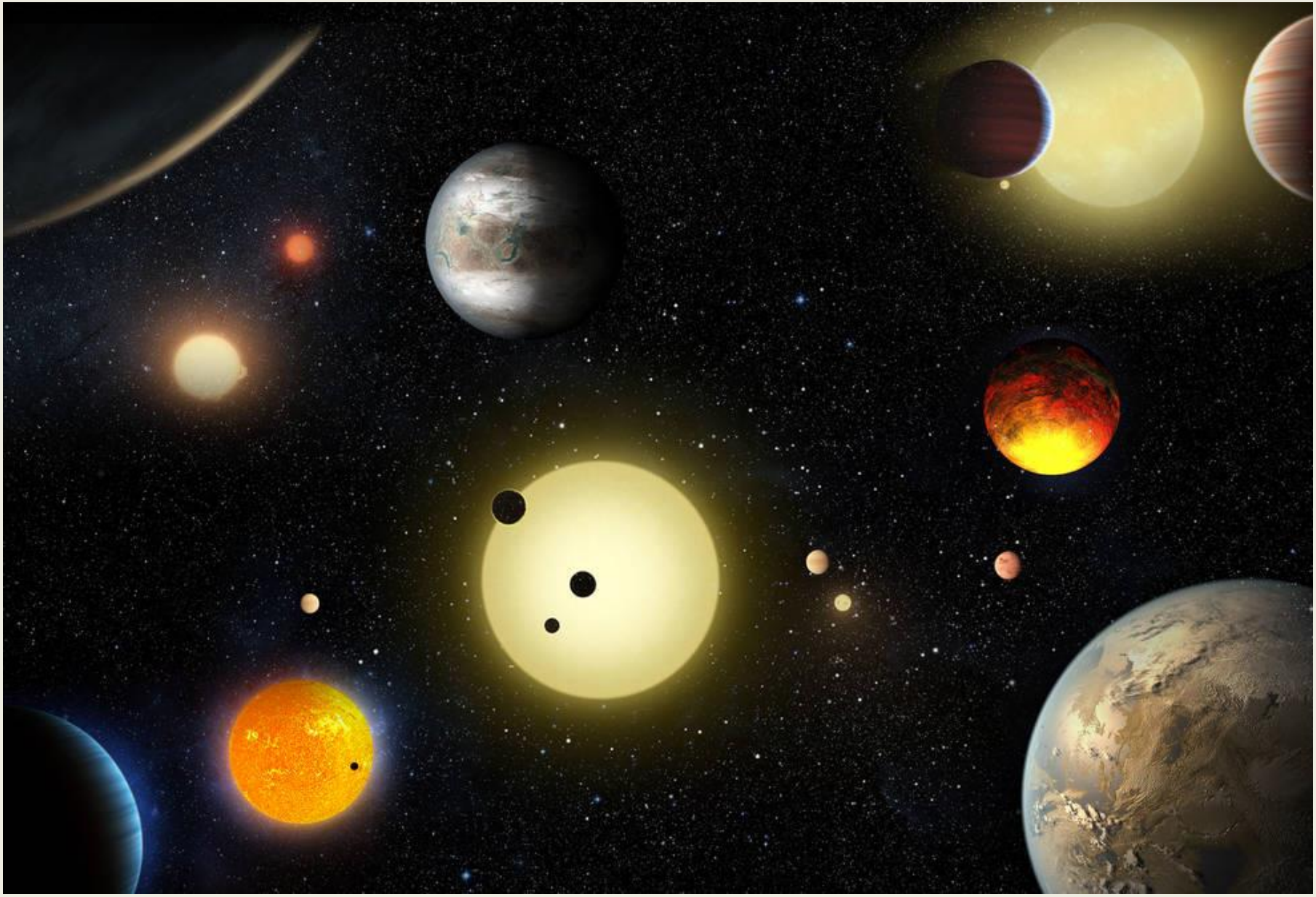
京都大学宇宙総合学研究ユニット
KYOTO UNIVERSITY UNIT OF SYNERGETIC STUDIES FOR SPACE
宇宙学セミナー （2017年2月10日）

Prediction of Climate Variation and its Application to Societies for Sustainable Development

（気候変動予測と持続可能な開発に向けた社会応用）

Toshio Yamagata
Prof. Emeritus of the Univ. of Tokyo
Director, Application Lab, JAMSTEC, Japan

三千個以上の系外惑星が発見されている （NASA)



Anthropocene

人類世、人新性

水惑星地球の変化・変動のなかで如何に人間安全保障を展開するか？

Under changes and variations of our planet Earth, how can we develop sustainable human security?

持続可能な「未来の地球」は持続可能な「未来の海」を必要とする。

Sustainable future Earth needs sustainable future Oceans.

アジア・太平洋地域において私たちはどのような未来開拓をすべきか？

How should we develop our sustainable future in the unique Asia-Pacific region?

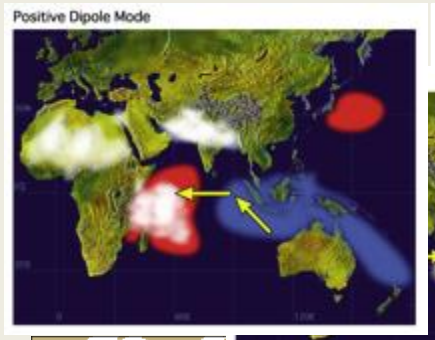
UN Sustainable Development Goals

（持続可能な開発目標）

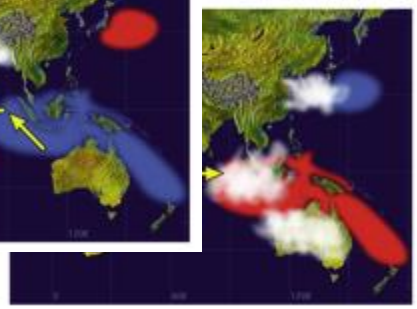
adopted by the UN sustainable development summit
as the post 2015 development agenda

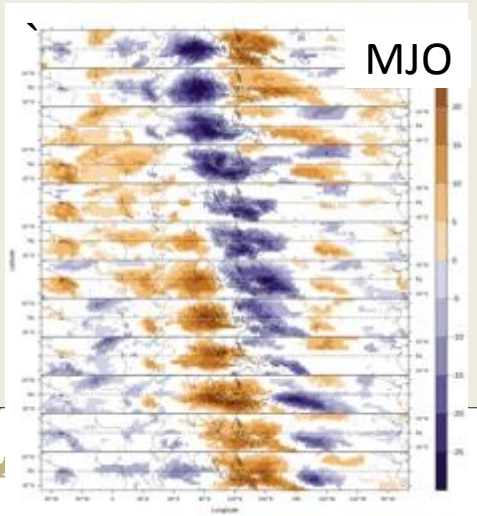
Key sustainability challenges in Asia and the Pacific
アジア・太平洋における持続可能性の課題

- **Climate variability and extremes under climate change, and related hazards and disasters from typhoons, floods and landslides etc. → Increasing billion dollar climate and ocean disasters**
- Pressures of urbanization – megacities, health, pollution
- Values and lifestyles - social pressures, rapid growth in economics, population, production, consumption, and global connectivity
- Biodiversity loss in hot spots and unvalued/undervalued ecosystem services
- Food, water, energy, land security nexus
- **Resilience, vulnerability, productivity of coastal, marine and terrestrial biomes**

