A new version of the climate model MIROC for the near-term climate prediction

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Near-term climate prediction in "KAKUSHIN" project

Leader: M. Kimoto (CCSR, Unit. Tokyo)
M. Ishii, S. Emori, H. Hasumi, T. Nishimura, S. Watanabe, T. Suzuki, T. Mochizuki, T. Takemura, M. Chikira, T. Ogura, R. Oishi, K. Takata, Y. Tsushima, H. Tatebe, Y. Chikamoto, M. Mori, K. Ogochi, Y. Komuro, + more

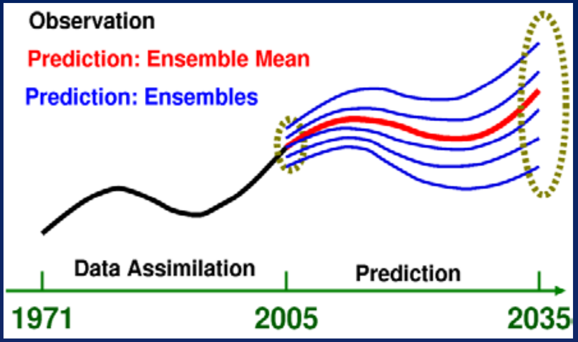
Joint collaboration at CCSR/NIES/FRCGC

- Climate model development: AOGCM *MIROC*
- Future climate projections

- Done by 2007: CMIP3/AR4 simulations
  - MIROC-hi (T106 atmos+1/4x1/6 deg ocn)
  - MIROC-med (T42 atmos+1/1x1 deg ocn)

- To be done by 2013: CMIP5/AR5 simulations
  - new MIROC-hi (T213 atmos+1/4x1/6 deg ocn)
  - new MIROC-med (T85 atmos+1/1x1 deg ocn)

Near-term climate prediction



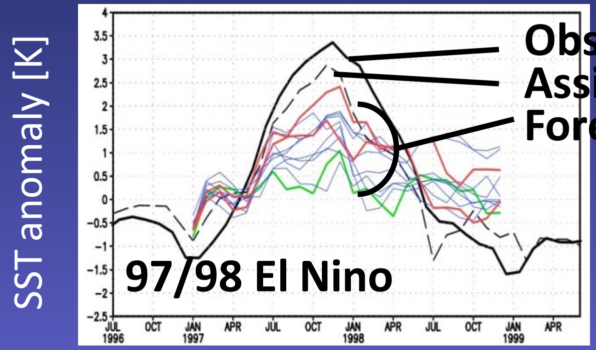
✓Future projections up to 2035 do not heavily depend on the emission scenarios (e.g., Stott and Kettleborough 2002)

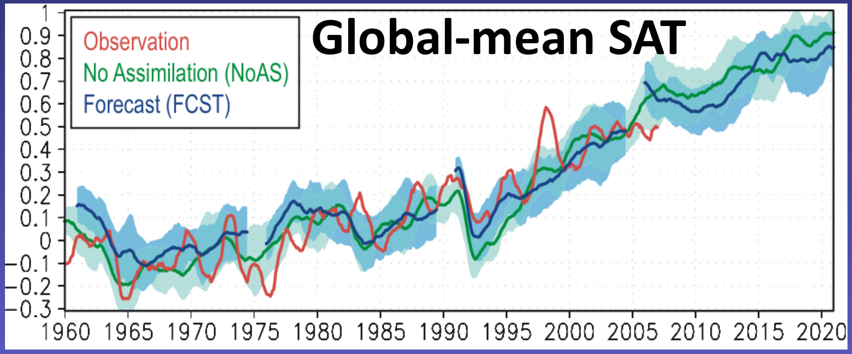
→ **Climate prediction as initial/boundary value problem**

