

The CarbonSat Earth Explorer 8 candidate mission: Error analysis for carbon dioxide and methane

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Introduction

CarbonSat [1,2] has been selected by ESA as one of two candidate missions for Earth Explorer 8 (EE-8). End of 2015 one mission will be selected for a launch in 2022.

The main Level 2 data products of CarbonSat are column-averaged dry air mole fractions of CO₂ and CH₄, i.e., XCO₂ and XCH₄, needed to get quantitative information on regional/local surface fluxes (emissions and uptake).

In addition, CarbonSat will deliver a number of scientifically interesting secondary data products such as Vegetation Chlorophyll / Solar-Induced Fluorescence (VCF / SIF) [2, 4].

The CO₂ and CH₄ source / sink applications require to meet demanding precision and accuracy requirements. Here we present error analysis results using the latest version of the CarbonSat retrieval algorithm (BESD/C) and the latest instrument and mission specification focussing on the minimum (threshold) performance. Some results are updates of results shown in [2,3].

CarbonSat mission goals

The main goal of CarbonSat is to advance our knowledge on the natural and man-made sources and sinks of the two most important anthropogenic greenhouse gases carbon dioxide (CO₂) and methane (CH₄) from the global via the sub-continental to the local scale.

CarbonSat will be the first satellite mission to image small scale emission hot spots of CO₂ (e.g., cities, volcanoes, industrial areas) and CH₄ (e.g., fossil fuel production, landfills, seeps) and to quantify their emissions and discriminate them from surrounding biospheric fluxes.

Selected references

[1] Bovensmann, H., Buchwitz, M., Burrows, J. P., Reuter, M., et al., A remote sensing technique for global monitoring of power plant CO₂ emissions from space and related applications, Atmos. Meas. Tech., 3, 781-811, 2010.

[2] Buchwitz, M., Reuter, M., Bovensmann, H., et al., Carbon Monitoring Satellite (CarbonSat): assessment of atmospheric CO₂ and CH₄ retrieval errors by error parameterization, Atmos. Meas. Tech., 6, 3477-3500, 2013.

[3] Buchwitz, M., Reuter, M., Bovensmann, H., et al., Carbon Monitoring Satellite (CarbonSat): assessment of scattering related atmospheric CO₂ and CH₄ retrieval errors and first results on implications for inferring city CO₂ emissions, Atmos. Meas. Tech. Discuss., 6, 4769-4850, 2013.

[4] Parazoo, N. C., Bowman, K., Frankenberg, C., et al., Interpreting seasonal changes in the carbon balance of southern Amazonia using measurements of XCO₂ and chlorophyll fluorescence from GOSAT, Geophys. Res. Lett., 40, 2829-2833, doi:10.1002/grl.50452, 2013.

