# Simultaneous observations of formaldehyde and glyoxal using MAX-DOAS as part of international remote sensing network SKYNET

**Syedul Hoque[1], Hitoshi Irie[1] , Alessandro Damiani[1] , Prajjwal Rawat[2] and Manish Naja[2]**

[1]Center for Environmental Remote Sensing (CEReS), Chiba University, Japan

[2]Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital , India

CHIBA UNIVERSITY

IRIE Lab.
A-SKY
Air Quality & Sky Research Laboratory
CHIBA UNIVERSITY

# SKYNET network

**Primary instrument: sky radiometer**

**Ground-based remote sensing network for aerosol-cloud-radiation researches**

**Still expanding with one main focus on satellite validations. (GCOM-C/SGLI, EarthCARE, GOSAT, GOSAT-2, Himawari-8/9, GEMS, ...).**

Sky radiometers at the Chiba site

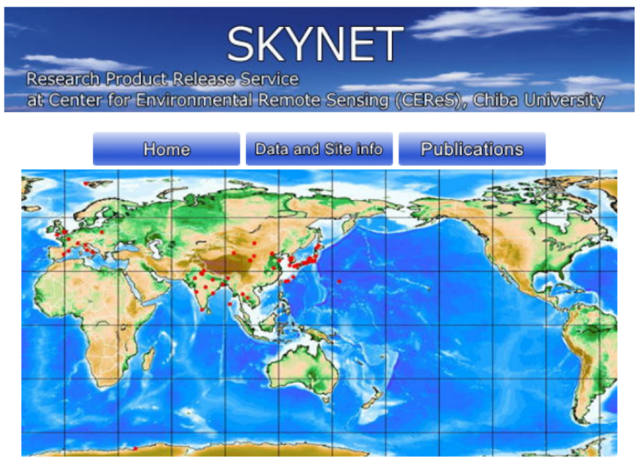



Fig. SKYNET/skyradiometer site map. Sites with data available as of July 30, 2013 are shown in red.

Fig. SKYNET workshops held at Chiba(Japan) in July 2013, at Hefei(China) in September 2014, and at Rome(Italy) in March 2016. Next workshop will be held in India.

## Retrieved products

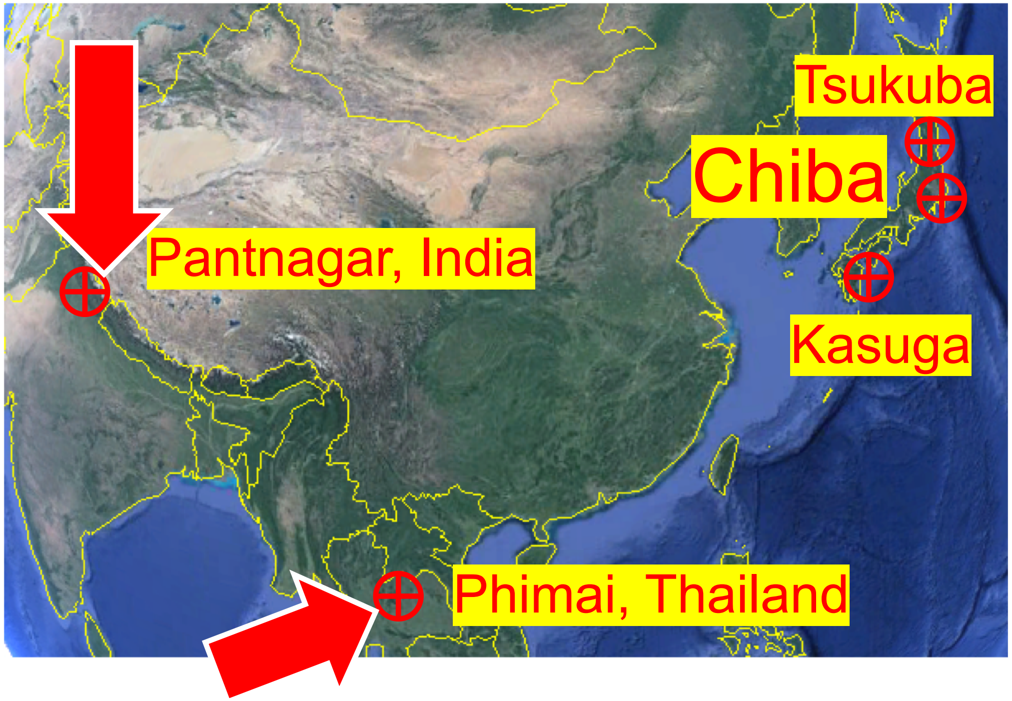
- Aerosol Optical Depth
- Single Scattering Albedo
- Real and imaginary refractive index
- Angstrom exponent
- Aerosol size distribution
- Water Vapor, Ozone

## Download

**http://atmos3.cr.chiba-u.jp/skynet/**

# MAX-DOAS as part of SKYNET

http://atmos3.cr.chiba-u.jp/skynet/




MAX-DOAS instruments at the Chiba site

## Retrieved products

- Aerosols at 357 & 476 nm
- $NO_2$(UV&vis), $SO_2$, $O_3$, $H_2O$
- Formaldehyde (HCHO), Glyoxal (CHOCHO)

Volatile Organic Compound(VOCs)

# Why VOCs are important ?

Fossil Fuel combustion and Industrial emission

Biomass burning

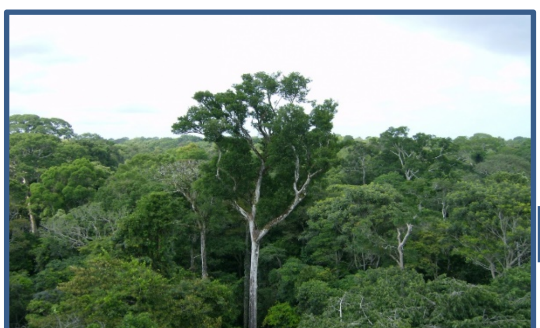
Anthropogenic sources

Important to address the high uncertainties from aerosols on the radiation budget

Secondary Organic Aerosols (SOA)

Oxidization reactions

Volatile Organic Compound(VOC)



Biogenic emissions

Dominant source

# Important VOC tracers in the atmosphere

VOCs $\xrightarrow{\text{oxidization}}$ HCHO, CHOCHO etc.

**The lifetime of HCHO and CHOCHO are ~ 2-3 hours**

**The sinks of HCHO and CHOCHO are photolysis, reaction with OH, and deposition**

**Can be used as tracer to classify dominant VOC emission sources (i.e., biogenic/anthropogenic/biomass burning)**

# Emission sources of CHOCHO & HCHO

Oxidization of biogenic VOCs

HCHO

Biogenic Sources

Oxidization of biogenic VOCs

CHOCHO

Virtually no direct emission except biomass burning

Direct emission from anthropogenic and biomass burning

Similar
Life time, sink

Difference
Source , yield

# Definition of the ratio, $R_{GF}$

$$R_{GF} = \frac{[\mathrm{CHOCHO}]}{[\mathrm{HCHO}]}$$

| Reference | $R_{GF}$ under biogenic influence (0.04 – 0.07) | $R_{GF}$ under anthropogenic influence ( < 0.03) |
|---|---|---|
| Vrekoussis et al., 2010 (satellite measurements) | Higher | Lower |
| DiGangi et al., 2012 (in situ measurements) | Lower | Higher |
| Miller et al., 2014 (Satellite measurements) | High and low depending on type of VOC | Intermediate |
| J.Kaiser et al., 2015 (Air borne in situ measurements) | High and low depending on type of VOC | Variable |

C

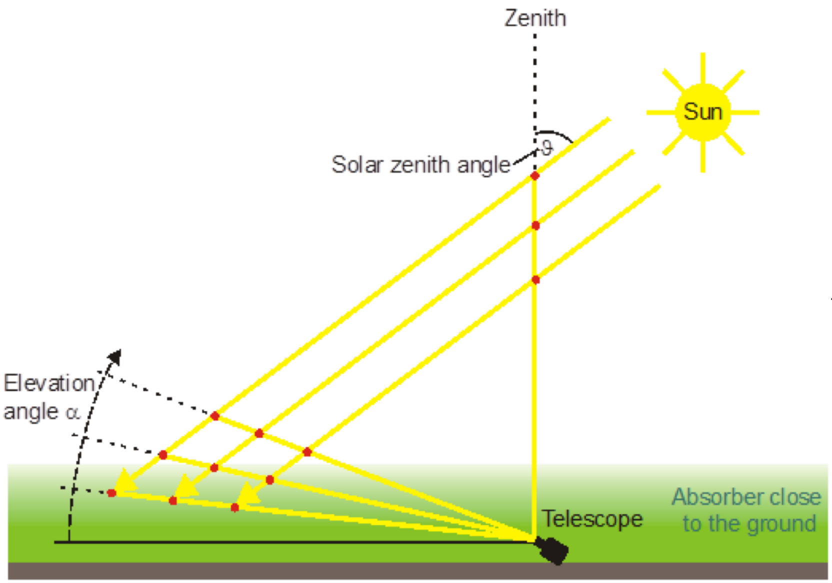
Thus the response of $R_{GF}$ to different VOC emission sources is still an open question

However, the value of $R_{GF}$ under different VOC emission scenariois is still under discussion.

# Methodology : MAX-DOAS

- **Multiple Axis Differential Optical Absorption Spectroscopy**

- **Measure scattered sunlight at different elevation angle covering the UV-Visible range (310-515 nm)**



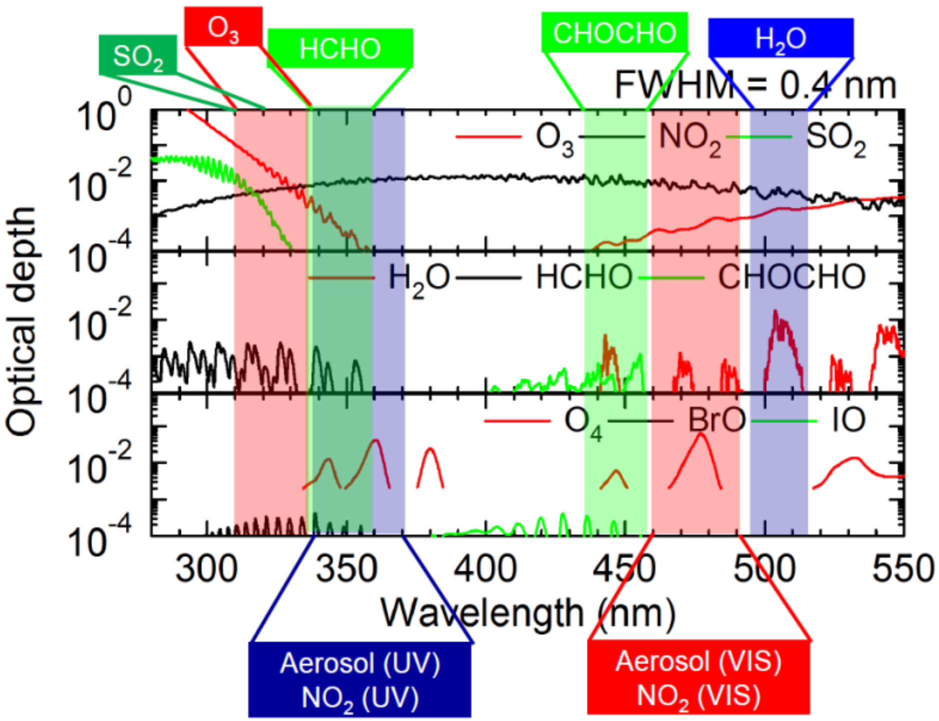

**The measured spectra is analyzed using the DOAS method which is based on the Beer – Lambert law**

$$I(\lambda) = I_o exp^{[-L.\sum(\sigma_j.c_j)+\varepsilon_R(\lambda)+\varepsilon_M(\lambda))]}$$

