# Simulated unintended biogeochemical effects of idealized land cover and land management changes

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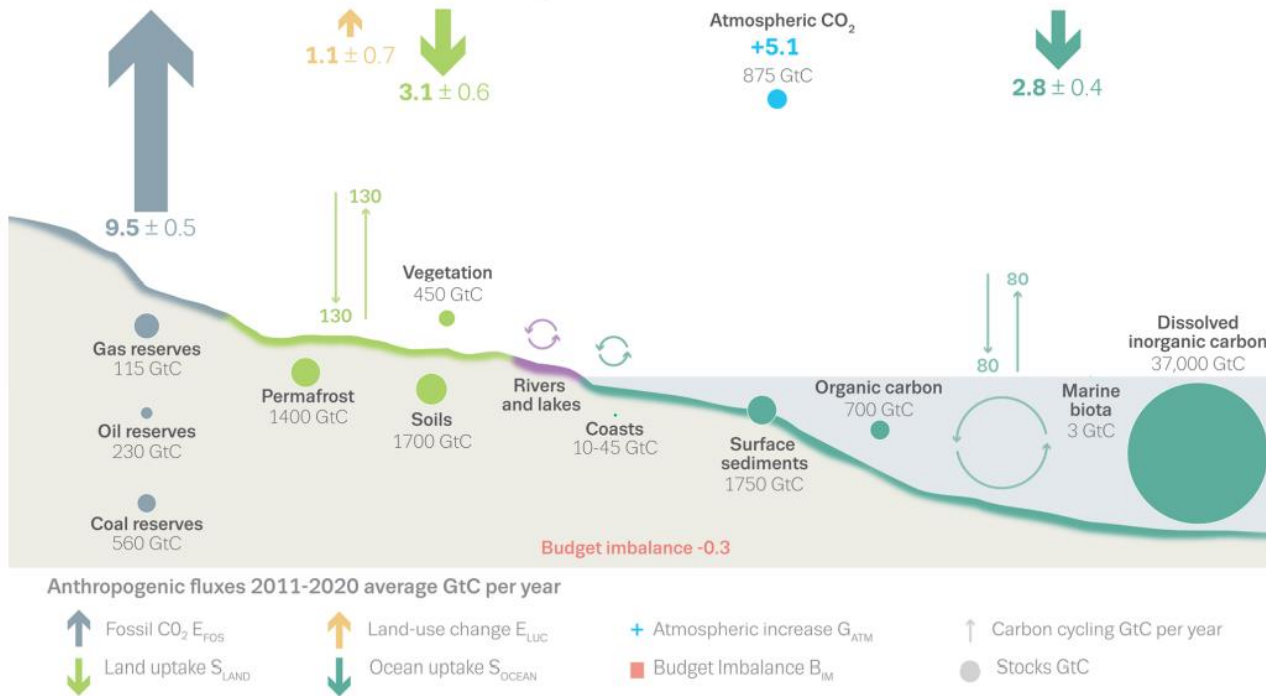[6] Royal Netherlands Meteorological Institute (KNMI), De Bilt, Netherlands

