Ocean-atmosphere coupled scale interactions in the Madden Julian Oscillation

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photo: western Pacific from R/V Vickers, TOGA COARE (C. DeMott)

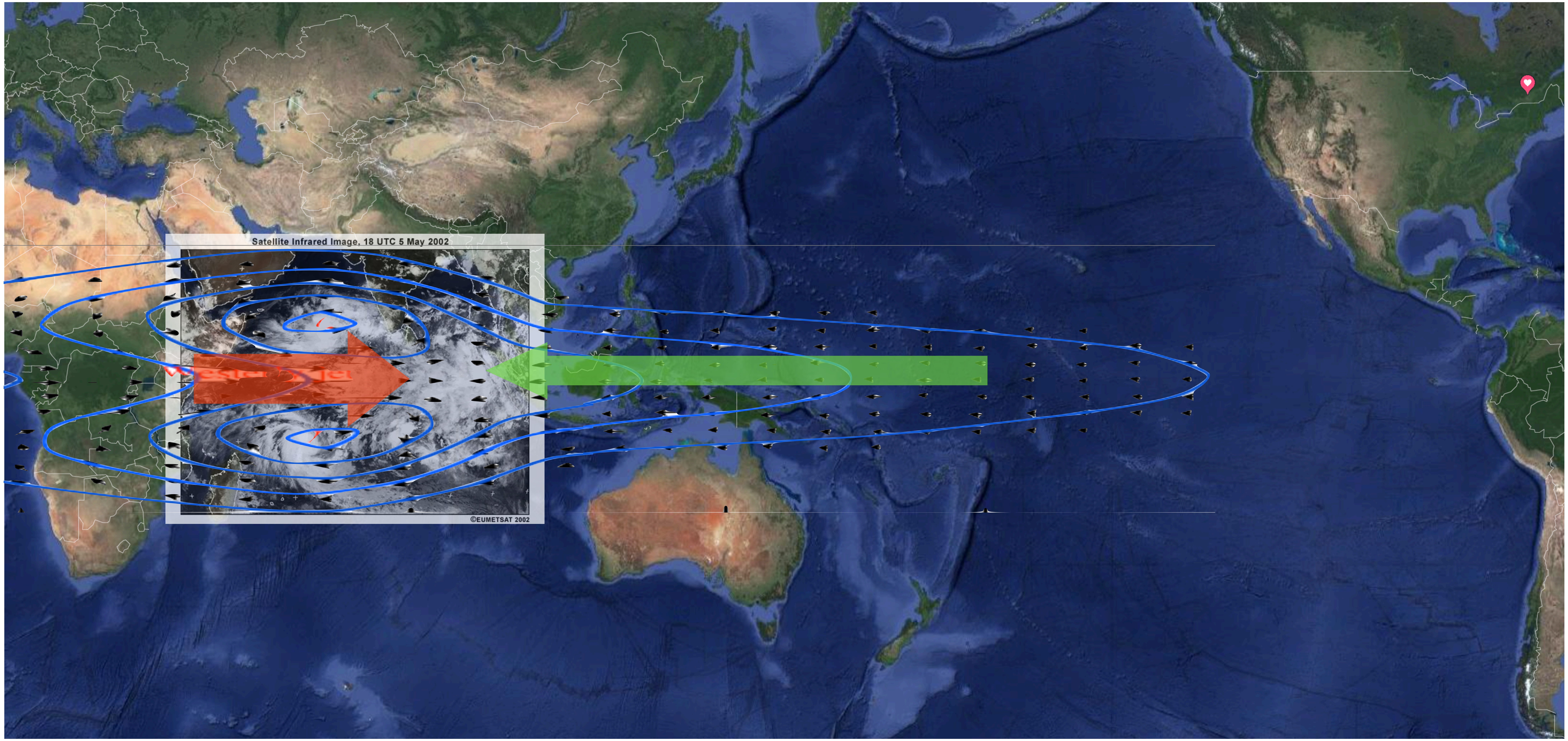
assumptions made in this talk

- the audience is familiar with Warm Pool upper ocean processes
- the audience may be less familiar with the atmospheric response to ocean state

goals of this talk

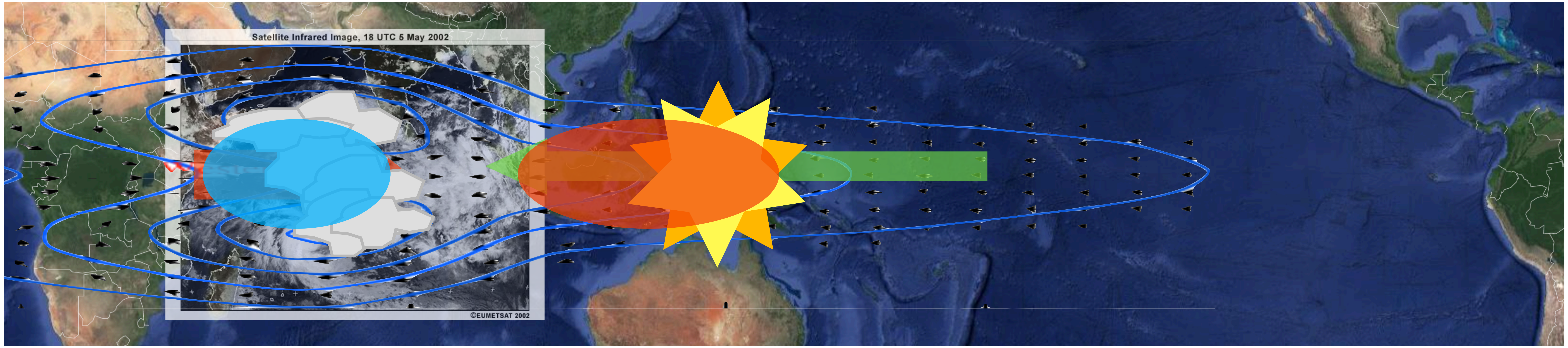
- to present scales of ocean-atmosphere interactions important to the MJO
- to summarize model deficiencies in their representation of these processes

scale of the Madden-Julian oscillation



scale of the Madden-Julian oscillation

30N

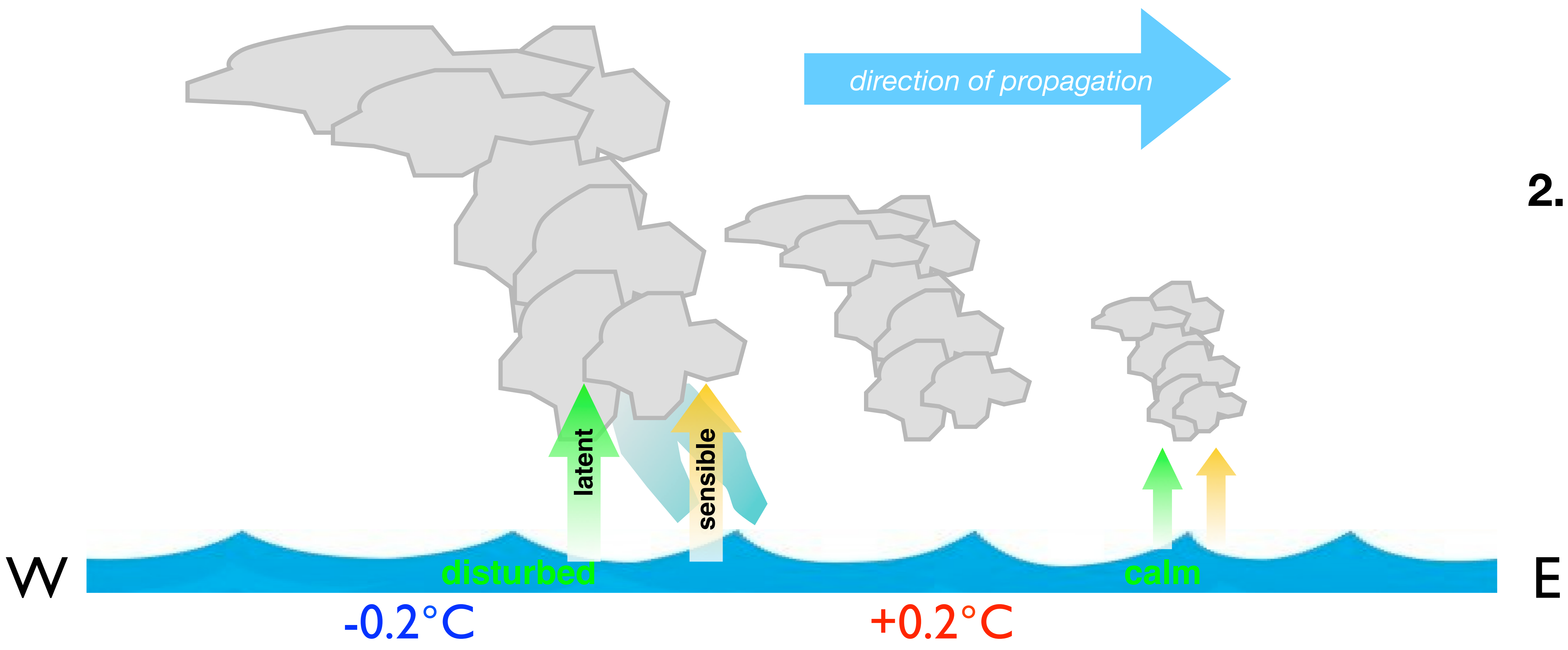


30S

“active” phase:
cloudy
windy
cooling/cold SSTs

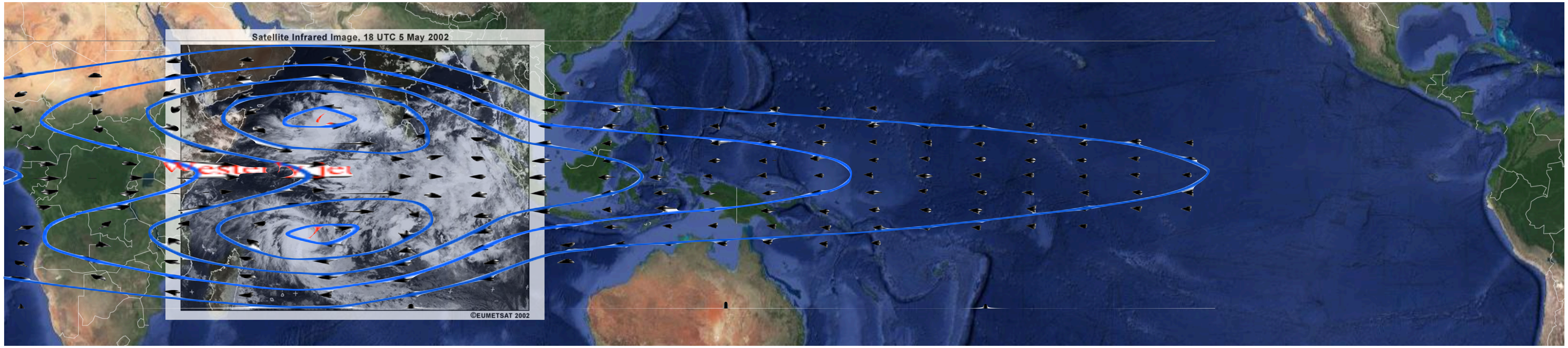
“suppressed” phase:
fewer clouds
calm
warming/warm SSTs

scale of the Madden-Julian oscillation



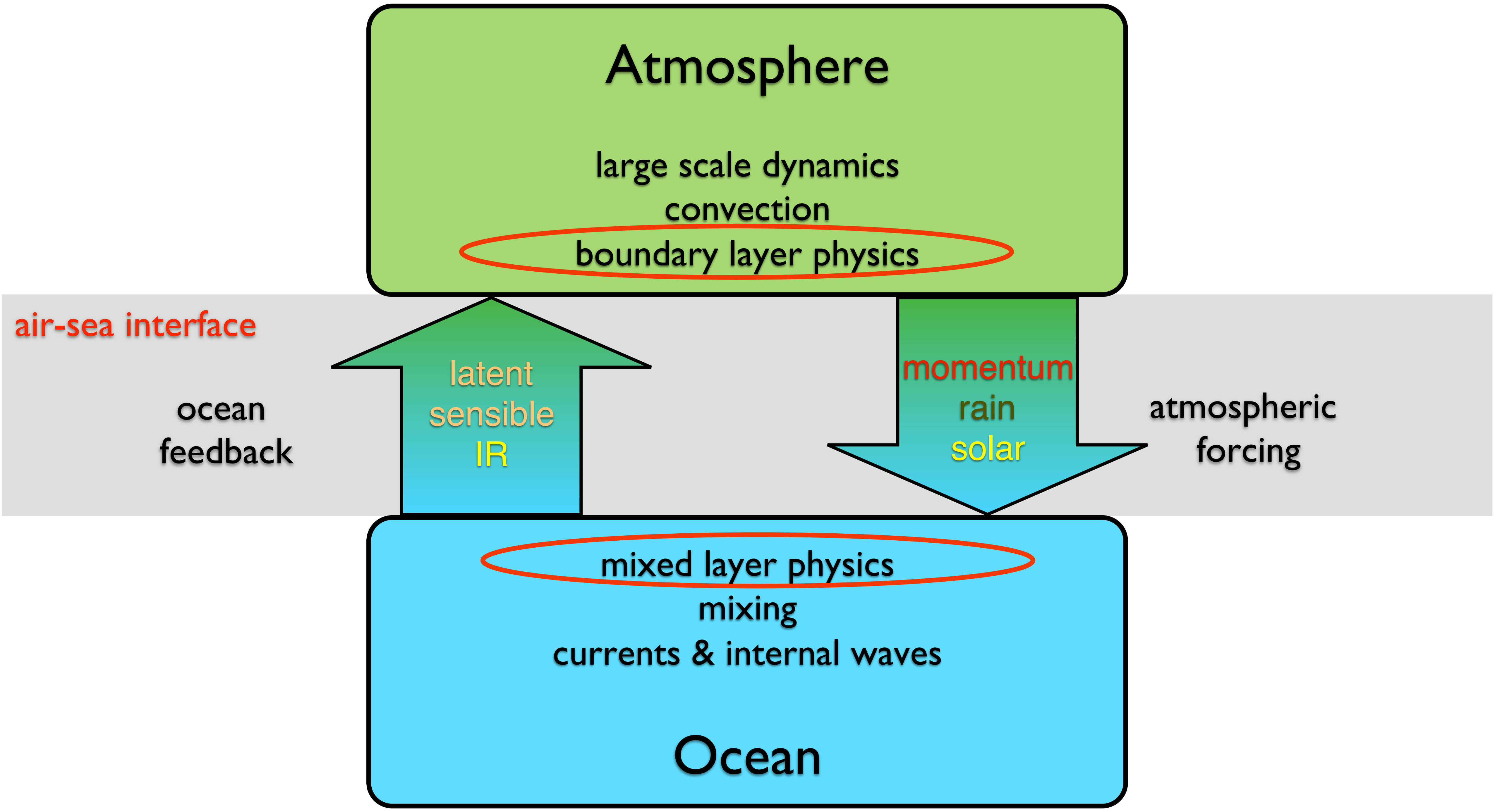
key issues for modeling the MJO:

1. What maintains convection?
2. What drives eastward propagation?

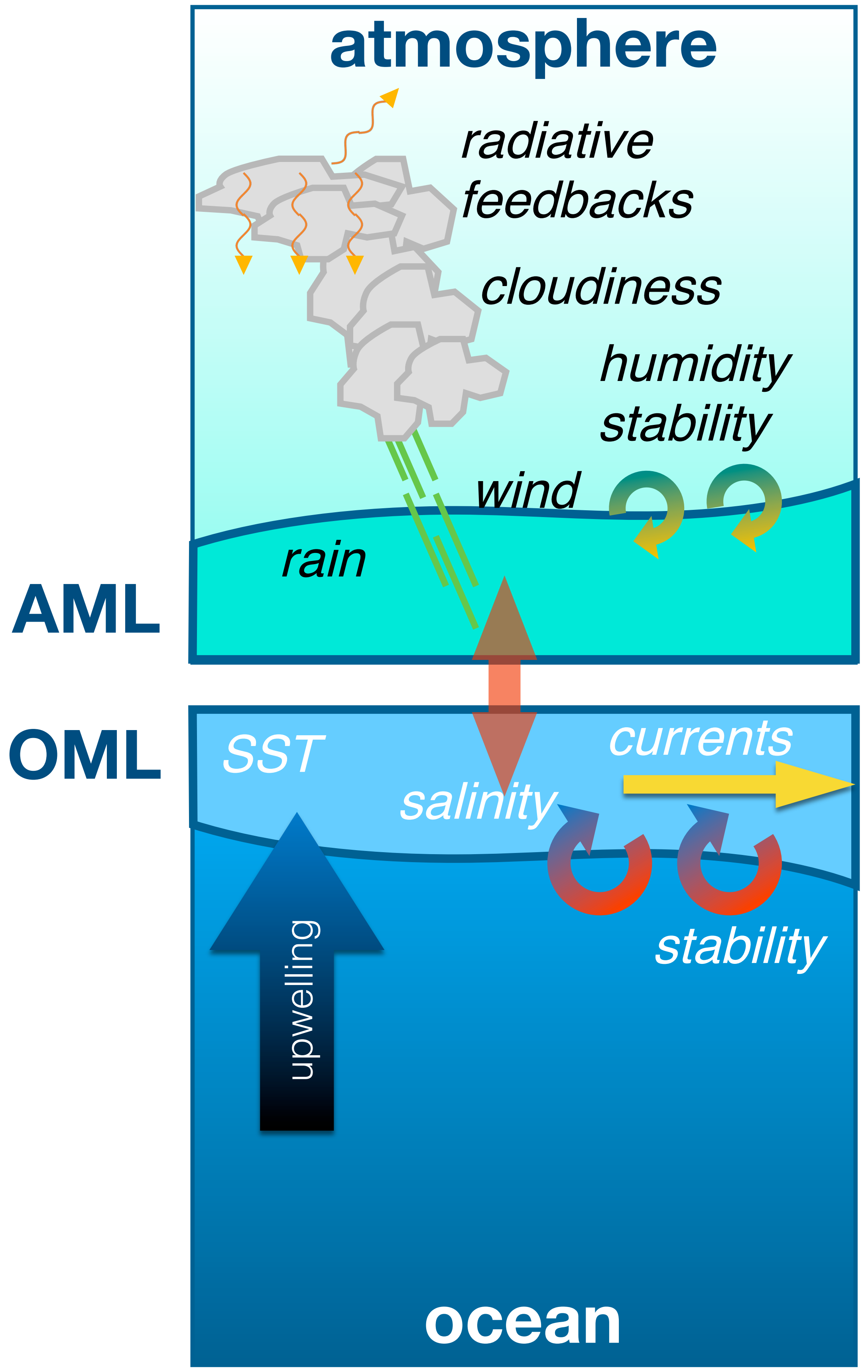


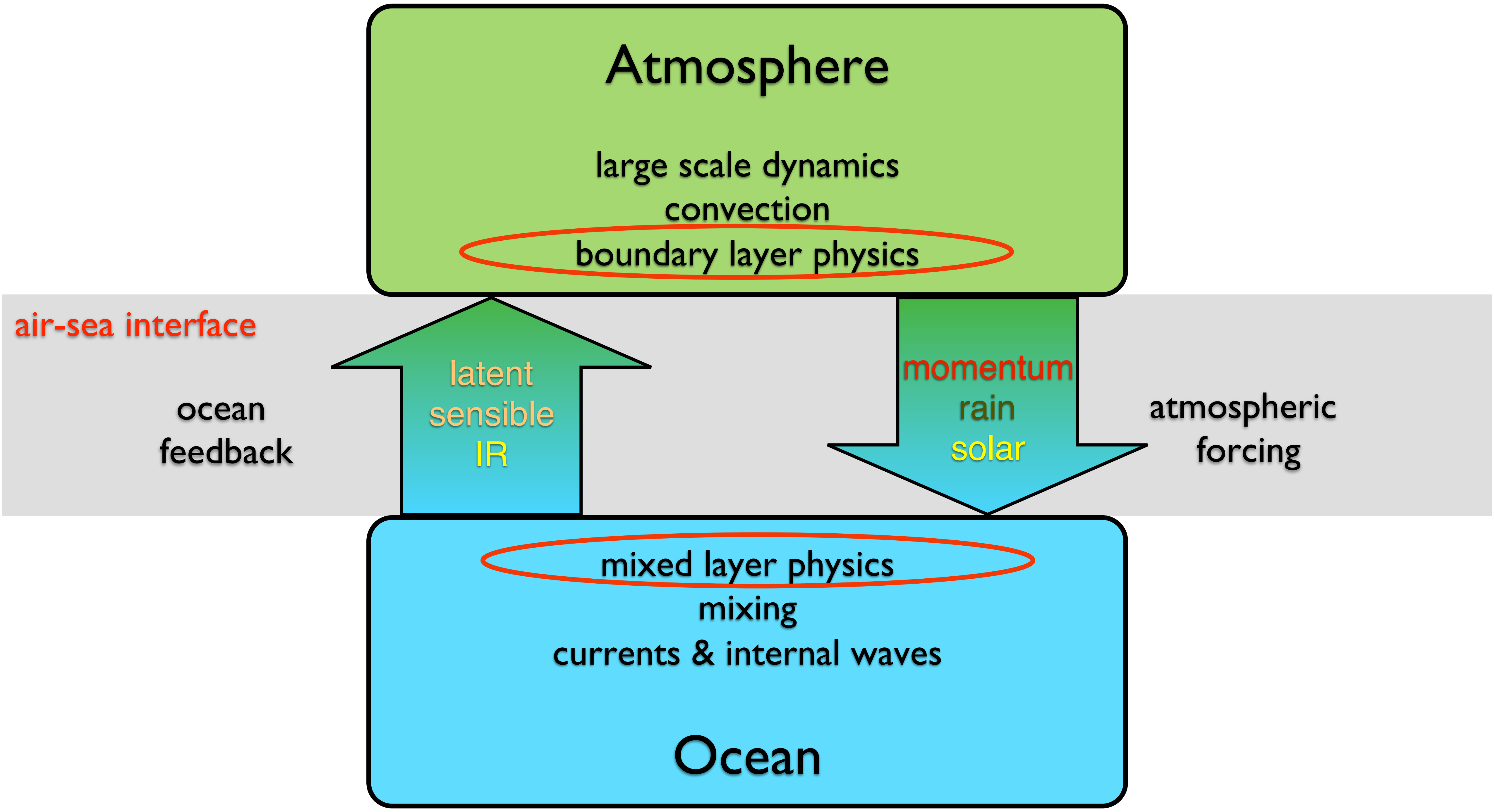
coupled processes within the MJO

“The atmosphere does not see SST;
it only senses it through surface fluxes.”
—Chidong Zhang (2005)



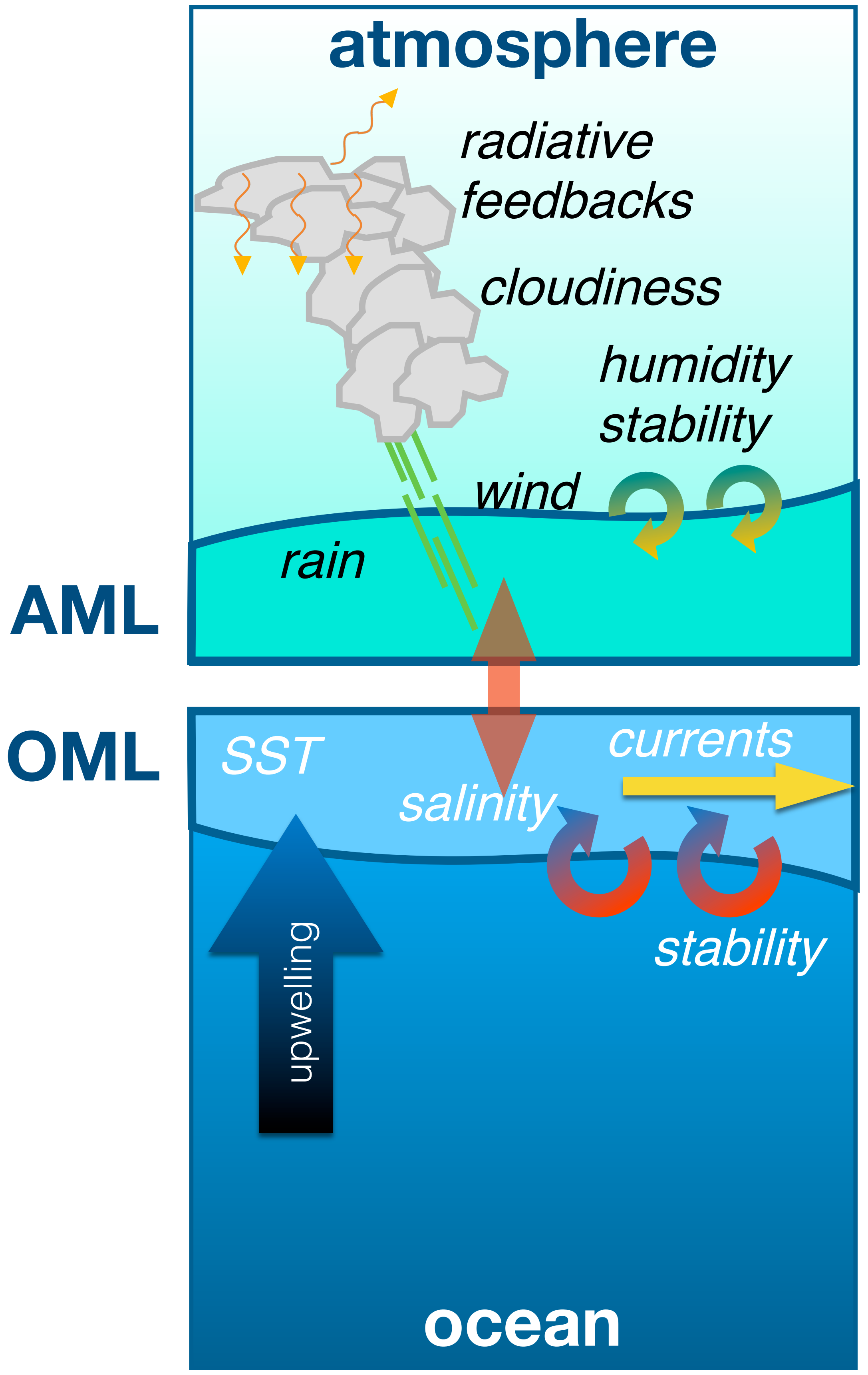
coupled processes within the MJO





understanding air-sea interactions within the MJO requires an understanding of processes that regulate the AML and OML energy budgets.

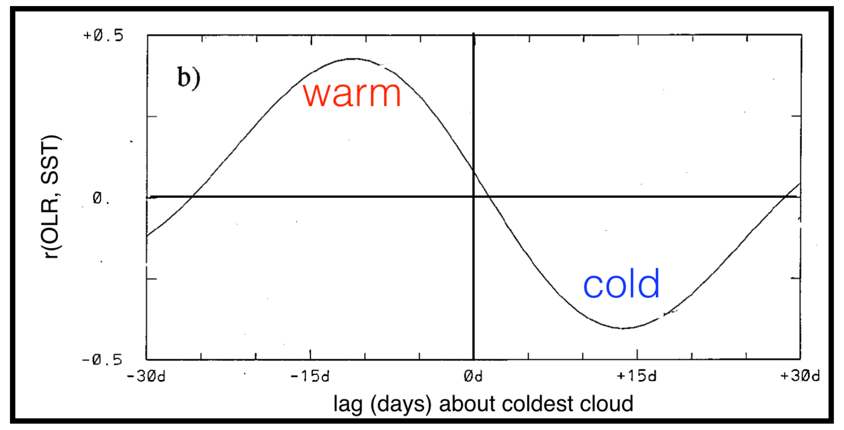
coupled processes within the MJO



what kinds of measurements are needed to characterize the AML and OML across scales in order to constrain models?

