Temporal and Spatial Scales in a Community Sediment Model Context

Motivation/Definitions

- Each problem/phenomenon has associated time and space scales
- Interested in processes spanning very wide range of scales—and their coupled behavior
- No single model can address the whole range of scales
  - Need a hierarchy of models
  - Models at disparate scales need to interact; “scaling”

Characteristic Scales

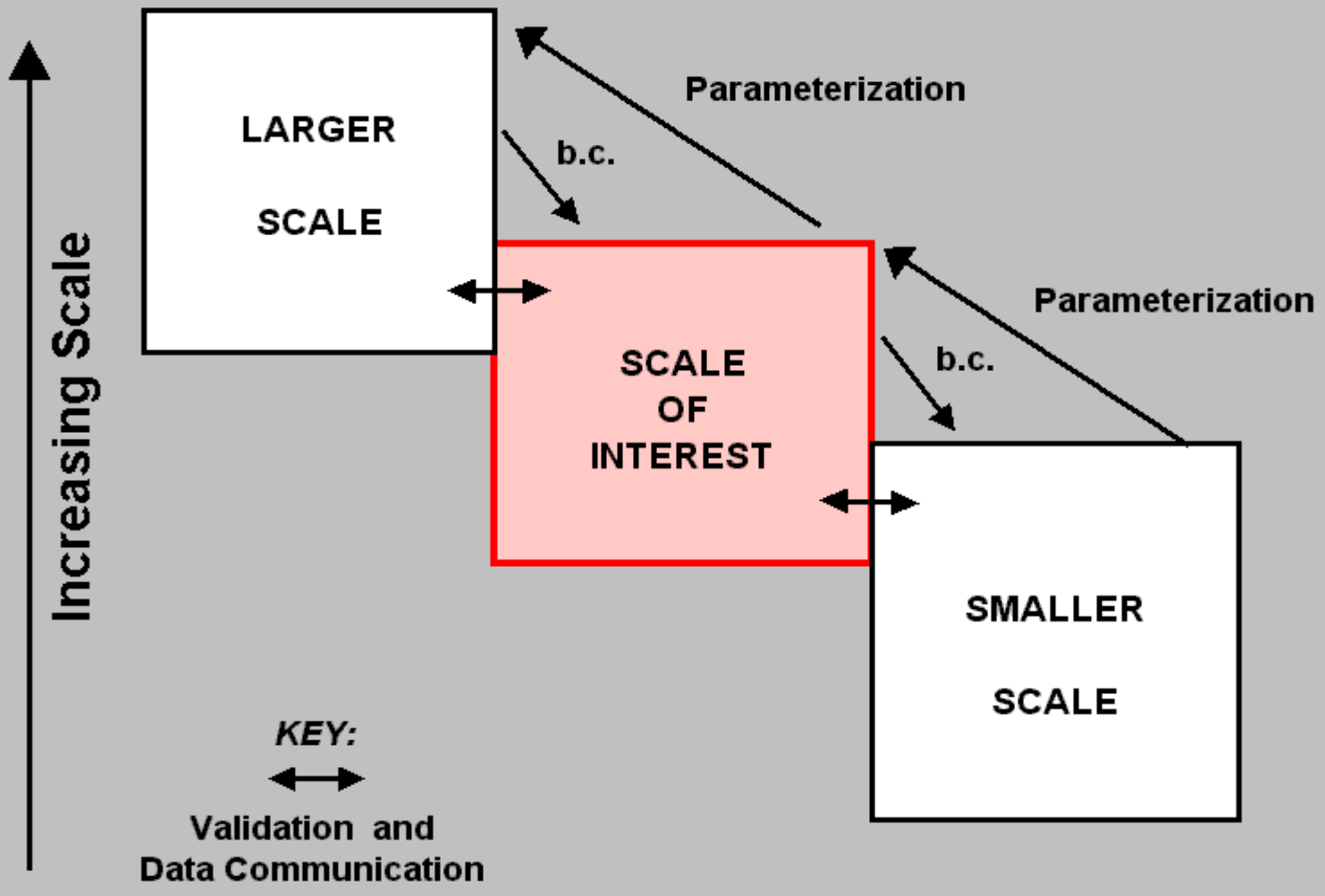
- Time: formation, evolution of feature(s) of interest
- Space: smallest features/heterogeneities to size of features of interest
- Time/space scales linked
- Component modules in the CSS would presumably be defined in terms of temporal and spatial scales over which they apply
- Therefore the temporal and spatial scaling applies both to the sedimentary system being investigated and to the modules used to simulate the system, but multiple module scales might be used for a given sedimentary system.

