# How much biology does GCOS need?

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# Lesson from Earth System Science

The unique properties of our planet arise from interactions between physics, chemistry and life

- The diagnostic difference between Global Climate Models (GCM) and Earth System Models (ESM) is the representation of biological pools and fluxes
- The ubiquitous presence in biology of strong non-linearities, regulatory feedbacks and adaptation is important source of potential abrupt change, in policy-relevant timescales

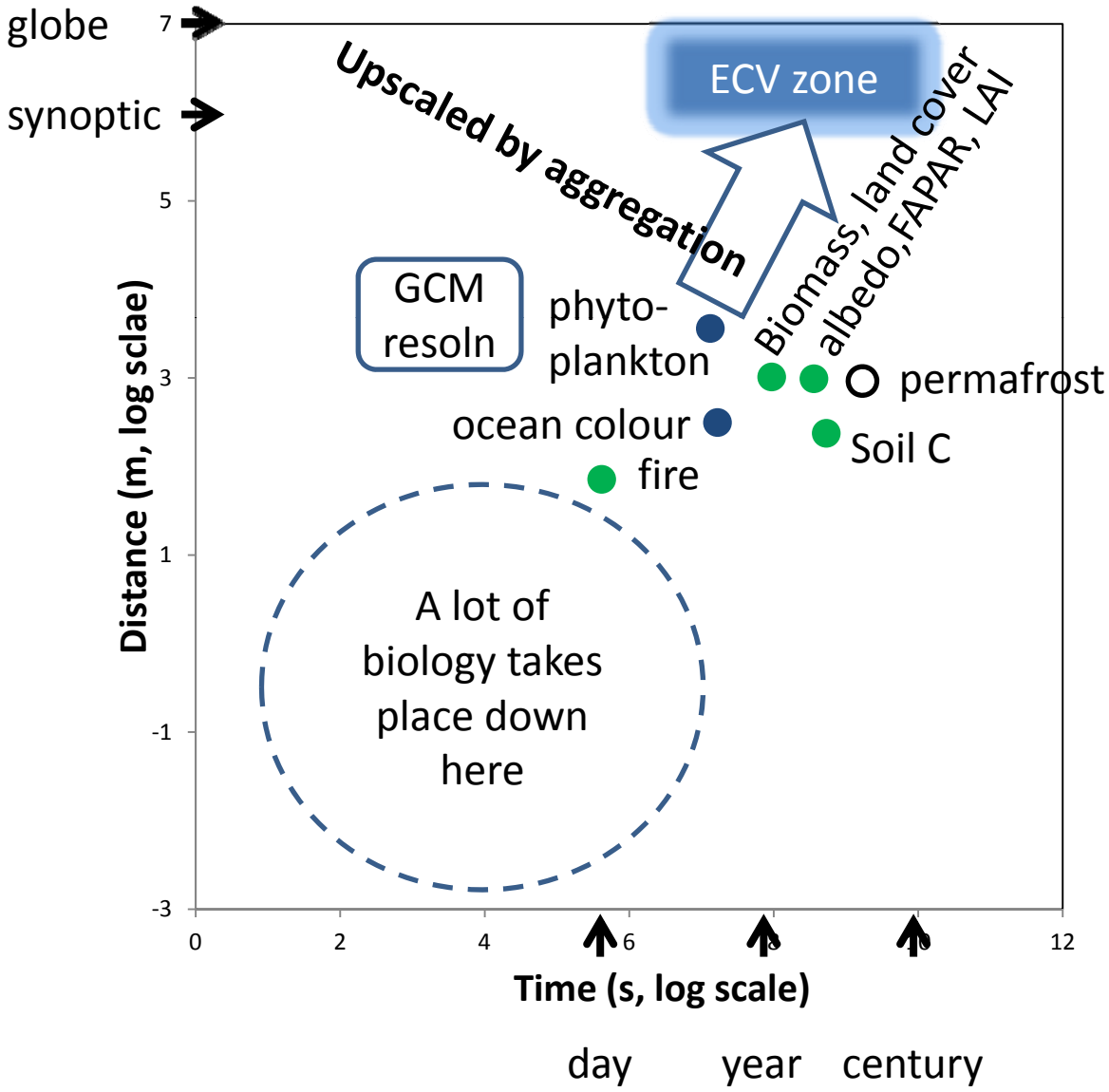
