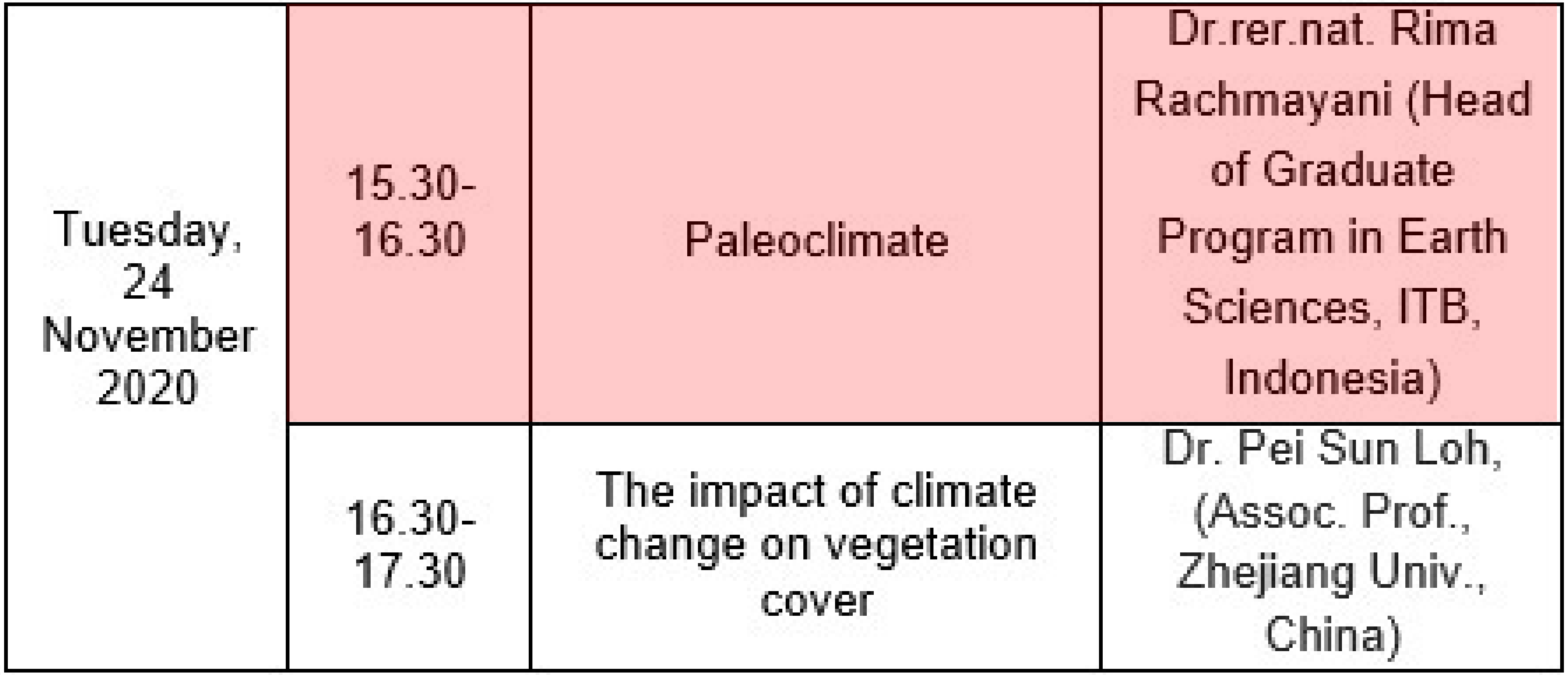


Tuesday, 24 November 2020	15.30-16.30	Paleoclimate	Dr.rer.nat. Rima Rachmayani (Head of Graduate Program in Earth Sciences, ITB, Indonesia)
	16.30-17.30	The impact of climate change on vegetation cover	Dr. Pei Sun Loh, (Assoc. Prof., Zhejiang Univ., China)

- Host, present, guide
- Reward: best student
- Questionnaire ➔ attendance
- Homework

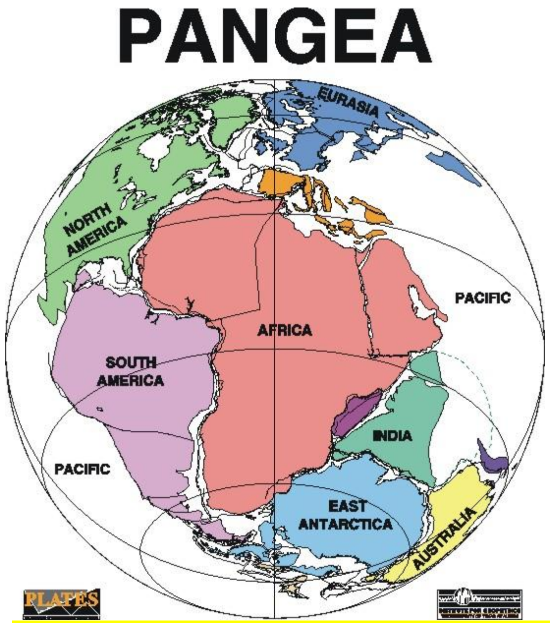
Modeling the Interglacial Climate Variability during the Late Quaternary

Rima Rachmayani[1]

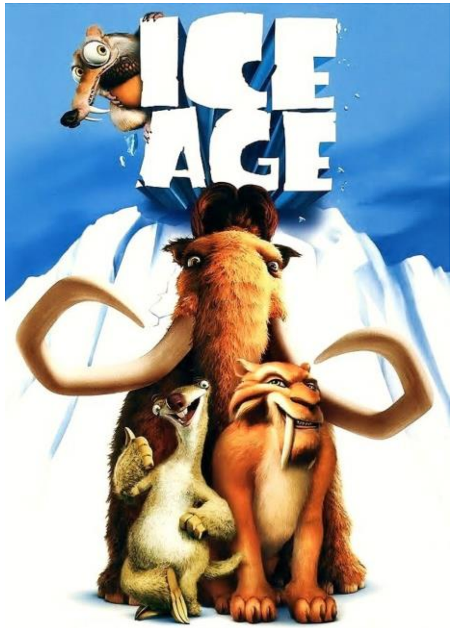
Matthias Prange[2,3] **and Michael Schulz**[2,3]

[1]Bandung Institute of Technology (ITB)
[2]Faculty of Geosciences, University of Bremen, Bremen, Germany
[3]MARUM –Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany

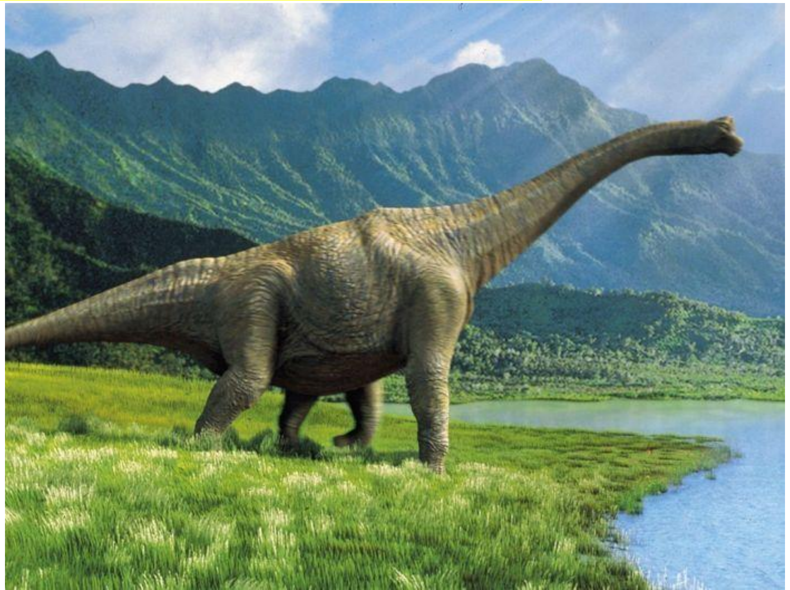
- Introduction
  - Definition of Paleoclimate
  - Late Quaternary period and orbital forcing.
  - The driving forces on monsoon systems.
  - Impact of vegetation on the precipitation.
- Method
- Results
  - North African- Indian monsoon during the Late Quaternary.
  - Climatic effect of obliquity during Marine Isotope Stage (MIS) 11 and 13.
  - Vegetation-precipitation feedback during MIS 1.
- Conclusions
- Outlook



Paleoclimate



1. Ancient; prehistoric; old
2. Early; primitive



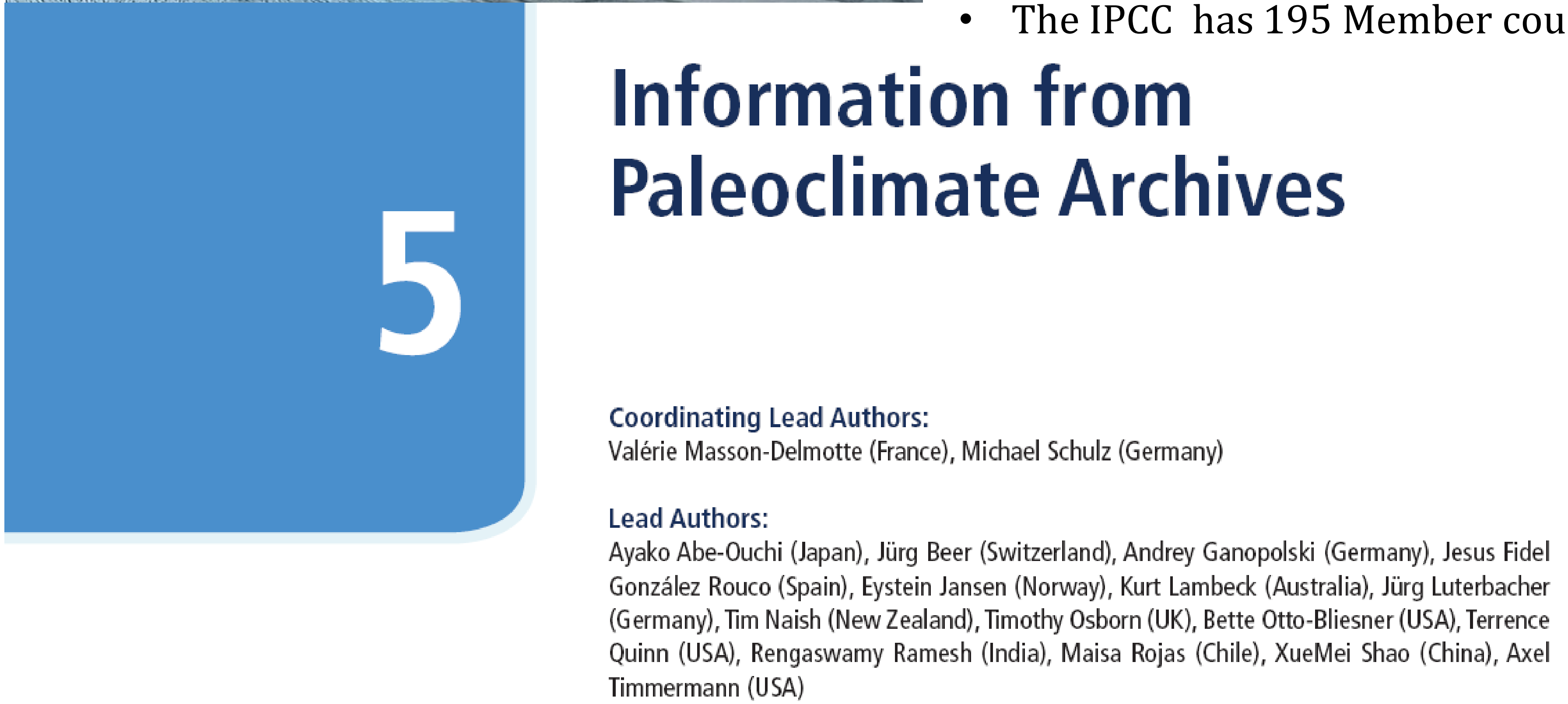
1. (Physical Geography) the long-term prevalent weather conditions of an area, determined by latitude, position relative to oceans or continents, altitude, etc
2. (Physical Geography) an area having a particular kind of climate

www.freedictionary.com

ipcc
INTERGOVERNMENTAL PANEL ON climate change

CLIMATE CHANGE 2013
The Physical Science Basis

- The United Nations body for assessing the science related to climate change.
- To provide policymakers with regular scientific assessments on climate change, its implications and potential future risks, as well as to put forward adaptation and mitigation options.
- Created by the United Nations Environment Programme (UN Environment) and the World Meteorological Organization (WMO) in 1988.
- The IPCC has 195 Member countries.



