A New Global HCHO Retrieval Technique based on Principal Component Analysis of Satellite Radiance Data: Implementation with OMPS and Preliminary Results

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Why Formaldehyde (HCHO)?

- Intermediate oxidation product of volatile organic compounds (VOCs)
  - Small global background from oxidation of methane
  - Relatively large regional sources (NMVOCs emitted from biogenic, anthropogenic, and biomass burning sources)
- Short-lived (lifetime: hours) - used to provide constraints on NMVOCs [*e.g.*, *Barkley et al.*, 2008; *Fu et al.*, 2007; *Palmer et al.*, 2003; *Zhu et al.*, 2014]
- Why NMVOCs? – precursors of tropospheric ozone and organic aerosols (*e.g.*, isoprene)

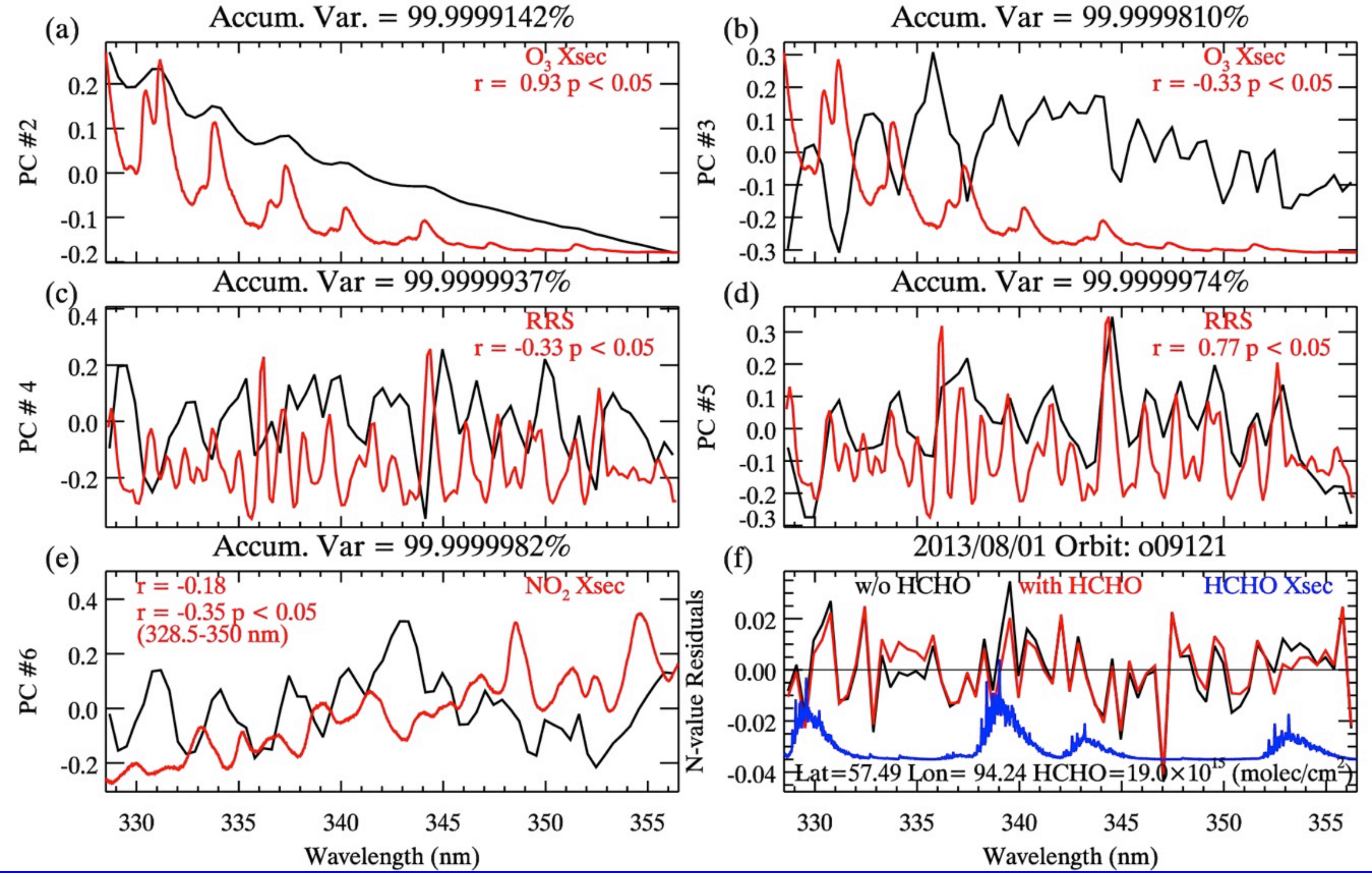
Space-based Detection of HCHO

- Absorption of UV in ~325-360 nm
- Weak signals, various interferences (BrO, O_3, NO_2, rotational Raman scattering or RRS, *aka* the Ring effect)
- DOAS-type algorithms using hyperspectral measurements to separate HCHO signals from interferences
- First demonstrated for GOME [*Chance et al.*, 2000]
- Products available from OMI [*e.g.*, *De Smedt et al.*, 2015; *González Abad et al.*, 2015], GOME-2 [*e.g.*, *De Smedt et al.*, 2012], SCIAMACHY [*e.g.*, *Wittrock et al.*, 2006]
- Still fairly large differences between satellites and/or algorithms [*e.g.*, *Zhu et al.*, 2016]

PCA-based Approach

- Based on successful PCA SO_2 algorithms
- Extract spectral features directly from satellite radiance data
- Use these features in spectral fitting to minimize interferences
- Preliminary implementation with OMPS :
  - PCs from each row, each orbit
  - Window: 328.5-356.5 nm
  - 8 PCs in fitting (no strong dependence on # of PCs)
  - Additional reference spectrum: BrO cross section
  - *A priori* profiles from GMI simulated climatology
  - A table lookup approach for Jacobians for each pixel: O_3 and cloud from NASA OMPS products

