

DOOS Science questions

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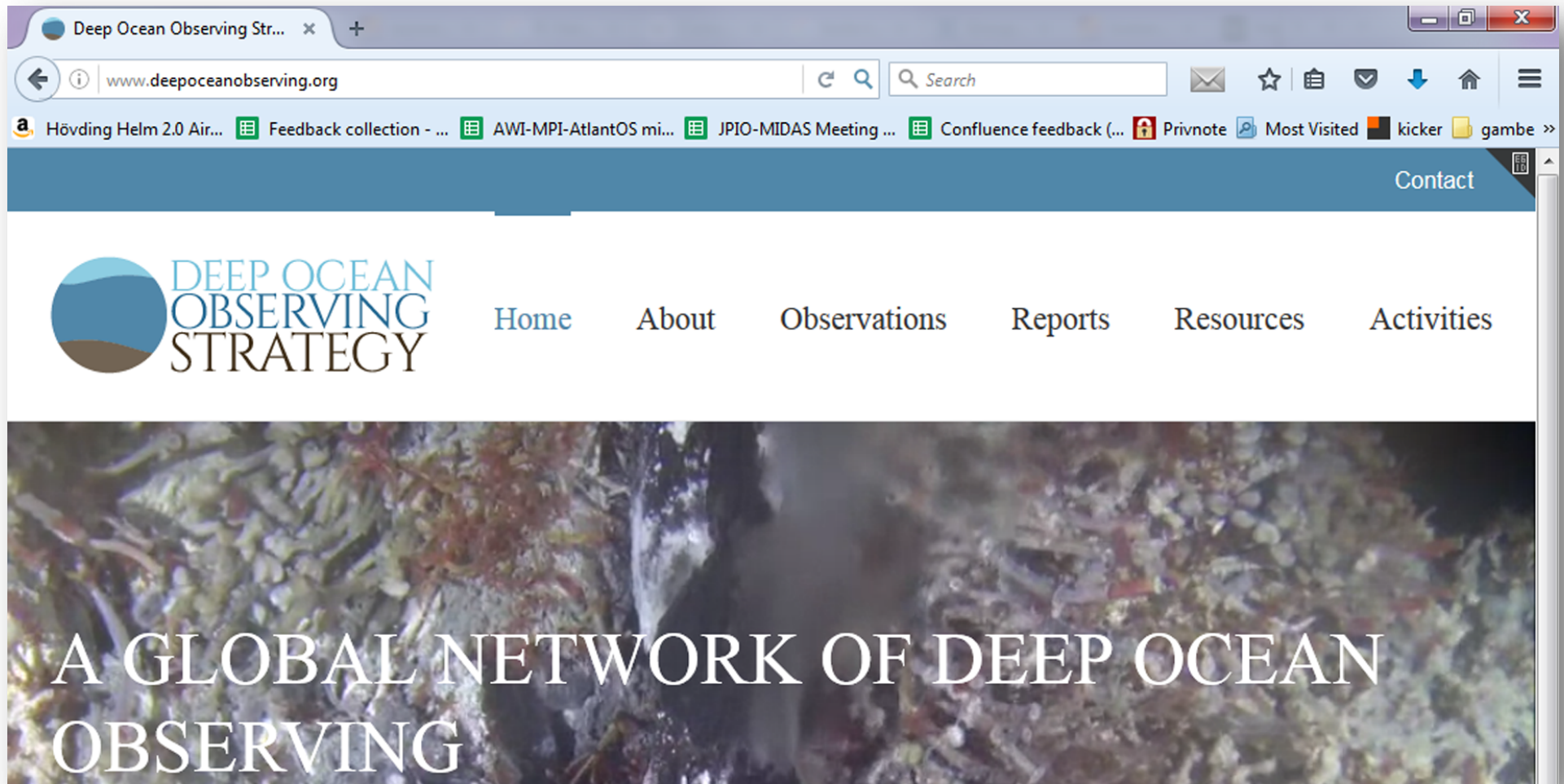
Alfred Wegener Institute, Bremerhaven, Germany



Background

DOOS mission

An international, community-based initiative to develop a roadmap aiming at an improved understanding of **baseline conditions** of the **global deep ocean** and its **response to climate variability** and **human disturbance**



Consultative report

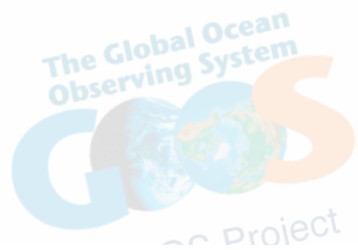
Starting point of specific 'deep-ocean questions'

- Rationale and scientific / societal needs for observations
- Identification of essential variables (i.e., EOVs) to observe
- Availability of appropriate methods / technologies



DEEP OCEAN
OBSERVING
STRATEGY

Consultative Draft, V5
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Contributing Authors & Affiliations

Physical/Climate

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Carbon/Biogeochemistry

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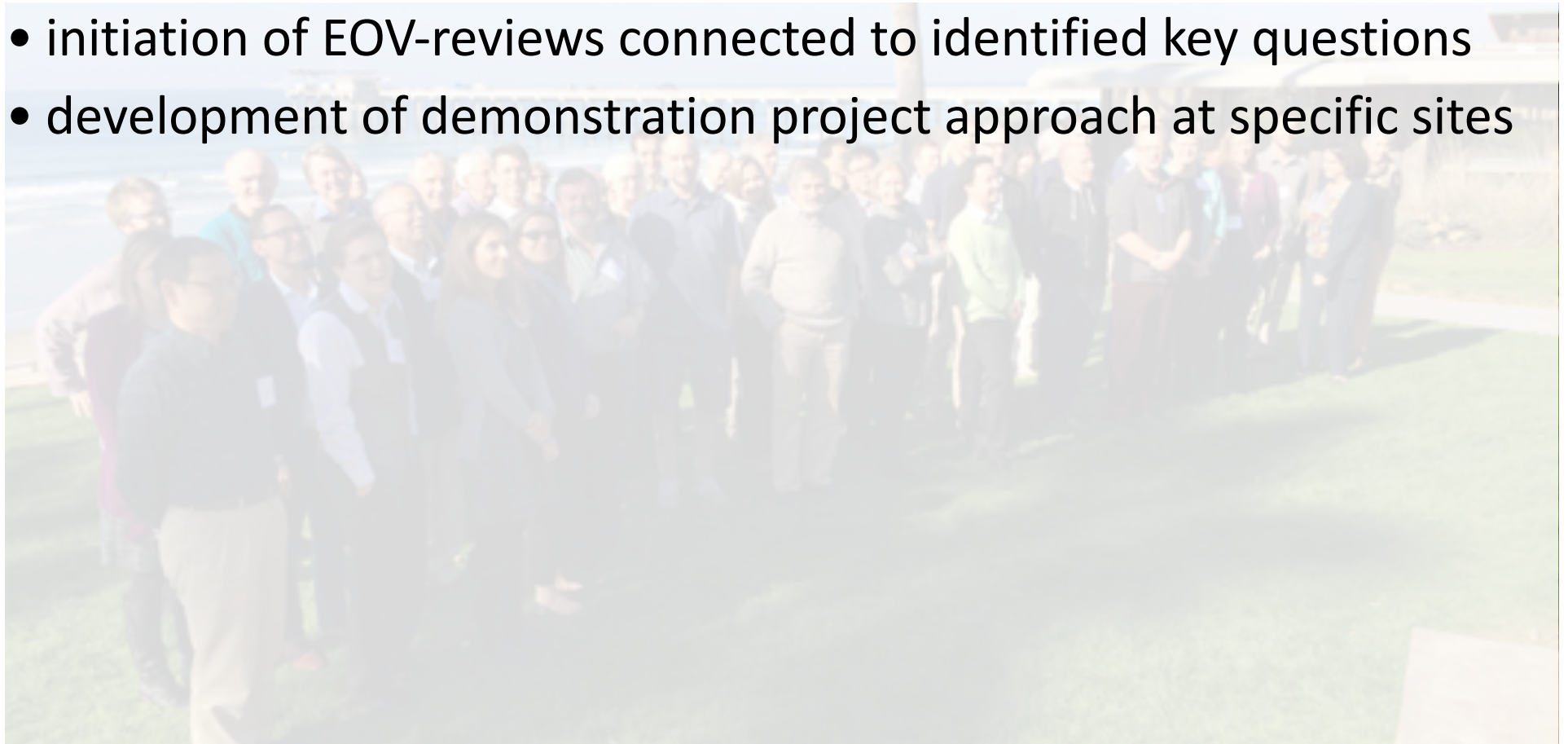
Biodiversity/Ecosystems

Antje Boetius
Lisa A. Levin
Myriam Sibuet

DOOS scoping workshop (Scripps, 2016)

Identification and specification of key scientific questions

- good representation of ocean observation communities
- broad spectrum of expertise (incl. modelling, data management, capacity building, deep ocean stakeholders, e.g., DOSI, ISA)
- initiation of EOVR-reviews connected to identified key questions
- development of demonstration project approach at specific sites



