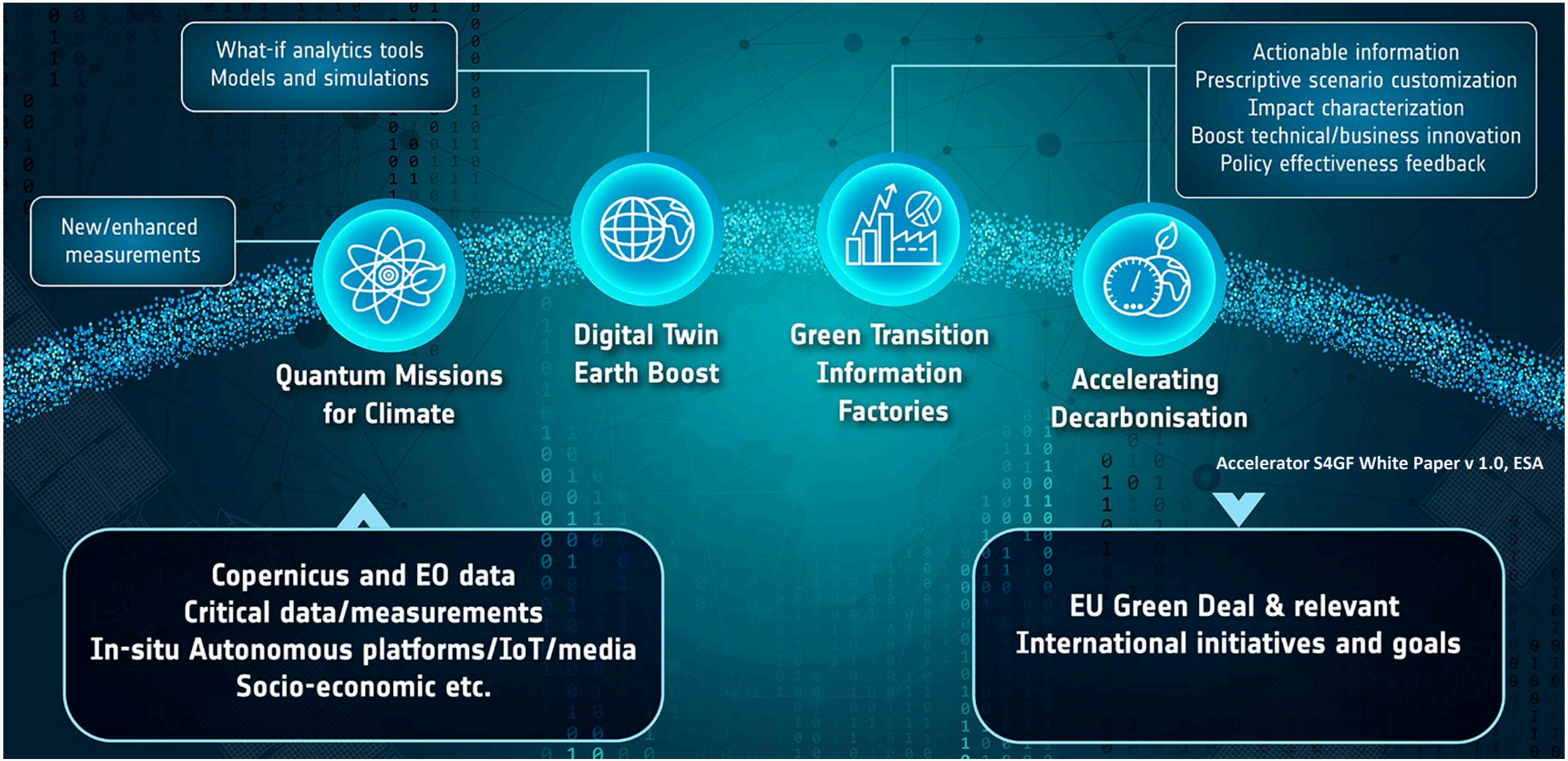
Quantum Missions for Climate: Accelerating space solutions for a green future