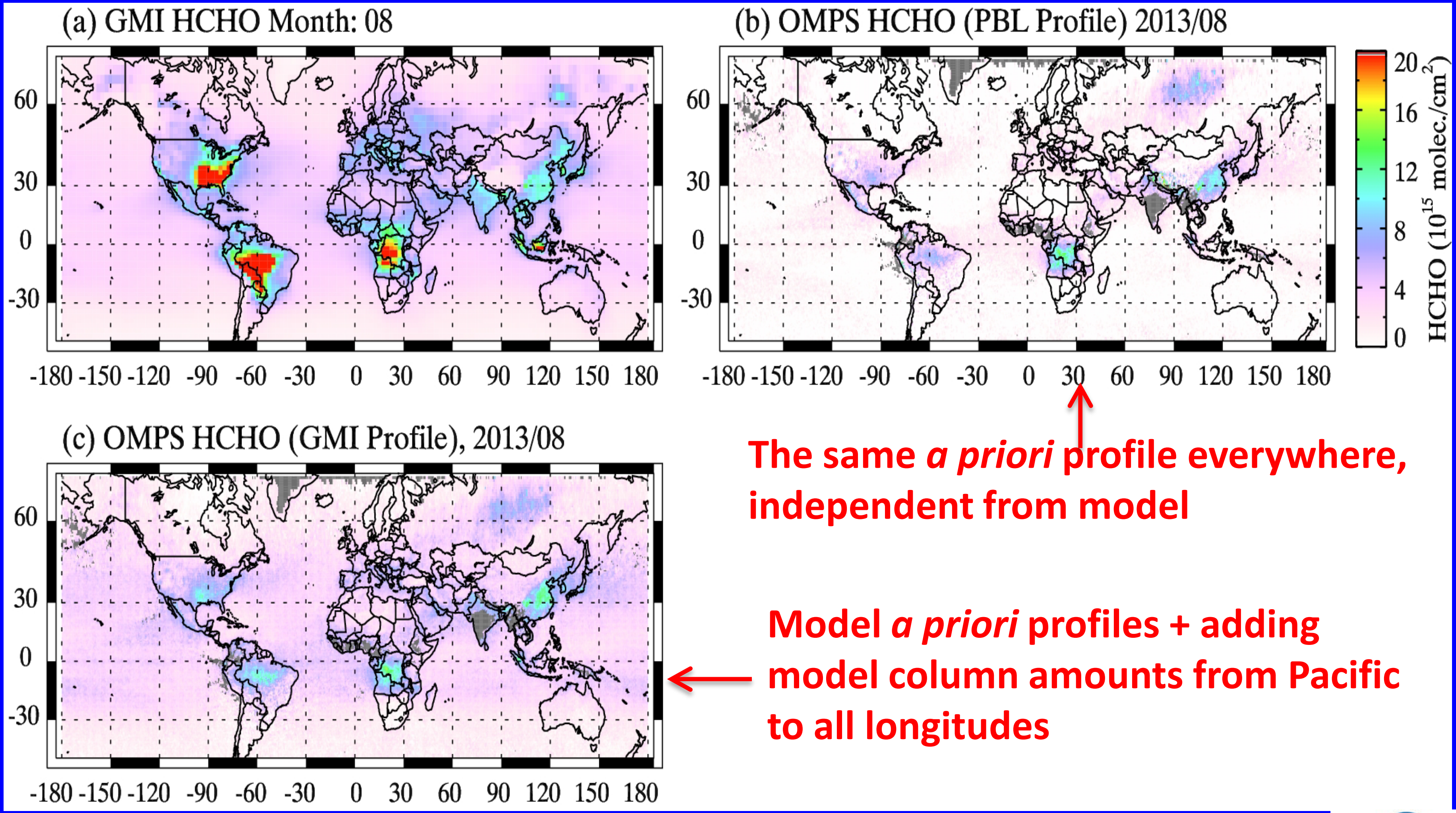
Principle Components and Residuals



Example PCs from **entire row** # 20, Orbit 9121 reveal clear, known physical features

[*Li et al.*, GRL, 2015]