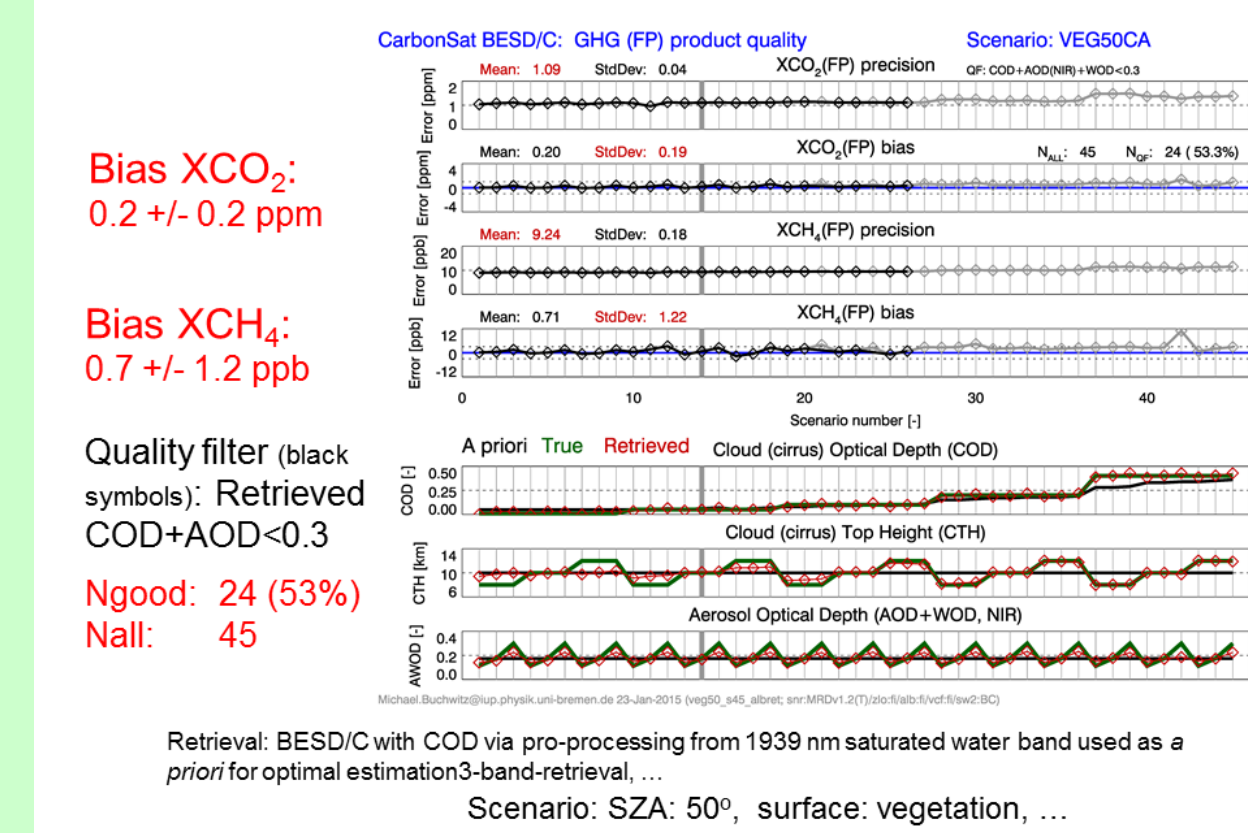
Error analysis results

CarbonSat: Error Budget Nadir/Land

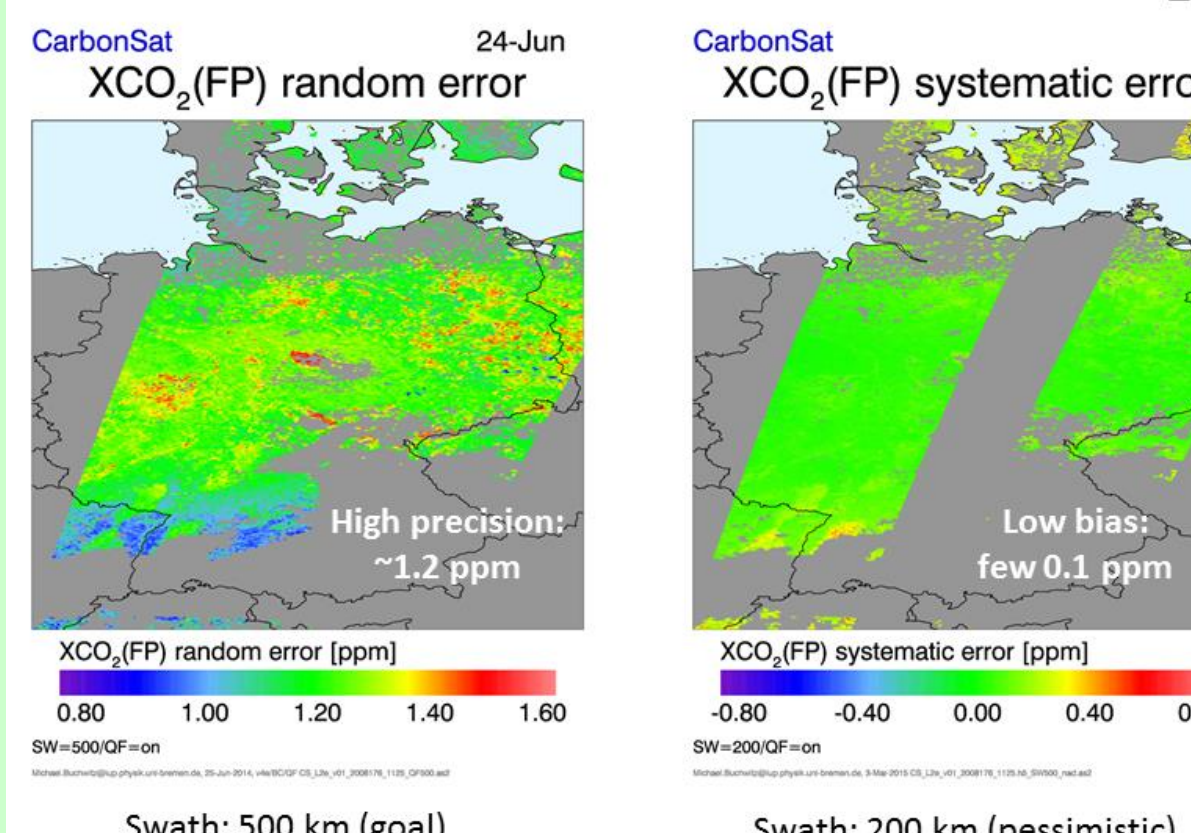
| CarbonSat XCO ₂ and XCH ₄ Error Budget Nadir/Land (v5) | | | | | | |
|------------------------------------------------------------------------------|------------------------|------------------------|---------------------------|-------------------------------------------------------------------|------------------------|------------------------|
| Error source | Overall uncertainty | | Required maximum error | | | |
| | XCO ₂ (ppm) | XCH ₄ (ppb) | Random error per sounding | Systematic error (monthly regional-scale, non-constant part only) | | |
| Algorithm | | | "Precision" | | "Relative accuracy" | |
| | XCO ₂ (ppm) | XCH ₄ (ppb) | XCO ₂ (ppm) | XCH ₄ (ppb) | XCO ₂ (ppm) | XCH ₄ (ppb) |
| Clouds & aerosols | 0.50 | 4.24 | 0.10 | 0.10 | 0.10 | 0.10 |
| Meteorology (p, T, H ₂ O) | 0.14 | 1.13 | 0.10 | 0.10 | 0.10 | 0.10 |
| Spectroscopy | 0.14 | 1.13 | 0.10 | 0.10 | 0.10 | 0.10 |