Science questions in brief

Physics-, biogeochemistry-, biology/ecosystem-centered

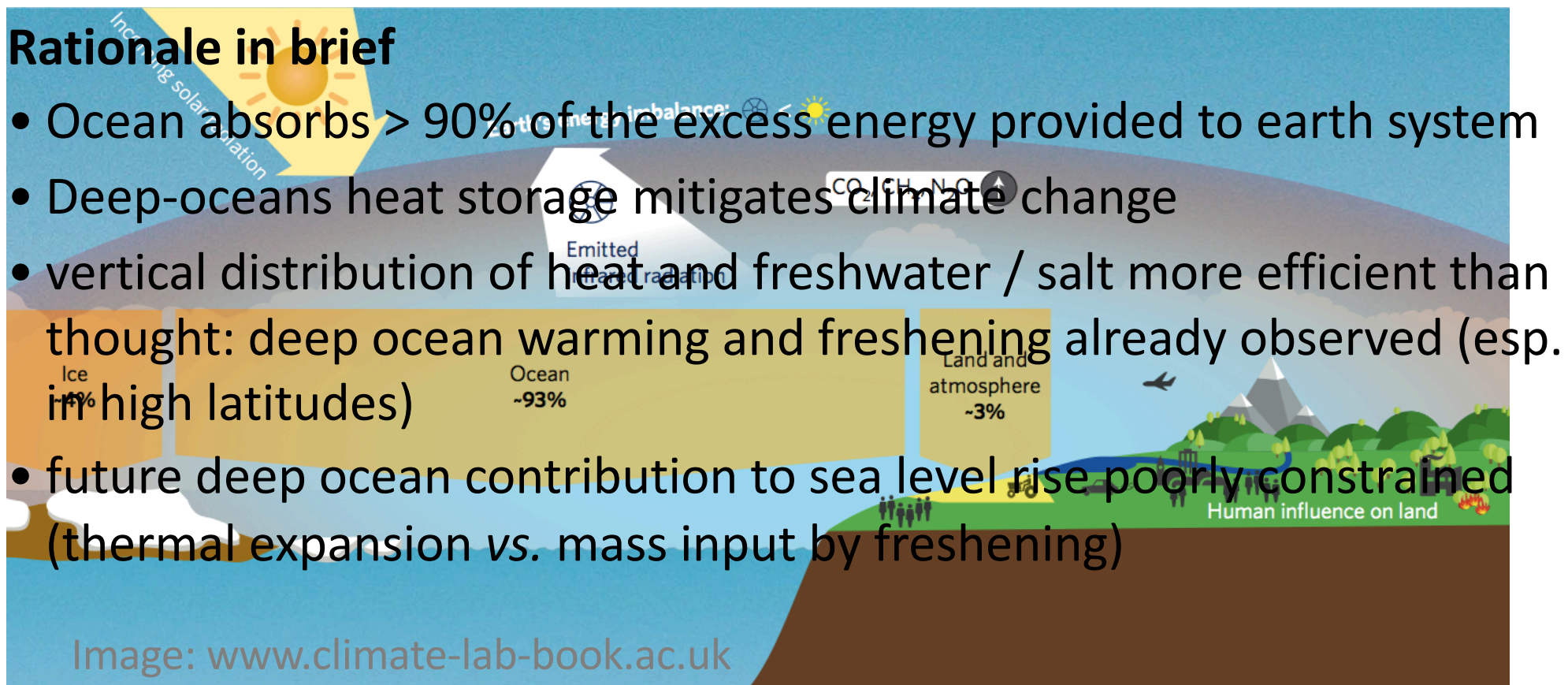
1. Deep ocean heat and freshwater budget
2. Climate effects on the global overturning circulation
3. Global change effects on deep ocean pelagic ecology
4. Global change effects on the carbon pump
5. Seafloor fluxes & connection to ocean circulation
6. Global change effects on sea floor biota and their functions

Deep ocean heat and freshwater budget

*What is the **role of the deep-ocean in the Earth's energy imbalance and land/sea water redistribution** on annual to multi-decadal time scales? This includes closing the **heat and freshwater budget**, the **warming and freshening of the deep ocean**, and their **contribution to sea level change**.*

Rationale in brief

- Ocean absorbs > 90% of the excess energy provided to earth system
- Deep-oceans heat storage mitigates climate change
- vertical distribution of heat and freshwater / salt more efficient than thought: deep ocean warming and freshening already observed (esp. in high latitudes)
- future deep ocean contribution to sea level rise poorly constrained (thermal expansion vs. mass input by freshening)

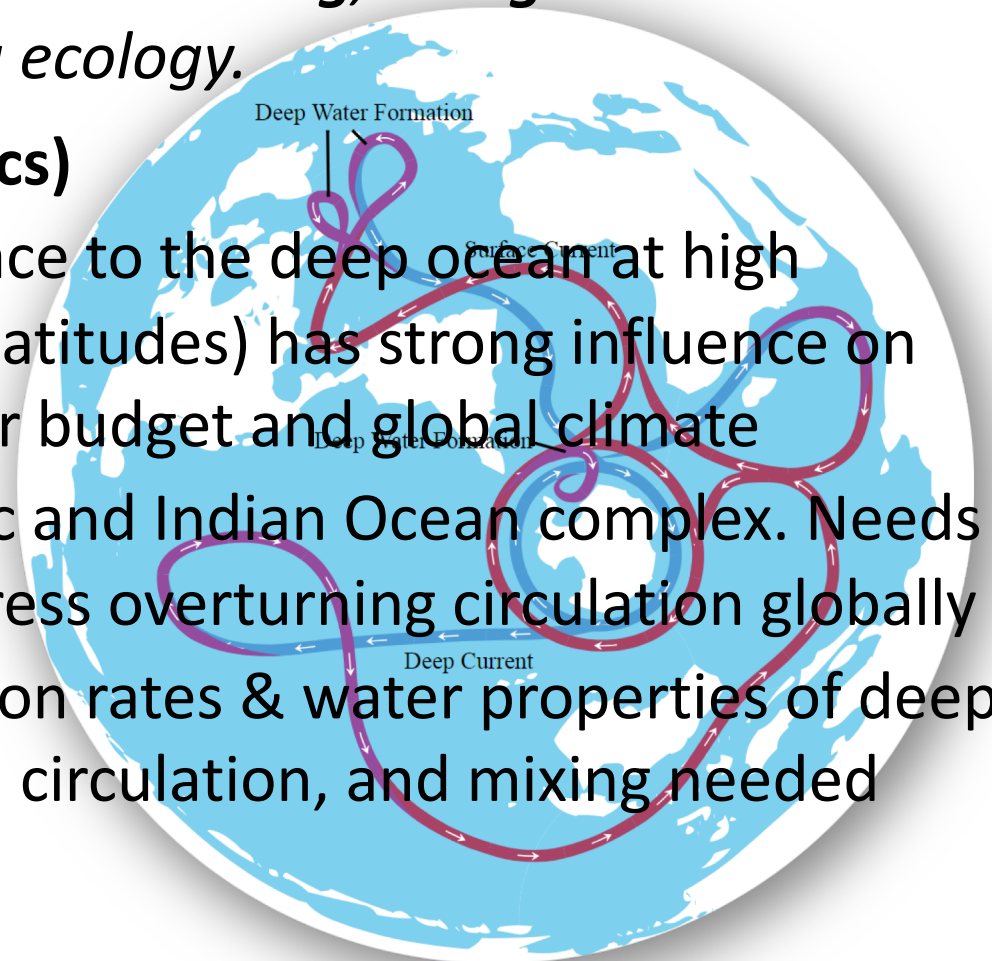


Climate effects on the global overturning circulation

*How are natural and anthropogenic **variations in climate connected to the global overturning circulation** and its variability? This includes variations in **deep and bottom water formation rates** and **water properties, circulation** and deep ocean **mixing**, and **geothermal heating**, and impacts on deep sea ecology.*

Rationale in brief (focus on physics)

- Transport of heat from the surface to the deep ocean at high latitudes (and *vice versa* at low latitudes) has strong influence on deep-ocean heat and freshwater budget and global climate
- Overturning circulation in Pacific and Indian Ocean complex. Needs to be better constrained to address overturning circulation globally
- Better understanding of formation rates & water properties of deep and bottom waters, deep-ocean circulation, and mixing needed



