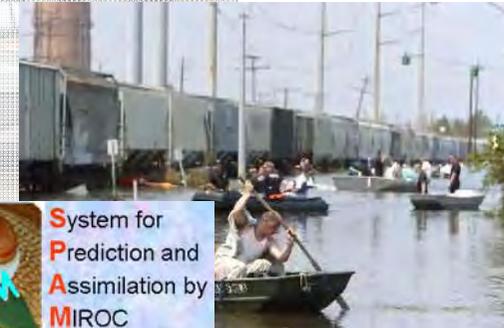




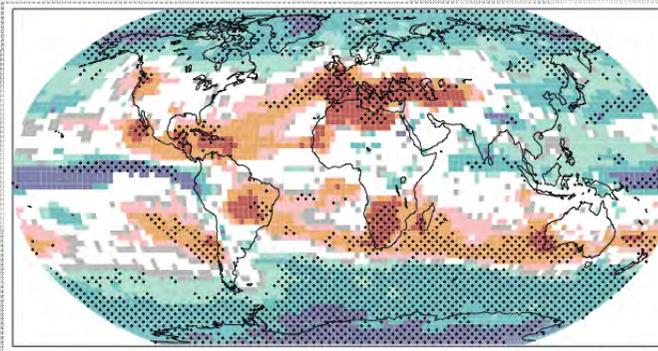
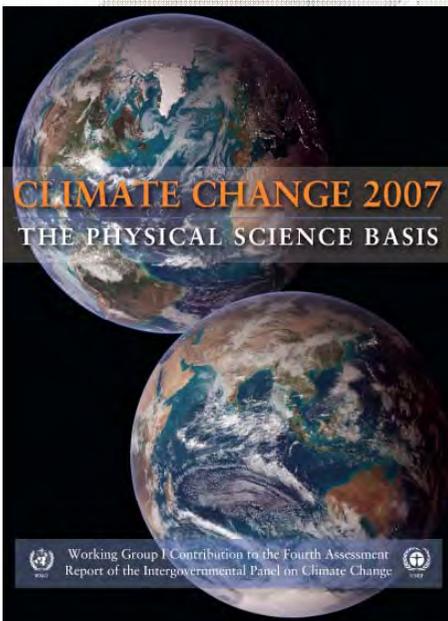
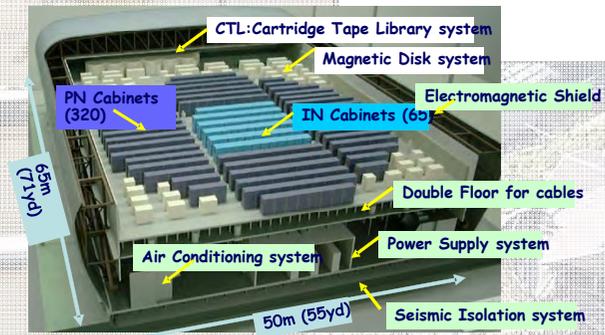
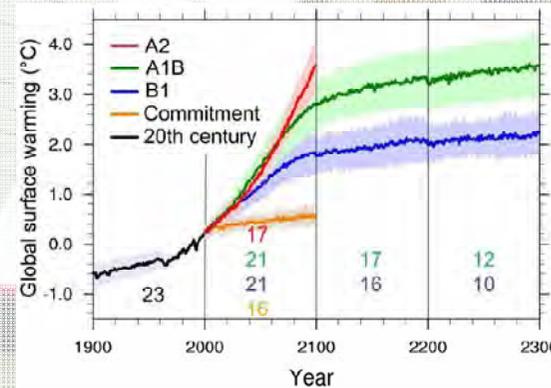
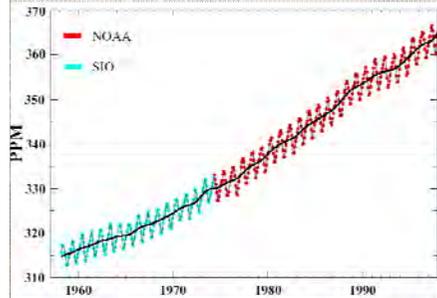
避けられない30年後の気候変化

木本 昌秀

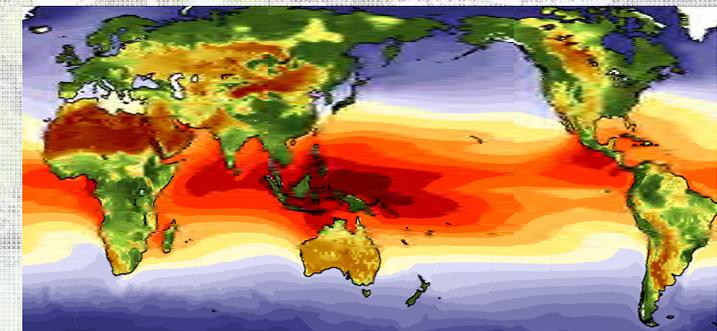
東京大学大気海洋研究所
and
Team SPAM



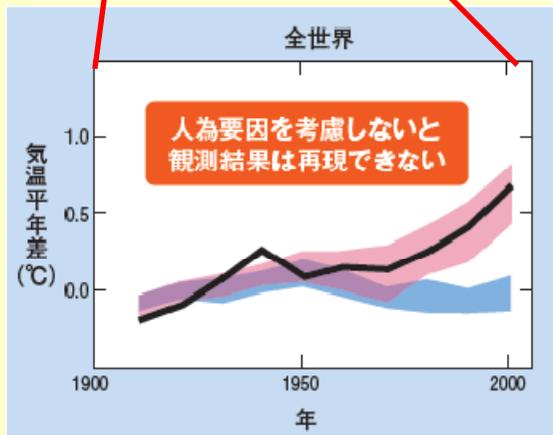
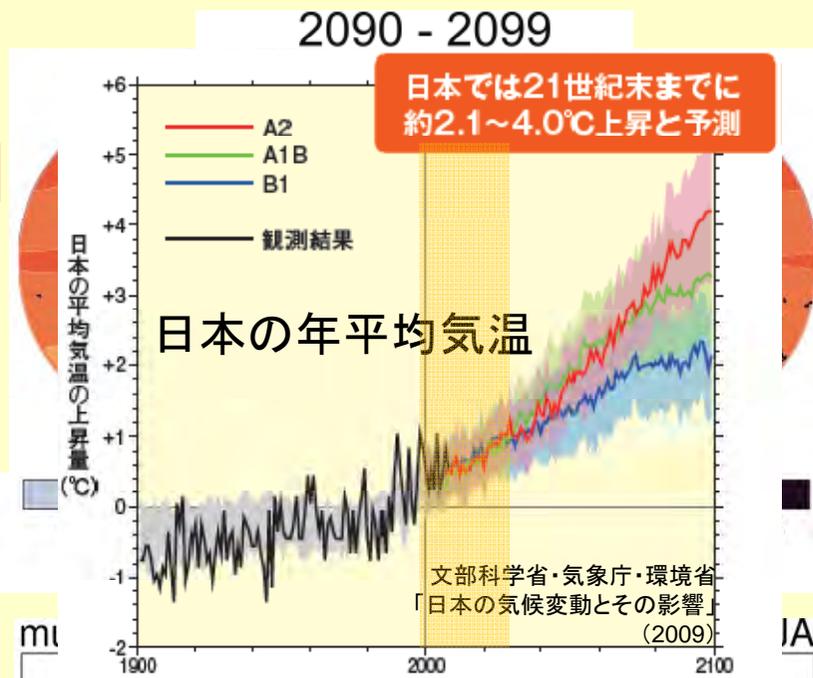
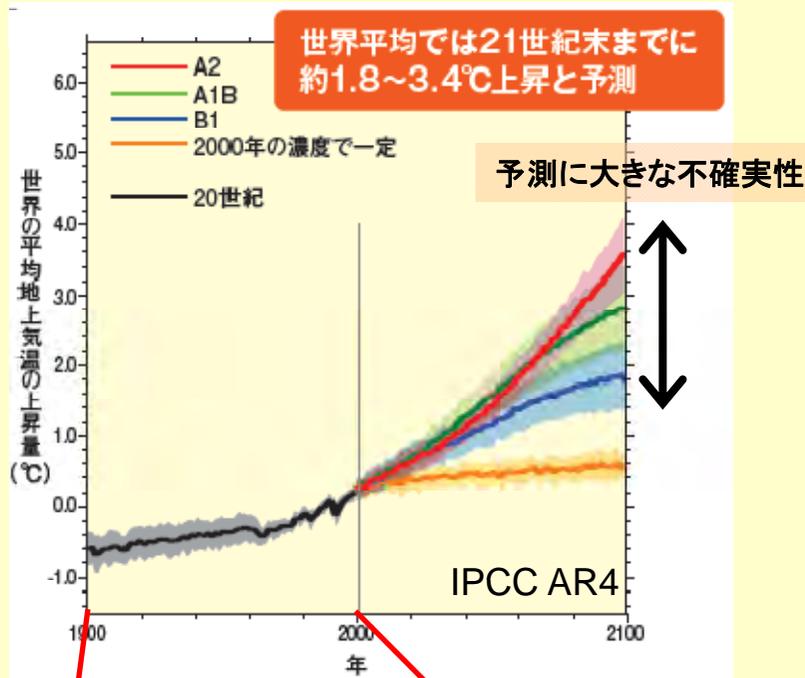
System for
Prediction and
Assimilation by
MIROC



