Contrasting response of Indian summer monsoon rainfall and Arabian Sea Upwelling to orbital forcing

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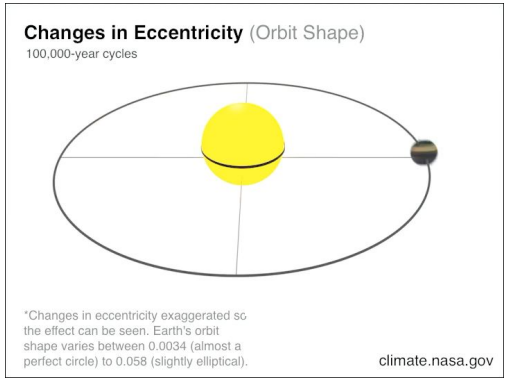
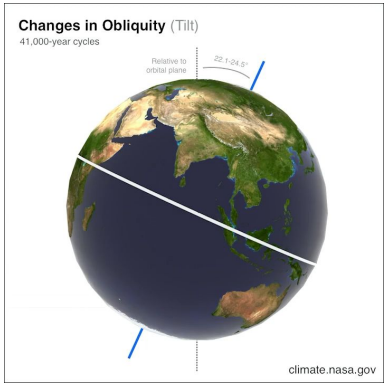
Orbital scale forcing

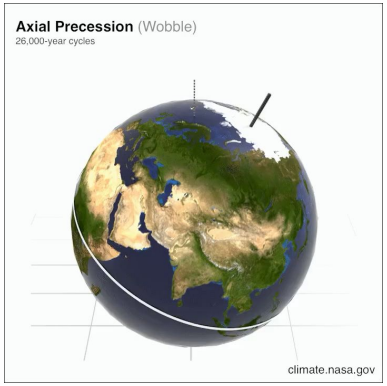
Eccentricity 100kyr

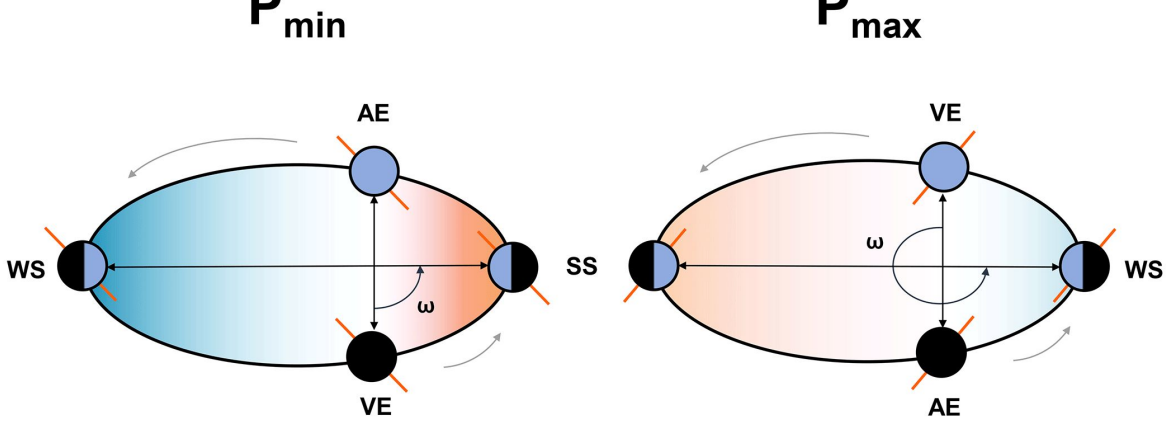


Obliquity 40kyr



Precession 20kyr



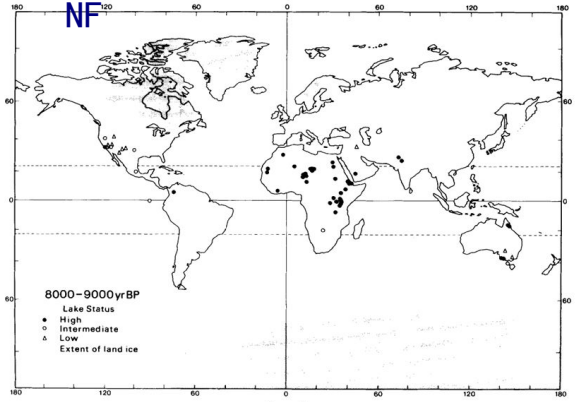


GCM 9ka-0

Space average	Surface temperature: 9000 years B.P. (°C)	Surface temperature: Modern (°C)	Surface temperature: Δ (K)	Surface temperature: S.L. (%)	Precipitation (cm/day): 9000 years B.P.	Precipitation (cm/day): Modern	Precipitation (cm/day): Δ	Precipitation (cm/day): S.L. (%)
T⇧ P⇧								
June to August								
Northern Hemisphere, land	24.5	23.8	0.7	1	0.45	0.41	0.04	5
Southern Hemisphere, land	2.0	1.7	0.3		0.47	0.45	0.02	
Global, land and ocean	17.7	17.5	0.2	5	0.35	0.35	0	

