IBS Center
for Climate Physics

A Multi-year Climate Prediction System Based on CESM2

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CESM based prediction systems

Model Ver.	Initialization Component	Initialization Period	# Ens	Forecast Length (years)	Forcing protocol	Ref.
CESM1.1	Ocn, Ice	1954–2015 (Nov)	40	10	CMIP5 (hist, RCP 4.5)	**CESM-DPLE** *Yeager et al.*, 2018
CESM1.0.3	Ocn	1960–2014 (Jan)	10	10	CMIP5	**Anomaly assimilation** *Chikamoto et al.*, 2019
CESM2.1	Ocn, Ice	1970–2019 (Feb, May, Aug, Nov)	20	2	CMIP6 (hist_smbb, SSP3-7.0)	**SMYLE** *Yeager et al.*, 2022
CESM2.1.4	**Ocn**	**1960–2021 (Jan)**	**20**	**5**	**CMIP6 (hist_smbb, SSP3-7.0)**	**-**

- **The Newly developed CESM2 multi-year prediction system**
  - **New model physics from CESM2**
  - **5-year prediction for multi-year predictability**
  - **Anomaly assimilation to minimize the model drift**

System Overview

Observation (OBS)

- 3 Observation (Analysis) dataset
- **EN4.2.2 (*Good et al.,* 2013)**
- **ProjD7.3 analysis (JMA) (*Ishii et al.*, 2017)**
- ORAS4 (ECMWF) (*Balmaseda et al.*, 2013)

3-D Ocean Temperature & Salinity anomaly assimilation

Initialization with ASSM, (1960~2021, Jan 1st) 5-year hindcast

Uninitialized run CESM2 Large Ensemble (LENS2)

- Total 100 members (Rodgers *et al.*, 2021)
- 10 members for ASSM (1231.011~020)

Assimilated run Initialization (ASSM)

- **30 (10 * 3) Ensemble members**
  - **10 members for EN4.2.2 (1950 ~ 2021)**
  - **10 members for ProjD7.3 (1955 ~ 2021)**
  - 10 members for ORAS4 (1958 ~ 2016, for validation)

Initialized run Hindcast & Forecast (HCST)

- **20 Ensemble members** (EN4, ProjD)
- **62 initialized years** (1960 ~ 2021)
- 6200 (62 * 20 * 5) simulation years (> 2 PB)

- **To examine the ocean assmilation effect to the earth system prediction (LENS2 <-> ASSM)**
- **To assess the potential predictability, actual skills (LENS2 + HCST <-> ASSM or OBS)**

- **Keywords:**
  CESM2, 5-year hindcast, Anomaly Assimilation, Predictability Sources from ocean

