



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

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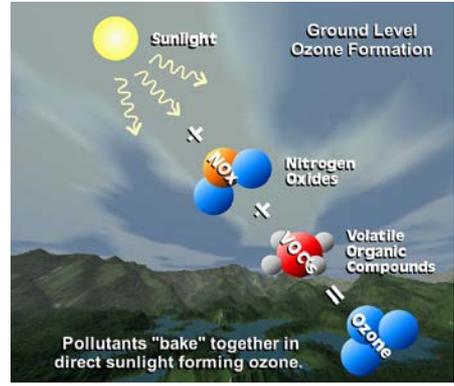
**Acknowledge:** NOAA JPSS Program for funding support;

# What is isoprene

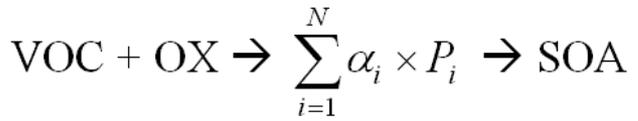
Isoprene (CH<sub>2</sub>=CH-C(CH<sub>3</sub>)=CH<sub>2</sub>) is a biogenic hydrocarbon emitted by trees, grasses and ocean phytoplankton.

❖ Purpose of emission: combat abiotic stresses;

❖ Ozone formation:

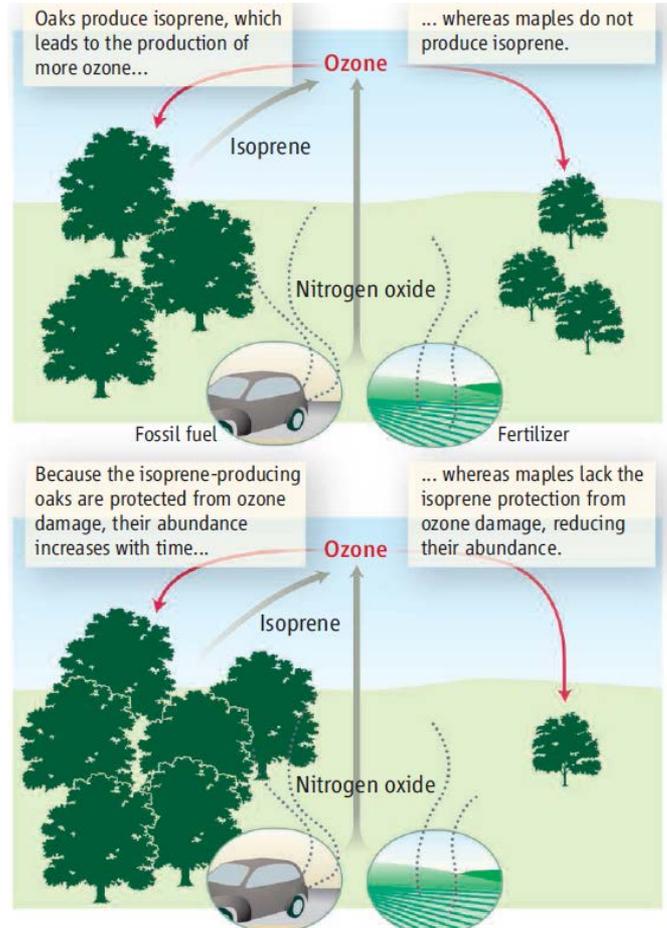


❖ Aerosol formation:



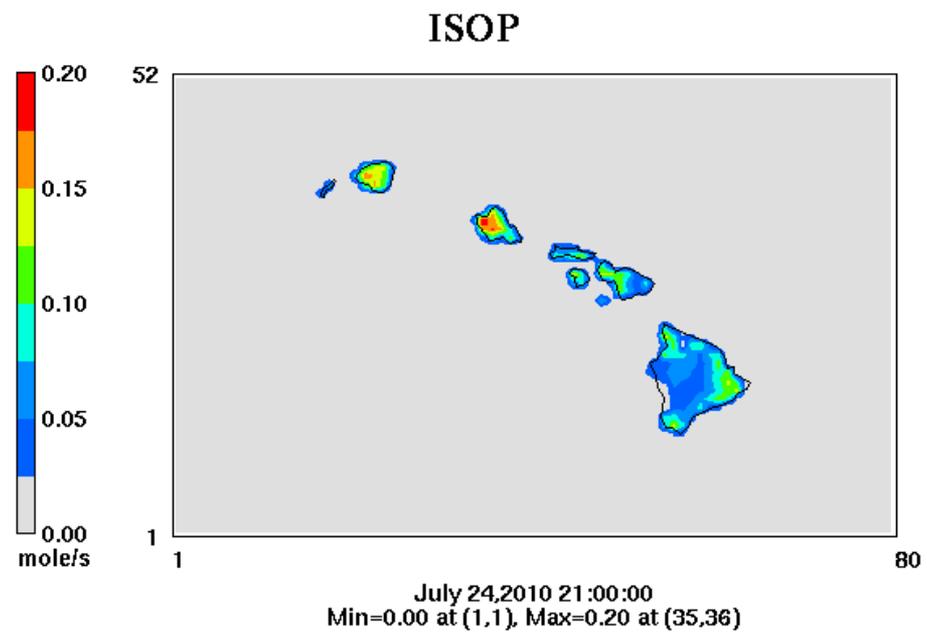
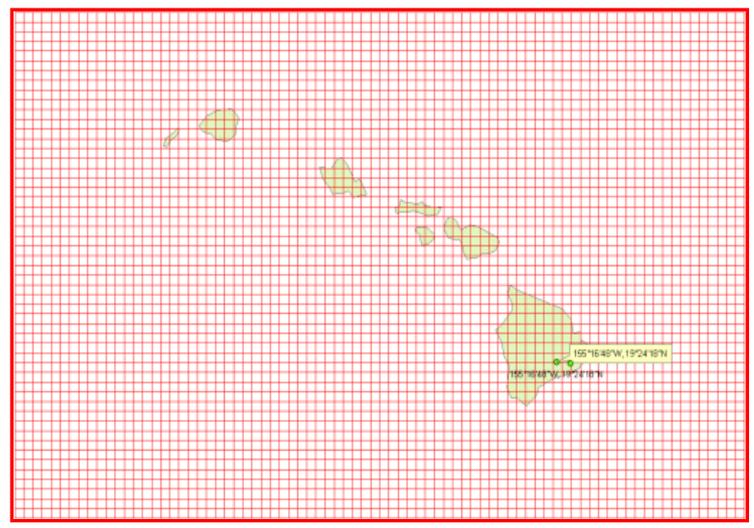
❖ Cloud formation: Cloud Condensation Nuclei (CCN);

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



(Lerdau, Science, 2007)

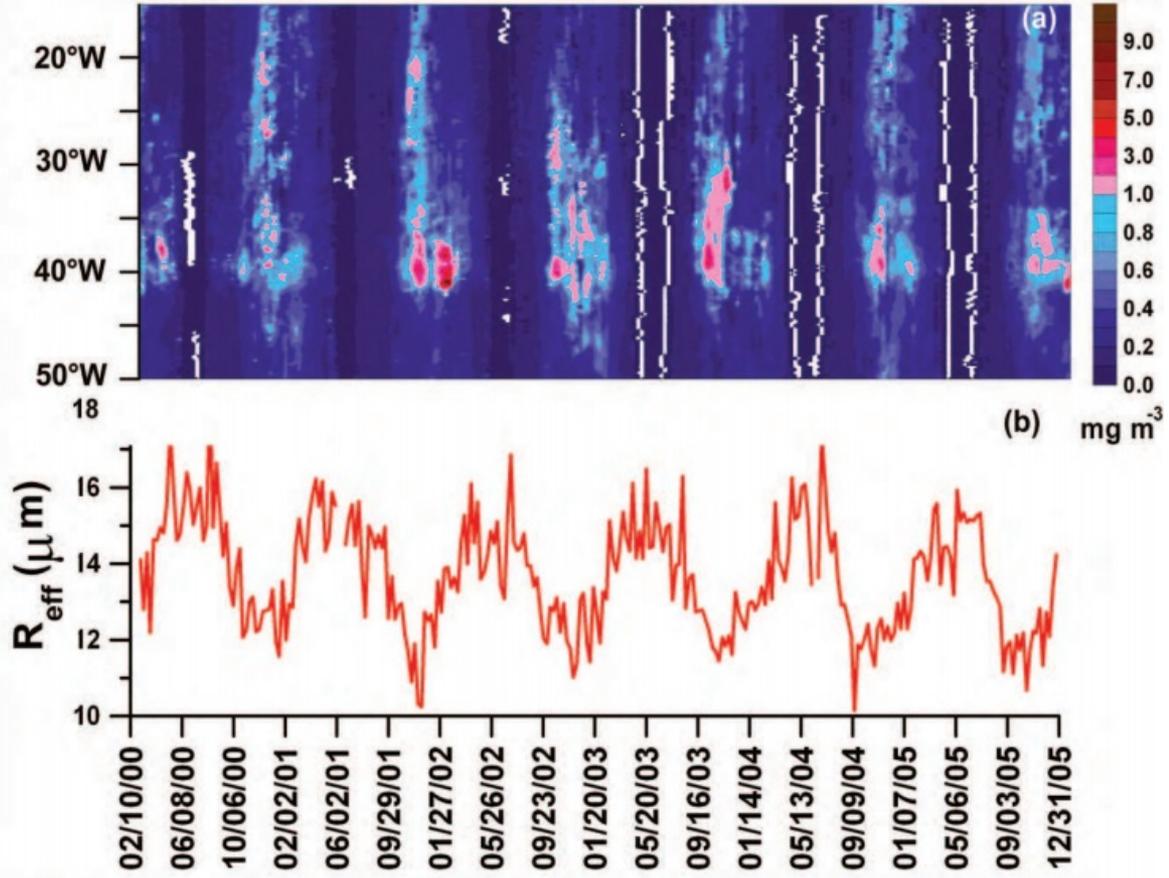
# National Air Quality Forecast over Hawaii



