Optimizing observation geometry using the agile GOSAT pointing mechanism for more precise and accurate X_{CO2} retrieval

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Presentation flow

Extraction of potential parameter sensitive to standard deviation of CO_2 column amount $\sigma(X_{CO2})$ as Level-2 product of GOSAT/TANSO.

← Statistical Analysis of Big data by using Quality Control Engine (QCE)

Result

CT angle is extracted. **Geometry among GOSAT, Sun and observation point** is very important.

Verification by analysis of Level-1 and Level-2 product.
-Global mapping of $\sigma(X_{CO2})$ for back-side , nadir and lateral scattering geometry.
-Pointing angle dependency of pressure height and SNR
-Polarization characteristics of O_2-A band region for 2 pointing angles.

← Conventional Analysis by using manual tool.

Result

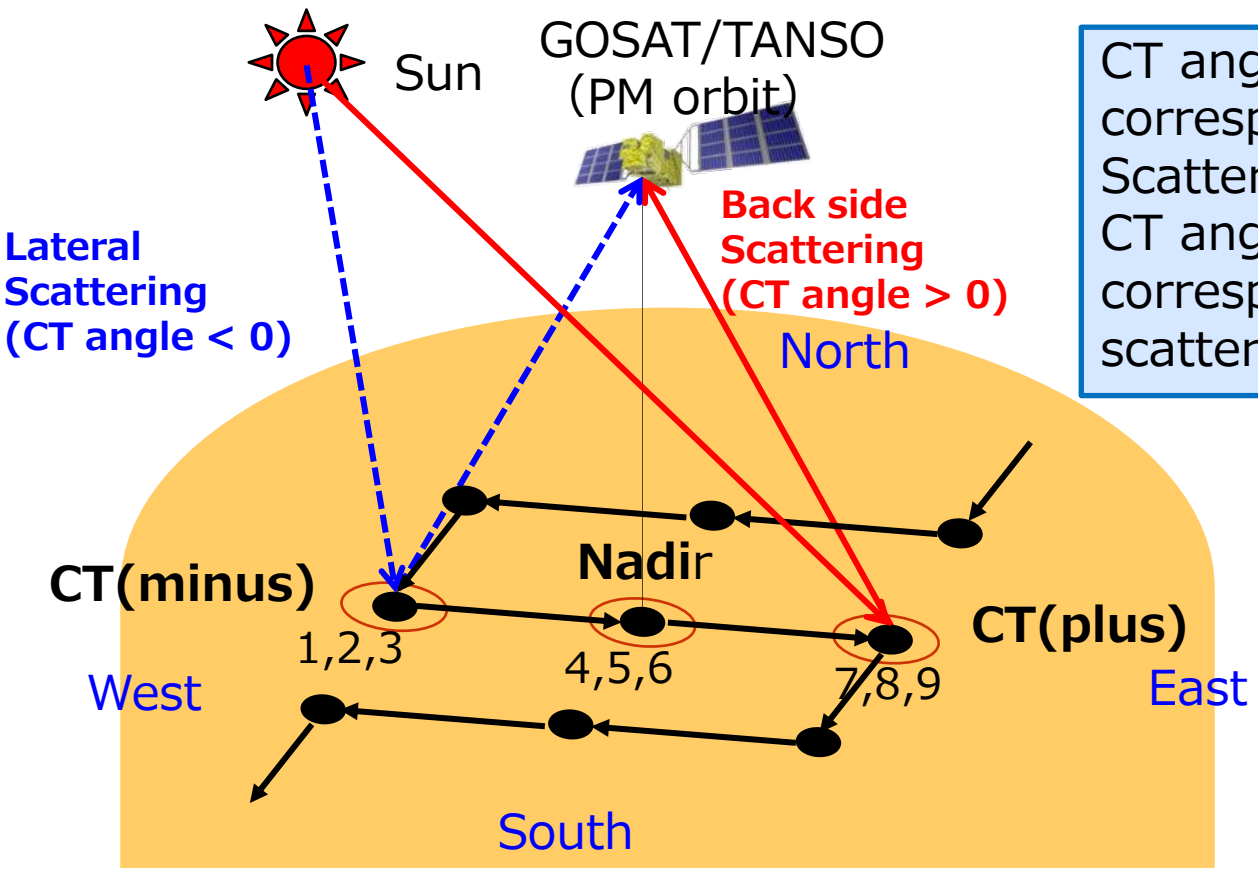
Small $\sigma(X_{CO2})$ (High accurate) for **laterals scattering** geometry because **aerosol affect is low**.

← Interpretation based on physics.

Future scope

On TANSO mission planning, **different optimal pointing angle** will be selected according to observation points (e.g. CT angle <0 (lateral scatter) for Sahara desert where atmosphere contain much aerosol).