Why we need new space solutions for climate

Today

- Climate change is accelerating and ubiquitous: sea level rise, retreating glaciers, more and heavier extremes, …
- Climate modelling moves towards climate monitoring: long and short time scales…
- Actionable information from space: powerful tool in the hands of European policy makers and industrial actors
- Digital twin Earths: bridge gaps modeler ↔ policy maker, space data ↔ citizen data

But

- Climate system is complicated, strongly coupled, numerous processes → many pieces of the puzzle are missing
- With current EO, key processes in climate system still difficult to measure (e.g. glacier melting, ocean warming) Similar for hazards (e.g. droughts, water stress). Also some anthropogenic activities are difficult to monitor (e.g. groundwater use, …)
- Global, regional, and local scales are linked (local processes e.g. land use, fires affect regional and global scale, e.g. land use ↔ local processes (e.g. sea level rise) depend on regional and global actors)

Need consistent high-resolution information across all scales. Now.

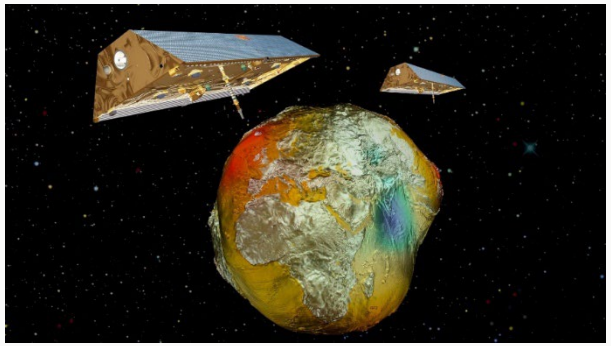
Why we need new space solutions for climate

Seamless Integration of space data with ESMs and digital twins

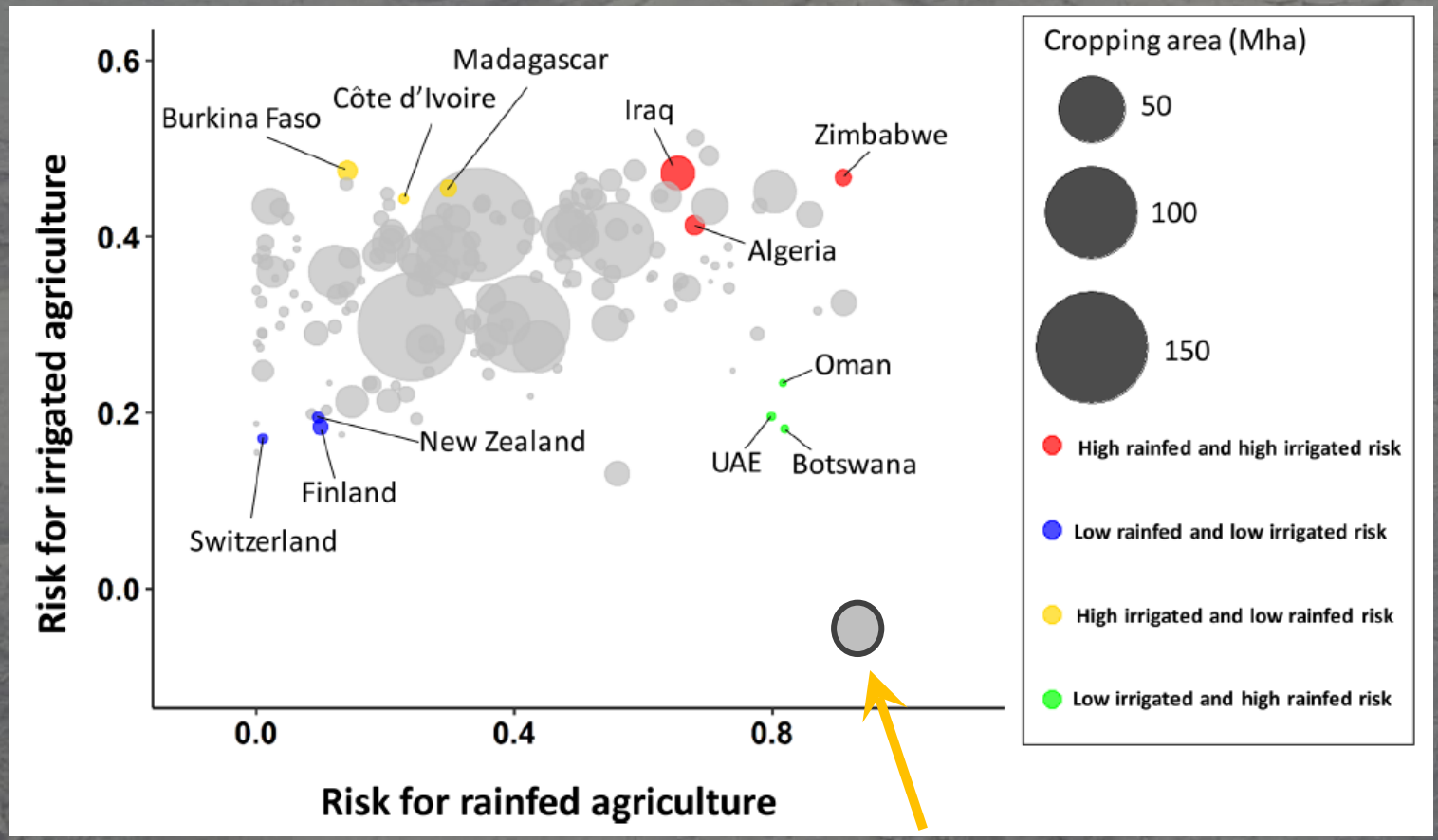
- Realism, physical consistency (mass, momentum, energy)
- Consistency across scales – space data backbone, aircraft, UAV, user data layer on top
- Consistency across temporal scales, long timescale … extremes
- Improves linkage between water, energy and carbon cycles in models
- What we do not yet have in a long-term is mass monitoring (→ quantum mission)

