Indonesian fires and drought

El Niño

Indian Ocean Dipole (IOD)

Monsoon

Xiaohua Pan[1,2], Mian Chin[2], Charles Ichoku[2], Robert Field [3,4]

1. *ESSIC at University of Maryland*
2. *NASA GSFC*
3. *Columbia University*
4. *NASA GISS*

EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER
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CONNECT

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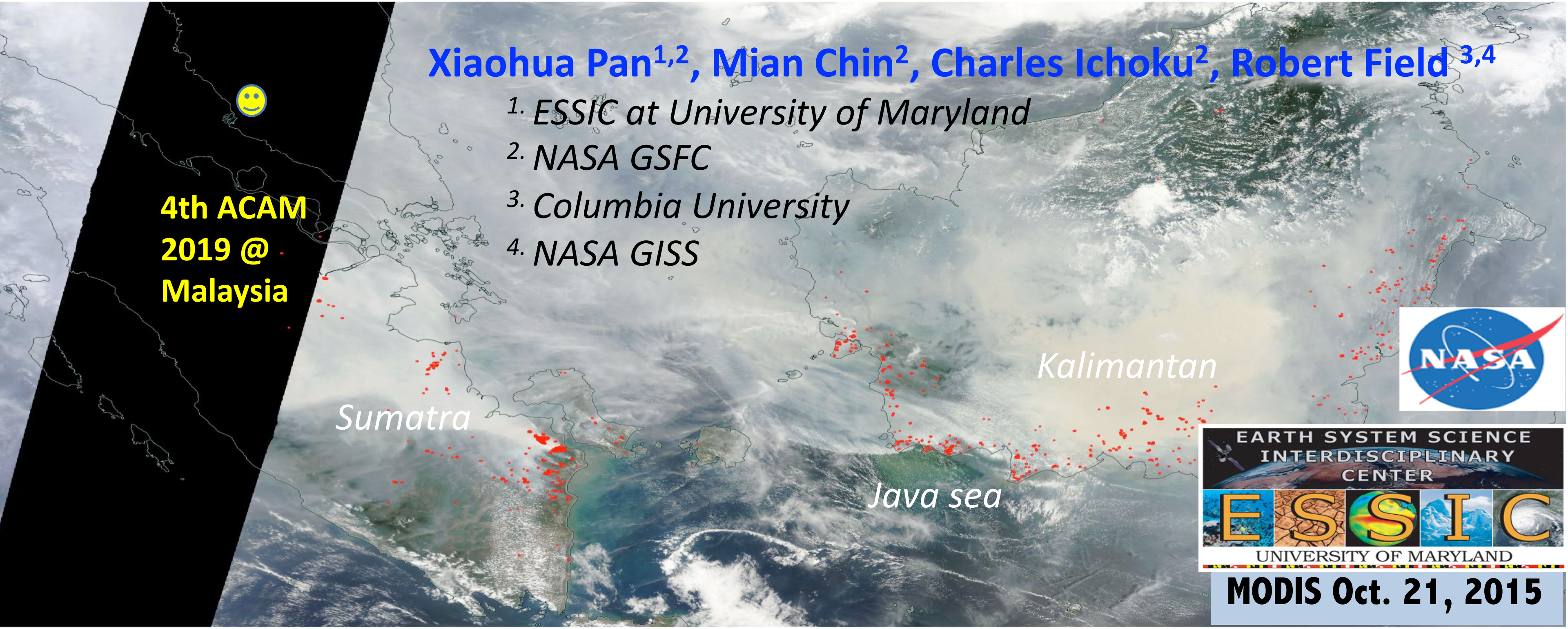
4th ACAM 2019 @ Malaysia



MODIS Oct. 21, 2015

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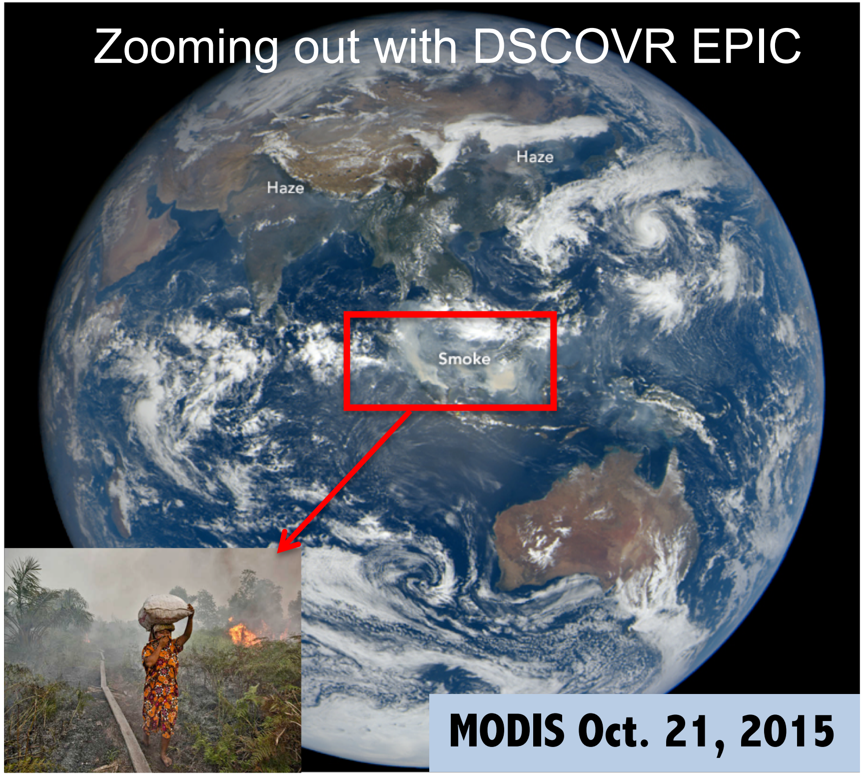
Why do Indonesian fires matter?



Source : http://earthobservatory.nasa.gov/Features/IndonesianFires/page1.php

Regional impact on air quality and health

- Indonesian fires have impact on entire tropical Asia: Indonesia, Singapore, Malaysia, Thailand
- Air quality measurements: the 1-hour $PM_{2.5}$ concentration reached a record high of 471µg/m³ at stations in the west of Singapore, and AERONET daily AOD was over 6 at stations in Borneo
- Costed $16.1 billion loss (~1.9% of its GDP in 2015)

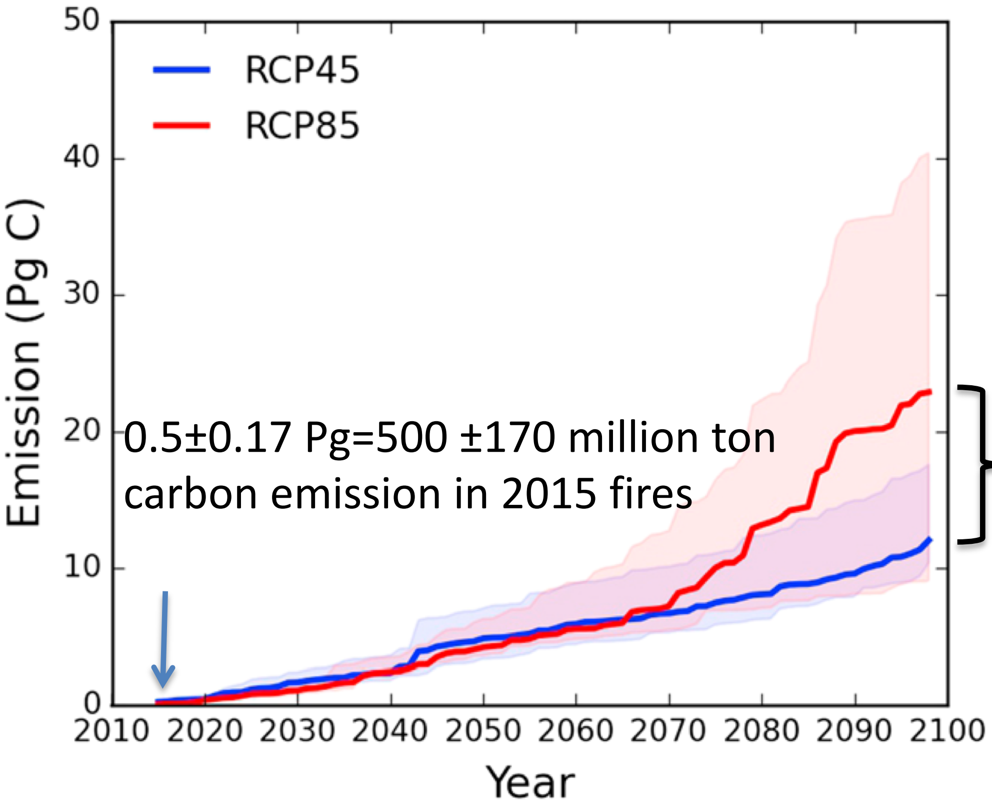
Global impact on carbon cycle and radiation