Coupling Between Scales

- Models based on interactions at scales of interest need information from other scales
- Smaller scales synthesized/parameterized
  - Constitutive relationships
  - Flux ‘laws’
  - Rules (or direct integration in some cases)
- Larger scales: Can be used to set boundary conditions and parameter constraints
- Examples
  - Coastal change on human time scales
  - Interpreting the rock record

Scale Nesting

- In some cases models or modules may be nested in temporal or spatial scales 1) at high resulution to bring high resolution to particular regions or 2) at low resolution to track evolving boundary conditions. Examples:
  - High resolution grids embedded in lower resolution grids (e.g., for floodplains or channels in drainage basin models)
  - High-frequency solutions may be used in some modules to characterize system components (e.g. bedforms or mixed-grain sediment transport) than cannot readily be parameterized at the longer time scales of the main model.


Increasing Scale
LARGER
SCALE
b.c.
Parameterization
SCALE
OF
INTEREST
b.c.
Parameterization
SMALLER
SCALE
KEY:
Validation and
Data Communication

Size and Space Domain

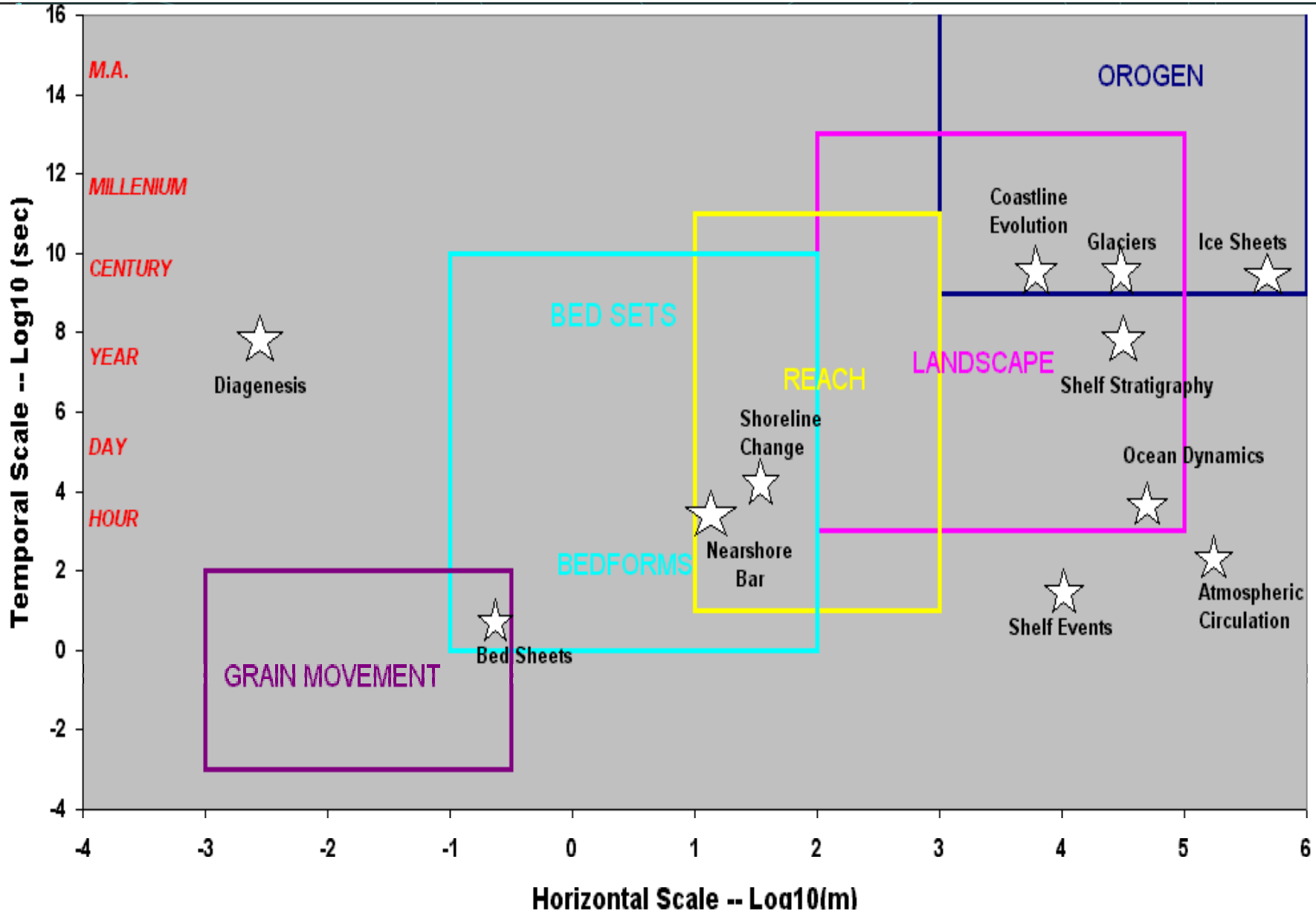
- Typical ranges of interest in a specific application span 3 orders of magnitude in space and time
  - Computational limitations (diminish through time)
  - Data set size, manipulation, and visualization
  - Corresponds to typical human range of comprehension
  - Focuses on specific scientific issues

