Variations in Atmospheric Hg Concentrations (GEM) and Fluxes over Deciduous Coniferous Forest in Japan

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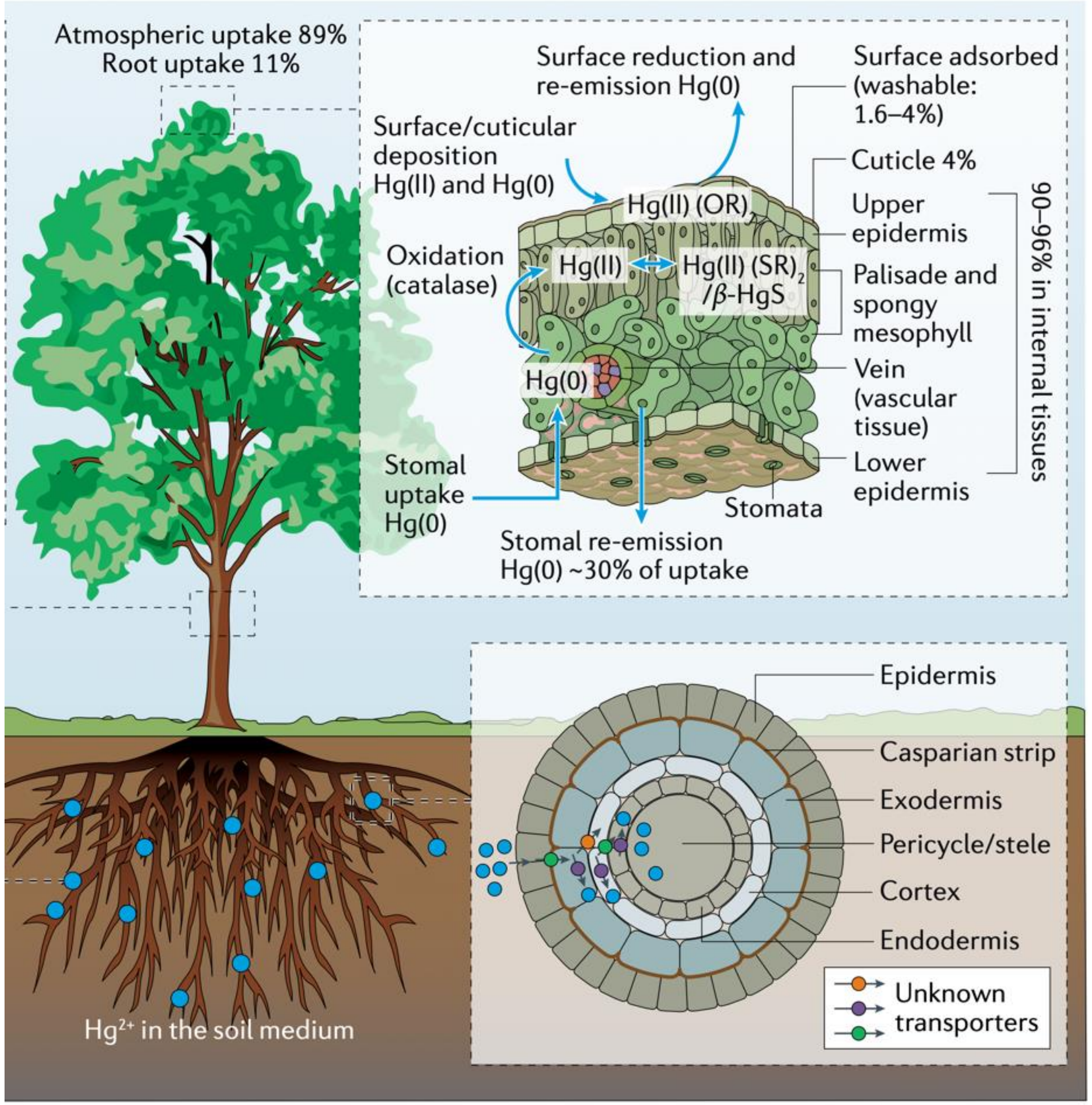
Hg monitoring in the Minamata Convention

- A fundamental scientific activity;

1. To evaluate the **global effectiveness of the convention**.
2. To ensure **national compliance**.

➢ **Understanding the natural variations in atmospheric Hg concentrations and the amount of Hg deposition is essential.**

Hg in Plants (Zhou et al., 2021)



- Foliar uptake of atmospheric Hg (Respiration & Photosynthesis)

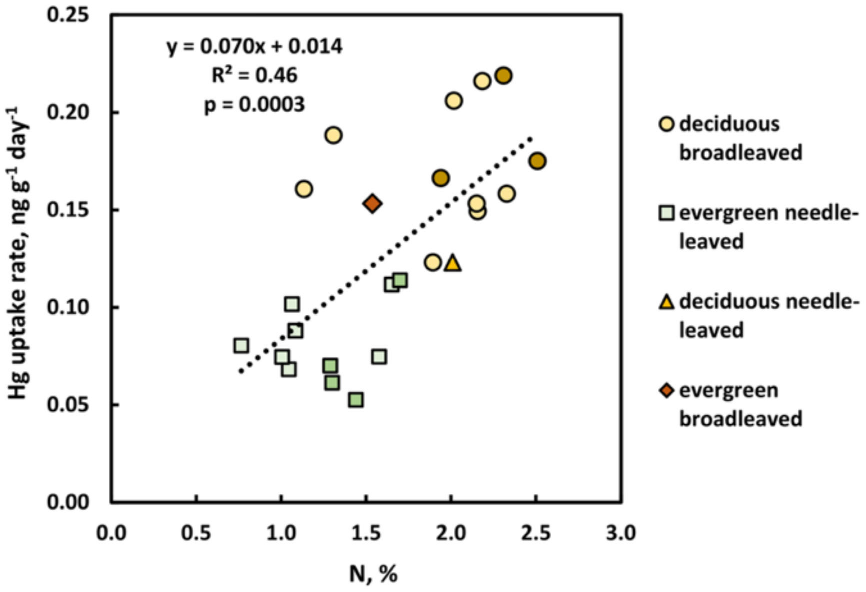
- Hg in Leaves

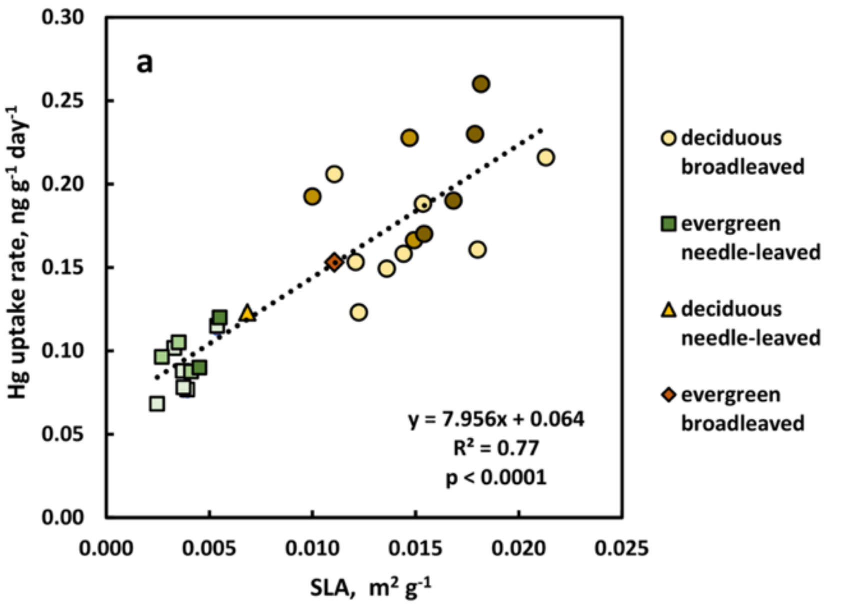
➢ ~89% by Atmospheric uptake
➢ ~11% by root uptake

➢ 90-96% of Hg in internal tissues

➢ ~30% of uptake Hg(0) is re-emitted.

Foliar Hg Uptake Rates in Plants (Pleijel et al., 2026)





- Hg uptake rates are related with;

1. **Leaf functional traits** (broadleaf or needle-leaf)
2. **Habits** (evergreen or deciduous)
3. **Nitrogen content** (N%)
4. **Specific Leaf Area** (SLA)

etc.