Observational Uncertainty & Model Drift

- **Observational uncertainty exists**
  -> multi-data assimilation

- **Weak drift in the hindcast simulation due to the anomaly assimilation**

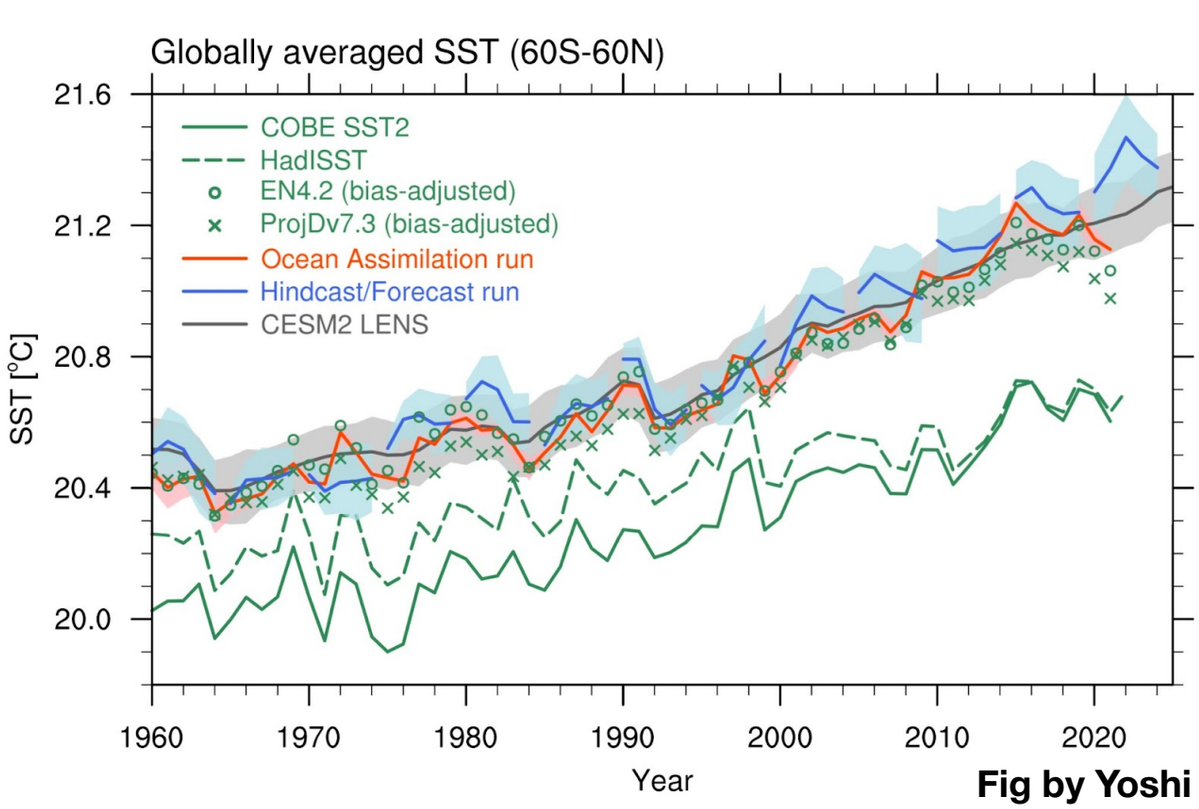
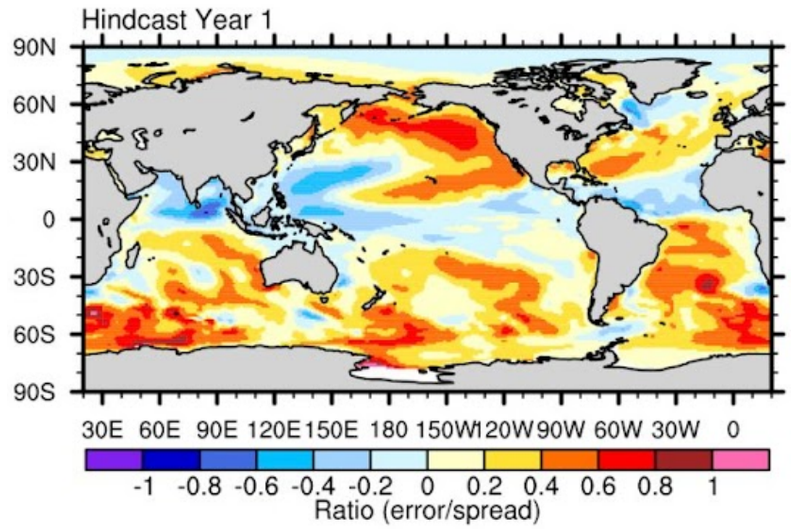


