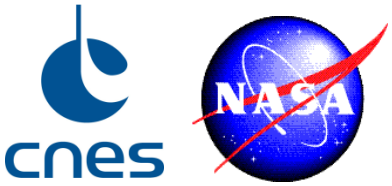


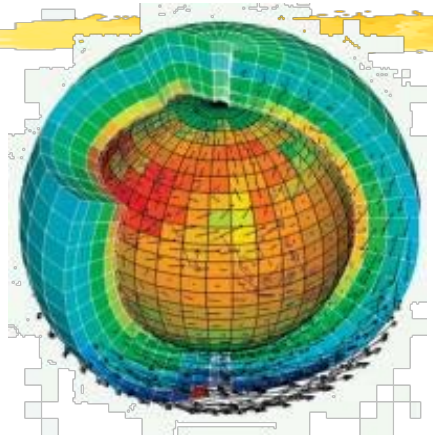
A lidar Aerosol Simulator for the COSP 2.0 Framework

Dave Winker & Nick Schutgens

Helene Chepfer, Po-Lun Ma, Rodrigo Guzman

- What do we mean by ‘simulator’?
- Why would I want one?
- History
- Simulator design, features
- Questions/Issues

COSP =
CFMIP Observations Simulator Package



Facilitate Model-Obs comparisons

Different spatial resolution, different spatial sampling, synoptic vs. asynoptic, instrument limitations, etc.

Observation simulator

CFMIP Observations Simulator Package (COSP)

- **"CALIPSO simulator" (developed at LMD)**
- **subgrid cloud overlap**
- **forward model for CALIPSO simulations**

Simulated CALIPSO-like dataset

Instrument Level 1 data is processed consistent with simulator algorithm

(*avoids retrievals*)

matching observational dataset (GOCCP) (Chepfer et al, 2010)

Same grid, same parameters

Goal: model-observation differences due only to model deficiencies

Genesis

- An “instrument simulator” developed to facilitate cloud comparisons between ISCCP and model simulations: Klein and Jakob (MWR,1999)
- COSP package now includes simulators for many additional sensors:
  - MODIS, CALIOP, MISR, CloudSat, …
- The lidar CALIOP cloud simulator in COSP has been widely used by CFMIP community
- Darmstadt, 2014: what about an aerosol simulator? Target Aerocom?

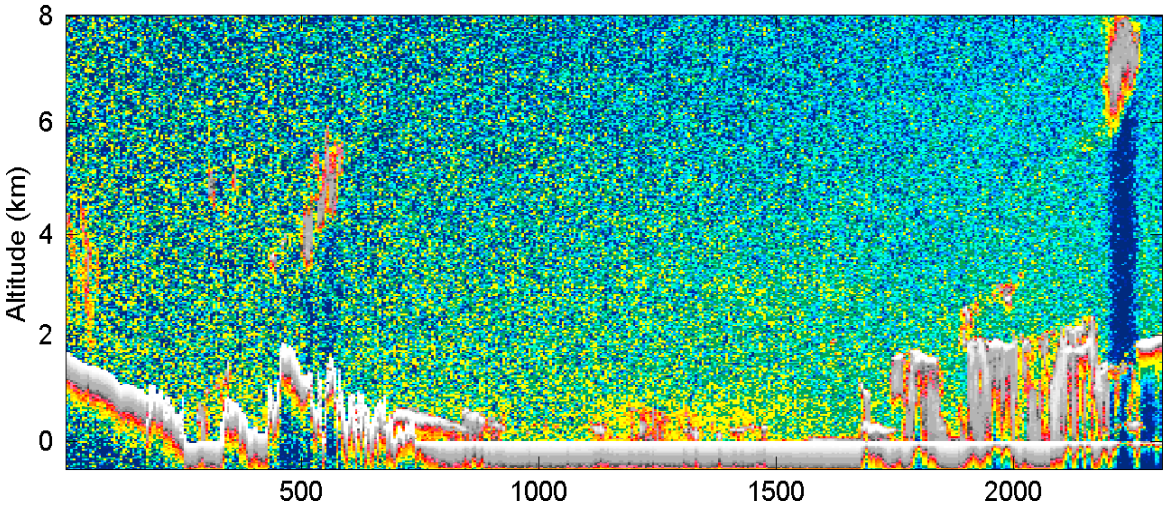
- Development of lidar aerosol simulator for CAM5-PNNL model
  - Ma et al. (Nat Comm 2018)
- Aerocom c. 2016: implement a more general simulator within COSP for all Aerocom models?

