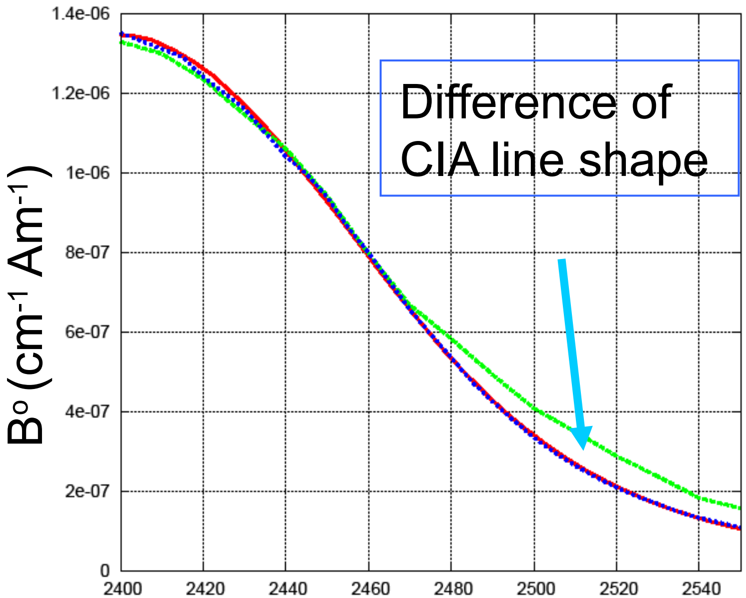
N2 continuum new model fit

Measurements : Lafferty (1996) 297K>T>228K accuracy ~ 2%

Menoux (1993) 297K>T>193K accuracy ~ 10%

Model CIA (J.M.Hartman) : $B_{N2-N2}(\sigma,T) = B^0(\sigma)\exp[\beta(\sigma).(\frac{1}{T_0}-\frac{1}{T})]$

Fit of B°



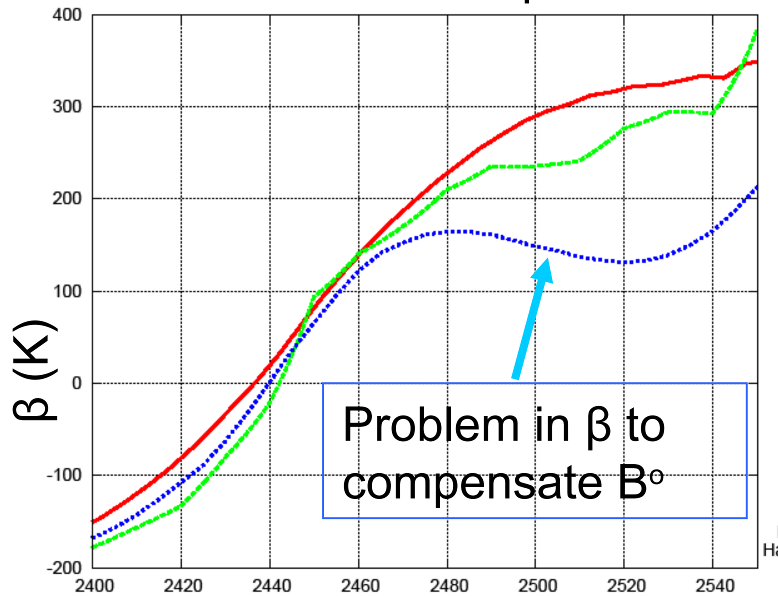
Fit using:

Lafferty Measurements

Menoux Measurements

Old parameters from Hartman

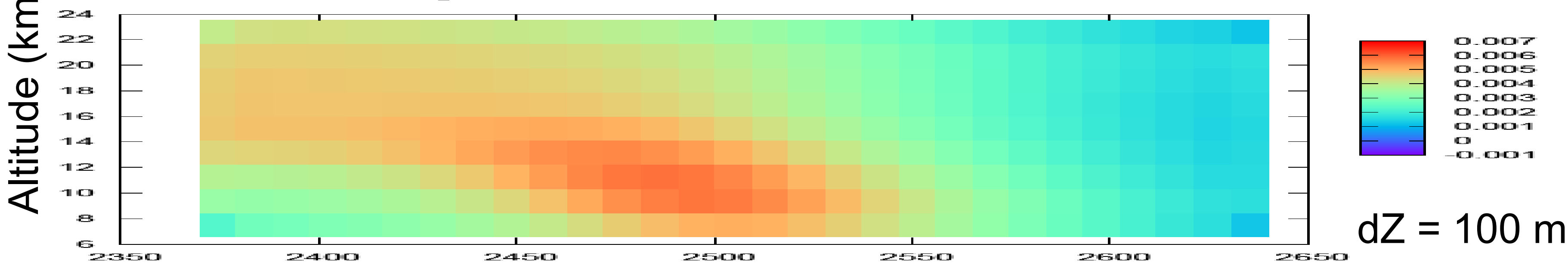
Fit of β



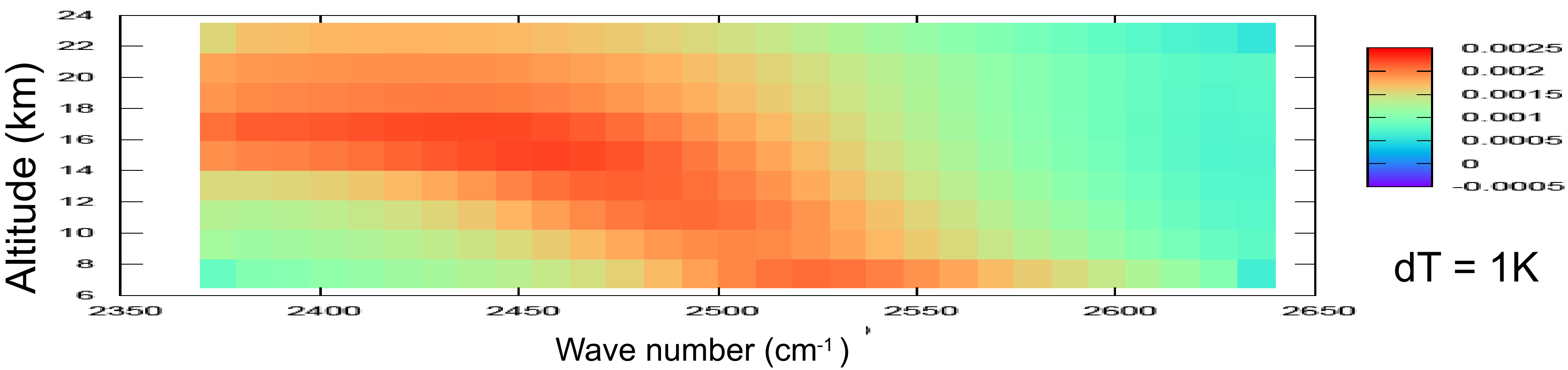
Recent discussion with Lafferty : agreement on this conclusion

N_2 continuum transmittance sensitivities

N_2 transmittance altitude sensitivity



N_2 transmittance temperature sensitivity

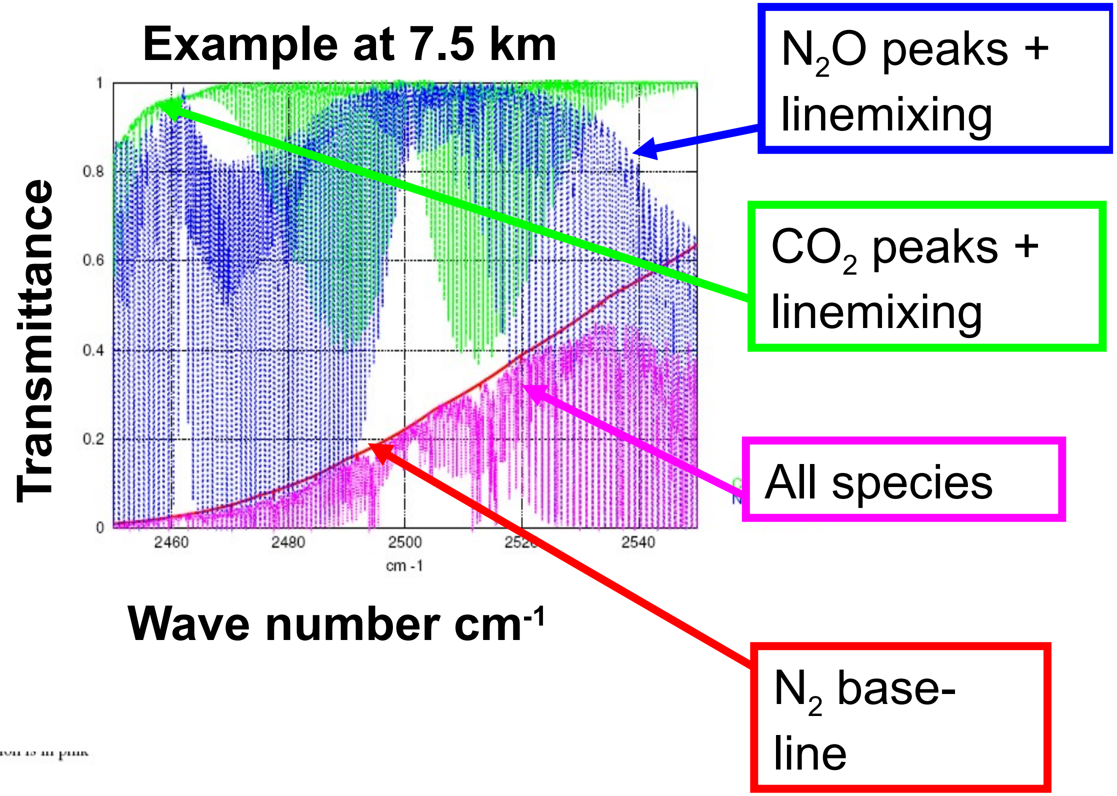


The sensitivity to 100m can be 3 times more important than sensitivity to 1K

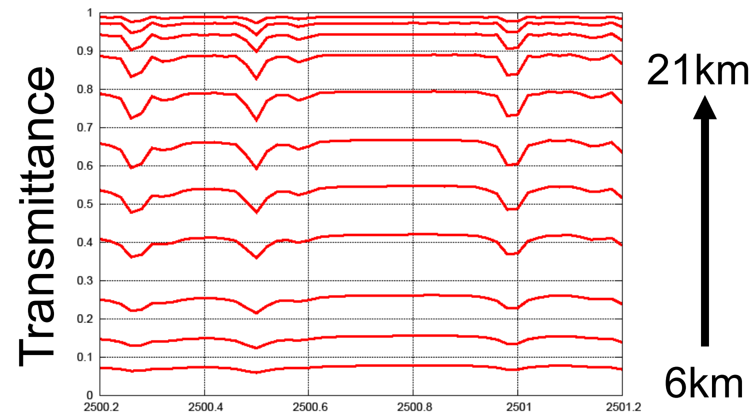
N_2 spectral micro-windows selection

Avoid CO_2 line-mixing impact

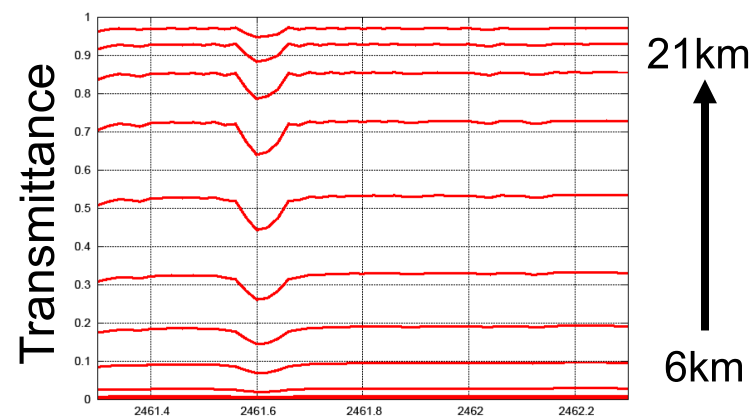
Avoid Species absorption peaks interferences