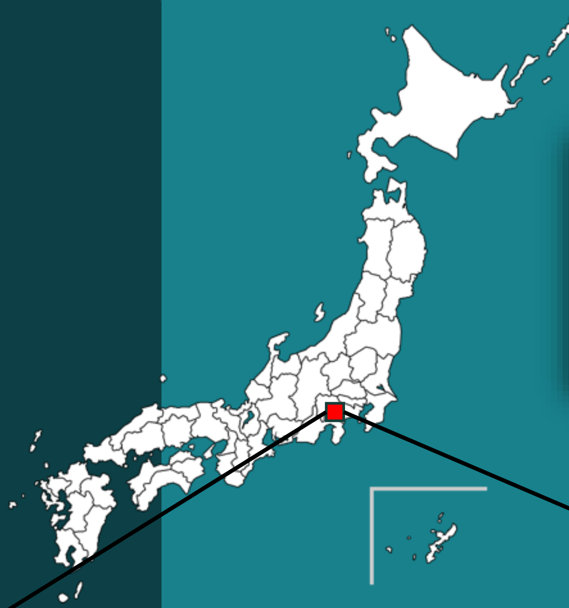
Hg^0 Deposition in Terrestrial Ecosystems

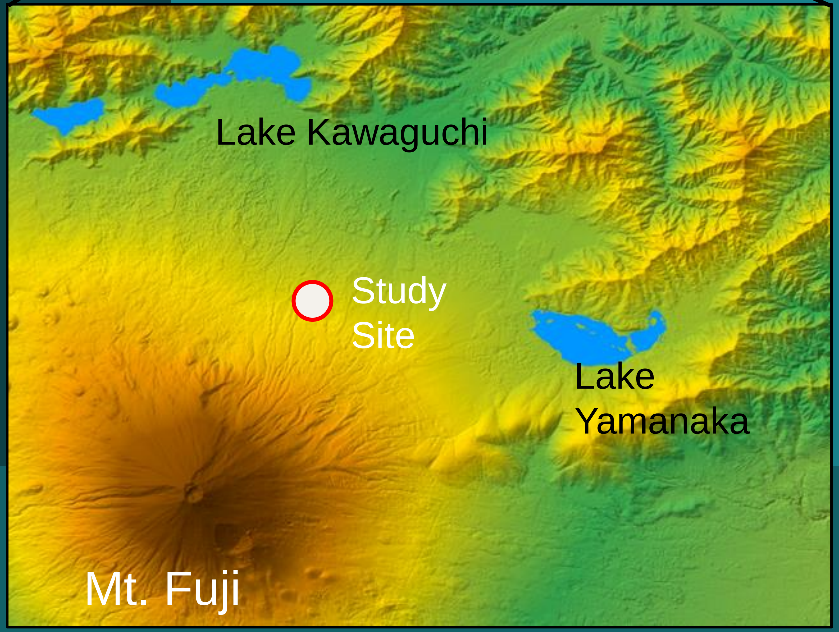
- Vegetation uptake represents the dominant pathway of atmospheric Hg deposition to terrestrial surfaces.

Biomes	Hg^0 Deposition (Growing season) $\mu g/m^2$	Ref.
Evergreen Broadleaf	**~ 53.9**	Wang et al., 2022
Deciduous Broadleaf	**~ 35.3**	Zhou et al., 2023
Evergreen Coniferous	**~ 12.6**	Zhou et al., 2023
Grassland	**~ 37.7**	Fritsche et al., 2008
Tundra	**~ 3.6**	Obrist et al., 2017
Agricultural Grazing Field	**~ 0.5**	MacSween et al., 2020

- **Deciduous coniferous ecosystem remains unexplored.**

Study Site: Fuji North Flux Observation Site





Japanese Larch

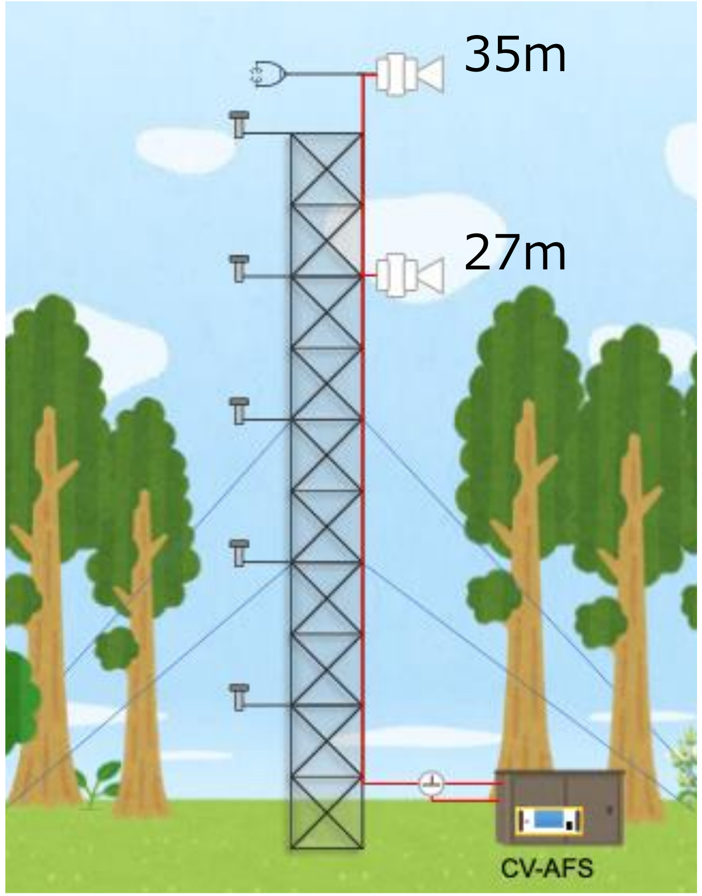
Summer

Winter

Site Information (A part of Fuji-Hakone-Izu National Park)

Elevation	1,030 m
Area	35 km^2
Mean Annual Temp.	~10.0 ºC
Mean Annal Precipitation	~1,500 mm
Vegetation Type	Deciduous Needle-Leaf Forest
Dominant Species	Japanese Larch（~80%）
Tree Height	~26 m
Growing Season	Mid-Apr. to Mid-Nov.

Monitoring Method since Feb., 2024



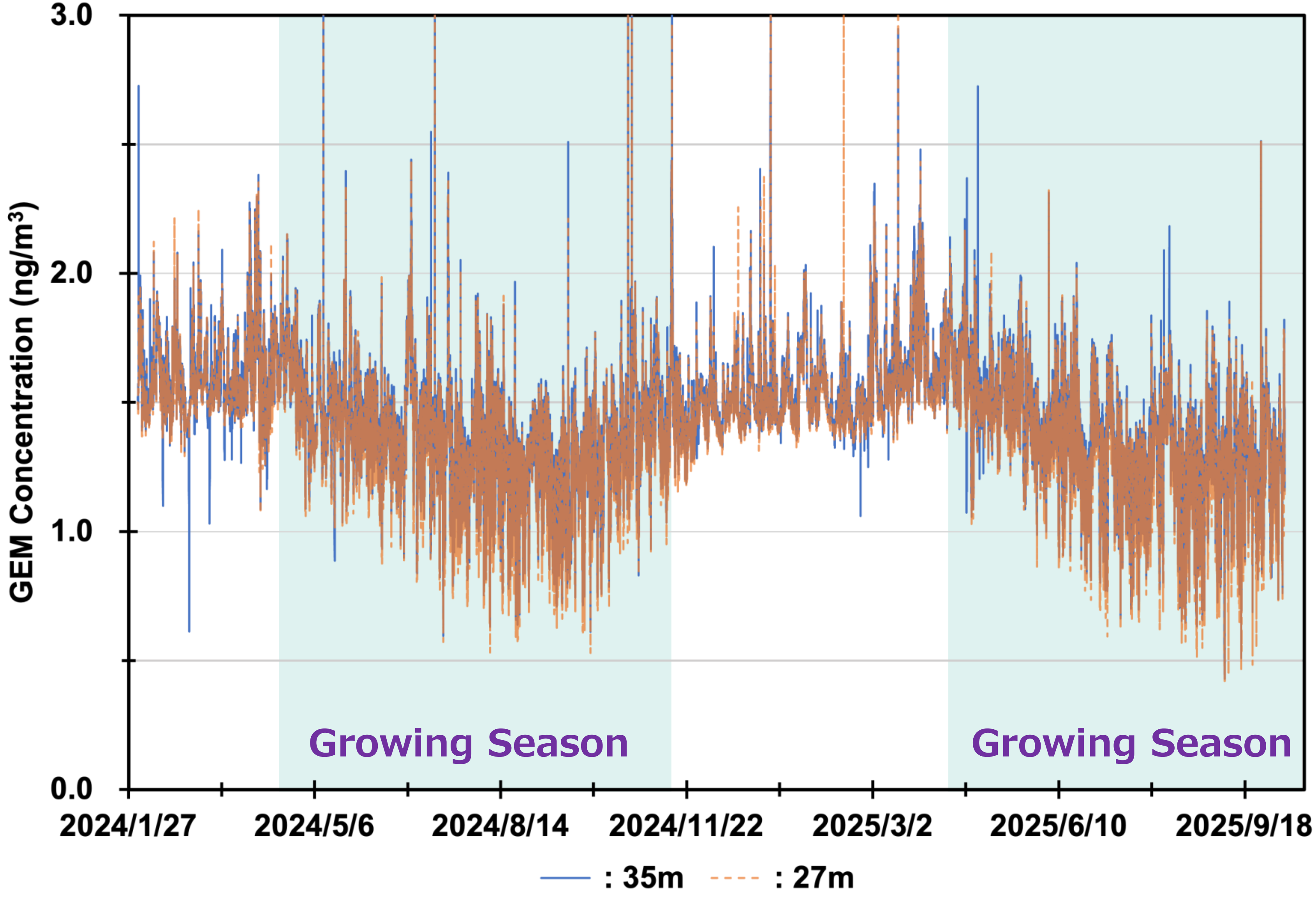
Flux Tower (35m)

Switching Valve

Tekran2537x

- GEM measurements at 27m and 35m every 10-min
- PFA Inlets and Lines
- Ancillary Data: Wind speed, direction, Air Temp, etc.

