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Remotely-sensed total-column observations over terrestrial and marine environments and their use for estimating surface nitrogen dioxide

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The Pandora spectrometer, an instrument that uses a direct-sun approach to column measurements of trace gases, has performed well in a range of polluted regimes in North America, Europe, and Asia. Pandora shows promise for (1) satellite validation of current (OMI and GOME) and future (TROPOMI and TEMPO) missions and (2) long-term observations of ground-truth ozone (O_3) and nitrogen dioxide (NO_2 - an O_3 precursor) column amounts that are important for monitoring the earth system. We report the first comparisons of a collocated Pandora, in situ surface, and OMI observations in two regions: (1) the industrialized South African Highveld and (2) the Eastern US coast in the Northern Atlantic Ocean. We contrast the performance of the remote-sensing instruments, satellite and ground, in each terrestrial and marine environment. The terrestrial ground-based measurements were made during January-March 2011 at the Welgegund atmospheric station of North-West University Potchefstroom, $\sim$ 100 km south-west of the Johannesburg-Pretoria conurbation. The marine ship-based surface measurements were completed during July-August 2014 in the North Atlantic as part of the Deposition of Atmospheric Nitrogen to Coastal Ecosystems (DANCE) campaign, $\sim$100 km east of the mid-Atlantic United States. Both locations have no local pollution source, but are influenced by terrestrial air masses from regional pollution sources. Comparisons of coincidental, quality-controlled OMI and Pandora total column O_3 and NO_2 measurements show statistically significant correlation in both environments. For NO_2, the difference between the two instruments is $\sim$ 20%, which is comparable to previous studies under similar conditions. Using the novel Knepp-Kollonige method, we derive surface NO_2 values from OMI and Pandora column measurements and compare to the land and sea in situ NO_2. The planetary boundary layer (PBL) height, a key variable in converting the column NO_2 amount to a surface value, was not measured directly at each location and a co-located Atmospheric InfraRed Sounder (AIRS) product, planetary boundary layer top, was used. The AIRS-estimated PBL height agreed within 10% of radiosonde-derived values (launched at the Irene weather station, 150 km northeast of Welgegund). Absolute differences between Pandora-estimated surface NO_2 and the in situ measurements were best at the terrestrial site ($\sim$0.5ppbv), while detecting clean marine air proved difficult for both OMI and Pandora with differences greater than 1ppbv. These observations highlight the impact air pollution can have on downwind terrestrial and marine locations as well as provide evaluation of satellite- and ground-based remote sensors in both environments.