Mw center 2500.7 cm-1 : 6-12km



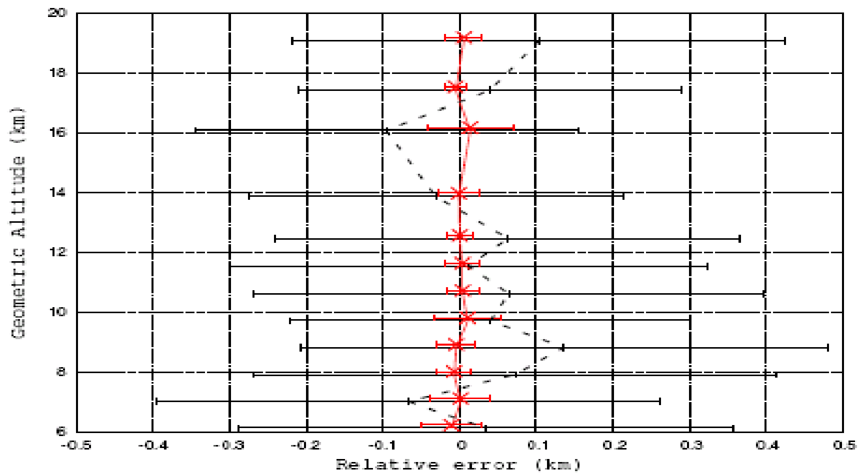
Mw center 2461.8 cm-1 : 12-20km



Pointing retrieval method

- ACE v2.2 first guess (P, T, z)
- Re-calculation of the altitudes levels of the “1km” grid to ensure continuity of the LTE with CMC values : During the retrieval the pressure levels of the “1km” grid are fixed but not T and z.
- Optimal iterative estimation using N_2 spectral windows
- For each iteration : P,T modifications on the tangent grid according to the Local Thermodynamic Equilibrium, density and the new tangent altitudes. Interpolation on a new real “1km” grid
- Rejection of occultation if any problem

Synthetic Z retrieval



Initial tangent height error : dispersion ~ 200m

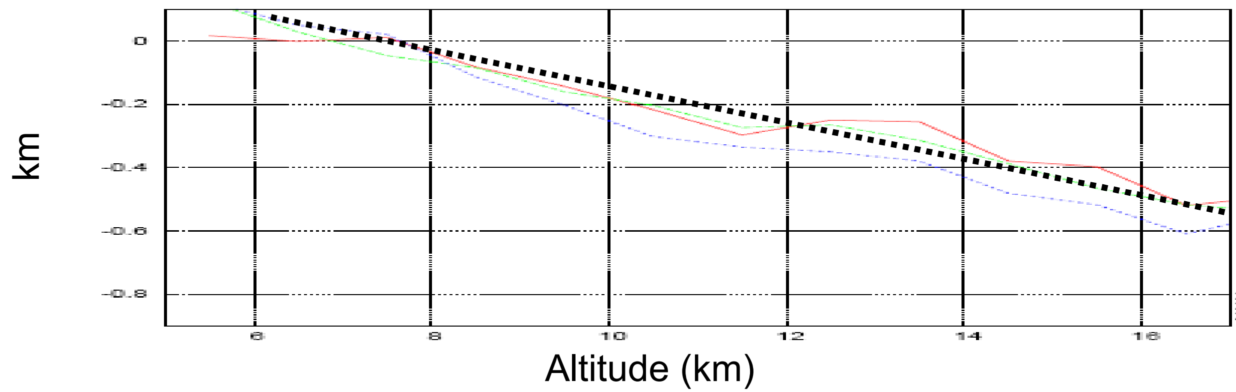
Retrieved tangent height error

Random noise

Error < 30m

N_2 retrieved altitude bias is altitude and latitude dependent

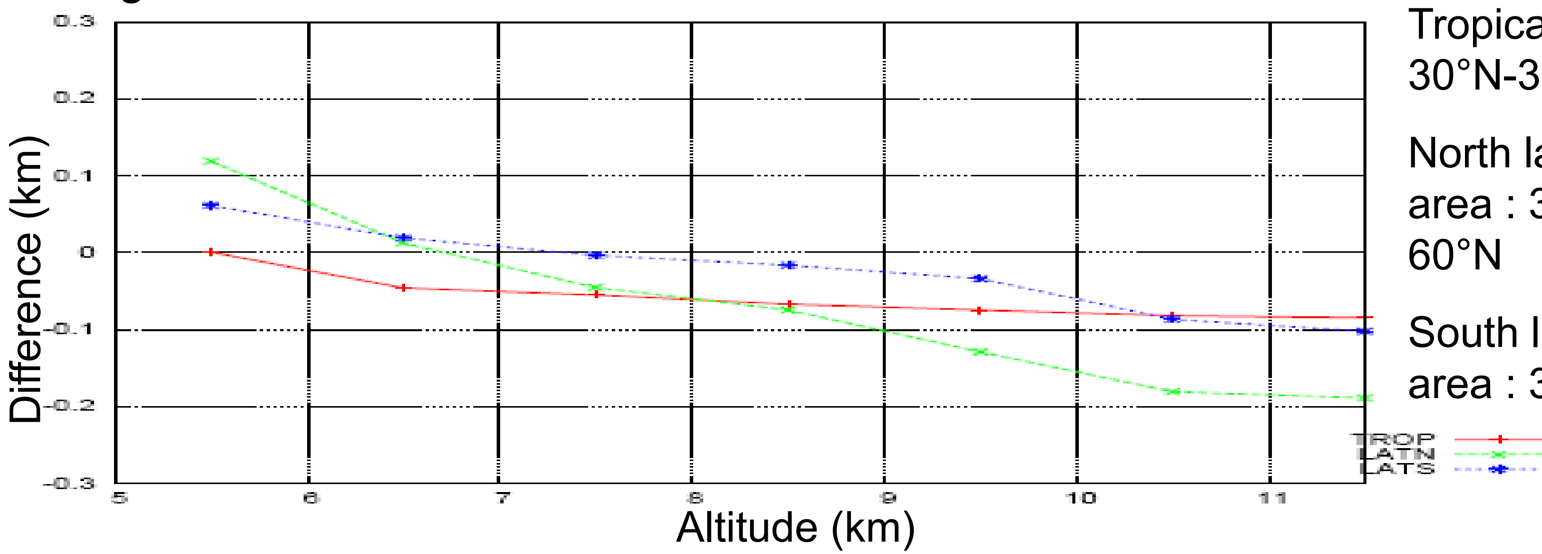
Difference between N_2 retrieved tangent height and ACE v2.2 products :