Kutzbach, 1981

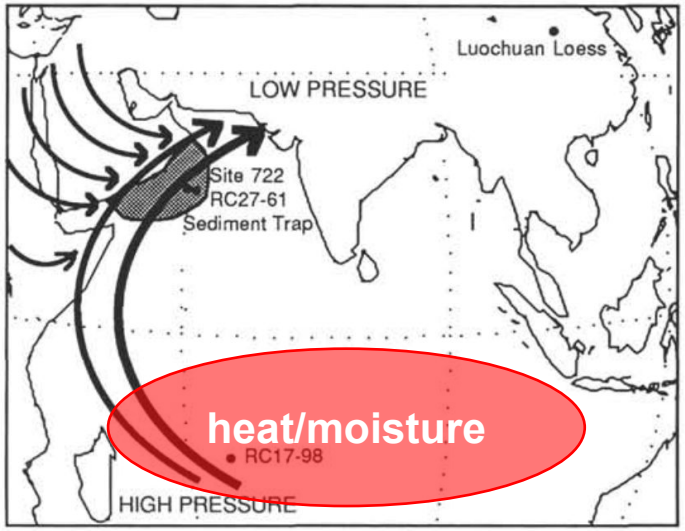
lake level proxies from NF



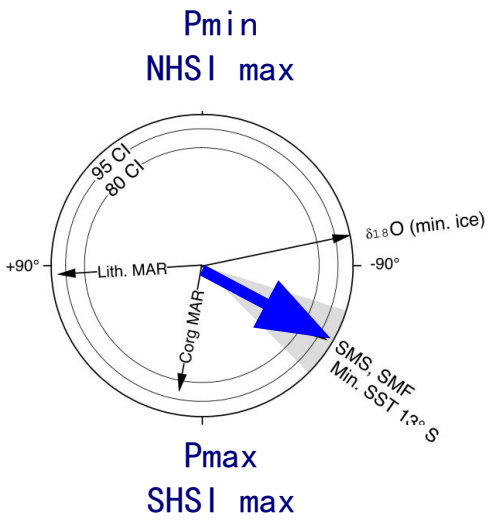
Street and Grove, 1978

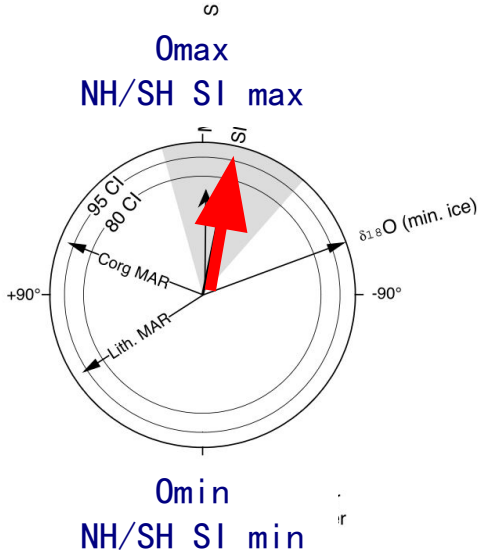
- NH summer insolation drives ASM

Arabian Sea upwelling



Clemens et al, 1991





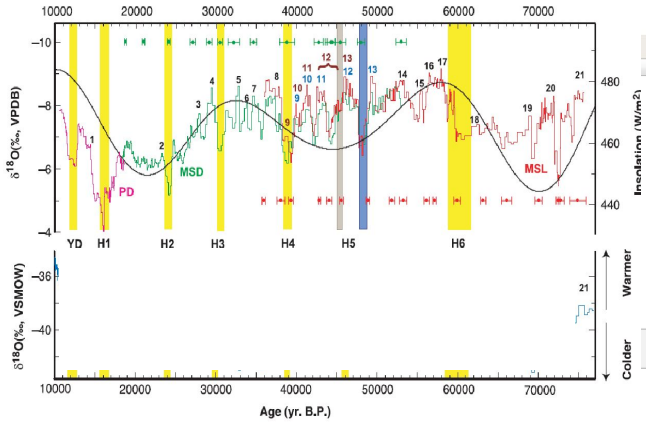
- SH summer insolation drives ASM via latent heat transport

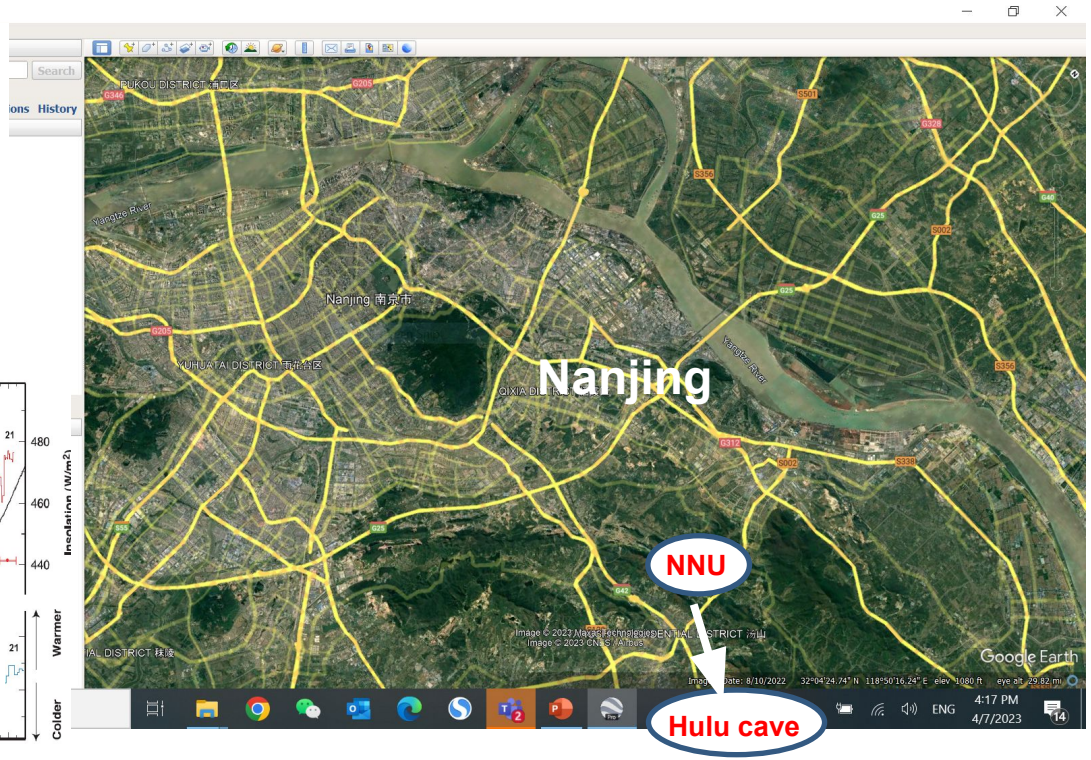
Hulu Cave

A High-Resolution Absolute-Dated Late Pleistocene Monsoon Record from Hulu Cave, China

Y. J. Wang,[1,3] H. Cheng,[2] R. L. Edwards,[2]* Z. S. An,[3] J. Y. Wu,[4] C.-C. Shen,[5] J. A. Dorale[6]

REPORTS





Wang et al, 2001

puzzling problem

1. What is the driving mechanism for ASM?

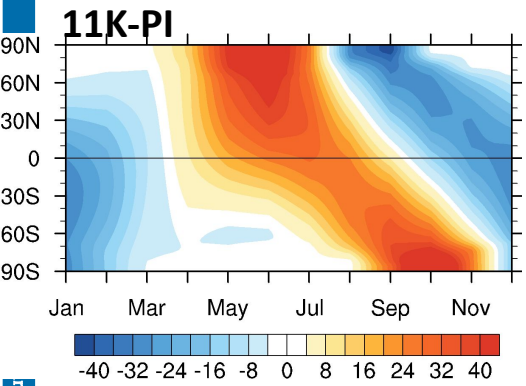
2. If the NHSI is responsible for the ASM, why Arabian Sea records have another type of features?