Observation geometry for 3-points mode



CT angle <0 geometry case corresponds to lateral Scattering
CT angle >0 geometry case corresponds to back side scattering

Standard deviation of X_{CO2} (σX_{CO2}) or Psurf (σPsurf) defined among successive 3 observations at the same observation points. (e.g. No. 1,2 and 3)

Statistical Analysis with Big data analysis approach

Purpose

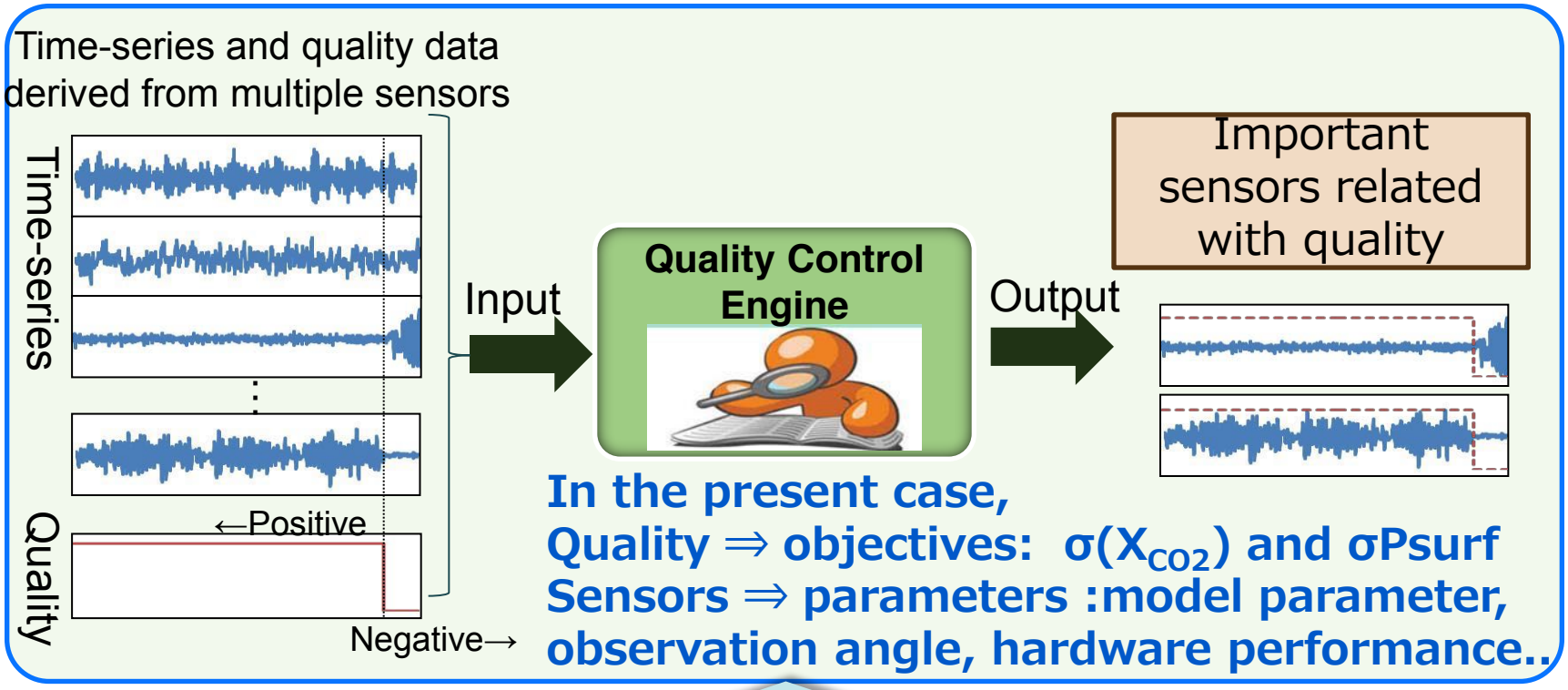
- Investigate factors which contribute to accuracy of column-averaged CO_2 dry air molecule fraction(X_{CO2}) by using statistical analysis , namely 'big data analysis' approach.
- All parameters as possible as we can were included , those which have not apparent relationship with accuracy of X_{CO2} , in order to prevent from any prejudice based on experience, heritage, common sense in the past.

Methodology

- Applied technology
  - Invariant analysis (Quality Control Engine :QCE)
  - Visualization of correlation between Quality and each factor
- Target data (TANSO-FTS, periods of 3 points operational mode) :
  - Level 2 product…GOSAT ACOS Level2 Standard Product V3.3 (Aug. 2010～May 2013)
  - Aeronet data (in-situ field observation data at Railroad Valley (RRV) in U.S.)
- Target of analysis :
  - **【Objective】**
    - ✓ Observation accuracy of X_{CO2} : standard deviation of X_{CO2} (see previous page)
    - ✓ Observation accuracy of Psurf : standard deviation of surface pressure (Previous page)
  - **【Parameter】**
    - ✓ Surface atmospheric pressure(Psur f)
    - ✓ Pointing angle (AT-axis, CT-axis)
    - ✓ Aerosol amount
    - ✓ Ground surface albedo
    - ✓ CO_2 information volume
    - ✓ Signal –to –Noise ratio(SNR) of spectra

Big Data Analytics – QCE

QCE: Quality Control Engine



【QCE: Quality Control Engine】 * NEC original

Characteristics #1 : Check all data features (basic statistics) “exhaustively”
Characteristics #2 : Determine usefulness of the data “automatically”

