# The Complex Refractive Indices of Free Iron Minerals, and Why They Matter

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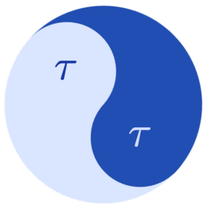



**Tables of Aerosol Optics**

- TAO is a MIRA topic (or subgroup)
- TAO is an open and dynamic community repository of optics computations
- TAO is meant to be an update of Shettle and Fenn (1979), OPAC, etc.

➡ Refractive indices are a key component of TAO

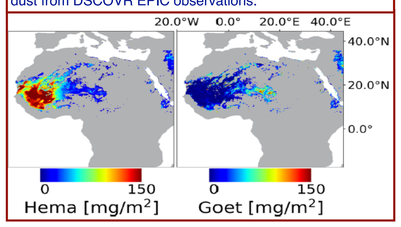
TAO Info

science.larc.nasa.gov/mira-wg/tao

## There are 13+ spectral refractive indices for hematite, so use closure as a guide

Sujung Go et al (ACP, 2022)

Go, Lyapustin, Schuster, Choi, Ginoux, Chin, Kalashnikova, Dubovik, Kim, da Silva, Holben, and Reid: Inferring iron-oxide species content in atmospheric mineral dust from DSCOVR EPIC observations.

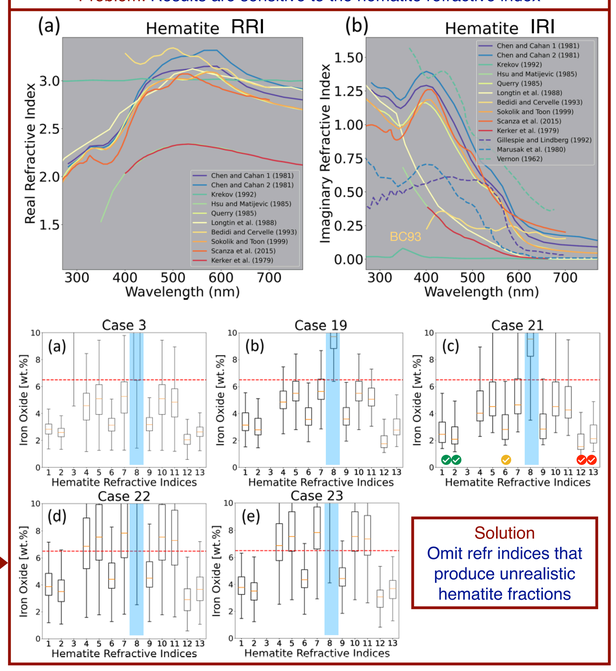



**Sensitivity Test for Hematite IRI**

Case 3: Western Africa
Case 19: Mexico, New Mexico
Case 21: Mexico, New Mexico
Case 22: Australia
Case 23: Australia

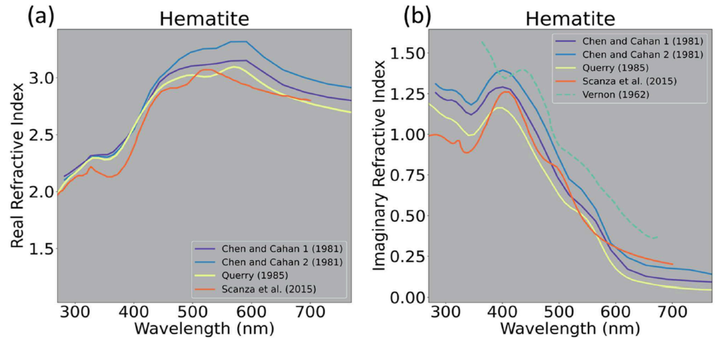
Hematite volume fractions need to be less than 6.5 wt% for consistency with *in situ* literature.

Problem: Results are sensitive to the hematite refractive index




Solution
Omit refr indices that produce unrealistic hematite fractions

- Only 5/13 hematite refractive indices result in retrieved hematite mass mixing ratios that are consistent with in situ measurements.
- Two of those five refractive indices have undocumented methodologies (red checks in table to right).
- Note below that Bedidi and Cervell (1993) also provides refractive indices for goethite, but that their imag RI for hematite is an outlier.