| Other | 0.14 | 1.13 | 0.10 | 0.10 | 0.10 | 0.10 |
| Instrument (Threshold) | 1.20 | 9.00 | 1.20 | 9.00 | 0.00 | 0.00 |
| Signal-to-Noise Ratio (SNR) | 0.20 | 1.97 | 0.17 | 1.80 | 0.10 | 0.10 |
| Radiometric: Multiplicative / absolute | 0.45 | 4.47 | 0.40 | 4.00 | 0.20 | 2.00 |
| Additive (zero level offset) | 0.20 | 1.97 | 0.17 | 1.80 | 0.10 | 0.10 |
| Instrument Spectral Response Function (ISRF) | 0.20 | 1.97 | 0.17 | 1.80 | 0.10 | 0.10 |
| Spectral calibration | 0.20 | 1.97 | 0.17 | 1.80 | 0.10 | 0.10 |
| Spatio-temporal co-registration | 0.48 | 3.90 | 0.48 | 3.90 | 0.00 | 0.00 |
| Heterogeneous scenes / Pseudo Noise (PN) | 0.32 | 2.62 | 0.30 | 2.50 | 0.10 | 0.10 |
| Other | 0.14 | 1.13 | 0.10 | 0.10 | 0.10 | 0.10 |
| Total (root-sum-square (RSS)) | 1.56 | 11.68 | 1.56 | 11.68 | 0.47 | 4.53 |
| Required (MRDv1.2, threshold (T)) | 3.00 | 12.00 | 0.50 | 5.00 | | |
| All values in % | | | | | | |
| Updated by Buchwitz et al. ESA ESRo Planning Symposium, Edinburgh 2016 | | | | | | |

