

長期予報の未来—より良い予測を目指して— Better climate information for society

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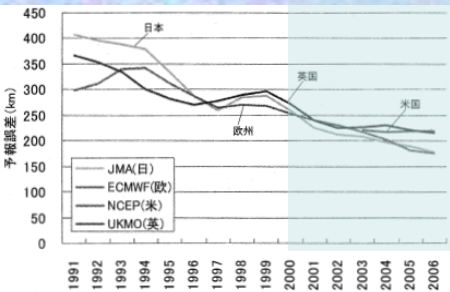
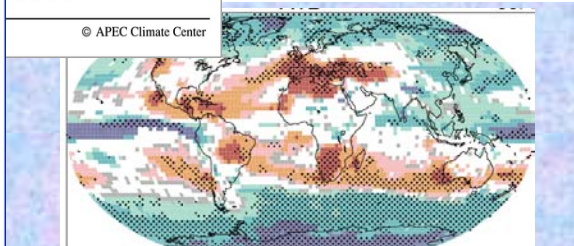
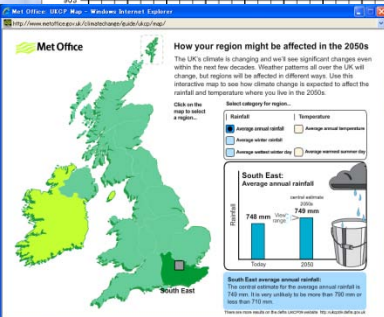
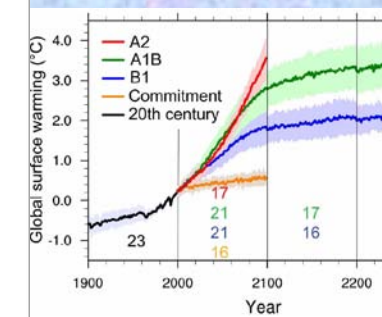
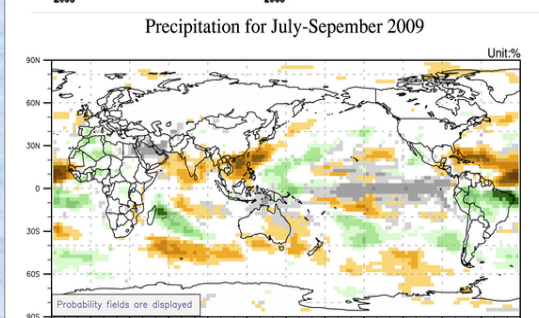
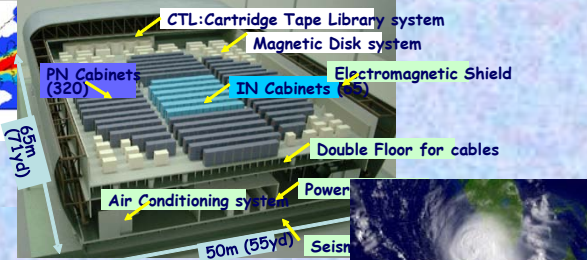
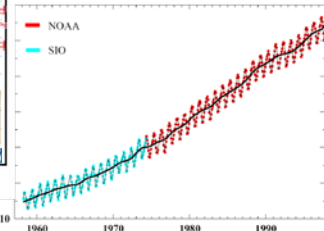
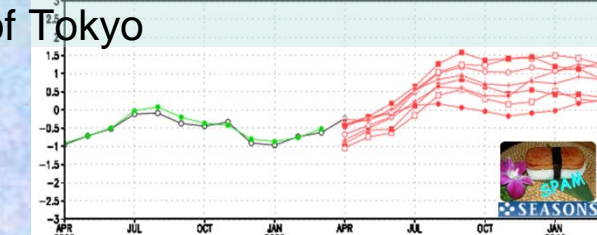
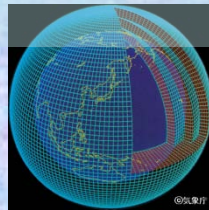
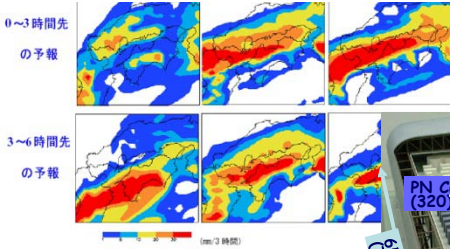


図 7.9 台風進路予報誤差 (2 日予報) (気象庁提供)



2010年夏の「異常気象」～日本では

さんま不漁



観測史上最も暑かった8月



四万十川で濁水



白菜価格高騰



寒い冬→寒い春、41年ぶりの遅い雪
猛暑～1898年の統計開始以来の最高値

2010年夏の「異常気象」～世界では

ロシア西部で猛暑



米国37州で暑夏



中国南部で豪雨



パキスタン洪水



南米で寒冬

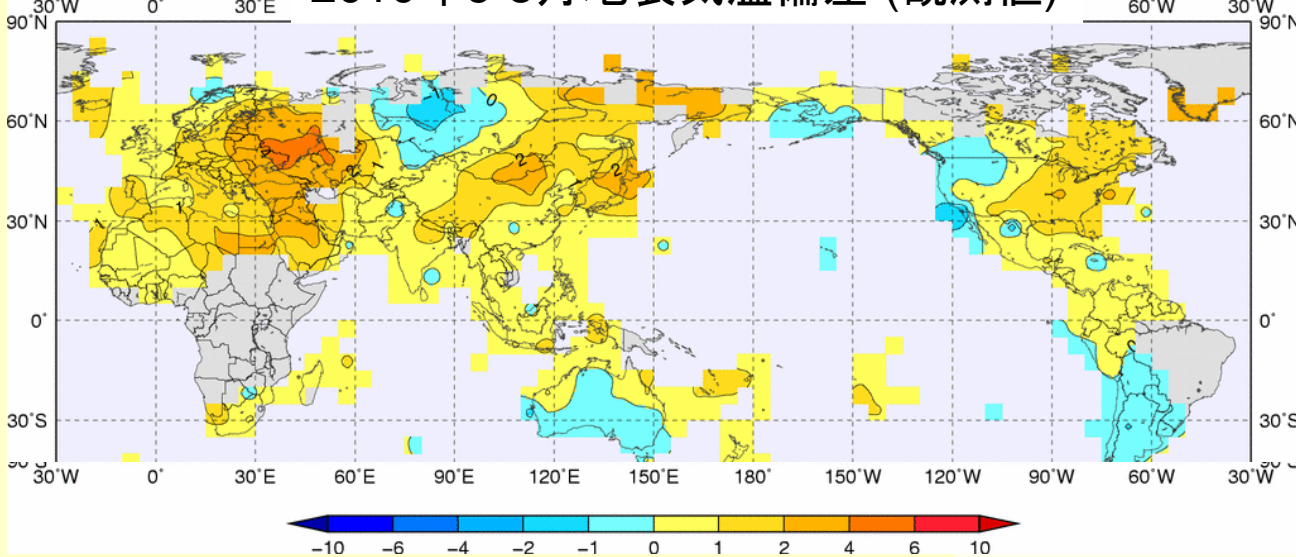


パキスタン: 2000万超被災、死者1500人
ボリビア・ペルー: 豪雪5万4千人に影響
ブエノスアイレス: 40年ぶり積雪
USA: 37州で夜間最高気温を記録

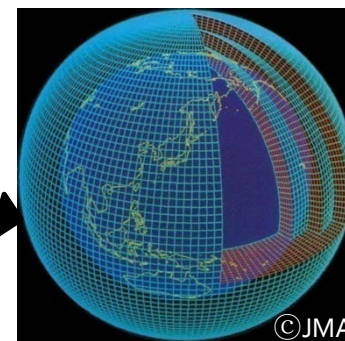
2010年夏の天候再現実験

2010年11月19日記者発表資料

2010年6-8月地表気温偏差 (観測値)



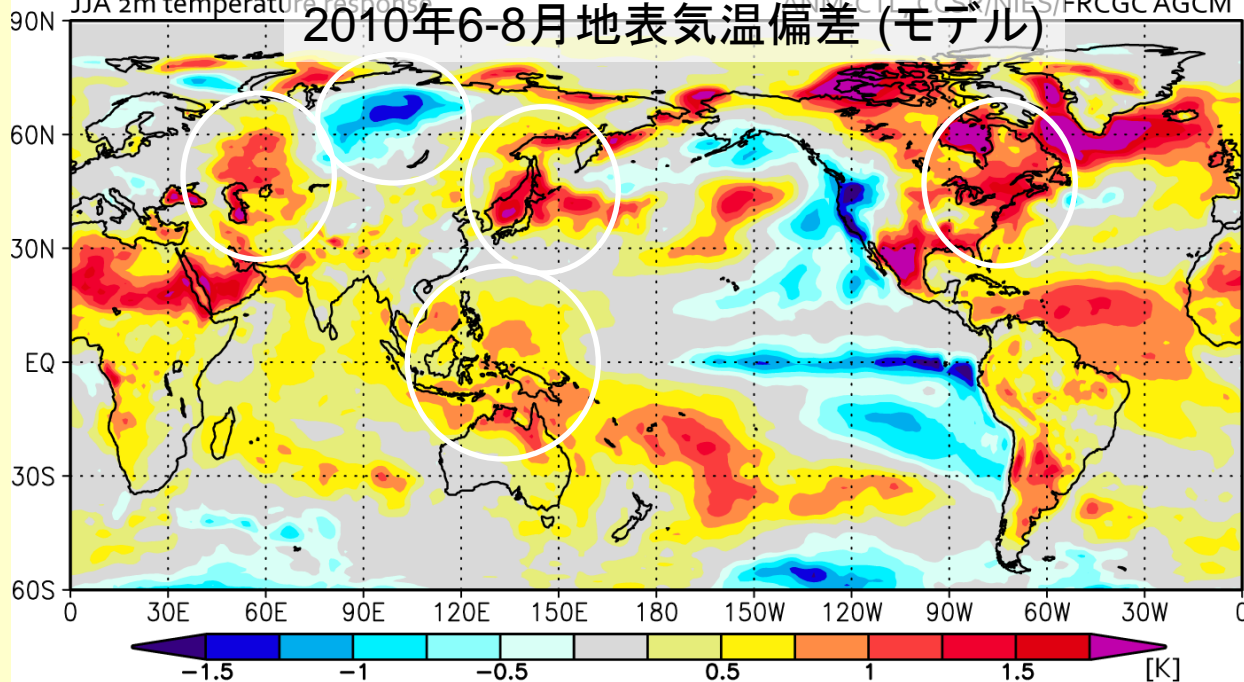
大気大循環モデル (AGCM)



観測された2010年の
海面水温、海水被覆率

異常気象のある部分は
海面水温変動と無関係
に生じるので、気温偏
差が再現できることは
あたりまえではない

JJA 2m temperature response 2010年6-8月地表気温偏差 (モデル)