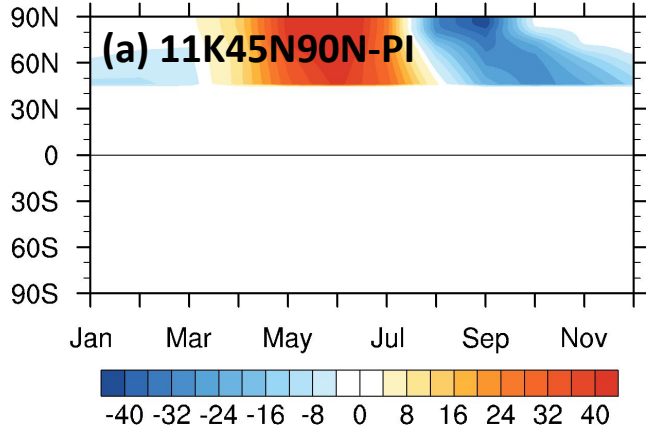
CESM1.2

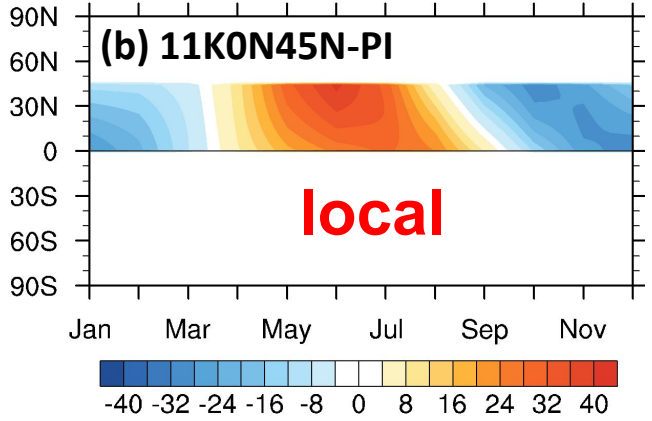
atm、lnd：1.9° x2.5°　ocn、cice：1°

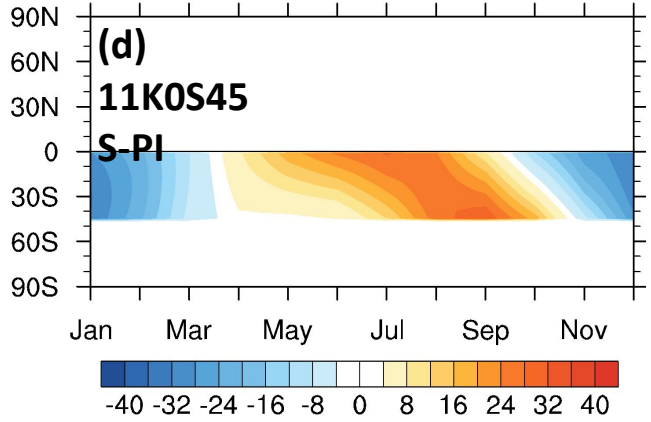
Orbital parameters:　11ka, PI

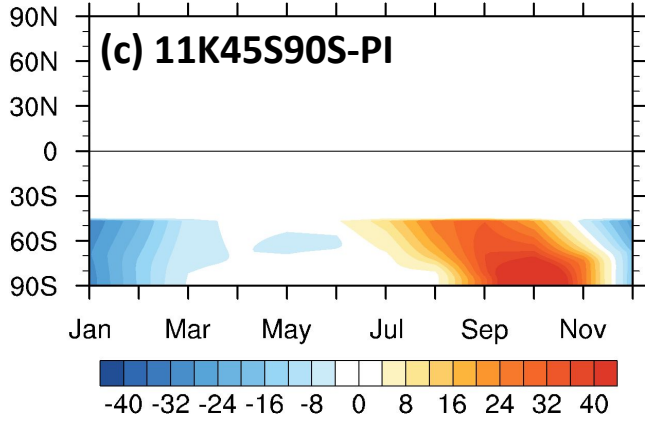
divide the insolation into 4 regions