Update of: Buchwitz et al., ESA Living Planet Symposium, Edinburgh, 2013

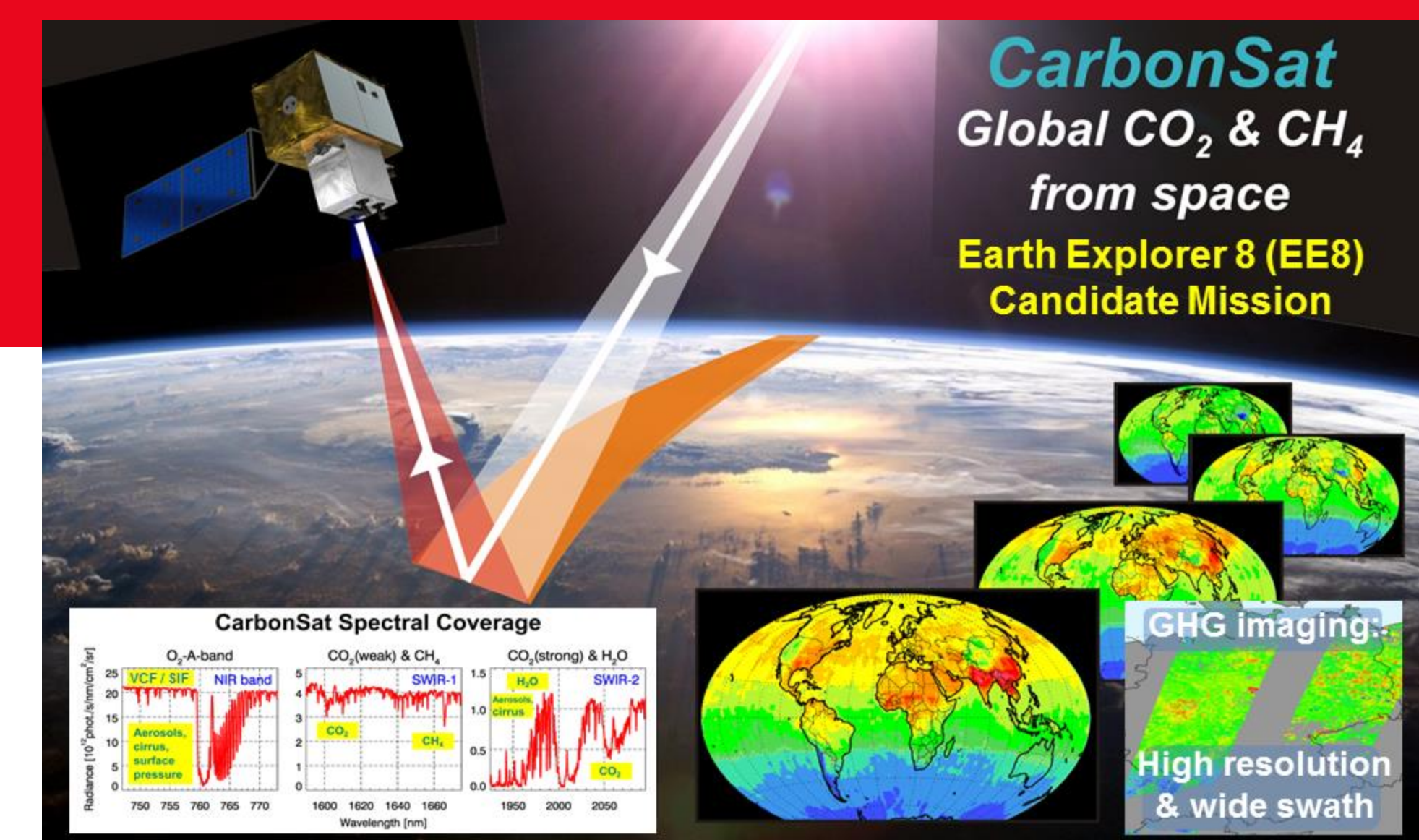
