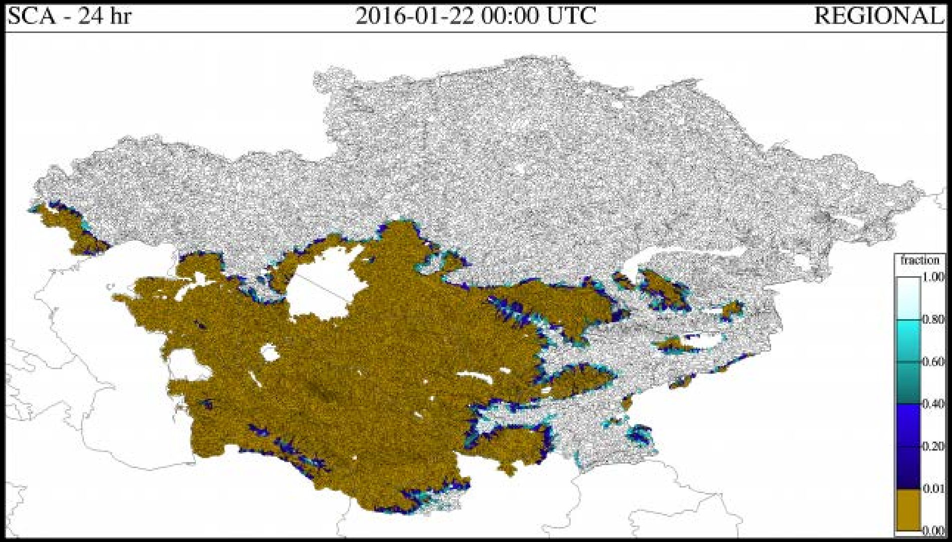
Central Asia Regional Flash Flood Guidance System
4-6 October 2016



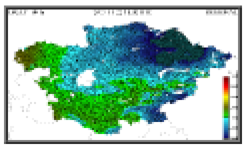
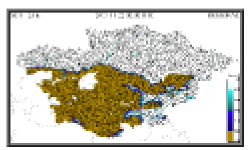
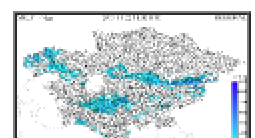
Central Asia Snow Accumulation, Ablation & Cover

Hydrologic Research Center

A Nonprofit, Public-Benefit Corporation

http://www.hrcwater.org

FFGS Snow Products

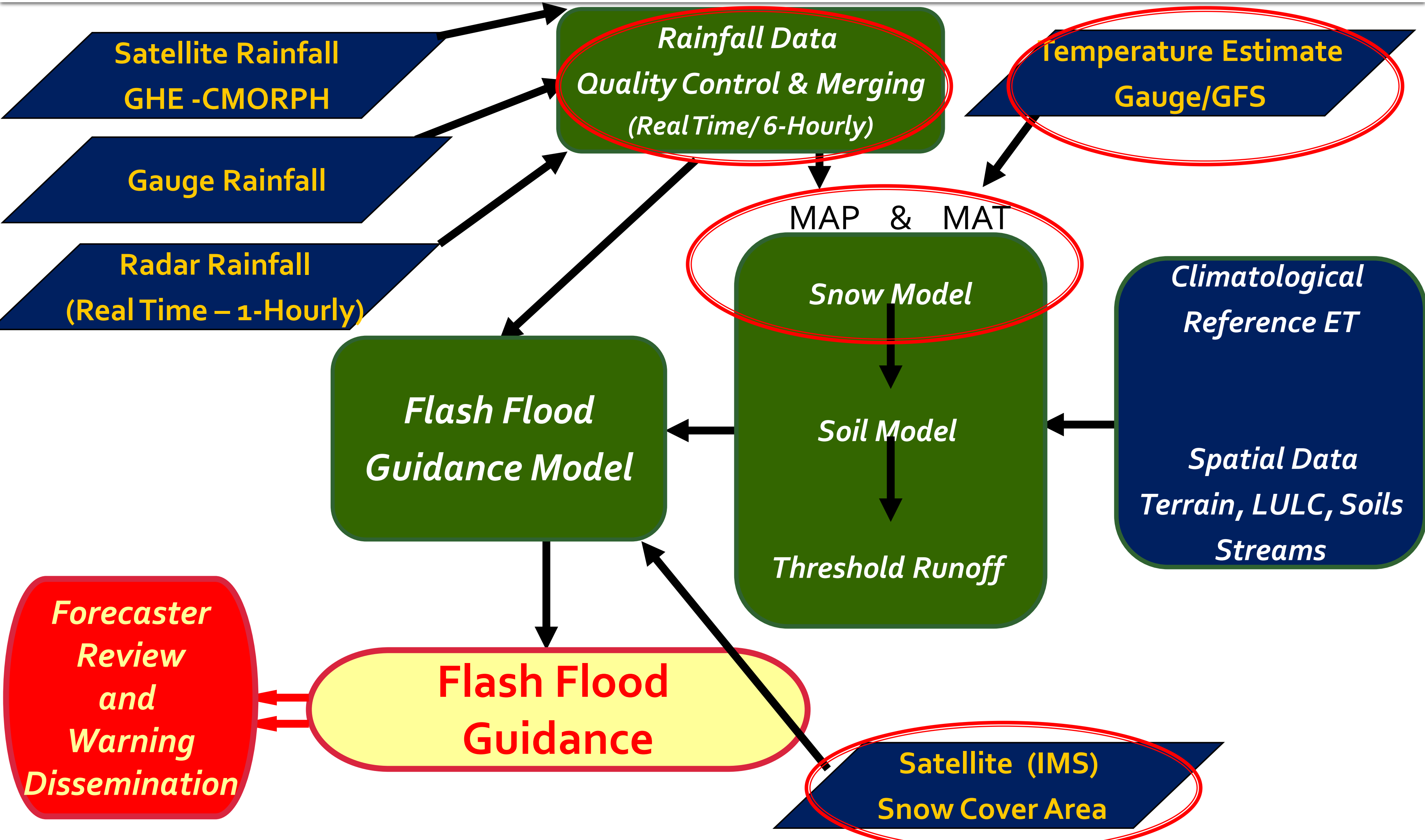
Snowpack Products				
DT	Gauge MAT	Latest IMS SCA	SWE	Melt
06-hr	 2015-11-22 18:00 UTC Text: view		 2015-11-22 18:00 UTC Text: view	
24-hr		 2015-11-22 00:00 UTC Text: view		 2015-11-22 18:00 UTC Text: view
4-day				 2015-11-22 18:00 UTC Text: view

Presentation Outline:

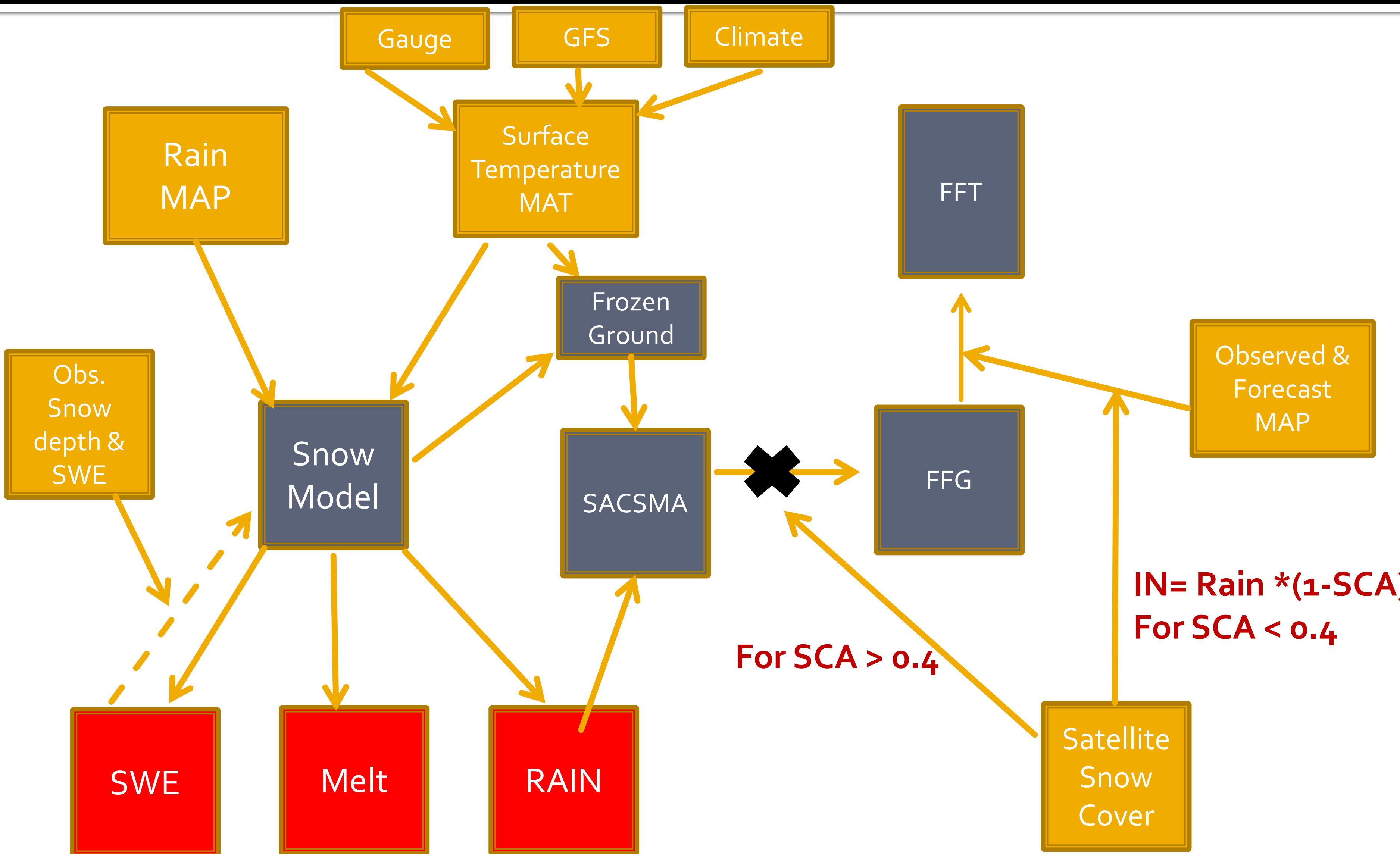
- FFGS Snow Components
- Snow Accumulation and Ablation Model
- Model Input (MAT and MAP)
- Snow Cover (IMS)