# Retrieval algorithm for MAX-DOAS observations

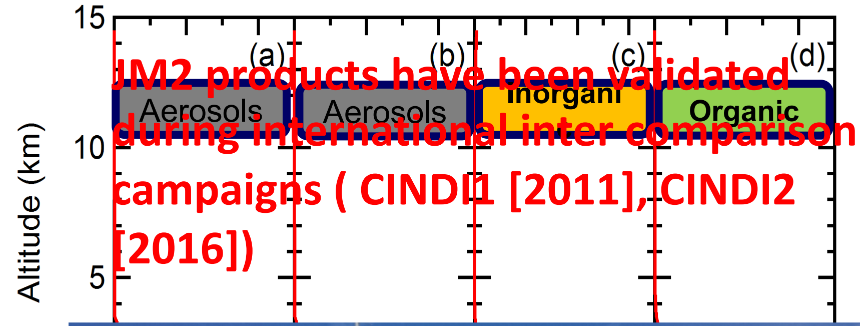
## Japanese MAX-DOAS profile retrieval algorithm v2

**JM2** Irie et al. (2011, 2015, 2016)




**Fitting Windows**

| | |
|---|---|
| HCHO | 336-359 |
| CHOCHO | 436-457 |



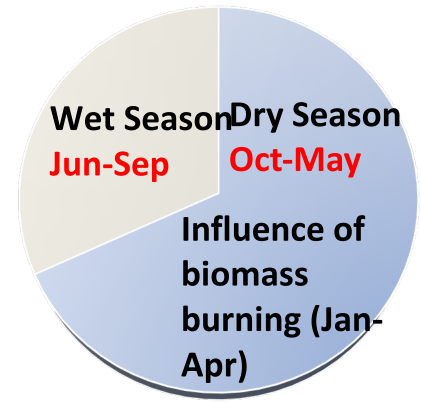

JM2 products have been validated during international inter comparison campaigns ( CINDI1 [2011], CINDI2 [2016])

Chiba University MAX-DOAS during CINDI 2 campaign in the Netherlands in 2016

# Sites: Phimai, Thailand


Phimai is Rural Site, no direct influence of any anthropogenic and industrial emission

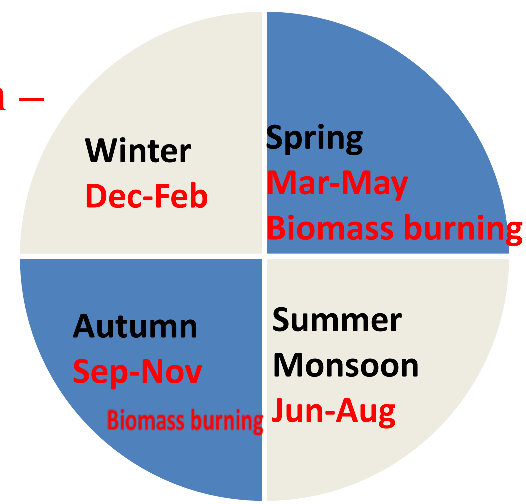
**Period : 2014/Oct – 2016/Sep**




# Pantnagar, India


- Semi-urban site
- Beside a roadside so expected to be influenced by vehicular emissions.
- Few industries located in nearby cities ~ 12 - ~25 km
- small local airport located ~ 3km of the site.

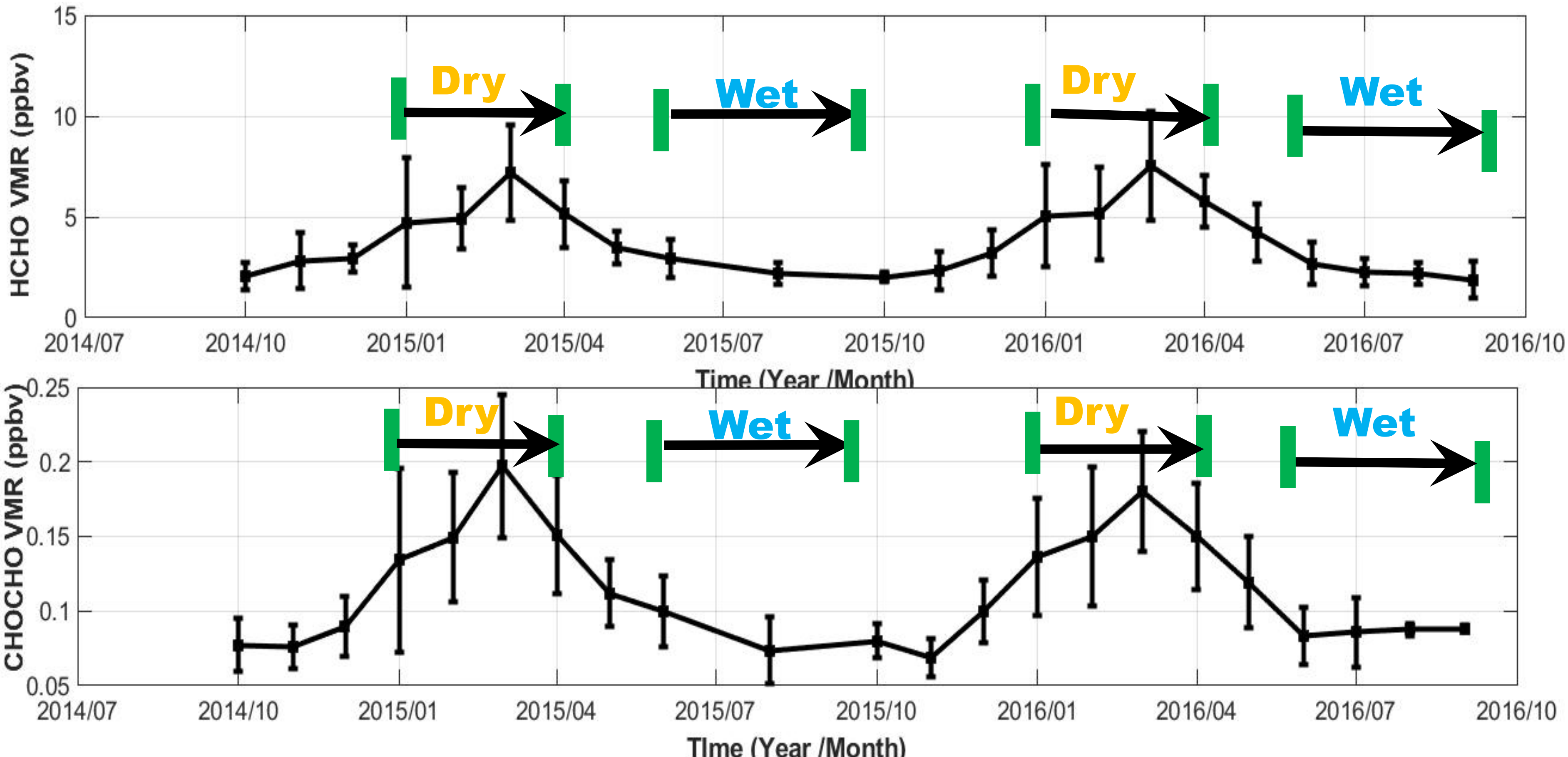
**Period : 2017/Jan – 2017/November**



# Results and Discussion

# Monthly time series in Phimai

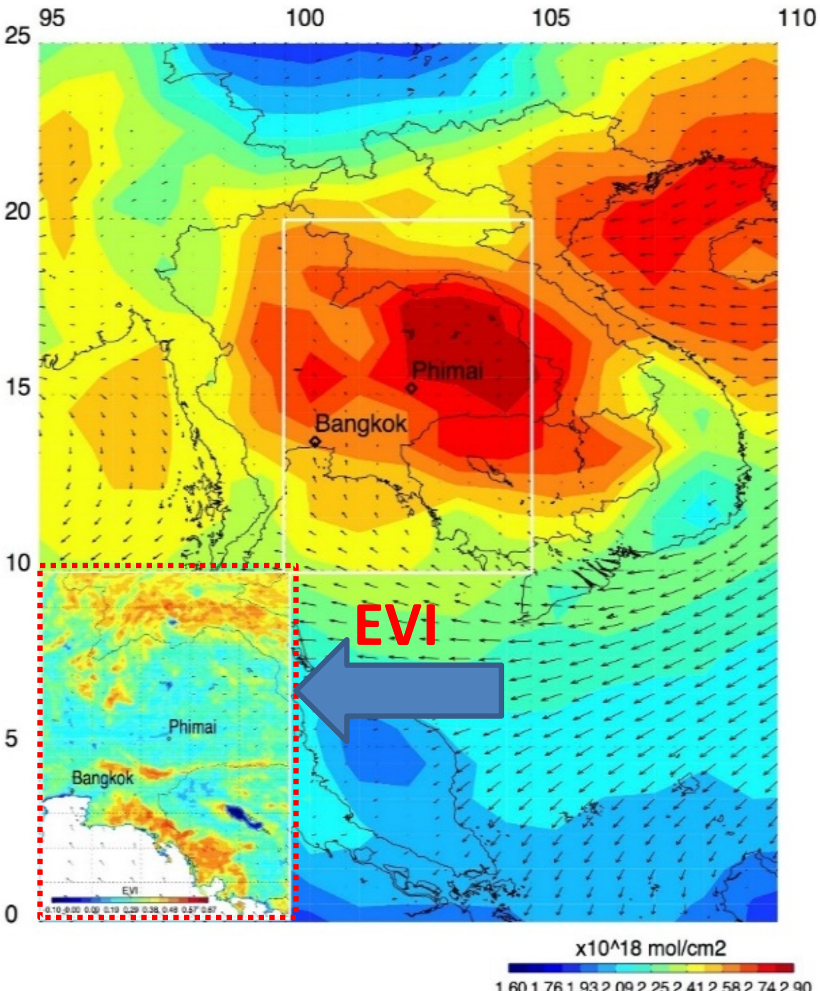
## Error bars are indicating the standard deviation