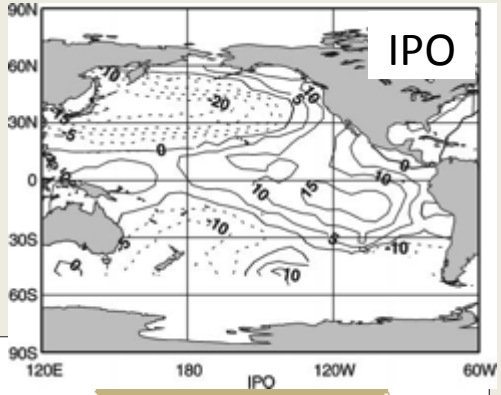


IOD

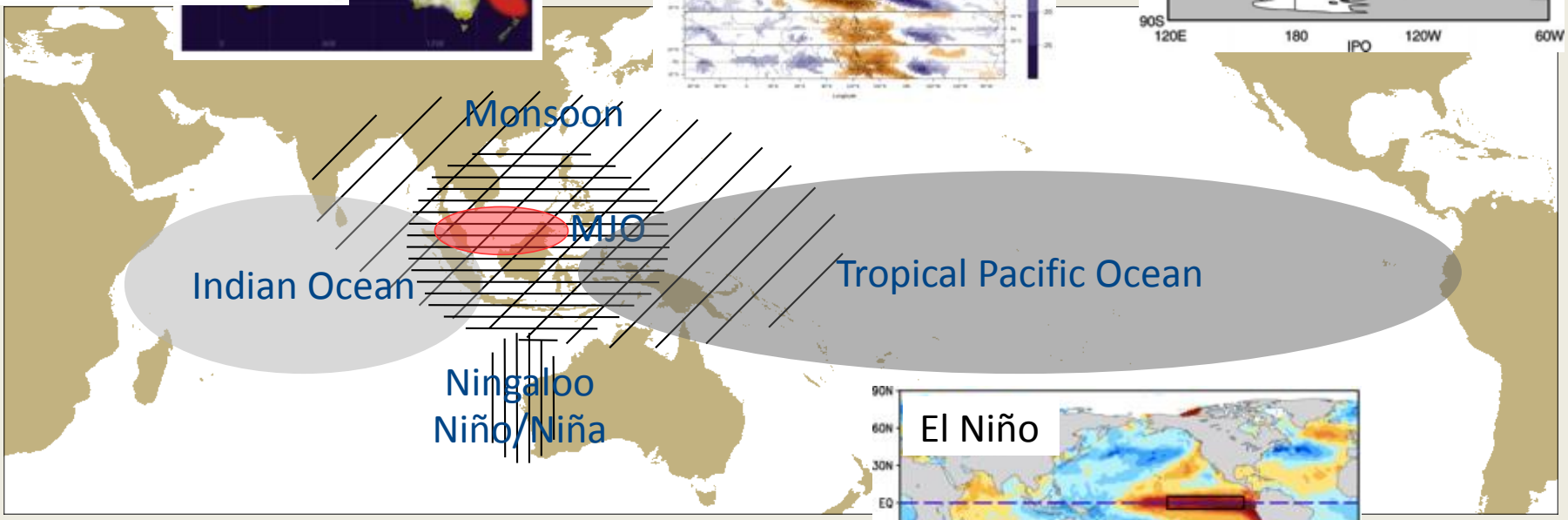


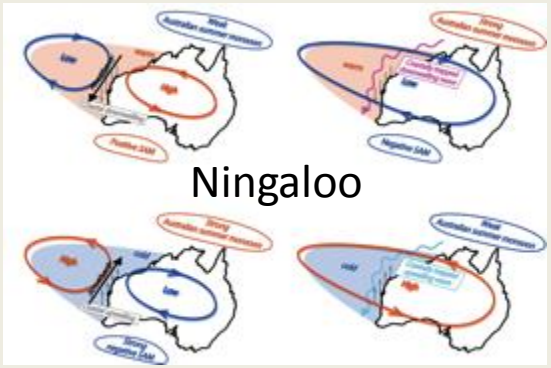


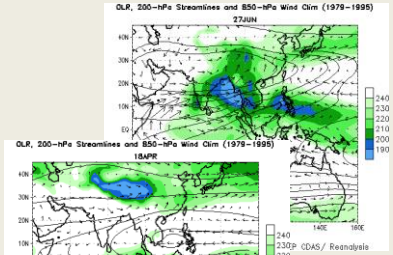
MJO



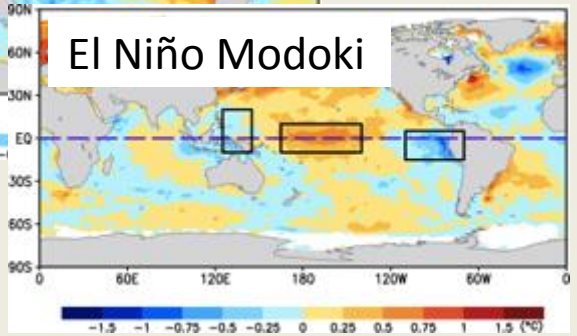
IPO



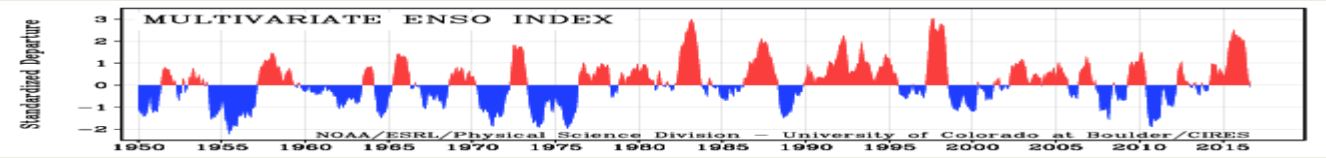




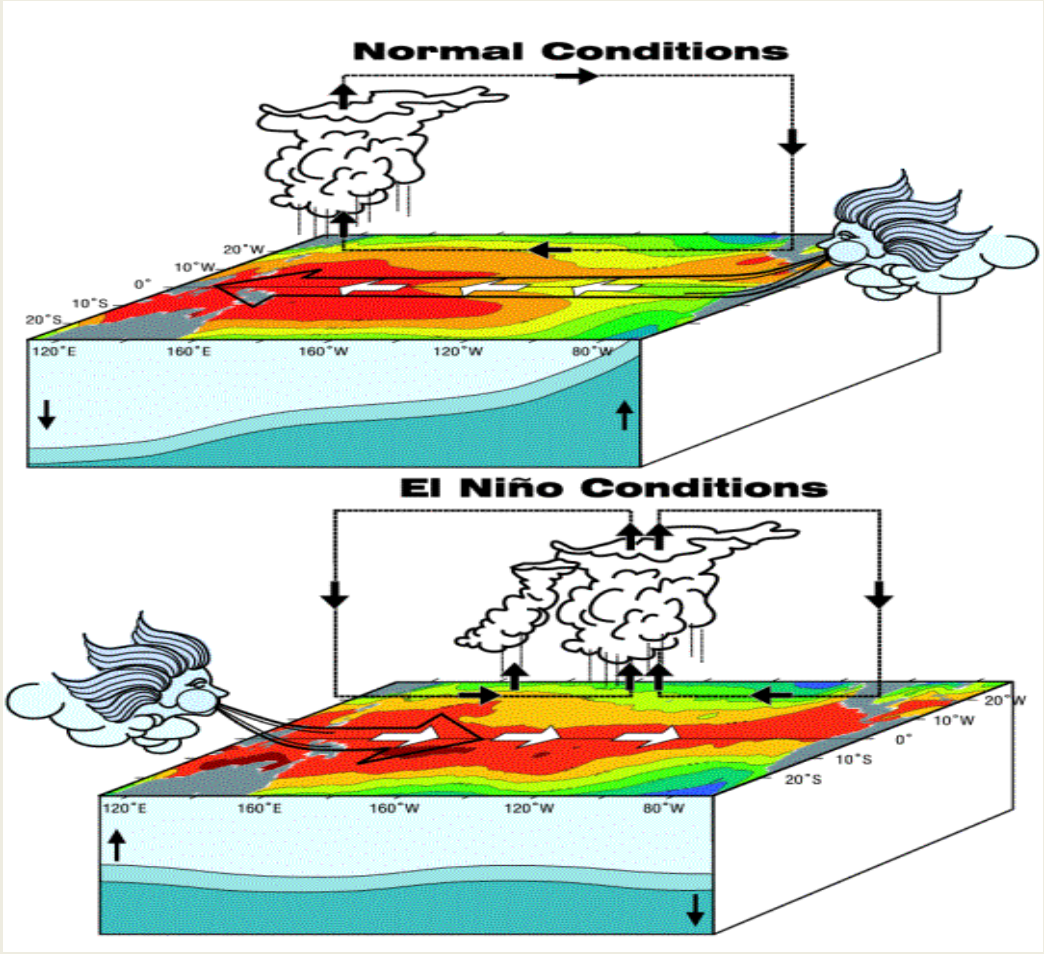
Monsoon



エルニーニョ現象の模式図
Schematic picture of El Niño



1900-1999



ラニーニャ
La Niña

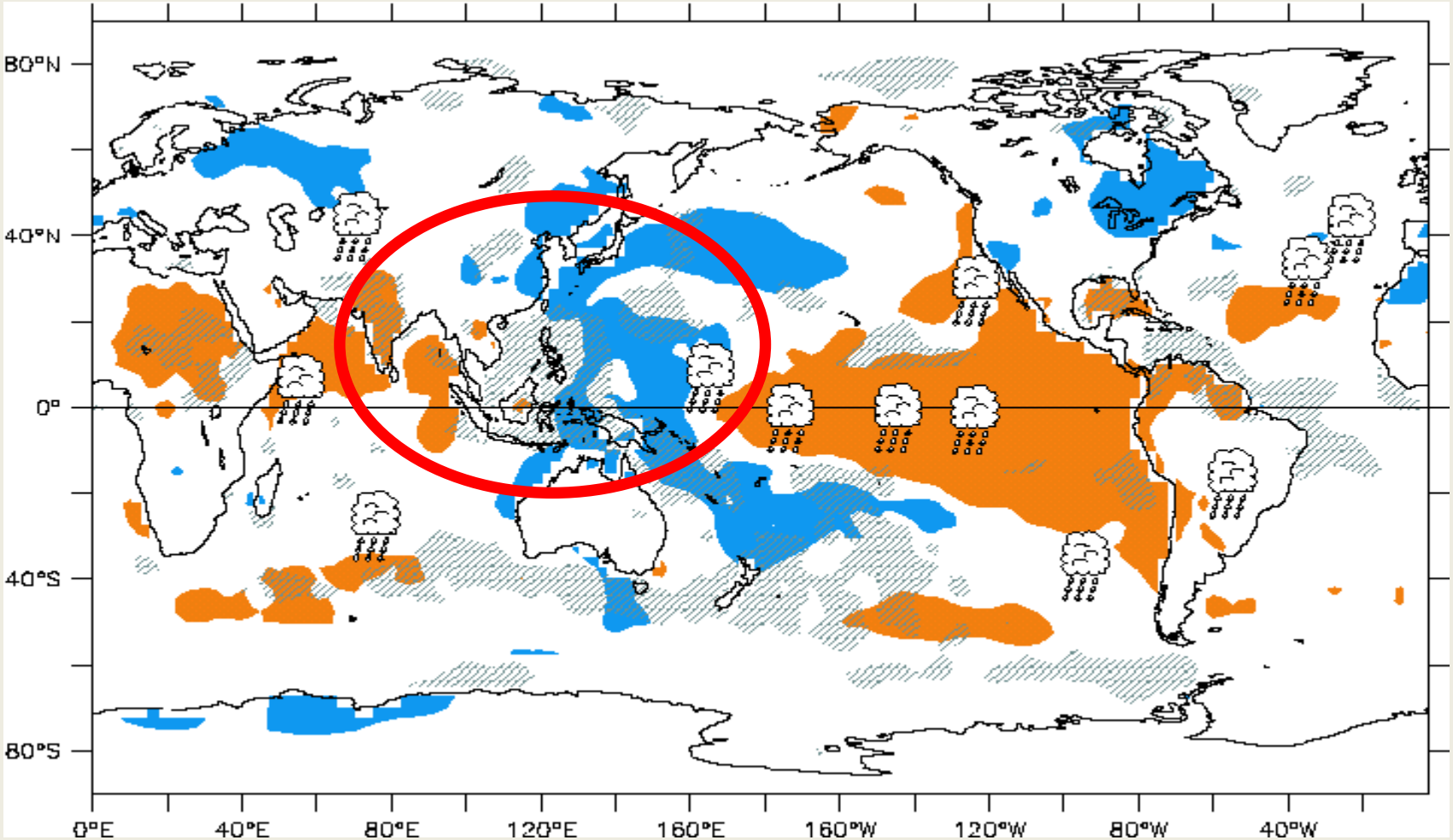
エルニーニョ
El Niño

エルニーニョ現象の世界各地への影響（夏）

Global impact of El Niño

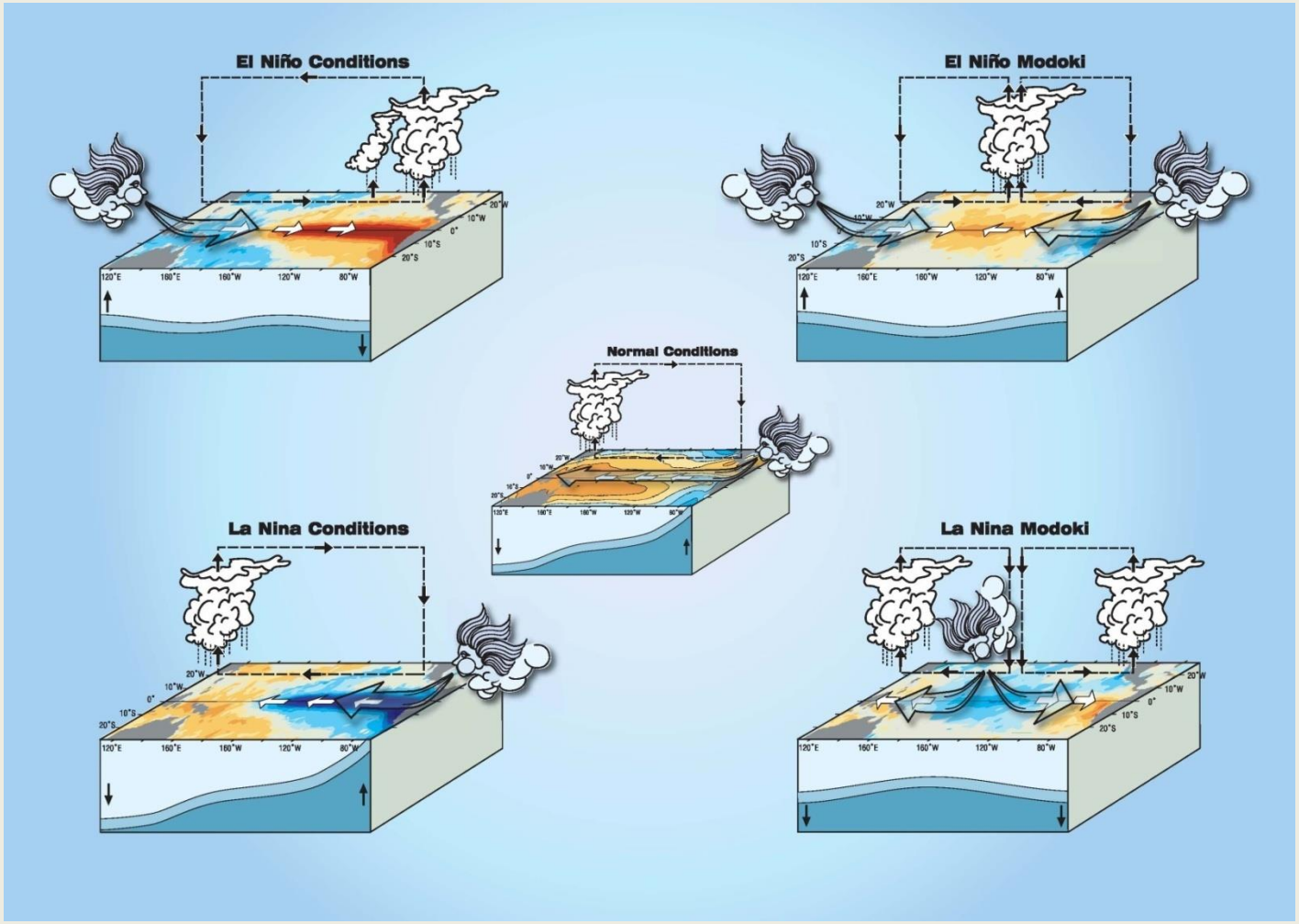
（Blue : cold area ; Orange : warm area）

(Shaded : dry area ; Cloud : wet area）



El Niño, La Niña, Modoki

Schematic pictures

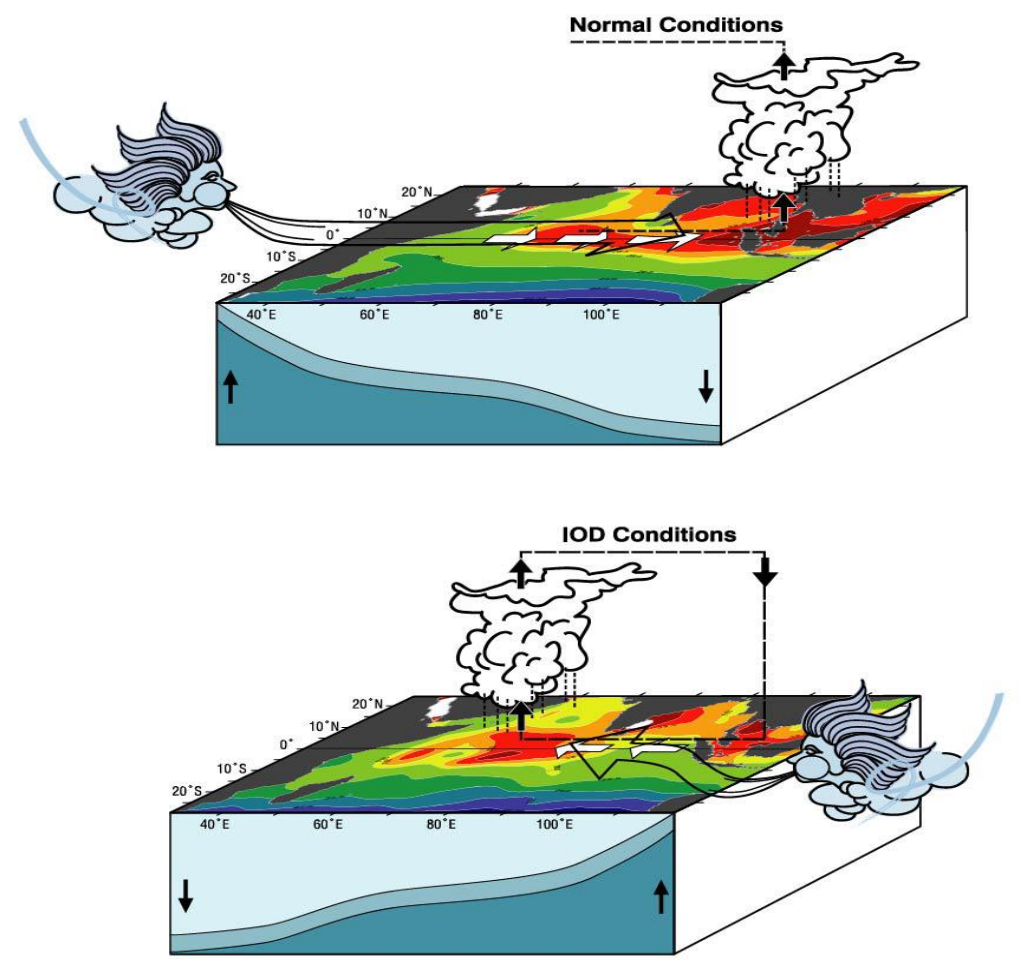


Ashok and Yamagata Nature 2009

ダイポールモード現象の模式図

Schematic picture of Indian Ocean Dipole

(discovered and coined by Saji et al. 1999, Nature)



1900-1999

負のダイポールモード

Negative IOD

Now even IOD Modoki
(Endo and Tozuka, 2016
Clim. Dynam.)

正のダイポールモード

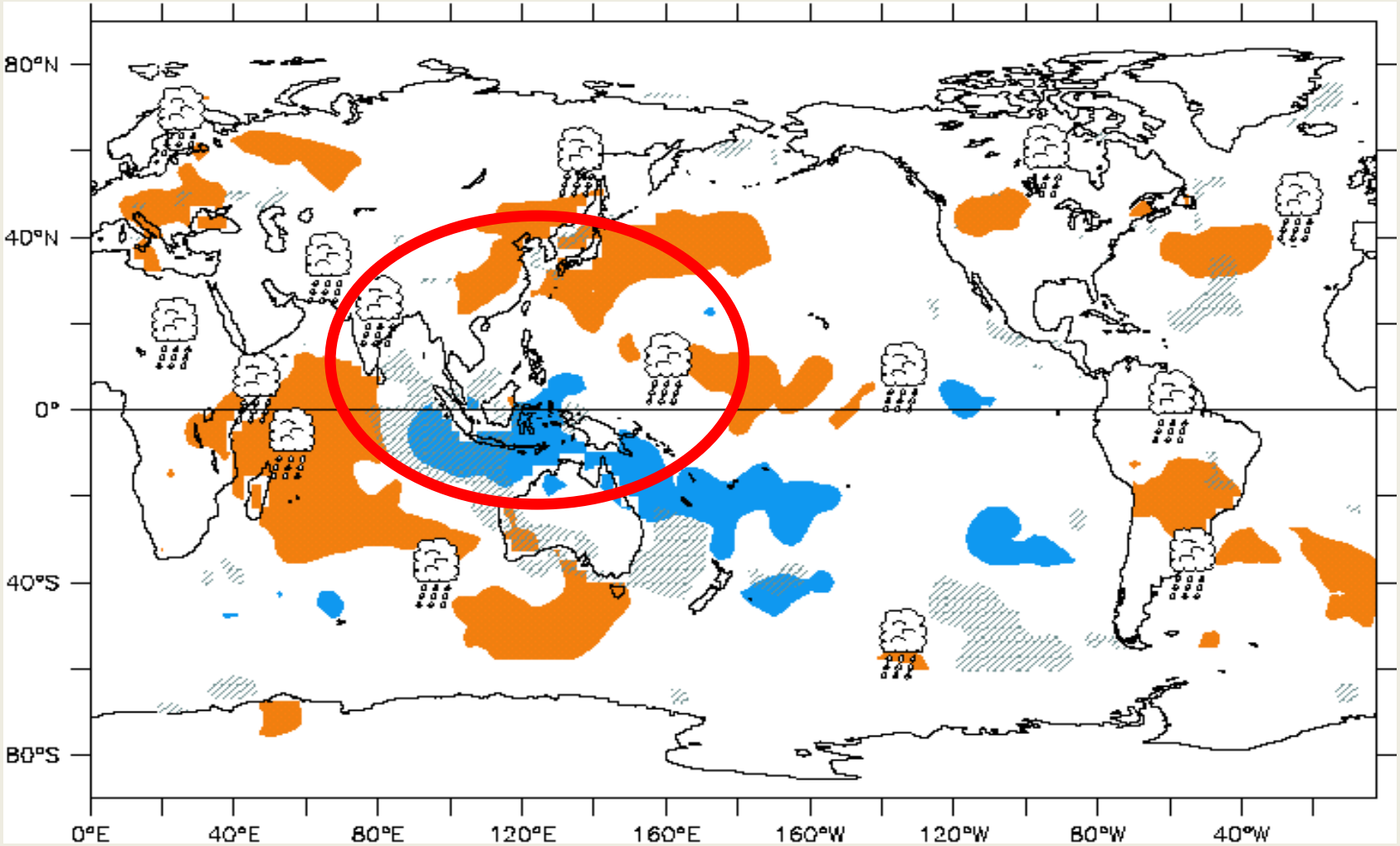
Positive IOD

ダイポールモード現象の世界各地への影響（夏）

Global impact of Indian Ocean Dipole (boreal summer)