Tier-1 Prediction System: SPAM

System for **P**rediction and **A**ssimilation by **M**IROC

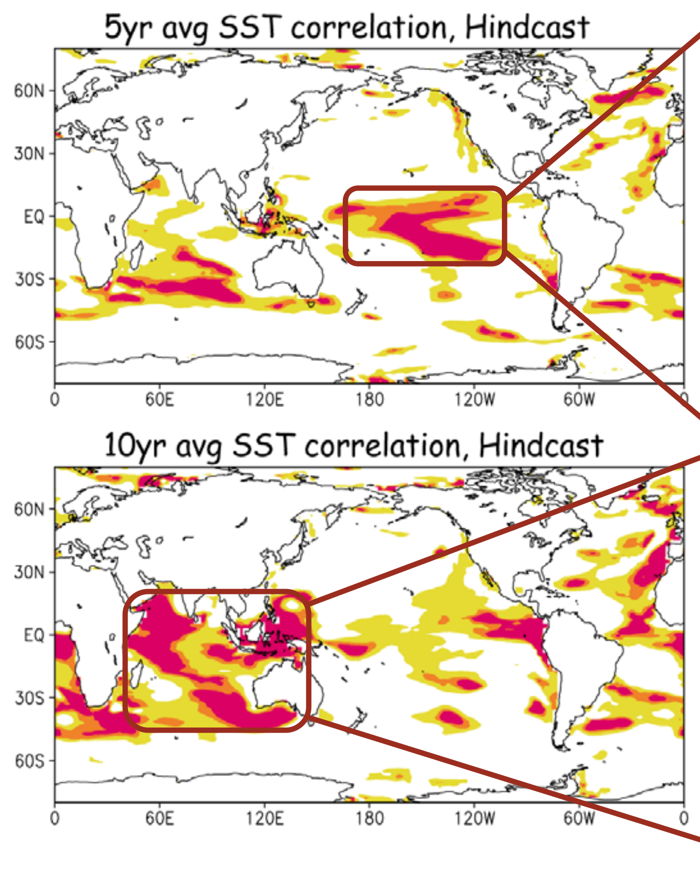
- ✓ Coupled data assimilation of gridded subsurface ocean data
- ✓ Target: seasonal-to-decadal climate variability (ENSO, PDO,…)
- ✓ Simple but practical initialization technique:
  - * IAU (Bloom et al. 1996) + Assimilation ensemble (10mem)

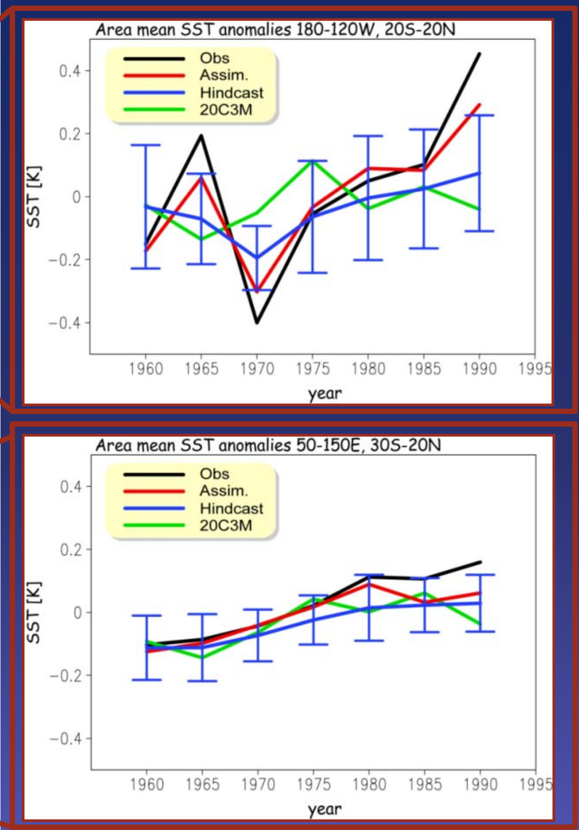




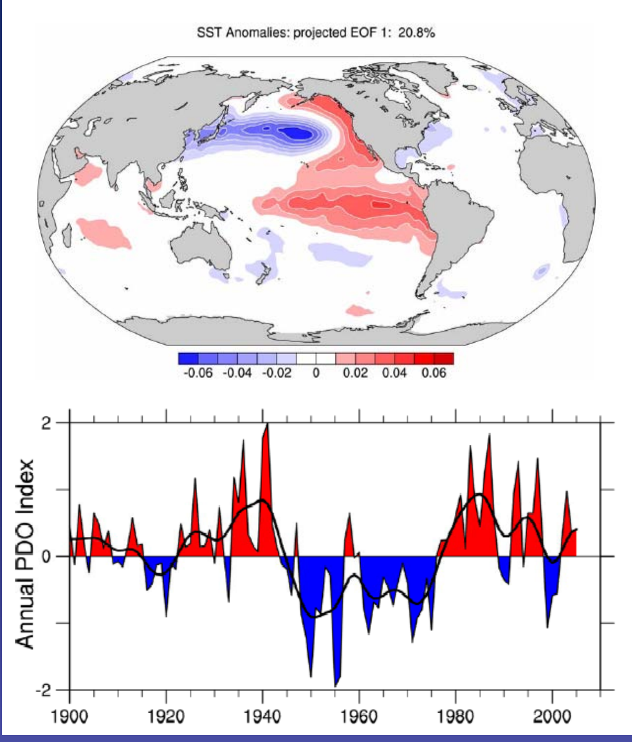
Pilot Decadal Prediction Experiments

- 7 sets starting from 1960, 65, 70, 75, 80, 85, and 90（each 10mem ensemble mean)
- annual mean is defined by the avg from Jul to subsequent Jun