©IPCC, 2007, WG1, AR4

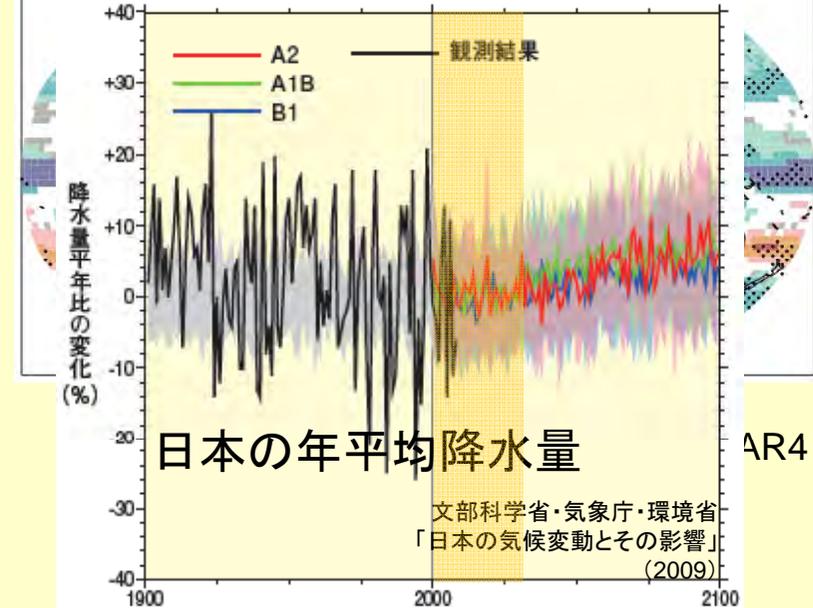


コンピュータによる地球温暖化の予測

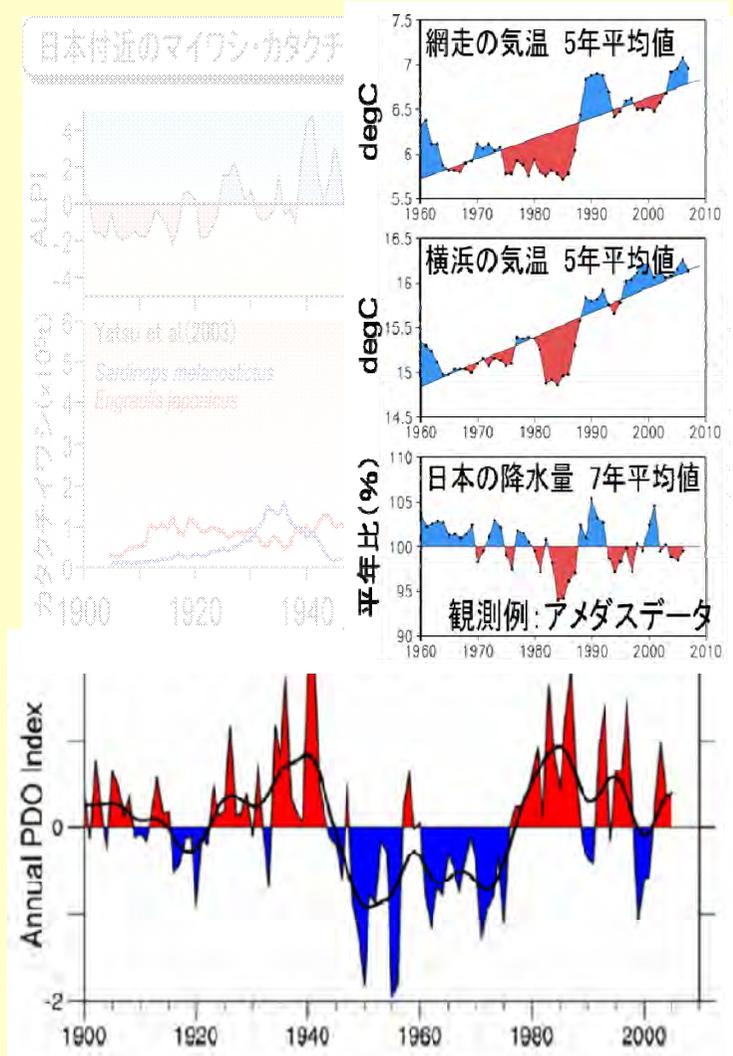


■ : 自然起源のみの強制力を用いたモデル
■ : 自然起源及び人為起源の強制力を用いたモデル
— : 観測値

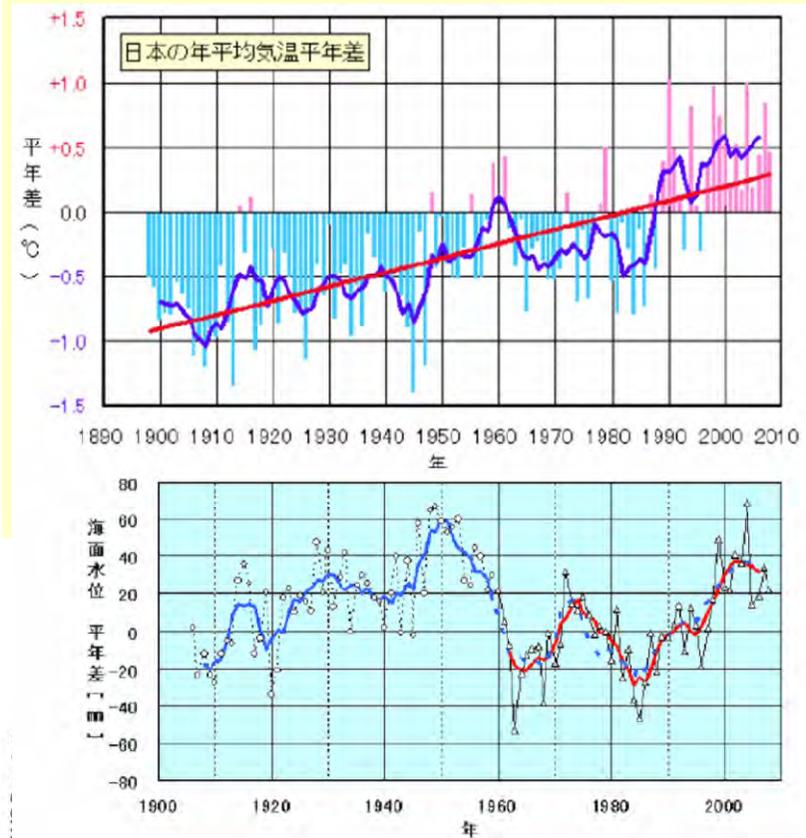
観測された気温の変化とモデルによるシミュレーションの比較



気候の十年規模変動

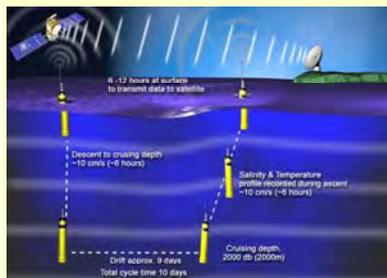
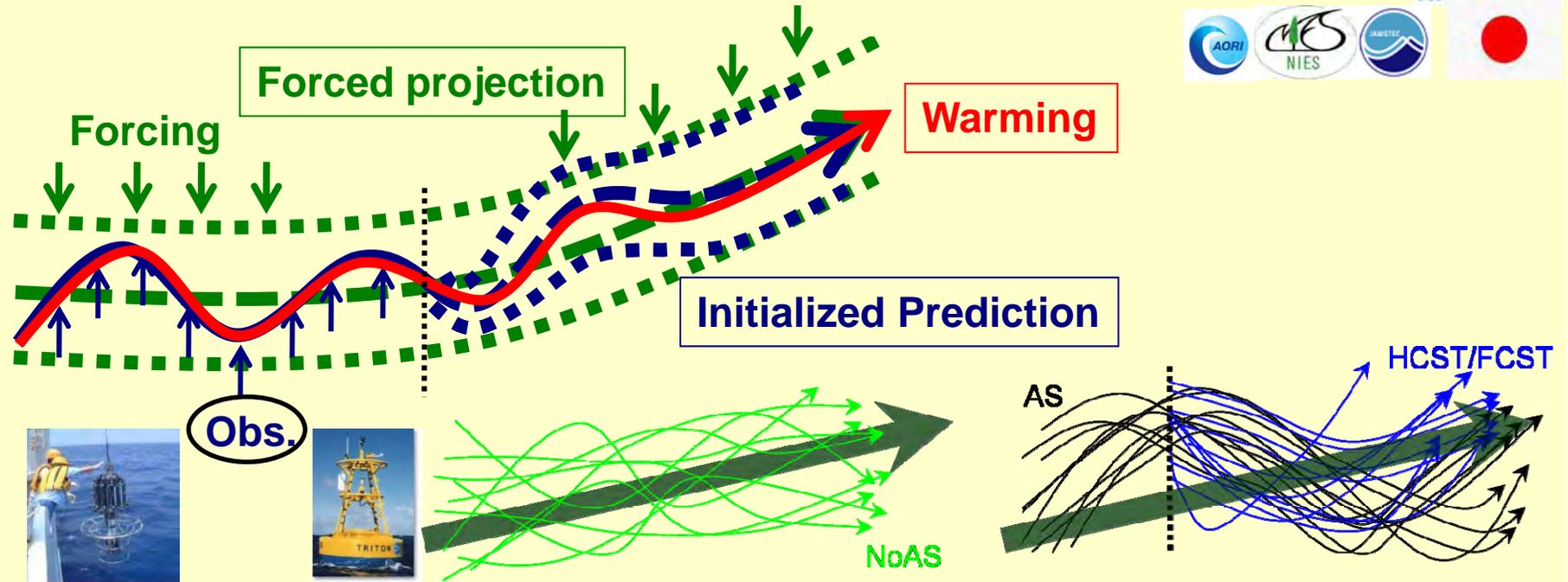


Pacific Decadal Oscillation (PDO)

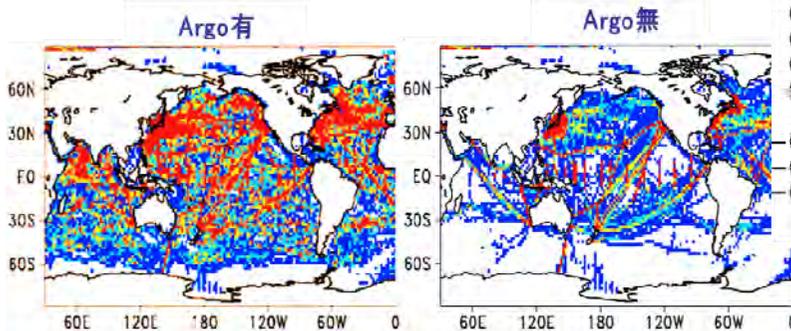


気候変動 = 強制 + 自然変動

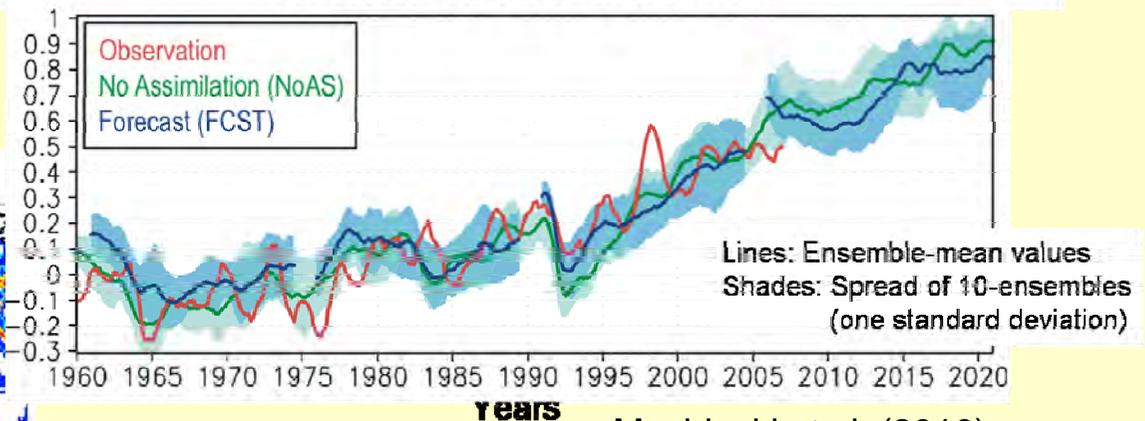
近未来(十年規模気候変動)予測



Argo subsurface ocean data network



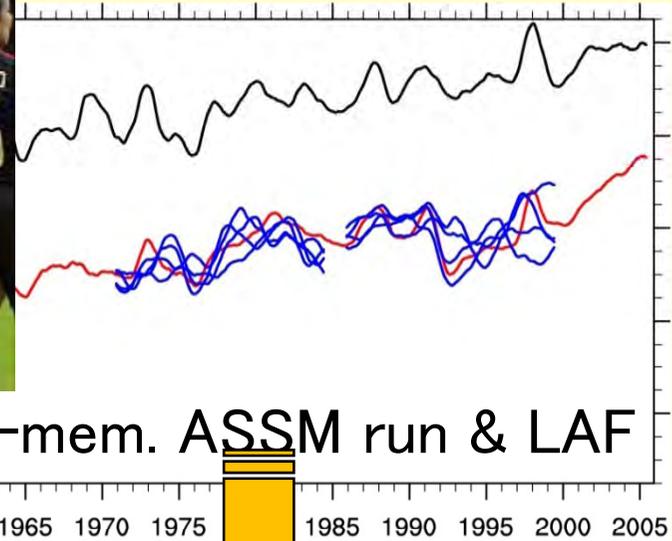
Global-mean Surface Air Temperature (SAT) anomaly relative to ave. 1961-1990



