MAX PLANCK INSTITUTE
FOR BIOGEOCHEMISTRY

ICON-Land: Current development lines

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ICON-LAND

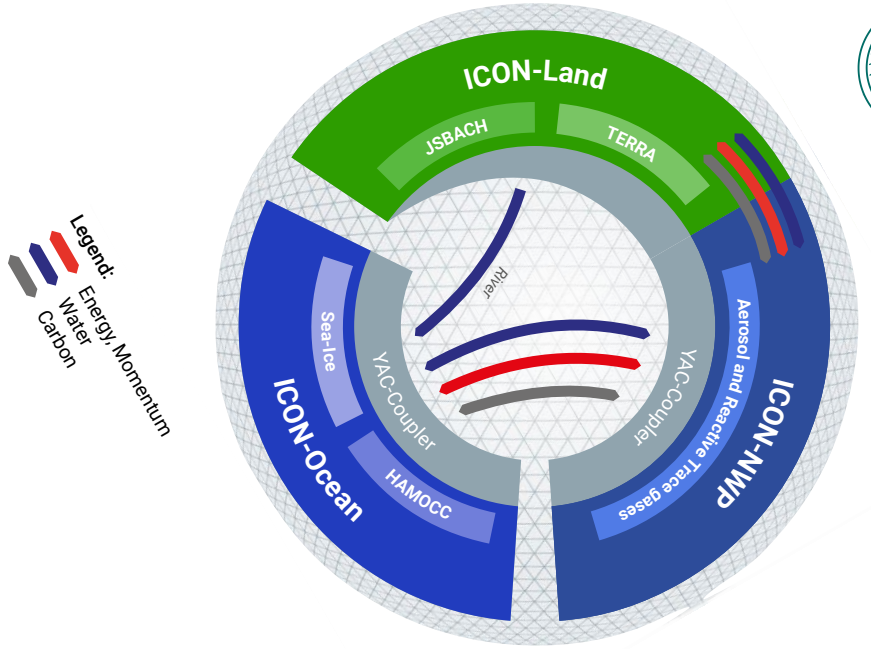
Framework for modelling land processes in ICON

Goals

Integration of concurrent process and surface descriptions in a flexible and easy-to-use way

Separate the infrastructure required to implement physical, bio-geophysical and bio-geochemical land processes from concrete process implementations accessed by abstract interfaces

Support various experimental configurations regarding scope and complexity, spatial and temporal extend, offline as well as coupled



ICON-Land is developed by a consortium:

- Victor Brovkin (MPI-M)
- Cathy Honegger (MPI-M)
- Julia Pongratz (LMU)
- Linda Schlemmer (DWD)
- Reiner Schnur (MPI-M)
- Sönke Zaehle (MPI-B)

ICON-LAND DEVELOPMENT LINES

Phase I: Integration of

- DWD (TERRA)
- MPI-M (JSBACH4)
- MPI-B (QUINCY)

models into ICON-Land with common coupling scheme (VDIFF)

Phase II: Consolidation of redundant code parts

- Hydrology
- Surface physics
- …
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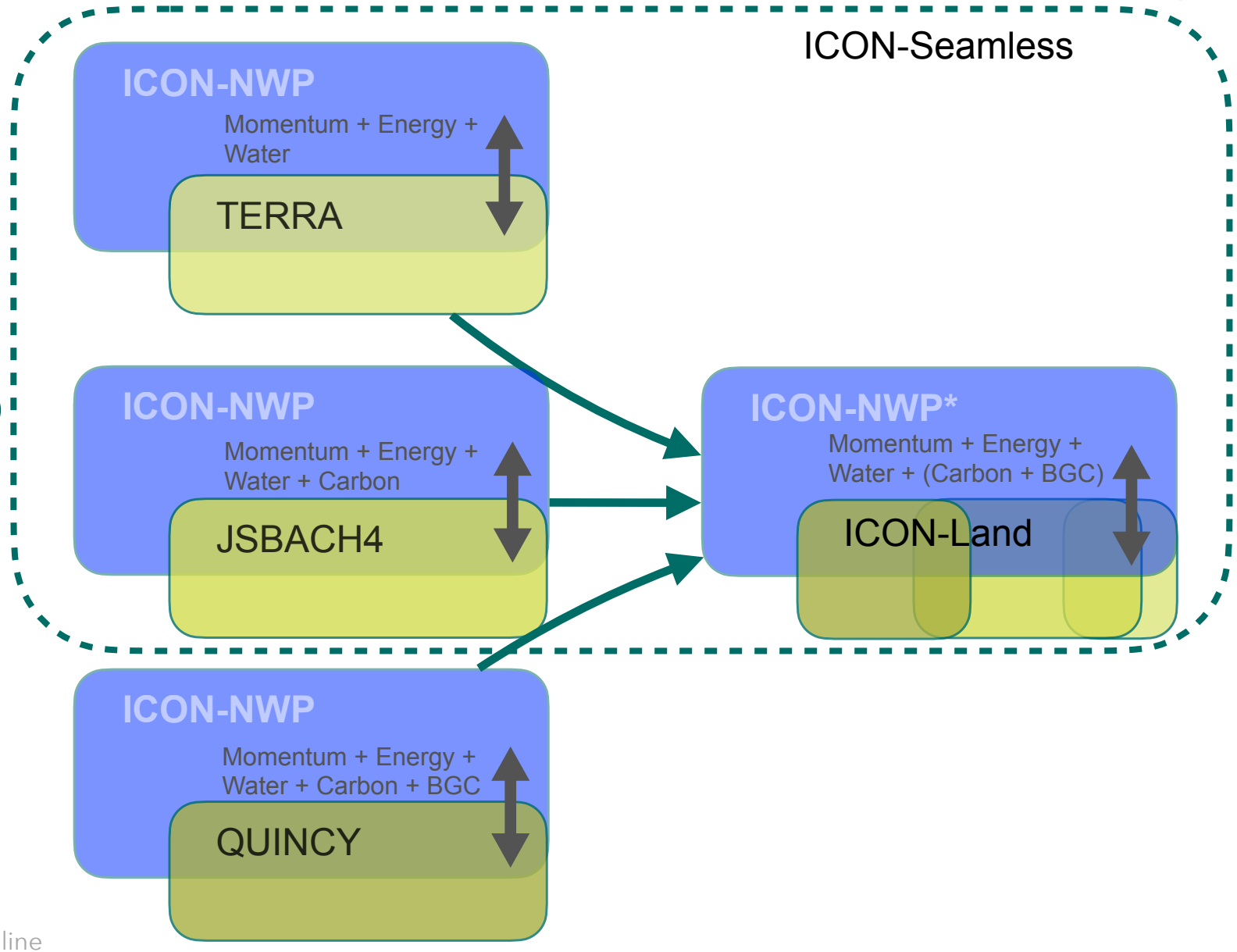

