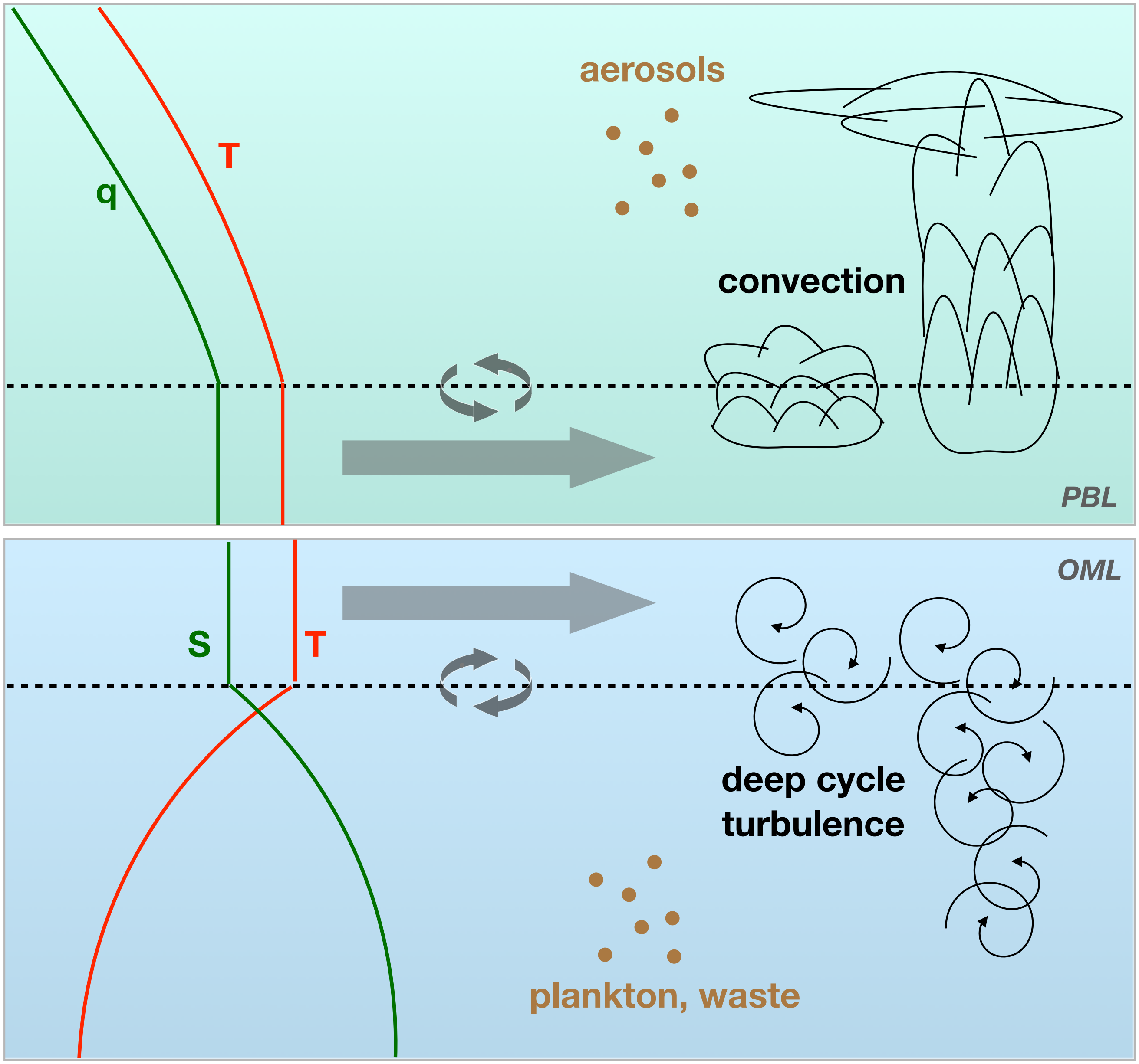
Challenging physics in seamless forecasts: Air-sea interactions in the tropics

Charlotte A. DeMott
Colorado State University

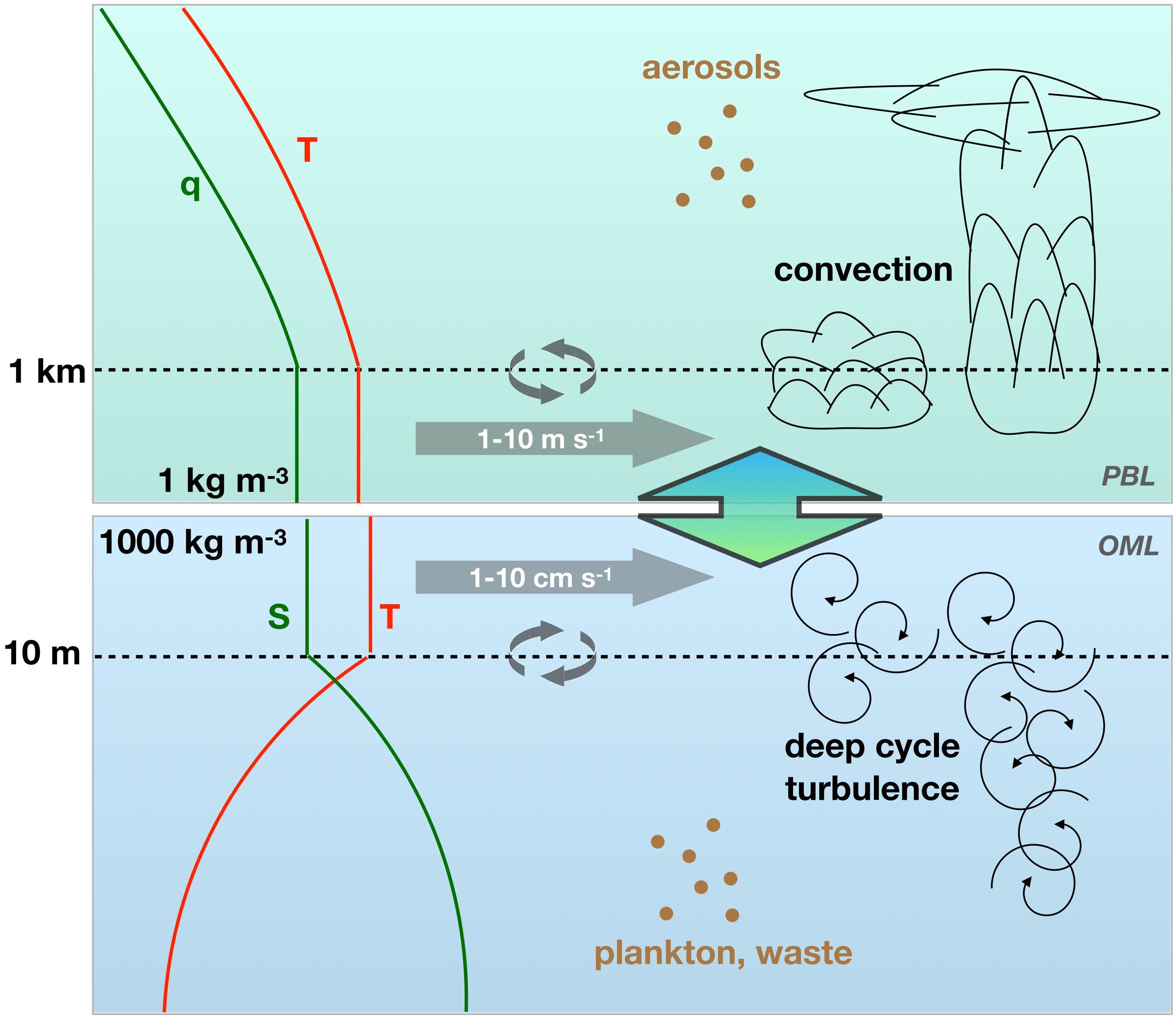
ECMWF Annual Seminar, 12-16 September 2022, Reading, UK

overview

ocean-atmosphere similarities



ocean-atmosphere differences



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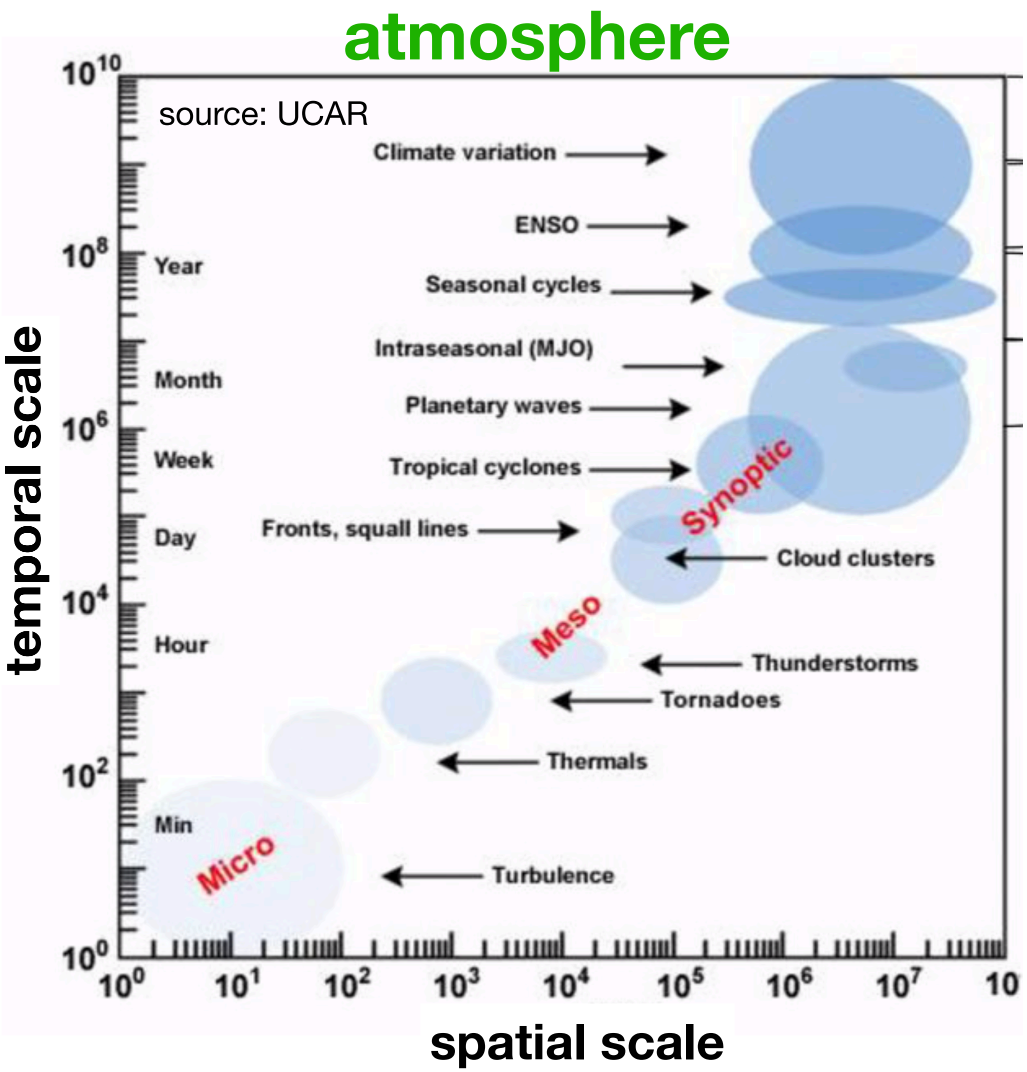
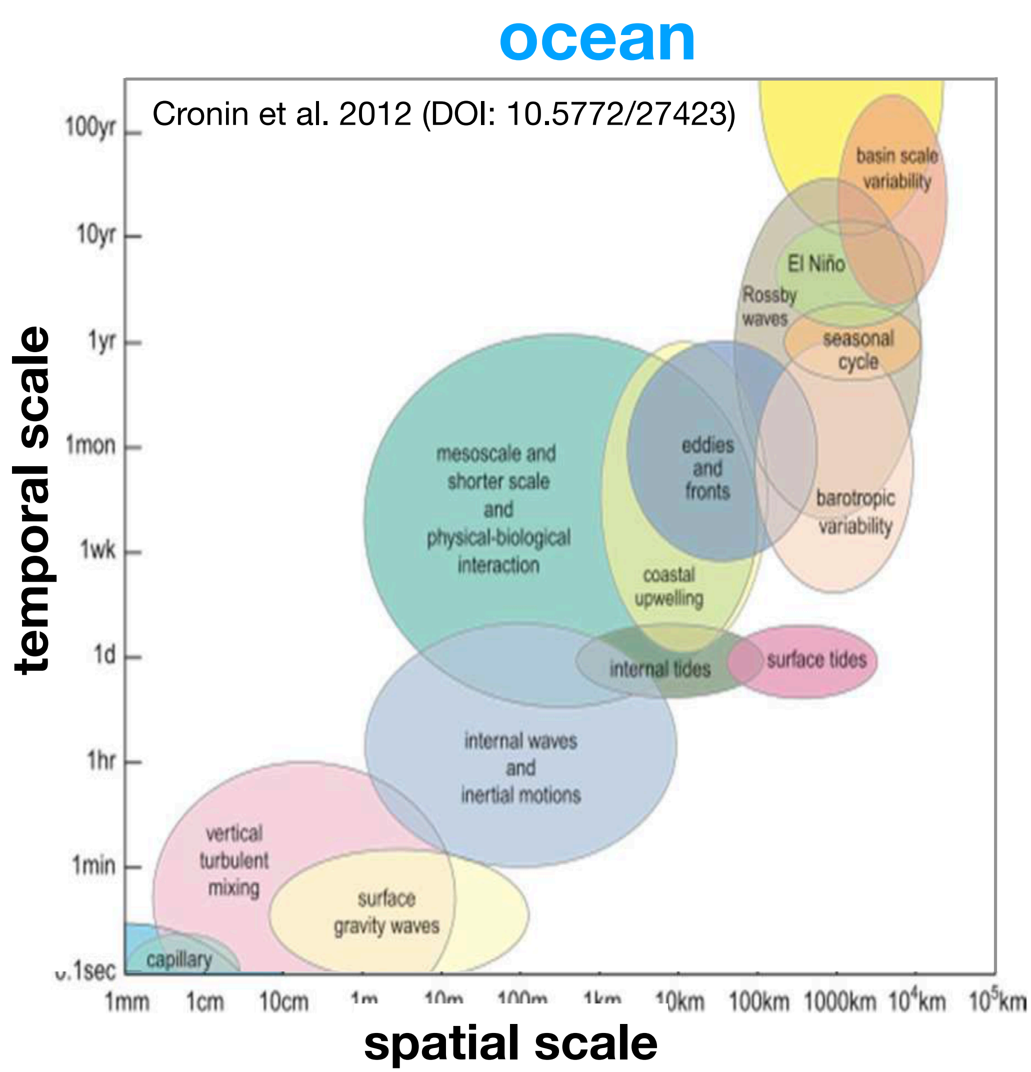
- ML depth: $\delta \sim 10^2$
- *u,v*: $\delta \sim 10^2$
- clouds are global; DCT mostly on Equator
- clouds regulate radiation; DCT does not

O-A density differences are responsible for different adjustment timescales

surface fluxes are the result of O-A constantly trying to equilibrate

Scales of variability: atmosphere & ocean





Each process is a link in a long chain

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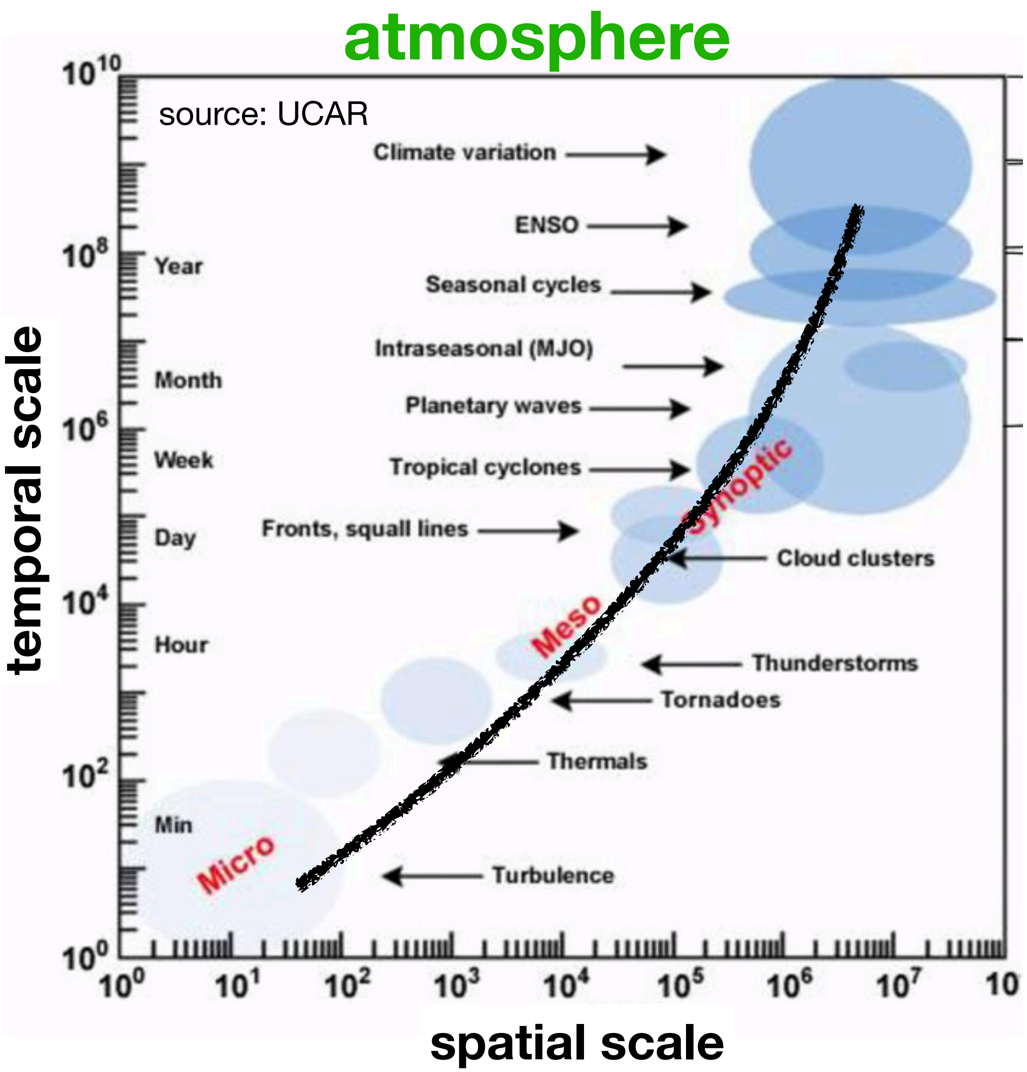