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.;

$C_W$  – isop. conc. in water

$C_A$  – isop. 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:

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

## Euphotic zone height (Gantt et al., 2009)

$$H_{\max} = (-\ln(\frac{2.5}{I_0}) / K_{490})$$

$I_0$  – ground radiation;  $K_{490}$  – diffuse attenuation coefficient in water

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

Determine emission factor (EF) and abundance (f);

No data available from JPSS, using SeaWiFS climatological data

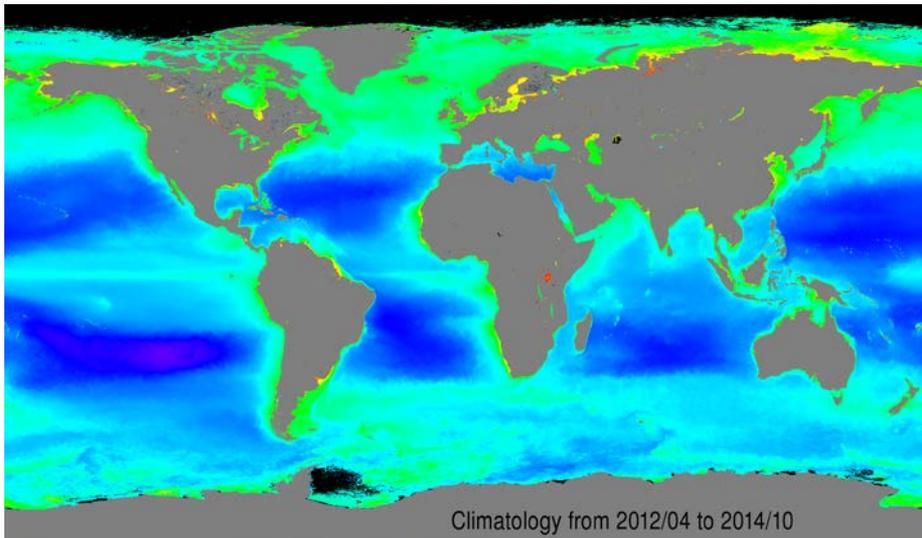
### JPSS Products Used:

- [Chl-a]
- Kd490
- PAR



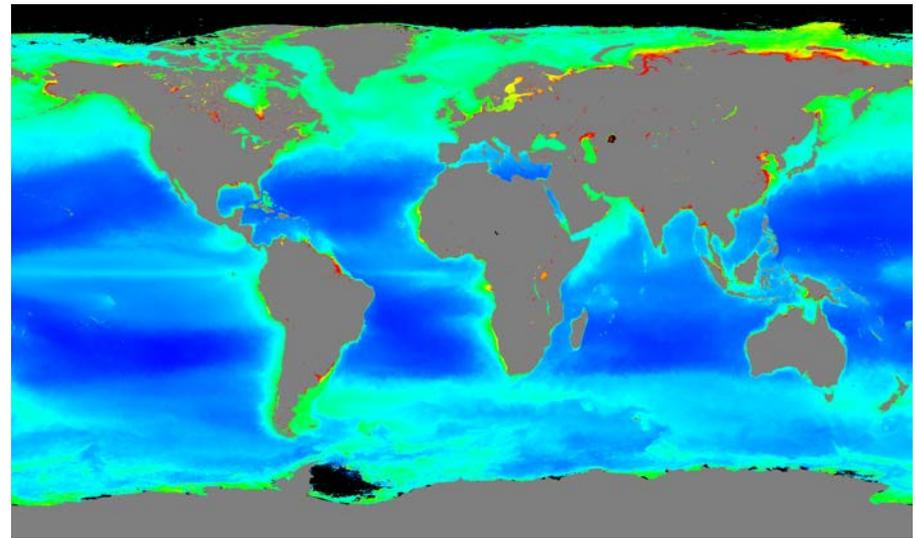
# Chlorophyll-a and $K_d(490)$

- ❖ **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



Climatology from 2012/04 to 2014/10

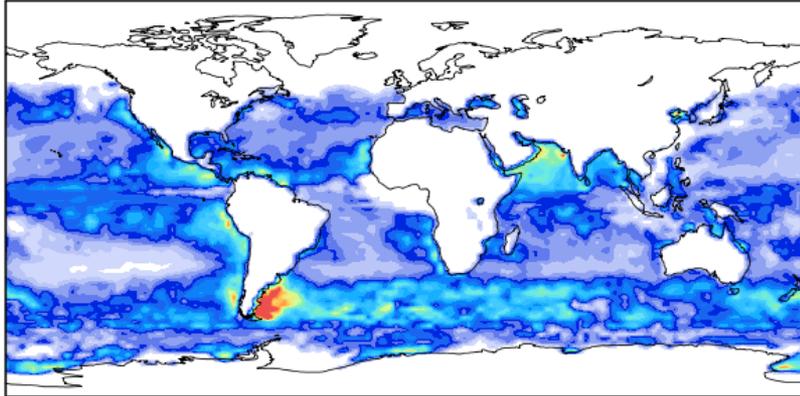
**Chlorophyll-a**



**$K_d(490)$**

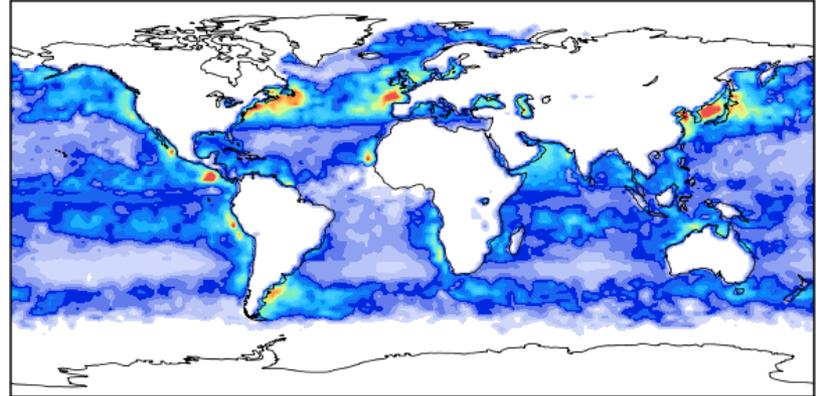
# Global Distribution of Marine Isoprene

JAN



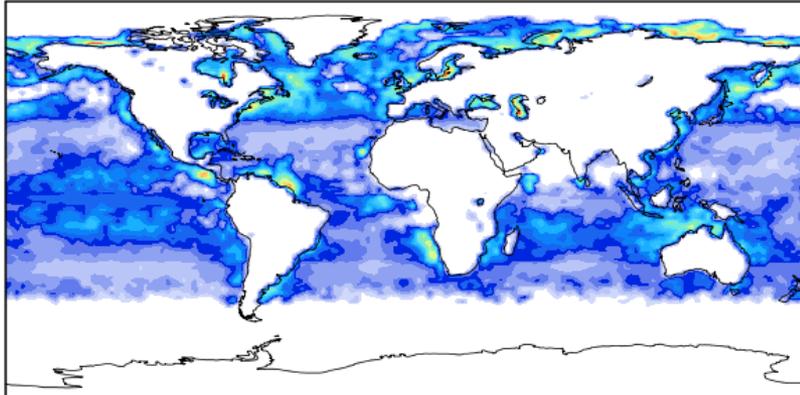
Marine Isoprene Emissions (molecules/cm<sup>2</sup>/s)  
0.0E+00 1.0E+05 2.0E+05 3.0E+05