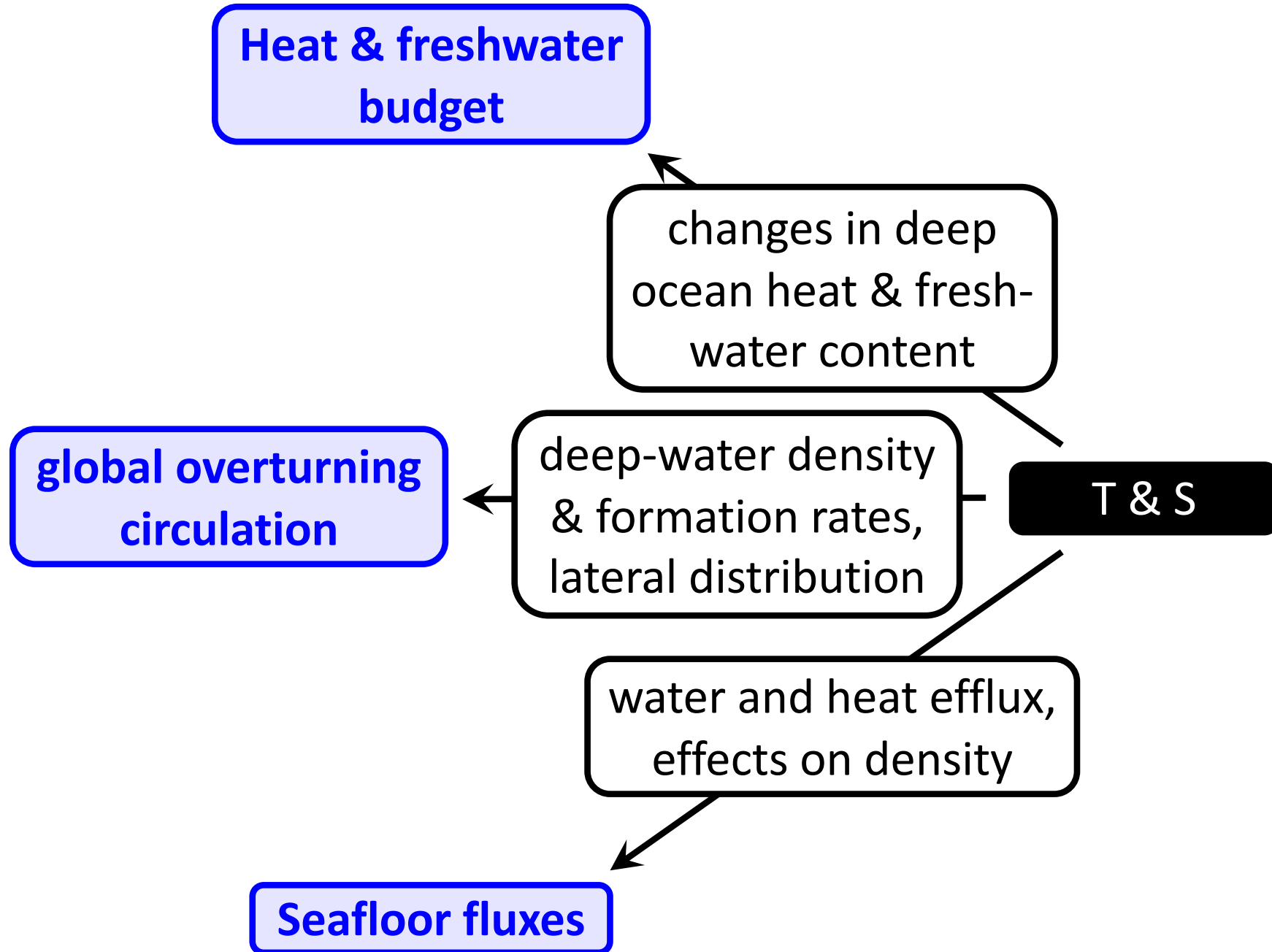
Seafloor fluxes & connection to ocean circulation

*What drives observed **variation in seafloor fluxes of heat, nutrients, tracers, oxygen and different carbon pools**? How are these quantities connected to larger-scale ocean circulation? This includes long term links between seafloor fluxes and greater oceanic **physical and biogeochemical processes**.*

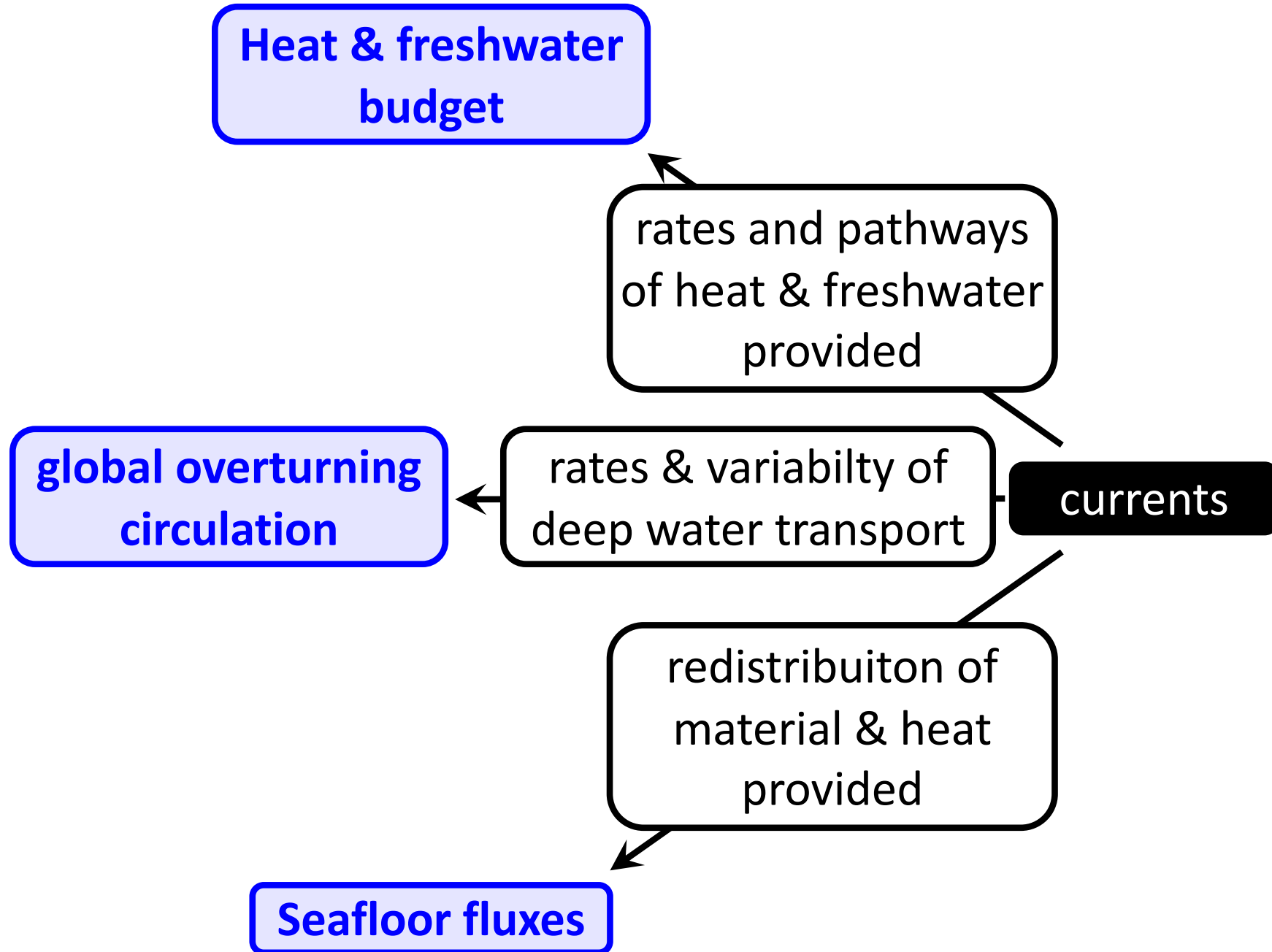
Rationale in brief (focus on physics)

- Ocean bottom geothermal fluxes may significantly contribute to the ocean heat budget. They may destabilize the density profile at depth, facilitating mixing and affecting circulation patterns
- Fluid, gas & mud effluxes release contribute solutes and greenhouse gases (CO₂, methane) to the deep ocean. Rates and feedback on atmospheric greenhouse gas concentrations needs to be better constrained

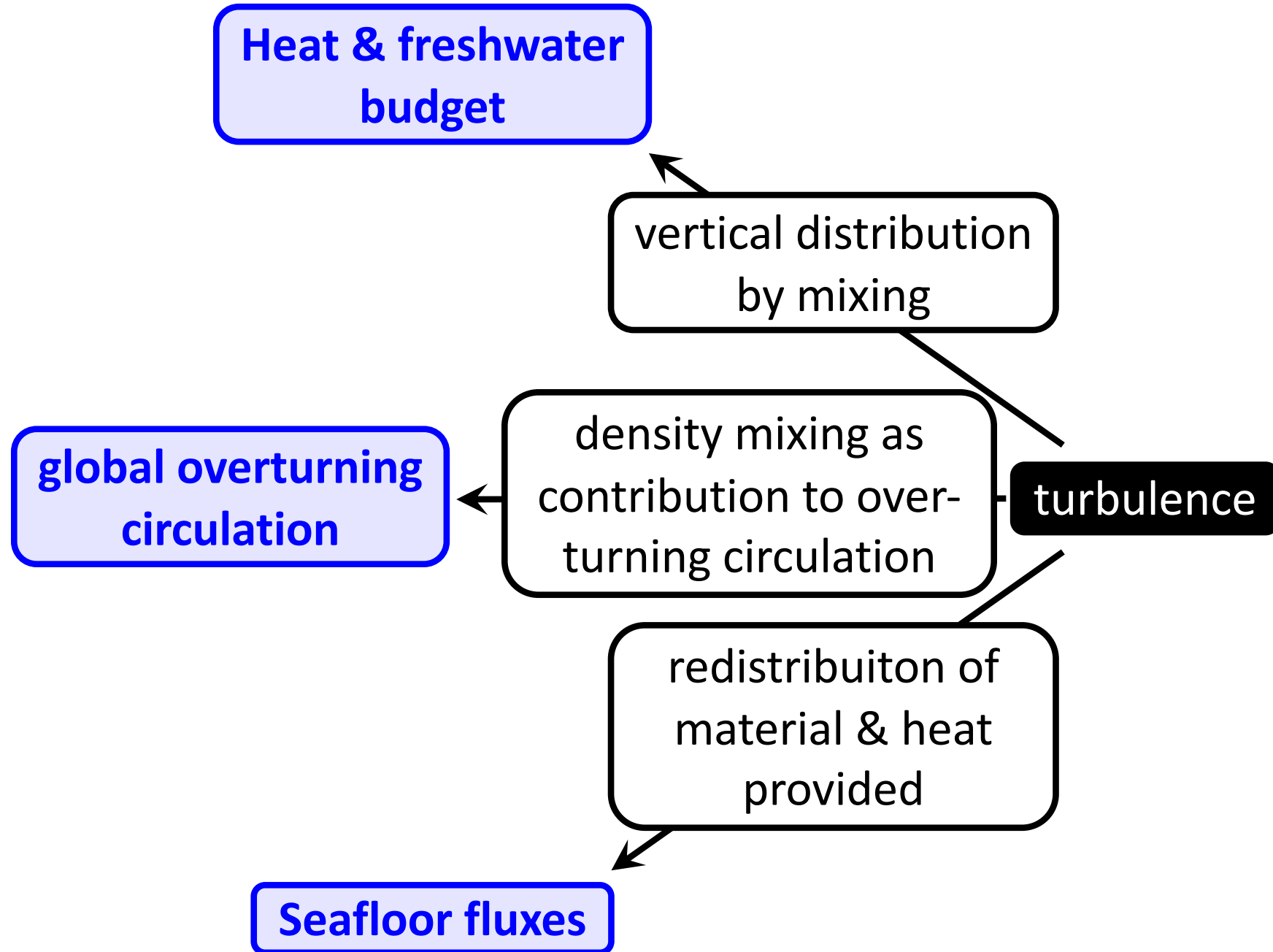
How to address physics-centered questions



