CSQ-48 Summary

Question	Knowledge Advancement Objectives	Observables	Measurement Requirements	Tools & Models	Policies / Benefits
How can we improve the monitoring and understanding of planetary heat exchange at regional scale, and which essential advancements can we achieve for research and monitoring on weather and climate patterns?	A) Thermodynamic coupling of the Earth's surface and the atmosphere to analyze critical feedback mechanisms, particularly for small-scale processes and variations to allow for improved weather and climate predictability B) Further develop better weather prediction on short time scales (2–12 weeks) aiming for advance warning of events such as heat waves and extreme precipitation, storms and long-term weather. C) Study the dynamic coupling for improved understanding of momentum and kinetic energy transfer between components of the Earth's system (ocean, atmosphere, cryosphere, land)	• Small scale (e.g., 25km resolution as discussed in Gentemann et al. 2021) measure of latent (e.g., wind speed, air-sea humidity difference) and sensible heat flux wind speed, air-sea temperature difference). • Near surface air temperature • Earth surface temperature, Sea surface temperature • Humidity • Wind (vector winds) • total ocean surface currents (e.g., 5km resolution as proposed under ODYSEA) • Ocean subsurface temperature • Planetary ocean and atmospheric heat transport • Net radiation	• High-spatial resolution (e.g., 25km) • High-temporal resolution to capture from extremes to long-term change (e.g., daily) • Sustainability to improve climate change monitoring	High-resolution models Atmospheric & oceanic & coupled assimilation systems (high-resolution, regional/nested)	CC mitigation and adaptation policy CC monitoring and stocktake Improvements of weather and climate forecast, CC prediction / climate models (validation, parametrization, detection & attribution) Disaster risk management Early warning systems Climate and national services

CSQ-48 Narrative

Regional scale exchanges at the interface between the Earth's surface and the atmosphere are a critical part of the global energy cycle, while fueling weather and climate variability and controlling important feedbacks such as for example through heat and moisture exchange (Bentamy et al., 2017; Cronin et al., 2019; Gulev et al., 2013). Observations at low spatial scale allowing to unlock small-scale processes and variations of the thermodynamic coupling are then key (Gentemann et al., 2021) (Fig. 5a) to allow for predictability from mere days to weeks as these small-scale features can affect large-scale weather and climate (Penny et al., 2019; Saravanan & Chang, 2019). For example, better weather prediction on short time scales (2–12 weeks) provide advance warning of events such as heat waves and extreme precipitation (Vitart & Robertson, 2018; White et al., 2017), which are known to enhance and occur more frequently under global warming (IPCC, 2021), with severe impacts on human systems (IPCC, 2022a). Moreover, small-scale air–sea interactions induce deep atmospheric circulation responses that affect mid-latitude storms and long-term weather (Gentemann et al., 2021). Also, the dynamic coupling of the atmosphere and the Earth surface plays an important role for understanding how momentum and kinetic energy are transferred between components of the Earth's system, such as between the ocean and atmosphere (Zippel et al., 2022) (Fig. 5b). Measurements of wind interactions and surface total currents (vectorial) are then key, which either do not meet WMO sampling requirements (esp. in resolving diurnal scale), or are faced to an observational gap. Beside the need for improved measurement techniques, consistency studies of flux estimates at regional scale have been used for developing reference data sets and uncertainty evaluations (Bentamy et al., 2017), and remain a promising tool for regional energy budget closure approaches, process understanding and uncertainty evaluations (e.g., Loeb et al., 2022; Mayer et al., 2017; Trenberth et al., 2019).

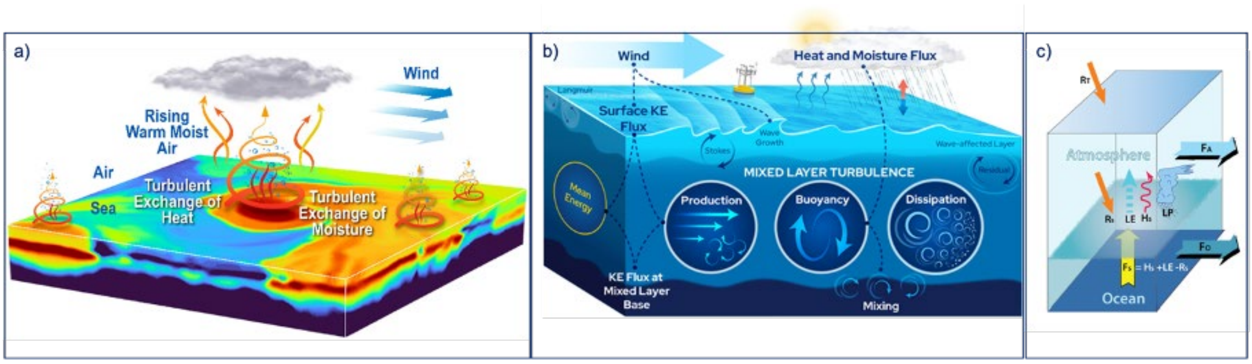

__Figure 5:__ a) Schematic representation of thermodynamic coupling and the role of turbulent fluxes at the air-sea interface. Figure from Genteman et al., 2021. b) Schematic representation of dynamic coupling highlighting surface processes and pathways for kinetic energy (KE) transfer between the atmosphere and the ocean. Dashed lines and solid dots indicate how terms in the vertically integrated mixed-layer turbulent kinetic energy (TKE) equation connect to the atmosphere, the wave-affected layer, the deeper ocean, and the mean kinetic energy (KE) equation. KE fluxes from the wind are split between viscous and wave-driven terms at the interface. The majority of wave-supported energy fluxes balance with terms in the wave-affected layer. Here, the focus is on the balance in the mixed-layer, where surface-driven production and buoyancy are primarily balanced by TKE dissipation rates. From Zippel et al., 2022. c) Schematic of the regional budget constraint approach tackeling the consistency of energy flows through the atmosphere (top) and ocean (below), include radiation at the top and surface RT and Rs, surface sensible heat flux Hs, and surface latent heat flux LE. Latent heat is realized

here in the atmosphere as precipitation LP. The vector transports of total vertically integrated energy in the atmosphere FA and ocean FO are indicated. Figure from Trenberth et al., 2019.