SIF Retrievals from the geostationary GeoCarb instrument

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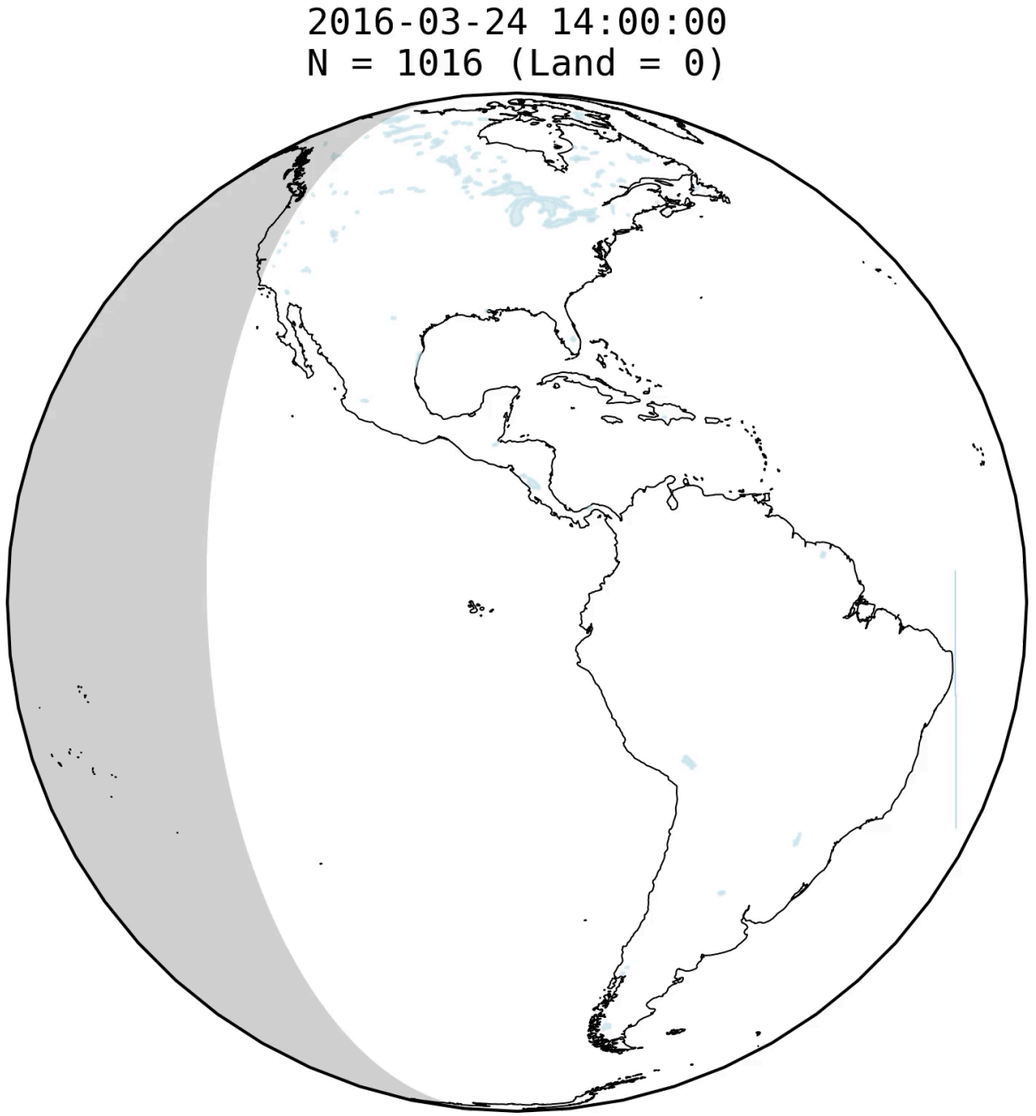
Introduction

- The GeoCarb instrument, like GOSAT, OCO-2 etc., will measure the O_2 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

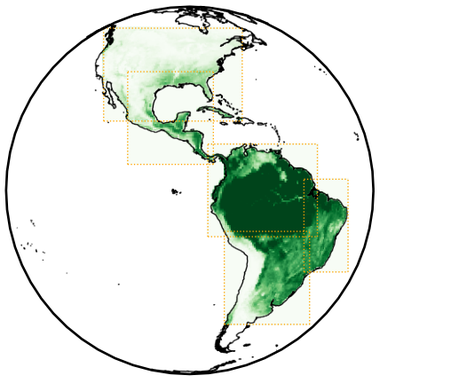
- In this study, we want to estimate how many SIF retrievals we can expect in a day
- .. and how cloud biases might look like