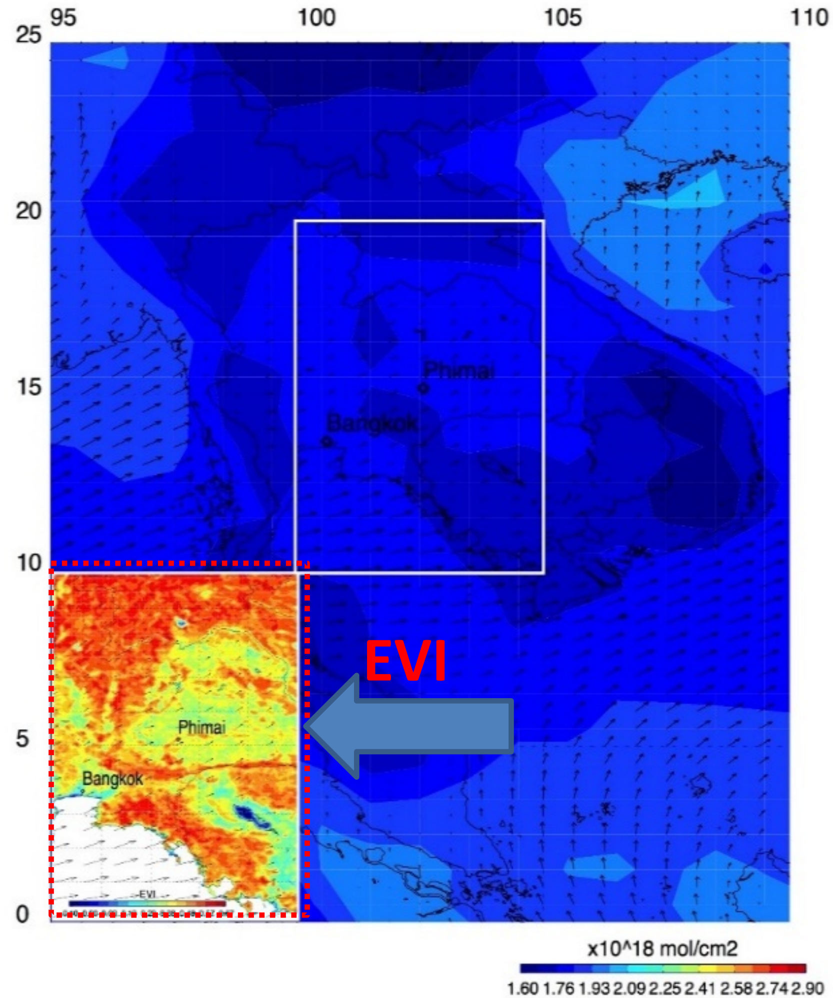



**The enhanced HCHO and CHOCHO during the dry season is likely due to biomass burning.**

# Supporting data for biomass burning

Carbon Monoxide (CO) Total columns from AIRS satellite




Dry Season

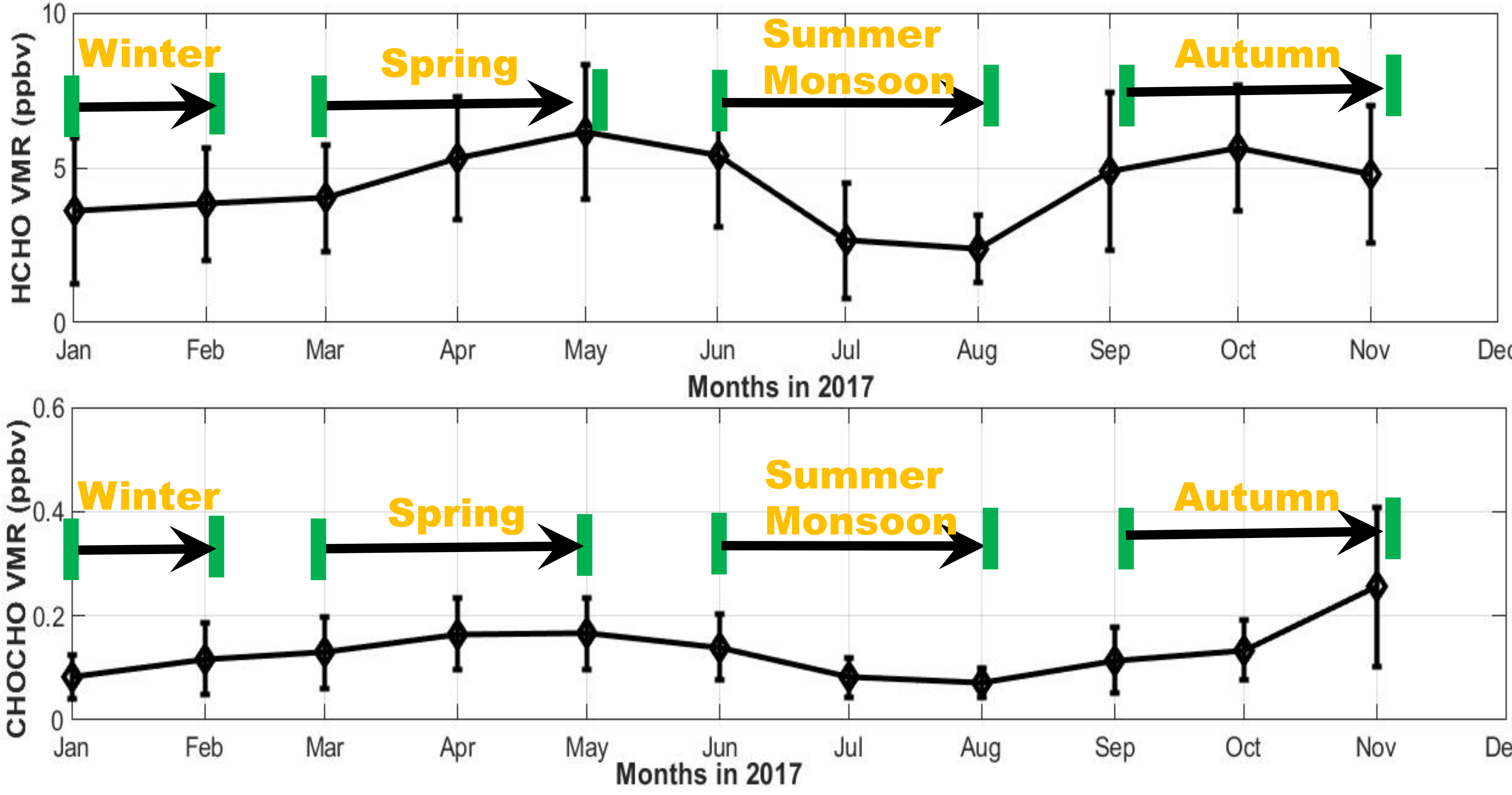
Dominant VOC during the dry season – biomass burning

Wet Season

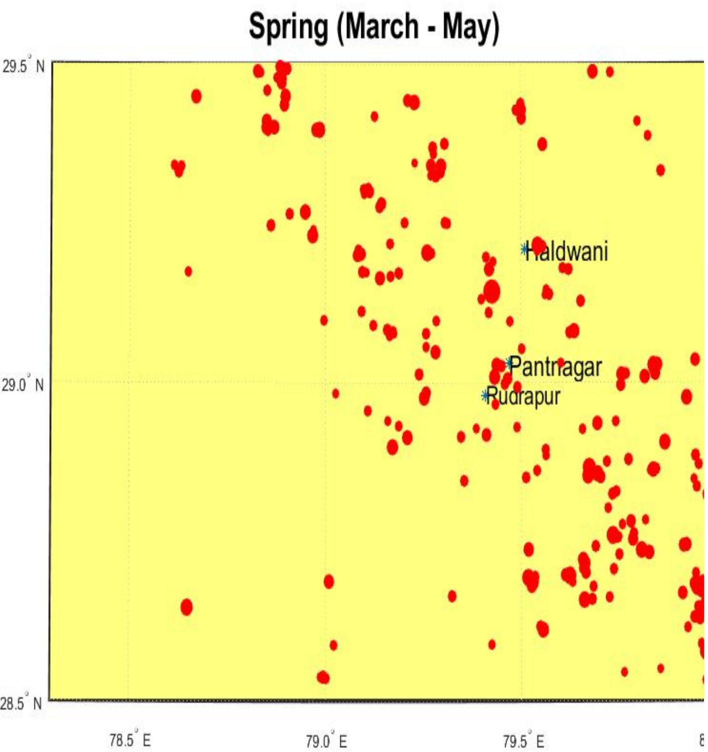
Dominant VOC during the wet season – biogenic emissions

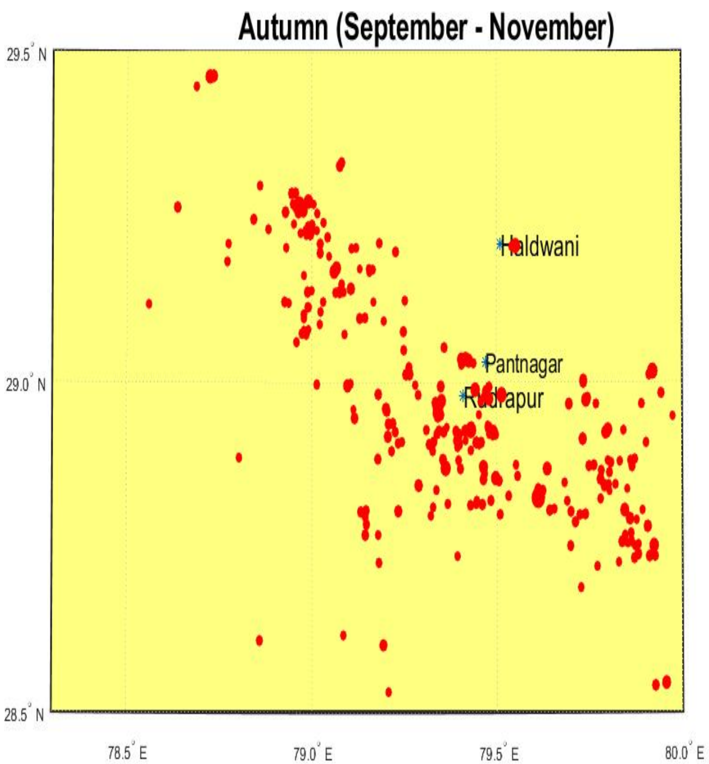
# Monthly Time Series in Pantnagar

## Error bars are indicating the standard deviation



# Dominant VOC sources in Pantnagar

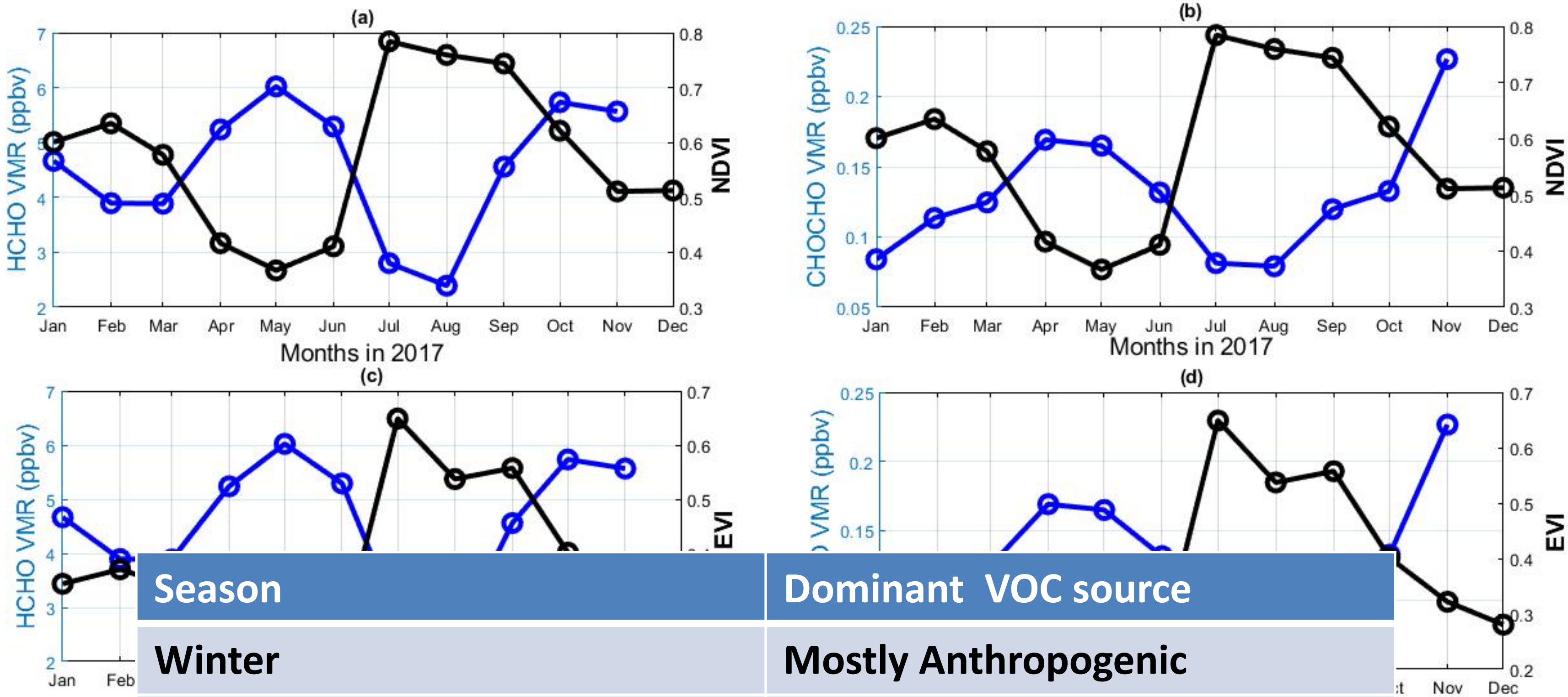



In addition, vehicular and industrial emissions also impact the VOC concentrations in Pantnagar

