SIF Retrievals from the geostationary GeoCarb instrument

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Introduction

• The GeoCarb instrument, like GOSAT, OCO-2 etc., will measure the O₂ A-band
• SIF retrievals using the established methods can thus be applied

• Why is GeoCarb SIF going to be exciting?
  – SIF from geostationary observation point gives us daily and sub-daily repeats
  – Dense spatial coverage due to scanning / imaging strategy
  – Measurements in particularly interesting regions: e.g. US Corn Belt, Amazon basin

• In this study, we want to estimate how many SIF retrievals we can expect in a day
• .. and how cloud biases might look like
One simulated (half-) day in the life of GeoCarb

• Placed into a geostationary orbit at 87W longitude
• GeoCarb instrument features a mirror for x-sweeps (E/W axis), with fixed “y-extent” (N/S axis – along slit)
• One sweep corresponds to a "scan box", with typical scan duration of ~1-2h
• Along-slit projects to 1016 spatial footprints, each footprint has spatial extent of 5.3 x 4.4 km² at nadir
• For this study, we simulate 5 scan boxes at full spatial resolution
  – Box 1: South America east (N = 250,952)
  – Box 2: South America south (N = 484,632)
  – Box 3: Amazon Basin (N = 626,872)
  – Box 4: North America / CONUS (N = 786,383)
  – Box 5: Central America (N = 488,696)
  – Total: N = 2,637,535 (in ~7 hrs)
For this study, we use "perfect" retrievals, i.e. we use the same solar model as truth.

SIF truth at surface is derived from MODIS GPP (0.5 deg), scaled with day of year and time of day.

Radiative transfer fully propagates the surface SIF to top-of-atmosphere using multiple scattering.

Presence of clouds and aerosols reduces SIF radiance at TOA.

That reduction is "manageable" for moderate optical depths, so we can observe BOA SIF for OD's where XGAS retrievals are not viable.

Simulated radiances have instrument noise applied.
High-resolution cloud fields

- To make use of high-(spatial)-resolution simulated scenes, we require equally resolved cloud fields
- We ingest *pre-operational* cloud retrievals from GOES-16, at 15-minute temporal intervals
  - Cloud top pressure (CTP, 5km)
  - Cloud optical depth (COD, 1km)
  - Cloud droplet effective radius (CPS, sub-km)
- Ice/cirrus cloud profiles obtained from ECMWF ERA-5
- Liquid water clouds are inserted as one-layer thick (~1-3 km) at the given CTP, ice water clouds use the full model profile
We utilize two retrieval algorithm concepts

- Physical retrieval (Frankenberg et al. 2011)
  - Uses solar- and instrument model, influence of gaseous absorbers in a model atmosphere

- Data-driven retrieval (Guanter et al. 2012)
  - Uses waveforms derived from measurements taken over non-vegetated surfaces
  - Fully linear retrieval, no iteration needed

Each concept has its own strengths

- “Physical” makes result of retrieval process more intuitive
- Data driven retrieval is fast (~250 µs vs. ~20 ms), but results depend on training data
Retrieval Results (#1)

- Retrievals in clear(-ish) scenes reproduces true TOA SIF
- For these scenes, variability is purely instrument noise-driven
Retrieval Results (#2)

- Picture changes when all scenes are considered
- Physical retrieval (at the moment) does not adjust for changing apparent surface pressure due to clouds
- Very obvious negative bias as result
- Data-driven retrieval captures some of that through the waveforms / principal components
- Physical retrieval thus more sensitive to clouds as true TOA is not recovered
Cloud bias

- Physical and data-driven retrieval compare well until total cloud + aerosol OD ~ 4.5 (r > 0.9)
- Physical retrieval is not sensitive to cloud top pressure, main bias comes from optical depth

- Number of land scenes with
  - Cloud OD < 0.1: ~390k (~23.5%)
  - Cloud OD < 1.0: ~470k (~28.5%)
  - Cloud OD < 4.5: ~750k (~45.3%)
- For scenes with COD < 4.5, data-driven retrieval yields slightly more SIF values at same magnitude of bias (to BOA truth)
Summary

- We simulated one half-day of GeoCARB SIF at full spatial resolution
- Made use of spatially highly-resolved cloud retrievals from GOES-16
- Performed SIF retrievals using two state-of-the-art algorithms
- Physical retrieval shows higher sensitivity to clouds (can be mitigated if desired)
- Both retrieval concepts perform almost equally well in these idealized conditions
- For this particular half-day, we see upwards of ~400,000 SIF retrievals with small bias (bias ~ clear sky scenes)

- BUT keep in mind – these simulations do not take into account 3D-effects from clouds, which can be substantial in the Amazon

- Thank you!