- Tropical peatland fires emit ≥300Mg (1Mg=1 ton) C per hectare, compared to 7.5-70MgC ha^{-1} from other habitat types (Cochrane, 2003).
- One of the world's largest CO_2 emitter (Hooijer et al. 2006). Indonesia fires released 227±27 Tg of carbon to atmosphere in Sept-Oct 2015, of which 83% is in CO_2 (692 million tons CO_2) (Huijnen et al. 2016).

Projection of fire carbon emissions- increase in EQAS

Yin et al. (2016)

- Based on 7 CMIP5 models
- in the absence of action to limit peatland burning



12,000-25,000 million tons carbon

Motivation: Advance our understanding on Indonesian fires

Fires are started by human

Establish palm oil plantation

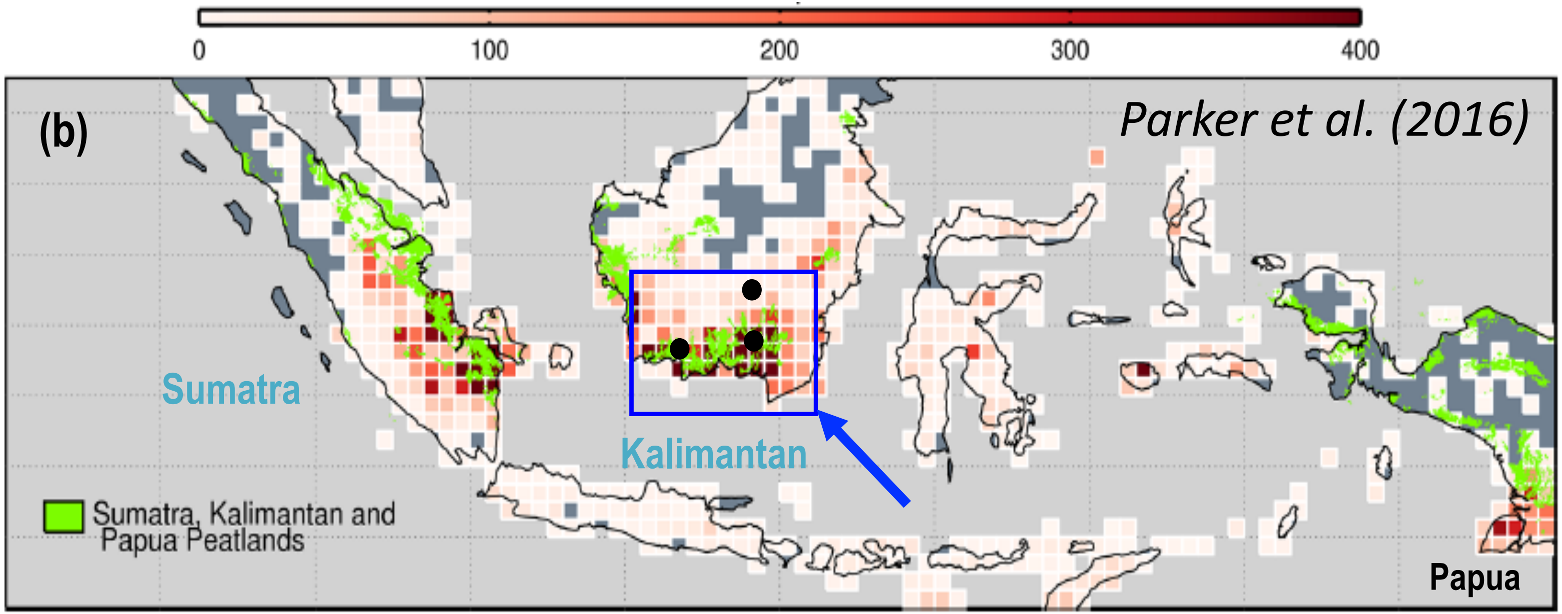
Convert forest to pasture

Burn agricultural waste

- ❑ Fire activities are a result of interplay between land use practices and climate variability
- ❑ Fires are commonly employed in land management to clean the fields, for example…
- ❑ But fires could spread underground into degraded peatlands, and become out of control in drought condition, especially during El Nino years (*Tacconi, 2016 Nature*).

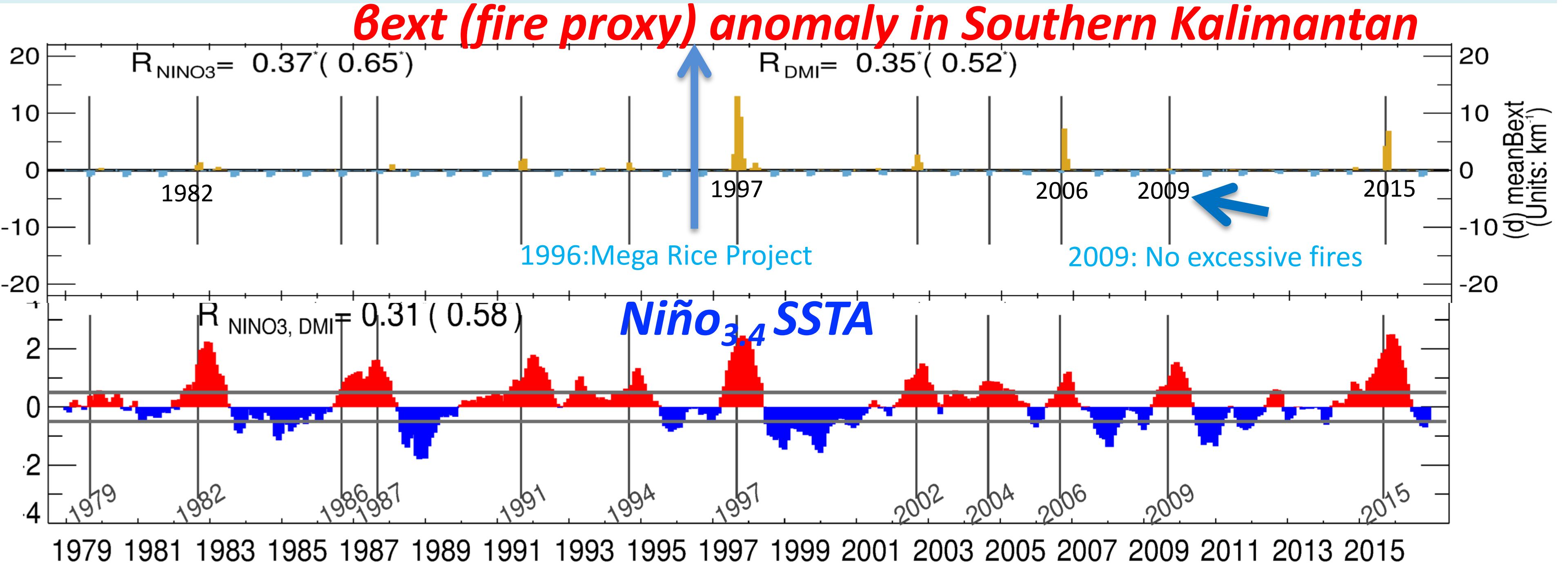
Study region

MODIS fire counts over Indonesia: September/October 2015:



- High frequencies of fire counts collocated with peatland in both southern Sumatra and southern Kalimantan during 2015 Indonesia fires
- Peatlands occupy 11-16 % land, but contribute 60-90% smoke and haze

Known and Unknown: Indonesian fires (1979-2016)



Known:

- **Human impact:** fire emission increased after 1996, likely attributable to the Mega rice project
- **Climate driver:** clear finger prints of El Niño with large fires occurring in El Niño years after 1996

Unknown: there was an exception- no severe fires in 2009, although it is an El Niño year stronger than 2006, implying that the severity of fires did not always follow the magnitude of El Niño→ investigate

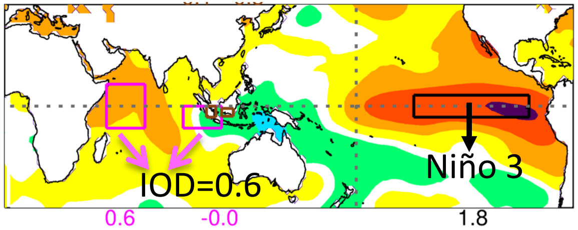
Unknown

1. Is the severity of Indonesian fires connected with the different types of El Niño and Asian winter monsoon?
2. How does Indian Ocean Dipole (IOD) impact Indonesian fires through interacting with the different types of El Niño?

Definition I: El Niño types/location (Aug-Oct of 1979-2016)

ERSST_
(°C)

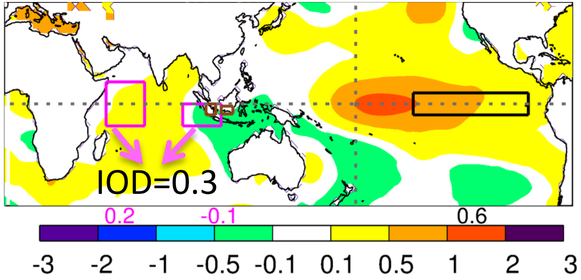
Eastern Pacific (EP) El Niño



1982,
1997,
2006,
2015

Composite of EP

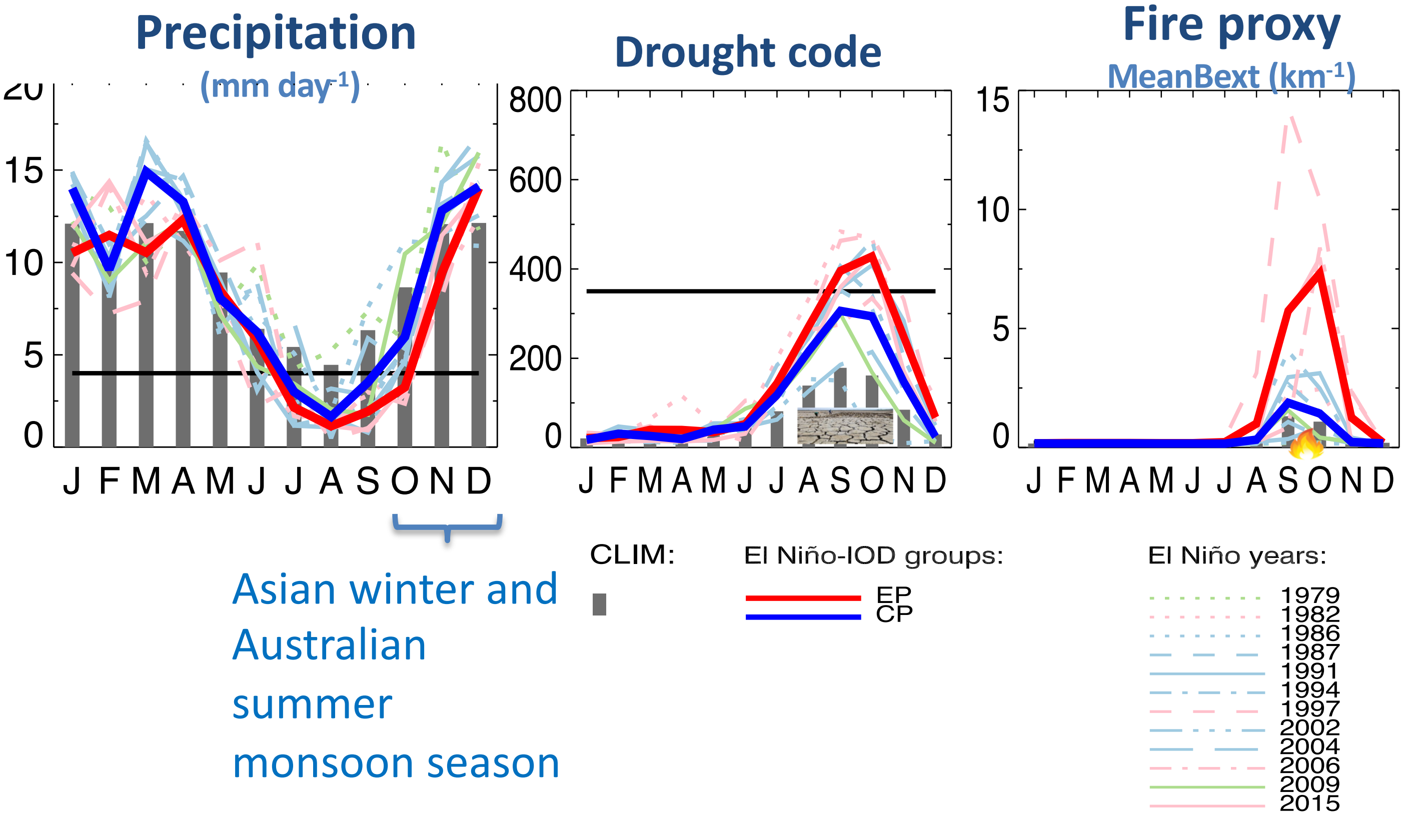
Central Pacific (CP) El Niño



1979,
1986,
1987,
1991,
1994,
2002,
2004,
2009

Composite of CP

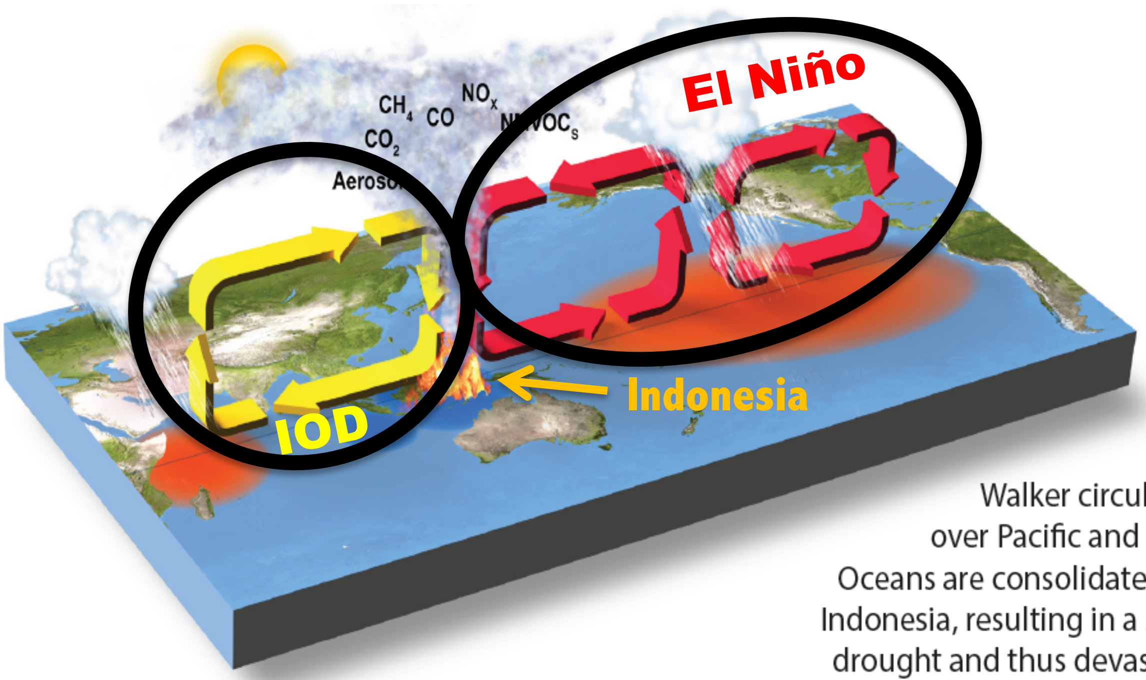
Comparison of Indonesian Drought and Fires: EP vs. CP types



Question 1:
Is the severity of Indonesian fires connected with the different types of El Niño and Asian winter monsoon?