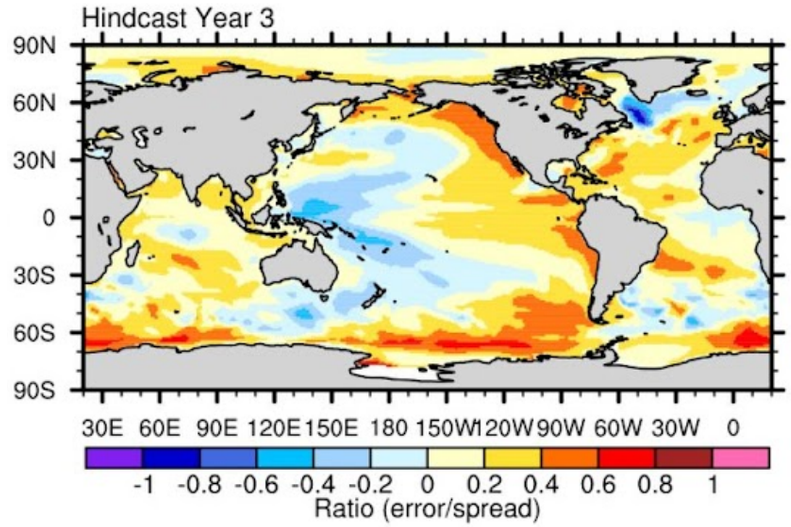
Fig by Yoshi

Drift $T_{drift}(\tau) = 1/N * \Sigma_{k=1}^{N}(T_k^{HCT} - T_k^{ODA})$

LY1



LY3



LY5

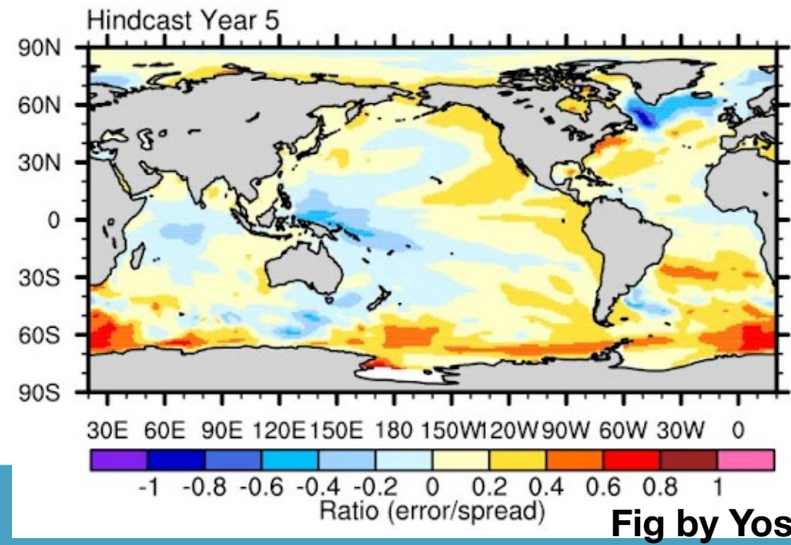
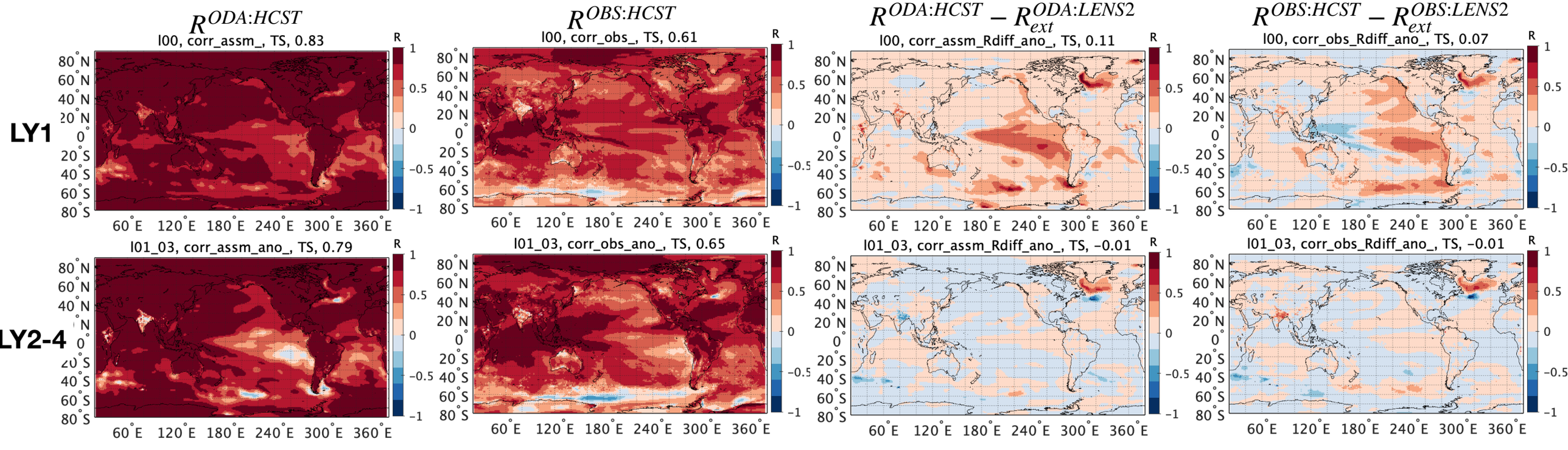