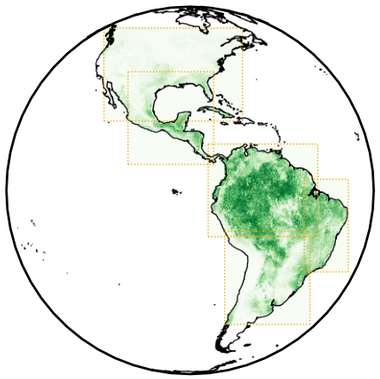
One simulated (half-) day in the life of GeoCarb

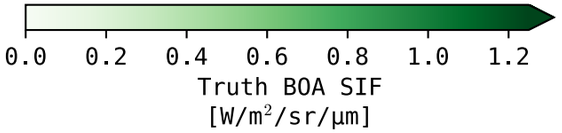
- Placed into a geostationary orbit at 87W longitude
- GeoCarb instrument features a mirror for x-sweeps (E/W axis), with fixed “y-extent” (N/S axis – along slit)
- One sweep corresponds to a ”scan box”, with typical scan duration of ~1-2h
- Along-slit projects to 1016 spatial footprints, each footprint has spatial extent of 5.3 x 4.4 km^2 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)

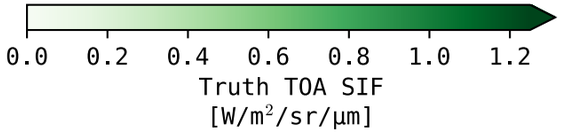


