# A few thoughts on CABLE

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# Our goal

- Develop a world-class global land surface model that is competitive in comprehensiveness and performance
- Where we are now?
  - World class only in some parts; such as biophysical and biogeochemical processes
  - Poor and absent in other areas, crops, land management, soil hydrology …

# 1: Nonlinear soil microbial models

**Nonlinear soil microbial modeling has been a very hot topic for the last 2 years since Allison et al. (2010), Nature Geoscience. Microbes are important.**

Hagerty et al. (2012). Nature Climate Change. *MGE does not but microbial turnover rate increases with warming*
Wieder et al. (2013). Nature Climate Change. *Microbes are important.*
Frey et al. (2013), Nature Climate Change. *MGE declines with warming*
*Karhu et al. (2014). Nature. T-sensitivbity of microbe community increase SOC –T sensitivity*
*Sulman et al. (2014). Nature Climate change. Priming is important!*
*Tang and Riley (2014) Nature Climate Change. Microbial and abiotic interactions*

***What is the issue?***

# 1: Nonlinear soil microbial models

Linear soil carbon model: $dC/dt = \text{input} - \mu_1 C$

$$dC_b/dt = \varepsilon\, \mu_1 C - \mu_b C_b$$

Nonlinear soil carbon model: $dC/dt = \text{input} - \mu_1 C_b C/(C+K_c)$

$$dC_b/dt = \varepsilon\, \mu_1 C_b C/(C+K_c) - \mu_b C_b$$

**Why nonlinear models?**

- More realistically representing the process of carbon decomposition (an enzyme-facilitated biochemical process)
- Priming response
- More flexible response of soil carbon to warming and increased litter input

**However**

- Unrealistic oscillation (see Wang et al. (2014))
- Not validated as well as the linear models.

# Contrasting response to warming

Nonlinear model

$$C_b = \frac{\varepsilon I}{\mu_b}$$

$$C = \frac{K_c}{\frac{\varepsilon}{\mu_b}\mu_l - 1}$$

Linear model

$$C_b = \frac{\varepsilon I}{\mu_b}$$

$$C = \frac{I}{\mu_l}$$

*In response to warming*

*Nonlinear model:* $\varepsilon\downarrow$ *or* $\mu_b\uparrow$, or both, $\rightarrow C\uparrow$;

*Linear model:* $\mu_l\uparrow$ $\rightarrow C\downarrow$;