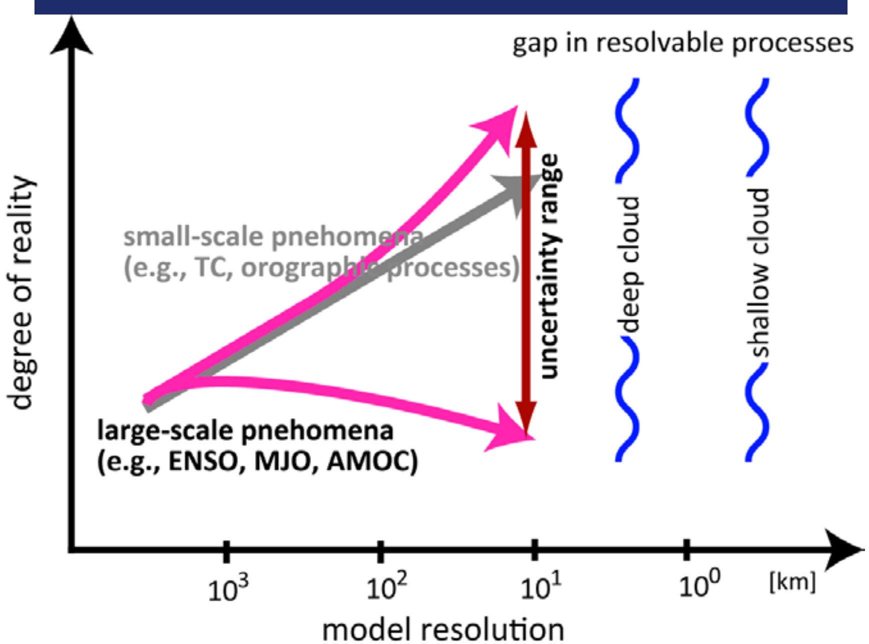
Pacific Decadal Oscillation (PDO); how long is it predictable?



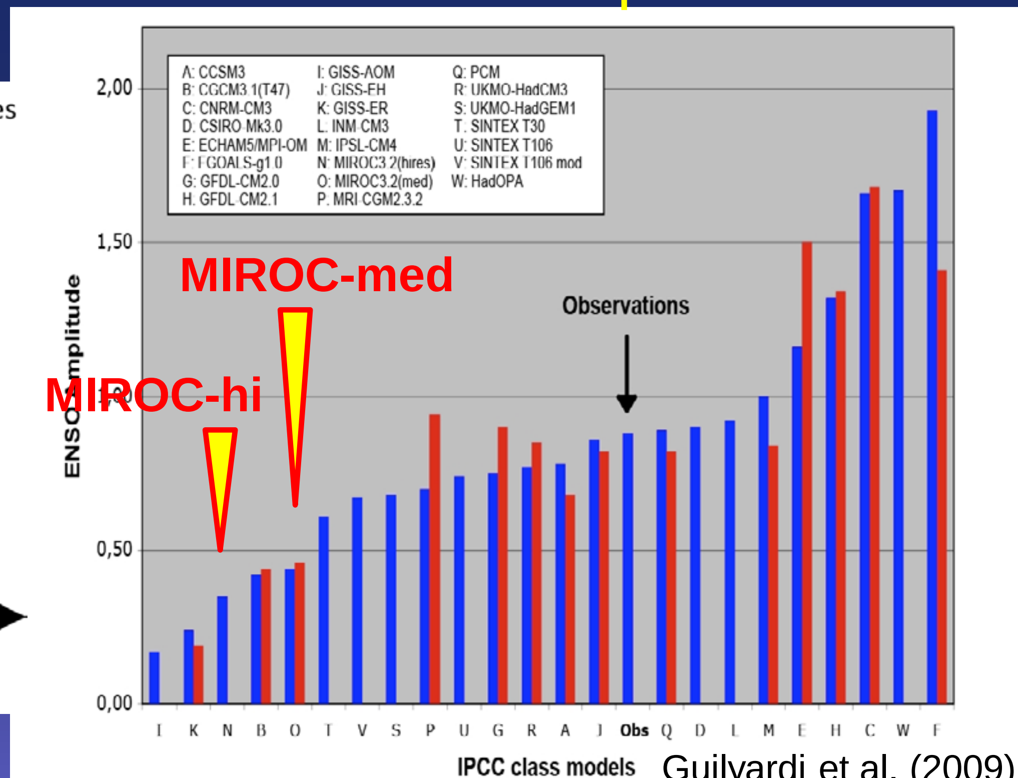
Modeling issue

- Can the (same) model with higher resolution produce better results in terms of the mean climate, variability, and climate change signals?

