Spatio-temporal Data Models of Biogeophysical Fields for Ecological Forecasting

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www.calmit.unl.edu/BDEI
How can image time series be used for ecological analysis, modeling, and forecasting?

Phases of image time series analysis:
1. Change detection – perceiving the differences
2. Change quantification – measuring the magnitudes of differences
3. Change assessment – determining the significances of differences
4. Change attribution – identifying/inferring the proximate causes

How are baselines determined?
weather data : climate data :: terrestrial image series : land surface expectations

What are the appropriate units of analysis for image time series?
The Challenge of Spatio-temporal Queries

[Q 1] Where did spring arrive earlier this year than last?
Point-wise comparisons between time instants

[Q 2] Was the area in which spring arrived earlier than the previous years greater than the area in which spring arrived later than the previous year?
Requires spatial aggregation that would require non-standard constructs

[Q 3] Where is spring likely to arrive earlier next year than this year?
Requests a forecast predicated on past and current knowledge

Incubation Activities include:
• Proof-of-Concept Projects – ongoing
• Generation of Exemplary Datasets – ongoing
• Cross-disciplinary Workshop – 4/ 2002
• Special Session at US Landscape Ecology Symposium – 4/ 2002
• Study Group on using IDL for handling image time series – current
AVHRR NDVI biweekly composites from 1990-2000: PCA by compositing period

- Peak separation date for C₄ grasses (DOY 159-172)
- Peak separation date for corn, soybeans summer row crops (DOY 215-228)
- Peak separation date for winter wheat (DOY 61-74)
Differential Seasonality
MODIS 500 m NDVI 2002 growing season

PC1
PC2

weights for PC1 & PC2

weights for PC1 only

compositing period

-0.5 -0.25 0 0.25 0.5
0 2 4 6 8 10 12 14

0.260 0.280

-0.25 0.25 0.5

-0.5 0 0.25 0.5

-0.25 0.25 0.5

-0.5 0 0.25 0.5
Characterizing spatio-temporal pattern: Establishing expected land surface phenologies

Expected spatio-temporal trajectories of surface greenness in contrasting Omernik Level III ecoregions

- Cascades #4
- Chihuahuan Deserts #24
- Nebraska Sand Hills #44
- Western Corn Belt Plains #47
- Southeast WI Till Plains #53
- Southern Florida Coastal Plain #76

source: G. Henebry, UNL

NDVI vs correlation length (km)
Interannual variation in spatio-temporal pattern: Identifying dynamical watchpoints for forecasting applications in land surface representation for NWP models.
An Exemplary Dataset of Linked Spatio-temporal Processes
Novel Views of the Archive: MIR Portrait of CONUS

Settlements & transportation networks appear as white patches and lines contrasted against the vegetated matrix.

Source: G. Henebry, CALMIT/UNL
International Cross-disciplinary Workshop on
Spatio-temporal Data Models of Biogeophysical Fields for Ecological Forecasting
held 8-10 April 2002
at the San Diego Supercomputer Center

- Experts in spatio-temporal databases
- Experts in spatial & spatio-temporal data mining
- Domain experts from ecology, physical geography, remote sensing

Position papers available at:
www.calmit.unl.edu/ BDEI/ workshop.htm
Five Reasons for the Perceived Gap between Disciplines

1. **Questions vs. Queries**
   - Principal mode of inquiry for domain scientists is analysis.
   - Questions often do not (or cannot) have unequivocal answers.
   - In contrast, database scientists seek generalized formulations to deliver an unequivocal solution to a query.

2. **Fog of Uncertainty**
   - Multiple issues on definition/characterization in data and data relationships:
     - Measurement error (precision & accuracy)
     - Vagueness of fields/variability of objects/challenge of dual representations
     - Thematic fuzziness / Dimensional fuzziness
     - Missing data / Appropriateness of interpolation/extrapolation
     - Propagation of uncertainty through models
Five Reasons for the Perceived Gap between Disciplines

3. Multiplicity of Views
   - Biogeophysical fields present the opportunity to derive multiple valid views of the data that are context and scale dependent and variable in time.

4. Examples of Worthy Targets
   - Lack of exemplary “solved” problems & showcase applications with wide appeal.
   - Need equivalent of Bongard problems to explore characterization of and querying to spatio-temporal patterns.

5. Institutional Support
   - General lack of support at universities and sponsoring agencies for:
     - Regular cross-disciplinary interactions
     - Sustained research collaborations
     - Technological training for domain scientists, both students and faculty.
Ecological Forecasting Using Image Time Series

1. Exploit operational monitoring of the land surface and the image archives to develop baselines/expectations

2. Evaluate current & recent observations in terms of the expectation - measure change & identify anomalies

3. Forecast next observations on the basis of recent past and historic context