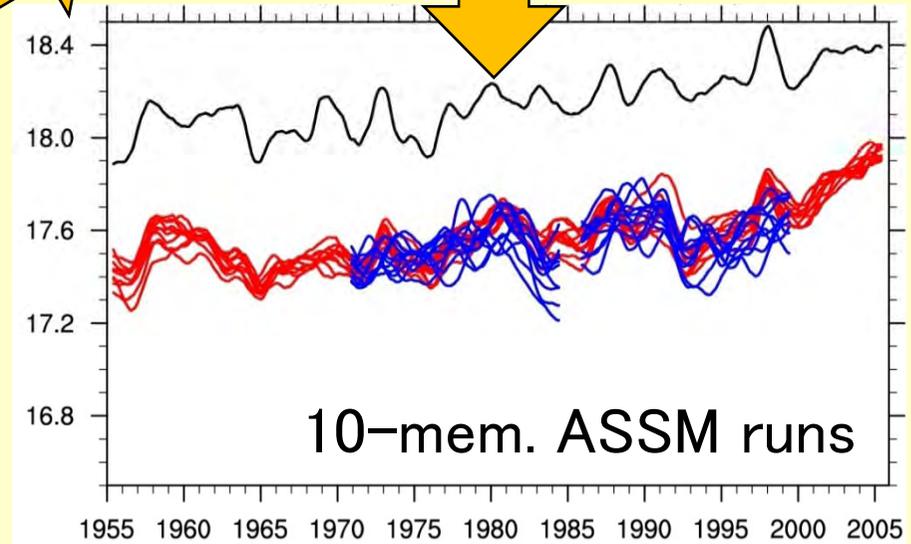
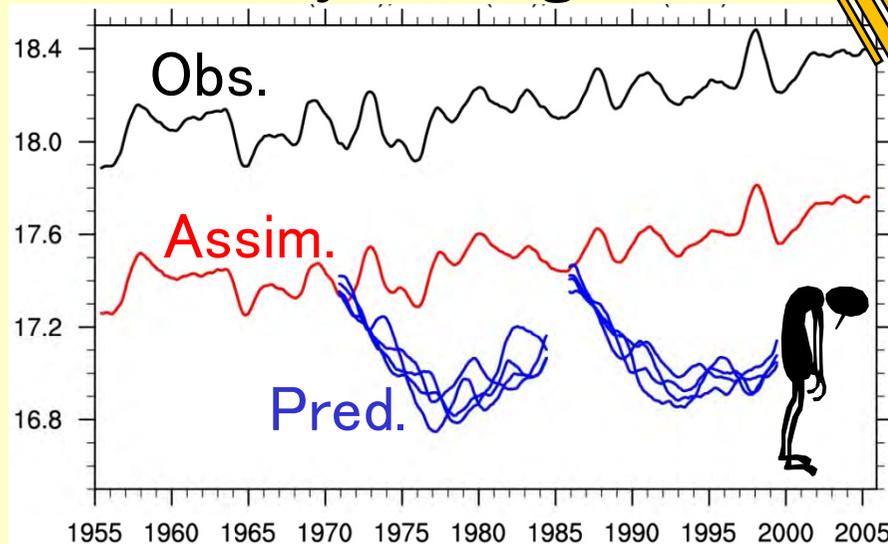
Mochizuki et al. (2010)

気候ドリフトの回避

- 海洋表層の水温・塩分の偏差のみを結合モデルに同化
- ~~Nudging~~ → IAU
- 同化強度の調整

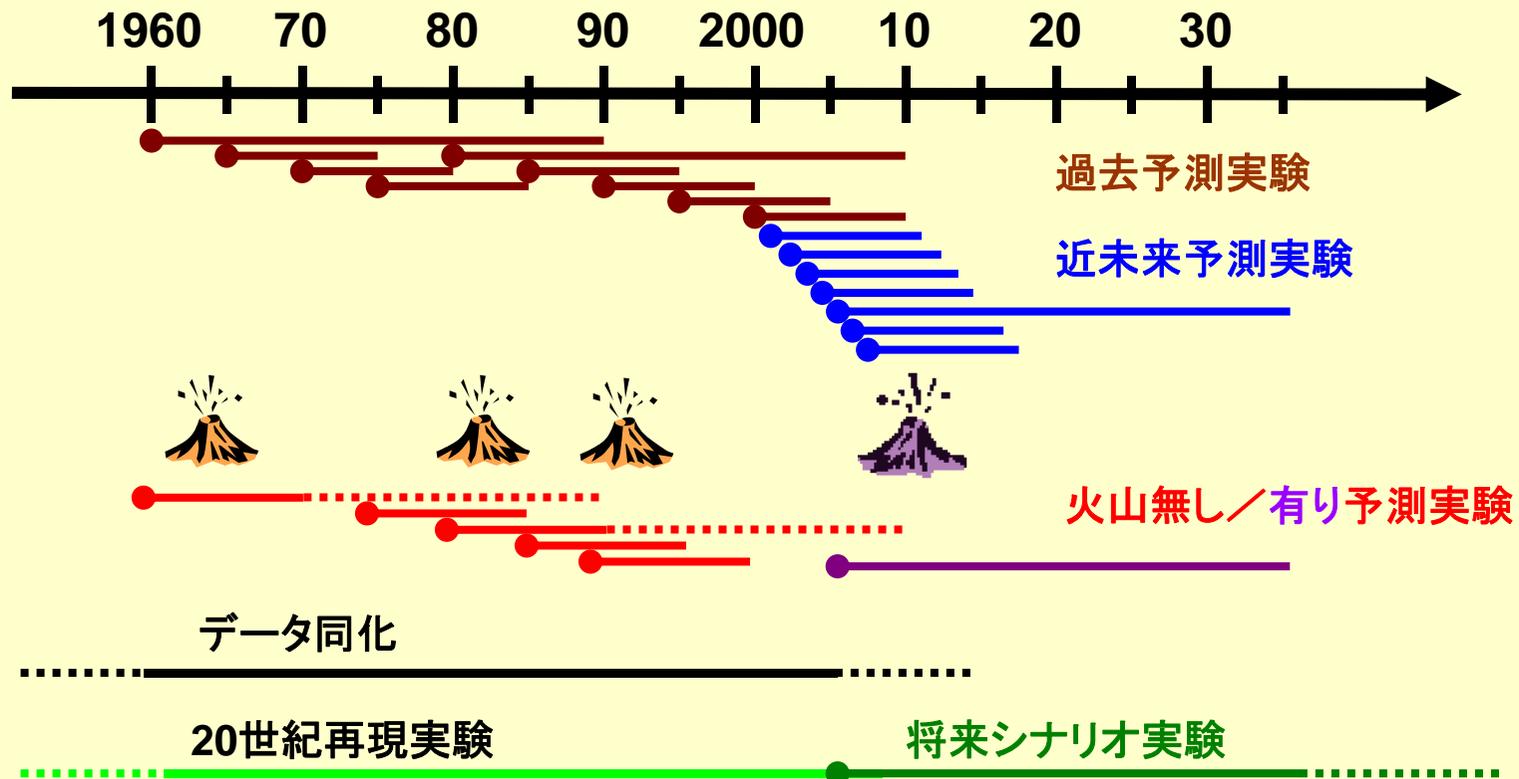


Globally averaged SST



The anomaly assimilation: Smith et al. (2007), Keenlyside et al. (2008)

近未来予測実験デザイン



- 観測された放射強制による過去実験, RCP4.5 シナリオに基く将来予測実験
- 100年のコントロール実験と80年の 1% CO₂ 漸増実験推奨.
- 派生実験 (XBT補正OFF実験、Argo OFF実験)
- CMIP5 total: 6600年 (10メンバー)

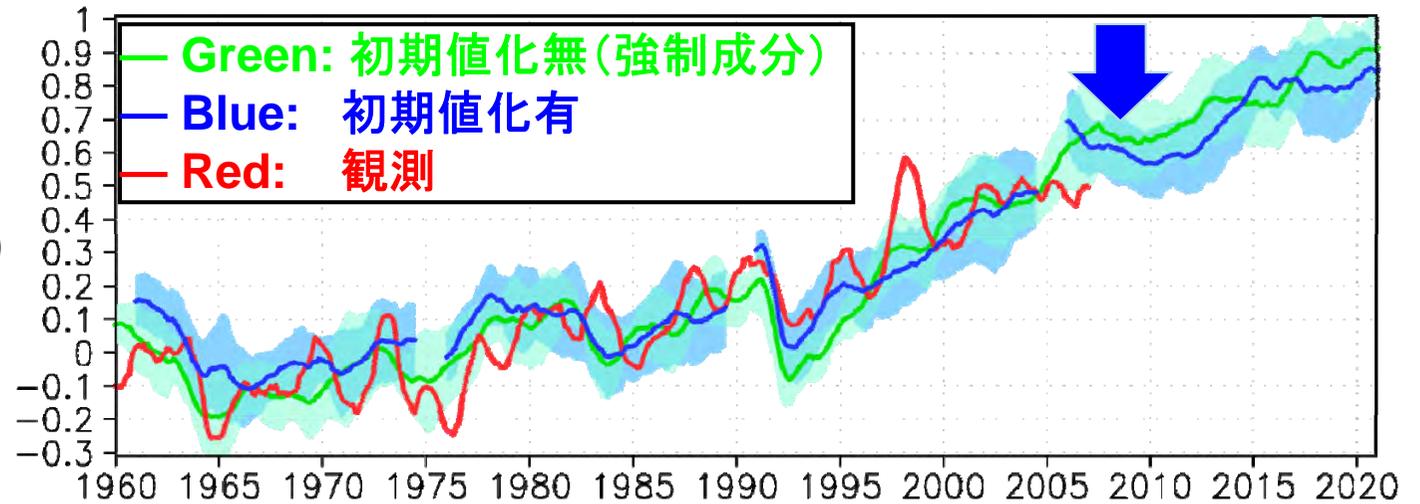
Decadal Prediction Experiments by MIROC

	MIROC3m	MIROC4h NEW	MIROC5 NEW
Atmosphere	300km L20	60km L56	155 km L44
Ocean	1.4°x0.5-1.4° L44	0.28°x0.19° L48	1.4°x 0.5-1.4° L50
Forcing	CMIP3/SRESA1B	CMIP5/RCP4.5	CMIP5/RCP4.5
Initialization	Ocean T&S IAU (0 ~ 700m)	Ocean T&S IAU (0~3000m) Eddy Conserving	Ocean T&S IAU (0~3000m)
Ensemble generation			
Ensemble Size			
20C3m	10	3	3
Assimilation	10	1	3
Hindcasts	10	3	6

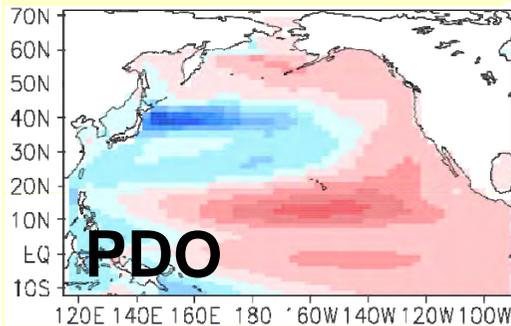
PDOの 予測可能性

Mochizuki et al. (2010)

