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Impacts of recent decadal changes in Asian aerosols on the East Asian summer monsoon: Roles of aerosol-radiation and aerosol-cloud interactions.

Buwen Dong, Rowan T. Sutton, Ellie Highwood and Laura Wilcox

NCAS-climate, Department of Meteorology, University of Reading

- **Aerosols emissions changes from 1970s to 2000s**
- **Model experiments**
- **Responses to changes in Asian aerosol emission changes**
- **Relative roles of ARI and ACI**
- **Summary**

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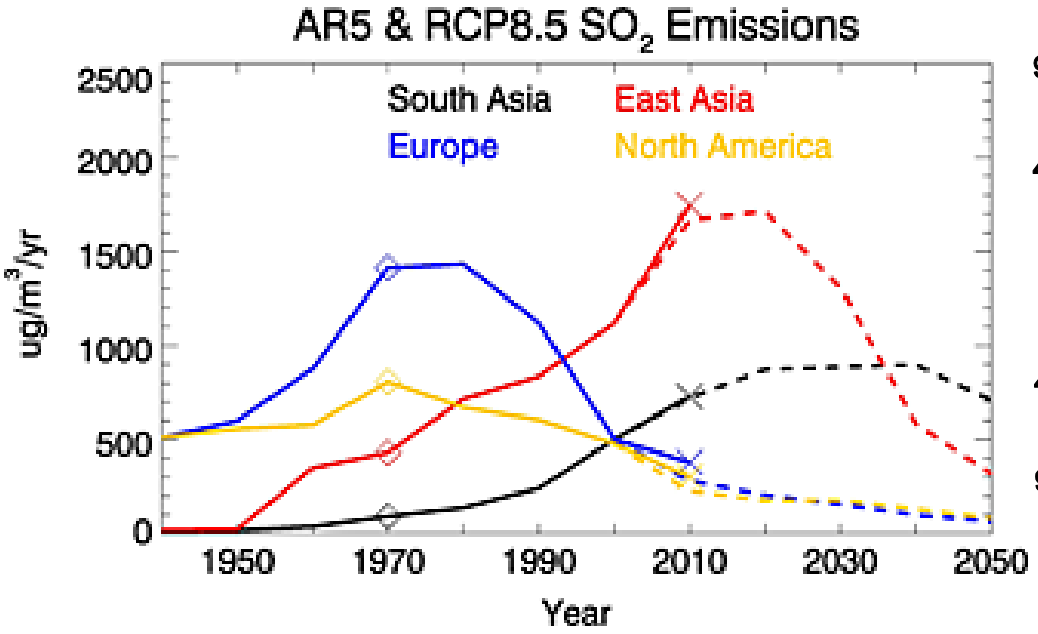
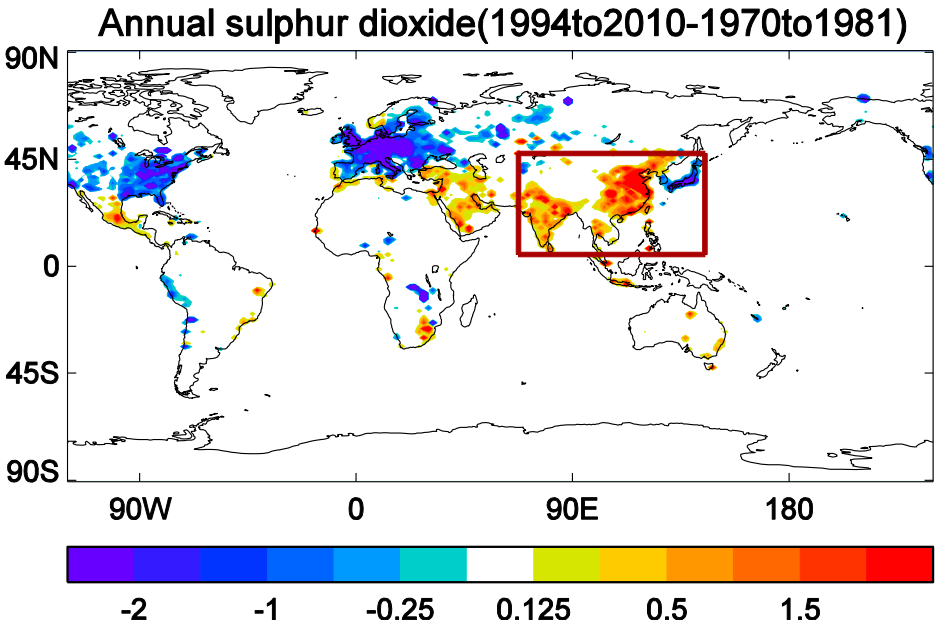
Time evolutions of regional aerosol emissions





Wang et al (2015)

Decreased emissions over Europe and North America from 1970s to 2000s and increased emissions over East and South Asia

MetUM-GOML1 modelling framework

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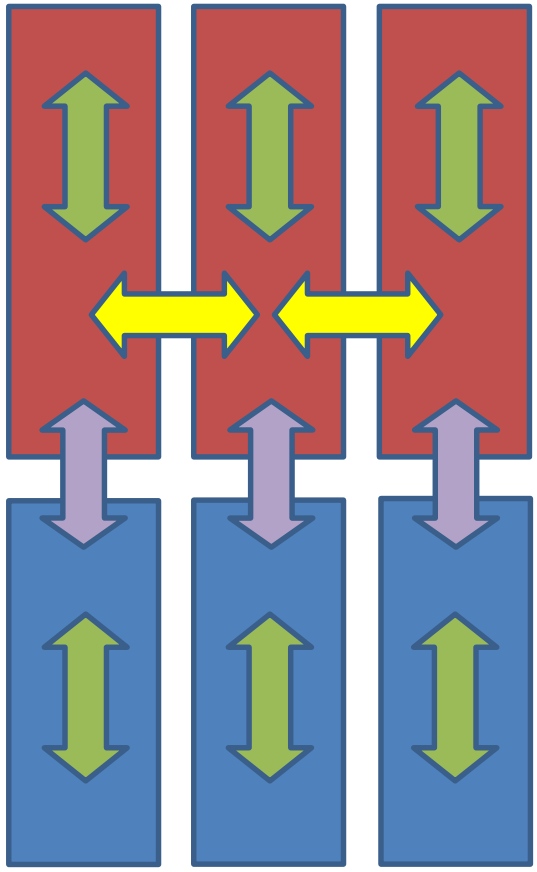

Met Office Unified Model (MetUM) global atmosphere

OASIS coupler
3 hourly exchanges

Multi-Column KPP one-dimensional ocean mixed-layer (vertically resolved)

Key advantages:

- **Cheap**: < 5% of the cost of AGCM, allowing high (1m) ocean vertical resolution
- **Controllable**: Easily constrainable to any desired ocean state (small SST biases)
  Flexible: Air-sea coupling can be applied selectively in space & time to explore role of coupling in a range of phenomena
- **Adaptable**: Works easily with any GCM grid

Climatological three-dimensional heat and salt tendencies are applied to represent
(a) the mean advection in the ocean
(b) corrections for biases in atmospheric surface fluxes **(Klingaman et al. 2011).**

E1: 1994 to 2010 mean AA forcing. E2: 1970-1981 AA forcing over Asia. E1ARI, and E2 ARI. Same GHG forcings in all experiments.
32 yrs with last 28 yrs used for analysis.