2010年夏の天候再現実験

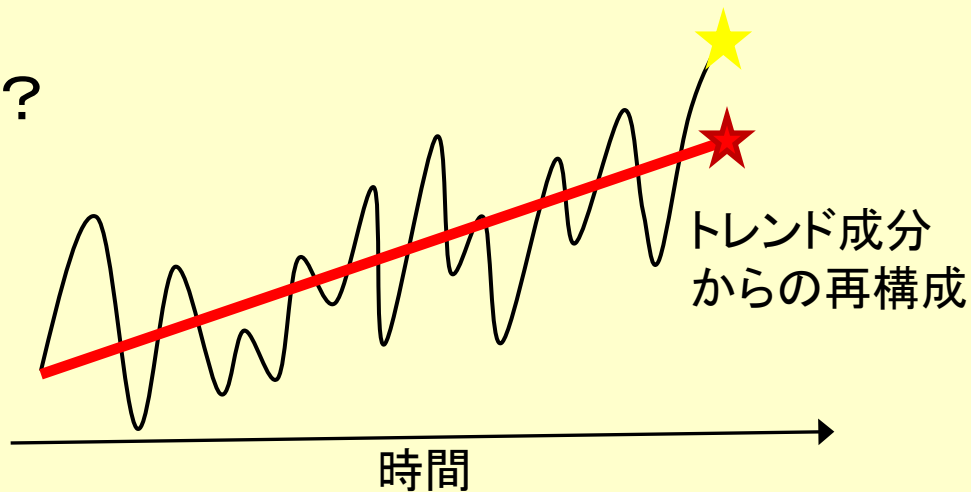
ある年の偏差

Q 今年の猛暑は温暖化のせい？

A

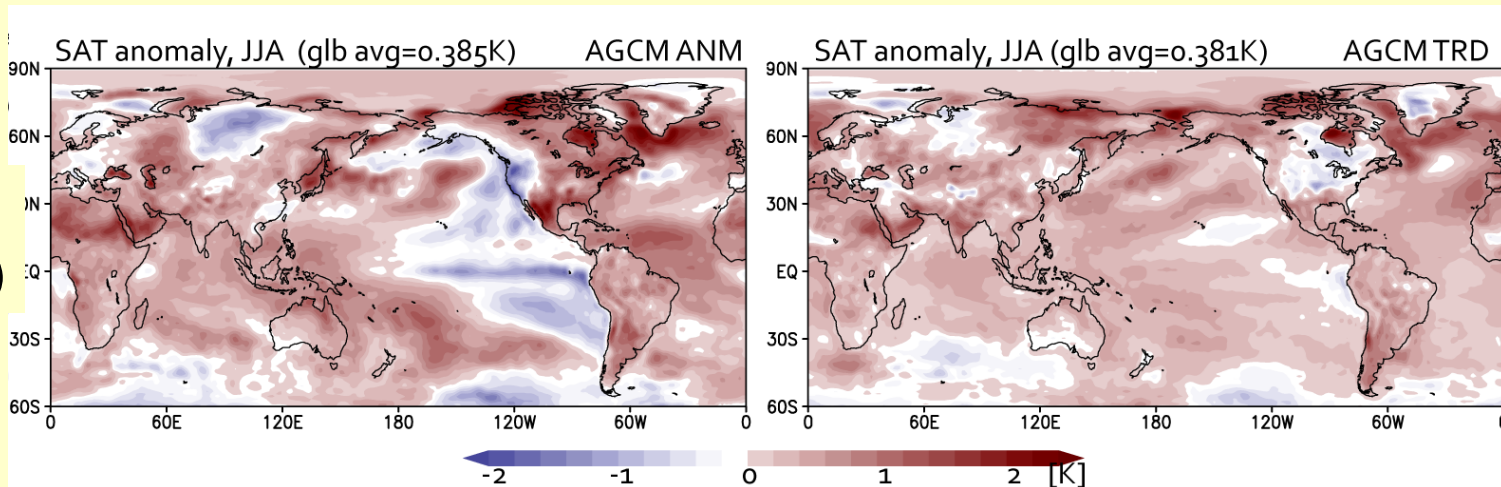


長期間の変化傾向
(トレンド)による
水温偏差をモデルに
与えると？



AGCM再現実験

AGCMトレンド実験



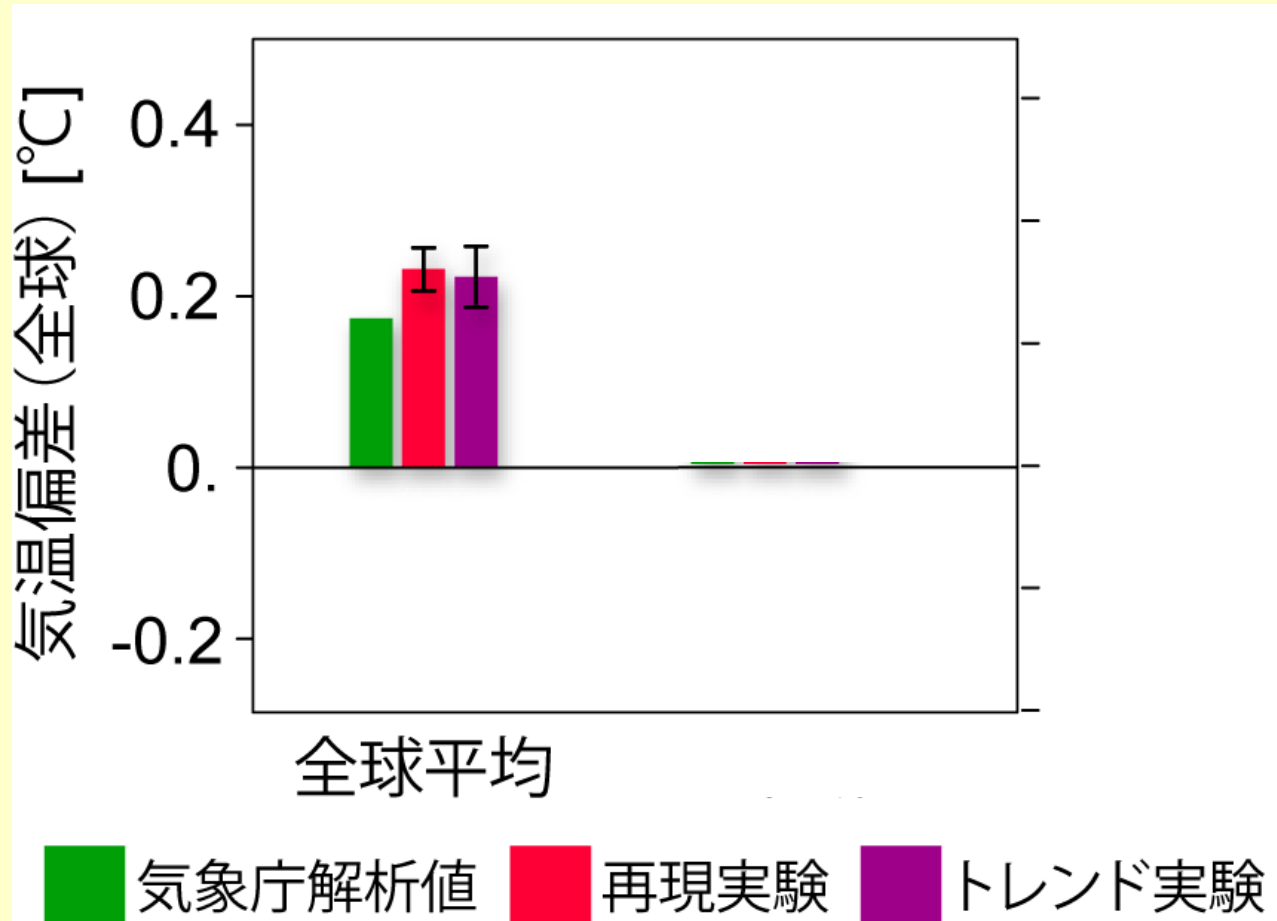
地表気温
偏差(AGCM)

今年の偏差分布には似ていないが全体的に昇温する応答

2010年夏の天候再現実験

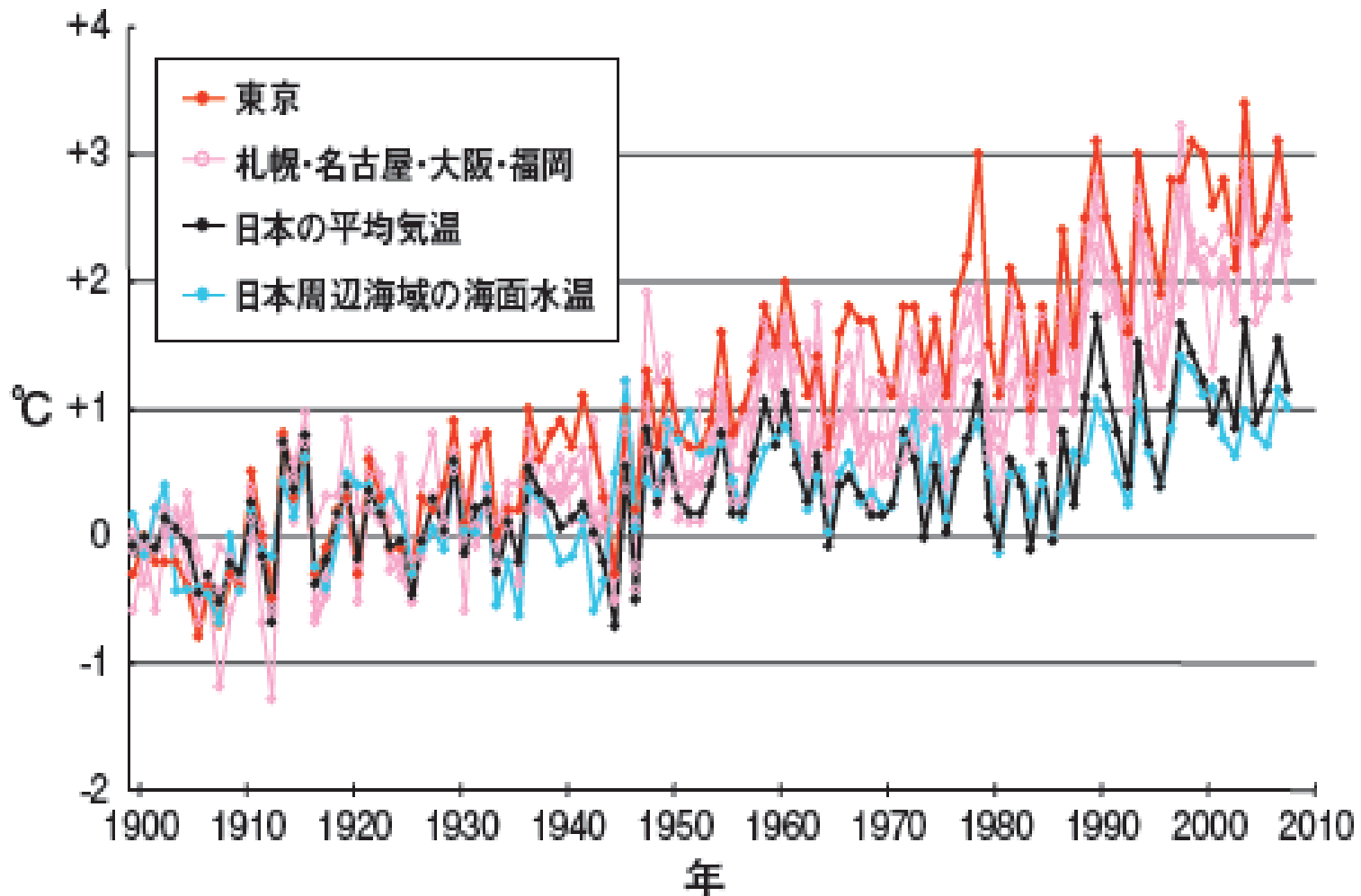
海水温・海氷の変化傾向(温暖化+長周期変動)は **日本** の暑夏を説明するか？

2010年夏季の
地表気温偏差



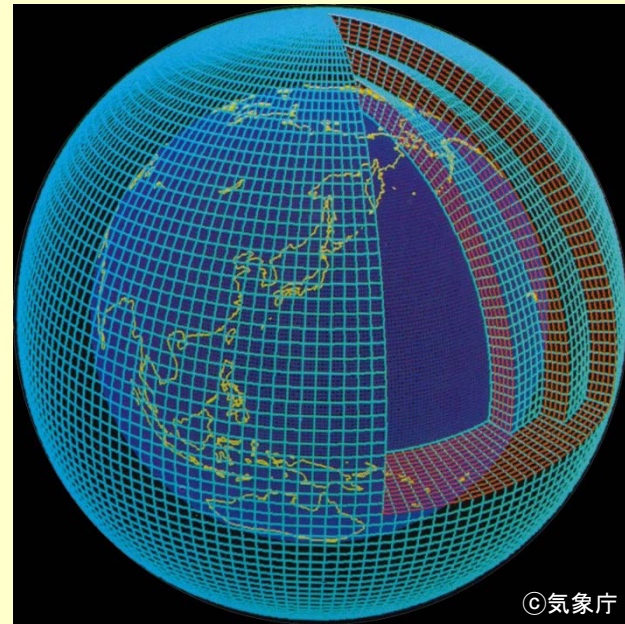
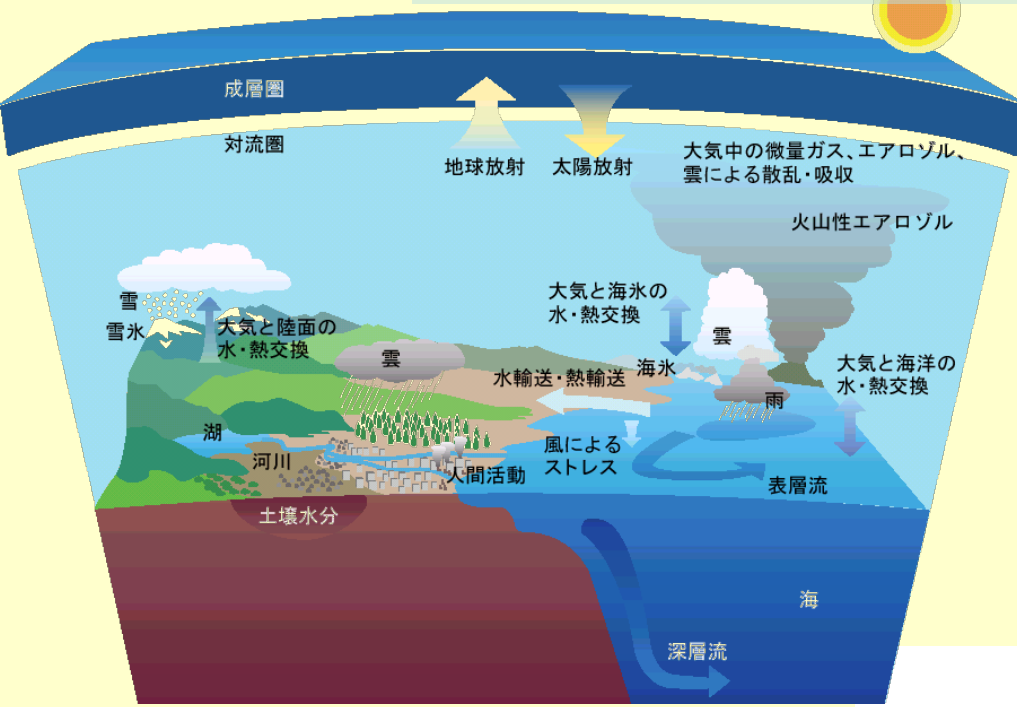
全球平均 ⇒ ほぼすべてトレンドによる

日本周辺 ⇒ 2-4割程度

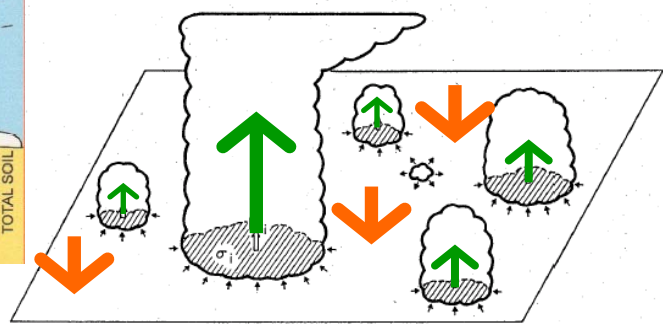
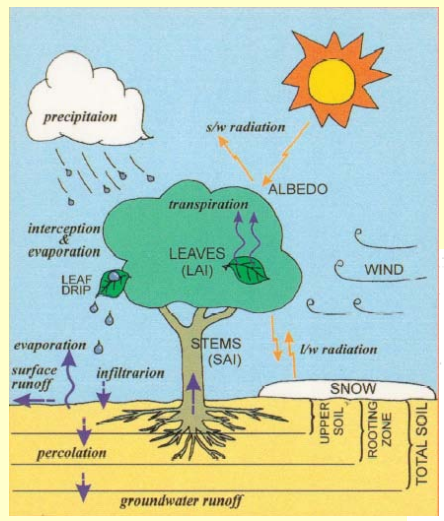