JSBACH4 WITHIN ICON-LAND

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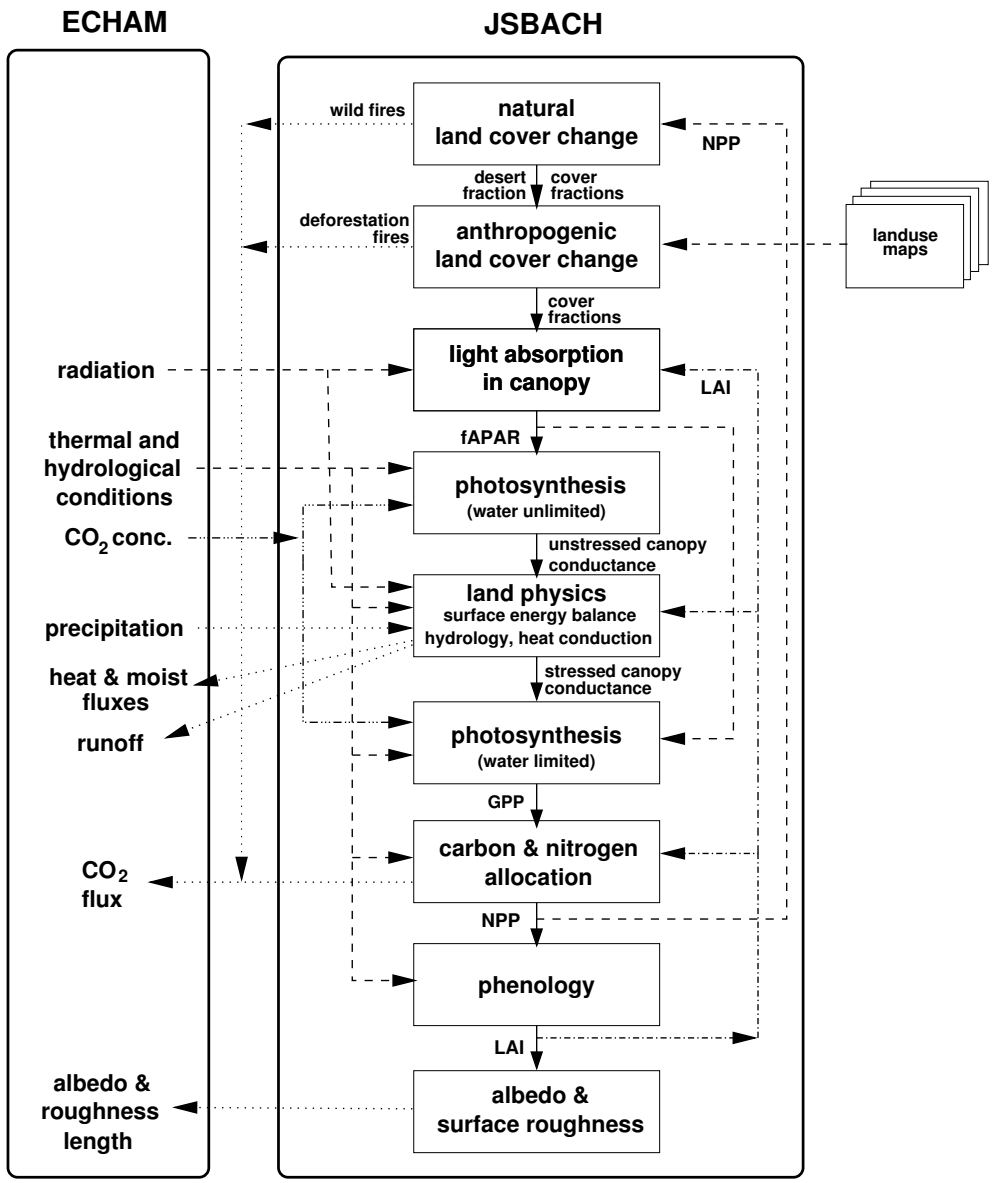
FÜR METEOROLOGIE