# Biogenic VOC sources in Pantnagar

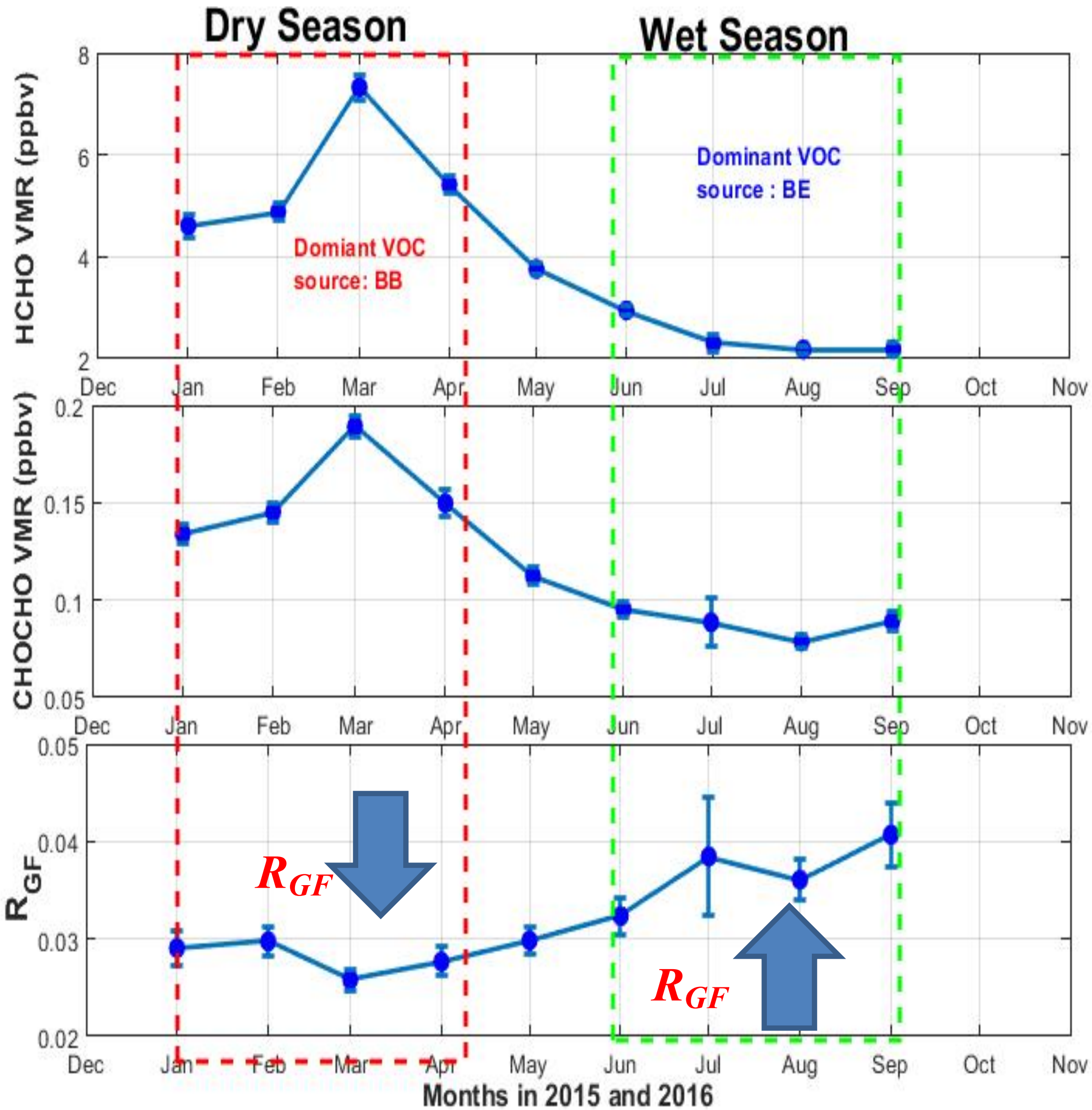
**Positive correlation is expectd among vegetation index (EVI/NDVI), HCHO, and CHOCHO if biogenic emission are dominant source**




| Season | Dominant VOC source |
|---|---|
| Winter | Mostly Anthropogenic |
| Spring | Anthropogenic + biomass burning |
| Summer monsoon | Mostly Anthropogenic |
| Autumn | Anthropogenic + biomass burning |

# Response of $R_{GF}$ in Phimai

**Error bars are indicating the 2σ standard error**




**HCHO & CHOCHO data of the same date and time were used to estimate the $R_{GF}$**

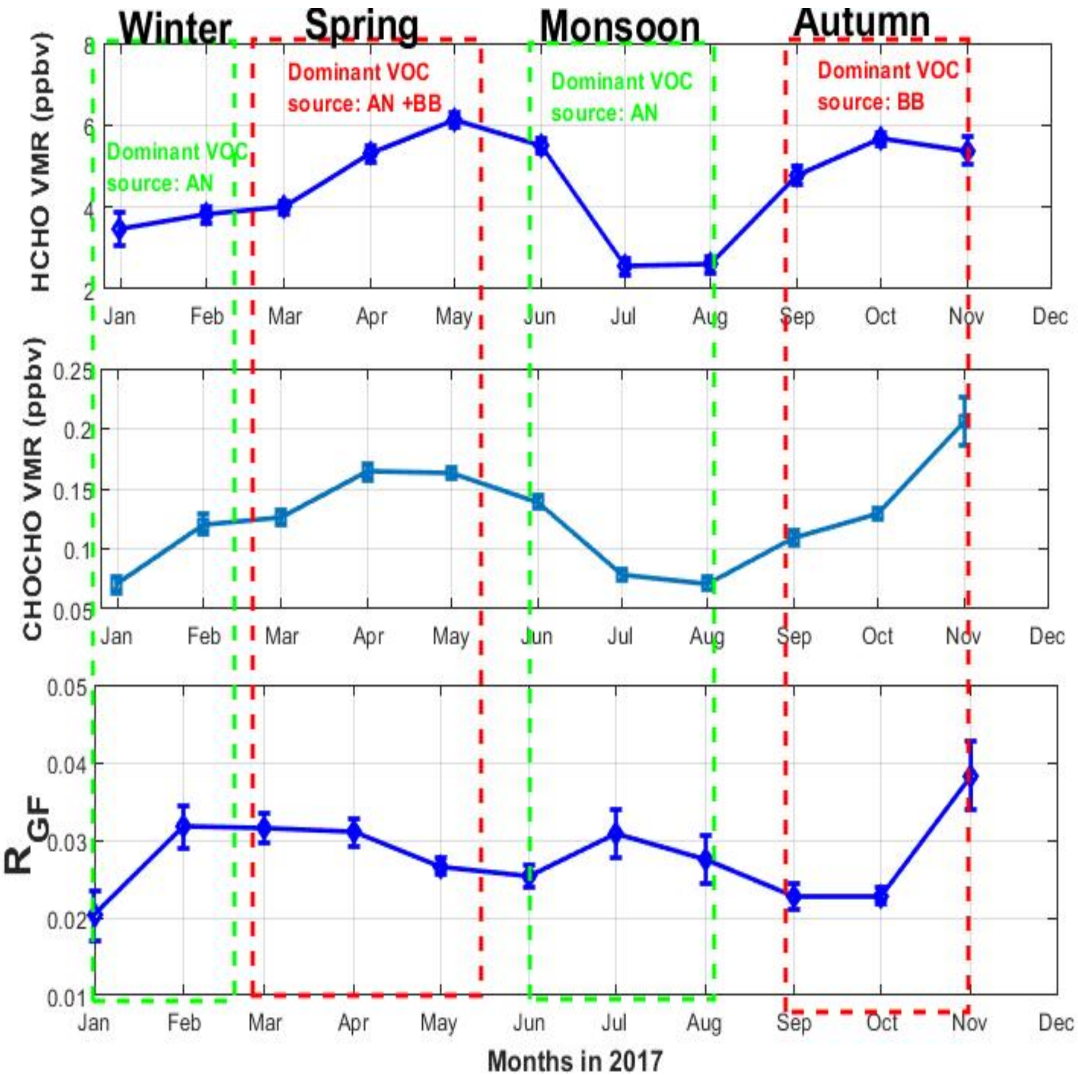
BB: Biomass Burning

BE: Biogenic Emissions

| Reference | $R_{GF}$ under anthropogenic/biomass burning | $R_{GF}$ under biogenic emission |
|---|---|---|
| Vrekoussis et al (2010) | ↓ | ↑ |
| Kaiser et al (2015) | ---- | ↑ |
| This study | ↓ | ↑ |

# Response of $R_{GF}$ in Pantnagar

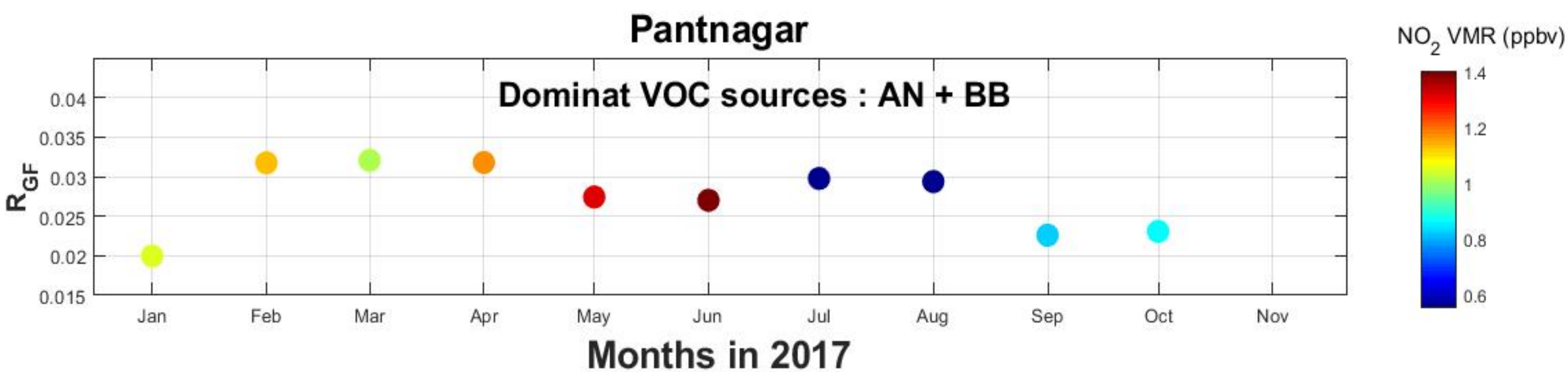
**Error bars are indicating the 2σ standard error**




BB: Biomass Burning $R_{GF}$

AN: Anthropogenic Emissions $R_{GF}$

# Response of $R_{GF}$

# Comparison with literature values

| Reference | Measurement platform | $R_{GF}$ under anthropogenic or/and biomass burning |
|---|---|---|
| Vrekoussis et al (2010) | Satellite | < 0.03 |
| Di Gangi et al (2012) | In- situ | ~ 0.03 |
| Miller et al (2014) | Satellite | < 0.04 |
| Ortega et al (2015) | MAX-DOAS | < 0.04 |
| Zarzana et al (2017) | In-situ | ~ 0.038 |
| This study | MAX-DOAS | Mostly ~ <0.035 |
| | | |

**Most of the studies find that, under the influence of anthropogenic and biomass burning the mean $R_{GF}$ tends to be ~< 0.04.**

# Conclusions

1.

| Site | $R_{GF}$ under biogenic influence | $R_{GF}$ under anthropogenic influence/biomass burning |
|---|---|---|
| **Phimai, Thailand** | ↑ | ↓ |
| **Pantnagar, India** | | ↓ |

# Conclusions

**2. Summarizig the existing literature values and from our observations, the $R_{GF}$ tends to be < 0.04 under the influence of anthropogenic and biomass burning**

| Reference | Measurement platform | $R_{GF}$ under anthropogenic or/and biomass burning |
|---|---|---|
| Vrekoussis et al (2010) | Satellite | < 0.03 |
| Di Gangi et al (2012) | In- situ | ~ 0.03 |
| Miller et al (2014) | Satellite | < 0.04 |
| Ortega et al (2015) | MAX-DOAS | < 0.04 |
| Zarzana et al (2017) | In-situ | ~ 0.038 |
| This study | MAX-DOAS | < 0.04 |
| | | |