日本の大都市、日本の平均気温、日本の周辺海域の海面水温の推移

気候モデル—コンピュータの中の地球



©気象庁



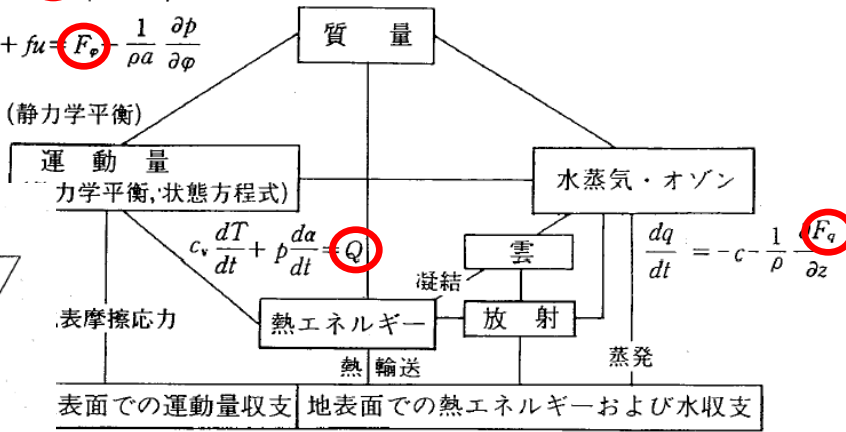
$$\frac{d\rho}{dt} + \rho \left(\frac{1}{a \cos \varphi} \frac{\partial u}{\partial \lambda} + \frac{1}{a \cos \varphi} \frac{\partial v \cos \varphi}{\partial \varphi} + \frac{\partial w}{\partial z} \right) = 0$$

$$\frac{du}{dt} - \frac{\tan \varphi}{a} uv - fv = F_\lambda - \frac{1}{\rho a \cos \varphi} \frac{\partial p}{\partial \lambda}$$

$$\frac{dv}{dt} + \frac{\tan \varphi}{a} u^2 + fu = F_\varphi - \frac{1}{\rho a} \frac{\partial p}{\partial \varphi}$$

$$0 = -g - \frac{1}{\rho} \frac{\partial p}{\partial z} \quad (\text{静力学平衡})$$

$$p = \rho RT$$



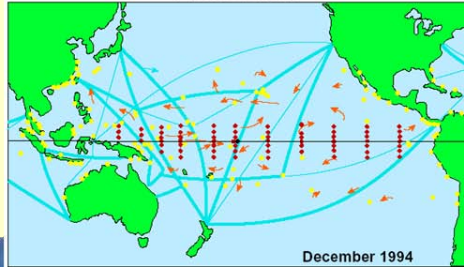
表面での運動量収支 | 地表面での熱エネルギーおよび水収支

エルニーニョ予測

The ENSO Observing System

The ENSO observing system build up during the TOGA period (right panel) is one of the main cornerstones for successful prediction of ENSO events. Without a continuous collection (in space and time) of different meteorological and oceanographic data using the capabilities of research vessels, ships of opportunity, surface and satellite observations and the evolving knowledge and technology of climate modelling successful forecasts of ENSO events would not be possible. Compared to the benefit of the society the cost for the maintenance of the observing system and the modelling resources are neglectable.

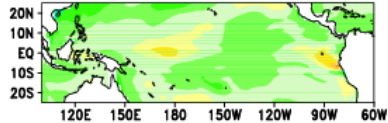
TOGA in Situ Ocean Observing System Pacific Basin



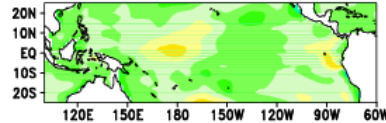
Photos: above and right: maintenance of the TAO array (courtesy NOAA/PMEL), upper right: "classical" sea surface temperature measurements (bucket) (courtesy G. Mehl)

AV/G1/99-6

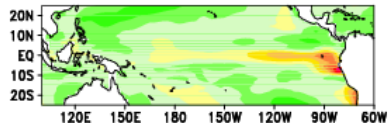
FCT INITIAL:00Z11MAR1997
1-month lead



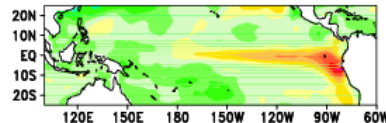
Obsevation 00Z10APR1997



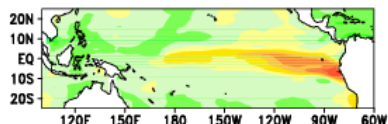
3-month lead



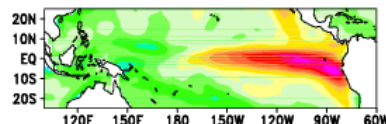
00Z09JUN1997



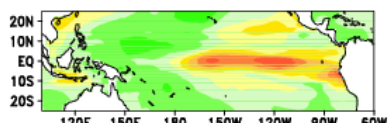
6-month lead



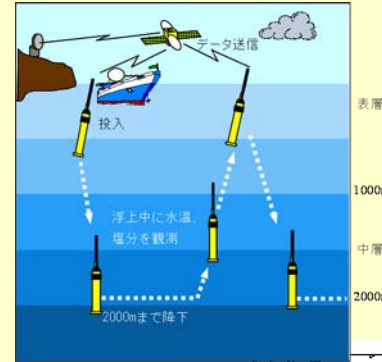
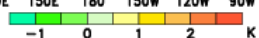
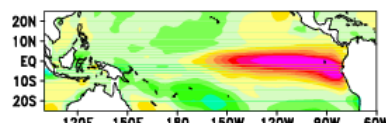
00Z07SEP1997



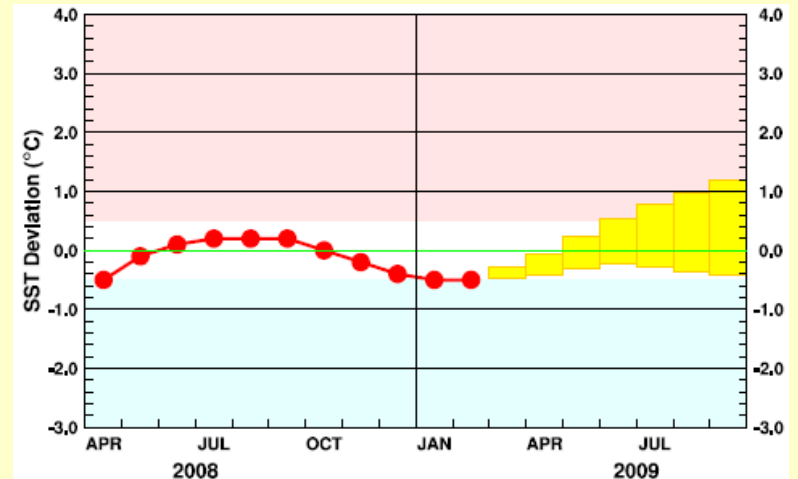
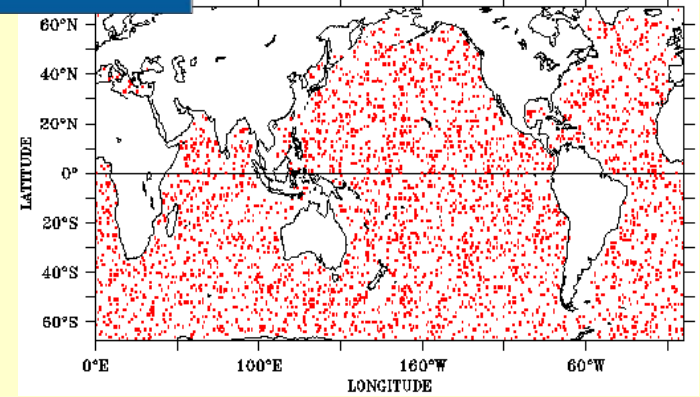
9-month lead



00Z06DEC1997



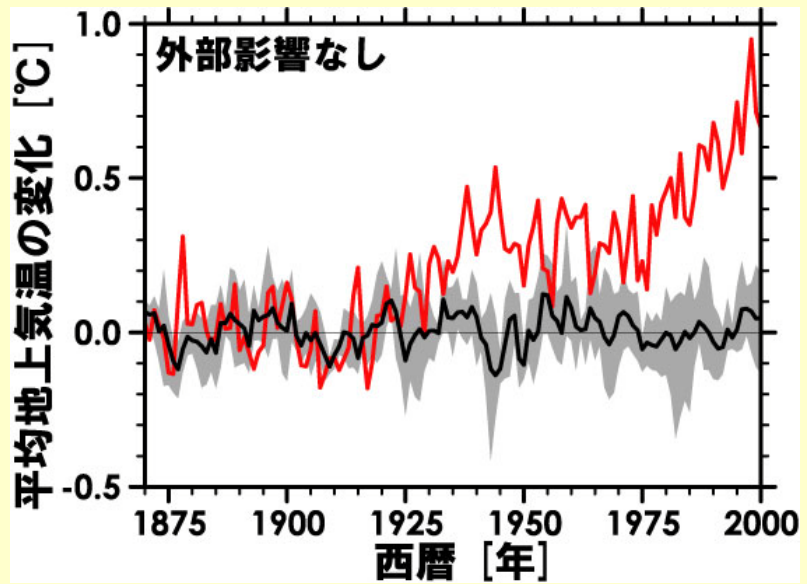
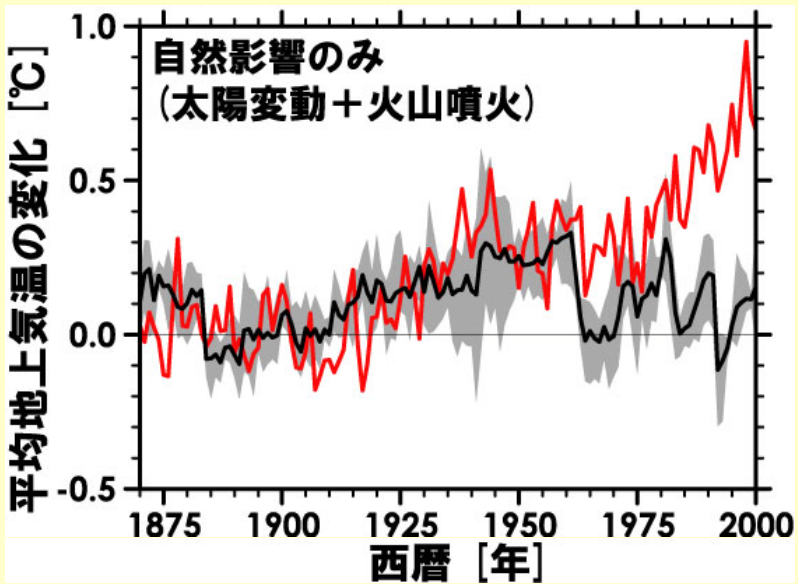
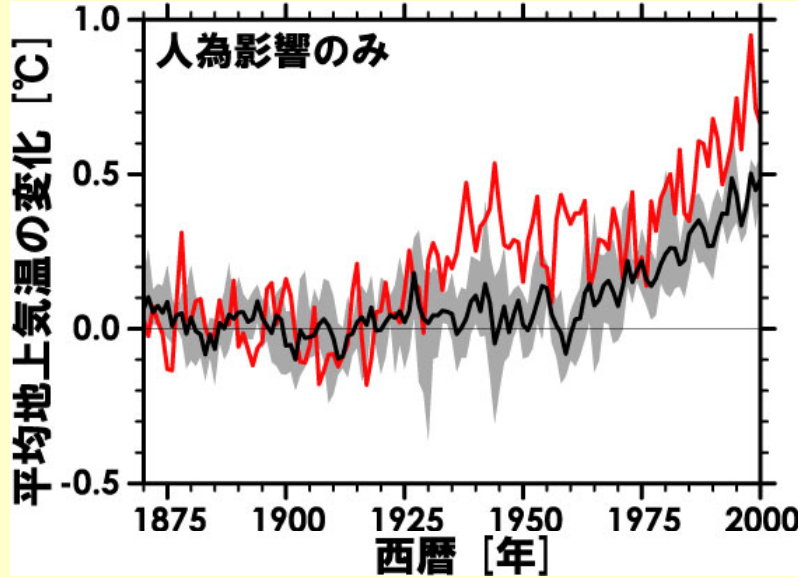
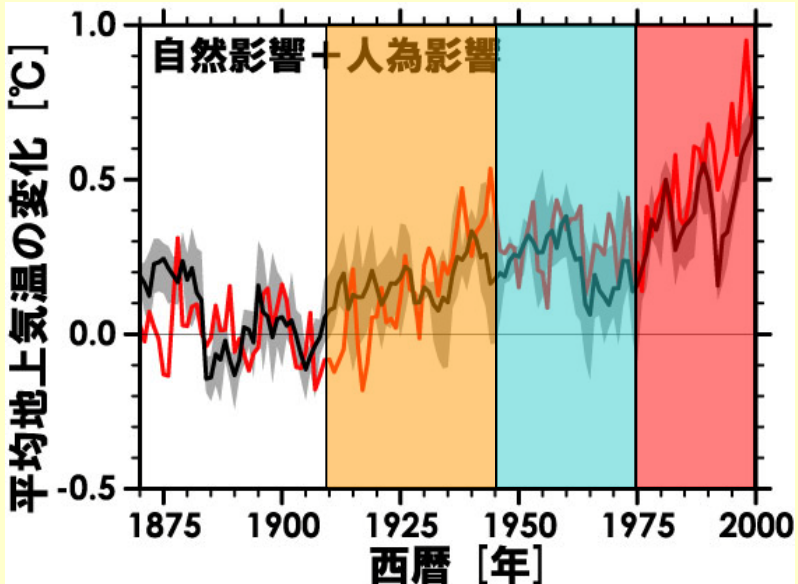
ARGO



20世紀気候再現実験



全球平均地表気温—18世紀末からの変化 Nozawa et al. (2005)



