Impacts of Ocean heat changes induced by the Pacific Decadal Oscillation (PDO) on Typhoon intensification in the Philippine Sea

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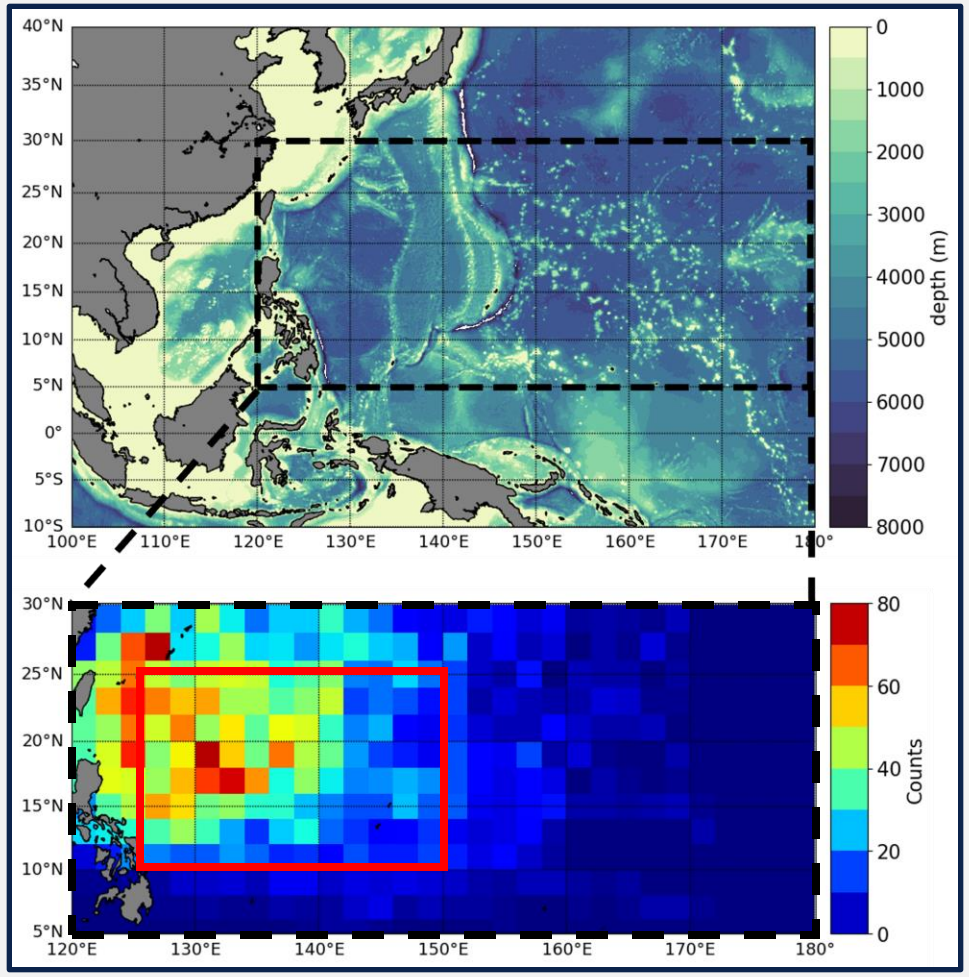
Map of Northwestern Pacific and heat map of the number of typhoons



➔ Typhoons have crucial impacts on human life and ecosystem

➔ Understanding the factors controlling typhoon intensity is important

➔ For accurate typhoon intensity prediction, identification of ocean's effect is required

➔ Northwestern Pacific is the most typhoon-active region in the world (Main Development Region)

➔ Research area : 10˚N-25˚N, 127˚E-150˚E

➔ Upper subsurface condition has influence to typhoon intensity Pun et al. (2013)

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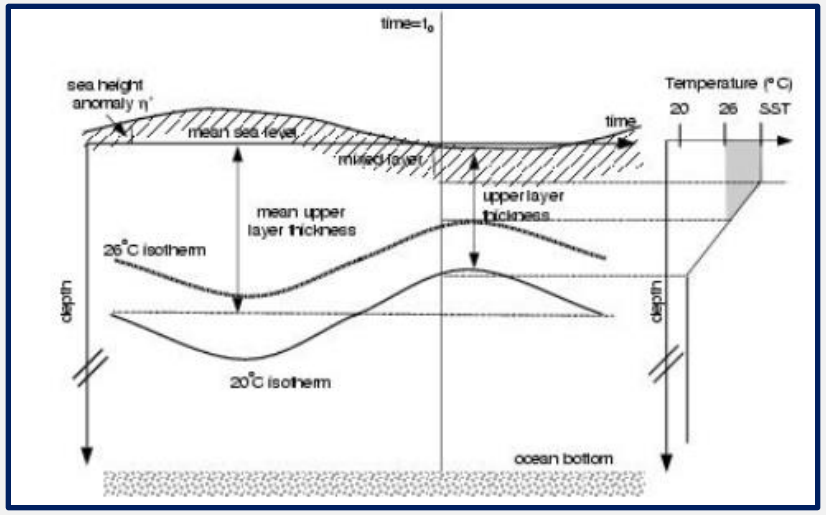
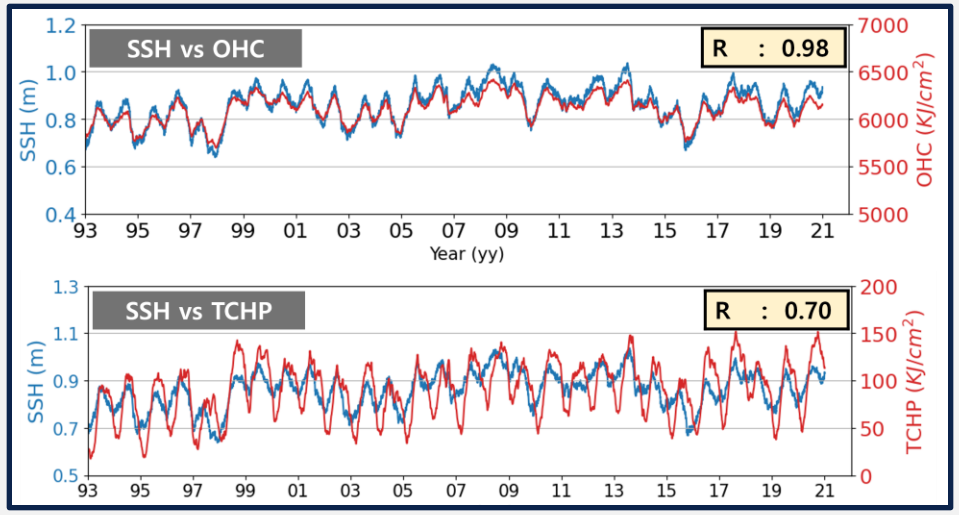
Tropical Cyclone Heat Potential (TCHP)