Processes included:

- Surface energy balance (implicitly coupled to atmosphere)
- Multi-layer soil + snow model for temperature and moisture
- Lakes: simple scheme for water temperature, ice thickness temperature, and snow
- Hydrologic discharge (HD): freshwater flux from land into oceans, coupled via YAC
- Phenology (LAI): leaf growth and shedding rates under environmental conditions
- Photosynthesis: Balance of assimilation and water loss via stomata
- Natural carbon cycle: transport of carbon through pools in vegetation and soil
- Natural disturbances of vegetation by fires and wind throw
- Land cover change (LCC)
  - Anthropogenic LCC by reading annual maps of cover fractions based on agricultural change
  - Natural LCC: dynamic vegetation based on bioclimatic limits

Nabel et al. 2020, GMD,
Schneck et al. 2022, GMD,
available under the MPI-M license

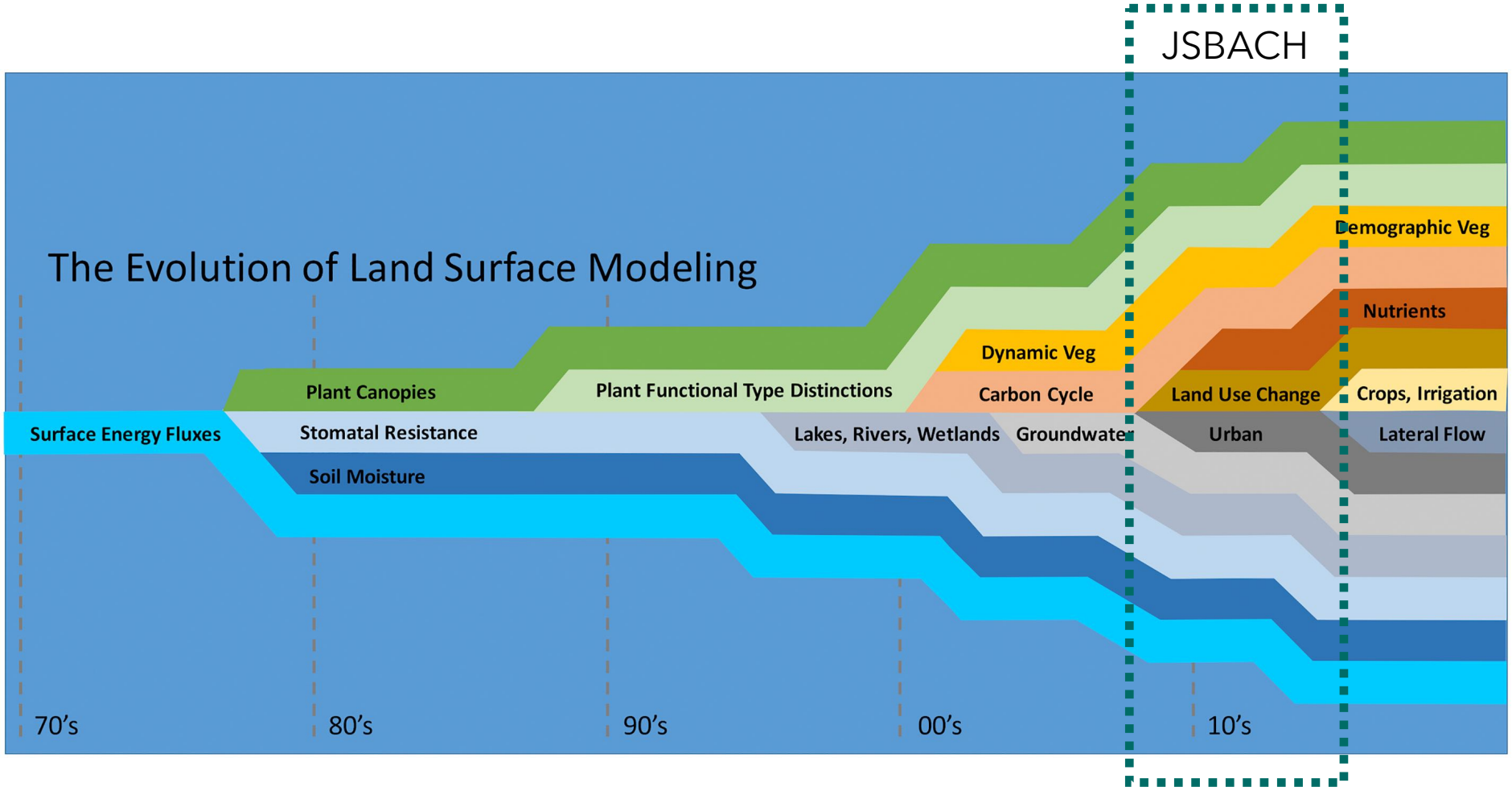
Version used within ICON-seamless



THE EVOLUTION OF LAND-SURFACE MODELLING