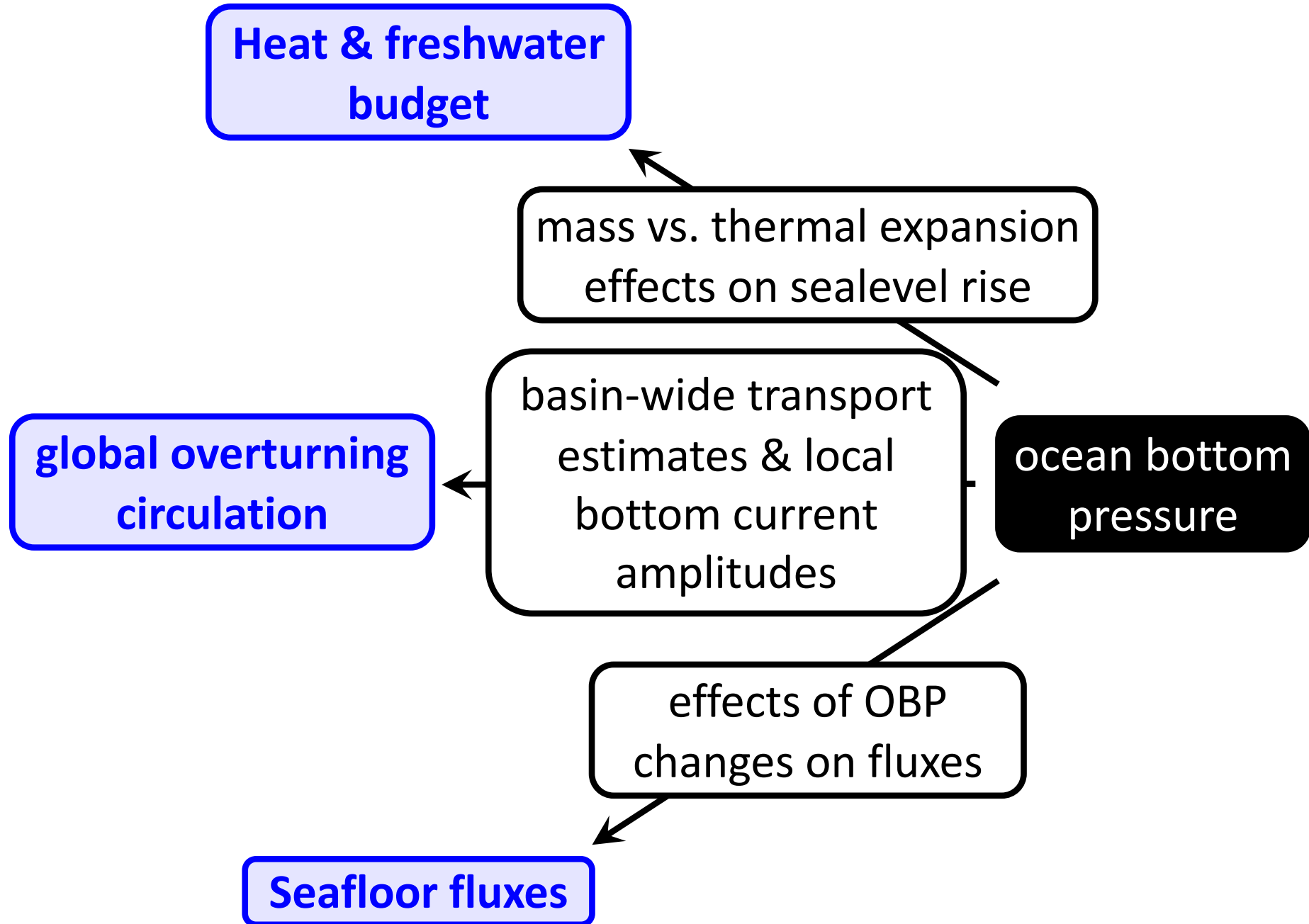
How to address physics-centered questions



How to address physics-centered questions



How to address physics-centered questions

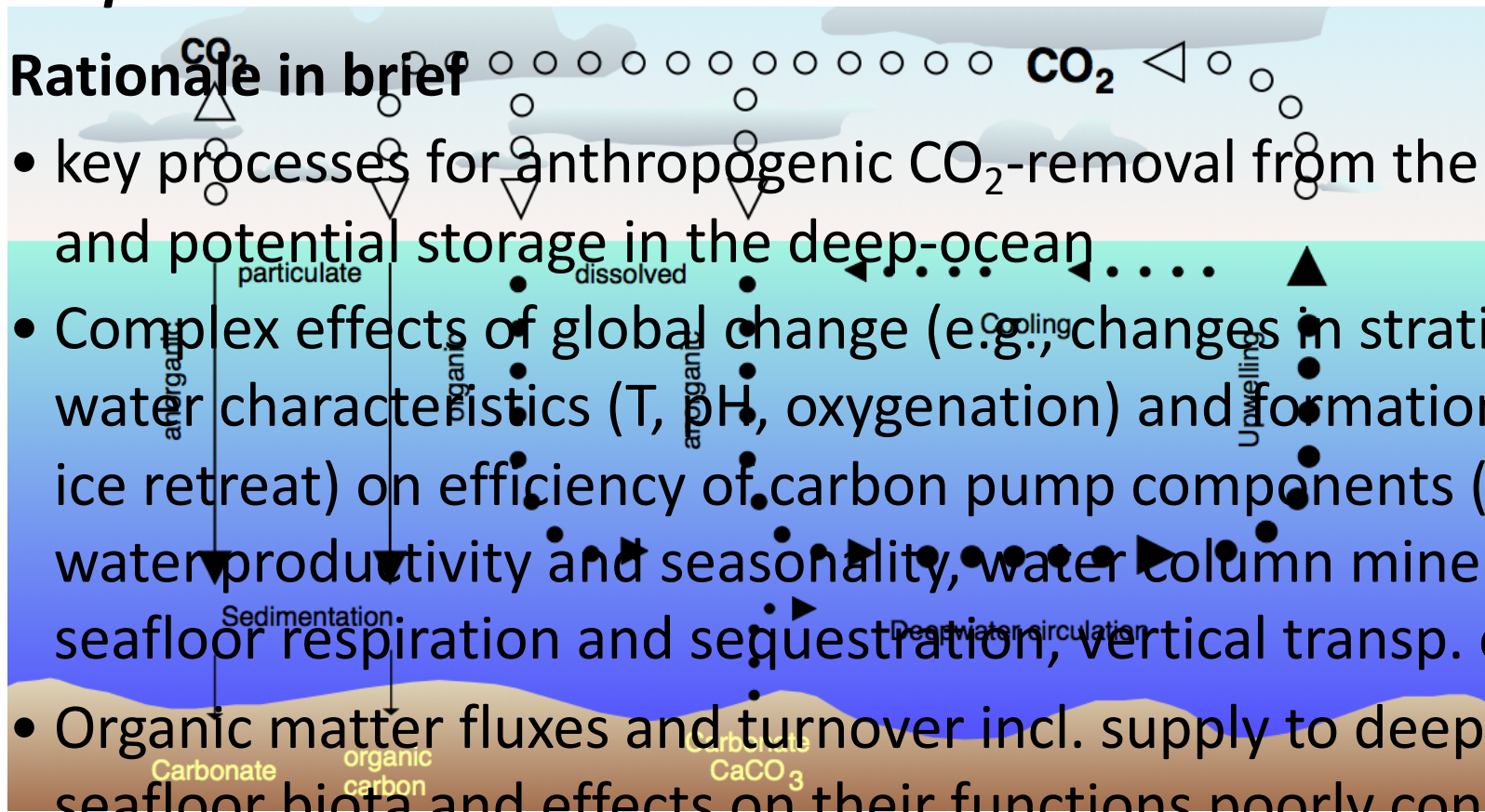


Global change effects on the carbon pump

*How might natural and anthropogenic **variations in climate influence the function of the solubility and biological carbon pumps, continental slope, nepheloid layer transport, and the sequestering of carbon in the deep ocean, and the organic carbon supply to deep-sea communities?***

Rationale in brief

- key processes for anthropogenic CO_2 -removal from the atmosphere and potential storage in the deep ocean
- Complex effects of global change (e.g., changes in stratification, deep water characteristics (T, pH, oxygenation) and formation rates, sea-ice retreat) on efficiency of carbon pump components (e.g., surface water productivity and seasonality, water column mineralization, seafloor respiration and sequestration, vertical transp. of DIC)
- Organic matter fluxes and turnover incl. supply to deep-water and seafloor biota and effects on their functions poorly constrained