Space gravity missions (>2003, GRACE/-FO):

- Unique mass change data, across modelling worlds (ocean, atmosphere, hydrology), first-time observable of groundwater change, glacier mass loss, large-scale water deficits, …
- Unique observable → groundwater, glacier mass, …
- But so far at few hundred km resolution, with monthly resolution, insufficient e.g. for drought monitoring/forecasting, hardly sufficient for integration with ESMs, gap between space and aircraft/UAV/… data
- Climate change detection & attribution needs long data sets (> 30y)

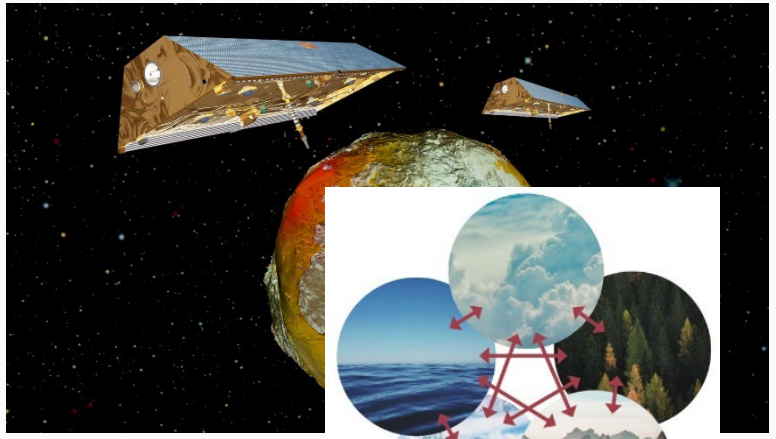


Example: Drought assessment (Meza et al 2020, NHESS: Assessing global drought risk at country level)