  → **Yes, but not everything**



ENSO amplitude



Guilyardi et al. (2009)

New Atmospheric Component of MIROC

	MIROC3.2	MIROC4.1
Dynamical core	Spectral + semi-Lagrangian scheme (Lin & Rood 1996)	Spectral+ semi-Lagrangian scheme (Lin & Rood 1996)
V. Coordinate	Sigma	Eta (hybrid sigma-p)
Radiation	2-stream DOM 37ch (Nakajima et al. 1986)	2-stream DOM 111ch (Sekiguchi et al. 2008)
Cloud	Diagnostic (LuTreut & Li 1991) + Simple water/ice partition	Prognostic PDF (Watanabe et al. 2008) + Ice microphysics (Wilson & Ballard 1999)
Turbulence	Level 2.0 (Mellor & Yamada 1982)	Level 2.5 (Nakanishi & Niino 2004)
Convection	Prognostic A-S + critical RH (Pan & Randall 1998, Emori et al. 2001)	Prognostic AS-type, but mostly new (Chikira et al. 2009)
Aerosols	simplified SPRINTARS (Takemura et al. 2002)	SPRINTARS + prognostic CCN (Takemura et al. 2005)
Land submodel	MATSIRO	MATSIRO mosaic

Cumulus convection scheme

Entrainment process

- Conventional A-S scheme: pre-defined
- New scheme: dependent upon buoyancy and cloud-base mass flux (original idea derived by Gregory 2000)

Cloud-type

- Conventional A-S scheme: defined by no. of layers
- New scheme: spectrum given by the cloud-base mass flux, no constraint by the no. of layers

Not necessary to use empirical RHcrit !

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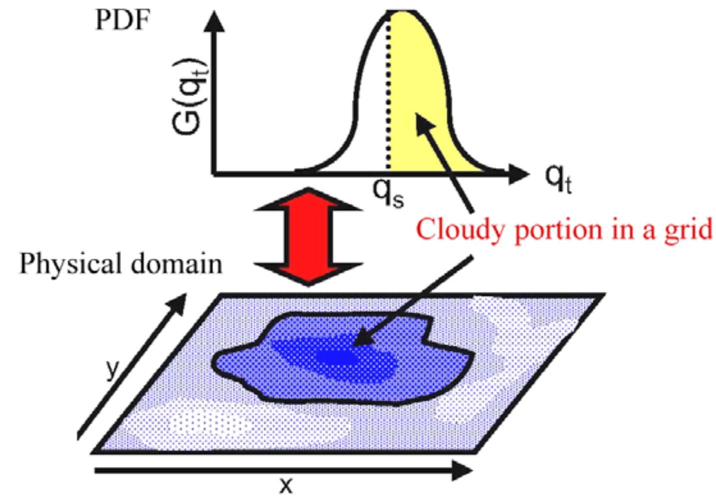
Hybrid prognostic cloud (HPC) scheme

➤ Large-scale condensation (LSC)



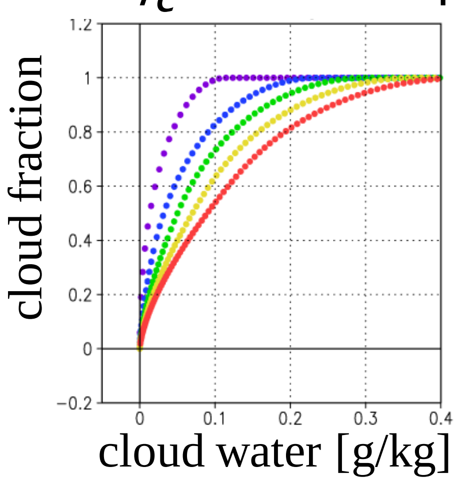
Tompkins (2005)

- ✓ Assume a subgrid-scale distribution of q_t' or $s=a_L(q_t'-\alpha_L T_l')$?
- ✓ Predict condensate amount and cloud?

$$C=\int_{-Q_c}^{\infty} G(s)ds \ , \quad q_c=\int_{-Q_c}^{\infty}(Q_c+s)G(s)ds \ , \quad Q_c=a_l\left\{\bar{q}_t-q_s(\bar{T}_l,\bar{p})\right\}$$

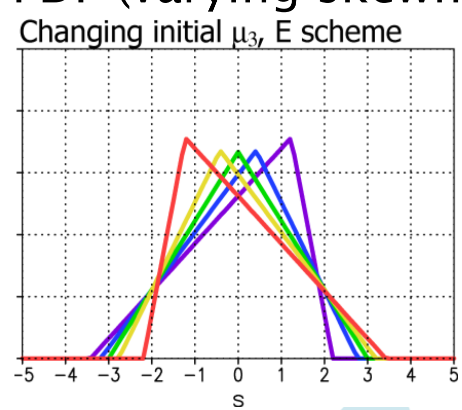
- ✓ Prognostic equations for PDF variance & skewness
- ✓ Quasi-reversible operator between grid quantities & PDF