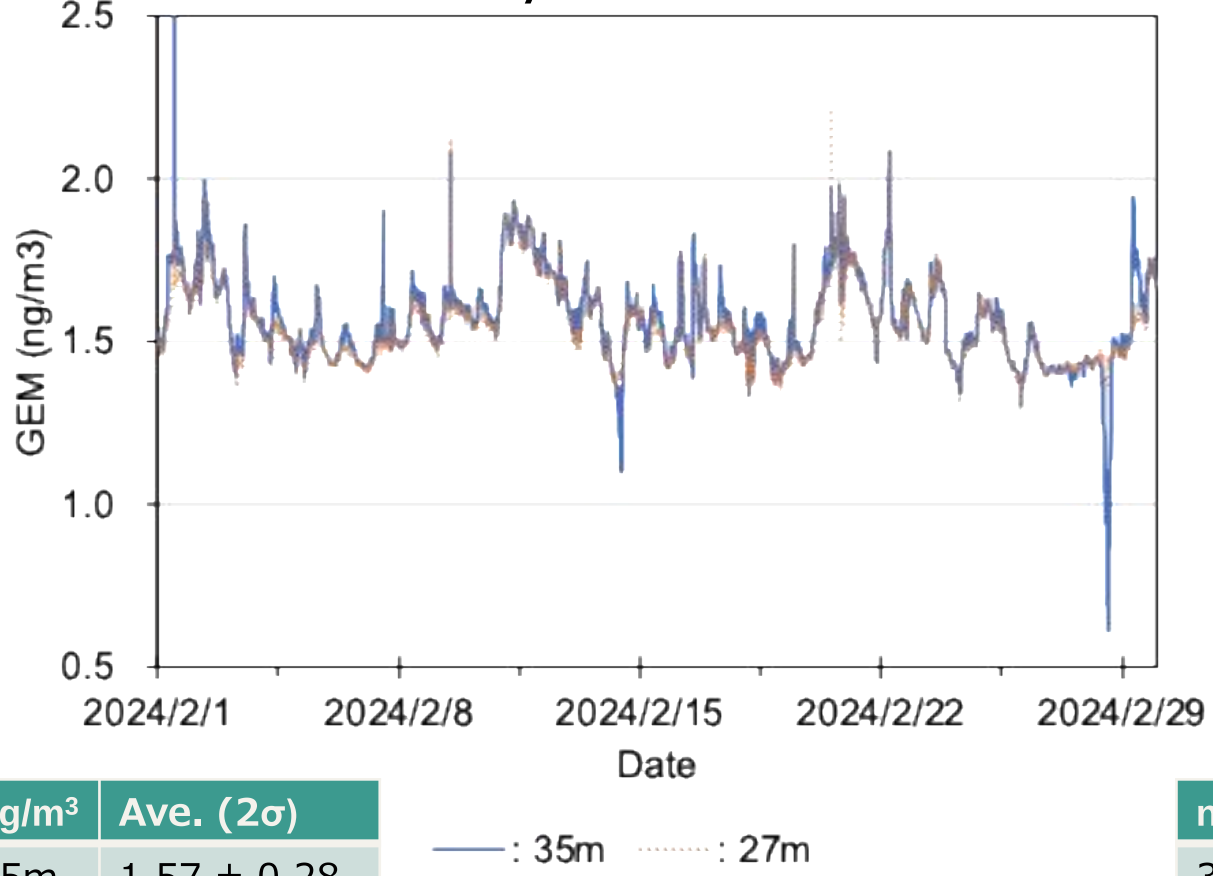
Continuous Hg Monitoring (Feb., 2024~)



	Ave. (2σ) ng/m^3
35m	1.44 ± 0.22
27m	1.42 ± 0.23

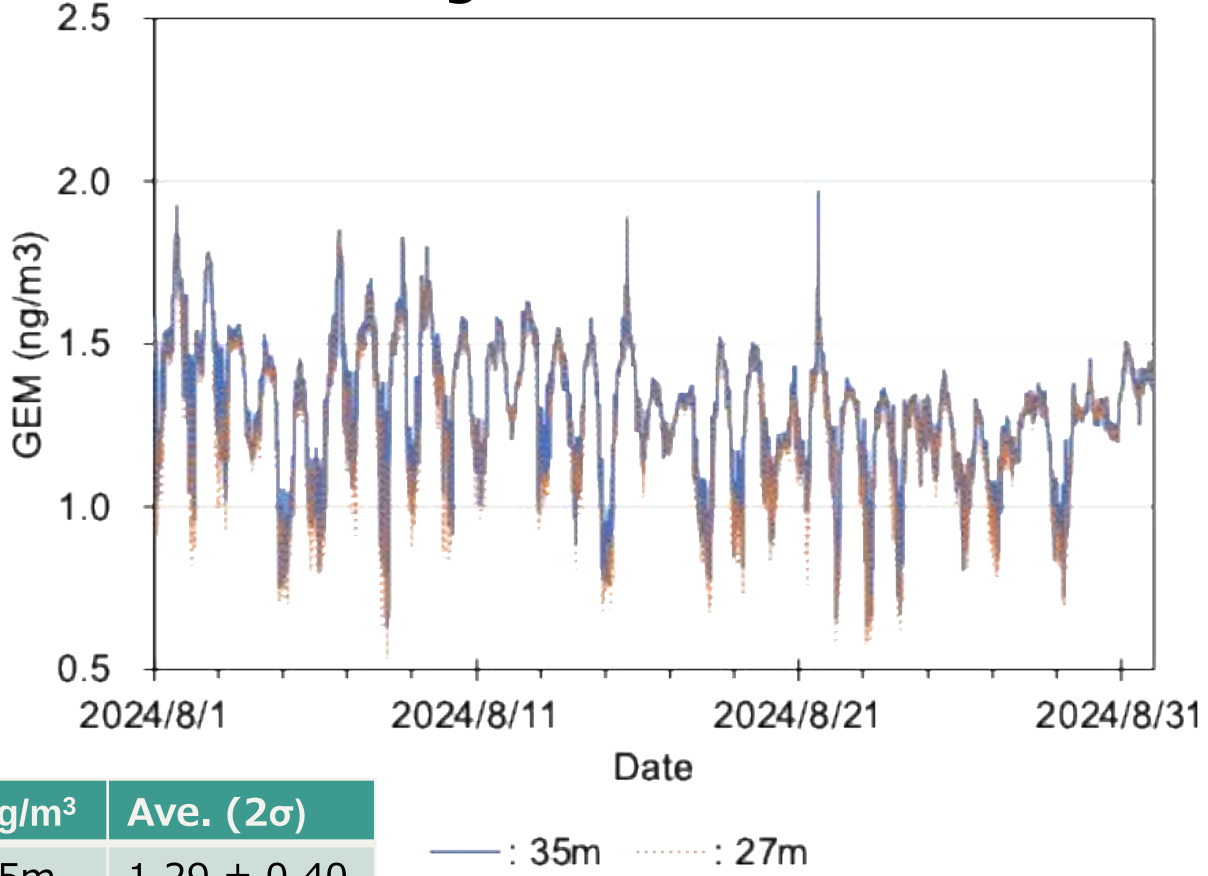
Monthly GEM Variations (2024 Feb. vs Aug.)

February (Non-Growing Season)



ng/m^3	Ave. (2σ)
35m	1.57 ± 0.28
27m	1.55 ± 0.24

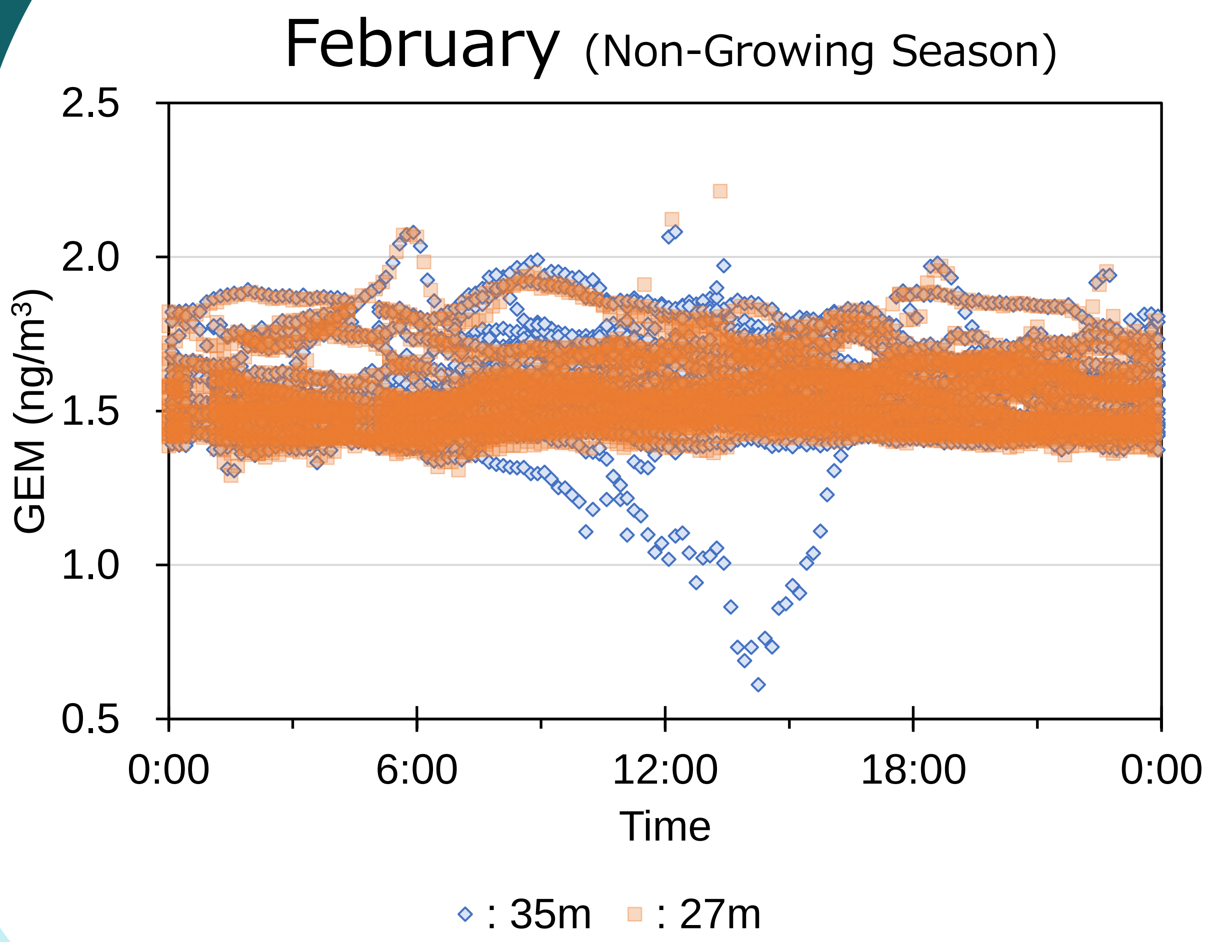
August (Growing Season)