（Blue：cold area；Orange：warm area）

(Shaded：dry area；Cloud：wet area）



Based on Saji and Yamagata, 2003, Climate Res.

Number of patients of hyperthermia (heatstroke)

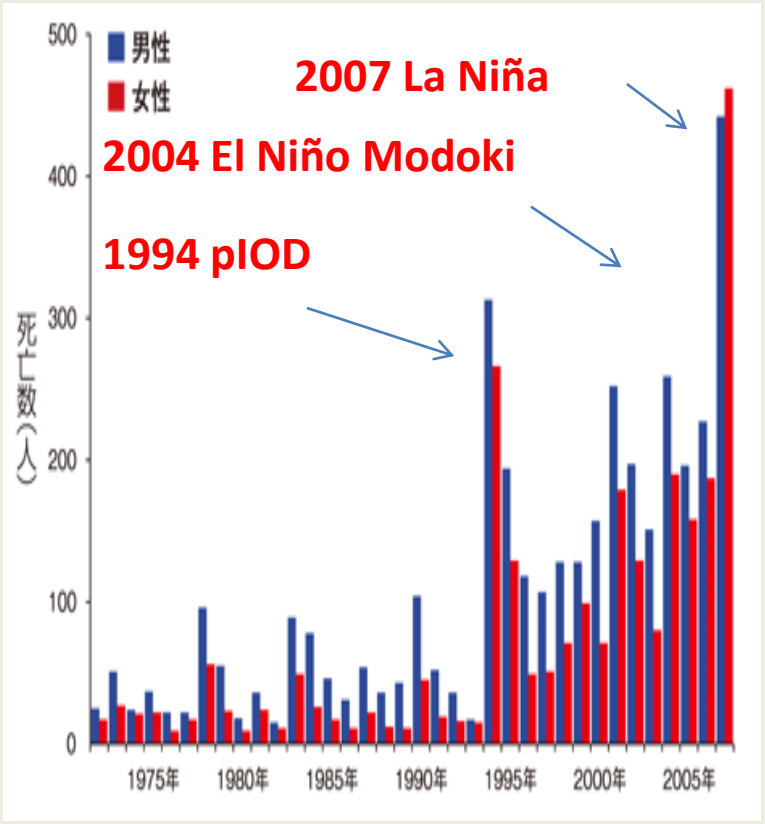
熱中症患者数 （mostly from NIES report）

Total Number of Deaths from 1968 to 2007: 6770

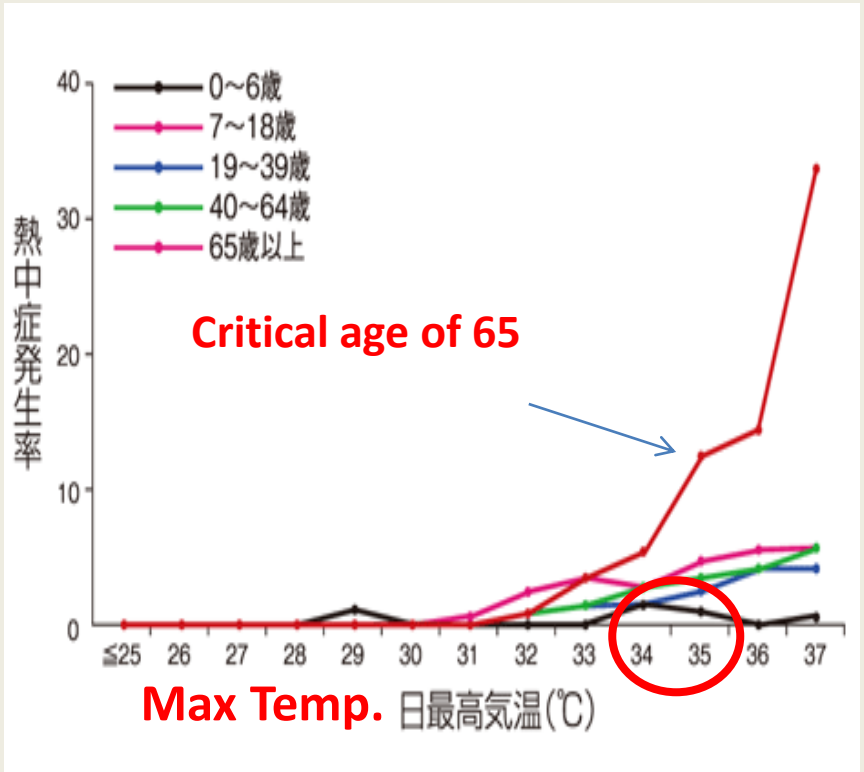
1982: 26 ← El Niño, 1994: 589 ← IOD, 2004: 449←El Niño Modoki, 2007: 904 ←La Niña+IOD

2010: Number of serious patients 56184, Deaths 1745 ← La Niña+IO capacitor effect

Number of Deaths （死者数）



Temp. & Age Dependence



Droughts and Bushfires due to IOD event in 2006

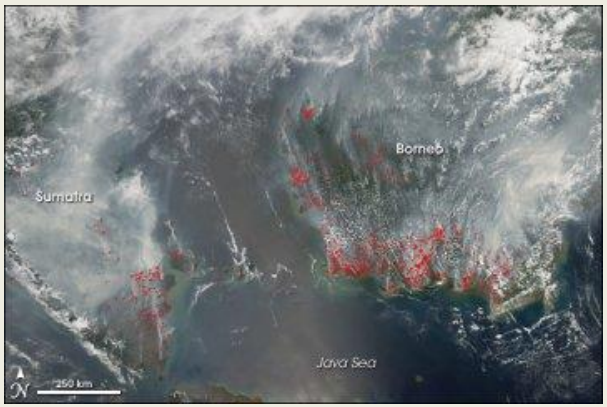
干ばつと叢林火災

Drought in Australia due to 2006 IOD

Water and Agricultural problems

Bush Fire in southeast Asia in 2006

Health and Transportation problems



Black Saturday Bushfires in Victoria, Australia ion Feb. 7, 2009
after 3 consecutive IODs in 2006,7, and 8

Burned down area: 4500Km^2 ; Death toll: 173→Immediate human security problem

More frequent IOD events expected in warmer climate

Nature Geoscience
Cai et al. (2013)

