CALIPSO and ATHENA-OAWL Performance Comparisons

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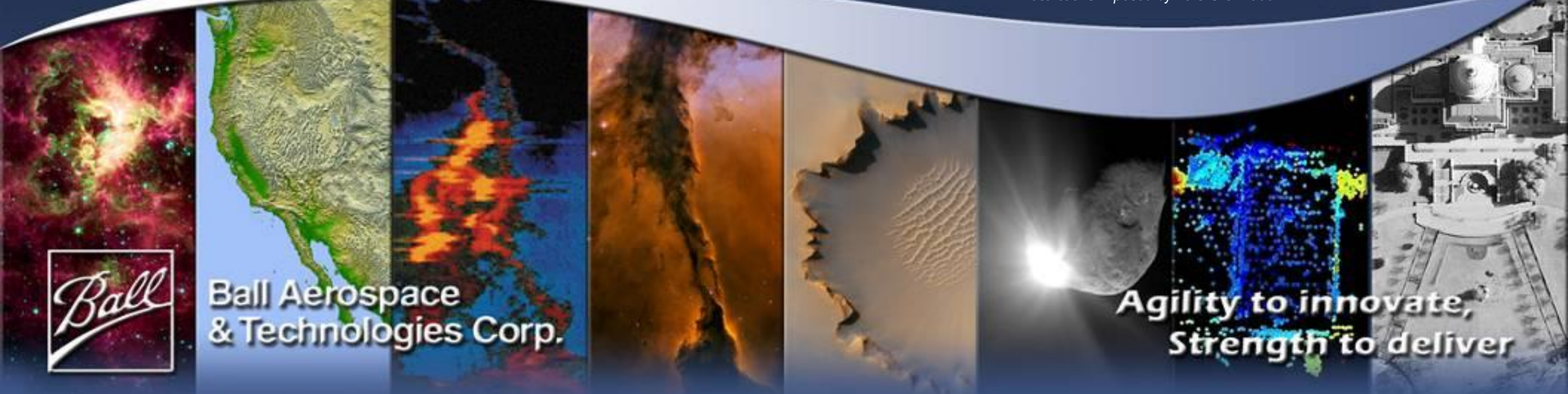


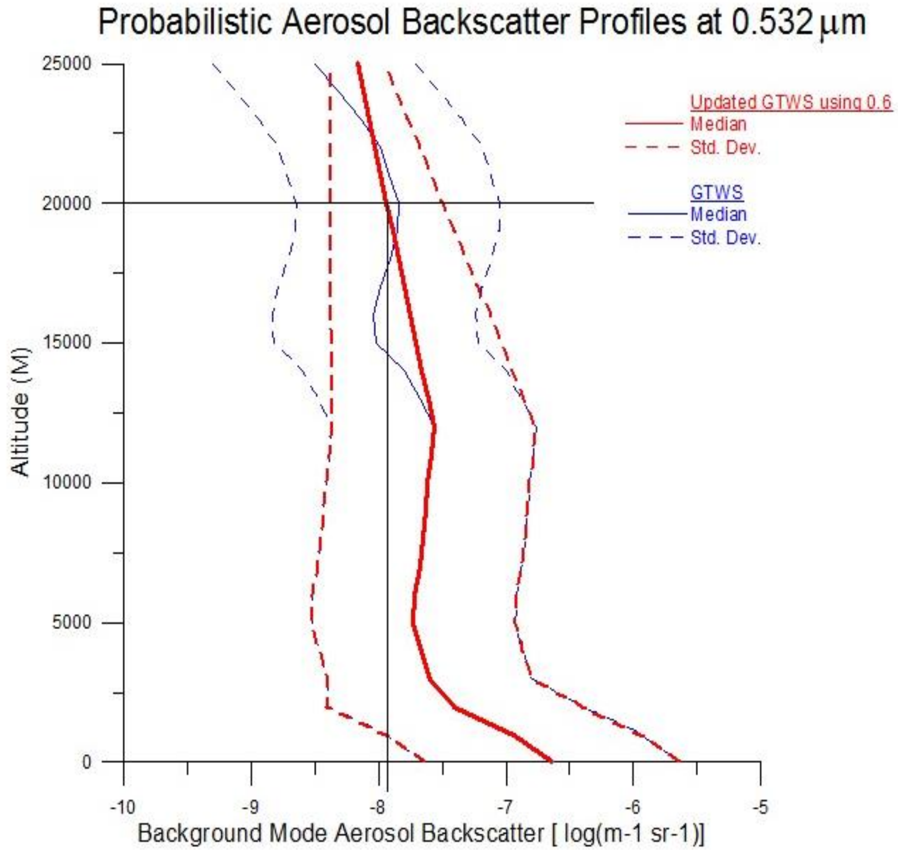
Outline

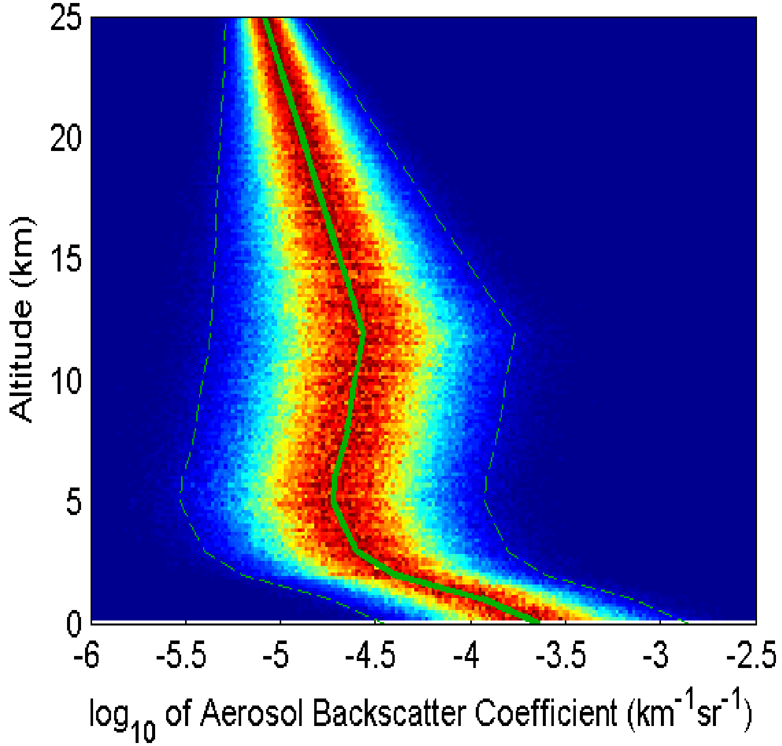
- Predicted ATHENA-OAWL Performance
- SNR vs CNR definitions
- ATHENA-OAWL vs. CALIPSO
- CALIPSO sensitivity
- CALIPSO + SWA-GRABOP profiles
- Implications for ATHENA-OAWL