Contributors related with σXCO2 estimated by QCE

No	Region	Rank	Contributor(parameter)	score	Comments by QCE
1	オーストラリア Australia	1	dof_co2_profile	1.41	Raw sensor value itself should be higher
		2	albedo_slope_o2	1.27	Higher values of sensor should be higher
		3	aerosol_water_aod_mid	0.49	Sensor should vary narrowly
		4	sounding_ct_angle	0.45	Raw sensor value itself should be lower
		5	albedo_slope_weak_co2	0.42	Overall values of the sensor should be higher
					↑Higher score corresponds to strong correlation with X(CO2)
2	アラビア Arabian Peninsula	1	aerosol_total_aod_mid	1.58	Sensor should vary narrowly
		2	surface_pressure_fph	1.49	Overall values of the sensor should be higher
		3	aerosol_kahn_3b_aod_low	1.13	Sensor should vary narrowly
		4	aerosol_total_aod_low	0.94	Sensor should vary narrowly
		5	aerosol_kahn_3b_aod_high	0.90	Imbalanced number of lower values and higher values. Sensor should have more low values and less high values
3	サハラ Sahara	1	albedo_slope_o2	1.97	Overall values of the sensor should be higher
		2	aerosol_total_aod_low	1.85	Imbalanced number of lower values and higher values. Sensor should have more low values and less high values
		3	dof_co2_profile	1.62	Raw sensor value itself should be higher
		4	aerosol_water_aod_mid	1.49	Sensor should vary narrowly
		5	aerosol_kahn_3b_aod_mid	1.06	Imbalanced number of lower values and higher values. Sensor should have more low values and less high values

Australia…Region with clear sky and little aerosol: X_{CO2} accuracy in this region is said to be high

- Boundary condition of atmospheric model ranked higher but these contributors are out of scope in the present discussion.
- CT angle was extracted as higher ranking (No.4). Smaller CT angle was correlated with higher X_{CO2} accuracy)
- On the other hand SNR, surface pressure (indicator of elevation) were not extracted.

Arabian Peninsula, Sahara… Region with clear sky but much aerosol: X_{CO2} accuracy in this region is said to be low

- Parameters related with aerosol are highly ranked. Smaller and more stable in time is correlated with higher X_{CO2} accuracy.

Product data analysis by conventional method～Level 2

Purpose

Verification of results of big data analysis, as follows.

CT angle really key parameter ? Is there any relation with SNR or surface pressure which have been ever thought to be critical factors?

Methodology

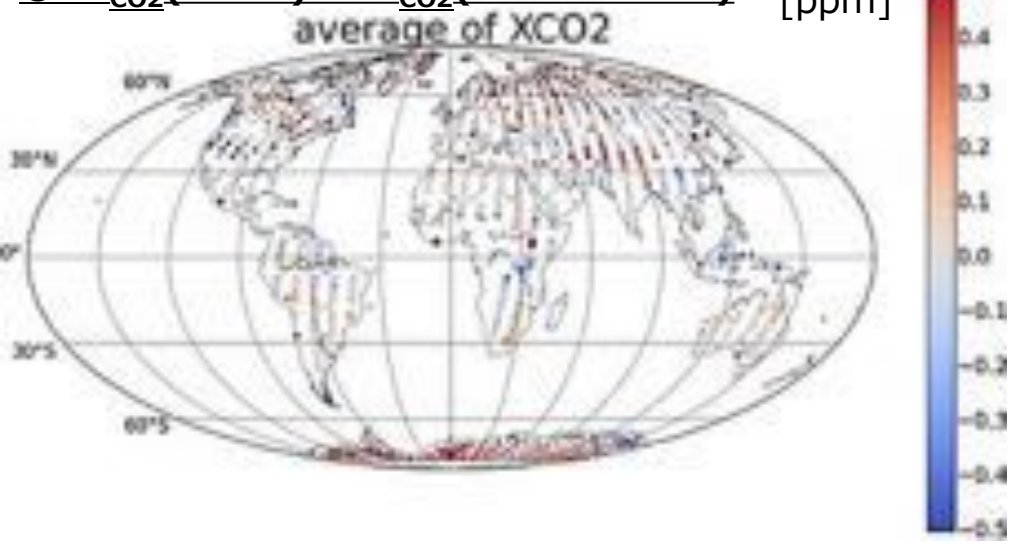
Global mapping of various Level 2 product Data for back side scattering geometry (CT angle>0), nadir and lateral scattering geometry (CT angle < 0)

- Target data (TANSO-FTS, periods of 3 points operational mode) :
  - Level 2 product…GOSAT ACOS Level2 Standard Product V3.3 (Aug. 2010～May 2013)
  - Aeronet data (on-sight field observation data at Railroad Valley (RRV) in U.S.)
- Objective
  - Standard deviation of X_{CO2} (σX_{CO2})
  - Surface pressure
  - SNR
  - Ratio of P-polarization state band/S-polarization state band (only for Band1)
    wavelength region: O_2-A absorption band, Fraunhofer lines and Atmospheric windows
  - Aerosol Optical thickness(AOT) *Indicator of aerosol amount
    In-situ measurement at Railroad Valley,U.S. (Validation site)