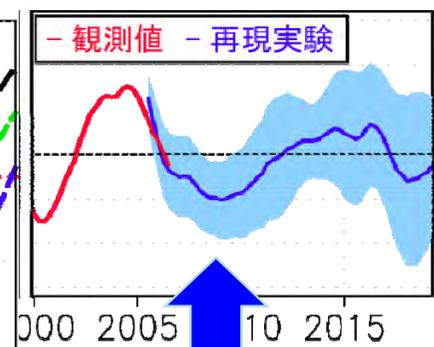
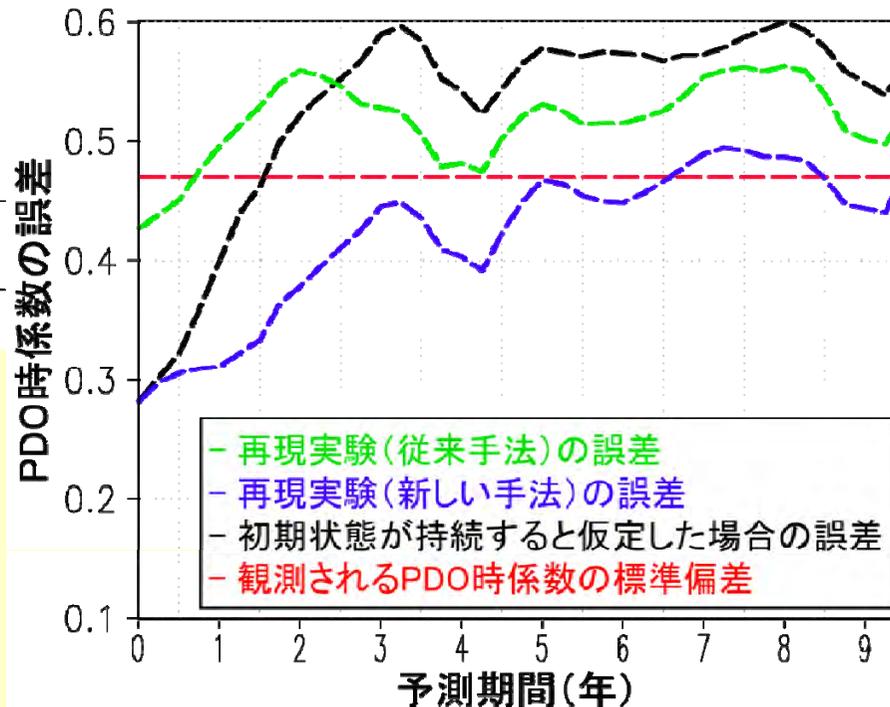
全球平均地表気温



強制成分からのずれ=自然変動



PDO成分の予測





System for
Prediction and
Assimilation by
MIROC

初期値化のインパクト

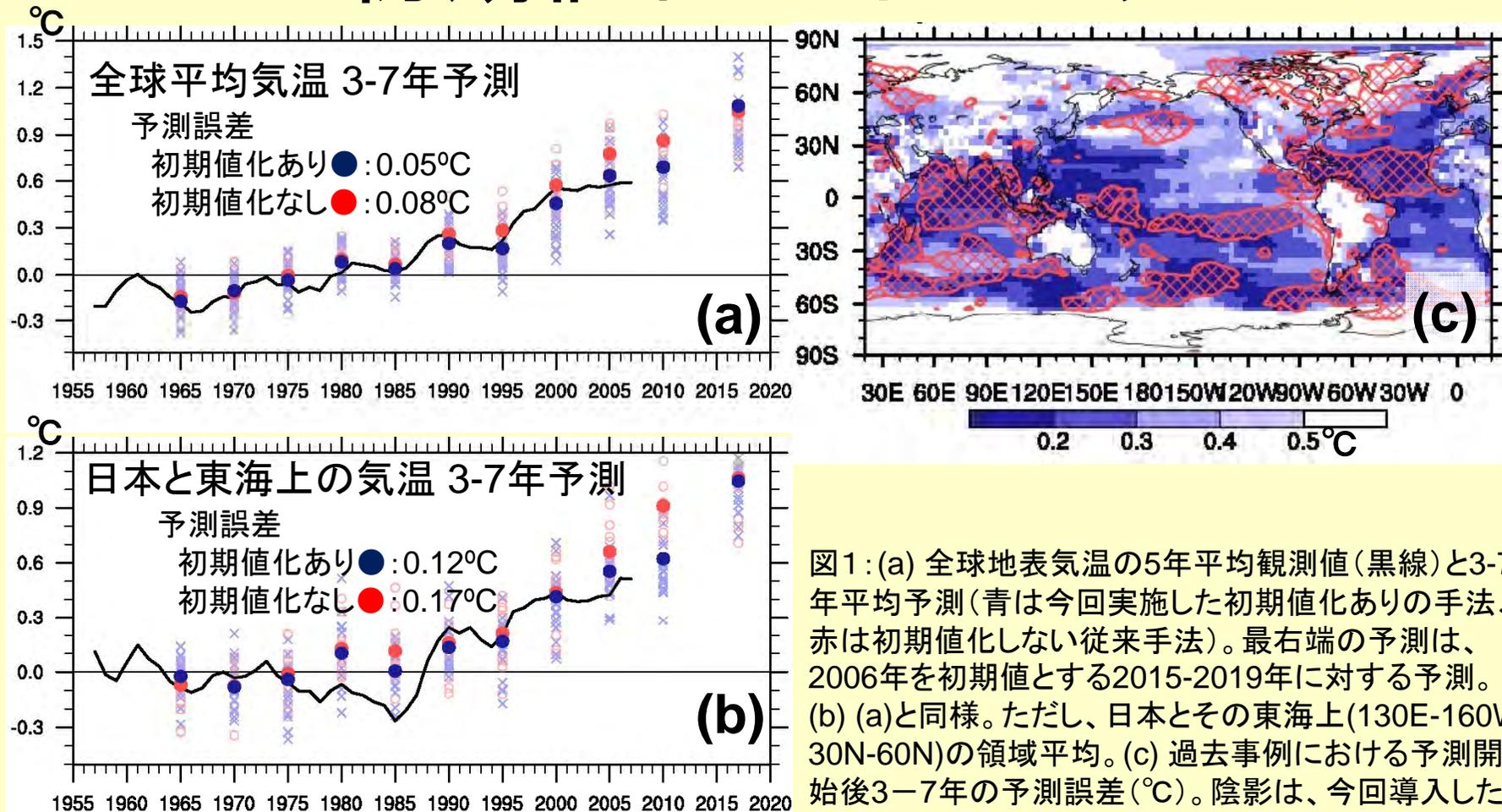
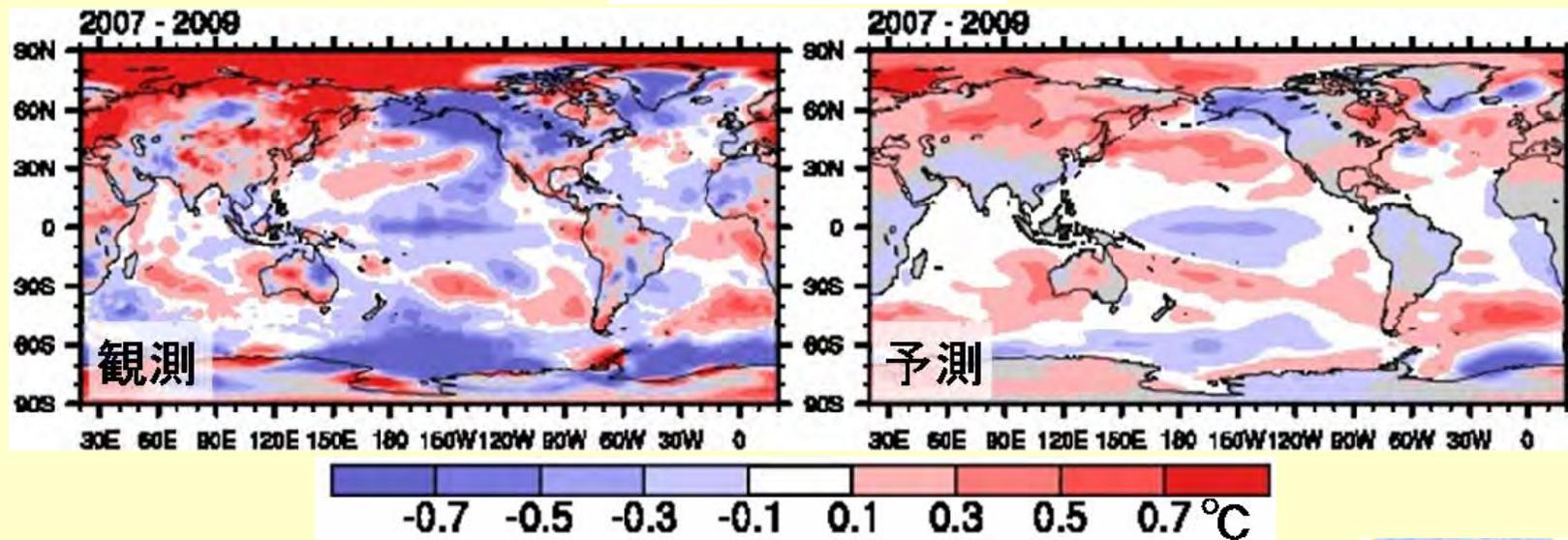
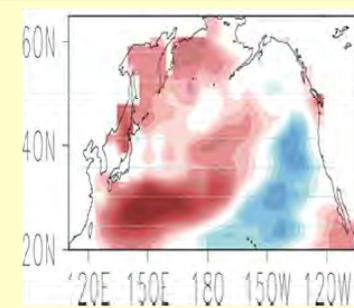
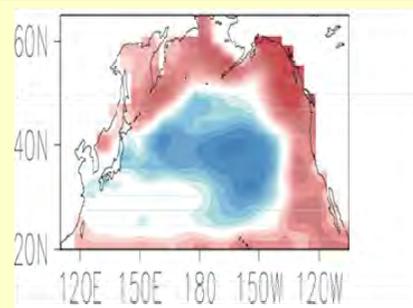
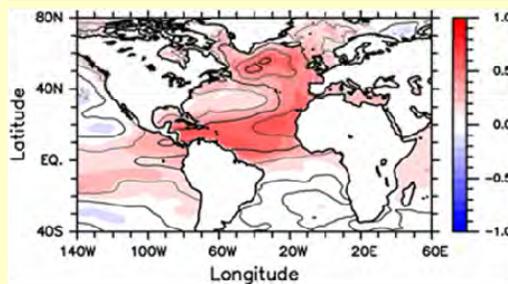
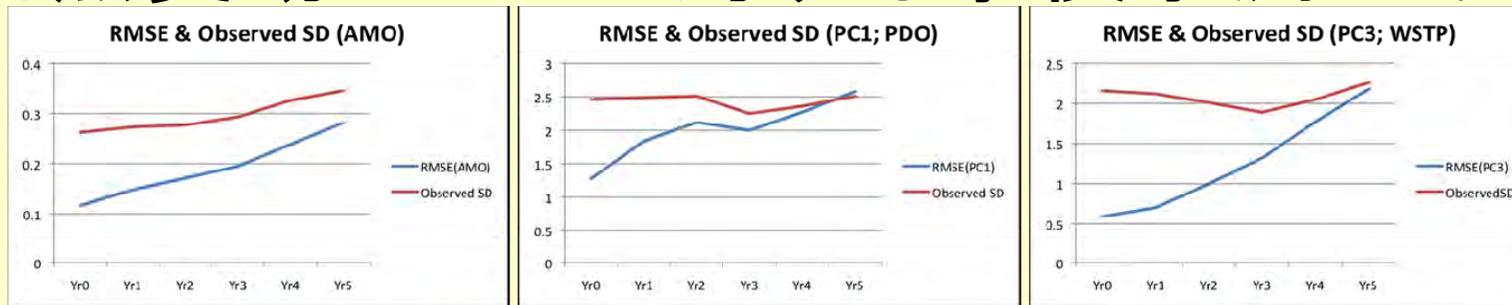


図1:(a) 全球地表気温の5年平均観測値(黒線)と3-7年平均予測(青は今回実施した初期値化ありの手法、赤は初期値化しない従来手法)。最右端の予測は、2006年を初期値とする2015-2019年に対する予測。(b) (a)と同様。ただし、日本とその東海上(130E-160W, 30N-60N)の領域平均。(c) 過去事例における予測開始後3-7年の予測誤差(°C)。陰影は、今回導入した初期値化で従来手法より10%以上誤差が減少した地域を示す。