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Changes in CDNC, CDER, and sulphate AOD due to changes in Asian emissions

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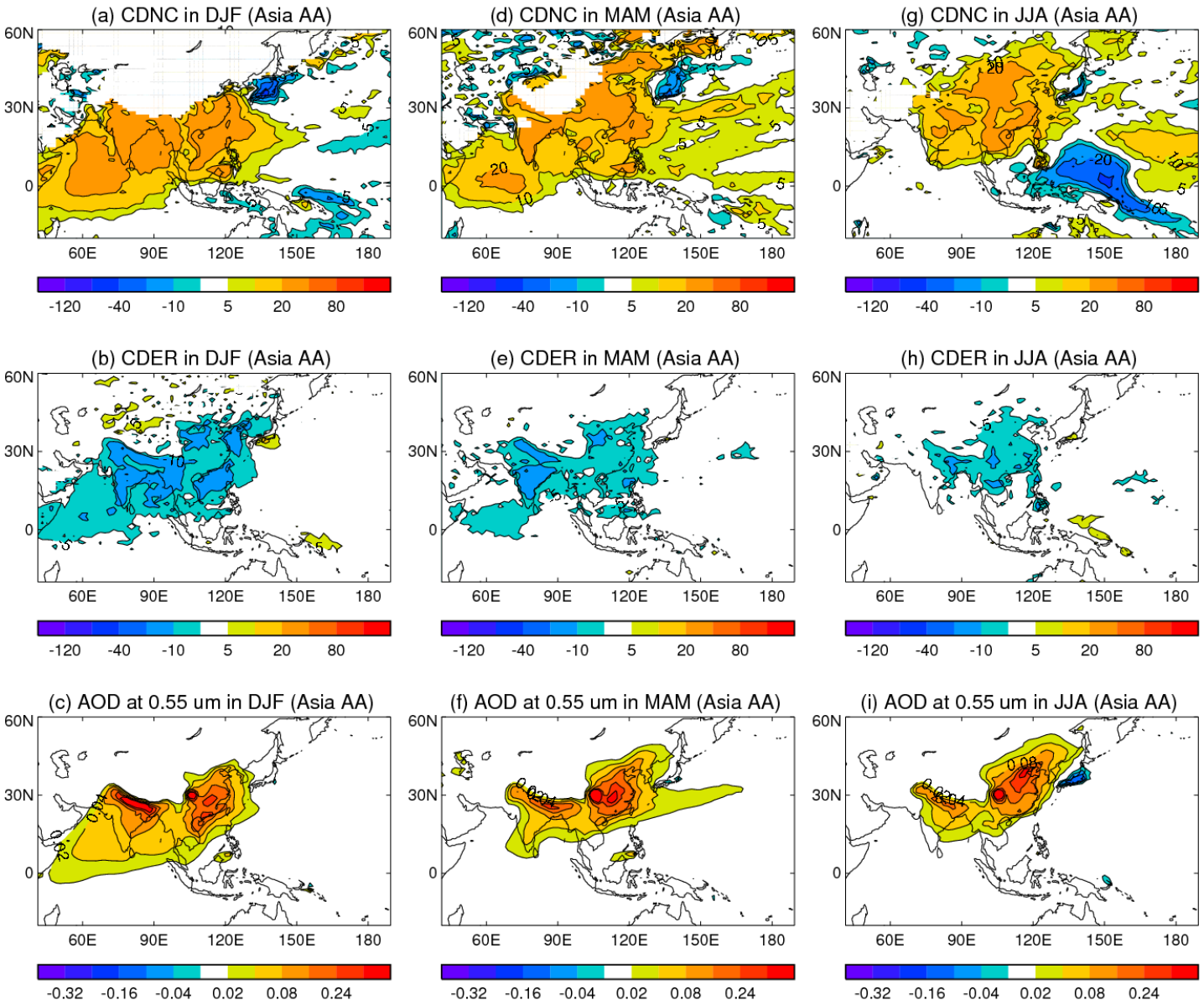

~20-40% increase in cloud droplet number concentration (CDNC) and ~5-10% decrease in cloud droplet effective radius (CDER) over Asia and surrounding regions due to the increase in AA emissions over Asia from 1970s to 2000s

Increase in local sulphate AOD by 0.2-0.4

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Clear seasonal evolutions despite seasonal cycle of emissions are very weak

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Processes in response to changes in AA emissions over Asia and adjacent oceans in JJA

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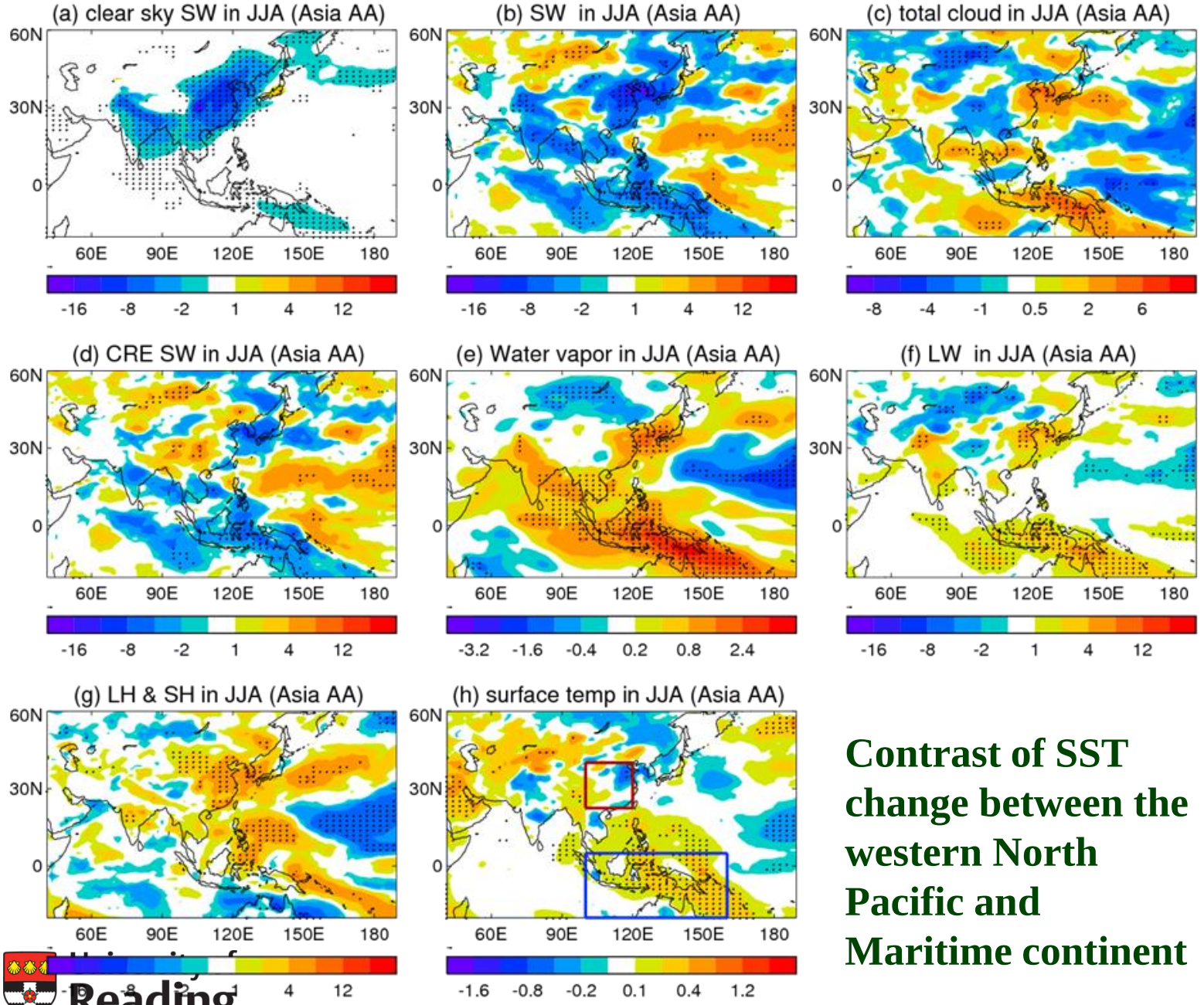