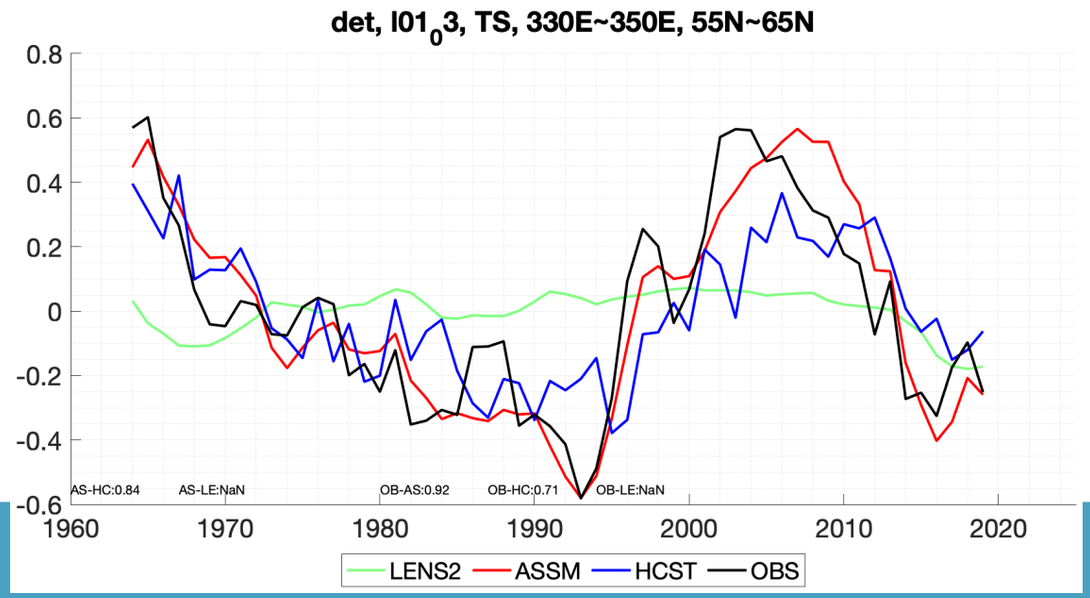
Fig by Yoshi

TS (yearly)
OBS (ERA5)
period : 1960~2020

ACC Skill & differences

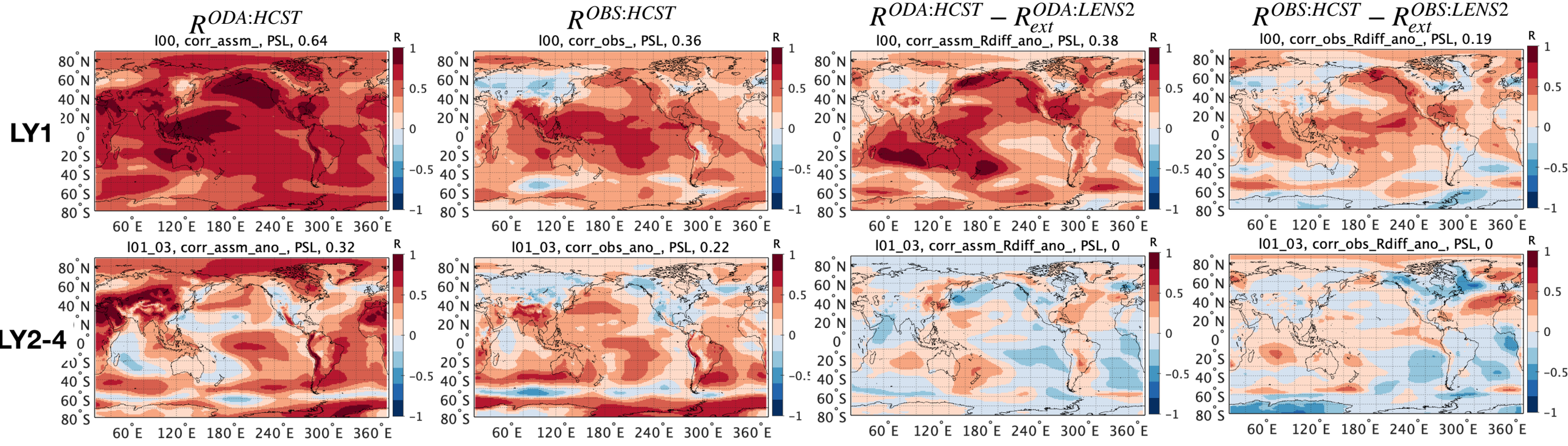


- **Large contribution of the external forcing in prediction skills**
- **LY1: Eastern Pacific (Niño driven skills)**
- **LY2-4: around Labrador sea (AMV?)**

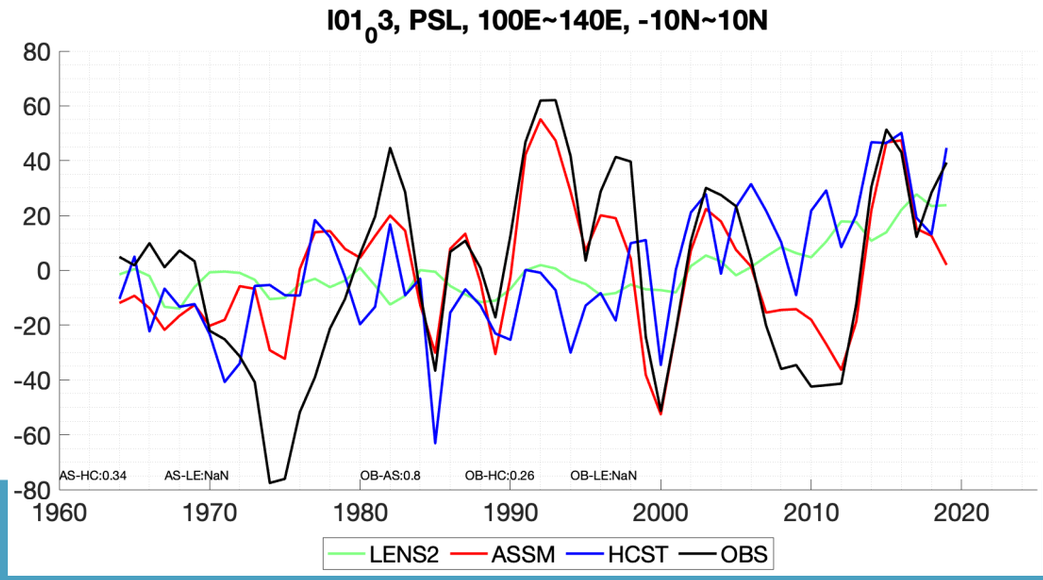


PSL (yearly)
OBS (ERA5)
period : 1960~2020

ACC Skill & differences



- **Large contribution of the external forcing**
- **LY1: Maritime continent (strong ocean-atmosphere interaction)**
- **LY2-4: Maritime continent?**

