SPATIAL, SEASONAL, AND SYNOPTIC VARIATIONS IN AIR TEMPERATURE LAPSE RATES

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ABSTRACT

The average atmospheric lapse rate of -0.65 °C/100m commonly applied in snowmelt/streamflow prediction models and other investigations of environmental processes is a spatially-global and temporally-climatic average (or standard). It should be applied with caution at other scales. The objective of this research is to evaluate daily surface (2 m) air temperature lapse rates at a spatial scale that has not been evaluated thoroughly in other literature. Specifically, seasonal and synoptic weather type variations in lapse rates will be evaluated for a basin less than 10,000 km^2. The performance of long-term average versus seasonal lapse rates is evaluated using cross-validation. Application of the lapse rates to forecasted air temperature is discussed.

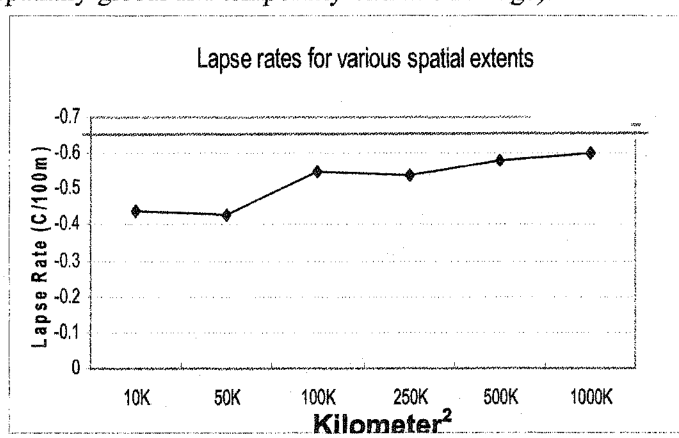
PRESENTATION EXTRACTS

Slide 2: Presentation Outline:

- Lapse rate literature review
- Objective
- Study Area
- Methods
  - Computing daily lapse rates
  - Synoptic classification system
  - Cross-validation comparing mean lapse rates
- Results
  - Effect of spatial scale
  - Seasonal variations in lapse rates
  - Synoptic variations in lapse rates
  - Recommended lapse rates for study area
- Summary and Conclusions

Slide 5: Lapse Rate Variation by Spatial Scale:

- Mean lapse rates represent 15 stations with similar elevation distributions within different spatial extents.
- Lapse rates approach the environmental lapse rate constant as spatial extent increases (the ELR is a spatially-global and temporally-climatic average).



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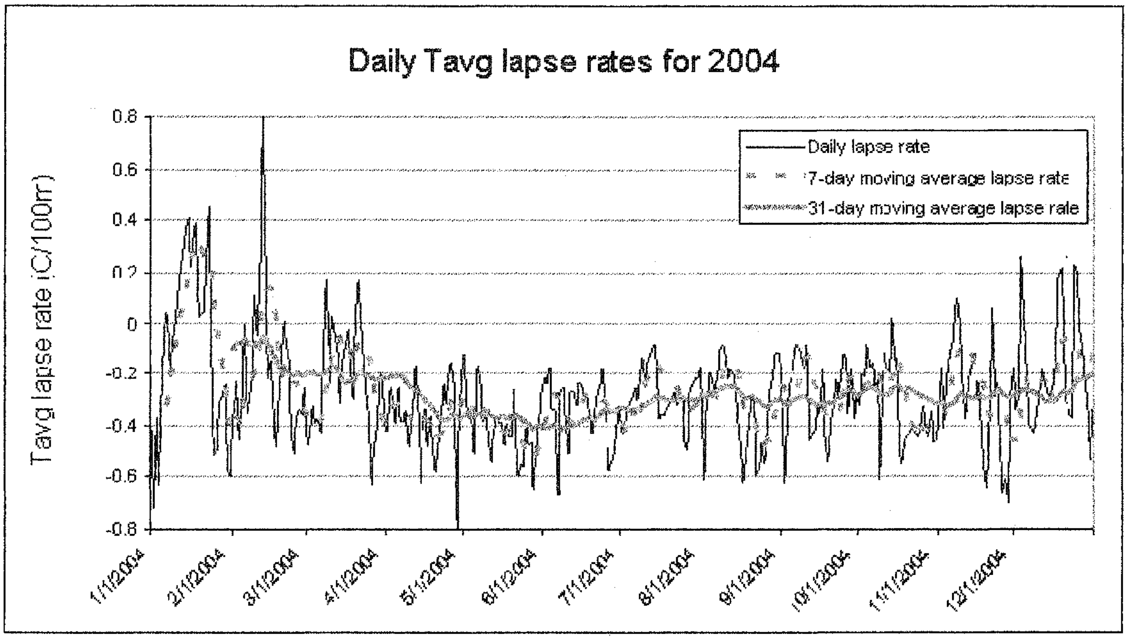
Slide 6: Daily lapse rate variation within a year:

- Area near North and South Forks of Boise River (10,000 km^2)



Slide 8: For relatively small basins:

- How variable are lapse rates at both daily and monthly time scales?
- Do different synoptic weather types significantly influence lapse rates?
- Will estimated air temperature be more accurate when using lapse rates that include seasonal and synoptic conditions? (compare these groups: ELR, regional lapse rate, monthly, synoptic).

Slide 10: Methods - Data Sources:

Temperature observation data sources

- National Weather Service's Cooperative Observer Program (NWS-COOP) stations.
- Natural Resources Conservation Service's SNOwpack TELemetery network (NRCS SNOTEL) stations.
- Daily maximum and minimum temperature observations were downloaded. Average temperature was computed as the mean of max and min.

Slide 11: Methods - Station Selection:

- Station selection criteria
  1. Located within ½-degree radius of center of study area.
  2. Similar periods of record.
  3. <15% missing data after quality control

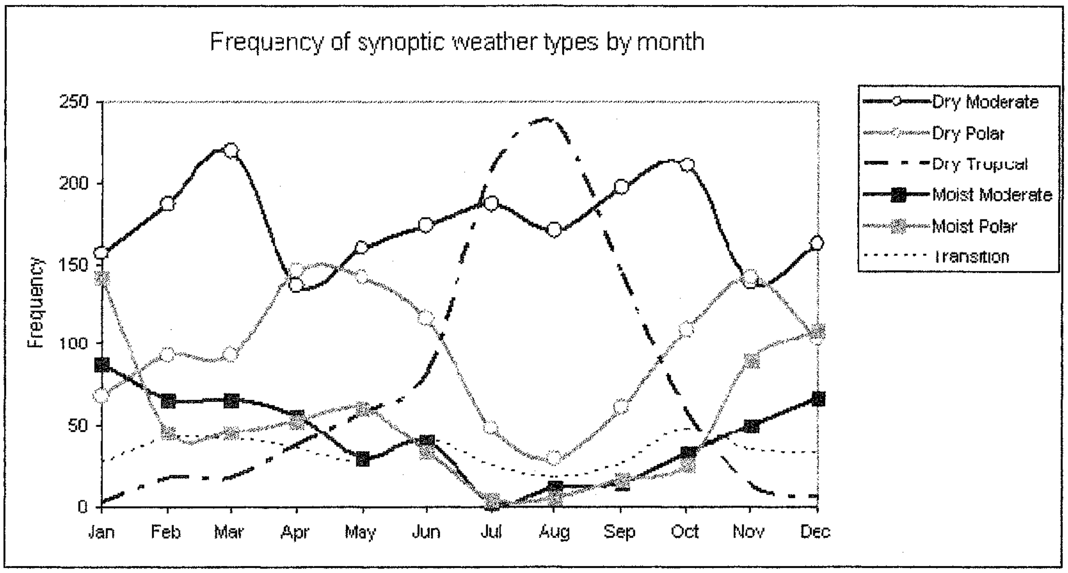
  Resulted in 14 stations (2 COOP, 12 SNOTEL) with an overlapping period of record from January 1, 1989 to December 31, 2004 (5,527 days).