C–q_c relationship



$$C,\ q_c \ \rightleftarrows \ \mathcal{V},\ S$$

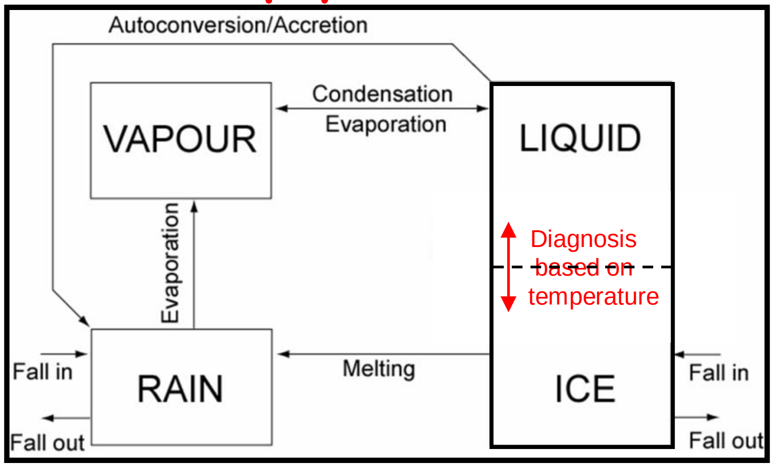
Basis PDF (varying skewness)



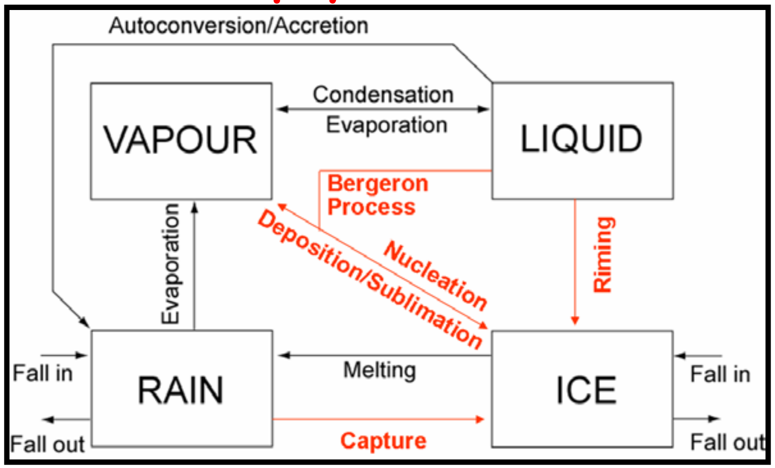
Similar approach:
Tompkins (2002, JAS)
Wilson & Gregory (2003, QJ)

Sophisticated ice-cloud microphysics

Cloud microphysics in MIROC3.2

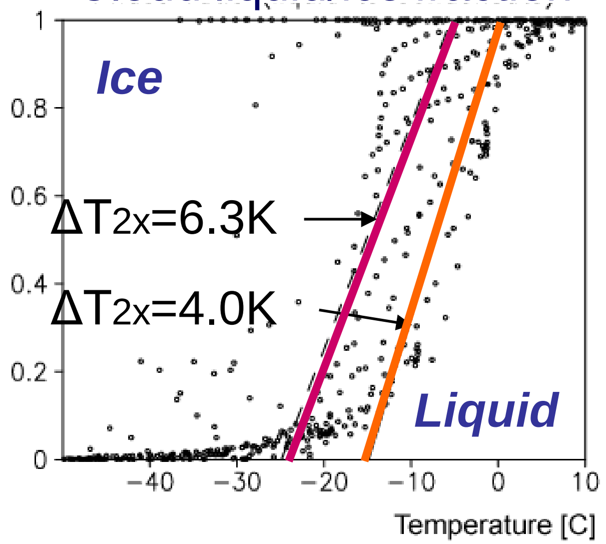


Cloud microphysics in MIROC4.1

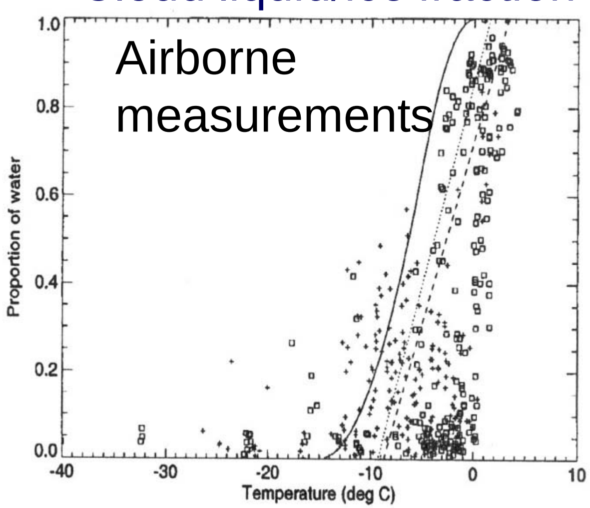


Wilson and Ballard (1999)

