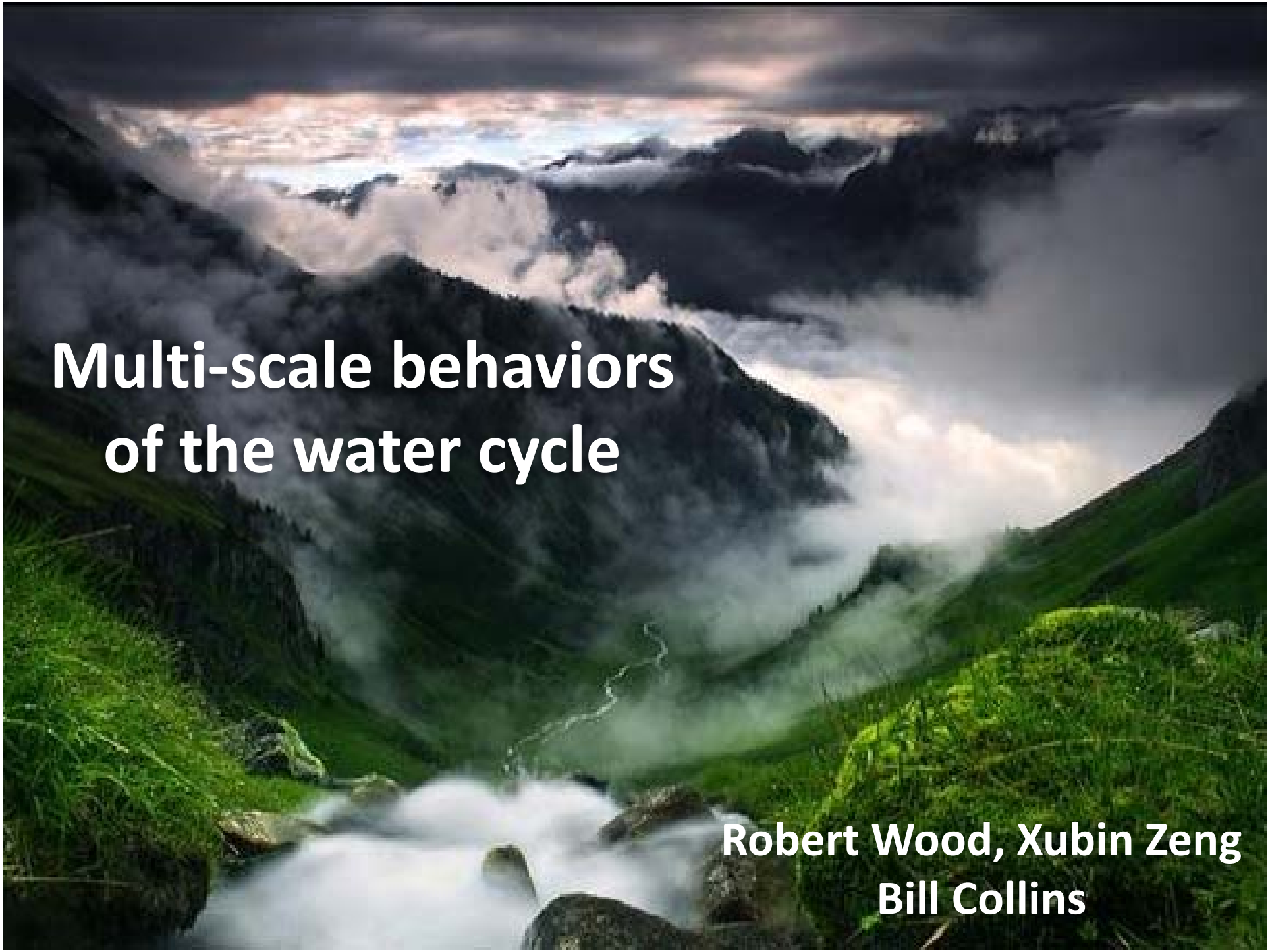