GRABOP Distributions - SWA

Global Reference Atmospheric Backscatter Opportunity Profile

(Dave Emmitt, SWA, Previous Talk)

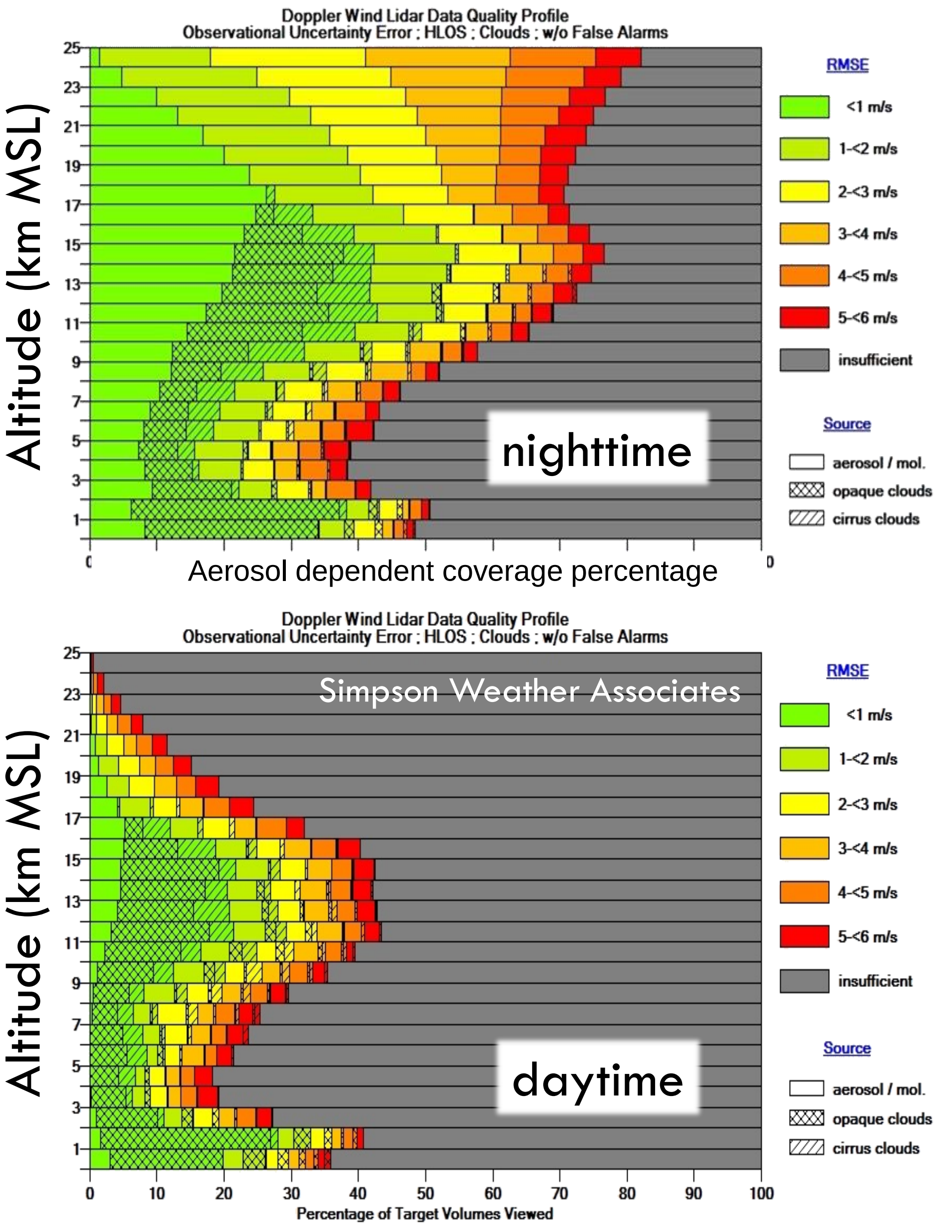




Altitude dependent distributions of aerosol backscatter coefficients based on the 532 nm GRABOP profiles.

532 nm ATHENA-OAWL Performance Prediction

- Performance Prediction Profiles from SWA
- Performance largely depends on aerosol loading
- 15.5 orbits → 8640 profile attempts/day (10s accum.)
- 2100-4000+ profiles (alt. dependent) with ≤ 3 m/s precision
- Compare to ~1200 radiosonde profiles/day



SNR vs CNR

$$P_r(R_z) = \frac{E_t \pi D^2}{R_z^2 \tau \sqrt{N}} T^2(R_z) \beta_{a+m}(R_z) \eta_t \eta_r$$

- CALIPSO "Signal-to-noise" (SNR): total return signal (from molecules and aerosols) vs. noise sources (signal shot, background, and dark)
  - CALIPSO users often incorporate "N" into SNR –
    - Not a per-shot SNR (ambiguous): "better SNR" achieved through more accumulation.
    - Signal *detectability* increases with $N^{-1/2}$.
    - But the terminology has become standard, so…
  - We clarify by using SNR(N) here.
- OAWL lidar signal will also use SNR(N)
- OAWL Wind "*Carrier signal to noise*" (CNR): related to fringe contrast, from the portion of the signal that forms a fringe in the interferometer
  - Wind speed precision improves with N (not CNR)

ATHENA-OAWL vs. CALIPSO

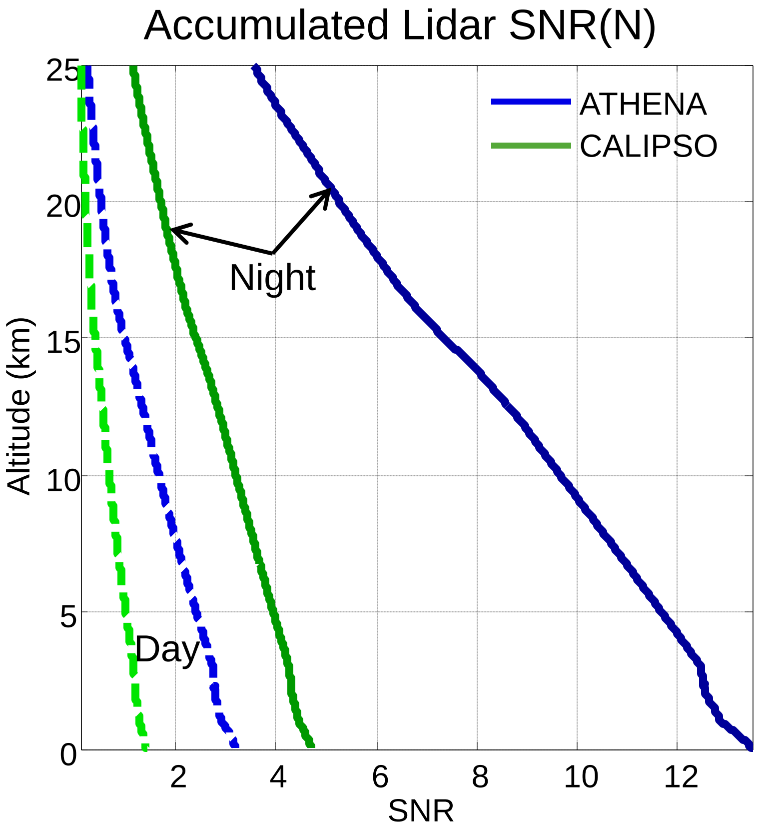
Primary lidar equation parameters:

Instrument Parameter	CALIPSO	A-OAWL	SNR Ratios
Wavelength(s)	1064 nm and 532 nm	532 nm	-
Laser Energy @ 532 nm	110 mJ (per wavelength – 220 mJ total)	160 mJ	1.21 ($P^{½}$)
Laser PRF	20 Hz	150 Hz	2.74 ($N^{½}$)
Telescope Aperture Diameter	1 m	0.7 m	0.49 (Area)
Background Light Filtering	30 pm etalon filter and 1 nm interference filter	Same	-
Detector Type	PMT, QE 0.15	PMT, QE 0.18	1.1
Orbit Altitude	705 km	~400 km	3.11 (R^{-2})
Pointing Angle	0.3° off nadir	40° off nadir	0.77

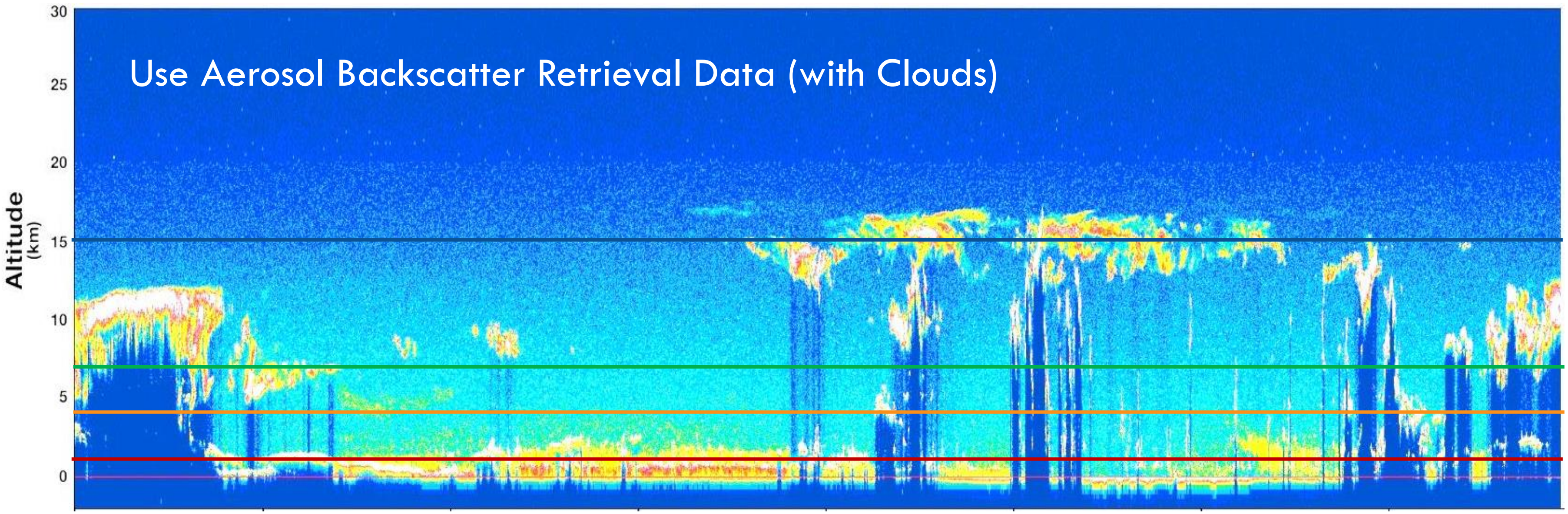
- For the *same* accumulation distances, range gates, altitudes, etc., ATHENA-OAWL will be >3x *more sensitive* than CALIPSO

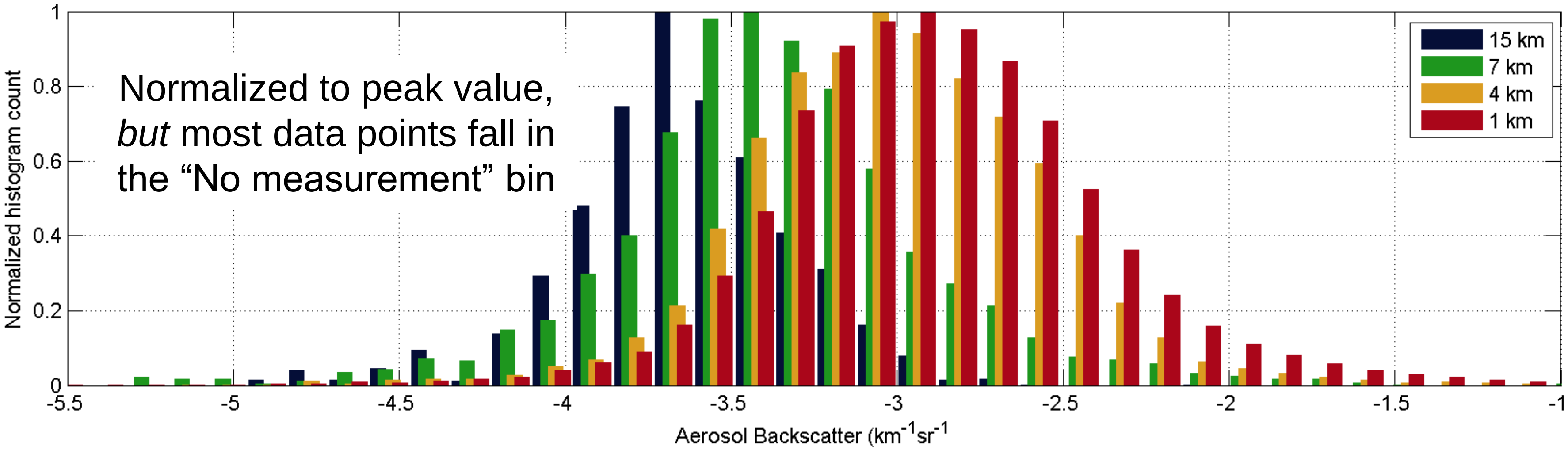
5km Lidar SNR(N) Comparison

- Radiometric model for OAWL based on that for CALIPSO
- ATHENA-OAWL & CALIPSO SNR
  - Day and Night performance
  - Same 5km (~0.7s) accumulation
  - Same 30 m range gates
  - Uses the 532 nm GRABOP profile
- Different angles taken into account
  - 0.3° for CALIPSO
  - 40° for ATHENA
- 5km is for sensitivity comparison: OAWL will use 70-80km accumulation for winds
- 2X profiles from ATHENA (one per look angle)