Lidar Aerosol Simulator

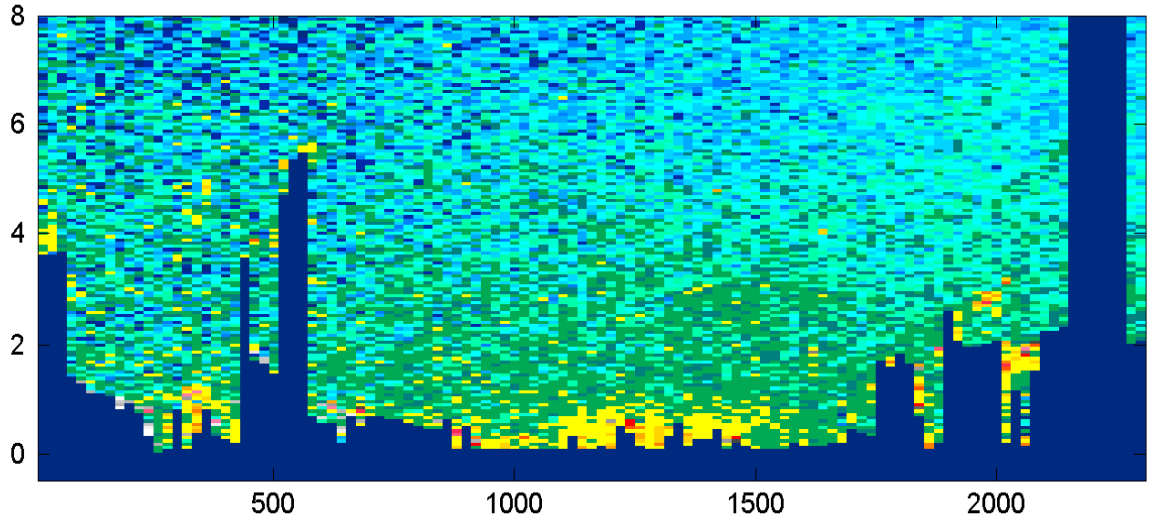
- Addresses issues of:
  - Blockage of lidar signal by clouds
  - Limited detection sensitivity
  - Extinction retrieval errors
  - Must avoid biases due to imperfectly simulated clouds

- Simulator concept:
  - Facilitates intercomparison of both Level 1 profiles and extinction
    - ✓ Comparison with Level 1 profiles avoids detection sensitivity issues
    - ✓ No assumptions on observation side, differences due only to model simulation of aerosol
  - Paired with a special CALIOP observational dataset: “Level 1.5”

Simulator 'Target': CALIOP Level 1.5 Product developed for NWP community ~ 10 years ago



Level 1:
532 nm attenuated backscatter profiles



Level 1.5:
cloud-masked version of L1, horizontally smoothed

Simulator Features

- Simulate lidar return signals from model aerosol extinction and backscatter profiles using the lidar equation:

$$\beta'(z) = (\beta_p(z) + \beta_m(z))\, e^{-2\tau(z)}$$

- Compute attenuated scattering ratio (SR'):

$$SR' = (\beta_m + \beta_p)\, e^{-2(\tau_p + \tau_m)} / \beta_m$$

- Simulator output contains:
  - β' and SR' profiles
  - Profiles of aerosol extinction coefficient as simulated by model

Simulator Design

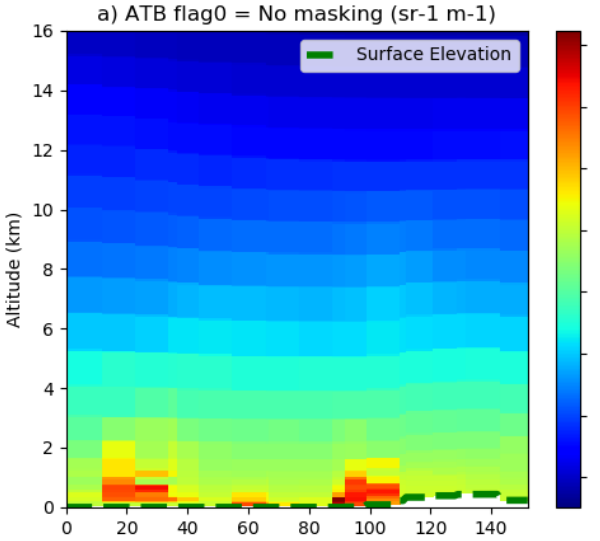
- Model inputs
  - Profiles of aerosol extinction and 180-backscatter coefficients
- Outputs
  - Profile of attenuated total backscatter: $(\beta_m + \beta_p)\, e^{-2(\tau_p + \tau_m)}$
  - Profile of aerosol scattering ratio: $(\beta_m + \beta_p)/\beta_m$
  - Aerosol extinction
    - ✓ Regridded from model to standard COSP grid
      - Also aids model intercomparison
- Four flavors of each profile:
  - Unadjusted profile
  - Cloud-masked
  - Masked for aerosol detection sensitivity
  - Masked for clouds and detection sensitivity