# Data availability/ collaboration

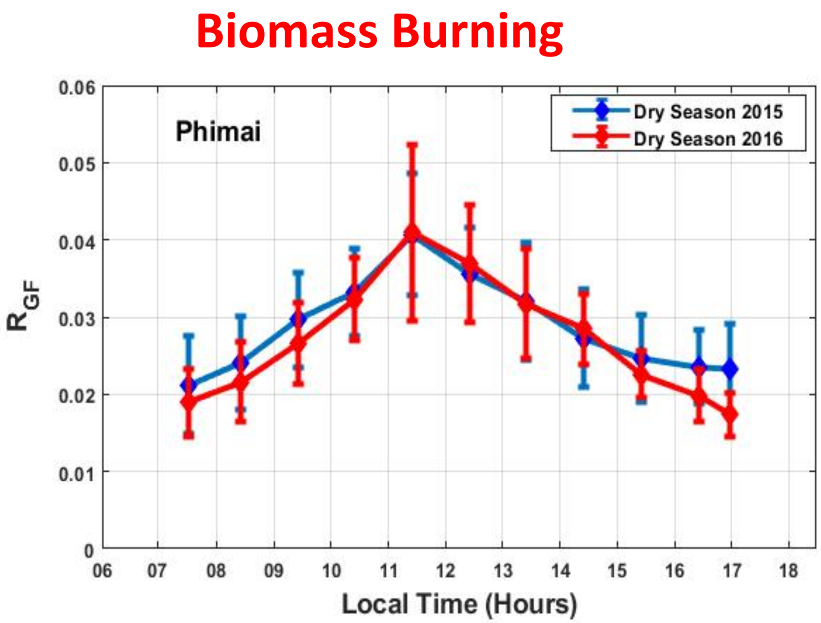
**Hitoshi Irie**
**hitoshi.irie@chiba-u.jp**

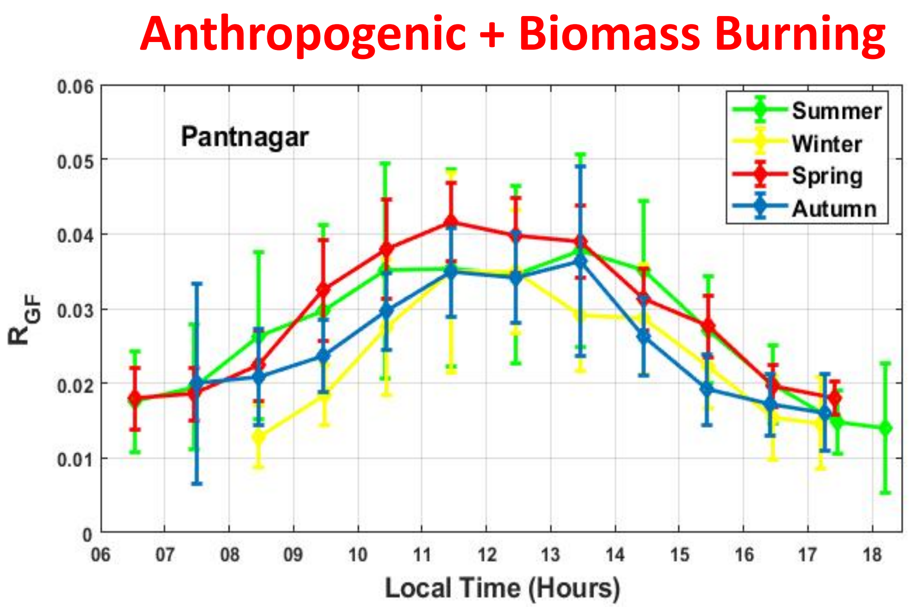
**Syedul Hoque**
**shoque@chiba-u.jp**

**http://atmos3.cr.chiba-u.jp/skynet/**

**Thank you**
**for your**
**Attention**

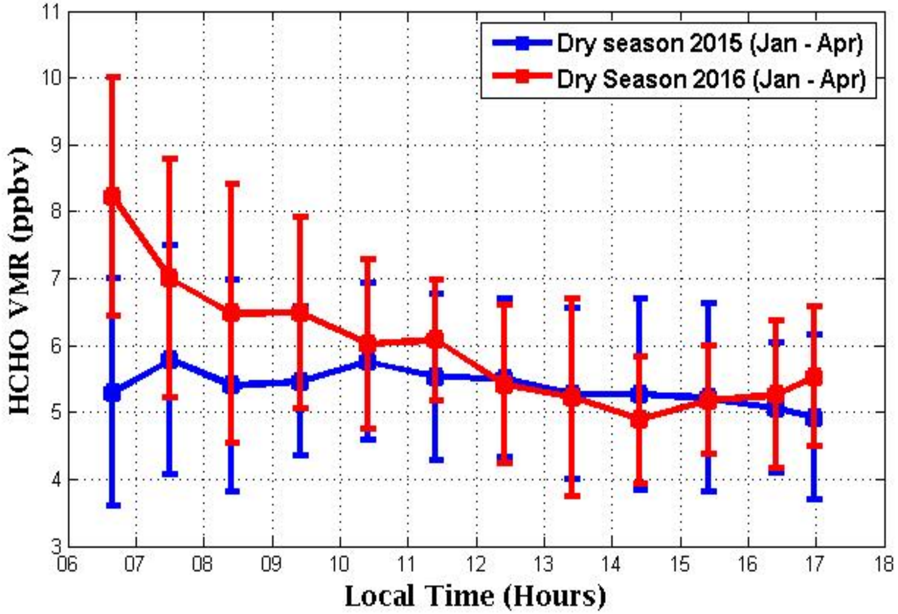
# Comparison of $R_{GF}$ between two sites

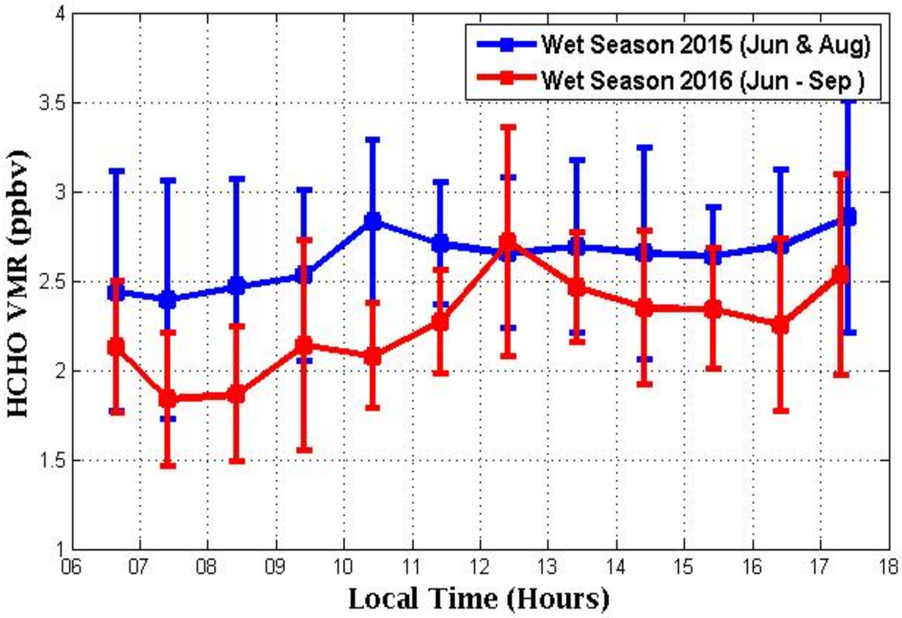


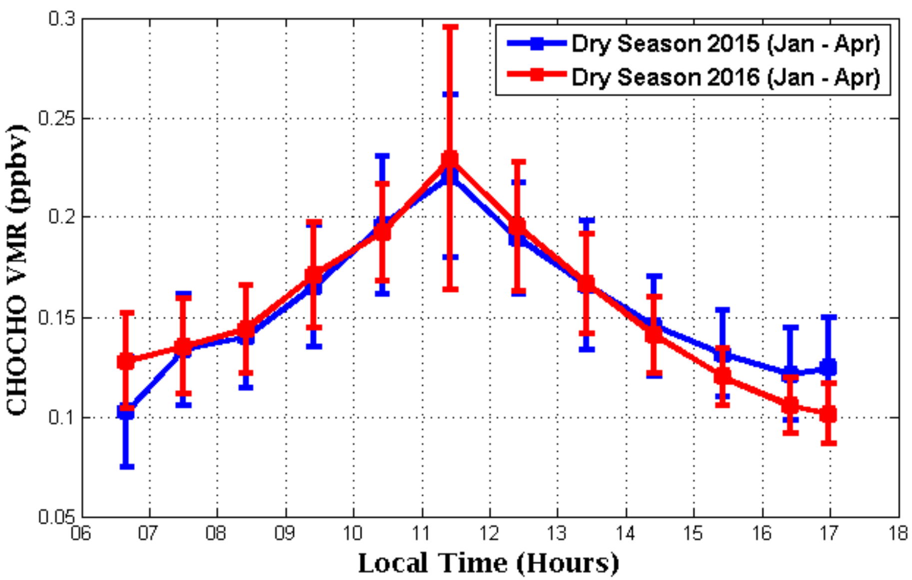

**- Despite being two different sites, $R_{GF}$ under the influence of biomass & anthropogenic emissions are found to be similar and mostly < 0.04.**