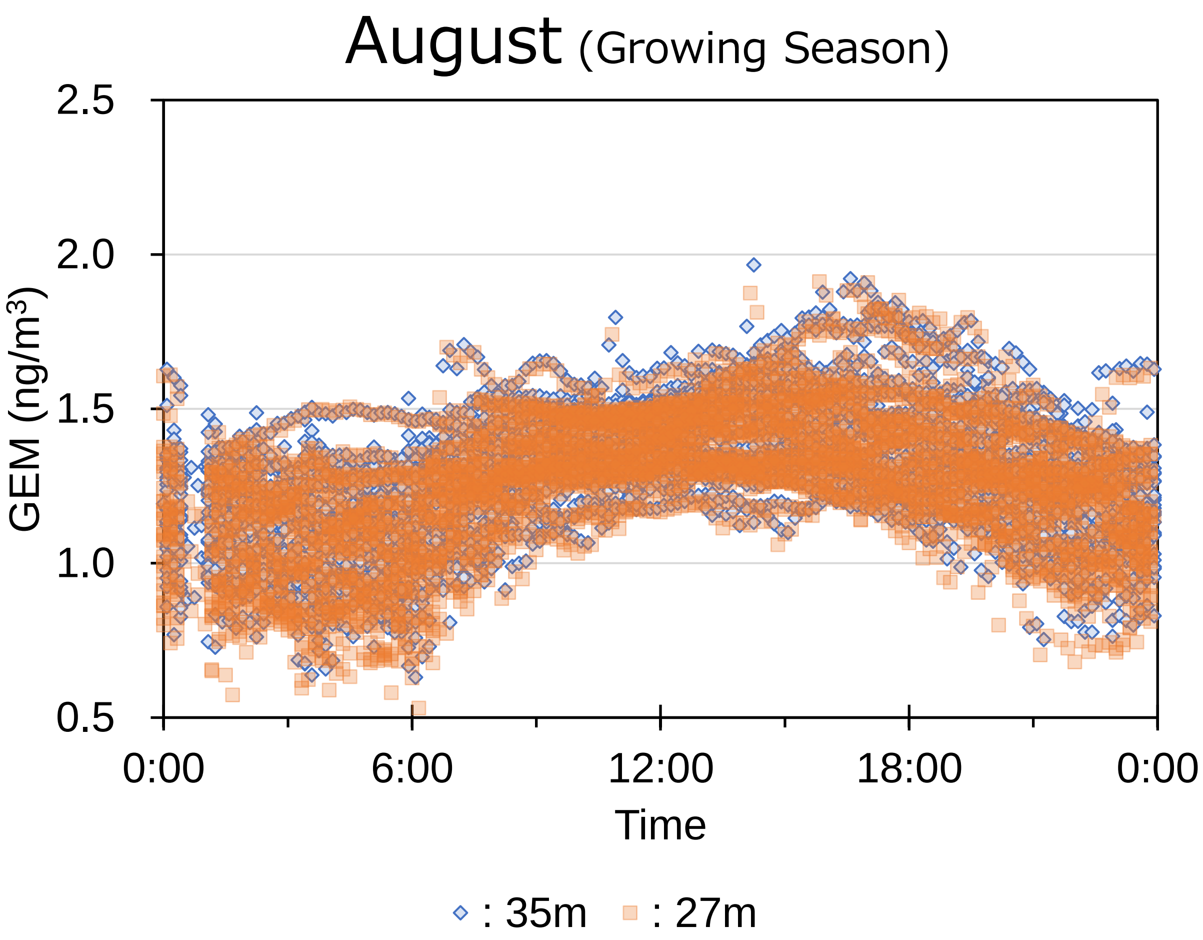


ng/m^3	Ave. (2σ)
35m	1.29 ± 0.40
27m	1.26 ± 0.44

- GEM concentrations in Aug were generally lower than Feb.
- The larger GEM variations during the late growing season

Diurnal GEM Variations (2024 Feb. vs Aug.)





- Feb. GEM Concentrations were nearly constant throughout the days.
- Aug. GEM Concentrations in the daytime were higher than the nights.

Causes of Diurnal Variations in GEM

① Daytime Anthropogenic Impacts?

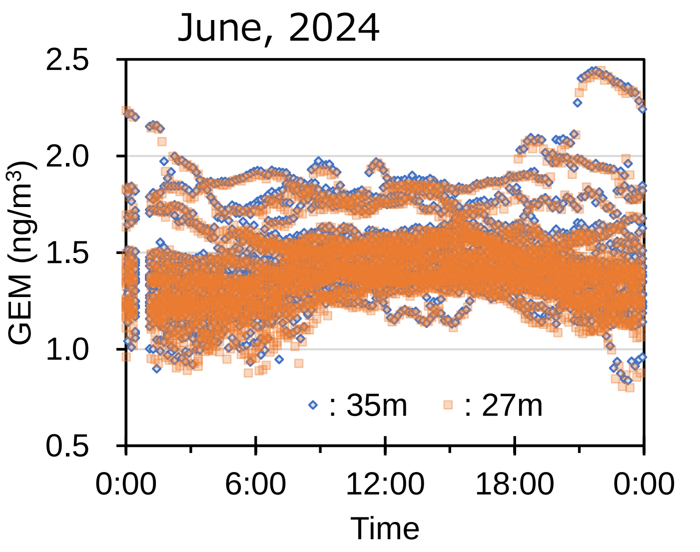
- In a **national park**
- Comparable to the **background GEM level**

② Daytime Long-range Transport Impacts?

- Not related to **wind direction**

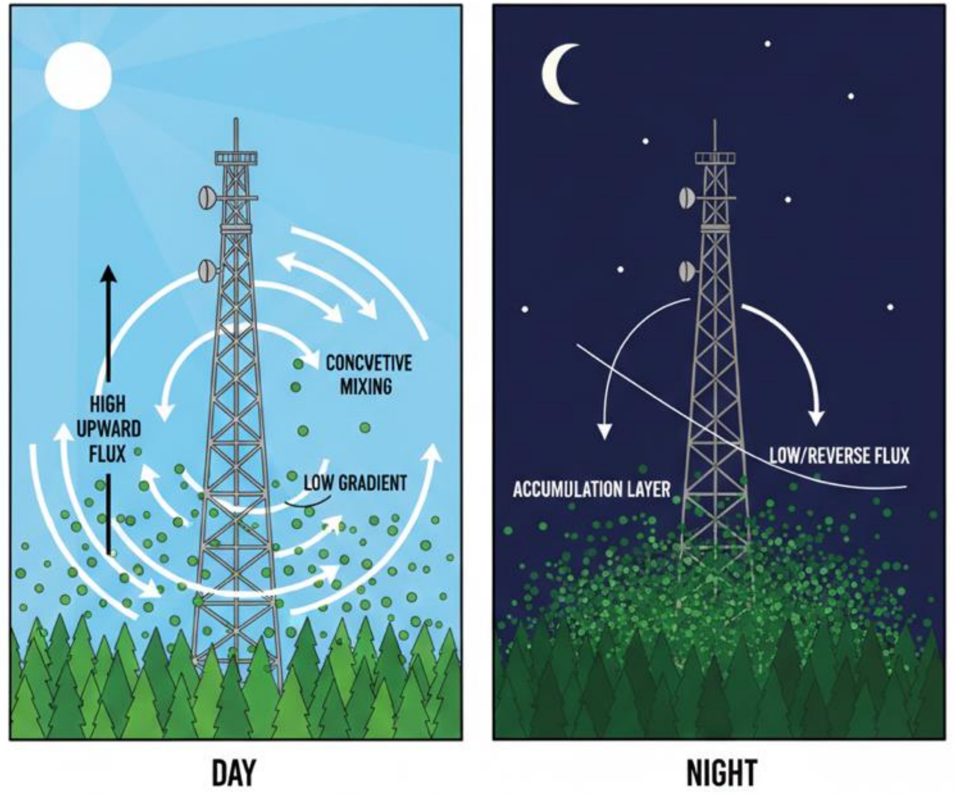
③ Nighttime Vegetative Impacts?