APR



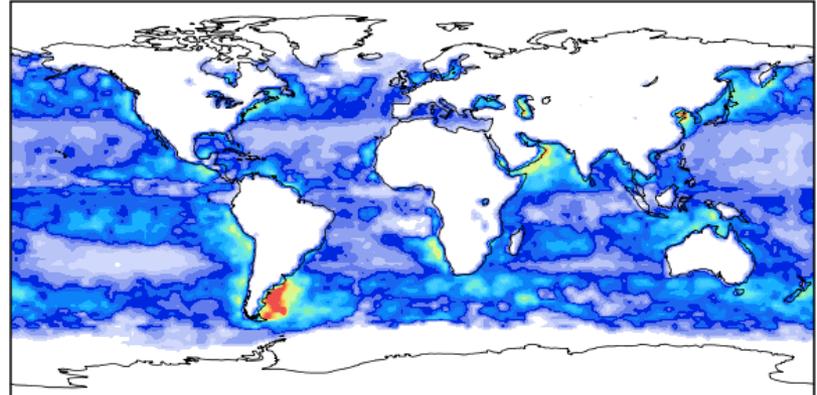
Marine Isoprene Emissions (molecules/cm<sup>2</sup>/s)  
0.0E+00 1.0E+05 2.0E+05 3.0E+05

JUL



Marine Isoprene Emissions (molecules/cm<sup>2</sup>/s)  
0.0E+00 1.0E+05 2.0E+05 3.0E+05

OCT

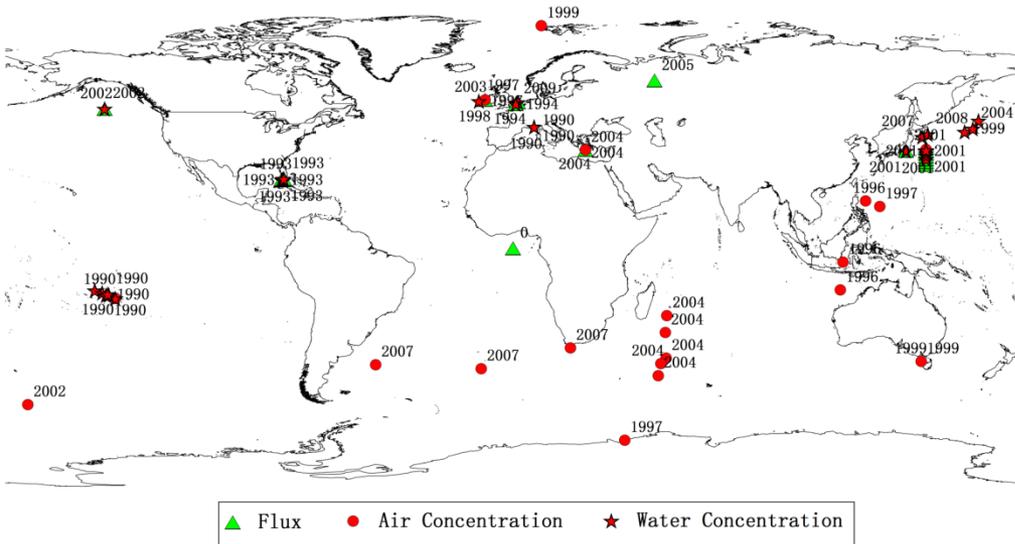


Marine Isoprene Emissions (molecules/cm<sup>2</sup>/s)  
0.0E+00 1.0E+05 2.0E+05 3.0E+05