OMPS Capable of Detecting HCHO Signals



The same *a priori* profile everywhere, independent from model

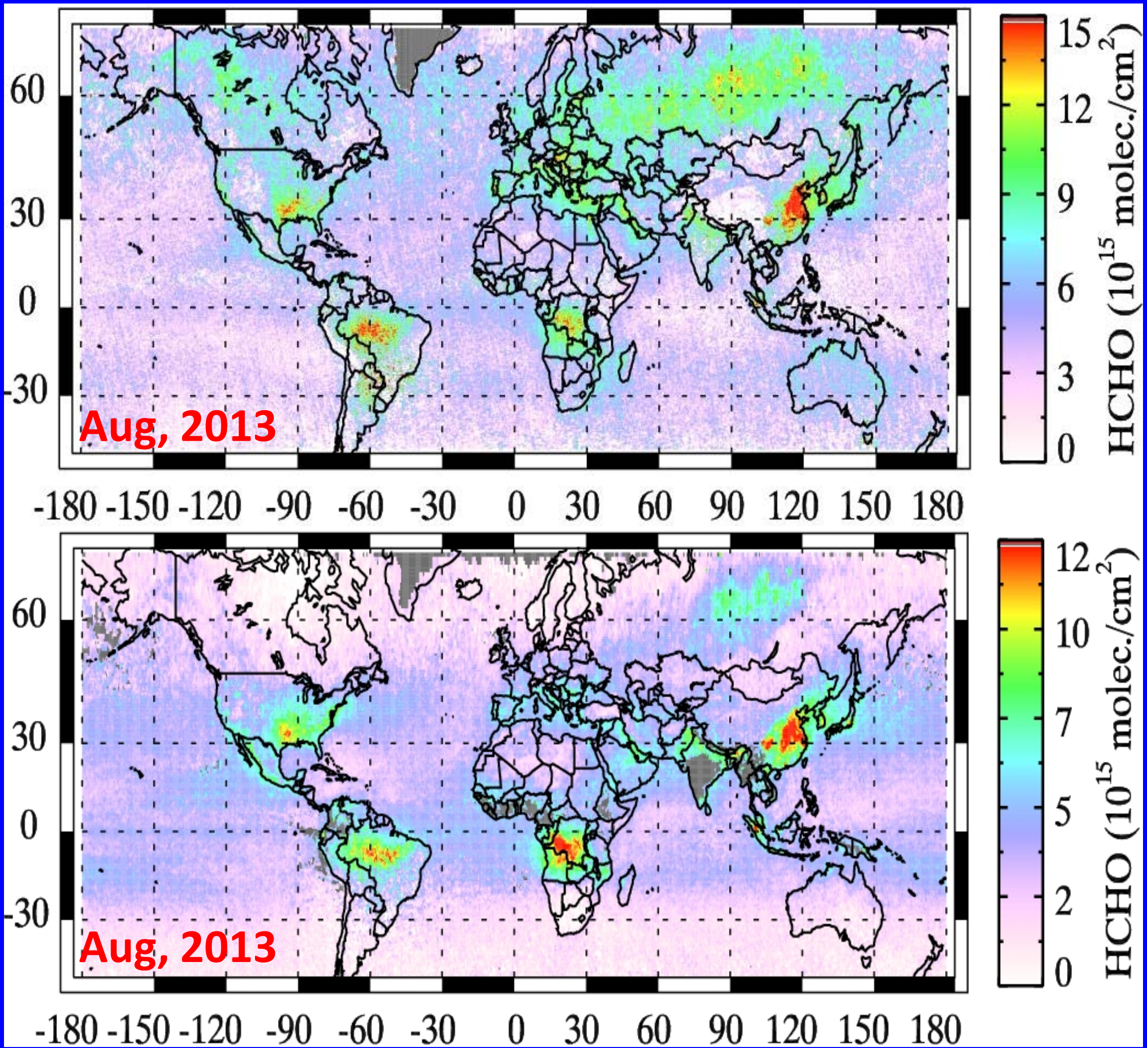
Model *a priori* profiles + adding model column amounts from Pacific to all longitudes