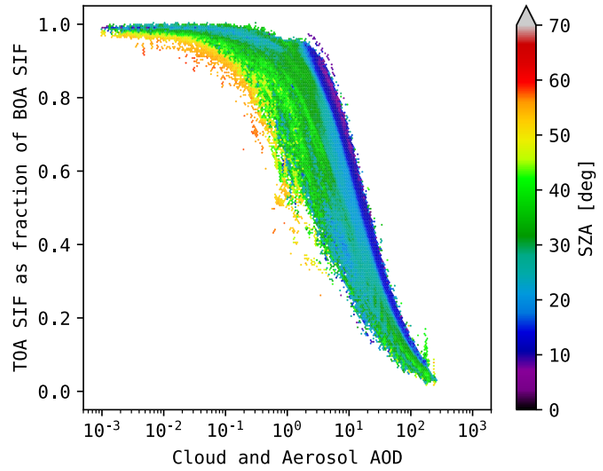
CSU Simulator







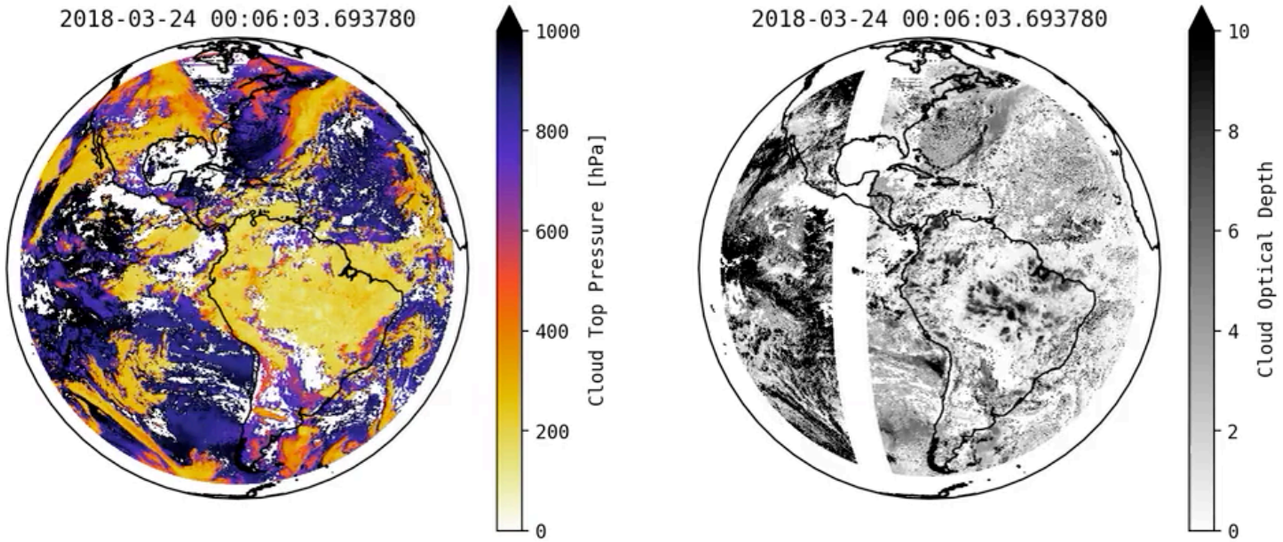




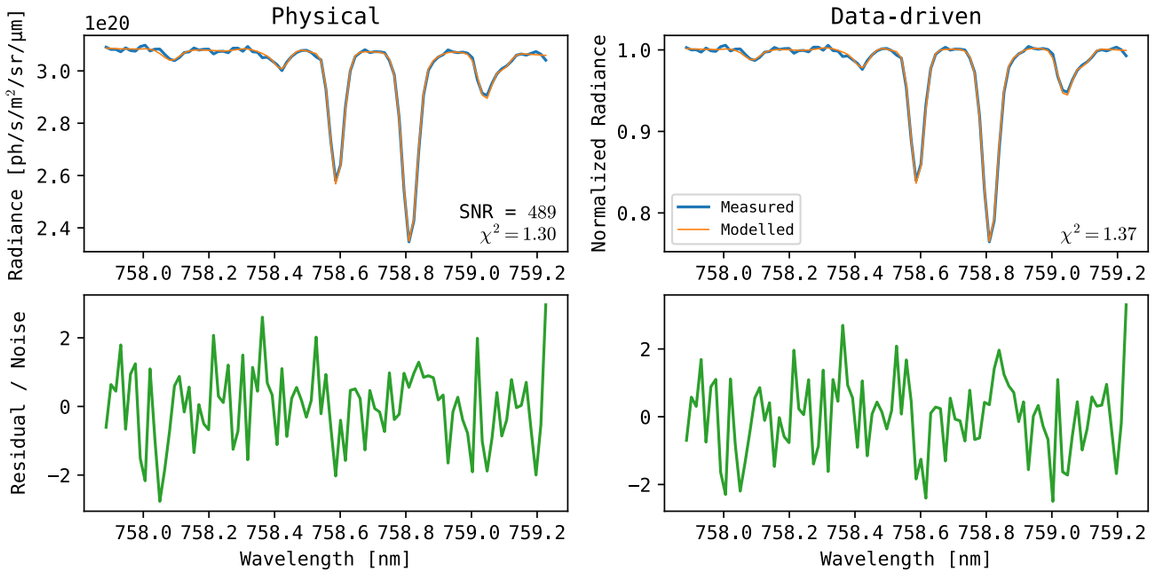
- For this study, we use ”perfect” retrievals, i.e. we use the same solar model as truth
- SIF truth at surface is derived from MODIS GPP (0.5 deg), scaled with day of year and time of day
- Radiative transfer fully propagates the surface SIF to top-of-atmosphere using multiple scattering
- Presence 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

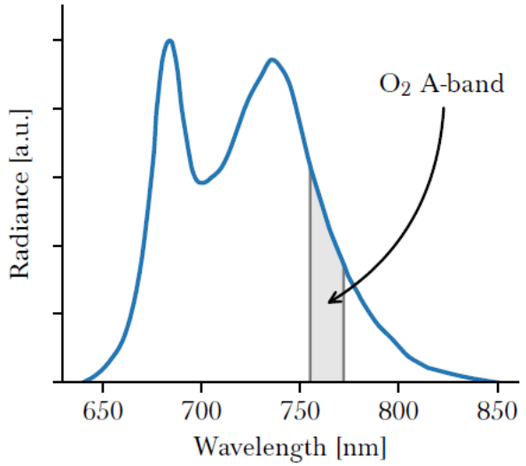


Retrievals of solar-induced chlorophyll fluorescence (SIF)