North hemisphere latitude band 50°

2005-2007

Averaged difference from 2004 to 2008 between 5 and 12 km:



Tropical area : 30°N-30°S

North latitude area : 30°N-60°N

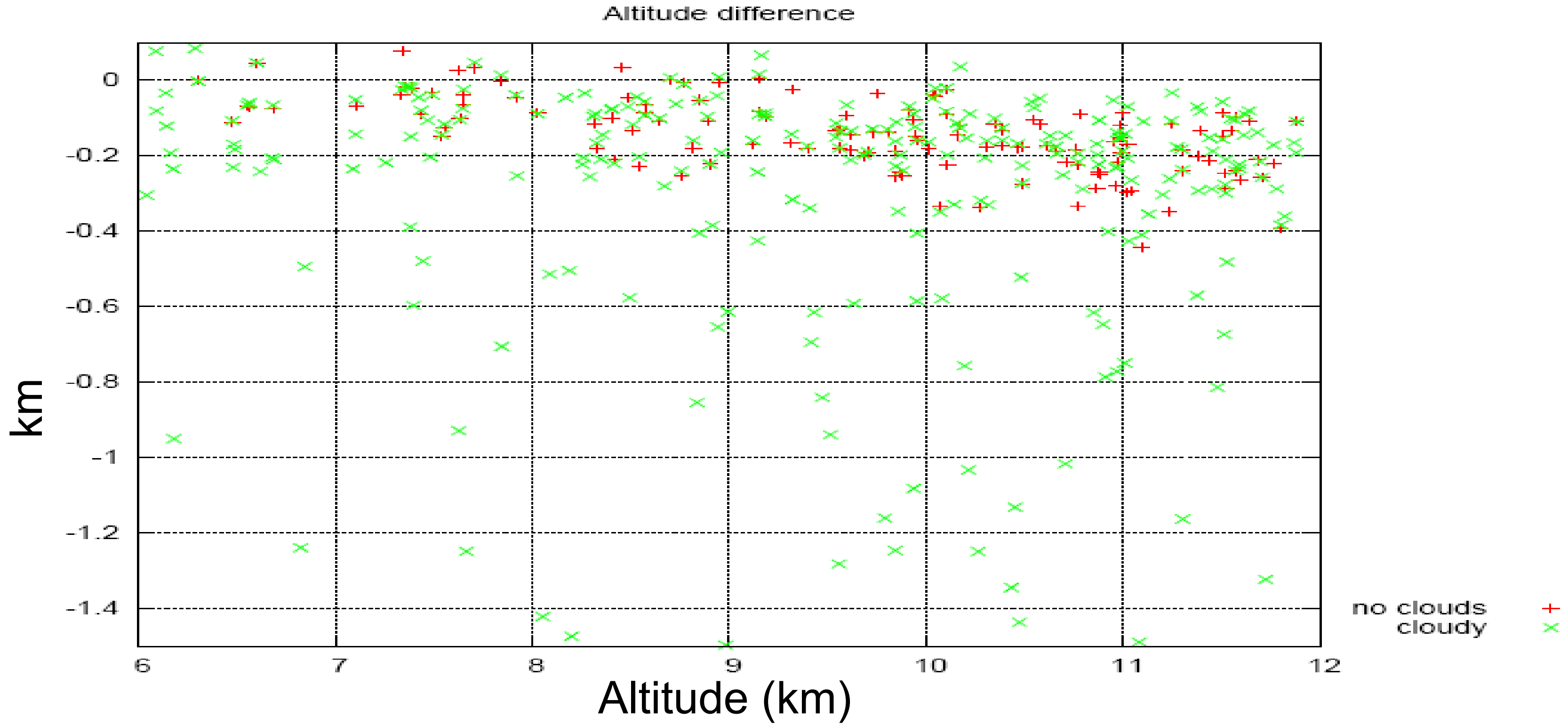
South latitude area : 30°S-60°S

Cloud effect ?

Example of cloud effect on altitude differences for the North latitude band at 40°N :