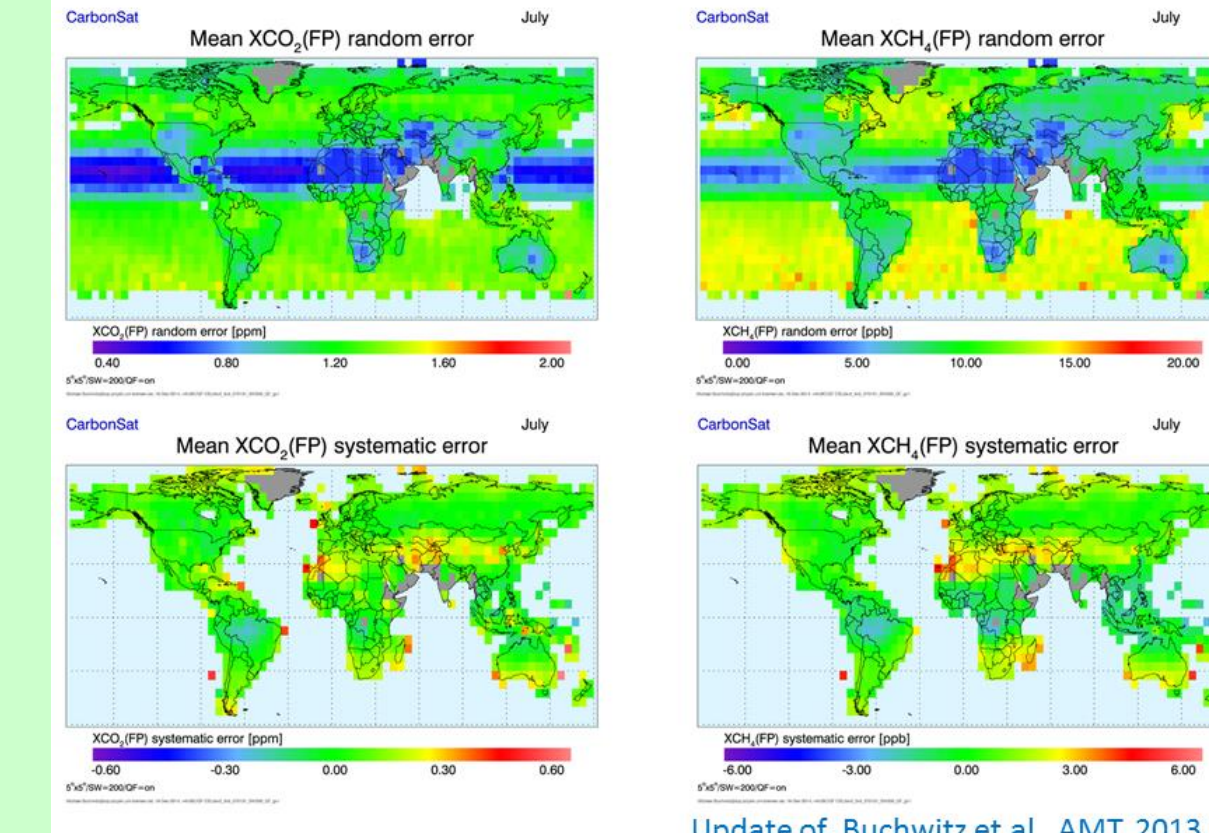
Simulated retrievals: Clouds & aerosols