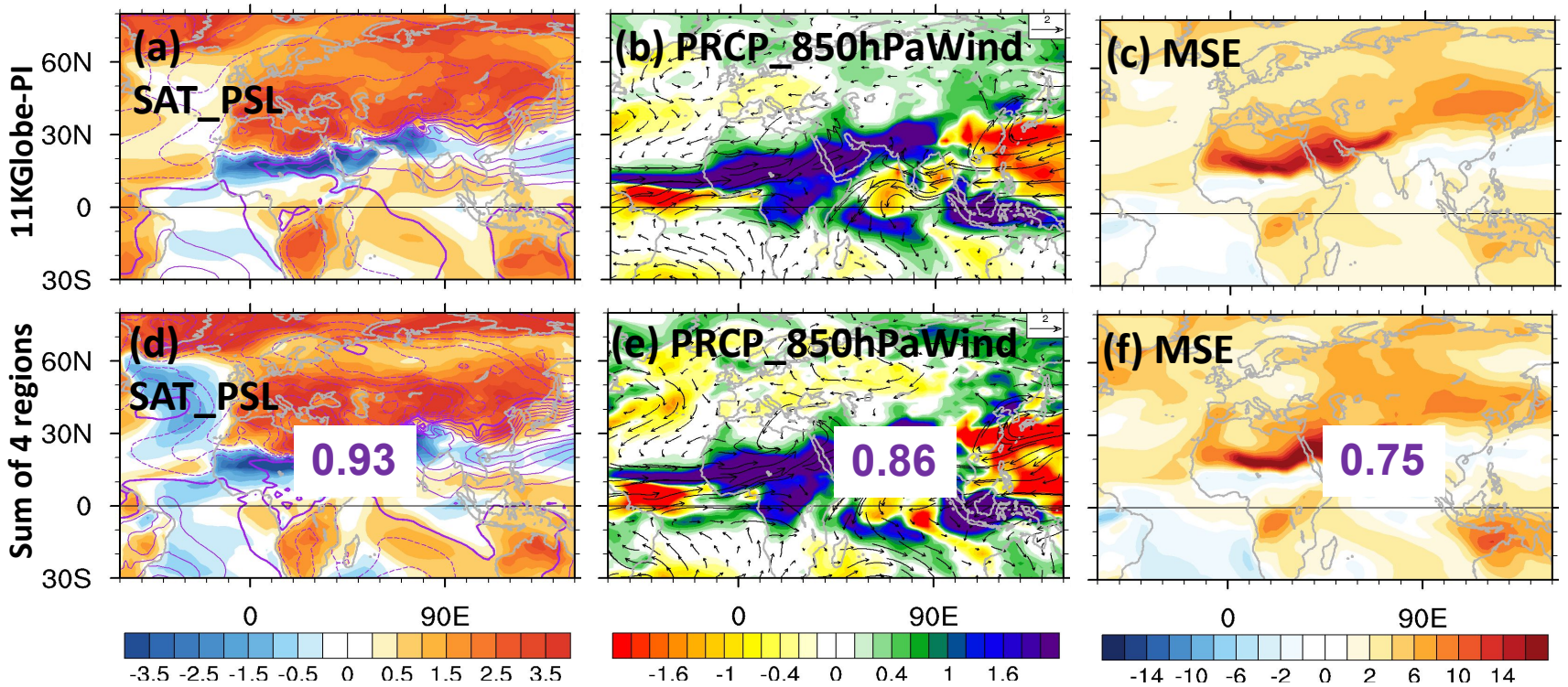








Monsoon climate is additive



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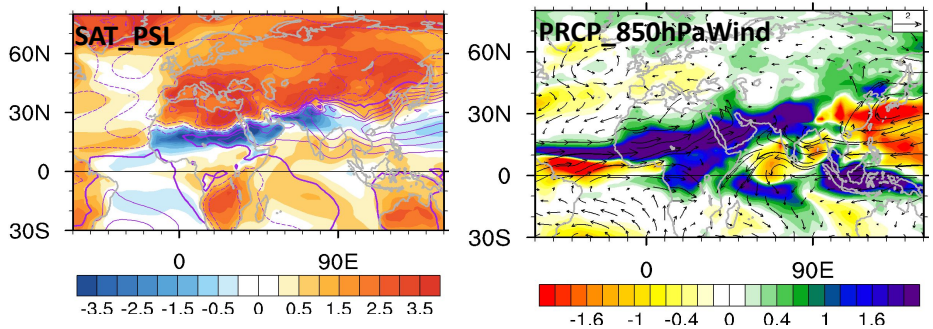
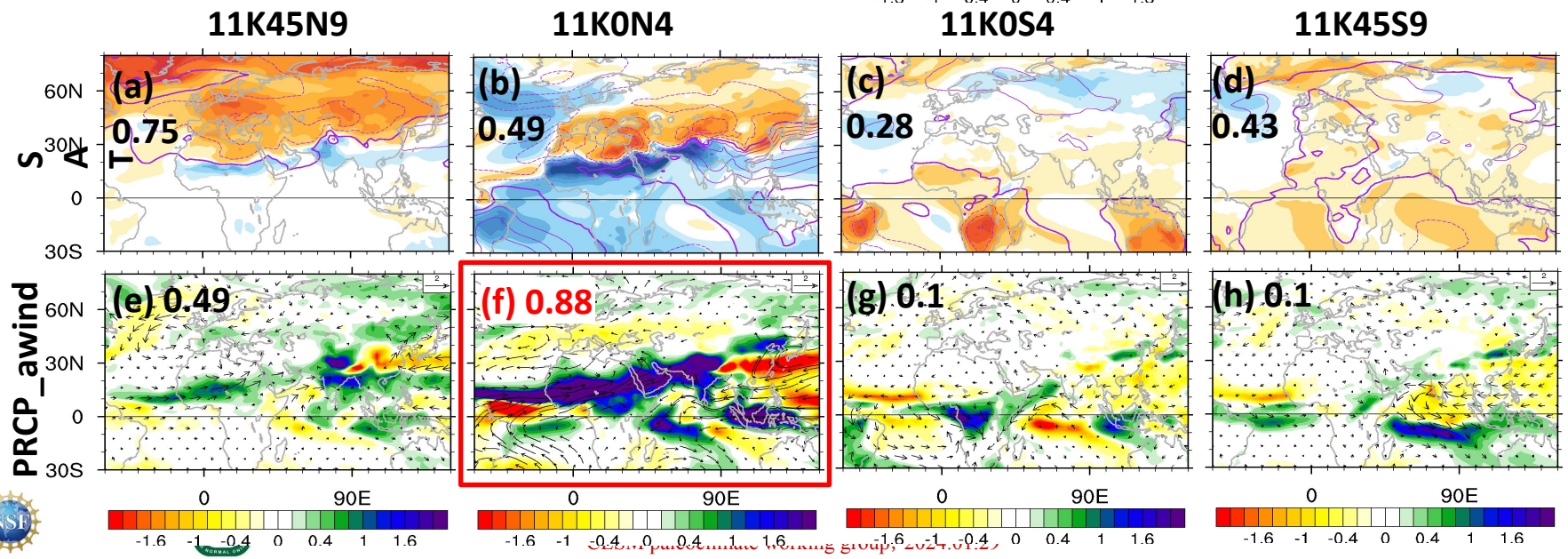
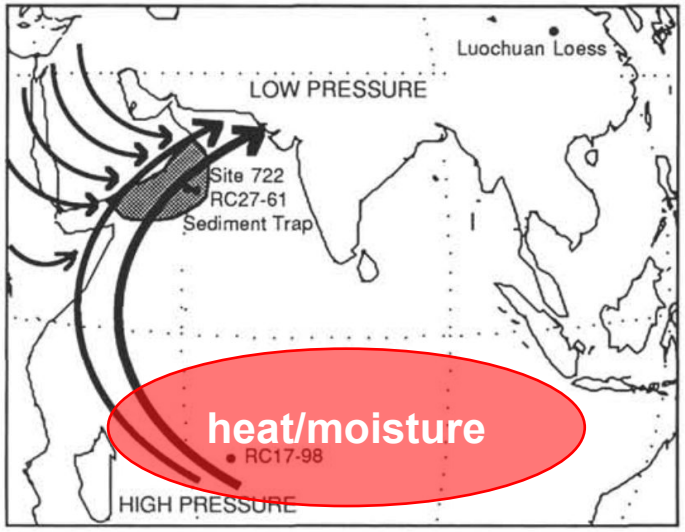
Local insolation drives ASM