Cloud liquid/ice fraction



Cloud liquid/ice fraction



Rotstayn et al. (2000)

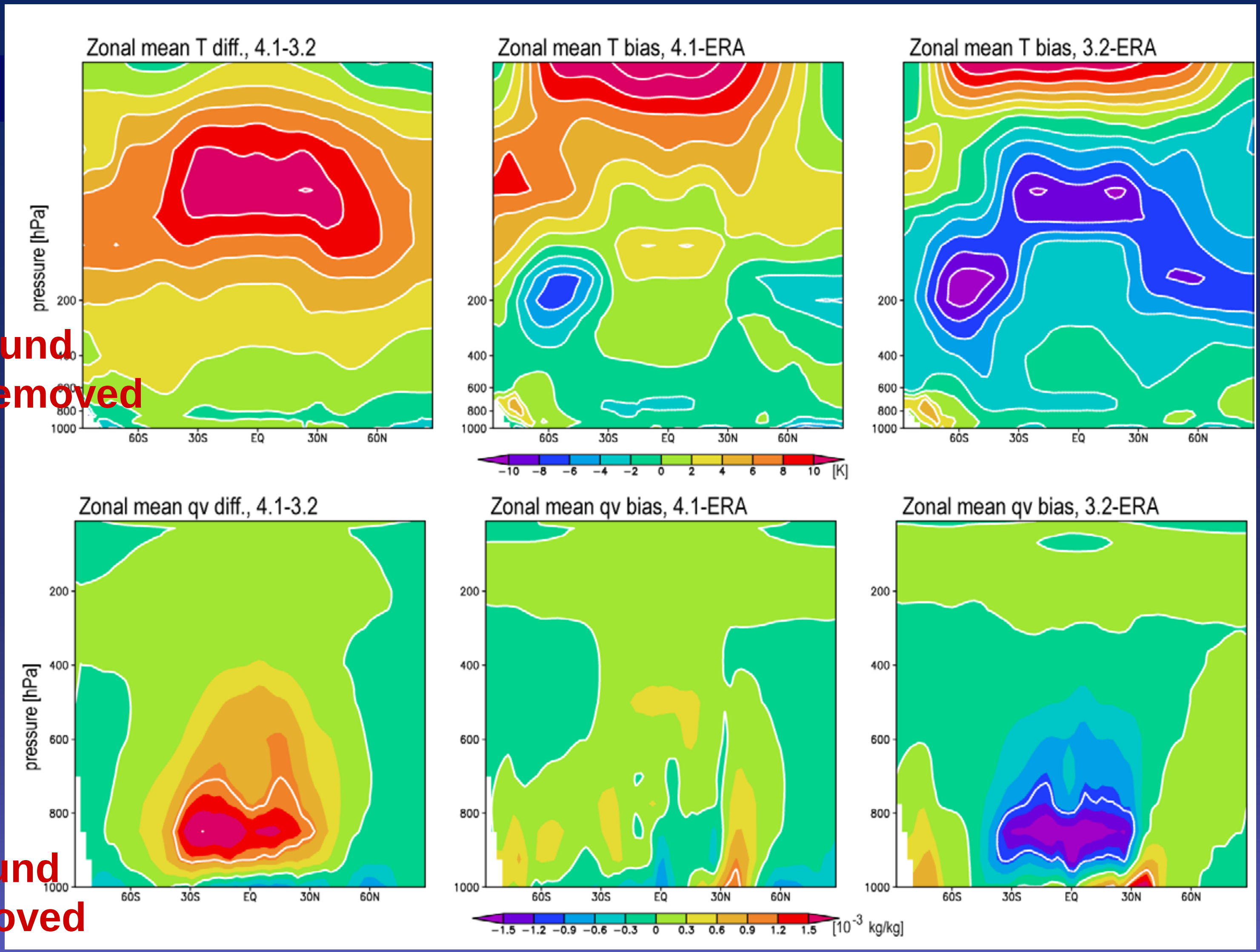
- In MIROC3.2 climate sensitivity has largely been affected by a parameter for cloud liquid/ice partition