Footprint of current (GRACE-FO) space missions: too big to cover many countries

Why we need new space solutions for climate



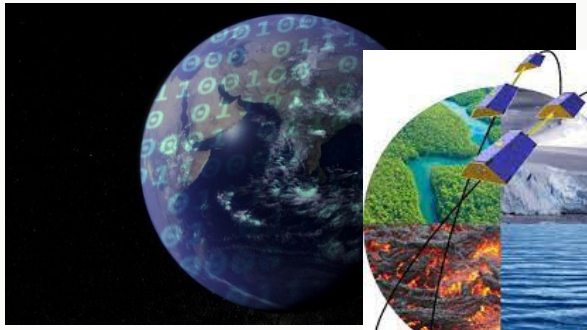
Need continuation of space mass change missions

- multidecadal data sets for climate
- Should be included in operational services such as Copernicus

MAGIC (Mass change And Geosciences International Constellation)

constellation required since

- higher spatio-temporal resolution for applications and to connect to operational services
- necessary step for QSG to fully exploit technology



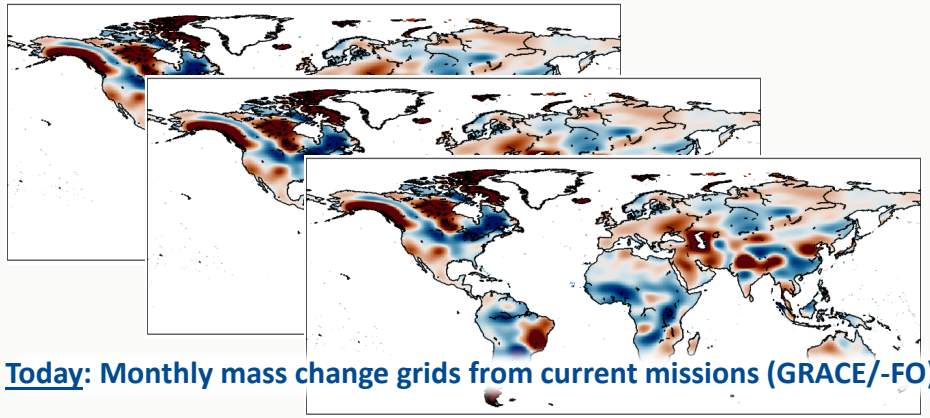
Need, for integration with models (digital twins)

- higher spatial resolution - 100km
- higher temporal resolution – daily, less temporal latency

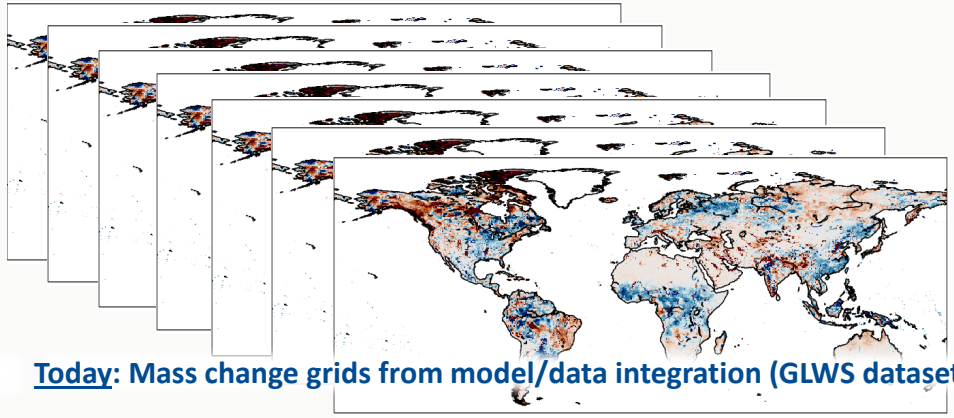
Cannot be achieved by combination with in-situ data, even if quantum leap in in-situ sensor technology

- Need a constellation of satellites for high temporal resolution. High temporal resolution at the same time improves spatial resolution (dealiasing)
- Limit in enhancing mass change products with conventional technology - breakthrough with quantum leap in satellite sensor technologies (quantum technology, cold-atom/hybrid accelerometers, quantum gradiometers)