How to address biogeochemistry-centered questions

Heat & freshwater
budget

Biological carbon
& solubility pump

organic material provided
to deep waters

global
circulation

bathypelagic
POC & DOC fluxes

Seafloor fluxes

How to address biogeochemistry-centered questions

Heat & freshwater
budget

Biological carbon
& solubility pump

organic material exported to
(& remineralized in) deep waters

global
circulation

Seafloor POC
quality & quantity

Seafloor fluxes

How to address biogeochemistry-centered questions

Heat & freshwater
budget

Biological carbon
& solubility pump

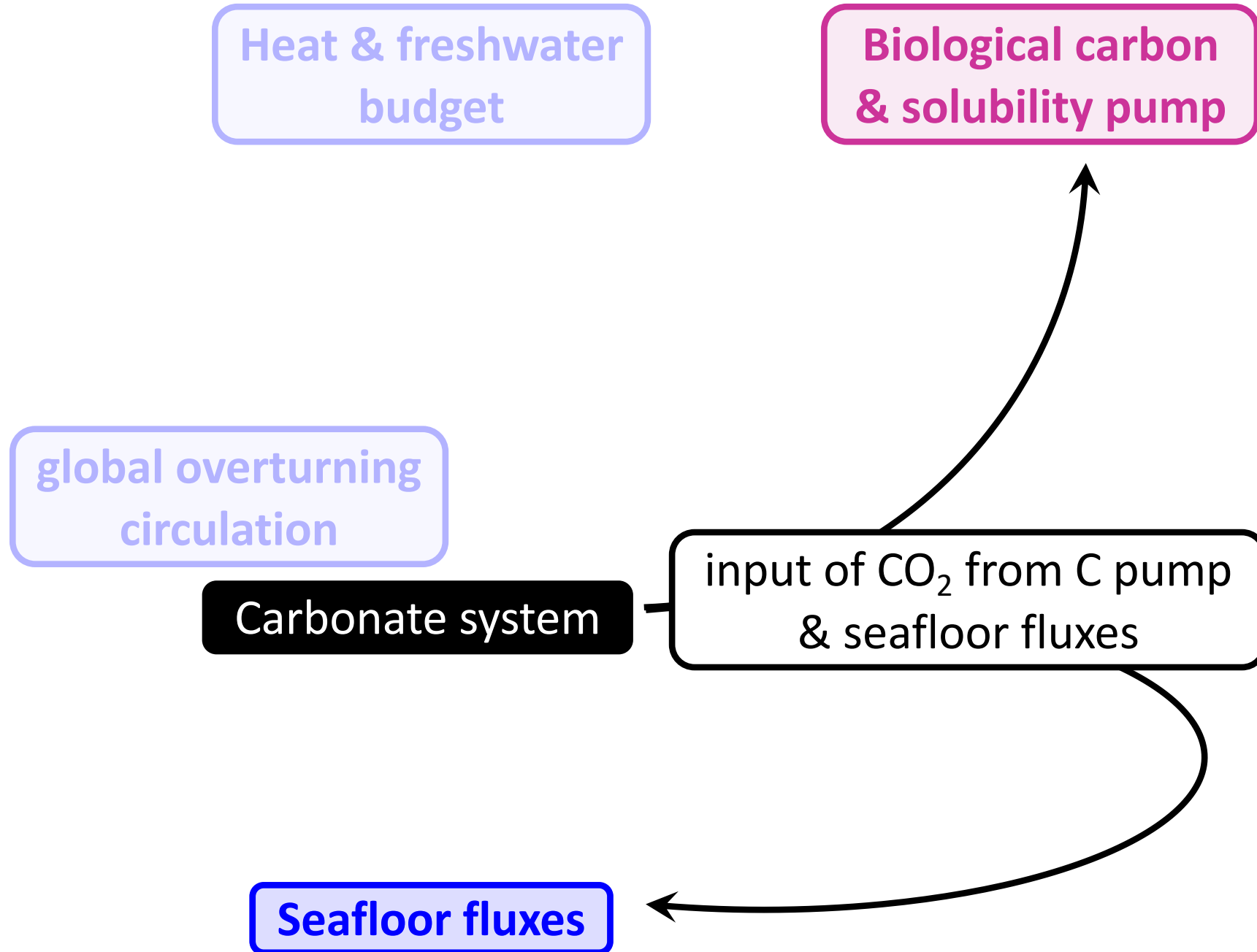
ultimate fate of OM
(rem mineralization / burial)

global
circulation

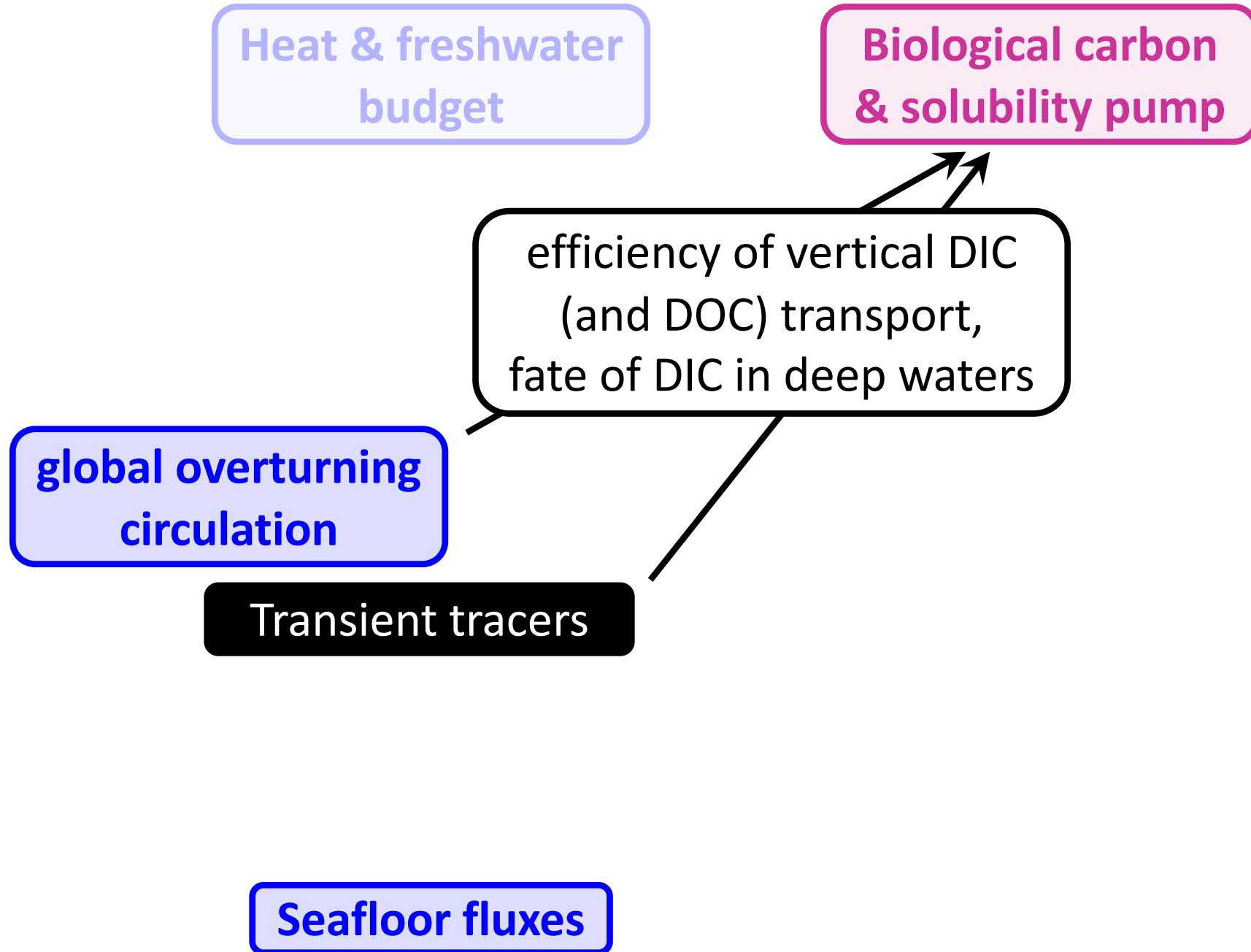
Seafloor respiration

Seafloor fluxes

How to address biogeochemistry-centered questions



How to address biogeochemistry-centered questions



Global change effects on deep ocean pelagic ecology

*How does **deep pelagic ecology** respond to natural variation and **multiple climate change stressors**, including warming, deoxygenation, acidification, changes in biological production, **as well as industrial activities**?*

Rationale in brief

- Deep-water communities provide important ecosystem services, including commercial fisheries and carbon sequestration
- Response to natural variability & global change related to shifts in deep-water conditions (warming, deoxygenation, acidification, changes in productivity and POC export) poorly understood
- Better understanding needed to assess future trends, improve climate change projections and management of deep-sea resources (e.g., VMEs) and use (e.g., deep-sea mining)