Green points : tangent height differences with no cloud rejection

Red points : tangent height differences with cloud rejection



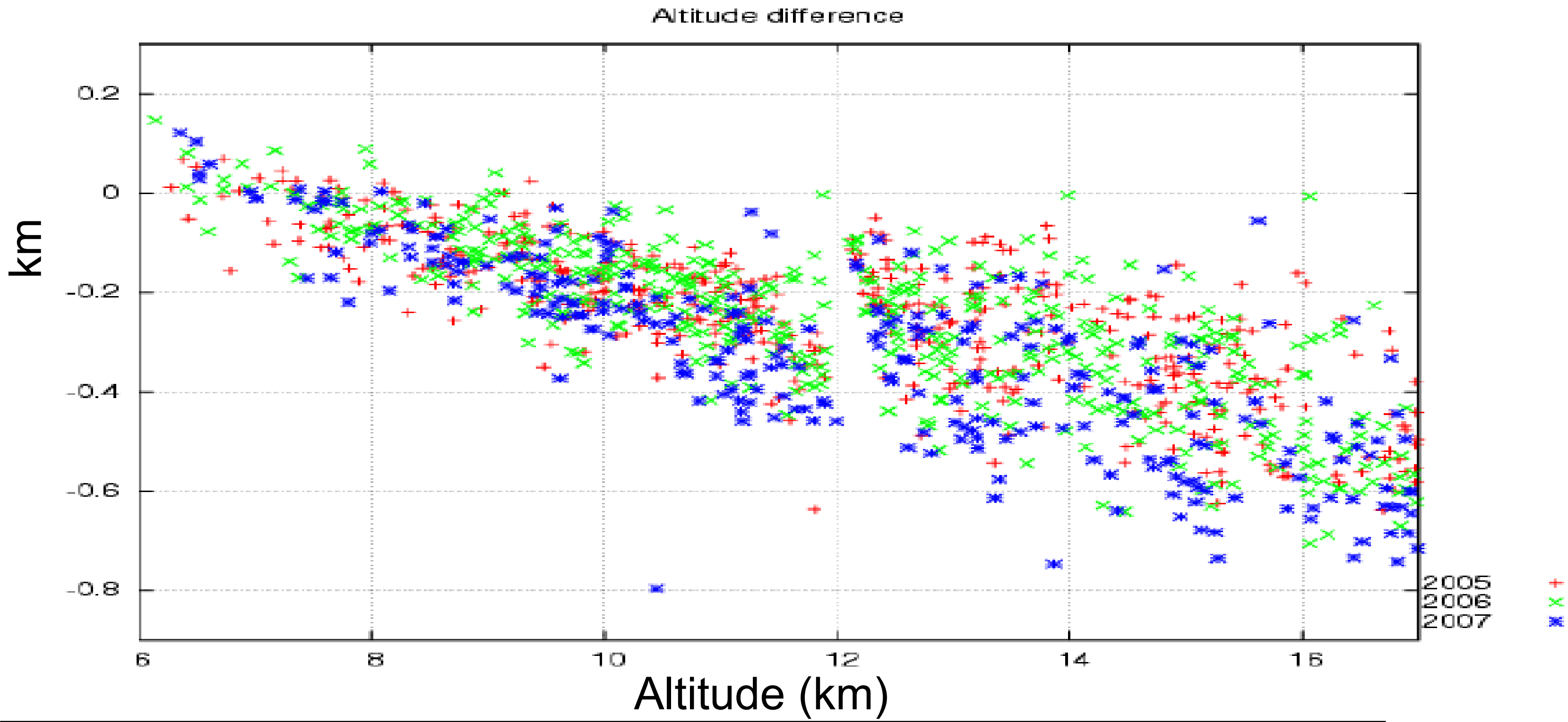
Dispersion of the tangent heights differences

North latitude band 50° from 2005 to 2007

Dispersion of difference with ACE v2.2 tangent heights:

6-12 km ~ 200m / 12-18 km ~ 300m

Expected dispersion due to CO2 ~ 150m



Conclusion on pointing retrieval

- New absorption temperature dependence model
- Good sensitivity to altitude
- Need to reject cloudy occultations
- N_2 bias solution :
  - Estimation of each latitude band mean difference dependence with altitude
  - Shift of ACE v2.2 altitudes with the mean latitudinal difference
  - Apply N_2 retrieval method : “Differential retrieval”
  - Shift again the results with the mean latitudinal difference

CO2 retrieval : method and characteristics

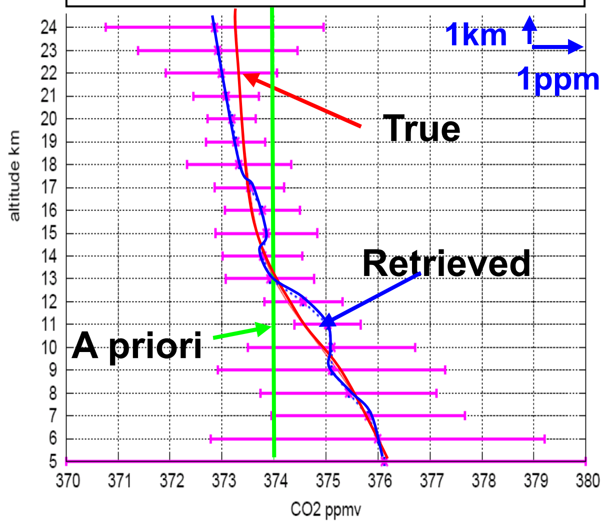
•Selection of spectral windows with low T sensitivity (E”) and few interferences.

•Transmittance and Jacobian calculation on 1km grid level with 4A/OP RTM.

•Optimal estimation using a regularization Matrix (R) from MOZART v2 air-transport and chemistry model CO_2 covariance matrix (S_a) and first order derivative Tikhonov regularisation matrix : $\mathbf{L}^T \mathbf{L}$

$$R = \alpha \cdot diag(S_a) \cdot L^T L$$

Synthetic retrieval (25 tests)