- Heat from surface to the depth of 26℃
- Upper ocean heat content
- Favorable ocean condition for typhoon intensification



https://blog.tempest.earth/gulf-of-mexico-and-mdr-getting-primed-in-the-atlantic-basin/



➔ Upper subsurface condition has influence to typhoon intensity Pun et al. (2013)

Tropical Cyclone Heat Potential (TCHP)
- Heat from surface to the depth of 26℃
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➔ Pacific Decadal Oscillation (PDO) causes SST & TCHP variation Wada and Chan. (2021)

➔ TCHP changes induced by PDO might affect typhoon intensification?

➔ Statistical analysis for long-term (30 years) between PDO → TCHP → Typhoon

Data

TCHP data

< GLORYS12V1 (GLORYS) >

- Duration & Time interval
  : Jan. 1st, 1993 - Dec. 31st, 2022, daily
- Variance : Temperature

$$TCHP = \sum_{z=0}^{D26} \rho C_p (T - 26) \triangle Z,$$

Leipper and Volgenau, 1972

Typhoon data

< JTWC Best Track Archive >

- Duration & Time interval
  : Jan. 1st, 1993 - Dec. 31st, 2022, 6 hourly
- Variance : Maximum wind speed (Vmax)
- Typhoon intensification

$$Vmax\ gradient = \frac{d}{dt} Vmax$$

PDO data

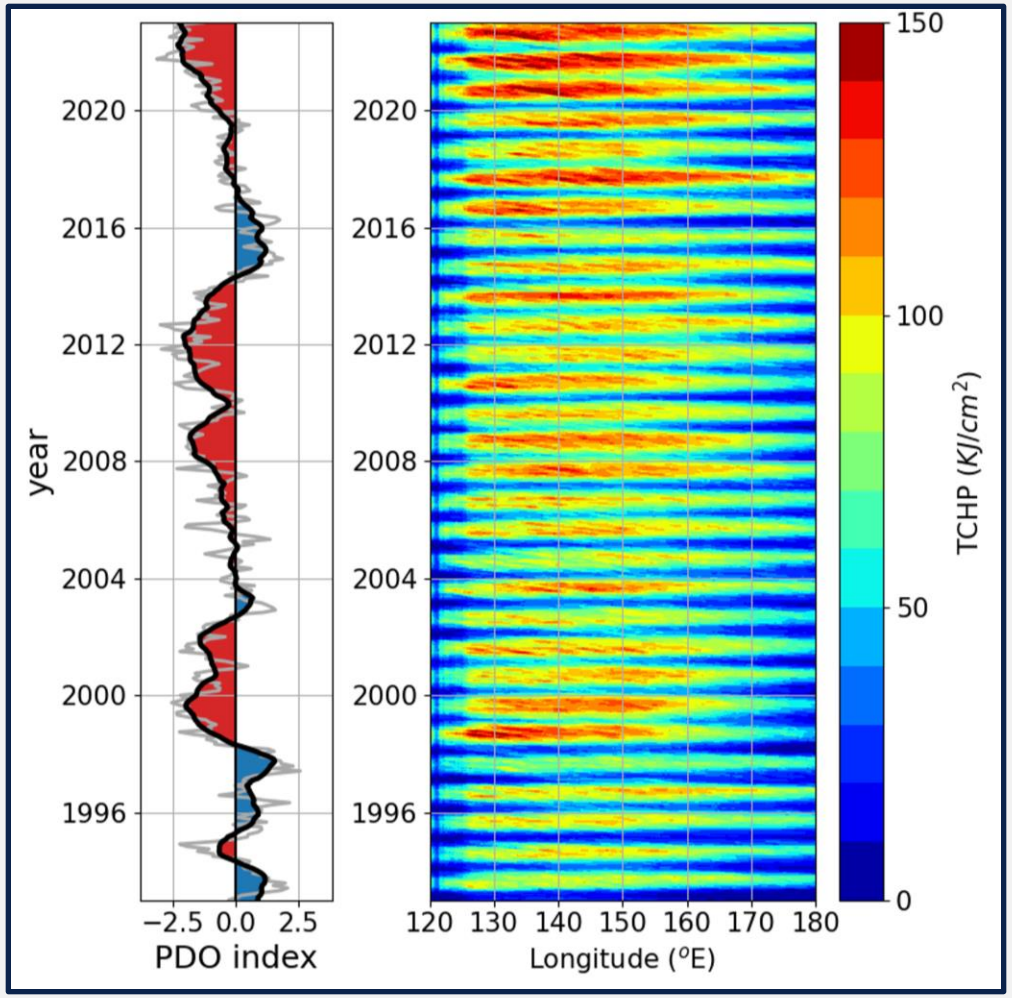
< PDO index >

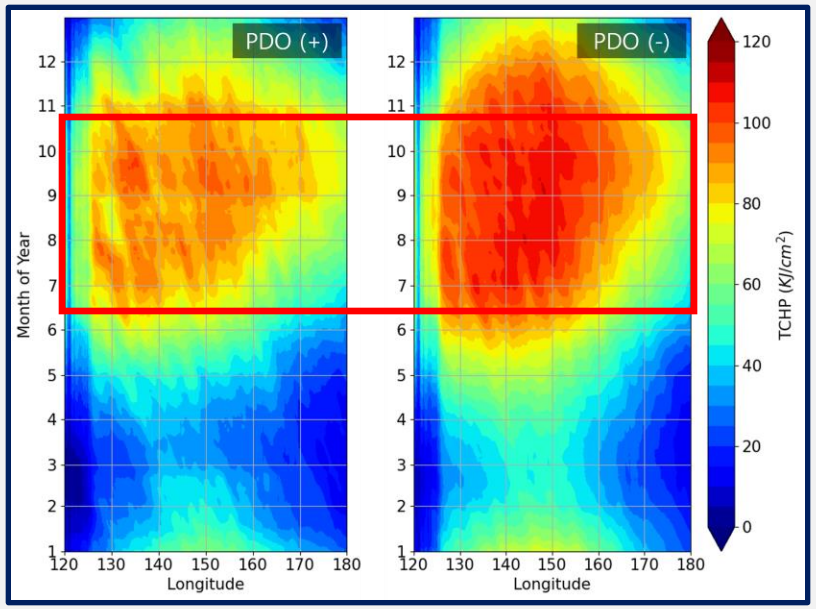
- National Oceanic and Atmospheric Administration (NOAA)
- Duration & Time interval : Jan. 1993 - Dec. 2022, monthly
- Strong PDO case (To check the different pattern of each phase)
  | PDO index | ≥ σ (σ = Standard deviation of all time PDO index (≒ 1.14))