- Model Evaluation

FFGS Snow Model Components



Modeling Schematic



Snow -17

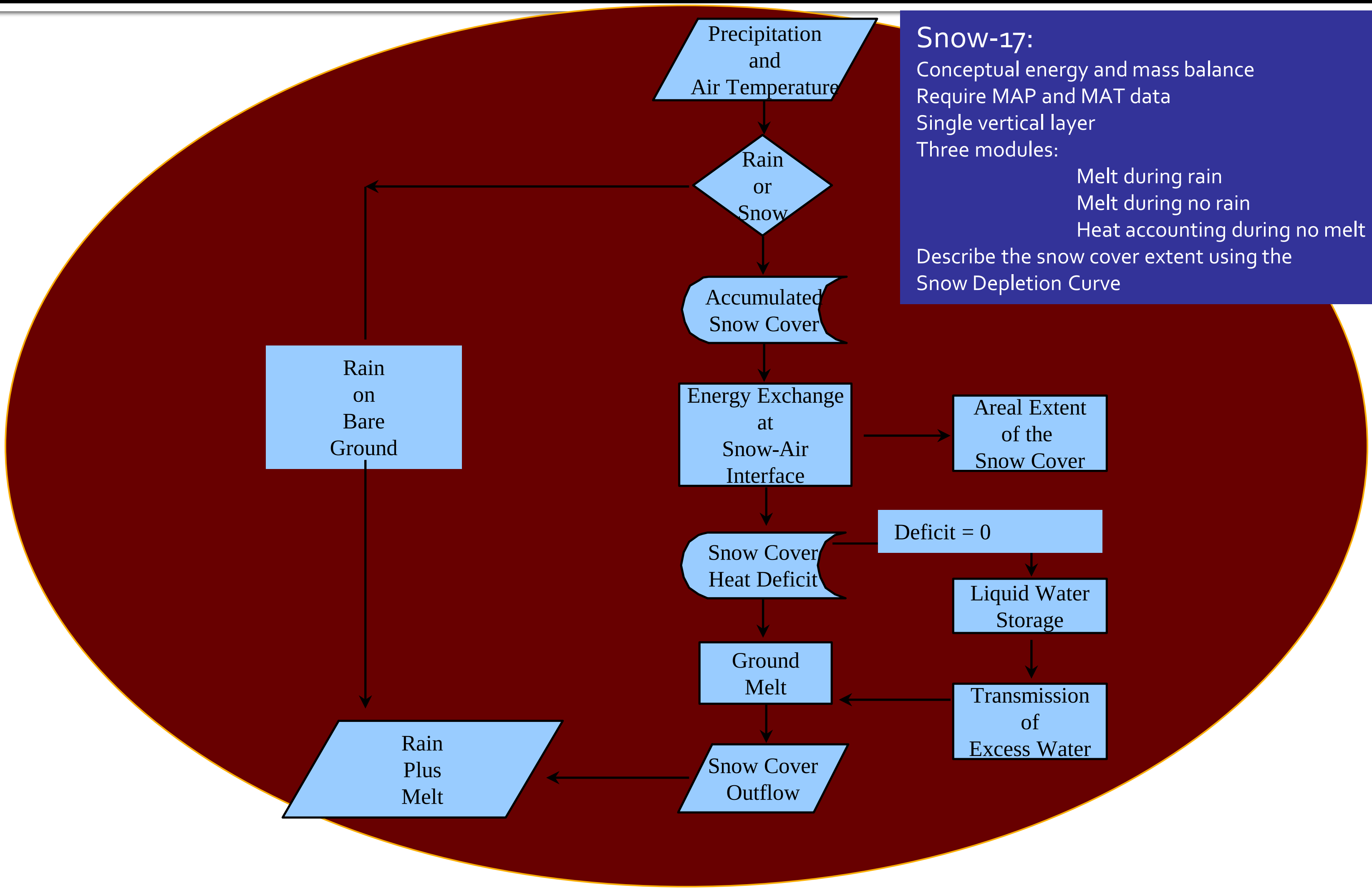
- **Anderson, Eric A., 1973: "National Weather Service River Forecast System -- Snow Accumulation and Ablation Model", *NOAA Technical Memorandum NWS HYDRO-17*, US Dept. of Commerce, Silver Spring, MD, 217p.**

- **Anderson, Eric, A., 1976: "A Point Energy and Mass Balance Model of a Snow Cover", *NOAA Technical Report 19*, U.S. Dept. of Commerce, Silver Spring, MD, 150p.**
- **http://www.nws.noaa.gov/oh/hrl/nwsrfs/users_manual/part2/_pdf/22snow17.pdf**

Snow Model

- Snow Accumulation and Ablation Model (SNOW-17) of the U.S. NWS (Anderson, 1973; Anderson, 2005)
- Operational model at the National Weather Service, U.S.A
- A conceptual areal lumped energy and mass balance model
- *Air Temperature* used as an index for pack energy and division of precipitation as rain or snow
- Considers: melt during no rain; melt during rain; no melt
- Model states track: snow water equivalent (SWE), heat deficit, liquid content, and snow cover area

SNOW-17 MODEL:



Snow-17:
Conceptual energy and mass balance
Require MAP and MAT data
Single vertical layer
Three modules:
- Melt during rain
- Melt during no rain
- Heat accounting during no melt

Describe the snow cover extent using the Snow Depletion Curve

Model Variables

States

- SWE - Snow water equivalent
- Liquid content – PLWHC parameter (vertical transmission through the pack)
- Heat Deficit - Energy required to bring the snowpack to isothermal 0º C
- ATI – Antecedent Temperature Index
- Snow Pack Depth – (Optional)
- SCA - Snow Cover Area

