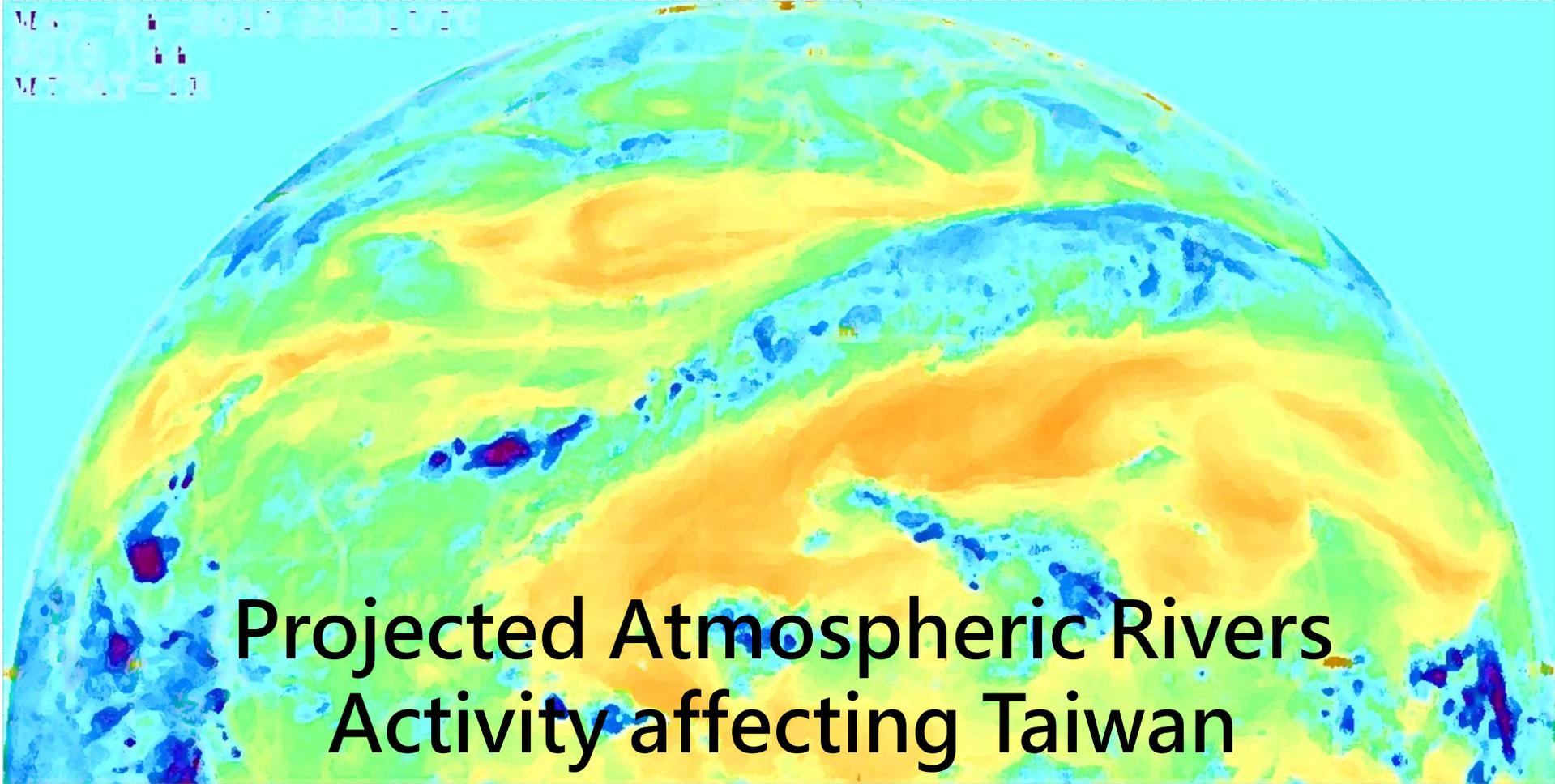


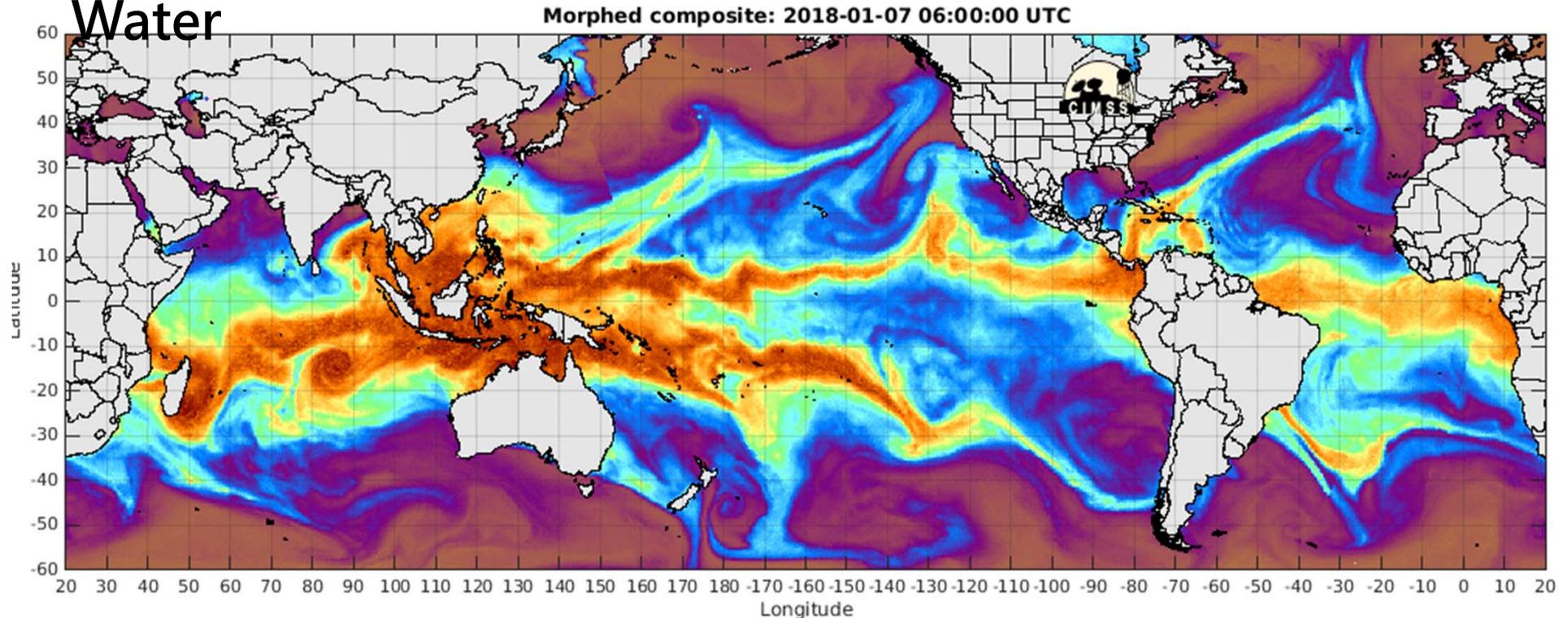
MSU-2.4-2010-2015
2010-11
MSU-SAT-10



Projected Atmospheric Rivers Activity affecting Taiwan

Ying-Ting Chen and Huang-Hsiung Hsu
Research Center for Environment Changes, Academia Sinica