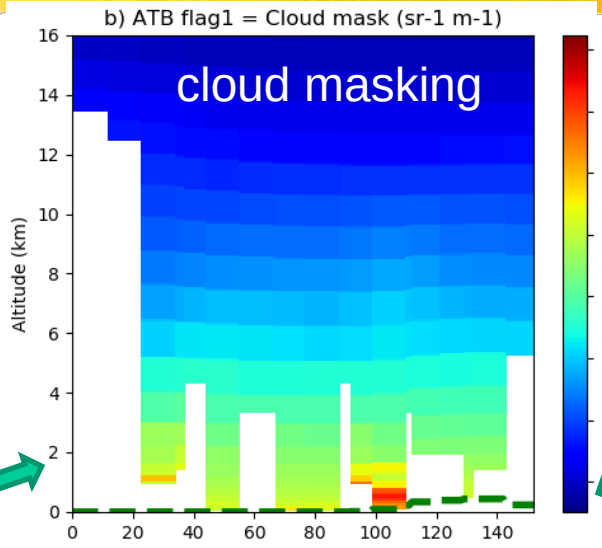
Other features

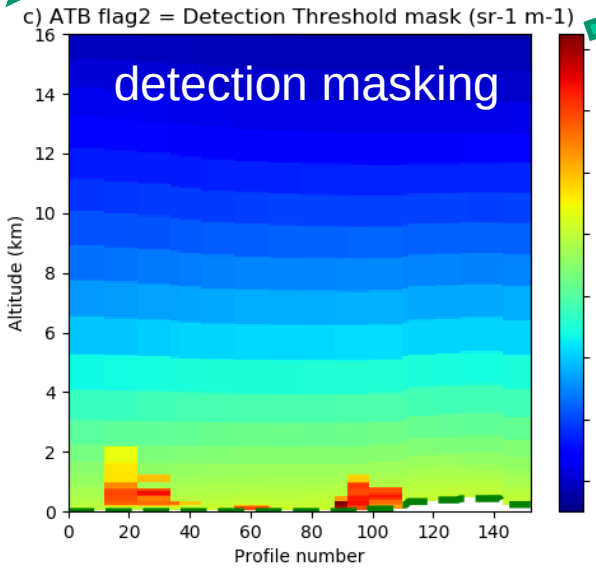
- Output profiles: 320 levels, 0 to 19.2 km (60 m vertical res)
- Computations at grid box scale only
  - No simulation of subcolumns
- Cloud masking:
  - Columns are masked from surface to altitude where cloud fraction in grid box is 100%