Contrast of SST change between the western North Pacific and Maritime continent

Increased Asian AA emissions

Increased AOD, CDNC & decreased CDER

Decreased Surface SW over Asia

Surface cooling over Asia and weakened EASM

Reduced precipitation, cloud, and soil moisture

Negative feedbacks on cooling

Weak local SAT change

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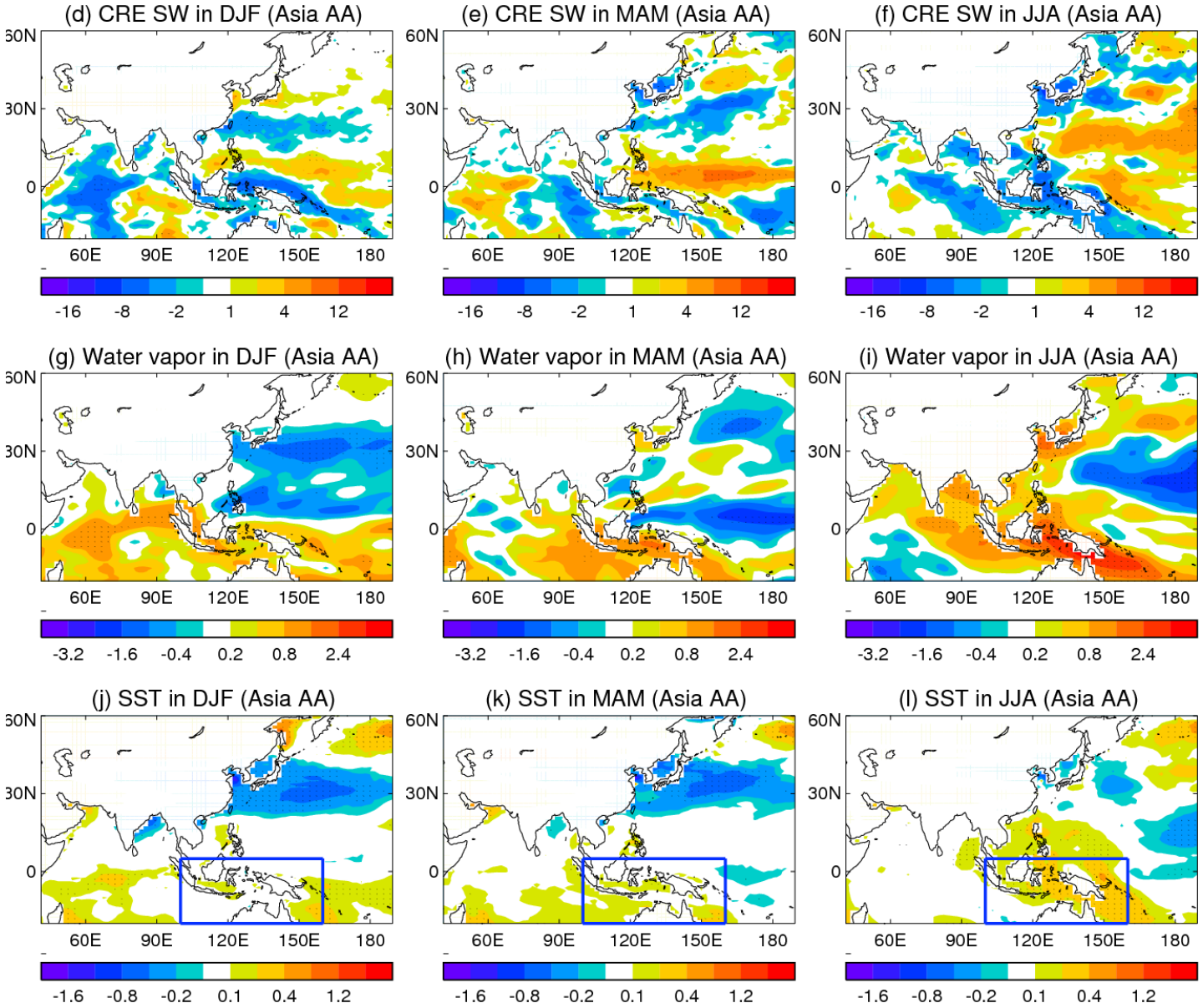
Responses to Asian AA changes in pre-summer seasons



Changes SW CRE on cooling over the western North Pacific

Role of increased water vapor for the warming over Maritime continent

Changes in circulation and precipitation in summer in response to Asian AA changes