Multiple Scales in Sedimentary Systems

- Scales may be set by:
  - Imposed boundaries or temporal scales (e.g., engineering problems)
  - Natural Scales
    - Mountain range
    - Floodplain
    - Individual Dune
    - Sand Grain

One Possible Scale Breakdown

- Orogen
- Landscape
- Reach
- Bedform
- Grain


Temporal Scale -- Log10 (sec)
Horizontal Scale -- Log10(m)
M.A.
MILLENIUM
CENTURY
YEAR
DAY
HOUR
OROGEN
BED SETS
REACH
LANDSCAPE
BEDFORMS
GRAIN MOVEMENT
Coastline Evolution
Glaciers
Ice Sheets
Diagenesis
Shelf Stratigraphy
Shoreline Change
Ocean Dynamics
Nearshore Bar
Atmospheric Circulation
Shelf Events
Bed Sheets

Orogen

- Examples: Himalayas, Appalachians & associated depositional basins
- Spatial Scale: >10^3 km
- Temporal Scale: >1 Century (10^9 sec)
- Whole “Source to Sink” System

Landscape

- Examples
  - Sedimentary basins
  - Continental shelves
  - River Basins
  - Coastlines
- Spatial Scale: 10^1 – 10^5 m
- Temporal Scale: 10^3 – 10^{13} sec