Strong positive PDO ≥ 1.14
Strong negative PDO ≤ 1.14

TCHP distribution change by PDO phases

TCHP Hovmöller diagram





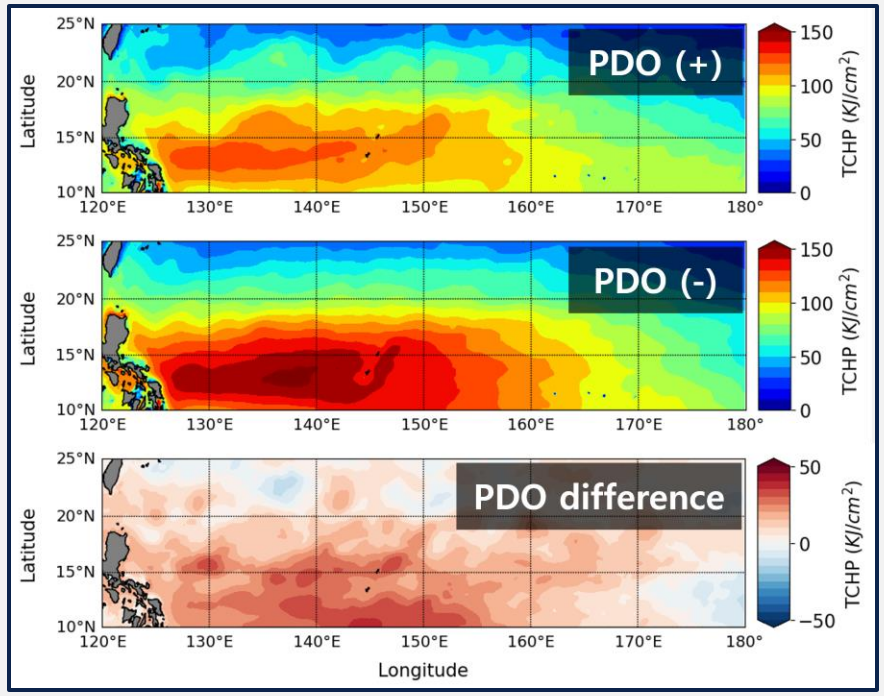
➔ Averaged between 10˚N~25˚N

➔ Mean TCHP : 51 KJ/cm², 64 KJ/cm²

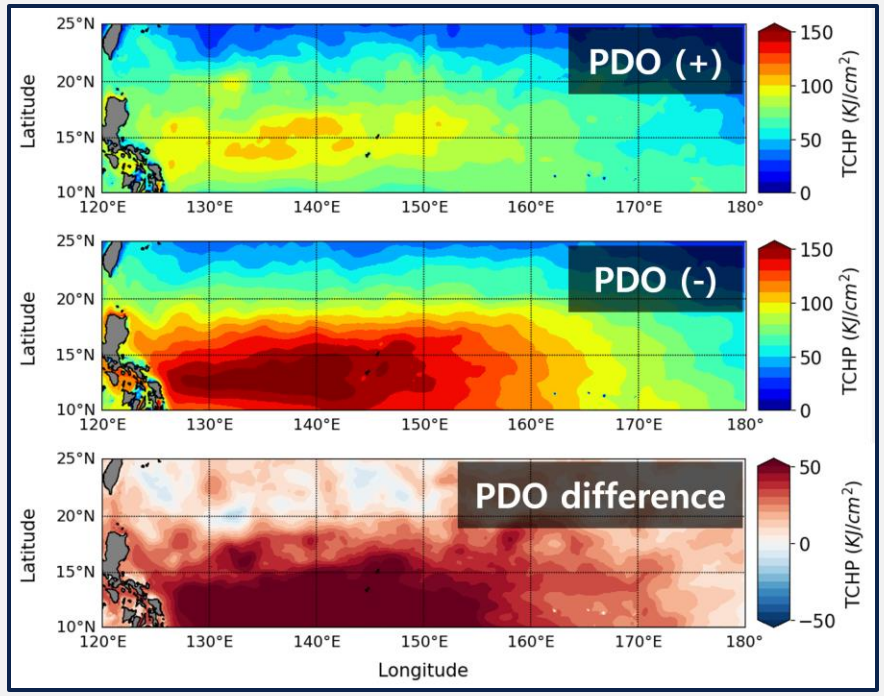
TCHP distribution change by PDO phases

TCHP distribution map

Normal PDO summer



Strong PDO summer



positive negative difference (negative – positive)