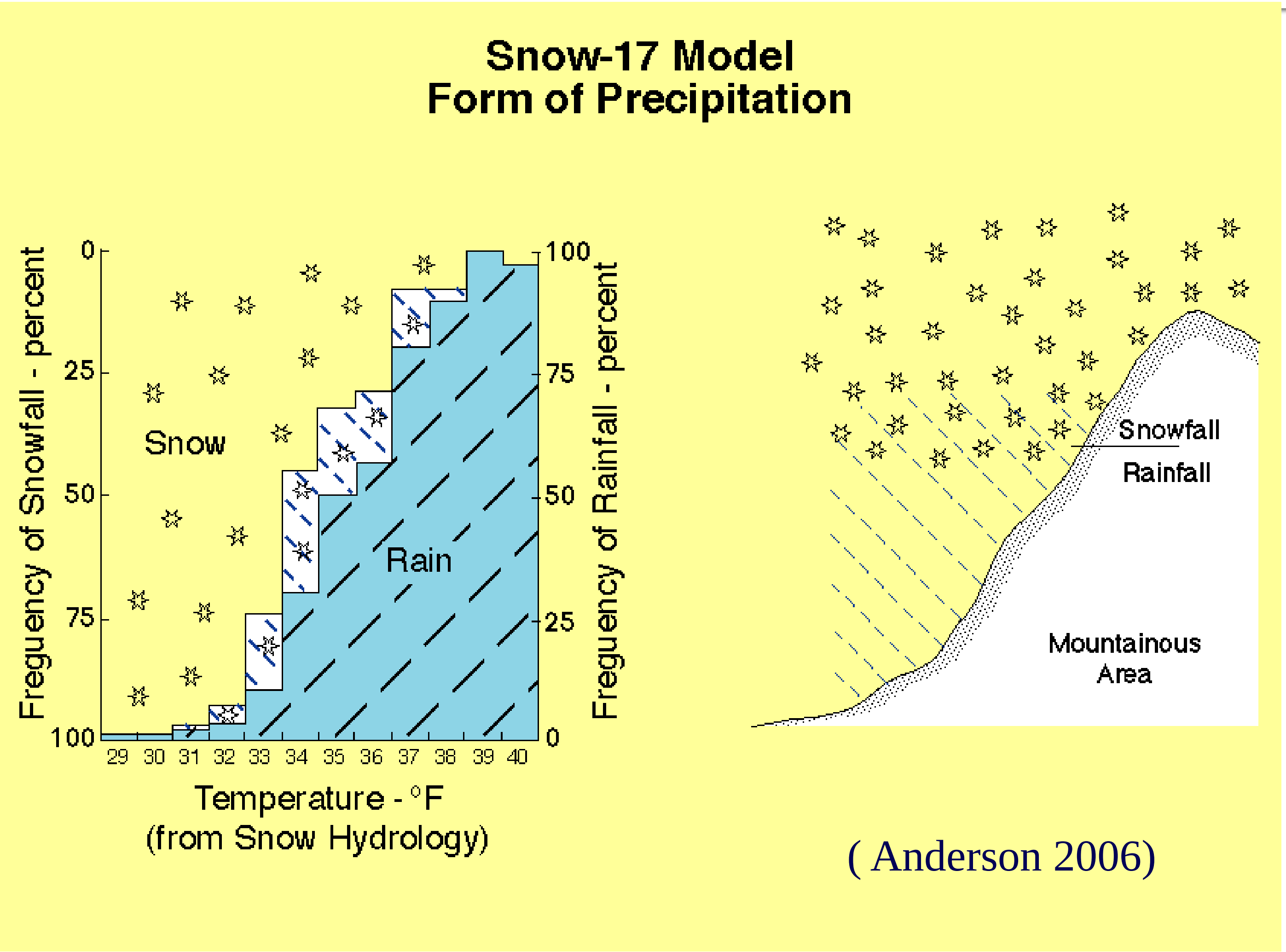
Output

- Rain plus Melt

Data Requirements

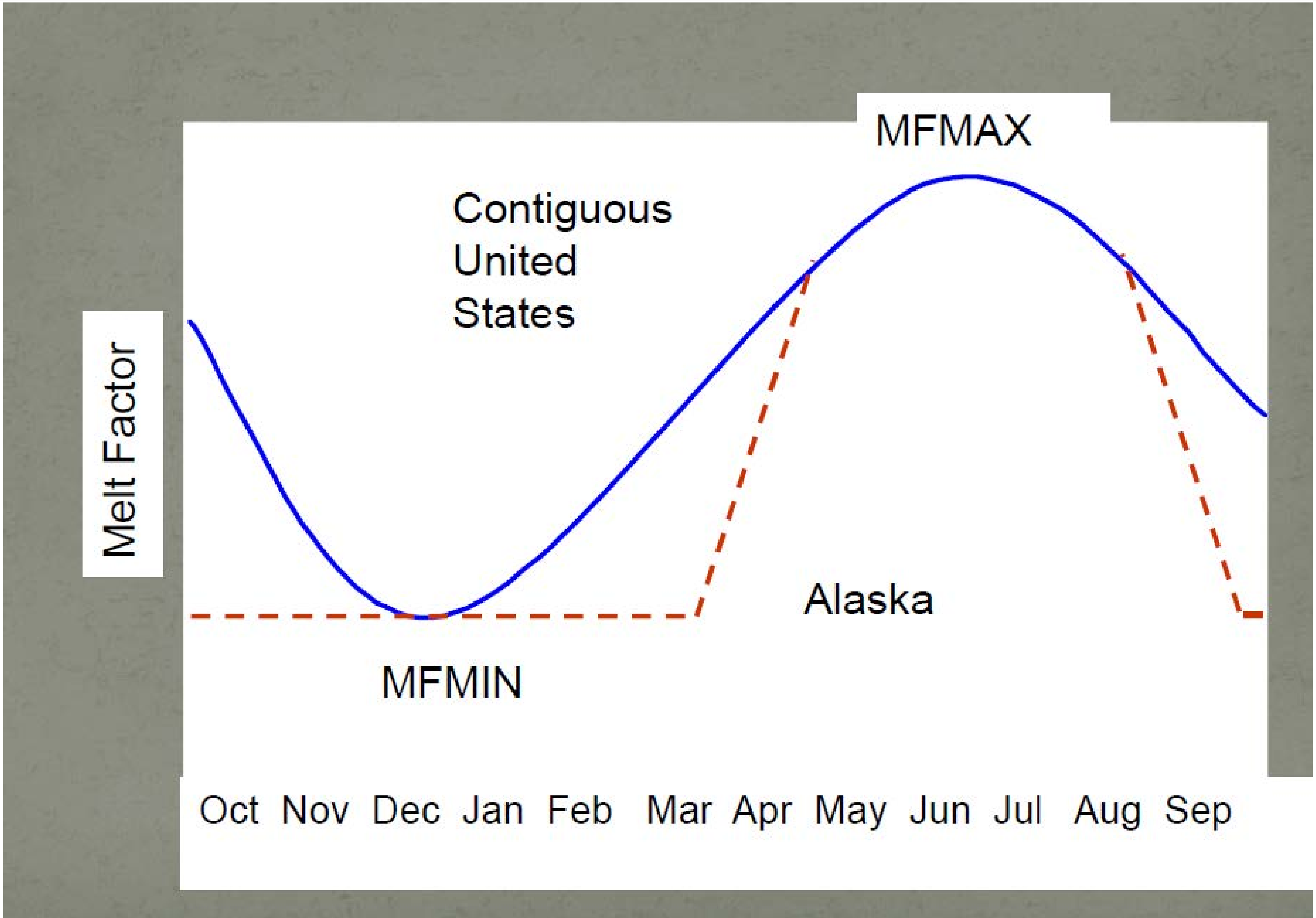
- Surface Air Temperature
  - Index for the pack energy balance and determine the form of precipitation (rain or snow)
- Precipitation
  - determine amount of snowfall and amount of rain-on-snow (PXTEMP)
  - SCF - Multiplying factor that adjusts precipitation data for gage catch deficiencies during periods of snowfall
- Other Data (when available)
  - Snowfall
  - Snow course and/or snow sensors (water-equivalent)
  - Areal extent of snow cover (satellite)

Rainfall or Snowfall ?



PXTEMP – threshold temperature parameter (2°C)

Seasonal Melt Factor (mm /(C 6-hr))



Snowmelt During Non-rain Periods

Energy balance equation is not used because of wide variability of meteorological conditions

(e.g. sunny overcast dry humid calm or windy)

Empirical relationship

$M = M_f * (T_a - MBASE)$

M_f = melt factor (mm * ºC^{-1} * Δt^{-1})

MBASE = base temperature where melt begins (ºC) (usually =0)

$$Mf = \left[\frac{MFMAX + MFMIN}{2} + \sin\left(\frac{n*2\pi}{366}\right) * \frac{MFMAX - MFMIN}{2}\right] * \frac{\Delta t}{6}$$

MFMAX = maximum melt factor, assumed to occur on June 21 (mm * ºC^{-1} * 6hr^{-1})

MFMIN = minimum melt factor, assumed to occur on December 21 (mm * ºC^{-1} * 6hr^{-1})

n = day number beginning with March 21

Experimental for the Sierra Nevada Snow Laboratory

Seasonal variation – solar radiation and albedo reduction with snow aging.

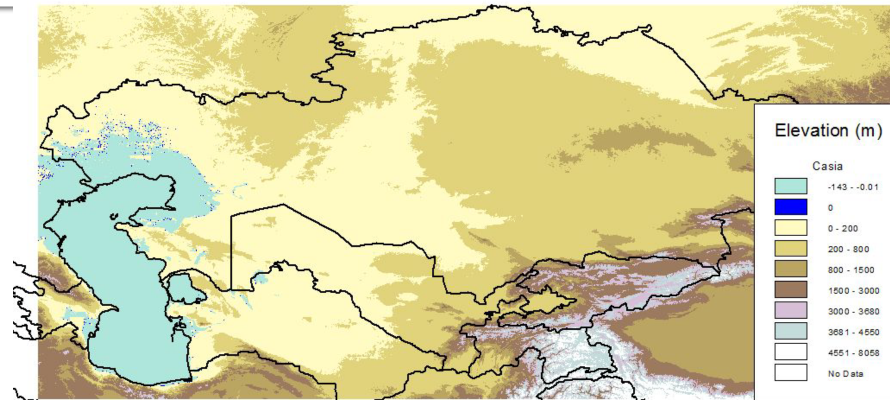
A Priori Estimate of Melt Factor

LAND COVER	MF_{MAX} (mm °C $6hr^{-1}$)	MF_{MIN} (mm °C $6hr^{-1}$)
Coniferous forest /persistent cloud cover	0.5 -0.7	0.2 - 0.4
Mixed forest Coniferous plus open and/or deciduous	0.8 – 1.2	0.1-0.3
Predominantly Deciduous	1.0-1.4	0.2- 0.6
Open Areas flat terrain	1.5-2.2	0.2-0.6
Mountainous terrain	0.9-1.3	0.1-0.3