The Atmospheric River(AR): 72-Hour Loop of Precipitable Water

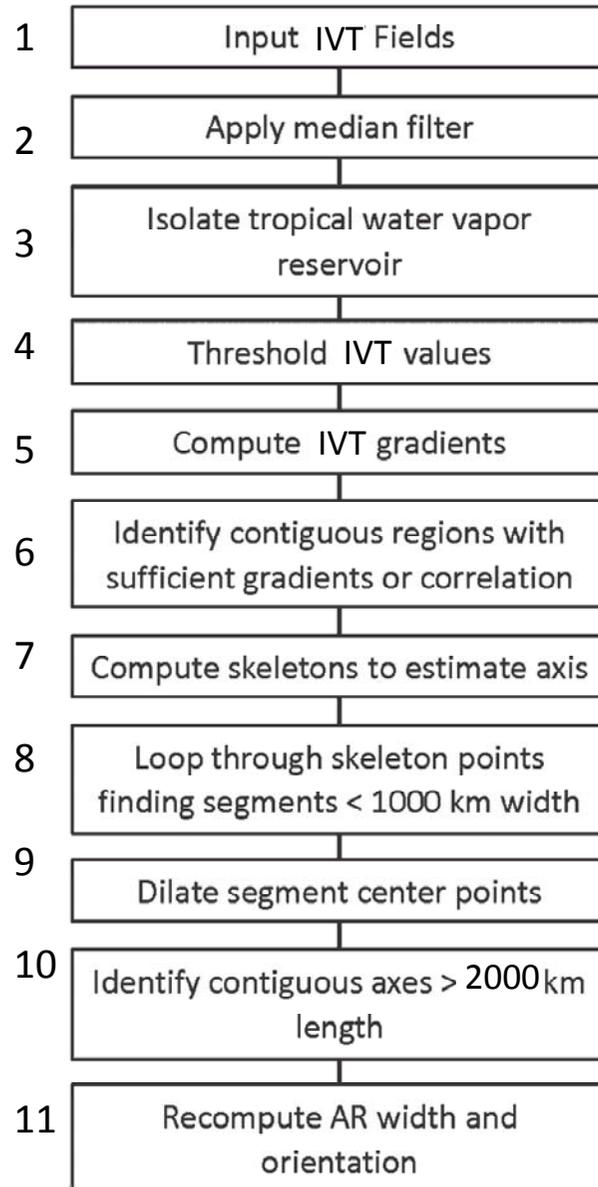


熱帶朝向極區傳送的水氣集中在數道狹窄水氣帶內，稱之為大氣河(Atmospheric River)。寬度約數百公里，長度卻可綿延數千公里，有時甚至橫跨整個大洋。

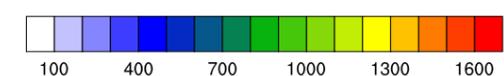
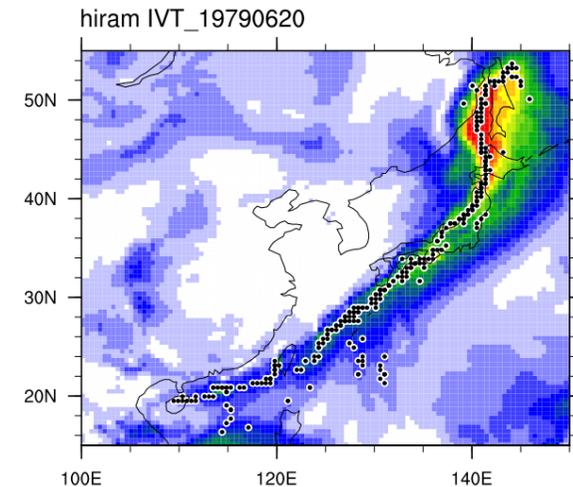
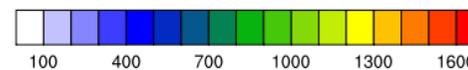
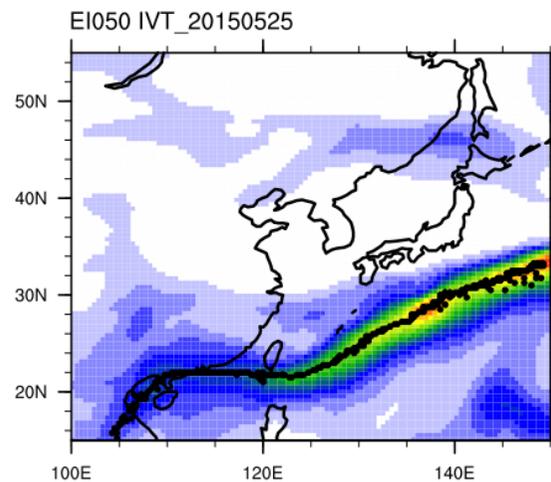
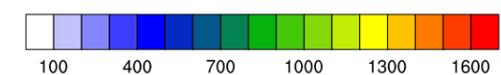
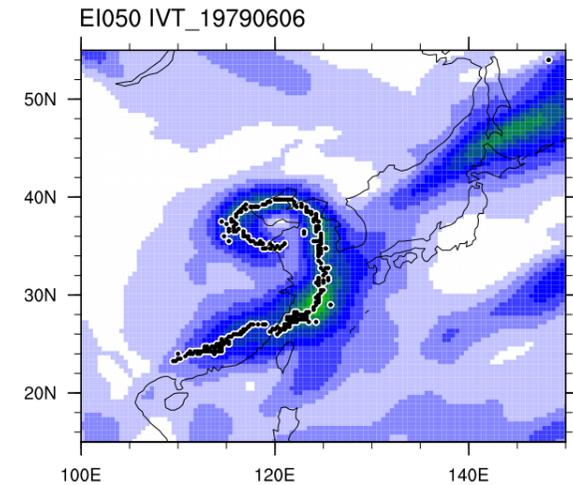
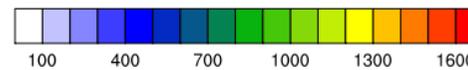
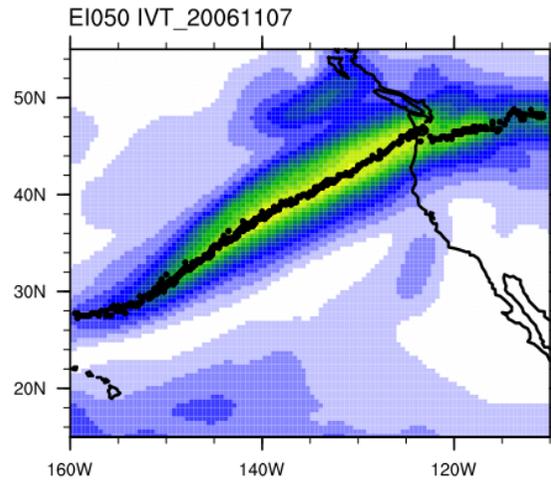
Data

- Reanalysis
 - 1979-2016 ERA-Interim, 0.75 degree, 6 hourly
- Model simulation
 - 1979-2008 HiRAM historical, ~23km, 6 hourly
 - 2075-2100 HiRAM RCP85, ~23km, 6 hourly

Integrated Vapor Transport (IVT) Method



(Wick et al., 2013)

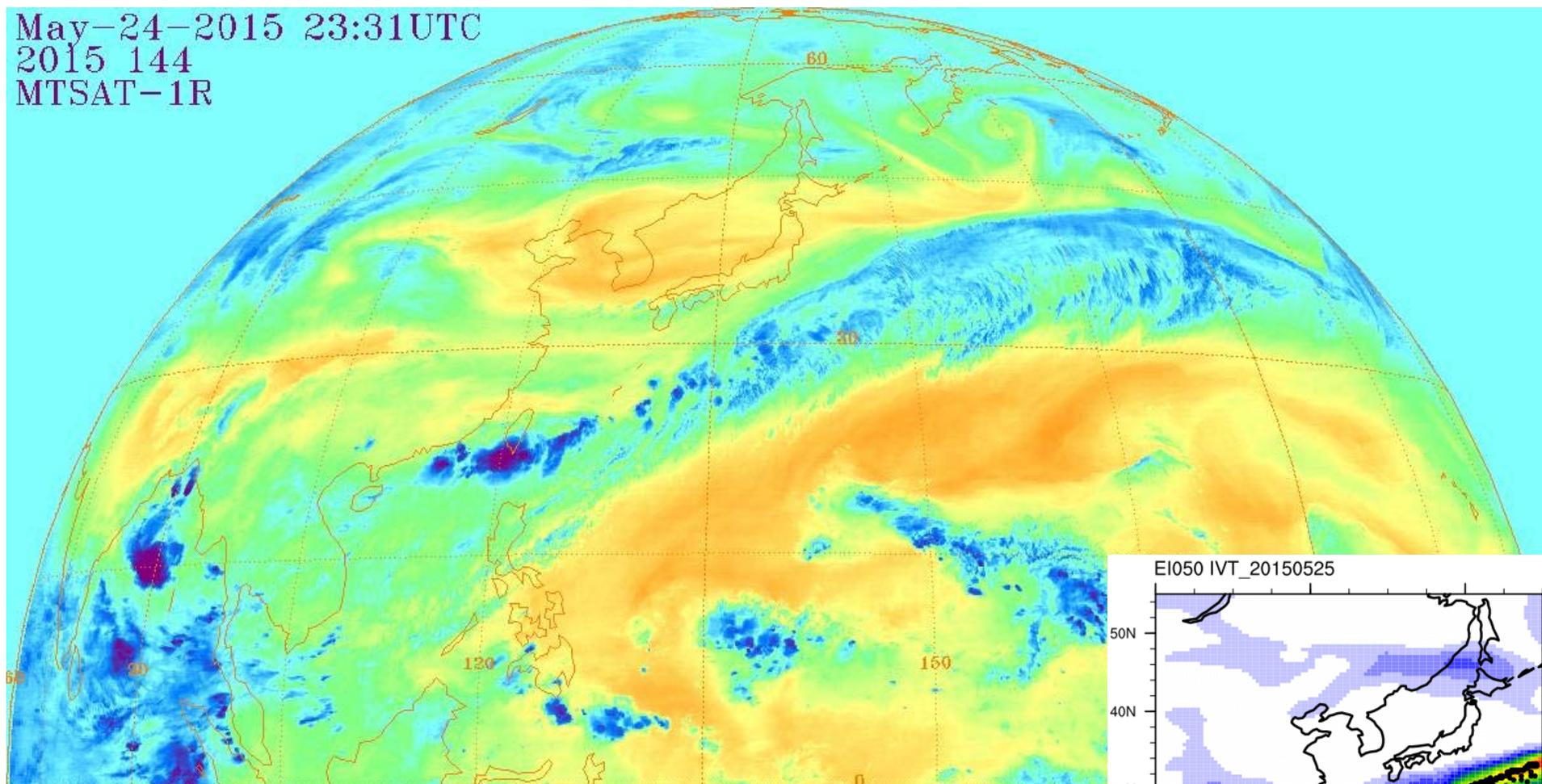


MTSAT 2

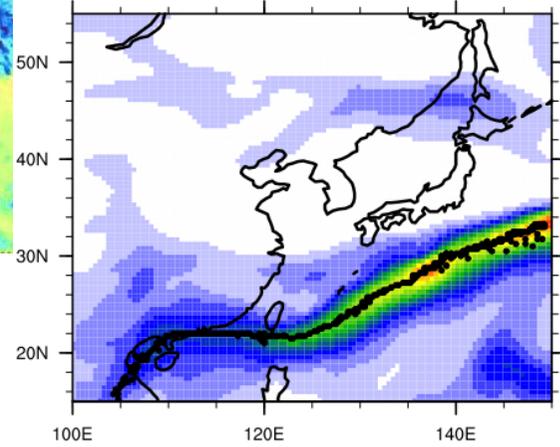
Water Vapor (~6.7 um)