- ❑ EP>CP: drought and fires are more intense and prolonged in EP than in CP

Both El Niño and IOD → Drought → Indonesian Fires



Walker circulations over Pacific and Indian Oceans are consolidated over Indonesia, resulting in a severe drought and thus devastating burning of forest and peatland.

- Both El Niño and IOD play important role in modulating severity of Indonesian fires through drought condition

Illustrated by Theophilus Griswold

Unknown

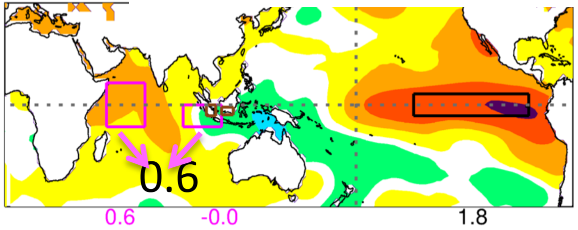
1. Is the severity of Indonesian fires connected with the different types of El Niño?
2. How does Indian Ocean Dipole (IOD) impact Indonesian fires through interacting with the different types of El Niño?

Definition II: Different IOD phases

EP El Niño type

Positive IOD

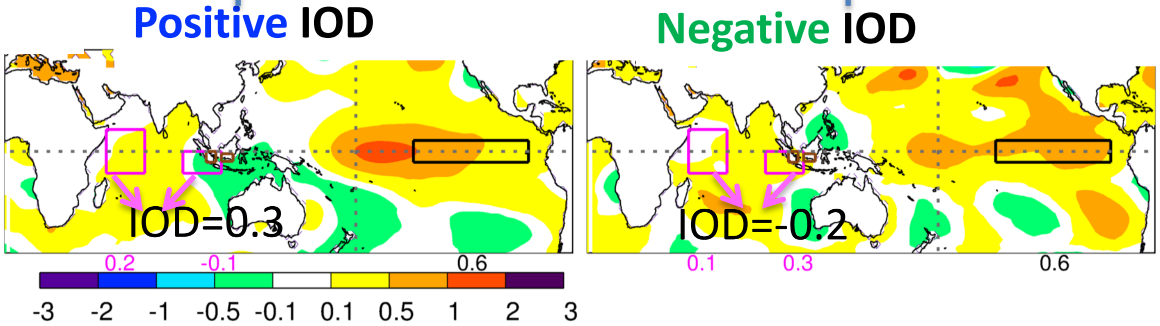
ERSST_
(°C)