10 microwindows (iso 3) 5-13km

15 microwindows (iso 1) 10-25km

Noise : Instrument + model + Temperature

Mean dispersion ~ 2.5 ppm

Retrieved CO_2 error < 1 ppm

Vertical resolution ~ 2km

Problem : CO2 microwindows from isotopologue 1 and isotopologue 3

Separation of CO_2 isotopologues

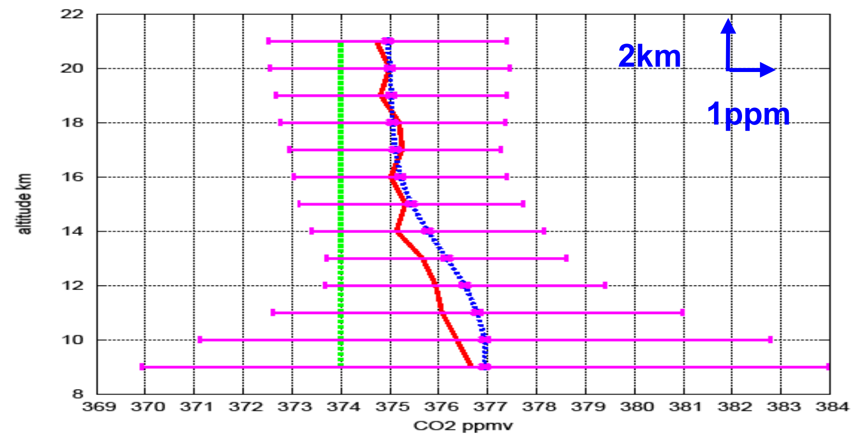
Noise : Model + T (1.5K)
instrument + CO_2

Isotopologue 1: 10-20km

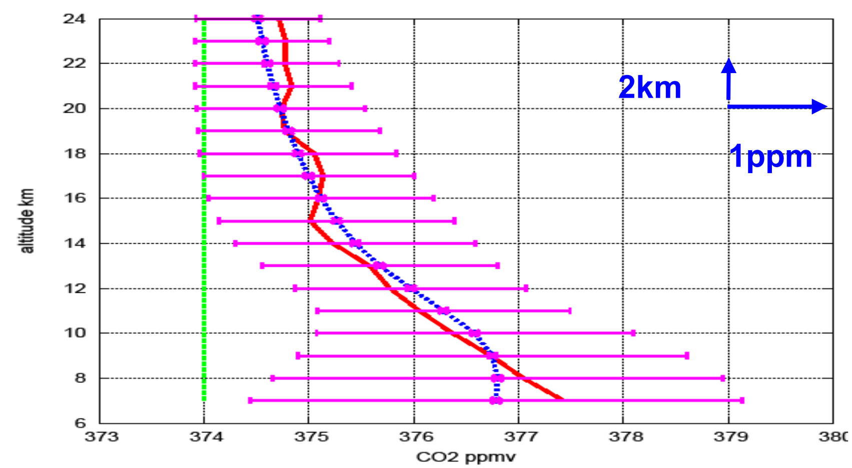
Mean error < 1ppm

Mean dispersion ~ 3 ppm

Synthetic retrieval (20 occ)



Synthetic retrieval (20 occ)



A priori

True profile

Retrieved

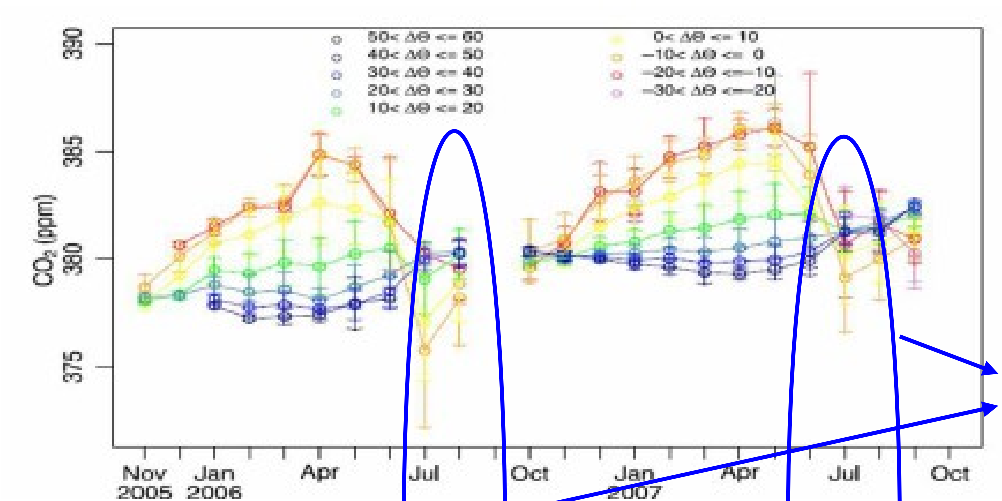
Dispersion

Isotopologue 3 : 6-12km

Mean error < 1ppm

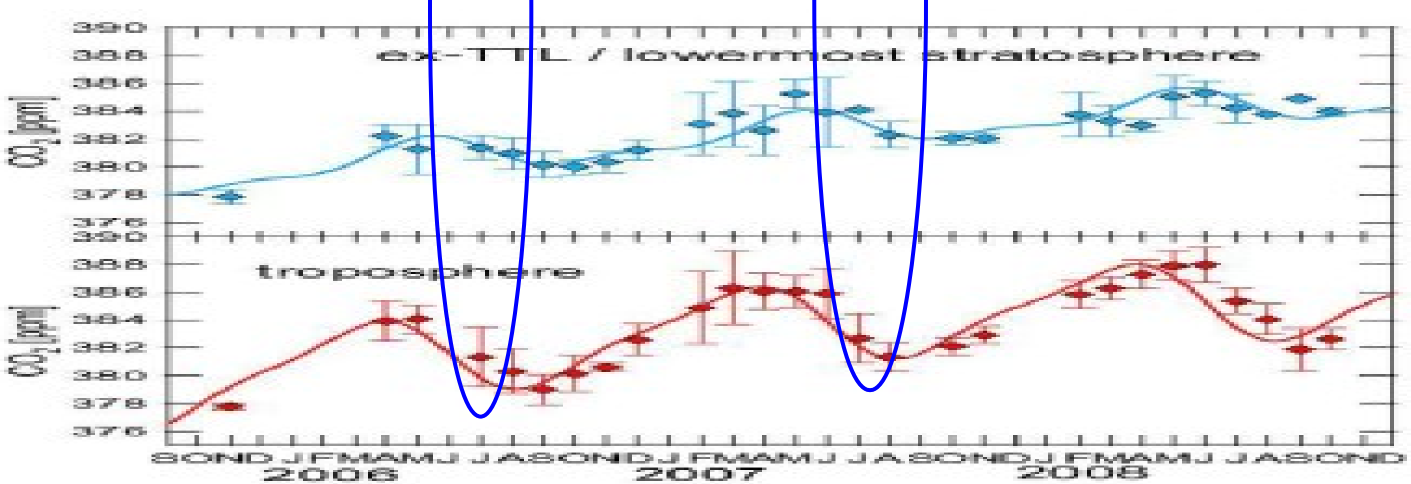
Mean dispersion ~ 2 ppm

Long Period aircrafts CO_2 observations



CONTRAIL measurements (*Matsueda et al., 2002, Sawa et al., 2008*).