自然変動モードに対する事後予測スキル

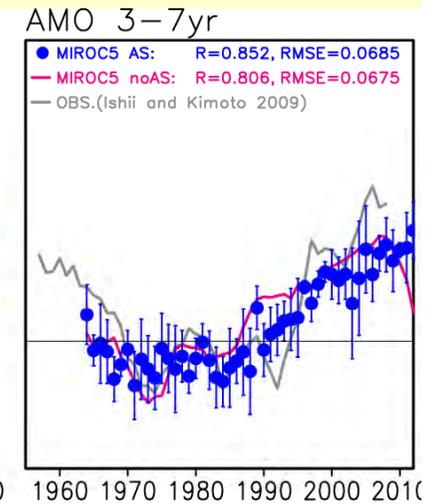
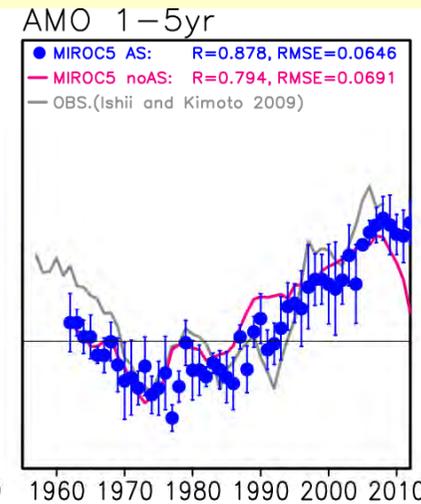
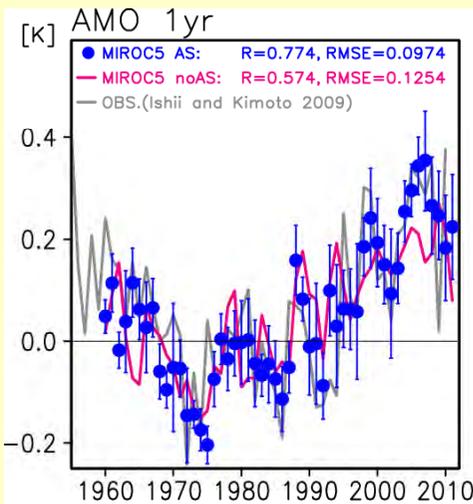
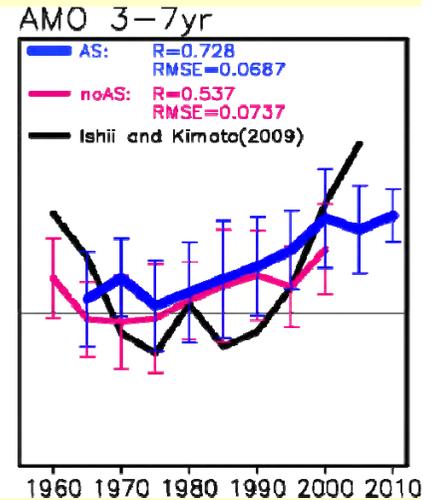
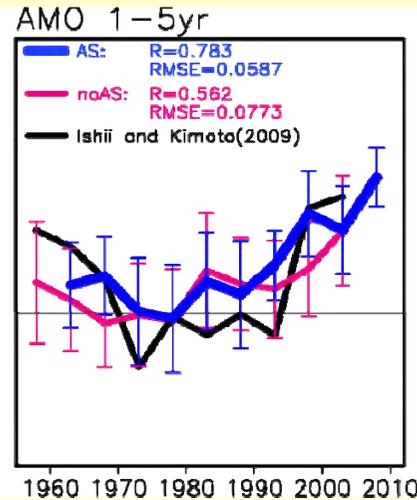
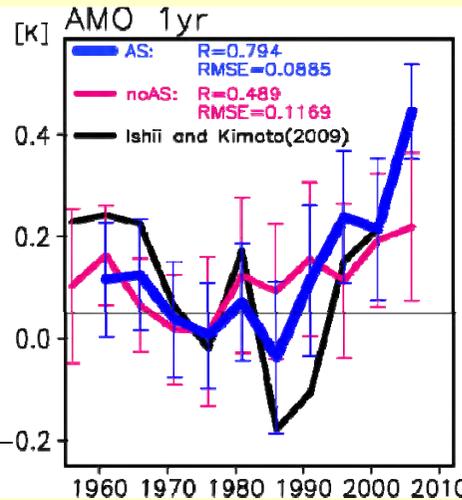
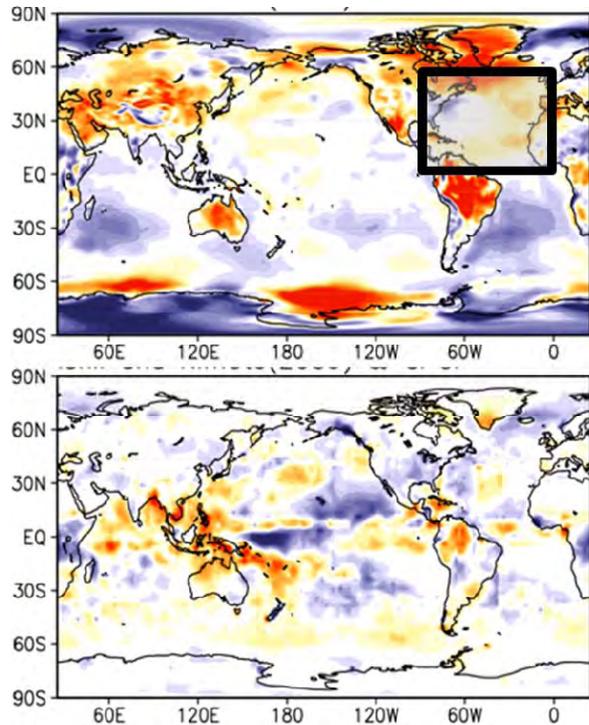


SAT(2007-2009; deviation from 2001-2005 mean)
Obs (left) and Prediction from 2006 (right)



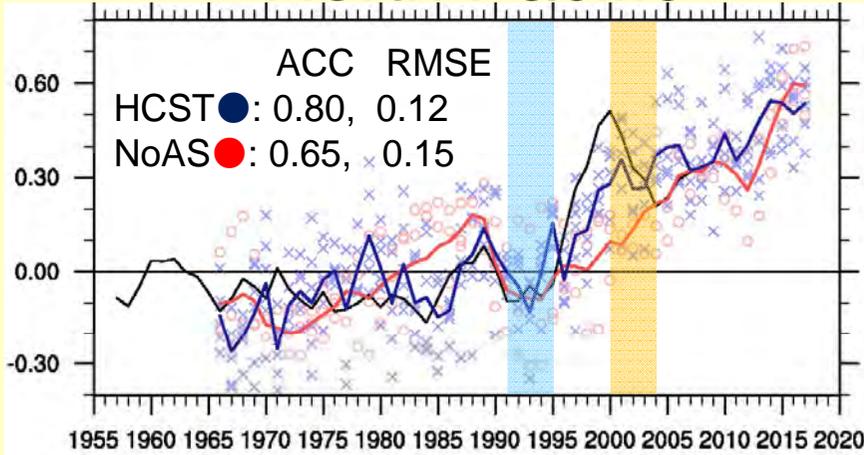
Atlantic Multidecadal Oscillation (AMO)

気温 (上) と降水 (下) に回帰

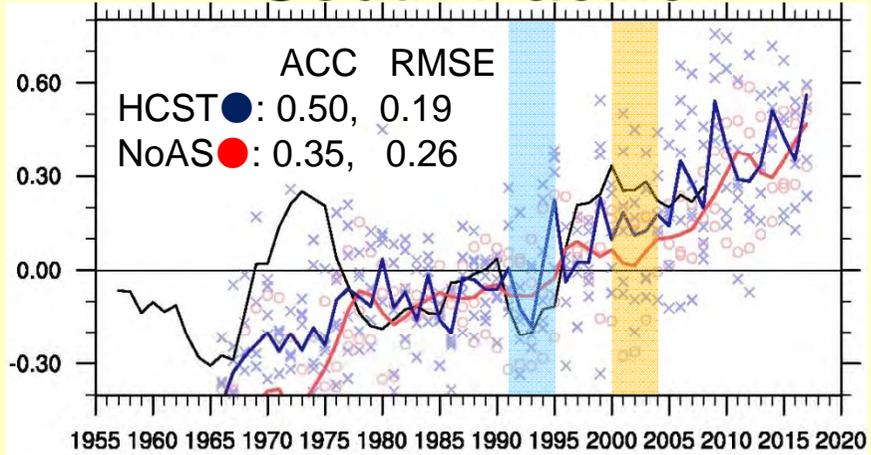


Climate shift in mid-1990s

North Pacific



South Pacific

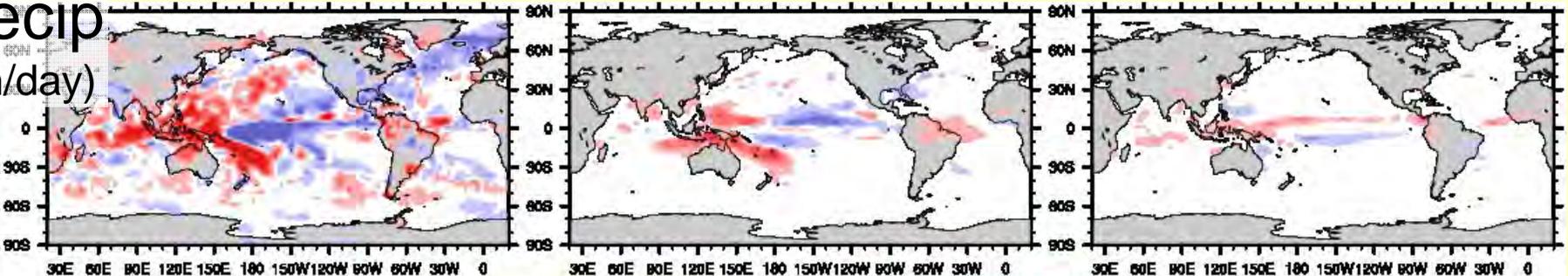


Obs

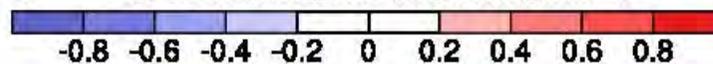
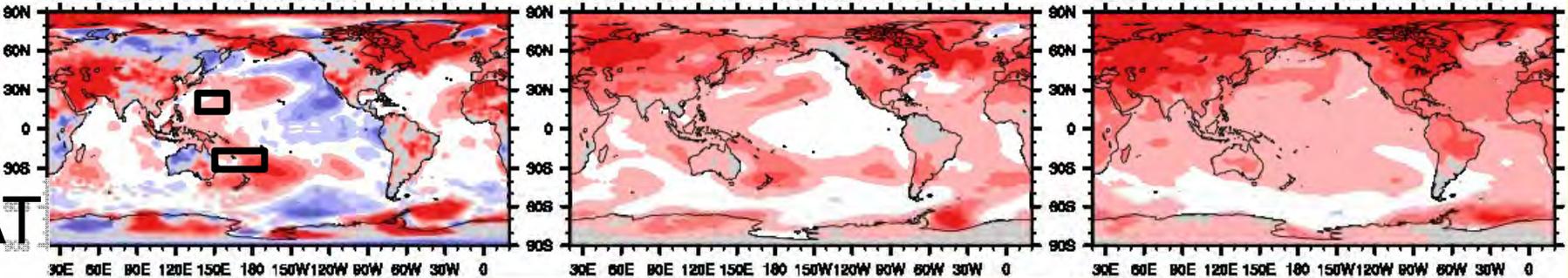
HCST

