# A GOLDEN ERA FOR ALPINE CATCHMENTS: HIGH RESOLUTION MODELING AND REMOTE SENSING

ETHAN GUTMANN

4<sup>TH</sup> ANNUAL INARCH WORKSHOP

26 OCTOBER 2018

PORTILLO, CL

# THE PROBLEM

MAKING MEASUREMENTS IN ALPINE TERRAIN IS DIFFICULT

# A DIFFERENT PROBLEM

The problem now is making optimal use of the tools and data we have

- Tremendous advances in remote sensing
  - ASO, InSAR, cubesats, and the growing legacy of landsat, etc.
- Tremendous advances in hydrology and atmospheric modeling
  - Long term convection permitting modeling
  - LES modeling over catchments
  - MESH, WRF-hydro, etc.

# **REMOTE SENSING**

- ASO provides snow (and forest) measurements we never thought possible 20 years ago
- Cubesats provide unprecedented image frequency
- Thermal Imagery provides a long history of land geophysical measurements





# REMOTE SENSING: ASO / LIDAR

- Snow depth maps provide basin totals
- Also reveal process scale information
  - Snow deposition on lee slopes
  - Snow ablation from south facing slopes
  - Snow scouring on windward slopes
  - Effects of individual trees!



## REMOTE SENSING: ANOTHER PATH

- Use of high-resolution satellite stereo pairs to map snow depth
- Stereo2SWE (Shean et al)
  - Simultaneously: Gascoin et al
- Lower accuracy (10s cm)
- Space based (global potential)
- Arctic DEM
- UAV applications



# REMOTE SENSING: OPTIMAL USAGE

- Snow depth maps quantify basin totals
- Perhaps more accurately than "calibrated" hydrology models can use
  - "Calibrated" models may compensate snow and soil/groundwater storage
  - When confronted with better snow data this can cause failures
- We should do better than uncalibrated models, purely statistical forecasts, or inconsistently calibrated models



# REMOTE SENSING: SNOW COVER

- Snow covered area
- Used to constrain hydrology (and atmospheric) models
- Historical:
  - 500m daily (MODIS)
  - 30m ~monthly (LANDSAT)
- Now:
  - ~3m "daily" (Planet)



# REMOTE SENSING: VEGETATION

- LiDAR (and stereo) derived canopy height / volume
- Snow interception

- "not very remote" sensing
  - Videos of tree sway can measure interception



## REMOTE SENSING: THERMAL DATA

- An untapped data source
- Difficult to work with
  - Sensitive to many factors
- Long time series of 60 m (Landsat) to 1 km (MODIS) imagery
- Directly related to surface energy balance
  - Rn + ET + H + G





# MODELING

- Long-term convection permitting modelling
- Intermediate Complexity Models for Alpine Research
- Large eddy simulation (snow drift permitting) scale
- MESH / WRF-hydro and the rise of hyperresolution
- Are models "better" than observations?





# CHANGES IN HURRICANES IN A WARMER CLIMATE

#### Hurricane Ivan (2005) Current climate

#### Hurricane Ivan (Future climate)

(Pseudo Global Warming approach, warmer and moister)

- Convection Permitting 13 year CONUS domain simulation (current and future climate)
- >30 named hurricanes in current climate and same hurricanes in warmer and moister climate
- Increases in maximum wind speed
- Large increases in maximum precipitation rates (> 50%)
- Substantial variability in change signal in different hurricanes





#### Water Vapor (Blues) Precipitation (Green to Red)



Changes in Hurricanes from a 13 Year Convection Permitting Pseudo-Global Warming Simulation, Gutmann et al. 2018, (Accepted in Journal of Climate) Corresponding Author: Ethan Gutmann, gutmann@ucar.edu Analysis funded by Det Norske Veritas (DNV) and CONUS simulation by NSF under NCAR Water System Program



WRF – PRISM

### MODELING: INTERMEDIATE COMPLEXITY ATMOSPHERIC MODEL



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# MODELING: SNOW DRIFT RESOLVING LES

- Large eddy simulation (LES)
  - snow drift permitting scales
- Are models "better" than observations?
  - For wind... where we don't have observations (everywhere)







# **BRINGING THEM TOGETHER**

- How can remote sensing improve modeling?
  - Holding the model's feet to the fire
- How can modeling improve remote sensing?
  - "better than obs" supporting data
- How can both be combined to improve alpine hydrology
  - Model-data fusion to produce better forcing dataset
  - Data for parameter estimation



### **MODEL – DATA FUSION**

- Snow covered area to constrain precipitation occurrence and phase
- GPM precipitation radar and cloud top further constraints
- Skin temperature measurements provide air-temperature covariate
- Using observed and modeled precipitation
  - Climatological obs or climatological model
  - Model spatial covariance or obs
  - ... other possibilities



# NEXT GENERATION CATCHMENT MODELS

- Hyper-resolution solves some problems, introduces others
  - Resolve slope, aspect, elevation, vegetation covariance
  - Hyper-resolution means hyper-parameter



- Hyper-resolution forcing requirements
- Hyper-resolution data for comparisons
  - Snow (and streamflow) provides an observable that integrates many relevant processes
- Needs hyper-resolution forcing



# THE REVOLUTION IN MODELS AND REMOTE SENSING

- New (and older underutilized) remote sensing datasets provide insight to Alpine Catchment processes
  - ASO / Lidar, Stereo, UAVs, thermal data, GPM, ...
- New atmospheric models are exceeding the skill of our "observations"
  - Precipitation, wind, ...short wave? Longwave?
  - Can provide excellent forcing for hydrologic models with caveats (chaos)
- The next major advance will be learning how to make better use of both of these datasets and combining them with existing station data