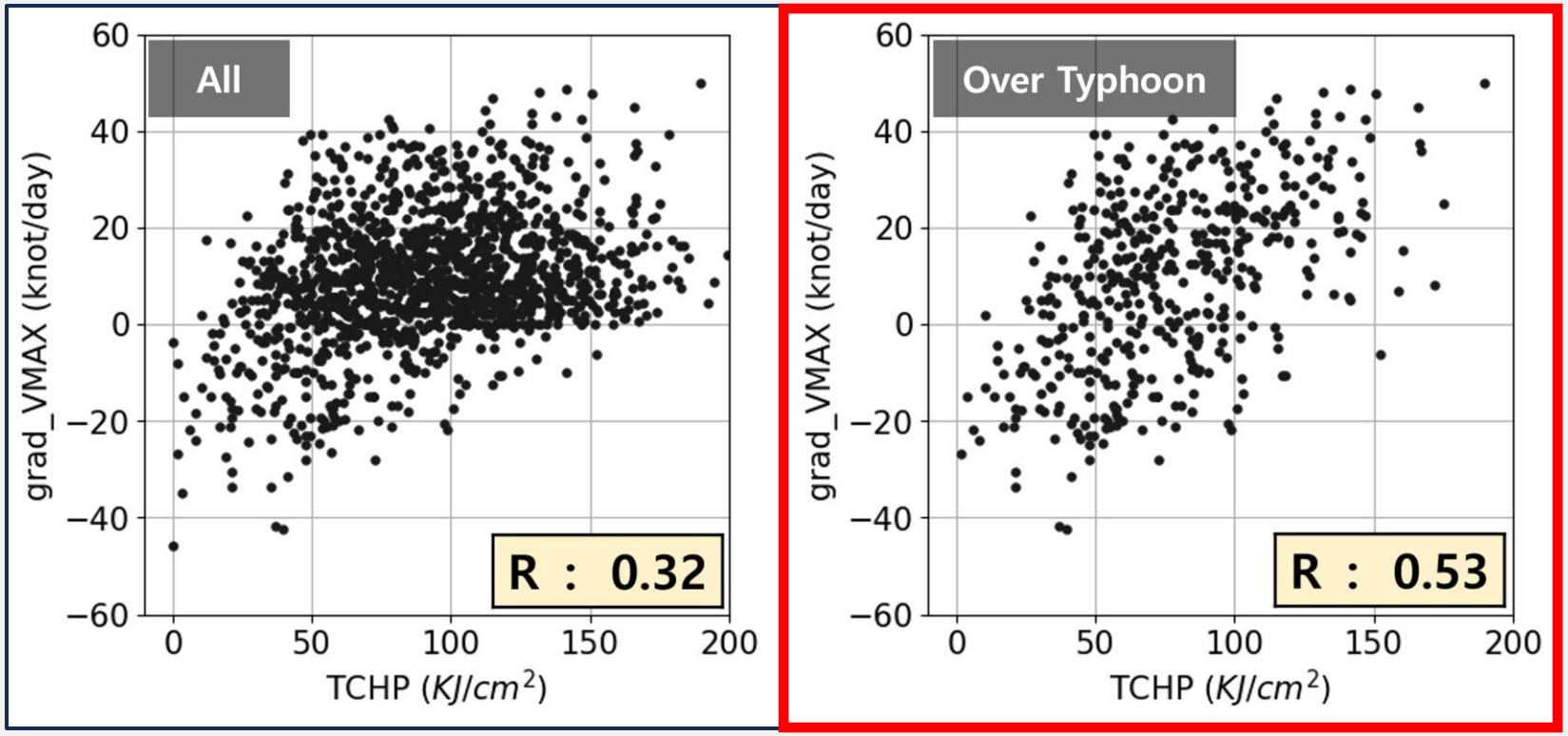
➔ Mean TCHP (Normal PDO) : 86 KJ/cm², 102 KJ/cm² (16 KJ/cm²)

➔ Mean TCHP (Strong PDO) : 74 KJ/cm², 105 KJ/cm² (31 KJ/cm²)

➔ Higher TCHP in the Northwestern Pacific during negative PDO phase

Relationship between TCHP and Typhoon intensification

TCHP vs. Vmax gradient scatter plot



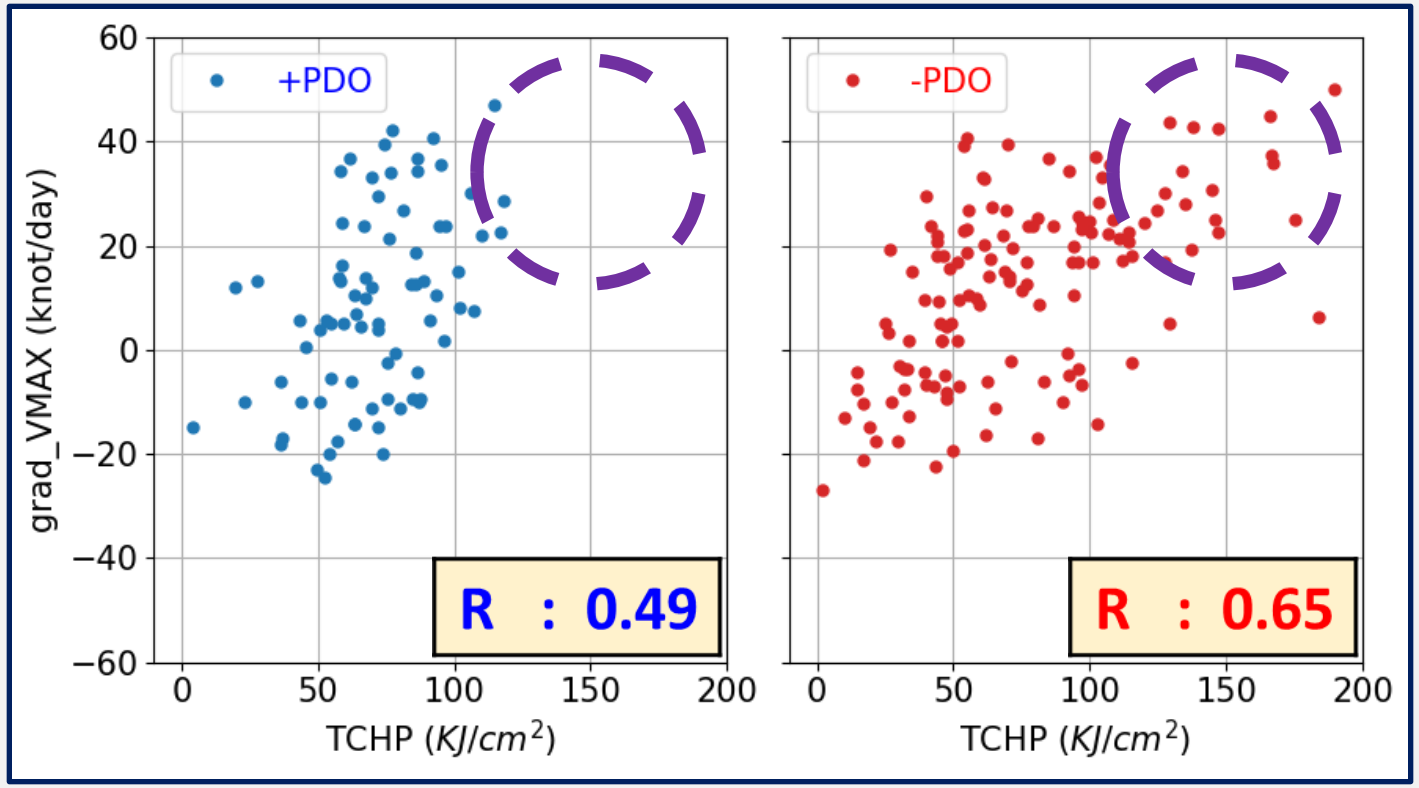
➔ Confidence level : 90%, Confidence interval : [0.28-0.36], [0.47-0.58]