# Biology in the GCOS ECVs

**(Biology includes everything from ecosystems down to genes)**

- Processes material to the global C cycle
  - Land+cryosphere <>atmosphere flux ~100 Pg/y (~-2.5 net)
    - Madelled Assimilation (FAPAR) but not Respiration other than Fire
  - Ocean<>atmosphere flux ~60 Pg/y (~-2.5 net)
    - Modelled Assimilation and inferred export to deep ocean
  - [net Anthropogenic flux ~ 10 Pg/y, ~1-2 from LUC]
    - Land use, Soil C and Aboveground Biomass
- Processes controlling  the surface energy balance
  - Albedo, leaf area

# Space and time as a filter

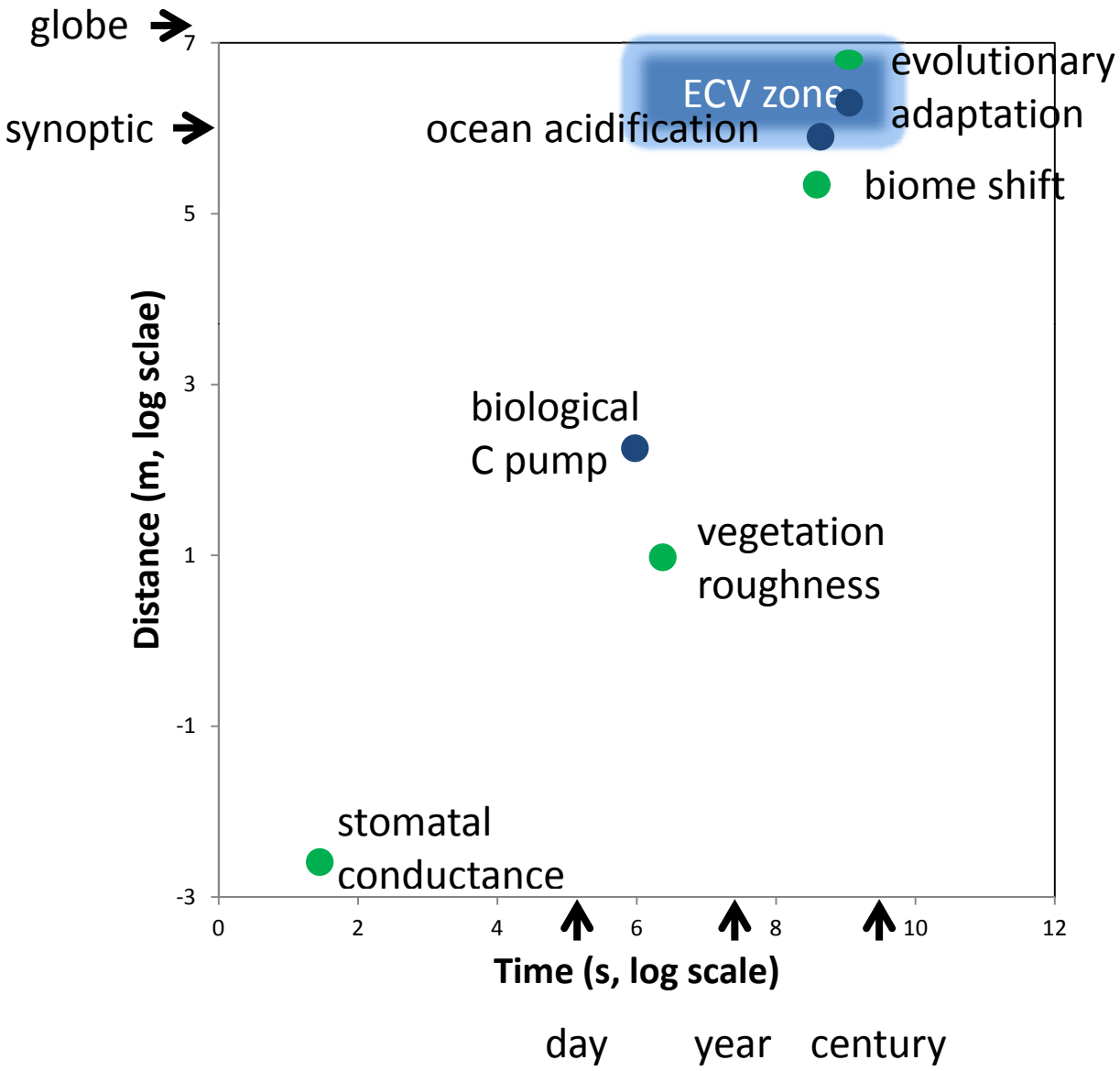
## to identify those observations that need to be monitored