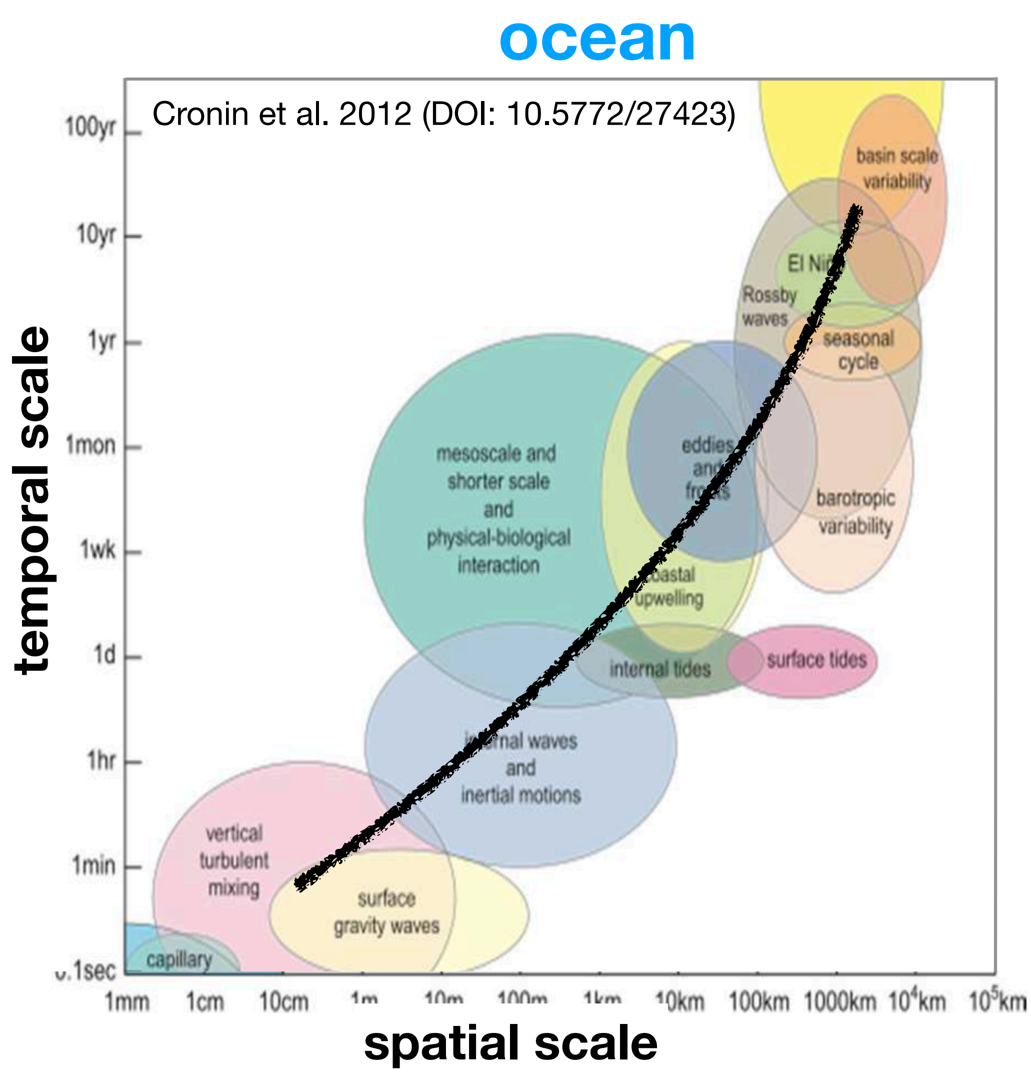

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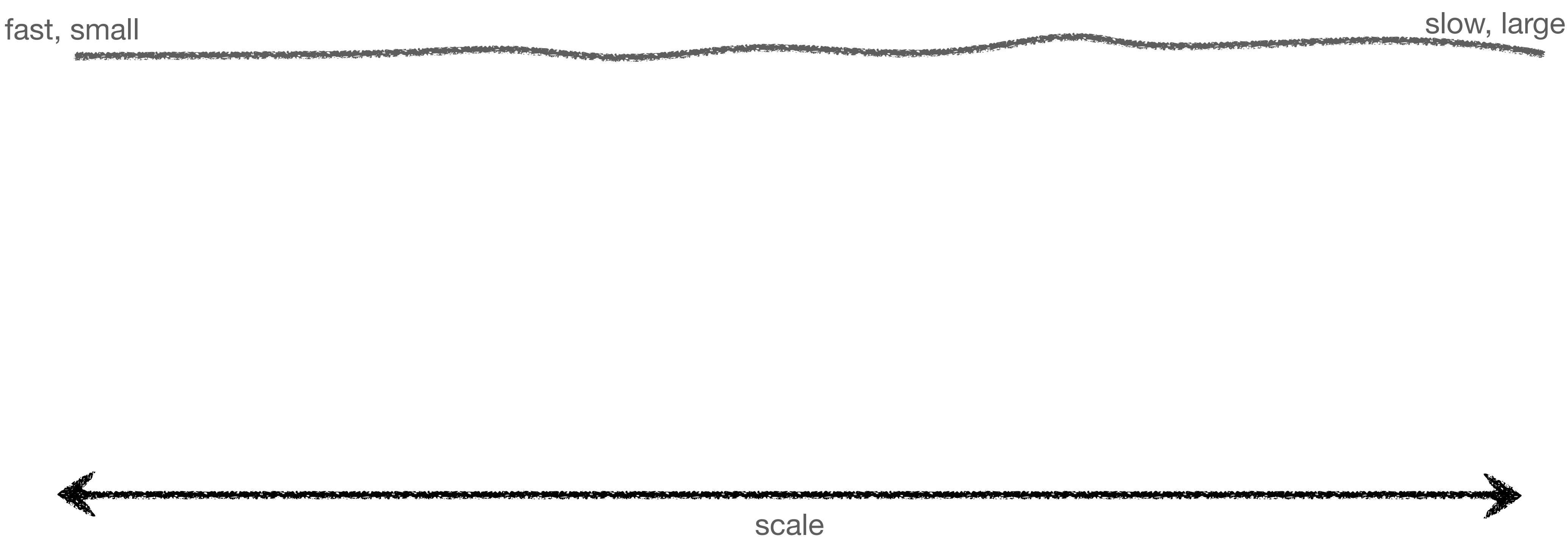
coupled cross-scale interactions



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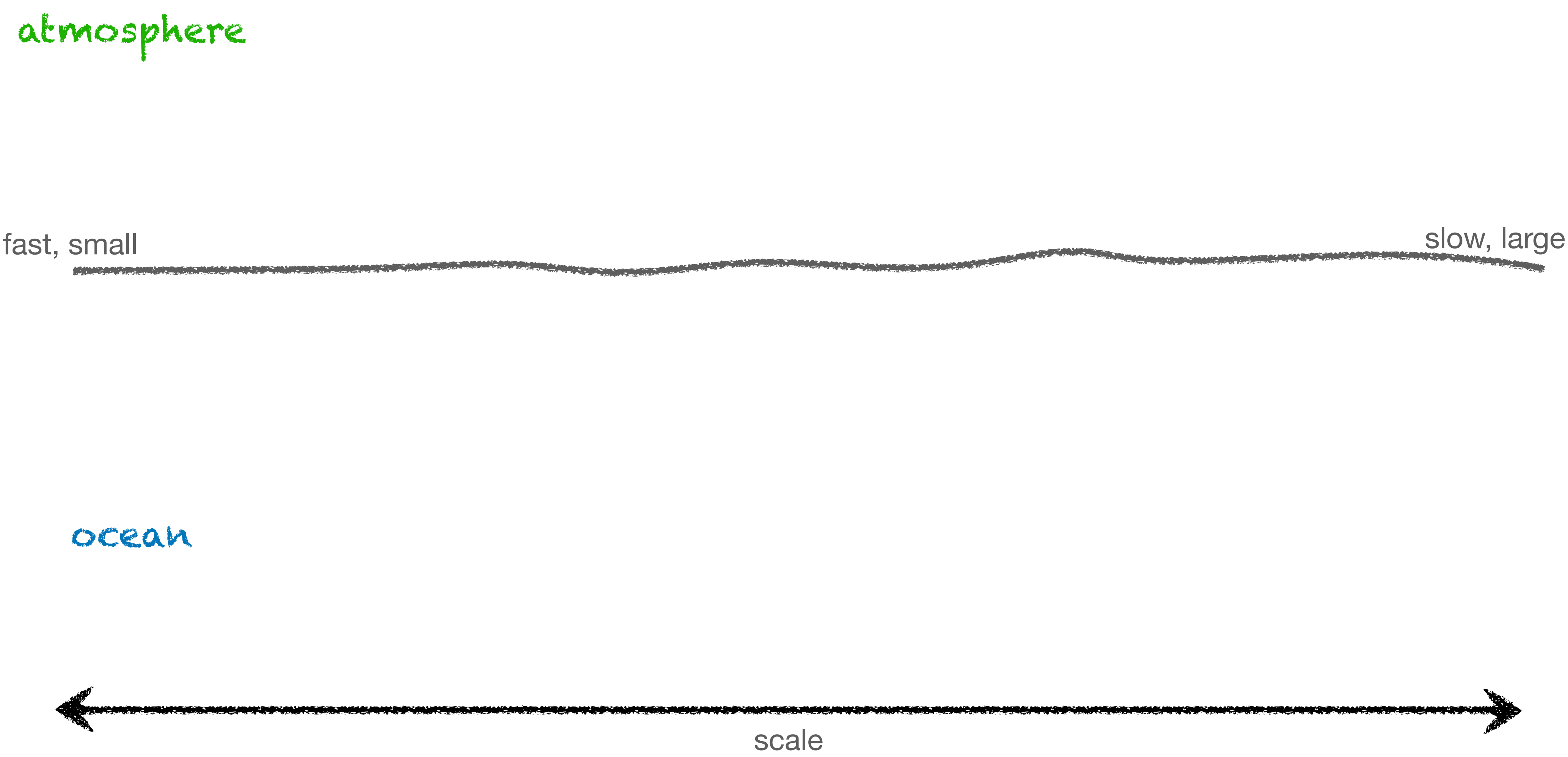

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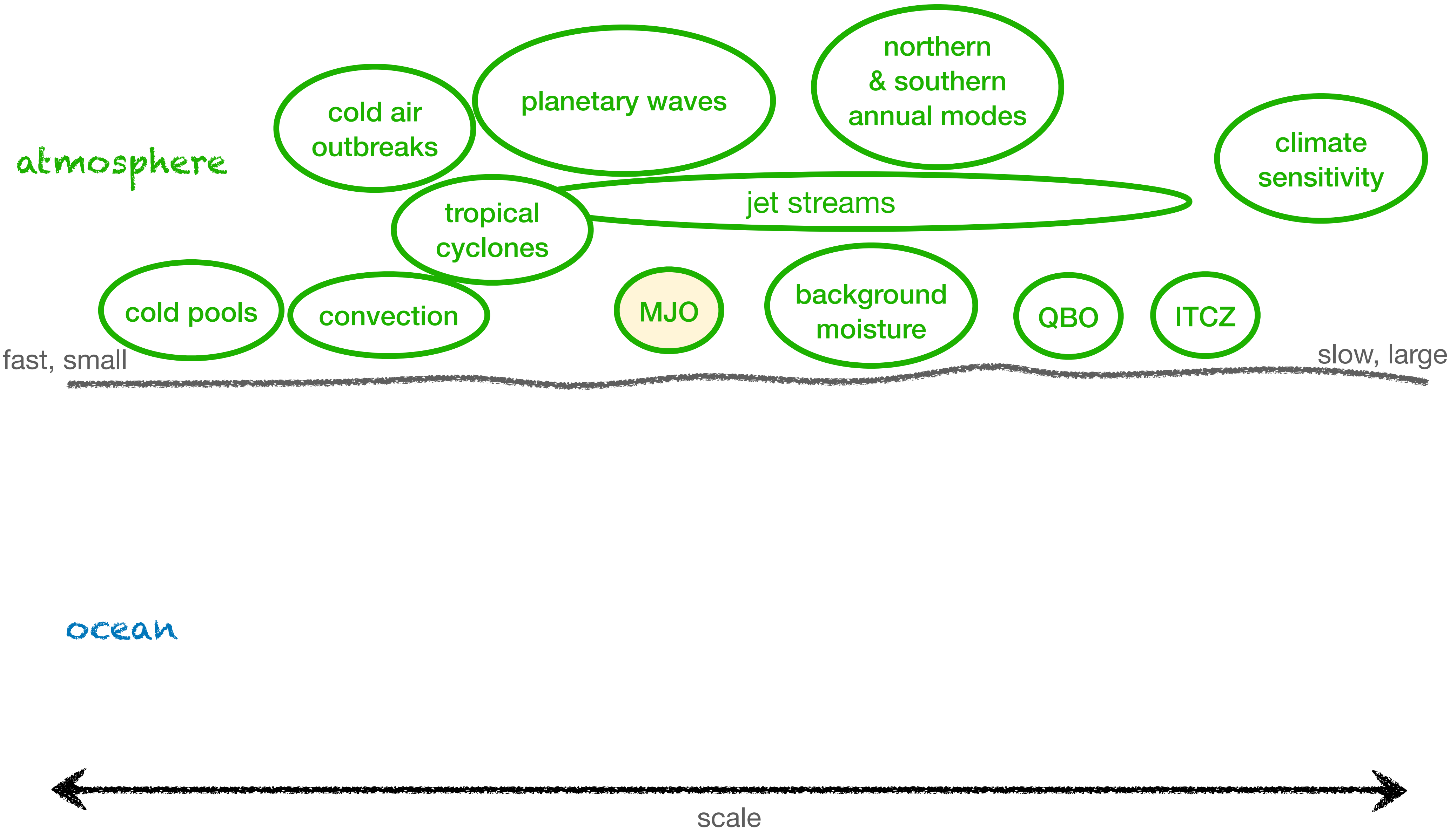

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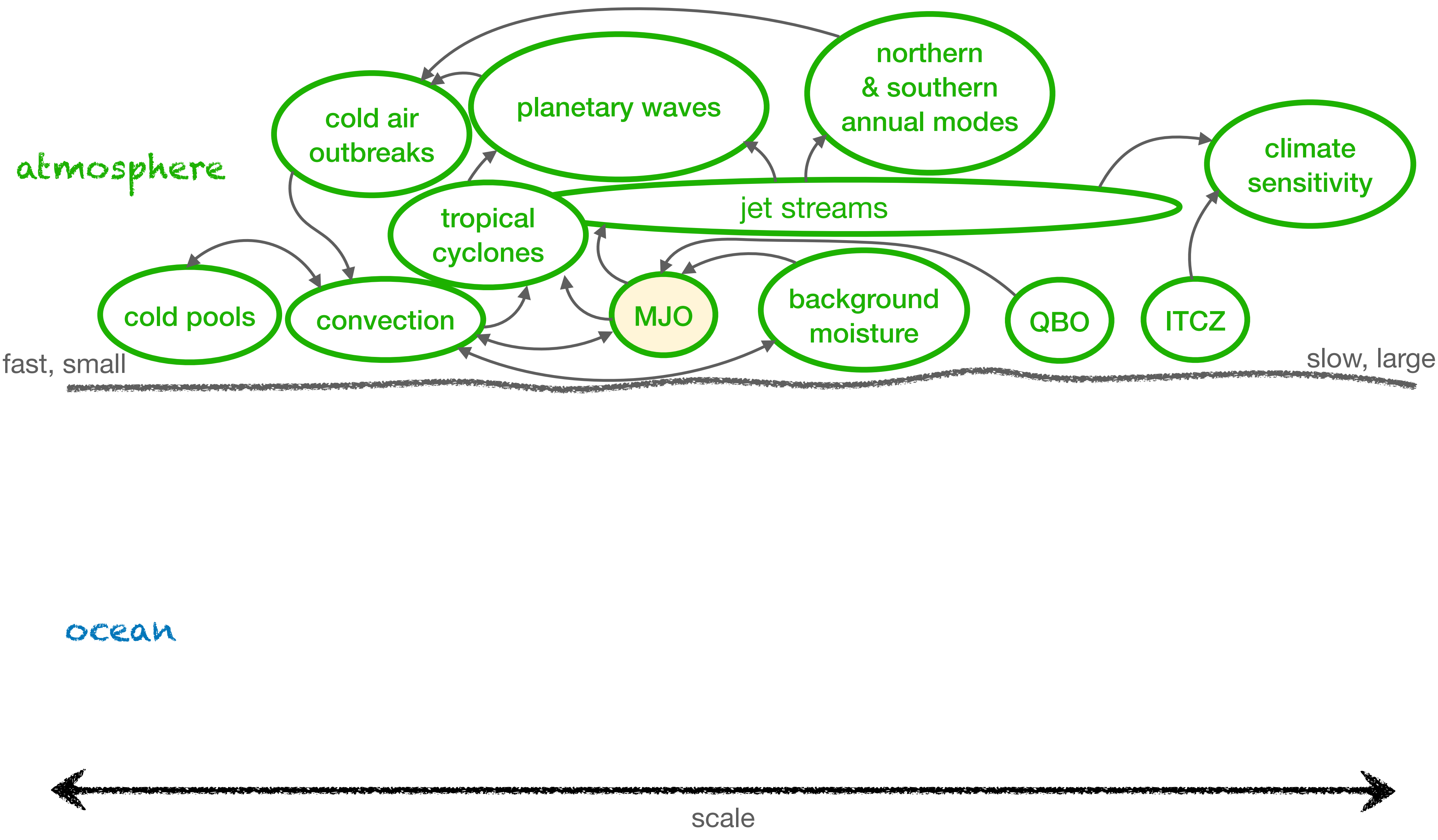

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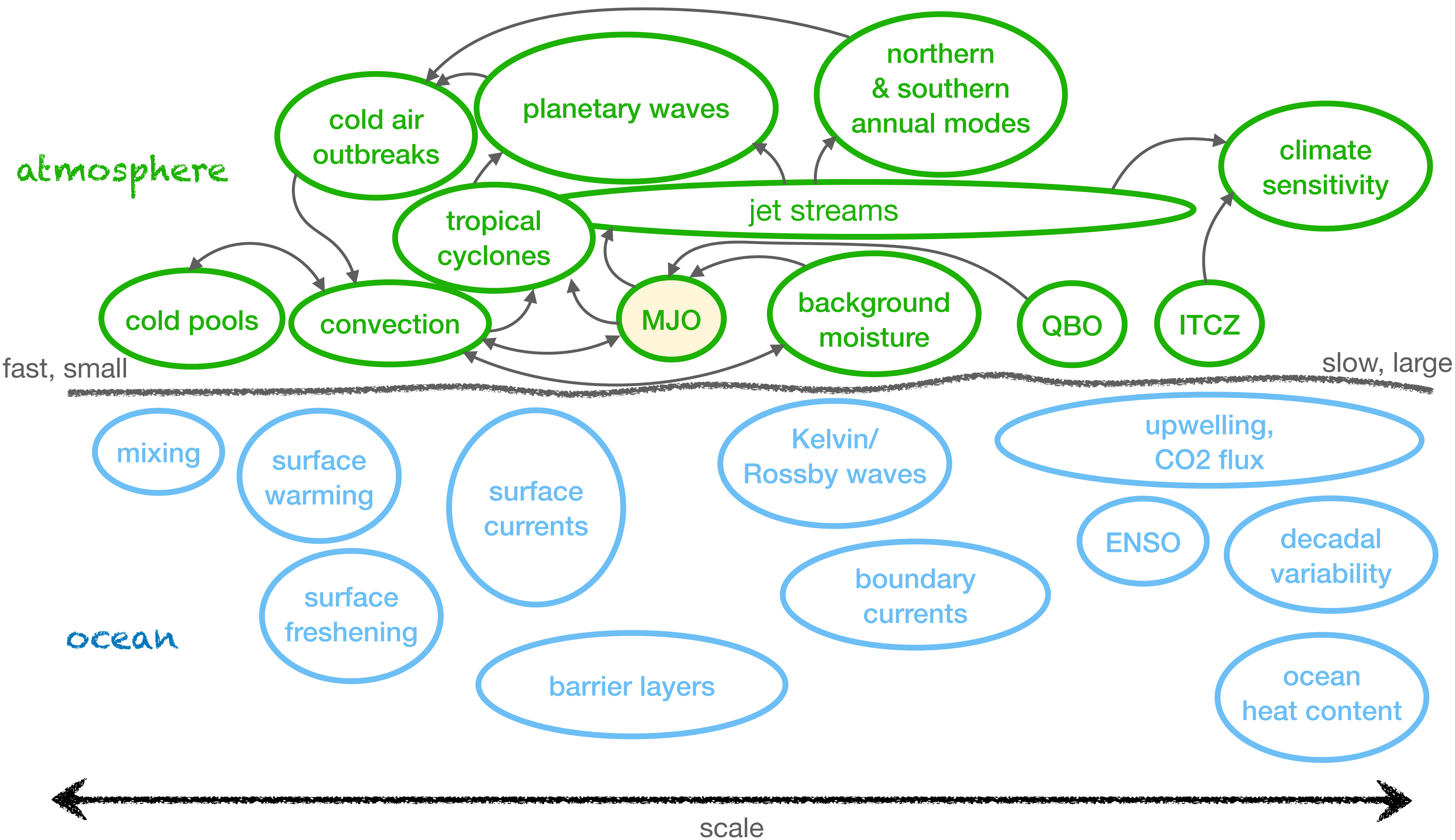