数値天気予報、気候シミュレーション略史

1875年：東京気象台

1913年：科学的手法による天気予報についての
V. Bjerknes論文

1922年：Richardsonによる手計算天気予報

1950年：ENIACによる最初の数値予報

1956年：最初の大気大循環数値実験

1988年：IPCC発足

1996年：気象庁力学的1か月予報開始

2002年：地球シミュレータ

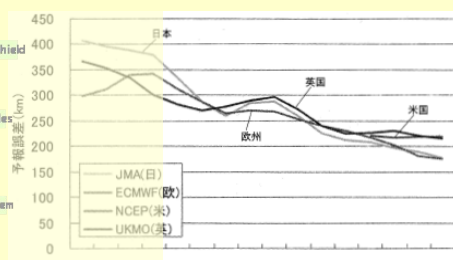
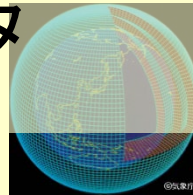
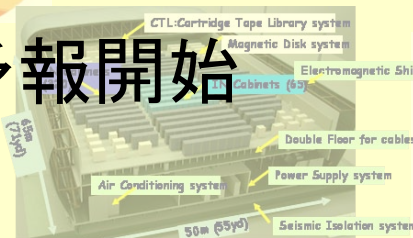
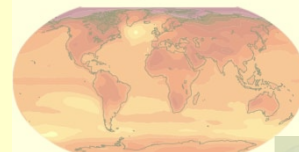
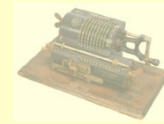
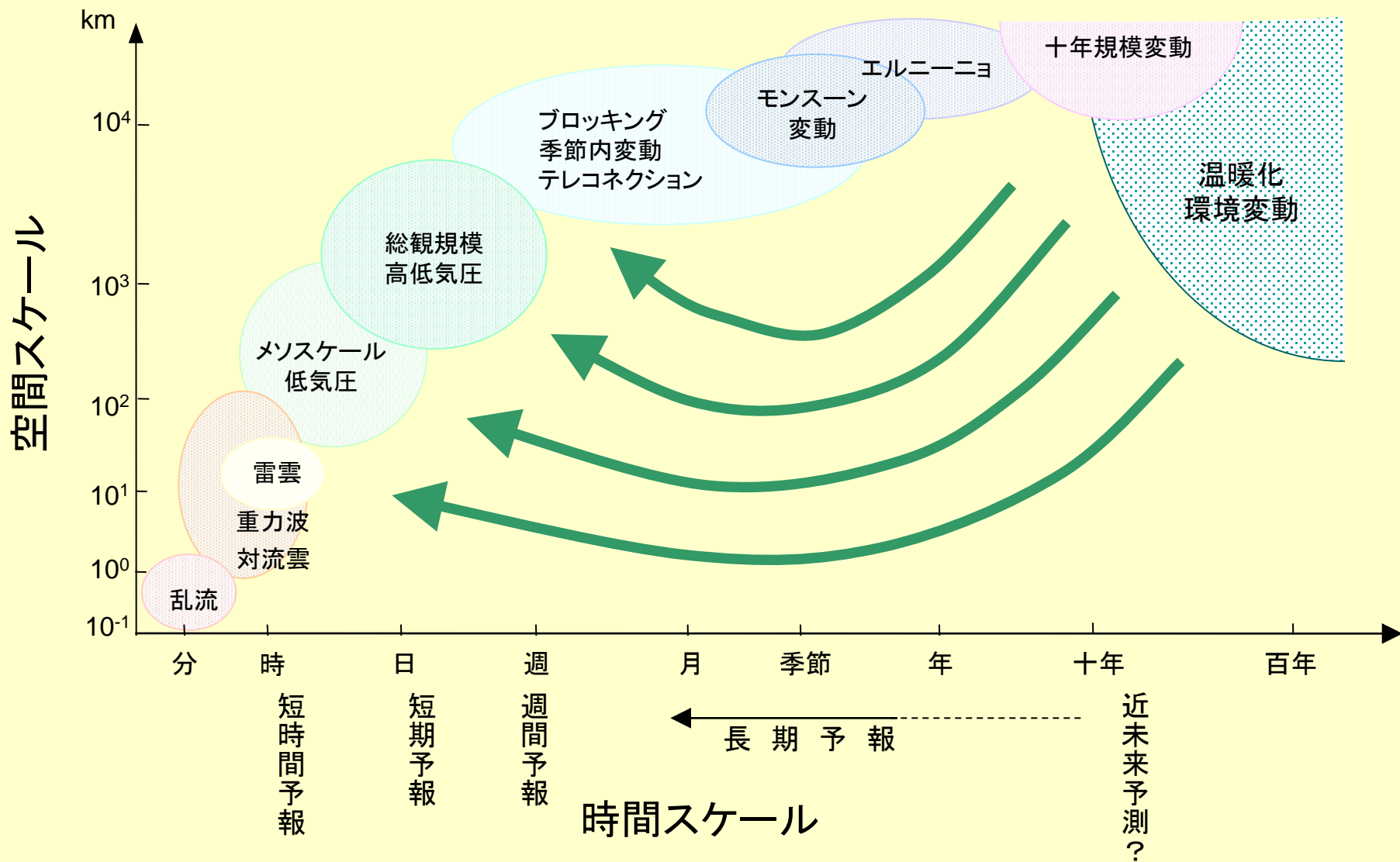
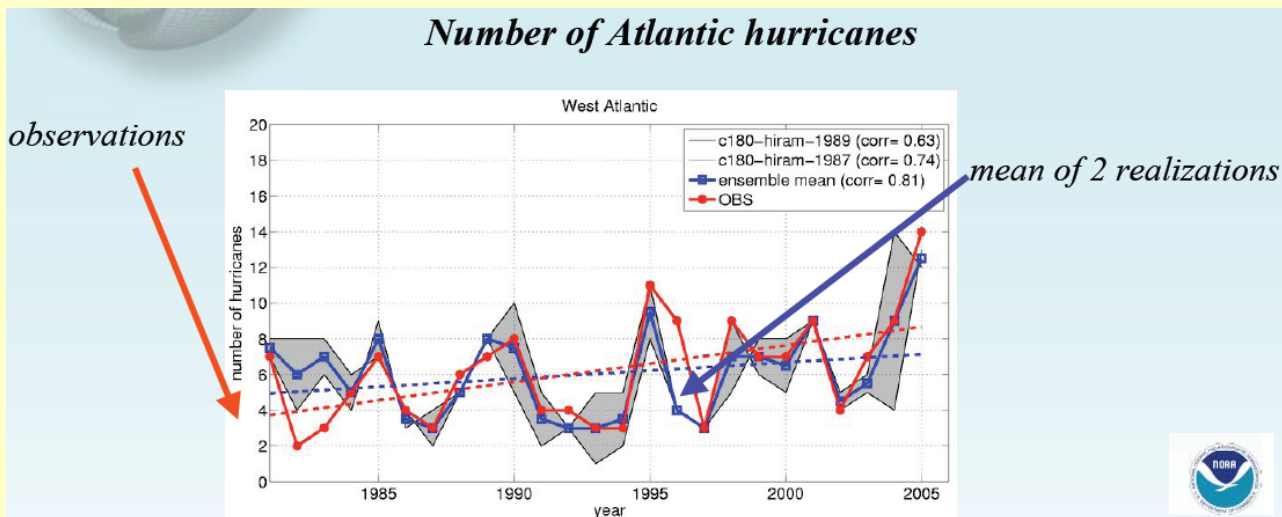


図7.9 台風進路予報誤差 (2日子報) (気象庁提供)

気象現象の時間・空間スケール

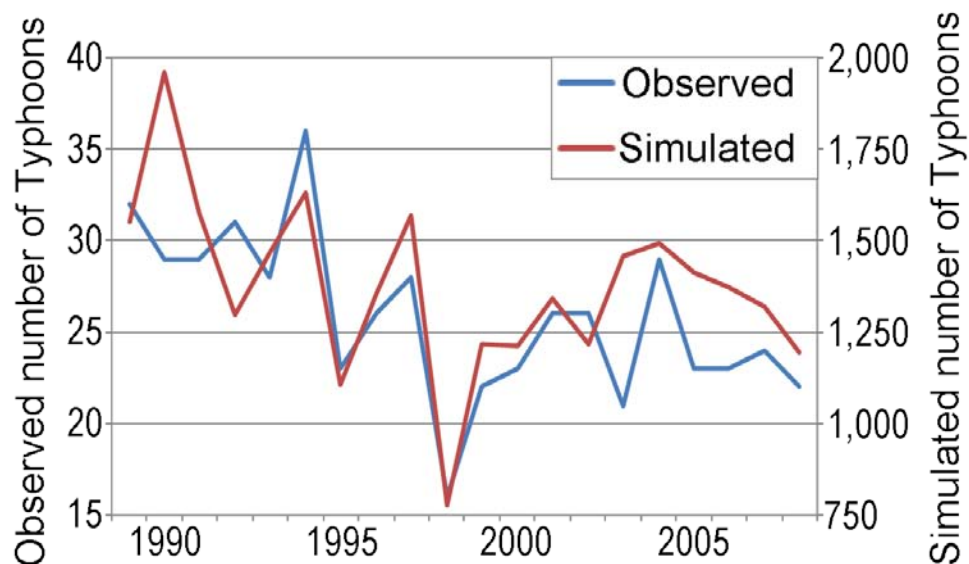
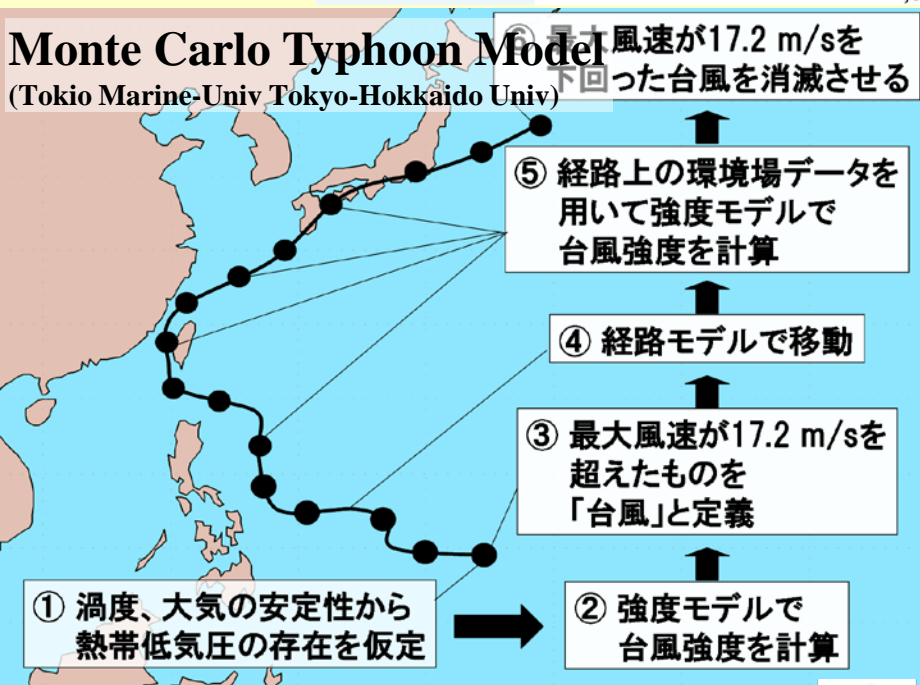


台風ポテンシャルの予測？



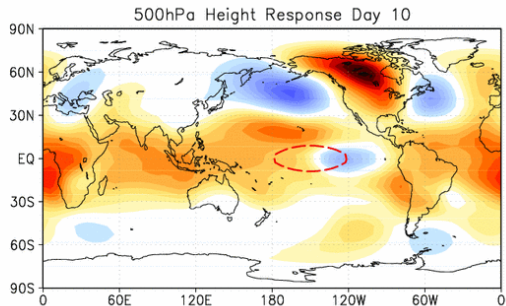
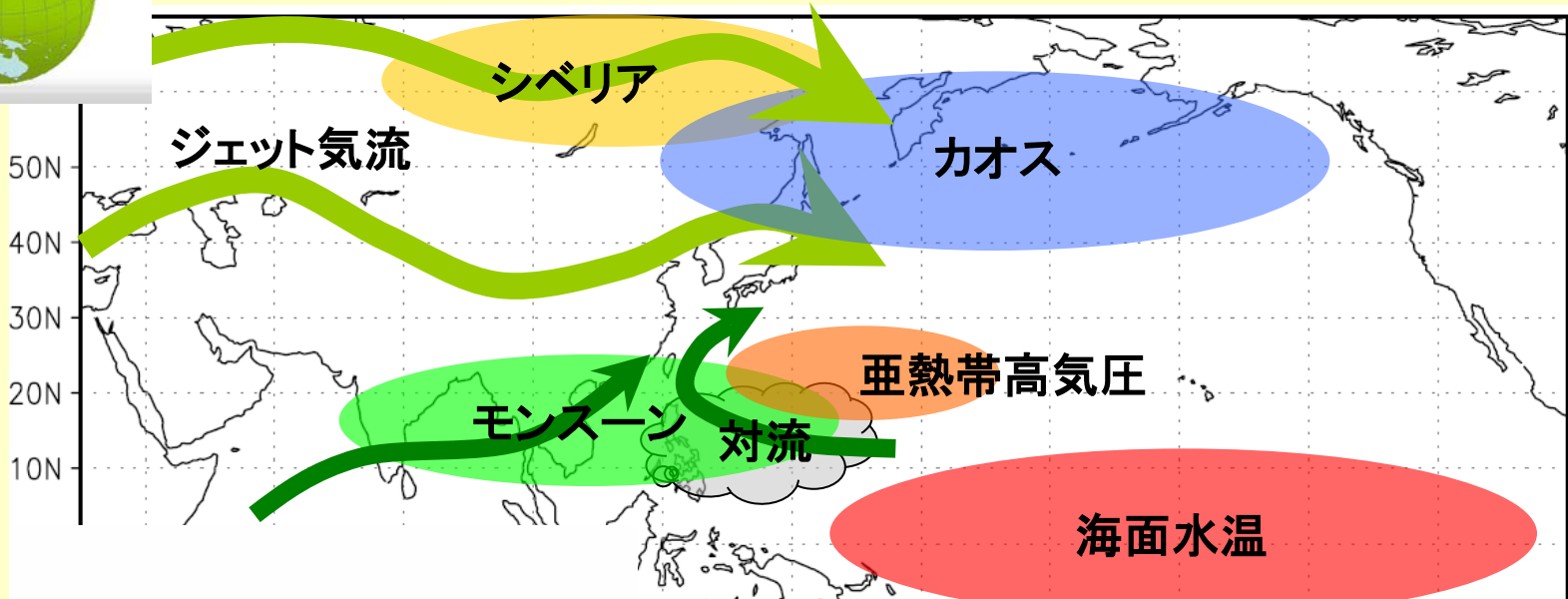
Monte Carlo Typhoon Model