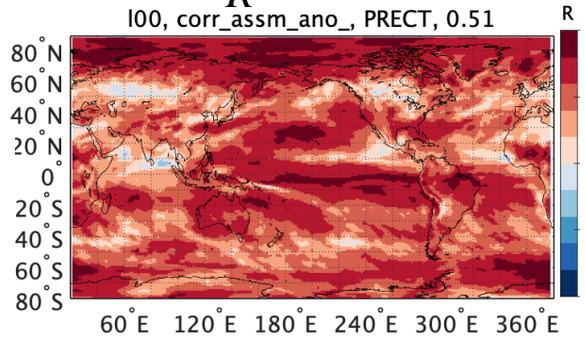


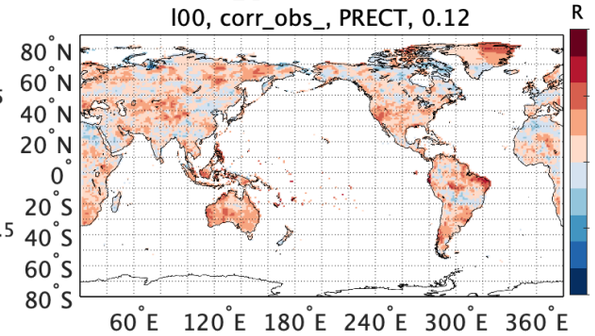
PRECT (yearly)
OBS (GPCC)
period : 1960~2019

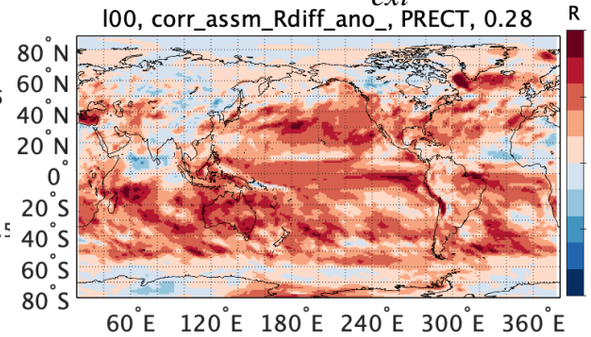
ACC Skill & differences

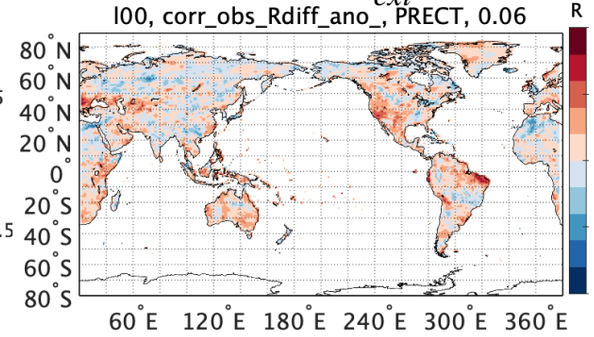
$R^{ODA:HCST}$ | $R^{OBS:HCST}$ | $R^{ODA:HCST} - R_{ext}^{ODA:LENS2}$ | $R^{OBS:HCST} - R_{ext}^{OBS:LENS2}$