NoAS

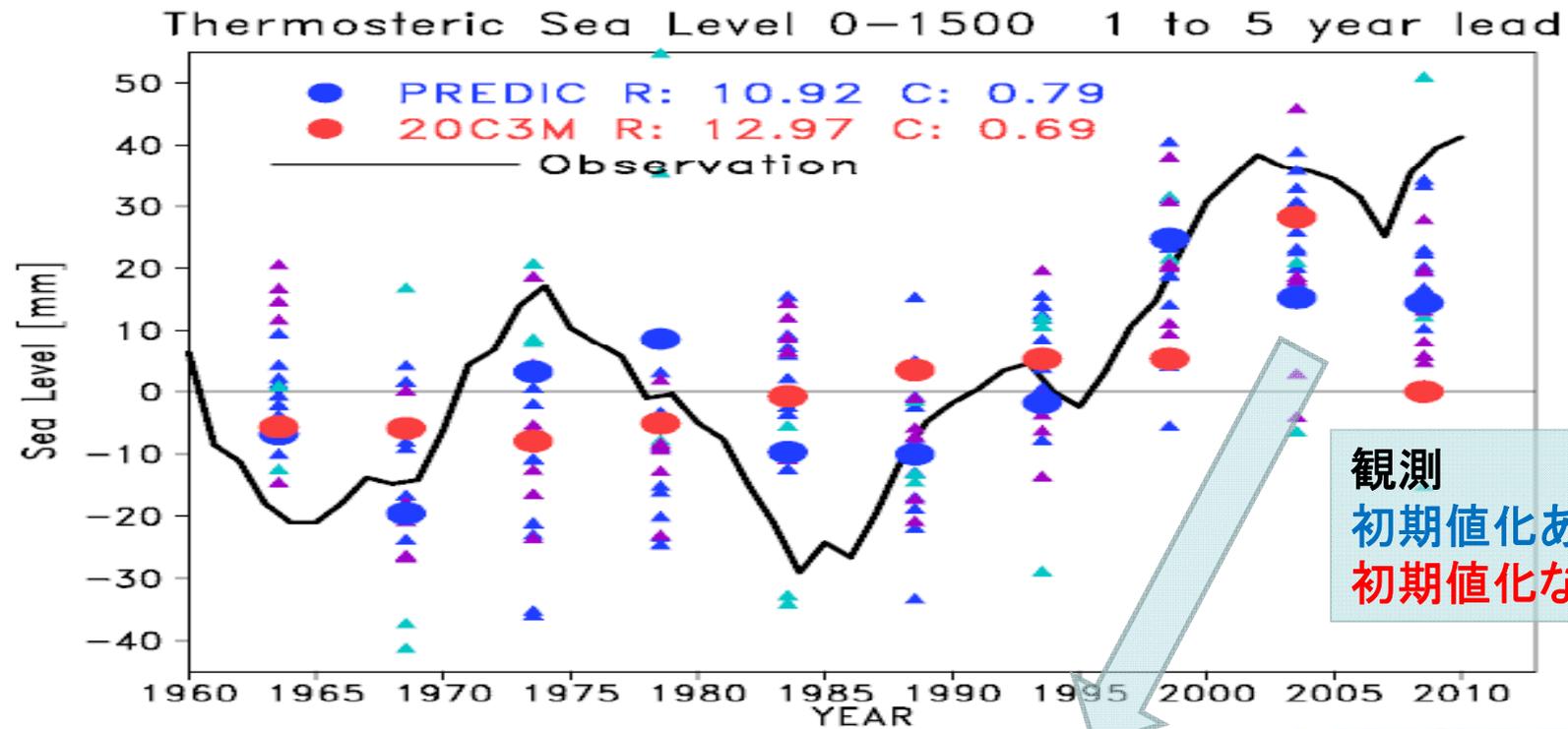
Precip
(mm/day)



SAT
(°C)

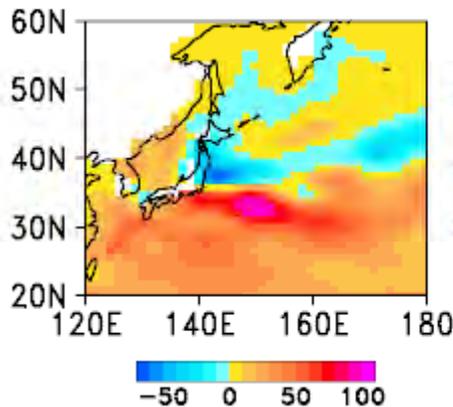


日本近海の水位変動

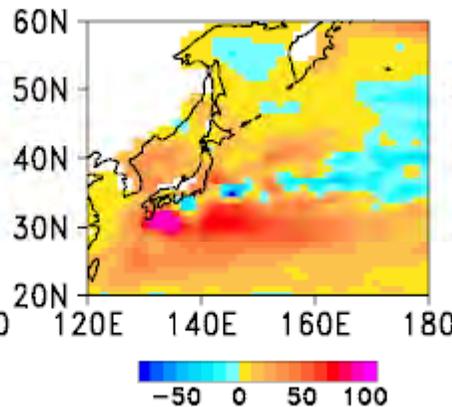


観測
初期値化あり予測
初期値化なし予測

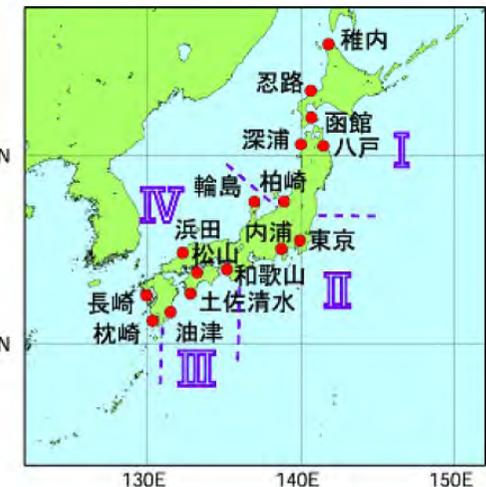
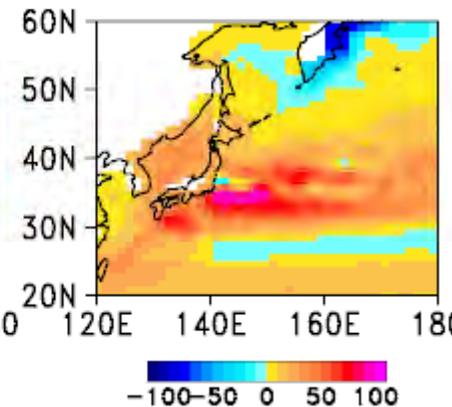
観測



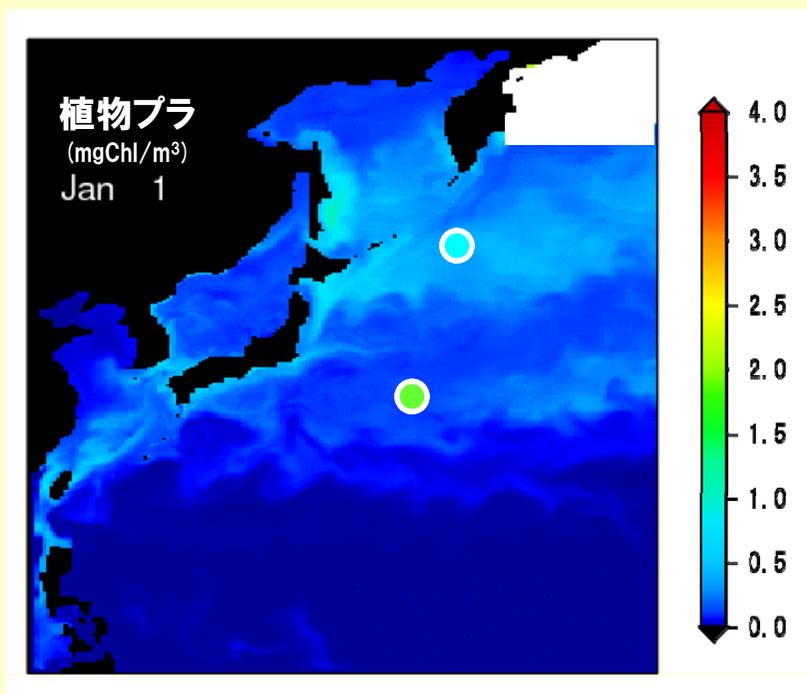
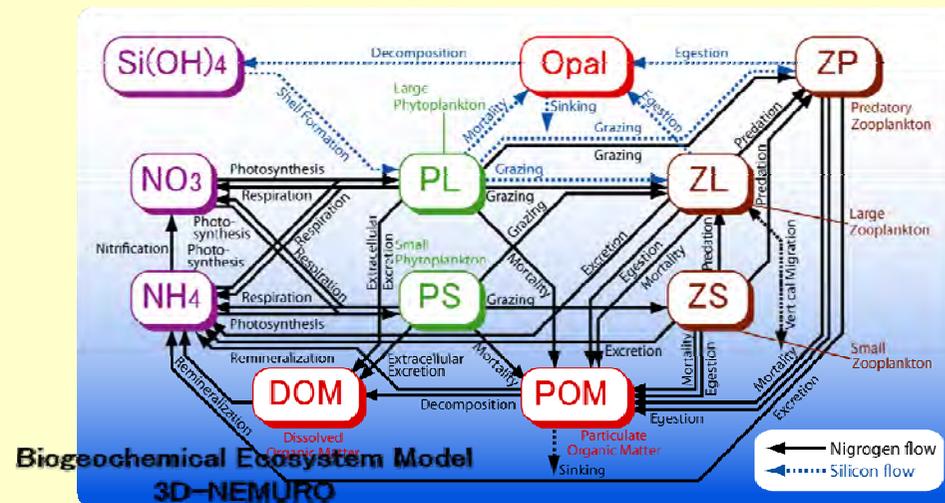
初期値化あり予測



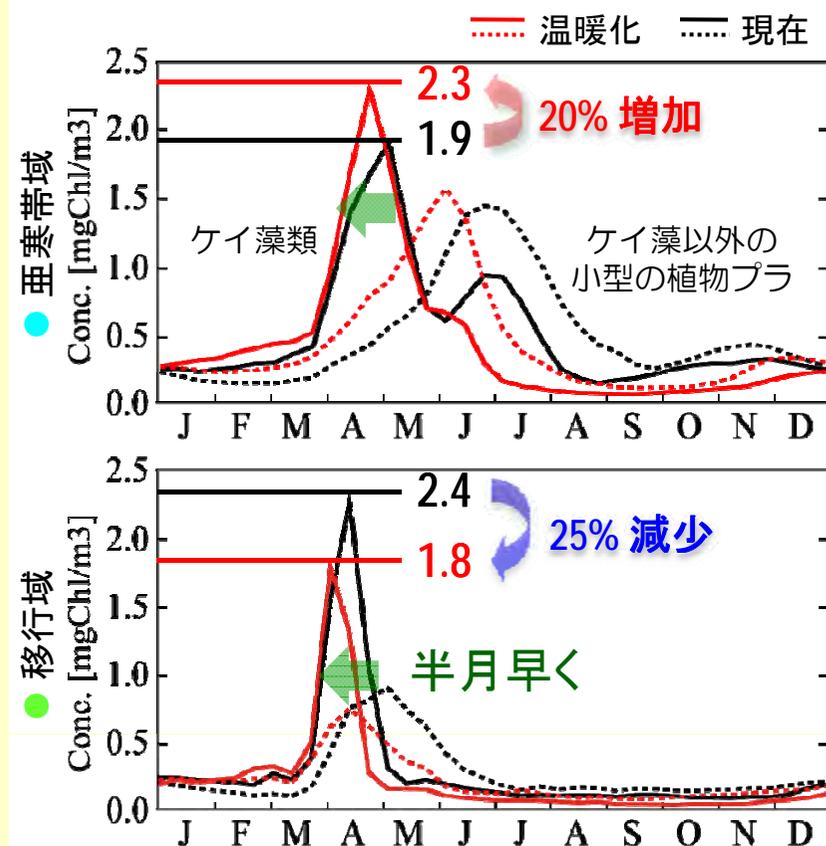
初期値化なし予測



温暖化に対する海洋生態系の応答 (季節変化)