- **Not significant** from Apr. to June



- **Atmospheric Rectification Effect**

A meteorological phenomenon where diurnal cycles in atmospheric stability and turbulence lead to a net, one-directional transport of a substance



Variations in Atmospheric Stability at Fuji North

- **Atmospheric Stability**

$$\zeta = \frac{z}{L}$$

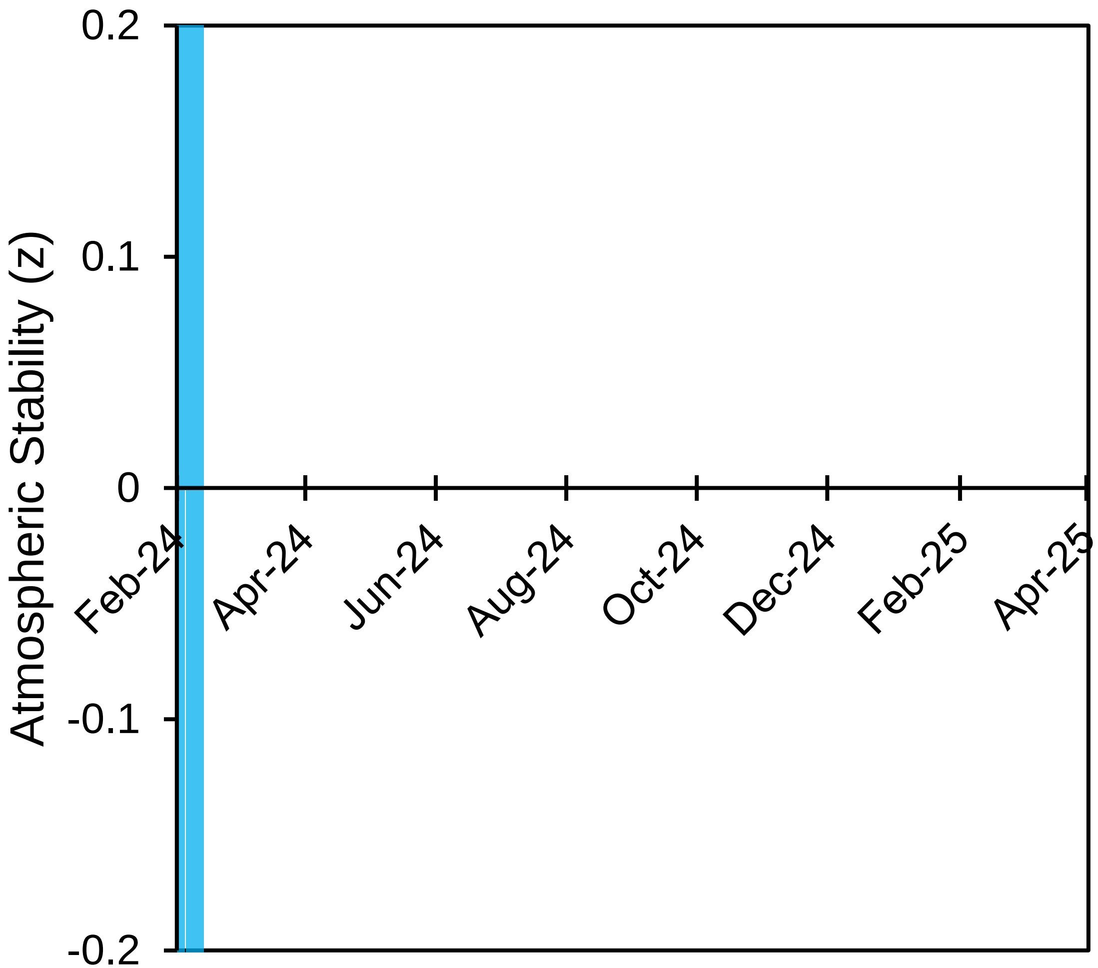
z: Height of Sonic Anemometer (35m) in cm
L: Monin-Obukhov Length

According to Peichl et al. (2013)

➢ Stable:
$\underline{\zeta > 0.1}$ (stop and return to its original level)

➢ Unstable:
$\underline{\zeta < -0.1}$ (keep rising)

➢ Neutral:
$\underline{-0.1 < \zeta < 0.1}$ (do neither strongly)



➢ Stable periods calculated at all times in the late growing season (July – Sept)

Micrometeorological Flux-gradient Method

$$\boxed{F = -K\frac{\Delta C}{\Delta Z}}$$

F :Hg^0 Flux ($ng \cdot m^{-2} \cdot sec^{-1}$)

K: Vertical Turbulent Exchange Coefficient (m^2/s)

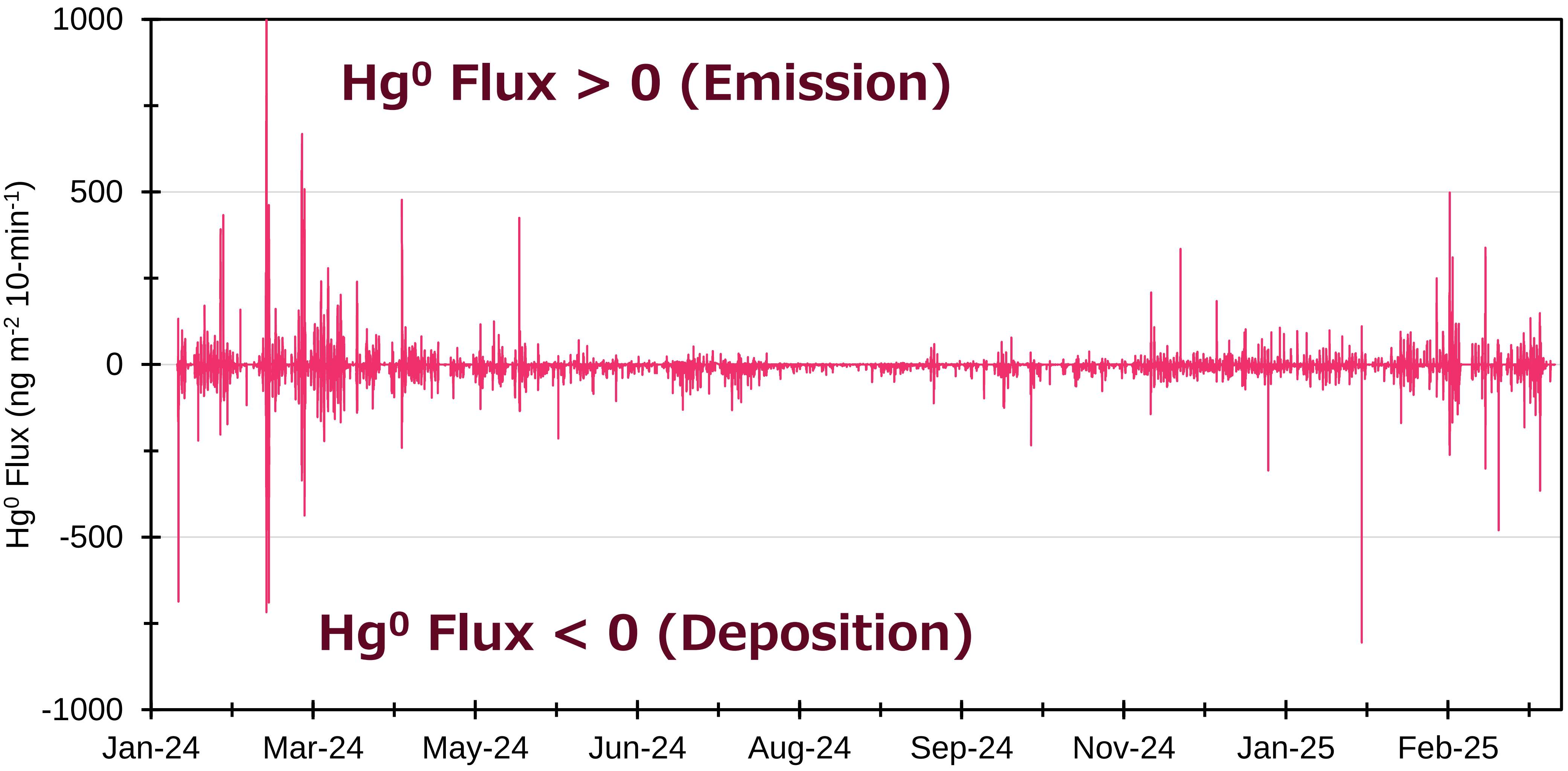
$$K = \frac{u^* k z}{\Phi_c(\zeta)}$$

- u^*:Fiction Velocity (m/s)
- k: Karman Constant (0.4)
- z: Height (m)
- $\Phi_c(\zeta)$: Integrated Similarity Function