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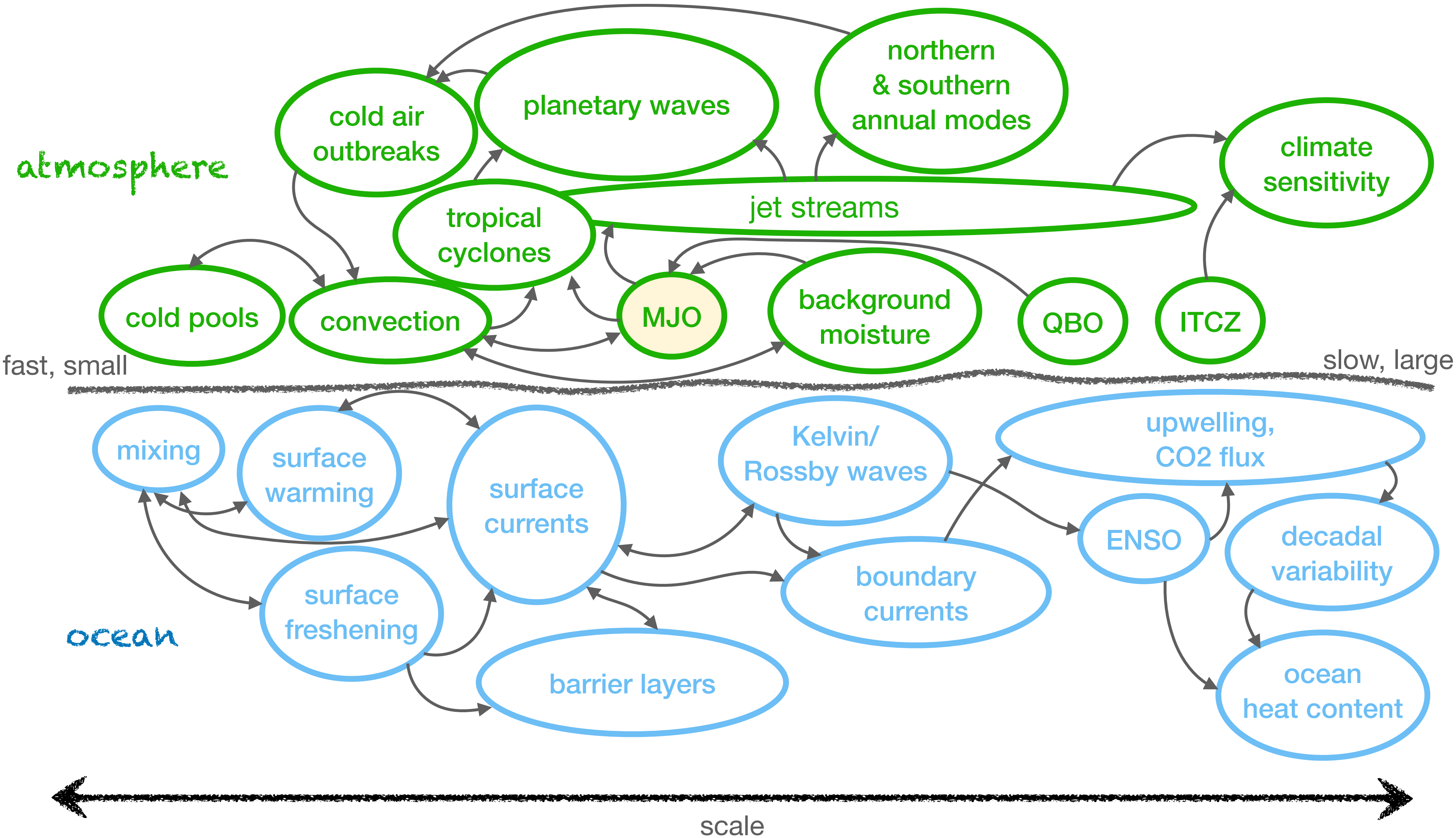

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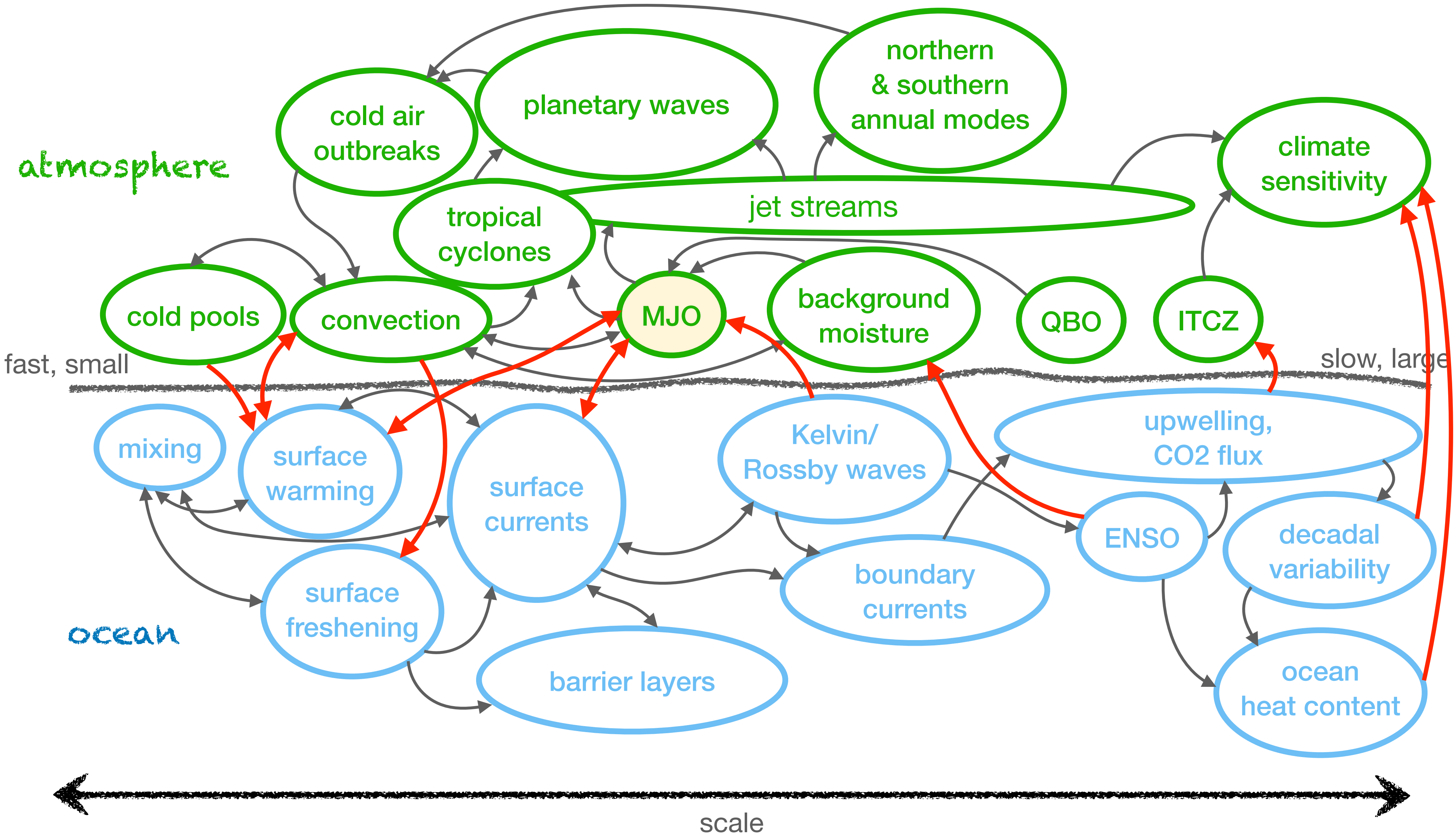
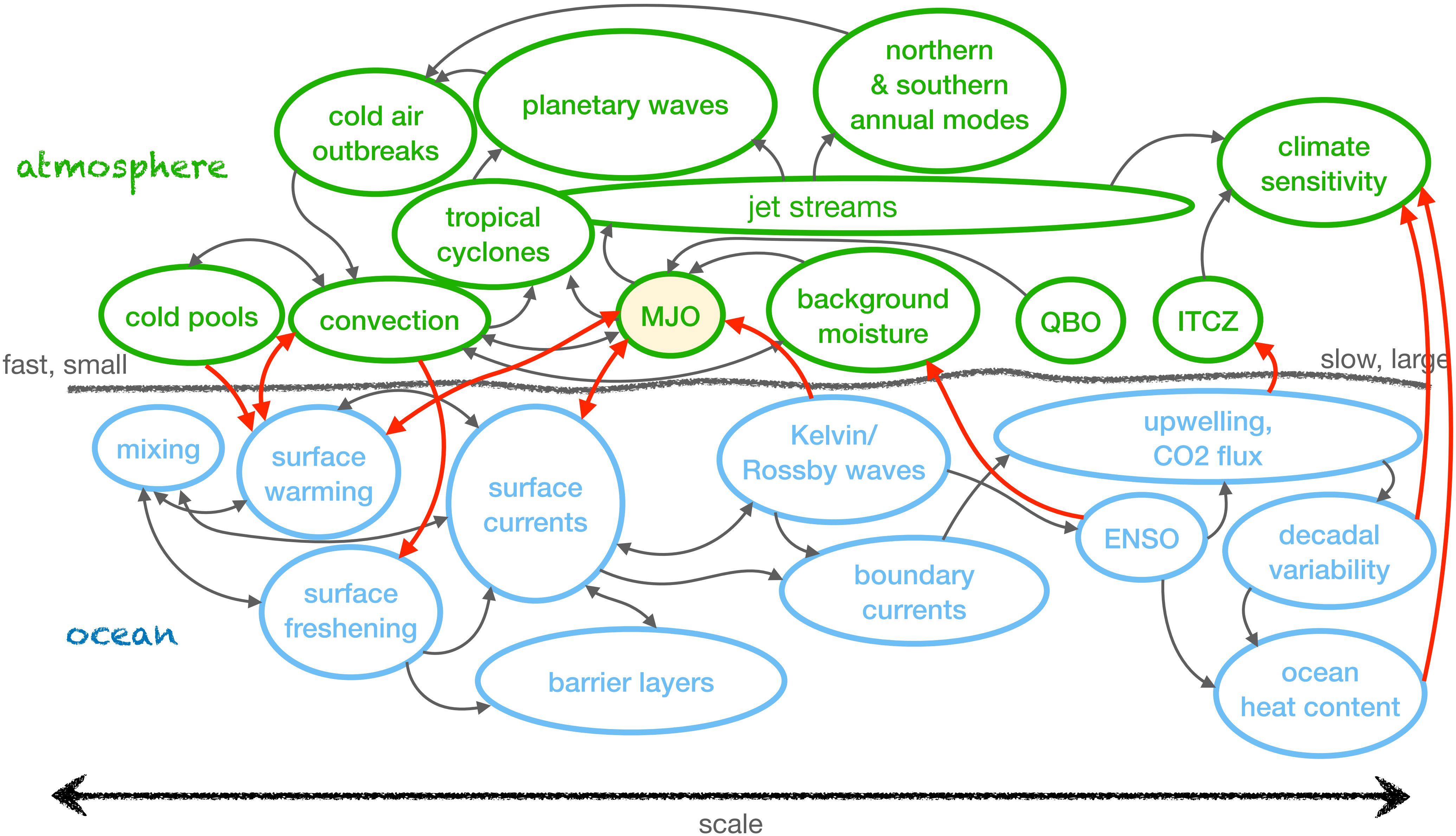


coupled cross-scale interactions

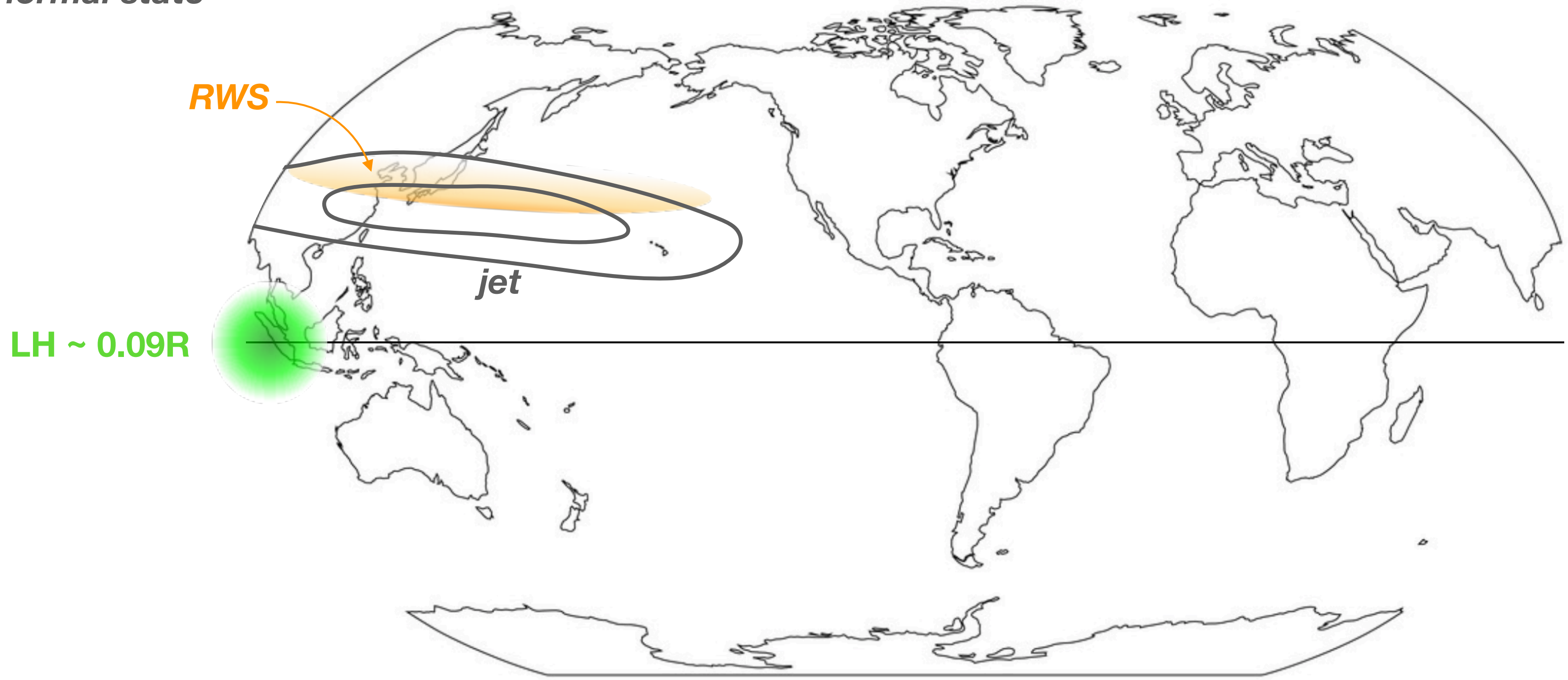
coupling is regulated by fluxes of heat, water, and momentum



coupled feedbacks in weather & climate simulation

Example: MJO teleconnections

normal state



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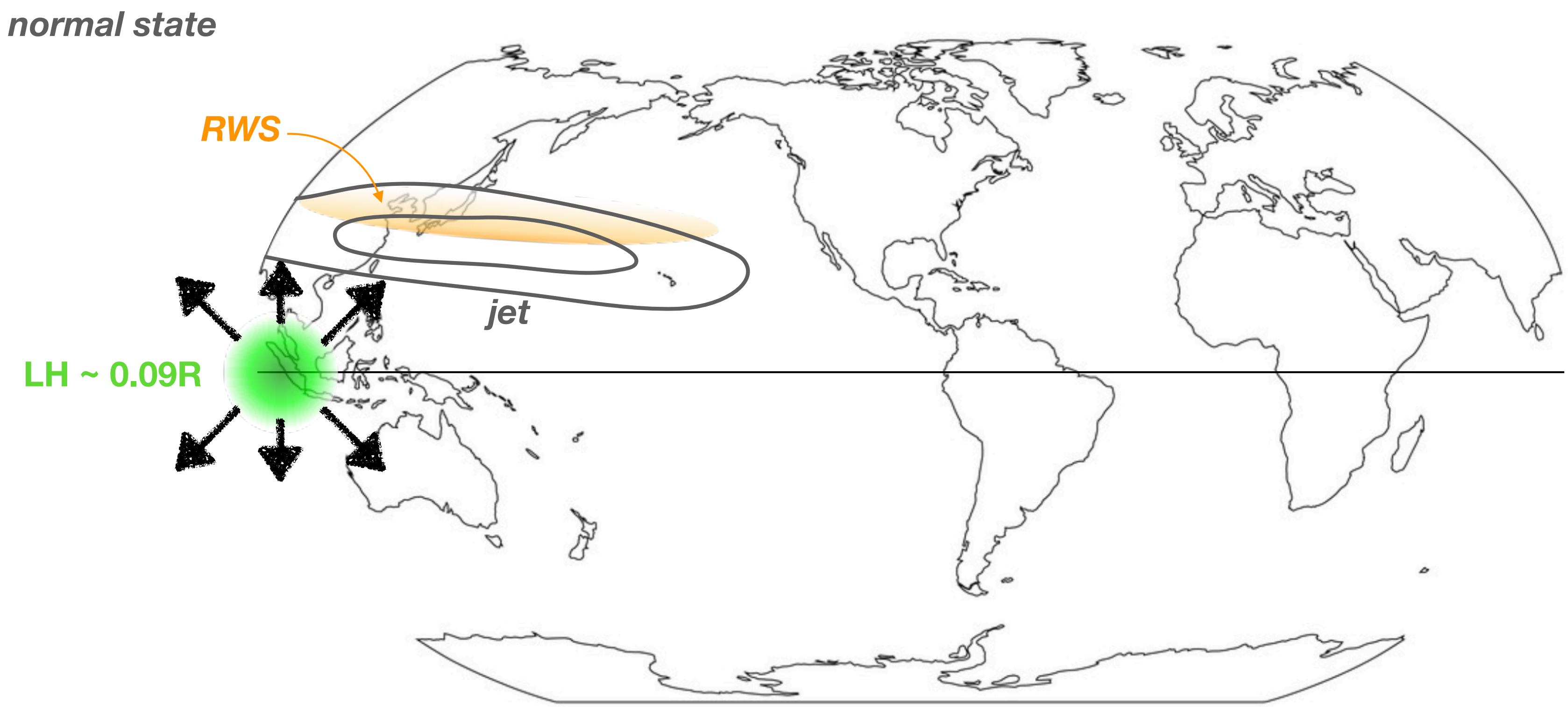

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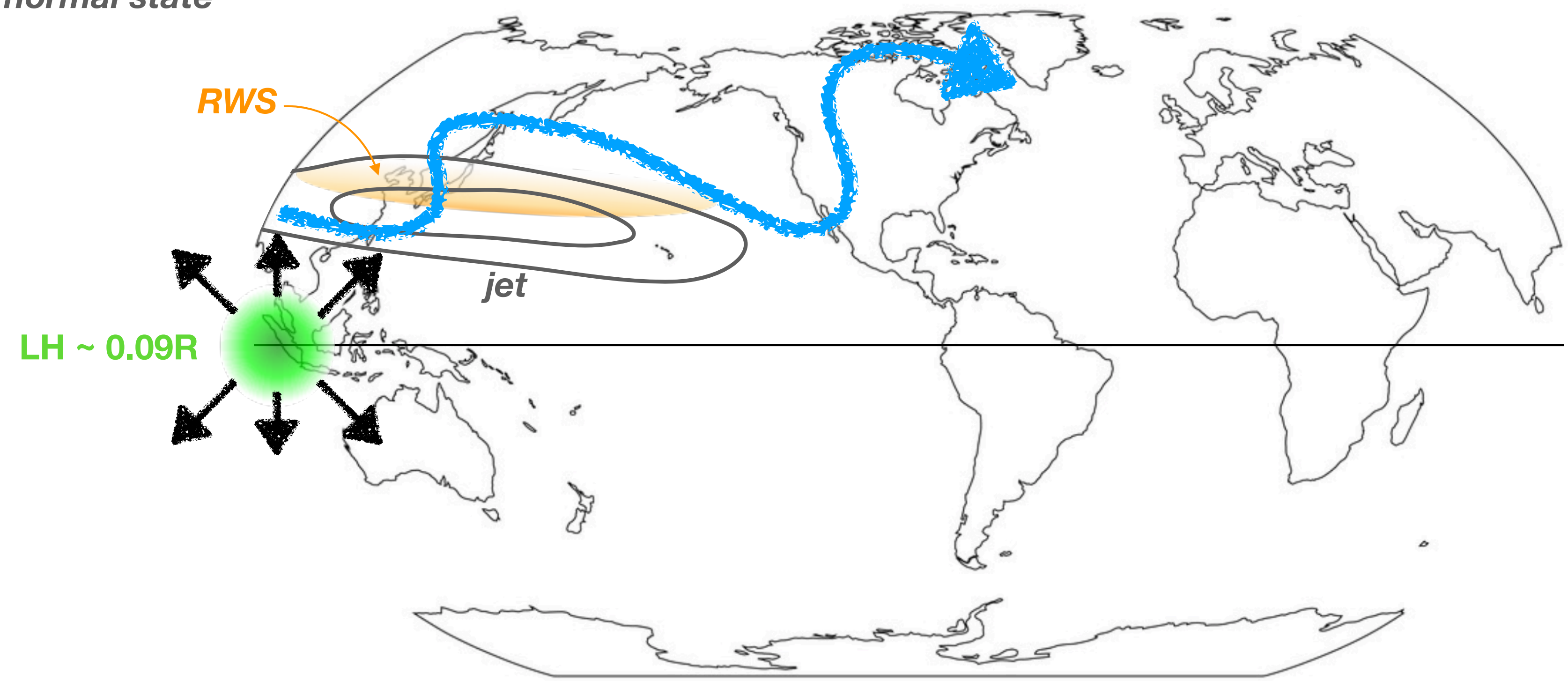