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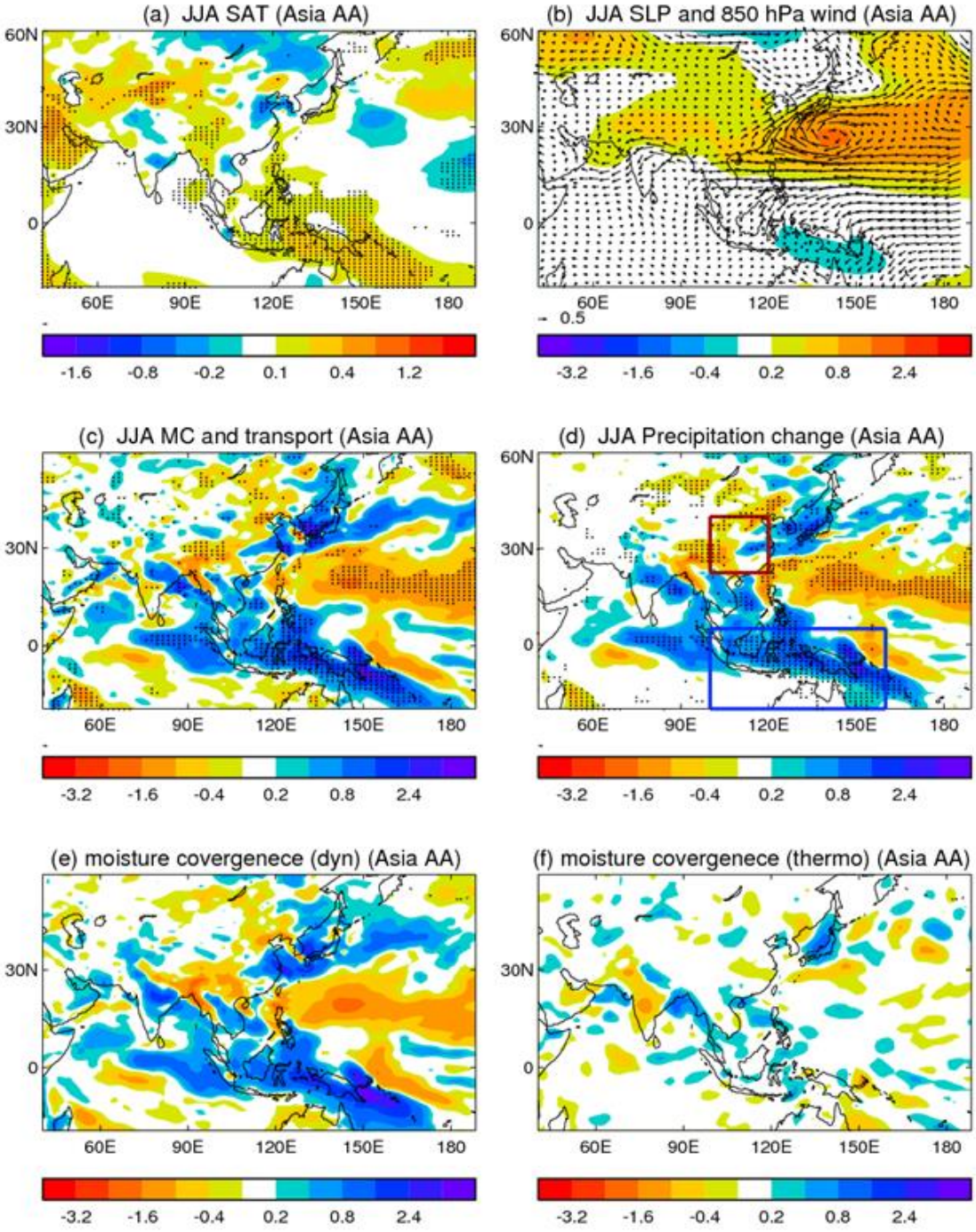
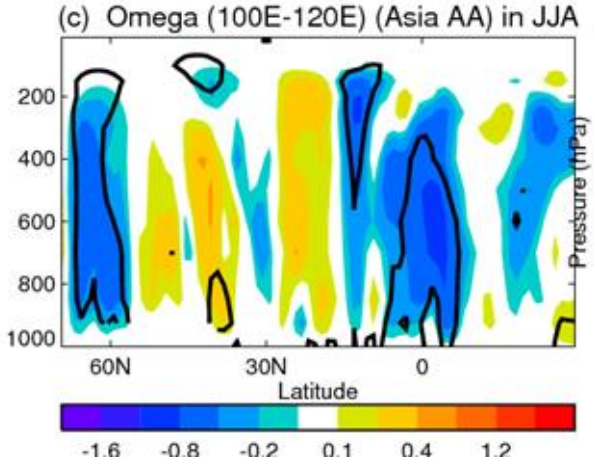


Changes in moisture transport convergence (divergence) responsible for increased (decreased) precipitation



Dynamical component related to circulation change dominates

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Processes in response to changes in AA emissions over Asia and adjacent oceans in JJA with only ARI

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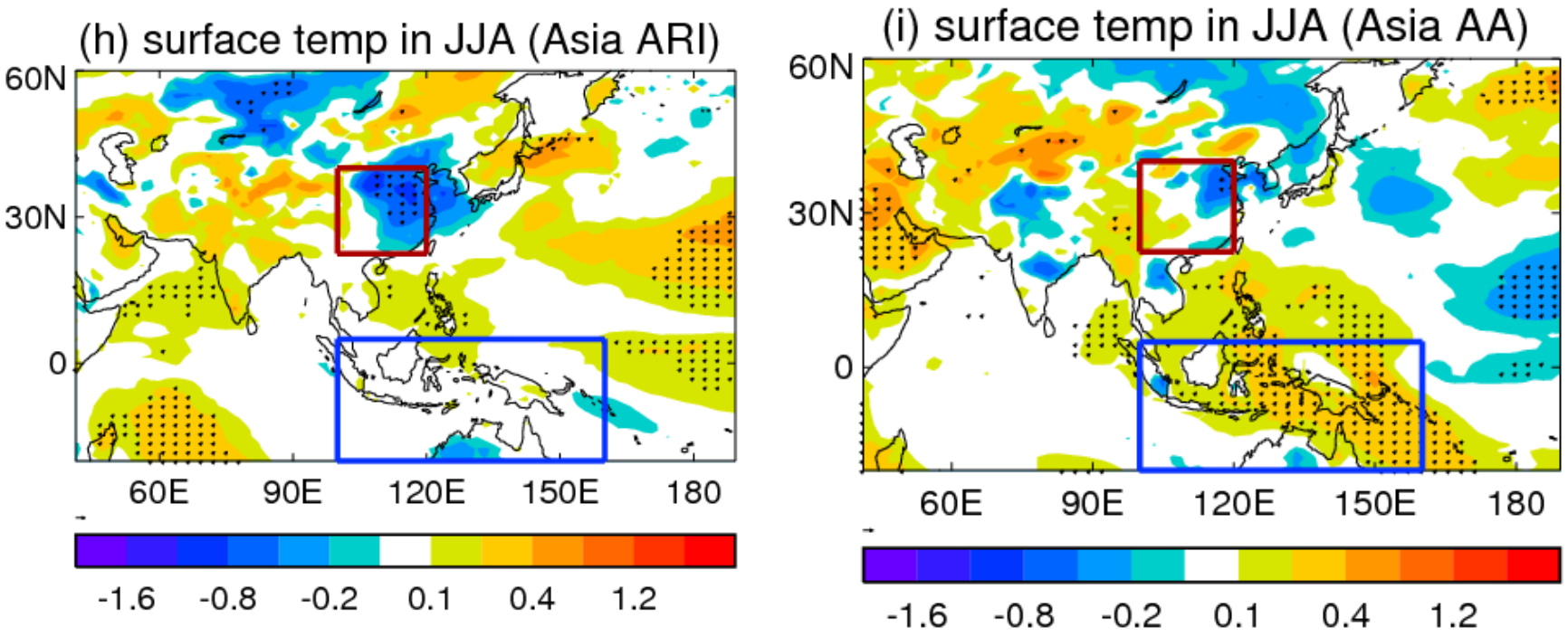

