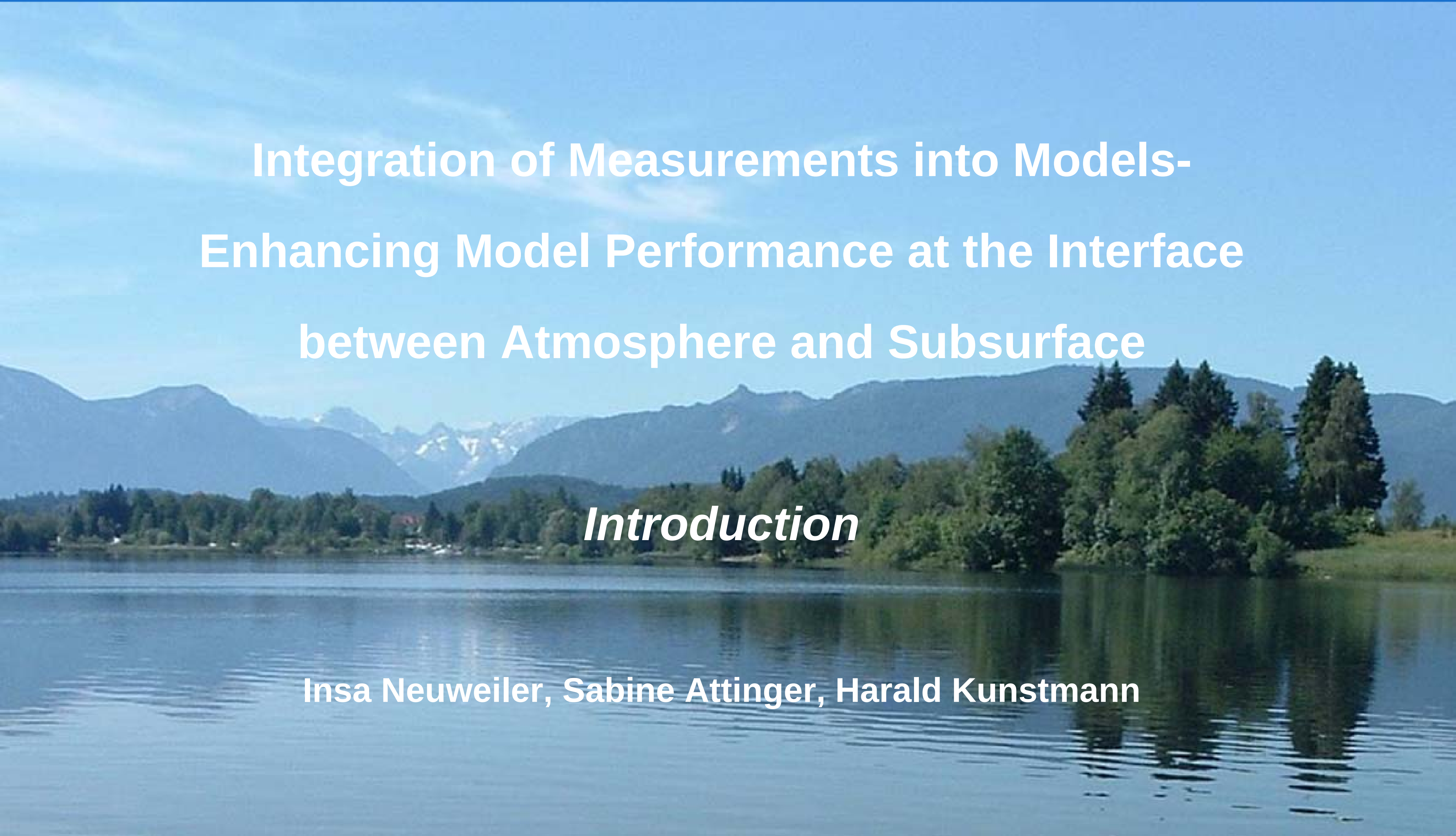


Integration of Measurements into Models- Enhancing Model Performance at the Interface between Atmosphere and Subsurface