(Tokio Marine-Univ Tokyo-Hokkaido Univ)



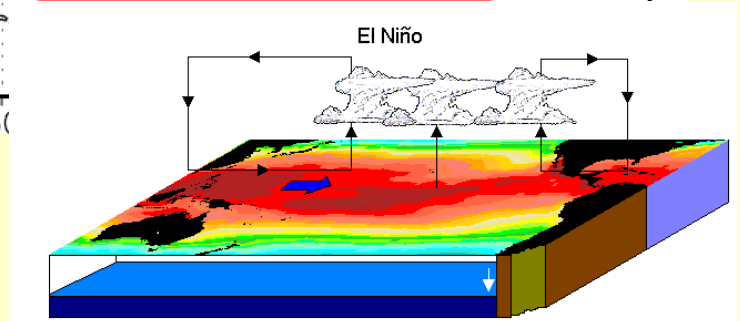
日本の天候に影響を与えるさまざまな要因

北極振動



テレコネクション

20E 140E 160



エルニーニョ

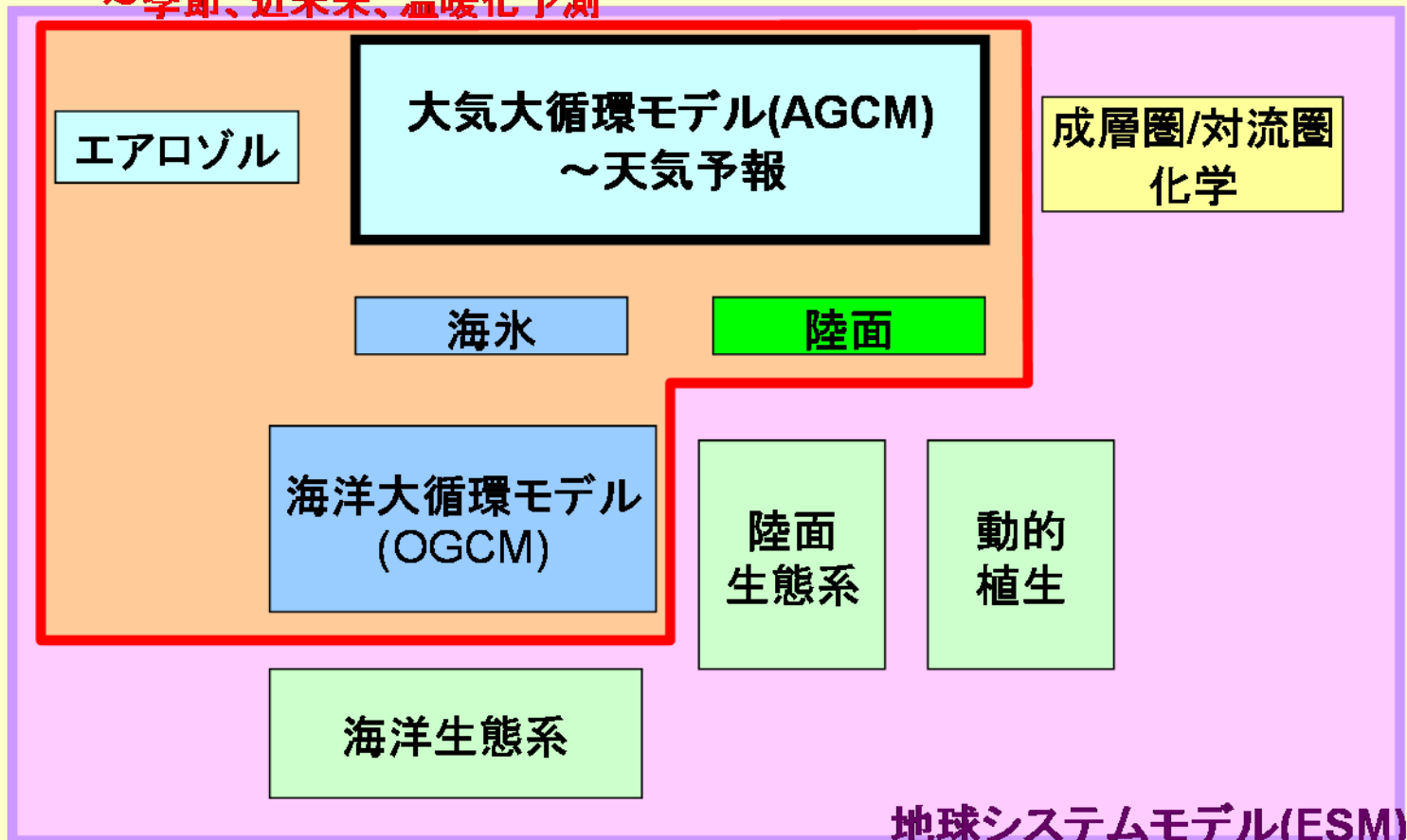
The World in Global Climate Models

Mid-1970s

Mid-1980s

大気海洋結合気候モデル(AOGCM)

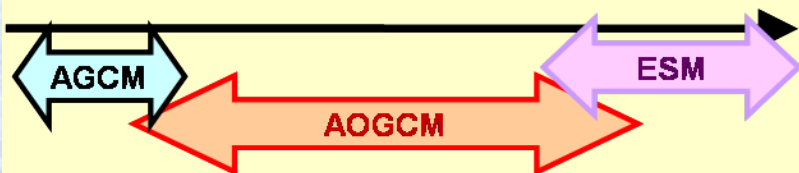
～季節、近未来、温暖化予測



地球システムモデル(ESM)

～炭素循環、環境予測

日 季節 年 10年 100年 300年

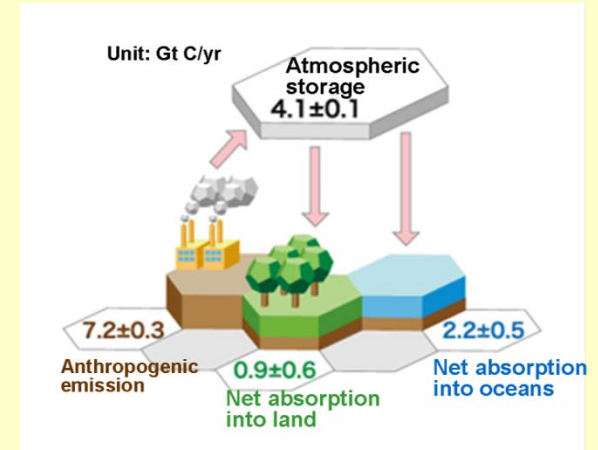
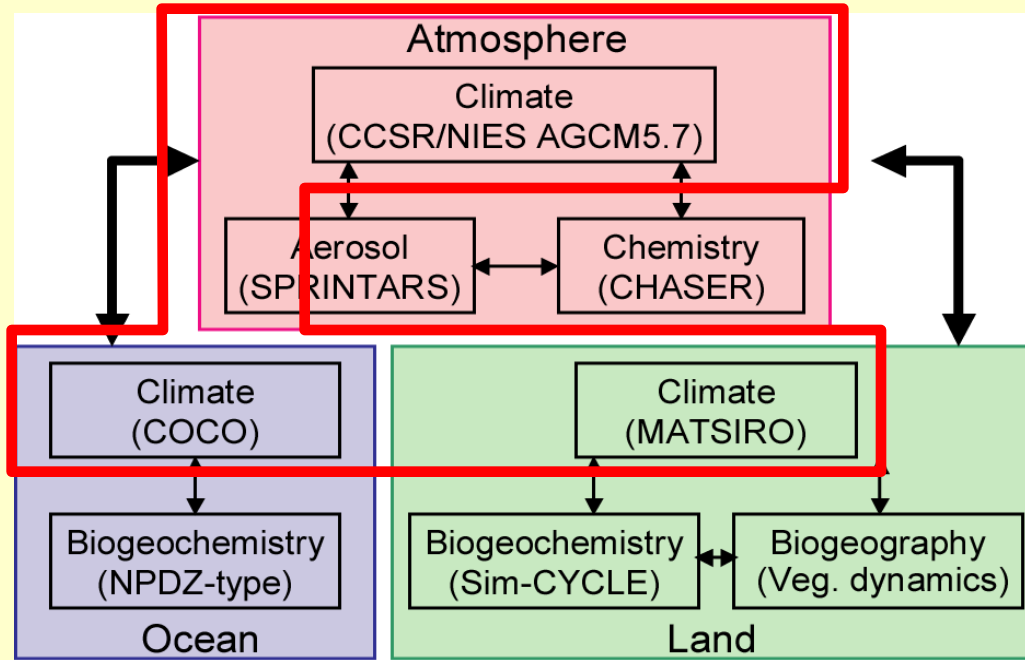


Circulation

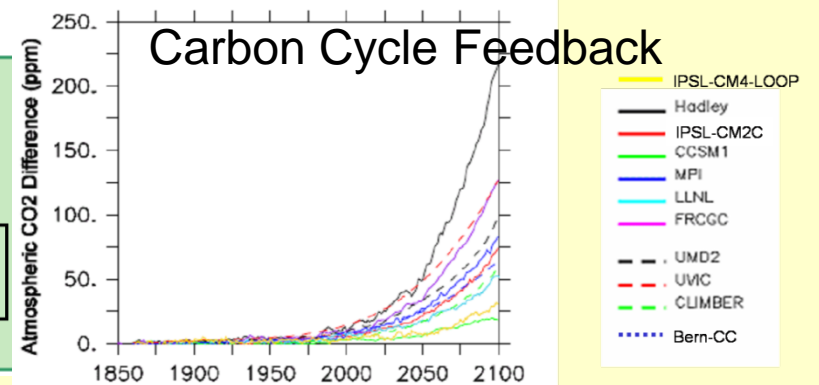
Interactive Vegetation

大気海洋結合モデルから地球システムモデルへ

Extension to the Stratosphere

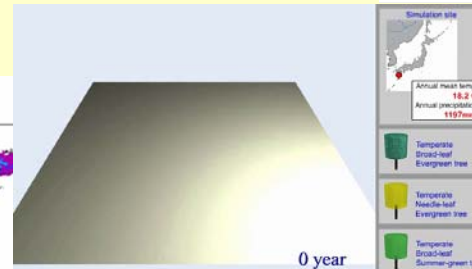
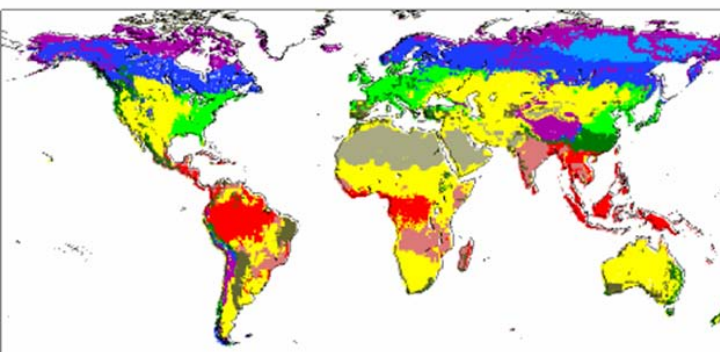


(Coupled Climate - Carbon Cycle Model Intercomparison Project)



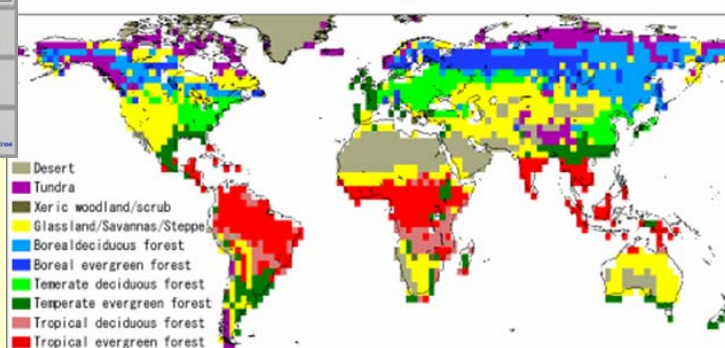
Friedlingstein et al. (2005, JC, in press)

Natural vegetation



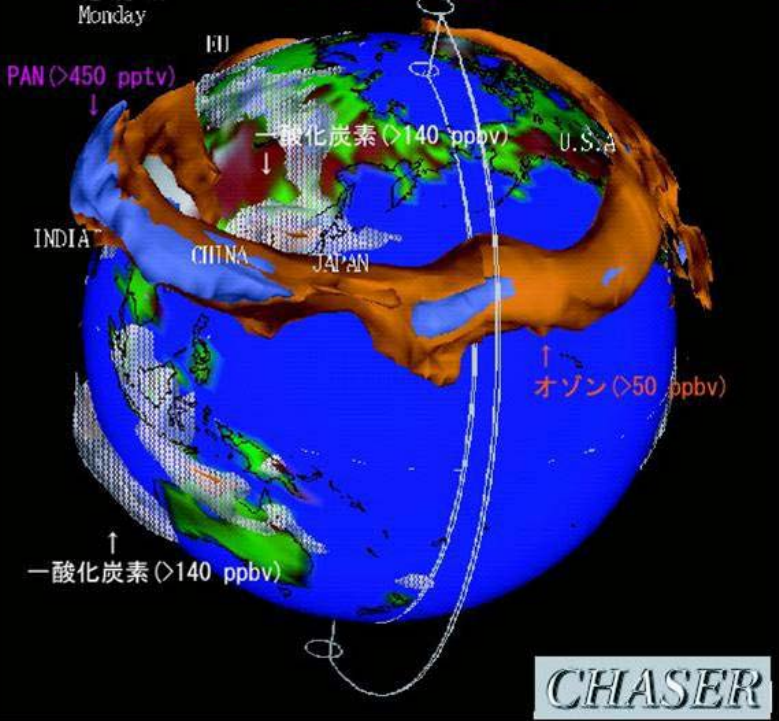
Dynamic Vegetation

Simulated vegetation



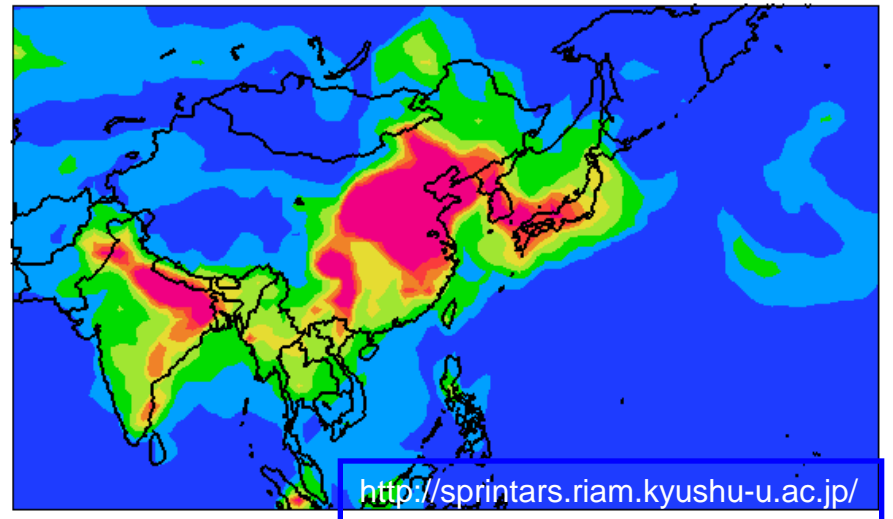
12:00:00
15 Sep 1996
12 of 61
Monday

Polluted Earth !