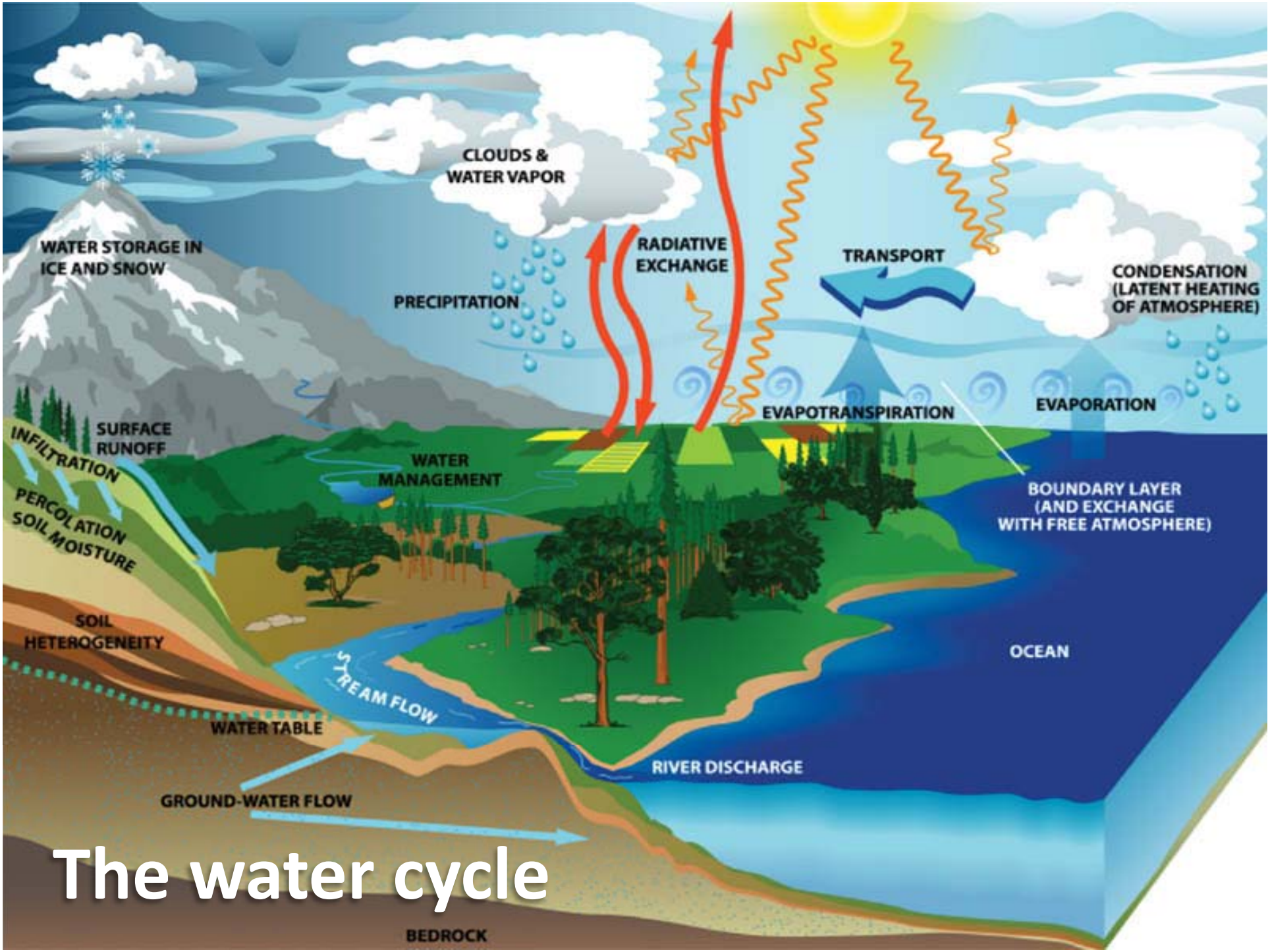