Very different SST responses over the Western North Pacific and the Maritime continent with including ARI only in comparison with total response

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Contrasted changes in SST in total responses and responses through ARI

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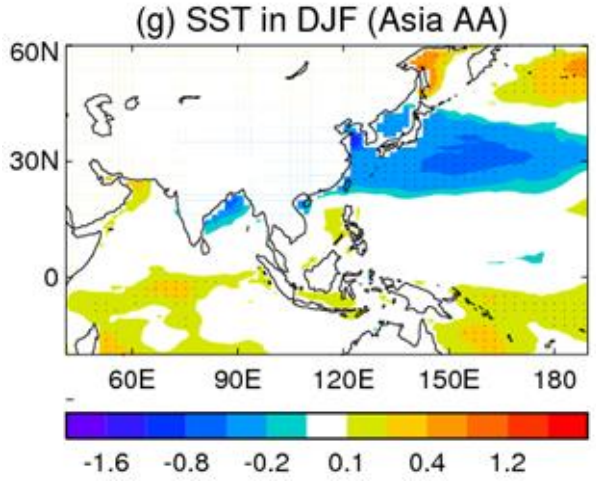

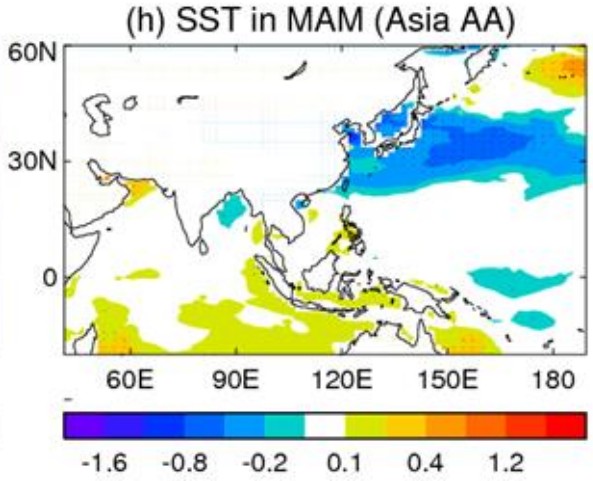

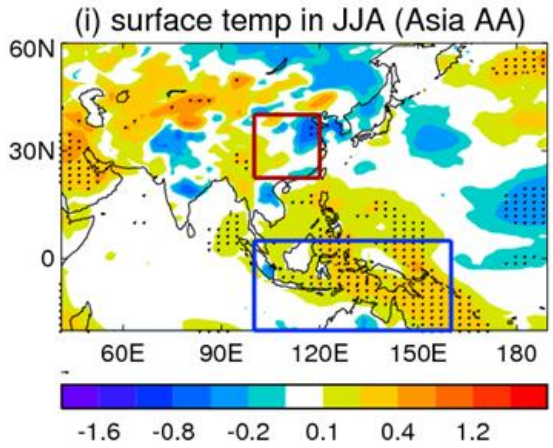

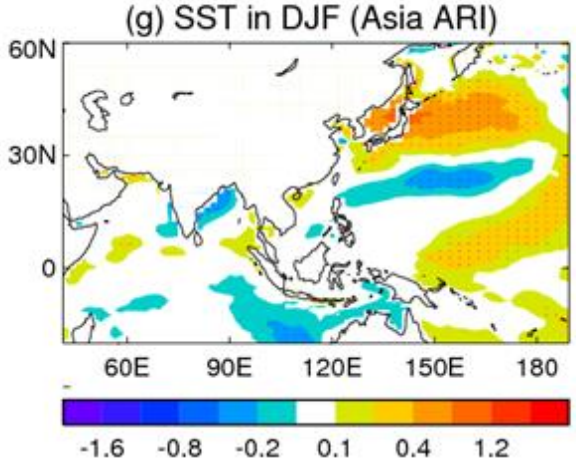

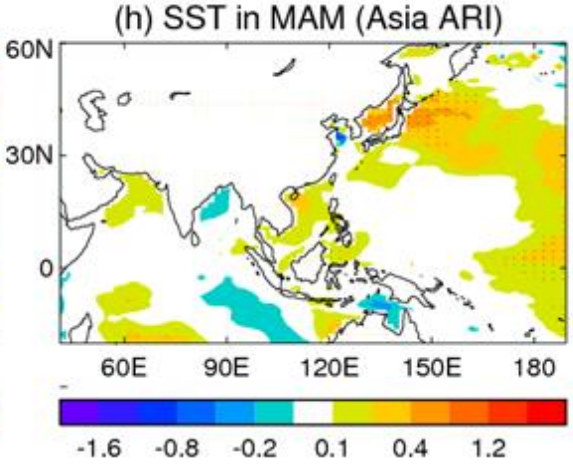

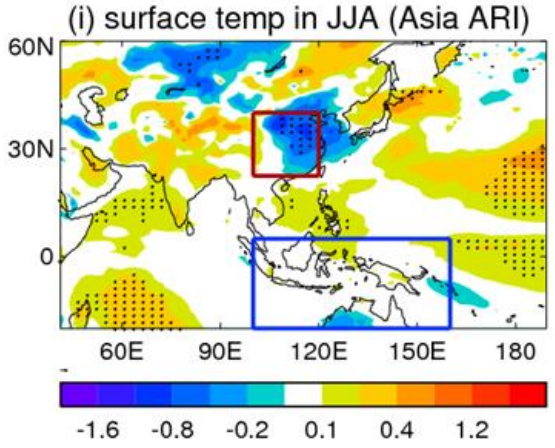

Very different SST responses over the Western North Pacific and the Maritime continent with including ARI only in comparison with total response

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Changes in circulation and precipitation in summer in response to Asian AA changes with including only ARI