LAMA CLIMA — Land Management for Climate Mitigation and Adaptation

LMU — LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

# Background: Gap in biogeochemical effect of LMLCC

## The global carbon cycle

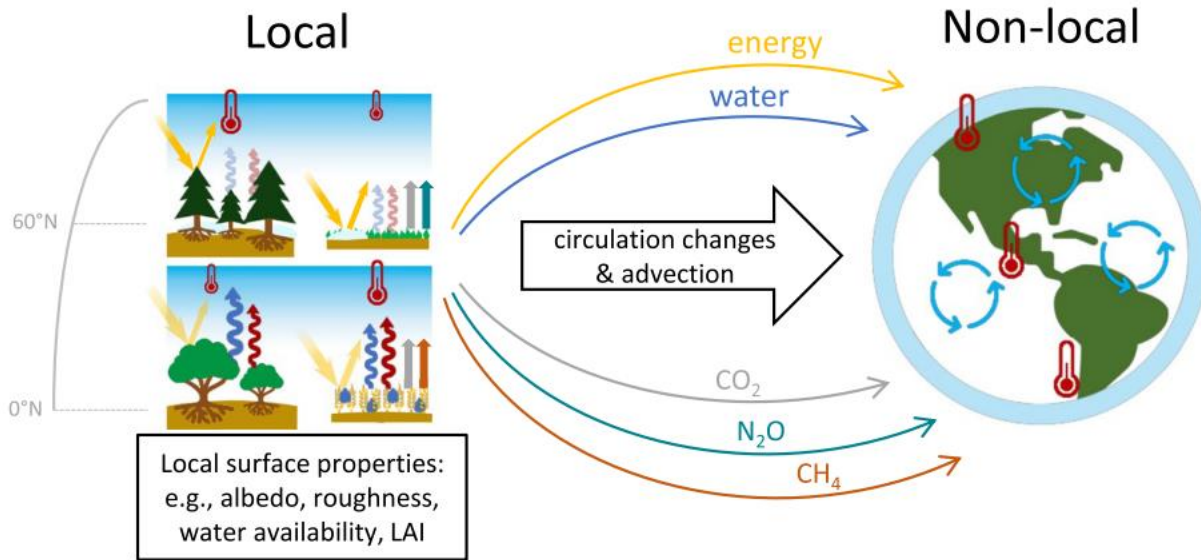

Friedlingstein et al 2022; Global Carbon Budget 2021

- LULCC emissions accounted for 10-15% of total anthropogenic co2 emissions.

- Previous studies focused on the direct effect of tree removal or regrowth on carbon fluxes.

# Background: Gap in biogeochemical effect of LMLCC



Pongratz et al 2021 CCCR

- LMLCC has an important influence on climate via biogeophysical effects.

- This influence reach far beyond the location of LMLCC, called the "nonlocal effect".

- Climate change will further affect the terrestrial carbon cycle.

- LMLCC has a nonlocal effect on the carbon cycle.

## Question：
**Whether the nonlocal biogeochemical effect non-negligible?**

# Simulations

| Simulation | Land Cover | Land Management |
|---|---|---|
| CTL | 2015 map | none |
| CROP | 50% crop map, 50% CTL map | none |
| FRST | 50% forest map, 50% CTL map | none |
| IRR | 50% crop map, 50% CTL map | irrigation |
| HARV | 50% forest map, 50% CTL map | wood harvesting (yr 2100 under RCP 8.5) |