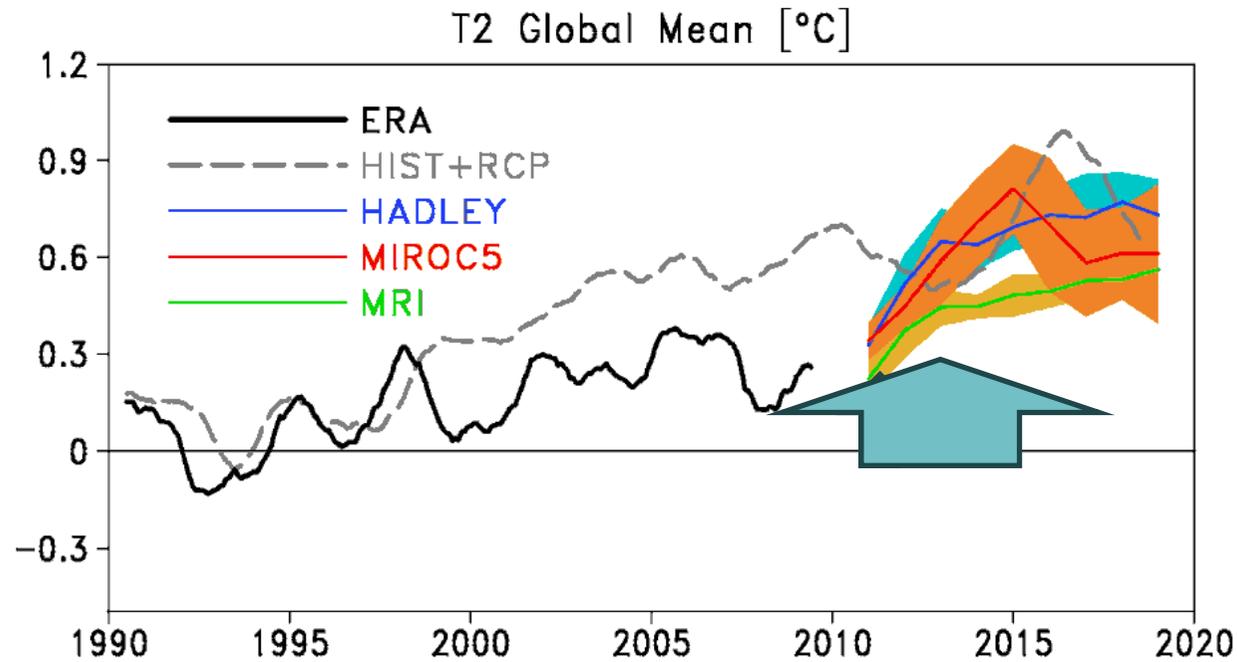


現在(y0046)のChl-a濃度の季節変化
表層10m平均

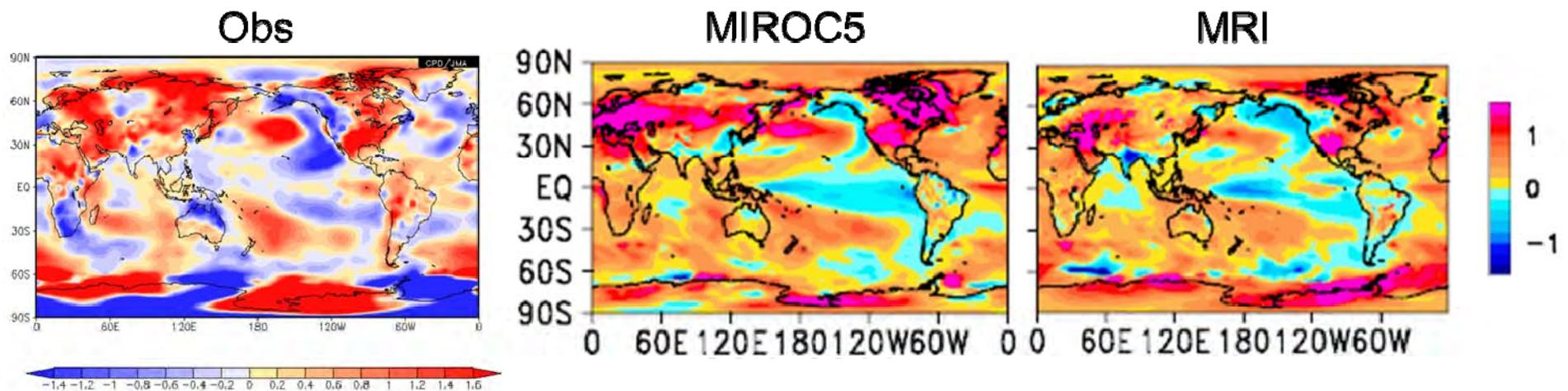


Slide courtesy of Y. Yamanaka

Prediction from Jan. 2011



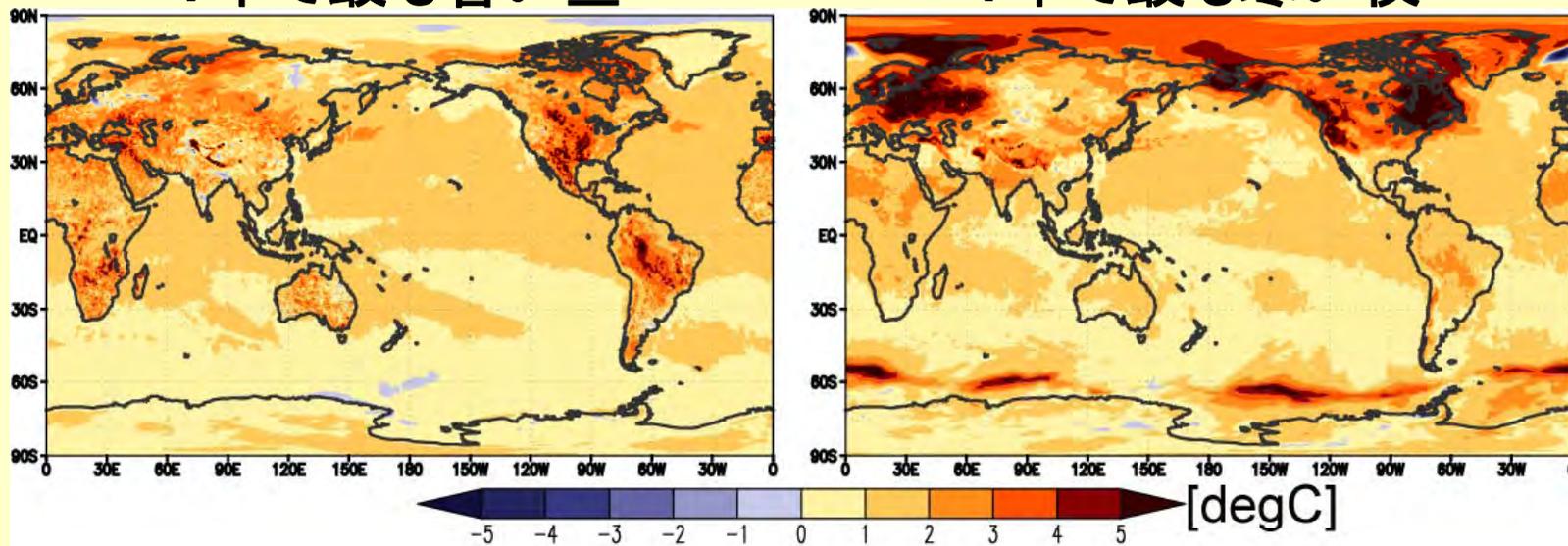
JJA 2011



気温と降水の極端現象の変化

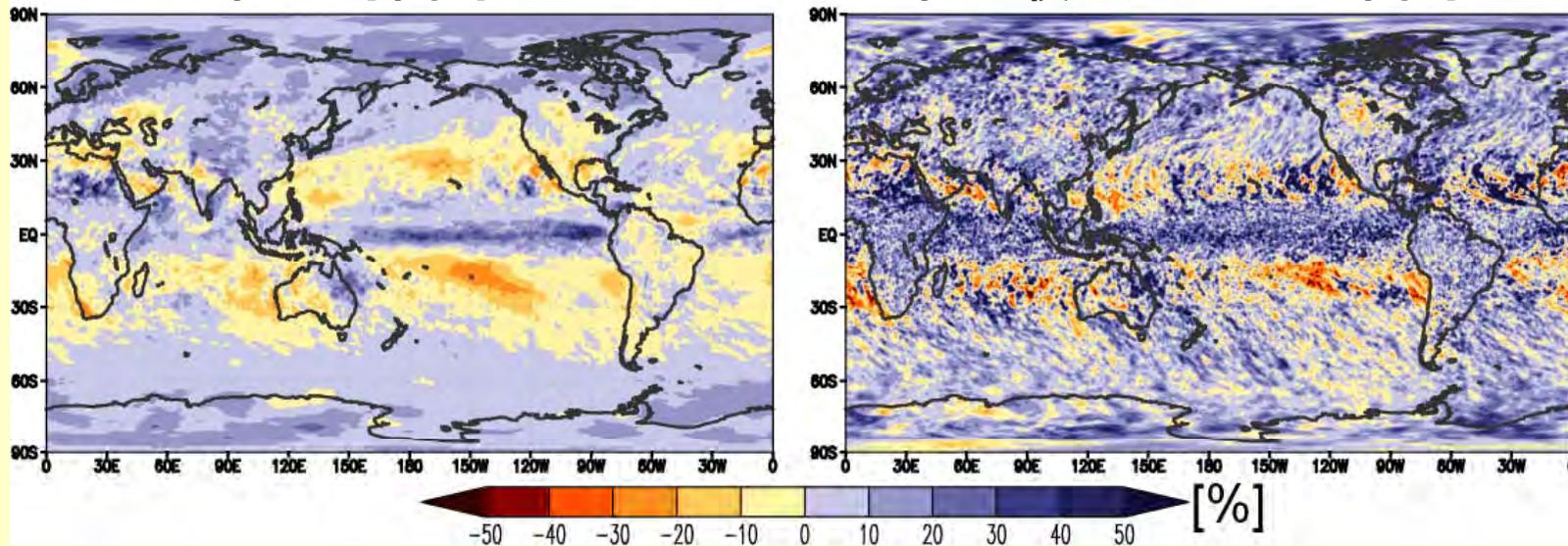
1年で最も暑い昼

1年で最も寒い夜



年平均降水量

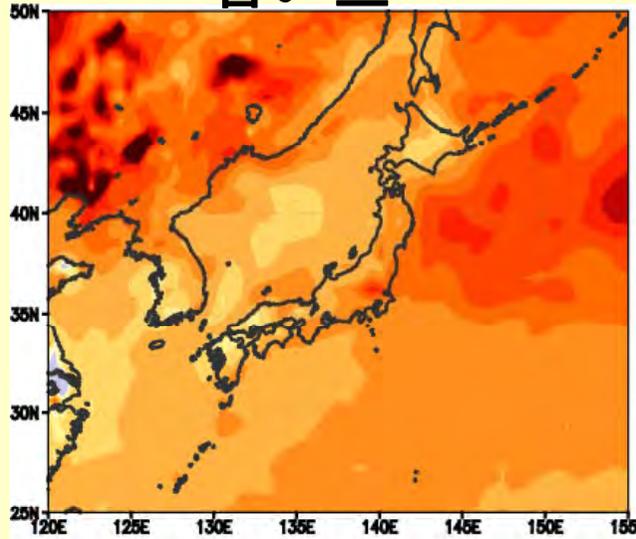
1年で最も大きい日降水量



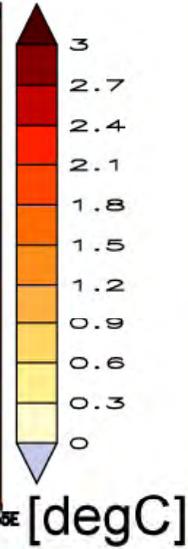
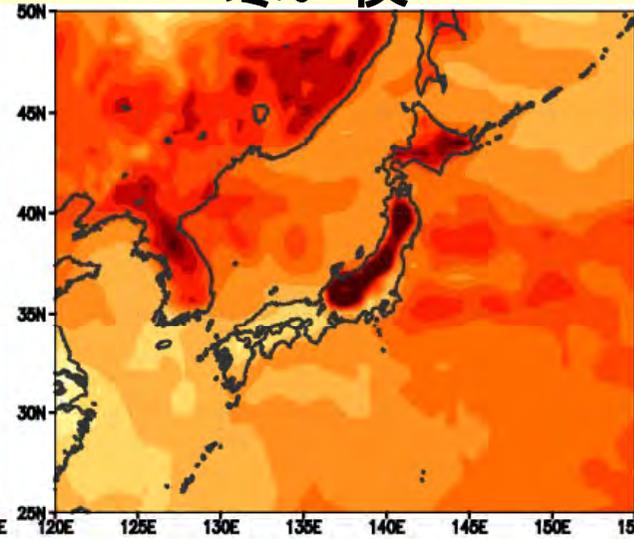
1971-2000年平均から2016-2035年平均への変化予測

日本の変化

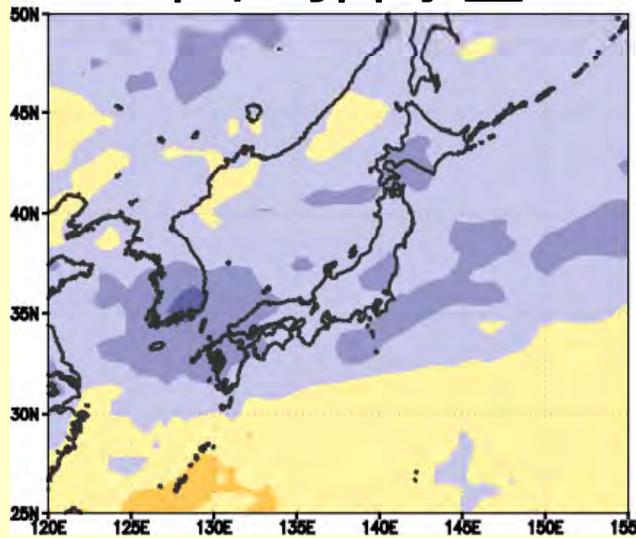
暑い昼



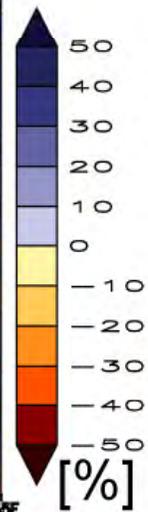
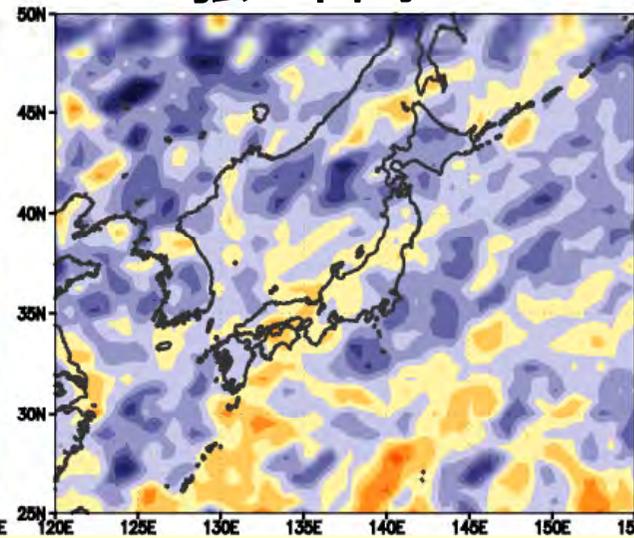
寒い夜



年平均降水量

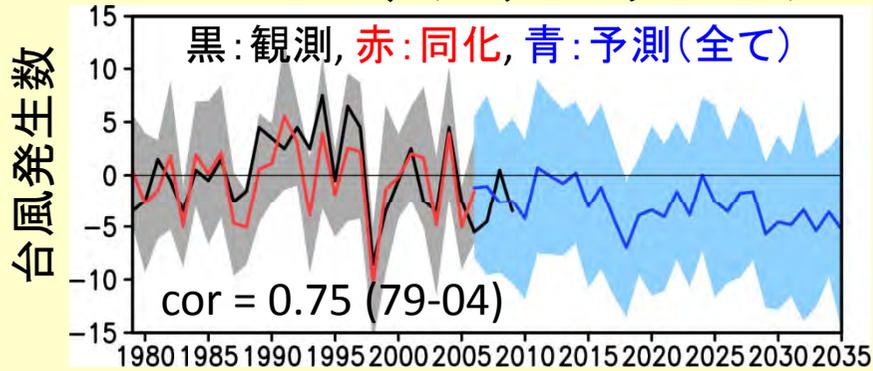