# Current status of 'biological' ECVs

| Essential Climate Variable | Status Space RS In situ | Spatial resol-ution and scale | Temporal revisit and duration of record | Accuracy (100-%error) |
|---|---|---|---|---|
| **Land cover** | **Operational** | ~1 km global | 5 year since 1990 | ~80% |
| **FAPAR** | **Semi-operational** | 300m over land | 8 day since 2000 | ~90% |
| **LAI** | **Semi-operational** | 300m over land | 8 day since 2000 | ~75% |
| **Albedo** | **Operational** | 0.3-20 km | Daily since 2000 | ~95% |
| **Aboveground Biomass** | **Research** | ~100 m over land | ~5 yearly since 2005 | ~70% |
| **Soil C** | **Sparse in situ, modelled** | Variable, interpolated | Essentially single time | ~65% |
| **Fire** | **Operational** | ~1km, worldwide | Daily since 2000 | ~85% |
| **Ocean colour** | **Operational** | ~300m, water | 8 daily since 2000 | ~95% |
| **Phytoplankton** | **Partly operational Research** | Patchy in situ 300m RS | Seasonal since 8 daily since 1994 | ~60% |
| Permafrost | Research | | | ~60% |

# Some other processes to consider



# Methane and other GHGs

**Biology is important in most. The concentration trends are well observed, but attribution to sources is inferred , and thus weakens projection**

| GHG | Forcing ($Wm^{-2}$; % of net) | Biogenic fraction of total cycle | Current estimation method+ error (only indirectly observed) |
|---|---|---|---|
| Carbon dioxide | 1.82 ± 0.19 79% | Dominant | Inferred from FAPAR, temp, LC, ocean colour |
| Methane | 0.48 ±0.05 20% | Major | Infer from LC, soil moisture and temperature |
| Nitrous oxide | 0.17 ± 0.03 7% | Major | Infer from LU, soil moisture and temperature |
| Ozone | 0.40 ± 0.20 17% | Substantial | Fires, plant functional type, LAI, temp |
| DMS | Small, indirect | Entire | Phytoplankton, ocean colour |

**Conclusion:**

**There is little incentive to put major effort into other GHGs while the $CO_2$ remains the dominant uncertainty. Ozone would then be the next target**

# Biological processes not yet included

**with climate system feedbacks capable of inducing abrupt change**

- **Soil respiration**
  - In particular, its temperature sensitivity
- **Ocean acidification**
  - coccolithophores as a key particulate flux
  - coral reefs as a defence against increasing storm severity
- **Permafrost vulnerability** and **post-melt fate**
  - The insulation provided by vegetation is critical
  - Will emissions occur as $CO_2$ (upland) or as $CH_4$ (lowland bog)?

# Slow but widespread change

Physiological, phenological, dispersal and evolutionary adaptation

- Resilience theory suggests that it is a gradual shift in ‘slow variables’ that typically results in regime change
- These slow variables are currently parameterised rather than monitored
- **Physiology**: the effects of rising $CO_2$ on stomatal conductance and ocean pH on calcification
- **Dispersal**: biome shift (=species composition change at the level of dominant functional types)
- **Evolution**: selection for new temperature optima and limits (especially in soil microrganisms)

## Climate matters to species, but

# do species matter to the climate?

- Community shift, independently of abundance, impacts carbon and water cycle dynamics through changes in parameters
- Biodiversity is summarised in ESMs at the level of broad functional groups
  - DVGMs and ocean biogeochemical models are becoming more sophisticated, and will soon grow out of simplistic approaches
- GEOBON is developing ‘Essential Biodiversity Variables’ which will allow quantification of tait attributes and detection of changes

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