Introduction

Insa Neuweiler, Sabine Attinger, Harald Kunstmann

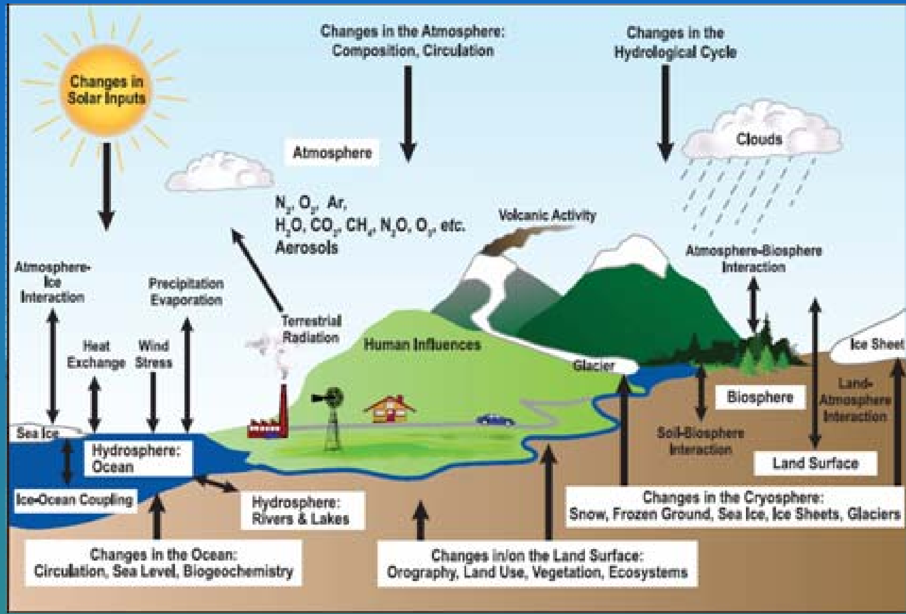
Motivation

- Water: problem of high societal relevance
  ⇒ coping with changing flood risk and water availability
  due to climate- & land use change
  ⇒ coping with water demands of ecosystem services
  ⇒ coping with freshwater demands of growing world population
  (quantity & quality)

- Decisions for sustainable water management usually based on hydrological modeling results

- Vulnerable regions are often ungauged ⇒ calibration/validation of models?

Motivation (II)



- Climate change impact research demands **INCREASED PREDICTABILITY & DECREASED UNCERTAINTY** bounds of hydrological modeling systems

- Hydrological processes:
  nonlinear & complex at all scales
  coupled with chemical & biological processes

- Close linkage & feedbacks
  atmosphere ↔ land surface ↔ subsurface:
  soil & vegetation = long & medium term memory of atmosphere
  atmosphere = main driver of terrestrial water fluxes

Motivation (II)

- **CURRENT ATMOSPHERIC & HYDROLOGICAL MODEL PERFORMANCE OFTEN**
  NOT SUFFICIENT FOR DECISION MAKING!

- Required: Improved knowledge and description of processes at interface between atmosphere and land surface

- Rapid development of measurement techniques and data sets

  … far beyond measurements of discharge, piezometric heads, solute transport

Variety of Observations: Examples

Traditionally: focus on DISCHARGE only, piezometric heads, solute transport
⇒ **LIMITED MODEL PREDICTABILITY AND RELIABILITY**

Required now: extension towards further state variables

- POINT/station measurements:
  1) latent heat fluxes (e.g. eddy covariance derived)
  2) soil moisture & temperature

