MODELS AND DATA ASSIMILATION

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DIFFERENT KINDS OF MODELS

Statistical models for interpolating SWE

Radiance models for forward modeling of remote sensing measurements

Snow models for predicting accumulation, ablation, densification, etc.
SNOW MODELING

Mass and energy conservation equations predict accumulation and ablation

Equations are easy to write, but the devil's in the details

SNOW MODELING
Mass and energy balance
SNOW MODELING LIMITATIONS

• SWE accumulation modeling limited by precipitation accuracy
• Interaction of wind with topography and vegetation produce difficult-to-model effects

Precipitation uncertainty and wind redistribution
Can a grain size model accurately model this spatial distribution?

**SNOW MODELING LIMITATIONS**

Albedo, grain size, and contaminants

Flanner and Zender, 2006

Dozier et al., 2009
SNOW MODELING LIMITATIONS

Density

Statistical model
CLPX eval.

Physical model
30-60+ kg m\(^{-3}\) RMSE

Boone and Etchevers, 2001

Sturm et al., 2010
DATA ASSIMILATION

Tools to integrate data streams to utilize the good features and compensate for the limitations of both models and observations, based on our confidence (uncertainty) in each
Data assimilation requires us to put a number on the uncertainty of each datastream.

DA estimate can be thought of as a weighted average - the weights are optimized based on uncertainties.

\[ \hat{h} = wh_{obs} + (1 - w)h_{mod} \]

\[ w = \frac{\sigma_m^2}{\sigma_m^2 + \sigma_o^2} \]

Simple example: modeled SWE at 90 m, with several snow pillows.

Near pillows, \( w = 0.9 \)?

Far from pillows, \( w = 0.05 \)?
Sequential assimilation: Model used to temporally interpolate between temporally sparse remote sensing measurements: e.g. airborne GAMMA, as NOHRSC does for SNODAS
April 1 SWE

SWE reconstruction: retrospective merger of SCA imagery and snow melt runoff via energy flux modeling

Can be done via reanalysis assimilation (weighing uncertainty) or deterministically

Girotto et al., in prep

1988

2011

Girotto et al., 2013
Model used to provide spatial distribution, observations provide SWE magnitude
Model used to downscale coarse GAMMA observations, and to extrapolate in situ observations
How well correlated is SWE at a single one km² ISA with SWE model errors at other locations?

End-member cases: Totally uncorrelated. Totally correlated.

Possible co-variates: distance, vegetation, others?

How much weight to give to each? Uncertainty

Liston et al., 2008
Modeling can be first guess for inverting radiometric quantities

CoReH2O requires a prior knowledge of grain size for accurate SWE inversion
First guess: SWE from 3-layer SAST at 90 m forced with disaggregated NLDAS (UCLA)

Predicted $T_b$ from MEMLS using improved Born approximation (Bern)

Aggregated $T_b$ (right)

AMSR-E (left)

Difference used to update SWE

Model here used to provide first-guess for radiance inversion, and to downscale coarse AMSR-E to 90 m resolution
Assimilation methods can also be used to merge multiple kinds of observations. GlobSnow sequentially merges passive microwave with synoptic weather stations based on their respective uncertainty.
SUMMARY

For optimally merging multiple datastreams

• We have to fully, adequately characterize measurement uncertainty, and how it varies across the landscape

• We have to better understand correlation: how does information at one point in space and time apply elsewhere?

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