Increased complexity to better represent biosphere in climate models

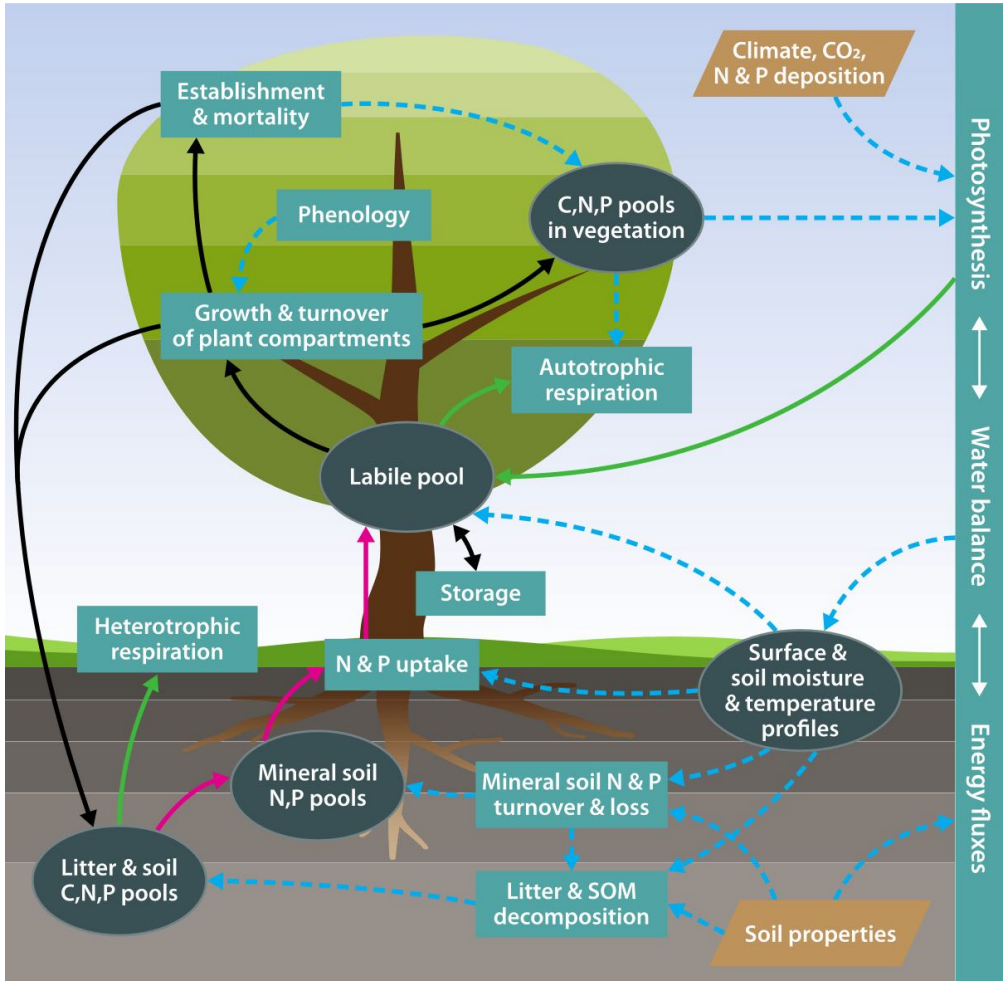
Increased diversity of purpose (process understanding, climate modelling & impacts, …),



- Versatile tools to study the biosphere
- "One model fits all" leads to code monsters that no-one can handle
- Reliance of old modules that may not reflect recent understanding

Fisher & Koven (2020)

QUINCY - NEW "BIOLOGY" MODEL FOR ICON-LAND



Thum et al. 2019, GMD, Yu et al. 2020, GMD,
available under the BSD-3-license consistent with MPI-M

Surface energy balance, Multilayer soil physics, Lakes and HD. Land cover change (LCC) (similar to JSBACH4)

Purpose

- Testbed for new process understanding relevant at climate scales (but typically starting at site / process level)
- Focus: seamless integration of the coupled carbon-nitrogen-phosphorus cycles into biogeophysical calculations
- Multi-constraint approach / ensembles
- By design modular
- Written to be part of ICON-Land