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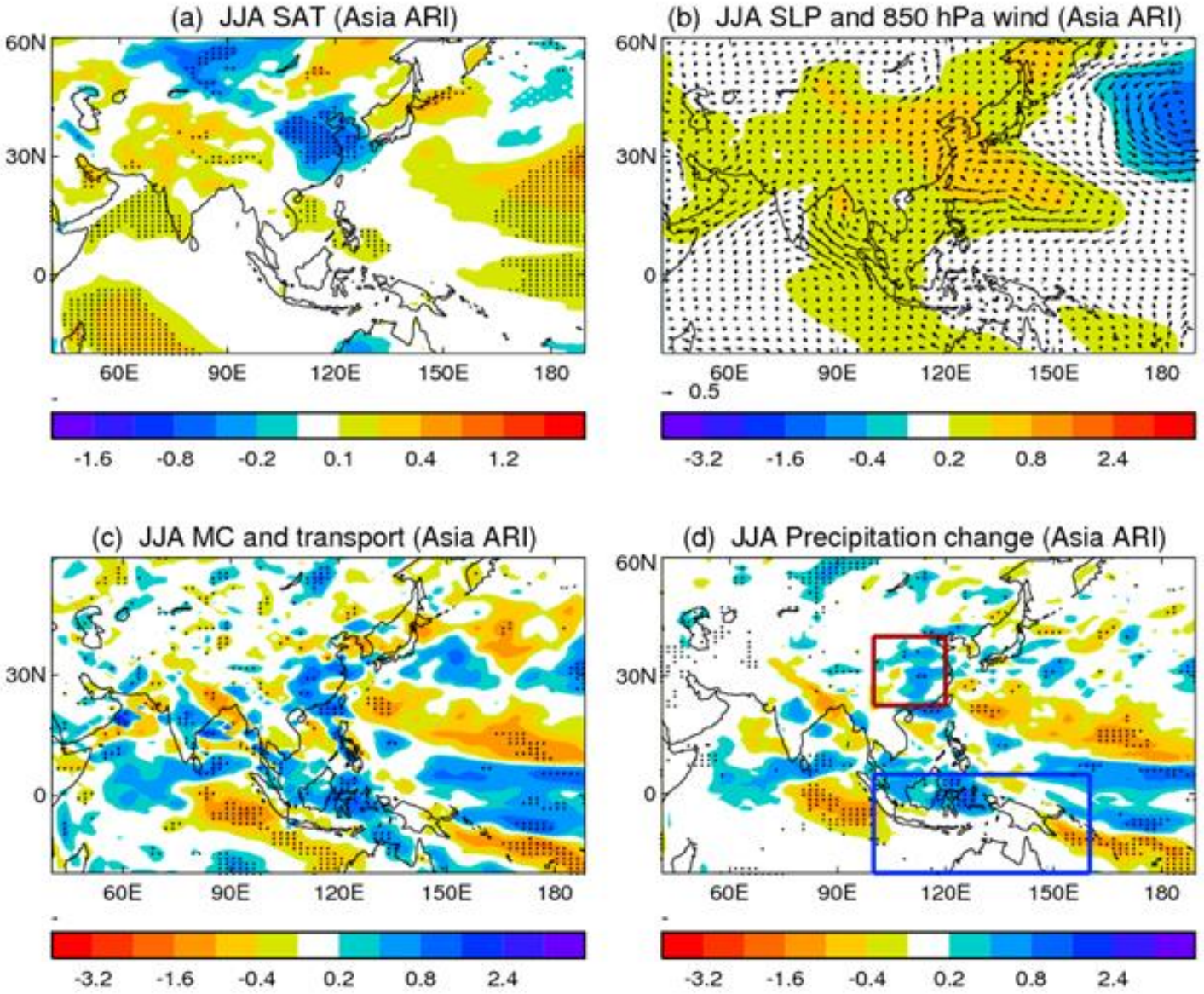

Generally weak changes in circulation, moisture transport convergence (divergence), and precipitation

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Implied changes in circulation and precipitation through ACI and total responses

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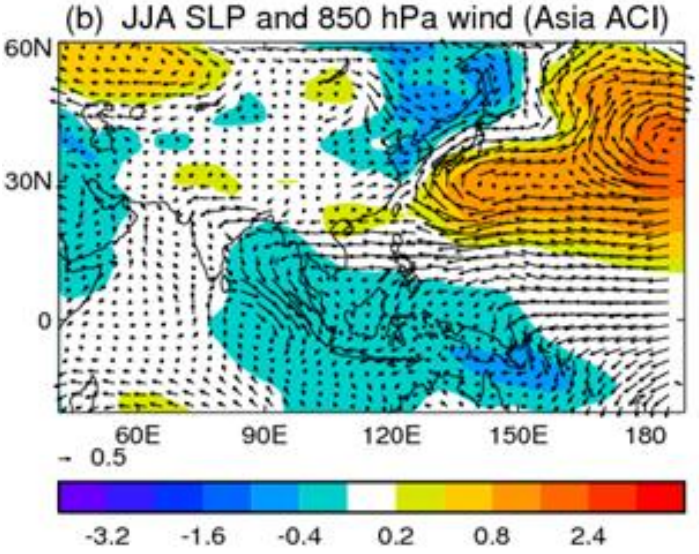
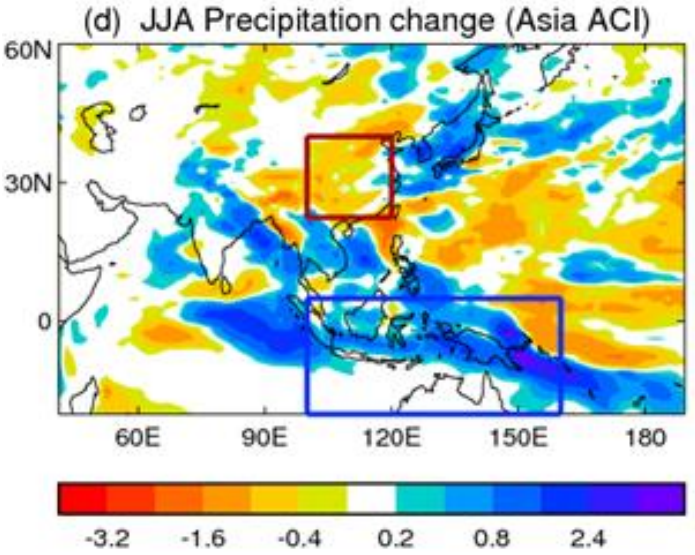
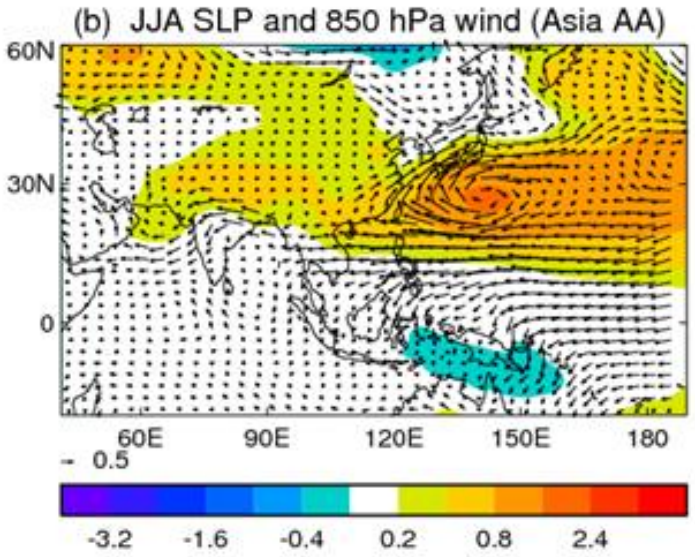
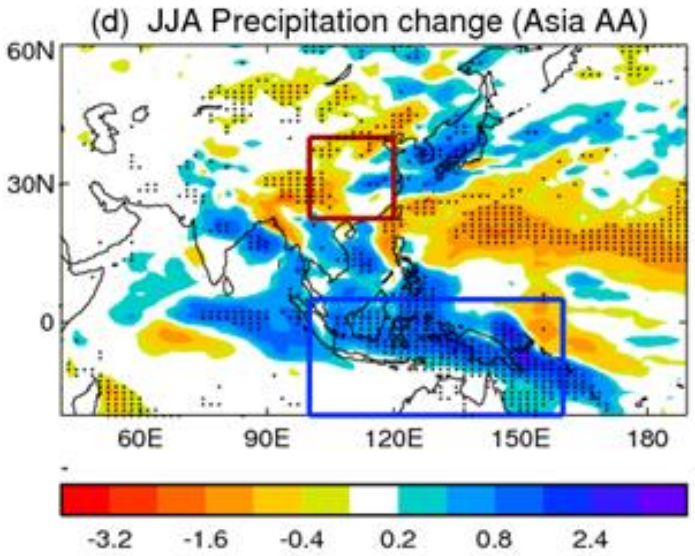
ACI