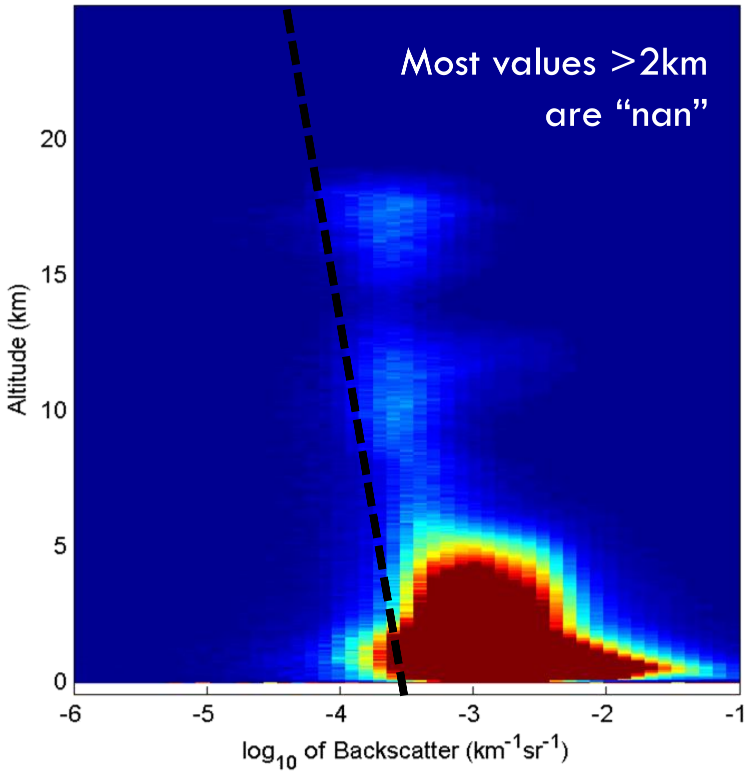
CALIPSO backscatter: histograms from 5km profiles



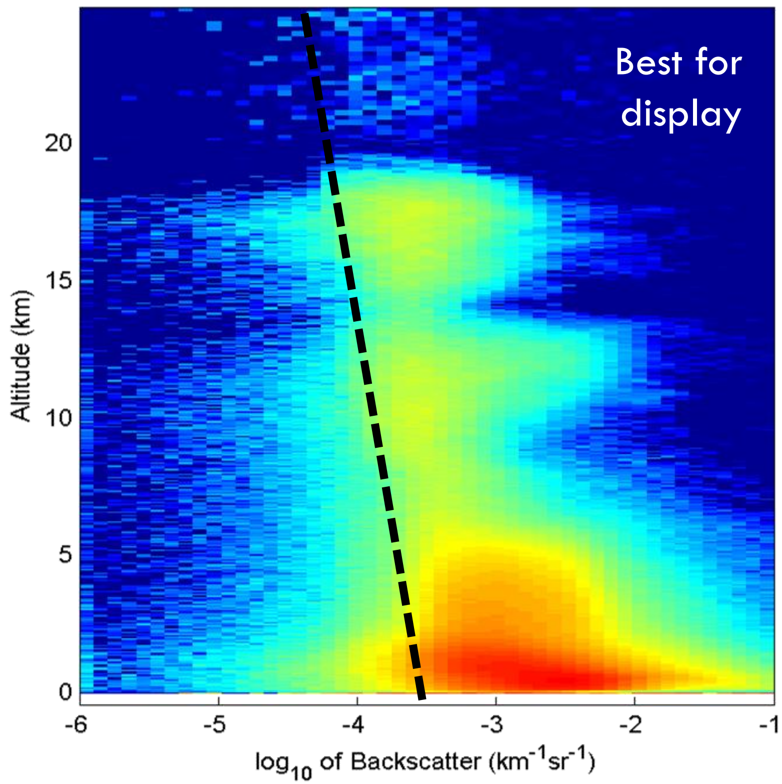


Distribution for every altitude: in color

Altitude-relative distribution of all profiles (linear color)

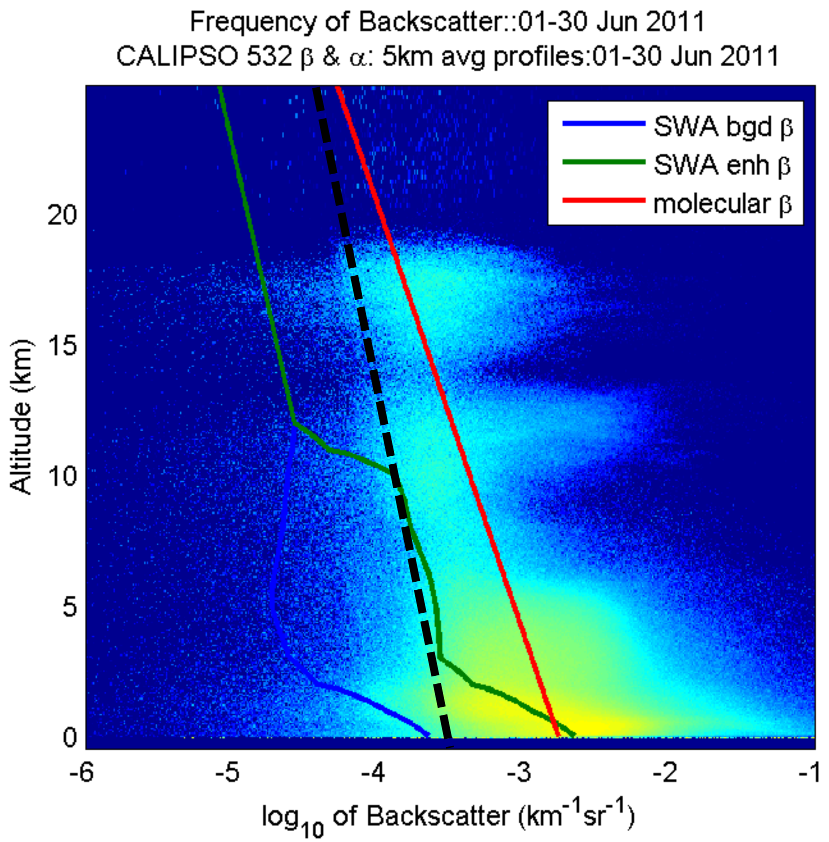


Altitude-relative distribution of all profiles (log-scale color)