2011 Flood Inundation in Thailand

Influences of La Niña and IPO

世界のサプライチェーンの寸断

Exhibit 15: Flood Inundation at the Rojana Industrial Park

Source: U.S. Marines

Super typhoon Haiyan hit the Philippines in 2013

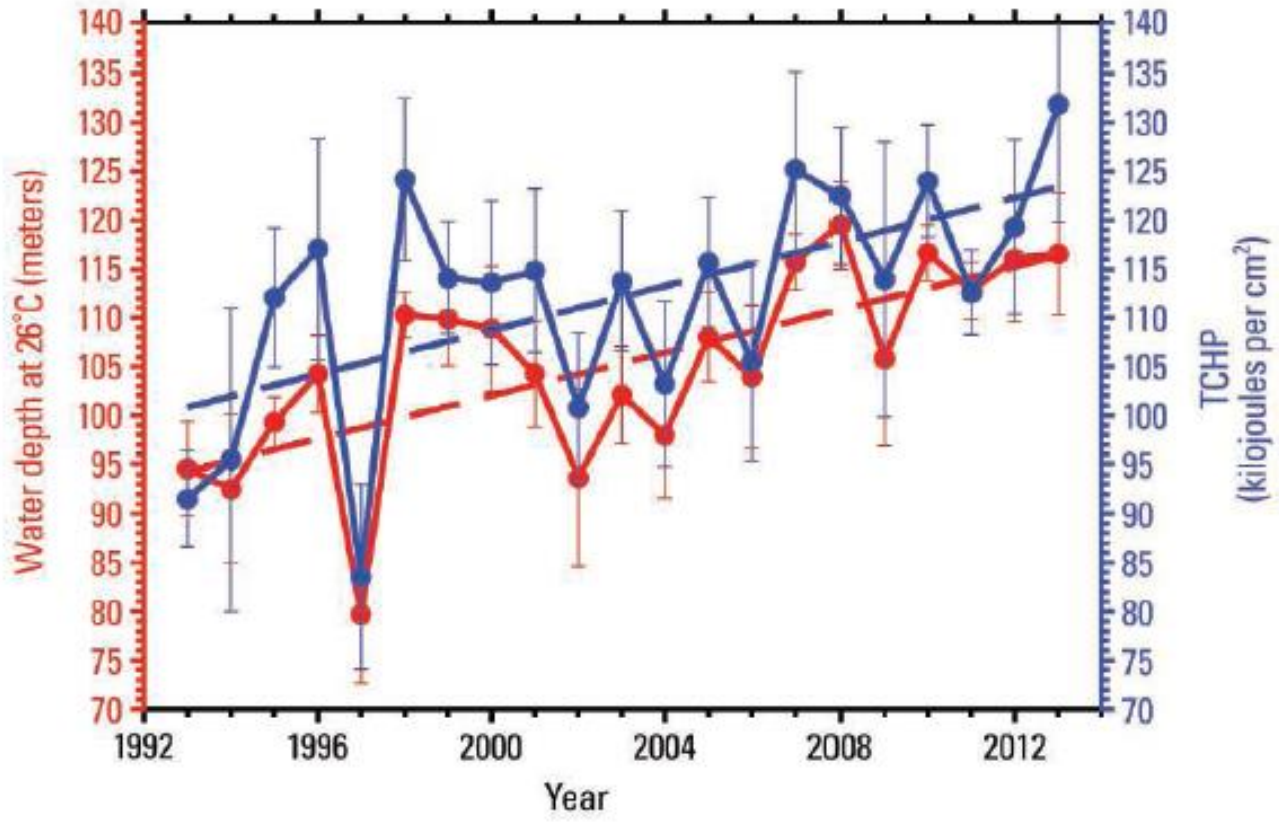
台風ハイエン（ヨランダ） 2013年11月 死者、行方不明者　約8000名

Record-breaking disaster
due to strong winds and storm surge
強風と高潮による災害

Two major climate factors: La Niña
and a positive phase of Interdecadal
Pacific Oscillation
ラニーニャと太平洋振動

Clues to Supertyphoon's Ferocity Found in the Western Pacific

Dennis Normile, Science 342, 29 Nov. 2013



Heated situation. Over 2 decades, a thickening layer of warm water (red) increased the storm-driving heat potential (blue) at the latitudes Haiyan traversed.

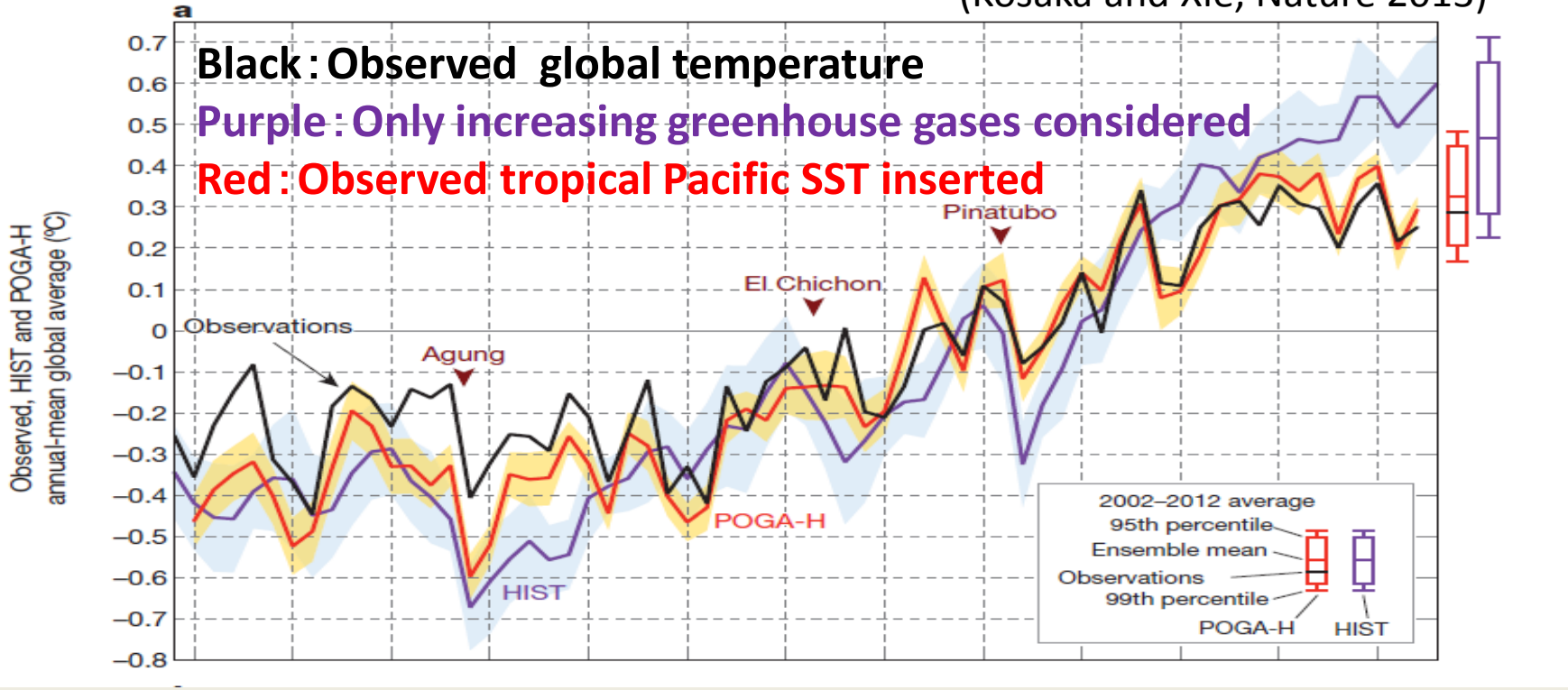
Acceleration of the global warming in coming decades ?

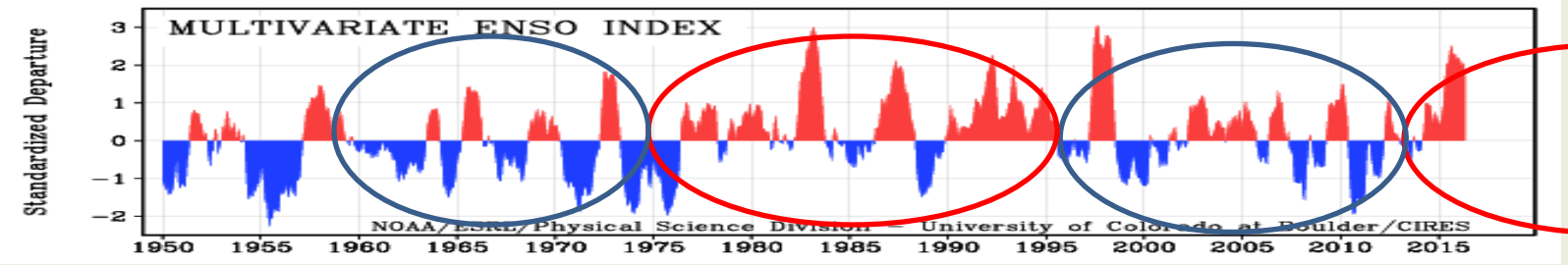
1998年から続いていた地球温暖化の停滞は終焉か

Interdercadal Pacific Oscillation vs. Global warming

More extreme events expected by acceleration of Global Warming

(Kosaka and Xie, Nature 2013)