May 24, 2015; 00:00 UTC

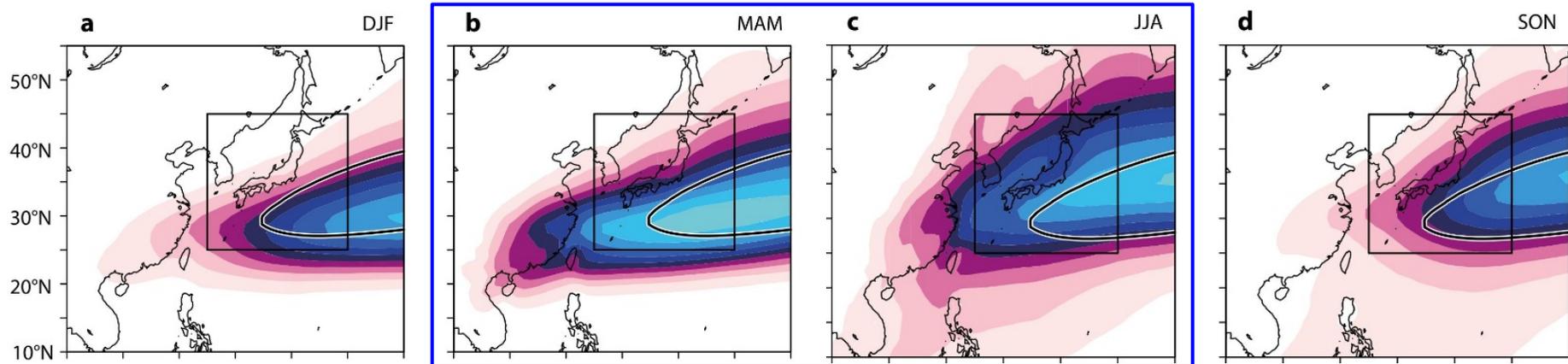
May-24-2015 23:31UTC
2015 144
MTSAT-1R



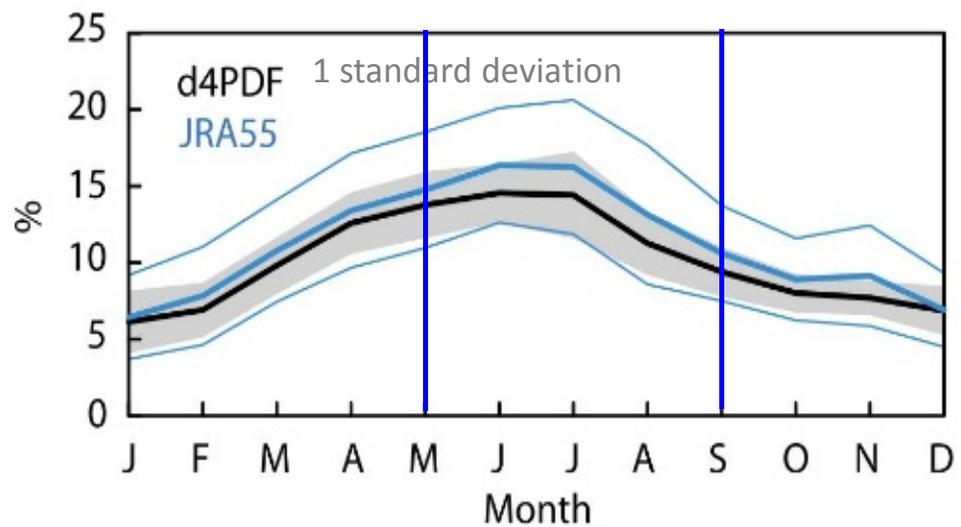
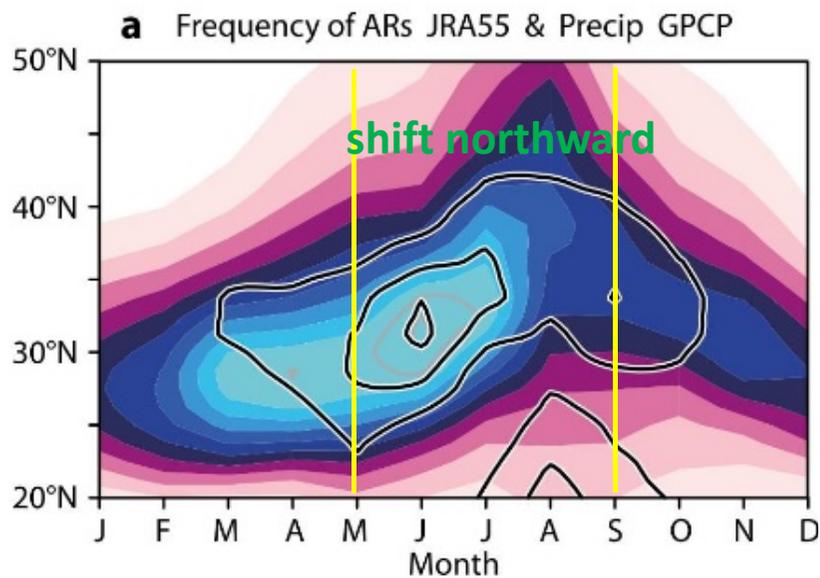
EI050 IVT_20150525



<https://www.ncdc.noaa.gov>



Black contour: annual-mean AR frequency



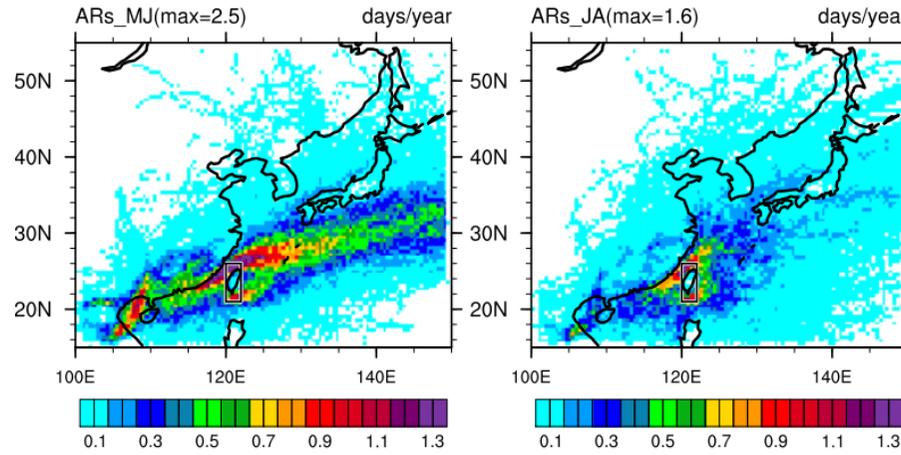
Black contour: precipitation(2, 4, and 6 mm/day)

Shading: AR frequency

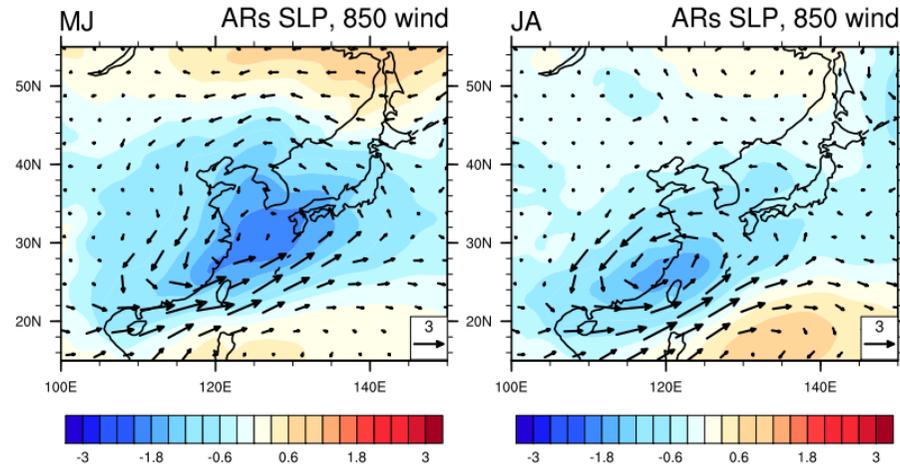
Thin gray contours represent AR frequency of 22% and 24%

Kamae et al.(2017)

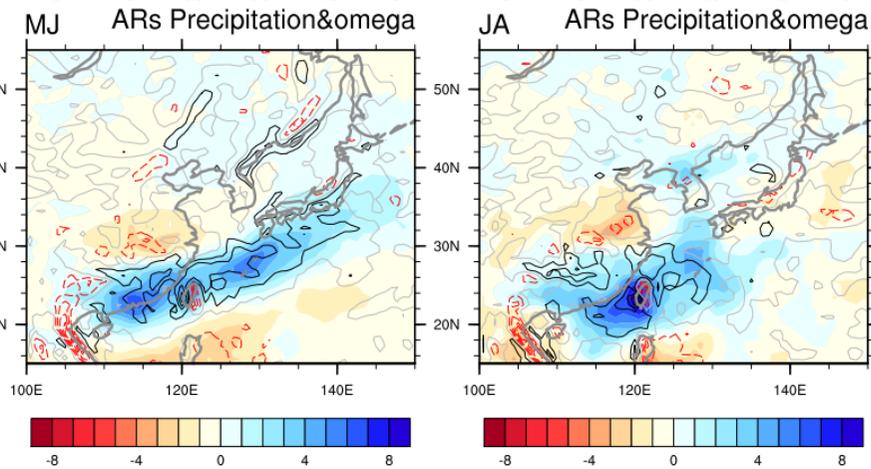
Frequency
(passed Taiwan)



SLP & 850 wind



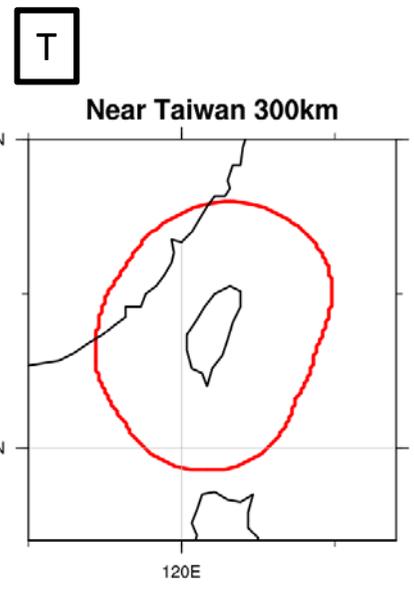
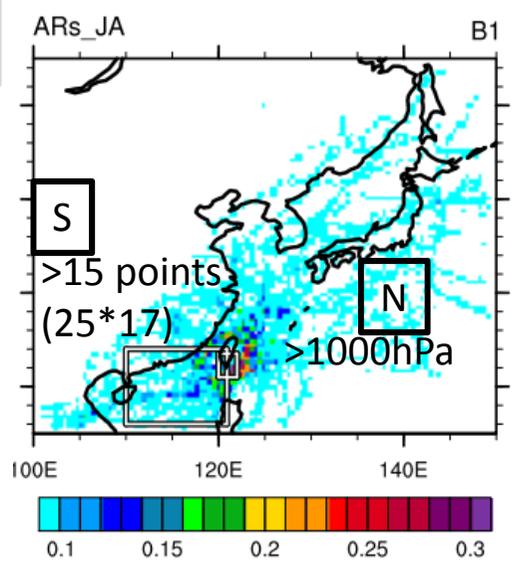
Precipitation(shading)
Omega(contour, *-1
Upward, downward)
Omega(*-1):-0.2~0.2, interval:0.02



侵襲台灣事件
合成距平
(ERA-Interim)

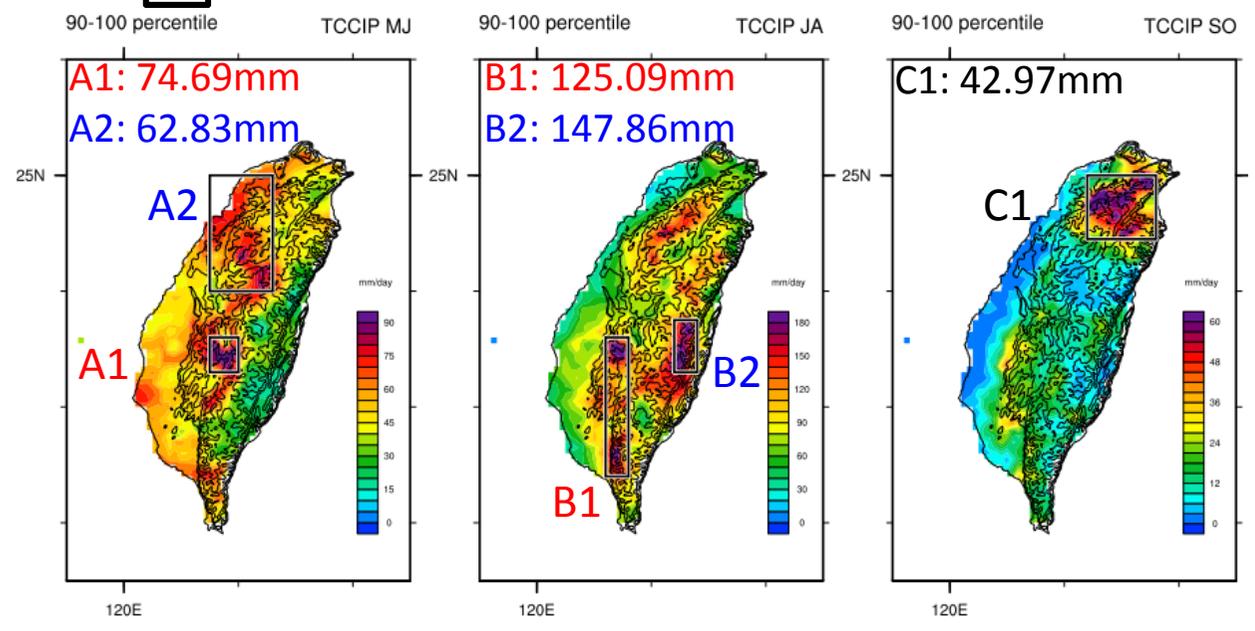
Atmospheric River (JA)

- R** B1 heavy rain & AR in TW (precipitation and AR points)
- S** southwesterly(AR points)
- N** not TC circulation(SLP)
- T** TC induce southwesterly