Global change effects on sea floor biota & their functions

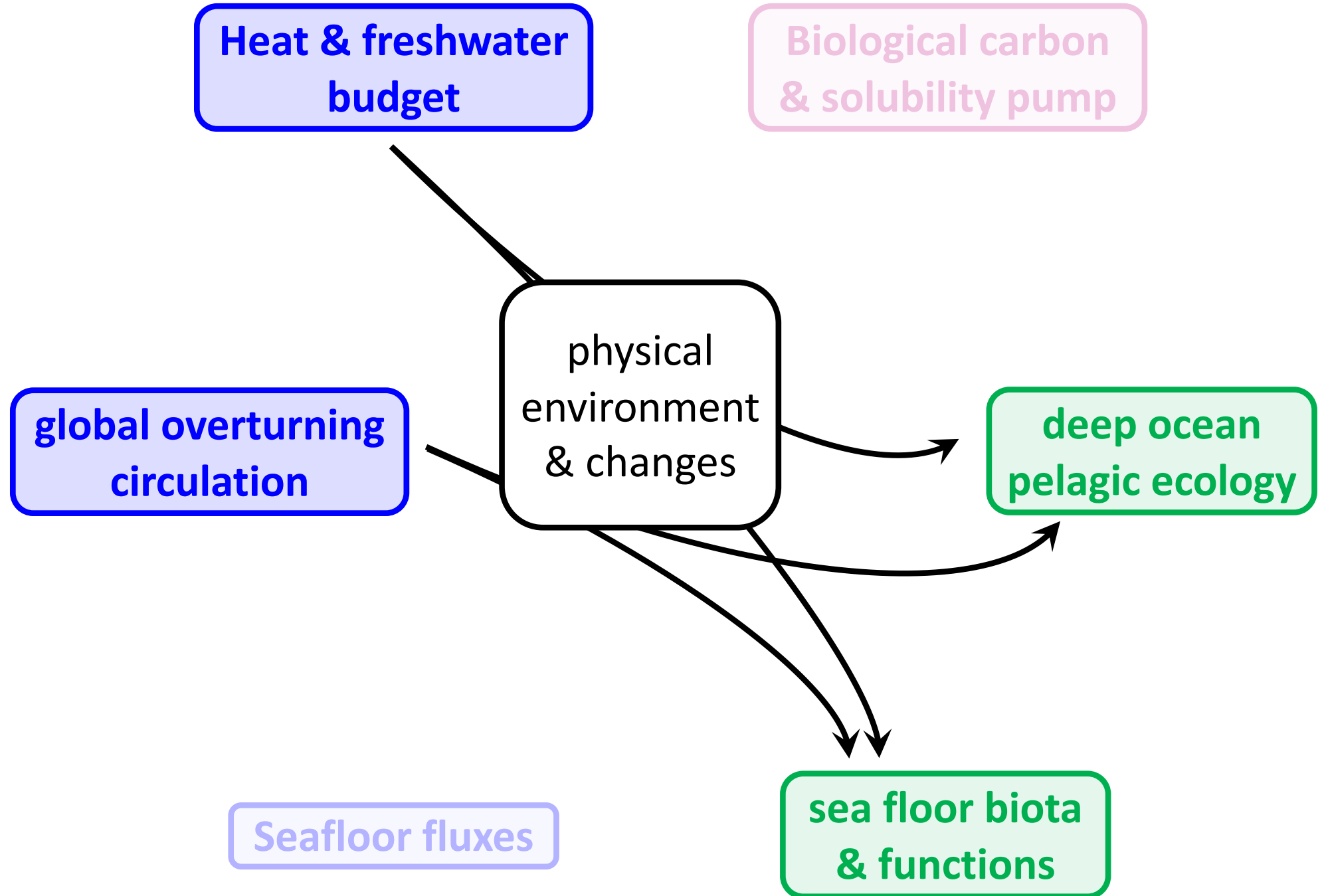
*How might **natural and anthropogenic variations in climate and resource industry activities** influence the **functional importance of animals and microbes in the deep sea and the seafloor**? What **environmental variations** do they experience **in space and time**? This includes consideration of benthic storms and currents, fluctuations in turbidity, T , pH , O_2 , and POC flux.*

Rationale

- Deep-sea benthic communities provide important functions and ecosystem services (e.g., organic matter remineralization, nutrient regeneration)
- Baseline conditions at the seafloor (incl. natural variability and global change related trends) to be constrained
- Important input to impact assessment & management for industrial activities (seabed mining, bottom trawling, oil and gas extraction)

Images: K. Smith, MBARI

How to address biology-/ecosystem-centered questions



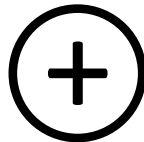
How to address biology-/ecosystem-centered questions

Heat & freshwater
budget

Biological carbon
& solubility pump

global overturning
circulation

carbonate system,
nutrients, O₂

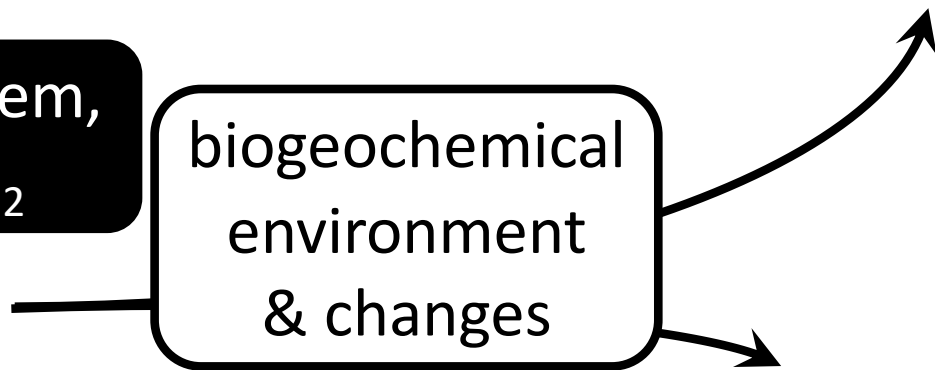


Seafloor fluxes

biogeochemical
environment
& changes

deep ocean
pelagic ecology

sea floor biota
& functions



How to address biology-/ecosystem-centered questions

Heat & freshwater
budget

Biological carbon
& solubility pump

global overturning
circulation

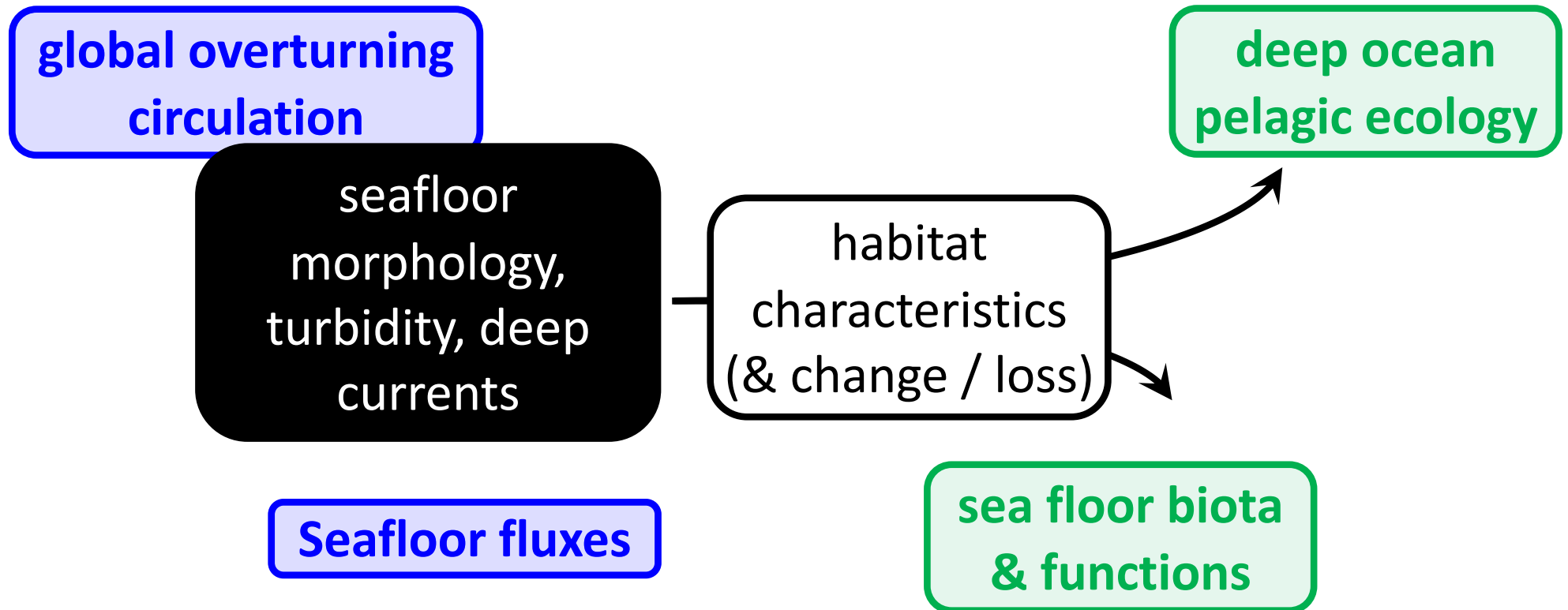
seafloor
morphology,
turbidity, deep
currents