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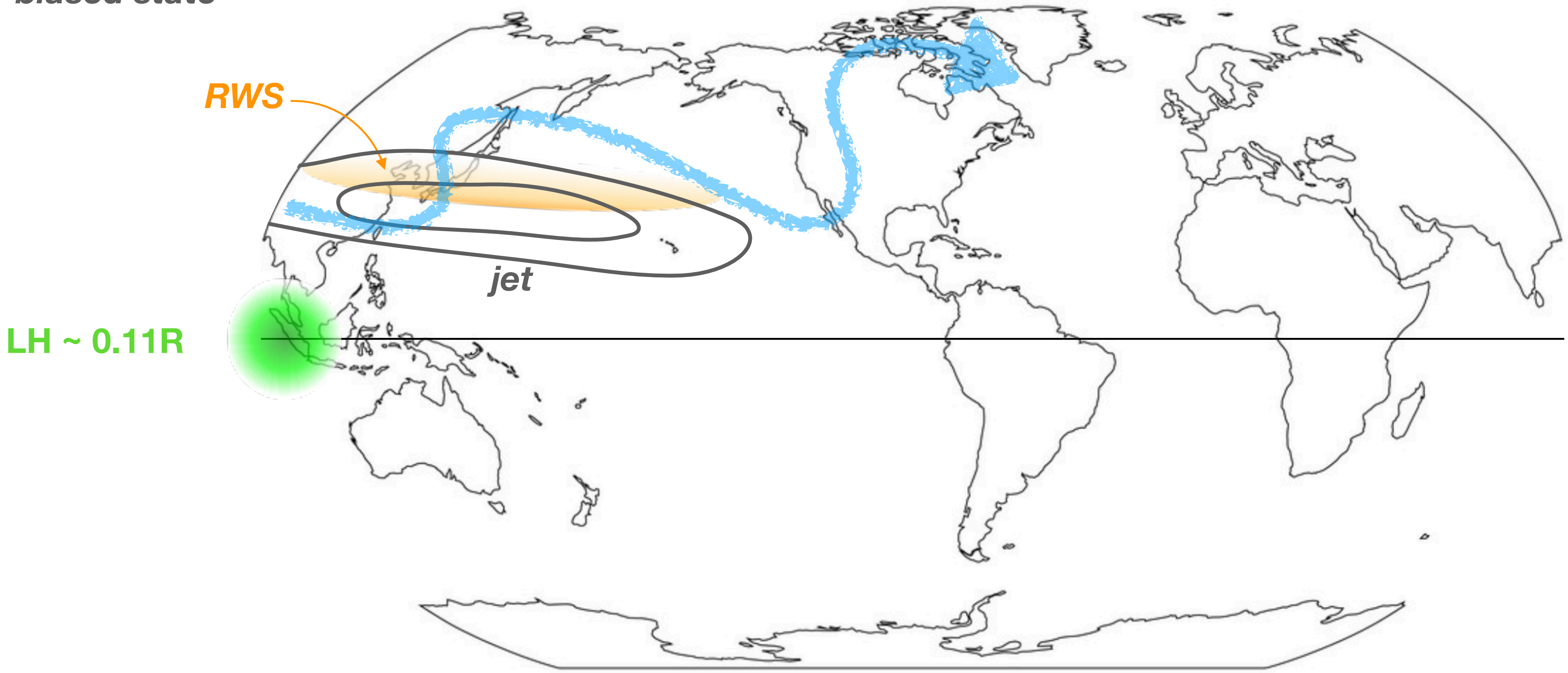

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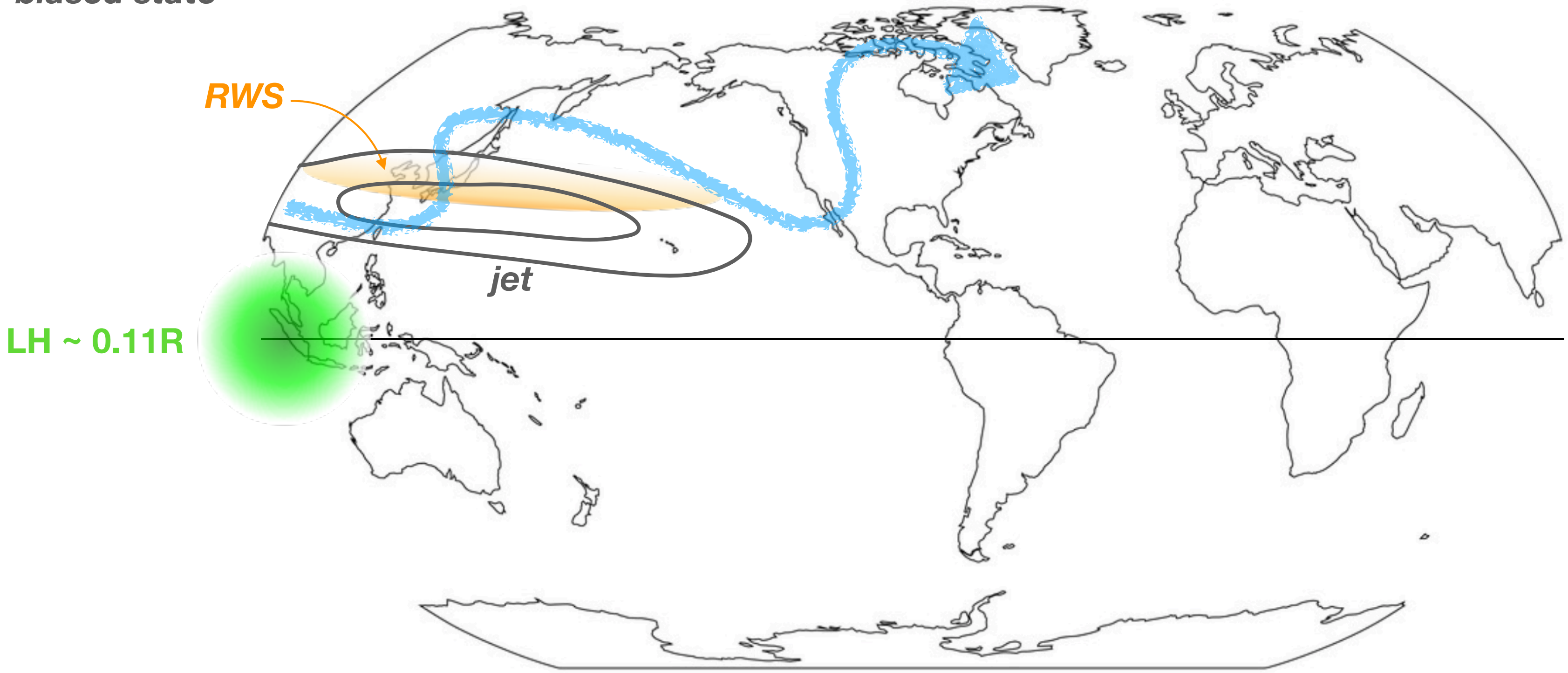

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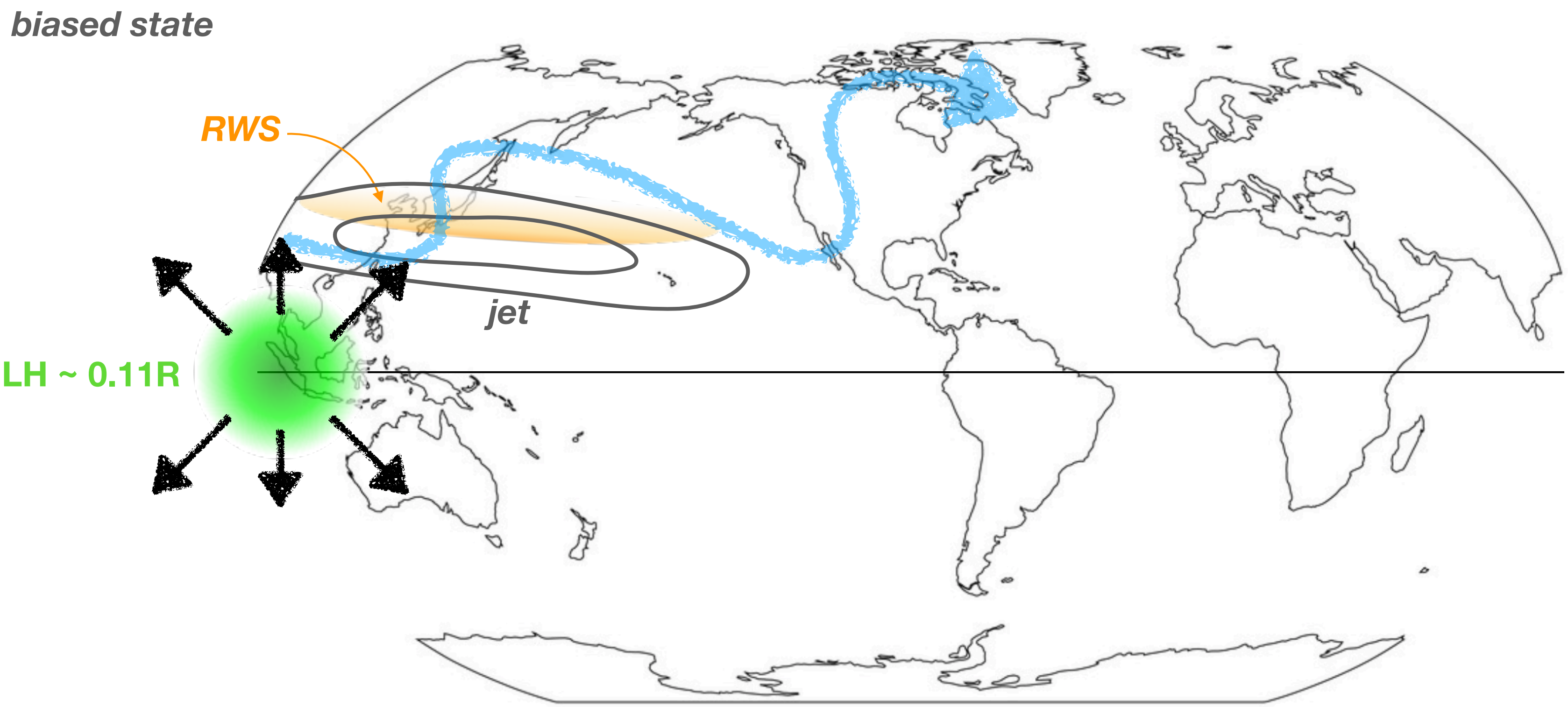

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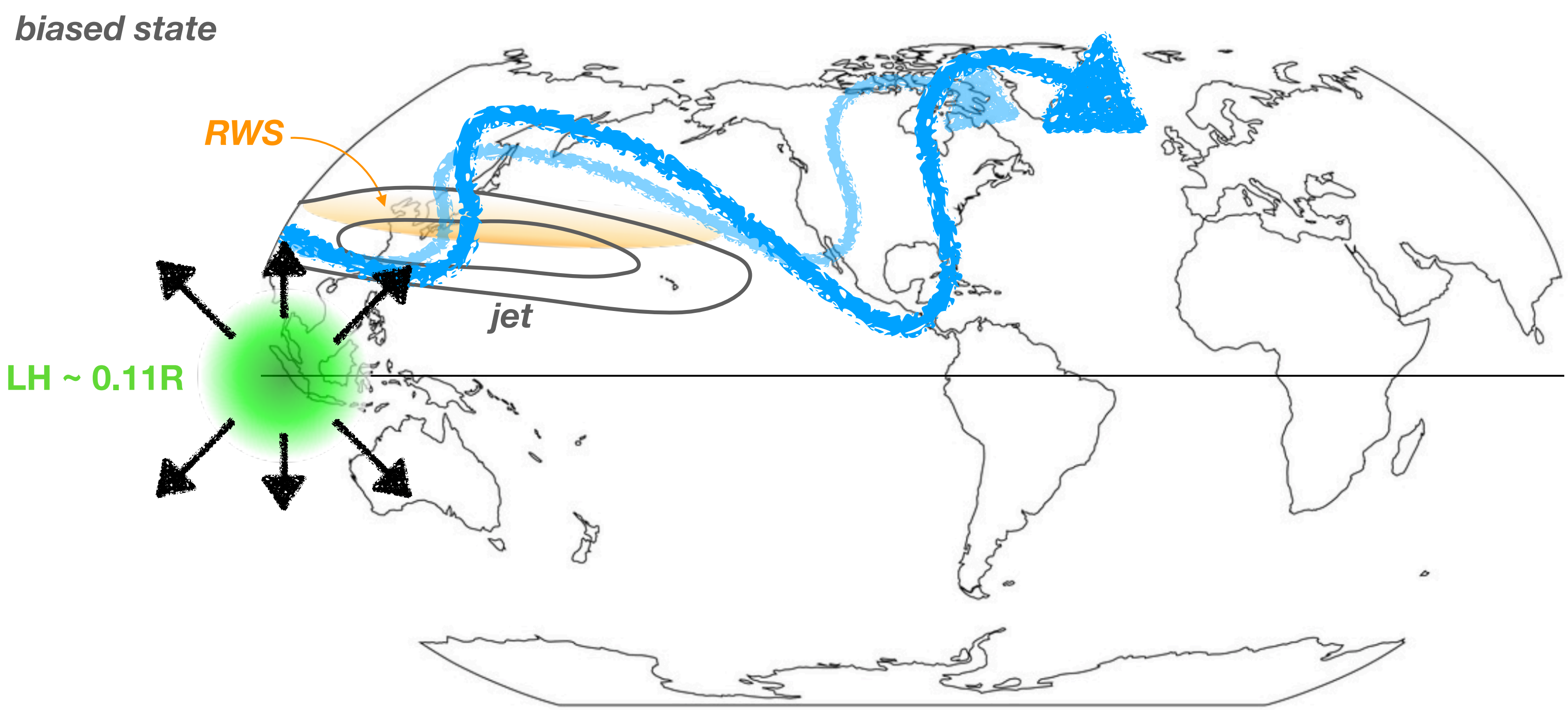

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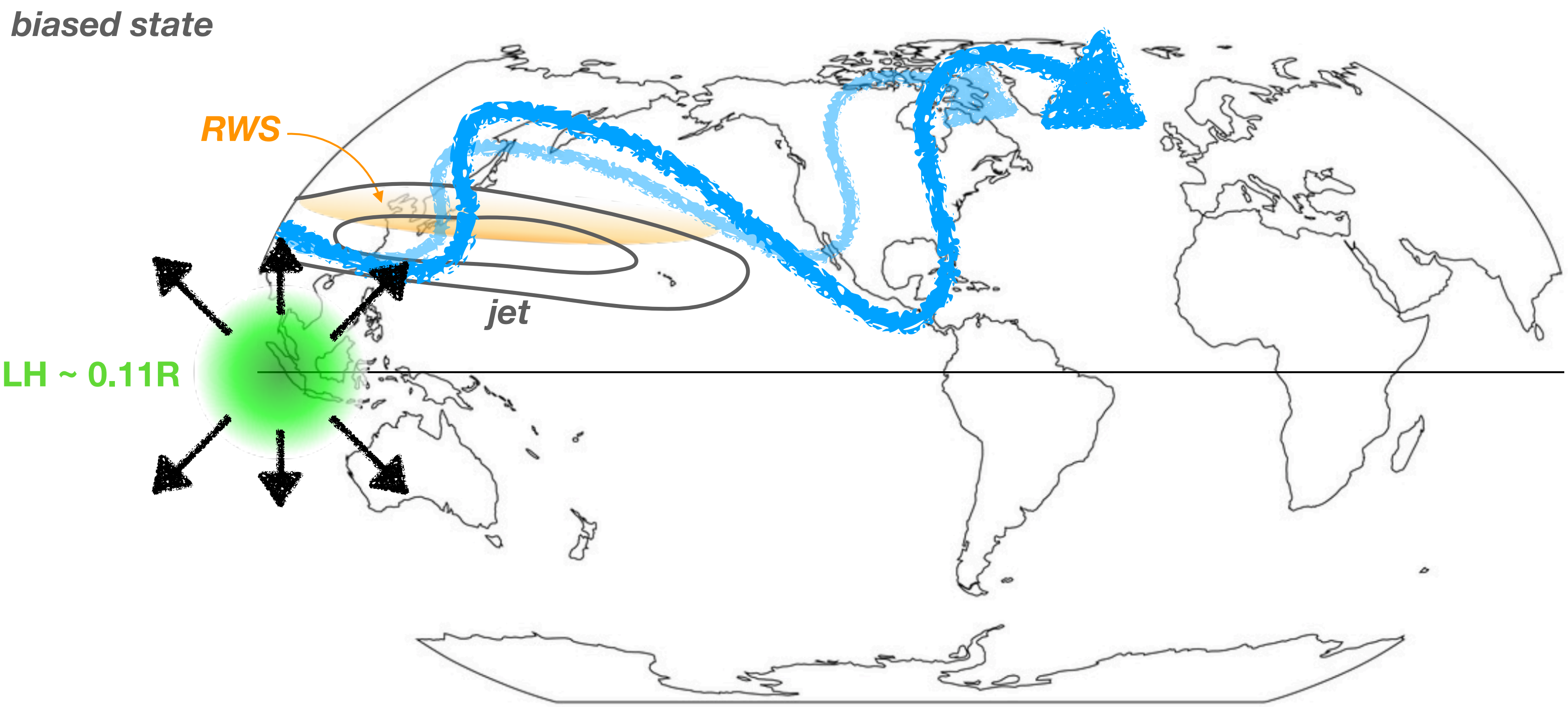

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- MJO amplitude biases -> jet stream biases