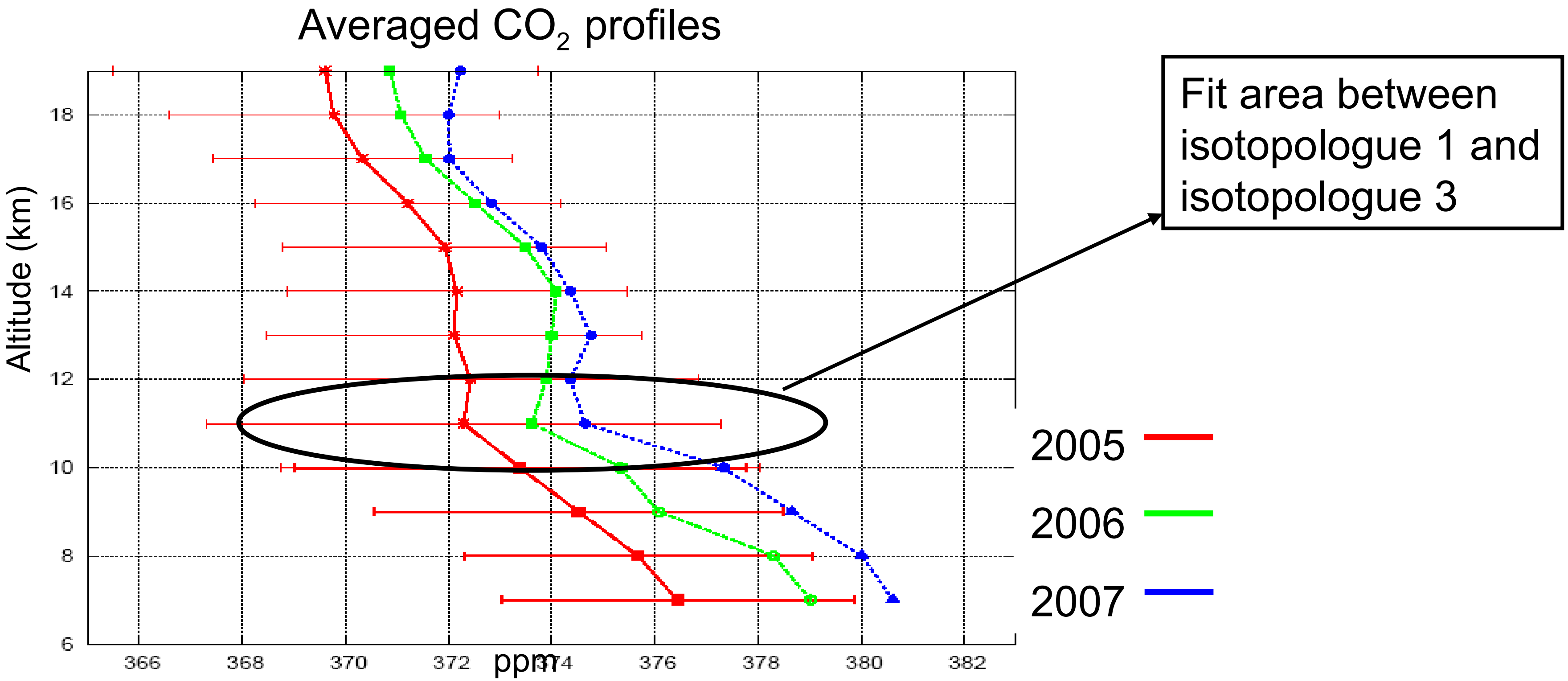
Troposphere CO_2 value is greater than Lower Most stratosphere value in summer



CARIBIC measurements

Brenninkmeijer et al., 1999, Schuck et al., 2009)