CarbonSat: Single ground pixel XCO₂

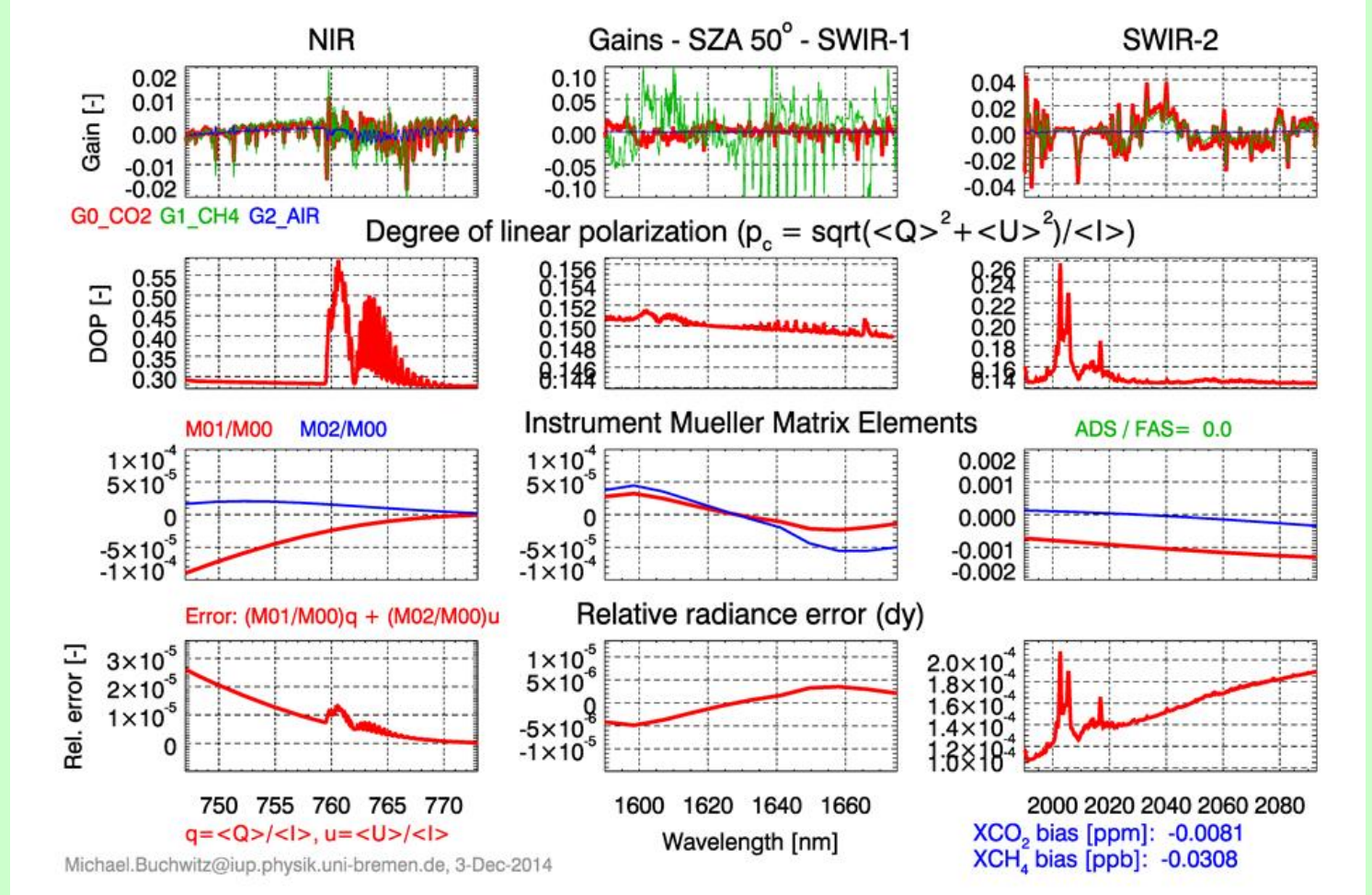


CarbonSat: XCO₂ and XCH₄ Monthly 5°x5°

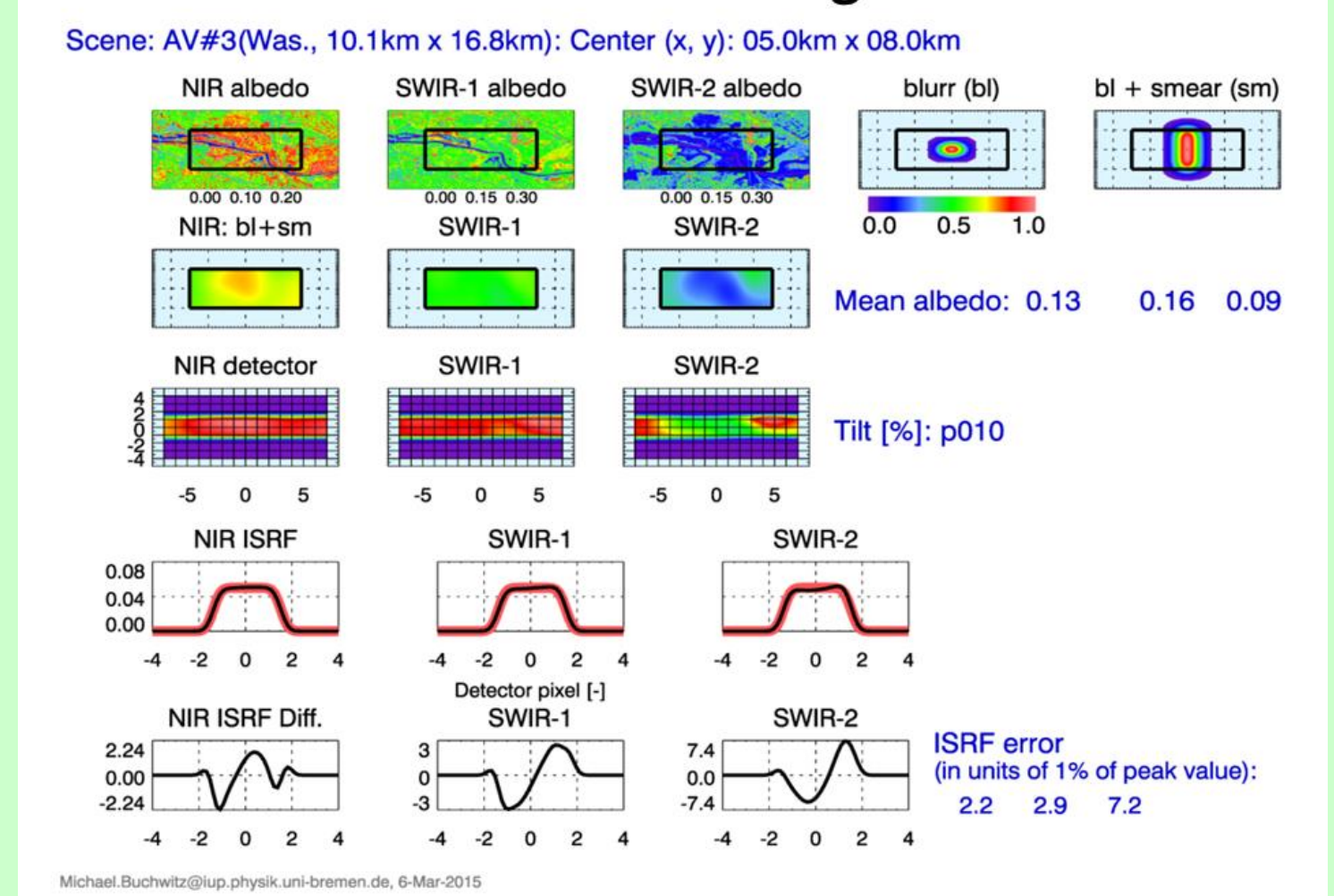


Selected results: Radiometric errors