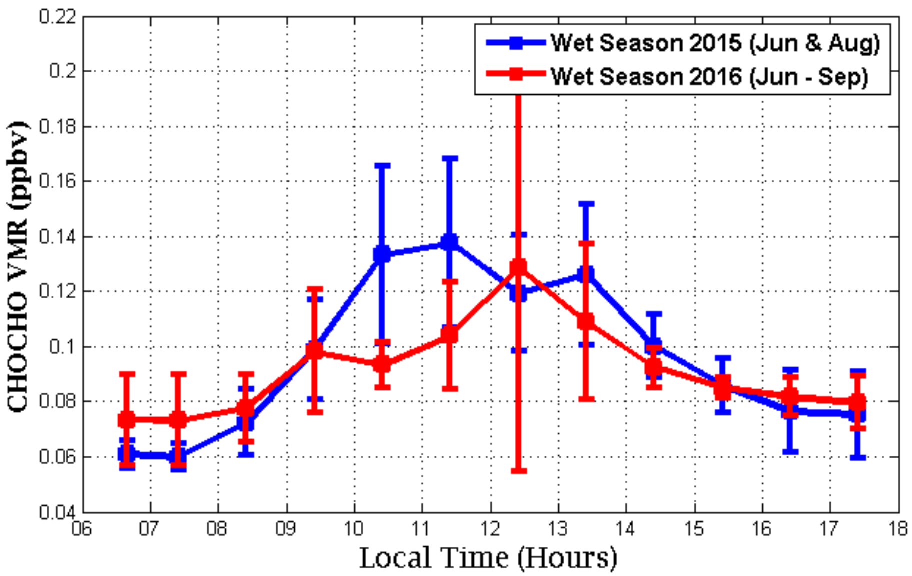
# HCHO diurnal variation



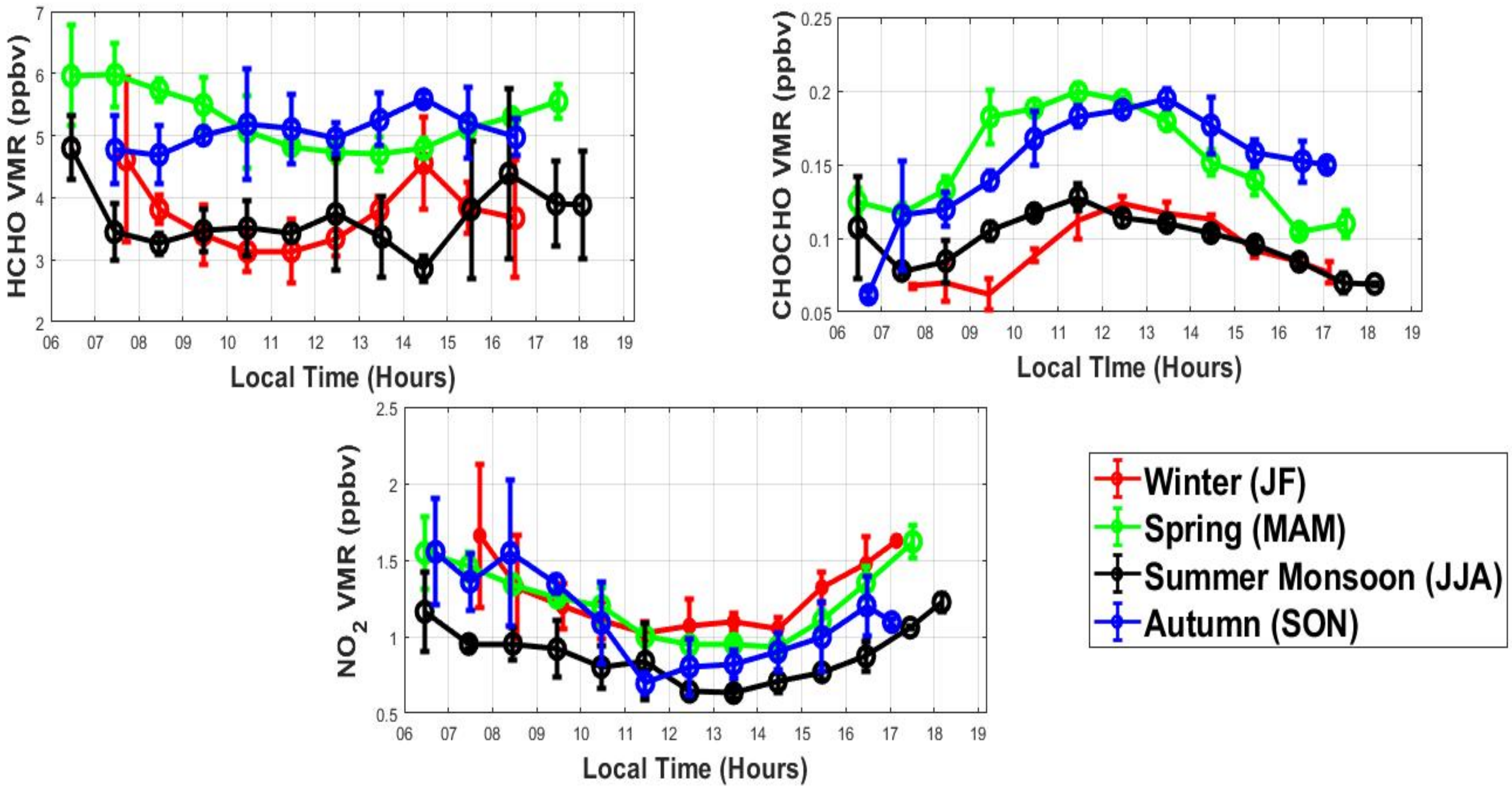



# CHOCHO diurnal variation

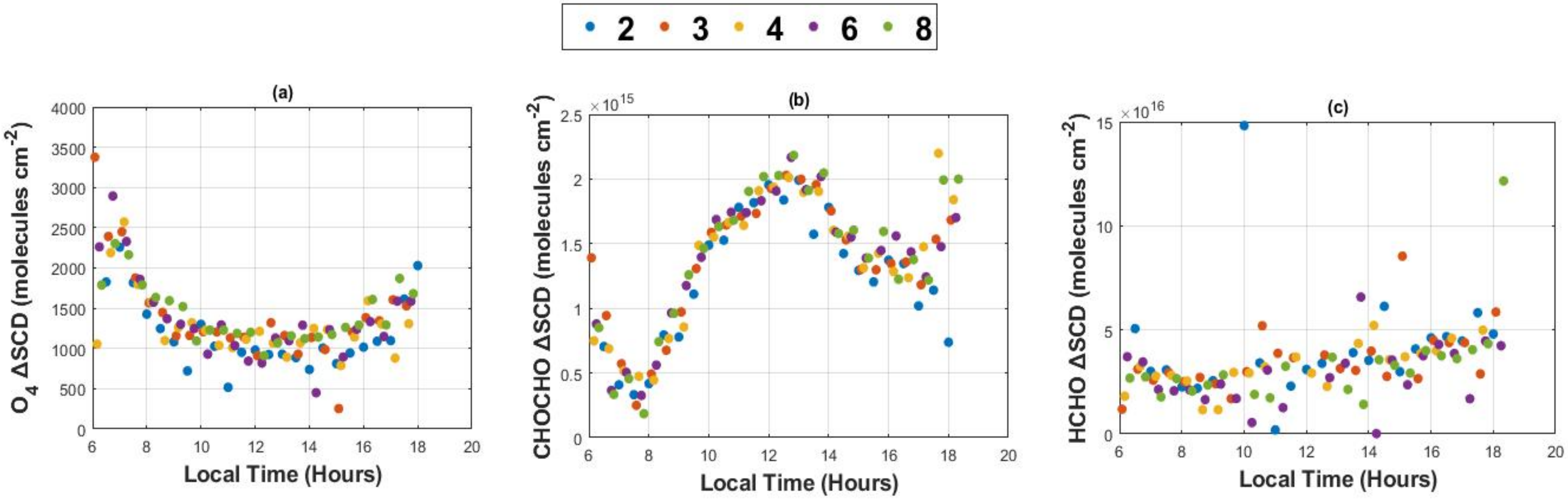


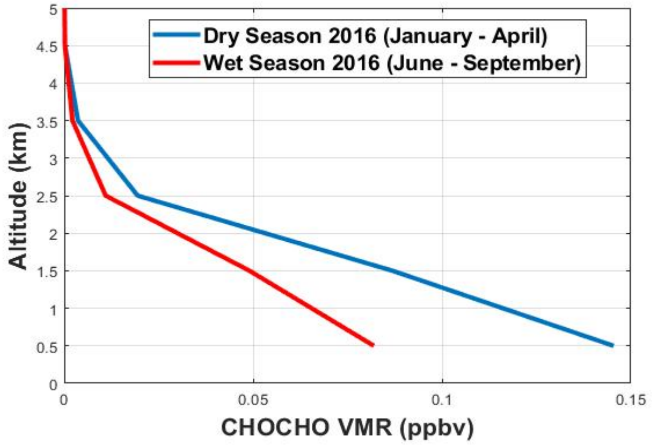



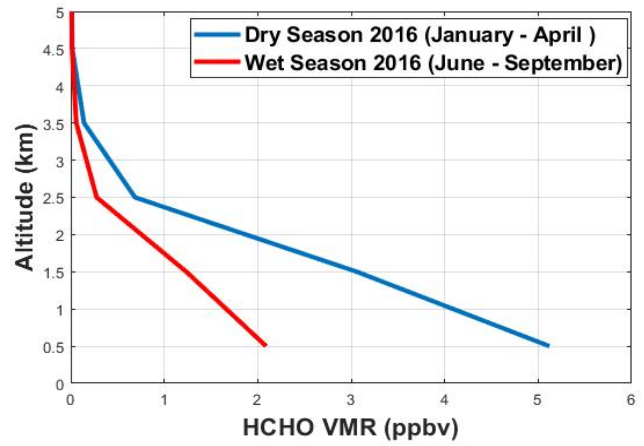
# CHOCHO, HCHO, NO2 diurnal variation in Pantnagar