Mean averaged profiles 2005-2007 for 50°N latitude band



Mean Trend ~ 2ppm/year ; Negative 7-15 km mean gradient ~ 4.5ppm

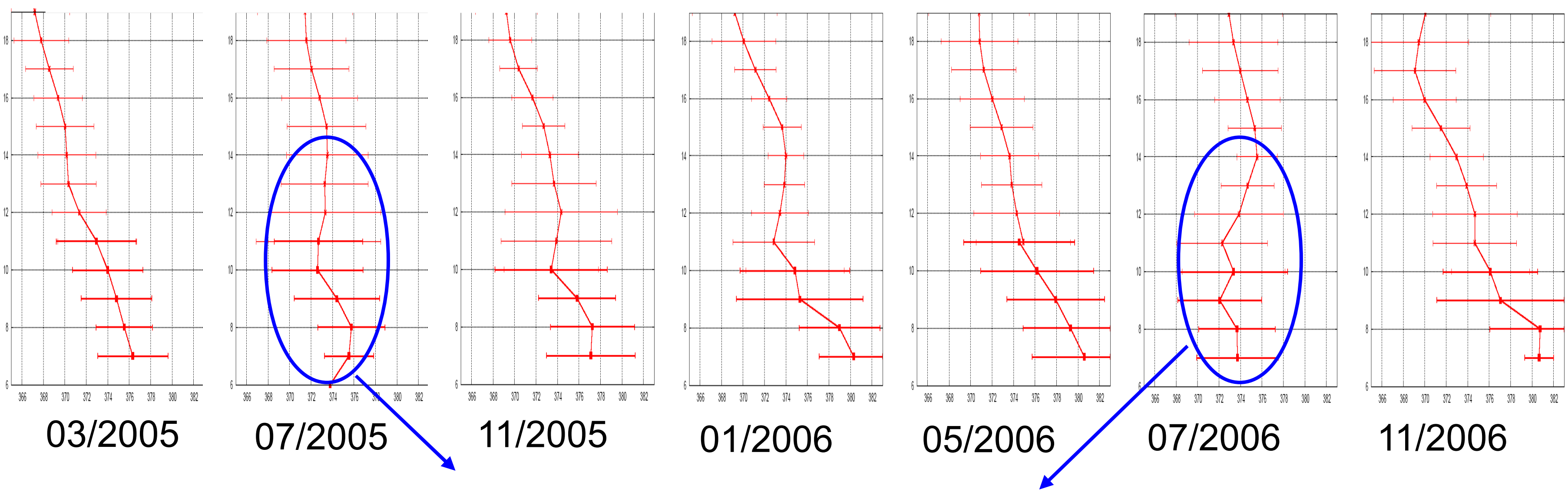
Standard deviation ~ 4-5 ppm

Problem : 2007 for altitudes > 12km

Monthly CO2 profile time-serie 2005-2006

Monthly averaged profiles from March 2005 to November 2006 for 50°N latitude band.

CO_2 range: 366-382 ppm / Altitude range: 6-18km



03/2005 07/2005 11/2005 01/2006 05/2006 07/2006 11/2006

Change of the 6-14 km vertical gradient shape in Summer

Decrease of the seasonal variations amplitude

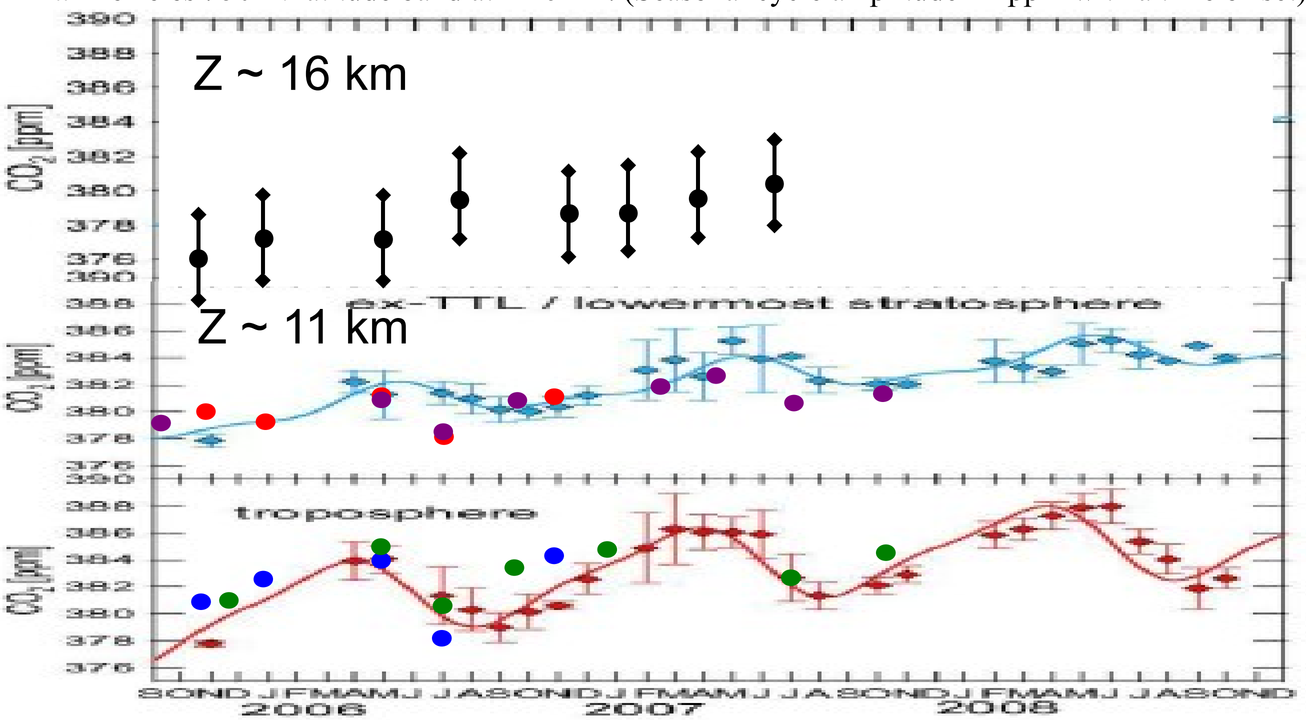
Blue circles : Mean monthly values (shifted to the mean annual CARIBIC value) from ACE retrieval at 7 km for the 50°N latitude band. Seasonal cycle amplitude : 5 ppm

Red circles : Mean monthly values from ACE retrieval at 11 km for the 50°N latitude band. Seasonal cycle amplitude : 3 ppm

Green circles : 40°N latitude band at 7 km

Purple circles : 40°N latitude band at 11 km

Dark circles : 50°N latitude band at ~ 16 km. (Seasonal cycle amplitude ~ 2ppm with a time offset)



Lines and diamonds: CARIBIC measurements for 40°N

Brenninkmeijer et al., 1999, Schuck et al., 2009)

Conclusion and future work

- Encouraging first results on CO_2 profiles time-series :
  - Trend and profiles vertical gradient coherent with aircraft measurements
  - Problems above 12 km due to altitude shift and N_2 bias
  - Not enough retrievals for a complete validation

- Pointing parameter retrieval is not really solved :
  - Bias not really understood
  - Refinement in P,T changes above 12 km
  - Validation of the method with increasing CO_2 profiles retrieval …

- Increase the number of coherent area for CO_2 retrieval validation