ARI & ACI





dominate role of ACI in shaping the total responses of circulation and precipitation to Asian AA emission increases

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Processes in response to changes in AA emissions over Asia and adjacent oceans in JJA with only ARI

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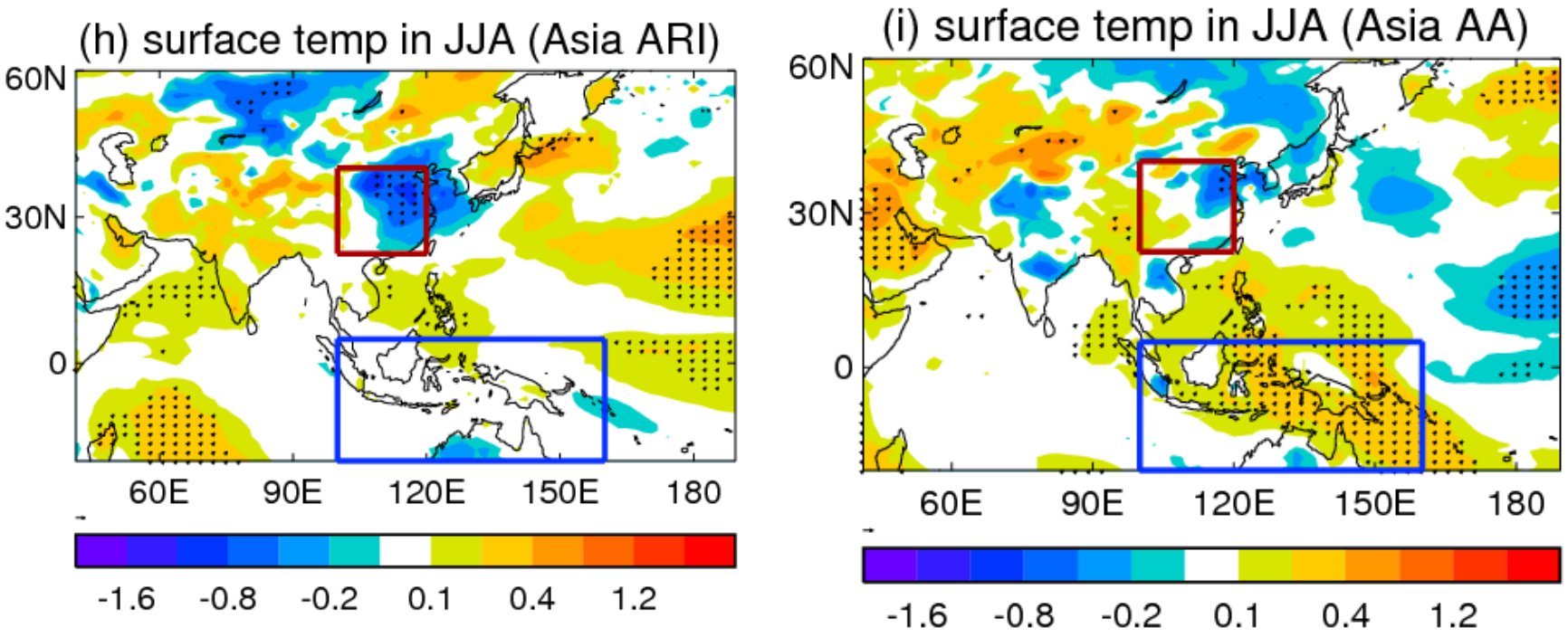

Very different SST responses over the Western North Pacific and the Maritime continent with including ARI only in comparison with total response

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Role of SST anomalies over the Maritime continent

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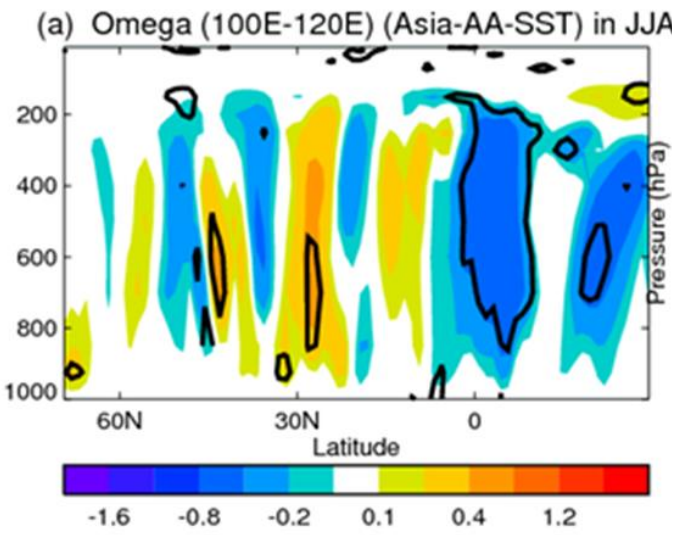
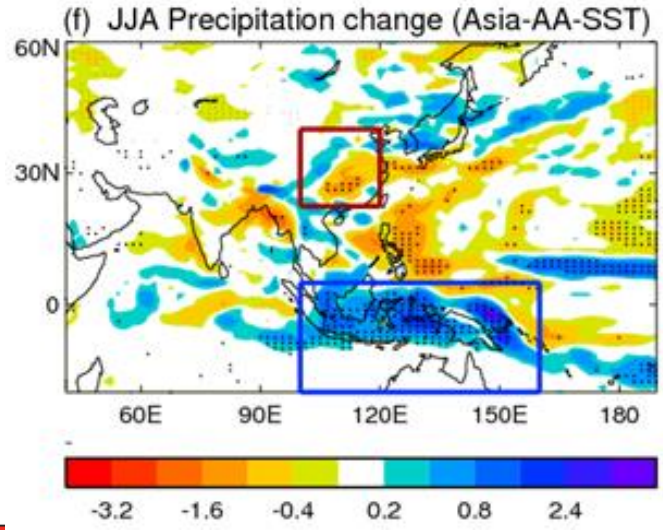
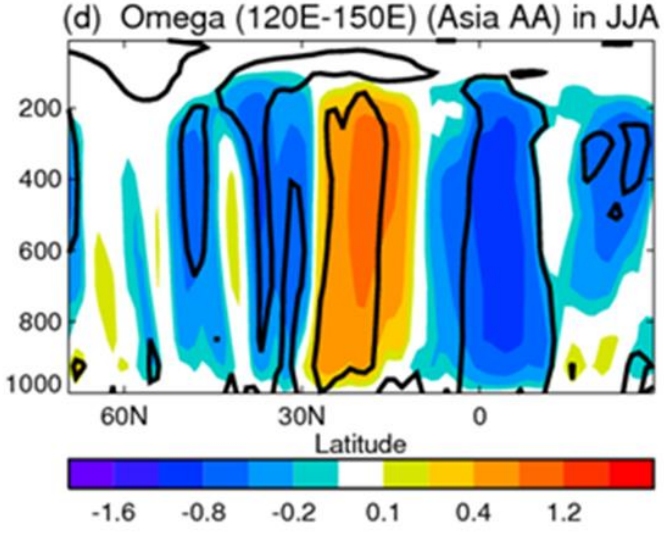
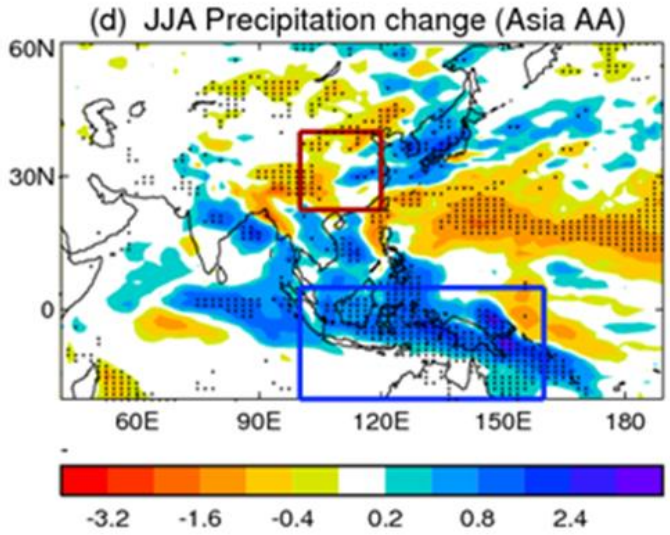
Response to SST changes over Maritime continent