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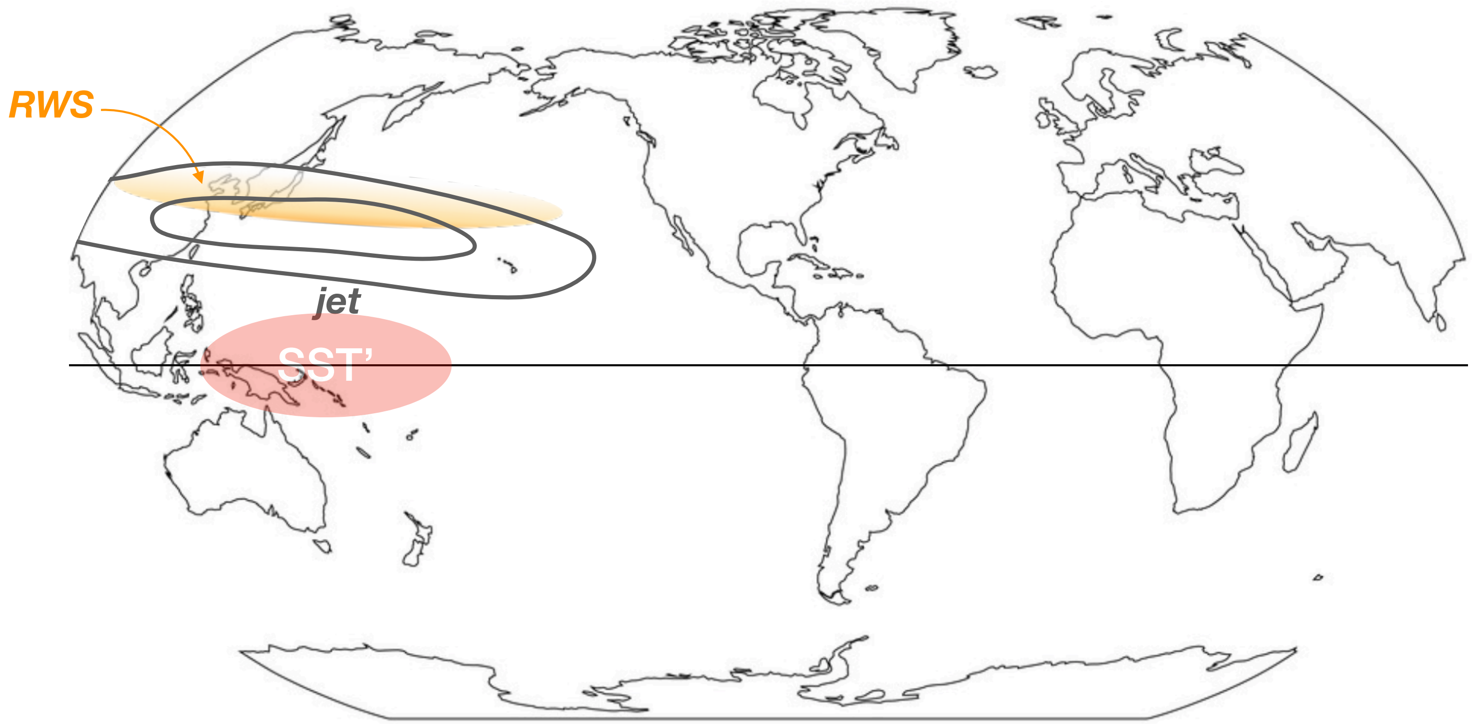

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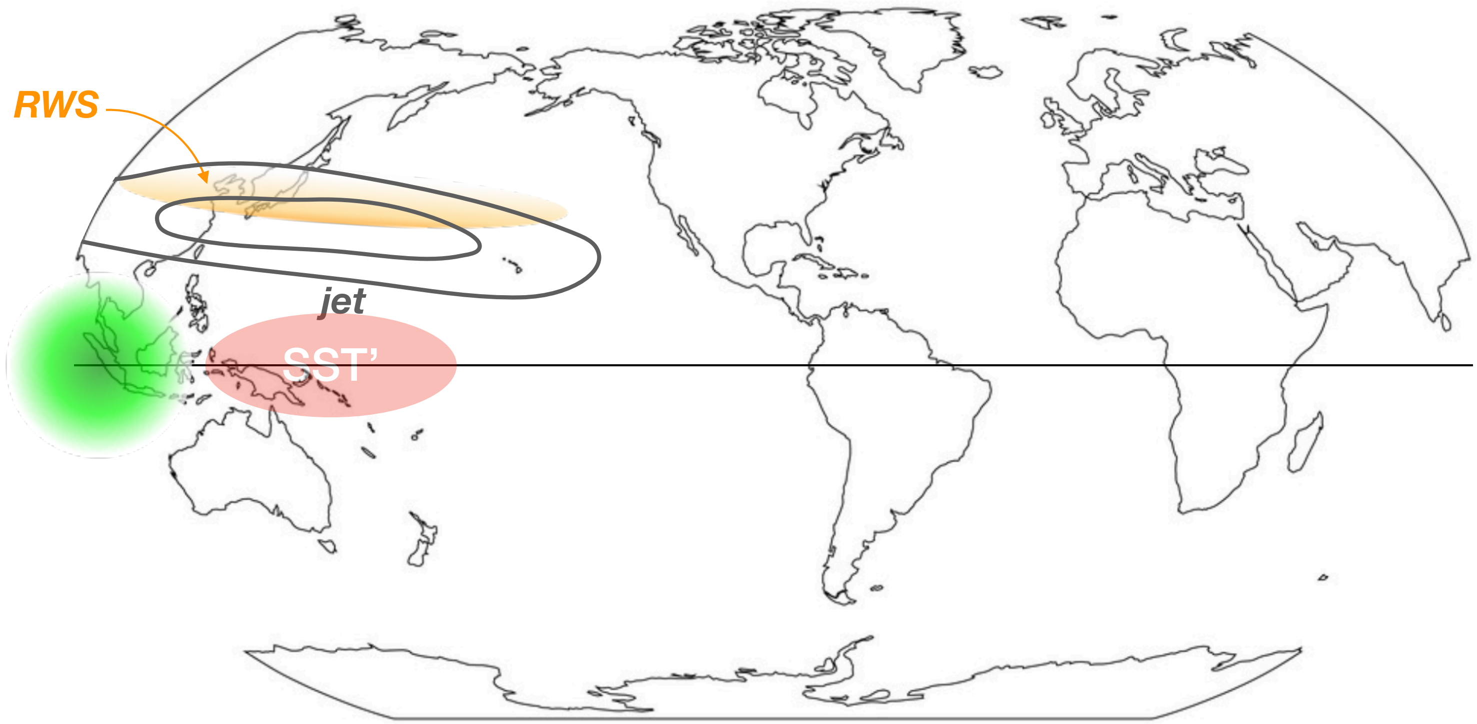

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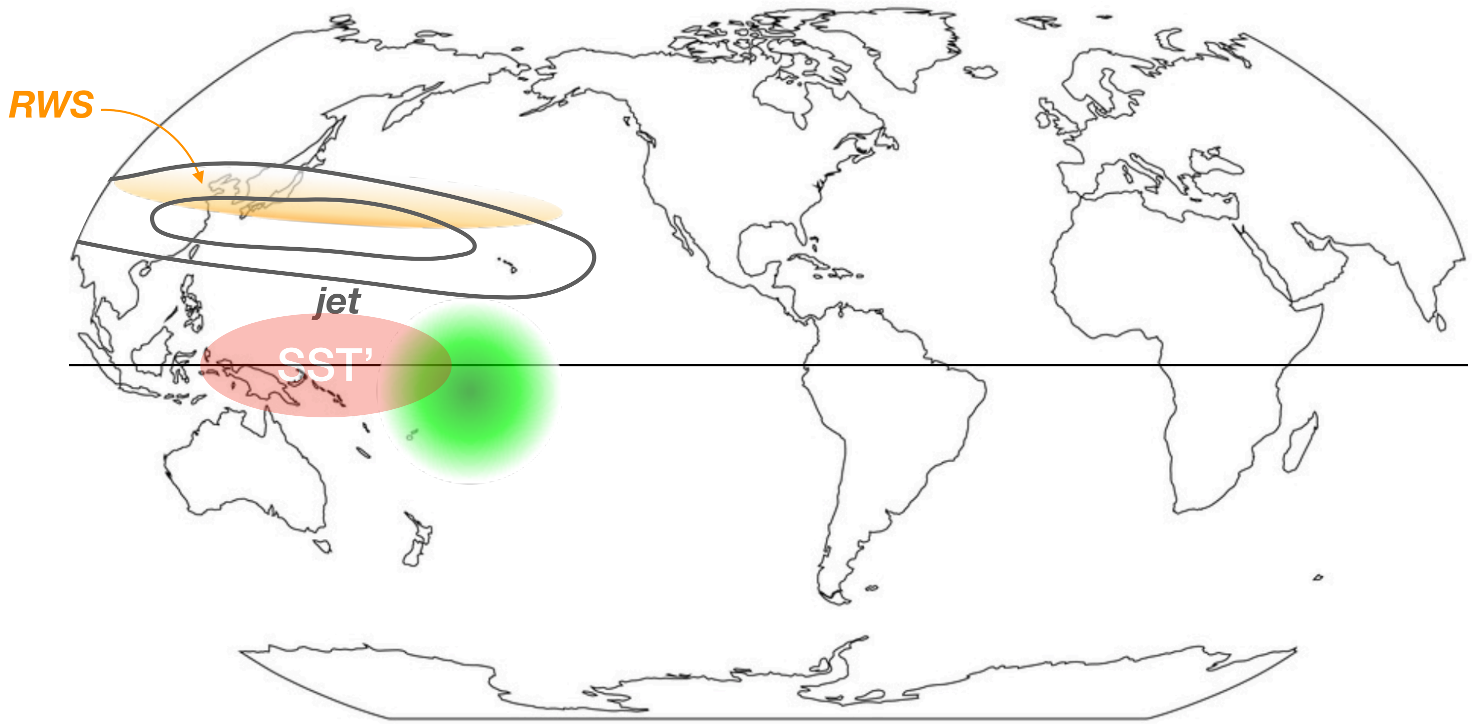

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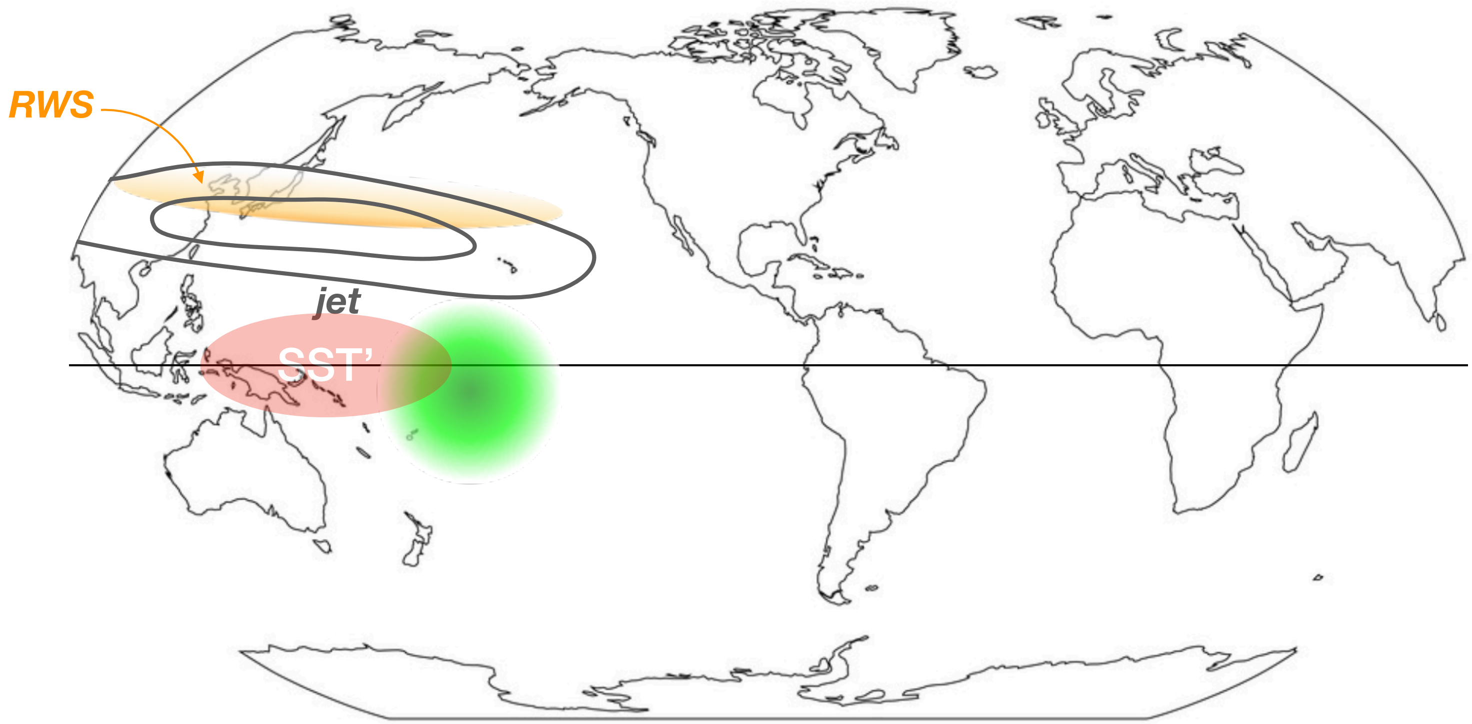

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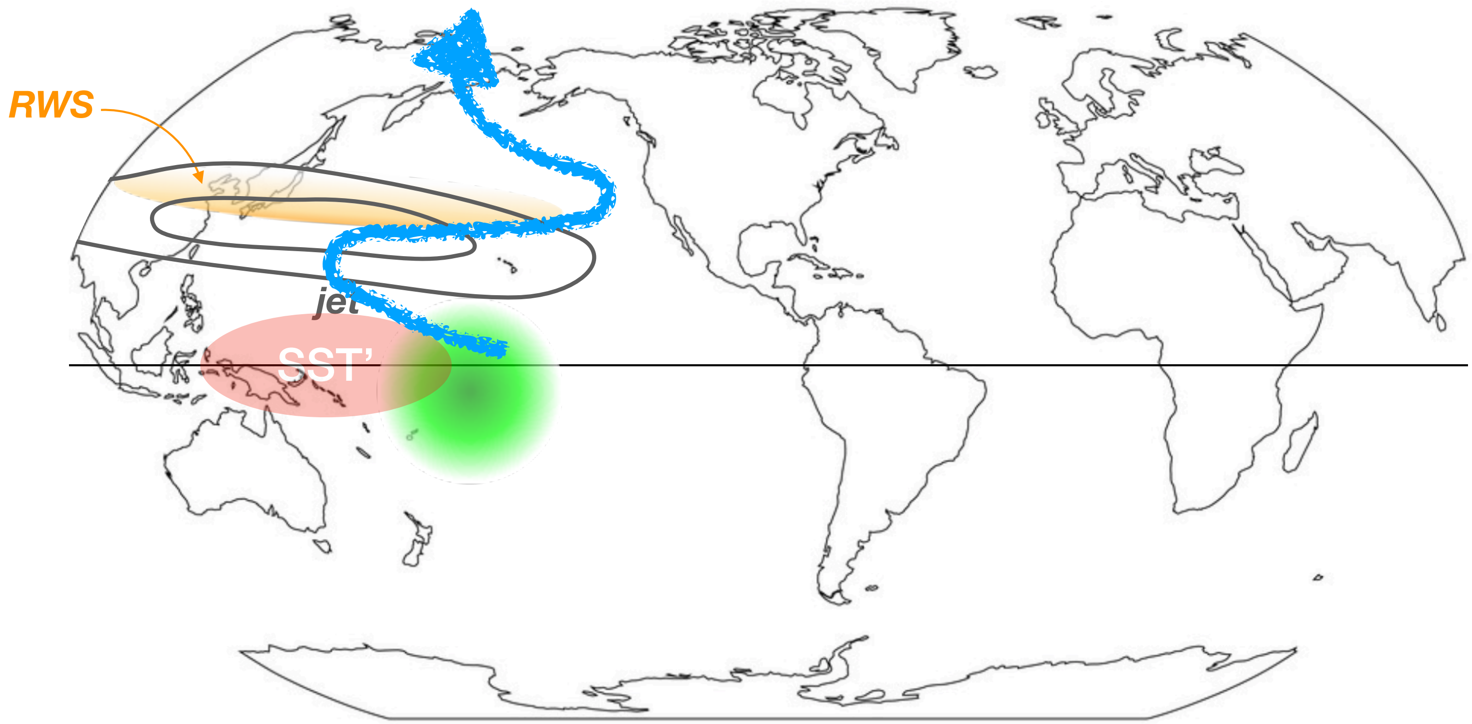

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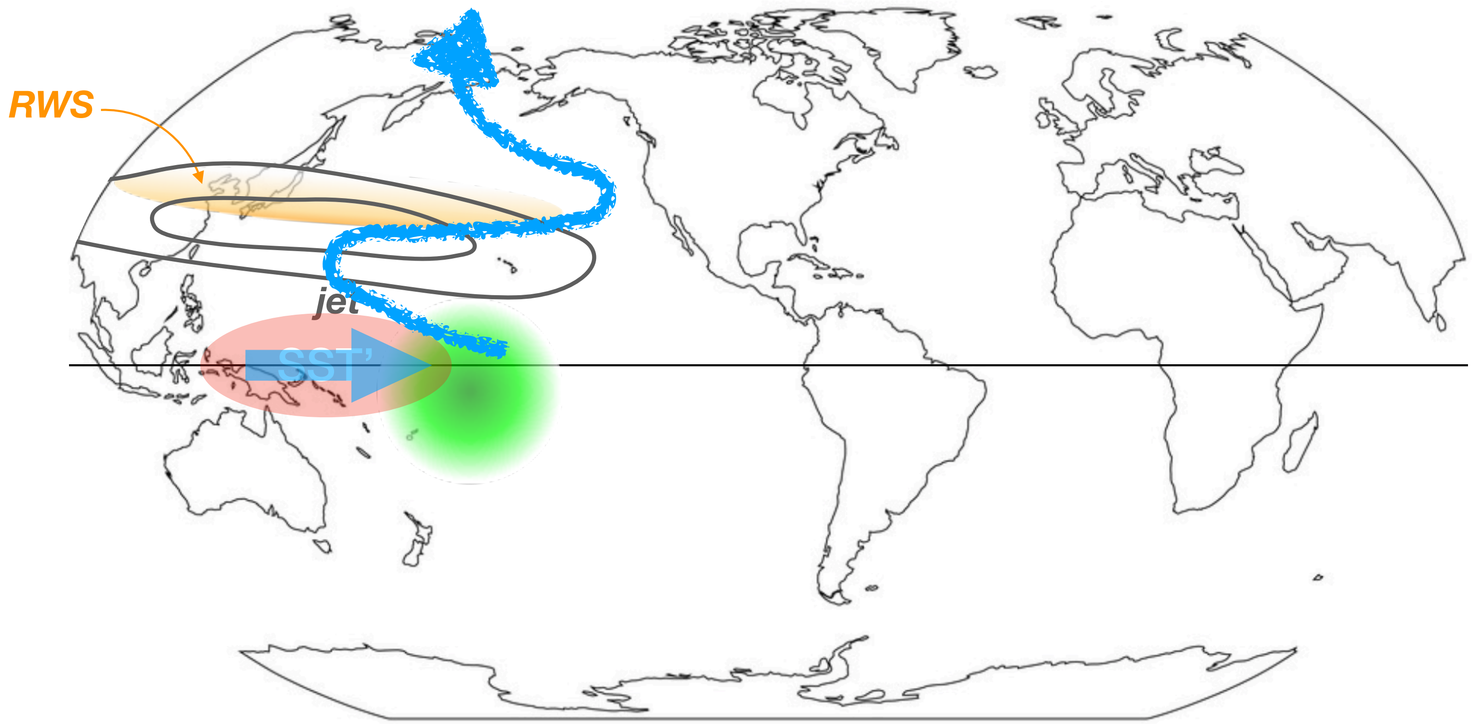

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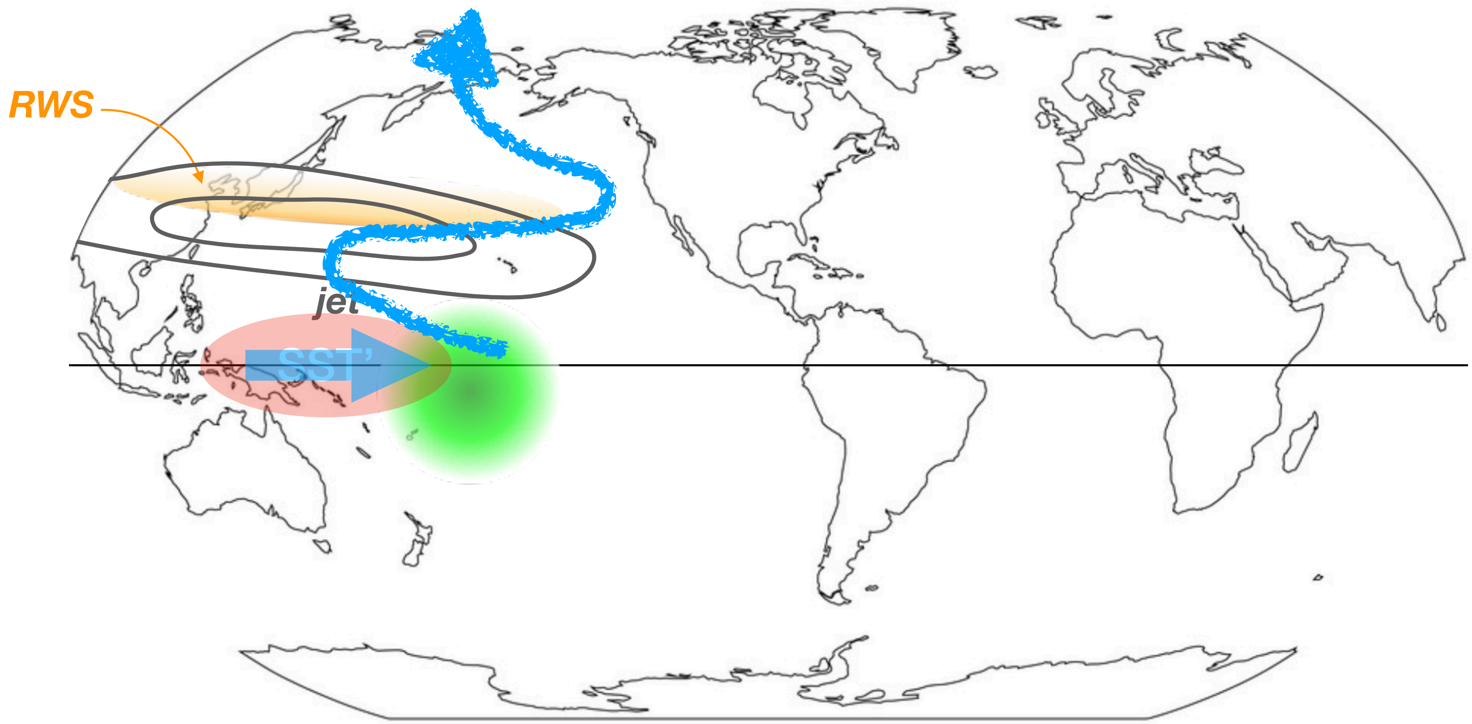