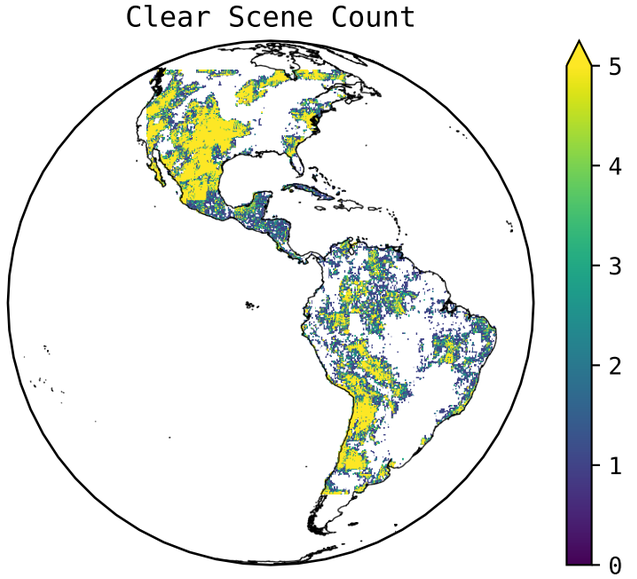
- We utilize two retrieval algorithm concepts
- Physical retrieval (Frankenberg et al. 2011)
  - Uses solar- and instrument model, influence of gaseous absorbers in a model atmosphere
- Data-driven retrieval (Guanter et al. 2012)
  - Uses waveforms derived from measurements taken over non-vegetated surfaces
  - Fully linear retrieval, no iteration needed

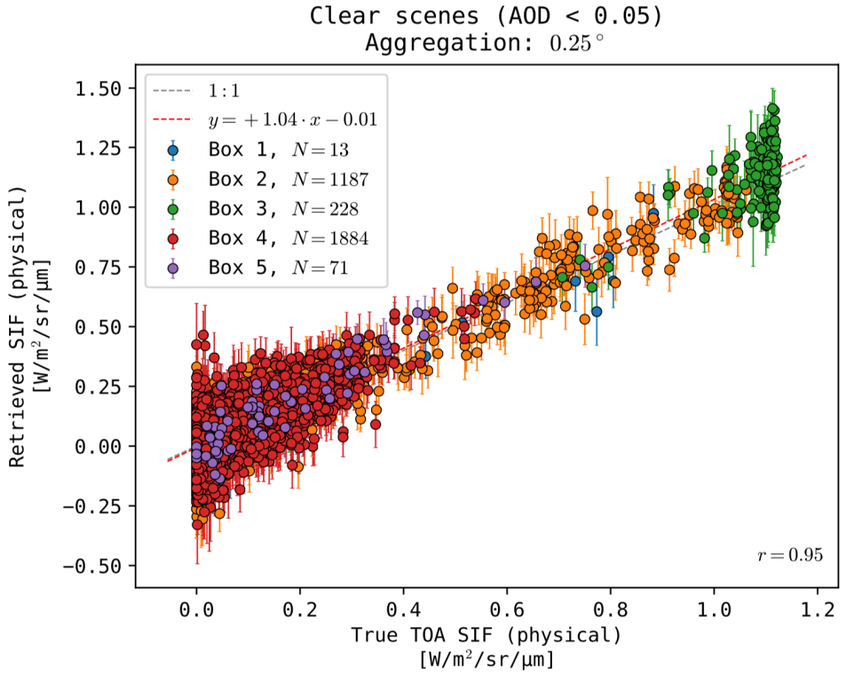
- Each concept has its own strengths
  - "Physical" makes result of retrieval process more intuitive
  - Data driven retrieval is fast (~250 µs vs. ~20 ms), but results depend on training data

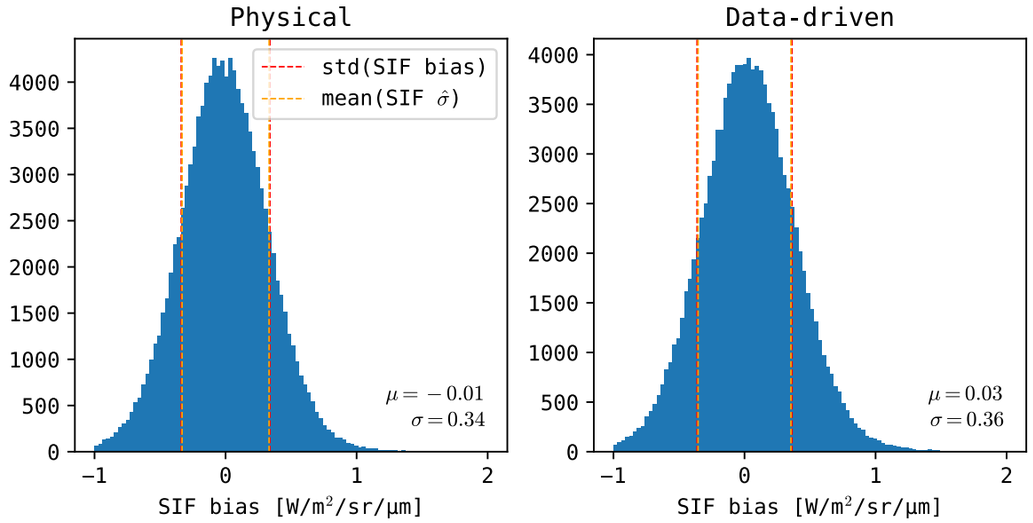


Retrieval Results (#1)

