Atmos. Meas. Tech. Discuss., 4, C1527–C1533, 2011
www.atmos-meas-tech-discuss.net/4/C1527/2011/

Atmospheric Measurement Techniques Discussions

Interactive comment on "High-resolution air quality monitoring from space: a fast retrieval scheme for CO from hyperspectral infrared measurements" *by* N. Smith et al.

N. Smith et al.

nadia.smith@ssec.wisc.edu

Received and published: 7 September 2011

Based on the strong agreement between the two reviewers, we can summarize the shortcomings of our paper as follows. First, the paper is too short and fails to sufficiently explain the context and mathematical foundation of the FLITS retrieval algorithm. Second, the application of FLITS is over simplified to a small oceanic CO plume. It is not uncommon to simplify retrieval validation or comparative studies e.g., George et al. (2009) limited their IASI CO comparisons to clear-sky daytime pixels; Fortems-Cheiney et al. (2009) similarly filtered out cloudy nighttime retrievals together with

those that were within 25 degrees of the poles and locations with surface emissivity greater than 0.98 (icy surface) or lower than 0.93 (over desert); and apart from filtering cloudy retrievals Illingworth et al. (2011) removed IASI-MOPITT matches from their comparisons where the surface pressures used in the retrievals differed more than 20 hPa. However, unlike theirs our results fail to sufficiently illustrate the usefulness of FLITS as a data processing tool for regional datasets. Third, we published an application of FLITS ahead of a detailed algorithm analysis (with error characterization and sensitivity studies) as was done with other IASI retrieval algorithms (Illingworth et al. 2010, Turquety et al. 2004, Chédin et al. 2003, Hadji-Lazarro et al. 1999, Clerbaux et al. 1998, Chevalier et al. 2005).

The study presented in this paper was originally designed as a validation study with aircraft measurements obtained from the HIAPER Pole-to-Pole Observations (HIPPO) of carbon cycle and greenhouse gases study. HIPPO was a field campaign over the Pacific and California coast for the time period 27-31 March 2010. We acknowledge the different approaches that can be taken in comparative studies e.g., Pommier et al. (2010) extended their in situ aircraft measurements with space-borne measurements (ACE-FTS) for full profile comparisons; while Warner et al. (2007) limited their comparison of MOPITT and AIRS with in situ measurements to 500 hPa. However, we found the spatial distribution of the HIPPO dataset to be the main limiting factor. IASI CO retrievals at 12 km resolution simply do not reflect localized patterns. In hindsight, we should have developed a more descriptive case study.

The FLITS algorithm was developed as a data processing tool with which to do retrievals of trace gases from hyperspectral infrared soundings for environmental monitoring. Rather than static data products, the FLITS retrievals are intermediate products that can be used for data assimilation or real-time analysis. We envisage that instead of replacing existing data products (the FLITS retrievals are by no means superior to the operational Level 2 products that available online in near real-time) or processing systems, FLITS can be incorporated into data assimilation routines or in operational monitoring systems to supplement the data pool for improved understanding of regional events and trends. A number of factors make FLITS a fast algorithm (in a qualitative sense by being computationally inexpensive) and thus ideal for the situations described. They are, a single value is retrieved per field of view (FOV), the value is retrieved in a single step, finite differencing jacobian vectors are calculated using simple arithmetic instead of analytical jacobian matrices that requires partial differentiation, a fast forward model is used to calculate top of atmosphere (TOA) radiances, and FLITS requires no pre- or post-processing routines.

The main characteristic that sets FLITS apart from other IASI CO physical retrieval algorithms is its linear treatment of the relationship between background atmospheric state and top of atmosphere radiance measurements. All the other IASI CO physical retrieval algorithms (that we are aware of) are based on the optimal estimation (OE) framework (Illingworth et al. 2010, Chevalier et al. 2005, Turquety et al. 2004, Lerner et al. 2002). The latter is heralded as a successful approach to the weakly non-linear inversion of atmospheric measurements (e.g., Rodgers 2000). However, OE is computationally complex and requires a number of iterations before a final result is achieved. A linear approach, in contrast, is computationally simple and a final result is achieved in a single step. Without going into full details here, it suffices to say that there are costs and benefits to both approaches.

In the paper we make two strong claims about the FLITS performance. First, we claim it gives a stable performance. When a highly non-linear problem is linearized the result can become very unstable due to the mistreatment of significant error sources. We recognize this and introduce a level of stability in the results through careful channel selection (by choosing three neighboring channels on the peaks of the four strongest absorption lines. This differs from the criteria for channel selection in the Level 2 algorithm that instead uses CO channels with low interference from other species), vertical integration (from mixing ratio to column density), and joint retrieval with skin temperature (CO degrees of freedom is highly correlated with surface temperature, especially

the thermal contrast between the surface and first atmospheric layer, see Deeter et al. 2007; Clerbaux et al. 2008, 2009; George et al. 2009; Pommier et al. 2010). Second, we claim that no spatial averaging is necessary to stabilize the results. This is not the first time that an algorithm achieves stability at single field of view resolution (see Illingworth et al. 2010, Turquety et al. 2004).

Given the reviewer feedback, we propose to do the following in a revised version of this paper:

- Discuss the full heritage of CO retrieval work followed by a detailed description of the FLITS mathematical framework.

- Highlight the dynamic nature of the FLITS algorithm with a full description of the background atmospheric state and surface parameters.

- Develop a case study over land and ocean in southern Africa to demonstrate its usefulness over large areas.

- Demonstrate the sensitivity of FLITS to different model background definitions, e.g. RAQMS versus ECMWF and NCEP/GDAS.