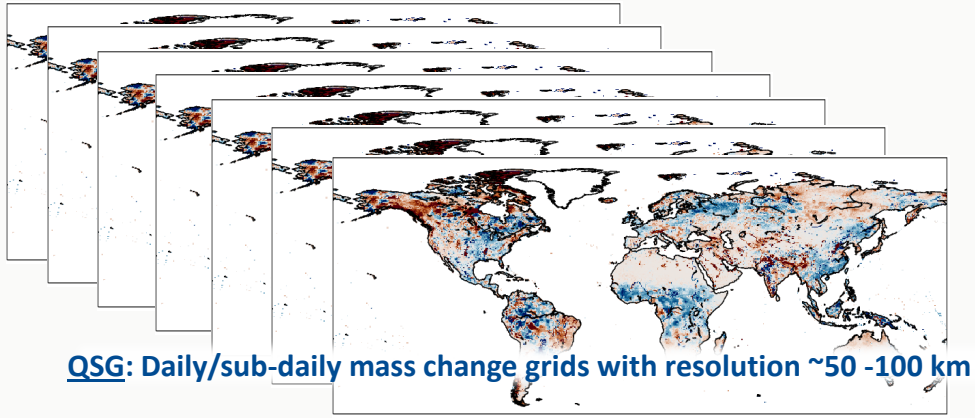
Enhanced data products…



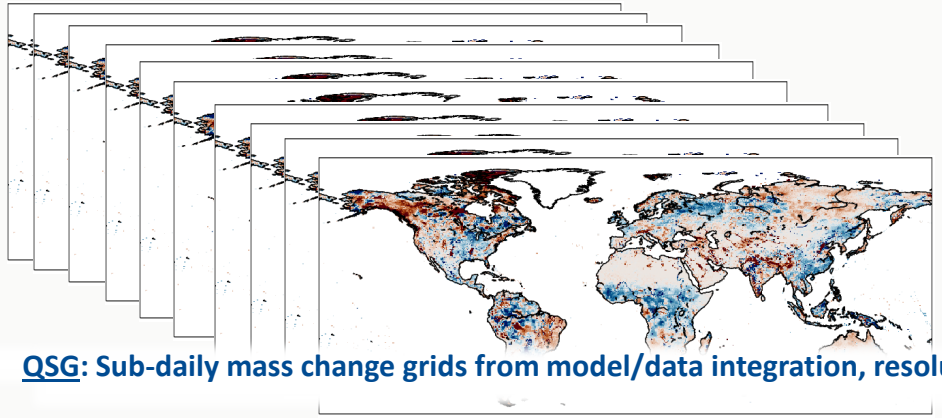
Today: Monthly mass change grids from current missions (GRACE/-FO), resolution ~300-400 km



Today: Mass change grids from model/data integration (GLWS dataset), resolution 50 km



QSG: Daily/sub-daily mass change grids with resolution ~50 -100 km



QSG: Sub-daily mass change grids from model/data integration, resolution 10 km

QSG should provide ~50 – 100 km spatial resolution, this will open the door to integration with ESMs at the 10 km scale.

From monthly, coarse resolution mass change maps to (sub-) daily higher-resolution maps

Hydrology/meteorology

- *Extreme events (monitoring/forecasting droughts and floods)*
- *Atmospheric moisture convergence and large flash floods / NRT via data assimilation*
- *Closure of energy and mass budgets in climate*
- *Diurnal cycle in land-atmosphere interaction*

Cryosphere

- *Mass balance of glaciers*
- *Ice shield dynamics*
- *Glacial isostatic adjustment*

Oceanography

- *Ocean dynamics (mean dynamic topography, currents)*
- *From global mean sea level budget to sea level budget for marginal seas (North Sea, Baltic, Mediterranean, ...)*

Solid Earth

- *Geohazards (landslides, Earthquakes, …)*
- *Lithospheric structure*

(list is not complete)