# The controversy: SOC in a warmer world?

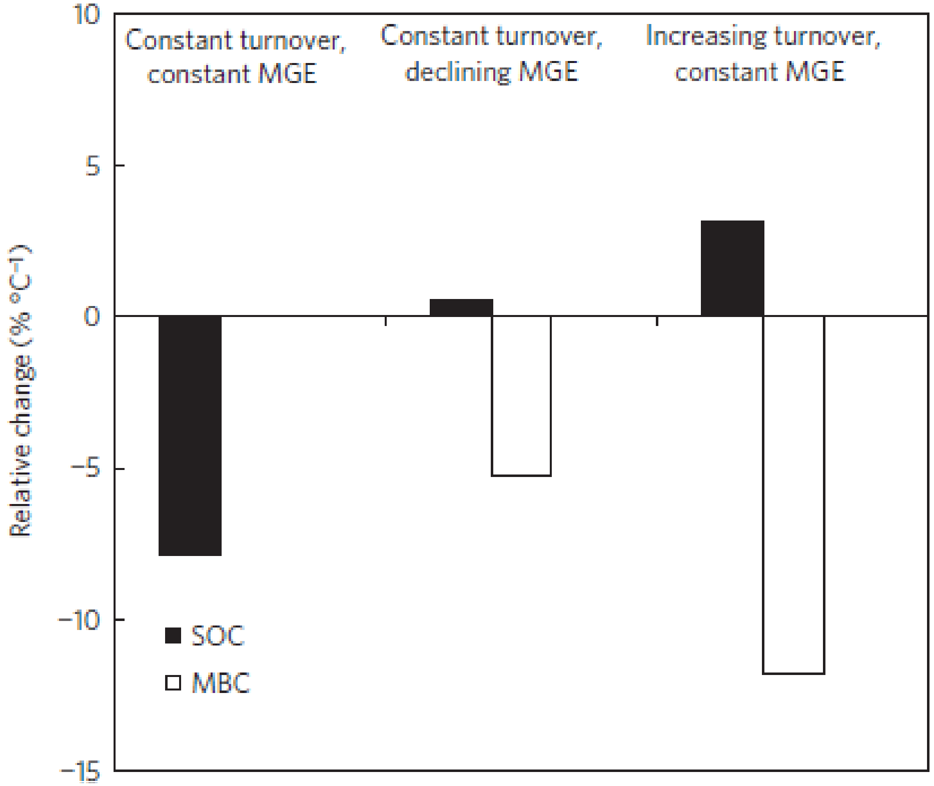



**Figure 4 | The relative change in soil organic C (SOC) and microbial biomass C (MBC) from 5 to 20 °C under three scenarios using the AWB model.** In the constant turnover, constant microbial growth efficiency (MGE) scenario there is no change in MBC with temperature.

Source: Hagerty et al. NCC 2014

# 2. Root functioning

Root functions in uptake of water and nutrients are poorly represented in nearly all global land surface models.

Tuzet-Leuning model:

$$g_{co2} = g_0 + \frac{aA}{c_i - \Gamma} \cdot f_{\psi v}$$

$$f_{\psi v} = \frac{1 + \exp[s_f \psi_f]}{1 + \exp[s_f(\psi_f - \psi_v)]}$$

**Advantage**:

- More realistically linking soil water supply with stomatal conductance;