- Demonstrate the sensitivity of FLITS to the spatial resolution of the background definition.

- Demonstrate the sensitivity of FLITS to surface parameters, skin temperature, emissivity and pressure.

- Demonstrate how the stability of FLITS is compromised with different channel selection criteria.

References:

Chédin, A., Saunders, R., Hollingworth, A., Scott, N., Matricardi, M., Etcheto, J., Clerbaux, C. Armante, R., and Crevoisier, C.: The feasibility of monitoring CO2 from high-resolution infrared sounders, J. Geophys. Res., 108(D2), 4064, doi:10.1029/2001JD001443, 2003.

Chevalier, F., Fisher, M., Peylin, P., Serrar, S., Bousquet, P., Bréon, F.-M., Chédin, A. and Ciais, P.: Inferring CO2 sources and sinks from satellite observations: method and application to TOVS data, J. Geophys. Res., 110, D24309, doi:10.1029/2005JD006390, 2005.

Clerbaux, C., Chazette, P., Hadji-Lazaro, J., Mégie, G., Müller, J.-F., and Clough, S. A.: Remote sensing of CO, CH4, and O3 using a space borne nadir-viewing intereferometer, J. Geophys. Res, 103, D15, 18 999–19 013, 1998.

Clerbaux, C, Edwards, D. P., Deeter, M., Emmons, L., Lamraque, J.-F., Tie, X. X., Massie, S. T., and Gille J.: Carbon monoxide pollution fromcities and urban areas observed by the Terra/MOPITT mission, Geophys. Res. Lett., 35, L103817, doi:10.1029/2007GL032300, 2008.

Clerbaux, C., Boynard, A., Clarrise, L., George, M., Hadji-Lazaro, J., Herbin, H., Hurtmans, D., Pommier, M., Razavi, A., Turquety, S., Wespes, C., and Coheur, P.-F.: Monitoring of atmospheric composition using the thermal infrared IASI/MetOp sounder, Atmos. Chem. Phys., 9, 6041–6054, 2009.

Deeter, M. N., Edwards, D. P., Gille, J. C., and Drummond, J. R.: Sensitivity of MOPITT observations to carbon monoxide in the lower troposphere, J. Geophys. Res.-Atmos., 112, D24306, doi:10.1029/2007JD008929, 2007.

Fortems-Cheiney, A., Chevallier, F., Pison, I., Bousquet, P., Carouge, C., Clerbaux, C., Coheur, P.-F., George, M., Hurtmands, D., and Szopa, S.: On the capability of IASI measurements to inform about CO surface emissions, Atmos. Chem. Phys., 9, 8735–8743, 2009.

George, M., Clerbaux, C., Hurtmans, D., Turquety, S., Coheur, P.-F., Pommier, M., Hadji-Lazaro, J., Edwards, D. P., Worden, H., Luo, M., Rinsland, C., and McMillan, W.: Carbon monoxide distributions from the IASI/METOP mission: evaluation with other

space-borne remote sensors, Atmos. Chem. Phys. Discuss., 9, 9793–9822, 2009.

Hadji-Lazaro, J., and Clerbaux C.: An inversion algorithm using neural networks to retrieve atmospheric CO total columns from high-resolution nadir radiances, J. Geophys. Res. 104(D19), 23841–23854, 2009.

Illingworth, S. M., Remedios, J. J., Boesch, H., Moore, D. P., Sembhi, H., Dudhia, A., and Walker, J. C.: A new optimal estimation retrieval scheme for carbon monoxide using IASI spectral radiances – Part 1: Sensitivity analysis, error budget and simulations, Atmos. Meas. Tech. Discuss. 3, 3747–3802, 2010.

Illingworth, S. M., Remedios, J. J., Boesh, H., Ho, S.-P., Edwards, D. P., Palmer, P. I., and Gonzi, S.: A comparison of OEM CO retrievals from the IASI and MOPITT instruments, Atmos. Meas. Tech., 4, 775–793, 2011.

Lerner, J. A., Weisz, E., and Kirchengast, G.: Temperature and humidity retrieval from simulated Infrared Atmospheric Sounding Interferometer (IASI) measurements, J. Quant. Spec. Rad. Trans., 107(D14), doi:10.1029.2001JD900254, 2002.

Pommier, M., Law, K. S., Clerbaux., C., Turquety, S., Hurtmans, D., Hadji-Lazaro, J., Coheur, P.-F., Schlager, H., Ancellet, G., Paris, J.-D., Nédélec, P., Diskin, G. S., Podolske, J. R., Holloway, J. S., and Bernath P.: IASI carbon monoxide validation over the Arctic during POLARCAT spring and summer campaigns, Atmos. Chem. Phys., 10, 10655–10678, 2010.

Rodgers, C.D.: Inverse methods for atmospheric sounding: theory and practice, World Scientific Publishing, Singapore, 2000.

Turquety et al. 2004: Turquety, S., J. Hadji-Lazaro, C. Clerbaux, D.S. Hauglustaine, S.A. Clough, V. Cassé, P. Schlüssel, and Mégie, G.: Operational trace gas retrieval algorithm for the Infrared Atmospheric Sounding Interferometer, J. Geophys. Res., 109(D21301), doi:10.1029/2004JD004821, 2004.

Warner, J., Comer, M. M., Barnet, C. D., McMillan, W. W., Wolf, W., Maddy, E., and Sachse, G.: A comparison of satellite tropospheric carbon monoxide measurements from AIRS and MOPITT during INTEX-A, J. Geophys. Res., 112, D12S17, doi:10.1029/2006JD007925 2007.

Interactive comment on Atmos. Meas. Tech. Discuss., 4, 3787, 2011.