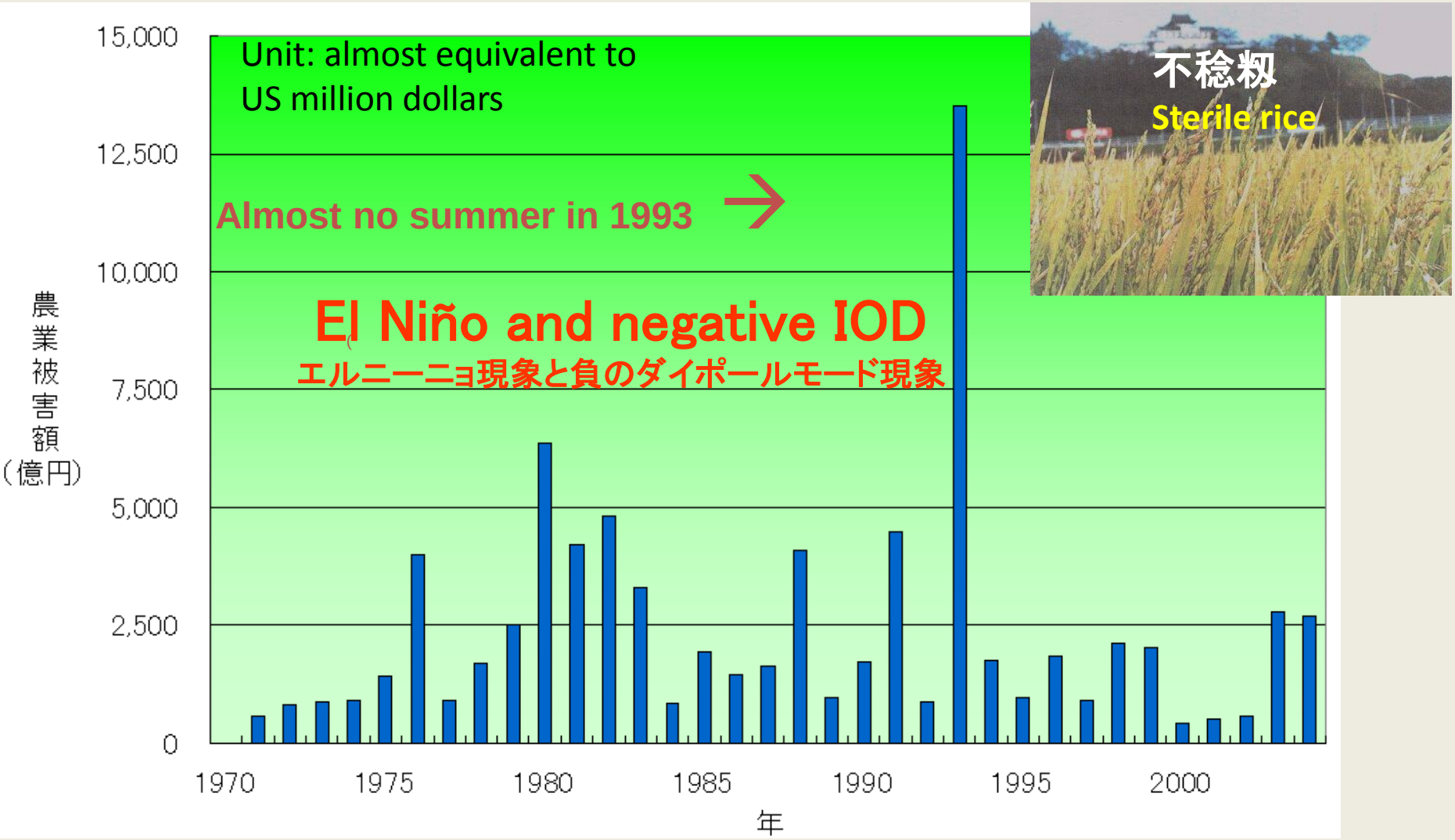


農作物被害

（気象庁資料による）

Agricultural loss in Japan（1971～2004）

Almost no harvest of rice in 1993 in Tohoku of Japan



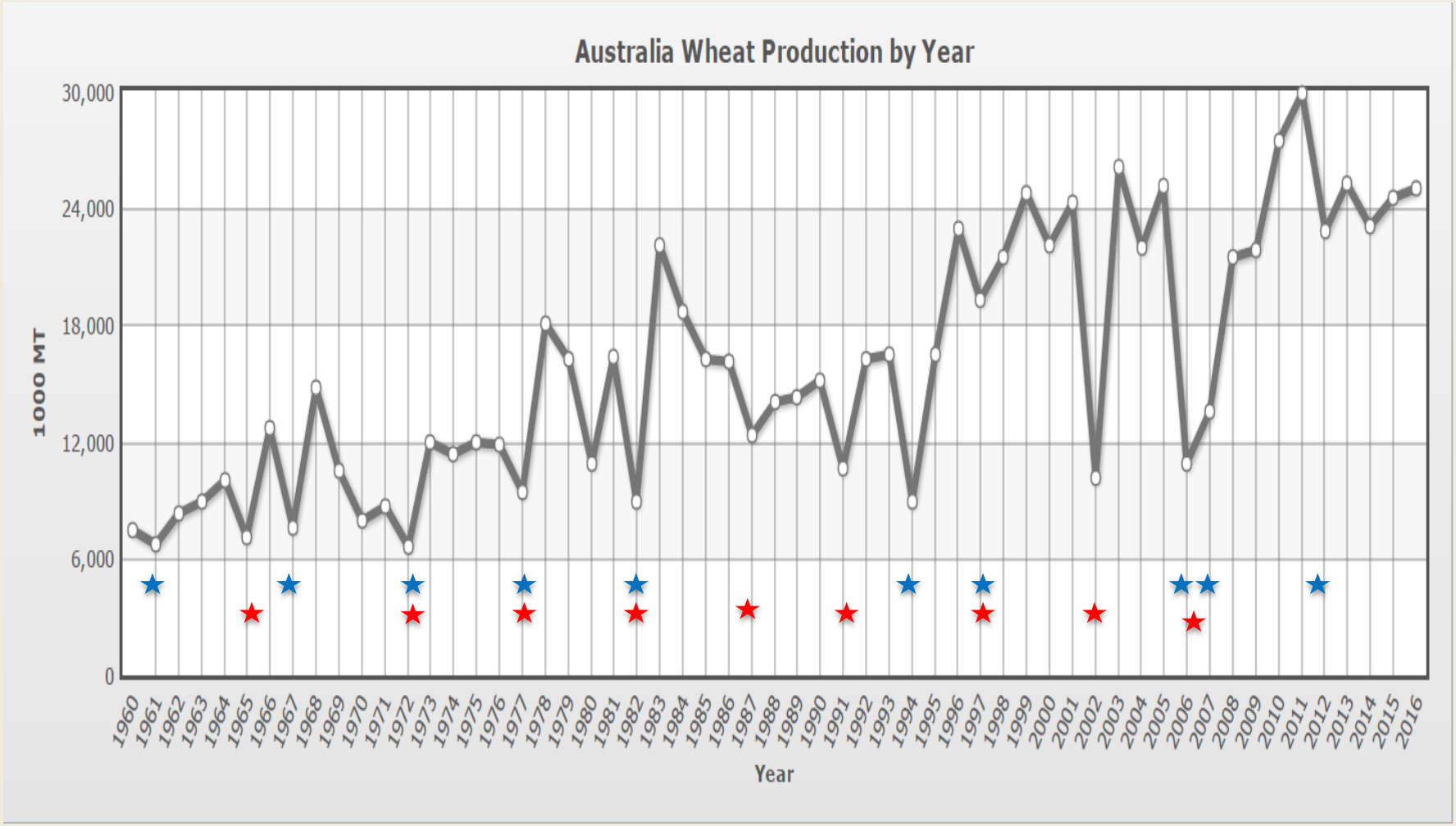
Winter Wheat Production in Australia

Australia Wheat Production

オーストラリアの小麦収量

（based on ABS and US Dept. of Agriculture）

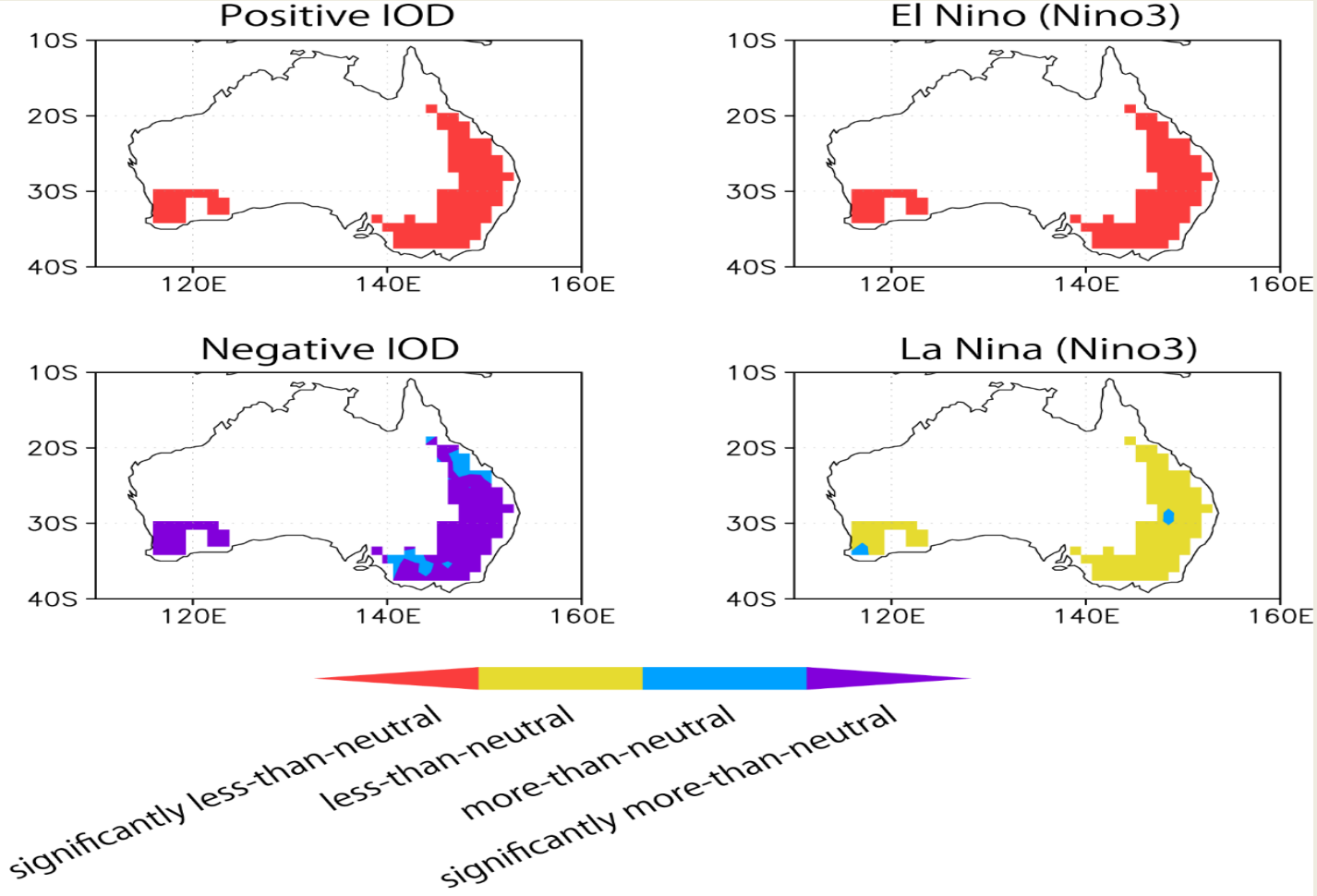
All major drops are related to Indian Ocean Dipole ★ and El Niño ★ events



Wheat yield anomaly at different phases of IOD and ENSO

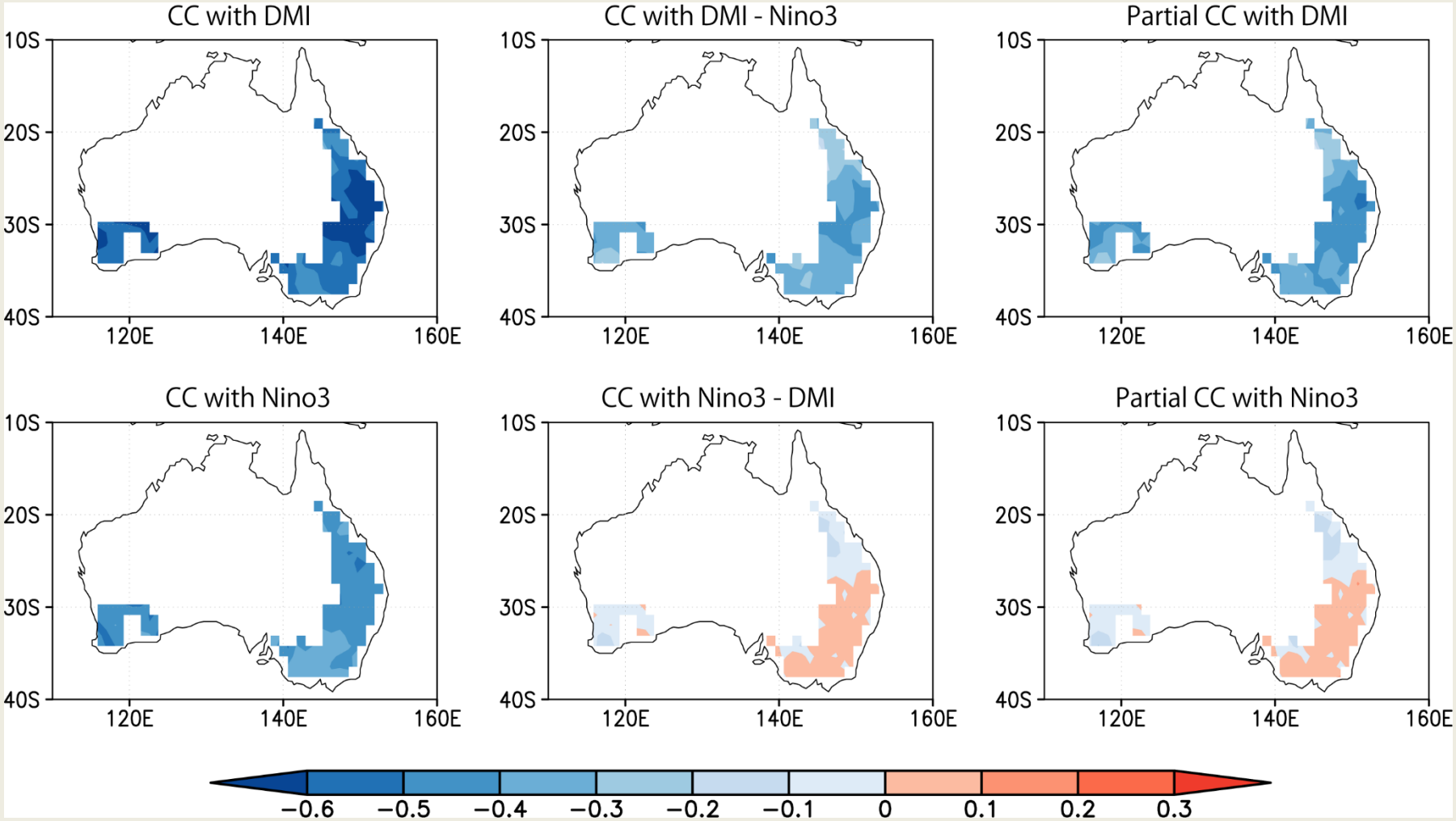
オーストラリアの小麦収量変動と気候変動現象の関係

(Chaoxia Yuan and T. Yamagata 2015, Scientific Reports)



IOD is much more important than ENSO in wheat yield in Australia

(C. Yuan and T. Yamagata, 2015)



2007 IOD / La Niña

The Weekly Times of Australia

24 Oct. 2007

Many newspapers in Japan

24-27 Oct. 2007

Early drought warning kept quiet

Signal failure

EXCLUSIVE

By XAVIER DUFF

AUSTRALIAN scientists were warned as early as March that Australia could be heading back into drought.

But the warning was kept under wraps for fear that it would lead to increased suicides in rural communities.