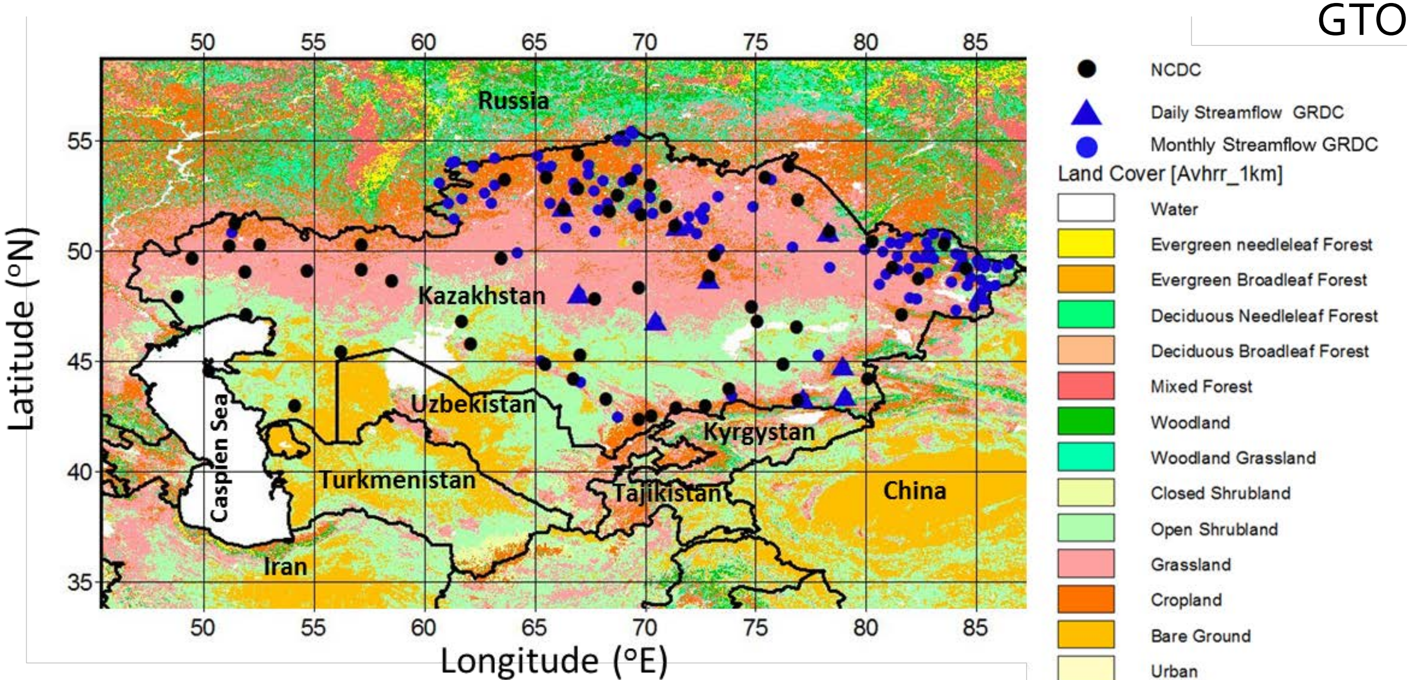
Table 2. Recommendation for MF_{MAX} and MF_{MIN} values (Anderson 2002)

Spatial Information

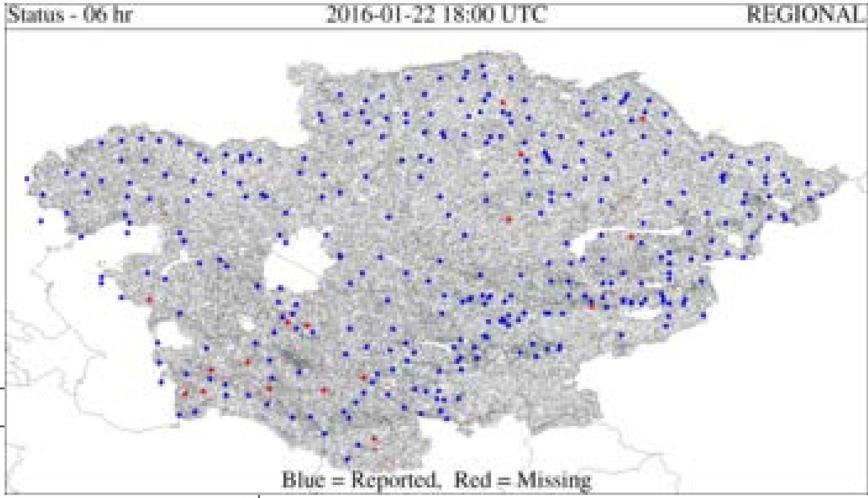
AVHRR Global Land Cover Product
GLCF 1 km resolution

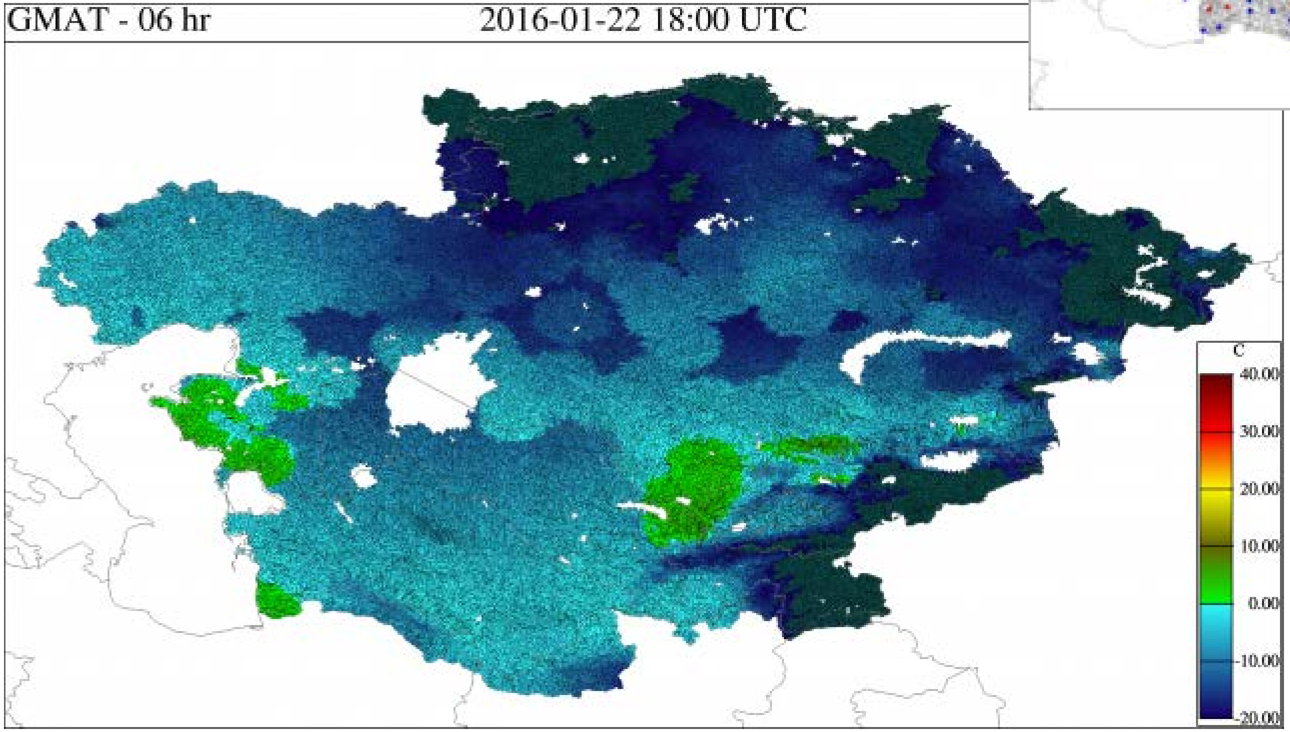


GTOPO –DEM (~km)



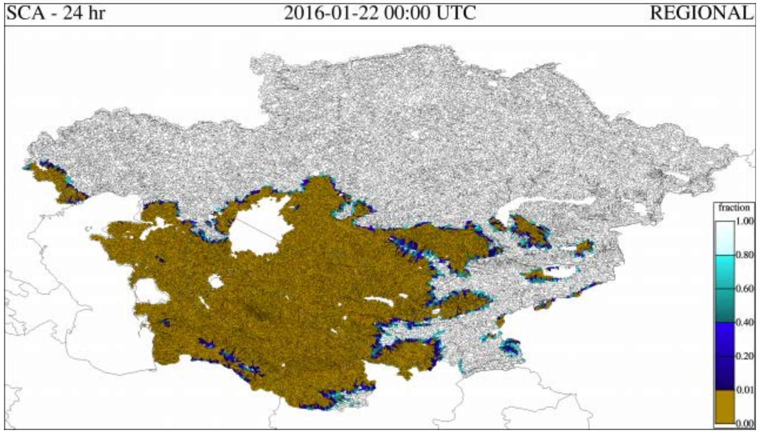
Monthly Climatological temperature
Climate Research Unit –East Anglia [1960-1990]