Seafloor fluxes

habitat
characteristics
(& change / loss)

deep ocean
pelagic ecology

sea floor biota
& functions



How to address biology-/ecosystem-centered questions

Heat & freshwater
budget

Biological carbon
& solubility pump

global overturning
circulation

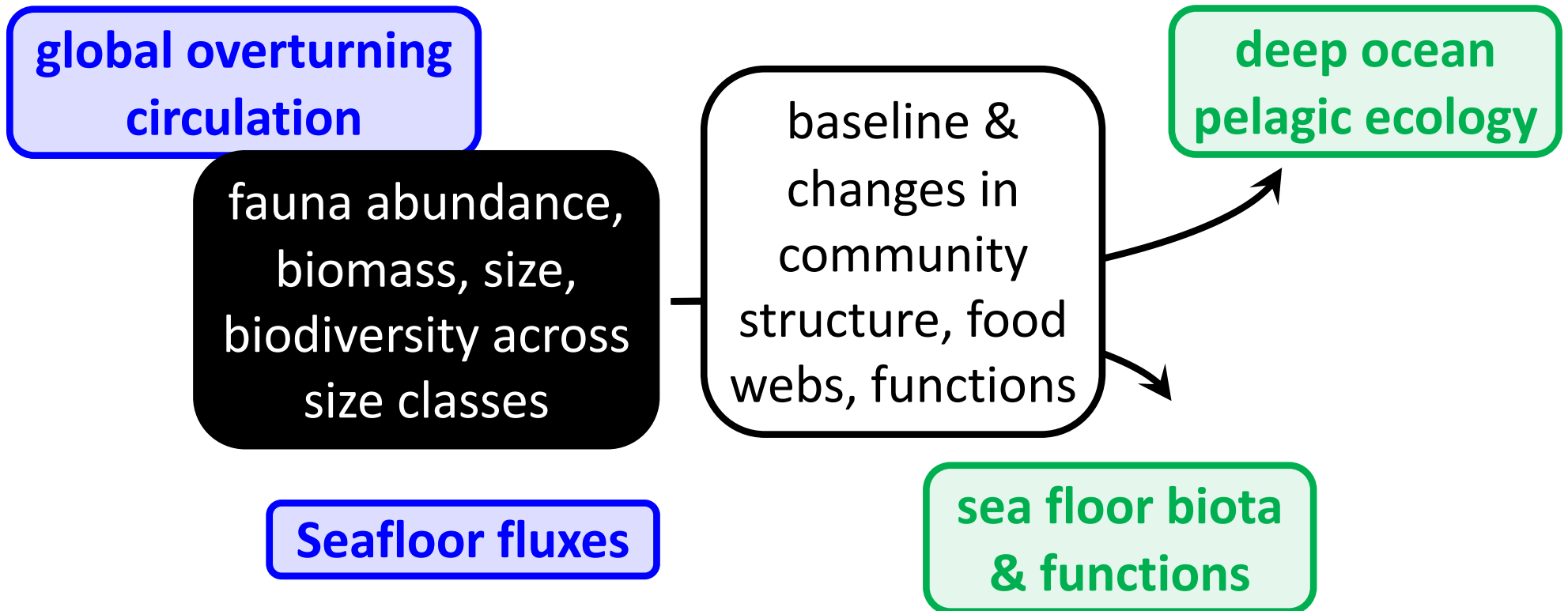
fauna abundance,
biomass, size,
biodiversity across
size classes

Seafloor fluxes

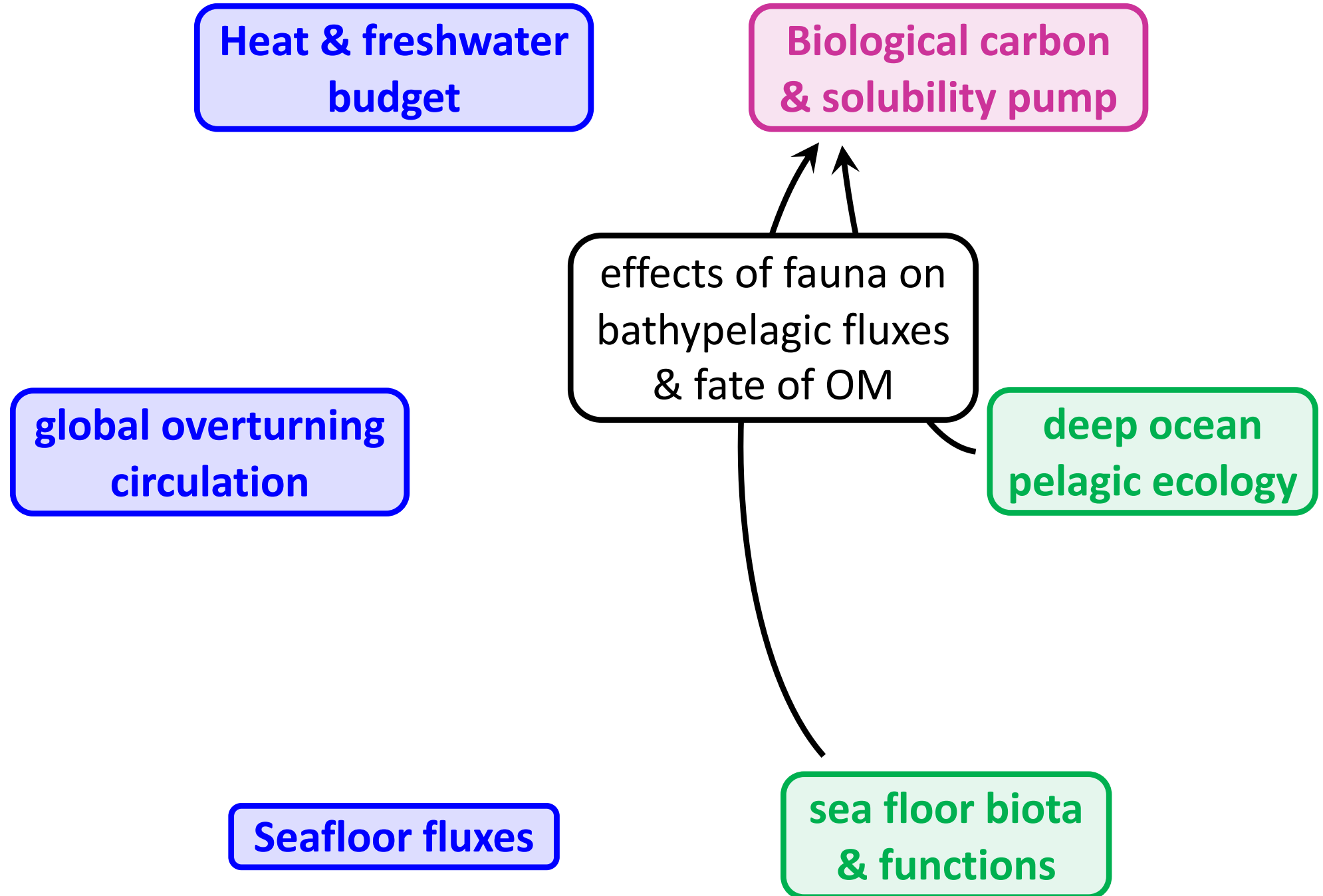
baseline &
changes in
community
structure, food
webs, functions