Multi-layer snow model + simple permafrost

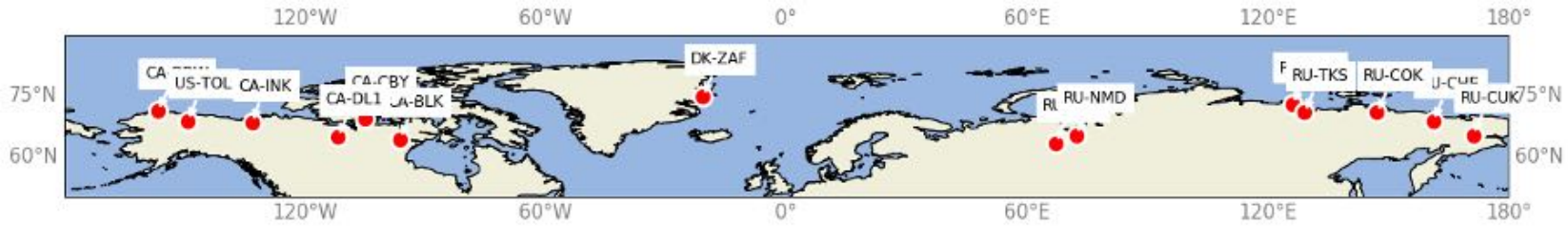
Phenology (LAI): dependent on plant physiology, stand properties and biogeochemistry, and trade-off between root and leaf growth

Photosynthesis: coupled N-P limited assimilation and water loss taking into account diffuse and direct radiation / sunlit and shaded leaves / plant buffering capacity

Natural biogeochemical cycles: coupled carbon-nitrogen-phosphorus biogeochemistry affecting plant growth and allocation, soil and litter dynamics, including stable C and N isotopes

Emission and deposition of N-trace gases (eg. NO_x, N_2O)

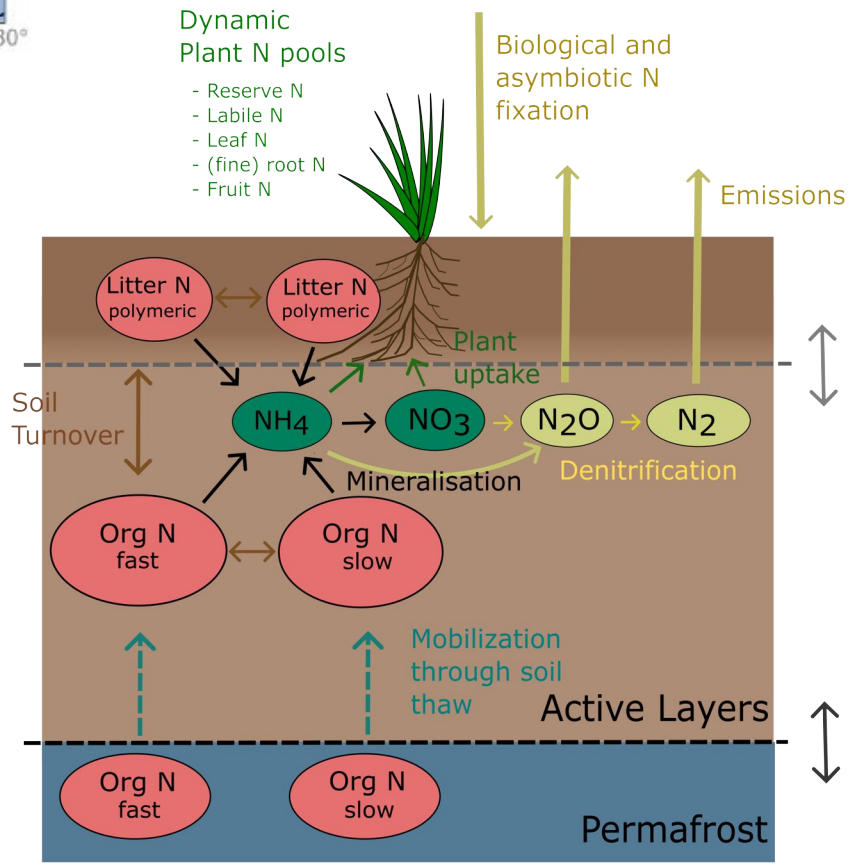
NUTRIENTS, PERMAFROST THAW & GHG-BALANCE