5

Information from Paleoclimate Archives

Coordinating Lead Authors:
Valérie Masson-Delmotte (France), Michael Schulz (Germany)

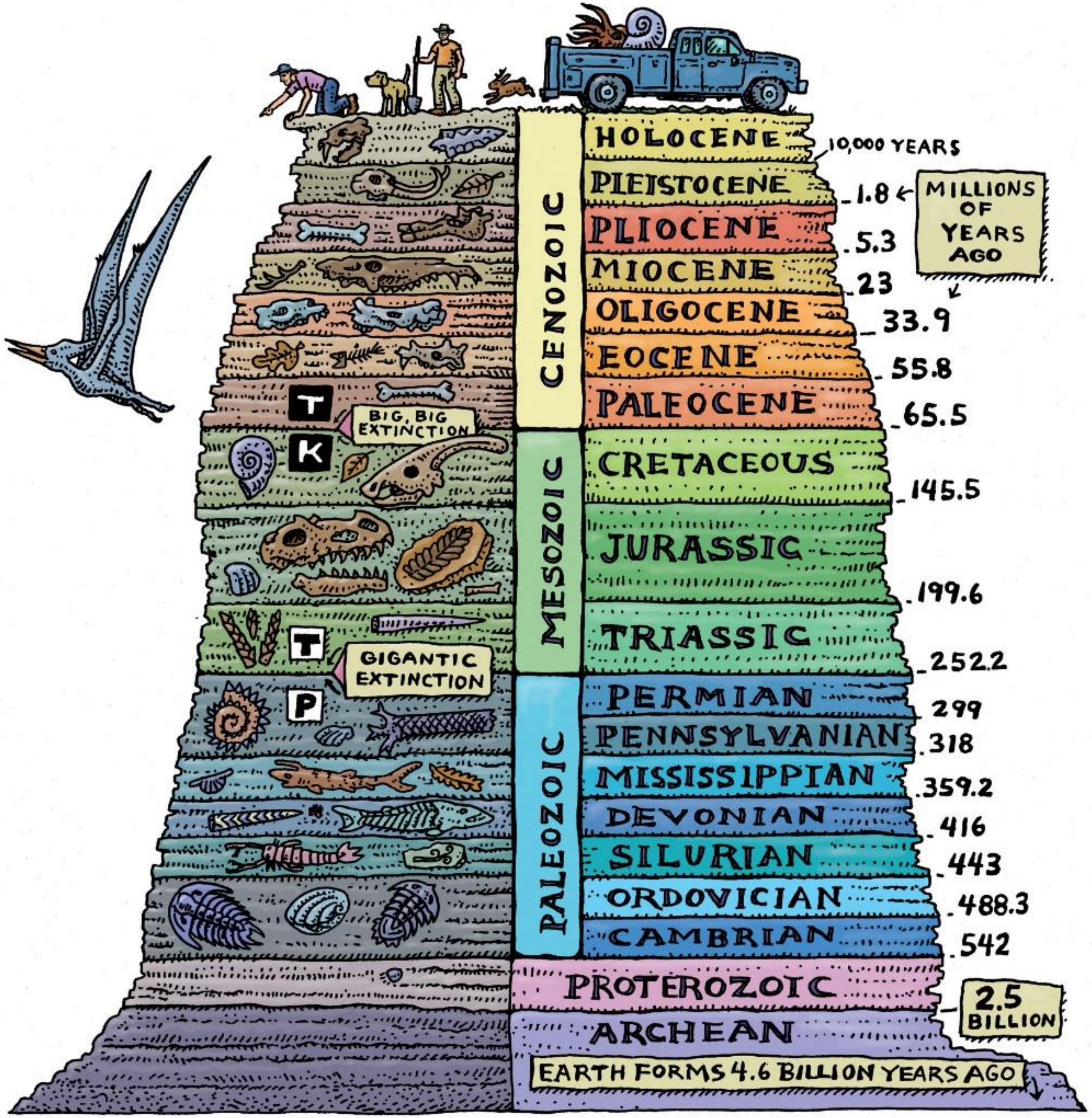
Lead Authors:
Ayako Abe-Ouchi (Japan), Jürg Beer (Switzerland), Andrey Ganopolski (Germany), Jesus Fidel González Rouco (Spain), Eystein Jansen (Norway), Kurt Lambeck (Australia), Jürg Luterbacher (Germany), Tim Naish (New Zealand), Timothy Osborn (UK), Bette Otto-Bliesner (USA), Terrence Quinn (USA), Rengaswamy Ramesh (India), Maisa Rojas (Chile), XueMei Shao (China), Axel Timmermann (USA)

www.ipcc.ch

Quaternary, in the geologic history of Earth, a unit of time within the Cenozoic Era, beginning 2,588,000 years ago and continuing to the present day.

The Quaternary is one of the best-studied parts of the geologic record ➔ it is well preserved in comparison with the other periods of geologic time (International Union of Geological Sciences (IUGS)

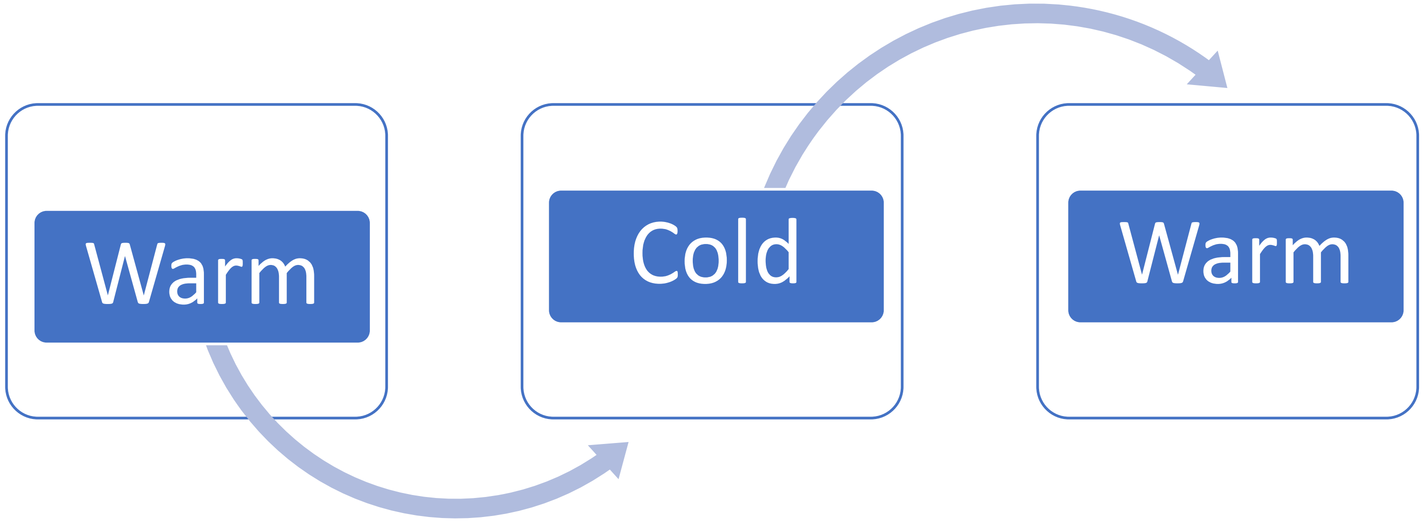
(https://www.britannica.com/science/Quaternary)



https://www.google.com/

Why Study Past Climates?

- It may help us to understand natural climate changes.
- The study of past climates may give us information into future climate scenarios.



Warm

Cold

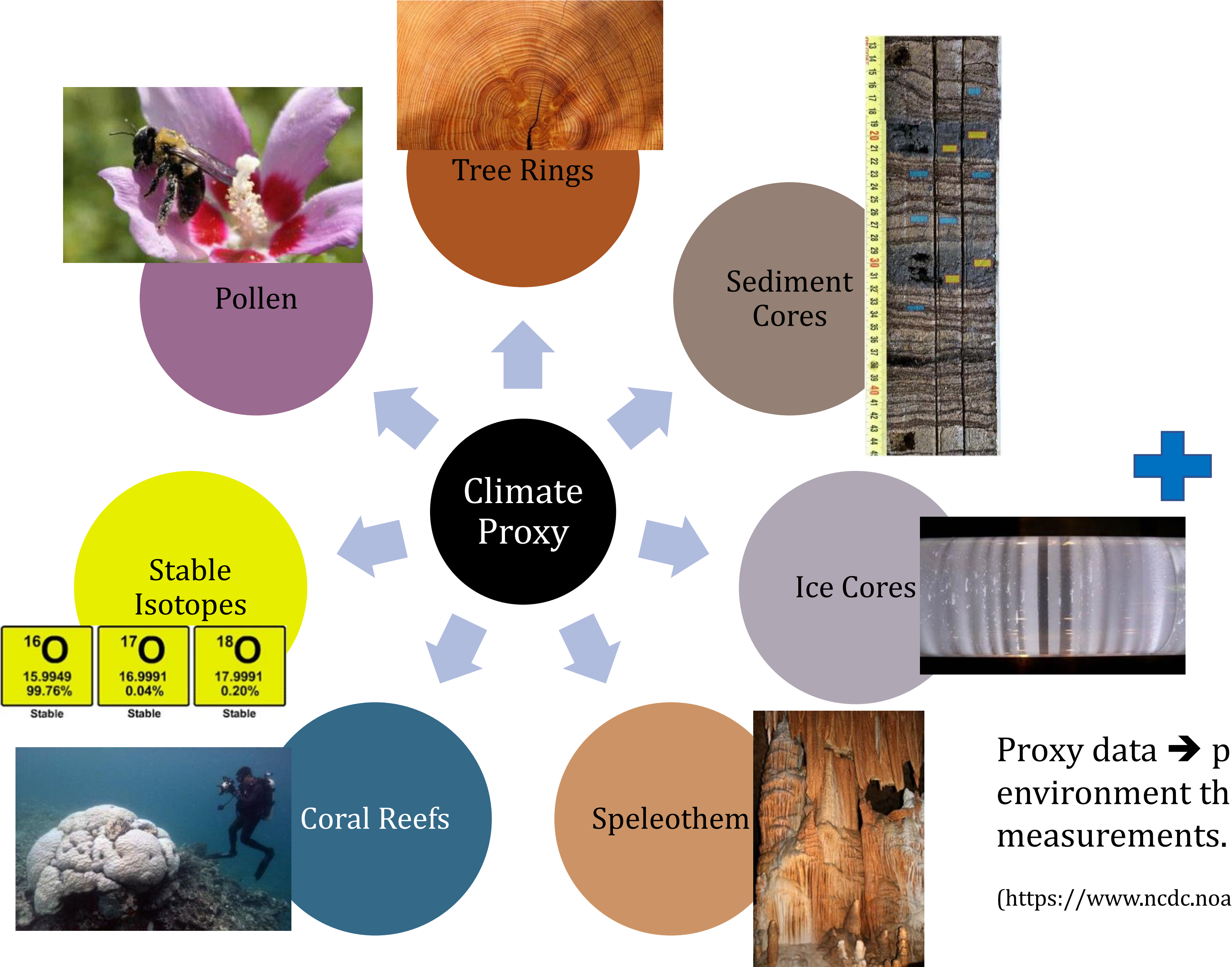
Warm

Interglacial

Glacial

Interglacial

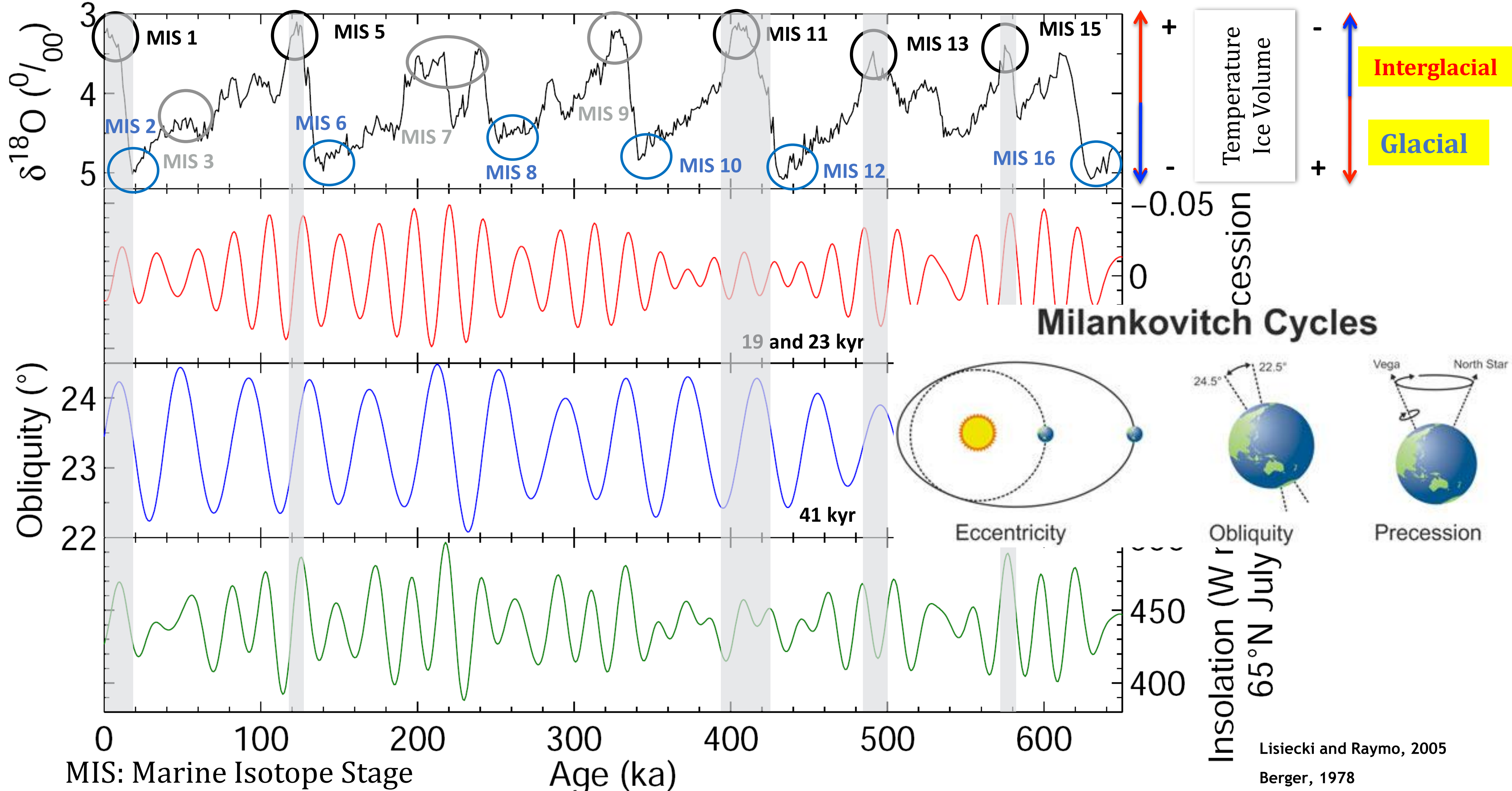
How do scientists' study past climate?