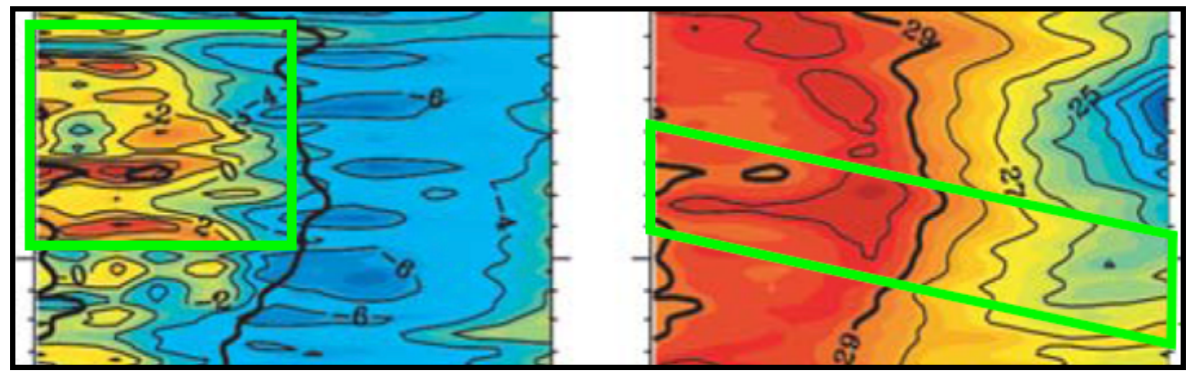
time scales of air-sea coupled processes