強い降水



近未来の台風変化予測(発生数・発生場所・経路・強度)

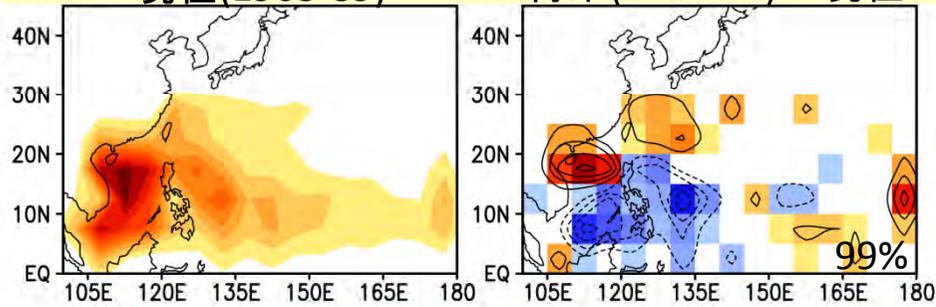
MIROCモデルアンサンブル



台風の発生頻度

現在(1963-89)

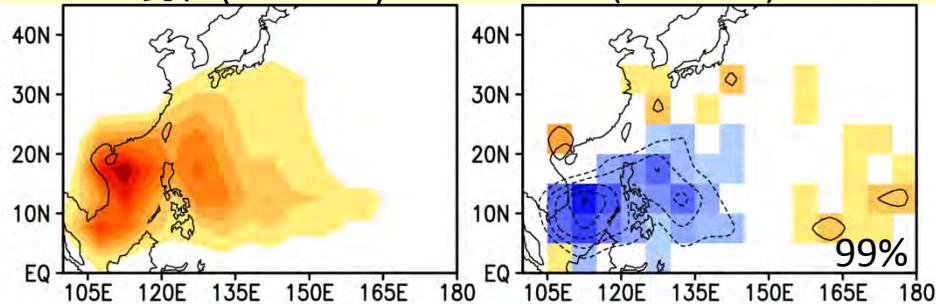
将来(2016-35) - 現在



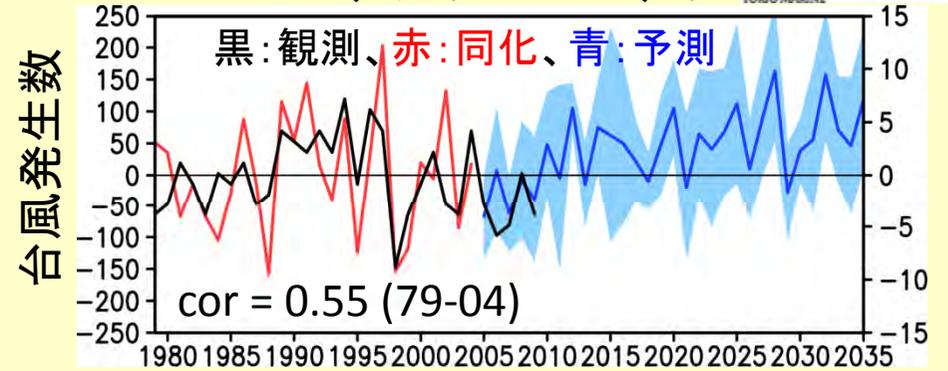
台風の存在頻度

現在(1963-89)

将来(2016-35) - 現在



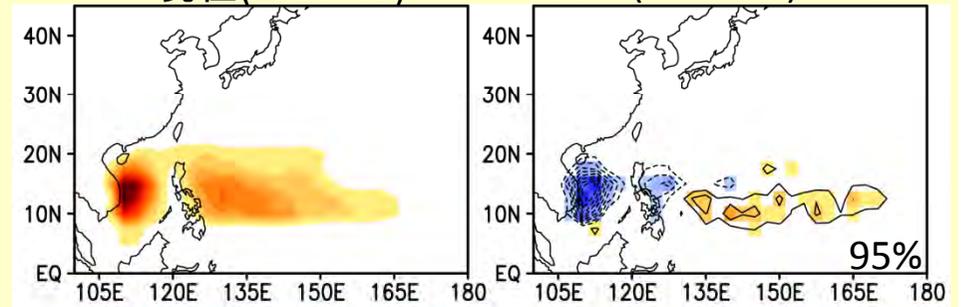
モンテカルロモデル



台風の発生頻度

現在(1950-89)

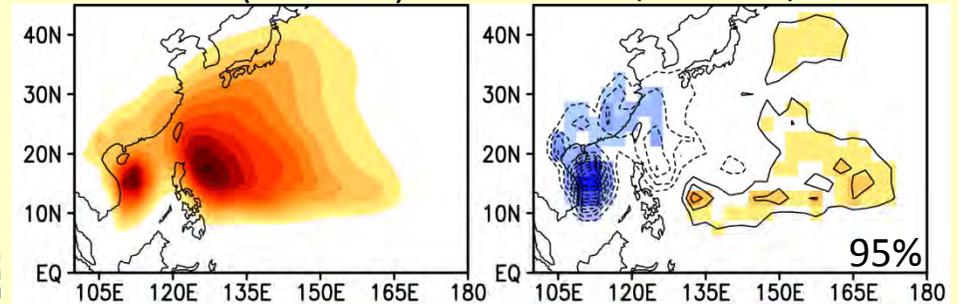
将来(2016-35) - 現在



台風の存在頻度

現在(1950-89)

将来(2016-35) - 現在



まとめと課題

- 人為強制＋自然変動の事後予測結果は良好
- 北大西洋や太平洋の十年規模自然気候変動モードに予測可能性
 - 太平洋～PDO, 90年代の気候シフト
 - 北大西洋～AMO, 熱帯双極子モード
 - 太平洋での台風ポテンシャルの予測可能性
 - 予測を通して自然変動のメカニズム解明へ
- 「想定外」の可能性(ピナツボ級の火山噴火、成層圏水蒸気変動等)～予測のアップデートが肝要
- 予測結果を用いた本格的な影響評価～リスクアセスメントへ(水災害、海洋生態系、農業等)