Multi-scale behaviors of the water cycle

Robert Wood, Xubin Zeng
Bill Collins

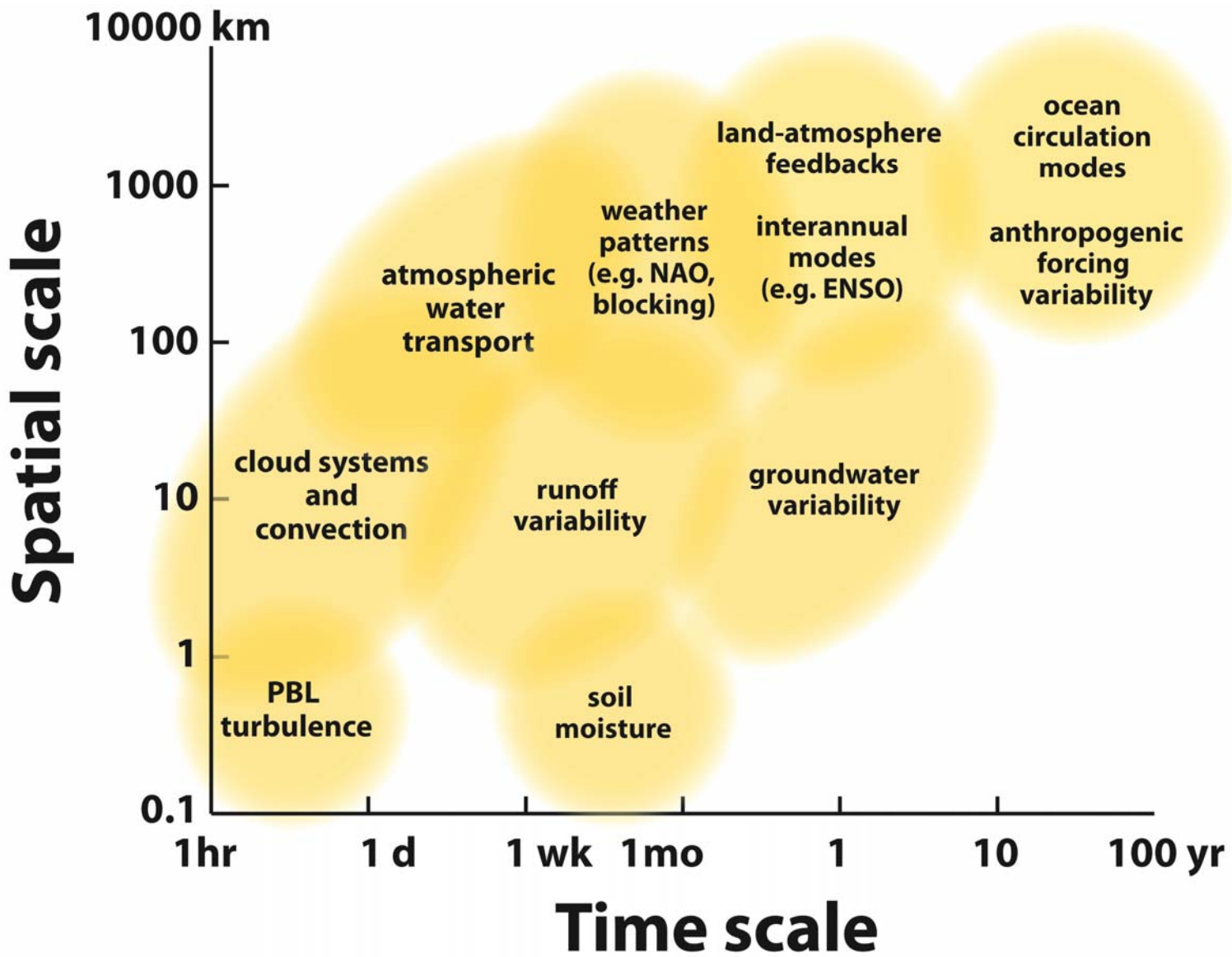


The water cycle

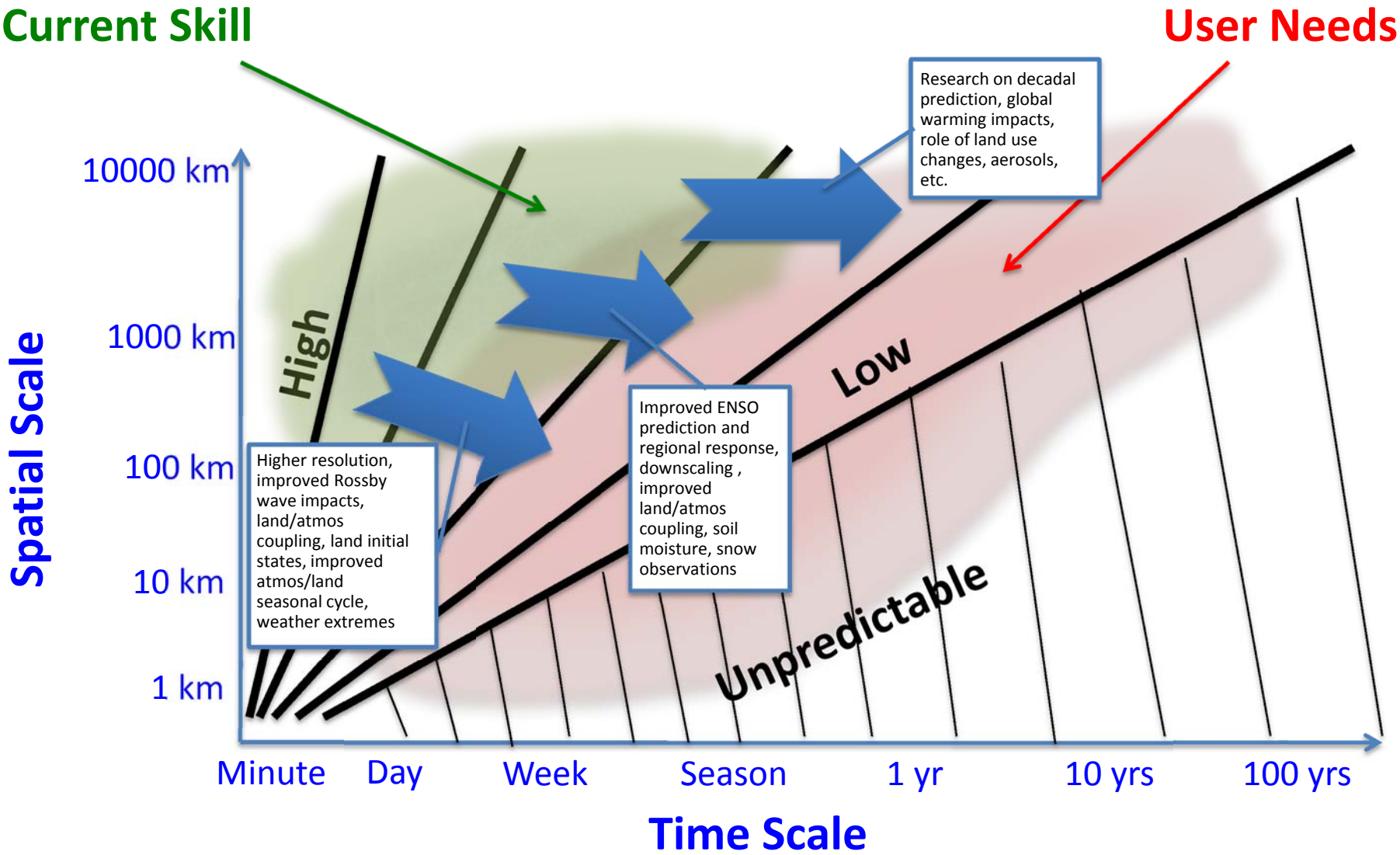
The Water Cycle: Inherently multi-scale

- Evaporation and precipitation have fundamentally different time and space scales
- Atmospheric transport pathways on synoptic scales
- Groundwater, soil moisture operate on short space scales but long timescales
- Clouds and precipitation form on a wide range of scales
- Oceans have long memory