Steven De Hertog et.al 2022 in review
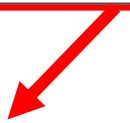
**checkerboard approach**
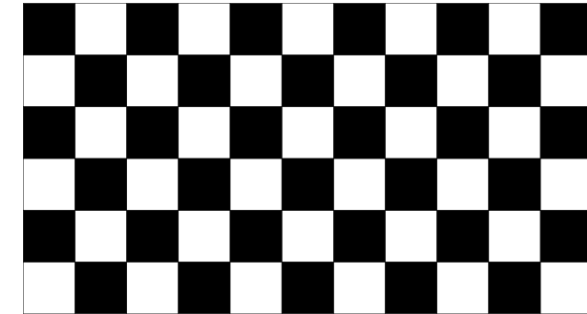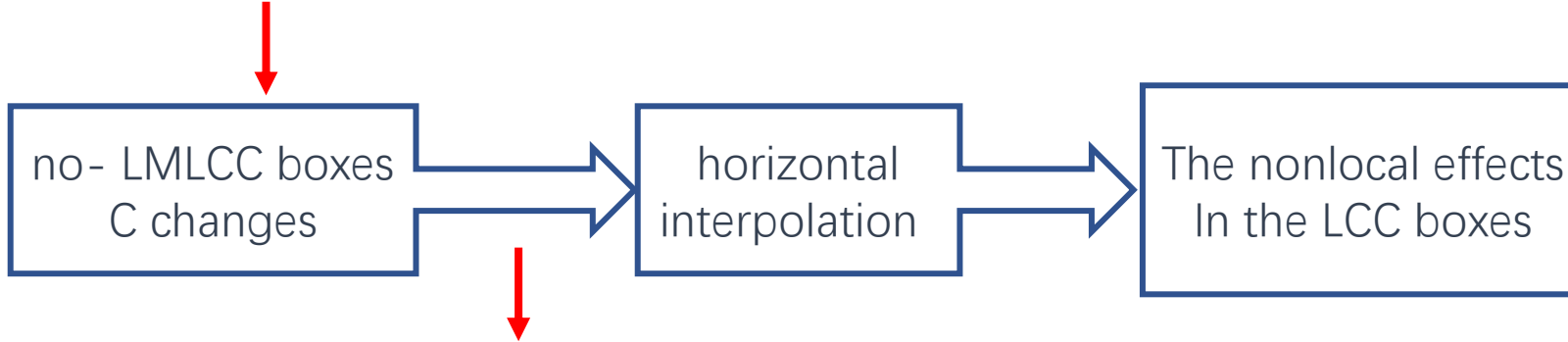**1 out of 2 grid cells are affected by the LMLCC**
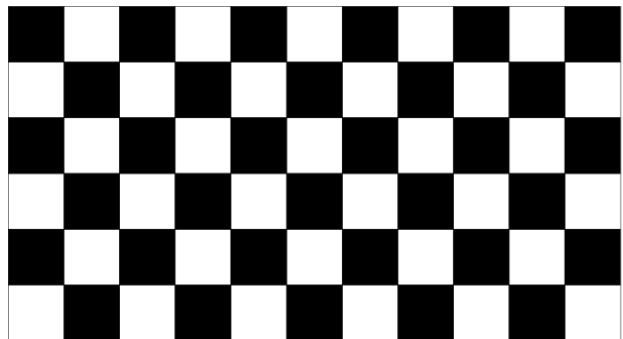


**ESMS: CESM, MPI-ESM, EC-EARTH**

# Nonlocal BGC effect

- **Signal separation approach( Winckler, J. et al 2017):**

**Sensitive simulations-the CTL**

```
┌──────────────┐      ┌──────────────┐      ┌──────────────┐
│ no- LMLCC    │      │ horizontal   │      │ The nonlocal │
│ boxes        │ ──▶  │ interpolation│ ──▶  │ effects      │
│ C changes    │      │              │      │ In the LCC   │
│              │      │              │      │ boxes        │
└──────────────┘      └──────────────┘      └──────────────┘
```

Assumption: nonlocal effects are present also in the LMLCC boxes.

## Implication of nonlocal BGC effect:

- **Unintended C changes in regions without changed land cover.**

- C changes is caused by remote climate changes from biogeophysical effects of LMLCC

- not accounting for the direct tree removal or regrowth effect.

# Results: Global integral of nonlocal BGC effect

## Carbon stock changes:

**The nonlocal effect is detectable for MPI-ESM and CESM for all three scenarios.**

- Cropland expansion: cLand : **-11.2GtC(-27.5GtC)** for MPI_ESM(CESM)

- Afforestation: cLand**: 6.85GtC (- 9.19GtC)** for MPI_ESM(CESM)

- Irrigation: cLand **17.83GtC** CESM

## Internal variability:

large interannual to interdecadal variability occurs, where the main uncertainty of Eluc comes from.