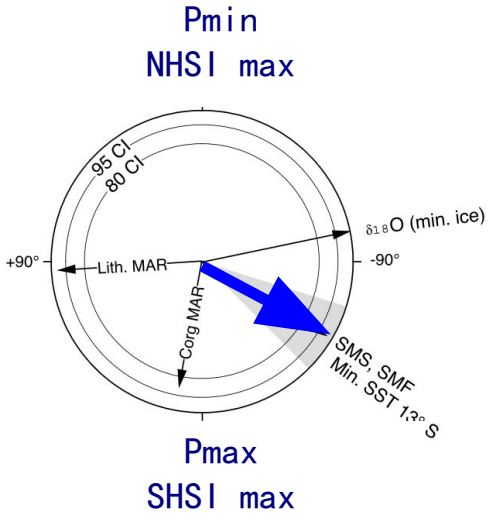


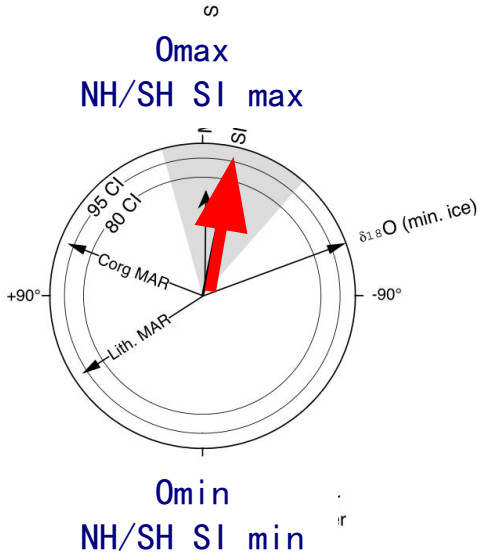


Arabian Sea upwelling



Clemens et al, 1991





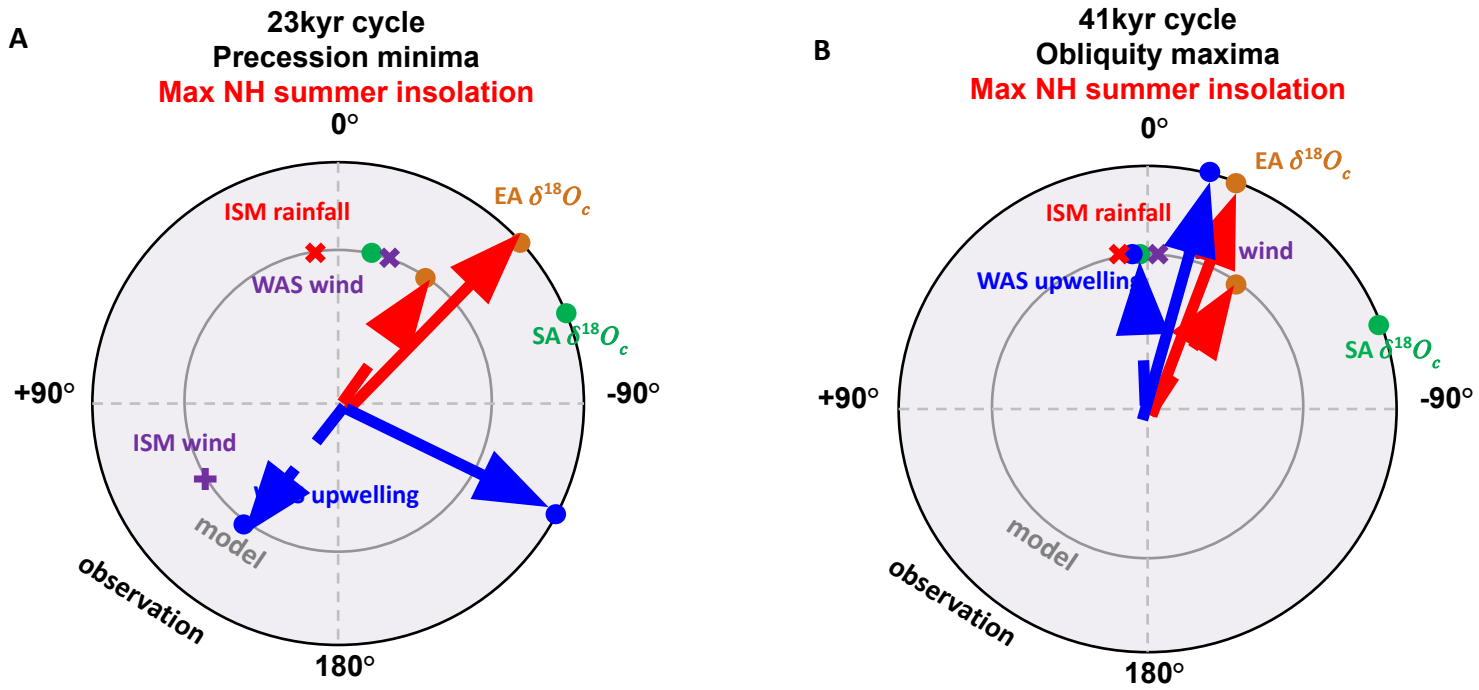
- SH summer insolation drives ASM via latent heat transport

iCESM

atm、lnd：1.9° x2.5°　ocn、cice：1°

Orbital parameters:　300kyr ago to present

100-year acceleration scheme



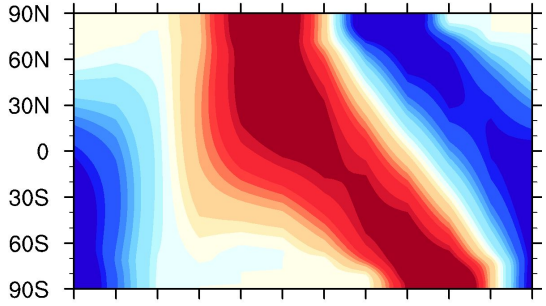
- ISM rainfall/isotope in-phase
- Arabian Sea upwelling out-phase in precession, in-phase in obliquity