➔ Significant relationship between TCHP and Vmax gradient

➔ Higher correlation in Typhoon cases

Typhoon intensification by PDO phases

TCHP vs. Vmax gradient scatter plot by PDO



➔ Confidence level : 90%, Confidence interval : [0.33-0.63], [0.52-0.73]

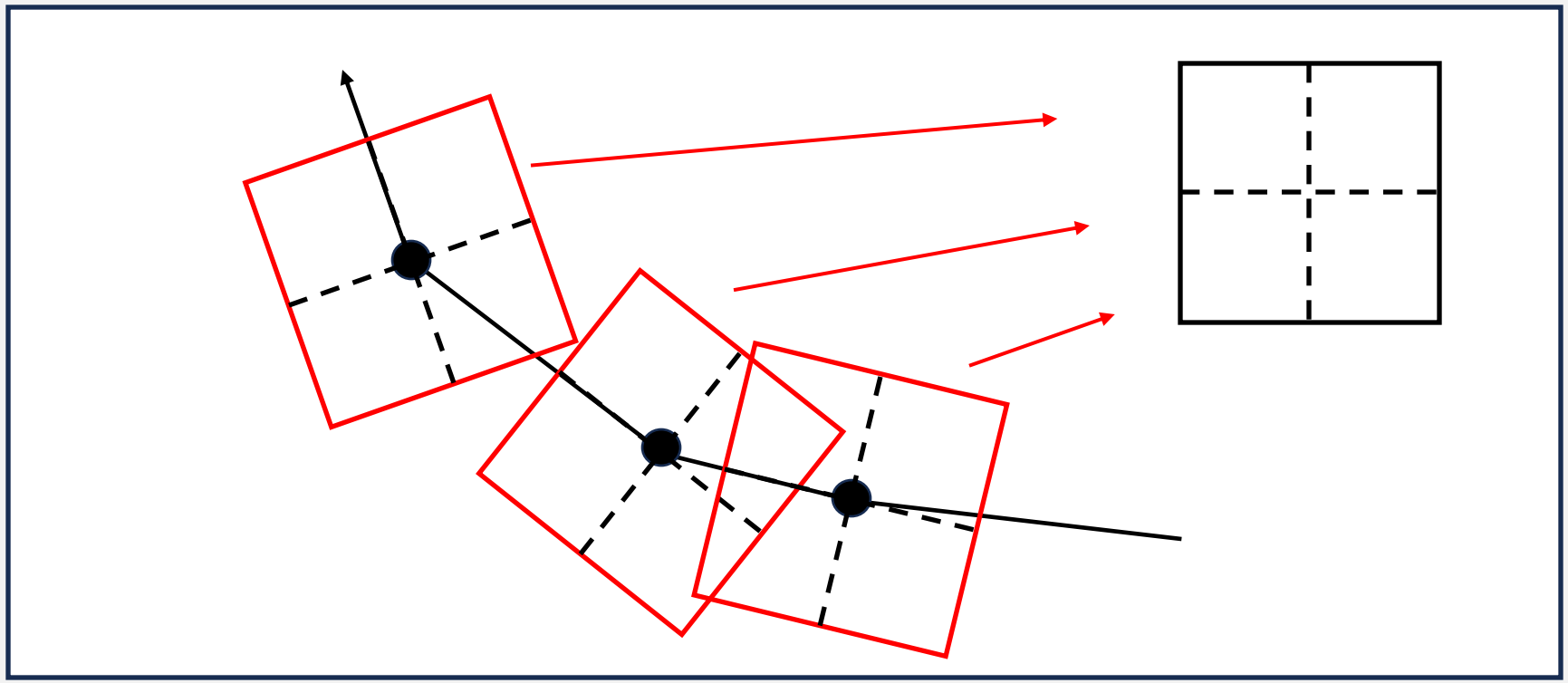
➔ Higher TCHP & Vmax gradient in PDO (-)

➔ Higher correlation in PDO (-)

➔ More possibility of typhoon intensification in PDO (-)

Typhoon intensification by PDO phases

Change of background TCHP during typhoon passage



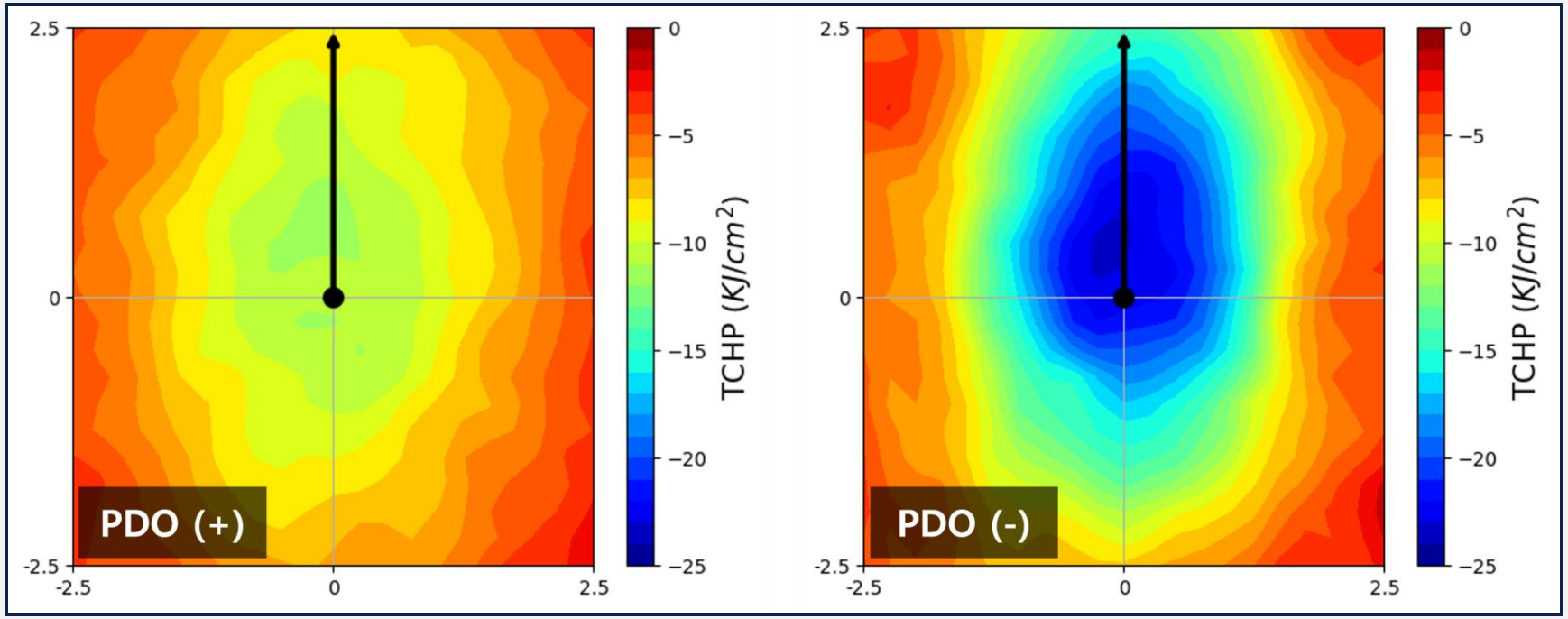
➔ Mean background TCHP of each Typhoon point