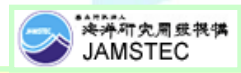
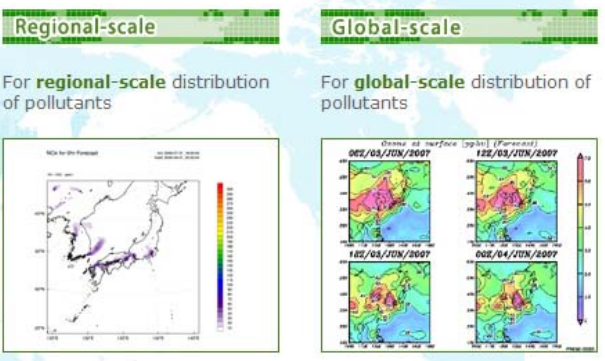


Forecast of atmospheric pollutant aerosols (movie)

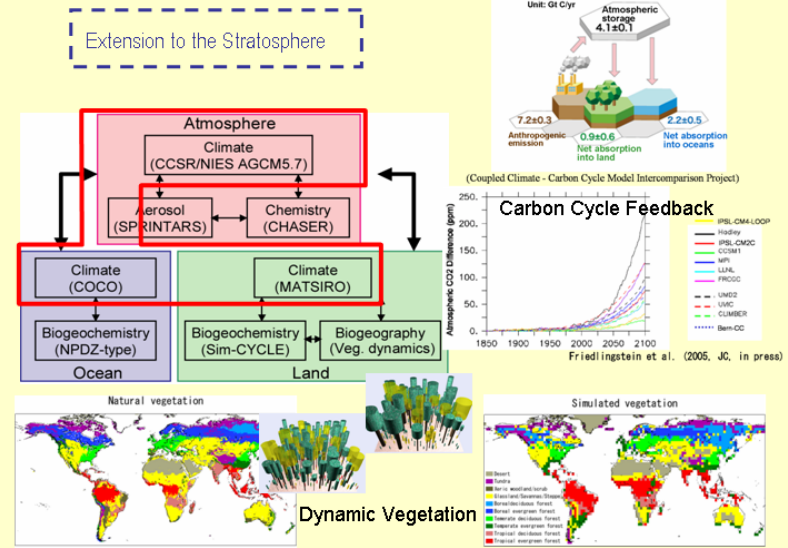
15:00JST 26MAY2008



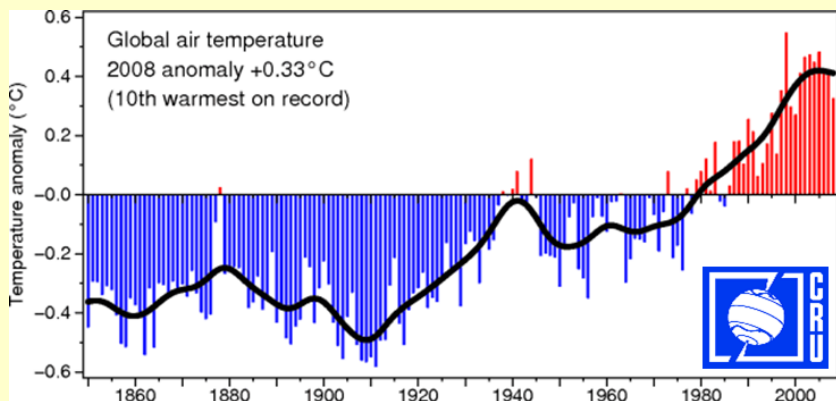
Global Chemical Weather Forecast System



MIROC-ESM: MIROC-based Earth System Model

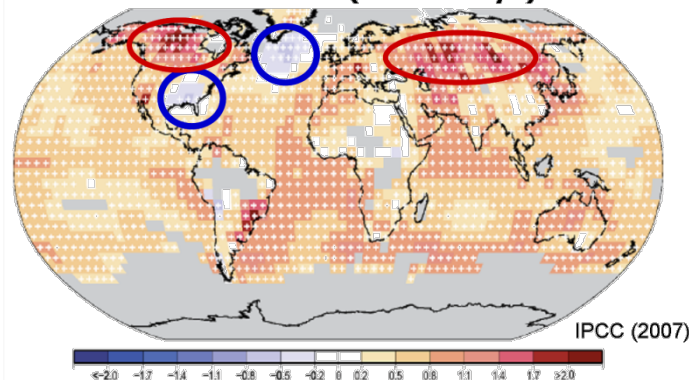


気候変動 = 強制 + 自然変動

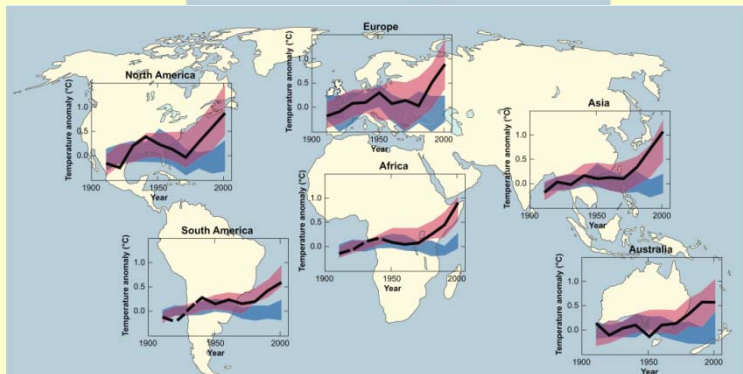
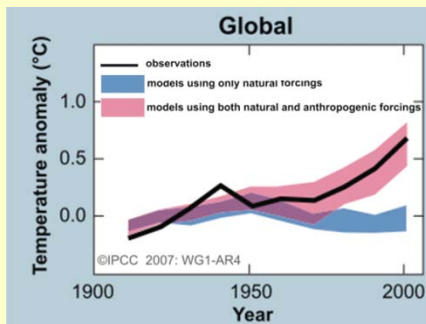


Linear trend of surface temperatures

1901 - 2005 ($^{\circ}\text{C Century}^{-1}$)

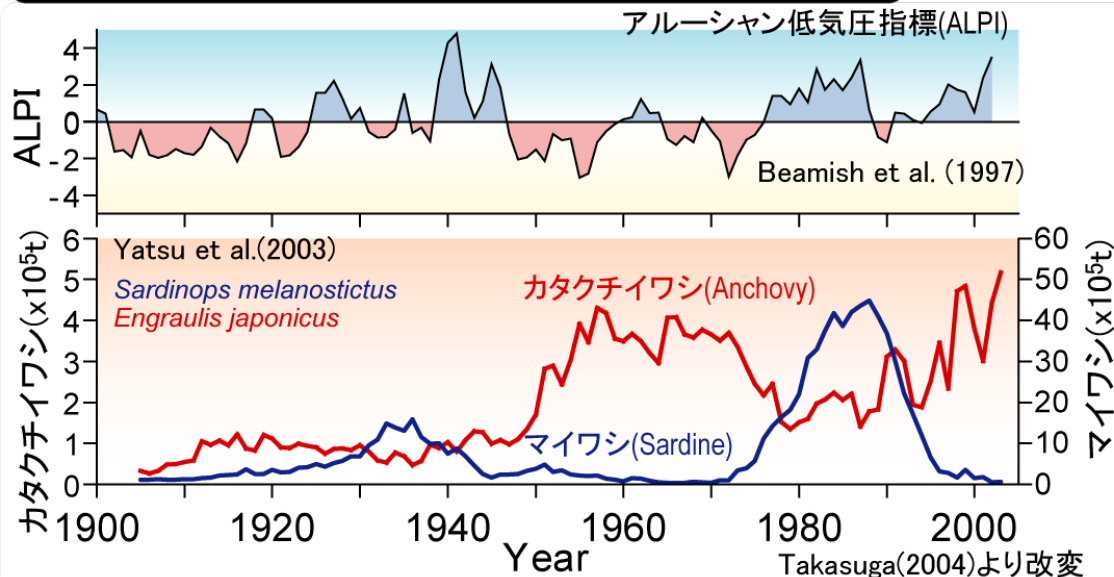


Mixture of internal variability and forced climate change

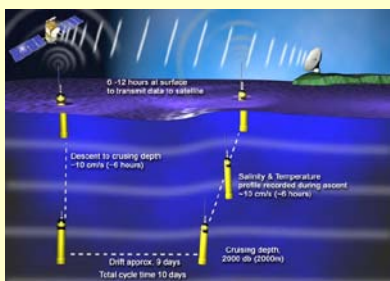
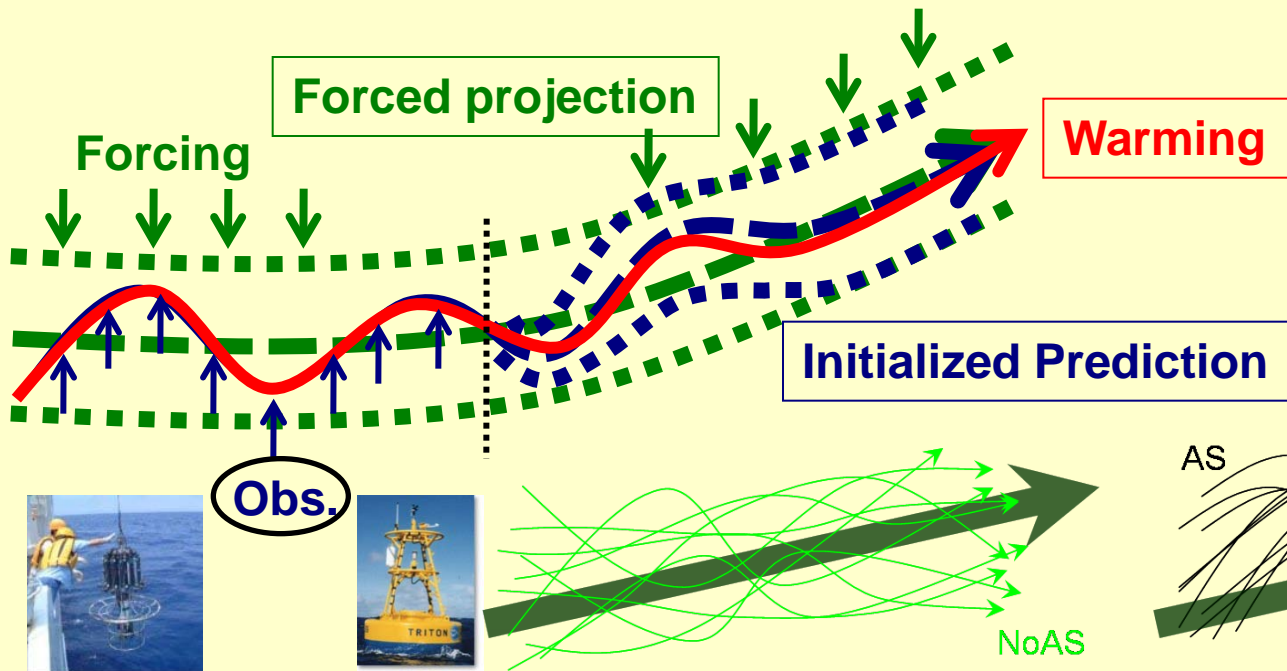