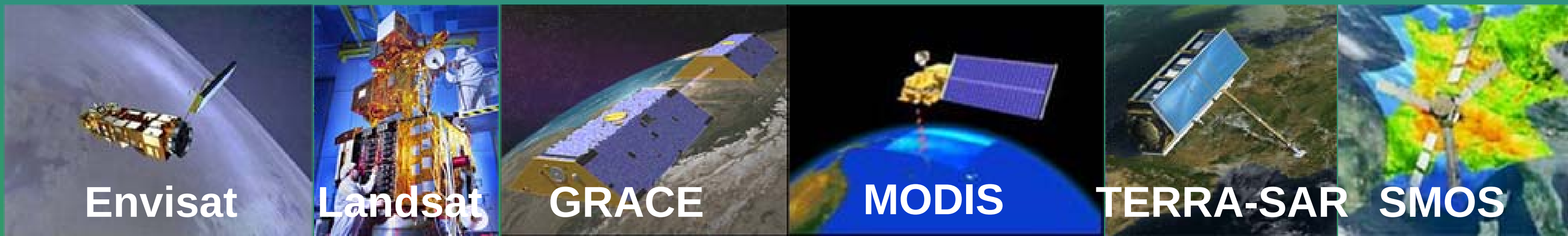
- LINE integral measurements:
  1) scintillometer derived sensible heat fluxes
  2) microwave attenuation derived precipitation

Variety of Observations: Examples (II)

- AREAL measurements ⇒ remote sensing

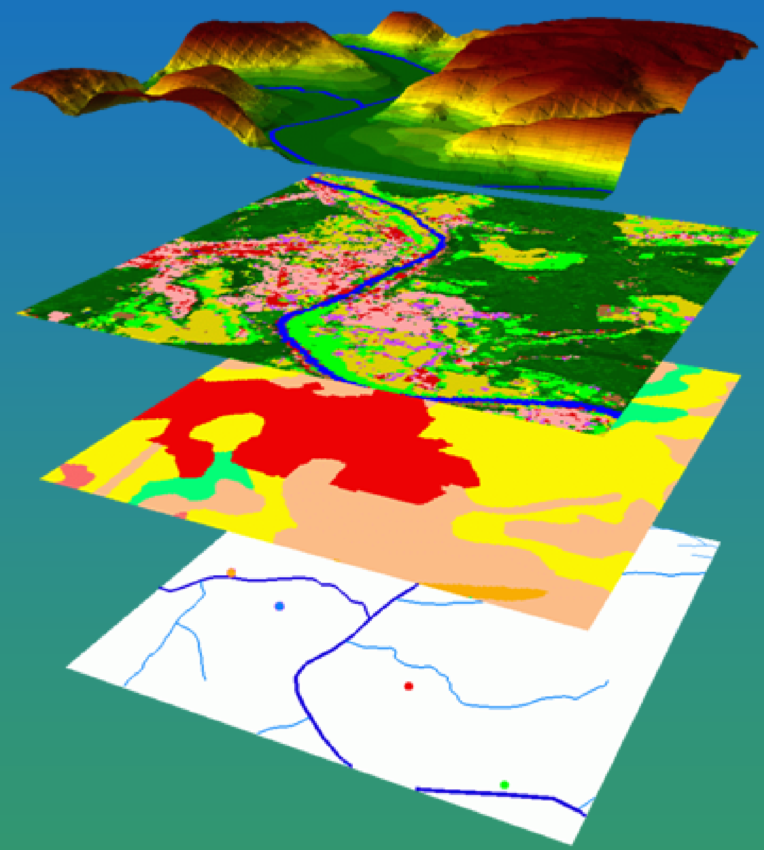
  1) Radar Systems
  - independent of cloud cover & daytime
  - observation of e.g. soil moisture
  - satellites SMOS (60x60 km², Δt=3 days)
    ENVISAT ASAR (up to150x150m²)
    Terra-SAR-X (up to 1x1 m²)

  2) Multi- and Hyperspectral Sensors
  - observation of e.g. surface temperatures
  - vegetation & snow cover dynamics
  - heat fluxes, using Energy Balance Models, e.g. SEBAL
  - satellites NOAA-AVHRR, MODIS, Landsat