LY1

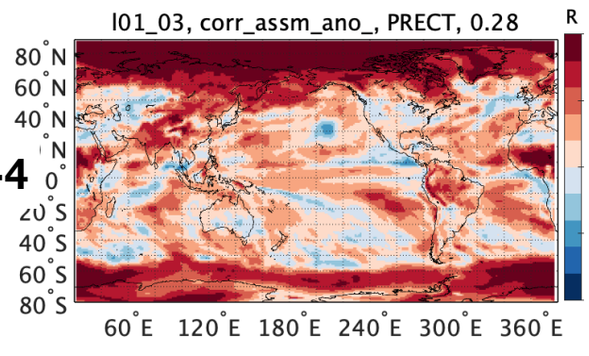


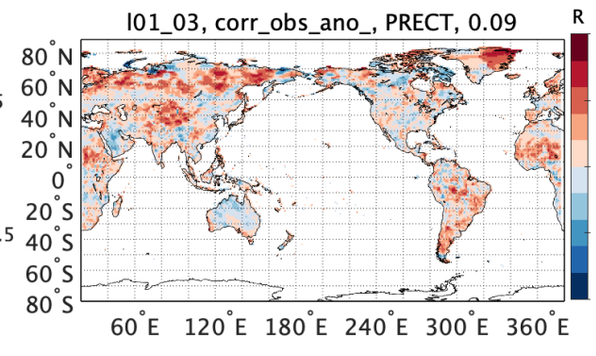


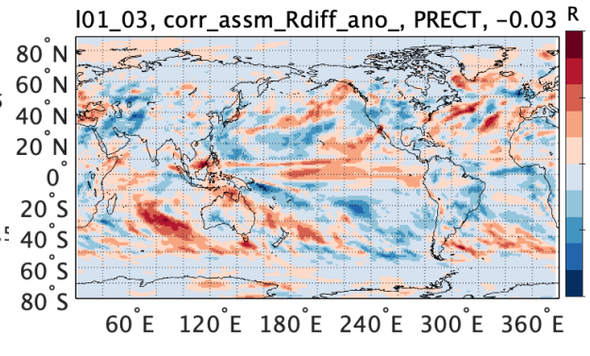


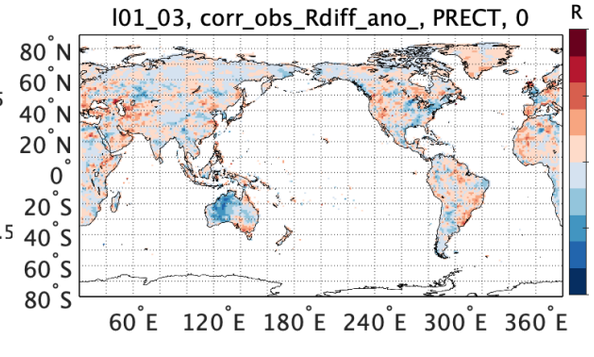


LY2-4





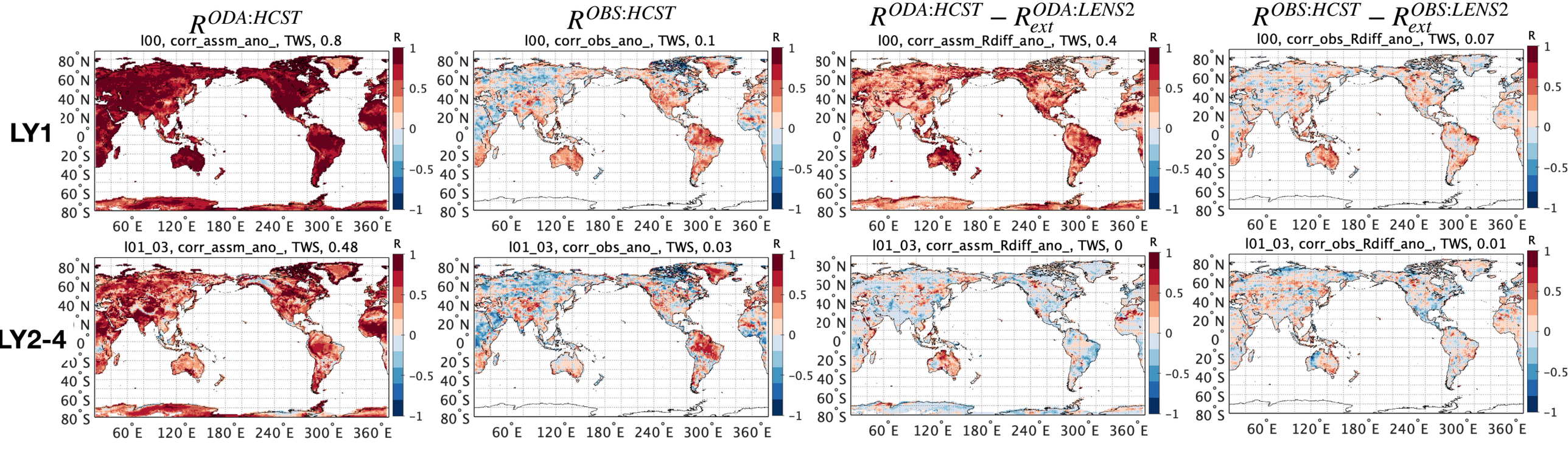




- **Large contribution of the external forcing in polar regions**
- **ΔACC: Southern hemisphere > northern hemisphere (larger ocean area)**
- **LY1: -50N ~ 50N**
- **LY2-4: Some oceanic regions**