Global mapping of σX_{CO2} for CT angles

①σX_{CO2}(Lateral scatter) –σX_{CO2}(Nadir) [ppm]

②σX_{CO2}(Nadir) –σX_{CO2}(Back scatter) [ppm]

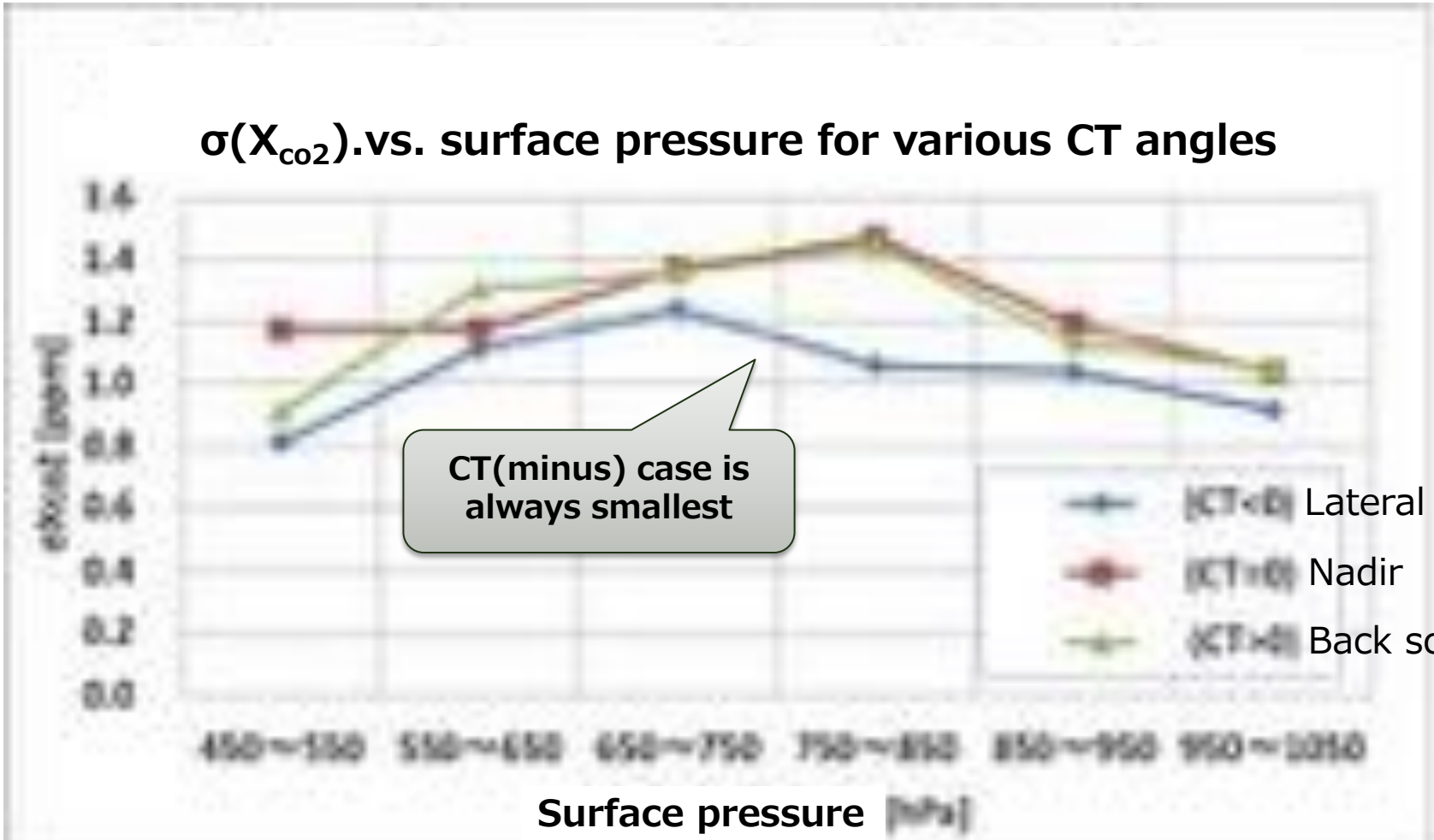


σX_{CO2} : standard deviation of X_{CO2}
Smaller means Higher accuracy

σX_{CO2}	Number of observation points
Lateral scatter .vs. Nadir	
Lateral scatter < Nadir	**2242**
Lateral scatter > Nadir	811
Nadir .vs. Back scatter	
Nadir < Back scatter	1603
Nadir > Back scatter	1451

Observations with lateral scatter are correlate with high accurate X_{CO2} product