Data: IBTrACS v03r09

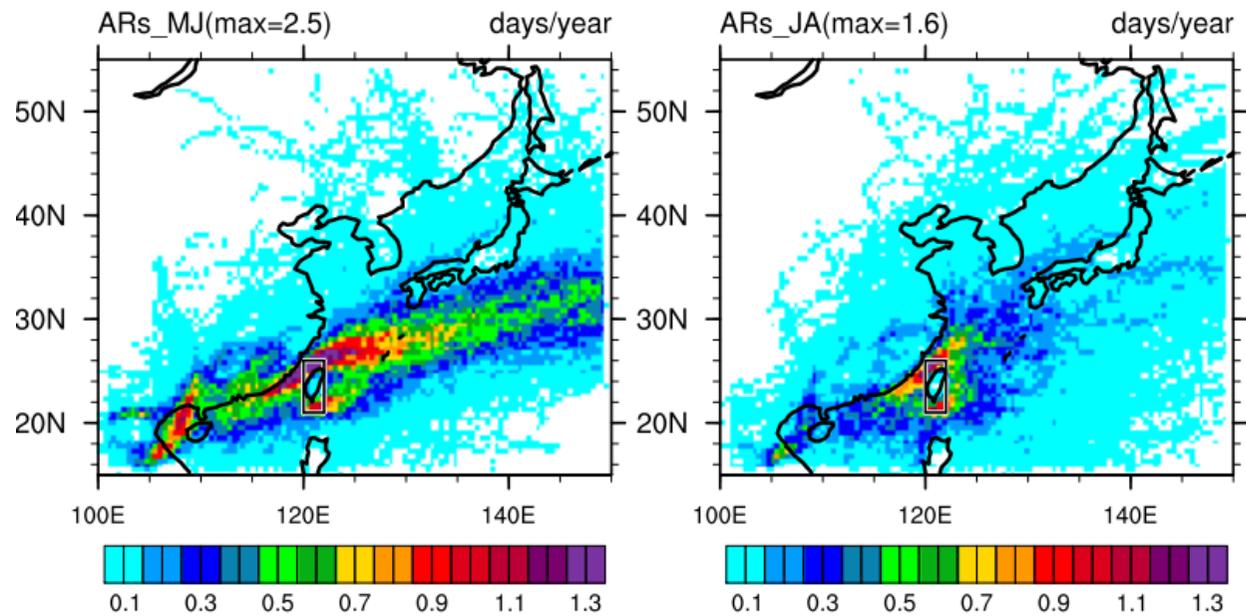
R TCCIP 5km grid 1979-2015 90-100 percentile mean



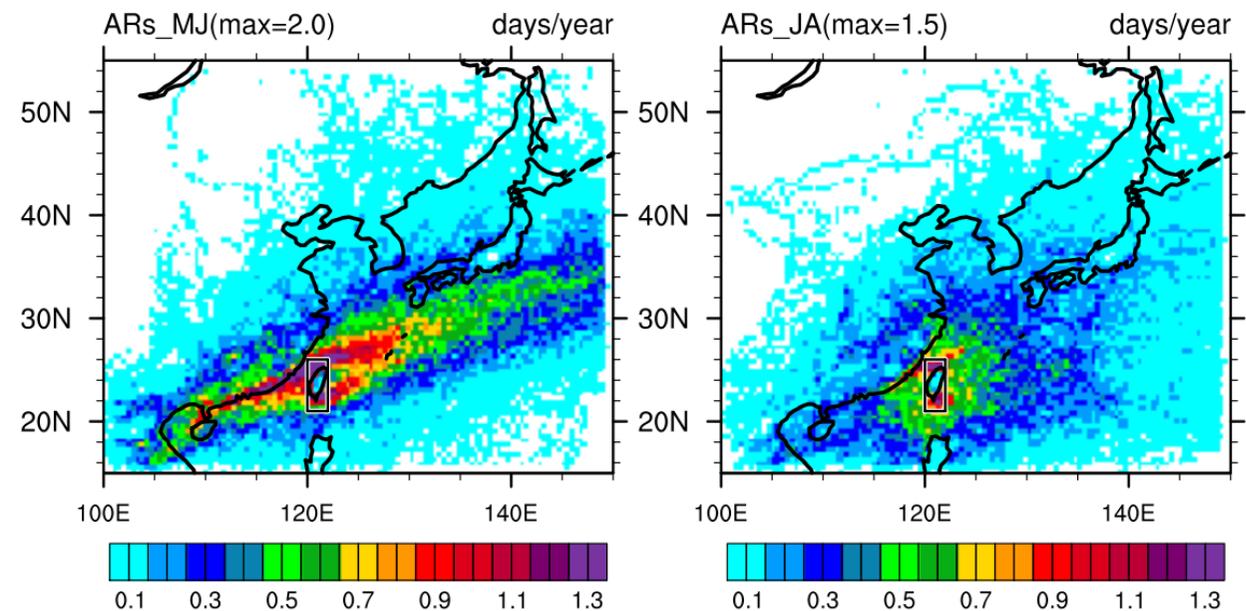
台灣東部海面向西北行經台灣北部海面朝東海、韓國方向前進，搭配適當的綜觀天氣型態，則這類颱風於過境台灣後，時常會引進旺盛的西南氣流造成豪雨

侵襲台灣事件

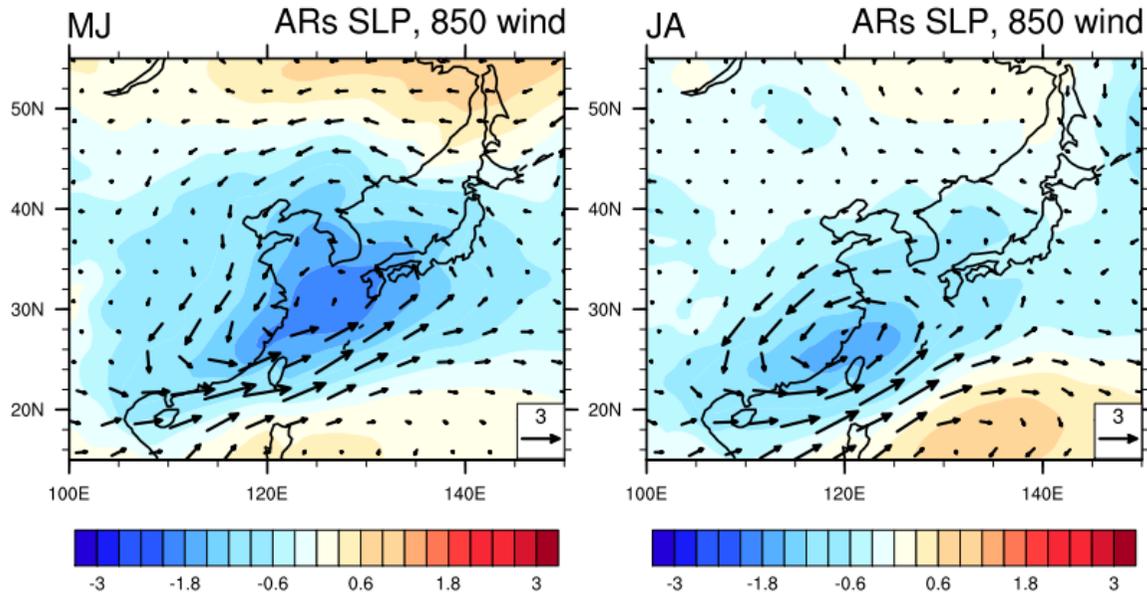
ERA-Interim



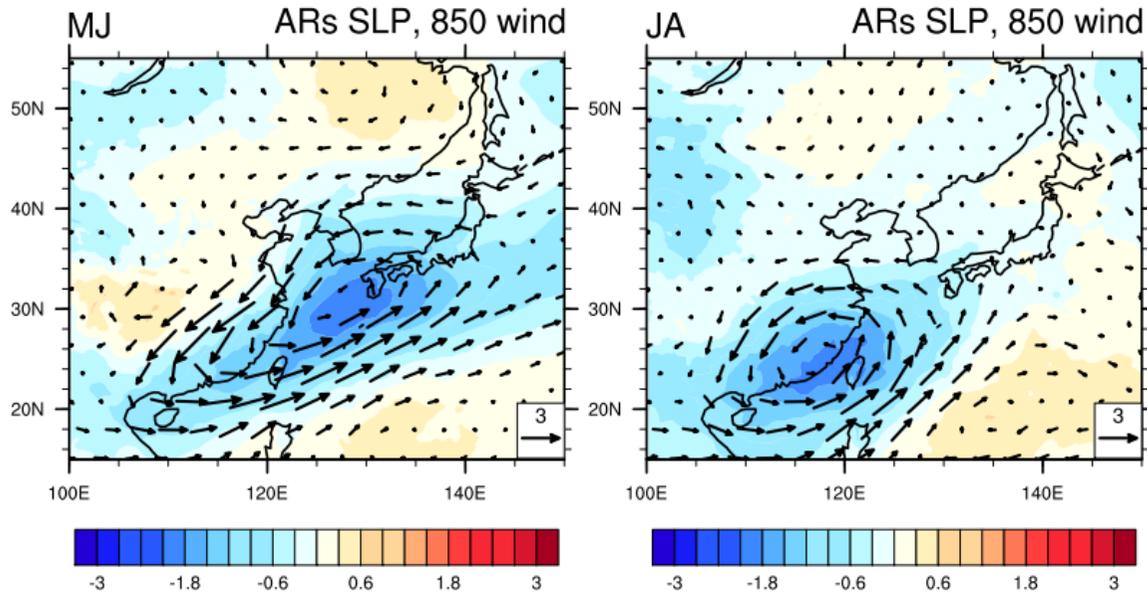
HiRAM
Historical



ERA-Interim (composite minus climatology)

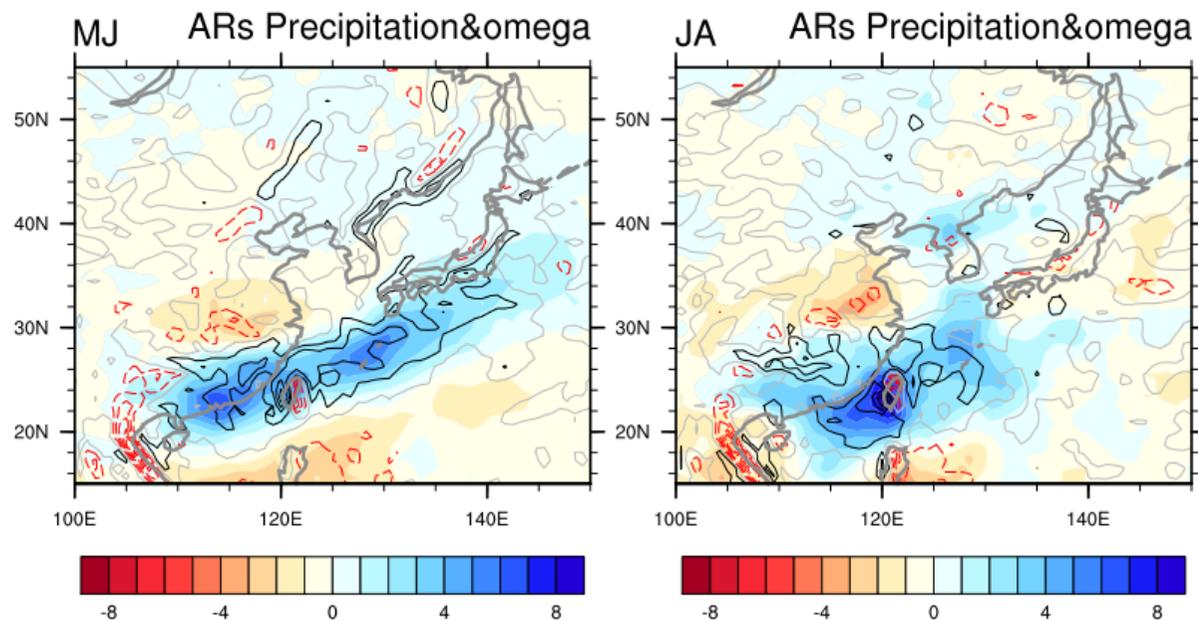


HiRAM historical (composite minus climatology)