Model performance: zonal-mean states

4.1-3.2 | **4.1bias** | **3.2bias**

Temperature

Specific humidity



Cold bias around tropopause removed

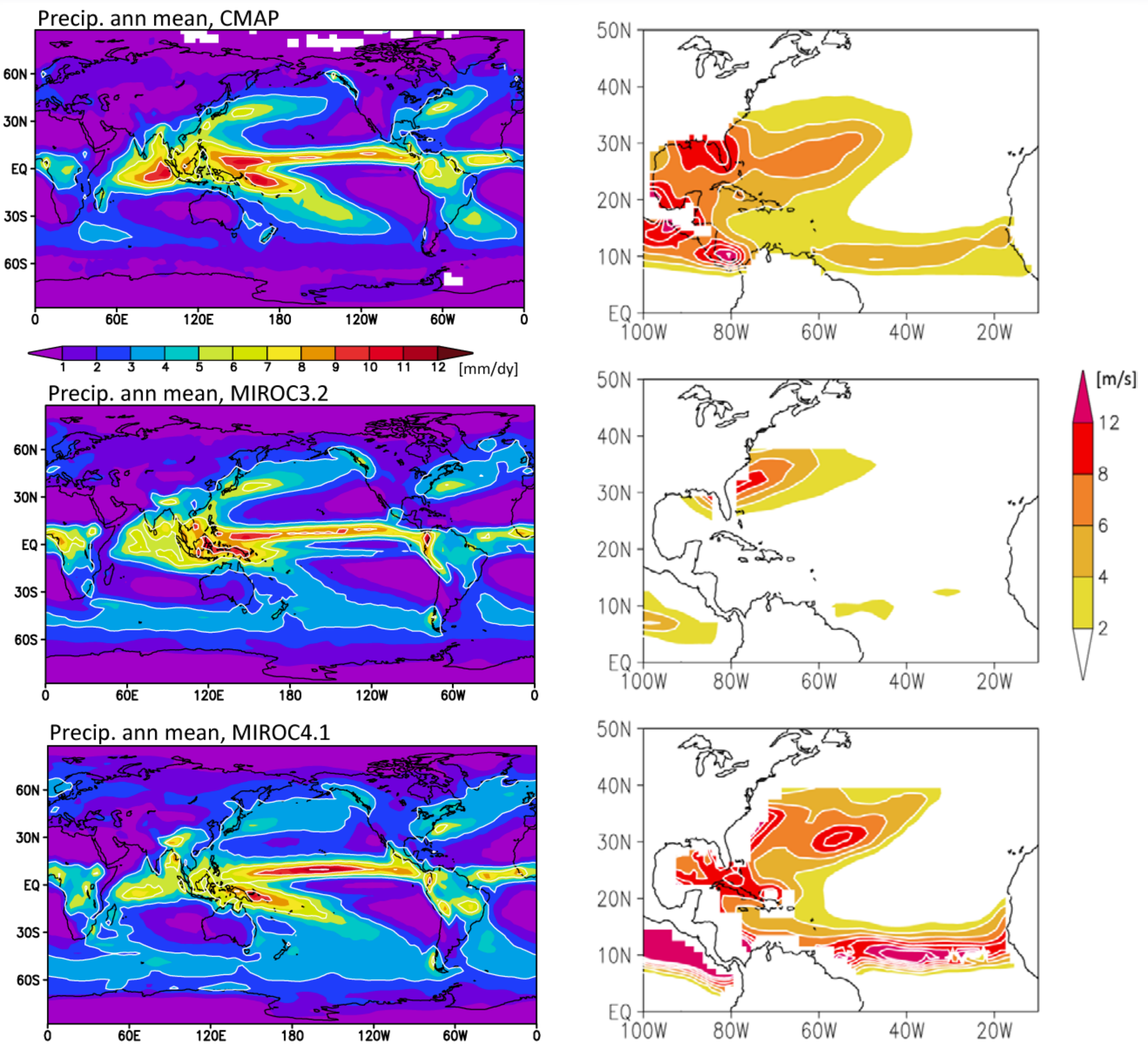
Dry bias around PBL top removed

Model performance: precipitation & genesis potential

Observation

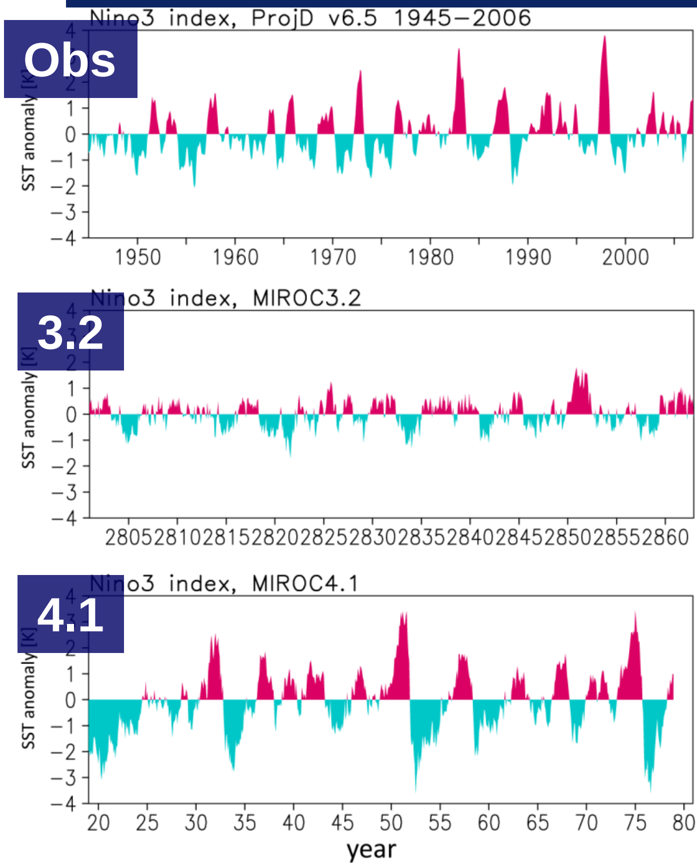
MIROC 3.2

MIROC 4.1

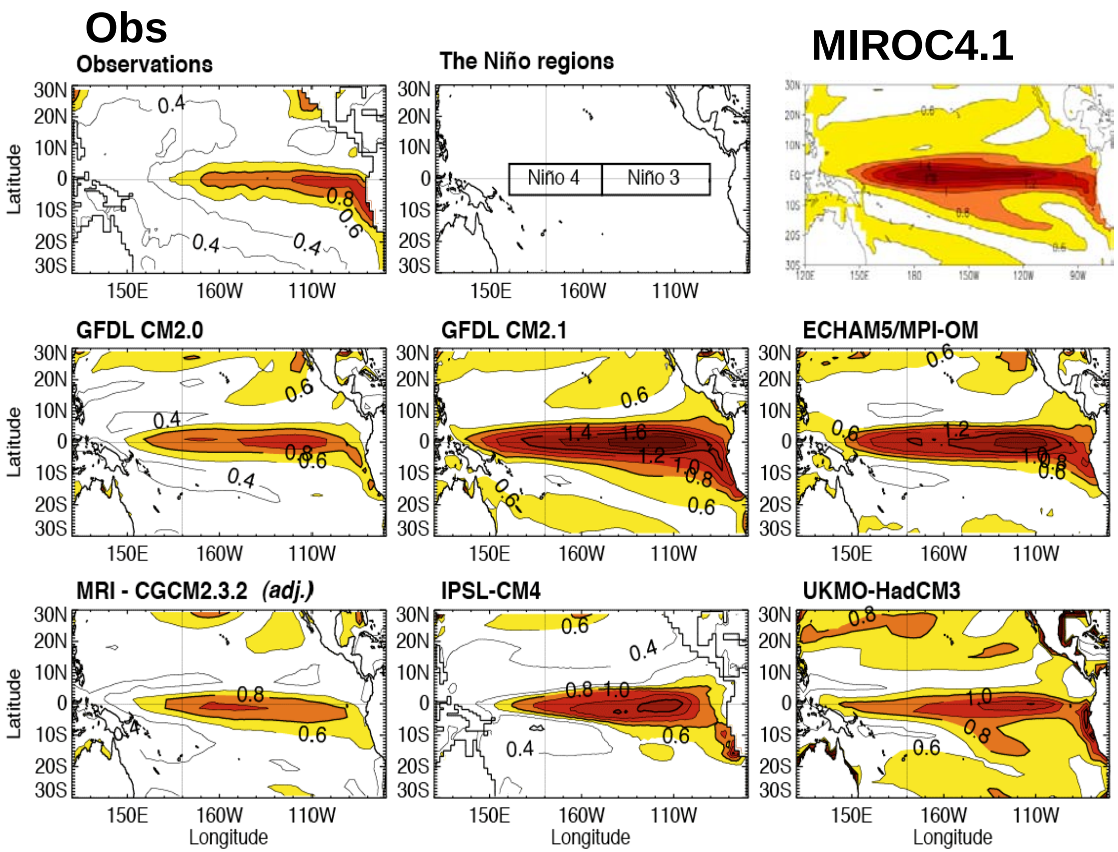


Model performance: ENSO

Nino3 index



SSTA standard deviation



Guilyardi et al. (2009)

ENSO amplitude can be controlled with a single parameter
Associated with the cumulus downdraught

Summary

- We developed a new version of MIROC, in which most of the schemes for physical processes are replaced
- Systematic model biases are reduced in many respects
- The model ENSO is much improved, and controlled by cumulus convection

Works to be done

- MIROC4.2
  - Coupling with new ocean-sea ice model COCO4.4
- Control simulation with new MIROC-med
- 20C3M+scenario runs