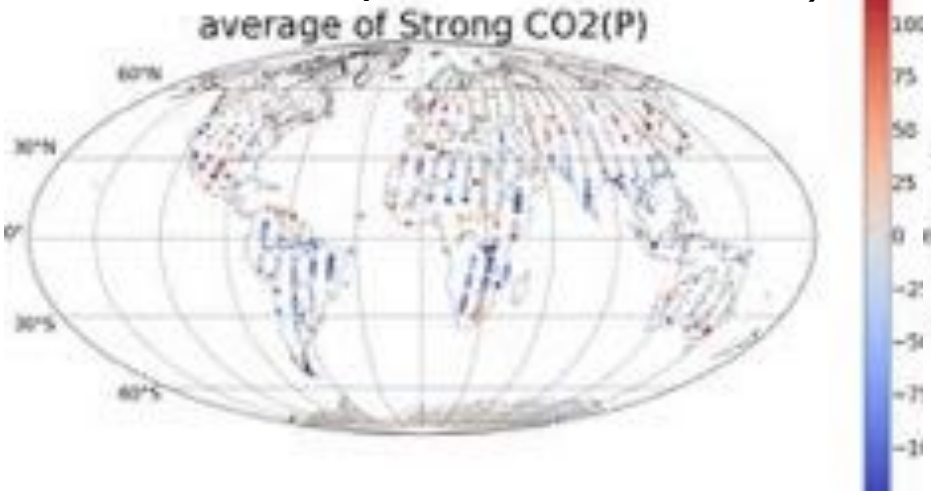
X_{CO2} accuracy .vs. surface pressure for various CT angles



-Lateral case is correlated with high accurate X_{CO2} product
-No obvious correlation between σ X_{CO2} between surface pressure

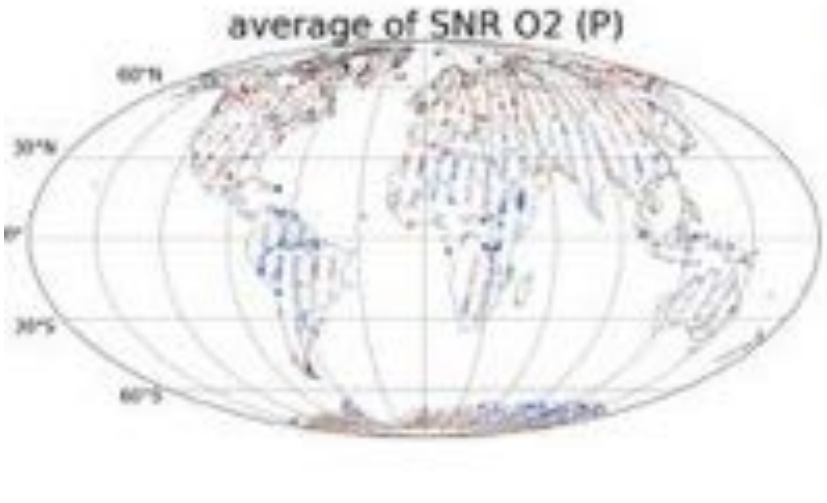
Global mapping of SNR for CT angles

Band3P SNR (lateral Scat.–Nadir)



Band2P SNR (lateral Scat.–Nadir)

Band1P SNR (lateral Scat.–Nadir)



Obviously more blue points than red points.
⇒ SNR in case of Nadir is higher than lateral scattering case.
⇒ Combined with fact that σX_{CO2} is lower for lateral scattering case than Nadir case, SNR is not dominant factor for X_{CO2} accuracy.

Product data analysis by conventional method ～Level 1

Purpose

Verification of results of big data analysis, as follows.

‘CT angle really key parameter ？ Is there any relation with SNR or surface pressure which have been ever thought to be critical factors? ‘