- Observations are available for sapwood conductance as one of key plant traits;
- Can simulate mid-day depression of stomatal conductance

# 3. Disturbance and nutrient cycling

**Questions: what happened to litter and soil N and P during and after fires?**

**Table 3** Percentage reduction in indices of N cycling caused by five repeated low-severity fires applied at three yr intervals, compared with the absence of fire for 14 yr (after Raison et al. 1993a).

| N cycling indicator | Reduction (%) |
|---|---|
| N mineralization – soil | 50(a) |
| – litter | 57 |
| N concentration in expanded leaves | 13 |
| N stock in foliage | 17 |
| N in annual leaf fall | 17 |

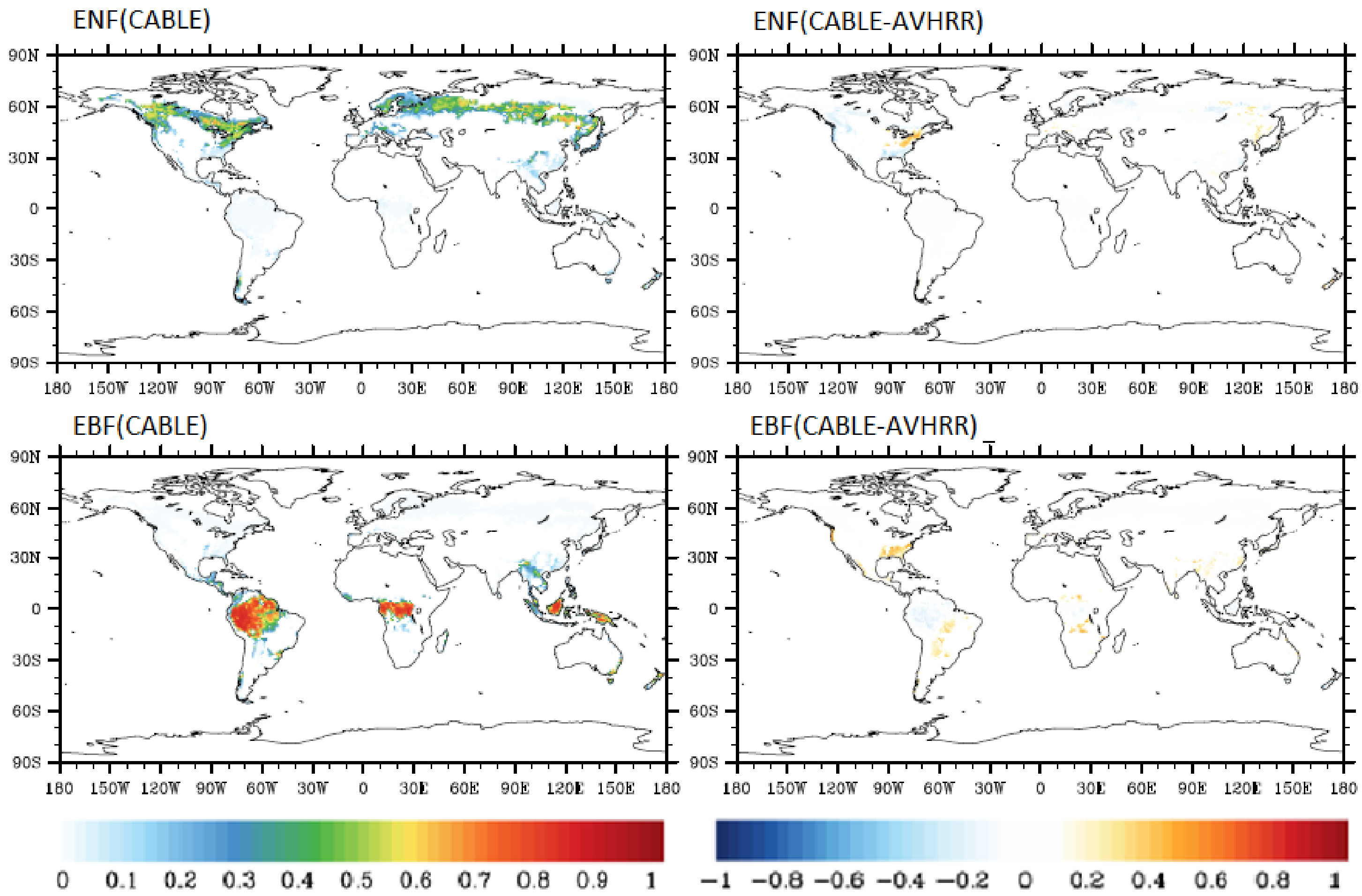
(a) 35% reduction after two fires, each 7 yr apart.