Slide 12 - 13: Methods – Synoptic Classification:

- Spatial Synoptic Classification (SSC2; Sheridan, 2002).
  - Allowed determination of local lapse rate response to the weather type.
  - Historic record readily available <http://sheridan.geog.kent.edu/ssc.html>.
- Weather conditions categorized daily into six different types or as transition.
  - Dry moderate – mild and dry; zonal flow aloft.
  - Dry polar – cool or cold, dry air, northerly winds, minimal cloud cover.
  - Dry tropical – hot, dry, sunny.
  - Moist moderate – cloudy, warm, humid.
  - Moist polar – cooler and less humid than moist moderate.

- Moist tropical – not frequent in study area.

Slide 15: Monthly frequency of synoptic conditions: Dry conditions dominate for 9 months of the year.



Slide 18: Methods – Cross Validation:

- Evaluating performance of mean lapse rates
    - Leave one year out iteratively.
    - Compute mean lapse rates for remaining years (predicted lapse rate dataset).
    - Compute daily lapse rates for year left out (observed lapse rate dataset)
    - Compute mean error (bias indicator), mean absolute error (MAE), and root mean square error (RMSE) from observed - predicted datasets.
- Application-oriented cross-validation
    - Replicated method used by hydrologic model (Snowmelt Runoff Model).
    - Applied monthly mean, ELR, and RL lapse rates to 3-day Tavg forecasts.
    - Single snowmelt season was evaluated (153 days).

Slide 25: Results – Recommended lapse rates

Month	Tmax (C/100m)	Tmin (C/100m)	Tavg (C/100m)
Jan	-0.43	-0.16^Δ	-0.28
Feb	-0.51	-0.21	-0.36^Δ
Mar	-0.54	-0.33	-0.43
Apr	-0.61^Δ	-0.36	-0.49
May	-0.63	-0.29	-0.46
Jun	-0.68	-0.19	-0.43
Jul	-0.66*	-0.008	-0.33
Aug	-0.70	.03	-0.33
Sept	-0.70	.03	-0.34
Oct	-0.68	-.05	-0.36^Δ
Nov	-0.53	-0.23	-0.38^Δ
Dec	-0.43	-0.12^Δ	-0.28

* Indicates mean NOT significantly different from the E.L.R.
^Δ Indicates mean NOT significantly different from the R.L.

Slide 27: Summary of Results – Daily and seasonal variation in lapse rates:

- Maximum temperature lapse rates least variable; minimum temperature most variable.

– Maximum temperature lapse rates have a distinct seasonal trend with steeper lapse rates occurring in summer.
– Minimum and average temperature lapse rates are steepest in spring and shallowest in late summer, early fall.
– Most monthly means are statistically different from both the Environmental Lapse Rate and Regional Lapse Rate.

Slide 28: Results – Variation of lapse rates by weather types:
– Temperature of the air mass appears to impact maximum temperature lapse rates.
– Moisture level of the air mass appears to influence minimum and average temperature lapse rates.
– Dry tropical conditions produce the largest difference in lapse rates between maximum and minimum temperature.

Slide 29: Conclusions for the 10,000 km2 basin:
- The ELR is solely applicable to maximum temperature (models often apply it to average temperature).
- Monthly lapse rates seem to be a practical combination of effective performance and easeof implementation.
  – If observations are not available, then the ELR may be adequate for maximum temperature and a regional lapse rate may be adequate for minimum and average temperature.
- Although a combination of season and synoptic types do explain some of the variance in daily lapse rates, they do not explain large amounts of it (~24% combined).