Total response to Asian AA changes





AA changes induced SST anomalies over the Maritime continent play an important role in circulation and precipitation responses

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Schematic of major processes in response to Asian AA emission increases

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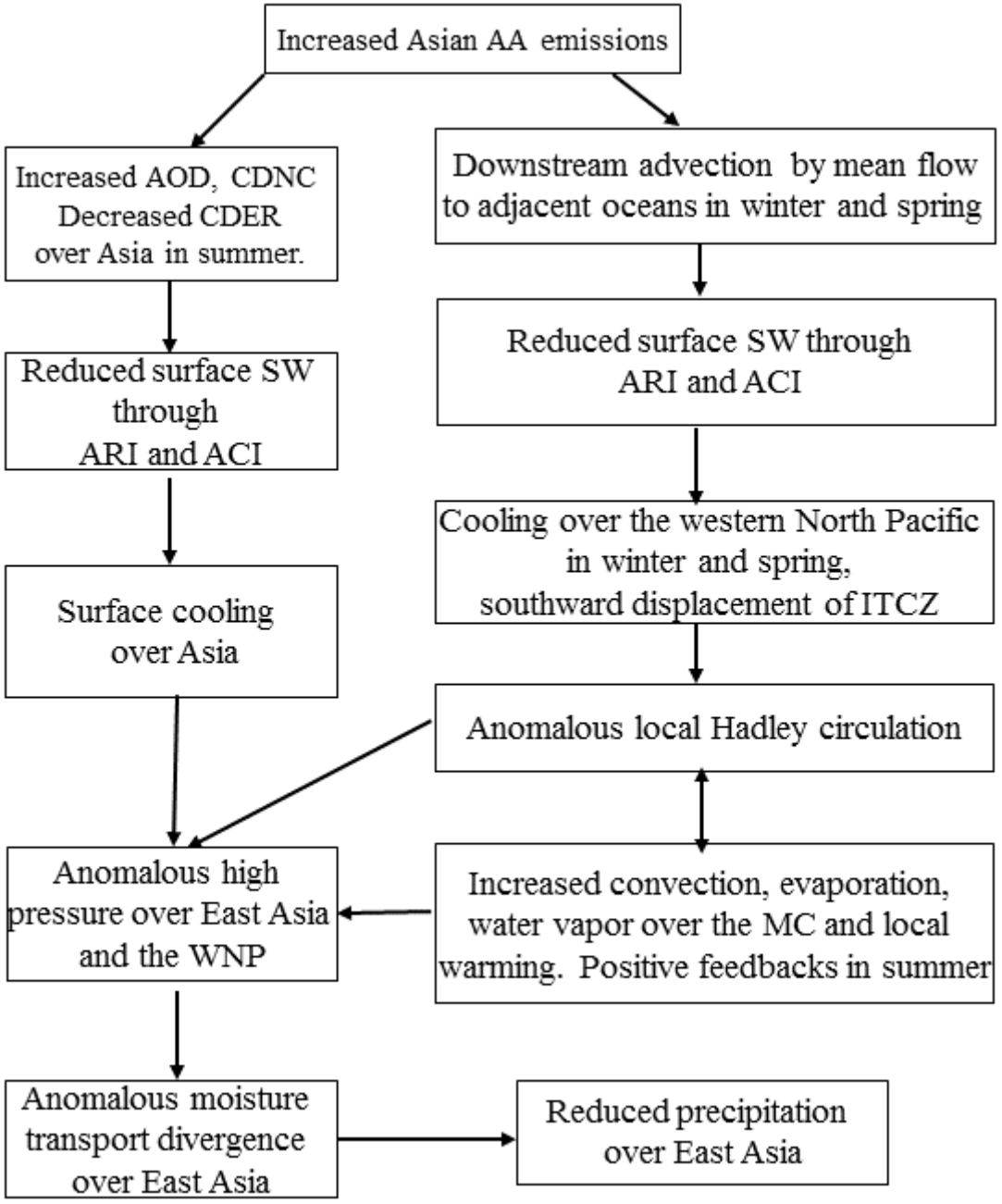

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Summary

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- **Increased AA emissions over Asia from 1970s to 2000s lead to decreased precipitation in boreal summer over East Asia, mainly resulted from anomalous moisture divergence related to anomalous circulation.**
- **The resulted changes in SSTs over the western Pacific in pre-monsoon seasons, including the western North Pacific (damped in summer by negative feedbacks) and the Maritime continent (amplified in summer by positive feedbacks) are important for changes in circulation in summer.**
- **With ARI only, SST responses over the MC and WNP are very weak. Weak changes in circulation and precipitation. This indicates a dominate role of ACI in shaping the total responses to Asian AA emission increases over adjacent ocean and land in East Asia.**
- **A sensitivity experiment with prescribed SST changes over the Maritime continent further supports that remote response of SSTs over the tropical western Pacific to Asian AA change plays a role in circulation and precipitation responses in boreal summer over East Asia.**

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