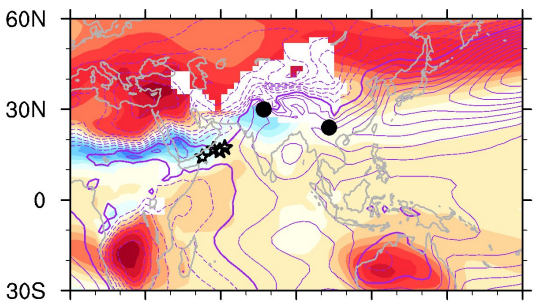
Insolation

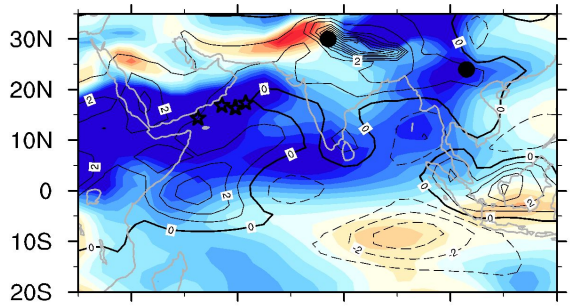
Temperature & SLP

Pmin-Pmax

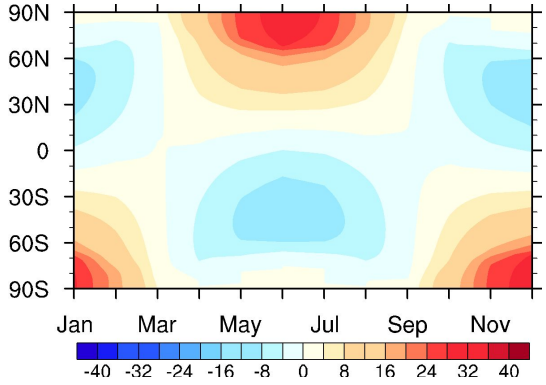
$\delta^{18}O_p$ (shading)& prcp(contours)

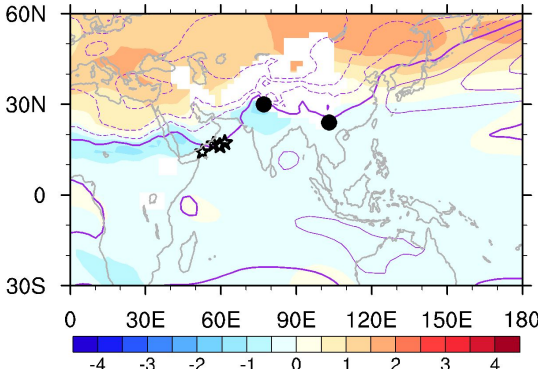


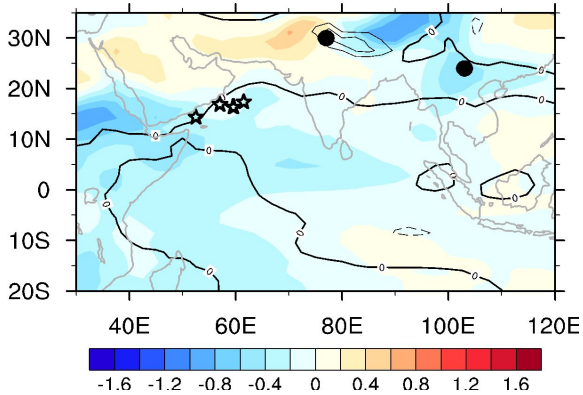




Omax-Omin







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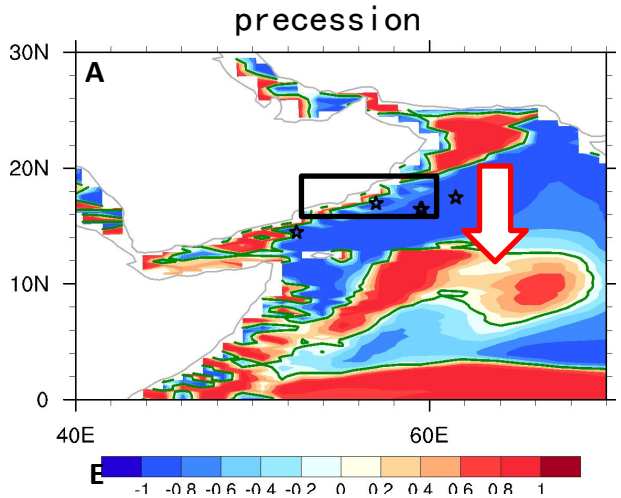
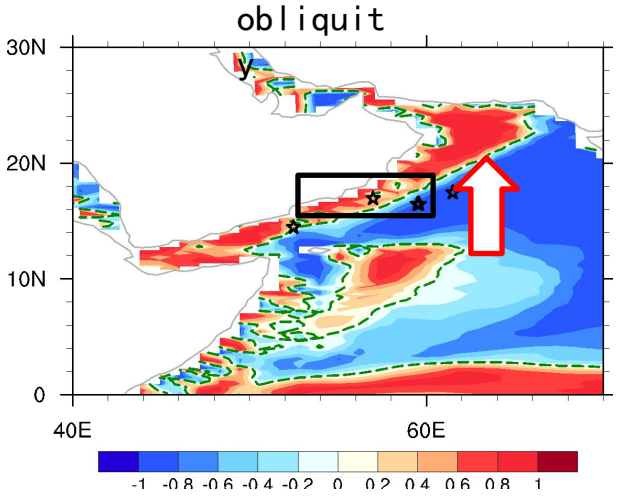
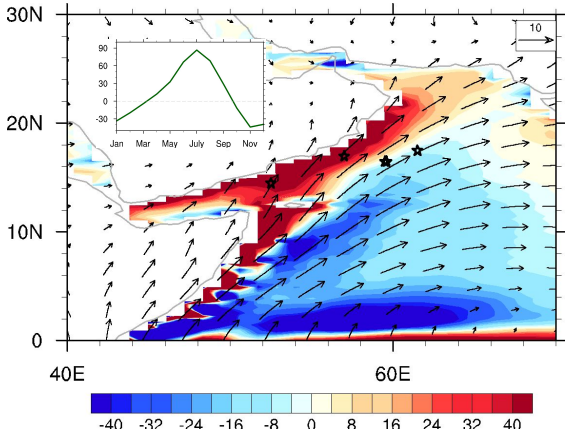