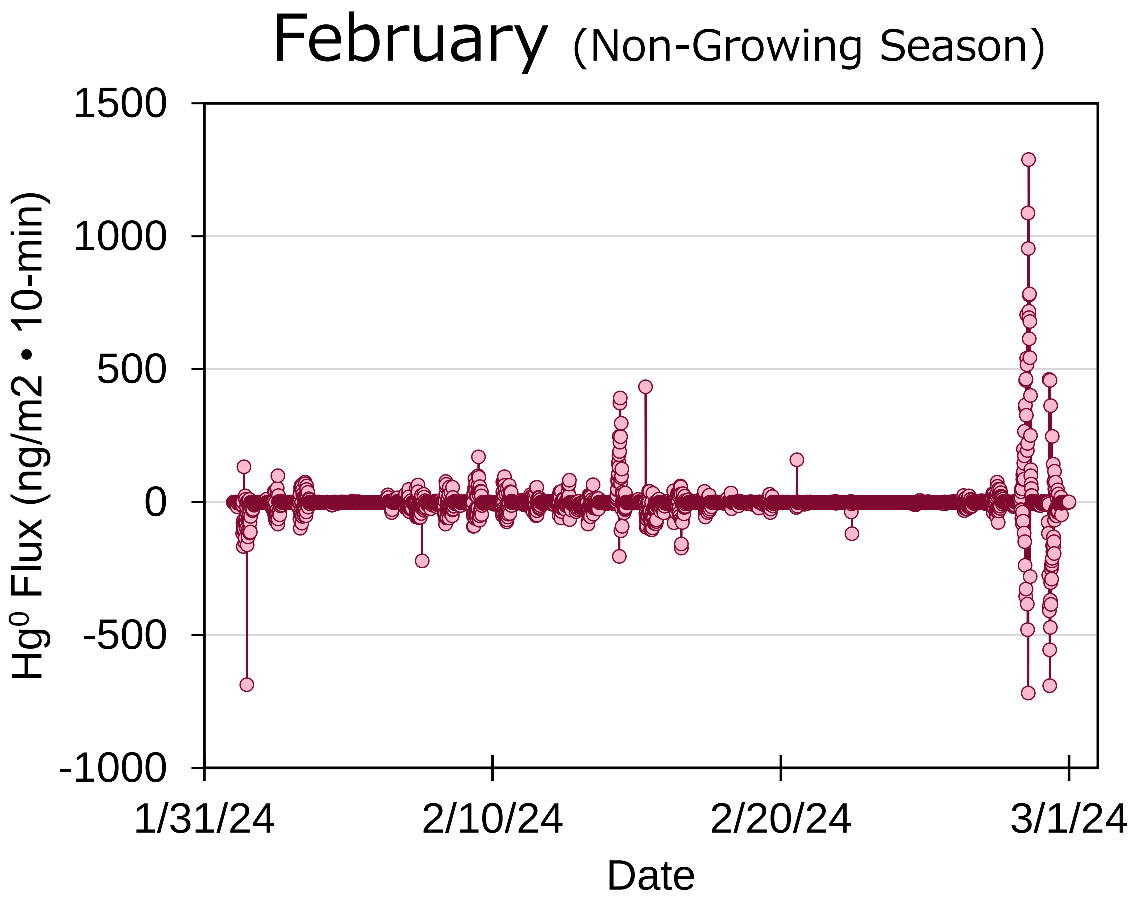
ΔC: Hg^0 Concentration gradient (ng/m^3)

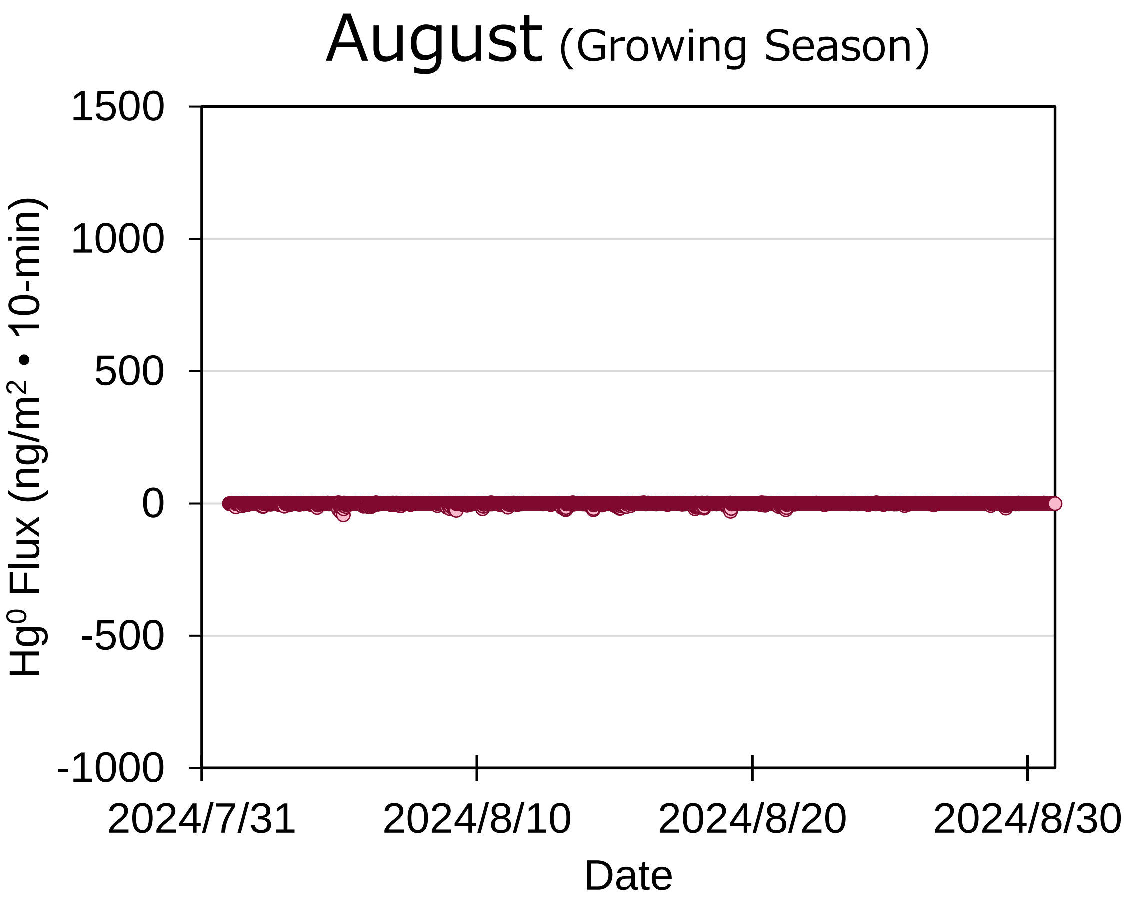
ΔZ: Difference in Inlet Height (m): 35m vs. 27m

Hg^0 Flux Variations (Feb. 2024 – Apr. 2025)