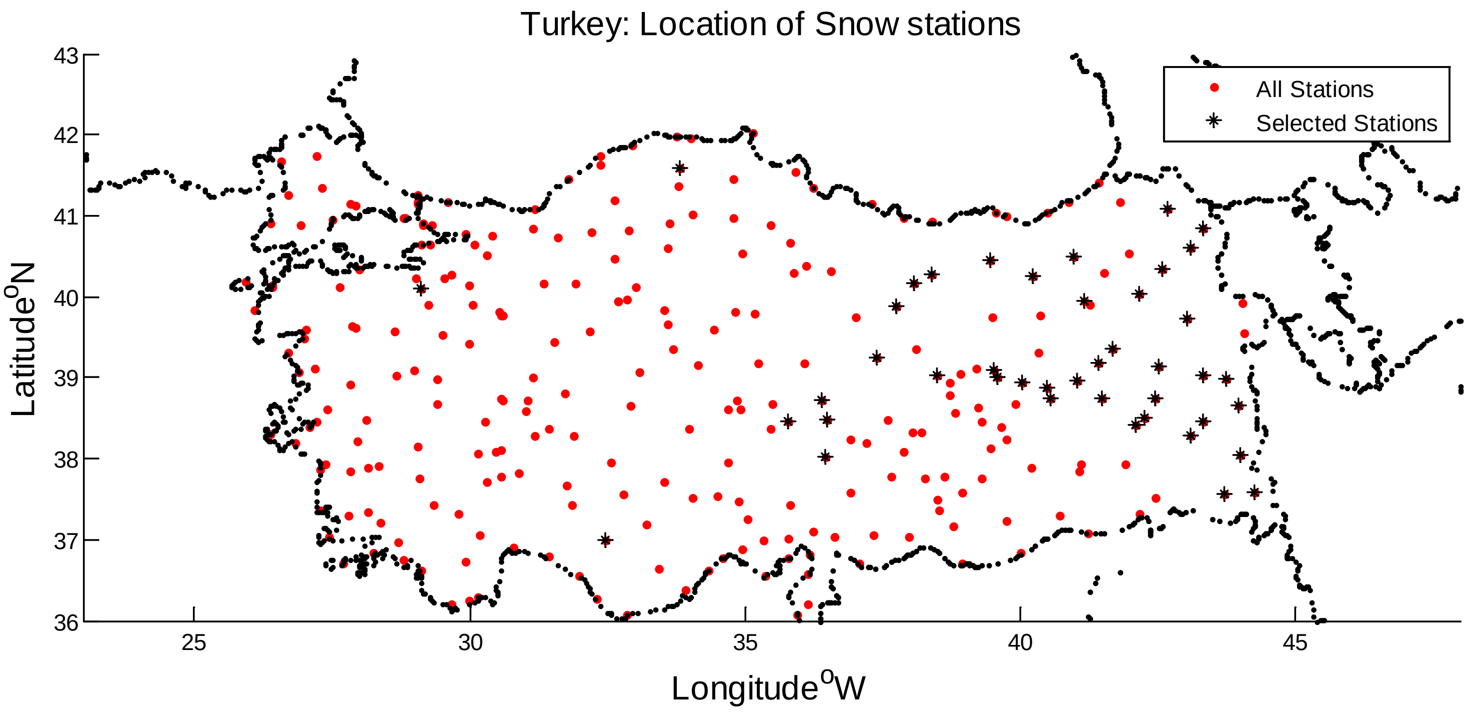


Satellite Snow Covered Area

- Interactive Multisensor Snow and Ice Mapping System (IMS), made available through National Snow and Ice Data Center, NOAA.
  http://nsidc.org/data/docs/noaa/g02156_ims_snow_ice_analysis/index.html
- Northern Hemisphere daily snow cover based on summary of multiple satellites at 4km x 4km resolution.
- Product defines: Snow covered land, sea ice, sea land (no snow)
- Since December 2014 a 1 km SCA and snow depth (4-km) products are available (to be evaluated for FFGS)
- Generally available within 1 day (often within several hours) following date of observation
- Archive is available for 2006-current
- **Helfrich et al., 2007 Hydrological Processes**

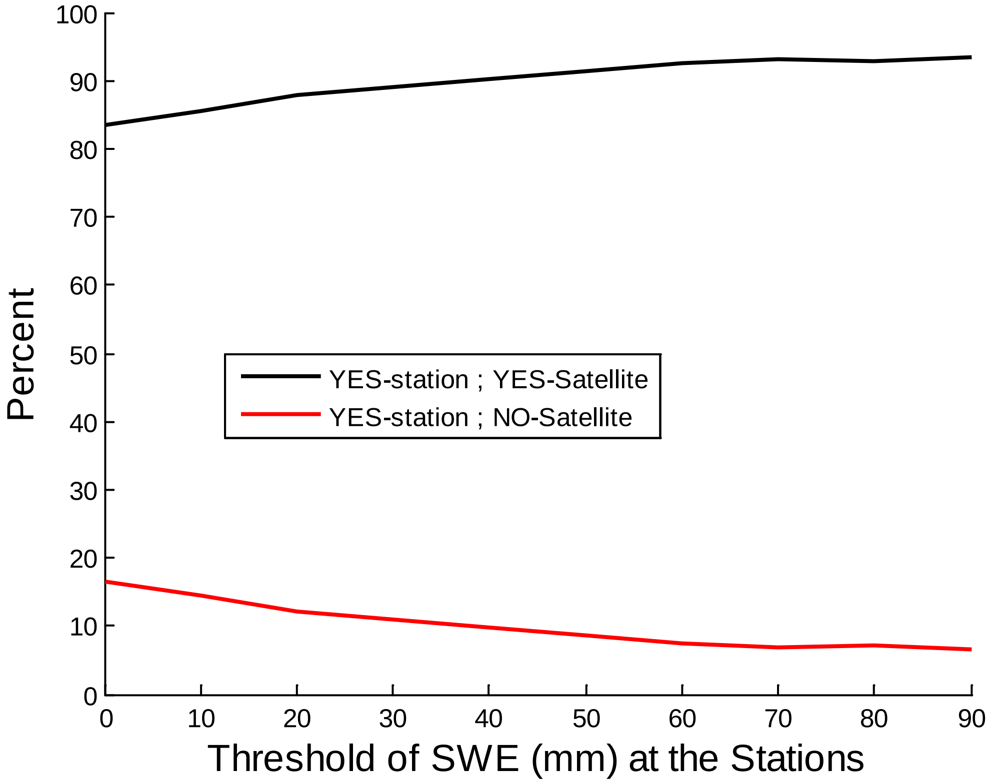


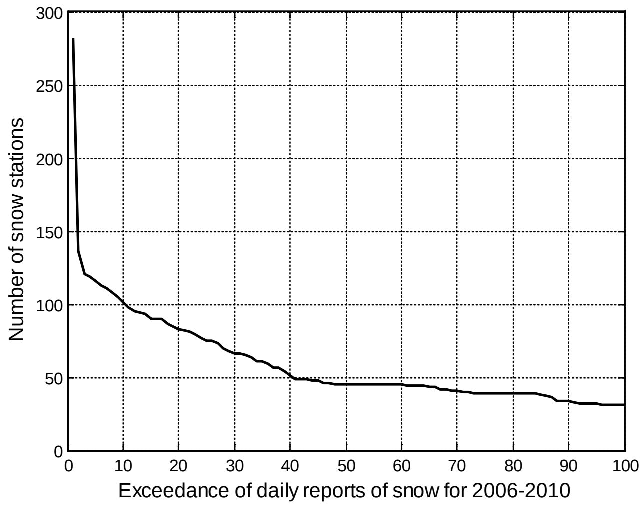
Comparison between snow stations and snow satellite



GOOD AGGREMMENT BETWEEN SNOW AT THE STATION AND THE CLOSEST GRID CELL

Comparison between snow stations to the 4km snow cover from the satellite 2006-2010
Data from 289 stations
139 stations reported one daily event or more.
The map shows the station locations that have frequent reports
7224 Daily total reports for these period
As the SWE increase as the t-hold for cover by the satellite the percent agreement and disagreement between the station and the satellite increases and decreases respectively