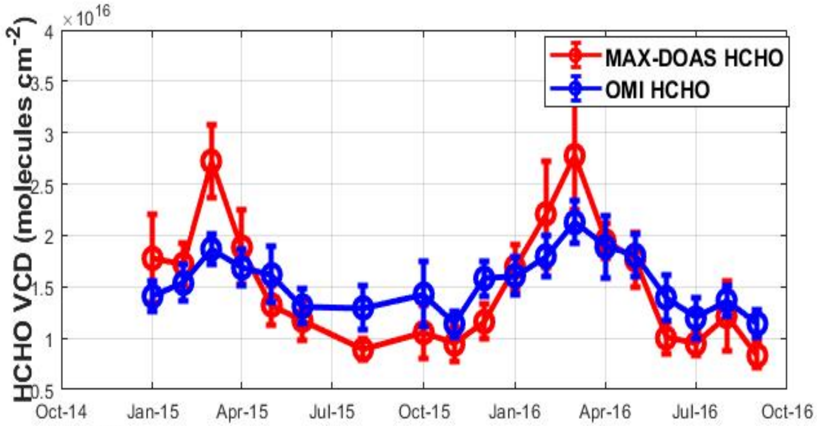
# Slant column density and profile

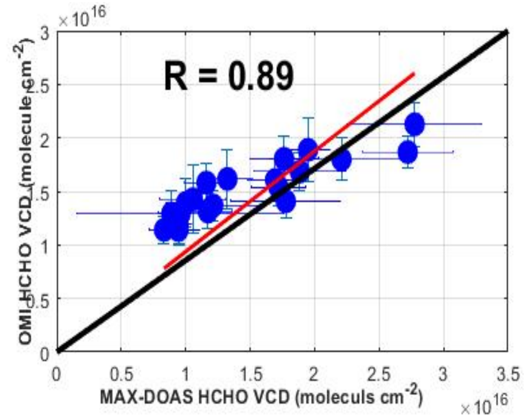


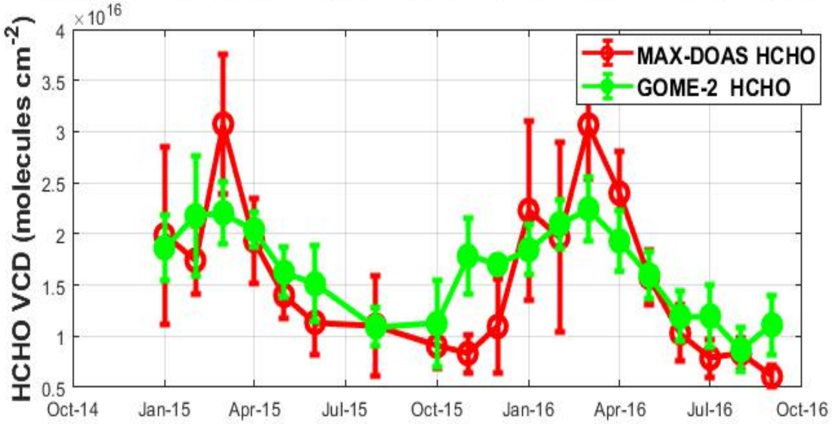



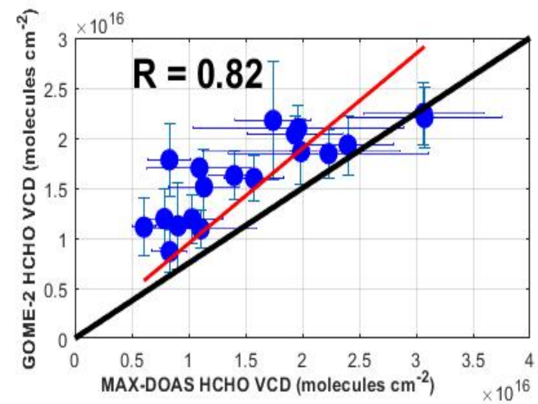



# Comparison with OMI and GOME-2 at Phimai

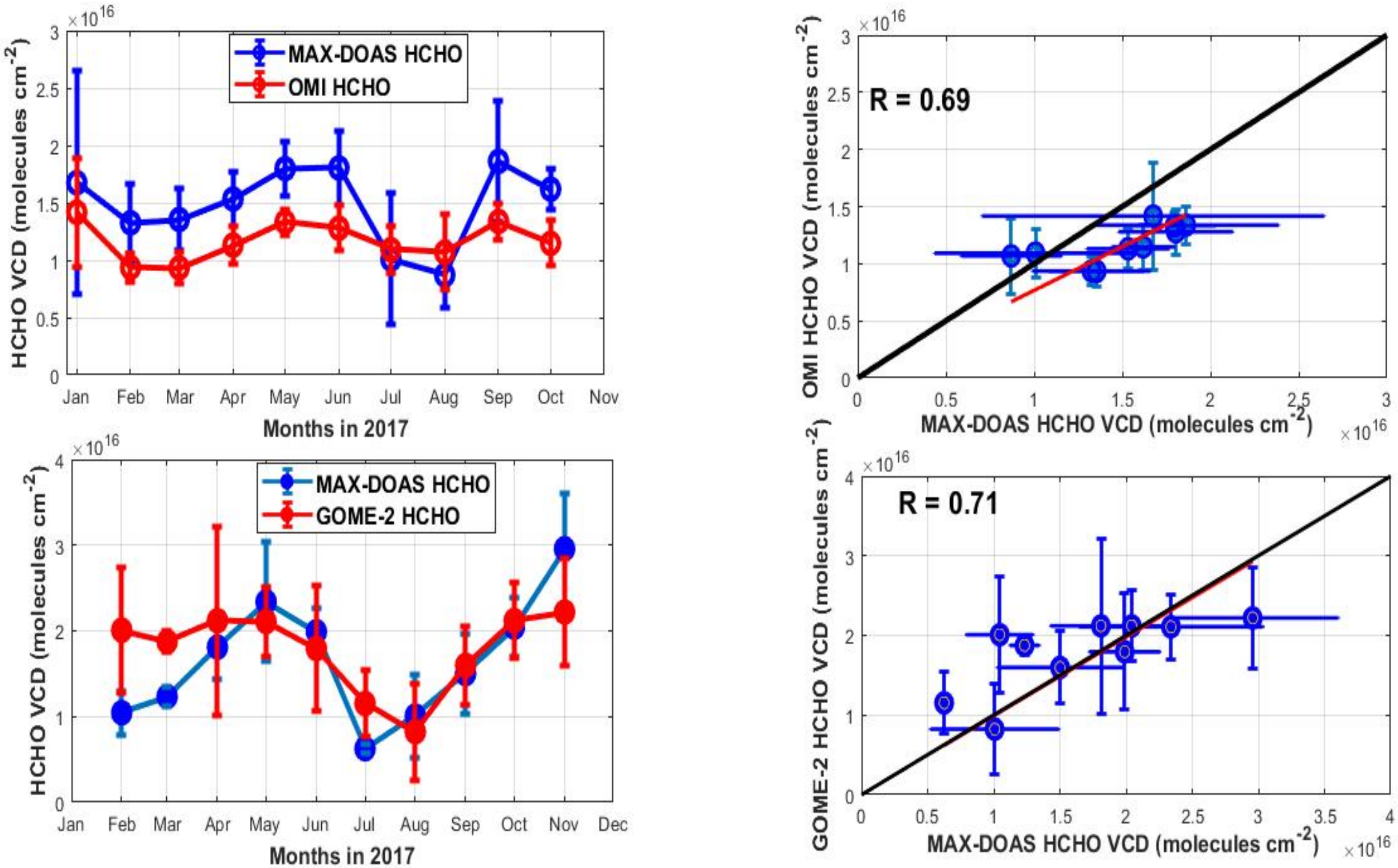


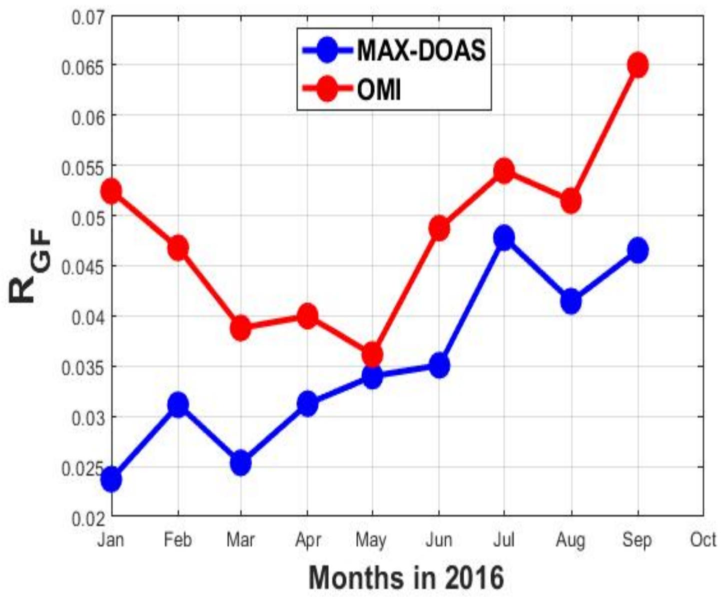



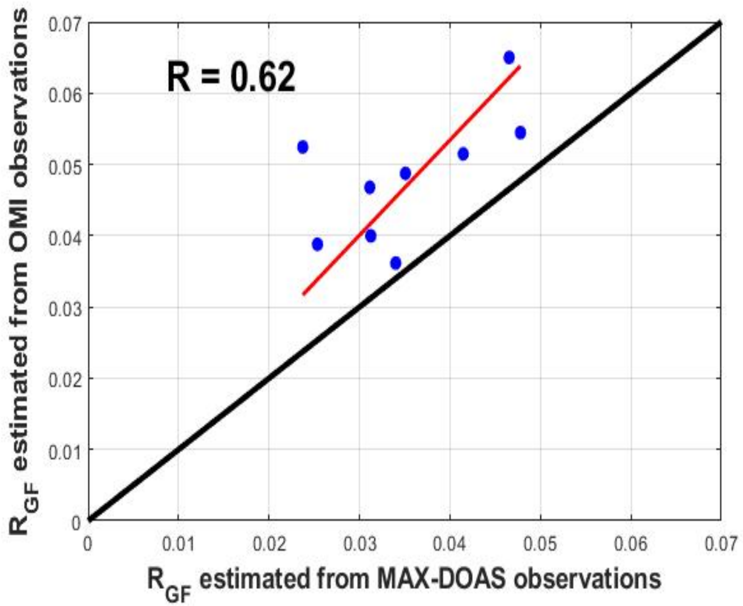



# Comparison with OMI and GOME-2 at Pantnagar

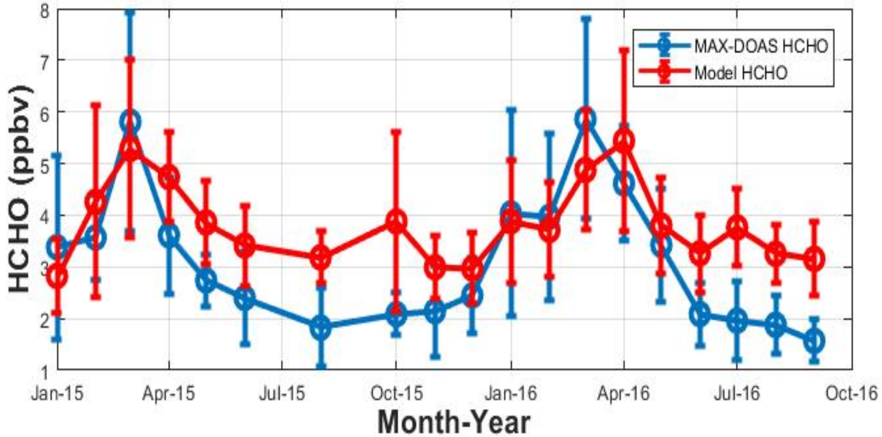


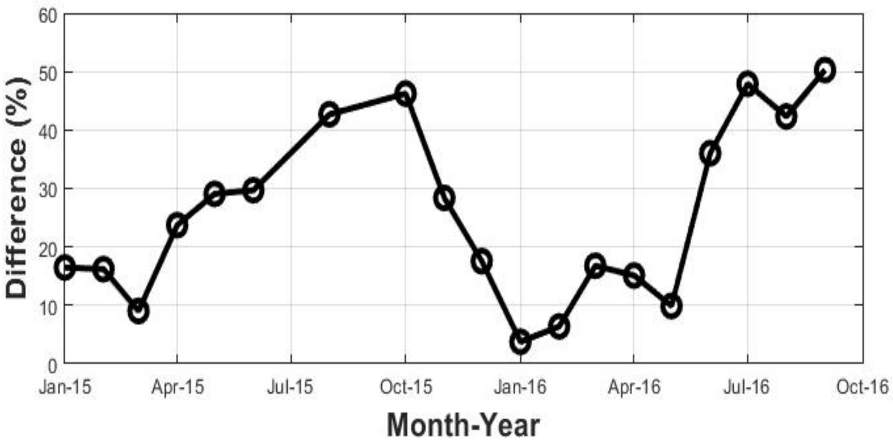
# Comparison with OMI RGF at Phimai

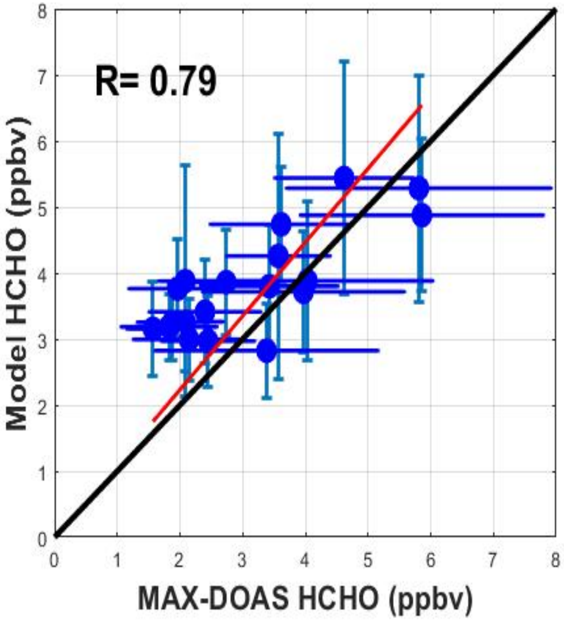


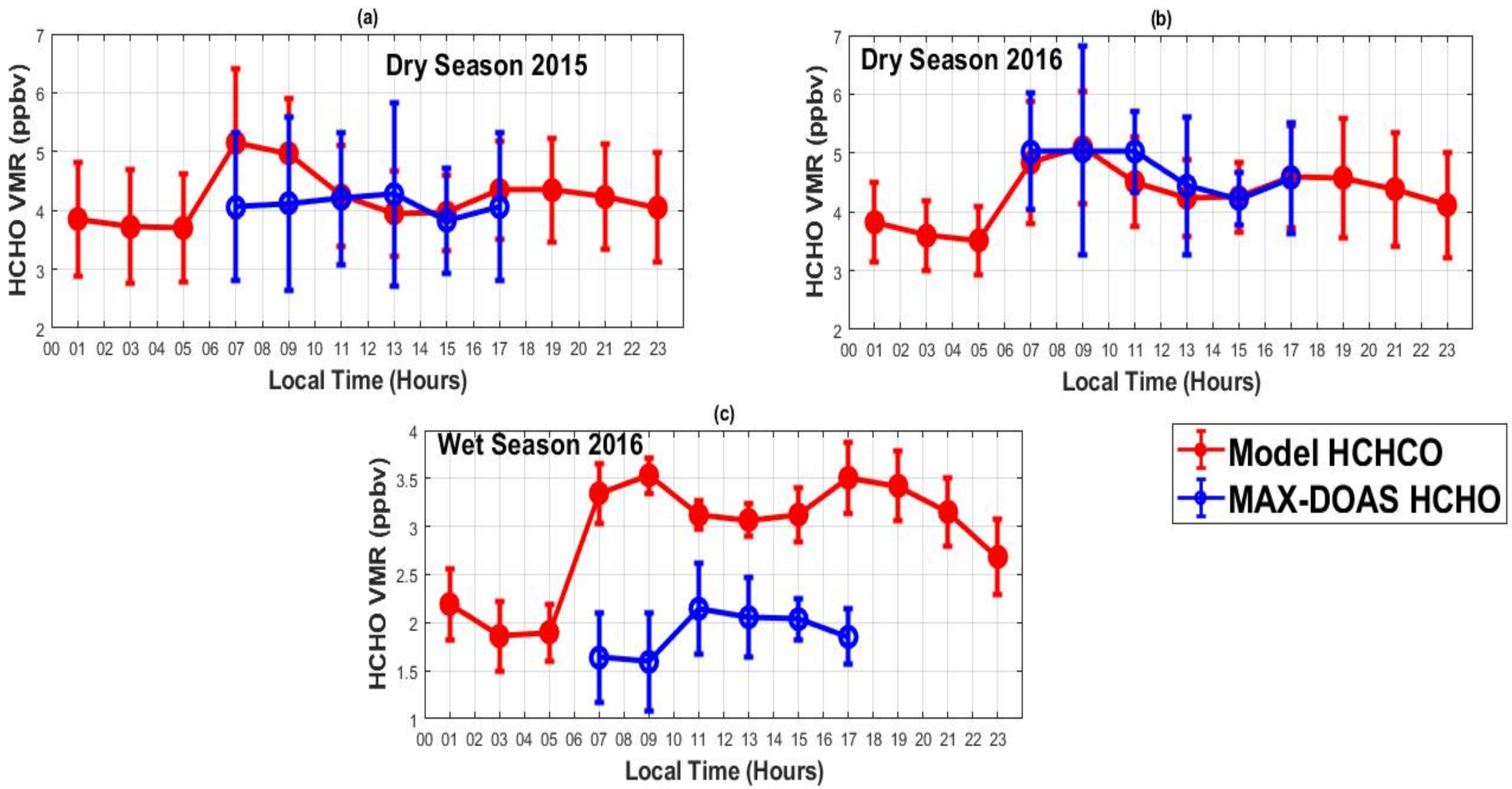
# Comparison with CHASER model for Phimai