TWS (yearly)
OBS (NOAA CPC)
period : 1960~2019

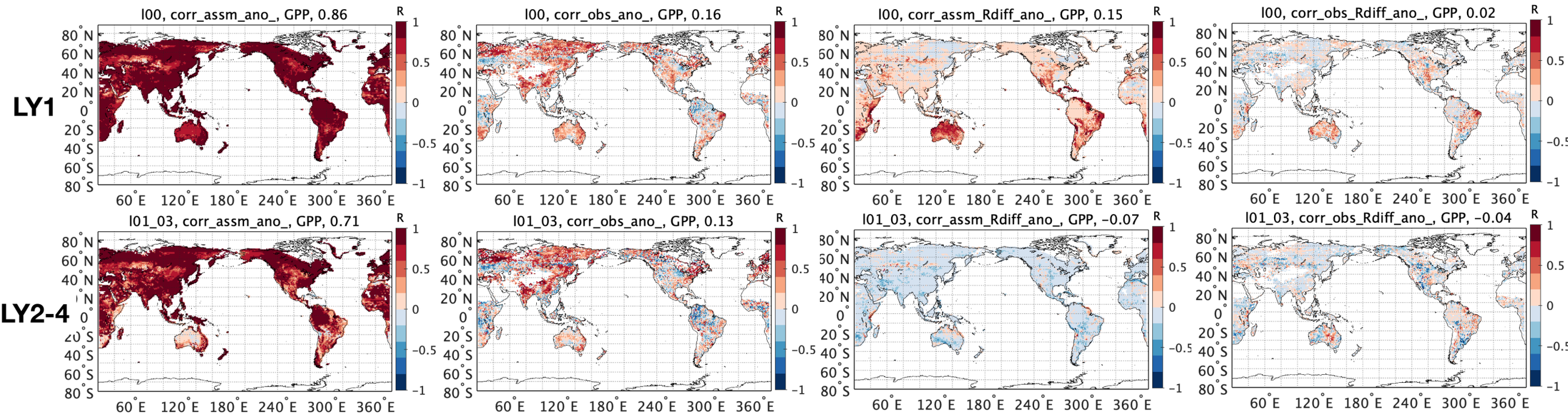
ACC Skill & differences



- **Large contribution of the external forcing**
- **LY1: Globally (especially in southern hemisphere)**
- **LY2-4: Austrailia, Gulf of California, Western Sahara, horn of Africa ...?**

GPP (yearly)
OBS (VODCA2GPP)
period : 1989~2019

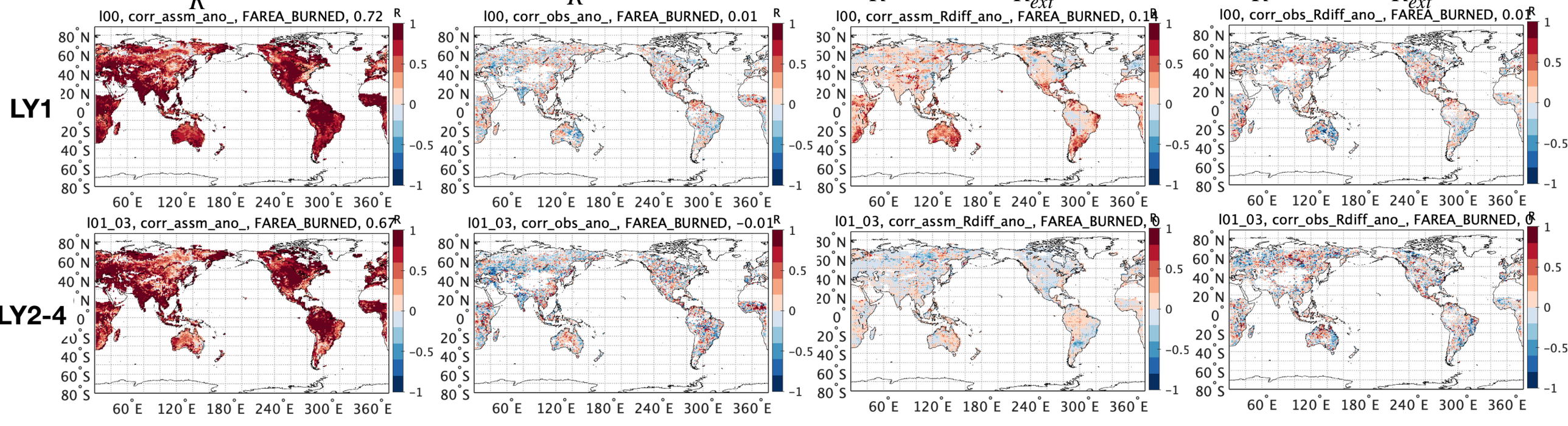
ACC Skill & differences



- **Large contribution of the trend, similar with TWS**
- **LY1: Austrailia, South America, South&East Africa**
- **LY2-4: X**