"I would warn against rushing to a public announcement," one weather scientist said in an email to colleagues in June. "Seasonal predictions can be very upsetting to the public who live in areas of risk."

Yet the secrecy came as grain growers across southern Australia — hopeful of a bumper season — entered hedge contracts that have since plunged the industry into $1 billion in debt.

The first warning that drought may be returning was made by a Japanese scientist during a meeting of international weather experts in March. At the time, Australian weather authorities were predicting a wet La Nina year.

However, the Japanese scientist's warning that a warmer Indian Ocean would knock out the La Nina winter and spring rain has come true.

Prof Toshio Yamagata, from the Japan Agency of Marine Earth Science and Technology, predicted a positive Indian Ocean Dipole, the Indian Ocean equivalent of the drought-inducing El Nino.

In an email to international colleagues on June 24, Prof Yamagata again warned that the eastern Indian Ocean near Australia remained cold, mirroring conditions of 1967.

That year, Victoria experienced a severe drought and Melbourne had its lowest rainfall on record.

"I think we had better go ahead about cautioning regional societies about possible floods/drought/hot conditions," Prof Yamagata wrote.

A member of Prof Yamagata's research team, Dr Swadhin Behera, also suggested that the information should be made public even if it was not definite, so that people could make their own judgments.

He drew on the experience of last year as an example.

"Last year (2006), becau... debate early on during the ...ment of IOD, we delayed release until August," D... wrote in an email to colle...

• Continued Page 4
• Rule's View, Page 15
• Editorial, Page 16

海面温度上昇 同時発生を予測

海洋研究開発機構

今秋、40年ぶりに同時に発生したインド洋と太平洋の海面温度の異常上昇を、いずれも予測することに、海洋研究開発機構が成功した。この二つは世界規模の異常気象を起こす現象で、単独では数年に一度起きている。非常にまれな同時発生まで予測できる同機構の手法は、今後の気候変動の研究に役立ちそうだ。

インド洋 太平洋

二つの現象のうち、「インド洋ダイポールモード現象」は、インド洋東部の海面温度が通常より低くなり、西部海域では上昇する。海洋機構は、この現象の単独の発生予測には昨年すでに成功している。

海洋機構は、過去約50年の海面温度などのデータを基に開発した予測モデルを使用。今年4月に観測した海面温度を入力し、スーパーコンピューター「地球シミュレータ」で5～7か月後の温度変化を見たところ、二つの現象が発生するとの予測を得た。

約半年前に予測

海洋機構が確立

海洋研究開発機構は24日、異常気象をもたらす太平洋のラニーニャ現象やインド洋ダイポールモード現象の発生を、コンピューターシミュレーションで約半年前に予測することに成功したと発表した。インド洋での観測で、ダイポールモード現象発生の2、3カ月前に水深100メートル前後で海水温が低下する前兆現象も発見した。長期予報の精度向上につながると期待される。

ペルー沖の… 面水温が下… 洋ダイポー… はジャワ島… が下がる。 の大規模… 異常気象を… ダイポール… 日本の猛暑… 摘される。 同機構の… ーブリーダ… らは、大気… る物理現象… ミュレーシ… 開発。今年… 海面水温の… し、9～11… 起こると予…

異常気象要因「インド洋ダイポールモ…

海洋機構、発生予測に…

海洋研究開発機構は24日、地球規模で異常気象を引き起こす要因となっているとされる「インド洋ダイポールモード（IOD）現象」の予測に成功したと発表した。EUとの共同研究で開発した計算モデルにより、今秋にIOD現象が発生するとの予測を今年4月にウェブで公表していた。更…以降の観測データを解析した結果、すでにIOD現象が発生していることや、それ以前に海洋内部で前兆現象が起きていたこともわか…

IODは… 側海域と東… 温度差が大… 現象。東側… の水温が下…

海面水温異常 40年ぶり同時発生

インド洋東部で夏から秋に海面水温が平年より下がる異常現象「ダイポールモード」（IOD）が2年連続で発生し、今年は1967年以来40年ぶりに、太平洋東部で海面水温が下がるラニーニャ現象と同時発生したと、海洋研究開発機構が24日発表した。日本では8月、国内最高気温が74年ぶりに更新されるほどの猛暑だったが、両現象が影響している可能性があるという。

IODはインド洋西部のアフリカ沖では海面水温が反対に高くなるため、昨年はアフリカ熱帯地域で洪水が多発し、今年もアフリカ東部で豪雨、オーストラリアで少雨となっている。

IODは海洋機構の山形… 俊男… 授）… が、… 逆の… い、… 発生… 整っ…

時事通信　2007/10/25 08:48:34

18:49 ◎４０年ぶり同時発生、猛暑に影響？＝インド洋と太平洋の異常現象－海洋機構

インド洋東部で夏から秋に海面水温が平年より下がる異常現象「ダイポールモード」（ＩＯＤ）が２年連続で発生し、今年は１９６７年以来４０年ぶりに、太平洋東部で海面水温が下がるラニーニャ現象と同時発生したと、海洋研究開発機構が２４日発表した。日本では８月、国内最高気温が７４年ぶりに更新されるほどの猛暑だったが、両現象が影響している可能性があるという。

ＩＯＤはインド洋西部のアフリカ沖では海面水温が反対に高くなるため、昨年はアフリカ熱帯地域で洪水が多発し、今年もアフリカ東部で豪雨、オーストラリアで少雨となっている。

ＩＯＤは海洋機構の山形俊男ディレクター（東大教授）らが９９年に発見したが、ラニーニャ現象やその逆のエルニーニョ現象と違い、まだ各国の気象機関が発生状況を発表する体制が整っていない。

海洋機構は、昨年のＩＯＤ発生時はスーパーコンピューター「地球シミュレータ」を使って前年１１月時点で予測することに成功。今年は４月時点で予測できており、予測精度の一層の向上が期待される。（了）

山形俊男（やまがた・としお）

〔社会部〕

Signal failure as drought warning kept quiet

• From Page 1

"But probably because of the delay, the announcement could not be utilised by people who were most affected by the 2006 IOD.

"Some of the farmers who kept calling us almost on a daily basis told us they could have benefited had the information about the IODs been passed on to them based on our model predictions."

But Australian scientist Prof Gary Meyers, from the University of Tasmania, who plays a key role in monitoring international weather patterns, wrote back, arguing more evidence was needed before rushing to an announcement.

"I would caution against rushing to a public announcement," he said. "Seasonal predictions can be very upsetting to the public who live in areas of risk."

Prof Yamagata then agreed, saying the release of such a forecast might trigger suicides among Australian farmers.

But grain growers said any hint of another dry year could have prevented some of the huge losses they now faced.

Prof Meyers told *The Weekly Times* that Prof Yamagata's computer model had predicted a positive IOD as early as March but two other computer models did not agree.

It was only in July that all the models agreed and the warnings of adverse Indian ocean temperatures were given to the Bureau of Meteorology for its seasonal forecasts.

Prof Meyers told *The Weekly Times* this week that while it turned out the Japanese model was correct and it appeared to be a good model, it was still in its early stages of development and its reliability was uncertain.

Releasing what could be a wrong forecast could cause as many problems as not releasing it, Prof Meyers said.

Monitoring and research into the Indian Ocean dipole was still in its infancy and much more data was needed for scientists to predict weather patterns with it, he said.

David Jones, from the Bureau of Meteorology's National Climate Centre, said the bureau factored in a range of Indian Ocean data into their seasonal outlooks.

"You could not rely on just one model," he said.

But he said most of the bureau's seasonal outlooks this year had forecast below-average rains.

Victorian Farmers Federation grains group president Geoff Nalder said even with the uncertainty of the models, farmers should have been told of Prof Yamagata's forecast, so they could make their own judgments.

Many growers had forward sold their crops in expectation of at least an average year and many had believed the predictions of a La Nina developing and good rains with it.

"I'm very disappointed that information was not widely circulated," Mr Nalder said.

"To have had a contrary view to the one that we were in for a bumper year would have slowed the momentum to forward positions and could have saved many farmers hundreds of thousands of dollars in washing out contracts."

Birchip farmer Leigh Weir, one of those unable to deliver enough grain against forward contracts, said knowing the Japanese prediction would definitely have helped.

"If there were doubts about the season, we would like to have known and we would have definitely reduced the amount we sold forward and washed out contracts much earlier than we did," Mr Weir said.

Palm Oil Production in Malaysia

Impact on Malaysian economy

Malaysia low output pulls up crude palm oil prices

The prices jumped 8.5% on Indonesia's plan to treble subsidy on biodiesel, price rise may be capped on lower demand from India and China

Dilip Kumar Jha | Mumbai
February 11, 2015 Last Updated at 22:38 IST

agrimoney.com

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14:57 UK, 10th May 2016, by Agrimoney.com

Malaysian palm oil production sharply lower due to drought

Palm oil production in Malaysia, the world's second ranked producers, is sharply down year on year, in the wake of regional droughts.

Malaysian palm oil production was down 23% year on year in April, at 1.3m tonnes, the Malaysian Palm Oil Board said.

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Palm prices to continue to find support from Asian dryness

Malaysian palm oil

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13:17 UK, 10th Feb 2016, by Mike Verdin

Palm output drop spurs talk of price premium to rival soyoil

Palm oil output in Malaysia made an even weaker start to 2016 than expected, fuelling expectations of a drop in output this year – and potentially of prices gaining an, unusual, premium to those of rival soyoil.

Malaysia's palm oil production fell by 19.3%, month on month, in January, to 1.13m tonnes, the Malaysian Palm Oil Board said.

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Commerz warns over palm prices, even as futures hit 20-month top

Palm oil futures fall as China fears

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Tuesday, 14 June 2016 | MYT 7:04 AM

Malaysian palm oil price drops for sixth session as output seen rising

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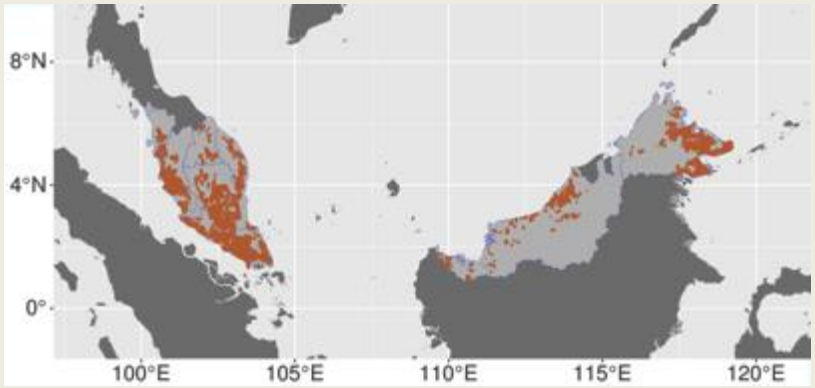
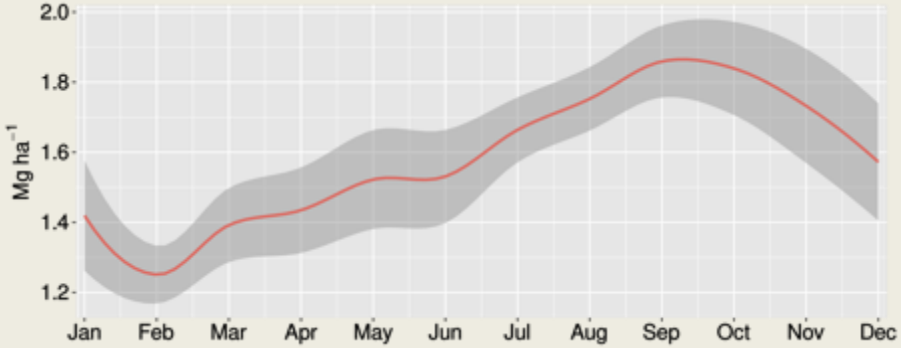
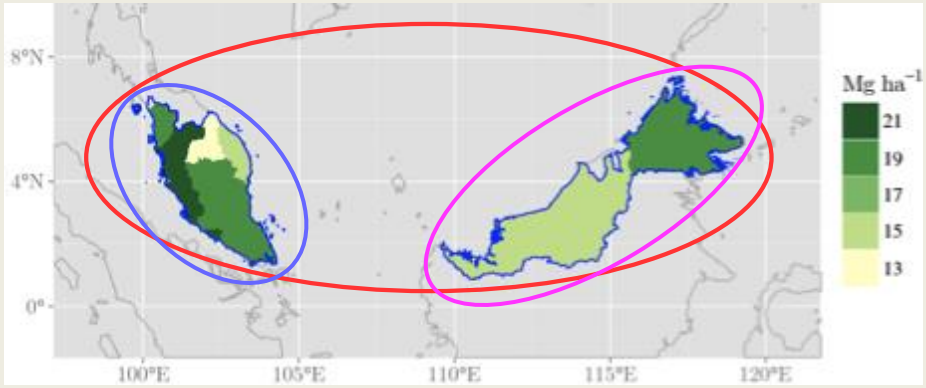
Palm oil futures for August delivery on the Bursa Malaysia Derivatives Exchange fell 2.1 percent to 2,525 ringgit ($618) per tonne at the closing trade. Traded volumes stood at 50,003 lots of 25 tonnes each, higher than the 2015 daily average of 44,600 lots.