The Water Cycle: Key space and time scales of important phenomena



Drought Predictability



Siegfried Schubert, *http://drought.wcrp-climate.org/workshop/ICPO_161_WCRP_Report.pdf*

Current status and gaps

- **Monitoring, field observation, and modeling have improved understanding**
  - Satellite remote sensing, observational network (e.g. ARM)
  - Improved model resolution and physics.
  - Most climate models have capability for comprehensive coupling
- **Gaps still remain**
  - Climate models still perform poorly in simulating coupled water cycle
  - PBL still poorly represented
  - Development of convective precipitation poorly handled.
  - Poor coupling between processes that are fundamentally coupled at subgrid scales, e.g. clouds and aerosols, precipitation and soil moisture
  - Poor understanding of how extreme precipitation might respond to changing forcing
  - Climate models unable to simulate pace of subtropical expansion
  - Representation of soil moisture and variability is poor
  - High-quality climate-quality observations still inadequate

Future directions and priorities #1

- **Promote research that emphasizes the coupled nature of the land-atmosphere-ocean system**
  - Improved snowfall and its subsequent melt, sublimation and runoff needs attention
  - Need to assimilate spaceborne, airborne, and surface in situ observations to provide consistent and integrated datasets (particularly over land)
- **Develop strategies for targeted observations of precipitating systems, especially those over land regions**
  - A focus on extreme precipitation events and their hydrological impacts is critical for understanding decadal and centennial water cycle variability.
  - Better understanding of the coupling of precipitating systems with the large scale atmospheric flow, land surface heterogeneities, orography, soil moisture, and aerosols
- **Further development of a new class of very high resolution Earth system models to explore key aspects of the water cycle**.
  - Can be used to identify key regional to global processes and connections between system components that are poorly handled in the climate models.
  - Atmospheric and land scientists need to work together to develop and test land-atmosphere coupled very high resolution regional models that can resolve clouds ~1 km scale) and simulate the 3D movement of soil moisture (~100 m).

Future directions and priorities #2

- **Improve representation of subgrid processes within atmospheric and land surface models.**
  - Current approaches ad-hoc and self-inconsistent manner.
  - The subgrid parameterization of processes (e.g., clouds, turbulence, topography) within grid cell.
  - Different subgrid processes strongly interact with each other
- **Develop team approaches which foster cross-disciplinary engagement and activities focused upon specific problems.**
  - Establishing teams of model developers, process modelers and observational scientists is critical.
  - Dedicated science teams focused on specific cross-disciplinary research themes for relatively short periods (e.g. 3-5 years) should be encouraged.
- **Identify regions for focused model development and evaluation efforts.**
  - Mechanisms dependent on regions and climate regimes
  - Need for comprehensive case studies over specific regions based on science, societal needs, and data availability.

Key questions for Topic 1

- What are the multi-scale characteristics of the water cycle for the atmospheric and terrestrial systems and the coupled system?
- What are the key multi-scale modeling needs of the community that will enable better prediction of water in the comprehensive human-earth system at regional to global scales?
- What modeling approaches can address the multi-scale challenges of the water cycle? What are their advantages and limitations?
- What are the implications of multi-scale behaviors on modeling water cycle extremes?
- What are the computational and observational requirements for each approach?
- Discuss case studies or regions for focused model development and evaluation efforts.