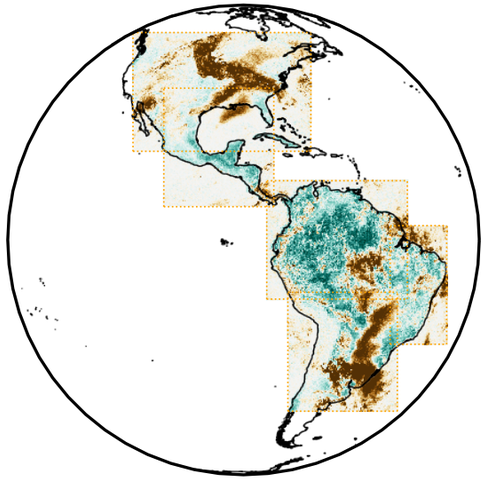
- Retrievals in clear(-ish) scenes reproduces true TOA SIF
- For these scenes, variability is purely instrument noise-driven

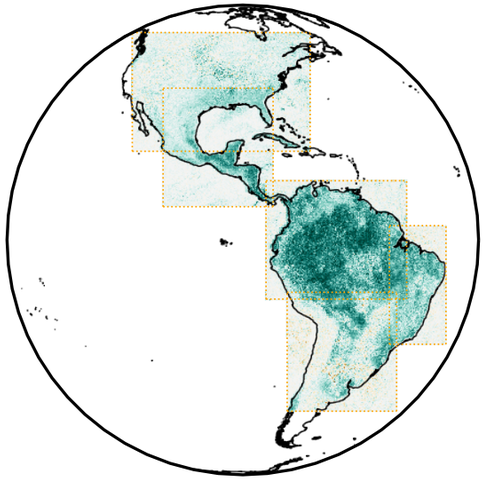


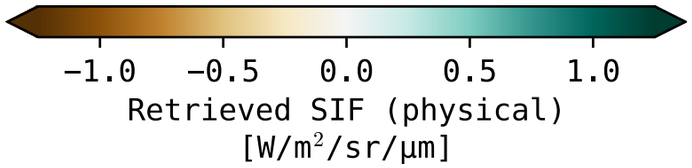


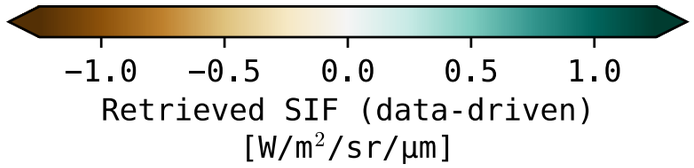


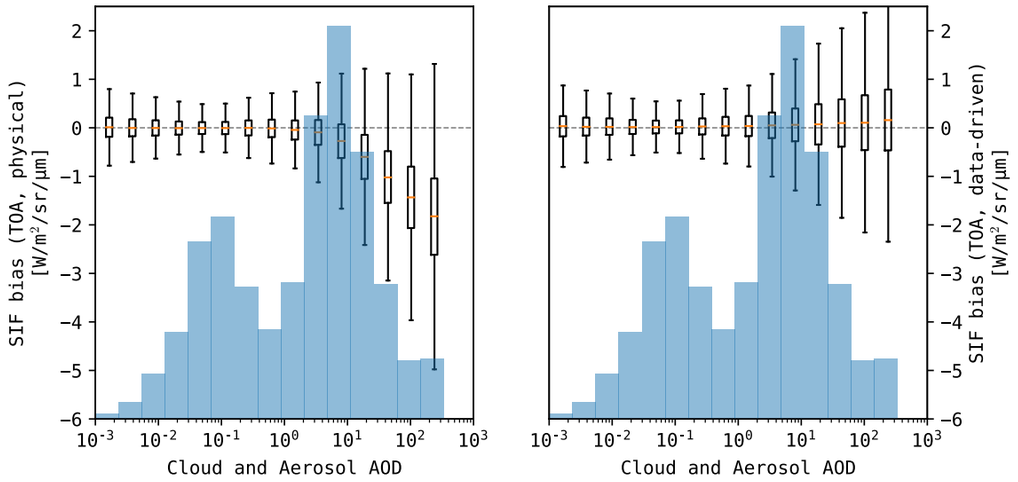
Retrieval Results (#2)