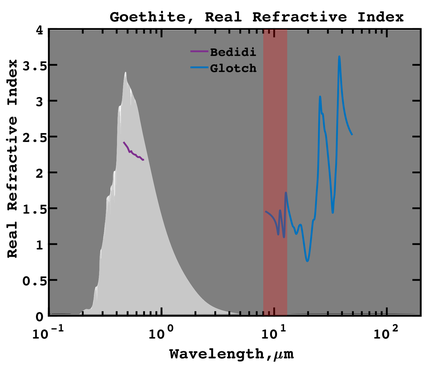


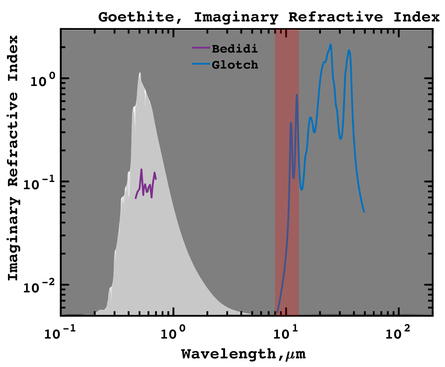

## Hematite Refractive Index Test (Go, ACP 2022)

**Table 1.** Summary of hematite refractive index information used in Fig. 3.

| | No. | Reference | Wavelength |
|---|---|---|---|
| ✓ | 1 | Chen and Cahan (1981) – 1* | 263–770 nm |
| ✓ | 2 | Chen and Cahan (1981) – 2* | |
| | 3 | Krekov (1992) | 200–4500 nm |
| | 4 | Gillespie and Lindberg (1992) | 250–700 nm |
| | 5 | Hsu and Matijevic (1985) | 350–650 nm |
| ✓ | 6 | Querry (1985) | 210–900 nm |
| | 7 | Longtin et al. (1988) | 200–$3 \times 10^5$ nm |
| | 8 | Bedidi and Cervelle (1993) | 350–750 nm |
| | 9 | Sokolik and Toon (1999) | 200–$5 \times 10^4$ nm |
| | 10 | Kerker et al. (1979) | 400–880 nm ($n$)<br>400–700 nm ($k$) |
| | 11 | Marusak et al. (1980) | 207–945 nm |
| ✓ | 12 | Vernon (1962) | 350–700 nm |
| ✓ | 13 | Scanza et al. (2015) | 100–$1 \times 10^6$ nm |

## Goethite is more abundant globally than hematite, but spectral refractive index measurements are rare




- Two forms of highly absorbing "free iron" are common in aeolian dust — hematite and goethite.
- Goethite is more abundant globally than hematite (e.g., Shi, Aeolian Research 2012; Formenti, JGR 2014).
- There is a single spectral measurement of goethite refractive index at visible wavelengths (Bedidi, JGR 1993).
- Likewise, there is a single measurement of goethite refractive index in the longwave (Glotch, Icarus 2009).

**Challenge to the community: Send me citations of goethite refractive index measurements for TAO!**

### Shortwave is especially problematic

**The only source is Bedidi and Cervell (JGR, 1993)**

- Soil moisture study — *pure samples were not necessary for their objectives.*
- Scattering of single mineral particles (moist and dry), $\lambda = 0.460$ to $0.700\ \mu m$
- Mie Theory was used to model scattering field of the soils.

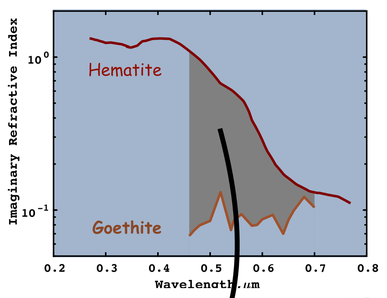
Complex refractive index computed using Koenigsberger formula, which is published in a French journal (Cervelle, 1970).

*Black Box*

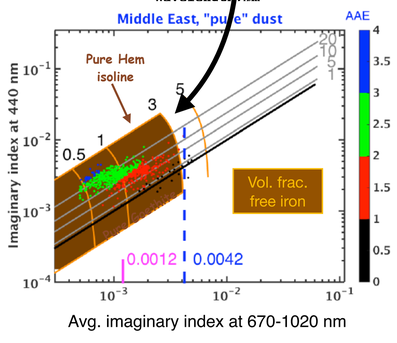
Cervelle, B., R. Caye, and J. Billard, Détermination de l'ellipsoïde Complex des indices de cristaux uniaxes fortement absorbants: Application à la pyrrholite hexagonale, *Bull Soc. Fr. Mineral. Cristallogr., 93*, 72-82, 1970.

## Why it is important to know the refractive index of goethite

Goethite and Hematite modulate the spectral dependence of mineral absorption




Thus, both mineral specta are required to model observations




Schuster et al part 1 (ACP, 2016)