Climate Modeling

Proxy data ➔ preserved physical characteristics of the environment that can stand in for direct measurements.

(https://www.ncdc.noaa.gov/news/what-are-proxy-data)



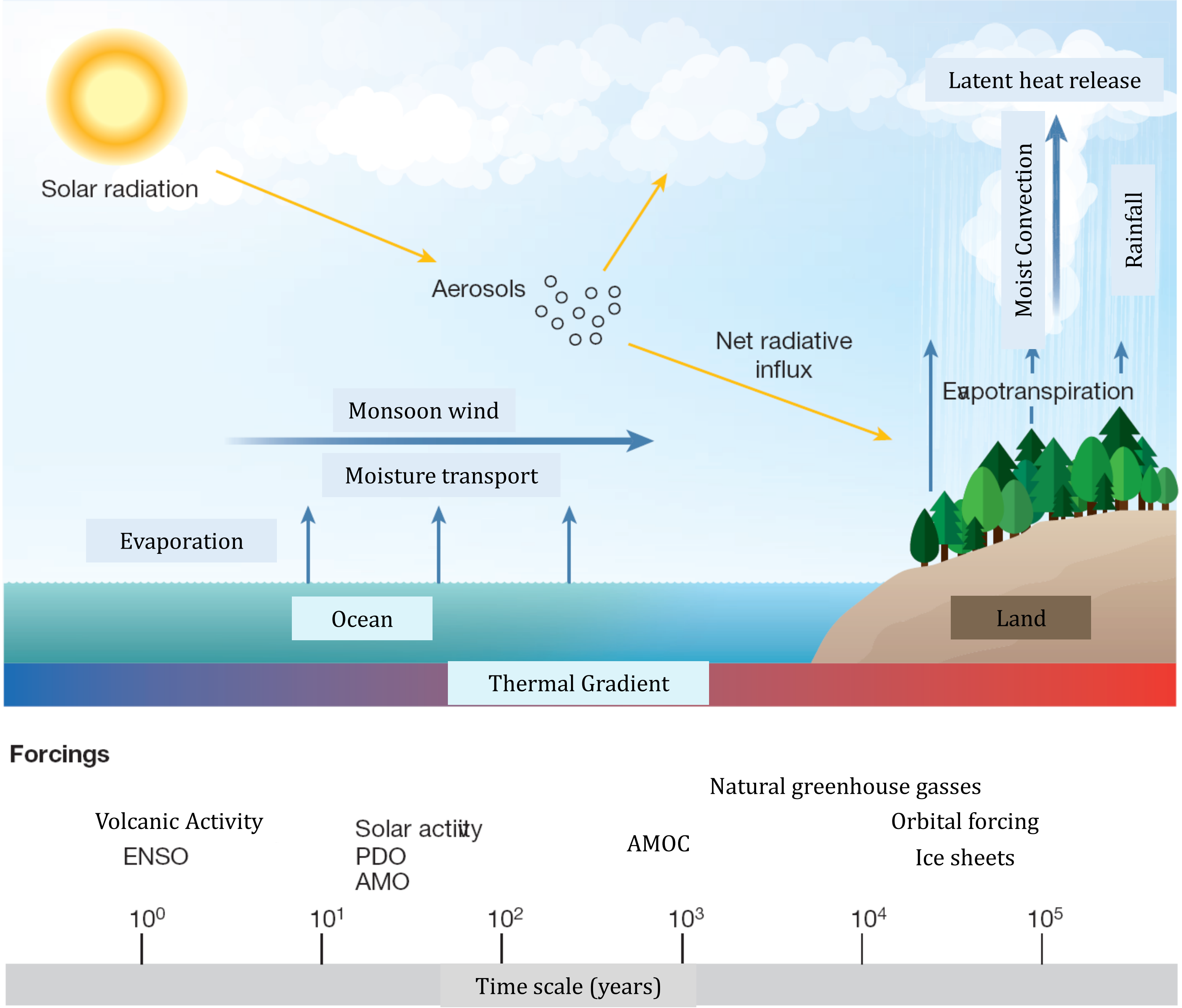
MIS: Marine Isotope Stage

Lisiecki and Raymo, 2005

Berger, 1978

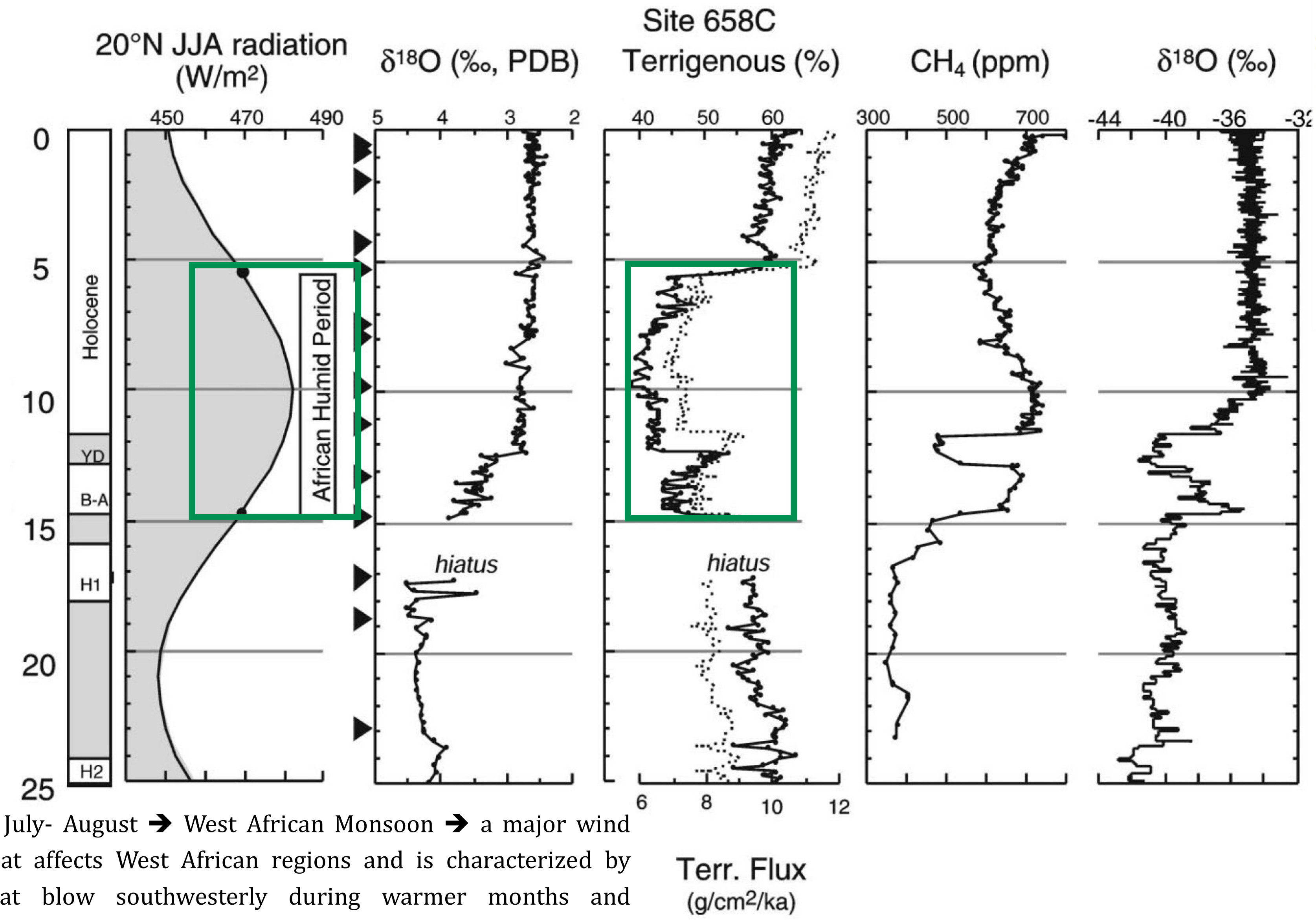
Driving forcing on monsoon system

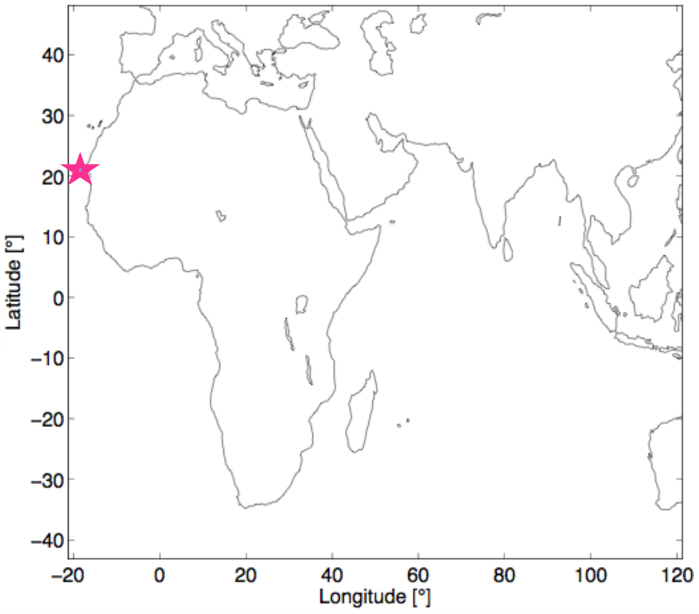
- **The components are closely coupled through feedback mechanism.**
- **Perturbation may affect the monsoon system**



Mohtadi et al., 2016

ODP site 658C: insolation maximum leads to wet conditions





- Terrigenous: sediment transported to the oceans by rivers and **wind** from land sources.
- **Strengthening of African monsoon**

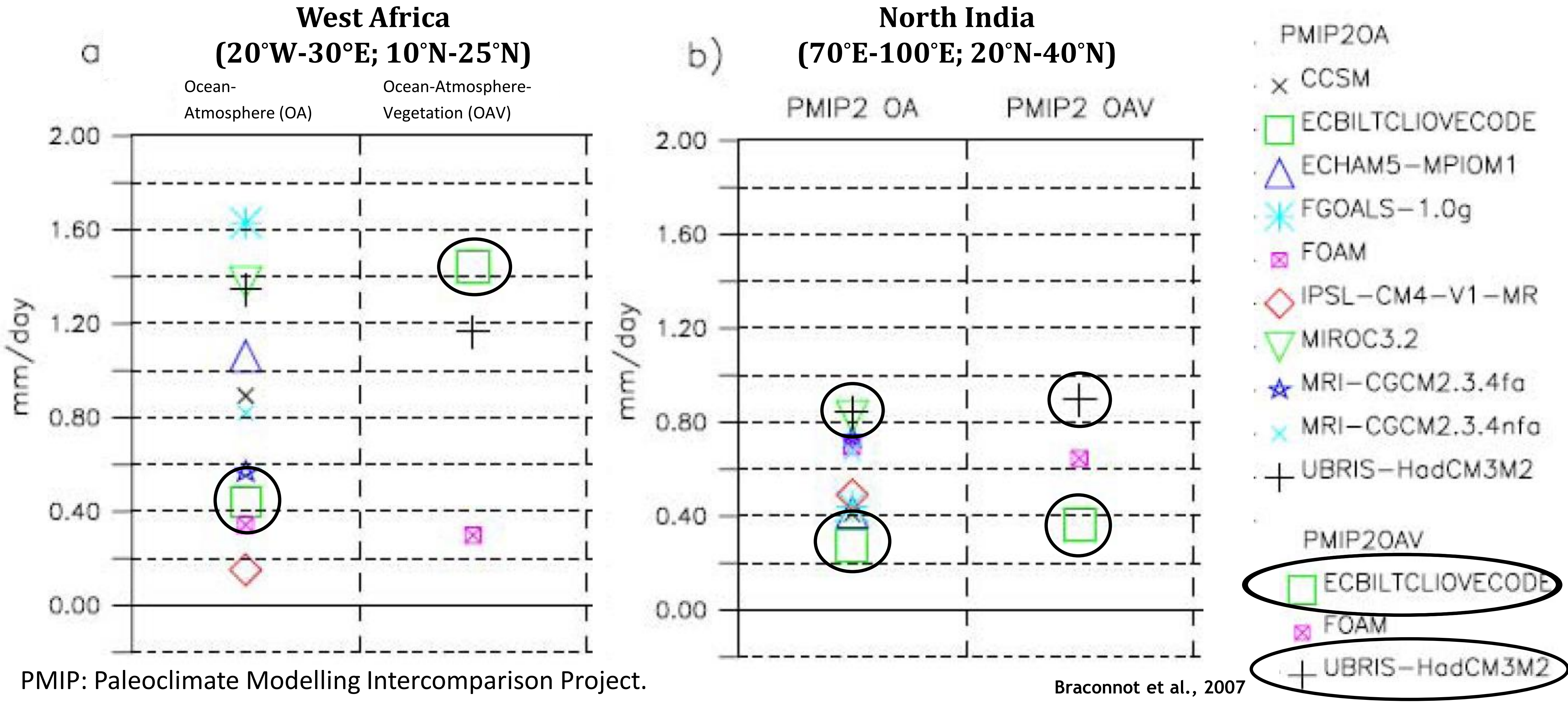
JJA: June- July- August ➔ West African Monsoon ➔ a major wind system that affects West African regions and is characterized by winds that blow southwesterly during warmer months and northeasterly during cooler months of the year

ODP: Ocean Drilling Program

deMenocal et al., 2000

Impact of vegetation on the precipitation

Summer (JJAS) precipitation changes in mid- Holocene



West Africa
(20°W-30°E; 10°N-25°N)

Ocean-Atmosphere (OA)

Ocean-Atmosphere-Vegetation (OAV)

North India
(70°E-100°E; 20°N-40°N)

PMIP: Paleoclimate Modelling Intercomparison Project.