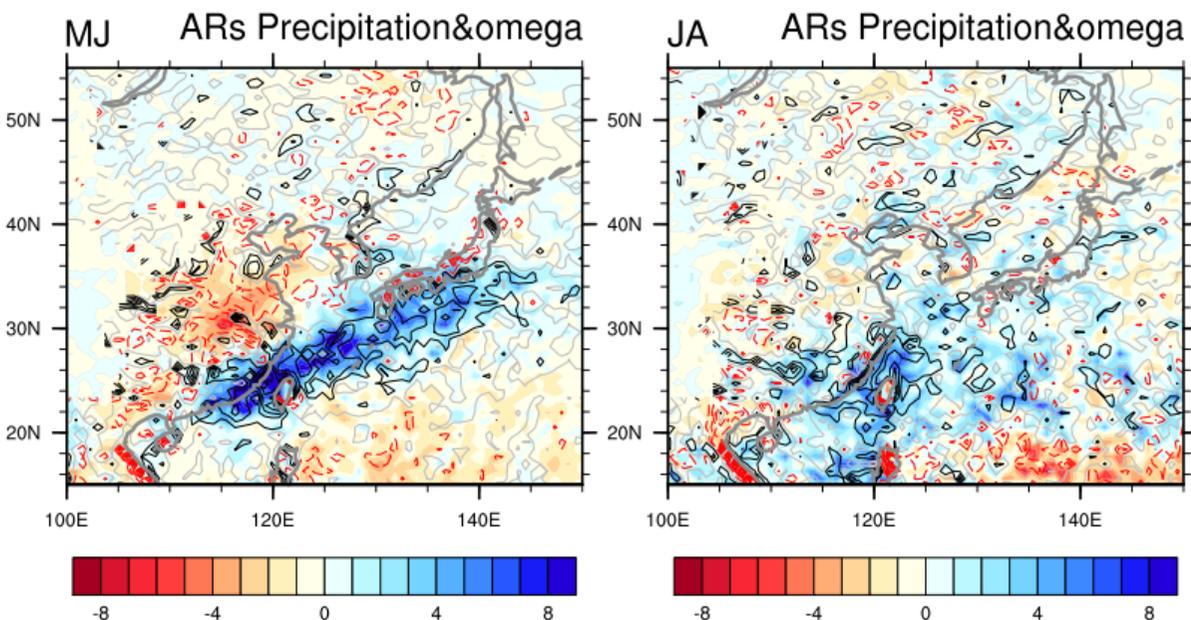


侵襲台灣事件
合成距平

ERA-Interim composite minus climatology



HiRAM historical composite minus climatology



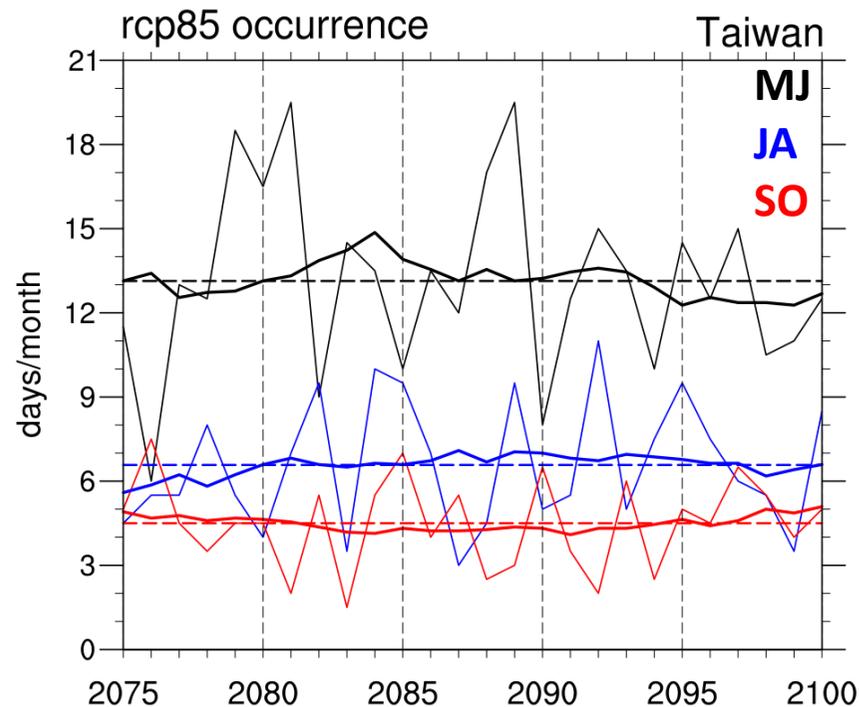
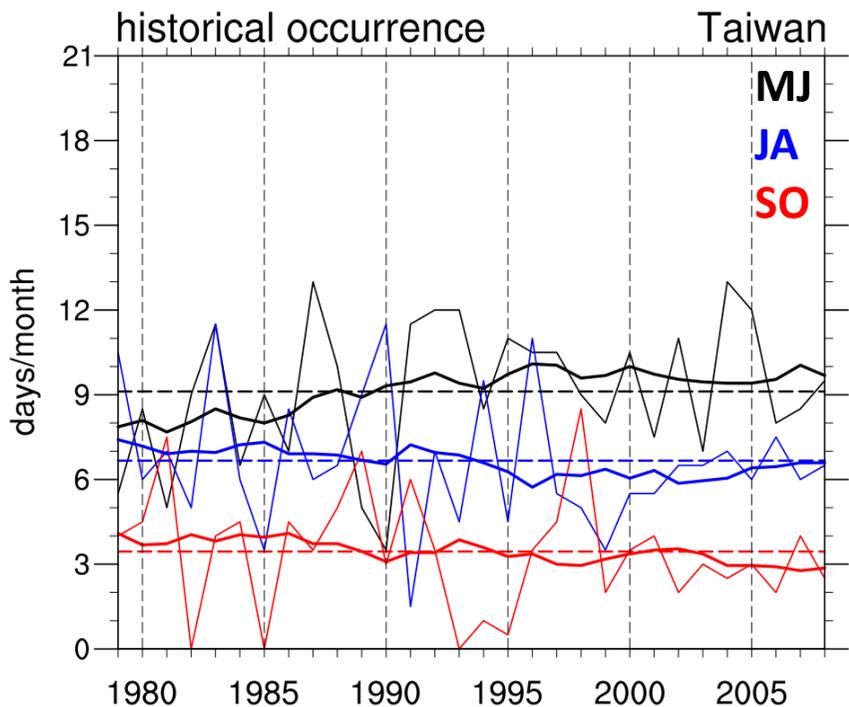
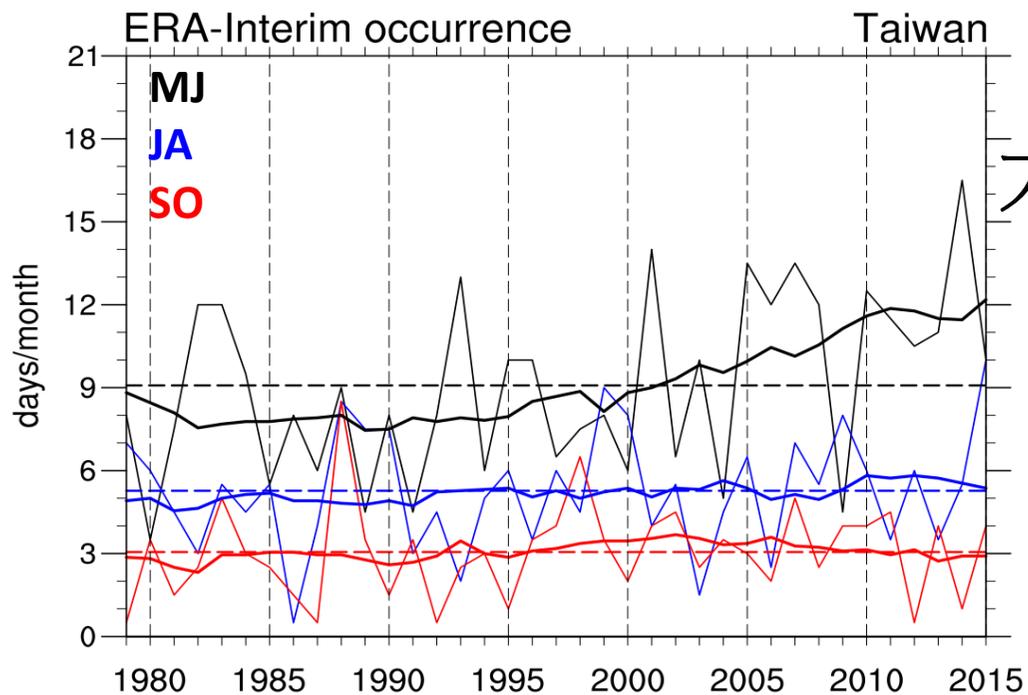
侵襲台灣事件
合成距平

Precipitation(shading)
Omega(contour, *-1
Positive, **negative**)
Omega(*-1):-0.2~0.2, interval:0.02

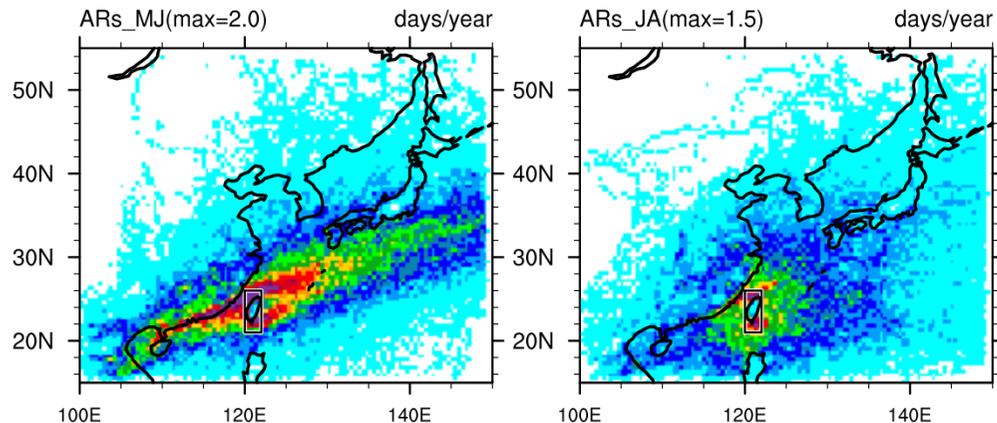
大氣河經過台灣の日數

ARs occurrence

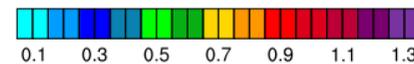
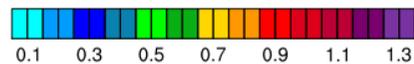
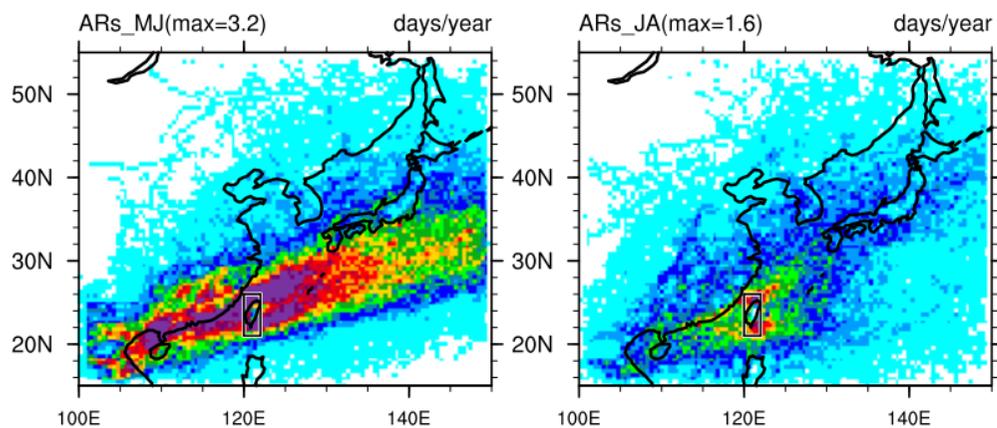
11 years running mean