1982,
1997,
2006,
2015

Definition II: Different IOD phases

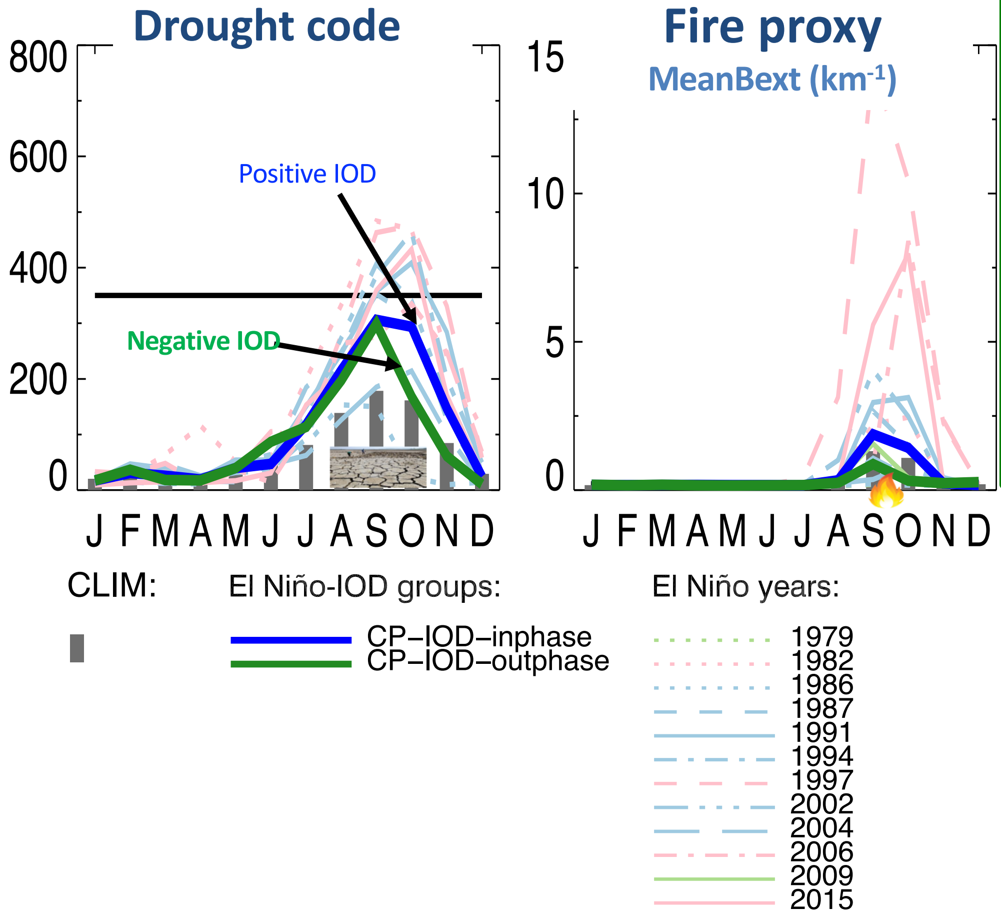
CP El Niño type



1986,
1987,
1991,
1994,
2002,
2004

1979,
2009

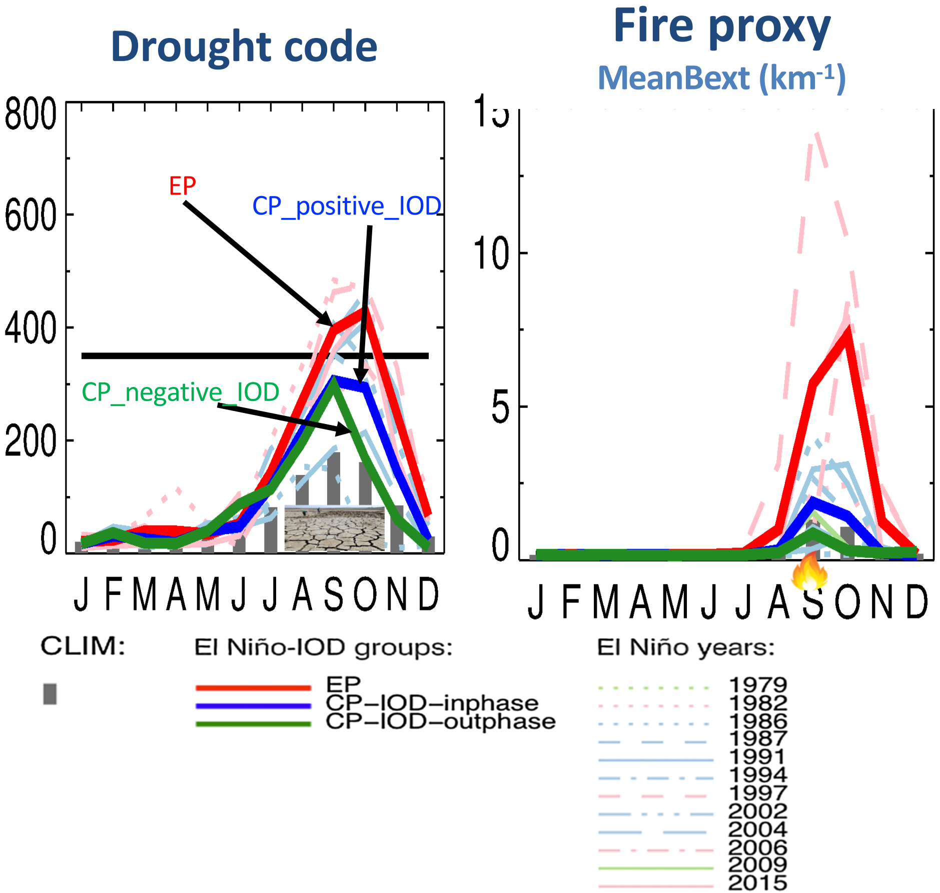
Comparison of Indonesian Drought and Fires: positive vs. negative IOD



Question 2: How does Indian Ocean Dipole (IOD) impact Indonesian fires?

- Drought and fires are weaker and last shorter if the IOD is negative; 2009 is one of such kind of El Nino years

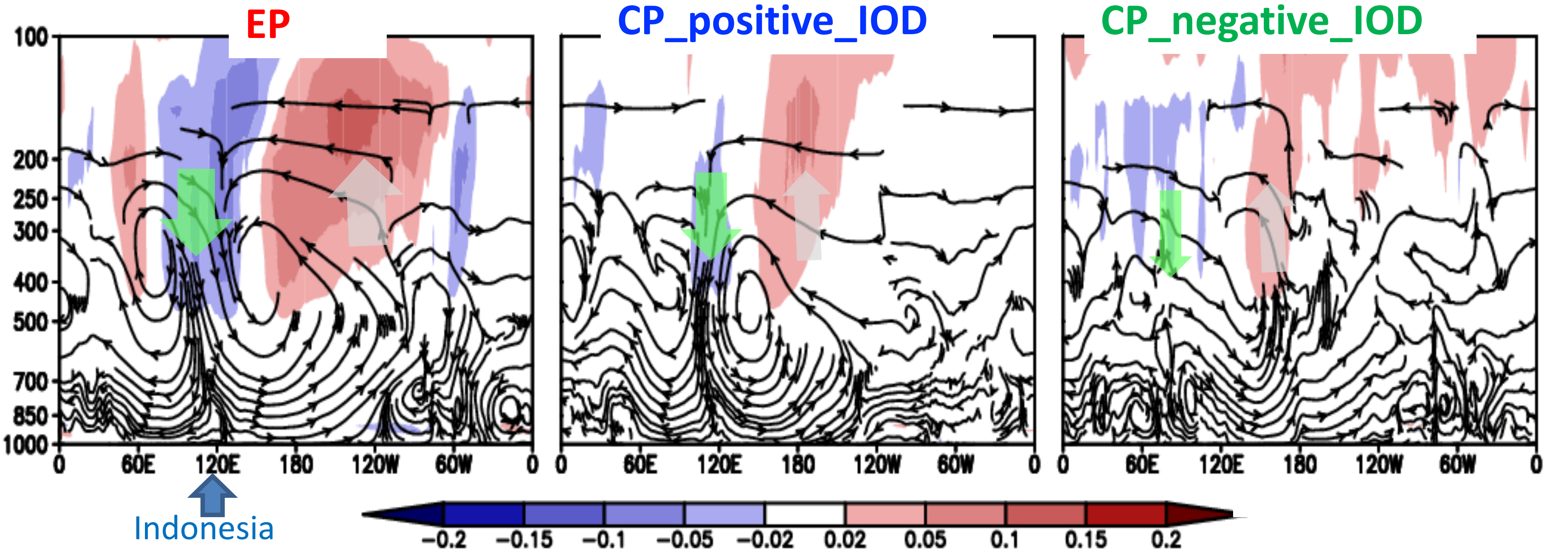
Summary: Comparison of Indonesian Drought and Fires in three group of El Niño-IOD



- ❑ the severity of Indonesian fires is connected with the different types of El Niño: drought and fires are more intense and prolonged in EP than in CP (EP>CP);
- ❑ The phase of IOD also plays an important role in modulating growth of Indonesian fires through drought condition: drought and fires are weaker if the IOD is negative (Positive IOD > negative IOD).

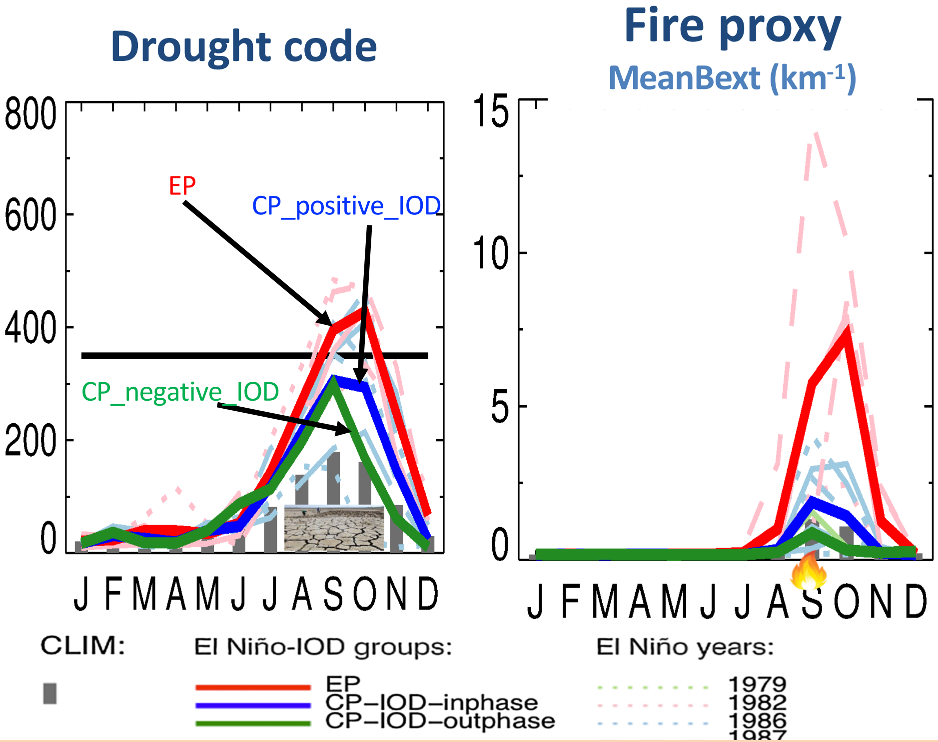
Physical explanation of distinct fire activities: SSTA in three group of El Niño-IOD → different intensity and location of the Walker circulation

Walker circulation (streamline) and cloud fraction anomalies (shaded) along equator Aug-Oct (MERRA2)



- ❑ Anomalous sinking motion over Indonesia which results in drought is stronger in EP group
- ❑ Anomalous sinking motion is weaker over Indonesia in two CP groups, especially weaker and moving westward when IOD is negative

Take-away messages



We found that Indonesian drought and fires:

- EP>CP;
- Positive IOD > negative IOD.

Contribution of this study: advances the previous understanding of the role of climate variability on Indonesian fire activity, by considering the modified monsoon rainfall by (i) the presence of different types of El Niño and (ii) the interaction between El Niño and the Indian Ocean Dipole (IOD).