Braconnot et al., 2007

Objectives

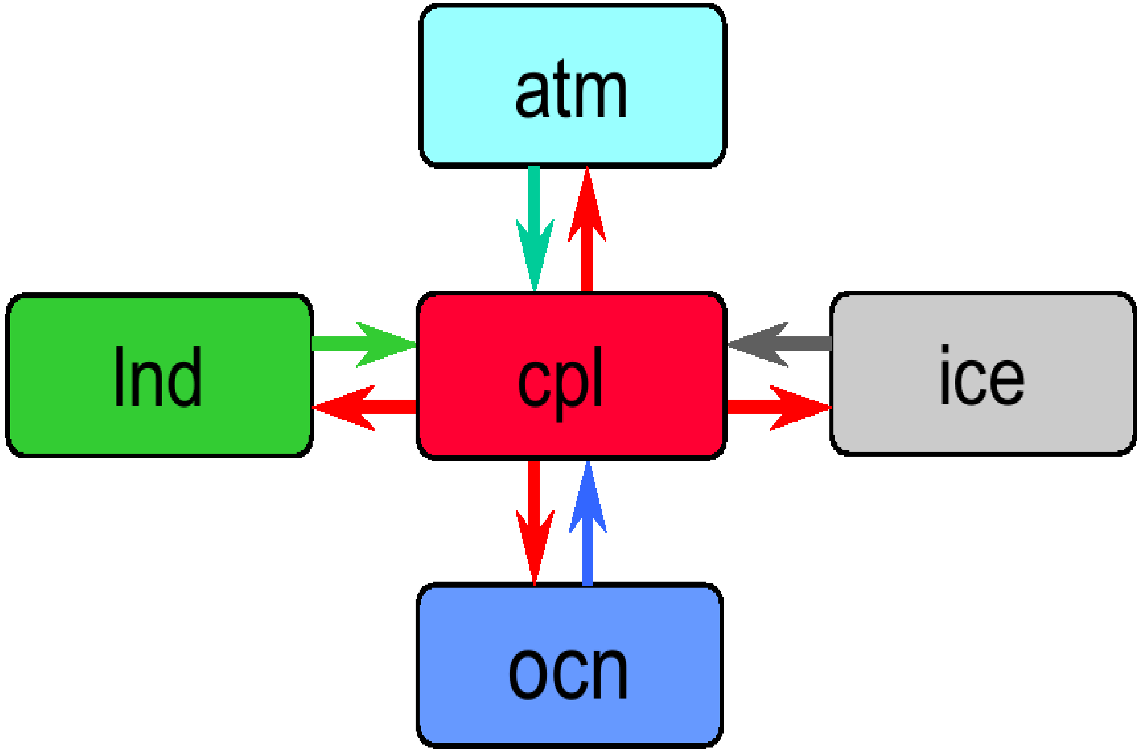
Investigate the effects of obliquity-precession-induced insolation anomalies on global surface climate (surface temperature and precipitation) during **MIS 15, MIS 13, MIS 11, MIS 5, MIS 1** to:

1. Study the response of North African- Indian monsoon systems to orbital forcing during the Late Quaternary.

2. Understand climatic effects of obliquity variations during **MIS 13** (495 & 516 ka) and **MIS 11** (394 & 416 ka).

3. Analyze vegetation-precipitation feedback over North Africa in mid- and early-Holocene (**MIS 1**).

Community Climate System Model version 3- Dynamic Global Vegetation Model (CCSM3-DGVM)



- CAM3: T31 (3.75°), 26 vertical layers.

- CLM3: T31 (3.75°), components: biogeophysics, biogeochemistry, hydrological cycle, DGVM (10 PFTs).

- POP version 1.4.3: displaced-pole grids (centered at Greenland) at approximately 3.6°(gx3v5) horizontal resolutions with 25 vertical levels.

- CSIM5: gx3v5 resolutions.

Experiments setup

Pre Industrial (PI) control run: ➔(Braconnot et al., 2007)

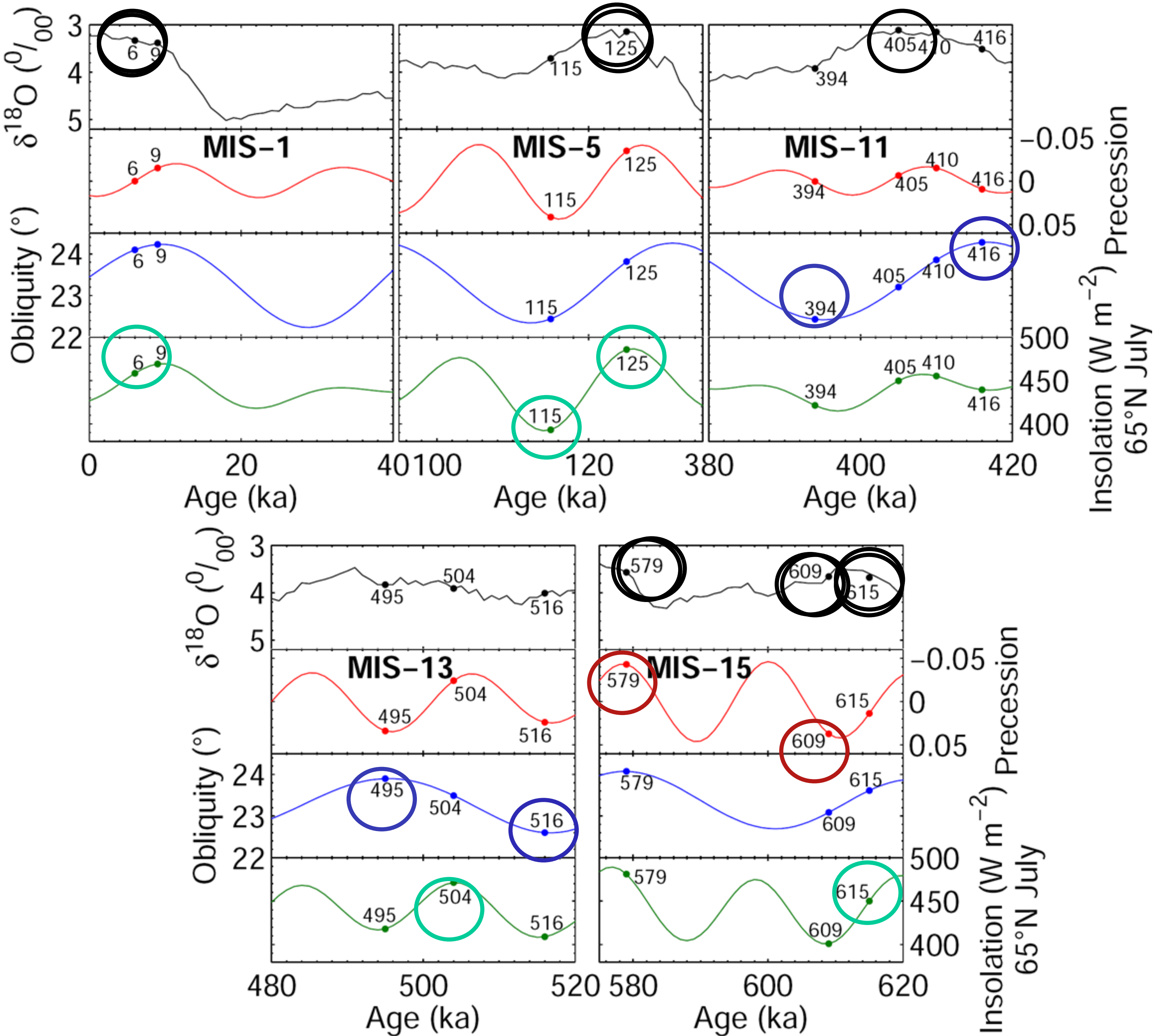
- Orbital and GHG forcing: PMIP.
- Ice sheet, ozone, aerosols, solar constant: PMIP.
- Solar constant: 1365 W m^{-2}.
- Integration: 1000 years starting from modern initial conditions.
- Fixed calendar.

Past climates (13 interglacial time slices):

- Branch off from year 600 of the PI and running for 400 years.
- Orbital forcing: Berger, 1978.
- GHG: EPICA Dome C (EDC3). ➔ Lüthi et al., 2008, Loulergue at al., 2008, Schilt et al., 2010
- Ice sheet, ozone, aerosols, solar constant: PI control run.
- Fixed calendar.
- 100 simulation years ➔ analysis ➔ summer (JJAS) and winter (DJF)