**If fire frequency and intensity will change with climate change, so will the effects of fire on forest nutrient cycling.**

# Trait-based plant functional types

- Global database of key plant traits now **are available** and have been **used** to analyze the costs and benefit of different plant strategies, GPP globally (Wright et al. 2004; Wang et al. 2012);
- Use of traits provide a **more objective** approach to define plant functional types and changes in the types and to simulate competition among different PFTs under past, present or future climate conditions;
- Reduce the empirical relationships in the current DGVM;
- Australia has some **world leaders** in the field

# A few key traits can explain the biogeography of evergreen forests




LU et al. unpublished data

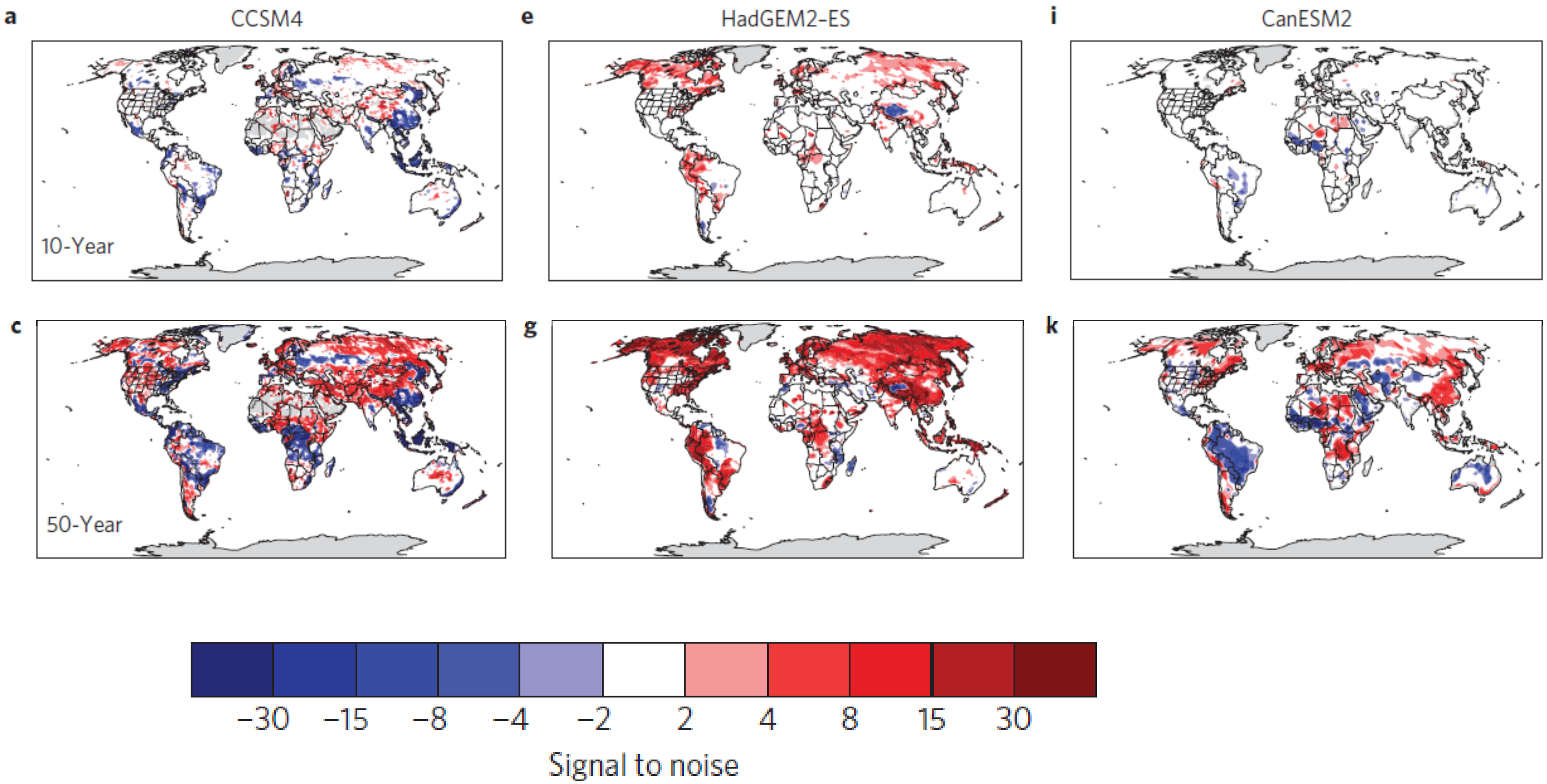
# More ensemble simulations

**Why do we need ensemble simulations**?

•To address model uncertainties from observations, parameter values and model formulations.

•It is particularly important for identifying signals from noisy data, such as large differences in the from different models, or one model with different parameters

# Detecting the signal of land NEE trend under a noisy climate forcing




Source: Lombardozzi et al. 2014, NCC

# CABLE applications

- Interactions with the integrated assessment models (IAMs):
- many questions in climate mitigation can not be addressed by the current ESMs alone, such as
  - how much land can we use for sequestering carbon?
  - Alternative energy sources?