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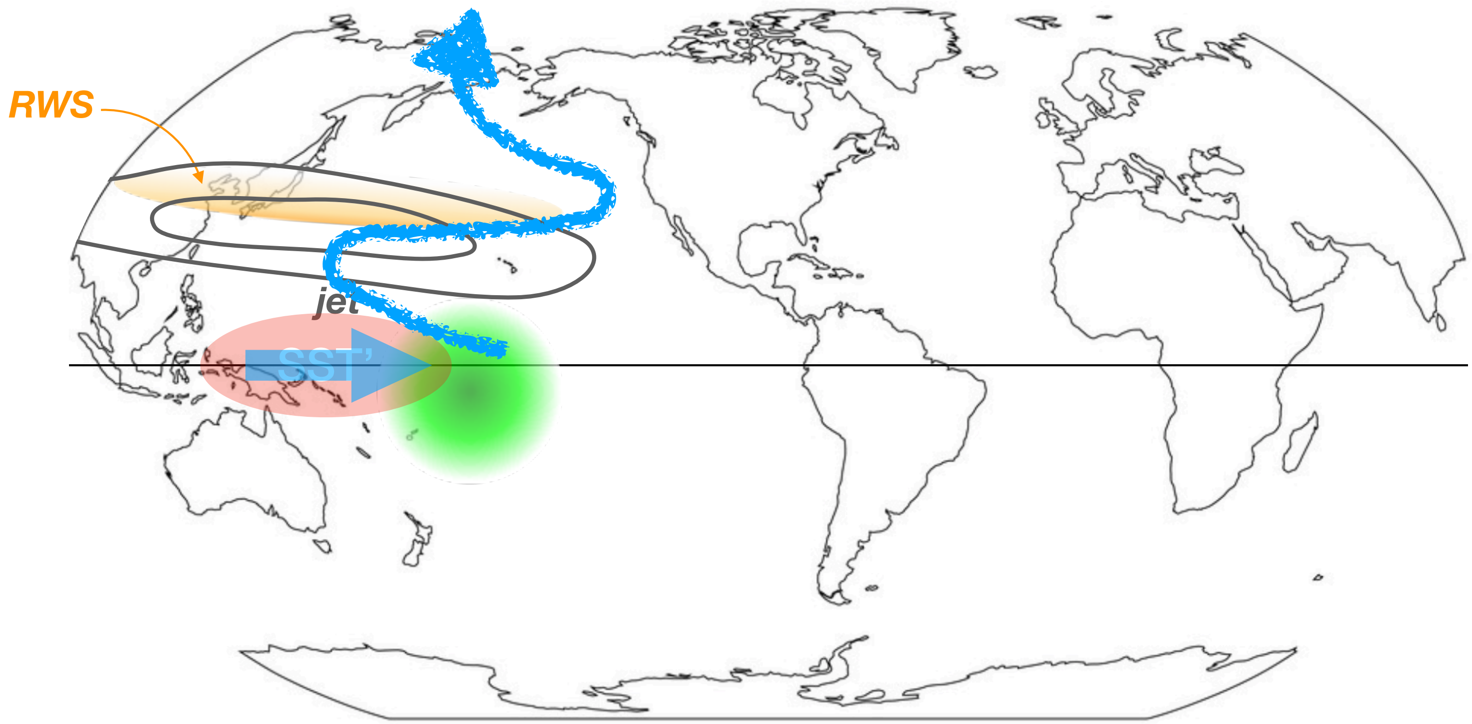

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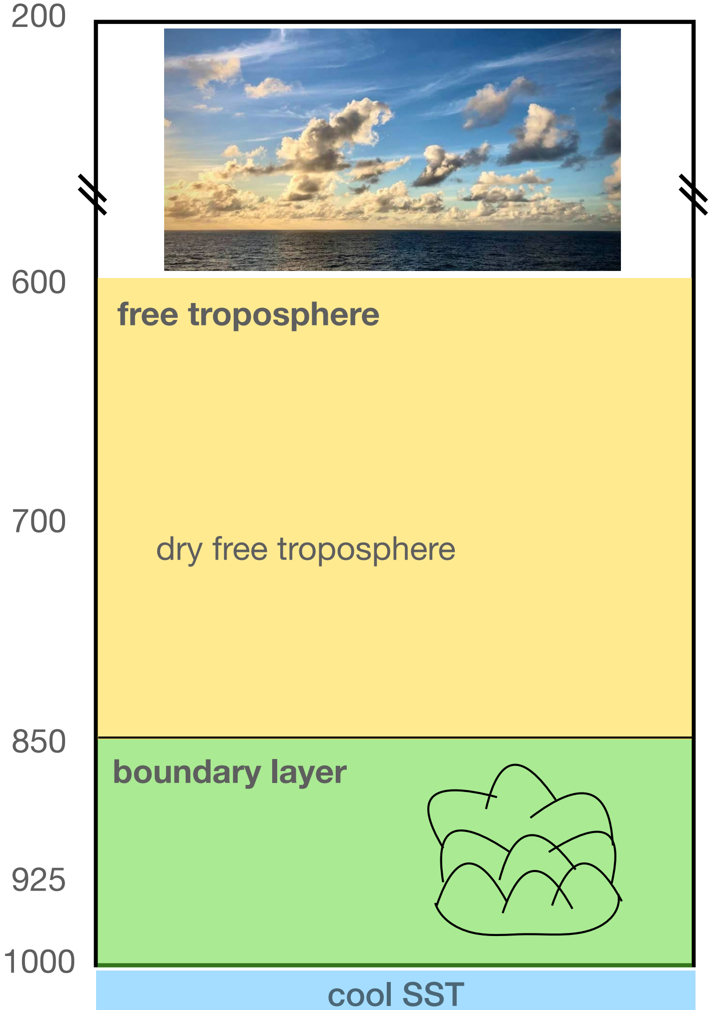
buoyancy perspective of tropical convection



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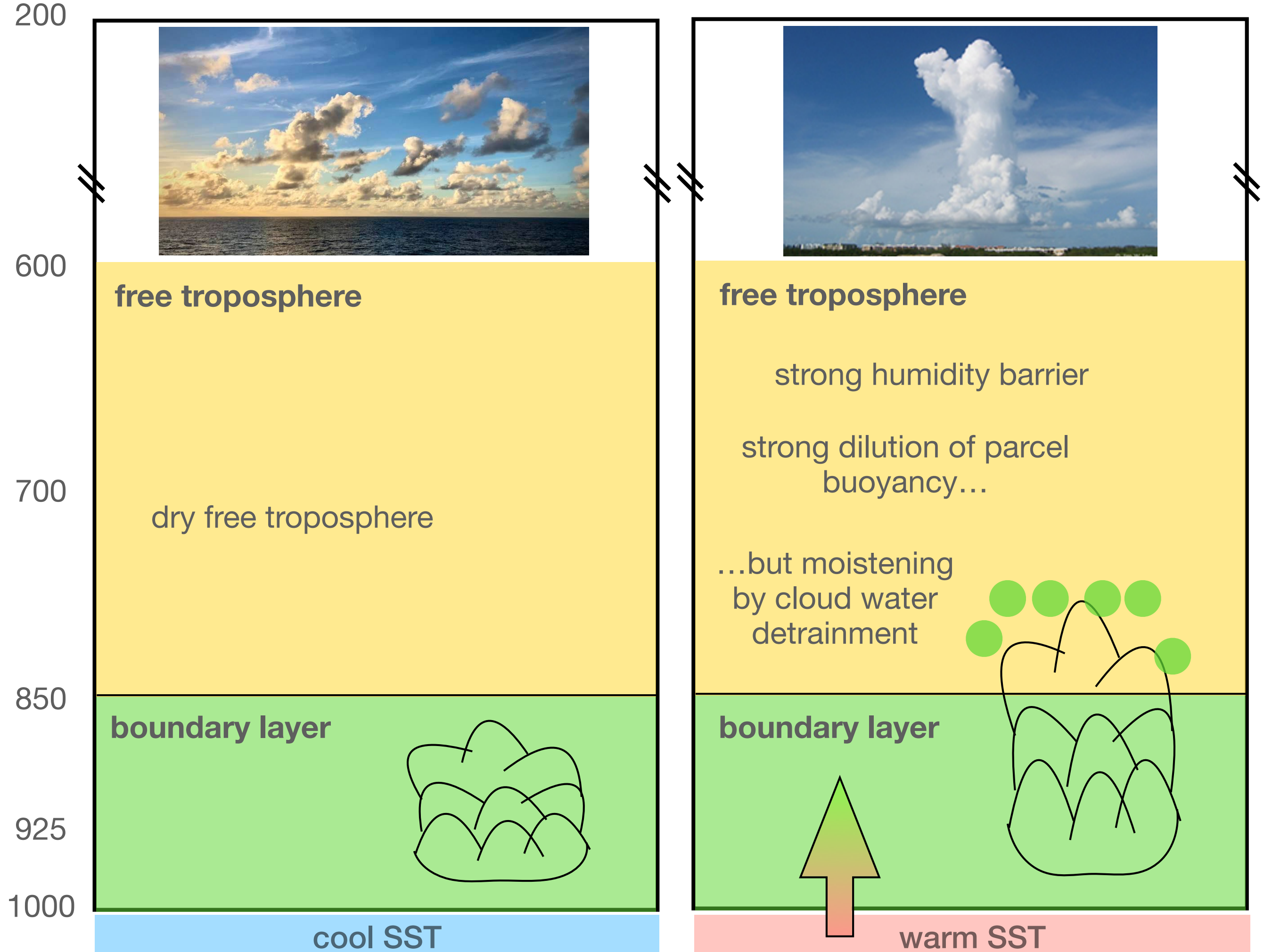

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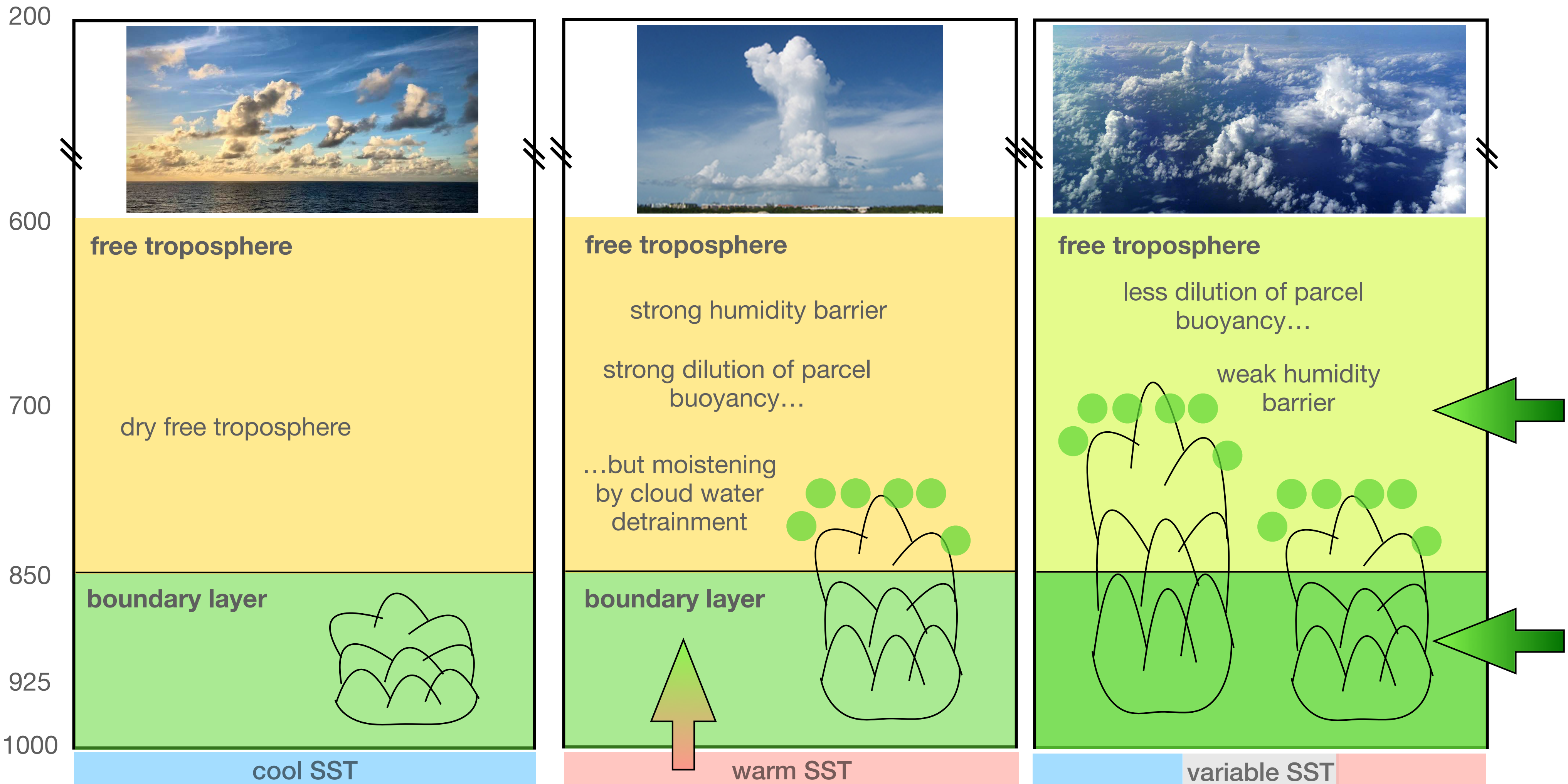

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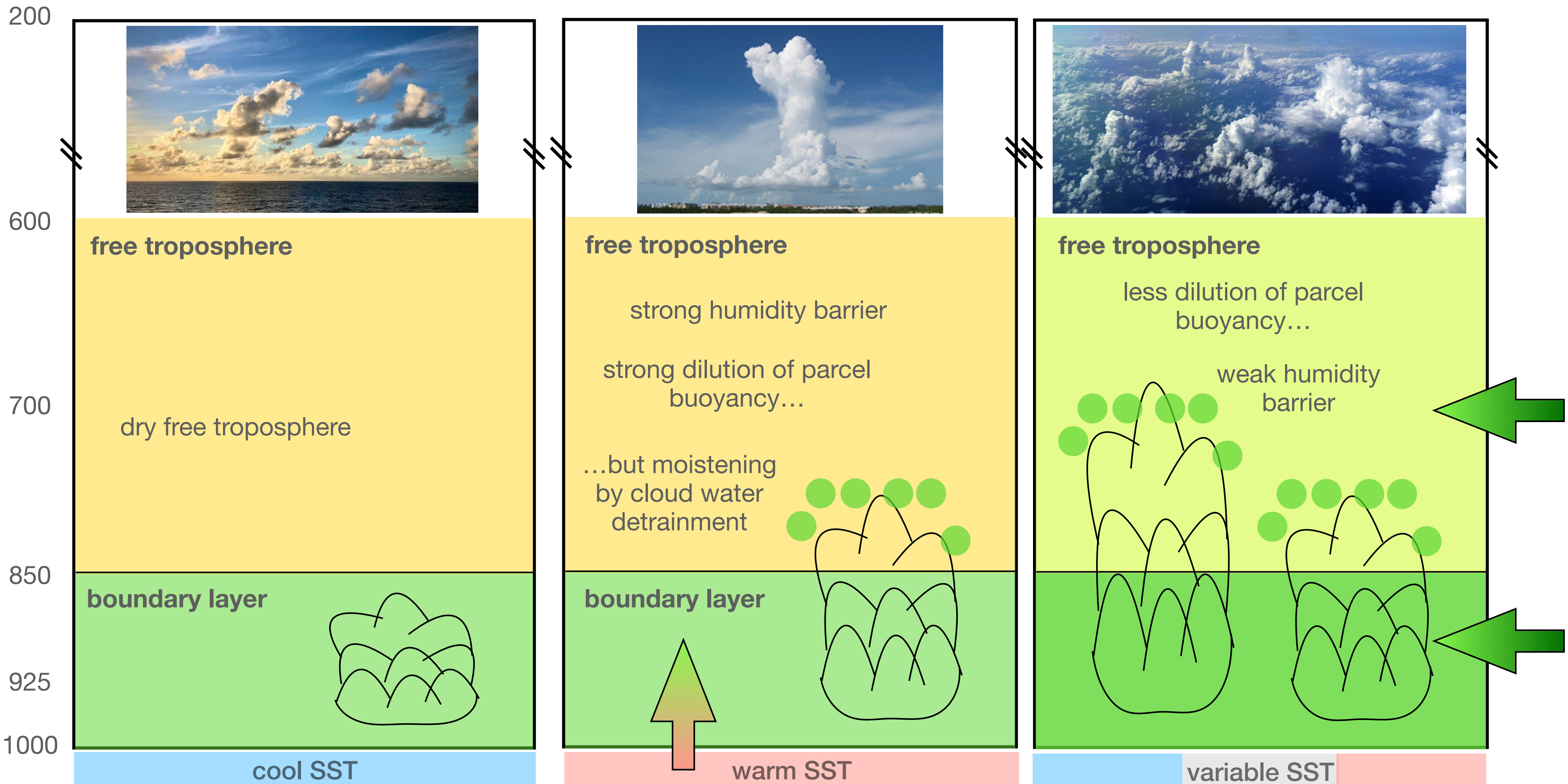
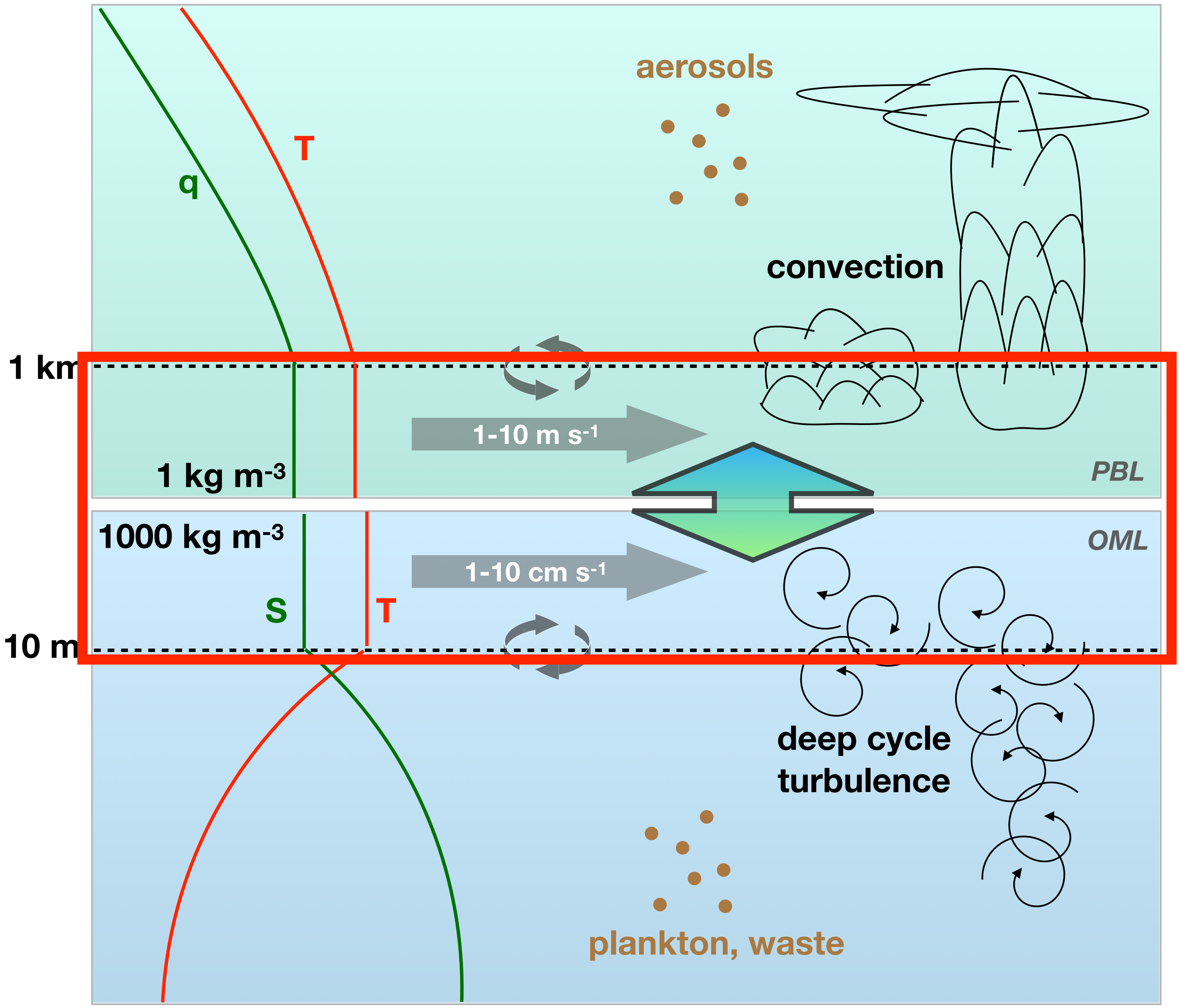


buoyancy profiles affected by:

- SST (ocean processes)
- T, q in MABL
- T, q above MABL

ocean-atmosphere differences



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surface fluxes are the result of O-A constantly trying to equilibrate

summary of introduction

- lower atmosphere, upper ocean vary on different timescales
- O-A surface fluxes destabilize atmospheric boundary layer
- convection “connects” boundary layer and lower free troposphere
- tropical convection initiates teleconnections

SST drift in forecast models

How might ocean forecasts affect the atmosphere?