FAREA_BURNED (yearly)
OBS (Modis_Fire_cci)
OBS period : 2001~2020

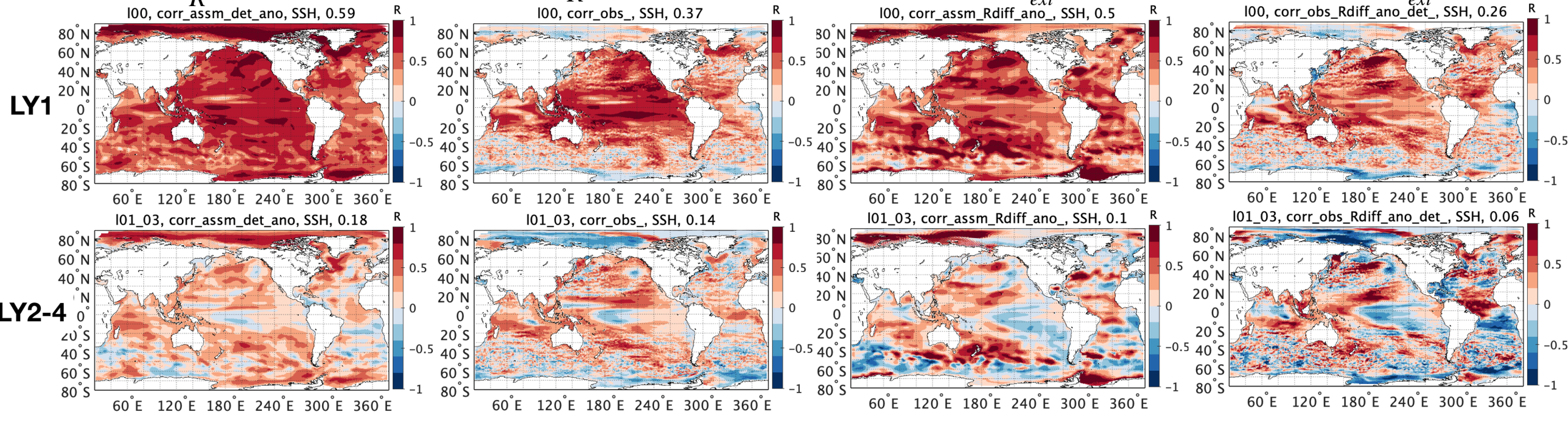
ACC Skill & differences



- **Similar with GPP**
- **Large contribution of the trend**
- **LY1: Austrailia, South America, South&East Africa**
- **LY2-4: X**

SSH; detrended (yearly)
OBS (CMEMS)
OBS period : 1993~2020

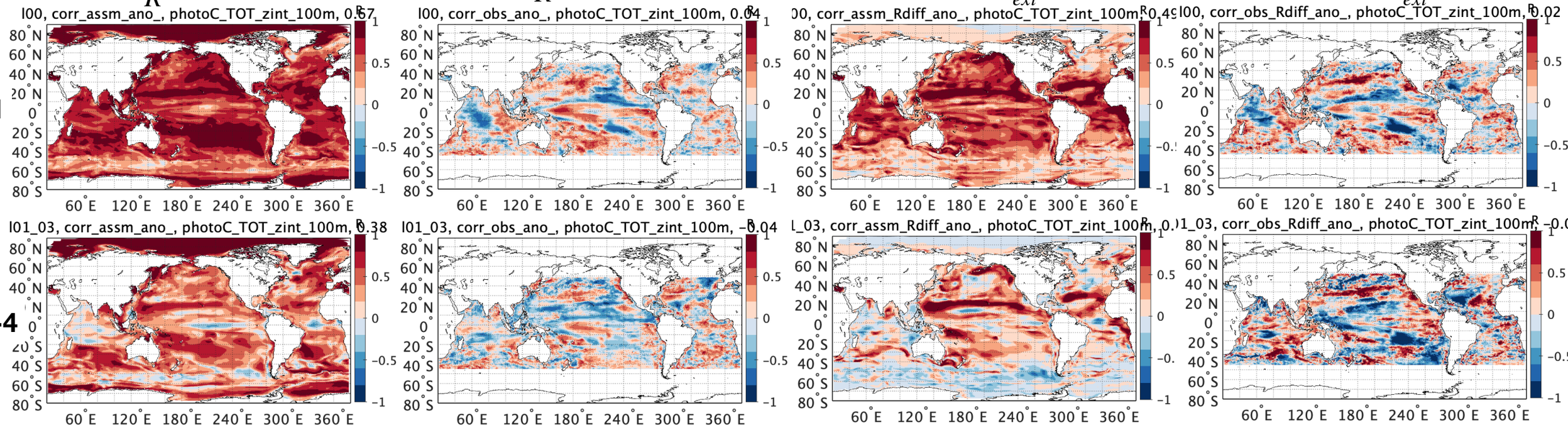
ACC Skill & differences



- **Multi-year predictable ocean variables**
- **LY1: Austrailia, South America, South&East Africa**
- **LY2-4: Tropical Atlantic, Western Pacific, Indian Ocean**

photoC_TOT_zint_100m (yearly)
OBS (OceanColour)
OBS period : 1998~2020

ACC Skill & differences



- **Potentially multi-year predictable**
- **LY1: -40N ~ 60N**
- **LY2-4: Subtropical regions, Northeastern Pacific, Eastern Atlantic**

Summary

- **Newly developed multi-year prediction system for S2D prediction**

- **Potential predictability of variables are different by predictability source**
  ATM <= LND < OCN
  Atmospheric white noise ~ slow oceanic red noise

- **Ongoing sub-projects:**
  Multi-year marine bgc predictability constrained by ocean circulation (Y-Y & Axel leads),
  ATM flux driven errors in ocean assimilated bgc simulation (Y-Y & Ingo leads),
  La niña & trans-basin interaction (Nahid & Yoshi leads),
  Statistics of extreme events (heat wave) (Alexia & J-Y leads),
  Multi-year predictability sources for terrestrial ecosystem (? & J-Y leads),
  Predictability of Atlantic decadal variability (Abhinav & J-Y leads)

- **Many variables are produced to assess predictability in CESM2 (> 1PB),**
  Data would be publicly opened soon, feel free to contact us

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