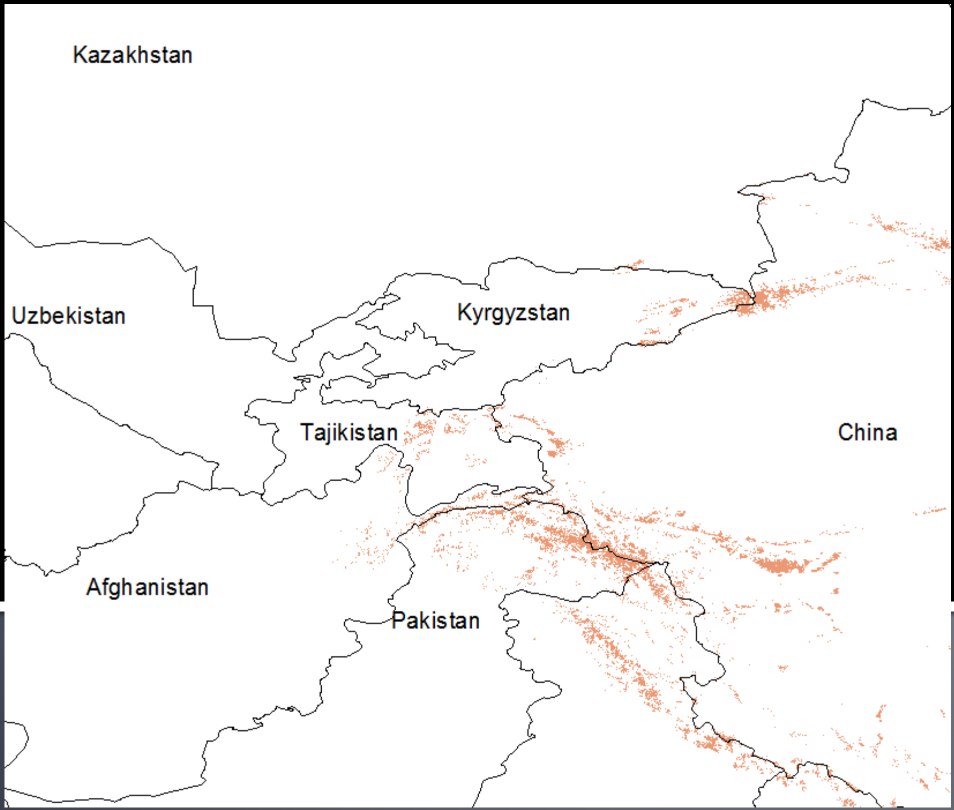




Incorporating Glacier mapping information in the FFGS

GLIMS: Global Land Ice Measurements from Space (http://www.glims.org/)

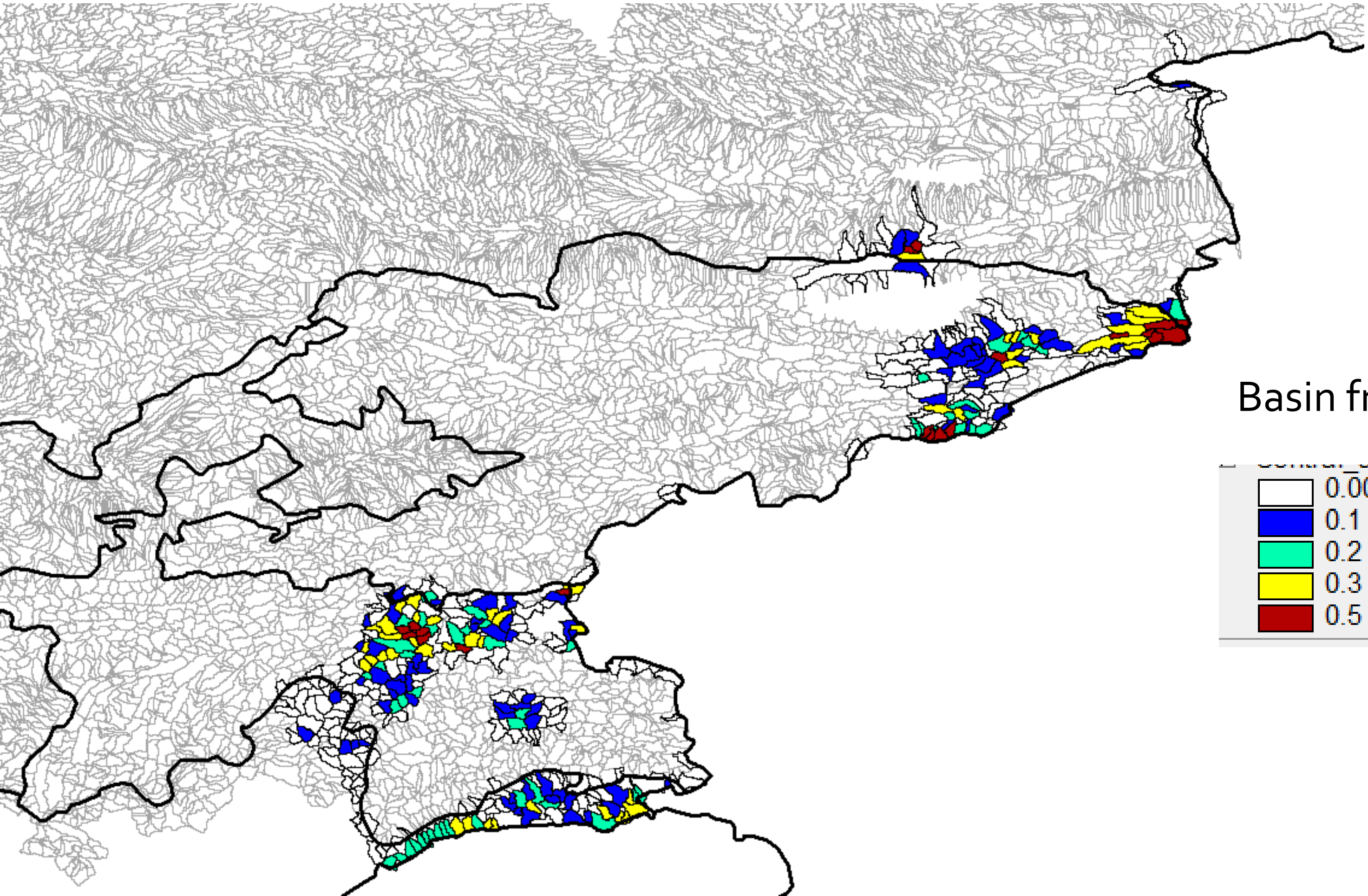
- National Snow and Ice Data Center
- Contribution from more than 60 institutions
- Based on data from ASTER (Advanced Spaceborne Thermal Emission and reflection Radiometer) and the Landsat Enhanced Thematic Mapper Plus (ETM+) as well as historical information derived from maps and aerial photographs.



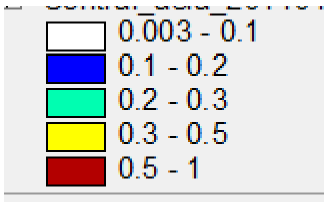
Map was updated in December 2014

Raup, B.H.; A. Racoviteanu; S.J.S. Khalsa; C. Helm; R. Armstrong; Y. Arnaud (2007). "The GLIMS Geospatial Glacier Database: a New Tool for Studying Glacier Change". Global and Planetary Change 56:101--110. (doi:10.1016/j.gloplacha.2006.07.018)

CARFFG Glacier percent cover



Basin fractional cover



FFG Modeling of Frozen Ground

- Frozen ground can have a significant effect on streamflow
- The modeling of frozen ground using a Frost Index (FI)
- Operational data source that can be used operationally in the FFGS (CFSv2)
- Evaluation of Regional Frost Index