Implication: drought early warning and air quality forecast

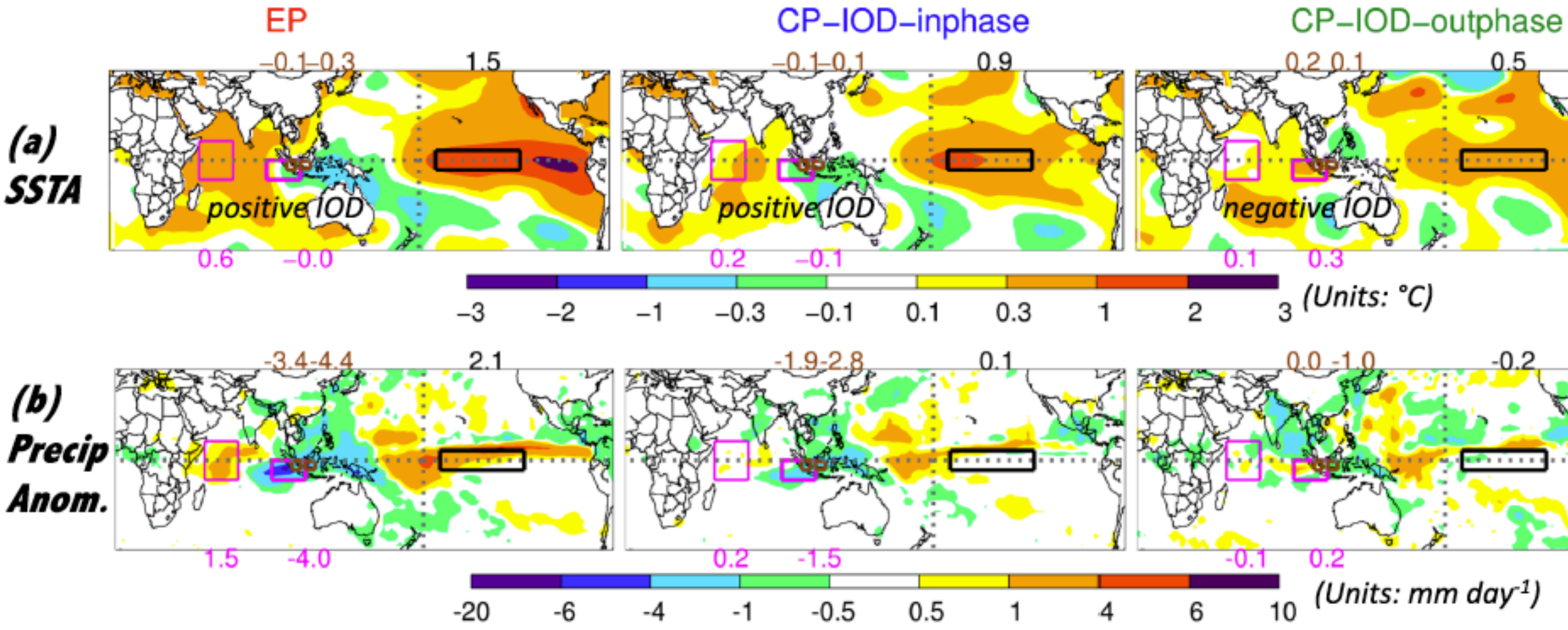
Paper: "Connecting Indonesian fires and drought with the type of El Niño and the phase of Indian Ocean Dipole during 1979-2016", JGR-atmosphere, July 2018 (6 citations so far ☺).

