Summary of PACE Atmospheric Correction Science Team discussion linking the 6 SWIR bands on OCI with the science obtained with those bands

10 March 2016

This is a compilation of discussion occurring on 25 Feb. and 10 March, plus email exchanges occurring in this same time frame.

Jeremy Werdell wrote:

"To clarify, the 1.2 and 1.6 um bands are absolutely part of the SWIR package for PACE. They were not part of the threshold requirements delivered to the Project from HQ - but, as I showed at the Town Hall on Mon, we are treating them as required per the SDT report."

Thus, the Project is moving forward with six required bands for OCI in the SWIR range. The four from the HQ threshold requirements:

0.94
1.38
2.1
2.25

and the two implicitly required in the SDT report:

1.2
1.6

all units in microns.

The need for SWIR bands for aerosol characterization and atmospheric correction has been justified for years. Characterization of coarse mode particles requires the longer wavelengths. There is evidence demonstrated from Landsat and from MODIS analyses that the 1.2 channels and 1.6 channels add important capability that cannot be duplicated with a 2 micron channel or multiple 2 micron channels alone.

Characterization of whitecaps also requires multiple channels in the SWIR spectral window regions, and the separation of whitecaps from other causes of bright pixels will require spectral information through the SWIR.

The 0.94 and 1.38 channels are necessary because they are not in spectral windows, but instead are situated in water vapor absorption bands. 0.94 is used in contrast to 0.86 to derive total column water vapor, an essential atmospheric quantity and the only measure of water vapor from PACE, because the absence of any thermal bands for thermal IR methods. The 1.38 channel is used to identify high clouds and is often the only recourse for identifying and correcting for thin cirrus from a single view radiometer like OCI.

From an aerosol perspective, continuity with MODIS aerosol products, over ocean and land, would require the 1.2, 1.6 and the 2.1 channels. However, we note that VIIRS and the next generation of GEO sensors are using 2.25 instead of 2.1. The switch from 2.1 in MODIS to 2.25 in VIIRS contributed to the difficulty in creating a continuous aerosol time series from the two sensors, but we adapted. However, we also note that while having a "2 micron" channel is important for aerosol retrievals over land and ocean, the retrievals are not sensitive to exactly where that band is placed. We can work with either 2.1 or 2.25. 2.1 gives us continuity with MODIS, 2.25 continuity with VIIRS.

Cloud characterization is more sensitive to the exact spectral location of the chosen SWIR bands. This is because cloud retrievals rely on the absorption strength of ice and liquid in the bands, and especially the difference in spectral contrast between water and ice. For a given particle effective radius, absorption strength is mostly determined by the imaginary part of the refractive index divided by wavelength. The table below gives absorption strength for ice and liquid in the (approximate) SWIR bands of RSP, MODIS, VIIRS and eMAS.

Instrument	band	m_i/lambda(ice)	m_i/lambda(liquid)
rsp	1.59000	0.000201640	6.52383e-05
rsp	2.25000	0.000118527	0.000180265
modis	1.64000	0.000148789	4.81663e-05
modis	2.13000	0.000263873	0.000189849
virrs	1.61000	0.000175843	5.71688e-05
virrs	2.25000	9.60386e-05	0.000168826
emas	1.60630	0.000179176	5.82033e-05
emas	1.66240	0.000134217	4.64742e-05
emas	2.02650	0.000743717	0.000428619
emas	2.07610	0.000528244	0.000271069
emas	2.12600	0.000278044	0.000193392
emas	2.17450	0.000149722	0.000161790
emas	2.22380	0.000101935	0.000158286
emas	2.27370	0.000103228	0.000183963
emas	2.32420	0.000157543	0.000233723
emas	2.37310	0.000217928	0.000322401

There are several cloud retrieval objectives and each objective is met best with different combinations of SWIR bands.