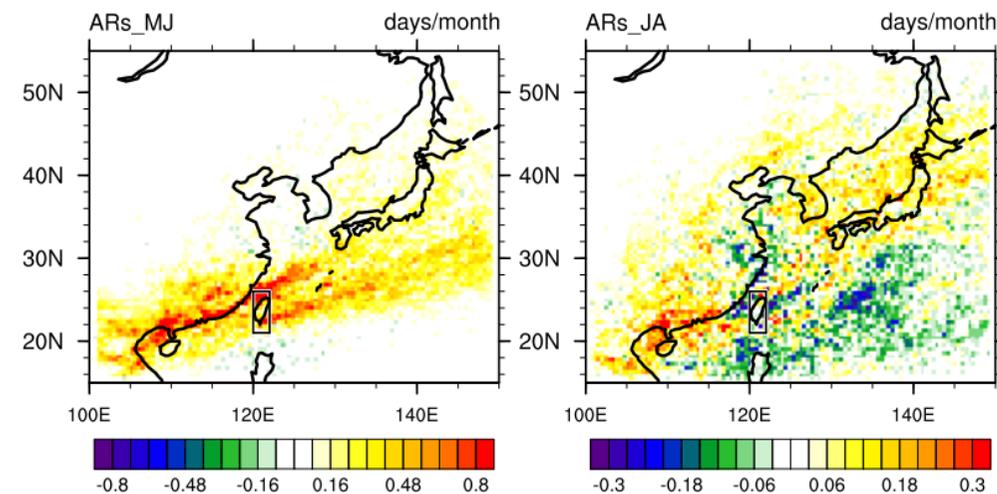
HiRAM
historical



HiRAM
rcp85

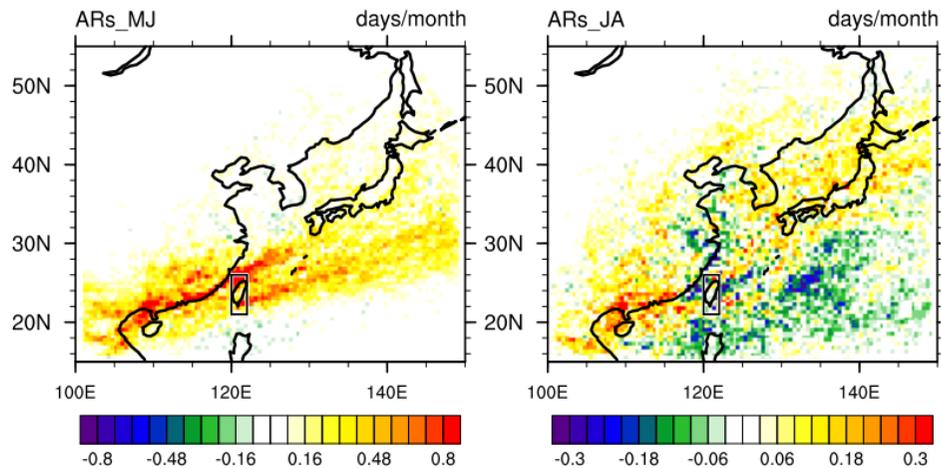


Rcp85-historical

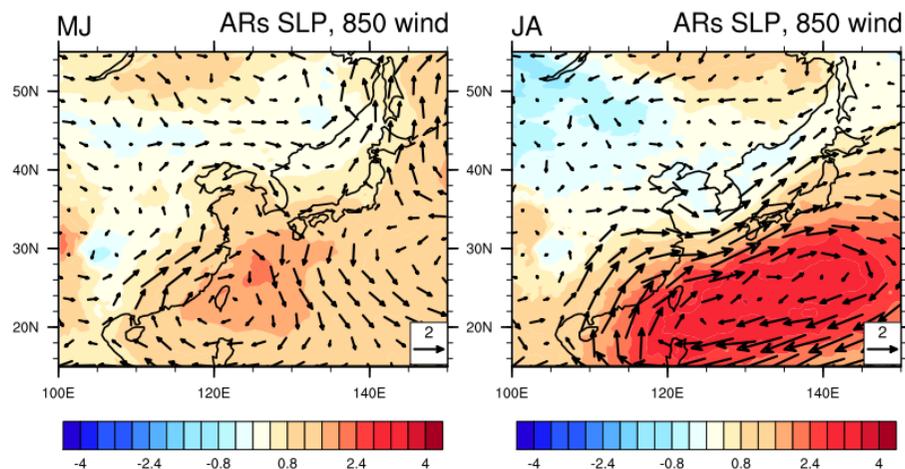


侵襲台灣事件
頻率變化

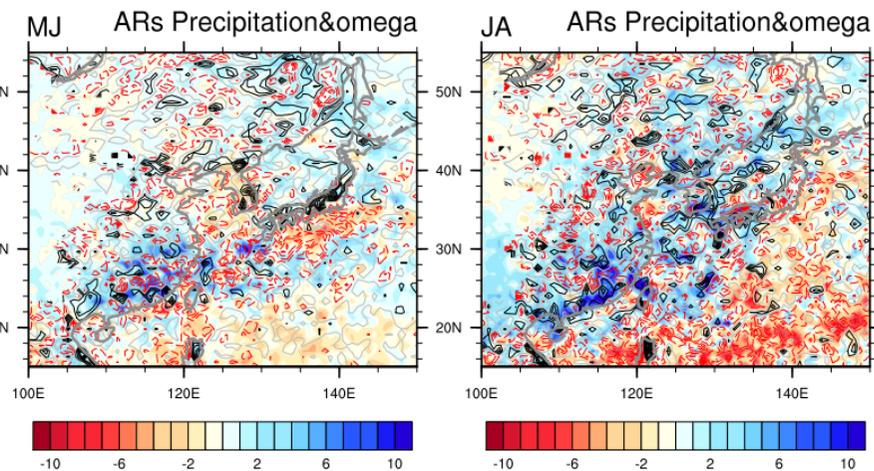
AR frequency
(Rcp85-historical)



SLP
850hPa wind field



Precipitation(shading)
Omega(contour, *-1
Upward, downward)



侵襲台灣事件
合成差異

Dynamical Response and Decomposition of the Moisture Flux

$$\delta MF \approx g^{-1} \left| \int_{p_s}^{p_t} \left(\underbrace{\bar{\mathbf{V}} \delta \bar{q}}_A + \underbrace{\delta \bar{\mathbf{V}} \bar{q}}_B + \underbrace{\delta (\overline{\mathbf{V}' q'})}_C \right) dp \right|$$

$$\delta(\cdot) = (\cdot)_{\text{RCP8.5}} - (\cdot)_{\text{historical}}$$

— : average ' : daily anomalies

A: thermodynamic response

$$\text{TH} = g^{-1} \left| \int_{p_s}^{p_t} \bar{\mathbf{V}} \cdot \delta \bar{q} \right| dp$$

B: dynamic response

$$\text{DYN} = g^{-1} \left| \int_{p_s}^{p_t} \delta \bar{\mathbf{V}} \cdot \bar{q} \right| dp$$

C: transient eddy response

$$\text{Eddy} = g^{-1} \left| \int_{p_s}^{p_t} \delta (\overline{\mathbf{V}' \cdot q'}) \right| dp$$