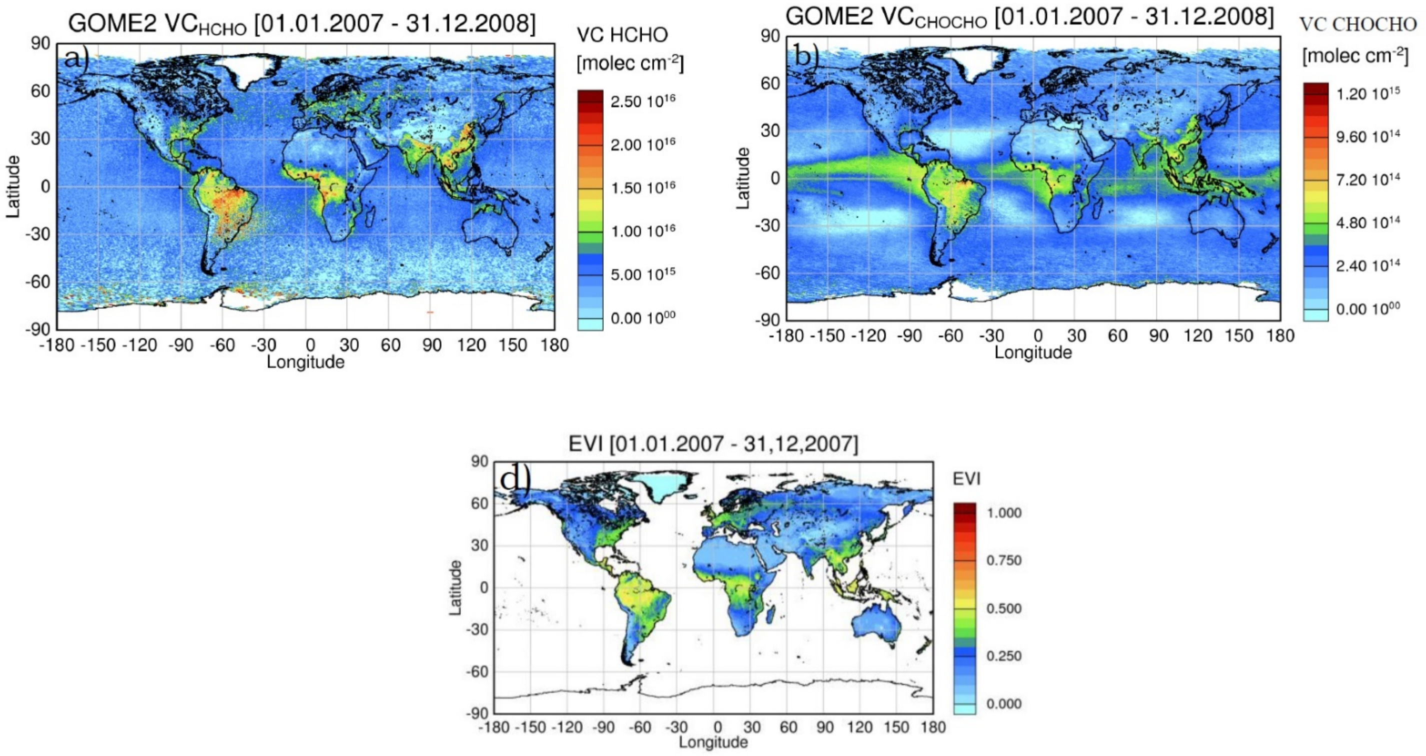



# Comparison with CHASER model for Phimai

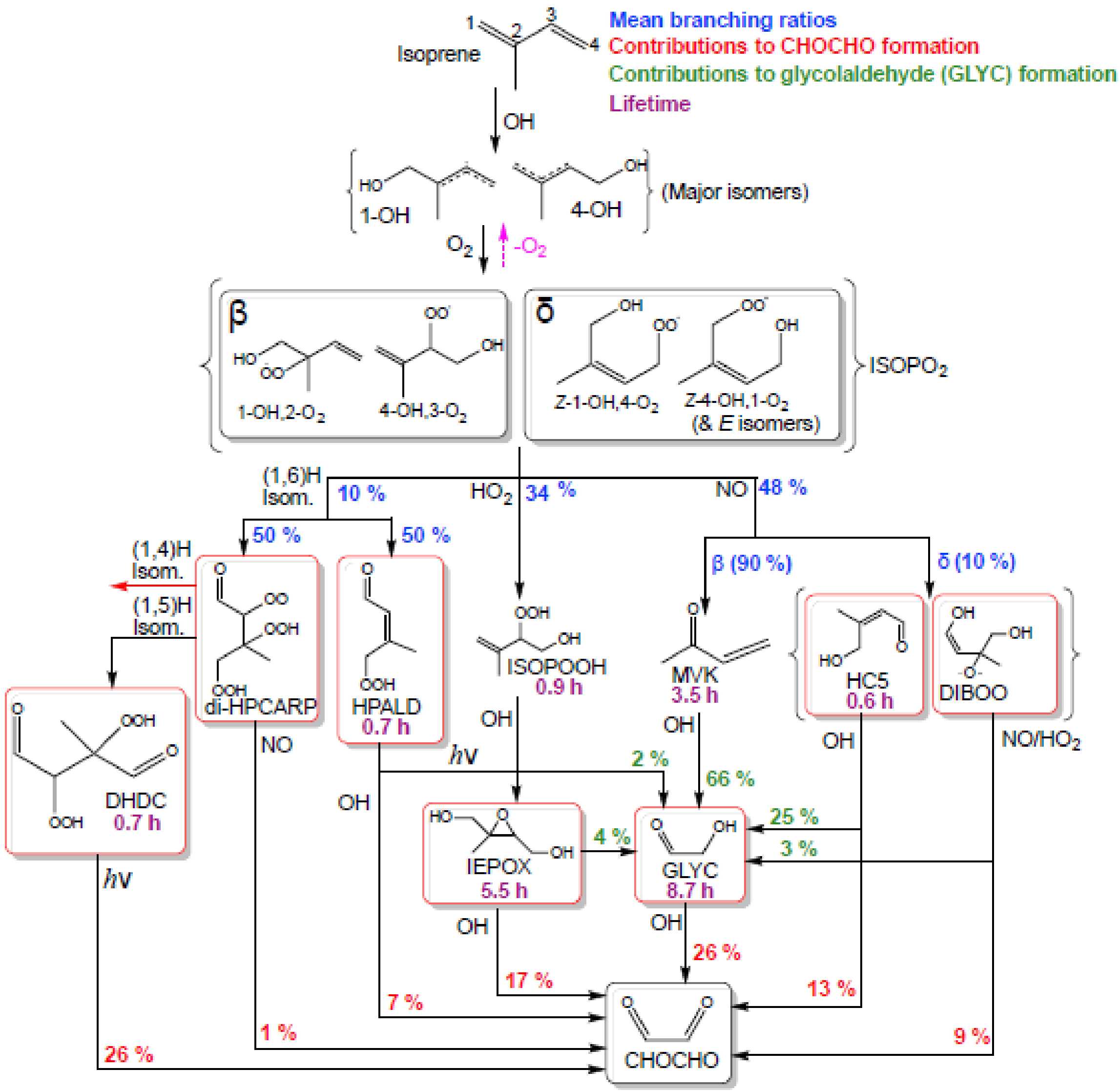


# Correlation between VOC tracers and vegetation



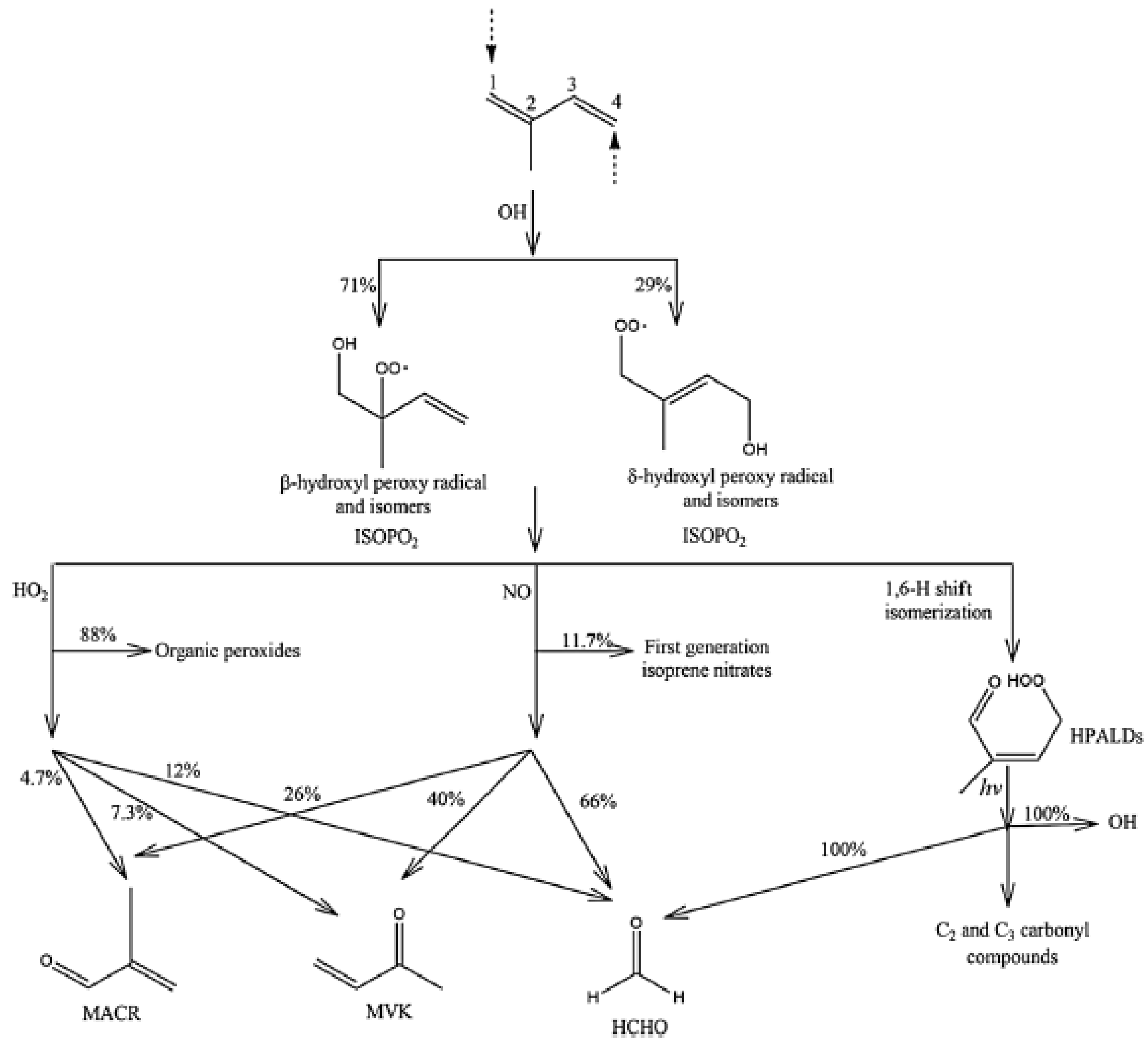

Vrekoussis et al (2010)

# CHOCHO formation from isoprenes




Miller et al (2017)

# HCHO formation from isoprenes




Mao et al (2013)