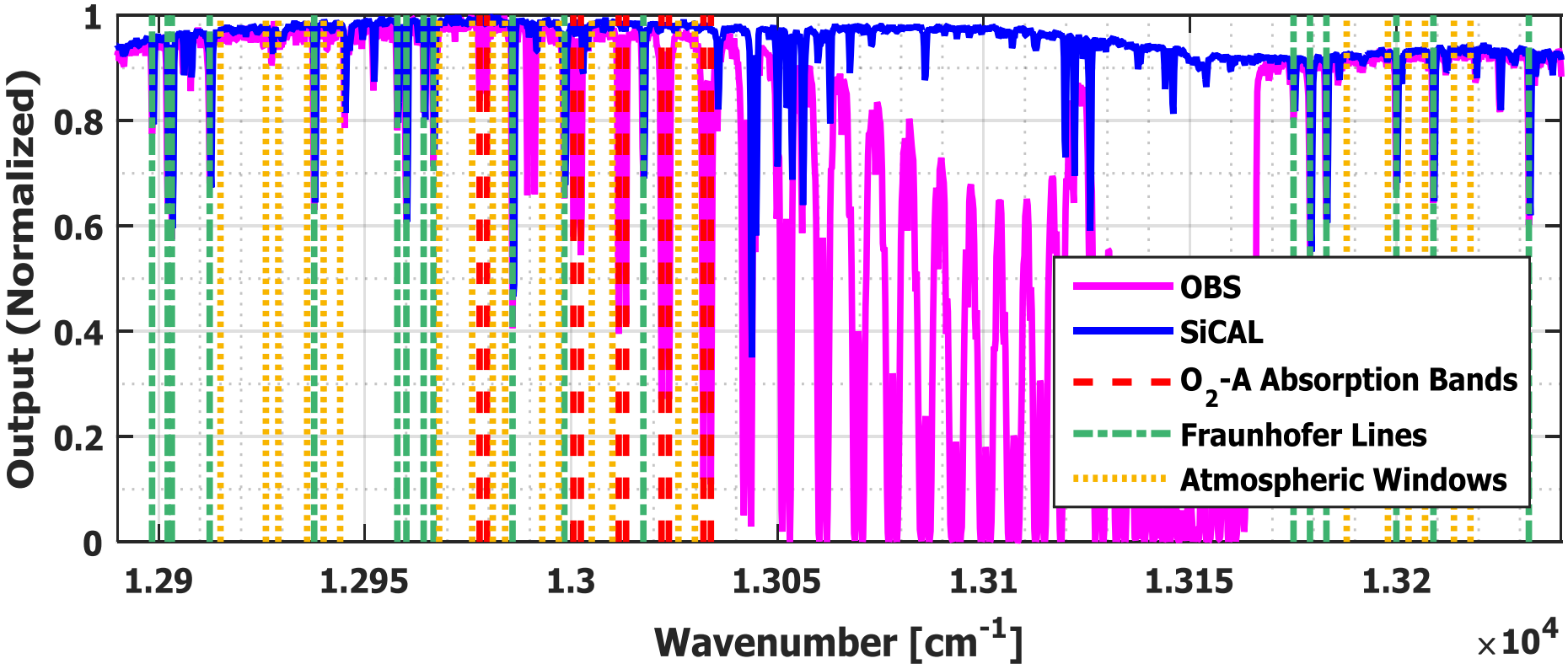
Methodology

Global mapping of various Level 1 product Data for back scattering geometry (CT angle>0), nadir and lateral scattering geometry (CT angle < 0)

- Target data（TANSO-FTS, periods of 3 points operational mode） :
  - Period of 3 points scanning mode of TANSO-FTS
  - Level 1 product…GOSAT Level1B product Ver.201201（August 2010～ July 2013）
  - Aeronet data (in-situ field observation data at Railroad Valley（RRV）in U.S.)
- Objectives
  - **Ratio of P-polarization state band/S-polarization state band (only for Band1)**
    Wavelength region: O_2-A absorption band, Fraunhofer lines and Atmospheric windows
  - **Optical depth of atmosphere (Indicator of aerosol amount)**
    In-situ measurement at Railroad Valley

Spectral analysis at Level 1

Typical sample of spectrum of Band1 observed by TANSO on-orbit



Blue : Solar diffuser

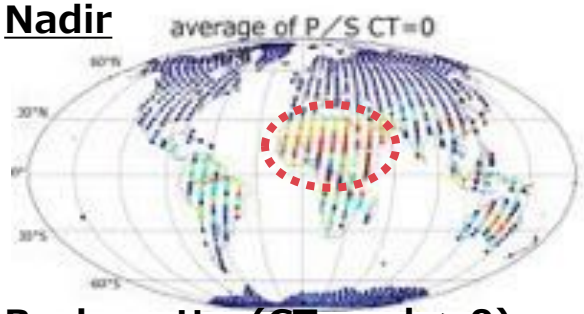
Magenta : Earth observation

Relation between polarization characteristics and CT-angels

Band1P spectra P/S-ratio (O_2-A band/Atm. window)

Lateral scatter(CT angle<0)

Nadir

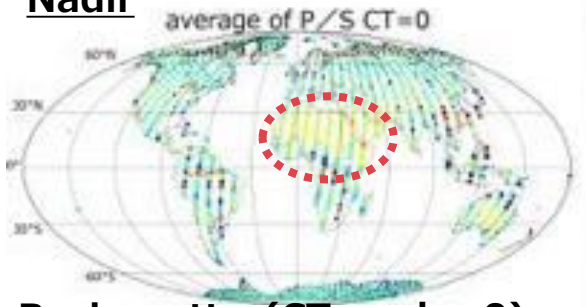


Back scatter(CT angle>0)

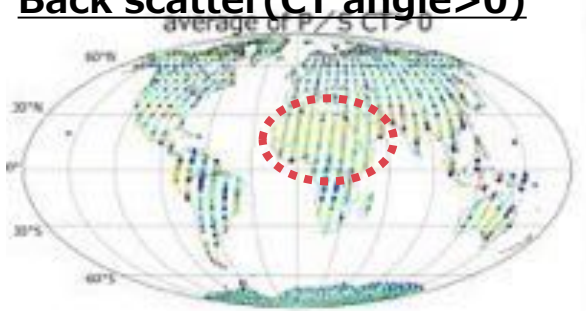
Band1P spectra P/S ratio (Fraunhofer/Atm. window)

Lateral scatter(CT angle<0)

Nadir



Back scatter(CT angle>0)