Thank you

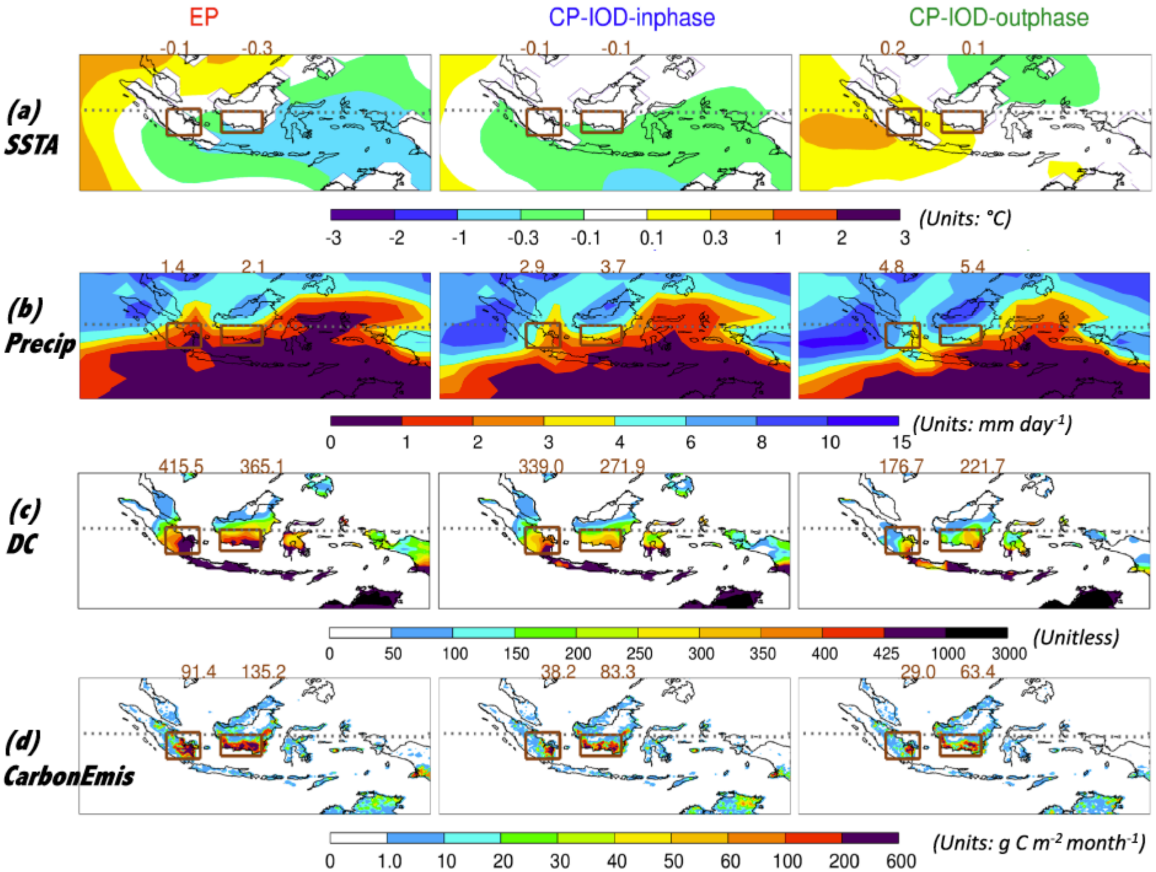
Implication

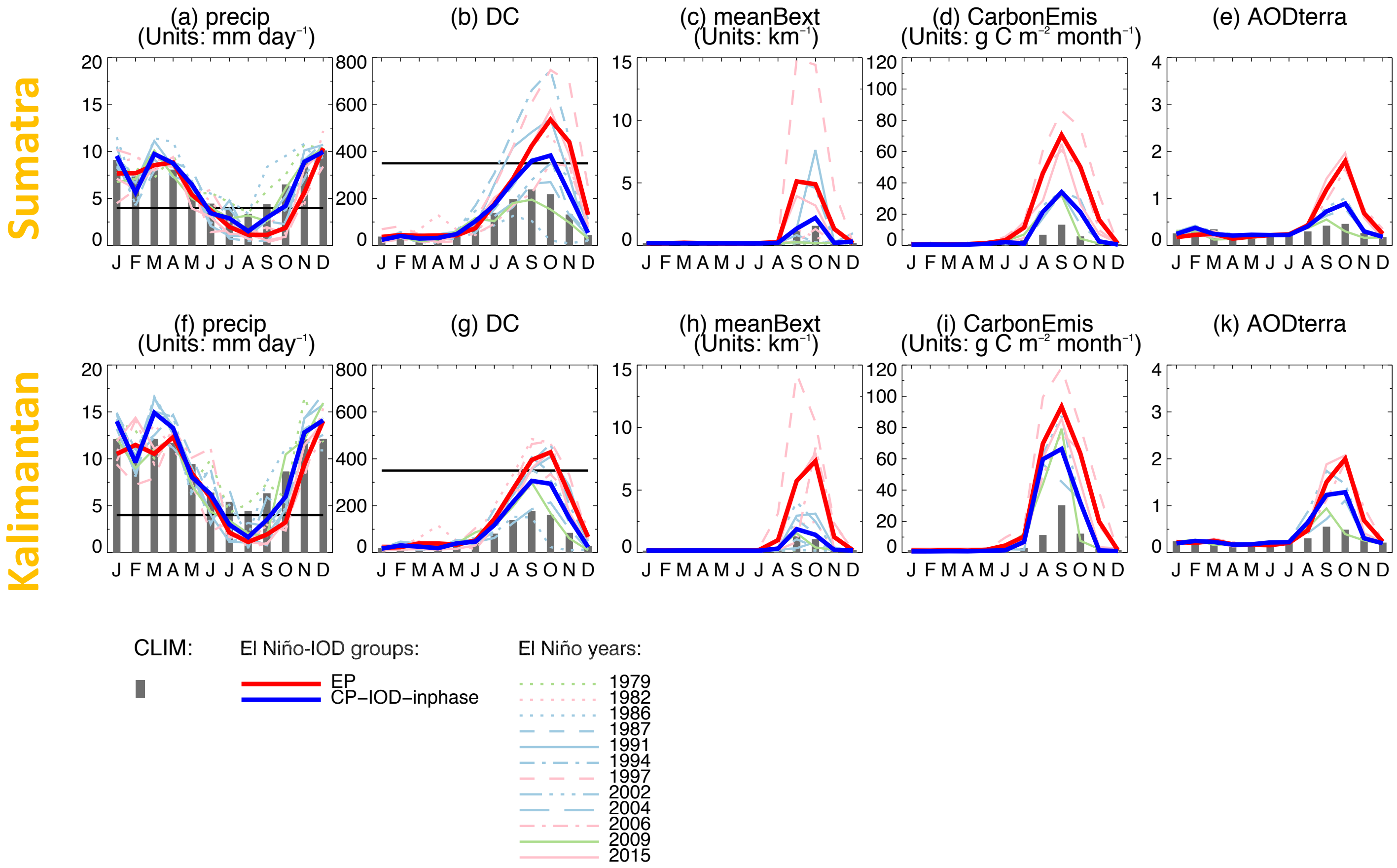
The outcome of this study can be applied to **drought early warning, fire management** and **air quality forecast** in Indonesia and neighboring countries **by identifying the type of El Niño + the phase of IOD** in advance.

SSTA and Precip in Aug-Oct

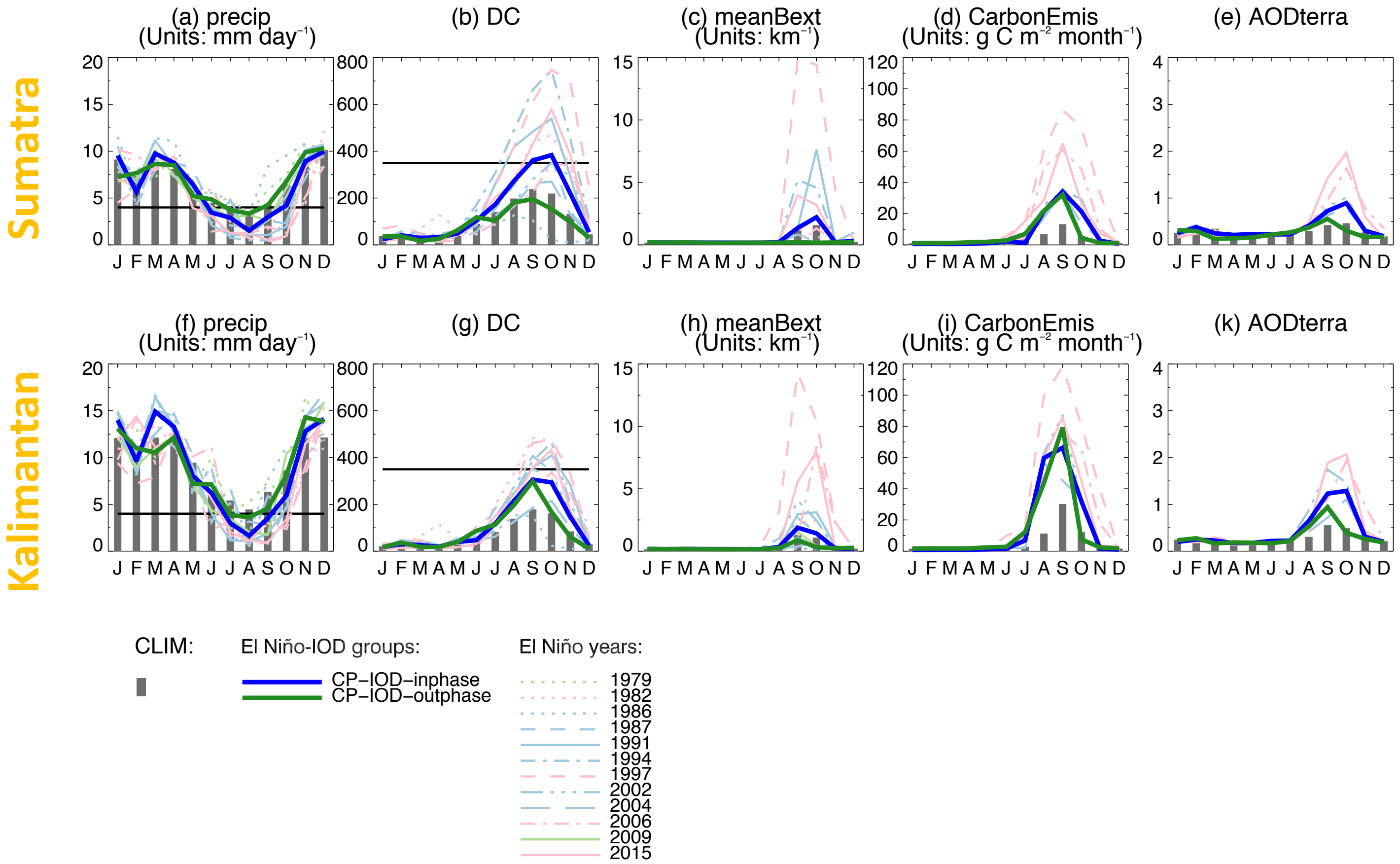


Climate and fire in Aug-Oct





Sumatra
Kalimantan
(a) precip (Units: mm day⁻¹)
(b) DC
(c) meanBext (Units: km⁻¹)
(d) CarbonEmis (Units: g C m⁻² month⁻¹)
(e) AODterra
(f) precip (Units: mm day⁻¹)
(g) DC
(h) meanBext (Units: km⁻¹)
(i) CarbonEmis (Units: g C m⁻² month⁻¹)
(k) AODterra
J F M A M J J A S O N D
CLIM:
El Niño-IOD groups:
EP
CP−IOD−inphase
El Niño years:
1979
1982
1986
1987
1991
1994
1997
2002
2004
2006
2009
2015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(a) precip (Units: mm day⁻¹)
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J F M A M J J A S O N D
CLIM:
El Niño-IOD groups:
CP–IOD–inphase
CP–IOD–outphase
El Niño years:
1979
1982
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Source: J. Miettinen et al. / Global Ecology and Conservation 6 (2016)