Radiometric errors: Polarization

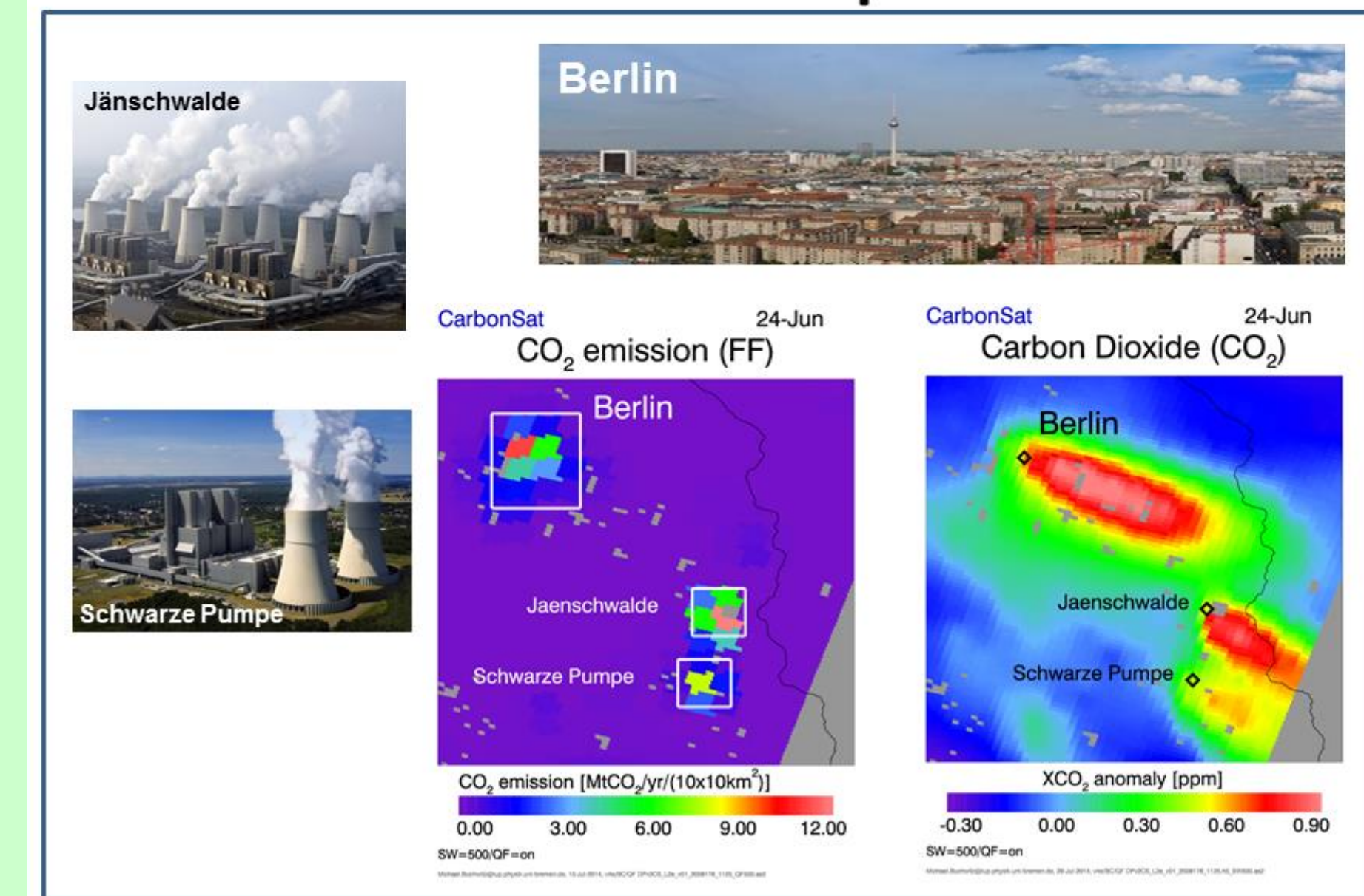


Radiometric errors: Inhomogeneous scenes

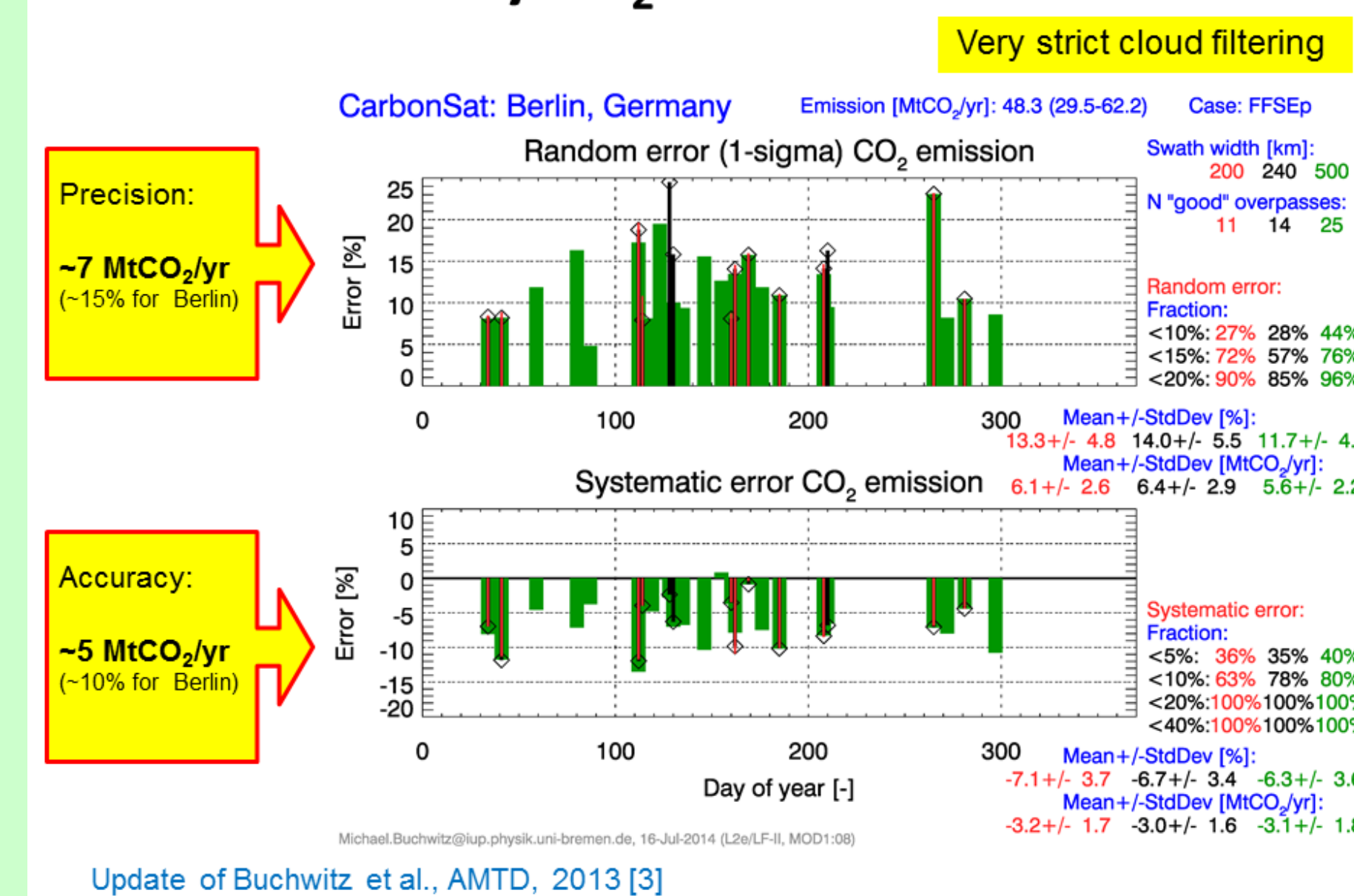


Selected applications: City and country-scale CO₂ fluxes

CarbonSat: Emission Hot Spots: Berlin area



CarbonSat: City CO₂ Emissions: Berlin



CarbonSat: Assessment for national scales