- **model**: ocean initialization
- **model**: SST drift
- **nature**: ocean initial state
- **nature**: ocean evolution

How might ocean forecasts affect the atmosphere?

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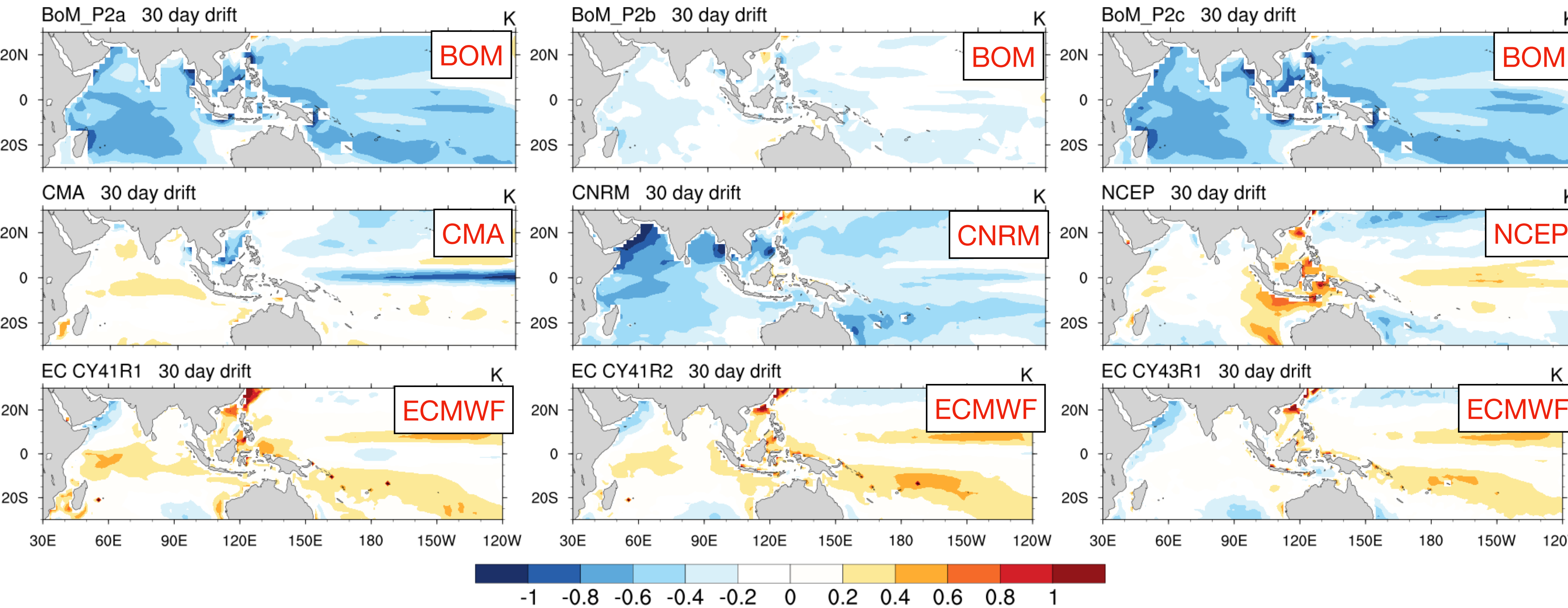
} my focus today

- **nature**: ocean initial state
- **nature**: ocean evolution

average 30-day SST drift in S2S database models

(Nov-Apr climatology)



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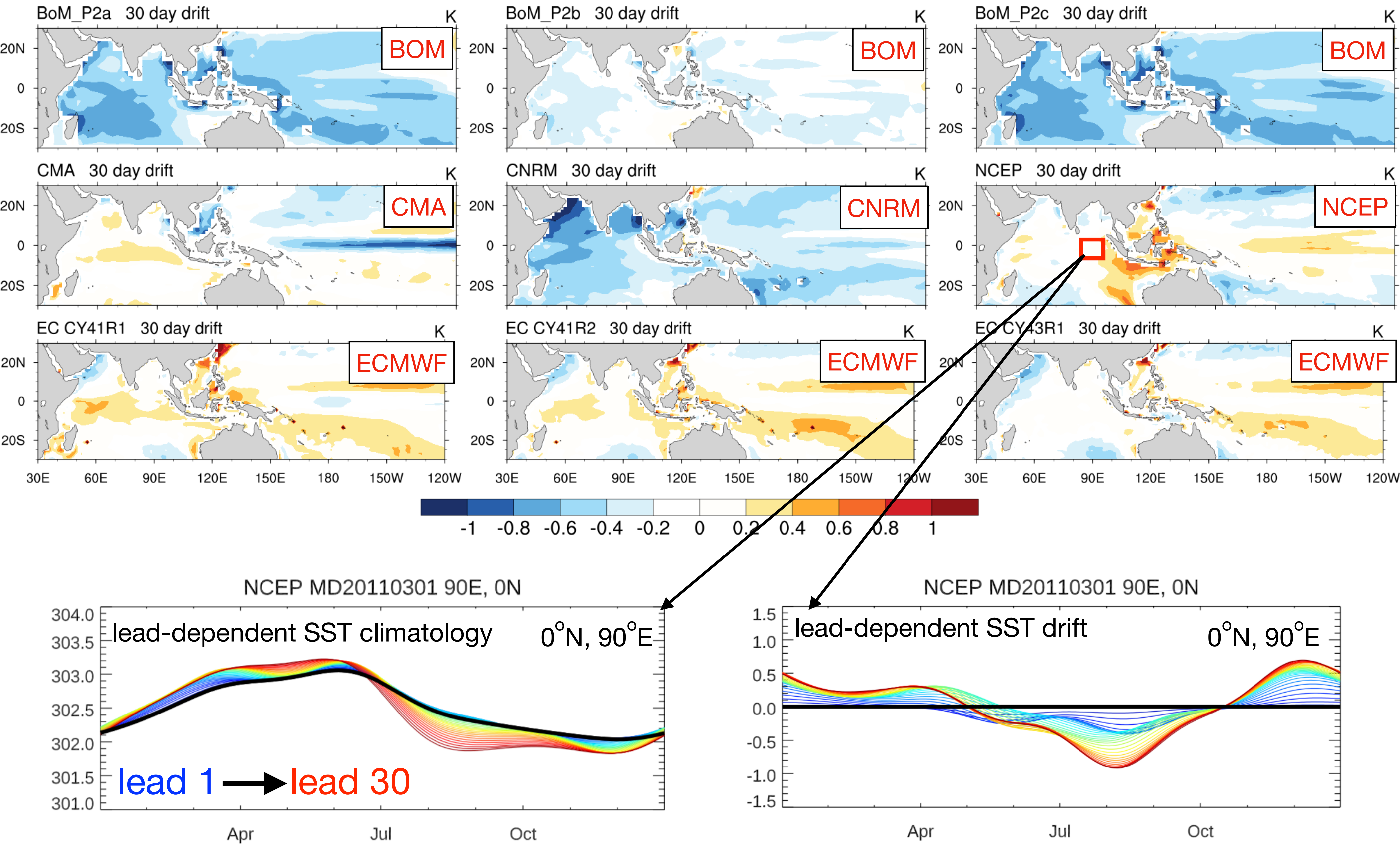
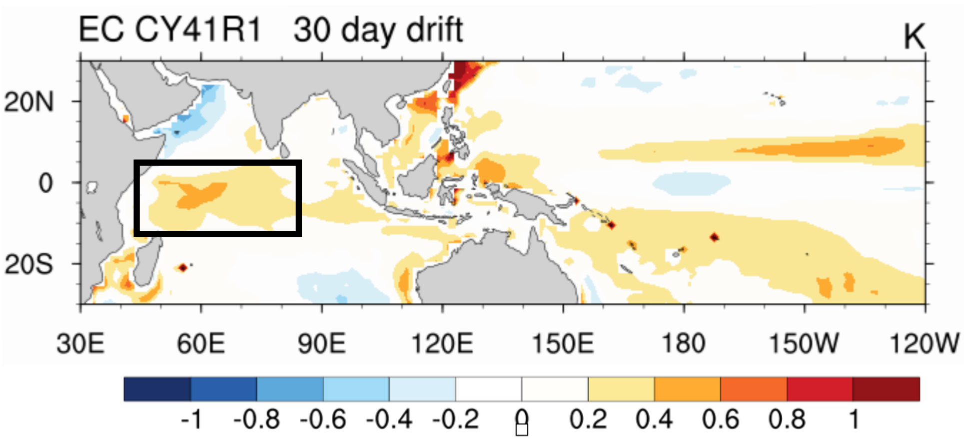


diagnosing mean state SST drift



SST drift can arise from drift in net surface heating (Qnet) or ocean processes:

$$\underline{\partial SST / \partial t} \sim \underline{Q_{net}} + \underline{ocnproc}$$

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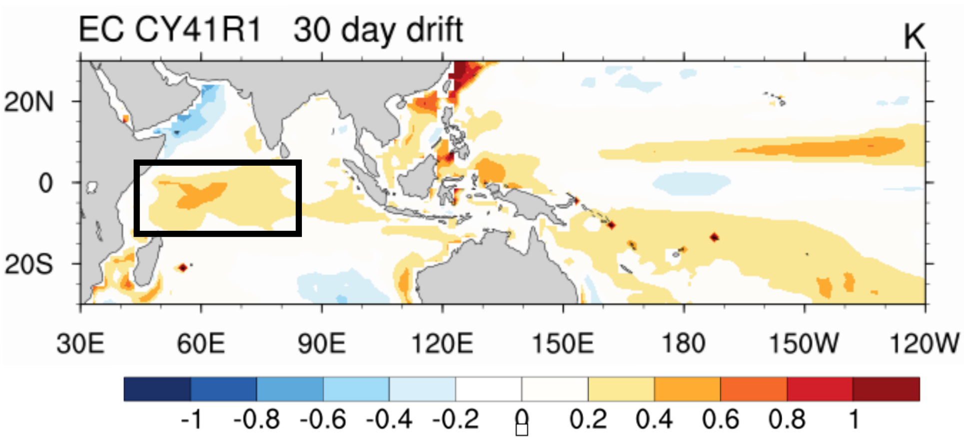
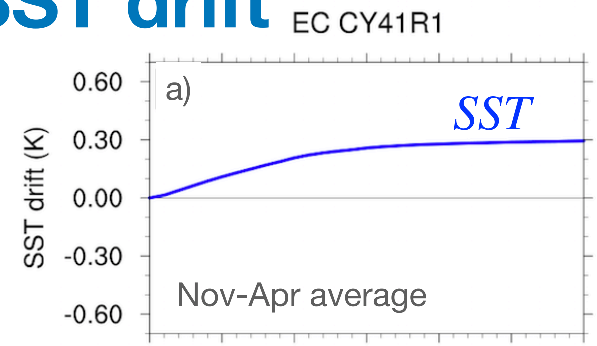




SST drift can arise from drift in net surface heating (Qnet) or ocean processes:

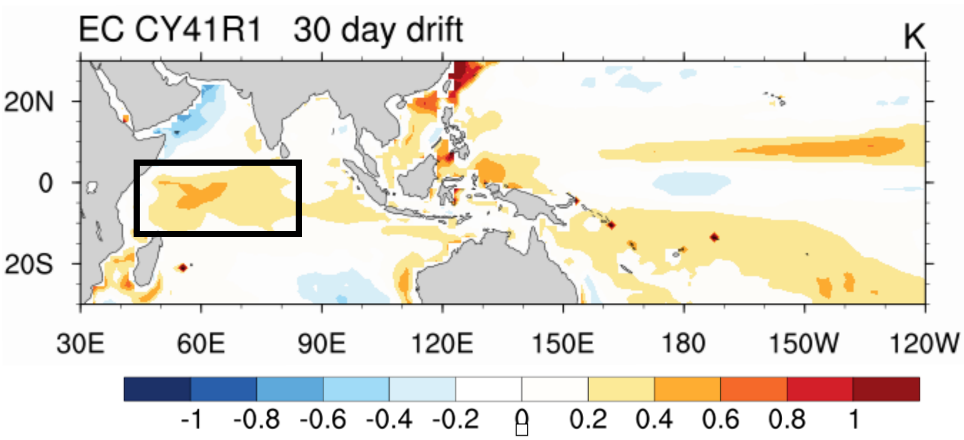
$$\partial SST/\partial t \sim Q_{net} + ocnproc$$

a) compute SST lead-dependent climatology

0 5 10 15 20 25 30

lead (days)

diagnosing mean state SST drift EC CY41R1



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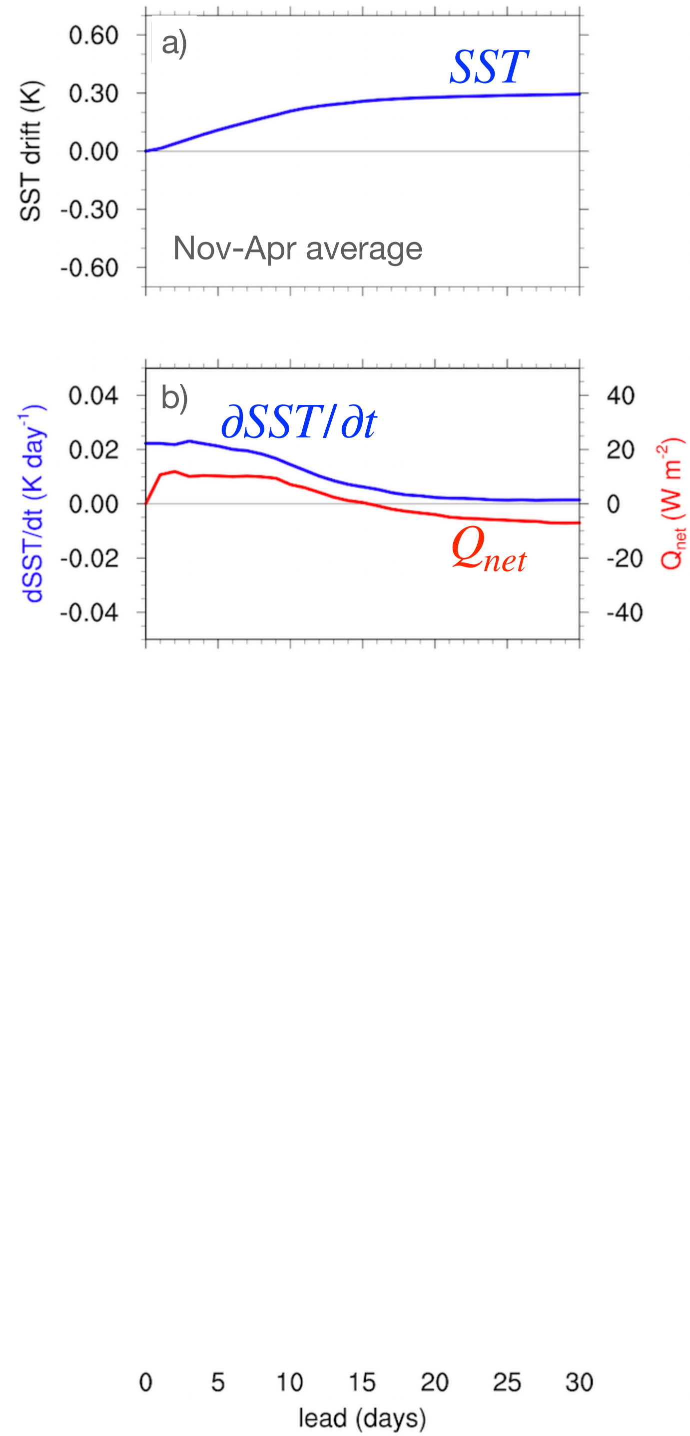
a) compute SST lead-dependent climatology

b) regress $\partial SST/\partial t$ onto Q_{net}



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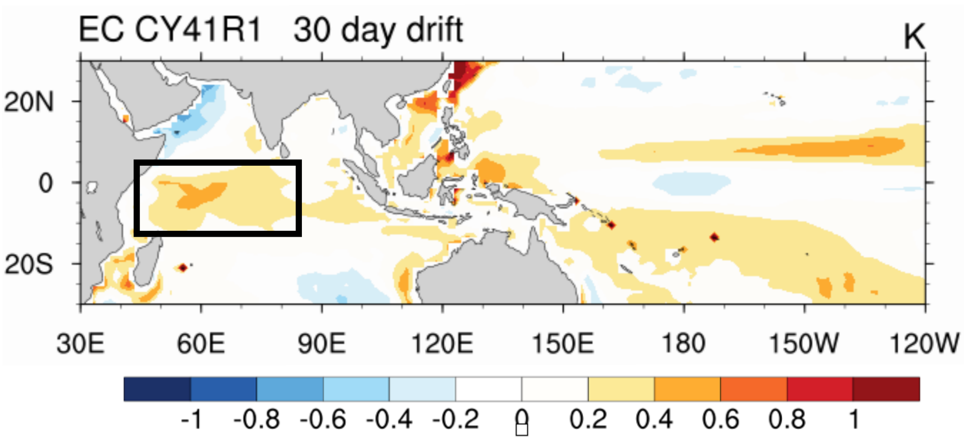