EPICA: European Project for Ice Coring in Antarctica
GHG: Greenhouse Gases

JJAS: June- July- August- September
DJF: December- January- February



Selection of Interglacial time slices

MIS 1: 6, 9 ka

MIS 5: 115, 125 ka

MIS 11: 394, 405, 416 ka

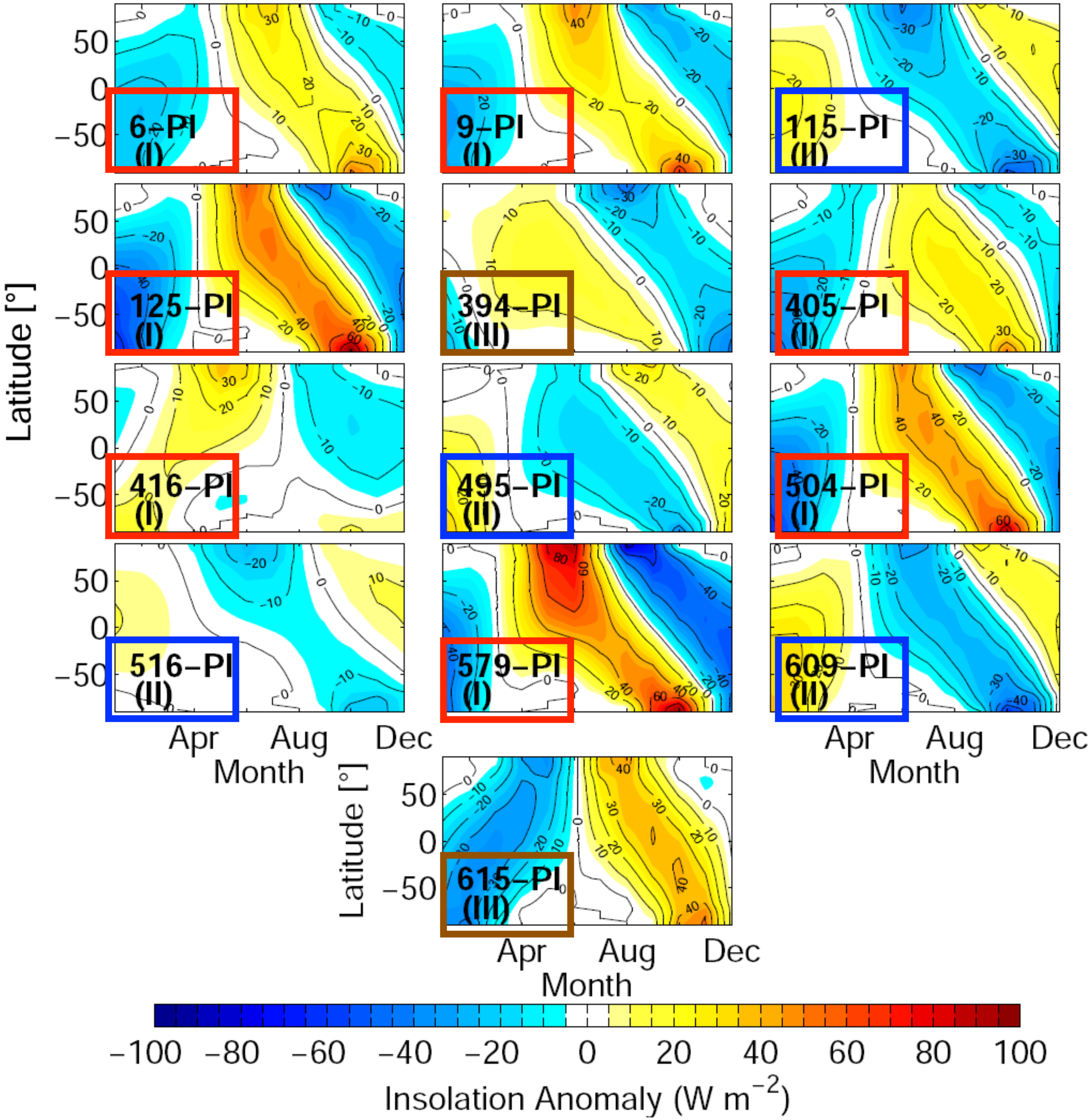
MIS 13: 495, 504, 516 ka

MIS 15: 579, 609, 615 ka

Berger, 1978

Lisiecki and Raymo, 2005

Insolation changes



I: high NH summer insolation

MIS 1: 6, 9 ka

MIS 5: 125 ka

MIS 11: 405, 416

MIS 13: 504 ka

MIS 15: 579 ka

II: low NH summer insolation

MIS 5: 115 ka

MIS 13: 495, 516 ka

MIS 15: 609 ka

III: spring-summer NH insolation

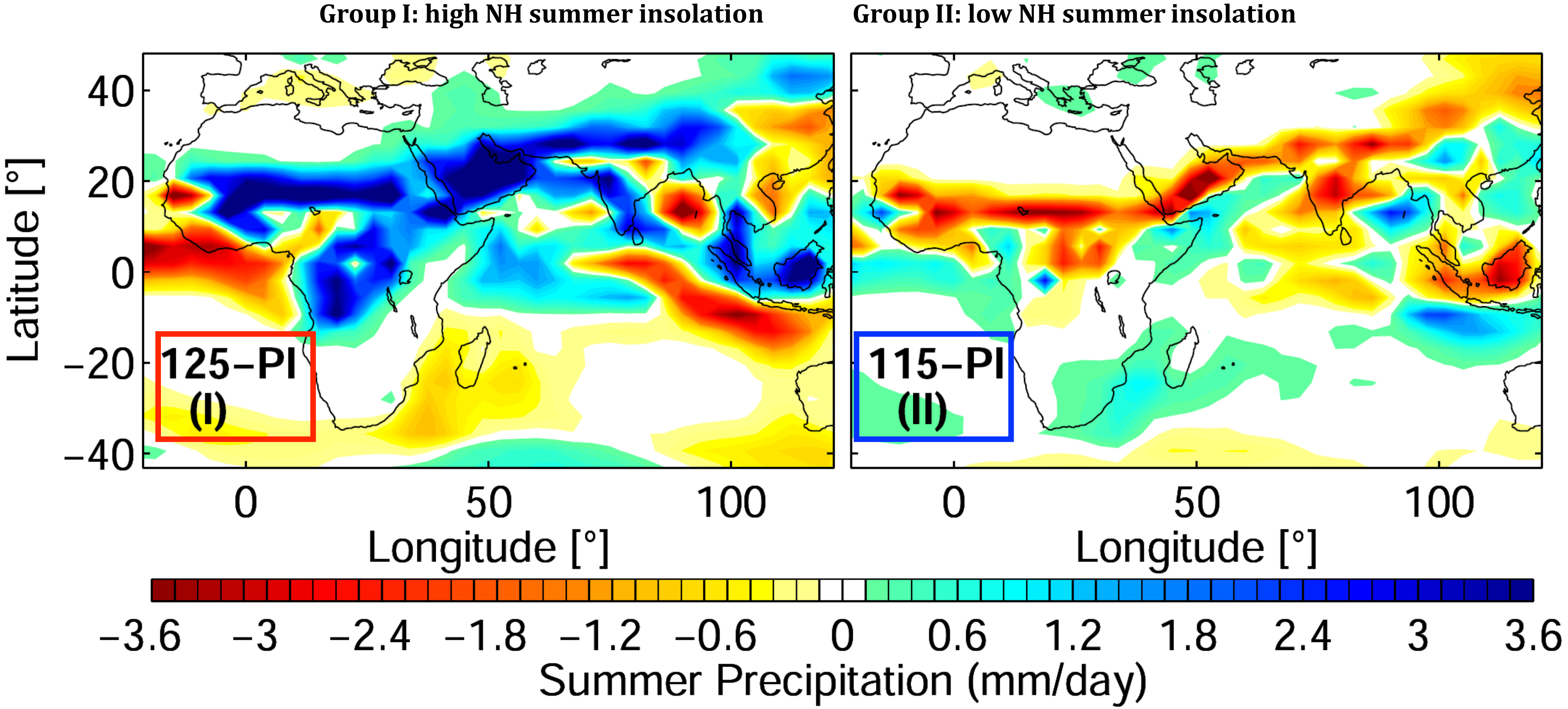
MIS 11: 394 ka

MIS 15: 615 ka

Rachmayani et al., 2016

1. Response of North African- Indian monsoon systems to orbital forcing during the Late Quaternary.

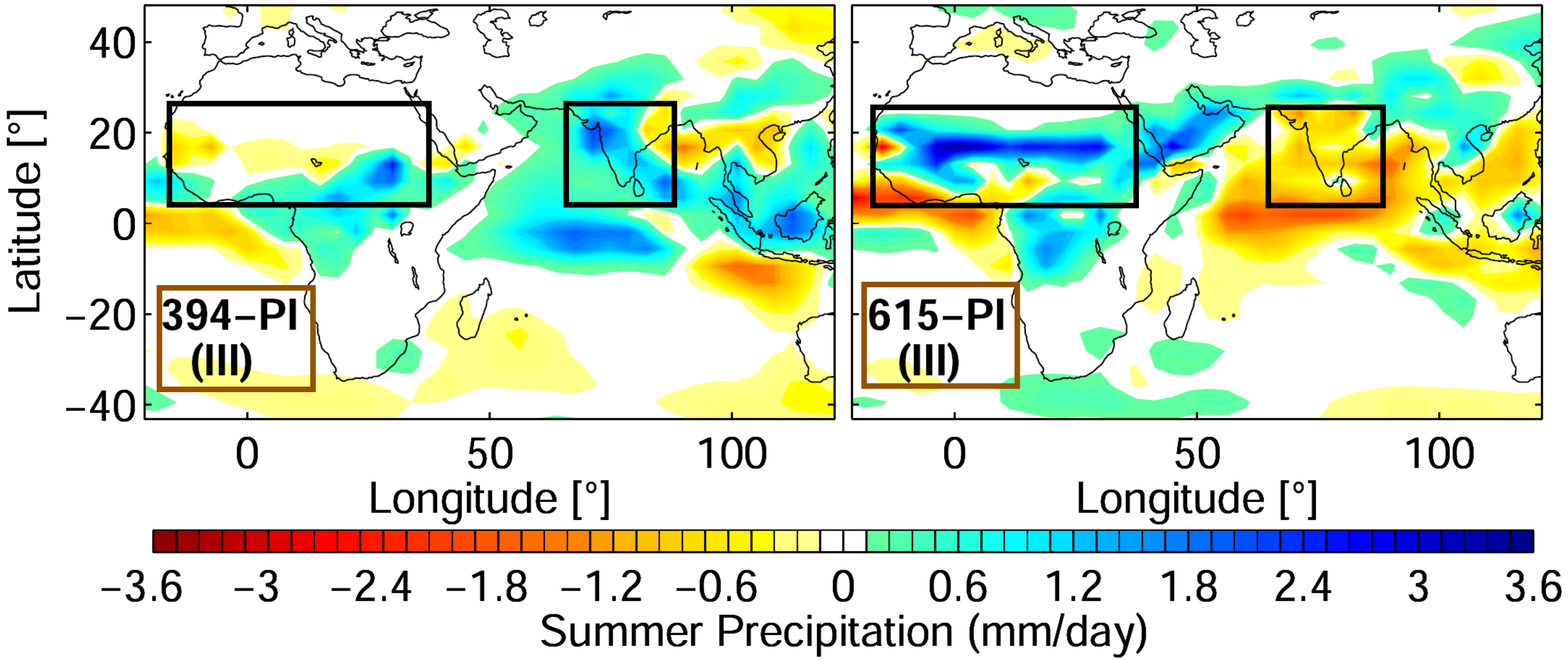
Summer (JJAS) Precipitation changes



Rachmayani et al., 2016

Summer (JJAS) Precipitation changes

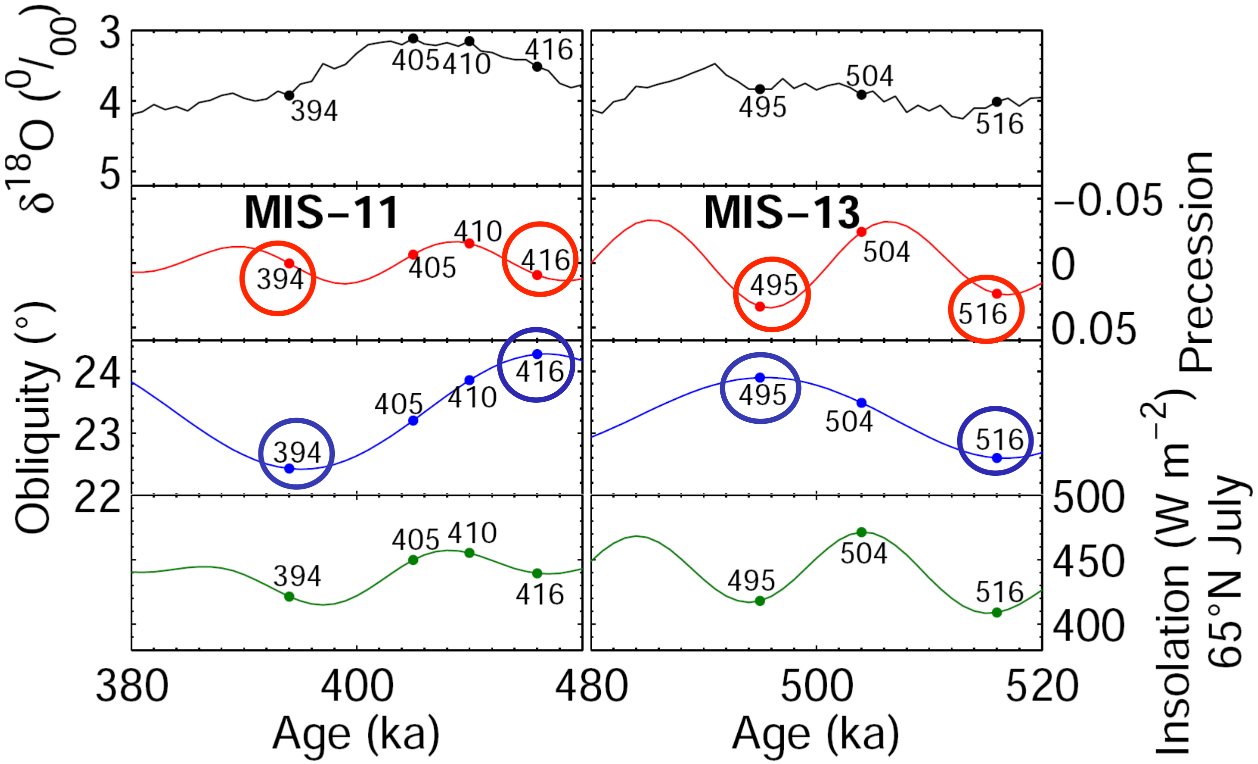
Group III: spring-summer NH summer insolation