[*Li et al.*, GRL, 2015]

Comparison with OMI DOAS HCHO

OMI DOAS (BIRA)

OMPS PCA (GSFC)

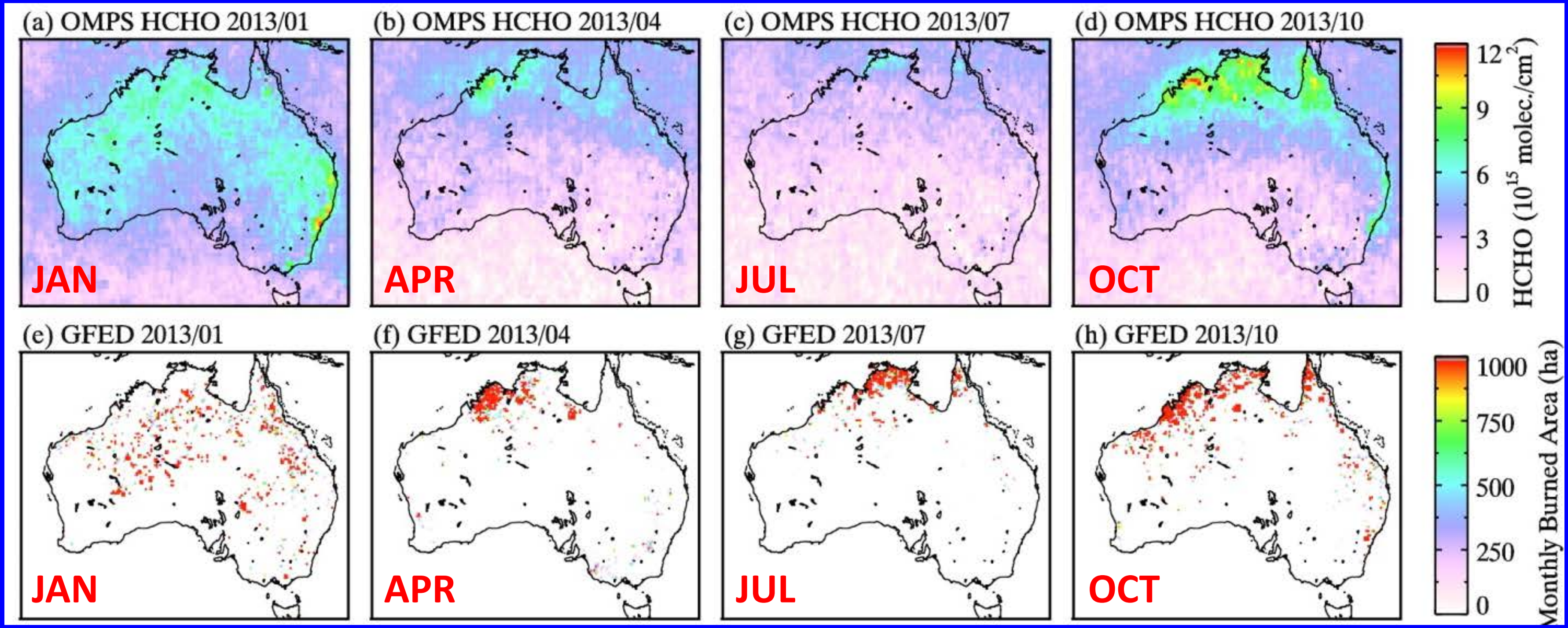


Two independent retrievals show fairly consistent spatial patterns in HCHO.
OMPS HCHO ~15-20% smaller than OMI, probably due to several instrumental and algorithmic factors (e.g., *a priori* profiles etc.).