©IPCC 2007 WG1-AR4

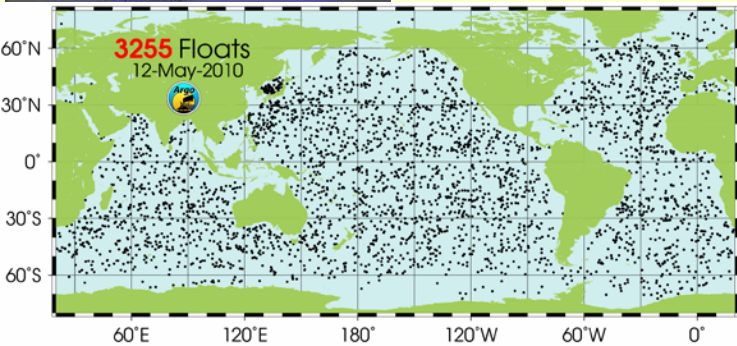
日本付近のマイワシ・カタクチイワシなどの魚種交替



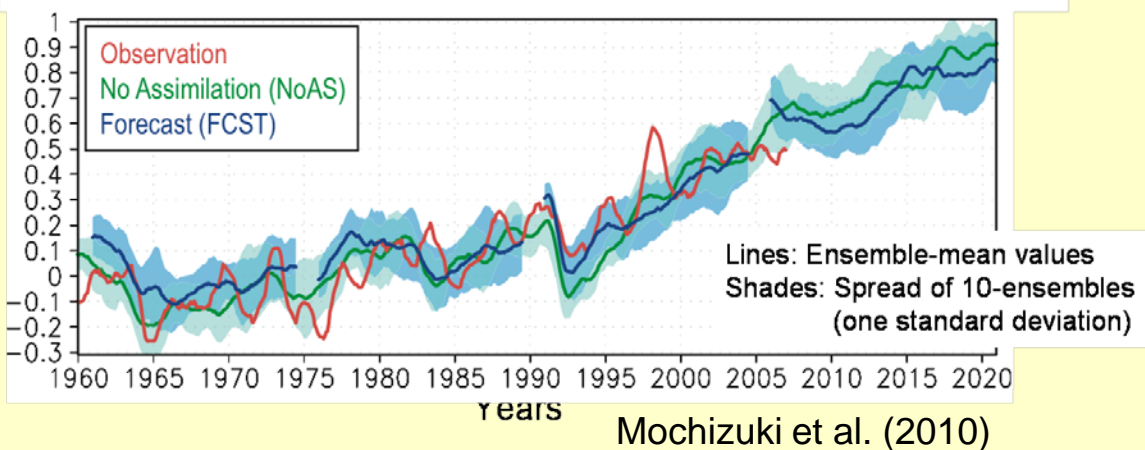
近未来予測



Argo subsurface ocean data network



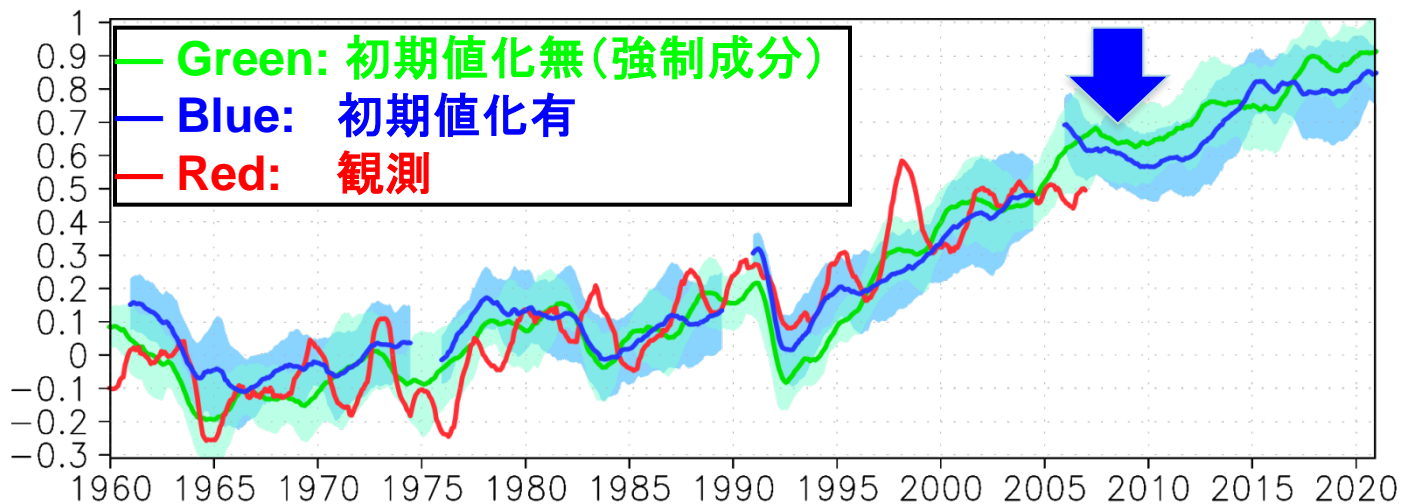
Global-mean Surface Air Temperature (SAT) anomaly relative to ave. 1961-1990



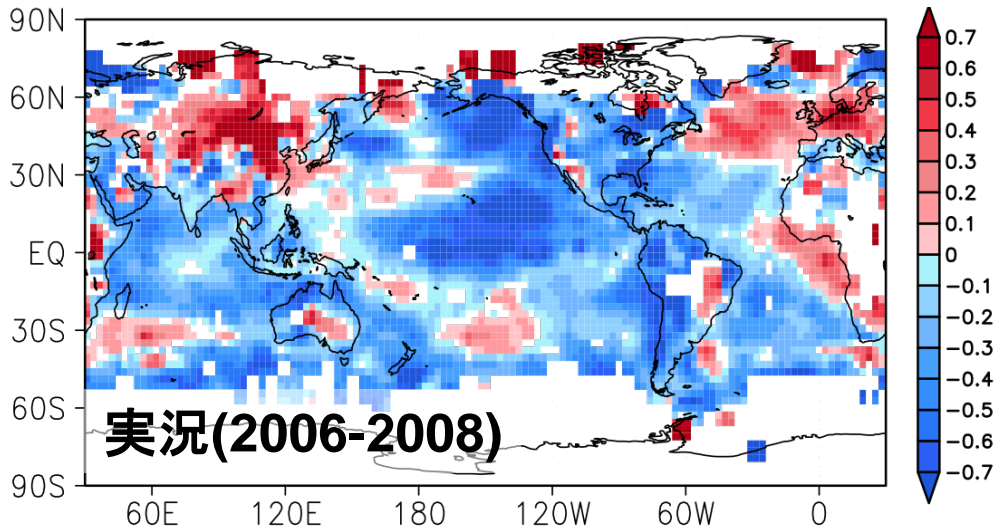
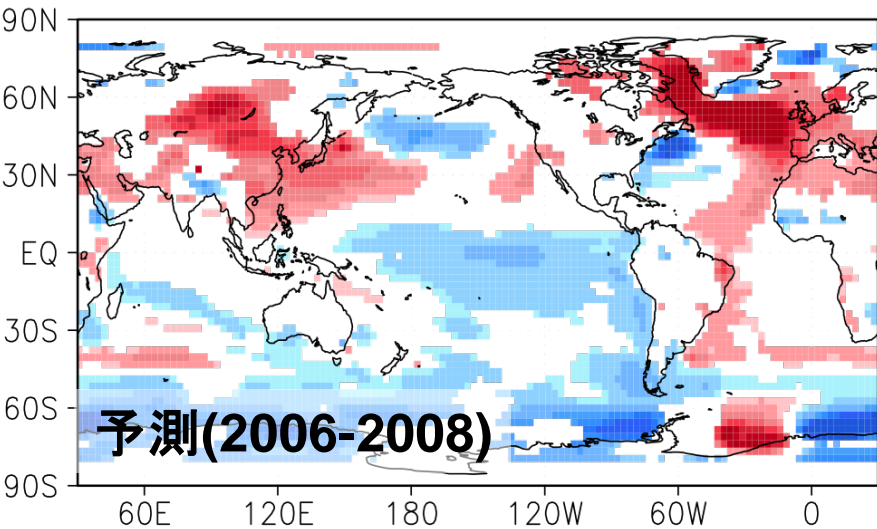
PDOの 予測可能性

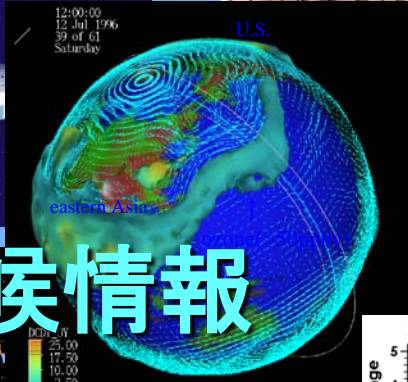
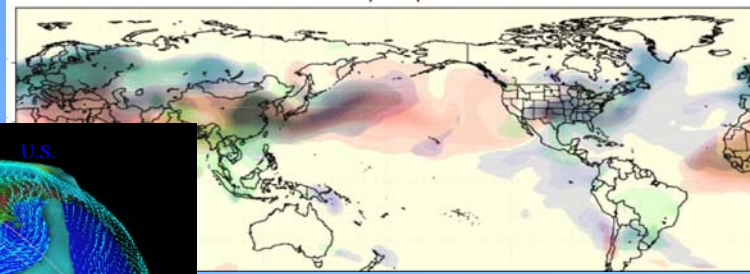
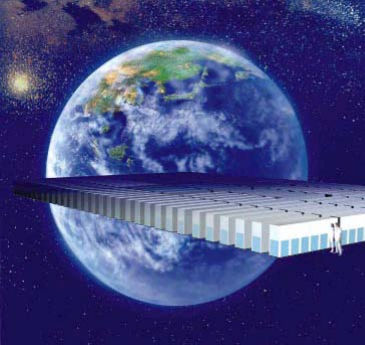
Mochizuki et al. (2010)

全球平均地表気温

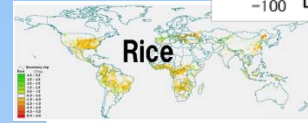
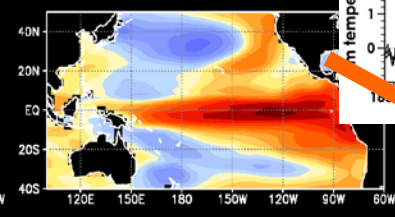
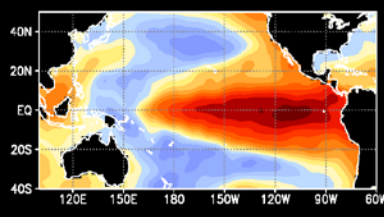
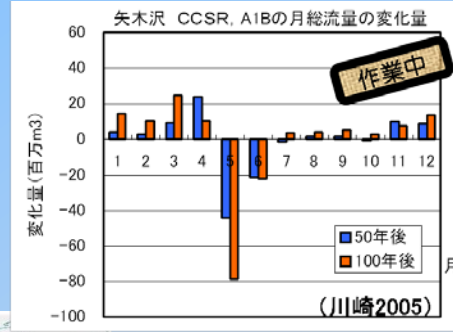
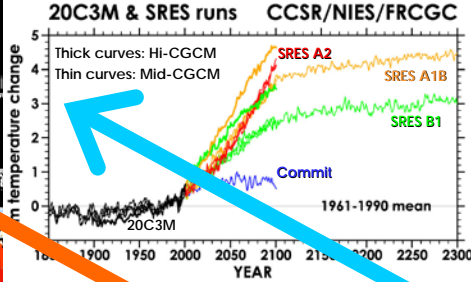
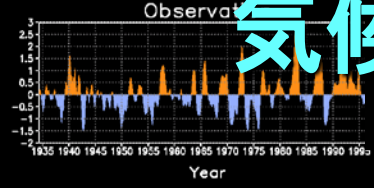


全球地表気温 (強制成分～温暖化傾向からのずれ)

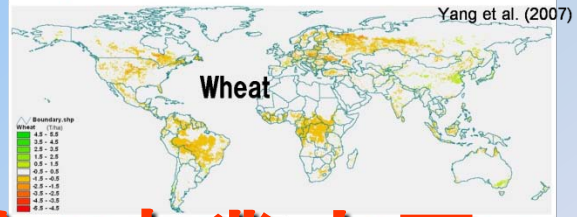




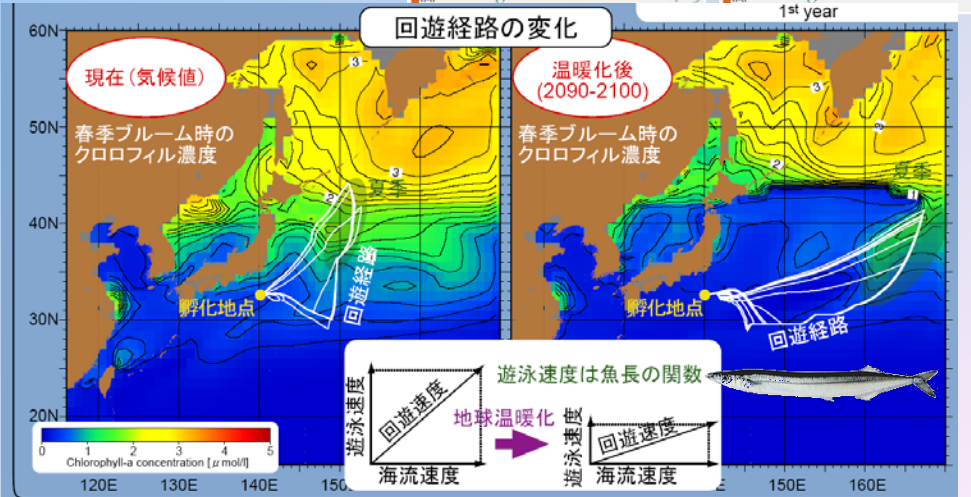
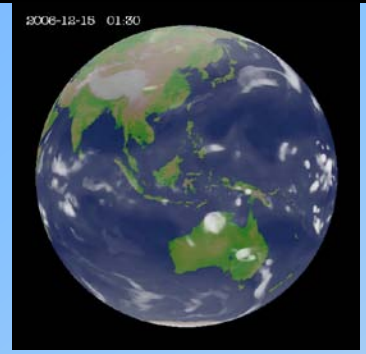
気候情報



Changes in crop yields in 2070-2100 from 1975-2005



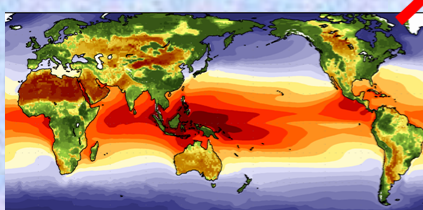
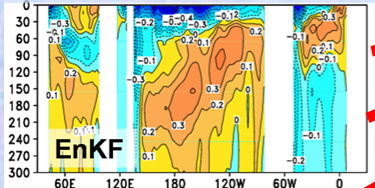
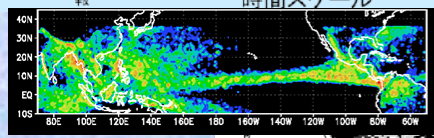
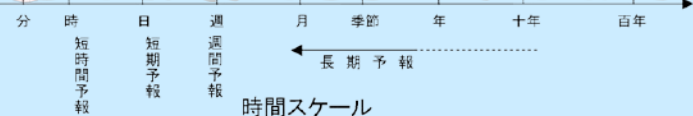
社会・産業応用



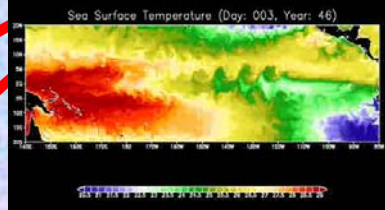
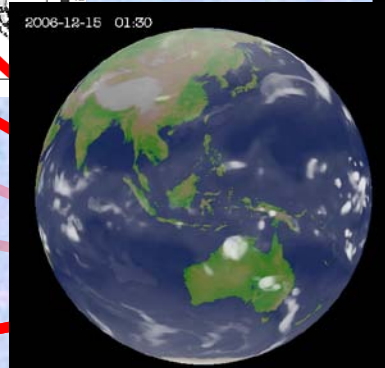
空間スケール



Seamless Prediction



Model



World Modelling Summit for Climate Prediction

ECMWF - Reading (UK), May 6-9, 2008

NEWS NATURE Vol 453:15 May 2008

They say they revolution

...will for major new modelling facility.