- The importance of simulating frozen ground

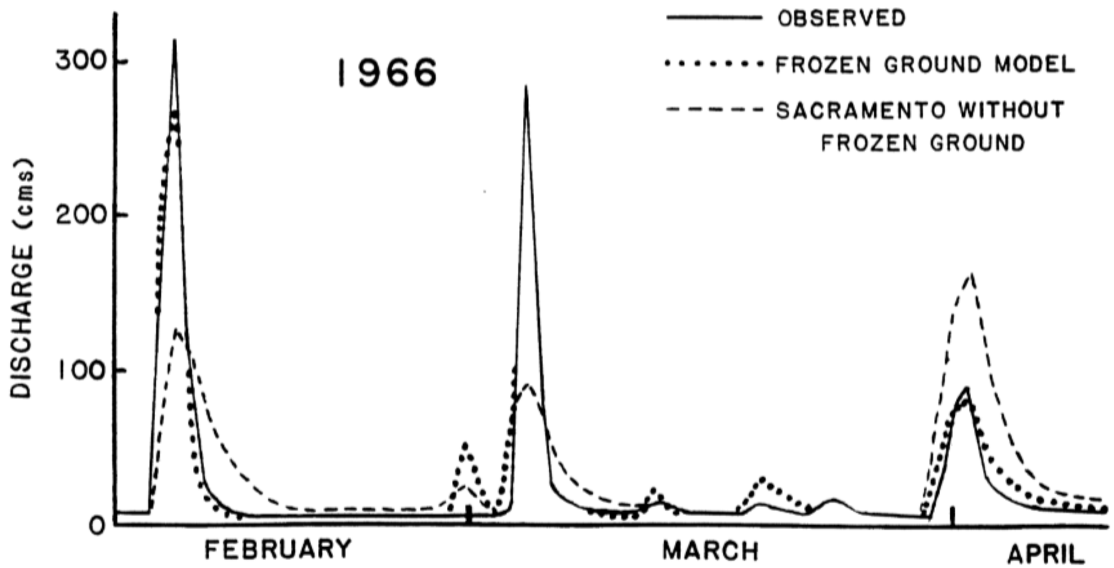
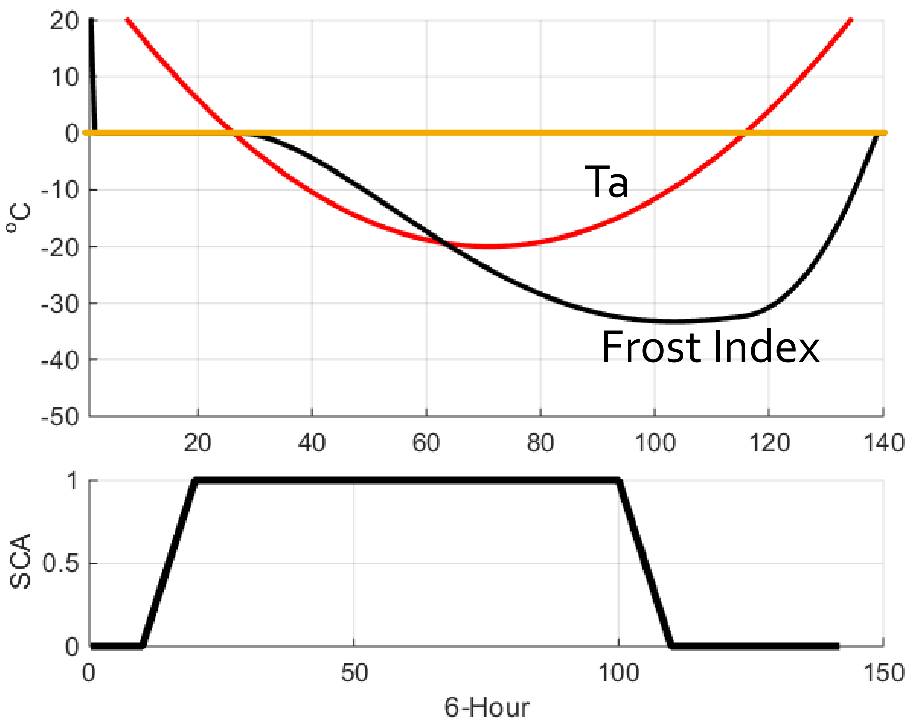


Figure 5. Hydrograph comparisons for the Root River during the two winters when frozen ground had the largest effect on runoff.

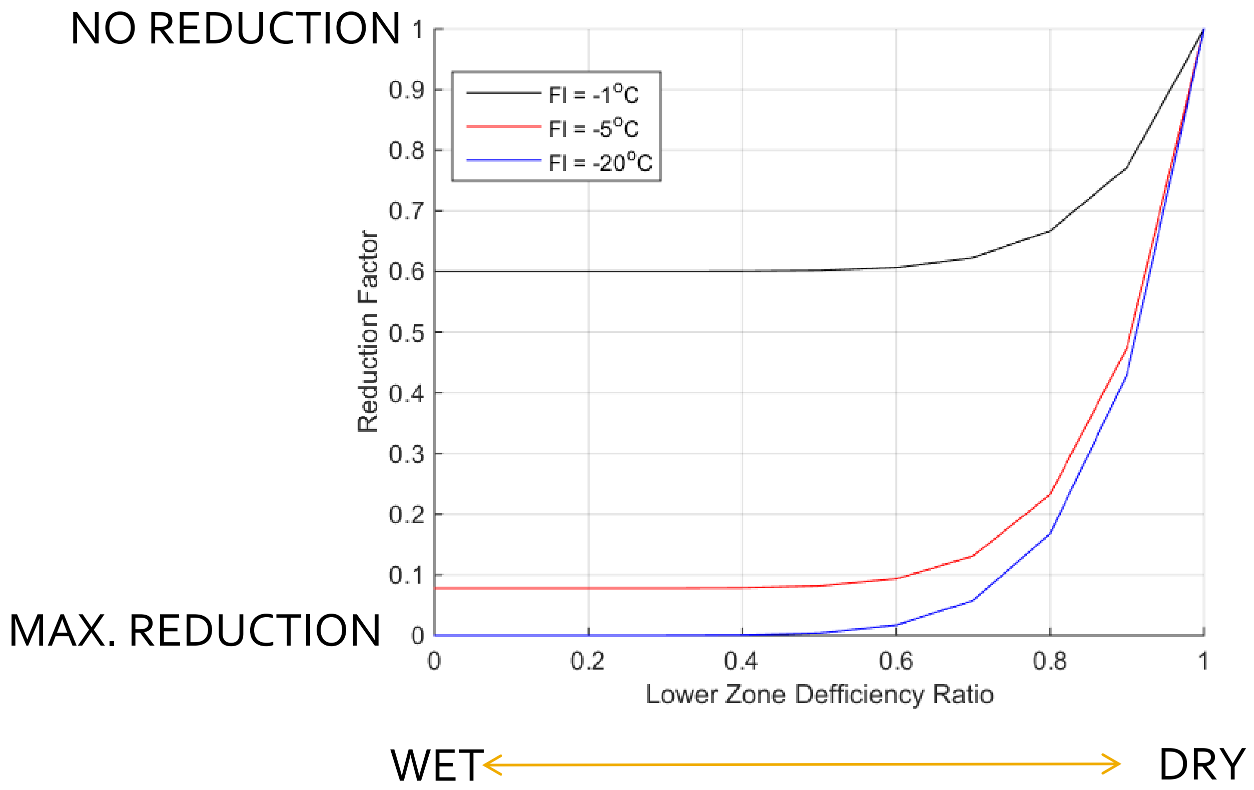
Frost Index [FI]

- Calculating an empirical Frost Index [FI] as a function of:
  - Air Surface Temperature [Ta]
  - Snow depth [SD]
  - Snow cover area [SCA]



Reduction Factor

- A multiplier that reduces percolation and interflow withdrawal rates as a function of soil moisture