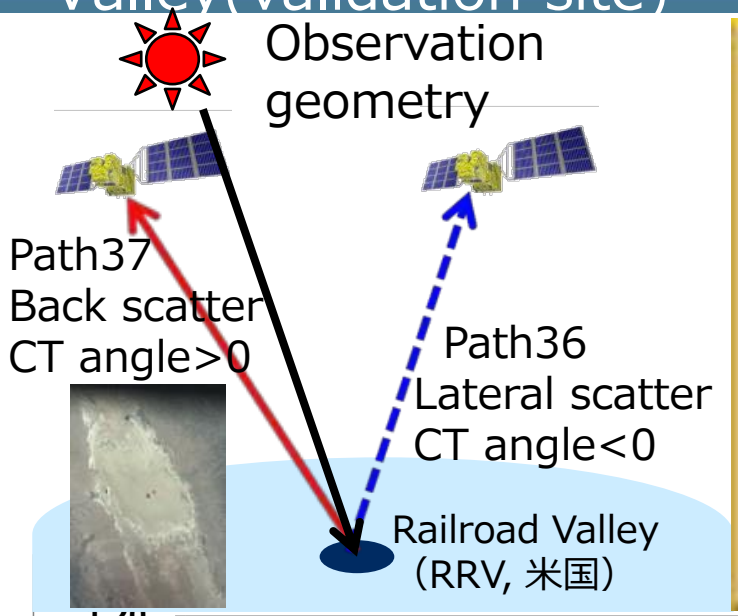
Global mapping investigation

In Sahara where is much aerosol in the air, clear correlation between P/S ratio and scattering direction(CT angle) in case of O2-A band.
On the other hand, no apparent relation in case of Fraunhofer line

This fact suggests some relation between O_2-A band and aerosol amount.

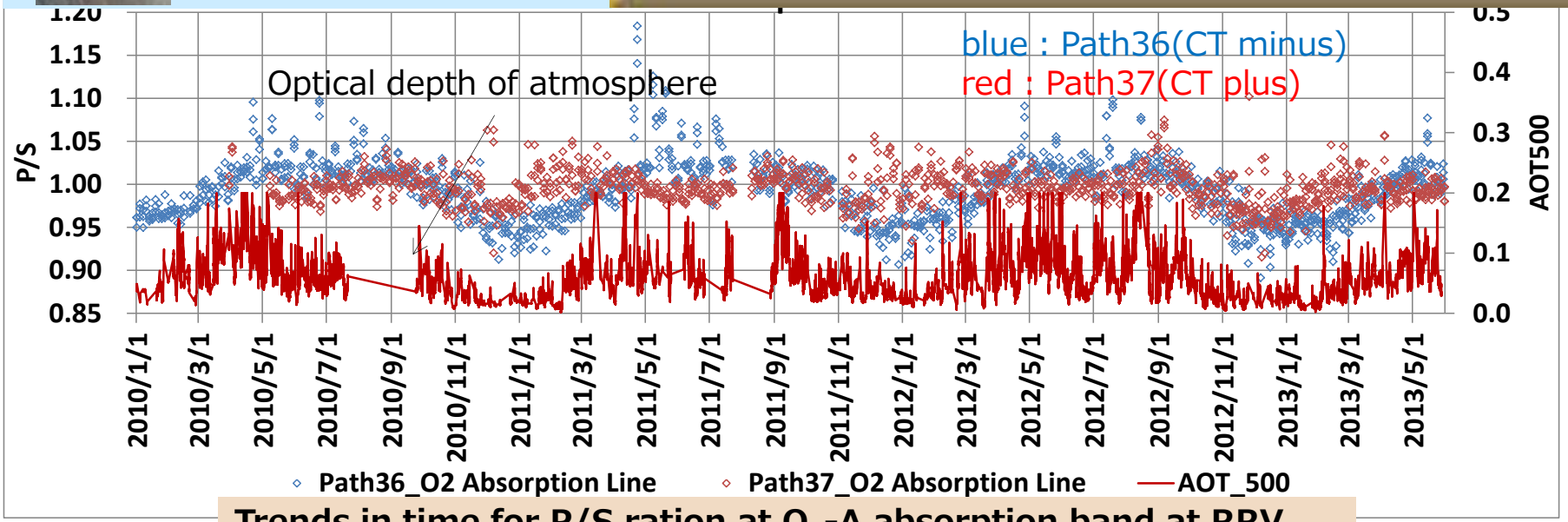
By taking advantage of polarization characteristics of O_2-A band, aerosol affect to X_{CO2} accuracy is expected to be decreased.