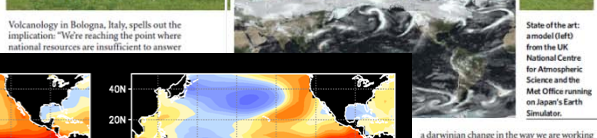
...for massive invest- search resources to help revolutionize modelling capabilities. The eventual aim is to provide probabilistic climate predictions that are as useful, and usable, as weather forecasts.

At the end of a four-day summit held last week at the European Centre for Medium-Range Weather Forecasts in Reading, UK, the scientists made the case for a climate-prediction project on the scale of the Human Genome Project. A key component of this scheme, which would cost something up to, or over, a billion dollars, would be a world climate research facility with computer power far beyond that currently used in the field.

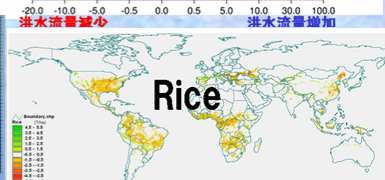
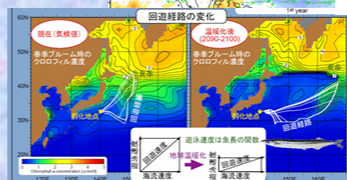
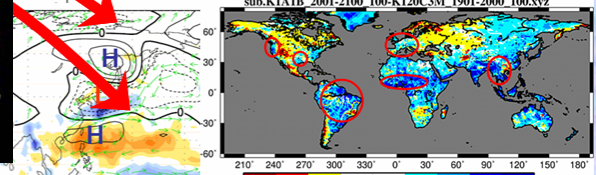
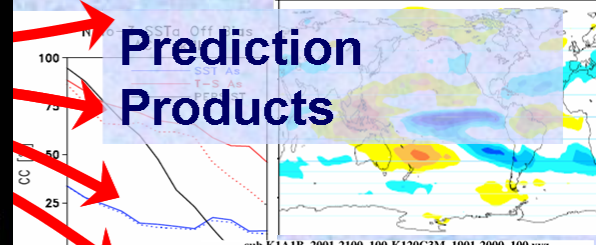
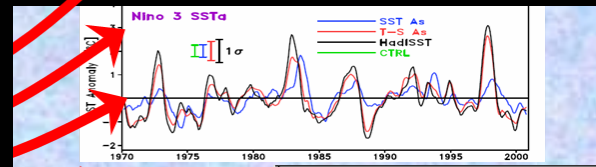
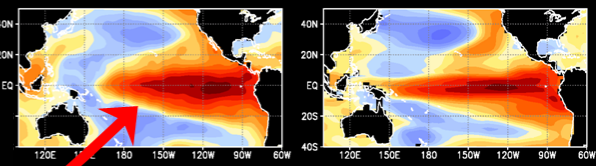
Questions on how severe the effects of global warming will be, and where regions will be hit in what ways, are beyond the capabilities of current climate models, at least in part because of computing constraints. Today's climate models are run on com-

...to spreads in the hundreds of petaflops — would allow modellers to study simulations at the kilometre scale, enabling better predictions on the activity of hurricanes and, eventually, the local deep convection that transfers much energy into the upper atmosphere (see 'A real solution?'). This research could then be fed into operational models.

The scientists think they could answer at least some of the 'big' questions on the effects of global warming if the technology was available. But national climate-modelling efforts, such as those of the Met Office in Exeter, UK, or the National Center for Atmospheric Research (NCAR) in

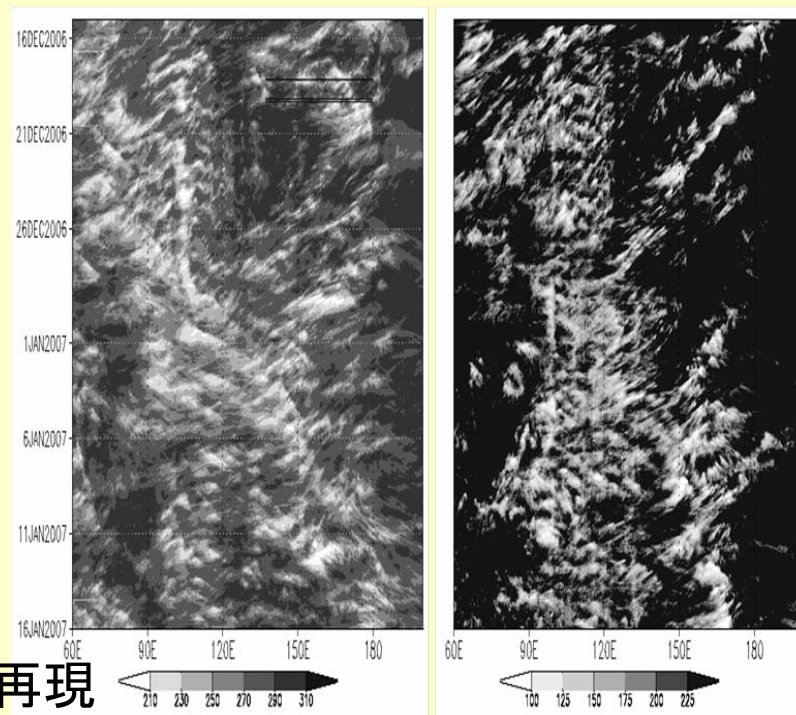
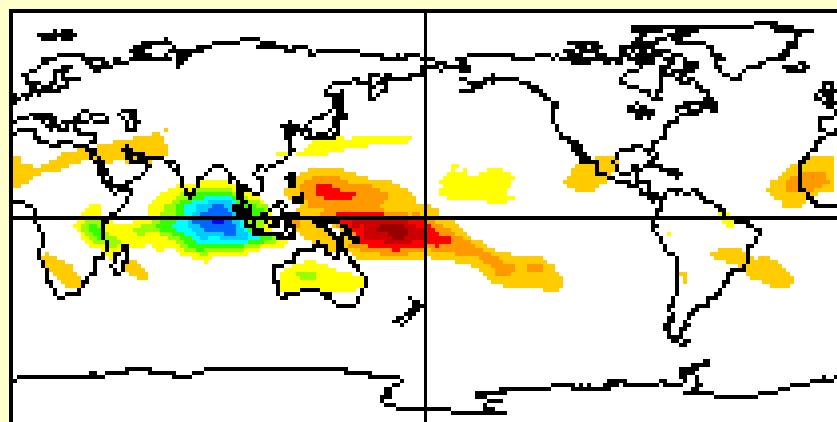
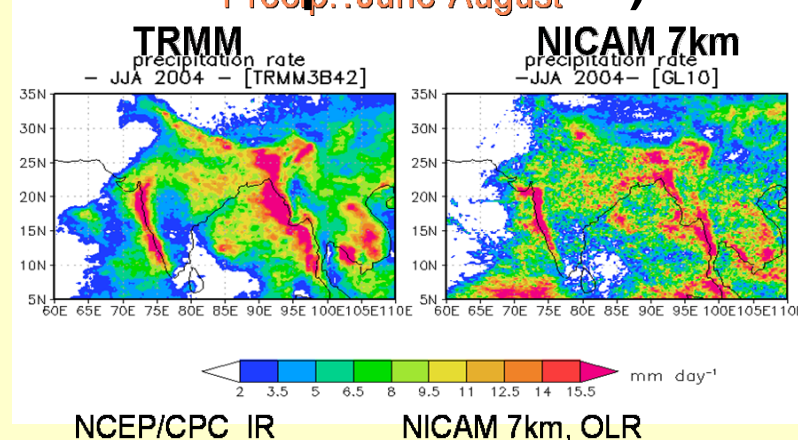
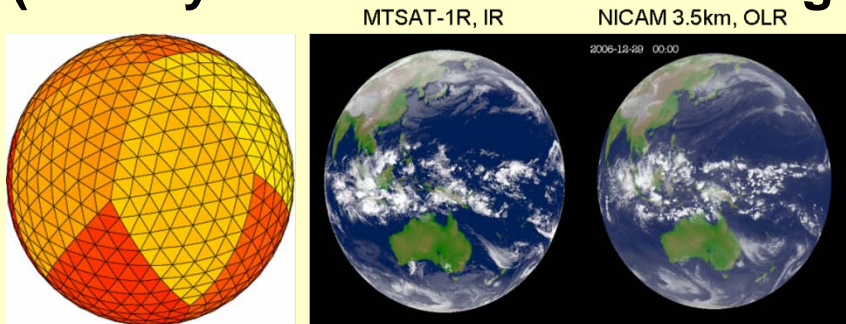


We need to breathe



全球雲システム解像モデルNICAM

(Non-hydrostatic ICosahedral grid-based Atmospheric Model)



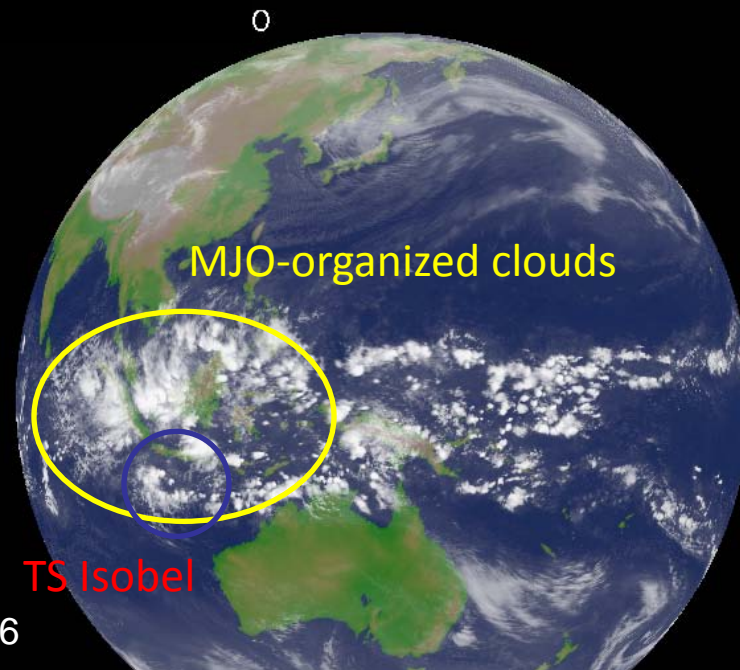
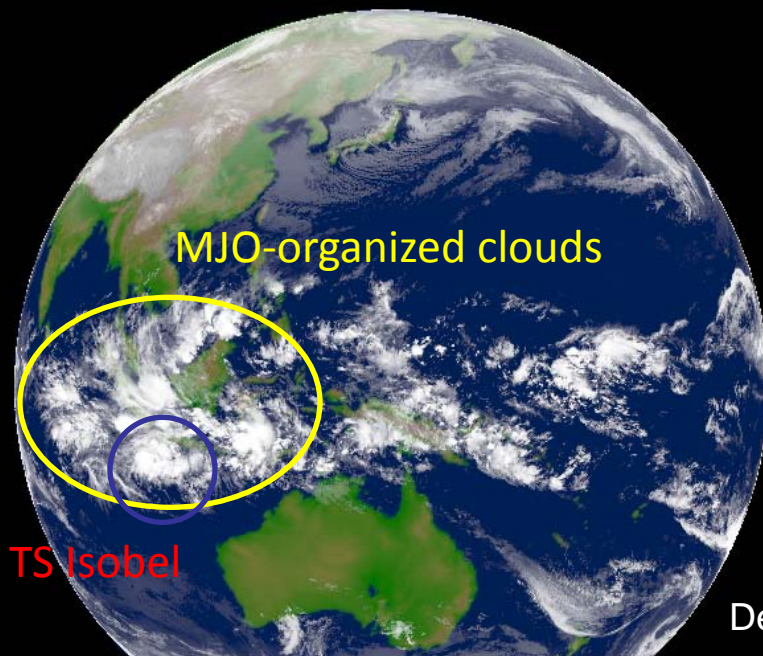
MJO (熱帯季節内振動) の再現

Miura et al. (2007, Science), Nasuno et al. (2009, JMSJ), Fudeyasu et al. (2009, GRL), Liu et al. (2009, MWR)

2週間先の台風発生を予測？

MTSAT-1R

NICAM



全球雲解像モデルNICAMにより初期値から2週間先の台風の発生予測の可能性が示された。ビギナーズラック？それともブレイクスルー？

Surface rain rate (mm hour⁻¹) by TRMM-TMI

Surface rain rate (mm hour⁻¹) by NICAM

