VIIRS Marine Isoprene: Linking Ocean Phytoplankton to Air Quality and Climate

Daniel Tong, Hang Lei, Li Pan, Pius Lee
NOAA Air Resources Laboratory (ARL), College Park, MD

Menghua Wang
NOAA Center for Satellite Applications and Research (STAR), College Park, MD

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What is isoprene

Isoprene (CH₂=CH-C(CH₃)=CH₂) is a biogenic hydrocarbon emitted by trees, grasses and ocean phytoplankton.

- **Purpose of emission:** combat abiotic stresses;

- **Ozone formation:**

- **Aerosol formation:**

\[
\text{VOC} + \text{OX} \rightarrow \sum_{i=1}^{N} \alpha_i \times P_i \rightarrow \text{SOA}
\]

- **Cloud formation:** Cloud Condensation Nuclei (CCN);

Ozone, Aerosol, cloudiness all at the central stage of climate change debate

A suite of reactive gases and aerosols emitted from the Ocean:

- Isoprene;
- Dimethyl Sulfide (DMS);
- Organic Aerosols;
Algae Bloom and Ocean Cloudiness

(Meskhidze and Nenes, Science, 2006)
A Review of Approaches for Marine Isoprene Emissions

- **Shaw et al. (2003):**

  \[ E_{iso} = [Chl - a] * V * EF \]

- **Palmer & Shaw (2005):**

  \[ E_{iso} = K_{AS} * (C_W - H * C_A) \]

  \[ P - C_W (k_i * C_{Xi} + k_{bio} + k_{AS} / Z_{ML}) - L_{MIX} = 0 \]

  - \( k_i \): chemical reaction rate for oxidant i;
  - \( k_{bio} \): bacterial loss rate;
  - \( L_{MIX} \): loss due to downward mixing;

- **Gantt et al. (2009):**

  \[ E_{iso} = SA * H_{max} *[Chl - a] * F_{iso} * \int_0^{H_{max}} P_{dh} \]

\( E_{iso} \): Isoprene emission;
\( [Chl-a] \): Isoprene emission;
\( V \): euphotic water volume;
\( EF \): Emission factor;
\( k_{AS} \): exchange coeff.;
\( C_W \): isoprene conc. in water;
\( C_A \): isoprene conc. in the air;
\( H \): Henry’s law constant;
\( P \): isoprene production;
\( H_{max} \): euphotic zone height;
\( Z_{ML} \): mixing layer height;
JPSS marine Isoprene algorithm (V1.0)

- Built upon several pioneering works:

\[ F = a \times [Chl] \times \sum_{i=1}^{N} (EF_i \times f_i) \times H_{\text{max}} \times \gamma \]

Euphotic zone height (Gantt et al., 2009)

\[ H_{\text{max}} = \left( -\ln \left( \frac{2.5}{I_0} \right) \right) / K_{490} \]

- \(I_0\) – ground radiation; \(K_{490}\) – diffuse attenuation coefficient in water

JPSS Products Used:
- [Chl-a]
- \(K_{d490}\)
- PAR

Phytoplankton Functional Types (PFTs) (Arnold et al., 2009)

Determine emission factor (EF) and abundance (f);
No data available from JPSS, using SeaWiFS climatological data
Chlorophyll-a and $K_d(490)$

- **Sensor/Satellite:** Visible Infrared Imaging Radiometer Suite (VIIRS) on SNPP
- **Ocean Color Data Processing:**
  - Multi-Sensor Level-1 to Level-2 (MSL12) is used for VIIRS ocean color data processing
  - Routine ocean color data production from SDR (Level-1B) to ocean color EDR (Level-2), and to global Level-3 data, including $nL_w$, chlorophyll-a, and $K_d(490)$.
  - Level 3: Products are mapped to the CoastWatch geographic regions
- **Algorithms (Ocean Color EDR Team):**
  - Chlorophyll-a concentration: VIIRS OC3 algorithm
  - Diffuse attenuation coefficient at 490 nm $K_d(490)$: Wang et al. (2009) algorithm
Global Distribution of Marine Isoprene

JAN

marine isoprene emissions (molecules/cm²/s)

0.0E+00  1.0E+05  2.0E+05  3.0E+05

APR

marine isoprene emissions (molecules/cm²/s)

0.0E+00  1.0E+05  2.0E+05  3.0E+05

JUL

marine isoprene emissions (molecules/cm²/s)

0.0E+00  1.0E+05  2.0E+05  3.0E+05

OCT

marine isoprene emissions (molecules/cm²/s)

0.0E+00  1.0E+05  2.0E+05  3.0E+05
Isoprene Observations and Reprocessing

**Issue:** Some data can not be directly used for product validation.

**Reprocessing Approach:** Air-sea mass transfer.

Convert seawater conc into flux:

$$E_{iso} = K_{AS} \times (C_W - H \times C_A)$$

- **$K_{AS}$** – exchange coeff.;
- **$C_W$** – isop. conc. in water
- **$C_A$** – isop. conc. in the air
- **$H$** – Henry’s law constant;

Calculate exchange coeff based on wind speed:

$$K_{AS} = 0.31 \times U^2 \times ((3913.15 - 162.13T + 2.67T^2 - 0.012T^3) / 660)^{-0.5}$$

- **$U$** – surface wind speed;
- **$T$** – Sea surface Temperature

(Wanninkhof et al., 2004)
Isoprene Product Validation (Cont.)

- Palmer & Shaw 2005
- Gantt et al. 2009
- Arnold et al. 2009
- This Study

The graph compares satellite isoprene flux (molecules/cm²/s) against observed isoprene flux (molecules/cm²/s). The data points represent various studies, with markers indicating different datasets.
NOAA National Air Quality Forecast Capability (NAQFC)

- Developed by OAR/Air Resources Laboratory; Operated by National Weather Service (NWS) (PM: I. Stajner).
- Provides national numeric air quality guidance for ozone (operational product) and PM$_{2.5}$ (particulate matter with diameter < 2.5 µm);

O$_3$ Forecasting

PM$_{2.5}$ Forecasting

http://airquality.weather.gov/

NAQFC is one of the major gateways to disseminate NOAA satellite observations and model prediction of air quality to the public.
Isoprene applications:
National and regional air quality forecasting

Global Isoprene (April 2014)

Isoprene into model domains
Terrestrial vs. marine isoprene emissions
(Preliminary Results)

Land Emission

Marine Emission

JPSS Isoprene product fills the gap of missing ocean emissions in air quality and climate models

JPSS Isoprene User Workshop: September 2, 2015 in College Park, MD
Contact: Daniel.Tong@noaa.gov for details