cropland expansion

af/reforestation

irrigation
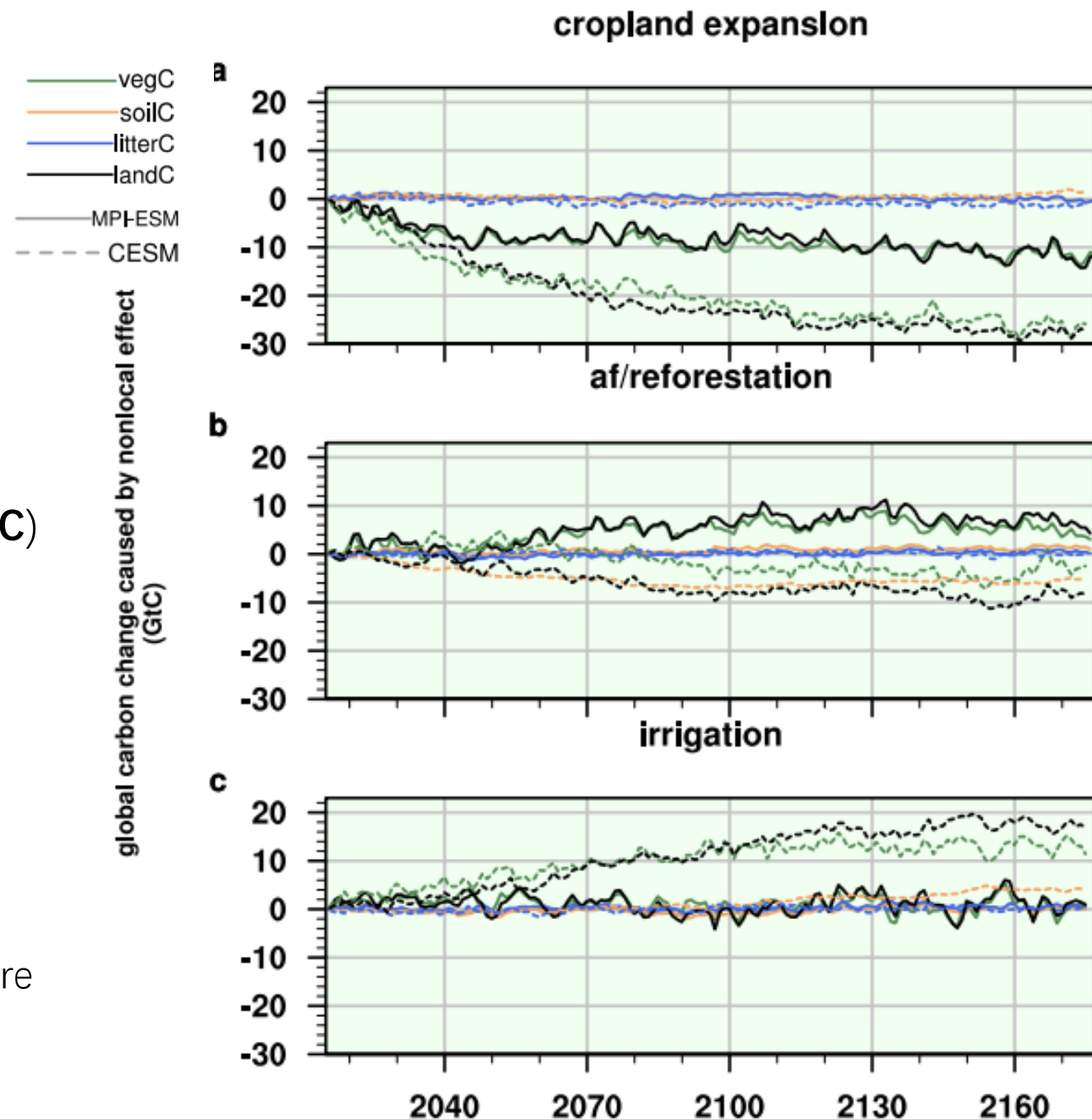
# Results: The spatial distribution -vegetation carbon changes
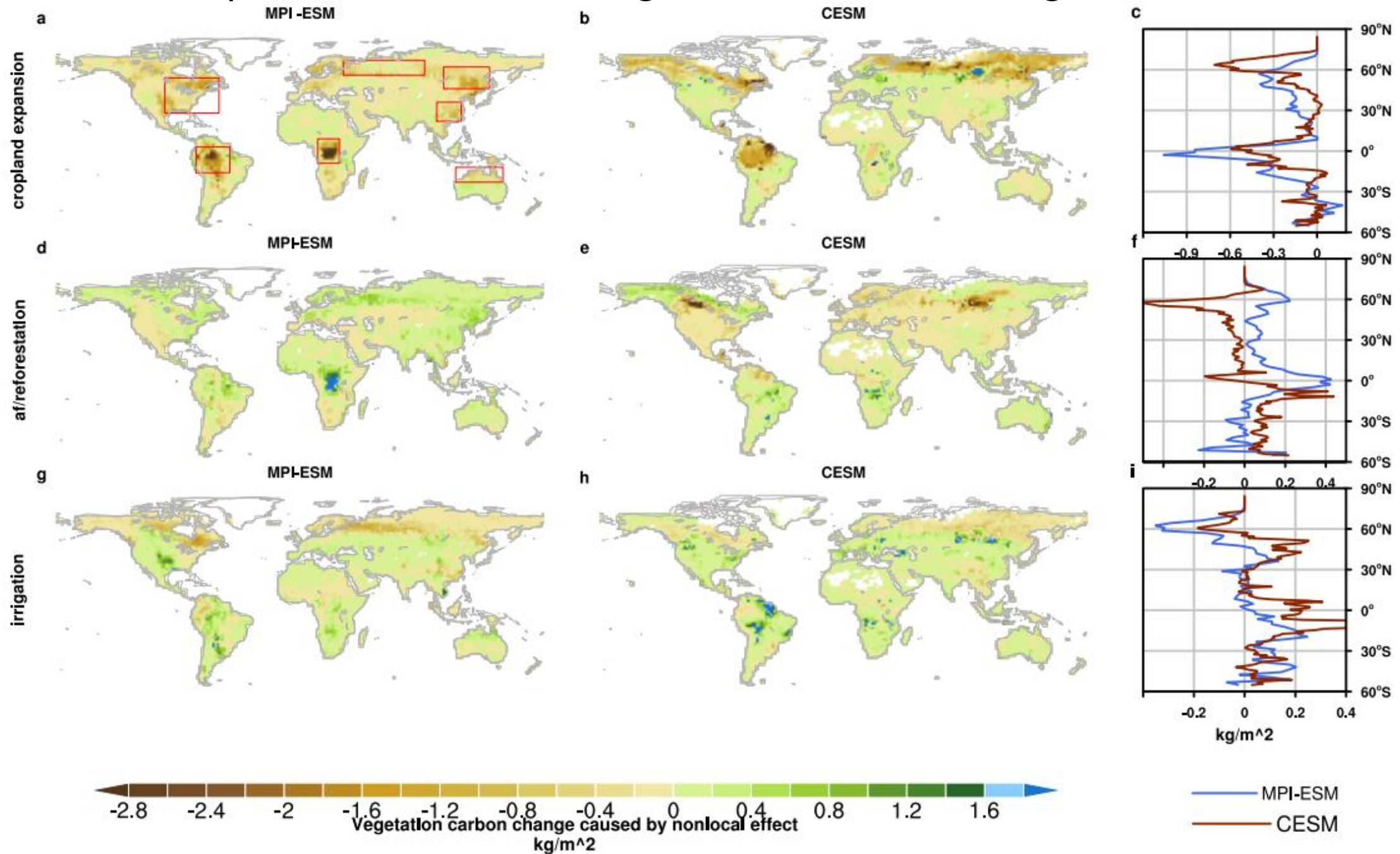
# Results
**Relative nonlocal effect compared with total effect**