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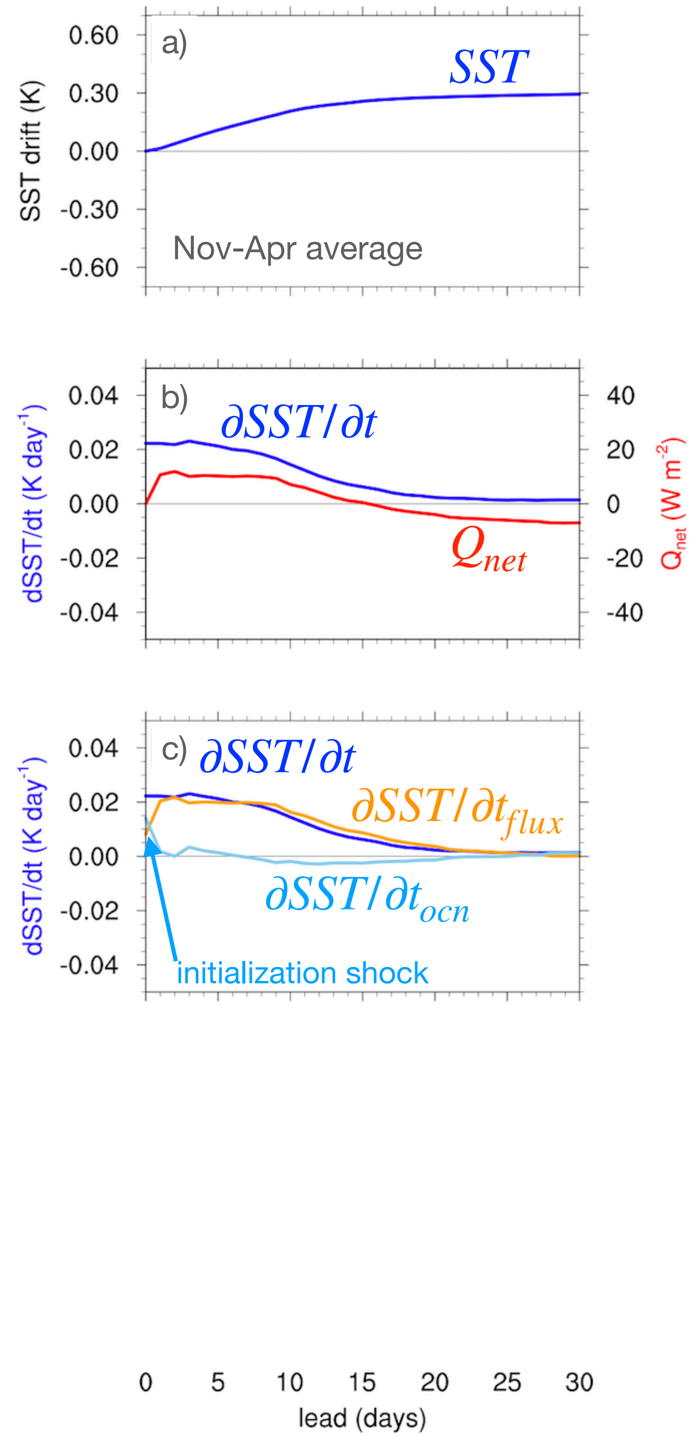
a) compute SST lead-dependent climatology

b) regress $\partial SST/\partial t$ onto Q_{net}

c) compute Q_{net}-predicted $\partial SST/\partial t$

c) residual is ocean-driven $\partial SST/\partial t$



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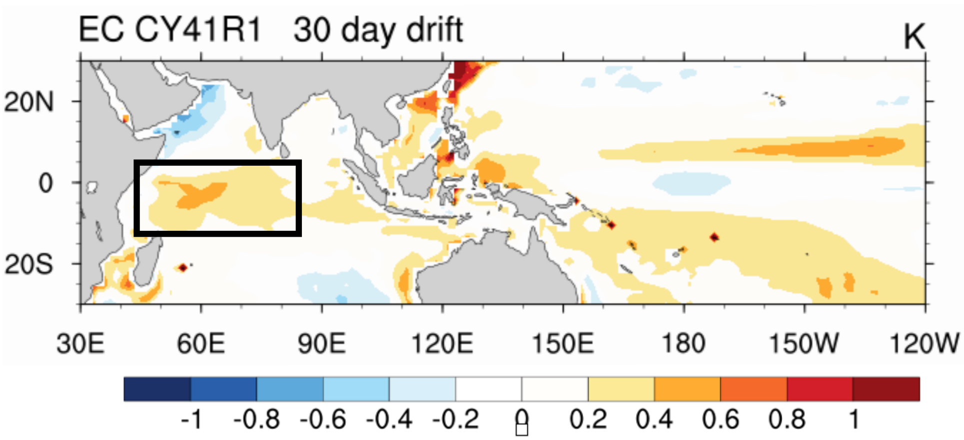

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$$\partial SST/\partial t \sim Q_{net} + ocnproc$$

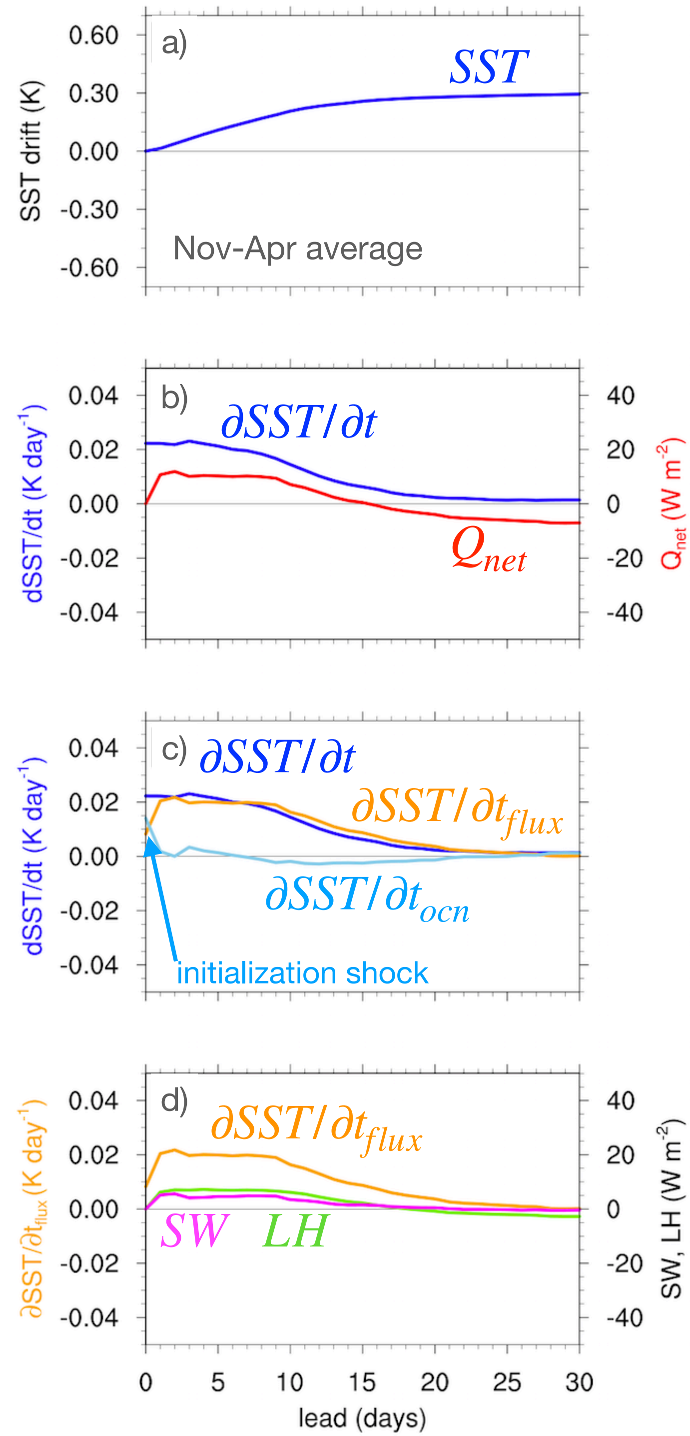
a) compute SST lead-dependent climatology

b) regress ∂SST/∂t onto Q_{net}

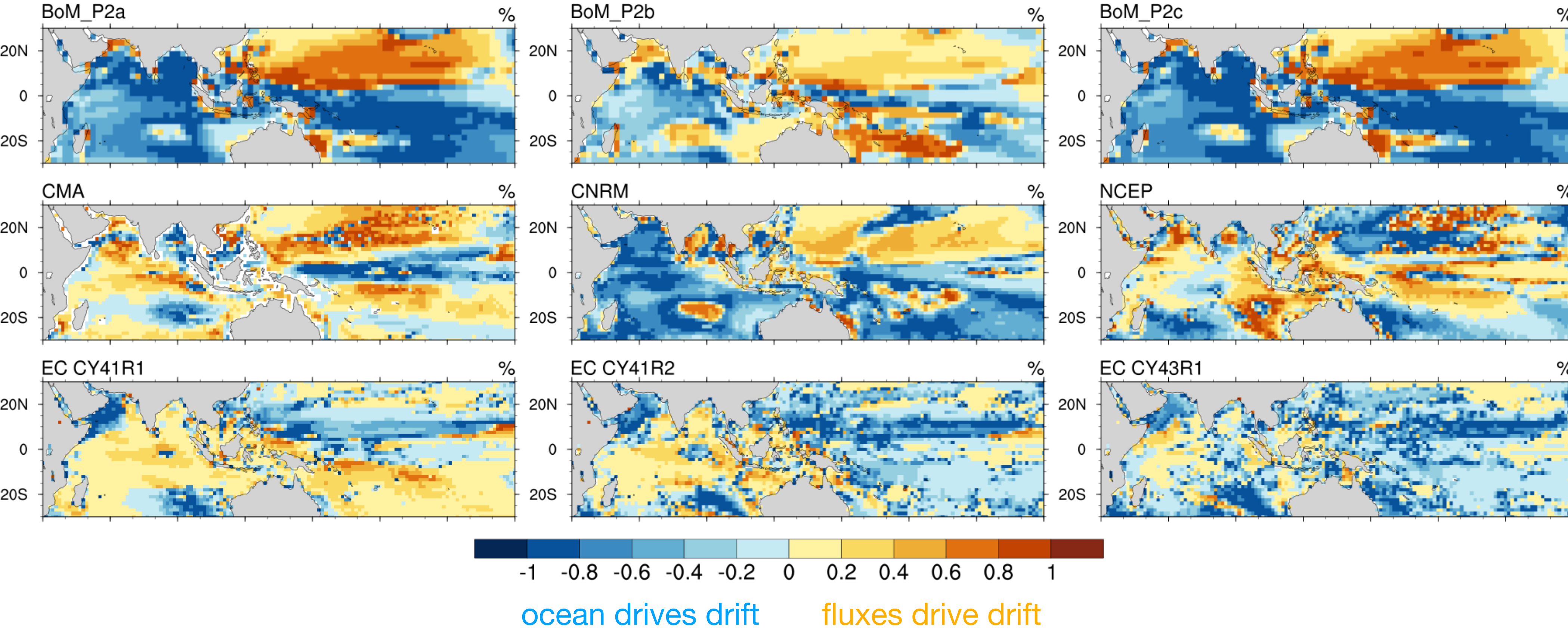
c) compute Q_{net}-predicted ∂SST/∂t

c) residual is ocean-driven ∂SST/∂t

d) for ECMWF, Q_{net} contributions equally driven by SW and LH drift (LW, SH contributions are small)



surface flux vs ocean dynamics for SST drift



as determined by a "balance factor" that compares RMSE of each time series (Halkides et al. 2015)

- large variety of SST drift sources across models
- ocean sources of drift: initialization shock, model biases, insufficient observations for initialization?

model biases that contribute to SST drift

- erroneous **(de)stabilization** of water column
  - surface heating
  - surface freshening

- erroneous **momentum flux** across air-sea interface
  - surface winds
  - representation of surface momentum flux: bulk parameterization, wave effects
  - representation of ocean mixing: affects surface currents, MLD

prospects for improvement

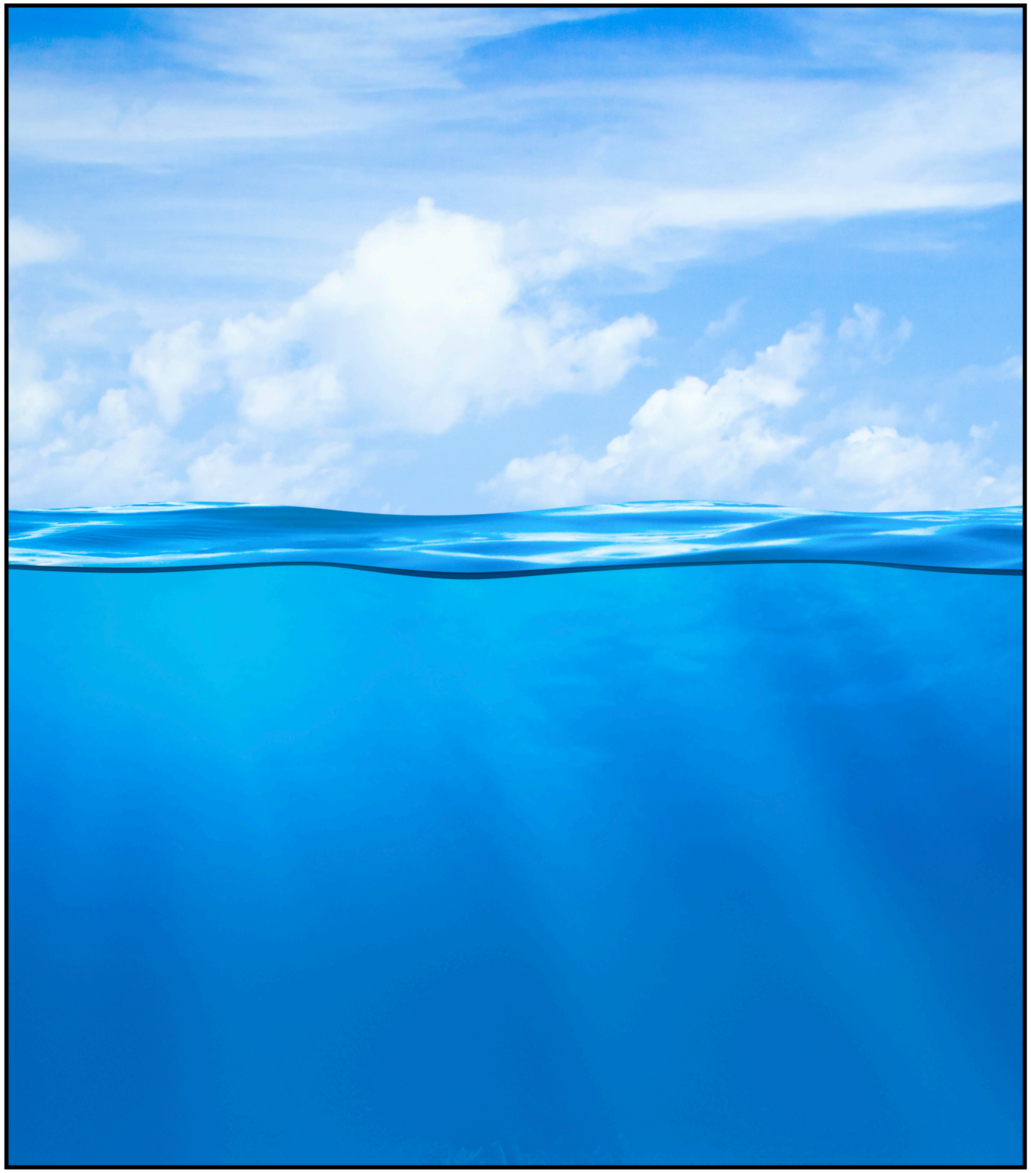
S2S ocean output variables to identify sources of bias

- **SST**: sea surface temperature
- **SSH**: sea surface height
- **SSS**: sea surface salinity
- *u*, *v* **surface currents**
- **MLD**: mixed layer depth
- **H300**: 0-300m ocean heat content
- **T20D**: 20C isotherm depth
- **sea ice concentration**

Ben Webber, Eliza Karlowska; U. East Anglia
Chris Roberts; ECMWF

Michael Jacox, NOAA PSL
Ángel Muñoz, Columbia/IRI
Dillon Amaya, NOAA PSL
Juliana Dias, NOAA PSL

future directions: a coupled observing strategy?



"Whole column" approach to measuring the upper ocean and lower atmosphere in process studies.

Sustained colocated, synchronous measurements of the tropical upper ocean and lower atmosphere are needed to:

- advance process understanding
- improve process representation in climate and forecast models
- accelerate progress in coupled data assimilation for improved forecast reliability

leveraging ideas put forth by TPOS2020, OASIS, US CLIVAR Tropical Pacific Observing Needs Workshop, and the US CLIVAR Air-Sea Transition Zone Study Group

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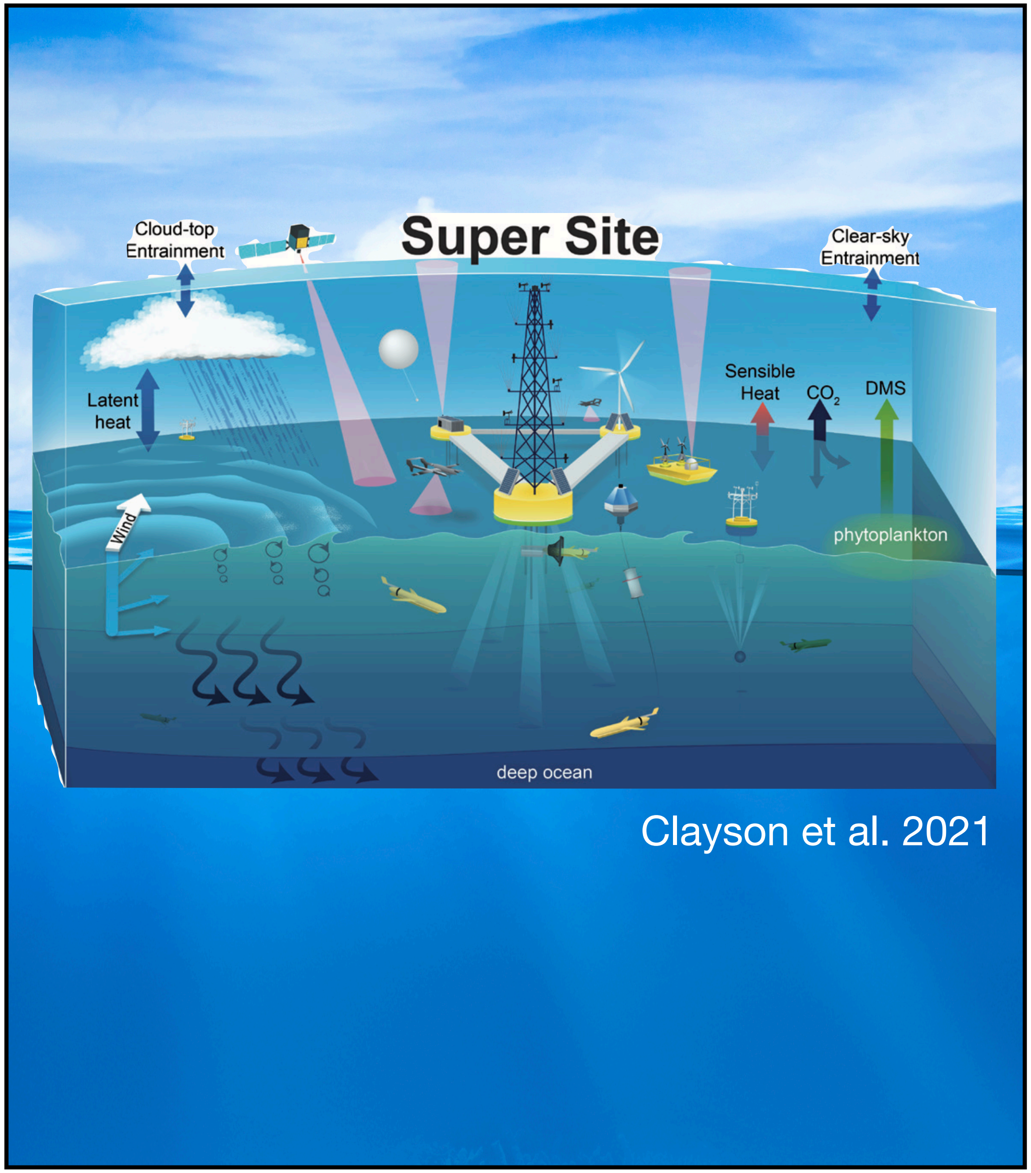

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Summary

- ocean forecast skill is important for forecasting atmospheric phenomena, and for commercial activity planning.

- ocean simulation (model) and ocean state (nature) can both affect MJO forecast skill.

- identifying sources of ocean forecast errors is difficult when limited to only SST.

- newly available ocean output variables have the potential to improve ocean process understanding and representation in forecast models