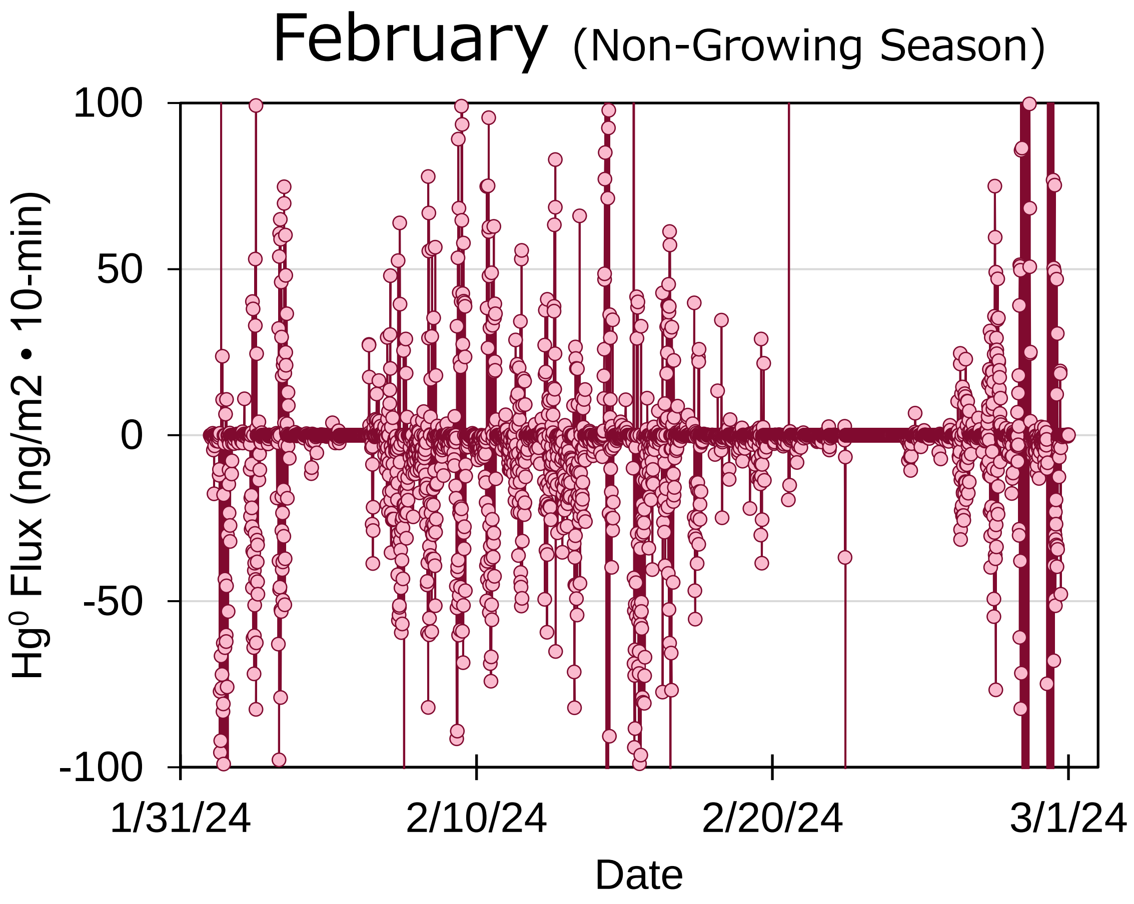


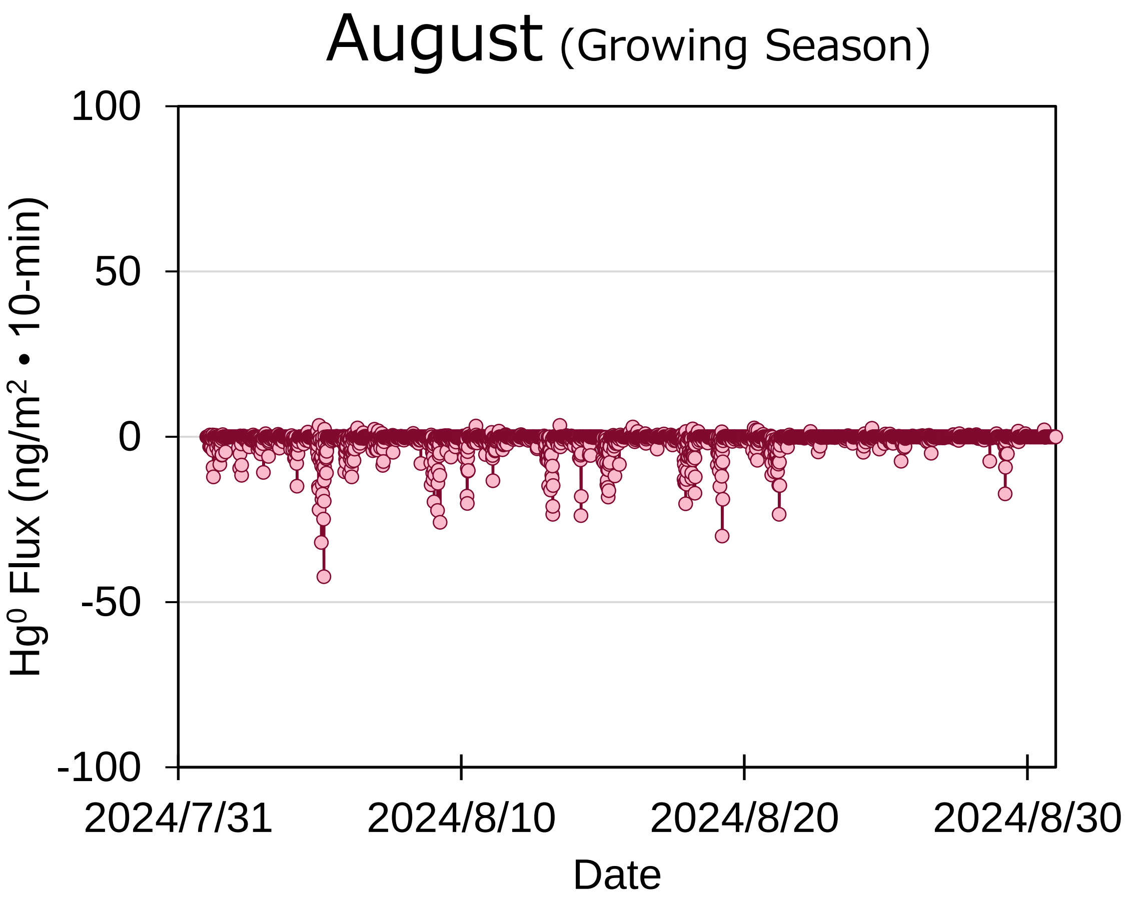
Monthly Hg^0-Flux Variations (2024 Feb. vs Aug.)





Monthly Hg^0-Flux Variations (2024 Feb. vs Aug.)

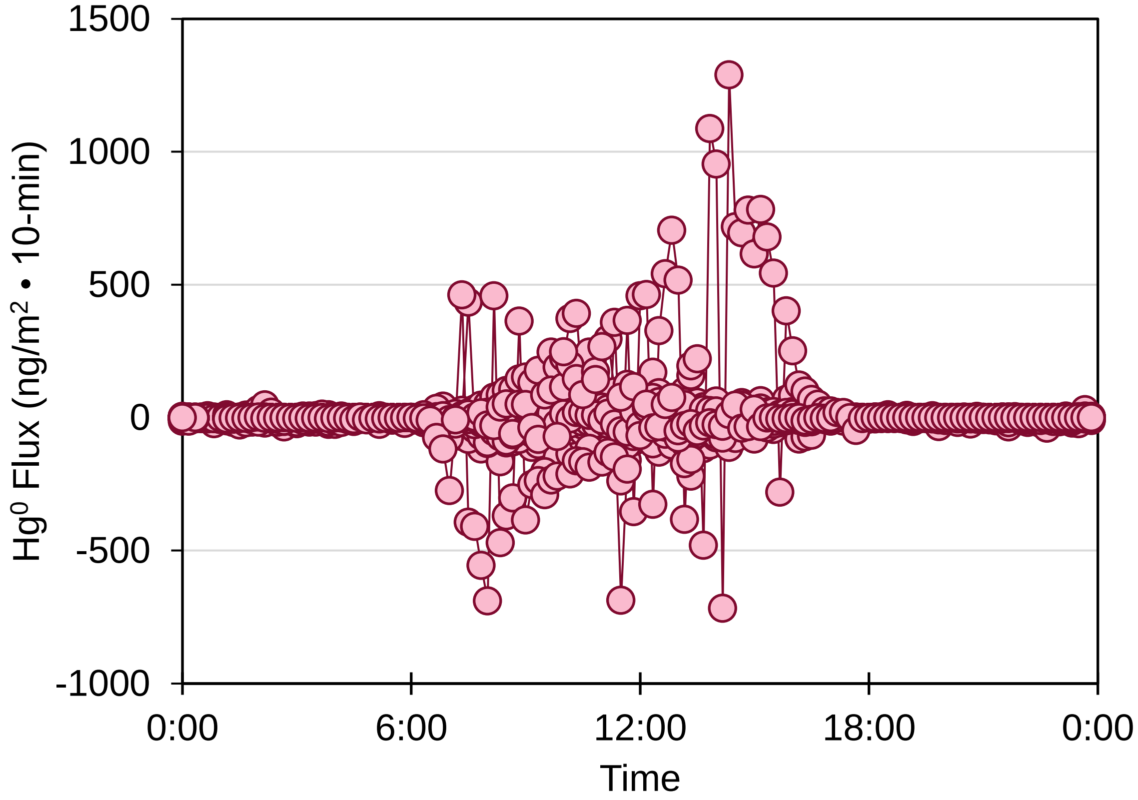




- Larger Hg^0-Flux variations in Feb.
- Not much Hg^0 emissions and deposition in Aug.

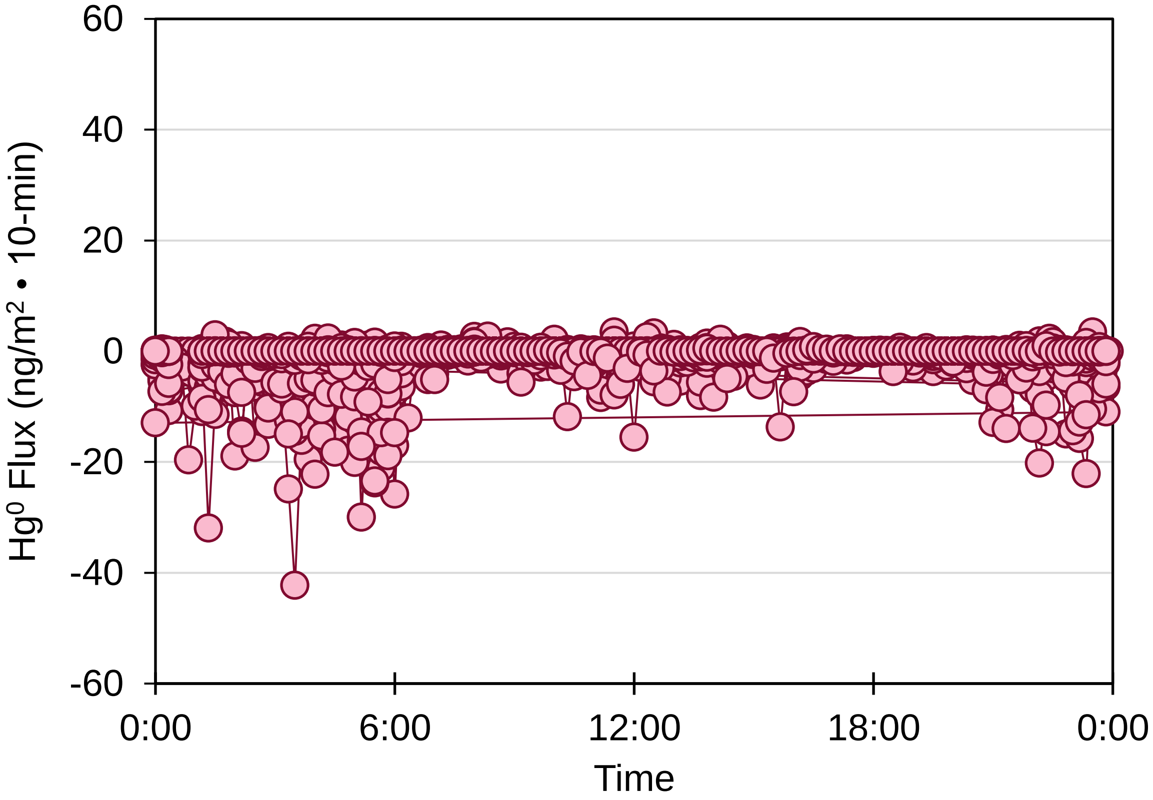
Diurnal Hg^0-Flux Variations (2024 Feb. vs Aug.)