Aim: Evaluate permafrost thaw effect on nutrient dynamics

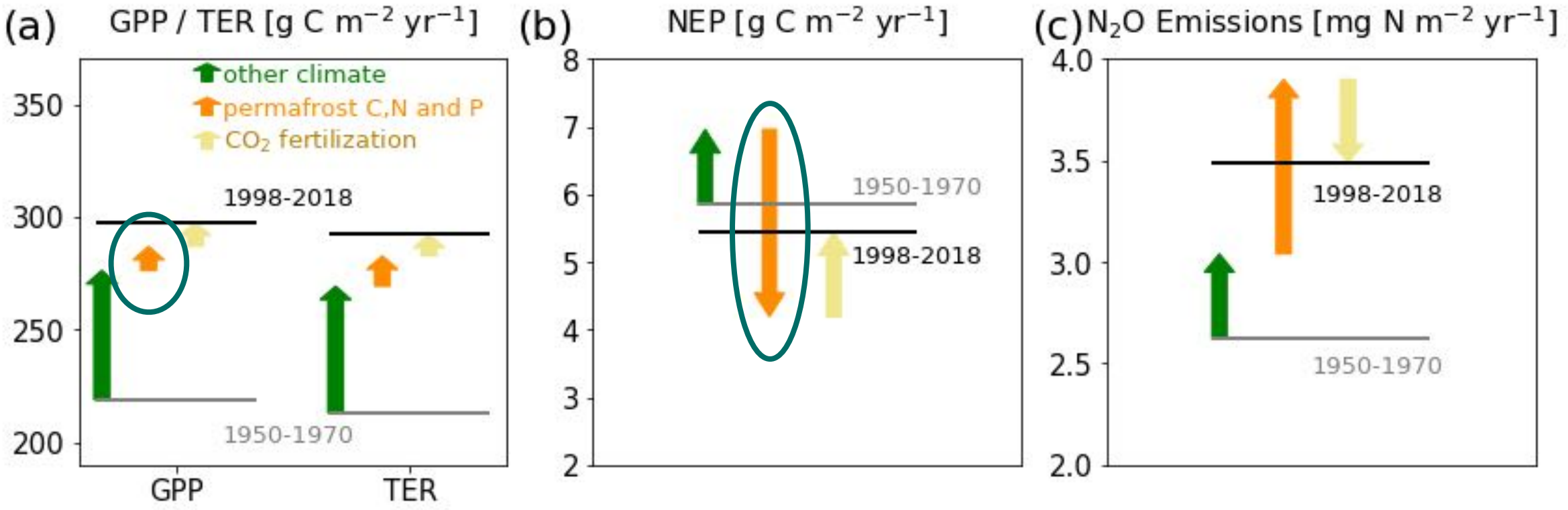
Coupled CNP-biogeochemistry of QUINCY with ICON-Land-like high-latitude physics (snow, permafrost, …)

- Increased thaw-depth increases organic matter decomposition
- Increased nutrient availability reduces nutrient limitation of vegetation
- Increases C uptake of these ecosystems in response to both CO_2 and climate change



Lacroix et al., 2022

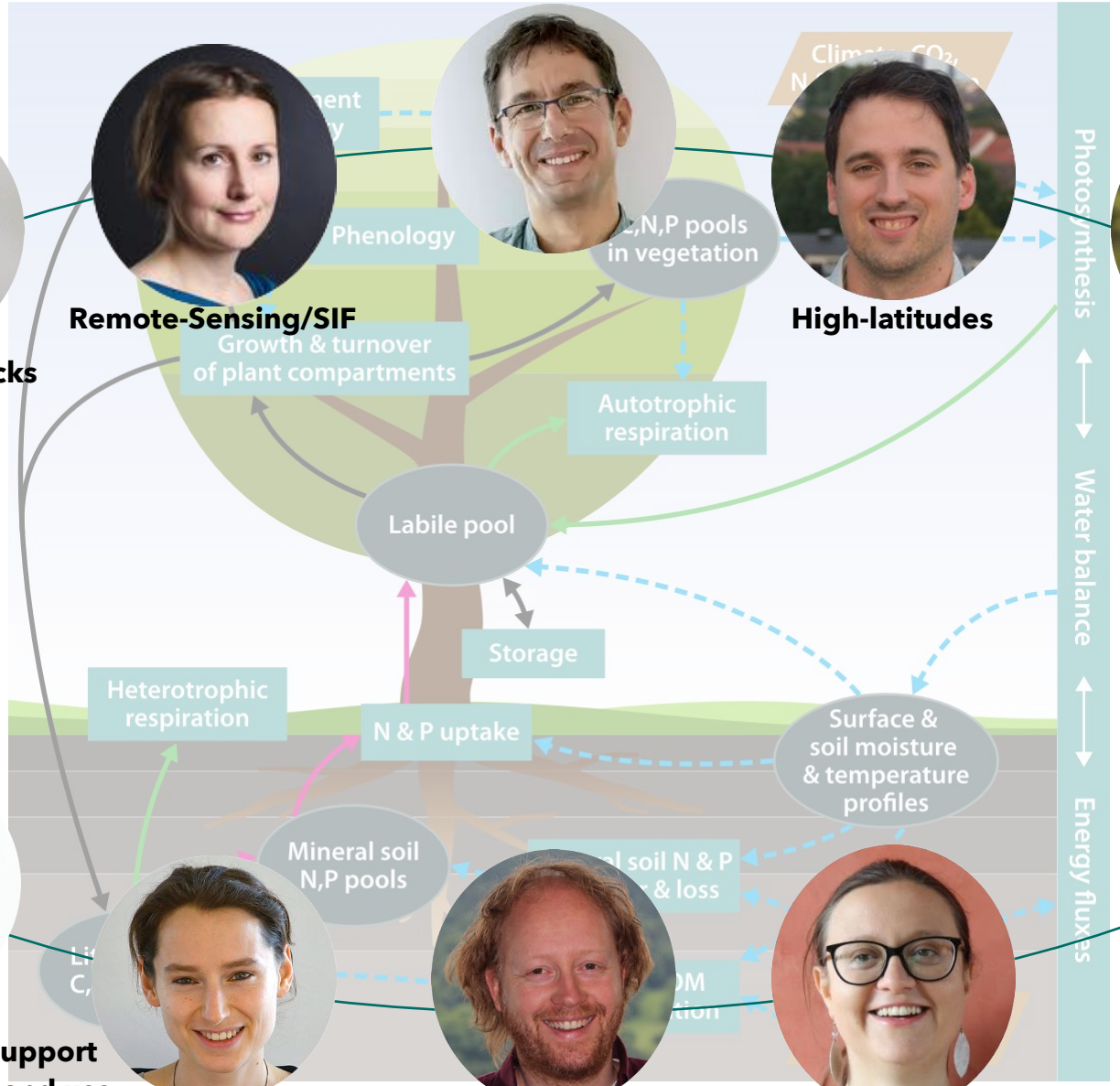
NUTRIENTS, PERMAFROST THAW & GHG-BALANCE