Plantation of palm trees (Lian Pin Koh et al.)



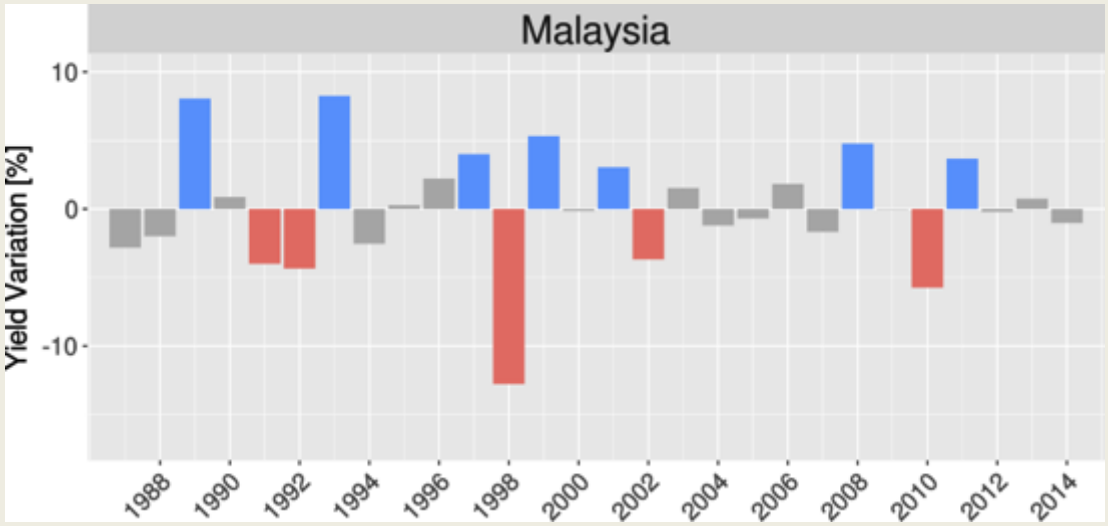
Monthly FFB yield (1987-2014)



Average annual yields per hectare (1987-2014)

- Indonesia and Malaysia account for **81%** of the total global production of palm oil,
- Malaysia itself accounts for **39%** of world palm oil production and **44%** of world exports,
- In 2011, accounting for **USD 16.8 billion** of Malaysia's Gross National Income,
- Fresh Fruit Bunch (FFB): **88 million Mg** from **4 million ha**. Average of **18.7 Mg ha^{-1}** (source: MPOB).

Malaysia
Peninsular
Sabah / Sarawak

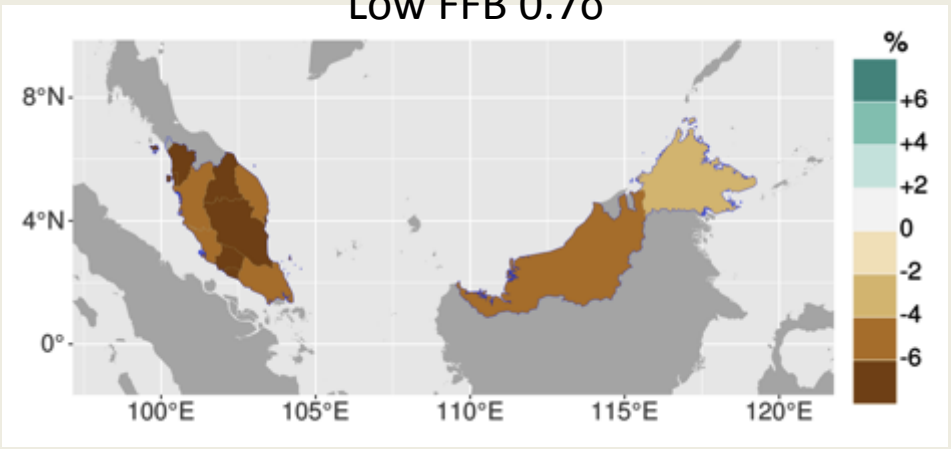


5 years with low FFB yield

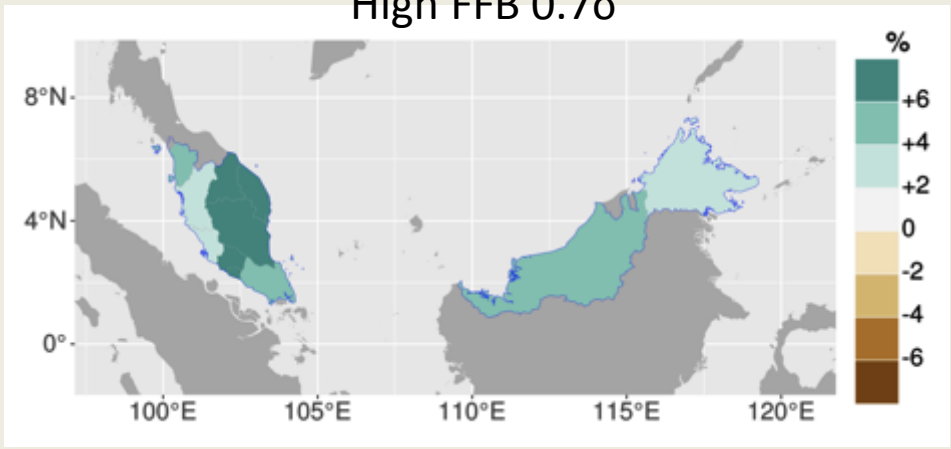
7 years with high FFB yield

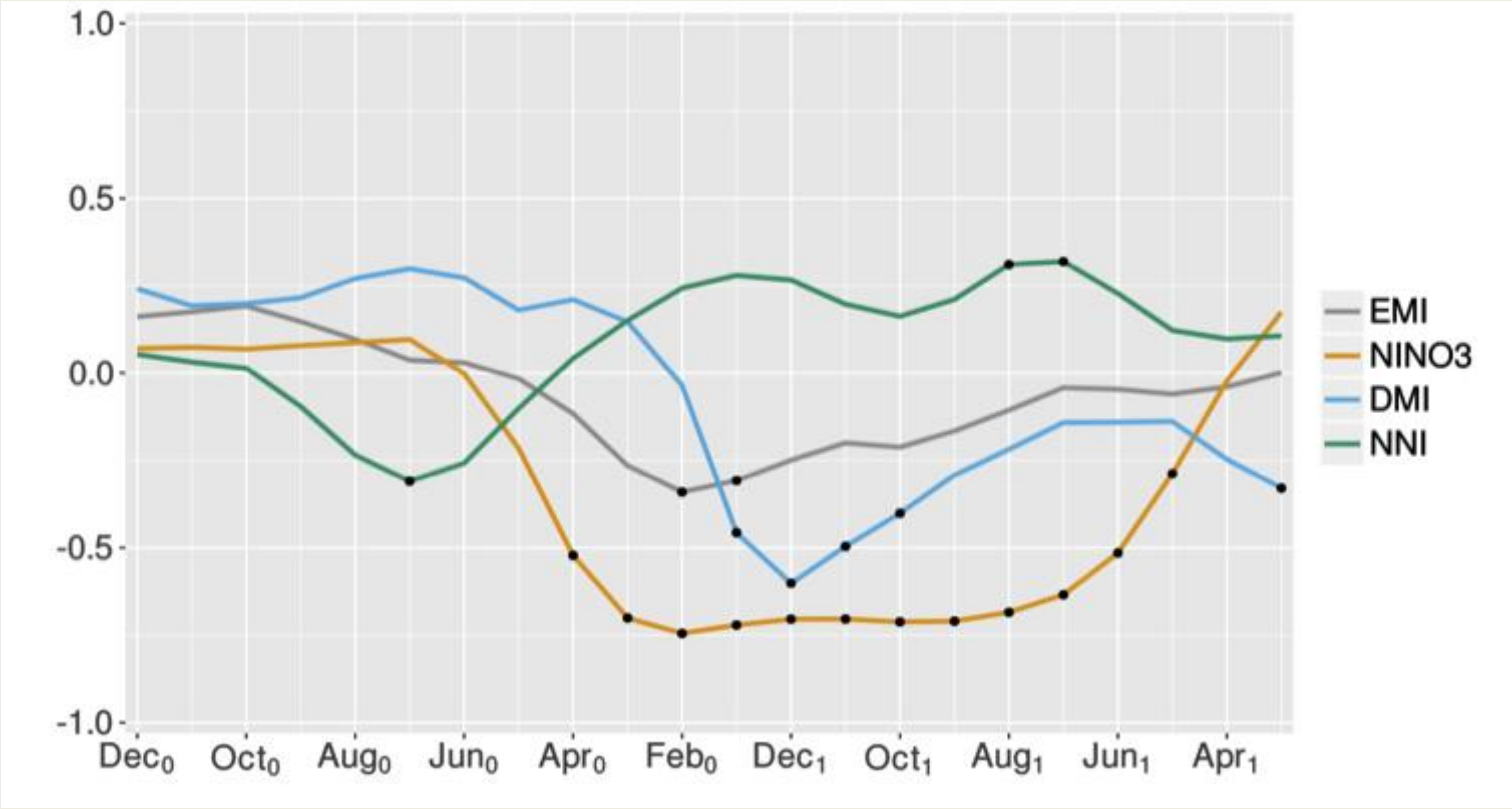
} relative to 0.7σ = 2.98%

Low FFB 0.7σ



High FFB 0.7σ





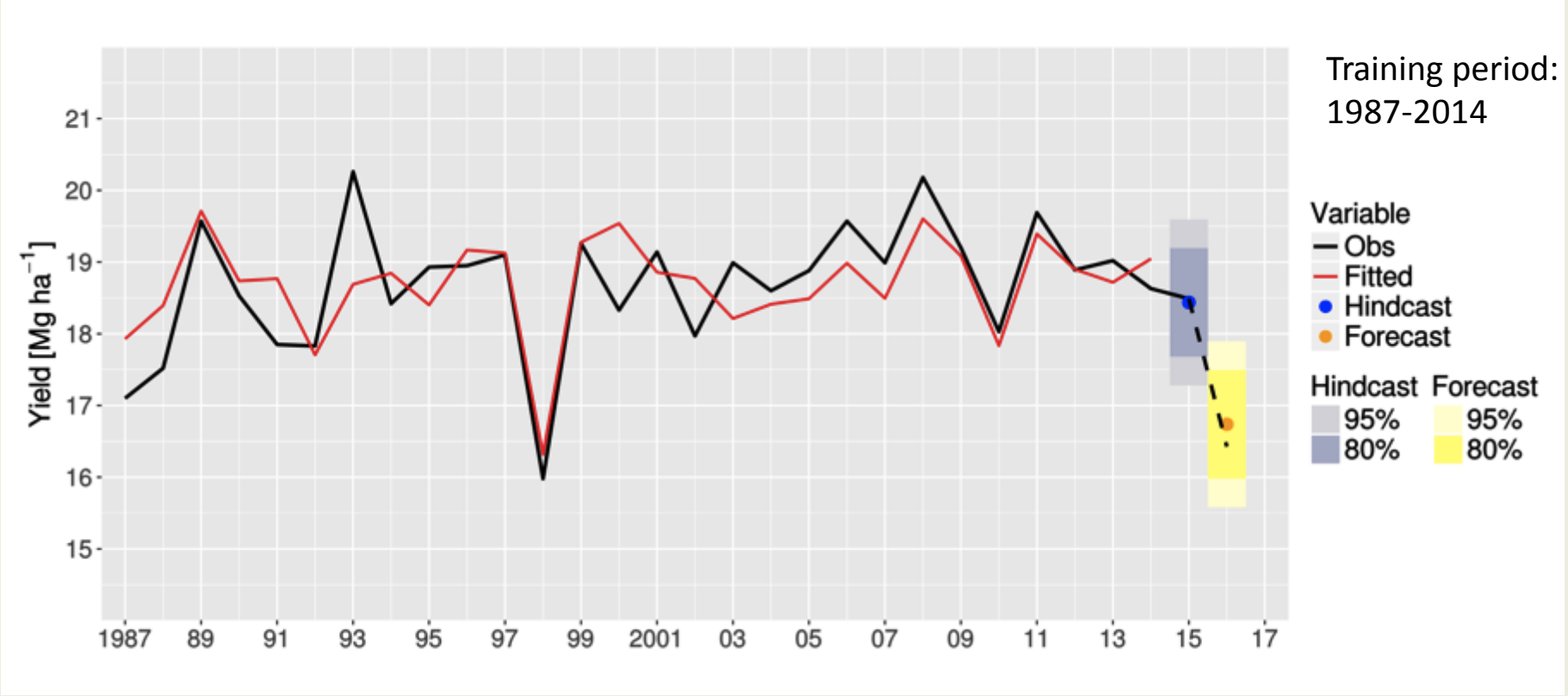
Lagged correlation between yearly FFB yield
(as in December) and different oceanic indices

→ ENSO is the main mode explaining of yearly FFB yield

- **Water stress** and **temperatures** constrain the yearly FFB yields,
- Solar radiation is **not so limiting** factor,
- At annual time scale, **ENSO** during the **previous winter season** is the main oceanic driver,
- **IOD** also appears as a potential **secondary** oceanic driver,
- **Ningaloo** region might also play a role by **modulating** the regional humidity flux.