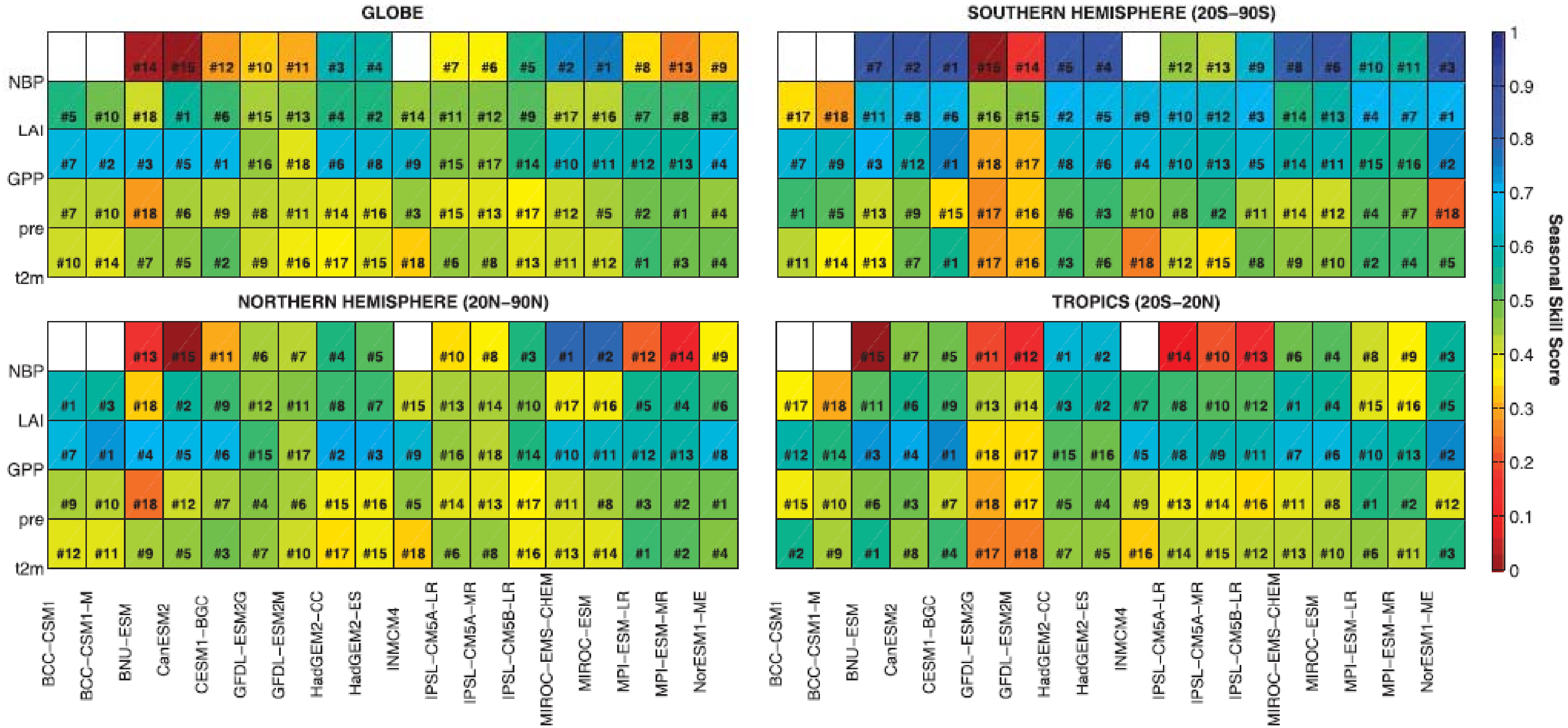
# Model benchmarking: beyond flux towers

TABLE 4. Observationally based datasets used to validate models. The spatial resolution is given as latitude × longitude.

| Variables | Reference | Temporal window | Spatial resolution | Temporal resolution |
|---|---|---|---|---|
| Temperature | CRU (Mitchell and Jones 2005) | 1901–2006 | Global (land), 0.5° × 0.5° | Monthly |
| Precipitation | CRU (Mitchell and Jones 2005) | 1901–2006 | Global (land), 0.5° × 0.5° | Monthly |
| SST | HadISST (Rayner et al. 2003) | 1870–2011 | Global, 1° × 1° | Monthly |
| MLD | de Boyer Montégut et al. (2004) | 1941–2008 | Global, 2°×2° | Climatology |
| GPP | MTE (Jung et al. 2009) | 1982–2008 | Global, 0.5° × 0.5° | Monthly |
| LAI | LAI3g (Zhu et al. 2013) | 1981–2011 | Global, ~0.08° × ~0.08° | 15 days |
| NBP | Inversion (Gurney et al. 2004) | 1995–2008 | Global, 0.5° × 0.5° | Monthly |
| | GCP (Le Quéré et al. 2009) | 1959–2008 | Global, spatial average | Yearly |
| Soil carbon | HSWD, (Nachtergaele et al. 2012) | — | Global, 1 km × 1 km | Annual value |
| Vegetation carbon | NDP-017b (Gibbs 2006) | — | Global, 0.5 × 0.5 | Annual value |
| $fgCO_2$ | Inversion (Gurney et al. 2004) | 1995–2008 | Global, 0.5° × 0.5° | Monthly |
| | GCP (Le Quéré et al. 2009) | 1959–2008 | Global, spatial average | Yearly |
| | Takahashi (Takahashi et al. 2009) | 2000 | Global, 4° × 5° | Climatology |
| NPP | SeaWiFS. (Behrenfeld and Falkowski 1997) | 1998–2007 | Global, 6 × 6 km | Monthly |

Global dataset of carbon cycle benchmarking. Source: Anav et al. 2013

# Model score




Anav et al. 2013 J of Climate

# Final comments

- It has been a journey of learning for all of us
- We must continue to work together and be creative and active internationally with
  - Original ideas
  - Novel applications