intraseasonal

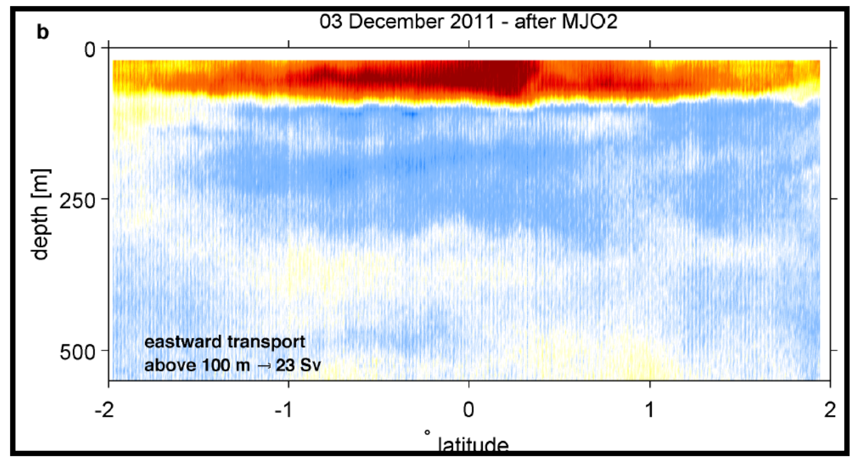


a myriad of processes and timescales

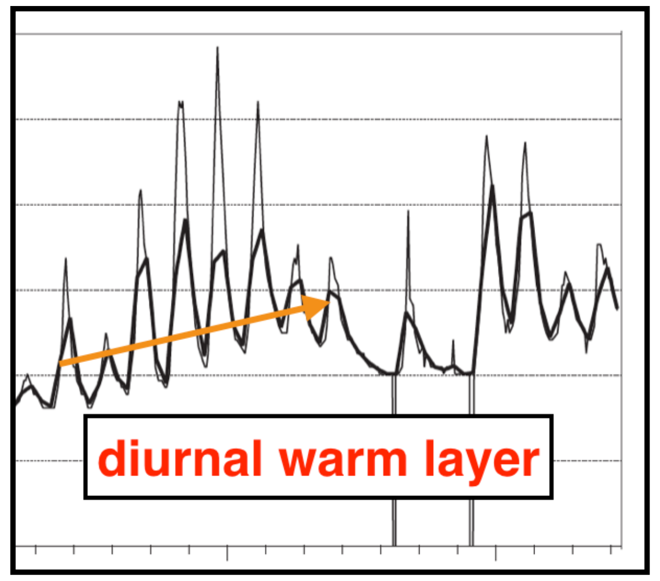
interannual



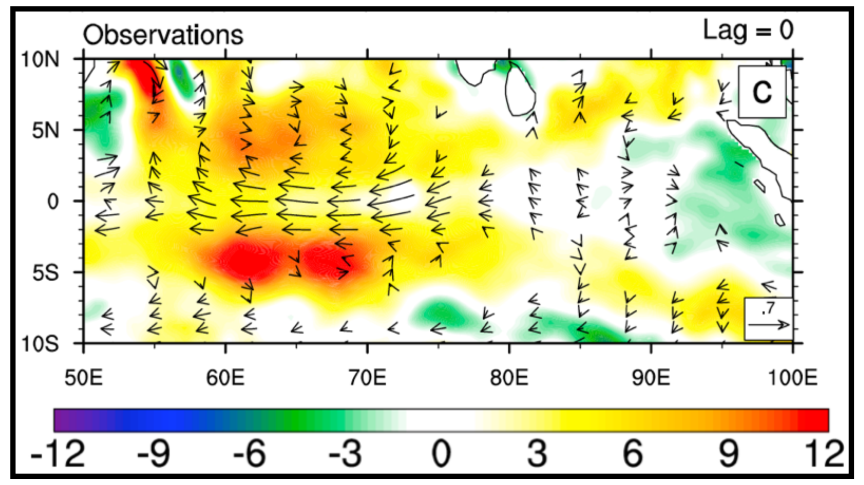
intraseasonal



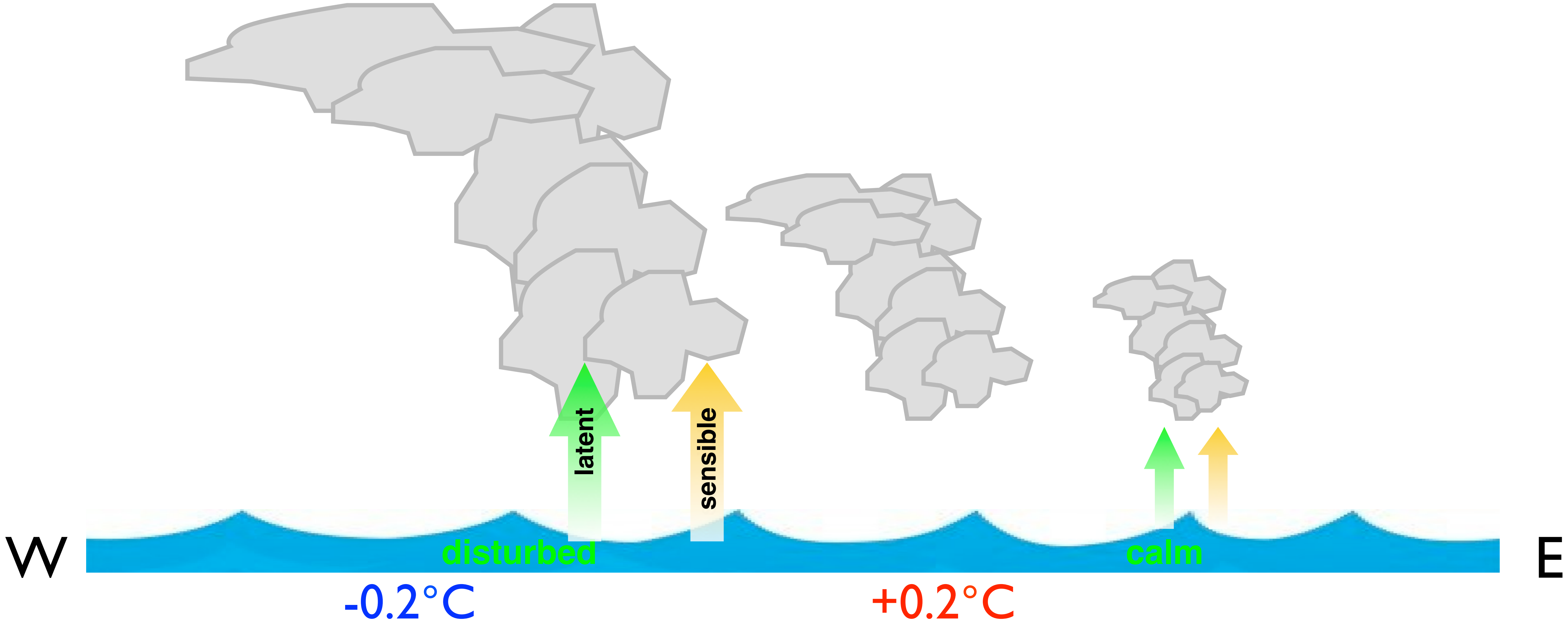
diurnal



seasonal

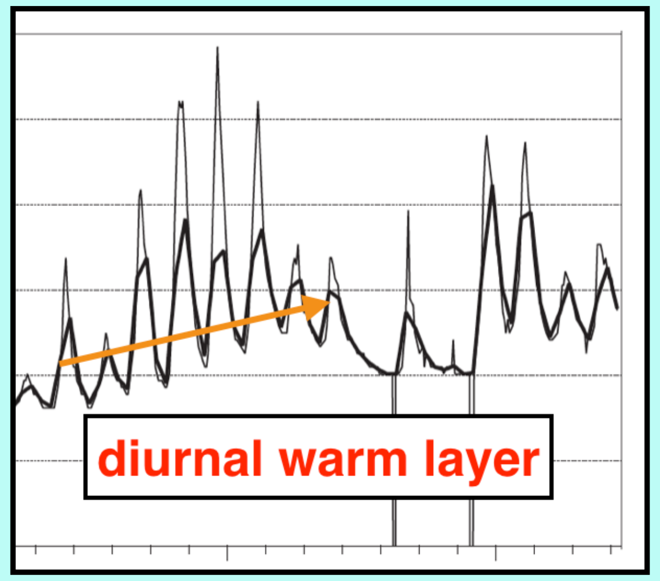


time scales of air-sea coupled processes

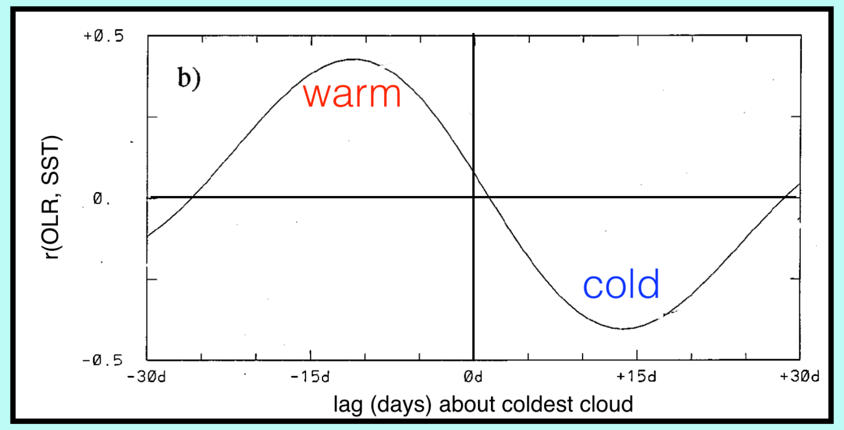


coupled feedbacks in the context of the MJO

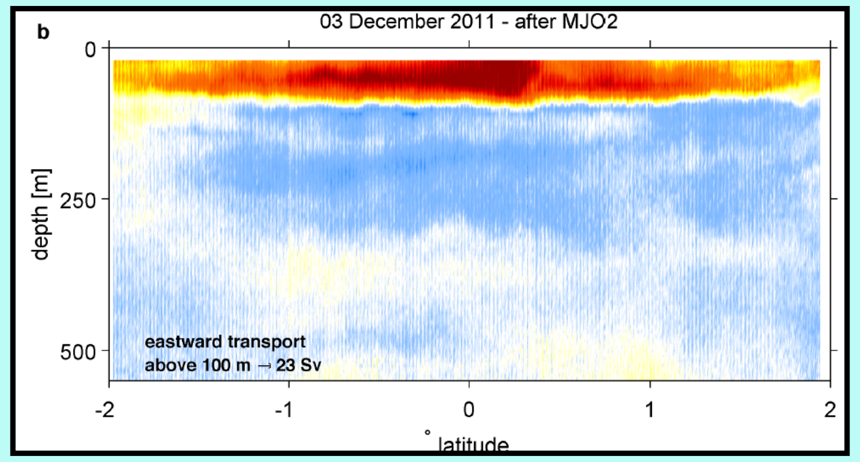
diurnal



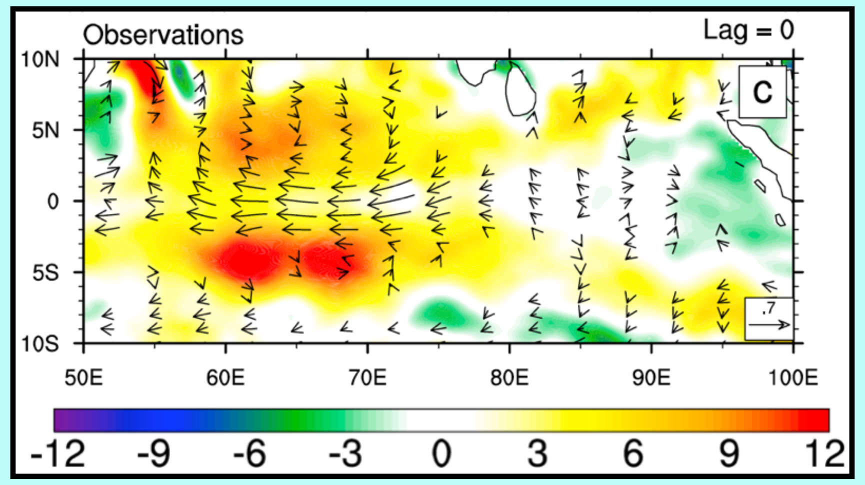
intraseasonal



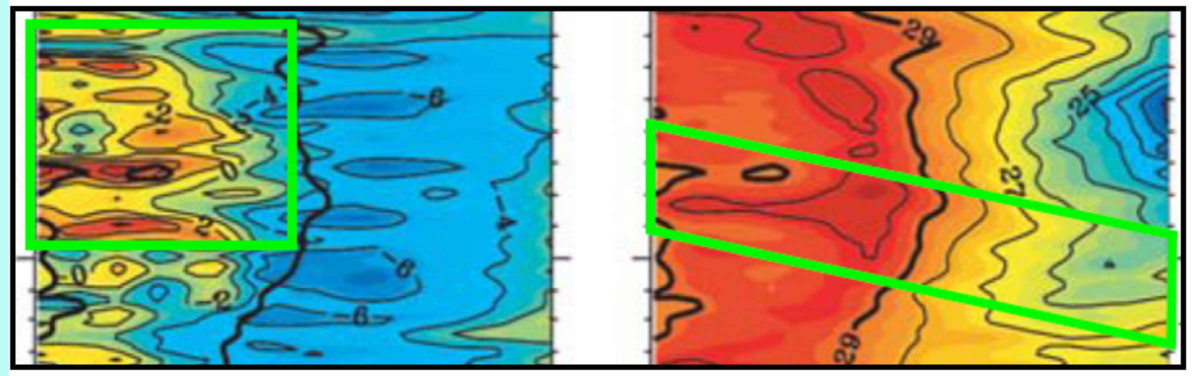
intraseasonal



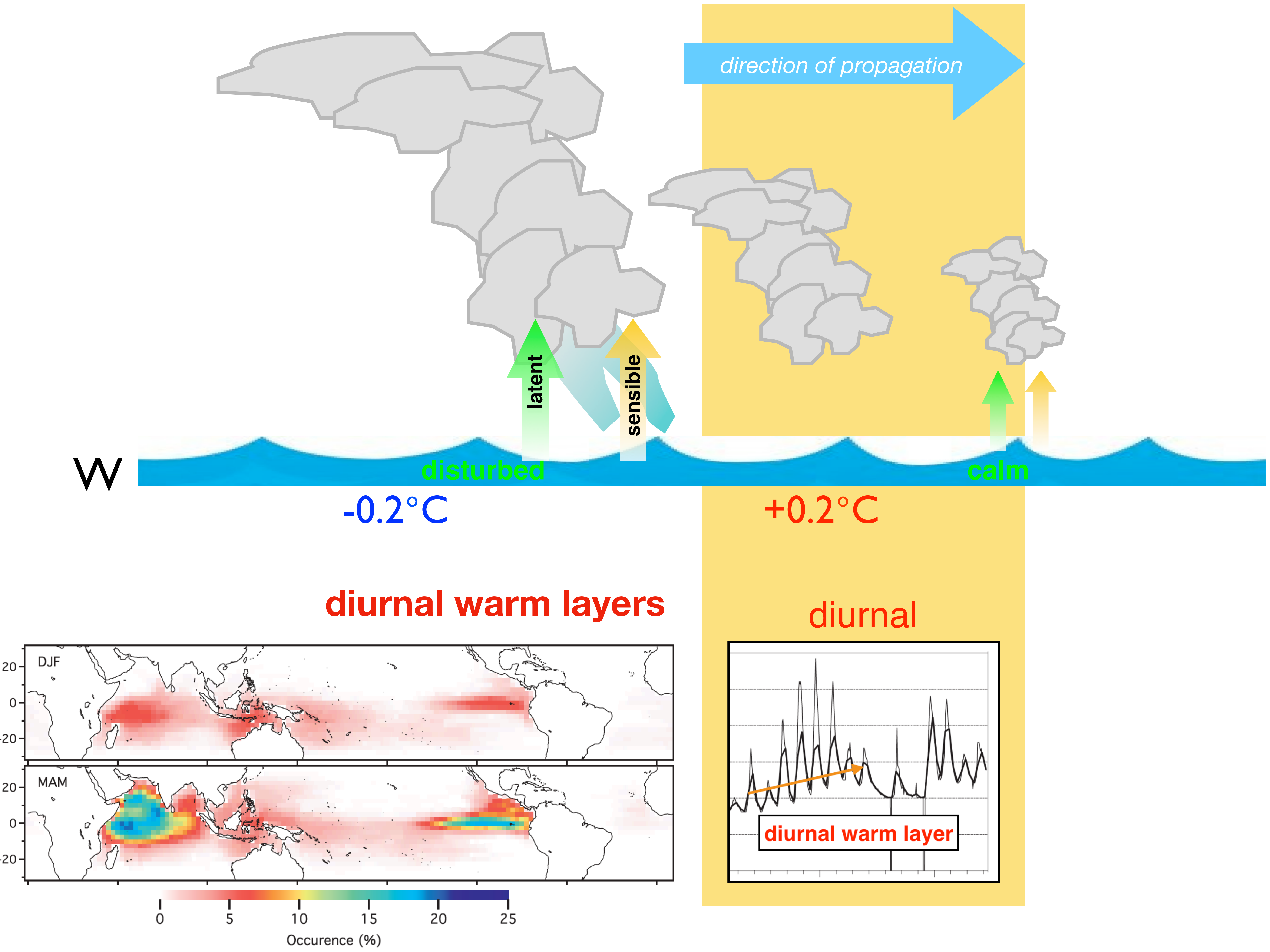
seasonal



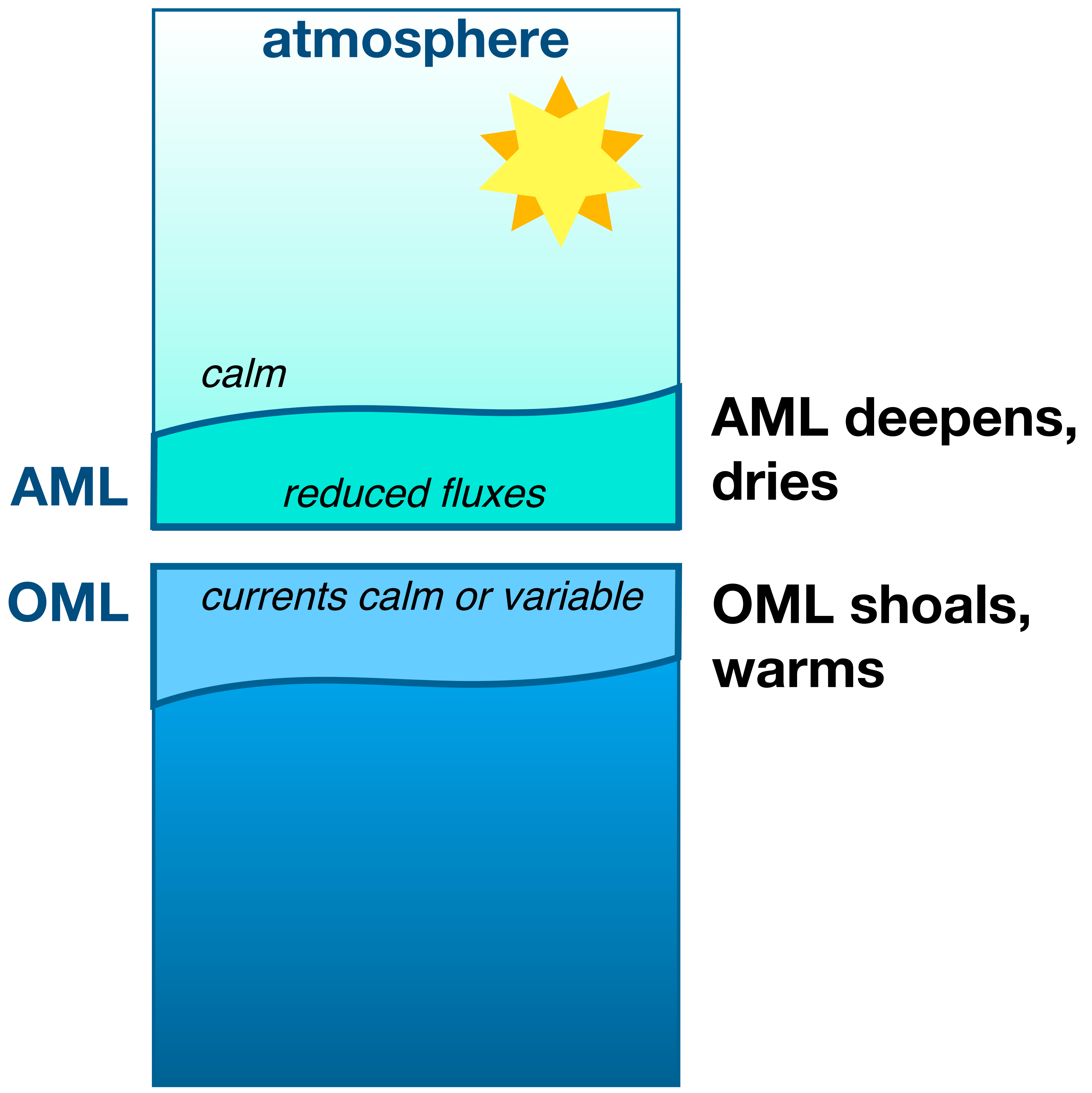
interannual



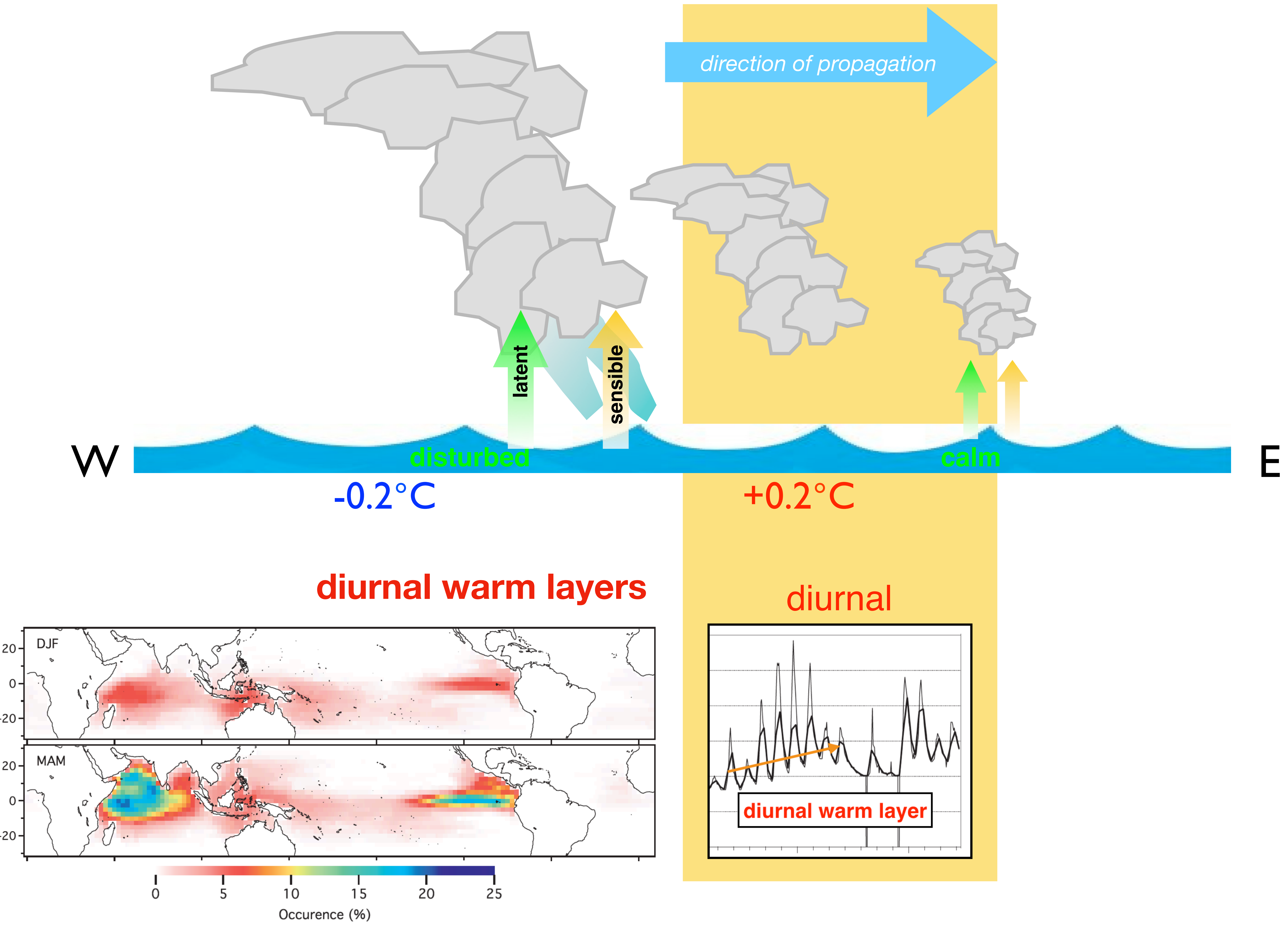
diurnal air-sea coupled processes



Bellenger and Duvel 2009



diurnal air-sea coupled processes



Bellenger and Duvel 2009

SUMMARY

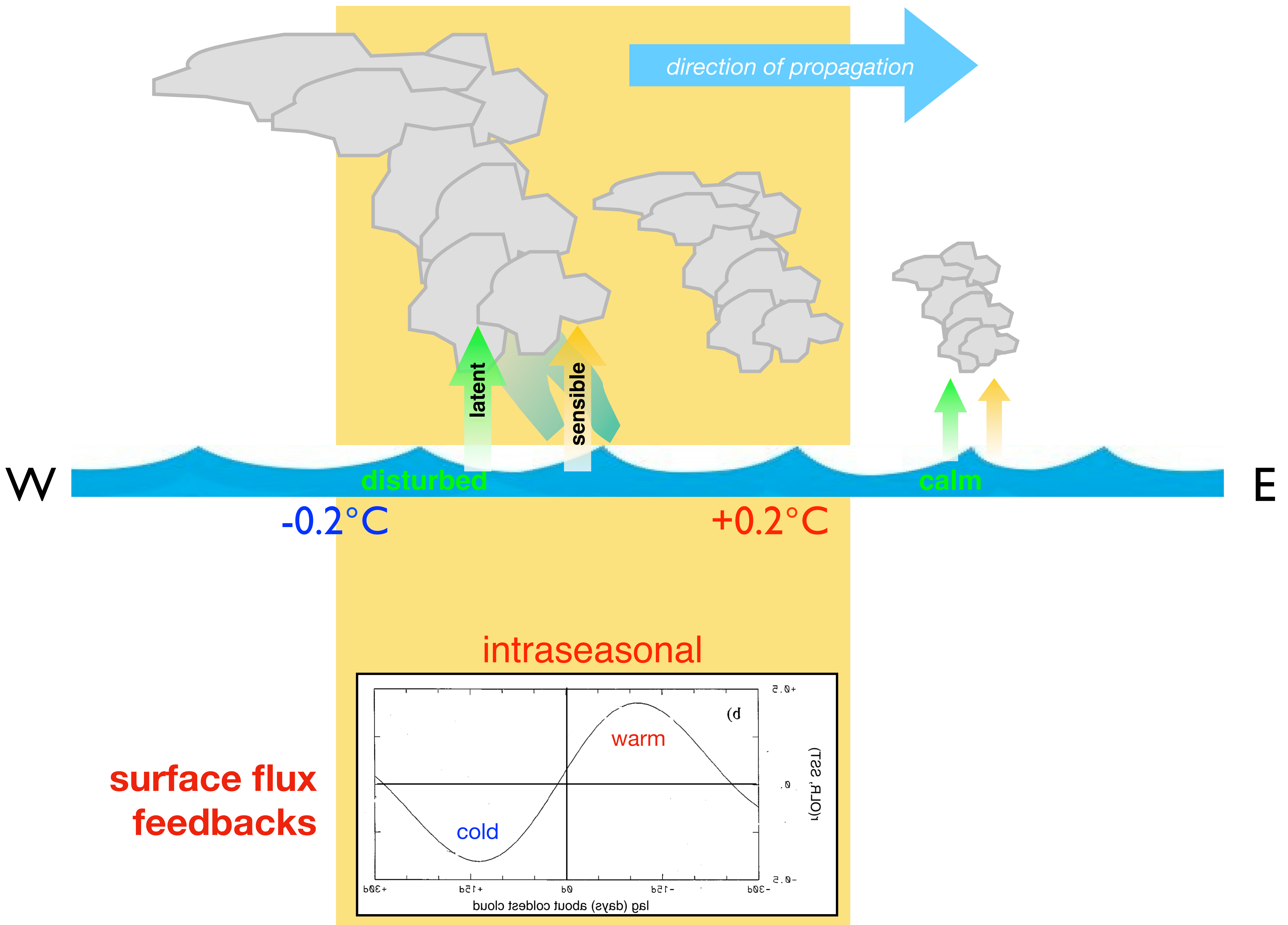
Ocean response depends upon:
- **light winds, large Q_{net}**
- **weak ocean currents?**
- **upper ocean stratification (salinity, T)**