# 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:**

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

$k_{AS}$  – 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:**

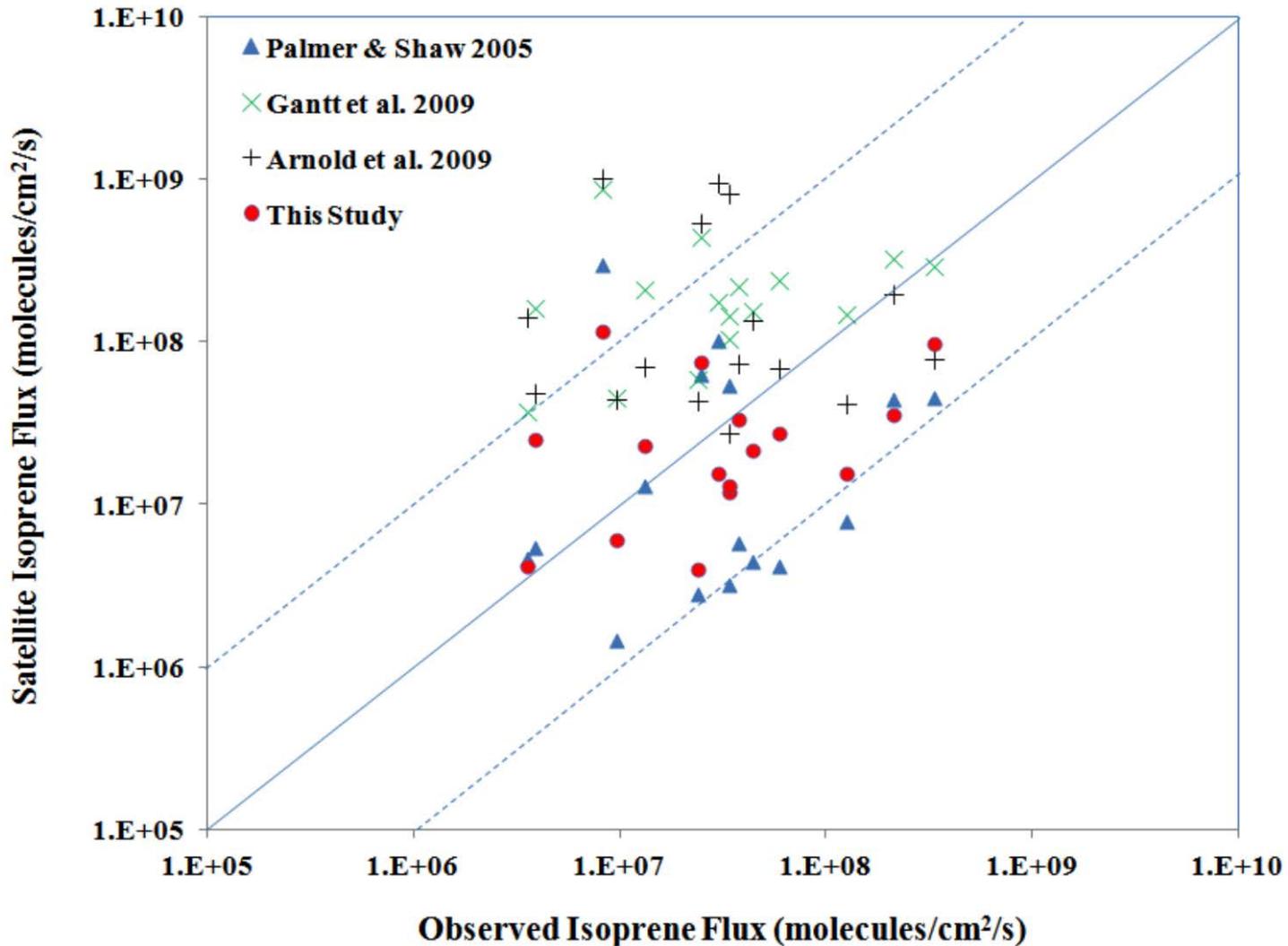
$$K_{AS} = 0.31 * U^2 \left( (3913.15 - 162.13T + 2.67T^2 - 0.012T^3) / 660 \right)^{-0.5}$$

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

(Wanninkhof et al., 2004)