Scientific Challenge

- Integration of observations of different TYPE and different SPATIAL AND TEMPORAL SCALES in hydrological models
- COMPARTMENT CROSSING MODELING: atmosphere ↔ land surface ↔ subsurface
- Joint consideration of WATER FLUXES & ENERGY FLUXES (& other fluxes: CO_2, trace gases, etc.)
- NONLINEAR & COUPLED PROCESSES complex and heterogeneous environment
- Accounting for FEEDBACKS between soil, vegetation, and atmosphere



- Scale gap: Δx,Δy atmosphere model >> Δx,Δy hydrological model

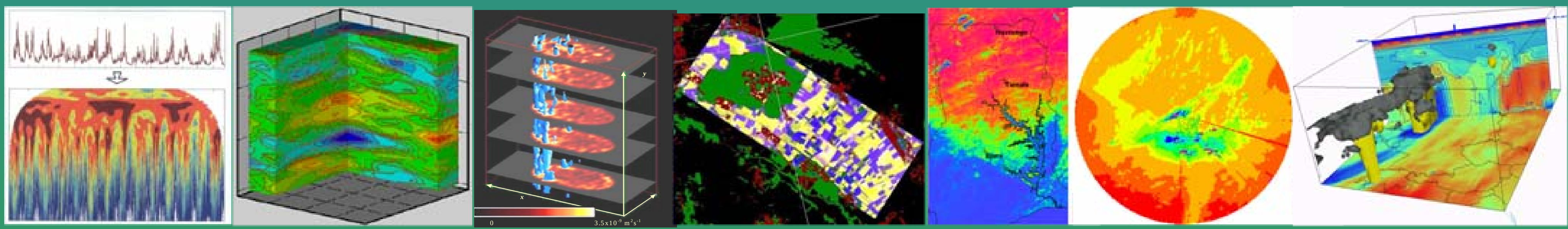
Scientific Challenge (II)

- Increased PARAMETER SPACE of compartment crossing modeling systems
  ⇒ efficient non-linear parameter estimation algorithms required
  ⇒ increased number of degree of freedom
  ⇒ non-uniqueness of solutions

- Non-uniqueness of solutions and errors of INDIRECT MEASUREMENTS

- Bridging the gap between MODELING SCALE & MEASUREMENT SCALE

- Development of new DATA ASSIMILATION & INTEGRATION ALGORITHMS for hydrological modeling systems



Objectives of Round Table Discussion

- Exchange of expertise in modeling & data integration techniques in geophysics, hydrological sciences and atmospheric sciences
- Comparison data integration techniques geophysics ↔ atmospheric sciences
  WHAT CAN HYDROLOGICAL AND ATMOSPHERIC SCIENTISTS LEARN FROM EACH OTHER?
- Identification of transferable methods that have potential for increased hydrological predictability
- Identification of methodological research gaps and model development/extension requirements
- Improved integration of remote sensing products in hydrological modeling systems
- Identification & planning of concerted compartment crossing measurement campaigns & modeling efforts (data sets & model approaches)

Specific Questions to be Addressed

- Major difficulties in joint modeling of water and energy fluxes?
- Approaches in individual disciplines to integrate observations on different temporal and spatial scales?
- Which observations in detail are available for our purposes?
- Current model approaches and developments for
  - regional,
  - distributed,
  - fully coupled water and energy fluxes,
  - joint atmosphere & land surface (soil & vegetation) modeling systems?
- New approaches for scale bridging (upscaling & downscaling) between atmosphere and hydrological models?
- Can we build on existing modules (→ focus on model coupling) or do we need to develop completely a new model system from scratch?


Thank you for your attention

Definition

Atmospheric sciences (Kalnay, 2003)
ASSIMILATION = Production of initial conditions through a *statistical combination of observations and modeling results*
Purpose: using all the available information, to determine as accurately as possible the state of the atmospheric (or oceanic) flow

Examples

- Empirical analysis schemes
- Least square methods
- Multivariate statistical data assimilation methods
- 3D-Var
- Dynamical and physical balance in the initial conditions

Hydrological/Geophysical Sciences
INTEGRATION = […Sabine ...]