➔ ΔTCHP : (TCHP of D+1) – (TCHP of D-1)

Ocean heat loss after Typhoon passage

Typhoon intensification by PDO phases

Change of background TCHP during typhoon passage



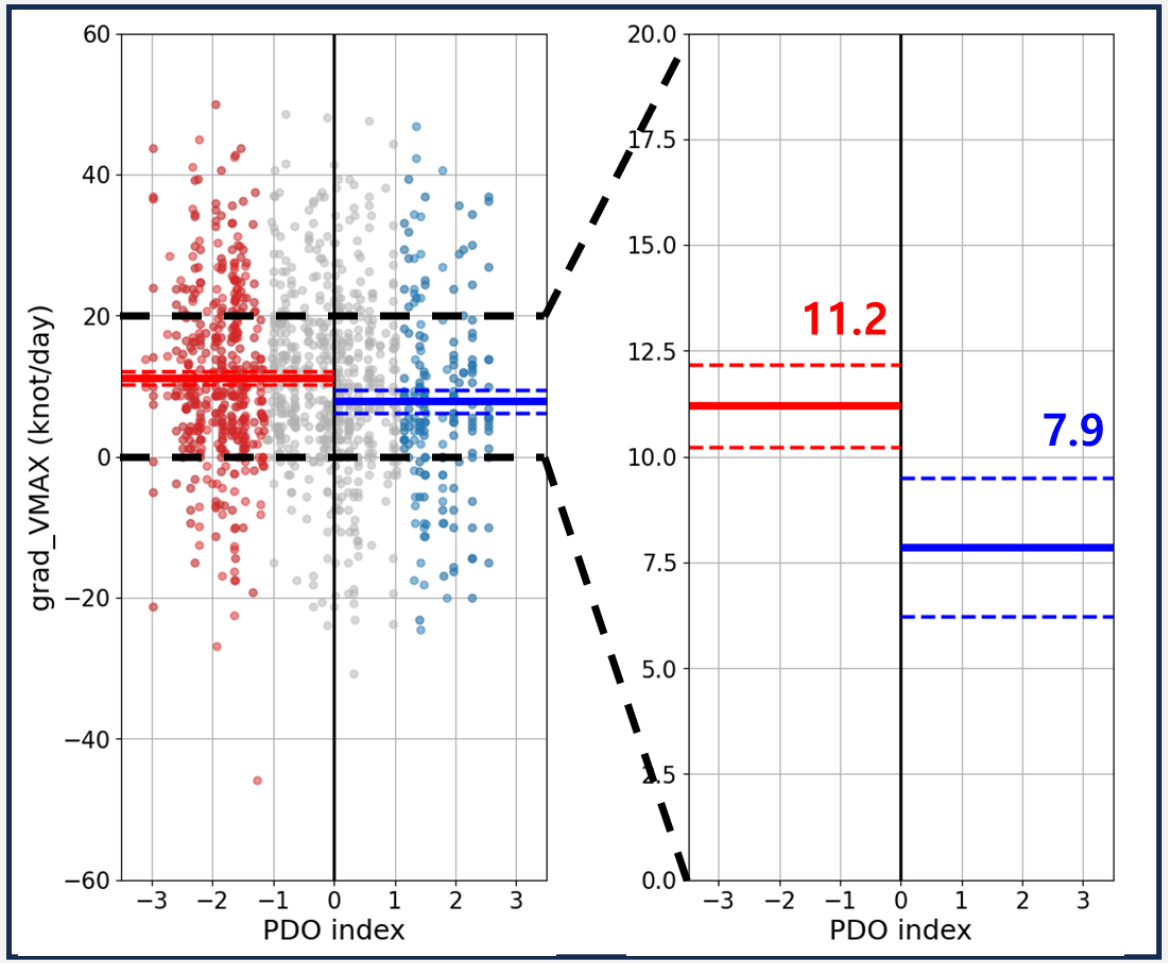
➔ ΔTCHP : D+1 Typhoon passage - D-1 Typhoon passage

➔ PDO (+) : -23.6 X 10^{18}KJ, PDO (-) : -34.3 X 10^{18}KJ

➔ More heat loss during negative PDO period

Typhoon intensification by PDO phases

Vmax gradient distribution by PDO



➔ Confidence level : 90%

Confidence interval

: [10.2-12.2], [6.1-9.6]

➔ Red dots : negative PDO

Blue dots : positive PDO

Gray dots : not strong cases

➔ More average typhoon intensification during PDO (-)

➔ Statistical analysis of the impact of long-term variability (PDO) on ocean characteristics (TCHP) and its effects on Typhoon intensification

- PDO-induced TCHP changes show good relationship with typhoon intensification
  1. TCHP distribution change by PDO phases
  2. Relationship between TCHP and Typhoon intensification
  3. Typhoon intensification by PDO phases

- Accurate ocean heat data is required for typhoon intensification analysis/prediction

GLORYS ?
- Update frequency is very low
- Not effective for typhoon prediction

➡ **Other Data?**

➔ Statistical analysis of the impact of long-term variability (PDO) on ocean characteristics (TCHP) and its effects on Typhoon intensification