# Isoprene Product Validation (Cont.)

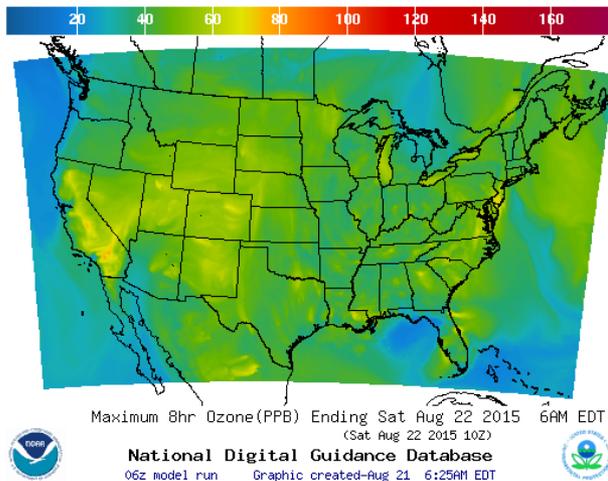




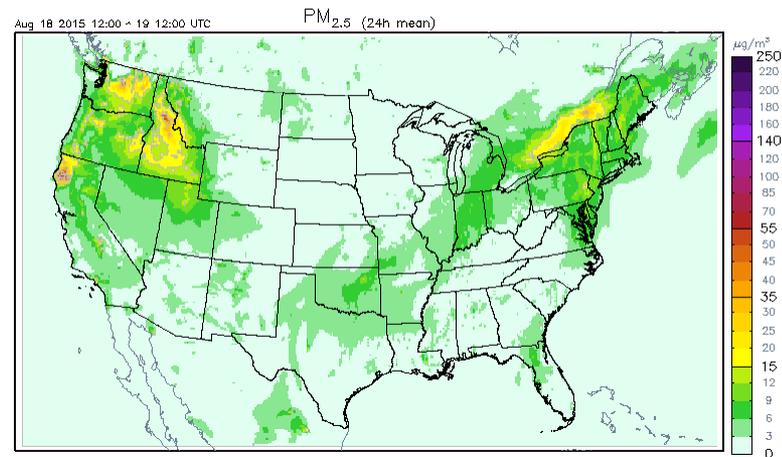
# NOAA National Air Quality Forecast Capability (NAQFC)

- ❖ 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<sub>2.5</sub> (particulate matter with diameter < 2.5 μm);

## O<sub>3</sub> Forecasting



## PM<sub>2.5</sub> Forecasting



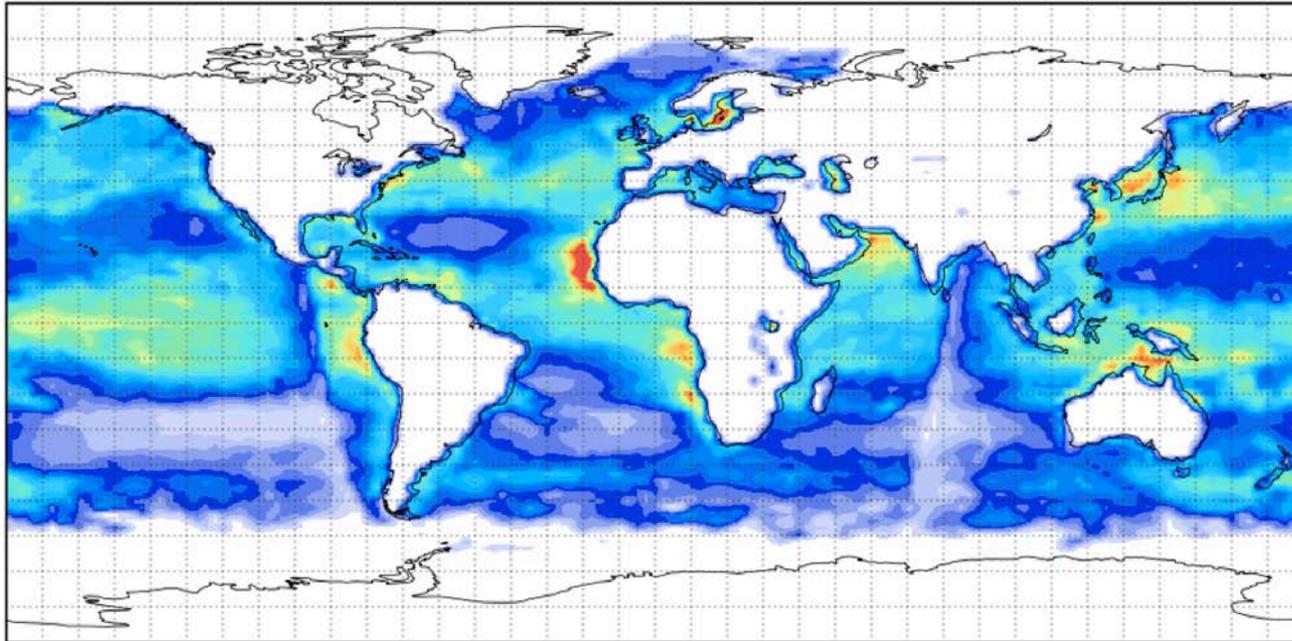
<http://airquality.weather.gov/>

**NAQFC is one of the major gateways to disseminate NOAA satellite observations and model prediction of air quality to the public.**