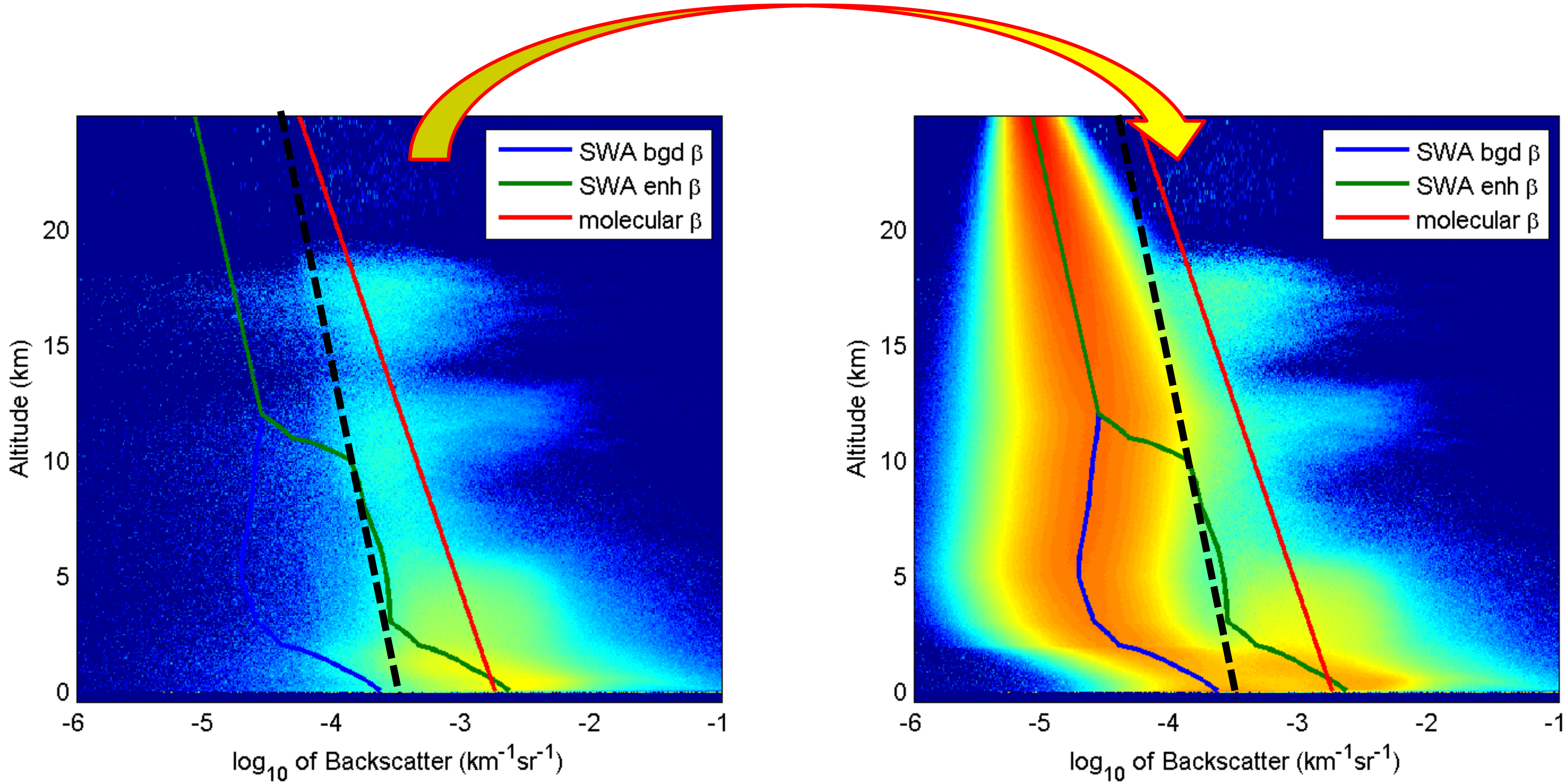
CALIPSO Backscatter histograms vs. altitude

- 1 month (June 2011) of 5km CALIPSO profiles within ±56° latitude
- Finer resolution (in β_a scale)
- Minimum CALIPSO detection vs. altitude
  - a sloped “edge”
  - edge smearing due to 5km averaging
- GRABOP profiles over-plotted for reference