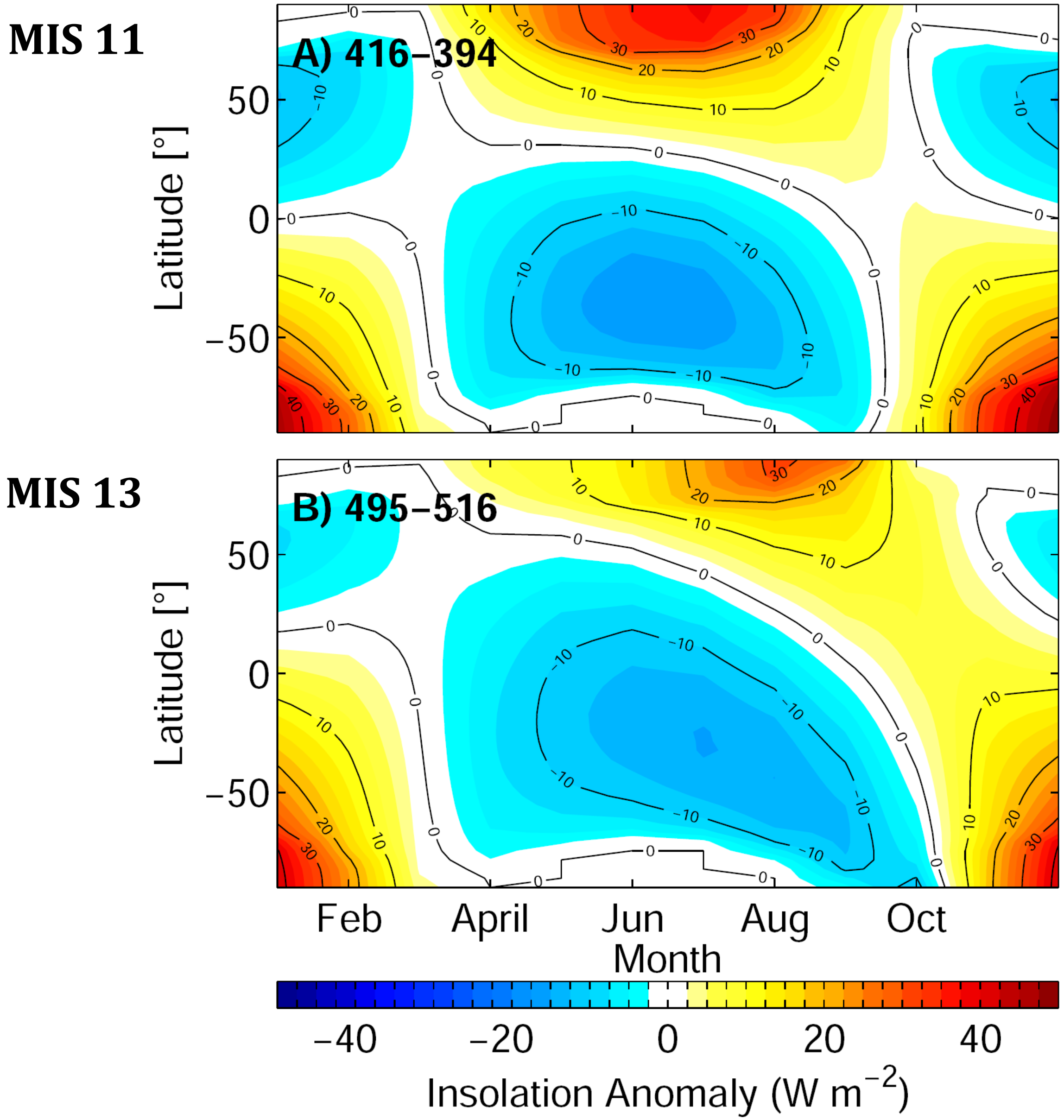


Rachmayani et al., 2016

2. Climatic effects of obliquity variations during MIS 13 and MIS 11.

Insolation changes



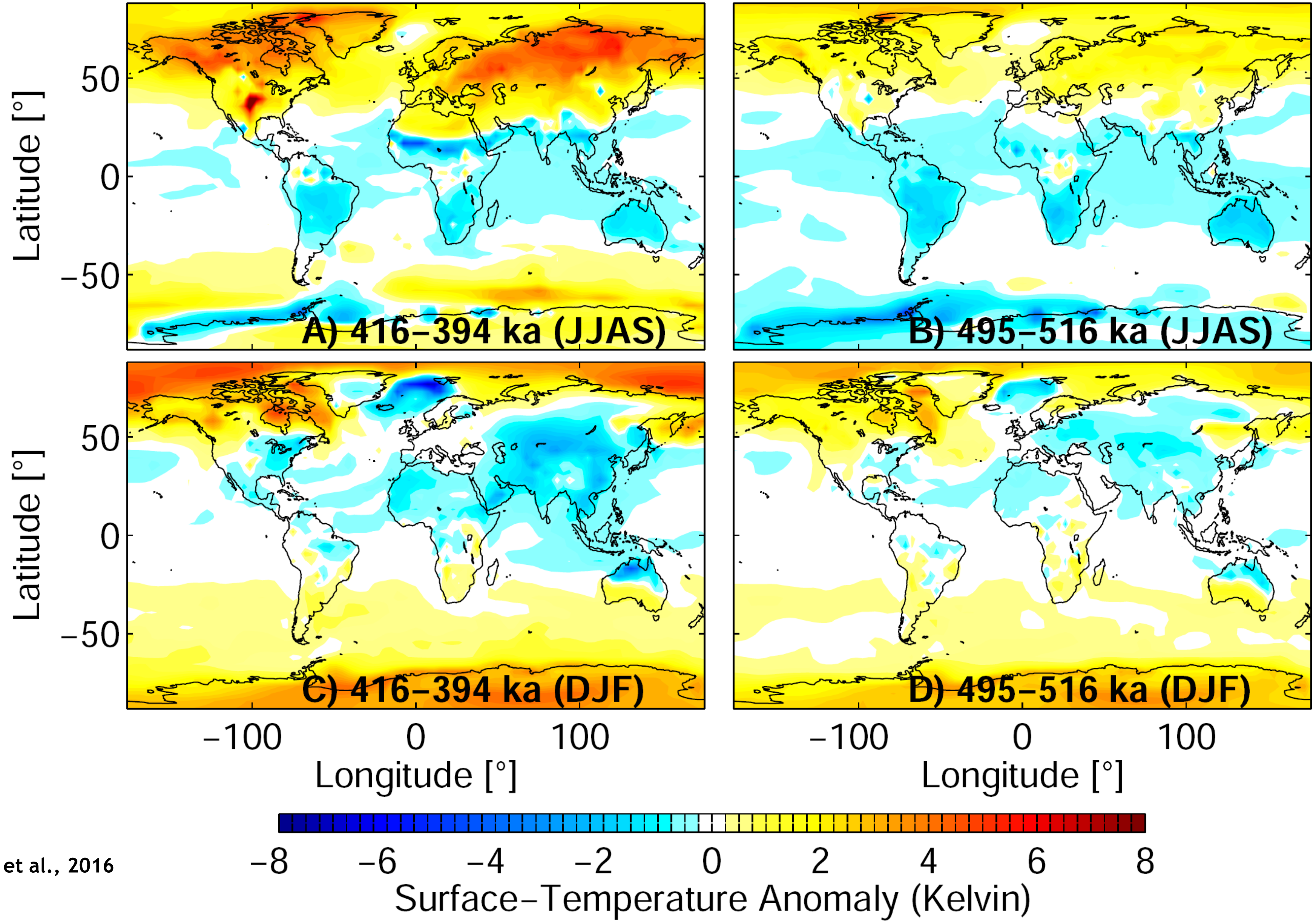


Rachmayani et al., 2016

Surface temperature changes

MIS 11

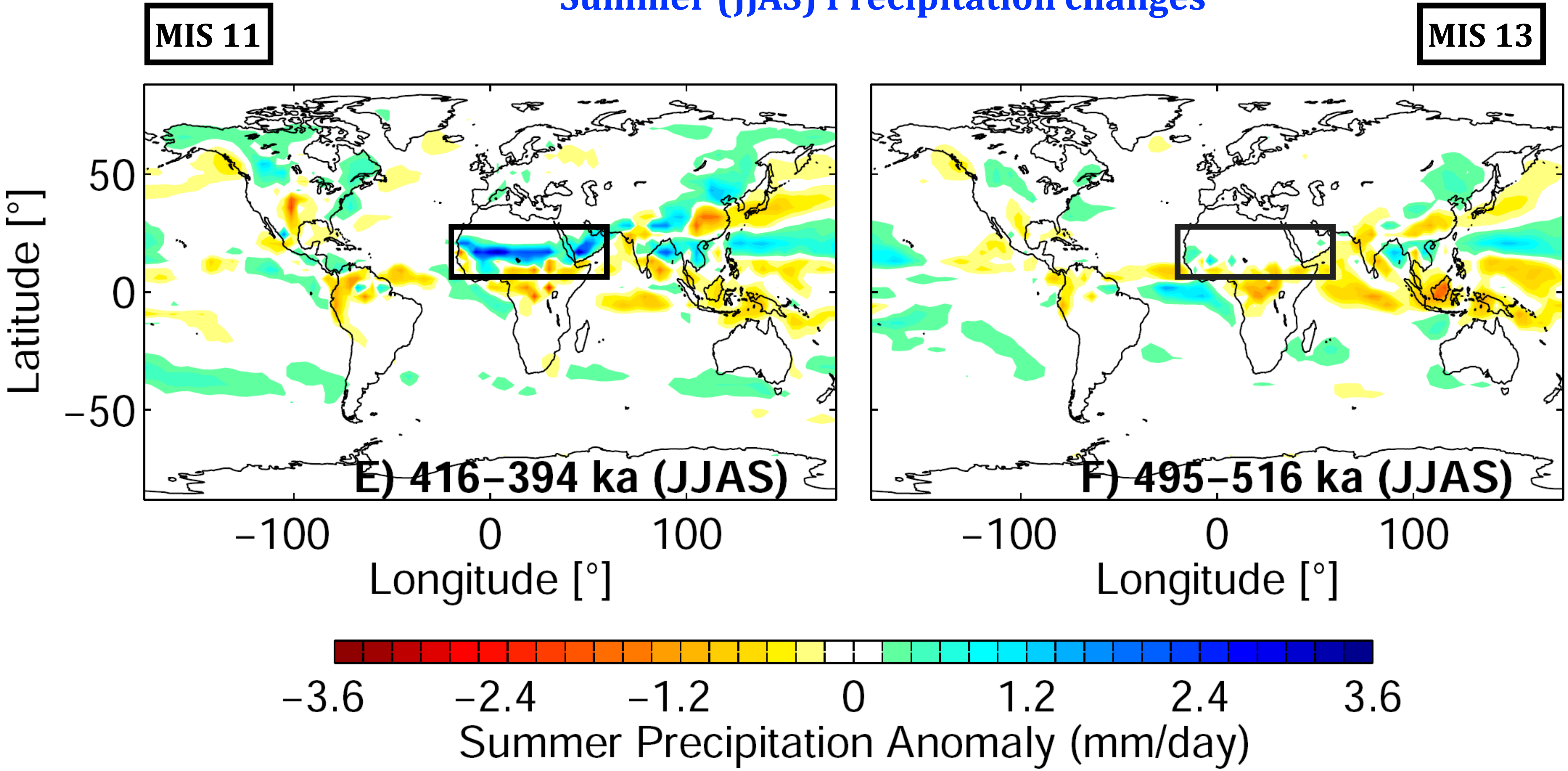
MIS 13



- ☐ Remnant effect
- ☐ GHG

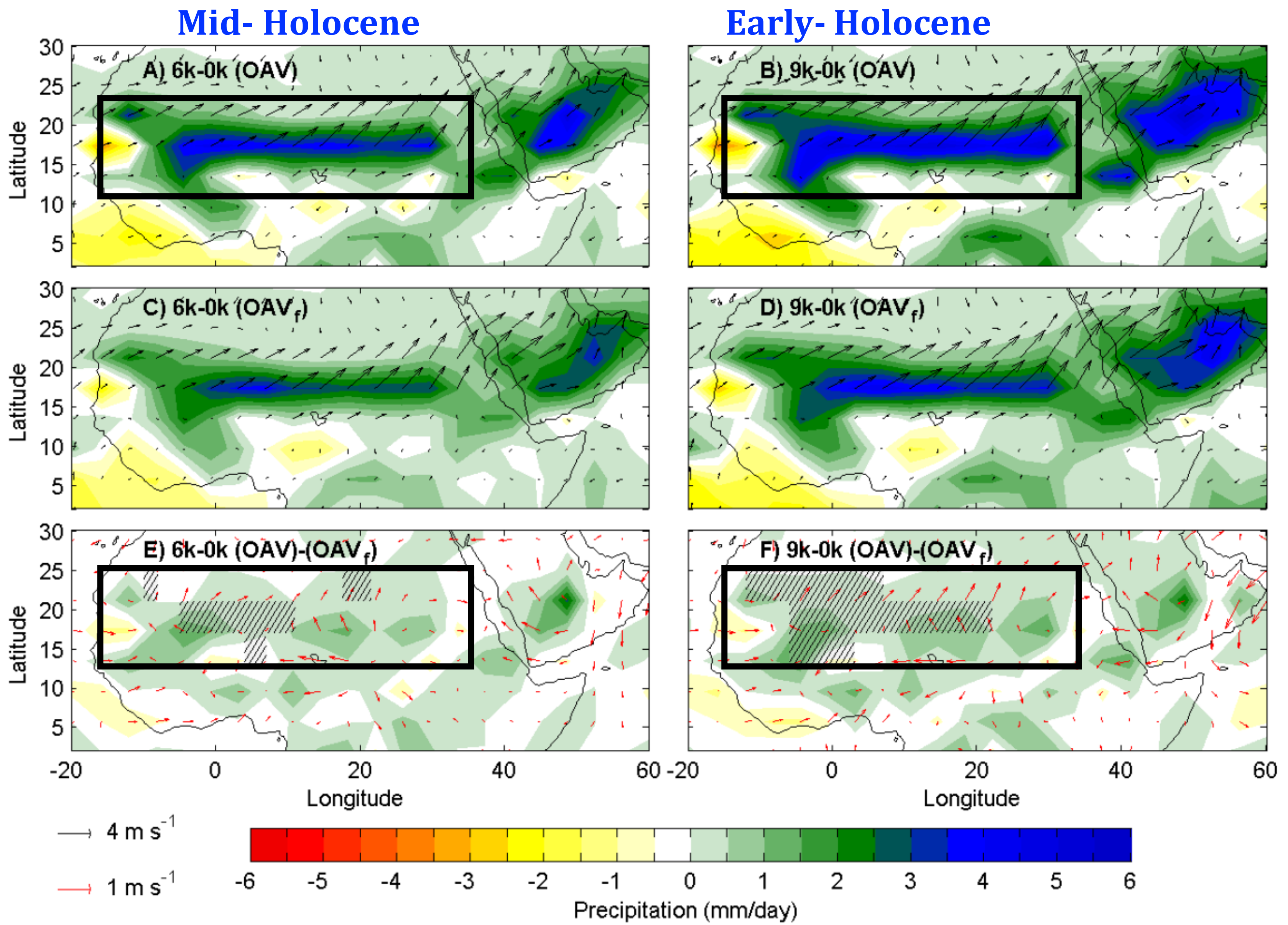
Rachmayani et al., 2016

Summer (JJAS) Precipitation changes



Rachmayani et al., 2016

3. Vegetation-precipitation feedback over North Africa in mid- and early-Holocene (MIS 1).

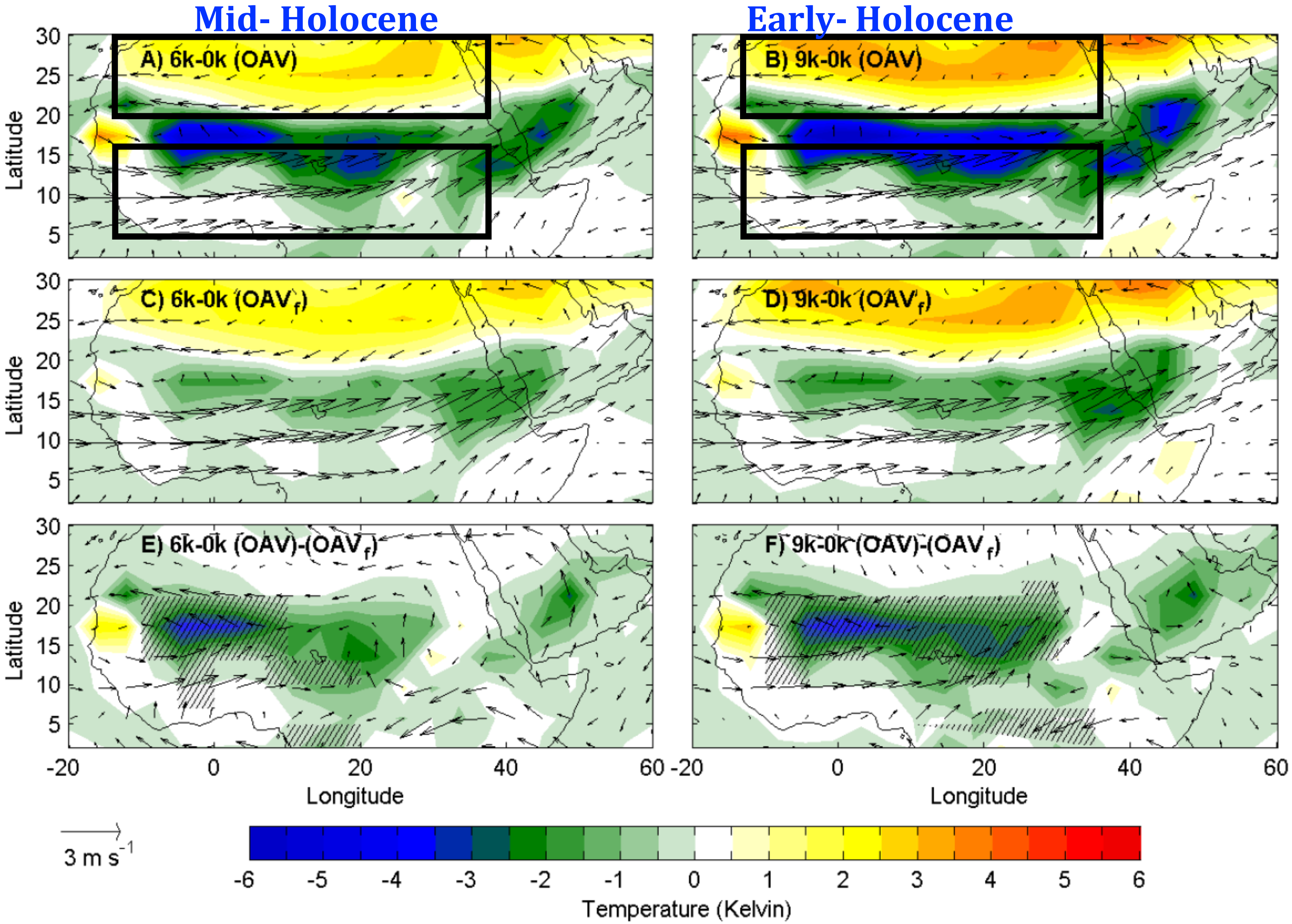


Summer (JJAS) Precipitation and surface wind changes

OAV: Ocean-Atmosphere-Vegetation, DGVM.