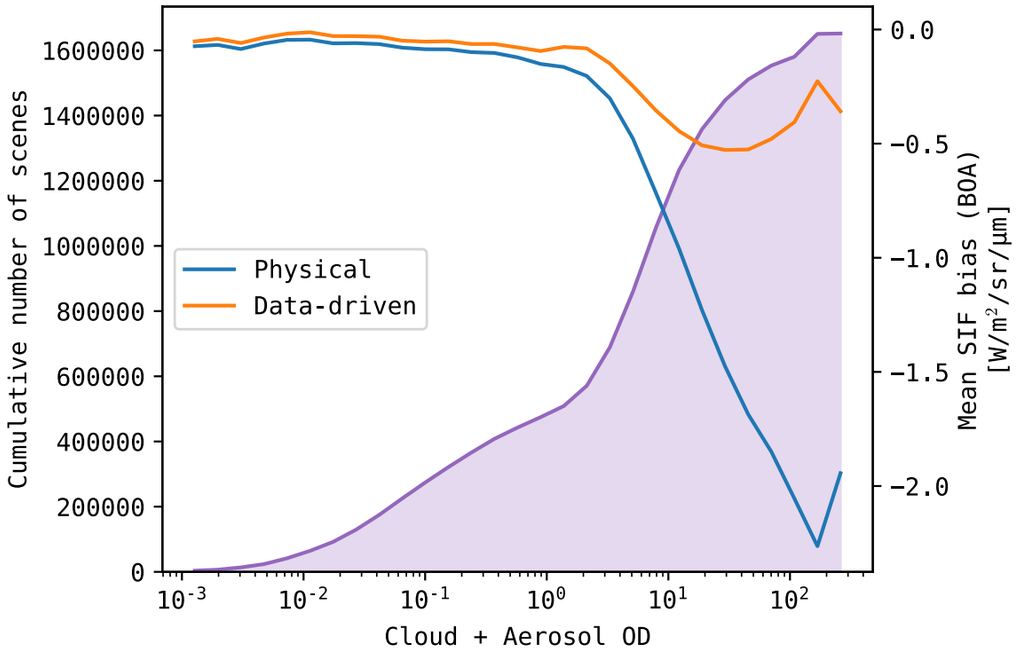


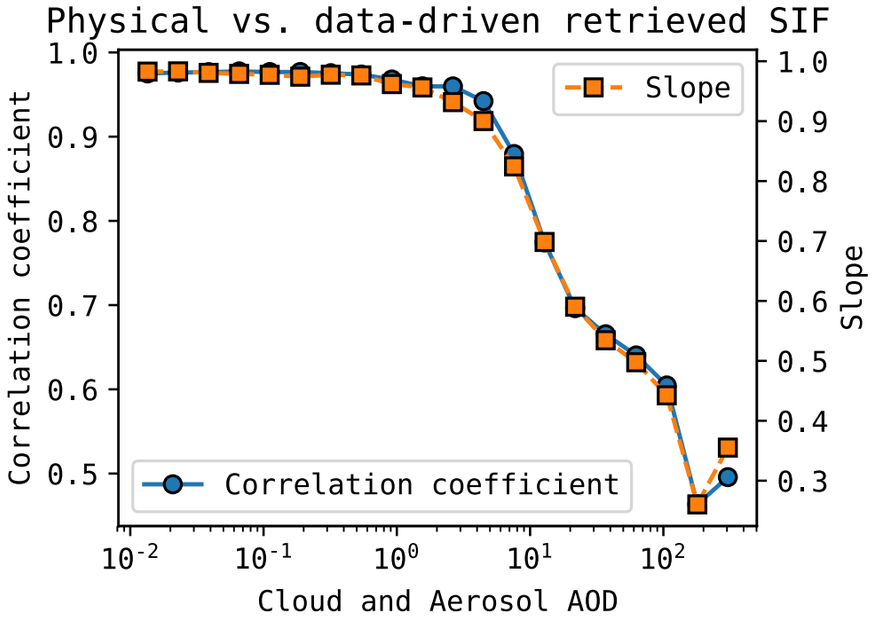


- Picture changes when all scenes are considered
- Physical retrieval (at the moment) does not adjust for changing apparent surface pressure due to clouds
- Very obvious negative bias as result
- Data-driven retrieval captures some of that through the waveforms / principal components
- Physical retrieval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