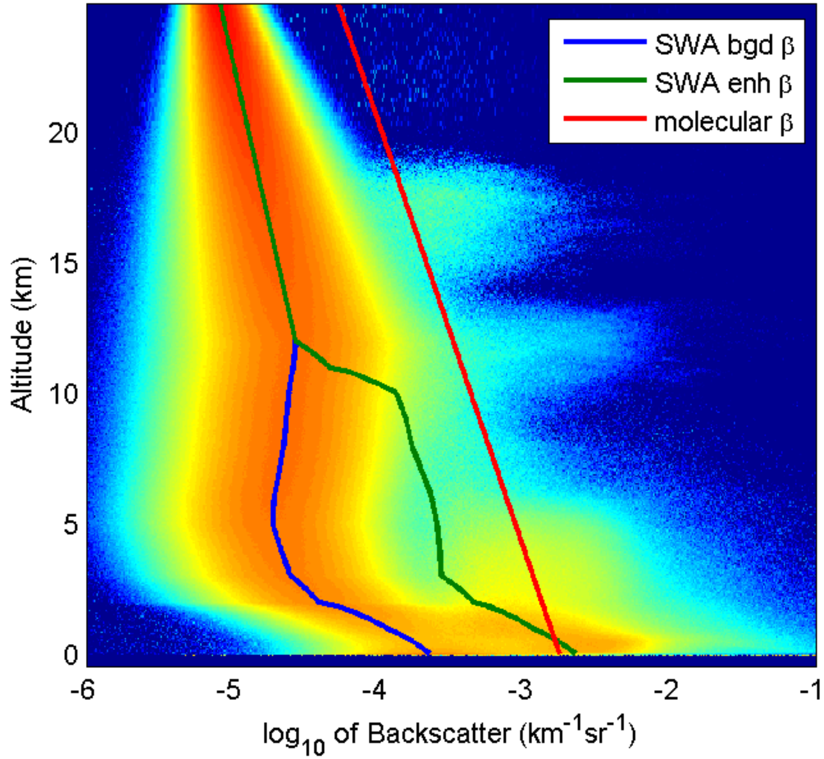
CALIPSO data + SWA Background Mode

Fill in missing profile data with a random value from the GRABOP Distribution

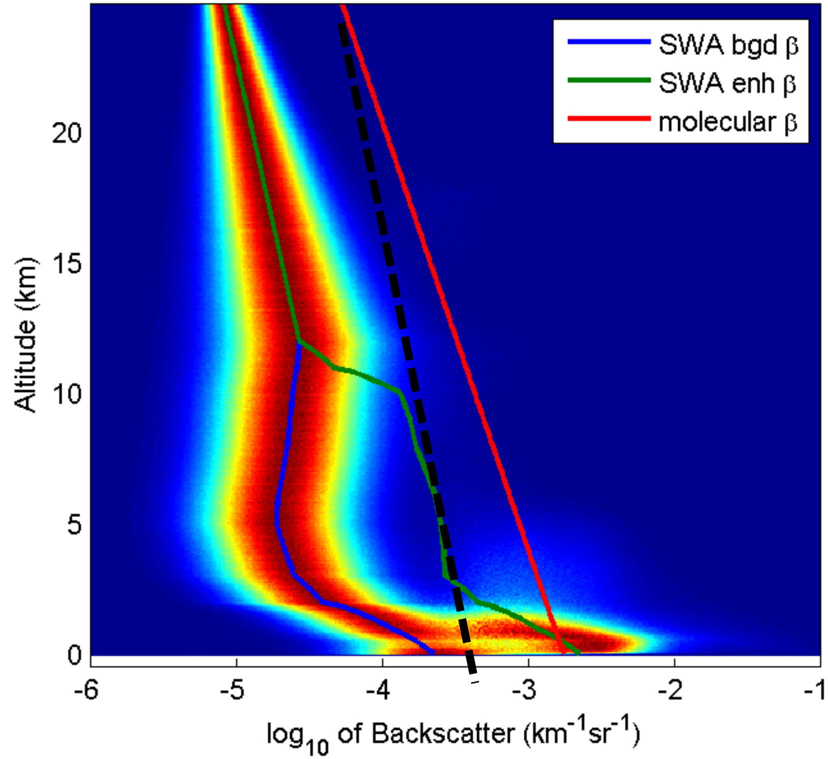


Log_{10} histogram count color scale

CALIPSO data + SWA Background Mode



Log$_{10}$ color of histogram count



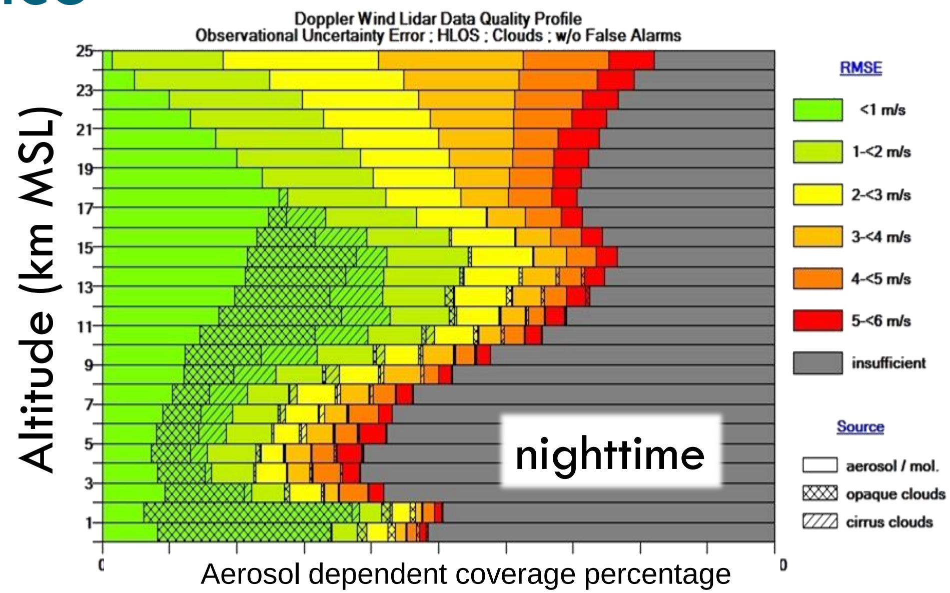
Linear color of histogram count

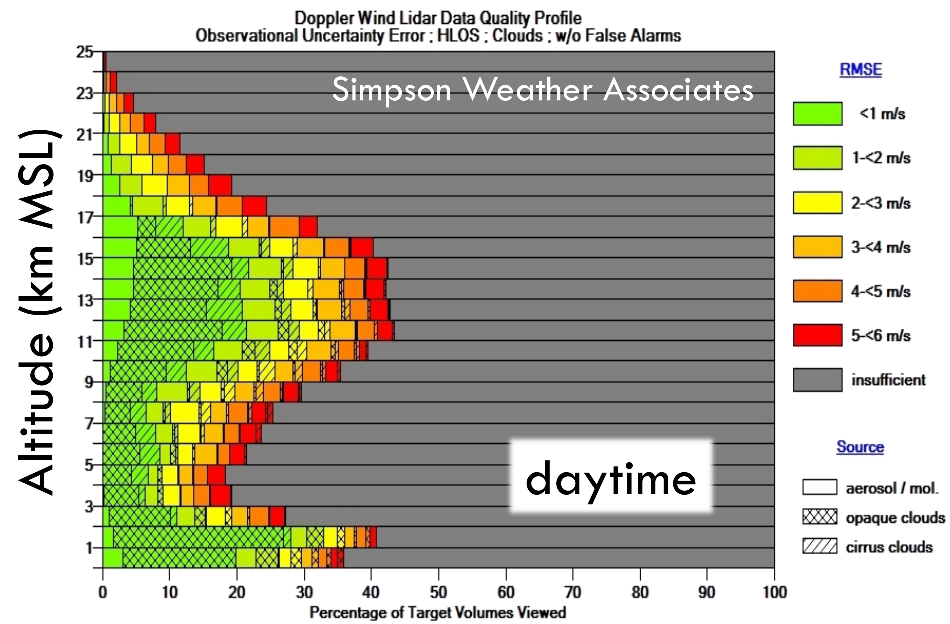
CALIPSO informs ATHENA-OAWL performance predictions

- CALIPSO doesn't see the background mode…
- …but it tells us *where* the 532 nm background mode is conservative.
  - In the lower troposphere – 532 BGD is conservative
  - Higher altitudes – 532 BGD is likely a good basis for prediction
  - "True" distributions lie somewhere in between (altitude dependent)
- Performance prediction models also take into account aerosol and cloud **extinction** (Provided by CALIPSO, filled in with the background mode model values)