P/S ratio at O2-A band region for 2 CT angles at Railroad Valley(validation site)



P/S ratio is fluctuate for Path 37.
⇒ Polarization state is variant for back scattering. Combined with fact that σ(X_{CO2}) is lower for lateral scattering case than back scattering case, P/S ratio fluctuation is correlated with X_{CO2} low accuracy

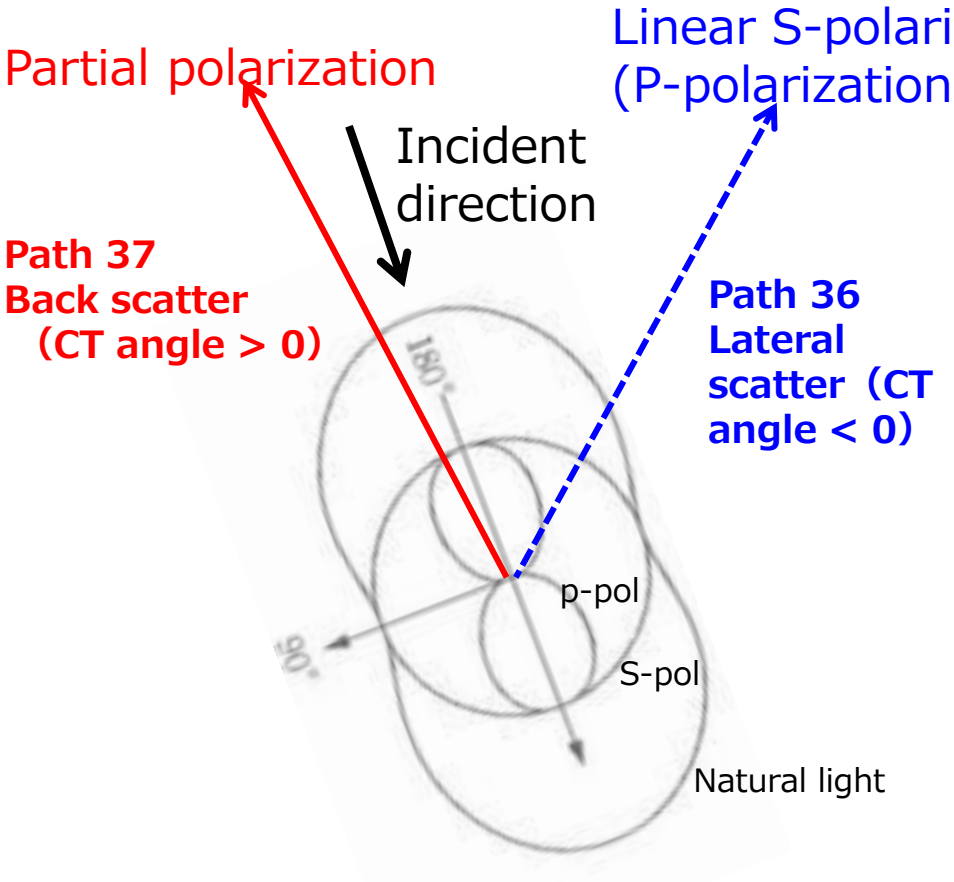
Trends of Aerosol Optical thickness (AOT)is correlated with P/S ratio for Path 36.
⇒ P/S ratio in case of lateral scattering is correlate with aerosol density.



Trends in time for P/S ration at O_2-A absorption band at RRV

Discussion

Aerosol scattering intensity map (in case of small aerosol radius)



Note: definition of P and S polarization in scattering plane is different or almost interchanged from that of TANSO, because scatter plane is almost perpendicular to orbit plane.)

- The reason why accuracy of X_{CO2} is high in case of lateral scattering is low intensity due to **anisotropy of aerosol scattering.**
- The reason why P/S ratio lateral scattering has correlation with aerosol density is **S-pol light (P-pol for TANSO) selectively scattered by aerosol.**
- The reason why P/S ratio is fluctuate in case of back scattering is **partial polarized light scattered.**

Conclusion

- In order for factorial analysis of improvement of X_{CO2} accuracy observed GOSAT/TANSO , following new hybrid method was introduced.
  - First, extraction of potential factors by finding direct correlation between Level 2 product as 'X_{CO2}' and any low level parameters like 'pointing angle ' on basis of big data analysis approach as a new statistic method
  - Next, for extracted factors, global mapping of product (band1 &2) or spectral profile analysis based on scientific and engineering approach as a conventional method.

- As a result of statistical analysis, 'pointing angle' was extracted as one of biggest contributors, except for boundary conditions of atmospheric or spectral model.

- Consecutive analysis by global mapping of product shows contribution of 'pointing angle' to X_{CO2} was again turn out to be larger than other contributor like SNR and surface pressure which have been ever thought to be critical factors.

- The reason why 'pointing angle' is important, is thought to be relation with aerosol scattering direction. If CT pointing angle is selected to be minus which realize scattering angle of about >~40deg (lateral scatter), aerosol affect to X_{CO2} can be decreased because aerosol scatter is occurred mainly in forward or backward direction with respect to incident light direction. Moreover, S-state linear polarized light in a sense of scattering plane (which corresponds to P-state band of TANSO) is selectively scattered in case of lateral scattering(CT angle <0). The observed light intensity in case of lateral scattering (CT angle <0) is more stable rather than in cased of back side scattering (CT angle >0)where partial polarized light is scattered.

- Reflected above 'hybrid analysis' conclusion , possibility of selection of the most preferable pointing angle to minimize aerosol affect will be studied on TANSO mission planning .(e.g. CT angle <0 for Sahara desert where atmosphere contain much aerosol)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