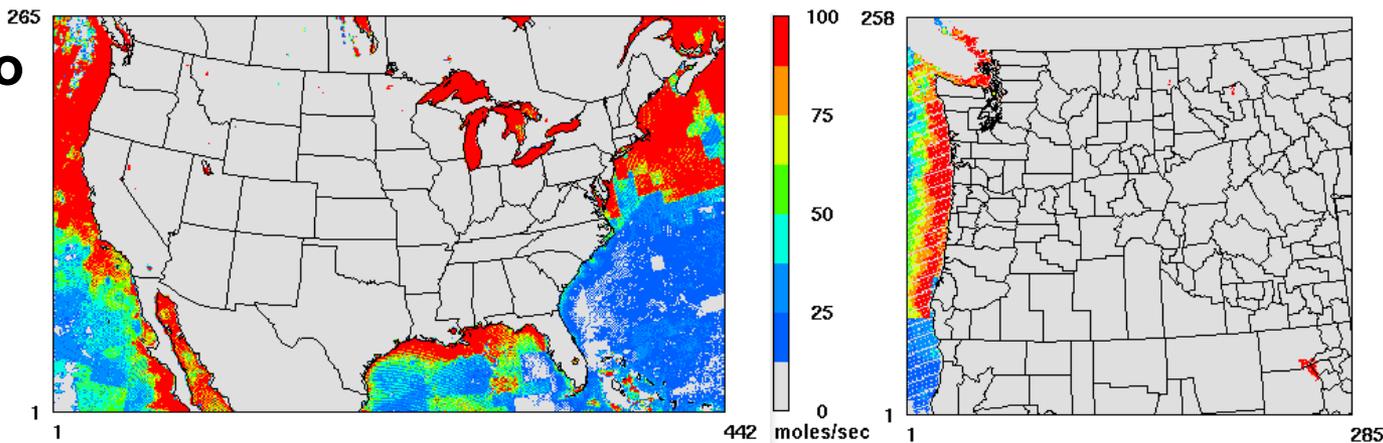
# Isoprene applications: National and regional air quality forecasting



**Global  
Isoprene  
(April 2014)**



**Isoprene into  
model  
domains**



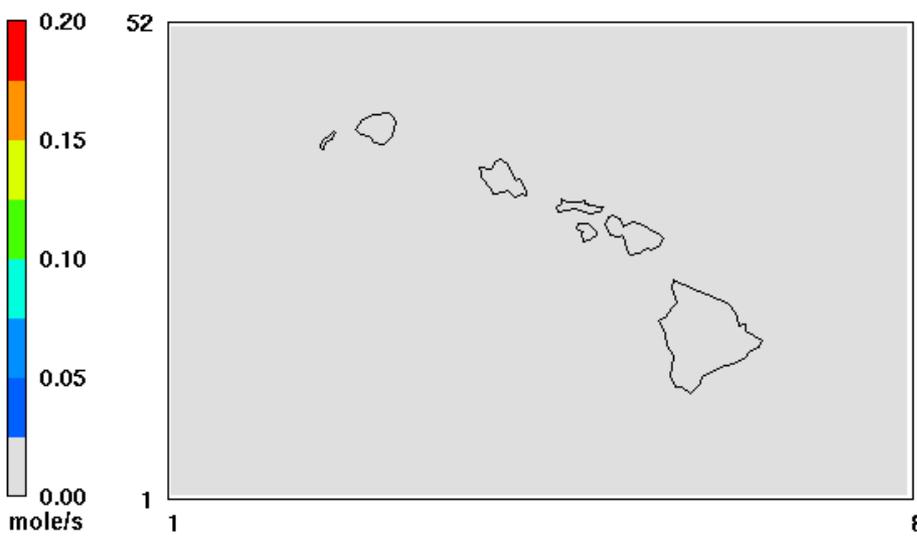


# Terrestrial vs. marine isoprene emissions

(Preliminary Results)

Land Emission

Marine Emission



July 24, 2010 12:00:00  
Min= 0.00 at (1,1), Max= 0.00 at (37,34)



July 21, 2010 12:00:00  
Min=0.00 at (1,1), Max=0.00 at (1,1)

**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](mailto:Daniel.Tong@noaa.gov) for details**