[*Li et al.*, GRL, 2015]

Seasonal Pattern: OMPS HCHO *vs.* Global Fire Emission Database - Australia

OMPS PCA HCHO Retrievals for 2013

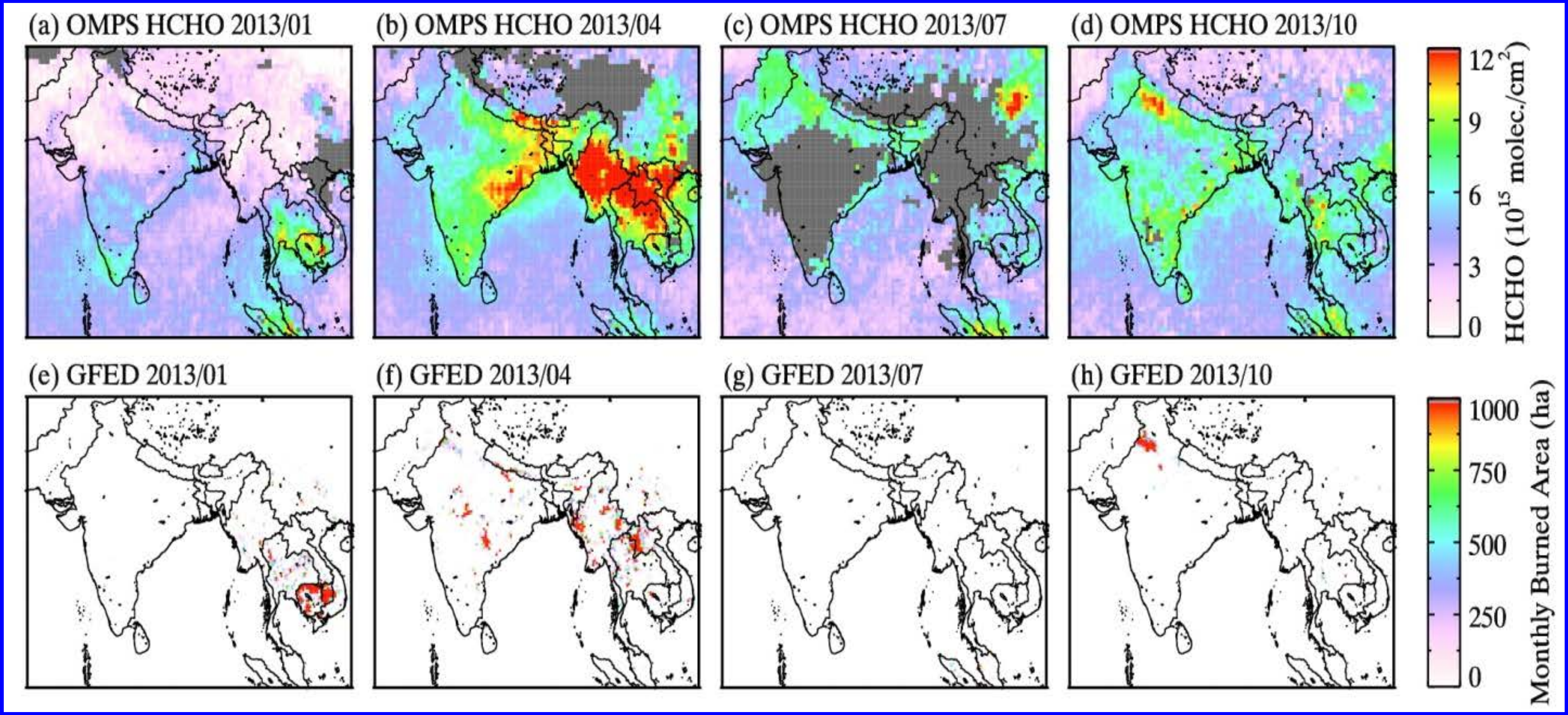


GFED Monthly Burnt Area (indicator of fires)

OMPS PCA HCHO retrievals show consistent spatial and seasonal patterns with fires in regions where seasonal biomass burning emissions dominate sources of NMVOCs (and HCHO). Biogenic emissions also contribute in the growing season (January).

Seasonal Pattern: OMPS HCHO *vs.* Global Fire Emission Database – South & Southeast Asia

OMPS PCA HCHO Retrievals for 2013



GFED Monthly Burnt Area (indicator of fires)

Work Underway

- OMPS PCA retrievals biased low – more detailed comparison has been planned in collaboration with BIRA
- Algorithm also implemented with OMI and will be implemented with TROPOMI
- Airborne HCHO measurements regularly taken over and near the San Francisco Bay Area (the Alpha Jet and COFFEE[1] payload)

Photo from *Hamill et al.* [2016]

[1]Compact **Formaldehyde** Fluorescence Experiment (Hanisco et al @NASA GSFC & Marrero et al @NASA Ames)

Conclusions

- The good news: OMPS provides an unplanned opportunity to continue the OMI HCHO data record (also demonstrated by *González Abad et al.* [2016]).
- A long-term data record will be crucial for investigating how biogenic emissions respond in a changing climate.
- More development underway.
- Inter-instrument consistency still an issue, but the PCA approach may offer a way to mitigate the issue.