precession
A
30N
20N
10N
0
40E
60E
B
-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1


obliquit
y
30N
20N
10N
0
40E
60E
-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

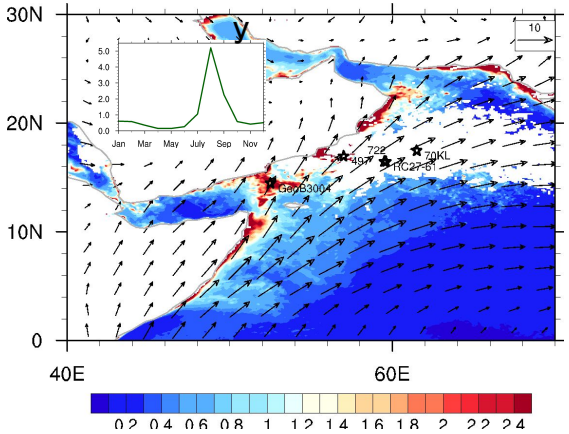
$$W_{Ekman} \approx \frac{1}{\rho_w f} \nabla \times \tau$$

precession



Summer upwelling vs wind

obliquit

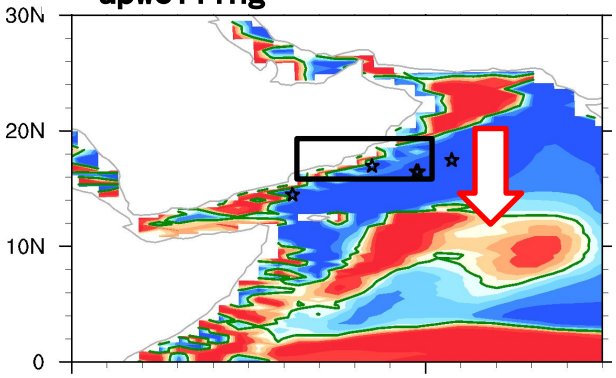


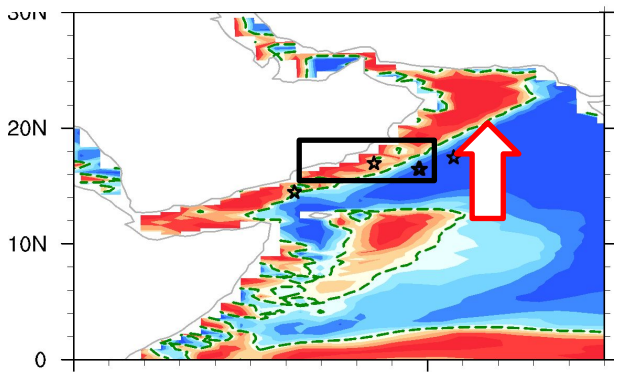
Chlorophyll concentration

precession

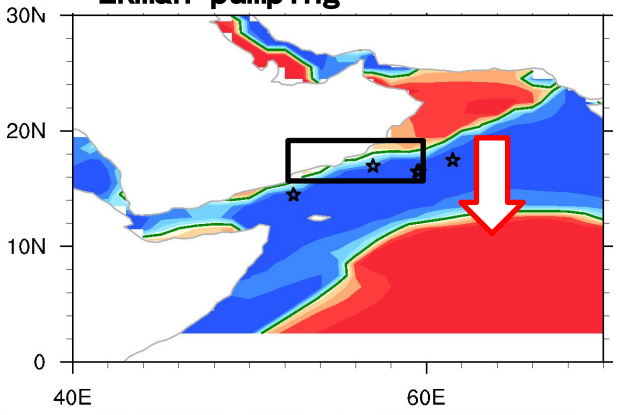
obliquit

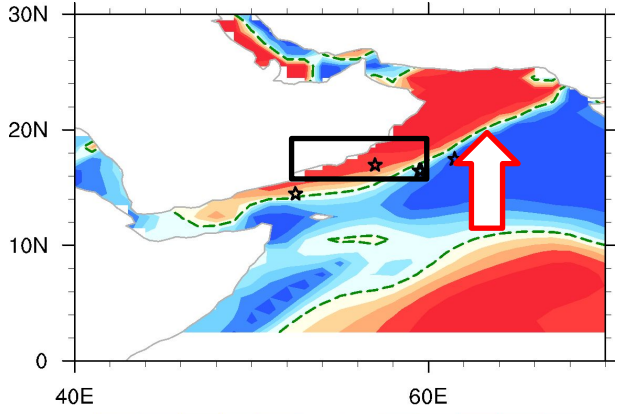
upwelling





Ekman pumping





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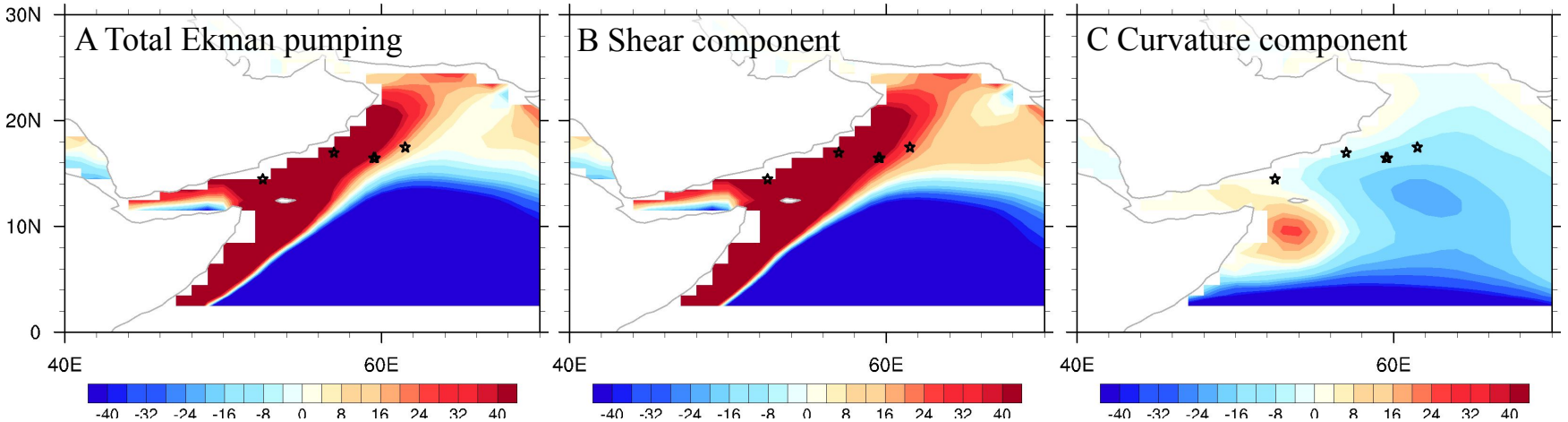
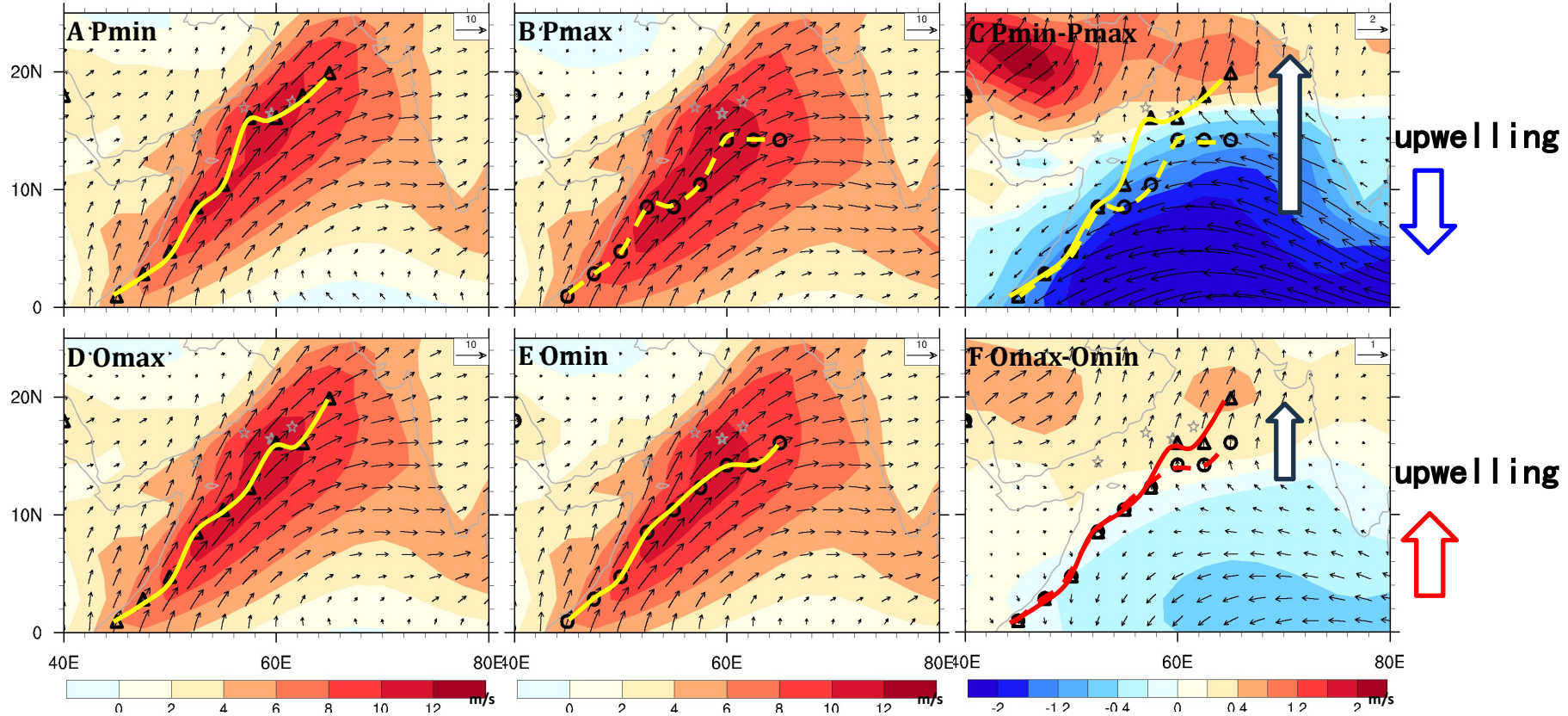
paleoclimate workin

$$\zeta = \nabla \times \tau = -\frac{\partial V}{\partial n} + \frac{V}{R_s}$$

shear and curvature




A Pmin
B Pmax
C Pmin-Pmax
D Omax
E Omin
F Omax-Omin
20N
10N
0
40E
60E
80E
upwelling
upwelling
m/s

Conclusions

1. **CESM simulates orbital-scale monsoon is largely consistent with observations**
2. **ASM is largely driven by local insolation**
3. **Arabian Sea upwelling reflects the position of LLJ, instead of ISM**

Wen, Q., Liu, Z., Liu, J. et al. Contrasting responses of Indian summer monsoon rainfall and Arabian Sea upwelling to orbital forcing. Commun Earth Environ 5, 409 (2024).

Wen Q, Liu Z, Zhu J, et al. Local insolation drives Afro-Asian monsoon at orbital-scale in holocene[J]. Geophysical Research Letters, 2022, 49(6): e2021GL097661.


GOOD LUCK
喜
乐
平
安
HAPPY NEW YEAR