Example: attenuated backscatter

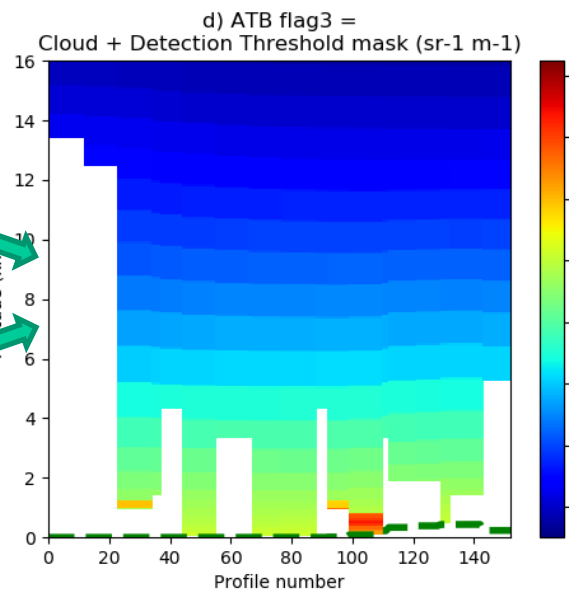
no masking





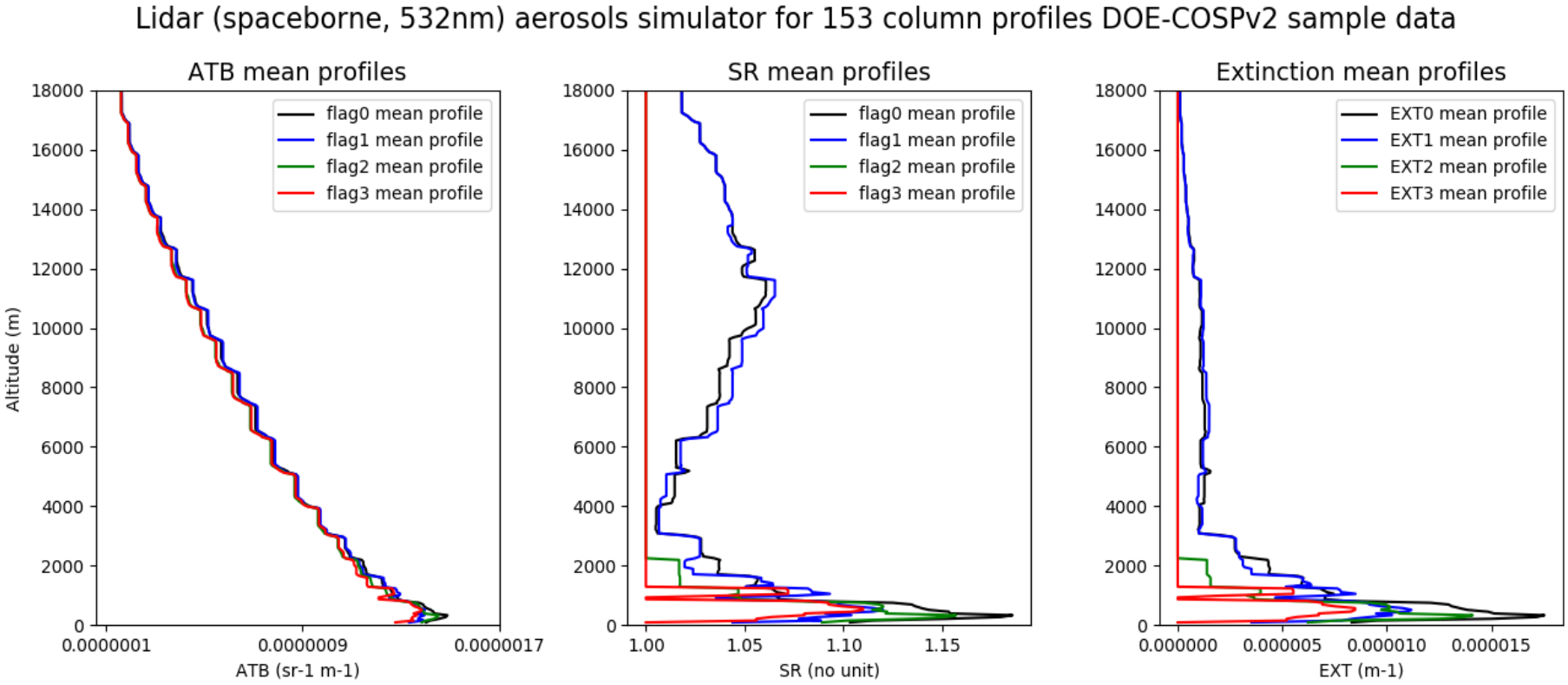


both masks



Profile Examples

Masking impacts on profiles:



Attenuated backscatter | Scattering Ratio | Extinction Coeff.

Possible ways to use Simulator

Level 1 approach:

- Compare simulated Level 1 profiles (β' or SR') with observations
  - Minimal uncertainty on observational side

Level 2 approach:

- Compare model aerosol extinction profiles with CALIOP retrieved extinction profiles
  - Involves CALIOP detection sensitivity and retrieval uncertainties

Level 3 approach:

- Produce monthly mean simulated and observational profiles on a global grid
  - Requires consideration of sampling issues

Next Steps

- Document details of simulator design and outputs
- Solicit feedback from modeling community (Aerocom)
- Revise and integrate into COSP 2.0 package

Questions/Issues

- Simulator produces monthly Level 3 product only?
- Daily/instantaneous (Level 2) product?
- Alternate approach?
  - Include an ‘aerosol mask’ in the Level 1.5 profile product
  - Indicate where CALIOP detected aerosol layers
  - Store retrieved aerosol profiles within detected layers
  - Compare model only where CALIOP detects layers