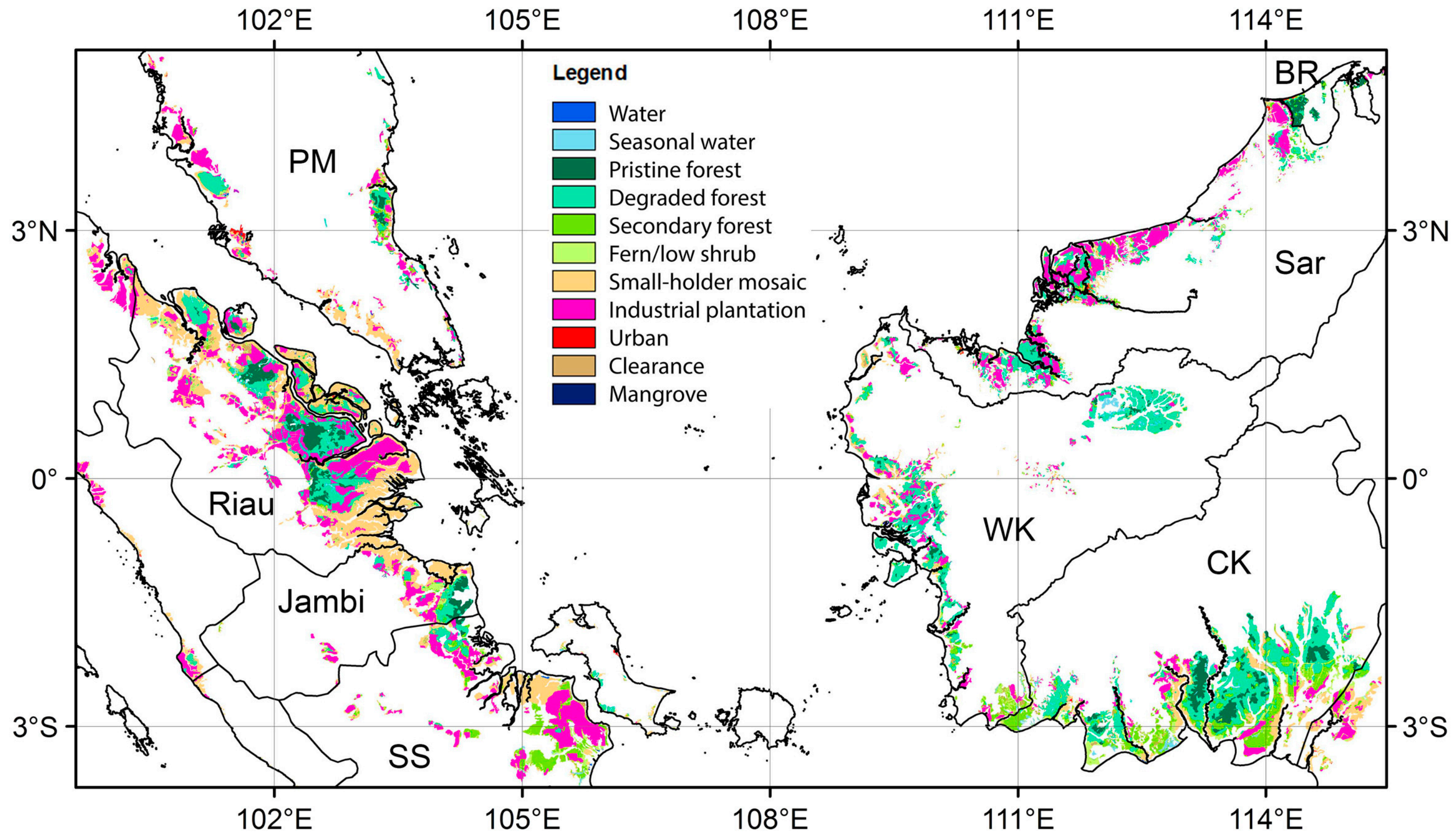

Fig. 2. Land cover 2015 in the major peat domes of the study area. Administrative areas referred in the text are identified as: PM = Peninsular Malaysia, Sar = Sarawak, BR = Brunei, SS = South Sumatra, WK = West Kalimantan and CK = Central Kalimantan.

Source: J. Miettinen et al. / Global Ecology and Conservation 6 (2016)

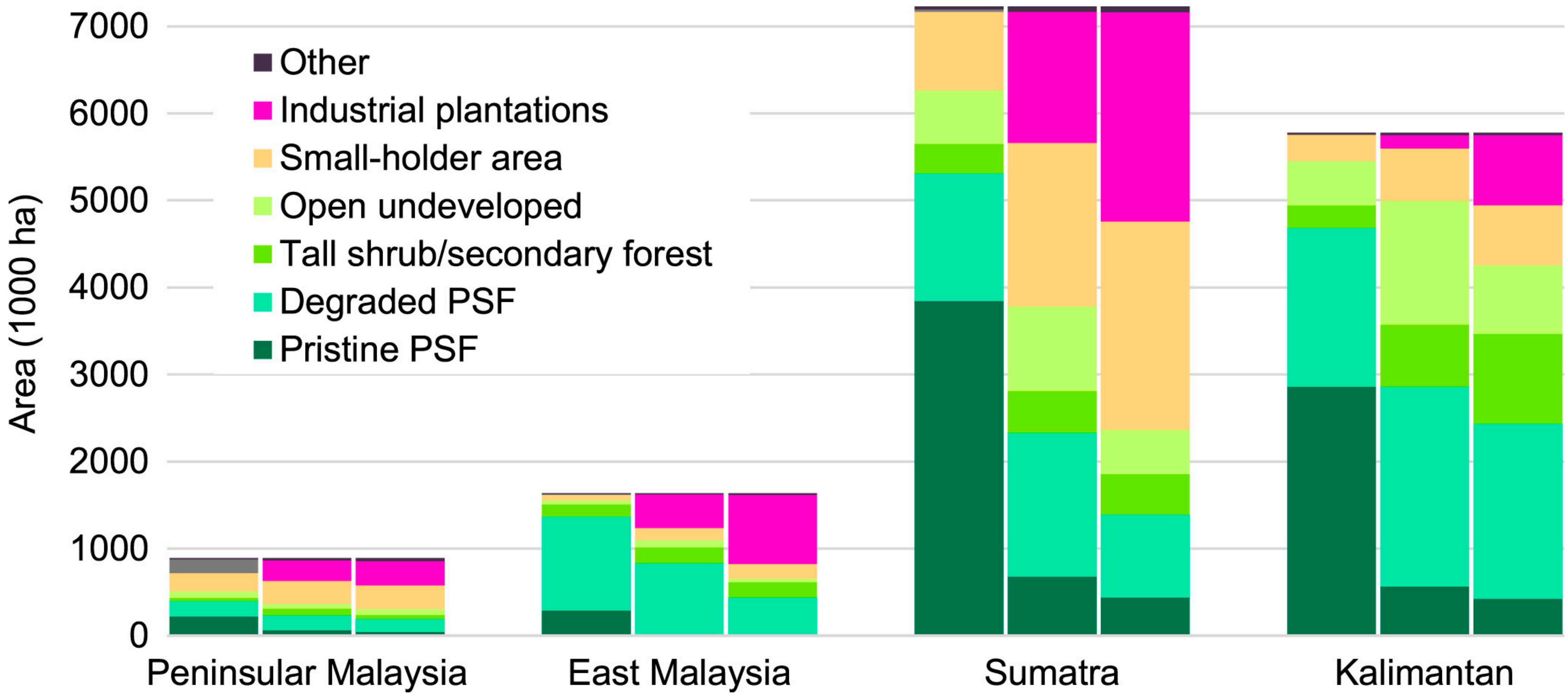

Fig. 3. Development of land cover distribution 1990–2007–2015 (left–centre–right) in the major sub-regions of the study area. East Malaysia contains Sarawak and Sabah. The ‘Open undeveloped’-class includes the original classes of ‘Seasonal water’, ‘Fern/low shrub’, ‘Clearance’.