Consequences for the atmosphere:
- **DWLs promote convective development, low-level convergence**
- **DWLs rectify onto intraseasonal SST'**
- **MJO propagation**

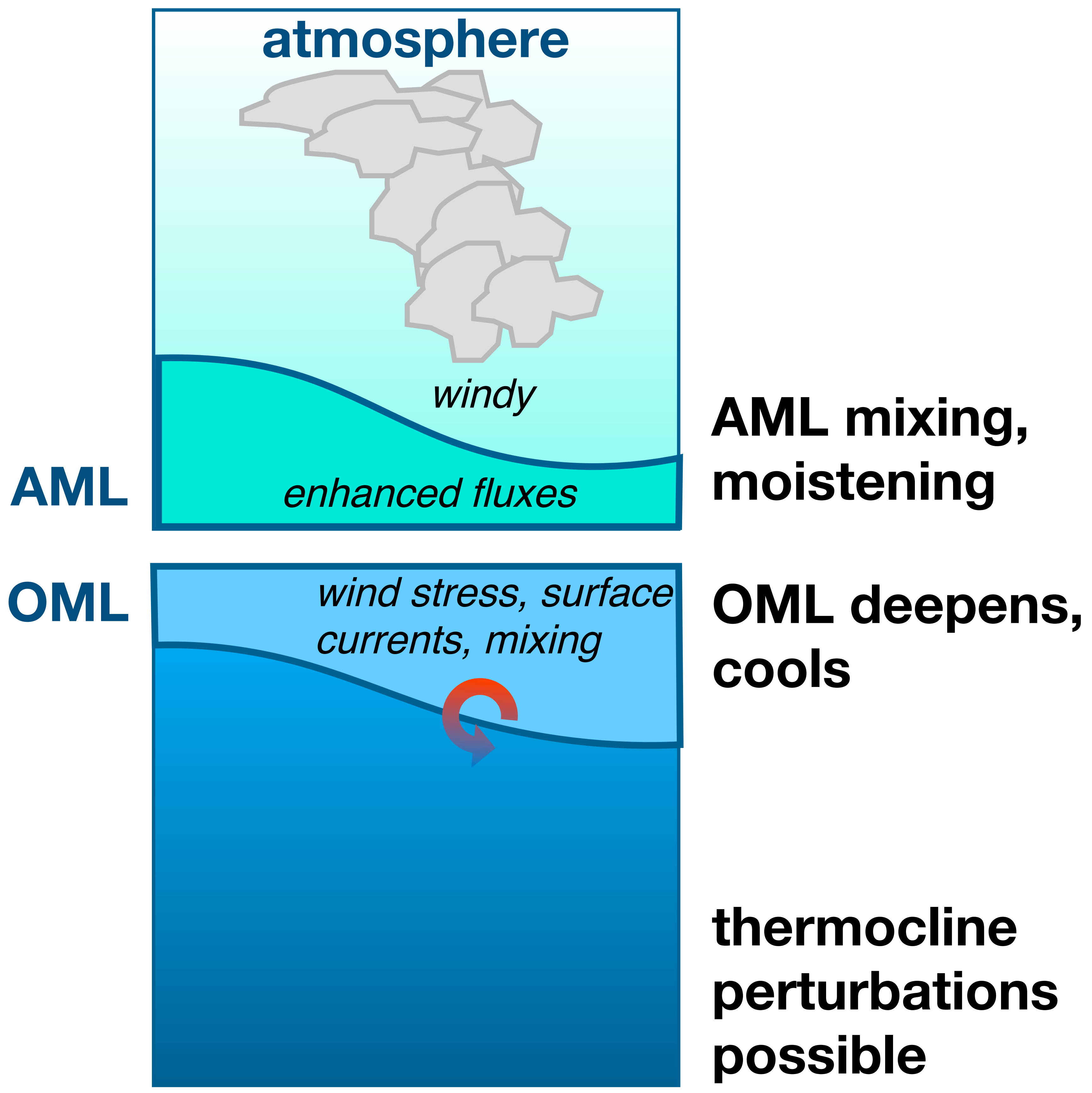
MODEL LIMITATIONS

- **insufficient vertical resolution of upper ocean**
- **insufficient coupling timestep**
- **wind speed, Qnet, rainfall biases (either too high or too low)**
- **convection too insensitive to column humidity**

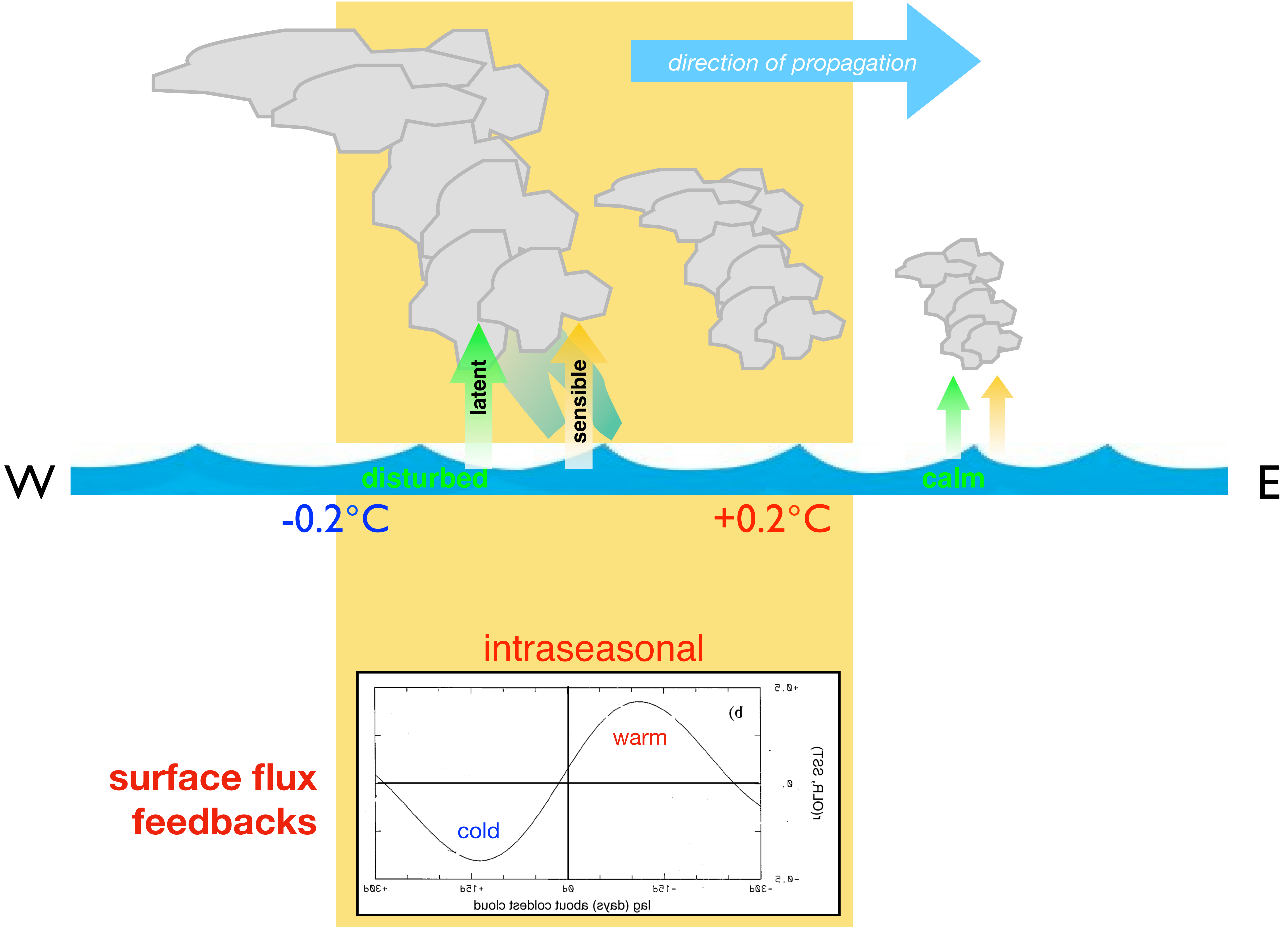
intraseasonal air-sea coupled processes



Hendon and Glick 1997



intraseasonal air-sea coupled processes



Hendon and Glick 1997

SUMMARY

Ocean response depends upon:

- wind speed, Q_{net}
- ocean currents
- upper ocean stratification (salinity, T)

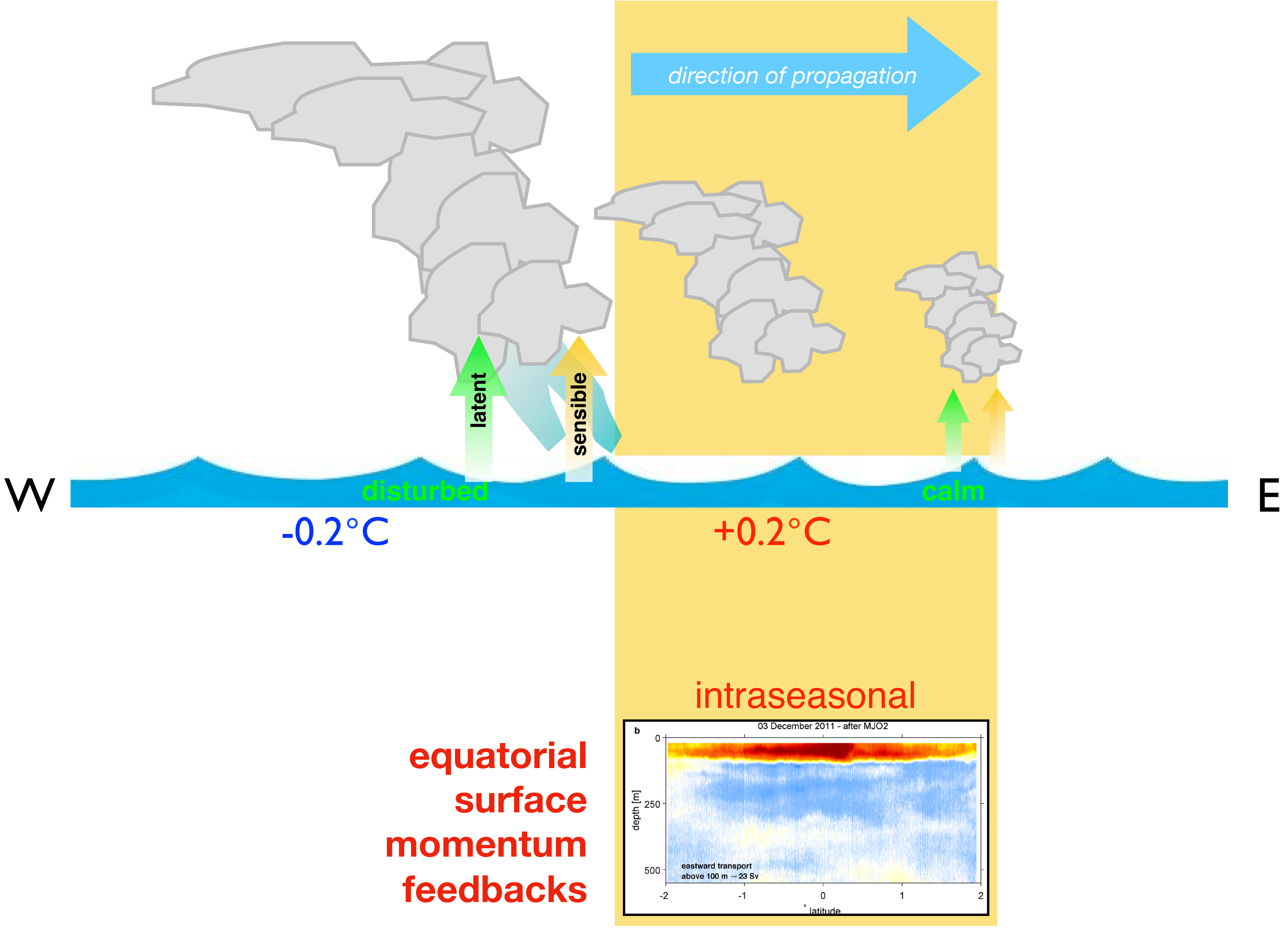
Consequences for the atmosphere:

- reduction of surface pressure over warm SST (MJO propagation)
- column moistening where it's rainy (MJO maintenance)
- reduced moistening west of convection (MJO propagation)

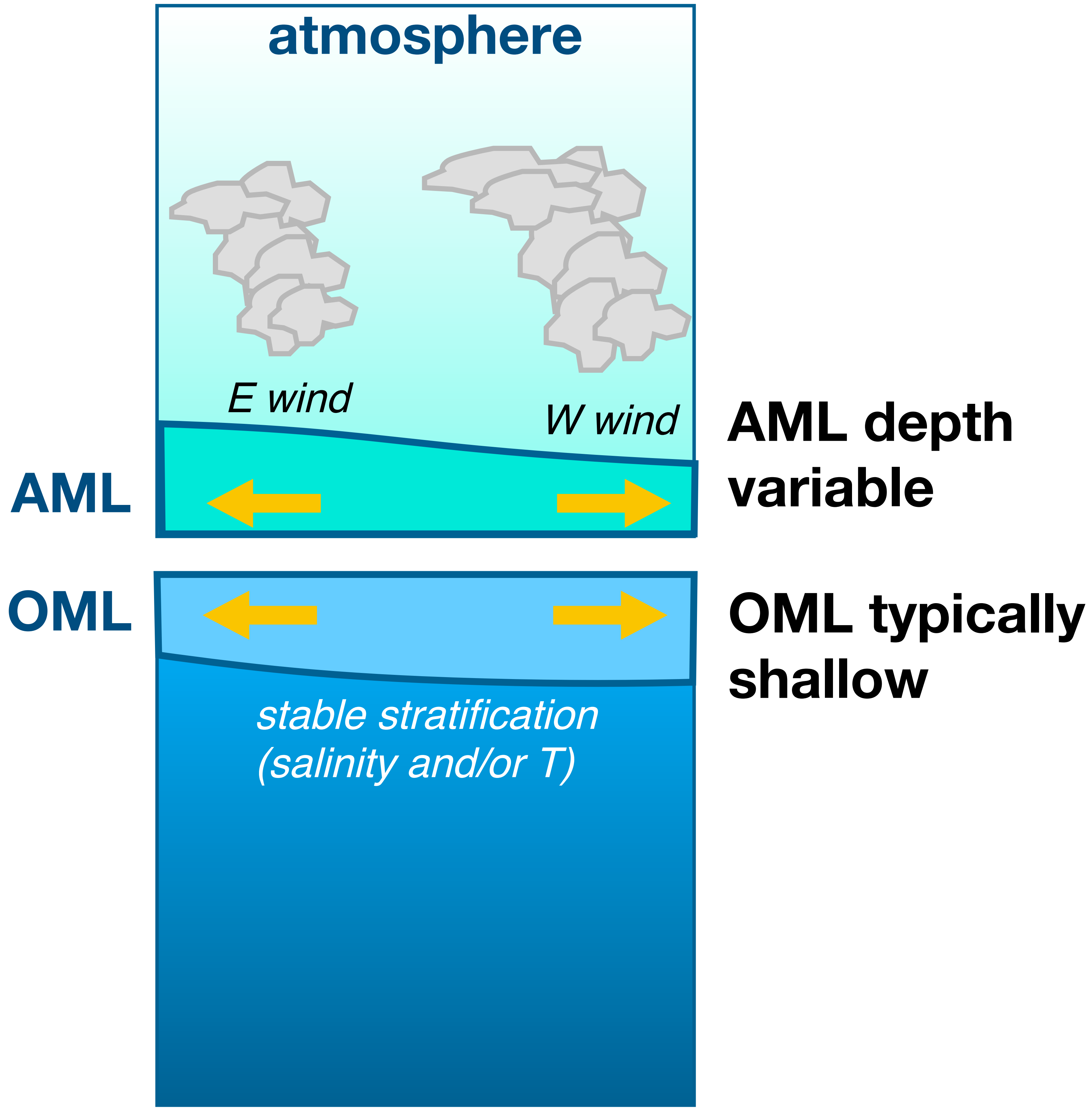
MODEL LIMITATIONS

- wind speed, AML humidity biases (either too high or too low)
- excessive column drying by atmospheric circulations
- weak cloud-radiation feedbacks

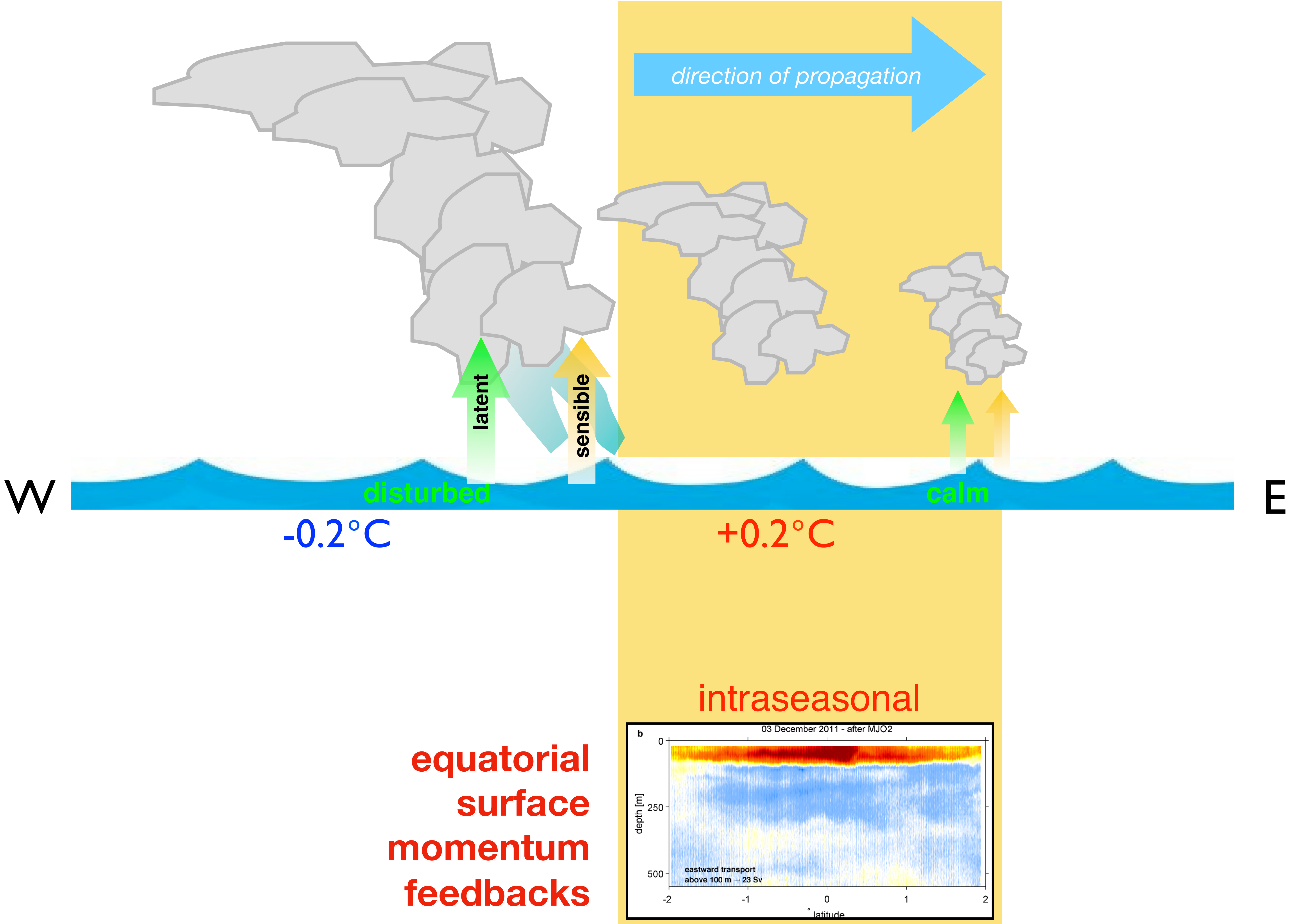
intraseasonal air-sea coupled processes



Moum et al. 2014



intraseasonal air-sea coupled processes



Moum et al. 2014

SUMMARY

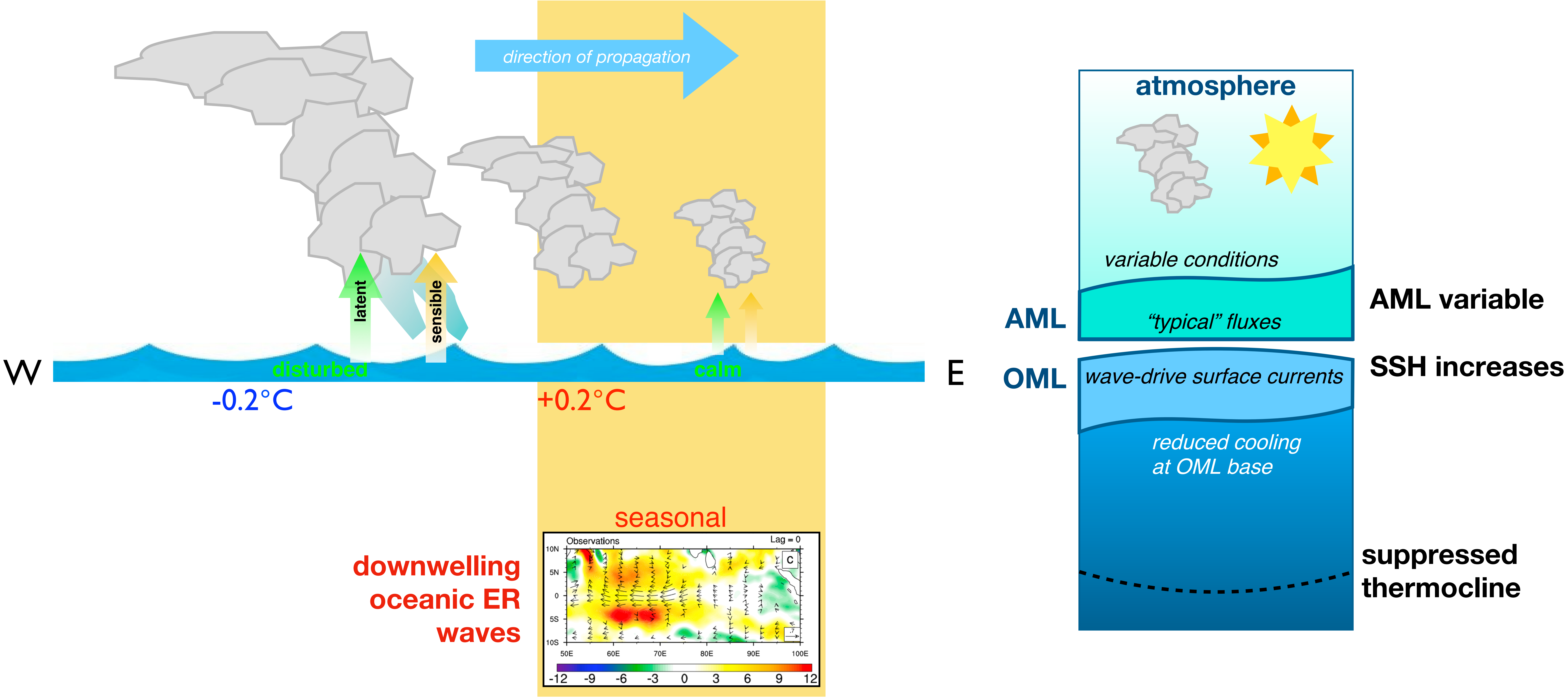
Ocean response depends upon:
- **direction of wind forcing (E or W)**
- **upper ocean stratification (salinity, T)**

Consequences for the atmosphere:
- **surface flux adjustments via wind stress-surface current interactions**
- **surface advection of warm or cold SST anomalies (Halkides et al. 2015)**
- **generation of strong, extensive SST gradients and low-level convergence (convective initiation; Back and Bretherton 2009)**

MODEL LIMITATIONS

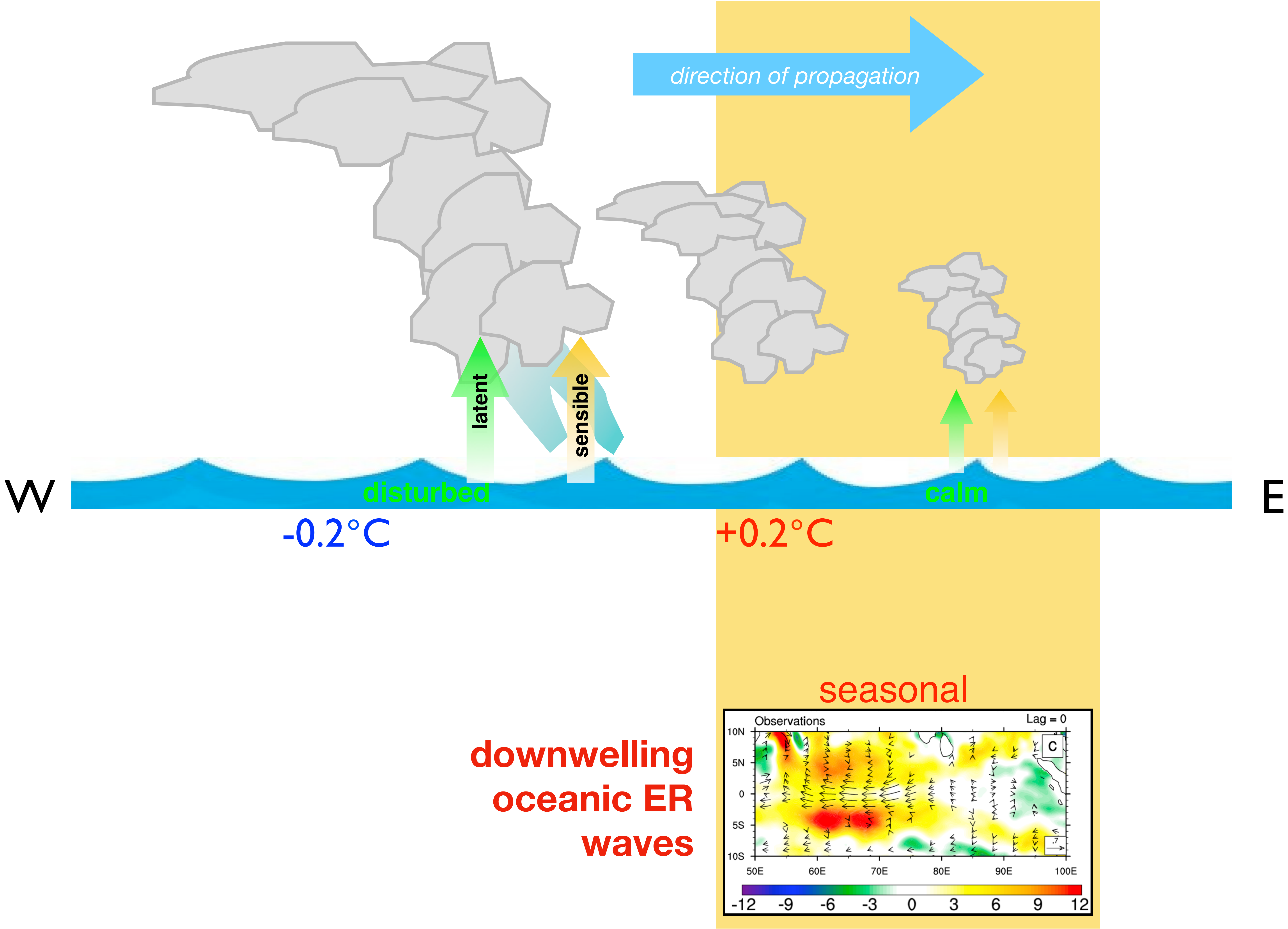
- **wind speed biases (either too high or too low)**
- **insufficient vertical resolution in ocean model**

seasonal air-sea coupled processes



Rydbeck and Jensen 2017

seasonal air-sea coupled processes



Rydbeck and Jensen 2017

SUMMARY

Ocean response depends upon:

- persistent surface winds
- "piling up" of surface waters

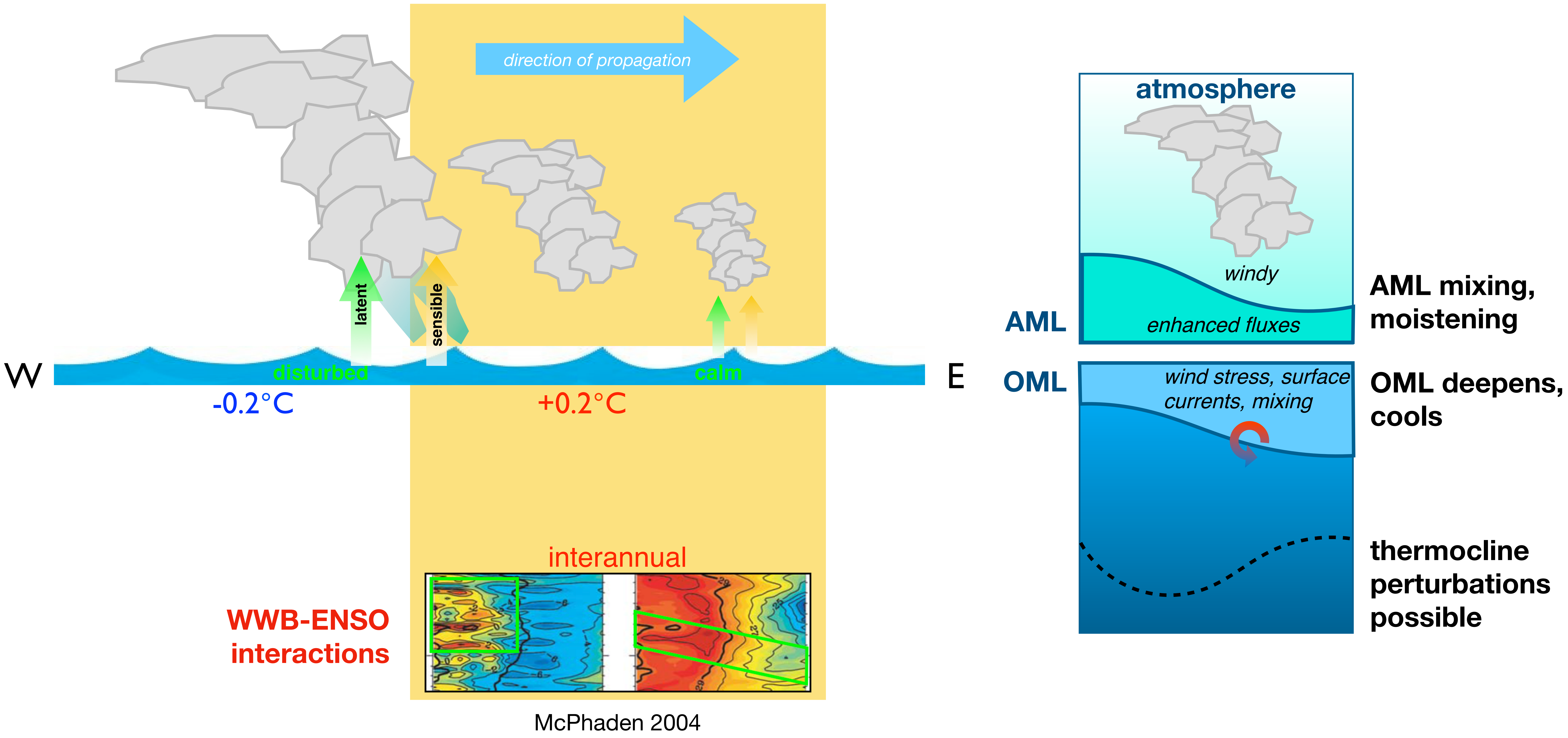
Consequences for the atmosphere:

- warm SSTs associated with ER waves have been associated with certain types of MJO initiation.

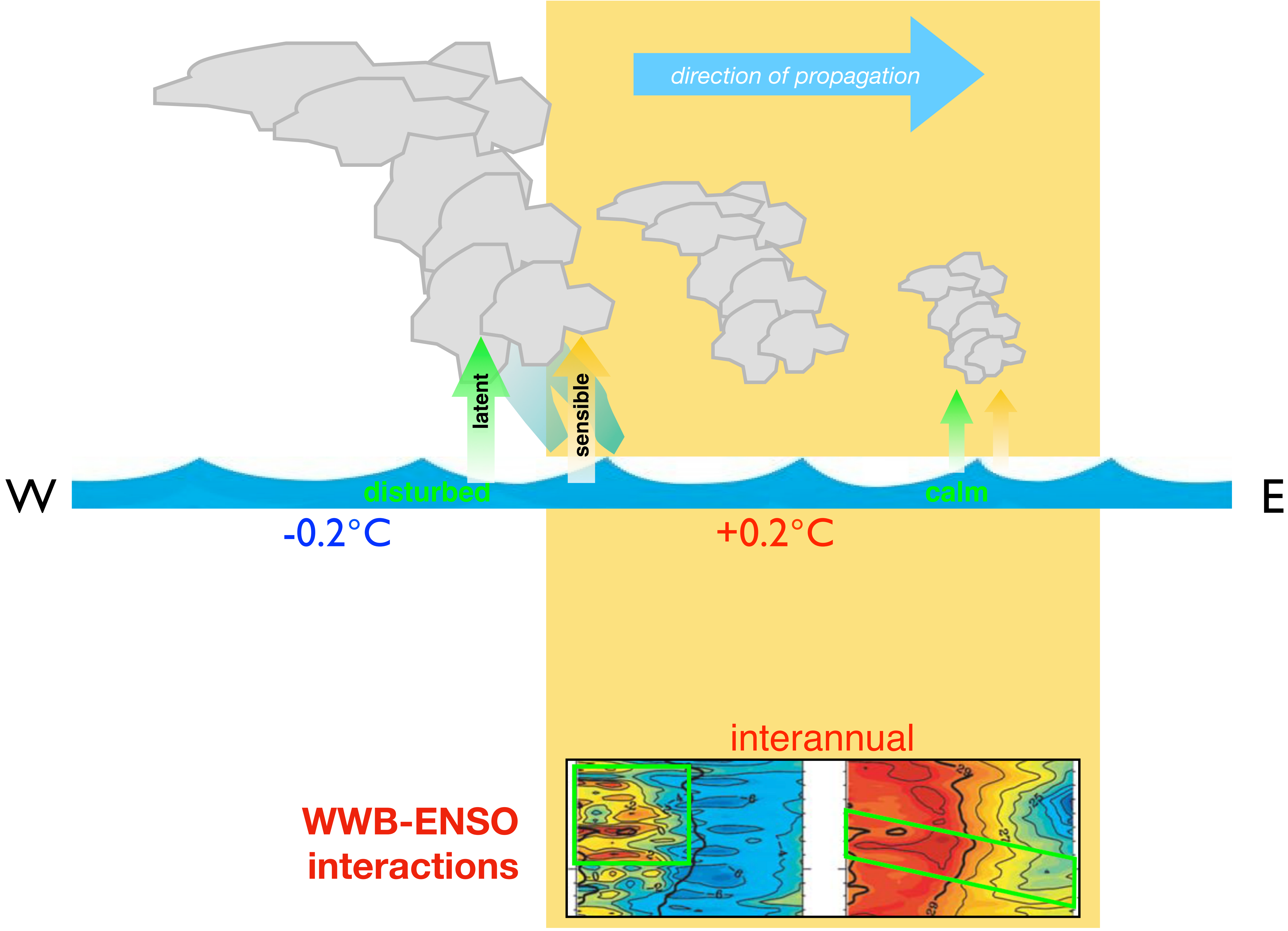
MODEL LIMITATIONS

- convective momentum transport biases (either too high or too low)
- ocean horizontal resolution (at least for climate models)
- little work on these wave types in coupled climate models

interannual air-sea coupled processes



interannual air-sea coupled processes



McPhaden 2004

SUMMARY

Ocean response depends upon:
- **MJO convection reaching the western Pacific**
- **sufficiently strong WWB (possibly multiple)**

Consequences for the atmosphere:
- **significant modulation of mean state moisture and MJO propagation (DeMott et al. 2018)**

MODEL LIMITATIONS

- **an exaggerated "barrier effect" of the Maritime Continent for MJO propagation**
- **convective momentum transport biases (too high or too low)**
- **coupled air-sea processes at the edge of the Warm Pool? (see next talk)**

summary of MJO coupled processes

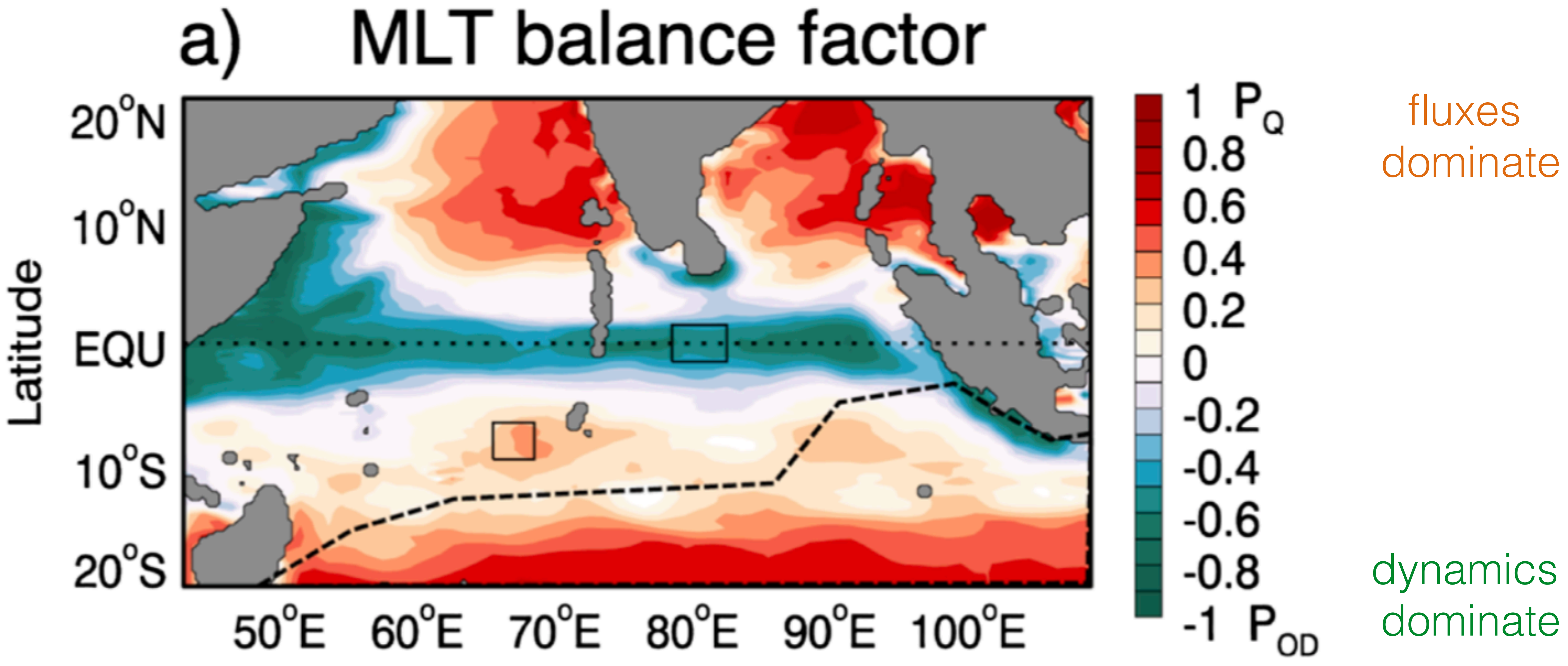
	Diurnal	Intraseasonal (fluxes)	Intraseasonal (momentum)	Seasonal	Interannual
key atmospheric conditions	calm winds low cloudiness	alternating periods of suppressed and active convection	multiple days of persistent easterly or westerly winds	multiple days of easterly (ER) or westerly (KW) winds	MJO in WPac, WWB
key ocean dependencies	reduced currents OML shoaling	regulated by surface currents, stratification	upper ocean stratification	reduced upper ocean stratification?	deep mixing or surface advection?
observational gaps	high-frequency stratification measurements	high-frequency AML humidity, ocean stratification	high vertical resolution stratification measurements		ocean stratification
model shortcomings	convection-humidity biases, ocean resolution, coupling frequency	convection-humidity biases (BL, free trop), ocean resolution, coupling frequency	MJO fidelity, ocean vertical resolution	coarse ocean horizontal resolution, insufficient study	MJO fidelity, WPac coupled processes?