→ Statistical forecast
→ Dynamical forecast

Forecast of yearly FFB yield in Malaysia



→ Linear model able to capture large part of the interannual variability

Seasonal climate prediction

SINTEX-F1 coupled GCM

(developed at APL, JAMSTEC under the EU-Japan collaboration；operational since 2005)

AGCM: ECHAM4.6 T106L19

Cumulus convection scheme: Tiedtk 1989

The Morcrette et al. (1986) radiation code.

OGCM: OPA8.2 2º×(0.5º~2º) L31

With GM scheme

The mixed-layer scheme:1.5 closure model (Blank and Delecluse 1983)

Coupler:
OASIS2.4
Every 2 hour
No flux correction
No sea ice model

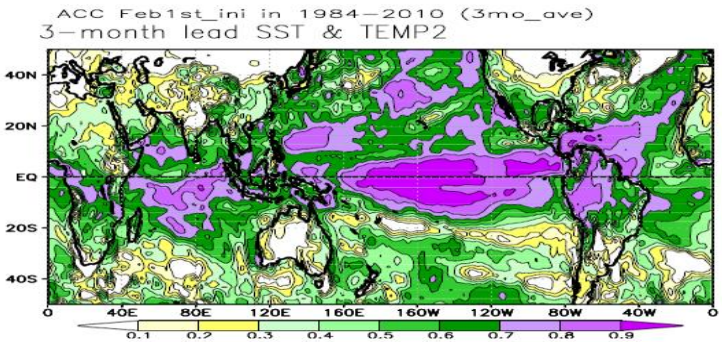
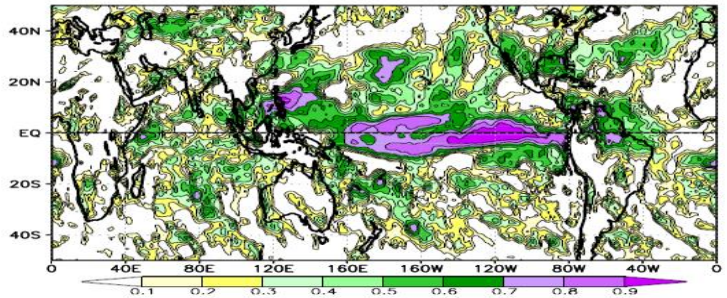
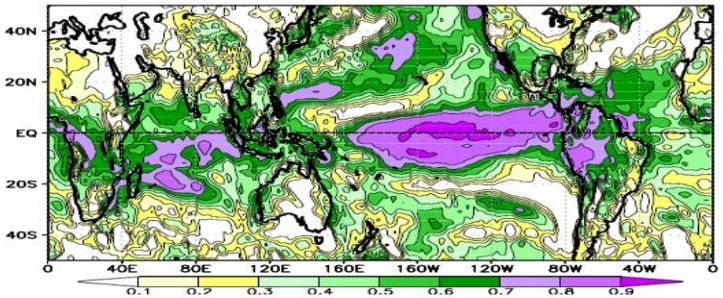
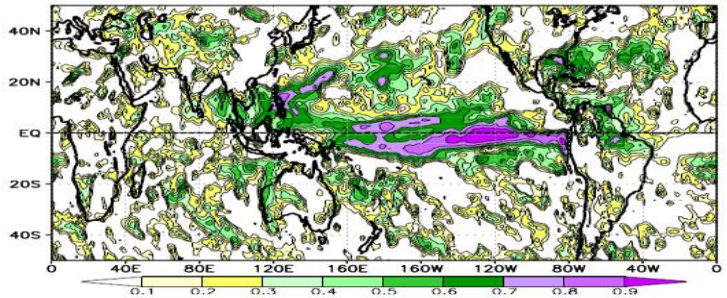
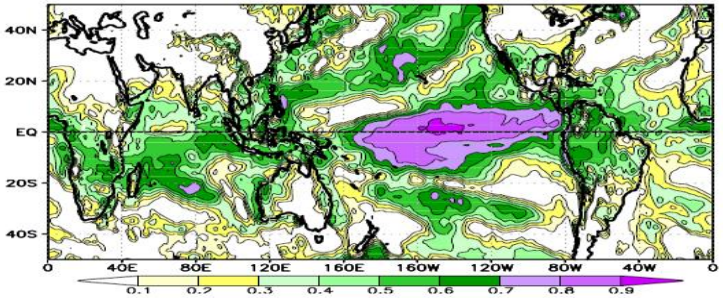
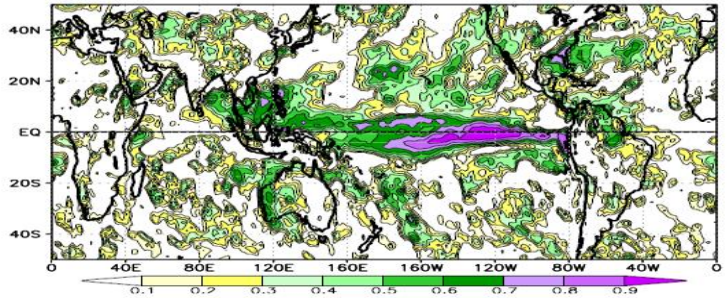
- Initialization: SST nudging system →3D VAR
- 27 ensemble members:
- Climate drift: each lead time in a posteriori manner using hindcast outputs
- Real-time seasonal forecast

(http://www.jamstec.go.jp/frcgc/research/d1/iod/seasonal/outlook.html)

Early warning of abnormal seasons is now almost available!

気候変動要素（気温、水温、降雨）とその影響の早期予測が実験的に可能に

http://www.jamstec.go.jp/frcgc/research/d1/iod/e/seasonal/outlook.html

Lead time	Surface Air Temperature Anomaly 地上、海上気温異常	Precipitation Anomaly 降水量異常
3 months		
6 months		
9 months		

Rich Application of Ocean and Climate Variability Prediction to Society

気候変動予測システムの豊かな可能性

Our societal, economic and industrial activities are highly vulnerable to abnormal seasons and extreme events induced by climate variations rooted in the oceans under the changing climate.

気候変化の下で進化を始めた海洋起源の気候変動現象。その結果として起きる季節の異常と極端現象が社会、経済、産業活動に大きな影響を与え始めた。

To mitigate impacts from such extreme events and to achieve sustainable wellness and well-being, to accelerate building an innovative climate prediction system by use of ocean-atmosphere coupled general circulation models harnessing the real-time satellite and *in situ* global observations and the simulation technology is urgent.

その影響を緩和し持続可能な良き生を達成するにはリアルタイム地球観測とシミュレーション技術を統合する大気海洋結合大循環モデルを用いた革新的な気候変動予測システムの構築を急ぐ必要がある。

This will lead to a good practice in demonstrating an active link between the provision of services and the collection and processing of data, thus contributing to decision-making.

このシステムはサービスとデータ収集・処理の間の活発な交流の良き例を与え、政策決定に貢献するであろう。

Asia-Pacific Regional Contribution to Future Earth

SIMSEA

Sustainability Initiative
in the Marginal Seas of South and East Asia

(http://simseaasiapacific.org/)

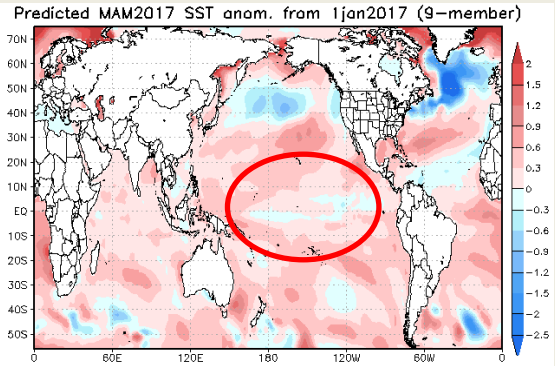
南及び東アジアの縁辺海における持続可能性イニシャチブ

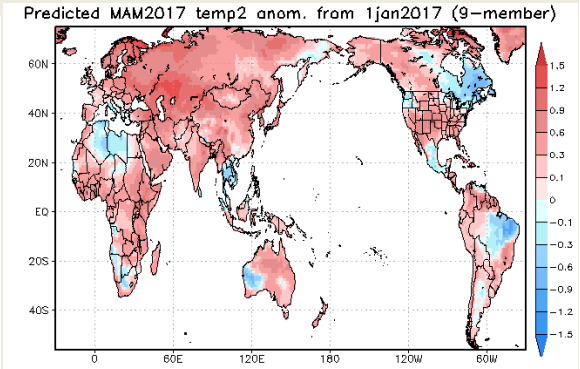
The idea was born at the 16th Meeting of ICSU RCAP (Regional Committee for Asia and the Pacific) in Seoul, Nov. 2013

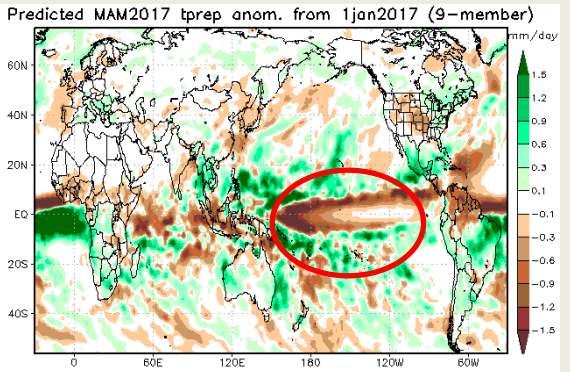
Predicted Climate in 2017

http://www.jamstec.go.jp/frcgc/research/d1/iod/seasonal/outlook.html

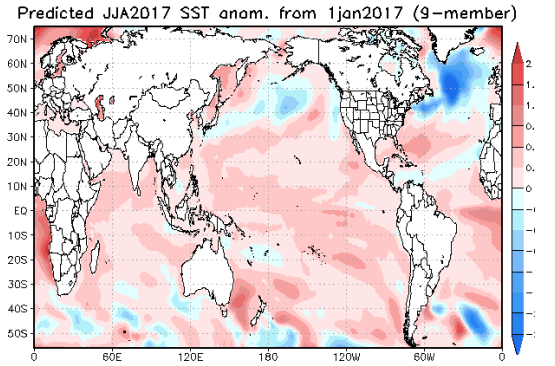
Spring

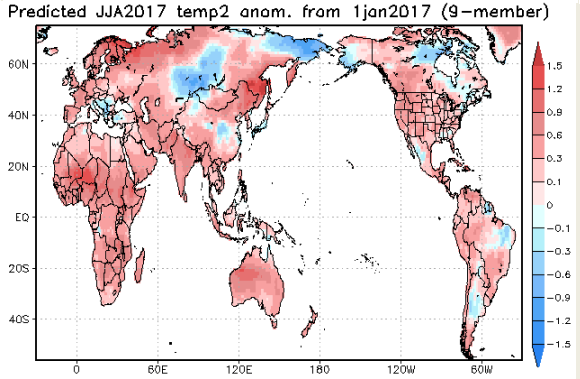


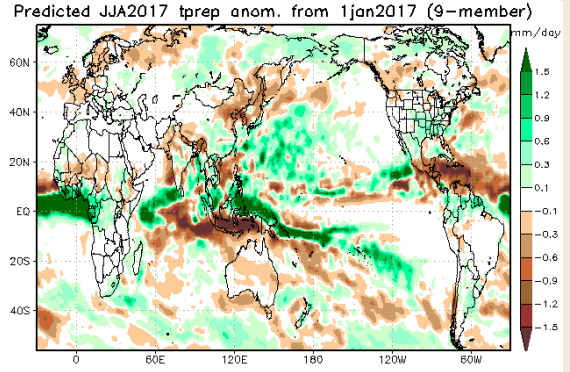




Summer







Fall