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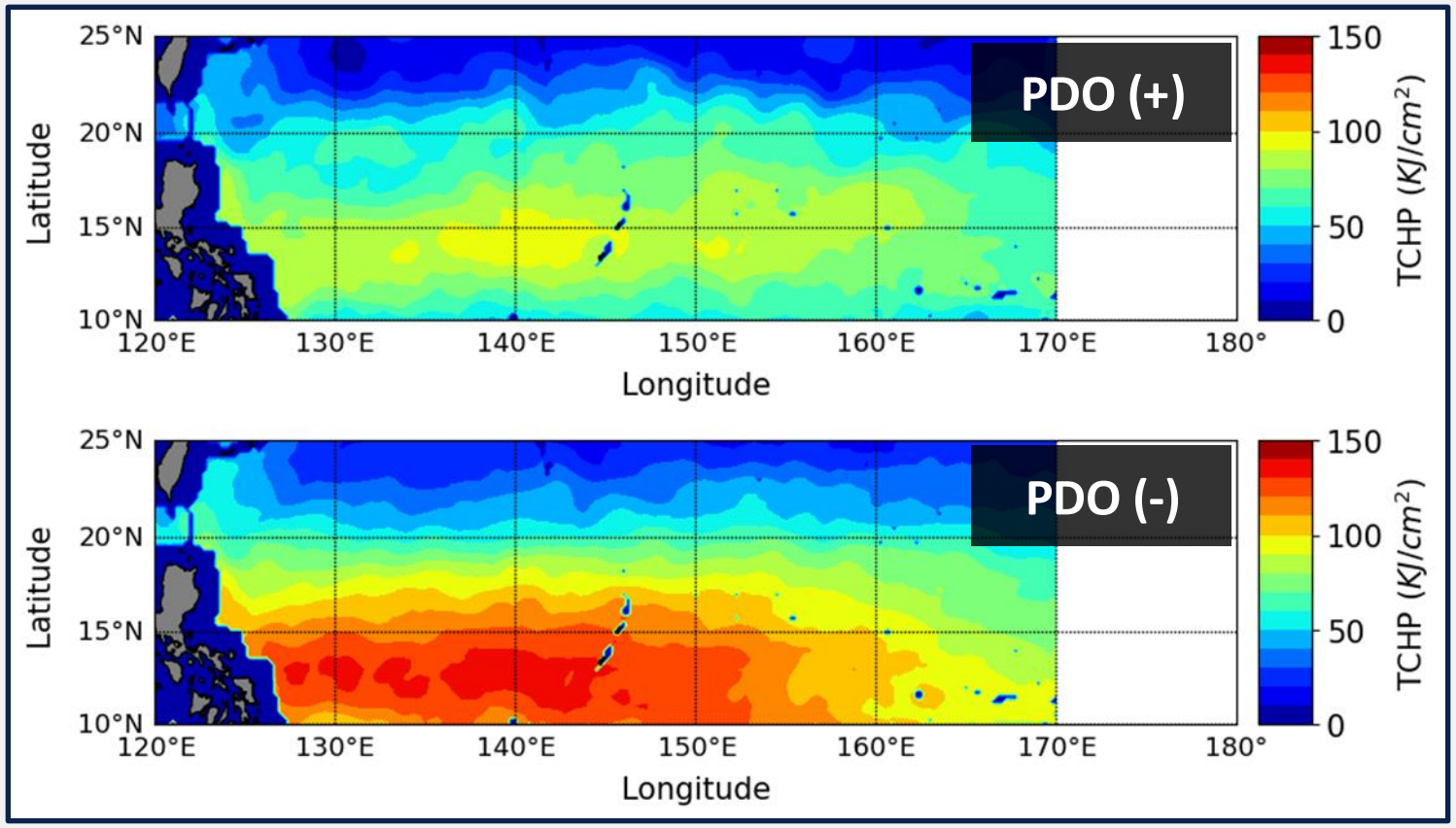
- Accurate ocean heat data is required for typhoon intensification analysis/prediction

AI model (Pro-net) Chae (2023)
- Produce near-real-time estimation
- Satellite-observed surface data (SST, SSS, ADT) ➔ Vertical temperature profile