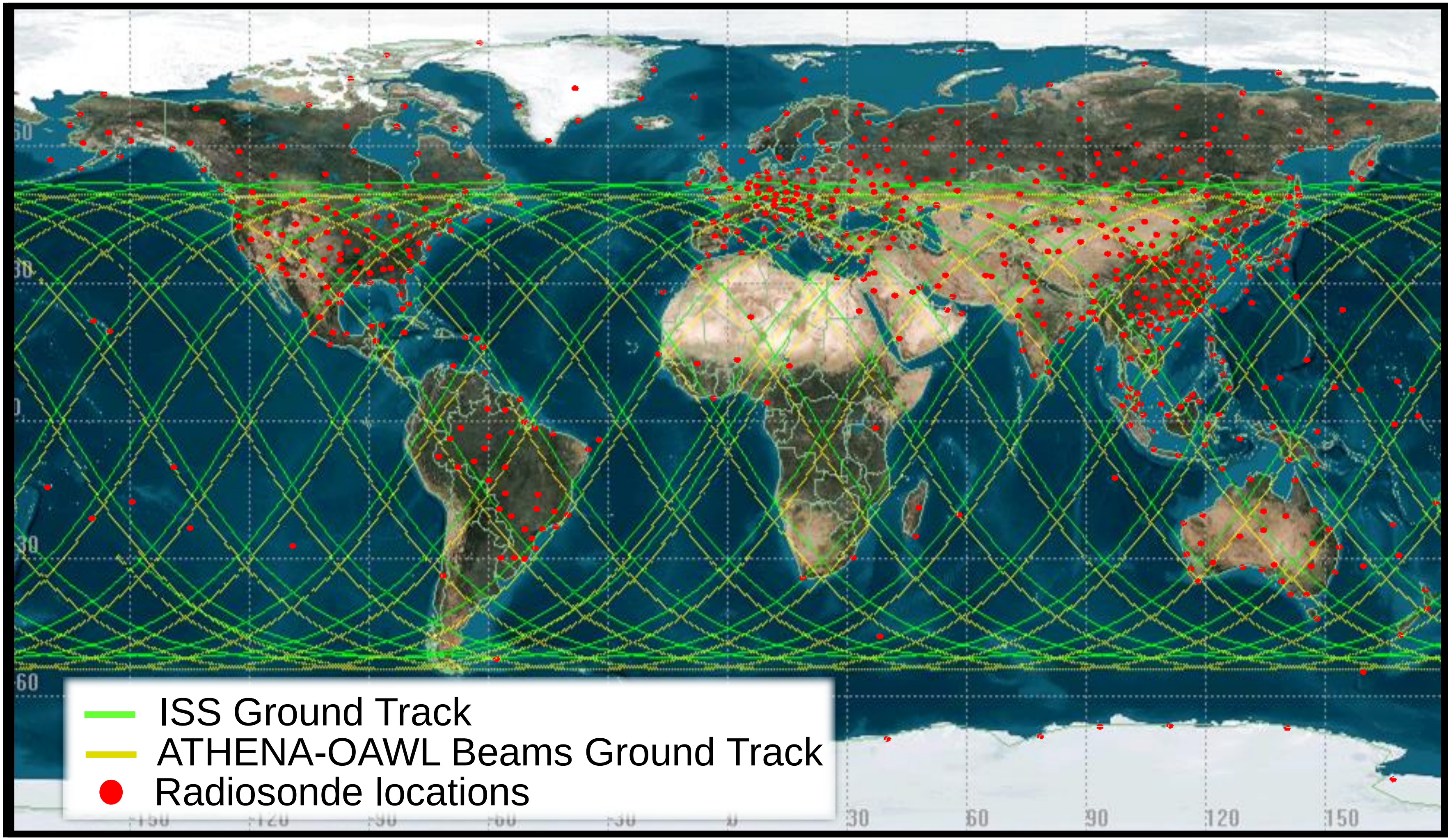
532 nm OAWL Performance
Nighttime vs. Daytime

- Still based on GRABOP background mode only
- 8640 profile attempts/day (10s accum.)
- 2100-4000+ profiles per 24 hours (alt. dependent) with ≤ 3 m/s precision