OAVf: Ocean-Atmosphere-Vegetation, fixed vegetation.

Rachmayani et al., 2015



Summer (JJAS) Temperature and mid-level (at 700 hPa) wind changes

Rachmayani et al., 2015

1. Response of North African- Indian monsoon systems to orbital forcing during the Late Quaternary.

- ❑ Low precession (high boreal summer insolation)
  ➔ high summer rainfall in the monsoon belt of North Africa to India.

- ❑ Maximum precession (low boreal summer insolation)
  ➔ dry conditions in the monsoon belt of North Africa to India.

- ❑ Opposite sign of monsoonal precipitation anomalies in North Africa and India
  ➔ two monsoon systems do not always vary in concert

2. Climatic effects of obliquity variations during MIS 13 and MIS 11.

- High-low obliquity

  ➔ strong summer warming over the NH extratropics and slight summer cooling in the tropics, moderate winter cooling over the NH continent and a strong winter warming at high latitudes.

- Polar summer remnant effect

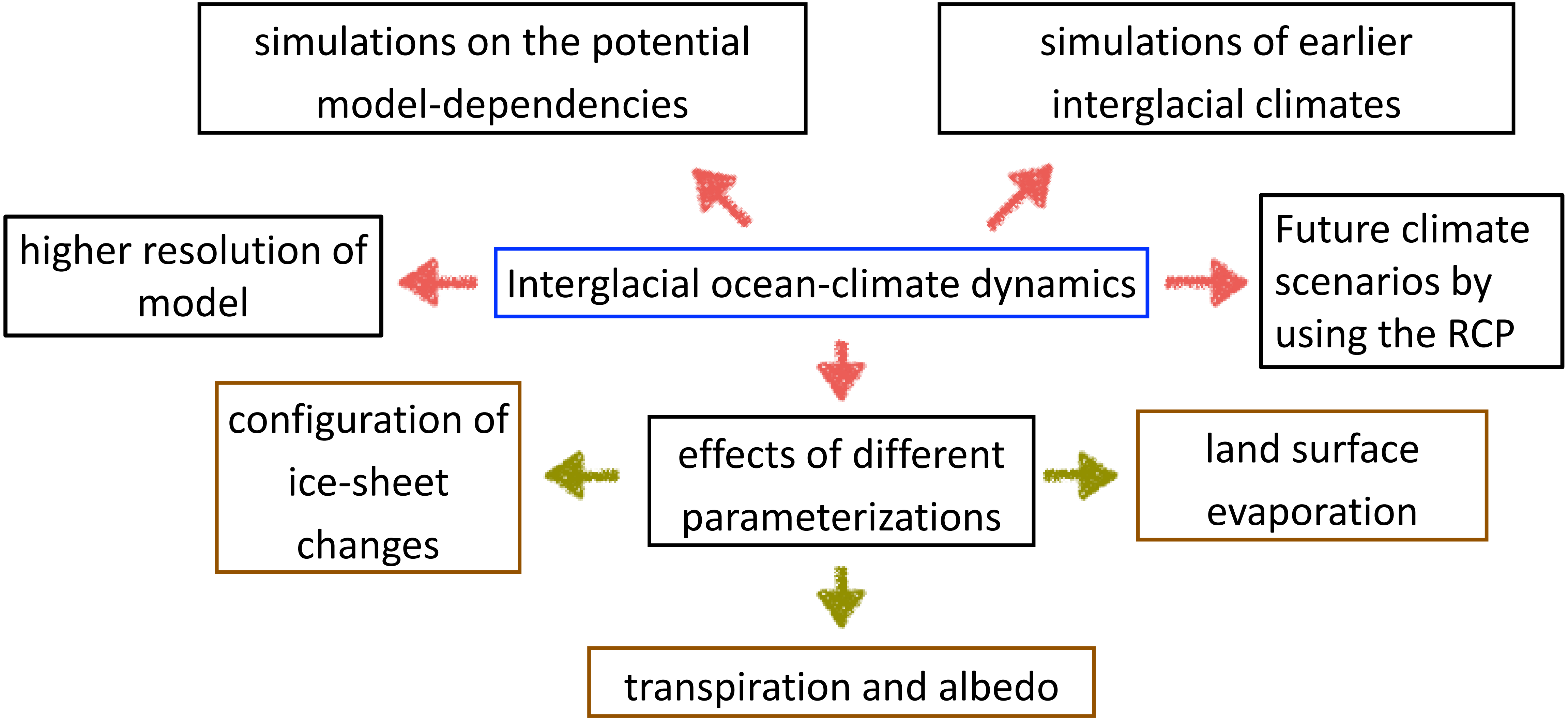
  ➔ summer warming at southern high latitude and winter warming temperature over Arctic realm.

- Obliquity ➔ strong African monsoon rainfall in MIS 11 case.
- The effect of high obliquity on monsoon can be counteracted by a large precession.

3. Vegetation-precipitation feedback over North Africa in mid- and early-Holocene (MIS 1).

- 20 % enhanced summer rainfall anomaly in both the early- and mid-Holocene with OAV experiments.

- The primary vegetation-atmosphere feedback ➔ surface latent heat flux anomalies by canopy evapotranspiration and African Easterly Jet.



Interglacial ocean-climate dynamics

simulations on the potential model-dependencies

simulations of earlier interglacial climates

higher resolution of model

Future climate scenarios by using the RCP

effects of different parameterizations

configuration of ice-sheet changes

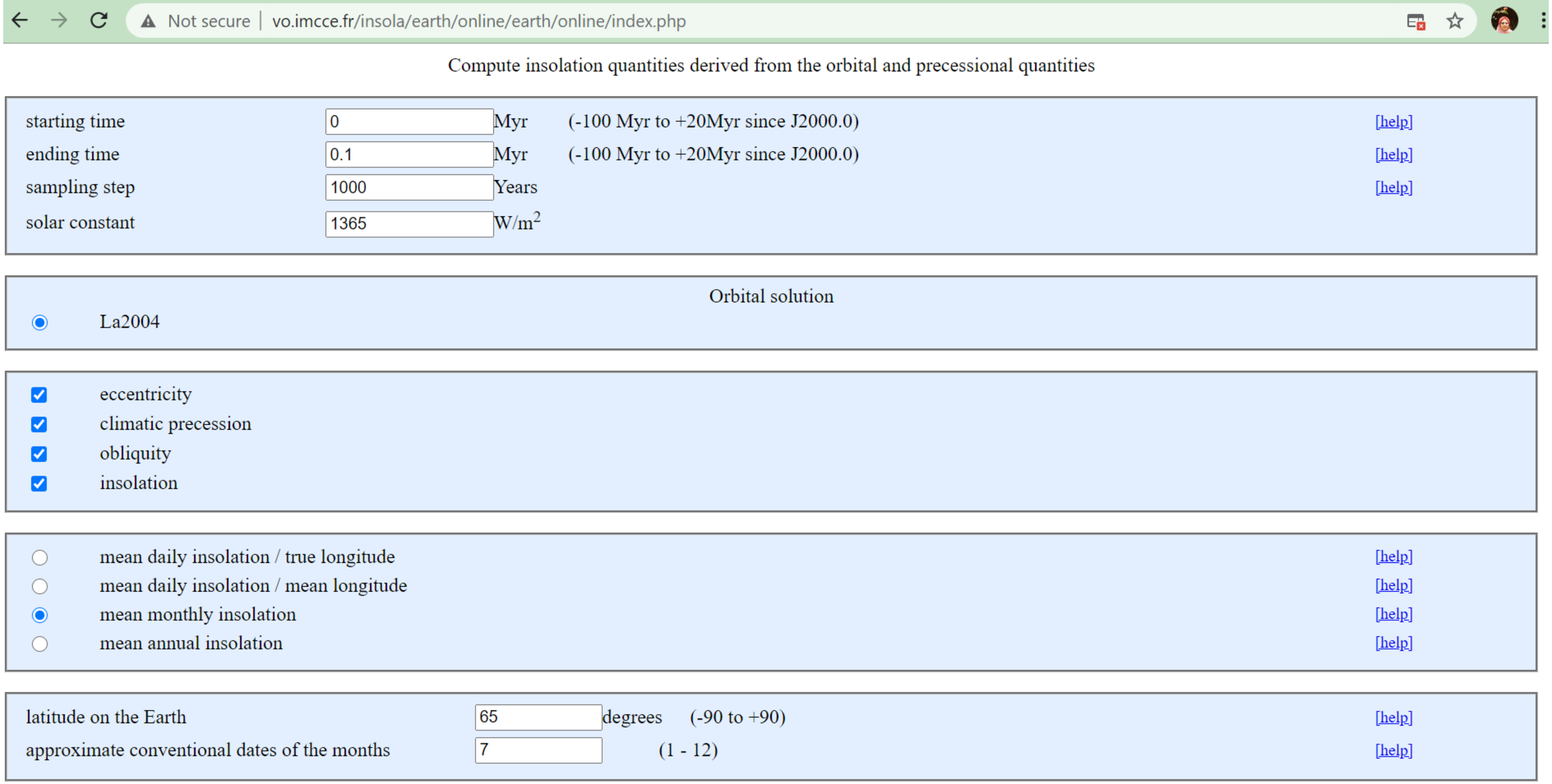
land surface evaporation

transpiration and albedo

RCP: Representative Concentration Pathways

Homework:

http://vo.imcce.fr/insola/earth/online/earth/online/index.php



Compute insolation quantities derived from the orbital and precessional quantities

starting time	0	Myr	(-100 Myr to +20Myr since J2000.0)	[help]
ending time	0.1	Myr	(-100 Myr to +20Myr since J2000.0)	[help]
sampling step	1000	Years		[help]
solar constant	1365	W/m^2		