February (Non-Growing Season)



Cumulative Hg^0 Flux: **-3.60** μg/m² (Feb)

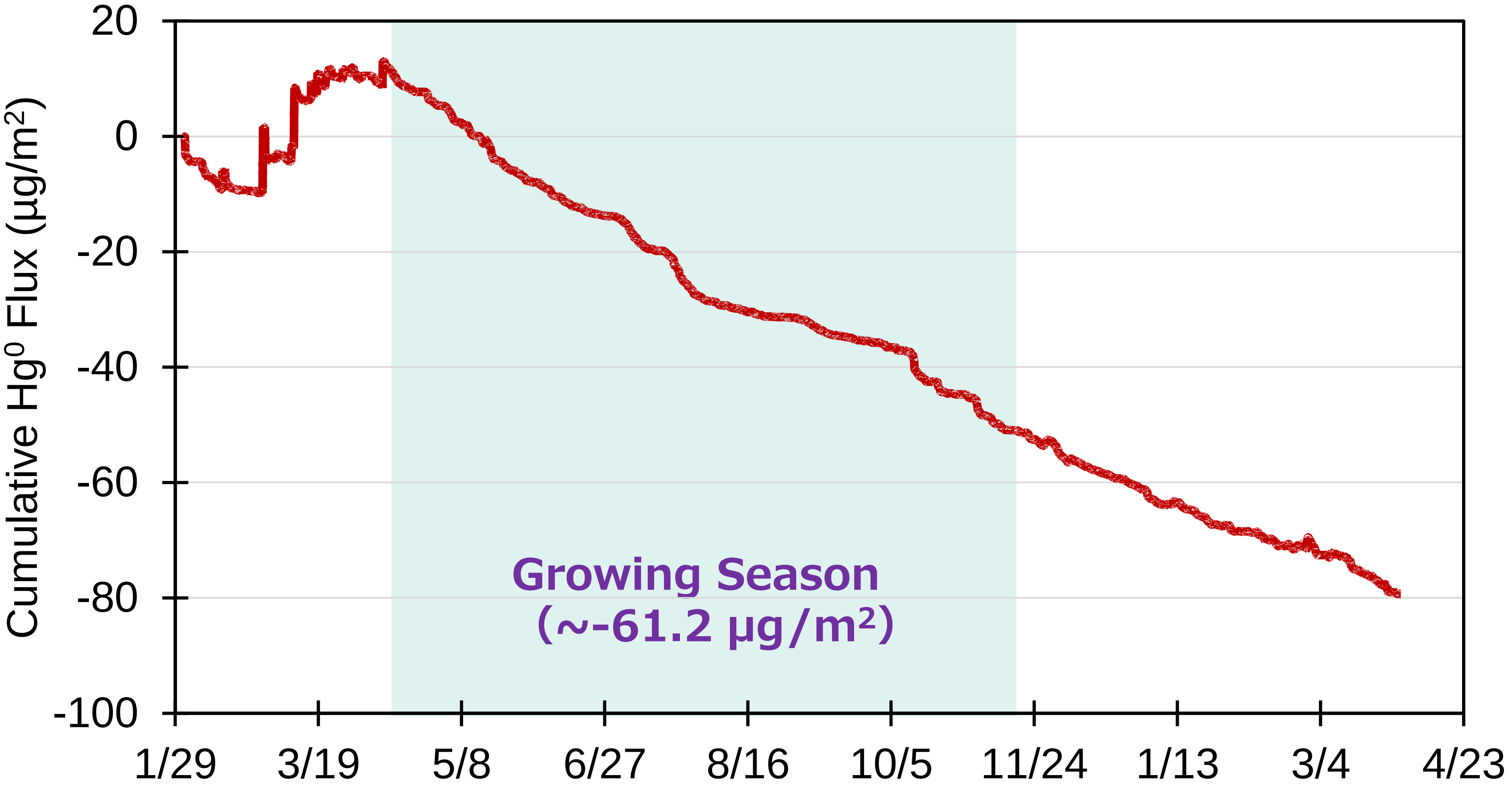
August (Growing Season)



Cumulative Hg^0 Flux: **-3.04** μg/m² (Aug)

- Both Hg^0 emissions and depositions in Feb. occur during the day.
- Hg^0 depositions in Aug. mostly occur in the nighttime.

Impact of Fuji-North Ecosystem on Hg Cycle



- From Feb. 2024 to Apr. 2025, **~79.3 μg/m²** of Hg^0 was deposited.

Hg^0 Deposition at Fuji-North in 2024

Biomes	Hg^0 Deposition (Growing season) $\mu g/m^2$	Ref.
Evergreen Broadleaf	**~ 53.9**	Wang et al., 2022
Deciduous Broadleaf	**~ 35.3**	Zhou et al., 2023
Evergreen Coniferous	**~ 12.6**	Zhou et al., 2023
Grassland	**~ 37.7**	Fritsche et al., 2008
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Agricultural Grazing Field	**~ 0.5**	MacSween et al., 2020
Deciduous Coniferous	**~ 61.2**	**Fuji-North**

Comparison with Hg Wet Deposition in Japan

(μg/m² yr⁻¹)	Hedo (Okinawa)	Oga (Akita)
2018	11.4	10.8
2019	16.6	9.3
2020	11.1	13.5
2021	13.2	9.5
2022	17.2	12.1
2023	10.9	11.8
2024	**16.6**	**8.5**
Annual Precip. (mm)	~ 3,000	~ 2,000

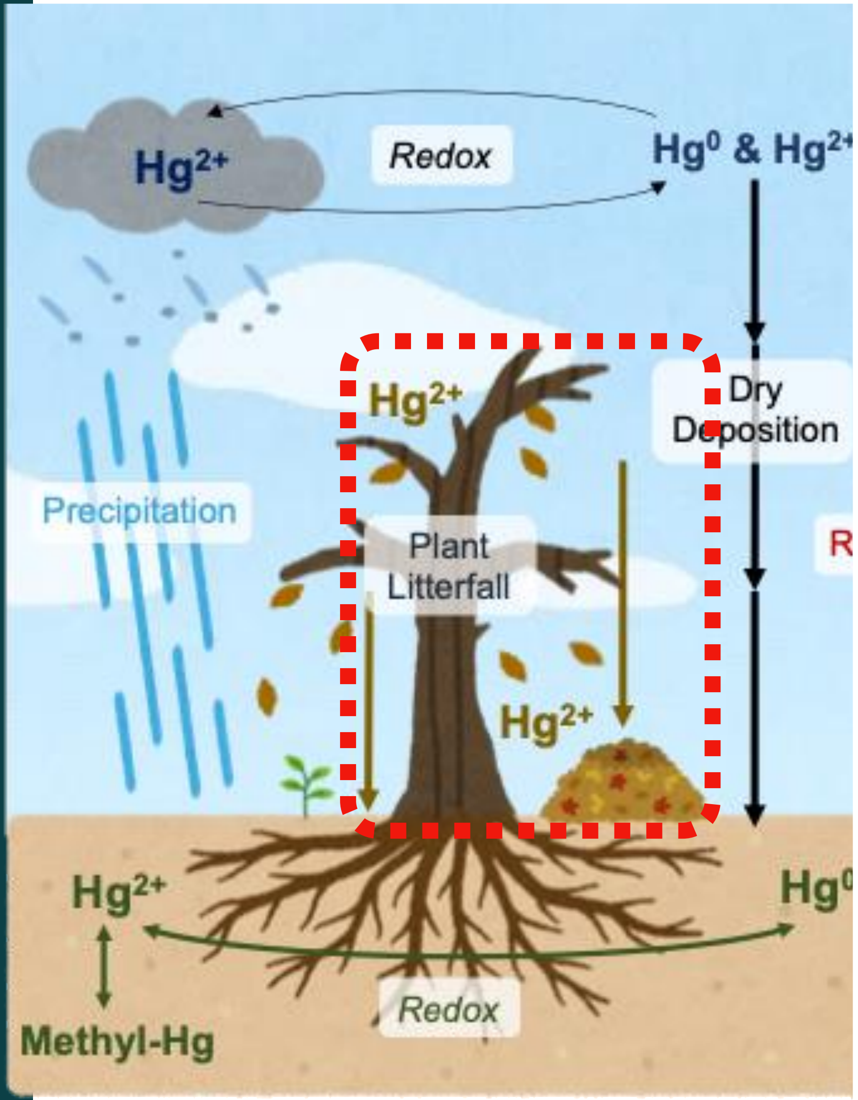
Hg^0 Deposition : ~ 61.2 μg/m²

@ Fuji-North (from Feb. to Dec. 2024)

Wet-Only Sampler in Tsukuba

Validation of Hg^0 Deposition by Hg Litterfall

Hg deposition by Litterfall



($\mu g/m^2\ yr^{-1}$)	Hg Deposition by Litterfall	Hg^0 Deposition by Flux Measurements; (Growing Season)
2023	74.9 ± 3.2	There are some missing observations. ↓
2024	93.2 ± 10.7	~ 61.2

82.9 ± 9.5 (89%)

Summary

1. Hg Monitoring in the deciduous coniferous forest offers valuable insight into the causes of natural variations in atmospheric Hg concentration seasonally and diurnally.

2. Amount of atmospheric Hg^0 deposition to the deciduous coniferous ecosystem can be greater than that of wet Hg deposition in Japan.