Nutrient release from permafrost thaw enhances growth
and thereby ± compensates for C loss from increased C loss,
but also leads to an increase in N_2O emissions

Lacroix et al., 2022

QUINCY - NEW "BIOLOGY" MODEL FOR ICON-LAND



Nitrogen feedbacks

Remote-Sensing/SIF

High-latitudes

Tropics

Plant-hydraulics & Drought

Soil processes

Disturbances

Soil-Vegetation Interactions

Computing support Disturbances

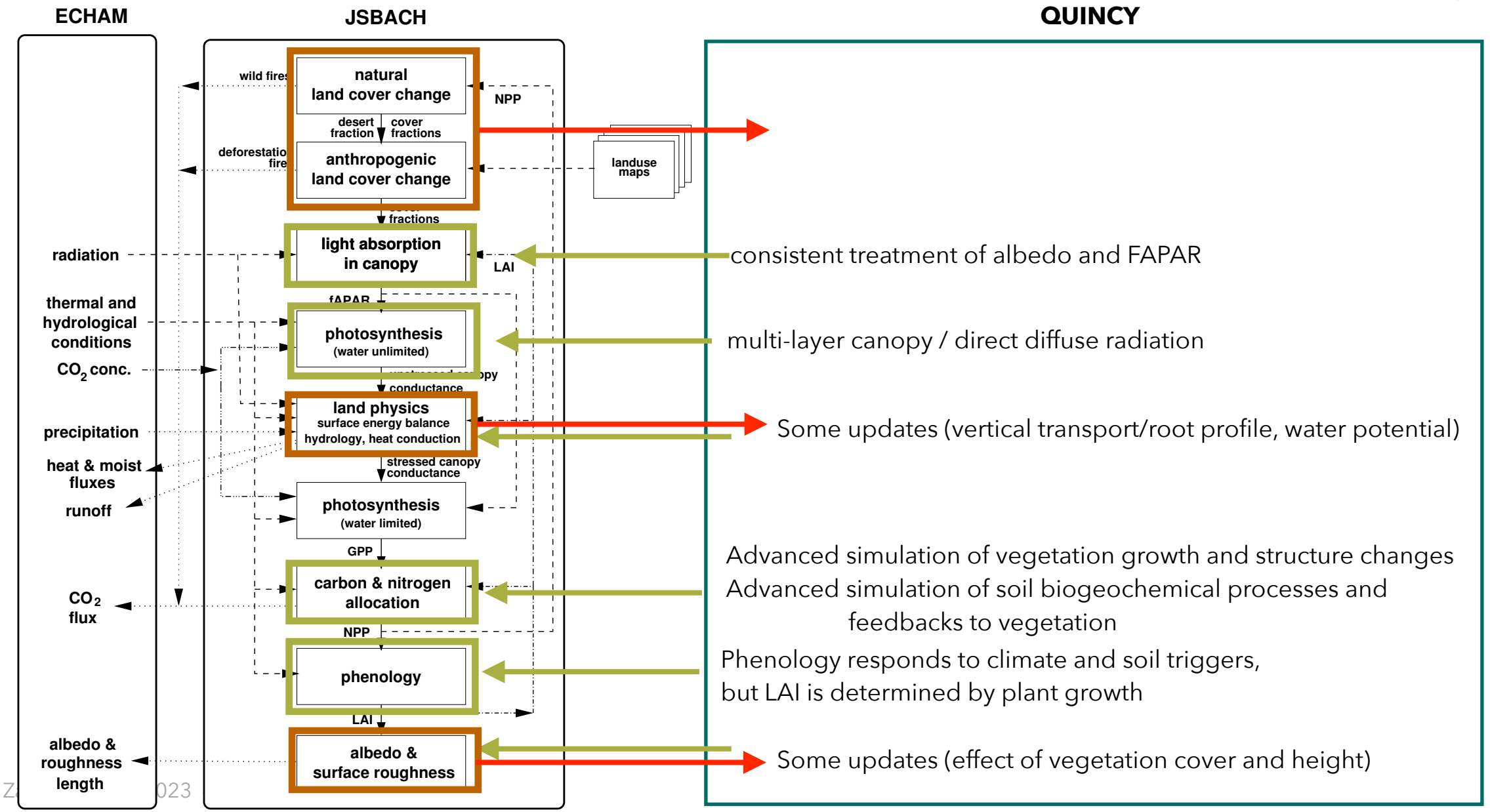
Plant nutrient use

Computing support ICON-Land / Land use

Computing support Infrastructure / QUINCY

Plant strategies & Acclimation

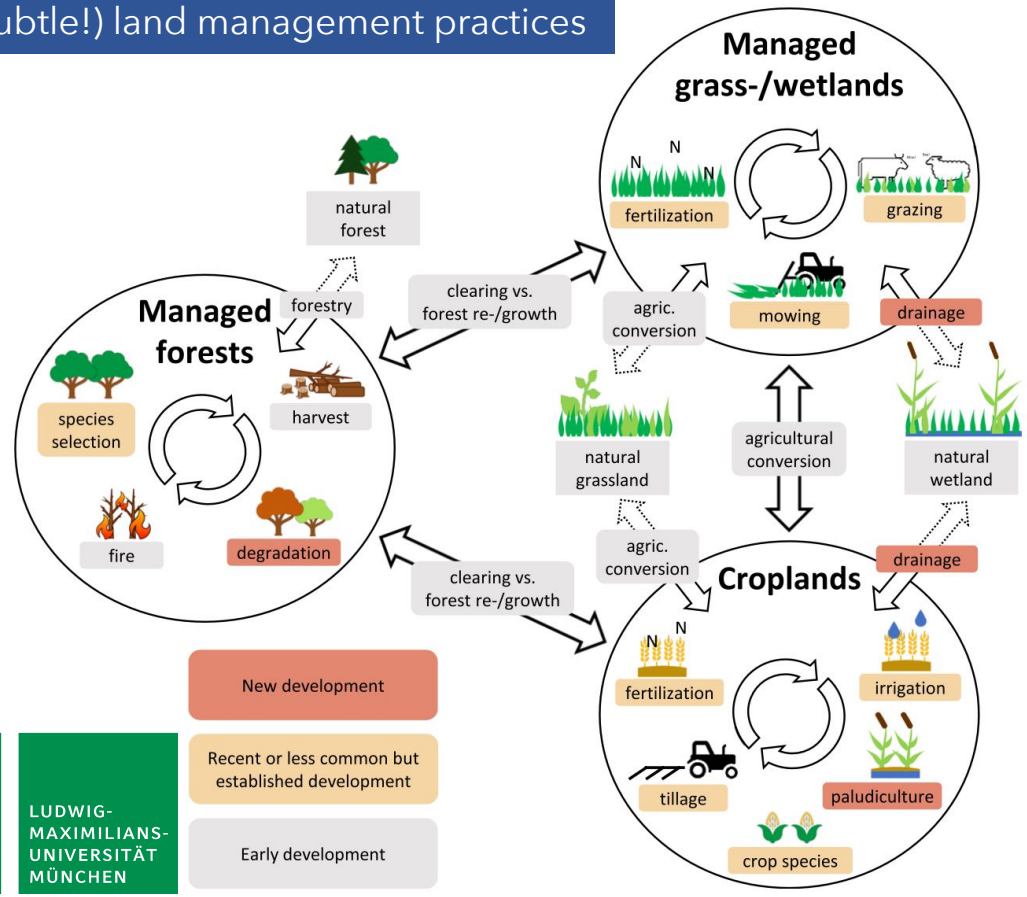
ICON-LAND JSBACH4 VS QUINCY



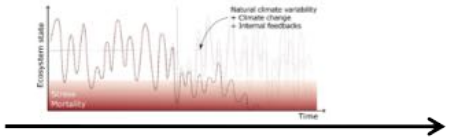
CHALLENGE: THE UGLY REALITY ON PLANET EARTH

Land-use change, land management and disturbance dynamics

Land use representation in Earth System Models moves beyond changes in vegetation types towards (only presumably more subtle!) land management practices



Integration of disturbance dynamics with nutrient cycles to capture long-term effects of disturbance regimes on climate



Historical and future scenarios
Explore uncertainty from internal variability

SPITFIRE
(prognostic hazard and impacts)

Insect and wind impacts

Prognostic insect and wind hazards

Drought impacts

2022/3 → 2024 → 2025 → 2026 → 2027

ForEXD
Forest vulnerability to compound extremes and disturbances in a changing climate

erc European Research Council

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

MAX-PLANCK-INSTITUT FÜR BIOGEOCHEMIE

ICON-LAND IN A NUTSHELL

ICON-Land: generic modelling framework for land processes

- operational JSBACH4 implementation
- Plan to integrate the NWP model TERRA
- “pre-operational” QUINCY implementation
- Unique opportunity to develop a modelling system that driven by complementary expertise
  - More players (MPIM, DWD, Uni, MPIB): development more challenging as in the past
  - Needed: define adequate complexity for specific applications

- QUINCY focus on „biology“ effects on land-surface processes and associated climate feedbacks, which should „seamlessly“ interact with relevant JSBACH4 processes
  - Tool to get fundamental land processes in the Earth system right
  - Interactions between vegetation and soil (both biogeochemistry, and water cycle)
  - Response to and lag-effects following climate variability/extremes
  - Advance theoretical understanding for known global patterns / process responses (esp. regarding biodiversity)

Thank you for your attention !!