deep ocean
pelagic ecology

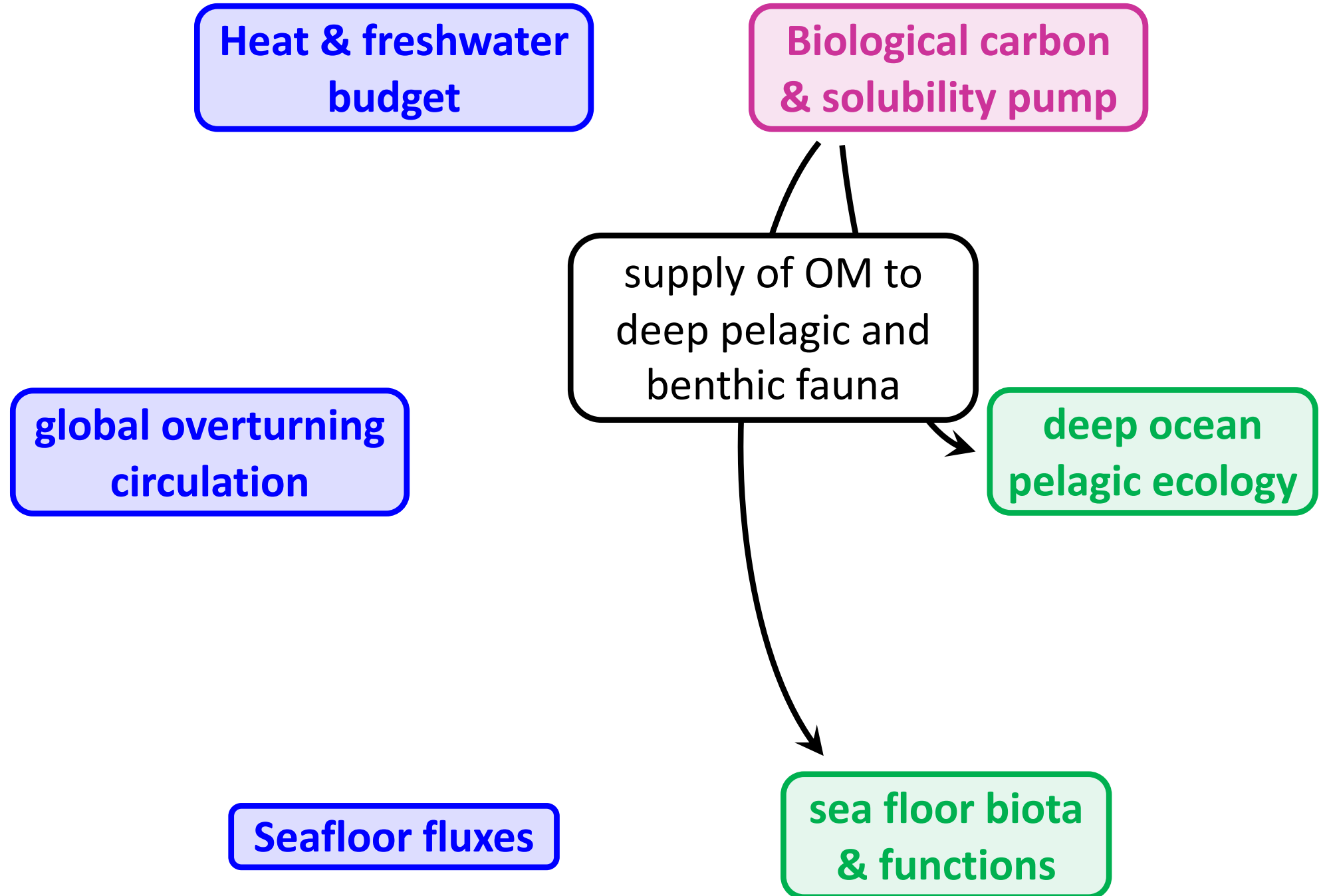
sea floor biota
& functions



How to address biology-/ecosystem-centered questions



How to address biology-/ecosystem-centered questions



Summary: Deep ocean observations serving multiple questions

Heat & freshwater
budget

Biological carbon
& solubility pump

Transient tracers

ocean bottom
pressure

bathypelagic
POC & DOC fluxes

global overturning
circulation

seafloor physical
habitat conditions

Seafloor respiration

deep ocean
pelagic ecology

turbulence

fauna abundance,
biomass, size,
biodiversity

Seafloor POC
quality & quantity

currents

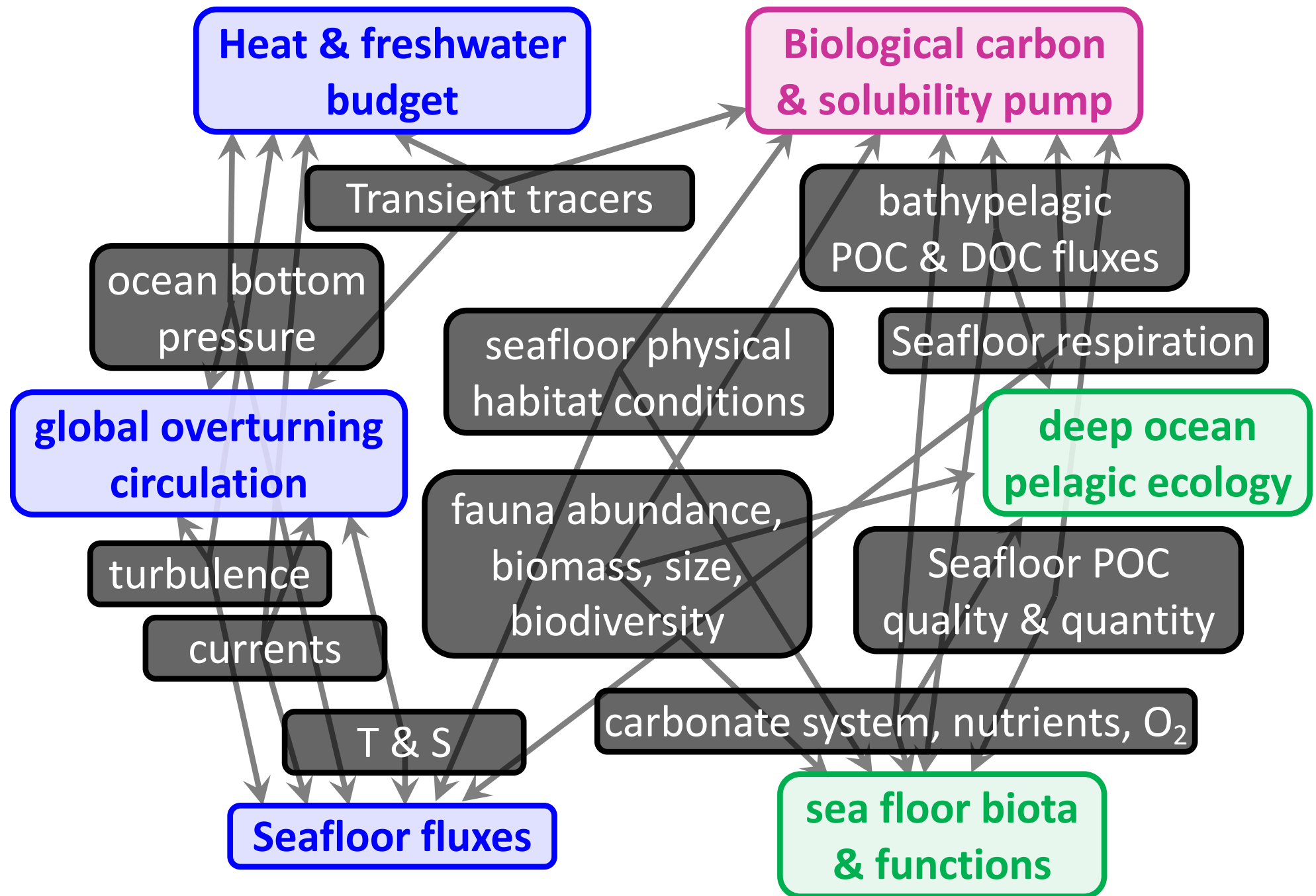
T & S

carbonate system, nutrients, O₂

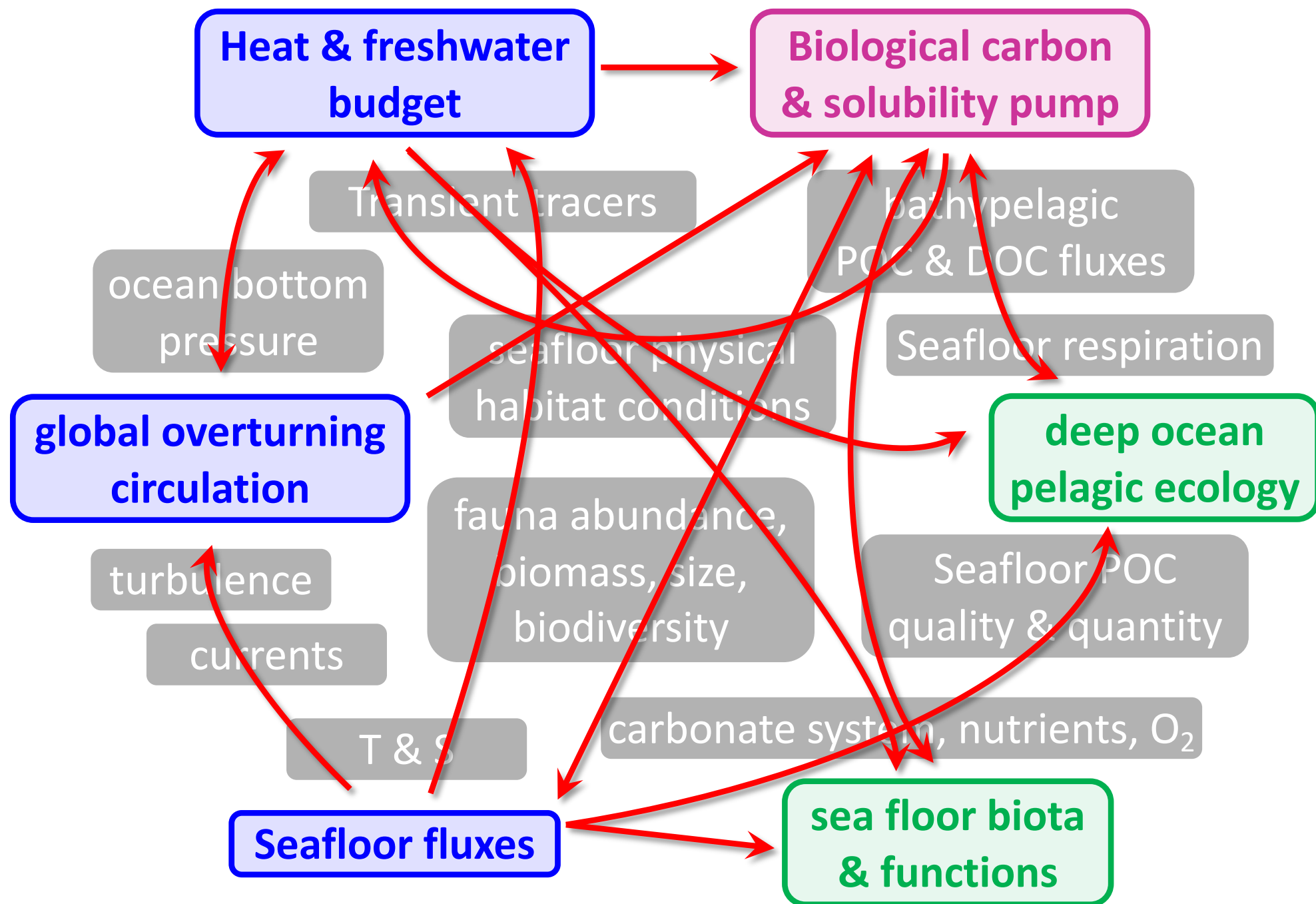
Seafloor fluxes

sea floor biota
& functions

Summary: Deep ocean observations serving multiple questions



Summary: Interconnections between key questions



Thank you!



Approaches to developing Working group topics

- **DOOS key questions** best-suited for OOI sites
- **OOI Science themes**, with addition to increase multidisciplinary and connection to DOOS questions
- topics readily/most **easily addressed with the instruments in place /** variables already measured at the OOI infrastructures
- developing from individual **scientific interests of workshop participants**
- topics suited to address ecosystem **variability along spatial & temp. scales** at OOI sites (pot. extending to other Pacific infrastructures)
- developing from **novel/emerging observation technologies / EOVs** to demonstrate feasibility of and **improve readiness**
- develop from societal drives and develop **topics best suited for direct knowledge transfer for societal benefit**

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[topic]

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[emphasis]

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[subhead]

[emphasis]

[normal text]

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