A minus B

Positive: thermodynamic dominate

Negative: dynamic dominate

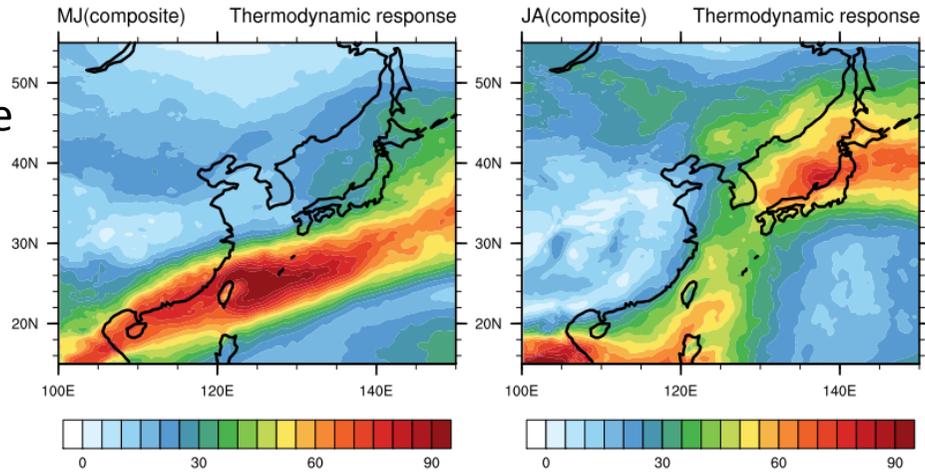
MF: positive

$$\sqrt{(uq^2 + vq^2)}$$

侵襲台灣AR合成

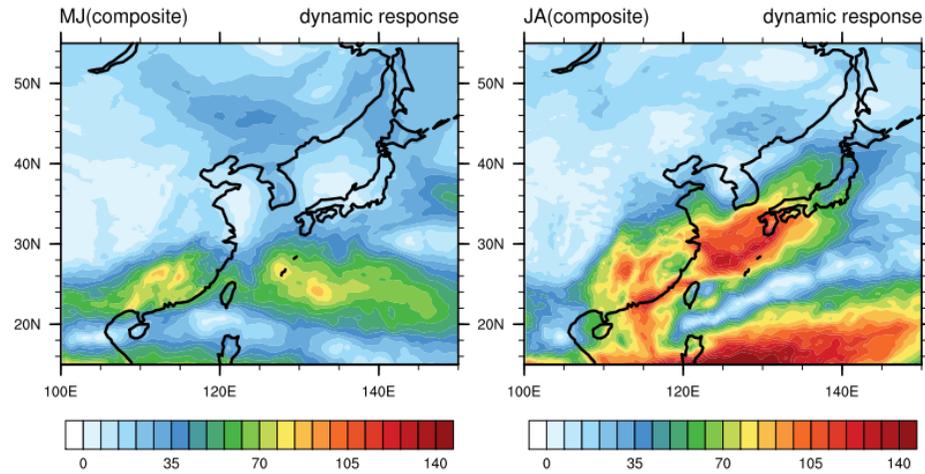
thermodynamic response

$$g^{-1} \int_{P_s}^{P_t} \bar{V} \cdot \delta \bar{q} dp$$



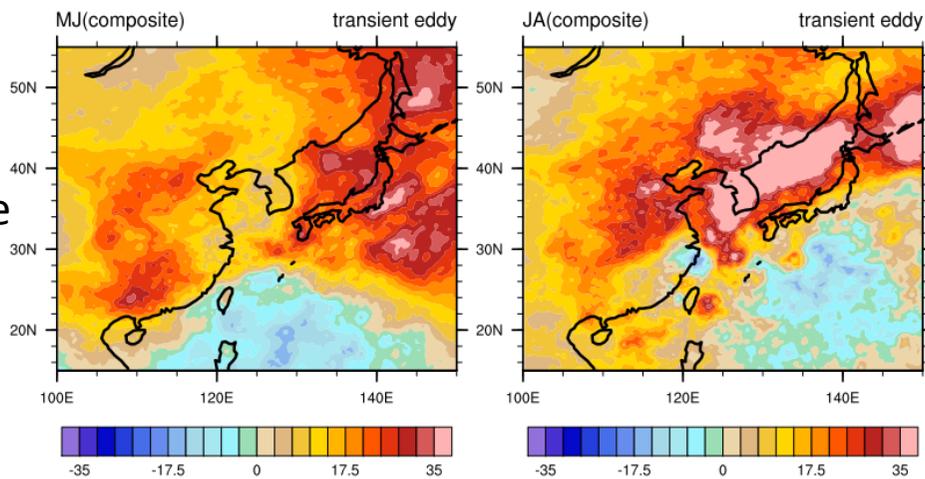
dynamic response

$$g^{-1} \int_{P_s}^{P_t} \delta \bar{V} \cdot \bar{q} dp$$



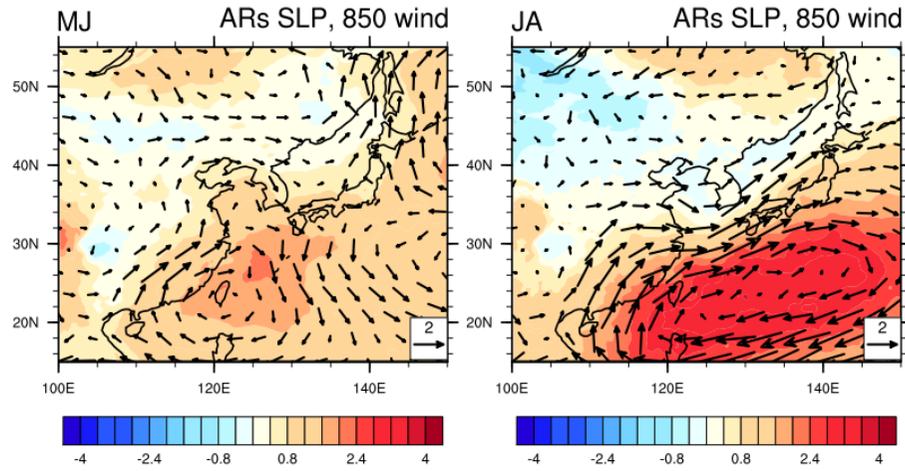
transient eddy response

$$g^{-1} \int_{P_s}^{P_t} \delta(\overline{V' \cdot q'}) dp$$

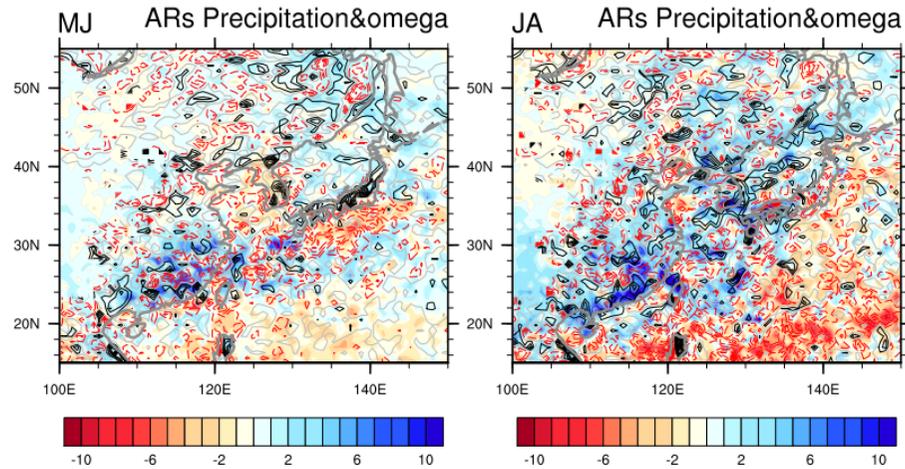


Composite difference

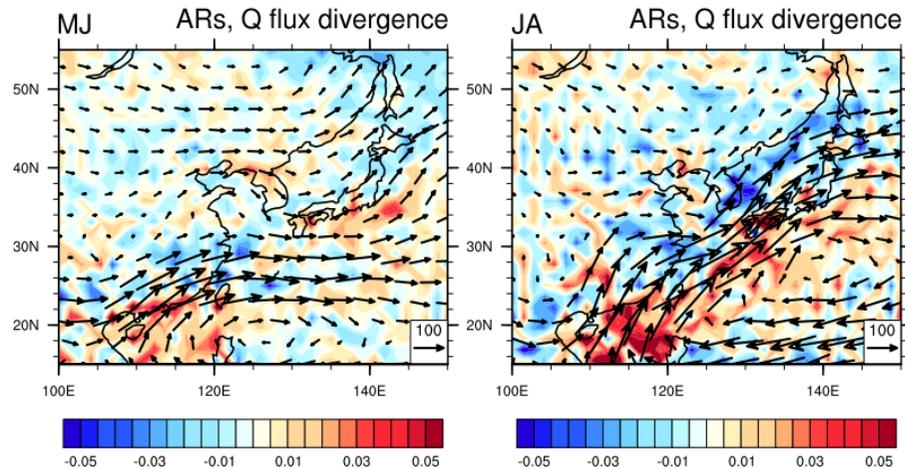
SLP
wind field



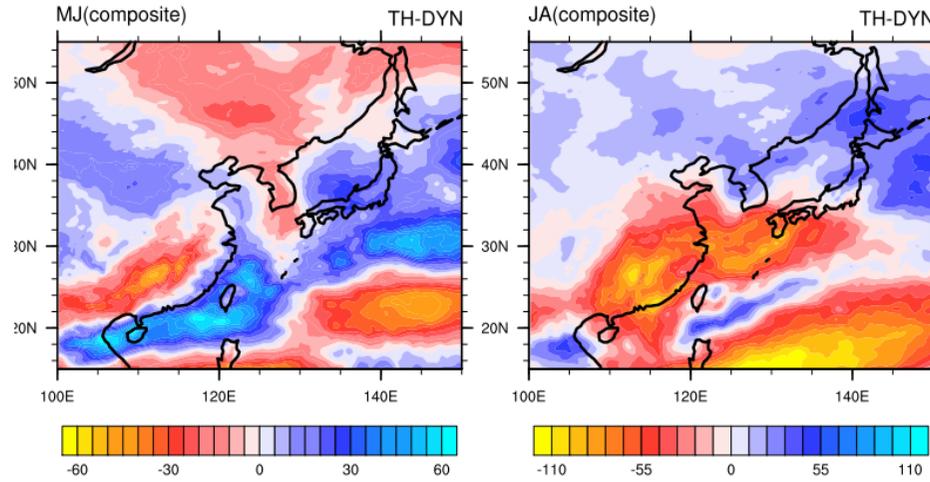
Precipitation (shading)
Omega (contour, *-1)
Positive, negative