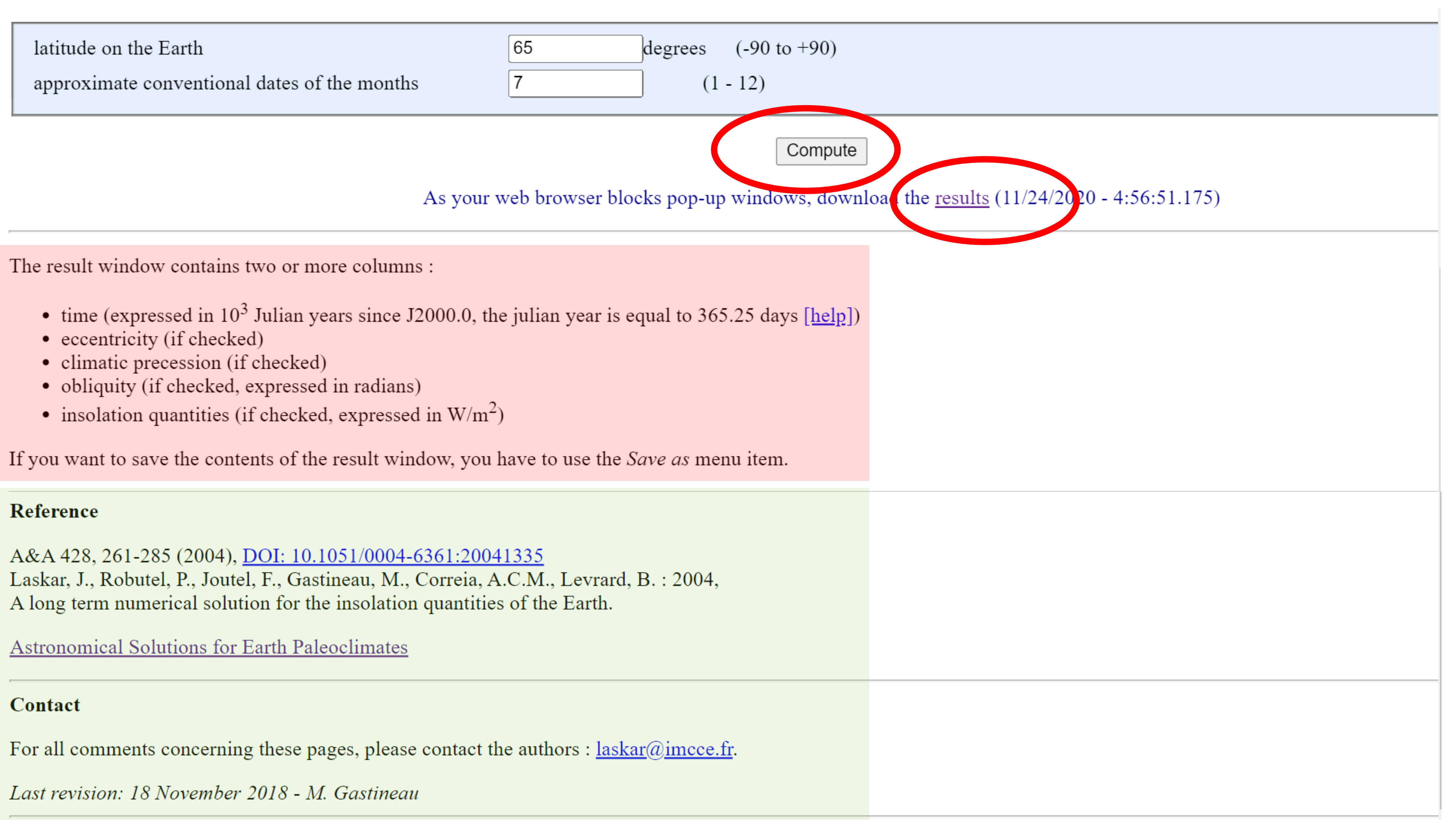
Orbital solution

● La2004

☑ eccentricity
☑ climatic precession
☑ obliquity
☑ insolation

○ mean daily insolation / true longitude [help]
○ mean daily insolation / mean longitude [help]
● mean monthly insolation [help]
○ mean annual insolation [help]

latitude on the Earth	65	degrees	(-90 to +90)	[help]
approximate conventional dates of the months	7		(1 - 12)	[help]



latitude on the Earth 65 degrees (-90 to +90)

approximate conventional dates of the months 7 (1 - 12)

As your web browser blocks pop-up windows, download the results (11/24/2020 - 4:56:51.175)

The result window contains two or more columns :

- time (expressed in 10^3 Julian years since J2000.0, the julian year is equal to 365.25 days [help])
- eccentricity (if checked)
- climatic precession (if checked)
- obliquity (if checked, expressed in radians)
- insolation quantities (if checked, expressed in W/m^2)

If you want to save the contents of the result window, you have to use the *Save as* menu item.

Reference

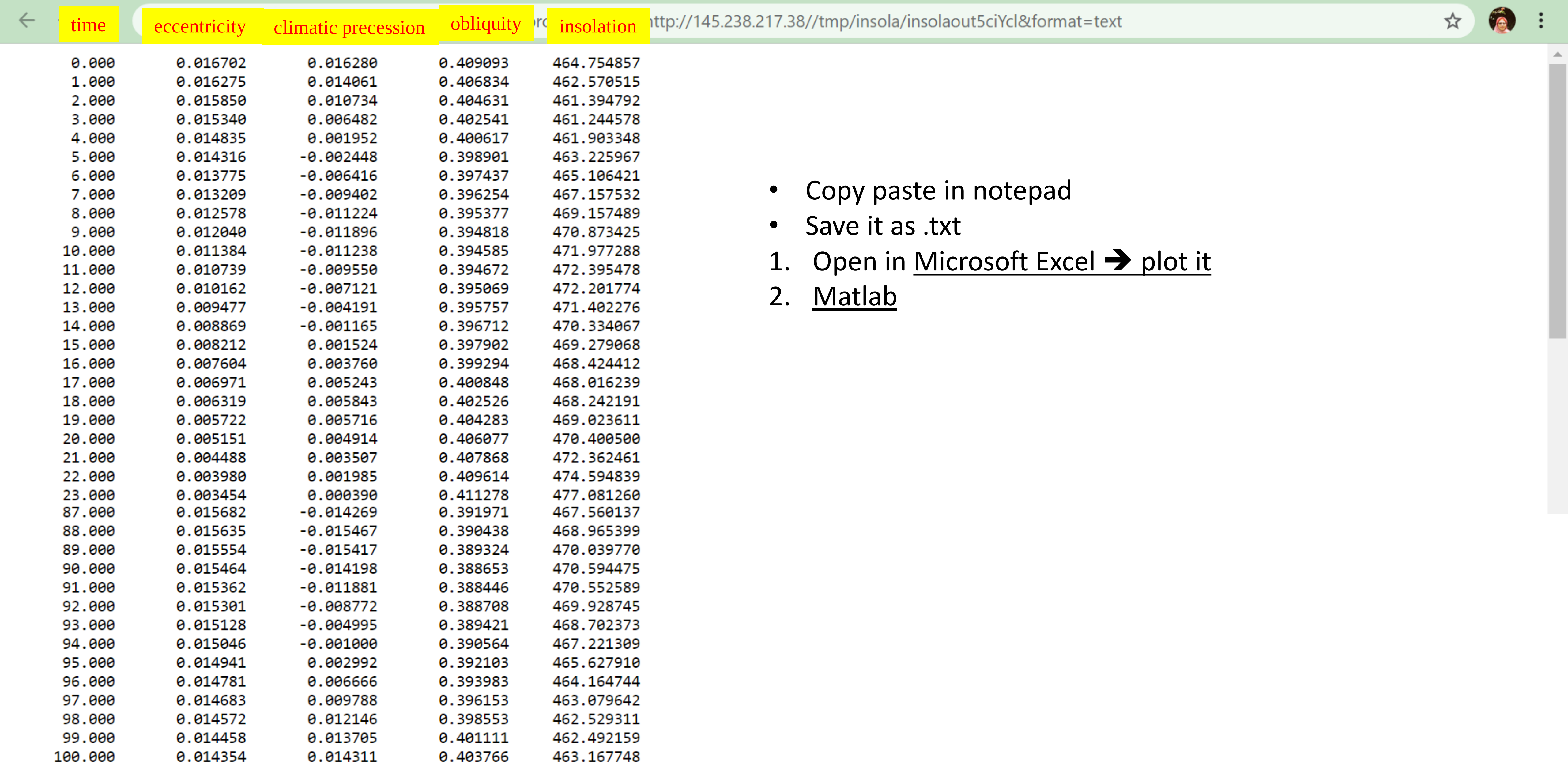
A&A 428, 261-285 (2004), DOI: 10.1051/0004-6361:20041335
Laskar, J., Robutel, P., Joutel, F., Gastineau, M., Correia, A.C.M., Levrard, B. : 2004,
A long term numerical solution for the insolation quantities of the Earth.

Astronomical Solutions for Earth Paleoclimates

Contact

For all comments concerning these pages, please contact the authors : laskar@imcce.fr.

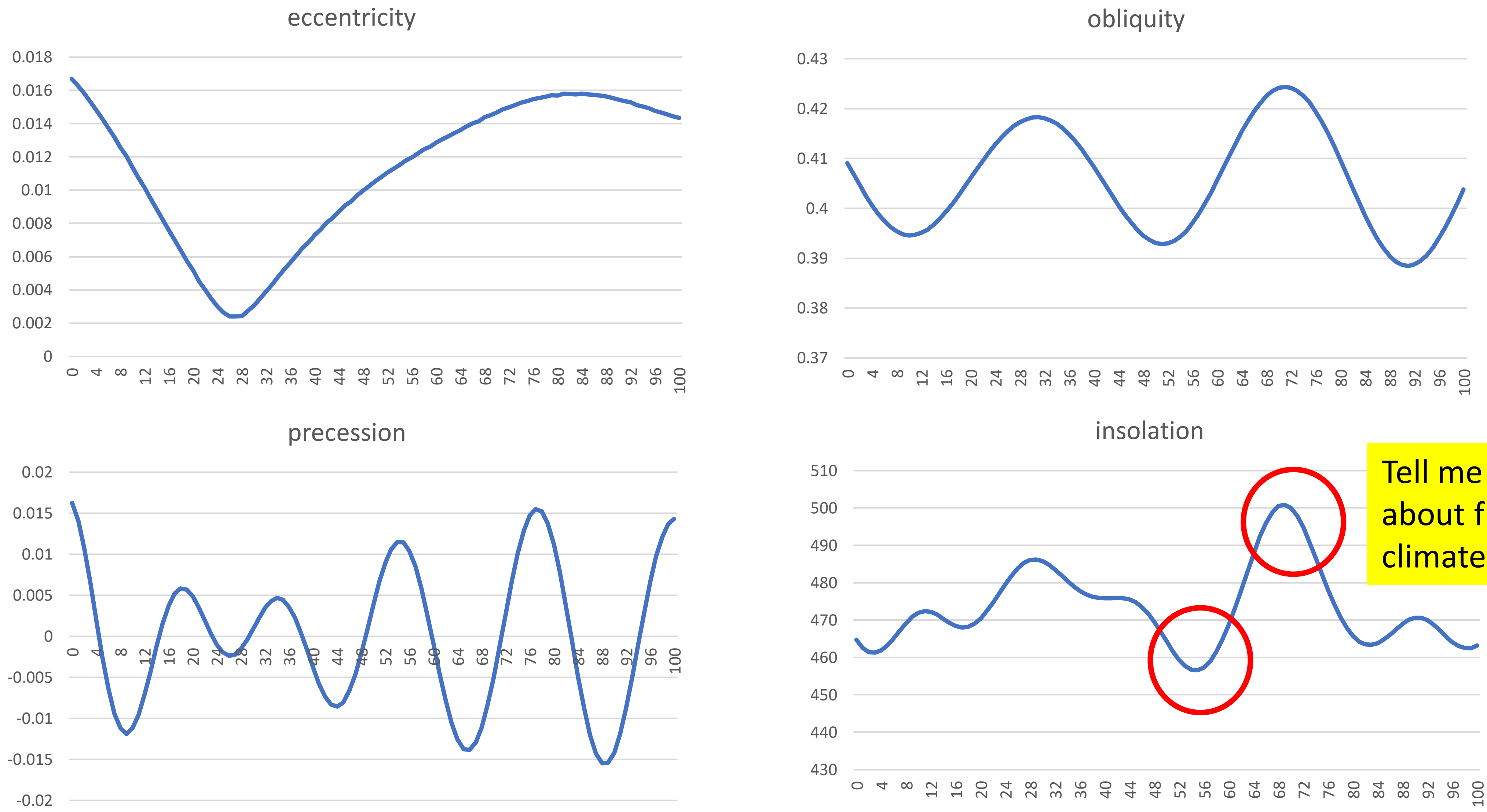
Last revision: 18 November 2018 - M. Gastineau



```
   time    eccentricity   climatic precession   obliquity   insolation
   0.000     0.016702      0.016280      0.409093     464.754857
   1.000     0.016275      0.014061      0.406834     462.570515
   2.000     0.015850      0.010734      0.404631     461.394792
   3.000     0.015340      0.006482      0.402541     461.244578
   4.000     0.014835      0.001952      0.400617     461.903348
   5.000     0.014316     -0.002448      0.398901     463.225967
   6.000     0.013775     -0.006416      0.397437     465.106421
   7.000     0.013209     -0.009402      0.396254     467.157532
   8.000     0.012578     -0.011224      0.395377     469.157489
   9.000     0.012040     -0.011896      0.394818     470.873425
  10.000     0.011384     -0.011238      0.394585     471.977288
  11.000     0.010739     -0.009550      0.394672     472.395478
  12.000     0.010162     -0.007121      0.395069     472.201774
  13.000     0.009477     -0.004191      0.395757     471.402276
  14.000     0.008869     -0.001165      0.396712     470.334067
  15.000     0.008212      0.001524      0.397902     469.279068
  16.000     0.007604      0.003760      0.399294     468.424412
  17.000     0.006971      0.005243      0.400848     468.016239
  18.000     0.006319      0.005843      0.402526     468.242191
  19.000     0.005722      0.005716      0.404283     469.023611
  20.000     0.005151      0.004914      0.406077     470.400500
  21.000     0.004488      0.003507      0.407868     472.362461
  22.000     0.003980      0.001985      0.409614     474.594839
  23.000     0.003454      0.000390      0.411278     477.081260
  87.000     0.015682     -0.014269      0.391971     467.560137
  88.000     0.015635     -0.015467      0.390438     468.965399
  89.000     0.015554     -0.015417      0.389324     470.039770
  90.000     0.015464     -0.014198      0.388653     470.594475
  91.000     0.015362     -0.011881      0.388446     470.552589
  92.000     0.015301     -0.008772      0.388708     469.928745
  93.000     0.015128     -0.004995      0.389421     468.702373
  94.000     0.015046     -0.001000      0.390564     467.221309
  95.000     0.014941      0.002992      0.392103     465.627910
  96.000     0.014781      0.006666      0.393983     464.164744
  97.000     0.014683      0.009788      0.396153     463.079642
  98.000     0.014572      0.012146      0.398553     462.529311
  99.000     0.014458      0.013705      0.401111     462.492159
 100.000     0.014354      0.014311      0.403766     463.167748
```

- Copy paste in notepad
- Save it as .txt

1. Open in <u>Microsoft Excel ➔ plot it</u>
2. <u>Matlab</u>



Tell me your opinion about future climate!

Time (kyr)

Send your homework ➔ rrachmayani@oceanography.itb.ac.id, rima.rachmayani@gmail.com ➔ .pdf or .docx ➔ paleo_work_yourname ➔ before the Friday lectures