- The relative importance of the nonlocal BGC is diverse among simulations and models.

- However, we can conclude that it is always important and unignorable. especially for irrigation scenario.
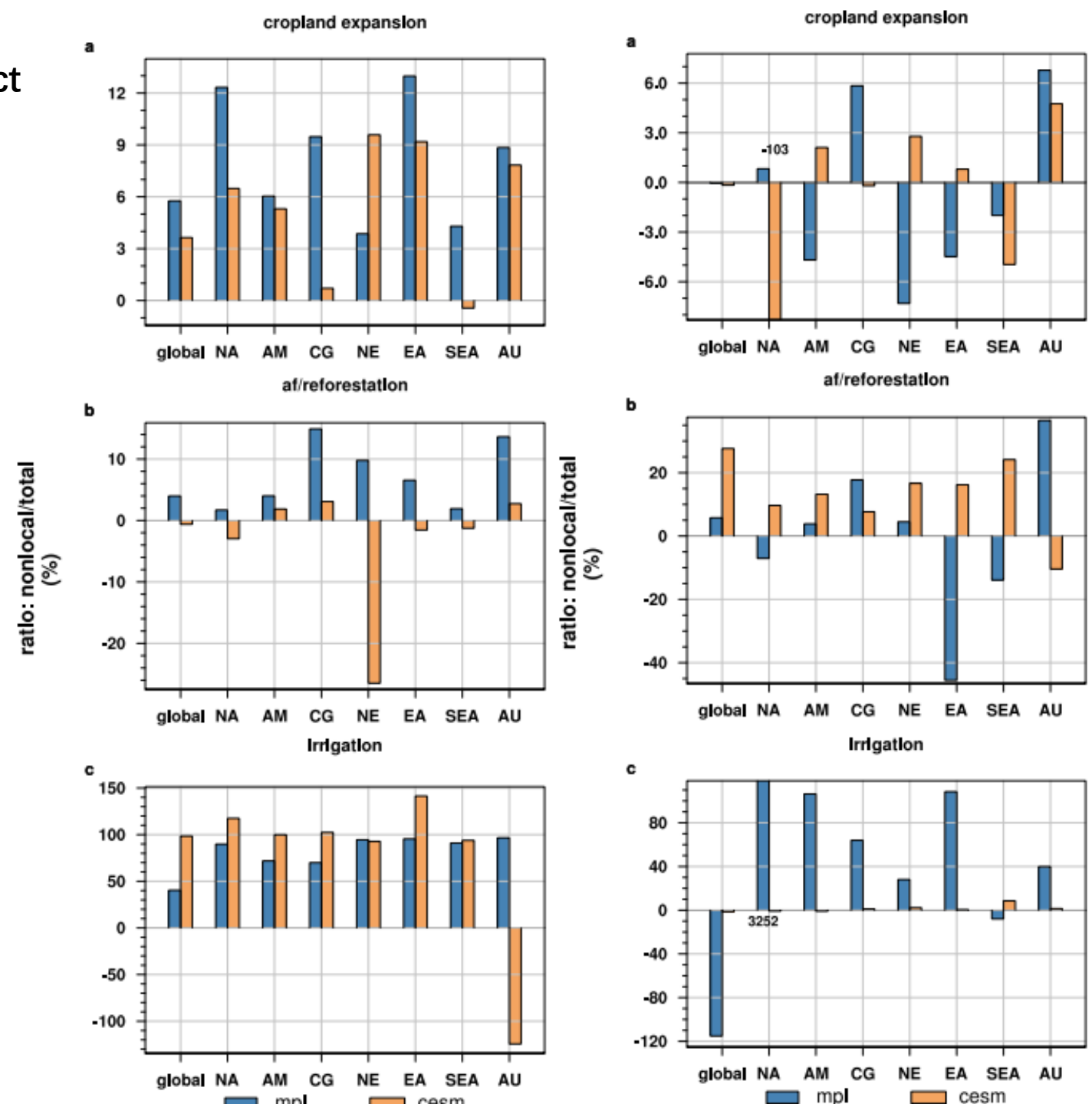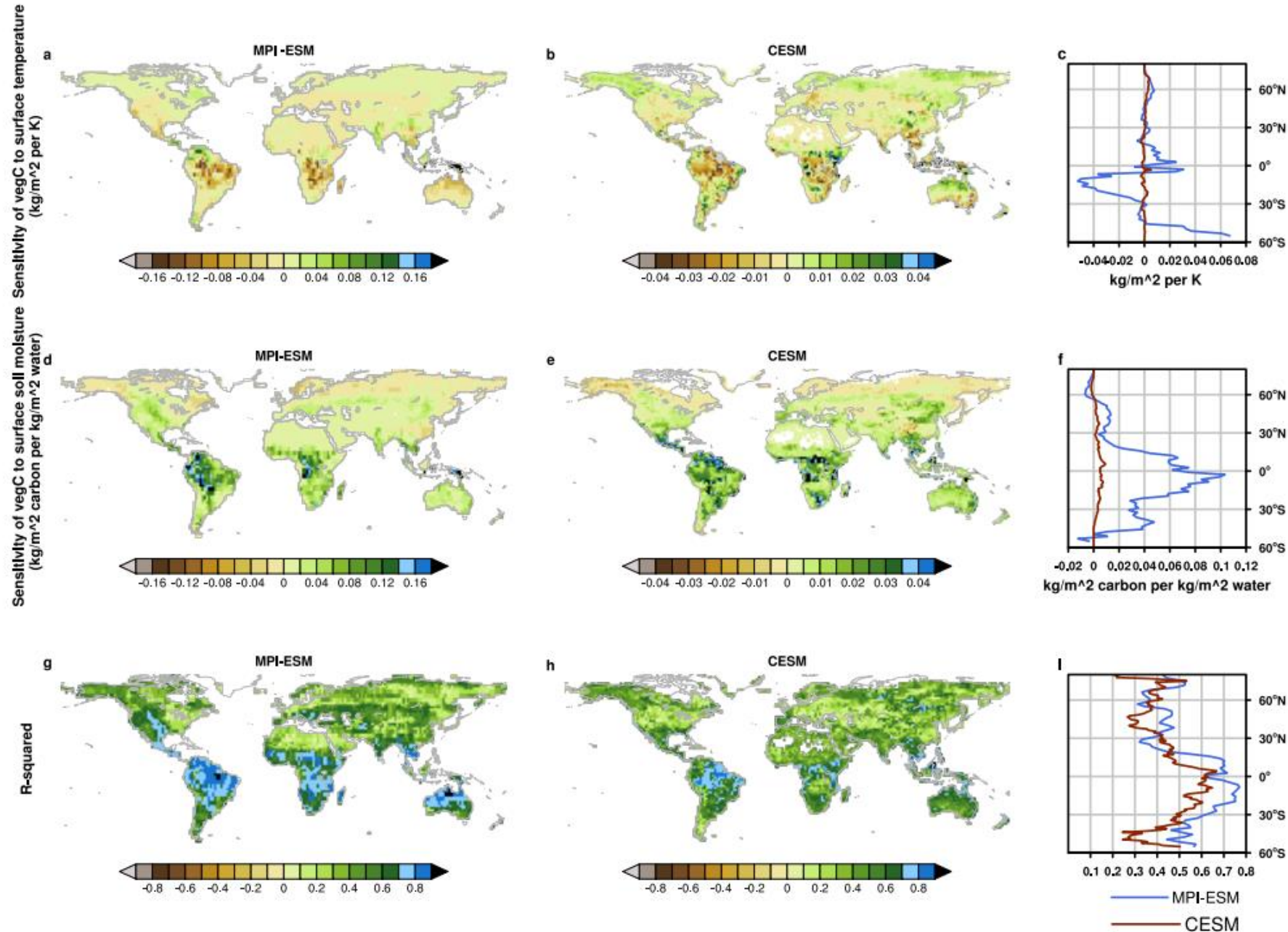
# Results: Time of emergence –vegetation carbon changes
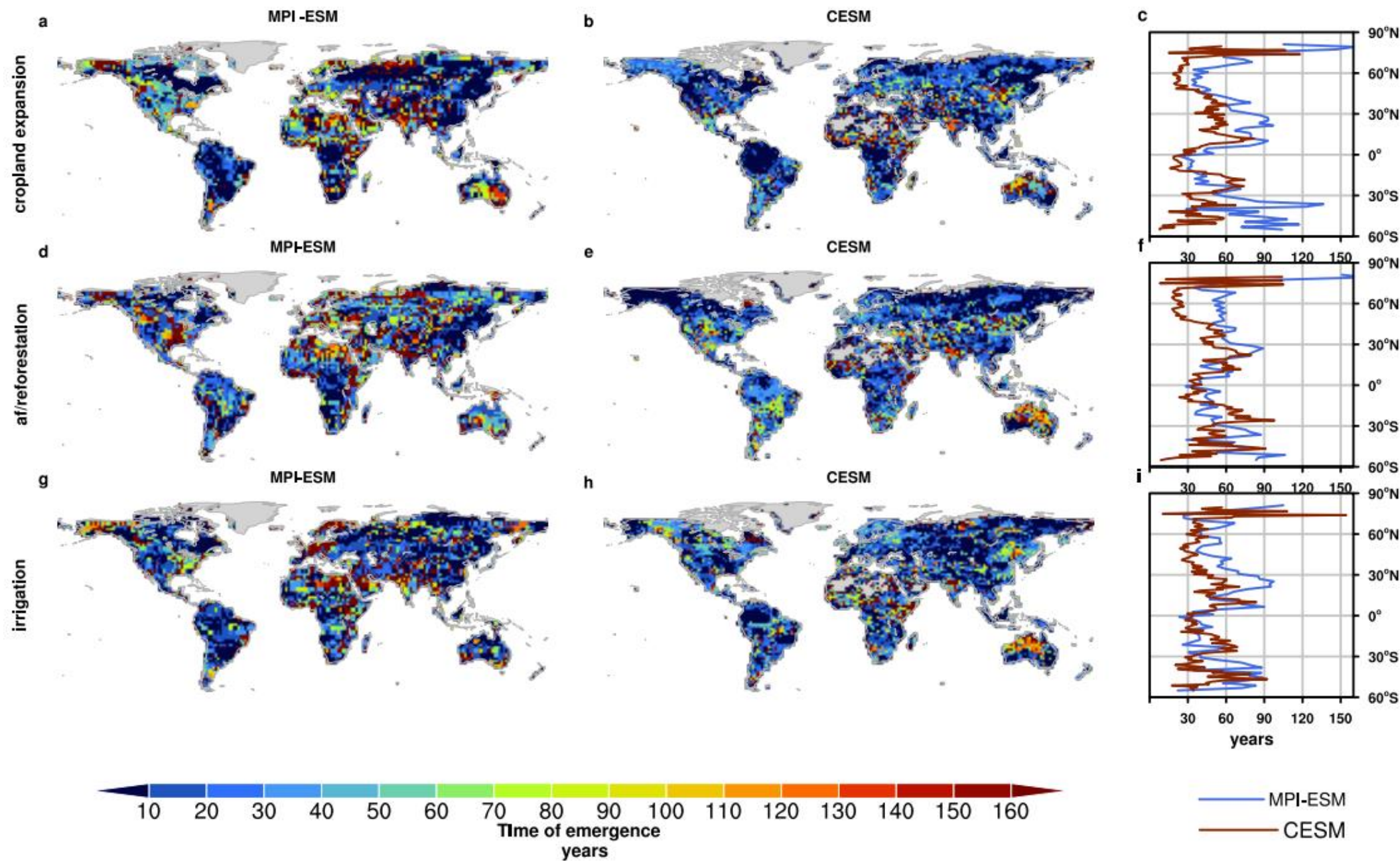
# Results: Attribution analysis–vegetation carbon changes–cropland expansion

# Take home messages

- The nonlocal BGC effect is prominent and cannot be ignored.
   Especially in forest regions and for irrigation scenario.

- The models are diverse in response magnitude but always consistent in the signal sign.

- TOE is always less than 40 years. For the forest region with large C stock changes, TOE is even less than ten years.

   **From a temporal perspective, it indicates the high accumulated effect, which further supports the non-negligible nonlocal BGC effect.**

- The model divergence comes from:

1.Different nonlocal climate changes caused by LMLCC

2. Magnitude difference of carbon cycle sensitivity to climate caused by the parameterization, land type, and land cover difference.