Trends and continuity in the AOD record for MODIS, VIIRS, and GEO sensors

Virginia Sawyer, Rob Levy
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Global average AOD Collections 5.1-6.1

- Offsets in Terra-Aqua AOD have decreased and become more constant with successive MODIS collections
- No more multi-year trends. Global average AOD changes seasonally, but not significantly over the 20-year MODIS mission
- This is thanks more to updates to L1b reflectances than to changes to the Dark Target algorithm itself
- Small offsets in L1b reflectances (±2-3%) lead to larger offsets in AOD (~10%)
Multiple wavelengths and regional trends

• Terra-Aqua offsets can vary by wavelength, which affects Ångström exponent and any other measure that compares multiple bands

• Lack of a trend on the global average does not mean there are no regional AOD trends

• Reductions in industrial and urban emissions over the last 20 years are almost exactly balanced by increases in AOD elsewhere

• Do Terra and Aqua agree?
• Linear regression of monthly average AOD since Aqua mission began, June 2002 – June 2020

• Trends are calculated for each L3 1°×1° grid cell and plotted only if significant (p ≤ 0.05)

• Difference in trends between Terra and Aqua is plotted only if both show a significant trend, but the two sensors broadly agree
• Decrease over eastern North America, Southeast Asia, and Europe in spring and summer coincides with emissions reductions to improve air quality
• Increase over India and outflow region peaks in fall and winter and coincides with an increase in agricultural burning
• Cause of widespread increase in AOD over the Southern Hemisphere oceans is unknown
Regional trends in Ångström exponent

- Ångström exponent is based on the ratio between AODs at 0.55 $\mu$m and 0.86 $\mu$m over ocean, and 0.47 $\mu$m and 0.66 $\mu$m over land.

- Trends would imply that particle sizes are increasing (orange, “dustier”) or decreasing (purple, “smokier”) over time, and could mean a change in aerosol composition or sources.

- This time Terra and Aqua show major disagreement, especially over ocean.
  - Aqua shows few significant trends but mostly decreased AE over tropical oceans.
  - Terra shows much more widespread trends, especially strong increases in AE over high latitude oceans (only measurable in summer).
Regional trends in fine mode fraction

- Fine mode fraction is derived from the Dark Target aerosol model solutions, but has similar patterns to Ångström exponent trends:
  - Terra shows an increase in fine mode aerosols in the high latitude oceans
  - Aqua shows few grid cells with any significant trend, but some decrease in fine mode aerosols over tropical oceans
- Very high edge values may be due to limited sampling at extreme latitudes
- Why do they disagree? Which trends are real?
- Terra and Aqua are not our only sources for Dark Target data...
Adding VIIRS SNPP to the Climate Data Record

- Dark Target ported to SNPP VIIRS is now on Worldview and LAADS, updated to version 1.1
- AOD offsets between SNPP and Aqua are smaller than those between Terra and Aqua
- Upcoming VIIRS NOAA-20 product will further extend the AOD satellite climate data record, but will also come with its own offsets
- Which one is “true”? Users who need a single unbroken data record may choose to transition from Aqua to NOAA-20, and adjust the others to match
Regional trends in VIIRS SNPP AOD, 2012-present

- Trends from 2012-2020 are not the same as from 2002-2020, and shorter records mean fewer significant grid cells.
- However, SH ocean and Southeast Asia show similar trends to the longer record, implying these changes are relatively steady.

VIIRS SNPP

Aqua

Terra

AOD seasonal change per year where $p \leq 0.05$
Dark Target for more sensors

- VIIRS NOAA-20 version is in development, and the same process will work for future VIIRS launches.
- Dark Target ports for the geostationary imagers aboard Himawari-8, GOES-E, and GOES-W.
- Geostationary Dark Target is capable of capturing the aerosol diurnal cycle, and opens the possibility of multi-sensor joint retrievals.
- Combined product is gridded 0.1°×0.1°, must account for different instrument resolutions and measurement intervals.
Summary and further questions

• Terra, Aqua, and SNPP roughly agree that while globally averaged AOD does not show multi-year trends, there are significant regional trends
  • Over land, they appear to match what we know of changes in air quality
  • Over ocean in the Southern Hemisphere, a slow but widespread increase in AOD needs to be explained

• Terra and Aqua disagree on whether particle size is changing, particularly in the SH ocean
  • Terra sees an increase in fine mode aerosol, but Aqua sees no significant change
  • Why do they agree on total AOD, but not on Ångström exponent or fine mode fraction?
  • Both are physically plausible, but we need more information

• VIIRS SNPP, geostationary imagers, and eventually NOAA-20 and future VIIRS have Dark Target ports with their own sources of data, albeit much shorter data records so far

• Each new sensor will have its own offsets and sources of trend disagreement