AI data analysis

TCHP distribution map

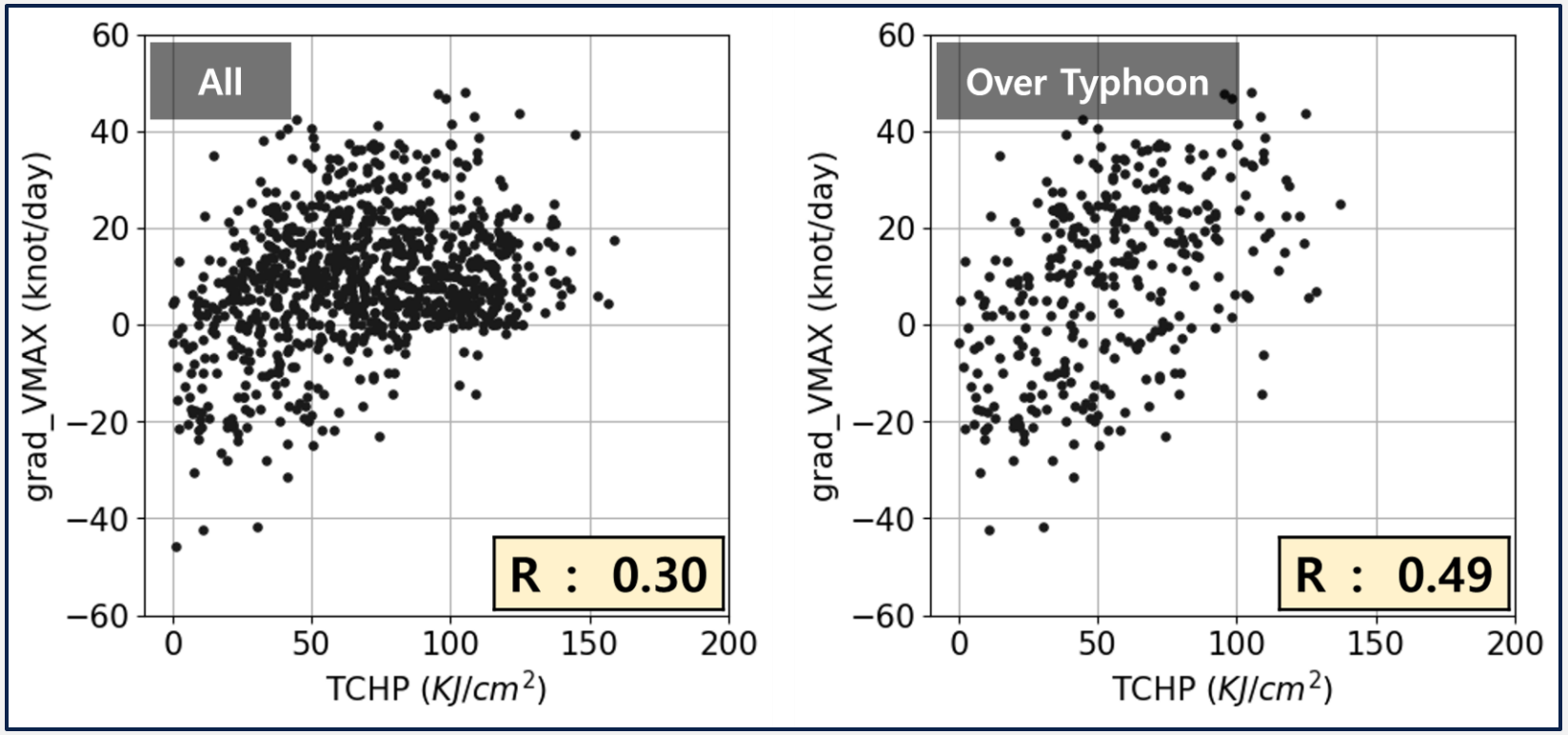


positive negative difference (negative – positive)

➔ Mean TCHP (Strong PDO) : 54 KJ/cm², 72 KJ/cm² (18 KJ/cm²)

AI data analysis

TCHP vs. Vmax gradient scatter plot

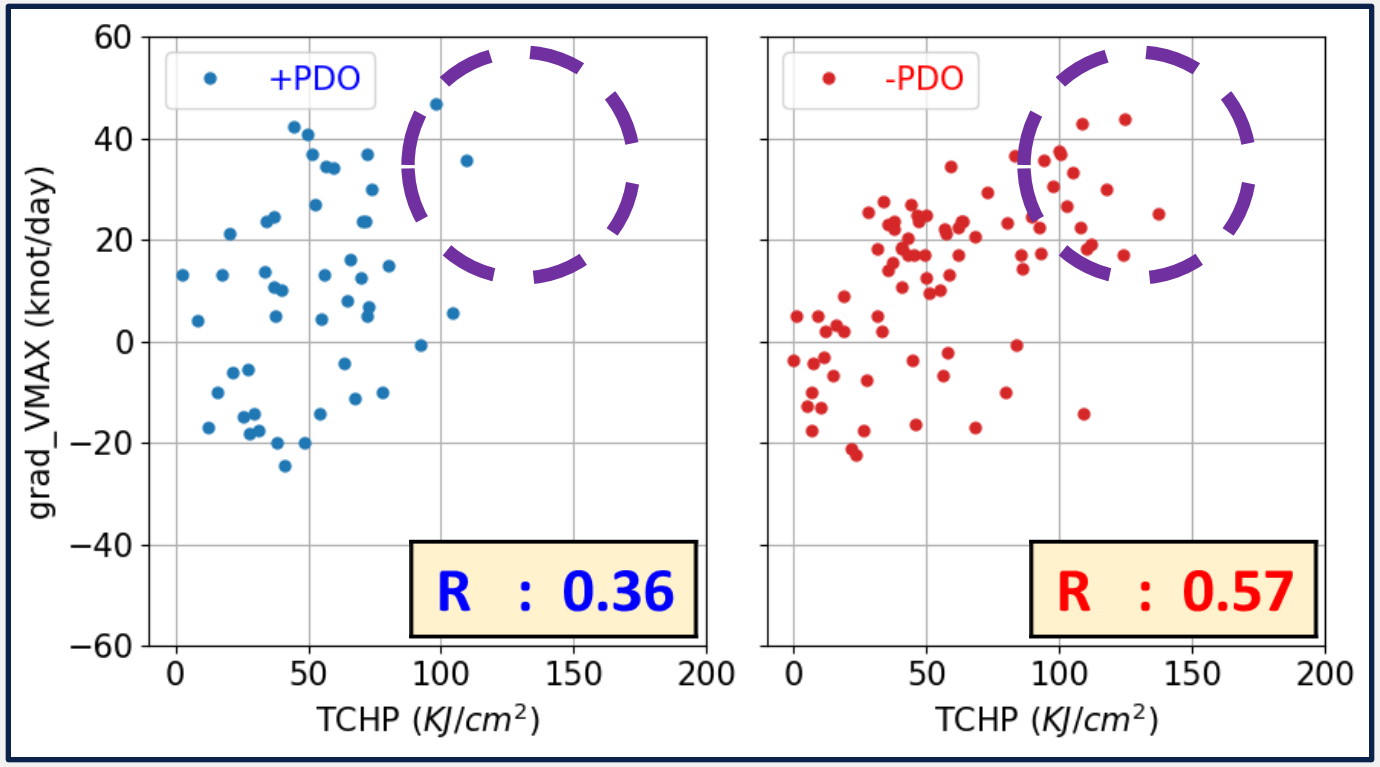


➔ Confidence level : 90%, Confidence interval : [0.25-0.35], [0.42-0.55]

➔ GLORYS result : All-0.32, Over Typhoon-0.53

AI data analysis

TCHP vs. Vmax gradient scatter plot by PDO



➔ Confidence level : 90%, Confidence interval : [0.15-0.55], [0.43-0.68]

➔ GLORYS results : PDO (+)-0.49, PDO (-)-0.65

➔ Statistical analysis of the impact of long-term variability (PDO) on ocean characteristics (TCHP) and its effects on Typhoon intensification

- PDO-induced TCHP changes show good relationship with typhoon intensification
  1. TCHP distribution change by PDO phases
  2. Relationship between TCHP and Typhoon intensification
  3. Typhoon intensification by PDO phases

- Accurate ocean heat data is required for typhoon intensification analysis/prediction

- AI model (Pro-net) can provide appropriate heat content information for further typhoon prediction

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Thank you

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