Moisture flux
And divergence



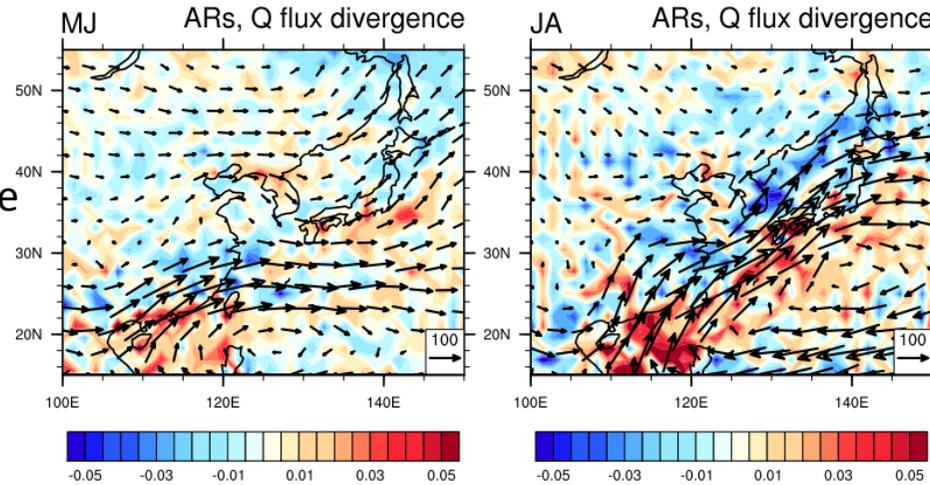
thermodynamic
- dynamic response



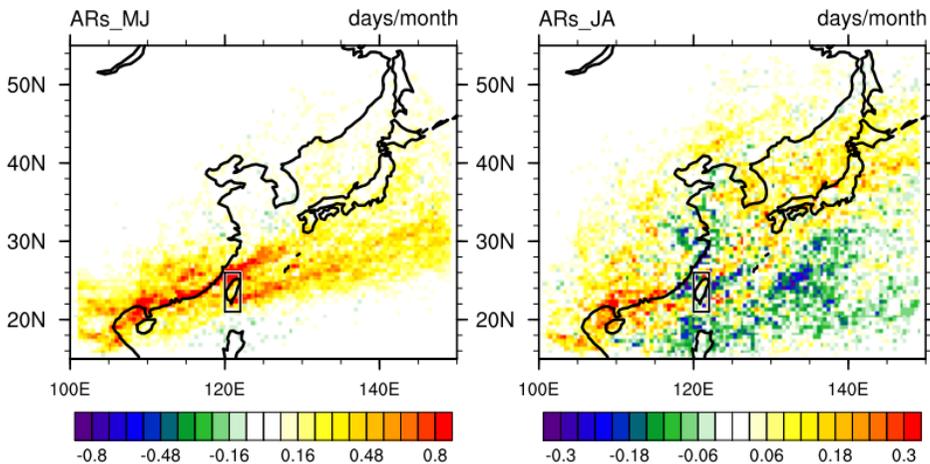
Positive:
thermodynamic
dominate

Negative: dynamic
dominate

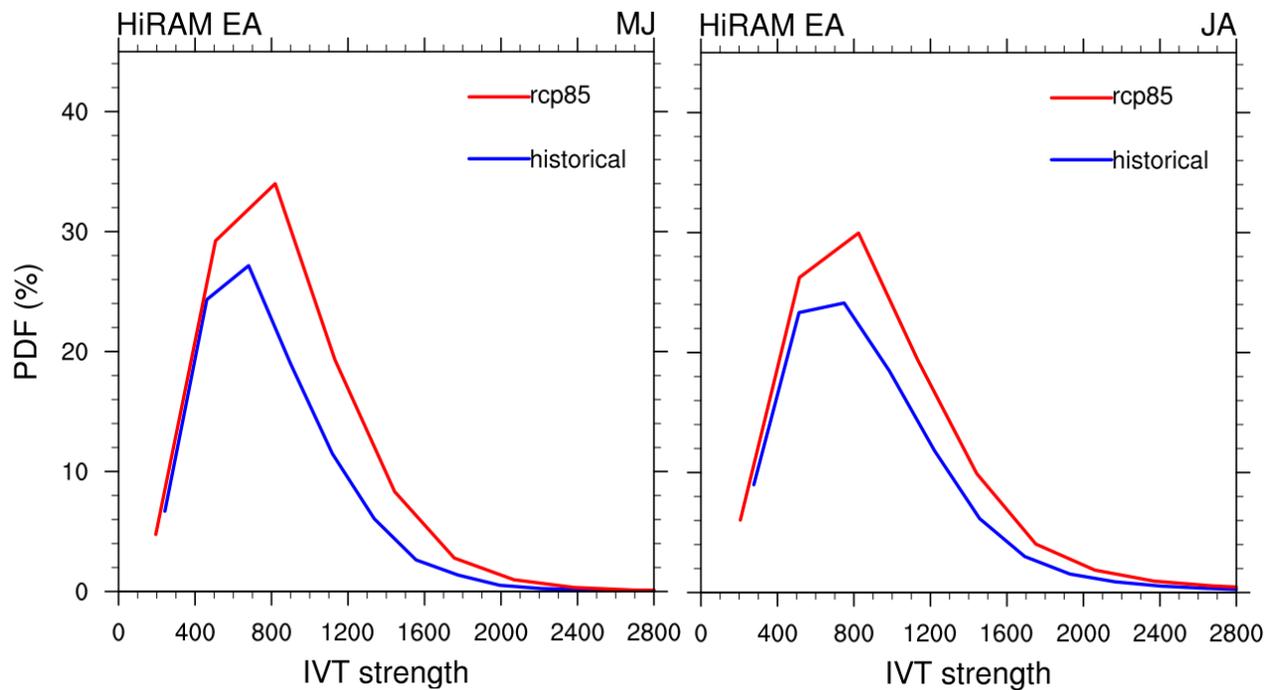
Moisture flux&divergence
Composite difference
(Rcp85 minus historical)



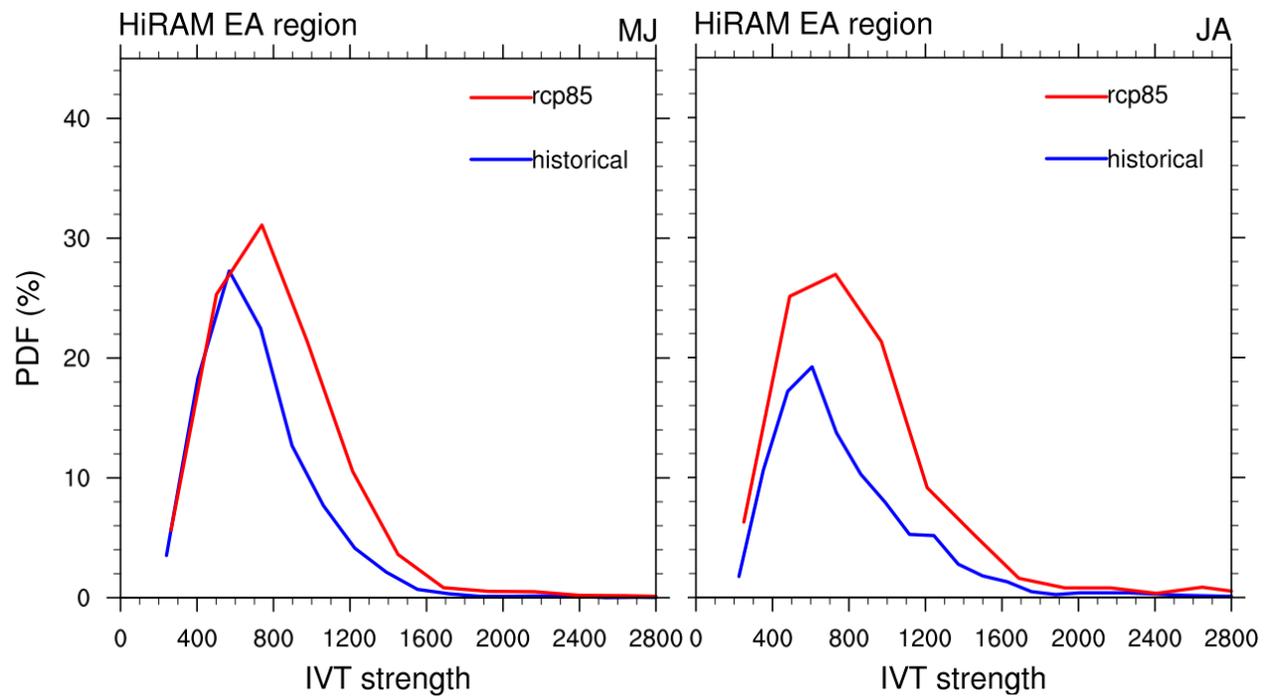
AR frequency
(Rcp85-historical)



侵襲台灣事件



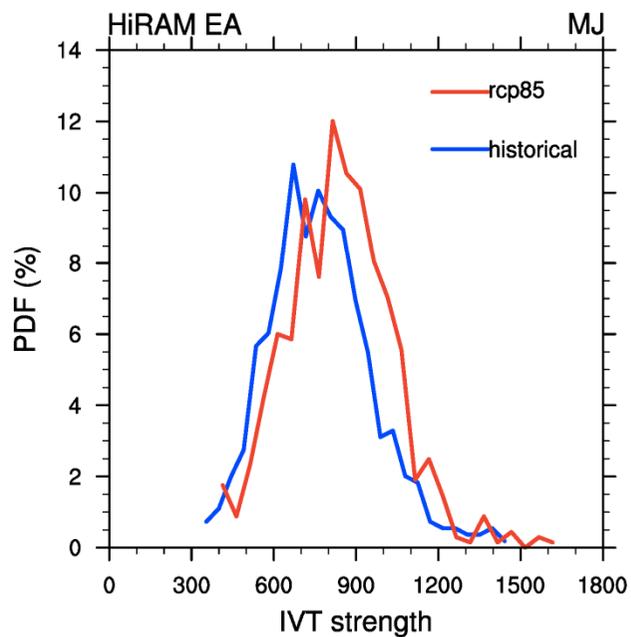
East Asia



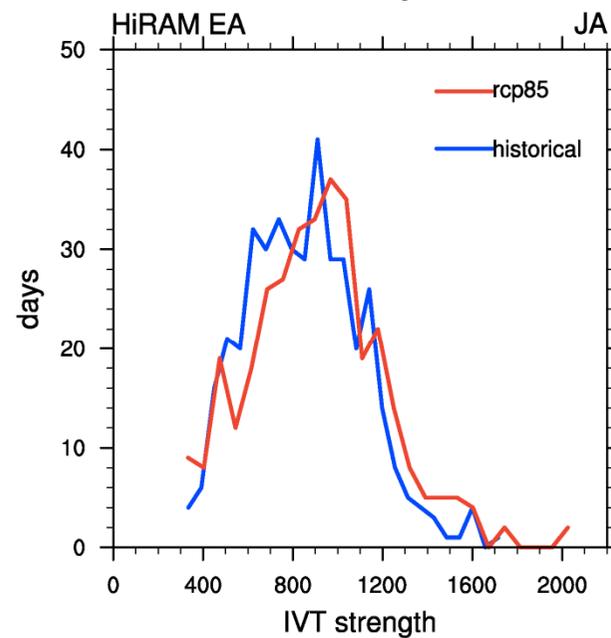
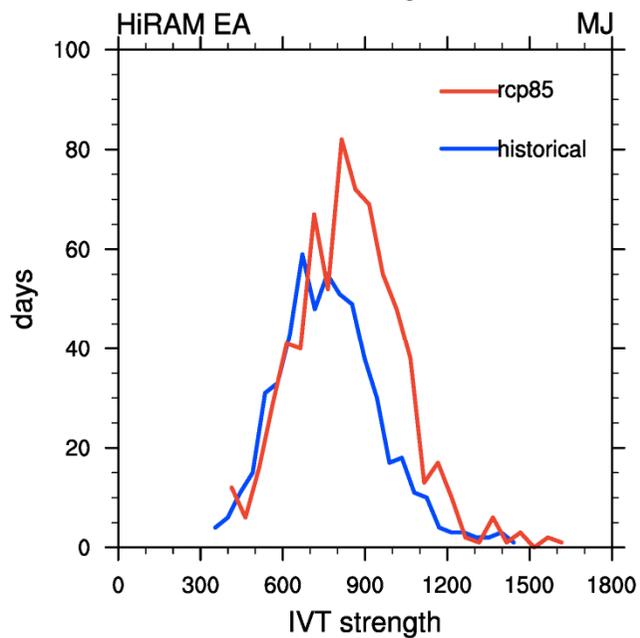
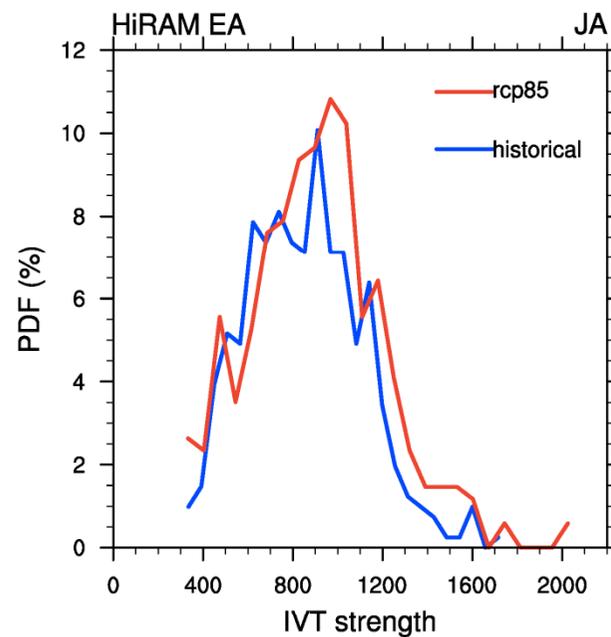
Taiwan

侵襲台灣事件
大氣河強度
機率密度函數

bin = 25



bin = 25



summary

- 影響台灣的大氣河常伴隨較強的垂直運動、低壓的西南風將水氣從熱帶輸送至台灣，台灣降水增加
- 世紀末，梅雨季大氣河頻率增加，夏季頻率趨勢較不明顯一致。大氣河的強度增強，極端大氣河事件更容易發生
- 世紀末，氣壓場雖不利於梅雨季大氣河發展，但整體的水氣輸送與輻合加強，熱力的貢獻使降水增加

Thank you for your attention.