Reach Scale

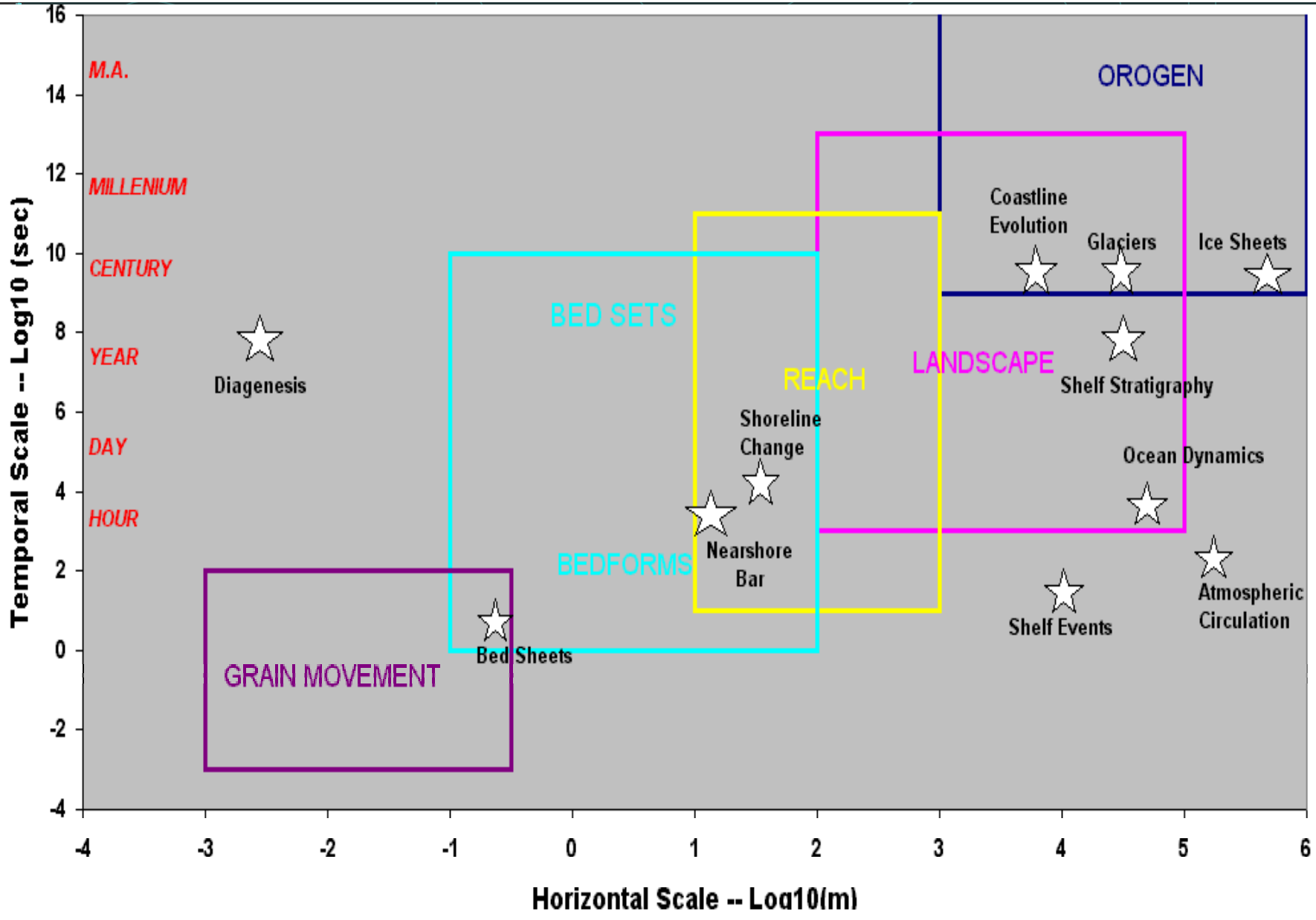
- Examples
  - Channels: Meandering, Braided, Distributary
  - Floodplain
  - 1st-order drainage basin
  - Hillslope or hollow
  - Surf zone
- Spatial Scale: 10^1 – 10^3 m
- Temporal Scale: 10^1 – 10^{11} sec

Bedform & Bed Sets Scale

- Examples
  - Dunes
  - Ripples
  - Alternate Bars
  - Offshore Bars
- Spatial Scale: 10^{-1} – 10^{2} m
- Temporal Scale: 1 – 10^{10} sec

Grain Processes Scale

- Examples
  - Saltation
  - Creep
  - Grain flows
- Spatial Scale: 10^{-3} – 1 m
- Temporal Scale: 10^{-3} – 10^{2} sec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Other Issues

- Many systems fall between or outside these scales:
  - Alluvial fans and deltas between Landscape and Reach Scale
  - Soil profiles below Reach Scale and clearly not a “bedform”
- Vertical scales typically 1/10 to 1/1000 of horizontal scales
- Engineering and human interactions generally at reach to bedform scale
- Techniques such as wavelet compression techniques might be useful to provide compressed high resolution storage to increase scale resolution.
- The data and visualization model components must have appropriate procedures to integrate datasets at different intrinsic scales of resolution

There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy.

- Although self-organization in nature tends to create natural scales, the particular time/space "boxes" identified here and their interconnections are lines drawn in the sand – arbitrary and subject to redefinition for particular model frameworks and environments.