summary of MJO coupled processes

	Diurnal	Intraseasonal (fluxes)	Intraseasonal (momentum)	Seasonal	Interannual
key atmospheric conditions	calm winds low cloudiness	alternating periods of suppressed and active convection	multiple days of persistent easterly or westerly winds	multiple days of easterly (ER) or westerly (KW) winds	MJO in WPac, WWB
key ocean dependencies	reduced currents OML **shoaling**	regulated by surface currents, **stratification**	upper ocean **stratification**	reduced upper ocean **stratification**?	deep mixing or surface advection?
observational gaps	high-frequency **stratification** measurements	high-frequency AML **humidity**, ocean **stratification**	high vertical resolution **stratification** measurements		ocean **stratification**
model shortcomings	convection-**humidity** biases, ocean **resolution**, coupling frequency	convection-**humidity** biases (BL, free trop), ocean **resolution**, coupling frequency	MJO fidelity, ocean vertical **resolution**	coarse ocean horizontal **resolution**, insufficient study	MJO fidelity, WPac coupled processes?

extra slides

SST cooling: fluxes vs dynamics



Halkides et al. (2015)

air-sea interaction diagnostics

Air Sea Interactions Diagnostic Plots

Page developed by M. Burt and C. DeMott

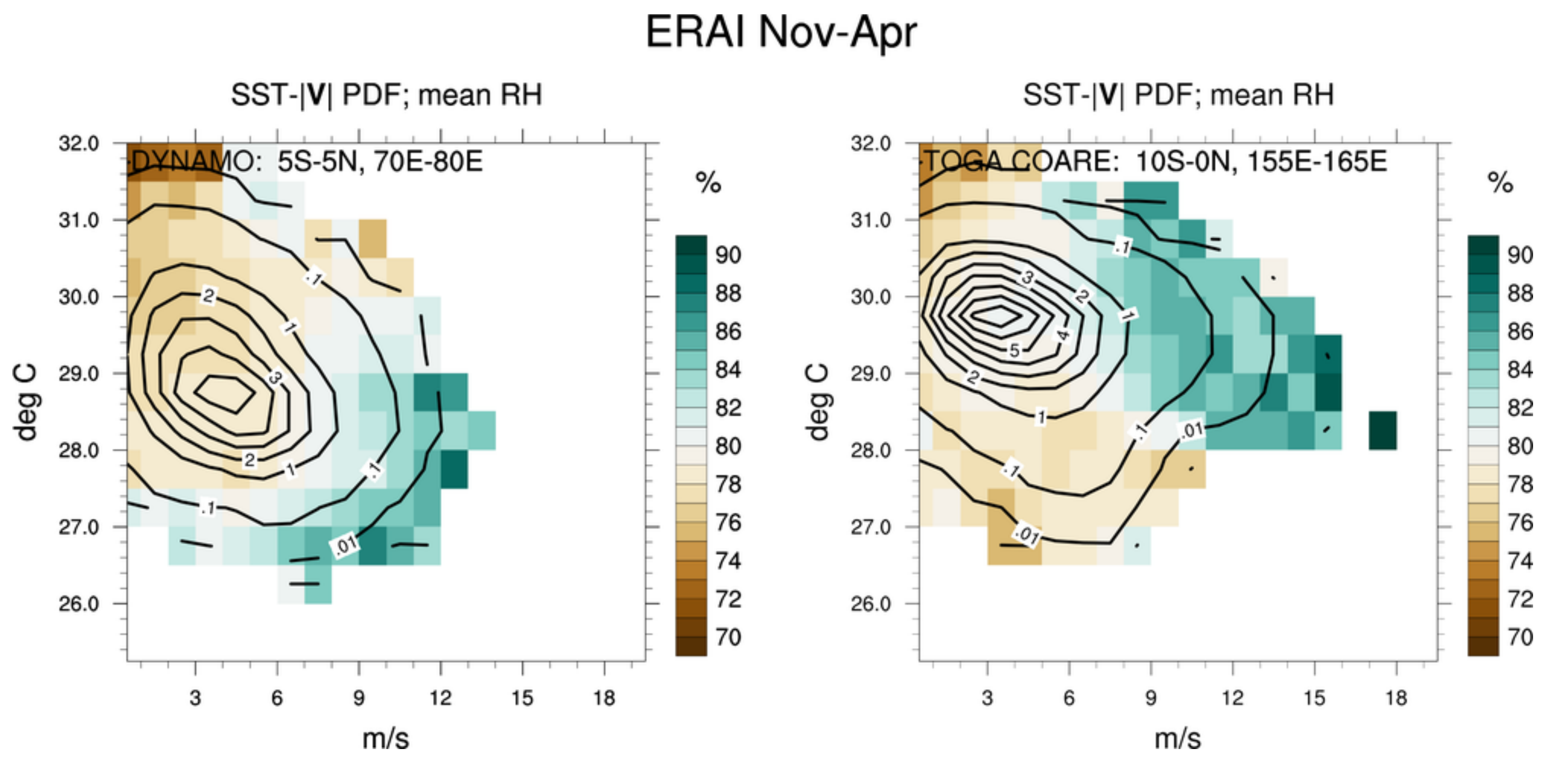
created on Wed Apr 4 19:50:07 UTC 2018

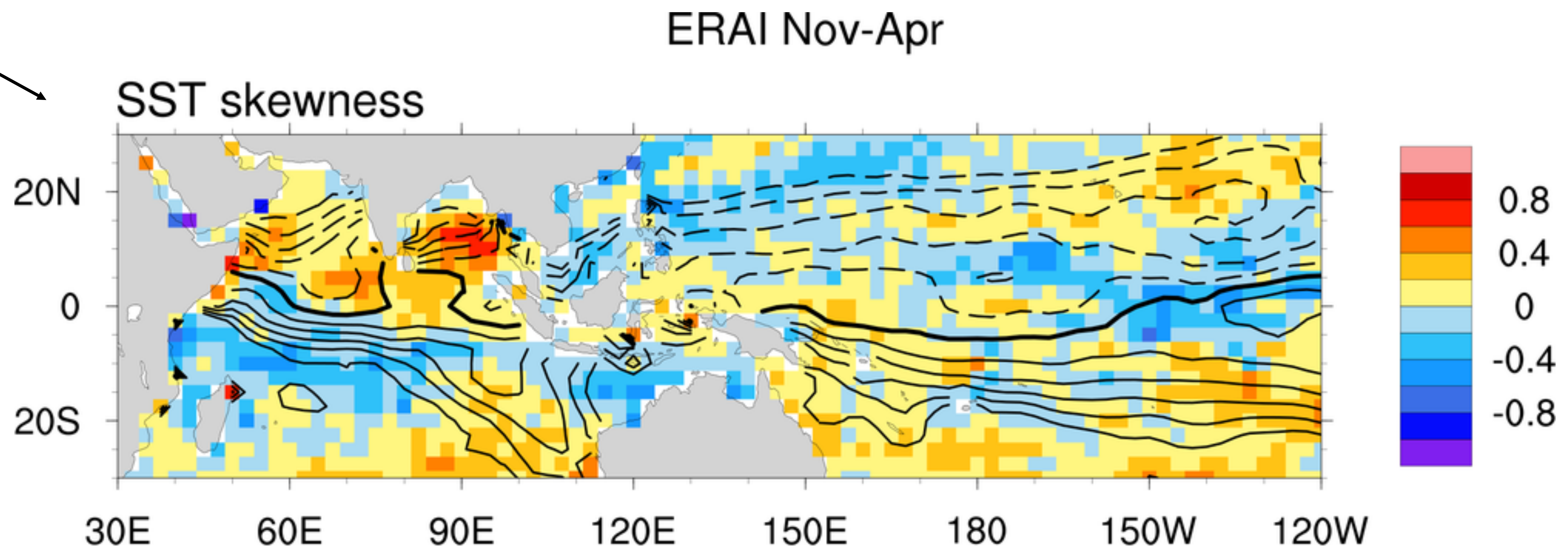
ERAI

Level 1 Diagnostics	May-Oct	Nov-Apr
Rain Wind SST Flux	plot	plot
Surface Energy Budget	plot	plot
LH Flux Component Std diff	plot	plot
SH Flux Component Std diff	plot	plot
LH Flux Component Stdev Ratio	plot	plot
SH Flux Component Stdev Ratio	plot	plot
RH by Wind SST PDF	plot	plot
U850 Westerly Percent	plot	plot
MSE	plot	plot
SST skewness	plot	plot

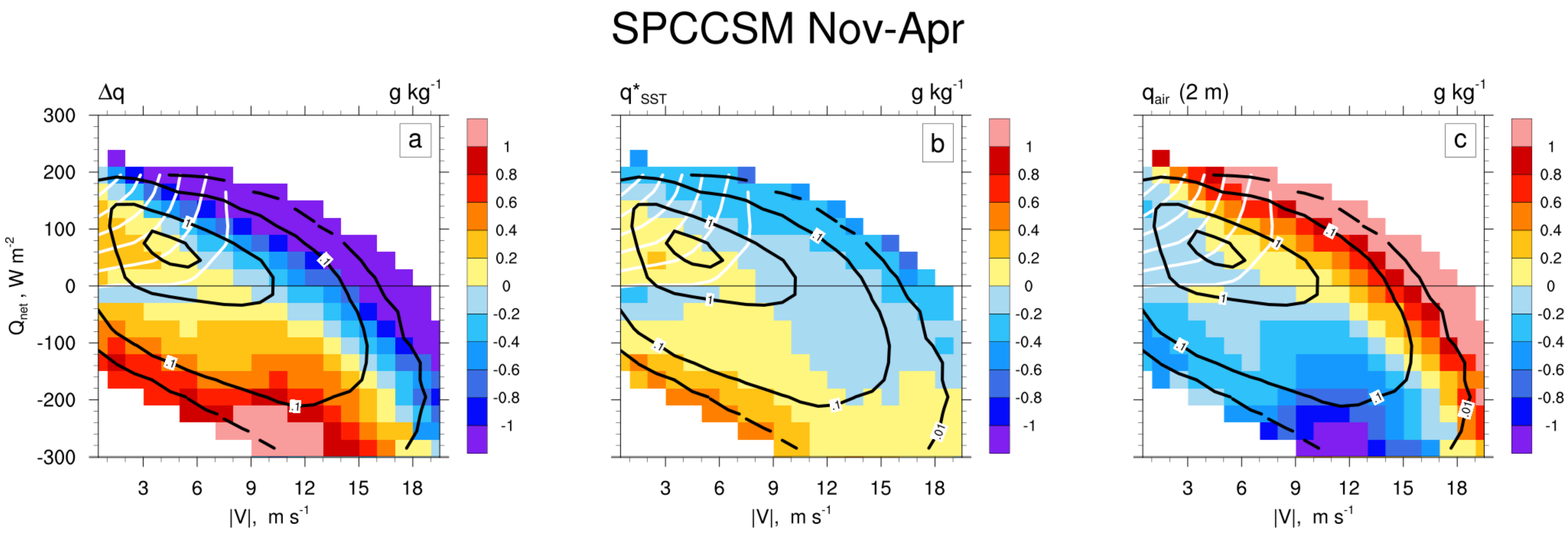
Level 2 Diagnostics	May-Oct	Nov-Apr
MSE Budget prop	plot	plot
LH Flux Component prop	plot	plot
SH Flux Component prop	plot	plot
Surface Energy Balance prop	plot	plot
MSE Budget (no prop)	plot	plot
LH Flux Component (no prop)	plot	plot
SH Flux Component (no prop)	plot	plot
Surface Energy Balance (no prop)	plot	plot
SST Effect Rain LH lags	plot	plot
SST Effect Rain SH lags	plot	plot
SST Effect (no prop)	plot	plot
Surface Energy Lags	plot	plot
Rainfall Wheeler-Kiladis plots (Sym)	plot	
Rainfall Wheeler-Kiladis plots (Asym)	plot	

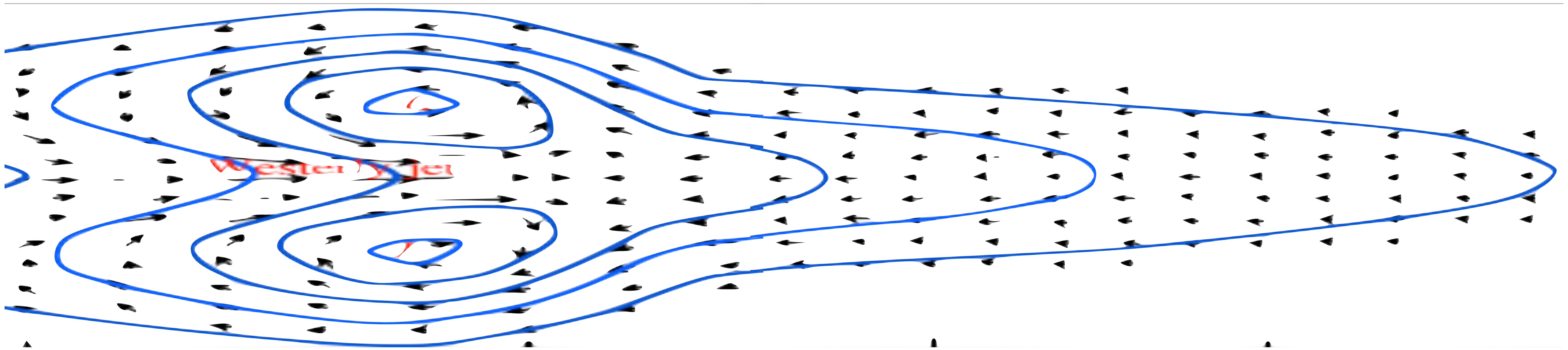
Level 3 Diagnostics	May-Oct	Nov-Apr
MSE Budget Regression	plot	plot
dMSEdt LH Flux Comp regressions	plot	plot
dMSEdt SH Flux Comp regressions	plot	plot
MSE LH Flux Comp regressions	plot	plot
MSE SH Flux Comp regressions	plot	plot
Qnet dSSTdt regression map	plot	plot
SST Effect Summary	plot	plot
MSE Budget PDF Line	plot	plot
MSE Mod Projection Maps	plot	plot





understanding fluxes in your model




Westerly jet