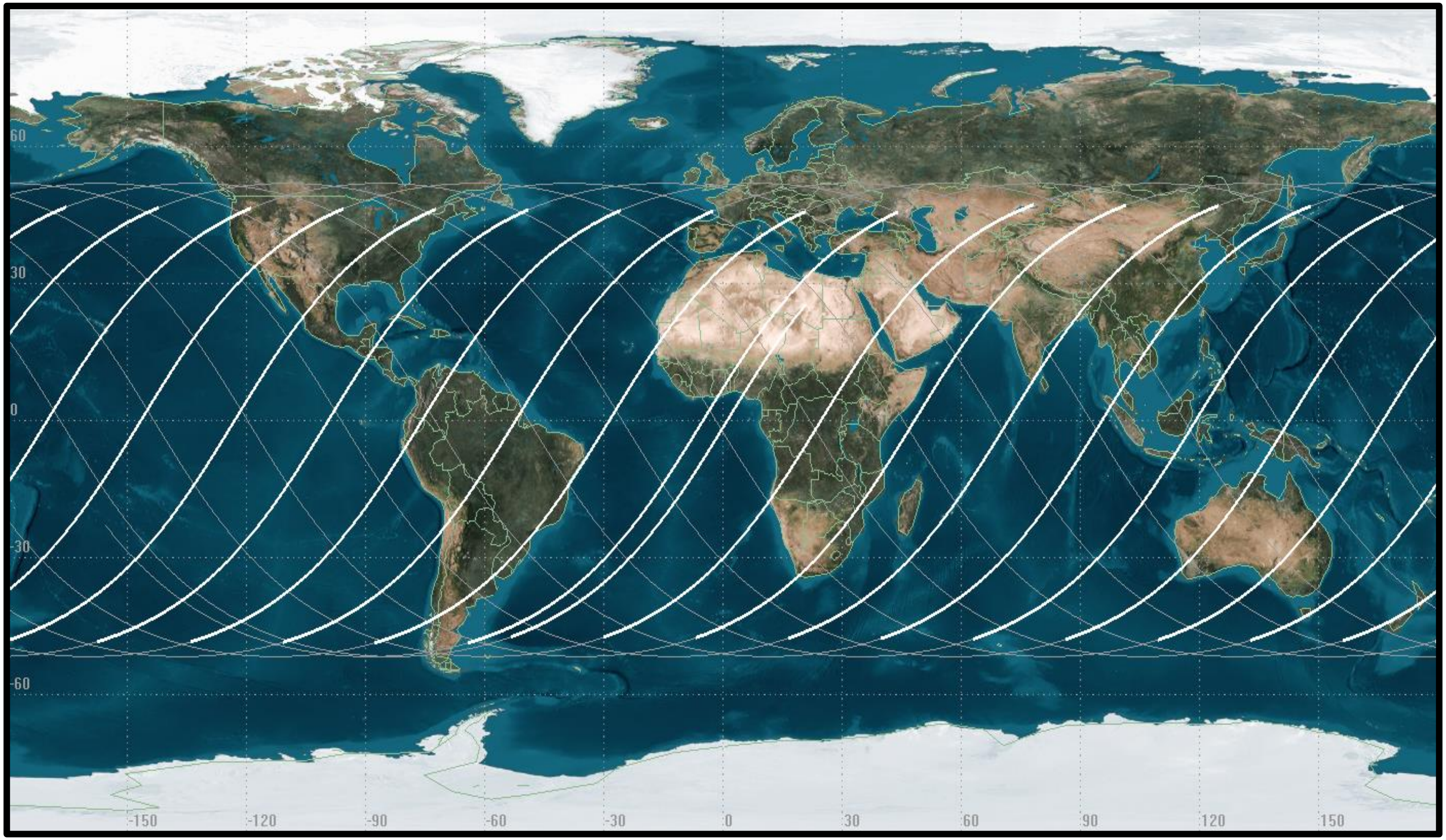




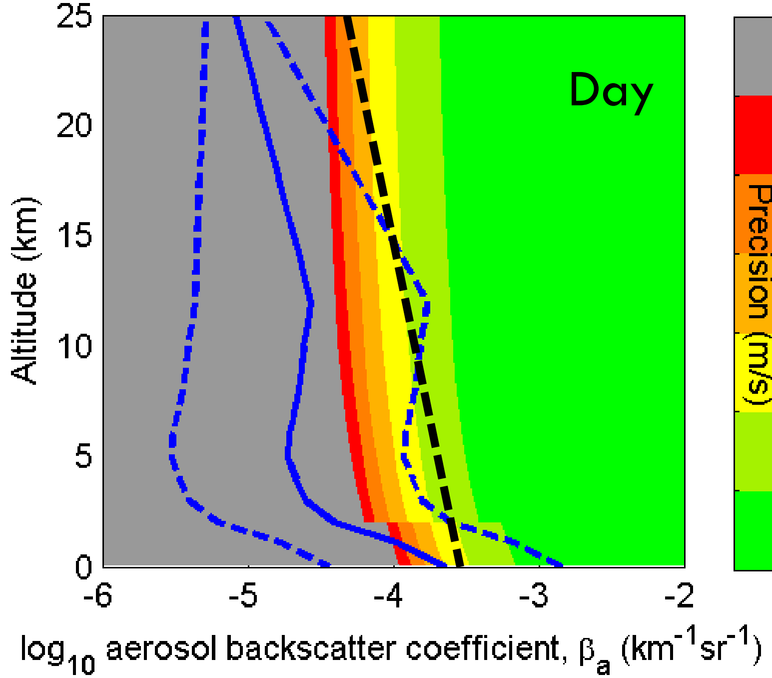
OAWL ISS Coverage (Example 24 hours)

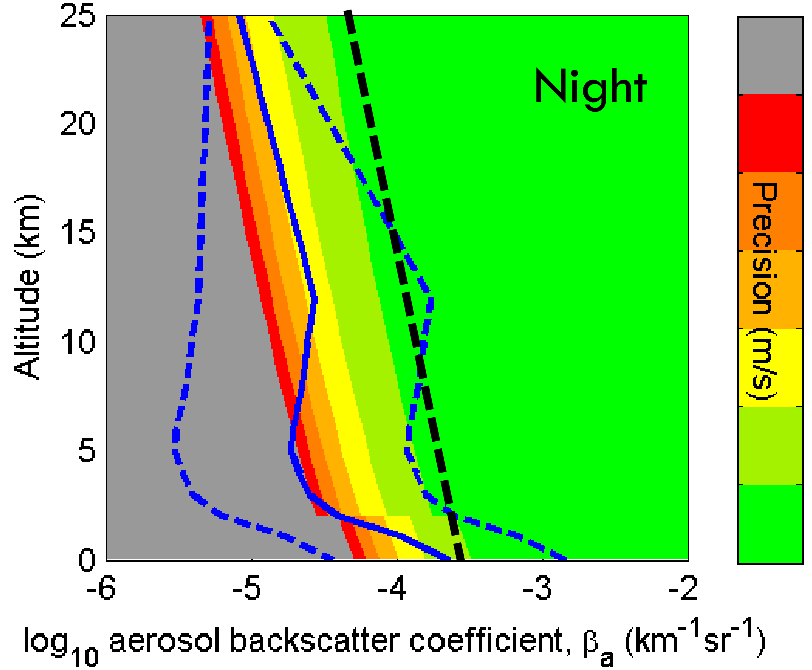


ISS Tracks – Night vs. Day



ATHENA-OAWL performance maps of precision vs. altitude/backscatter





Almost everywhere CALIPSO makes an aerosol backscatter measurement
ATHENA-OAWL would have better than 3 m/s precision (day)
and better than 2 m/s precision (night)

Future efforts in this area…

- Generation of **shot coverage files** (timing, pointing, ISS motion, → maps of atmospheric coverage)
  - Strong STK (software good for orbit geometry) expertise at Ball
- Integration of **CALIPSO extinction** (including cloud extinction), filled in with GRABOP extinction profiles
- Extension from 1-month global distribution profiles to distribution profiles for **annual/spatial variations**
- Work with SWA to combine CALIPSO results, and CALIPSO/OAWL instrument models with **nature run** (clouds, etc.) to improve prediction estimates.
- Incorporation of **jitter/vibration/pointing** effects on performance (accuracy and precision)
- **Wind processing testbed:** Combine radiometric model with OAWL signal models and processing algorithms and use them to test/further develop:
  - pointing angle correction algorithms
  - cloud processing/weighting algorithms
  - Forward/aft overlap opportunities
  - LOS winds processed into horizontal wind speed & direction
  - Aerosol studies (two looks)

Summary

- ATHENA-OAWL designs build on those from CALIPSO/CALIOP.
- CALIPSO performance helps to validate expectations for ATHENA.
- GRABOP background mode profiles indicate sufficient performance to meet ATHENA mission goals.
- 2x+ more profiles from ATHENA-OAWL than provided by the radiosonde network
  - With better global distribution
- CALIPSO data suggest there will often be more aerosols than predicted by background mode.
  - Good news for ATHENA-OAWL performance
- ATHENA-OAWL is expected to be at least 3x more sensitive than CALIPSO for the same accumulation time/range.
- Measurements in the forward-looking ATHENA-OAWL profiles will have overlap with the aft-looking profiles → 2x measurements for aerosol studies.