The retrieval of cloud thermodynamic phase is a critical first step in being able to provide useful cloud optical property retrievals. Phase determination is obtained using bands with differing amounts of absorption for liquid and ice phase. Previous satellite instruments have taken advantage of varying phase absorption in both the SWIR and IR. Since PACE will be flying without an IR sensor, it is important to understand the information content in the SWIR. Information content studies by Coddington et al. have shown the benefit of both 2135 and 2225 nm channels for improving the knowledge in cloud effective radius leading to quantifiable improvements in discriminating a particular cloud optical thickness (COT) and cloud effective radius (CER) pair of a certain thermodynamic phase from a different COT/CER pair of the other thermodynamic phase (Figure 1). The results of Figure 1 can be summarized as:

• The PACE MCR channel set (865, 1640, 2135, and 2250 nm) provides significantly improved skill over either the MODIS (865, 1640, and 2135 nm) or VIIRS channel set, especially for moderate and larger cloud optical thickness (COT) and/or larger cloud effective radius (CER).
• The VIIRS channel set (865, 1640, and 2250 nm) provides only minor improvement in phase skill over the MODIS channel set for moderate COT (~10 for liquid, ~4 for ice) and relatively small CER (~ <10 μm for both liquid and ice).
• Optically thin clouds will remain the most problematic irrespective of thermodynamic phase and channel set combination.

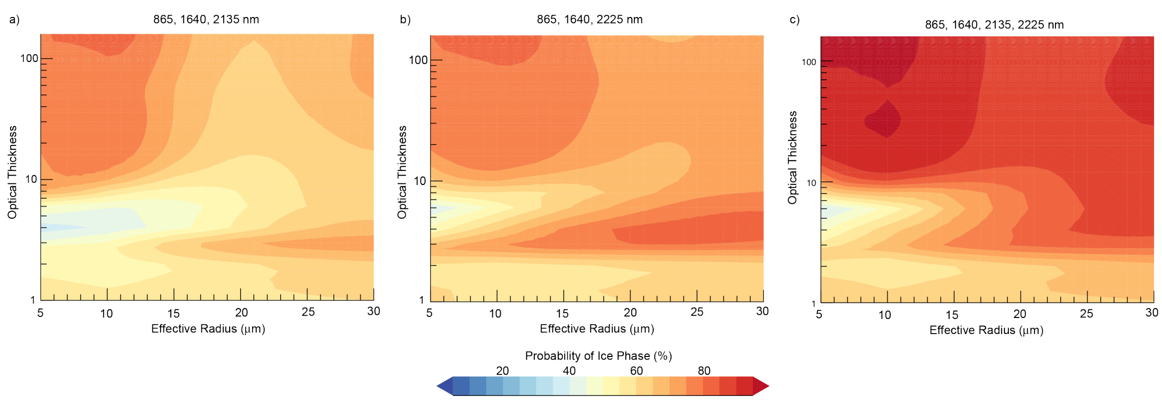

Figure 1: The probability of correctly discriminating ice thermodynamic phase for a broad range in cloud optical thickness and droplet effective radius and as a function of different location and number of channels in the shortwave infrared region (i.e. near 2 microns): a) The MODIS channel set (865, 1640, and 2135 nm), b) the VIIRS channel set (865, 1640, 2225 nm), and c) the PACE channel set (865, 1640, 2135, and 2225 nm).

For Cloud Optical Thickness (COT) and Cloud Effective Radius (CER), current retrieval algorithms use a combination of spectral channels, including 0.66, 0.86, 1.2, 1.64 and either 2.13 from MODIS or 2.225 from VIIRS. Having both 2 μm channels on OCI will allow continuity with MODIS and VIIRS cloud data records.

A third objective is to obtain vertical profile information from the contrast in absorption between two bands. This is especially relevant for ice clouds. Success in this retrieval for ice clouds has been achieved using the combination of 1.6 and 2.250 bands (van Diedenhoven et al., GRL, submitted)