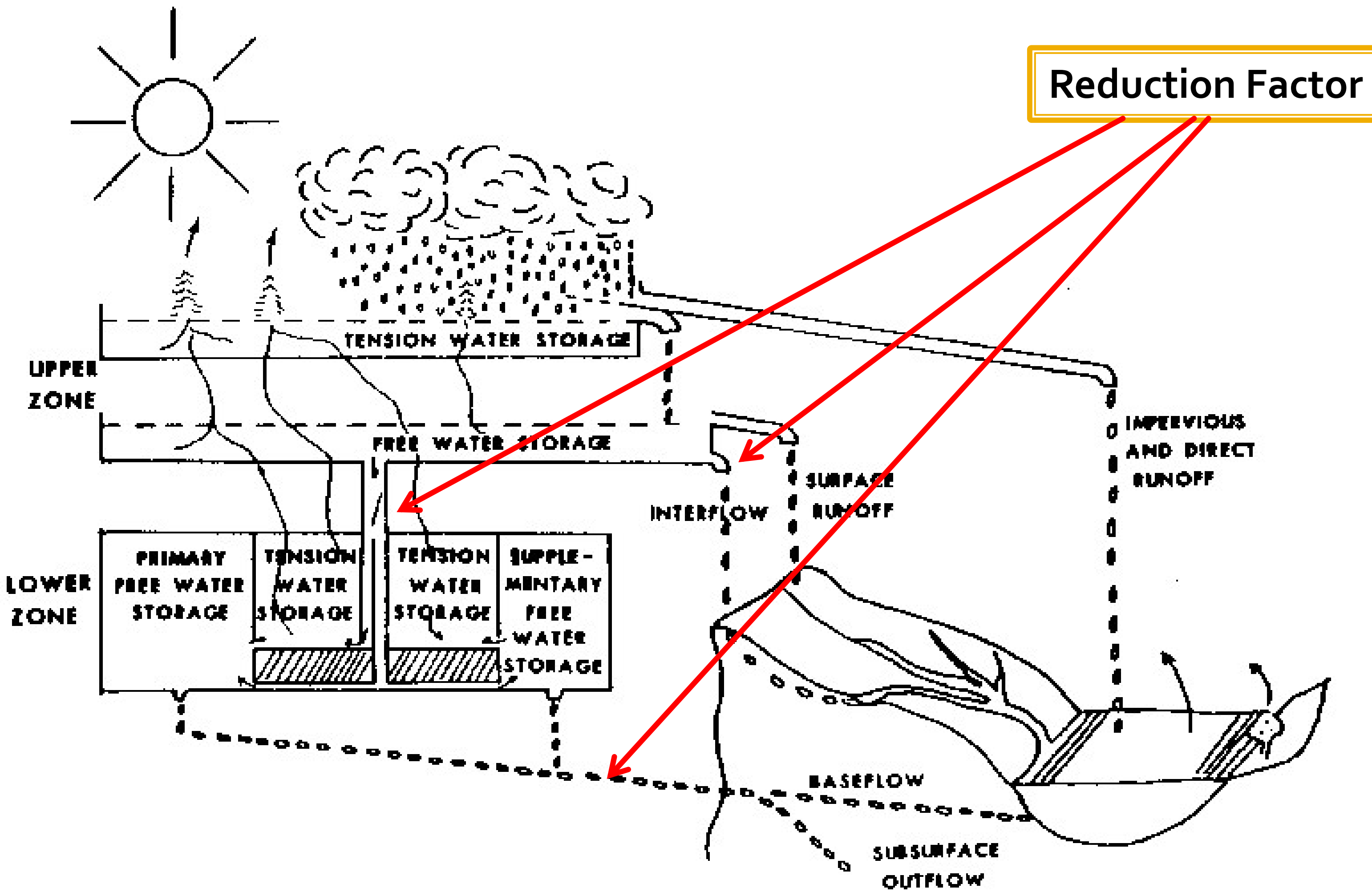
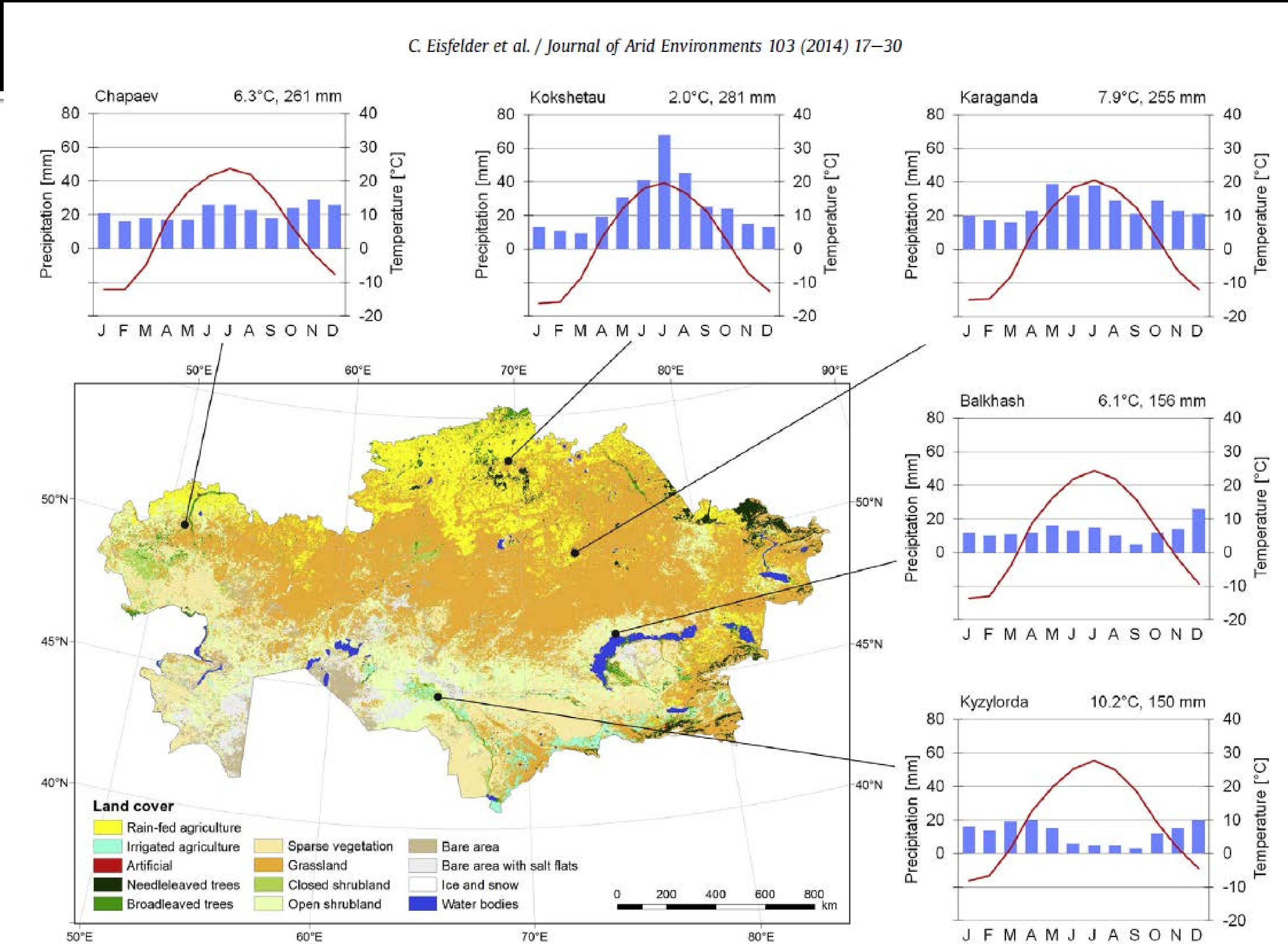


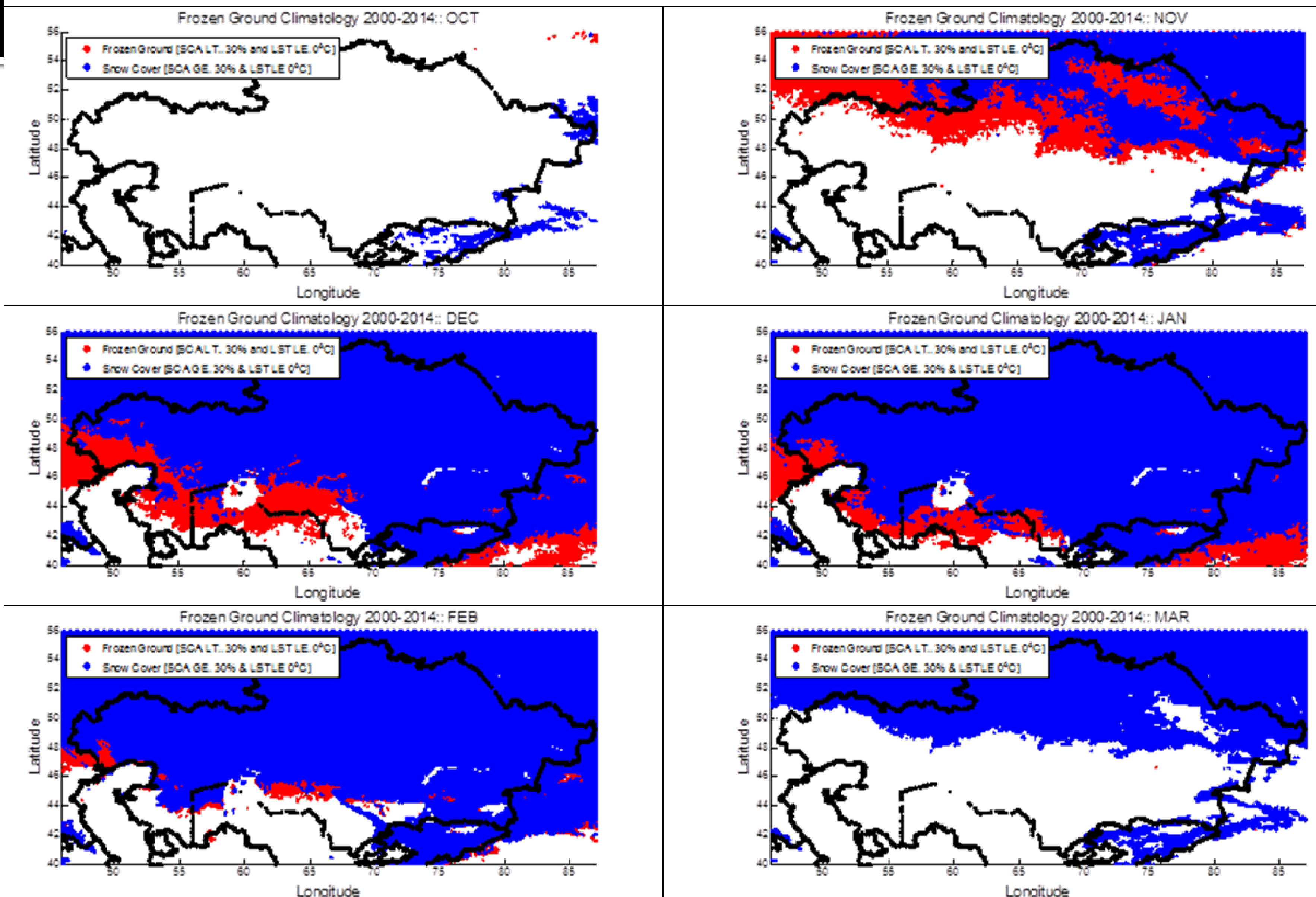
Figure 1. Illustration of a generalized hydrologic model.

Kazakhstan Climate and Land Cover

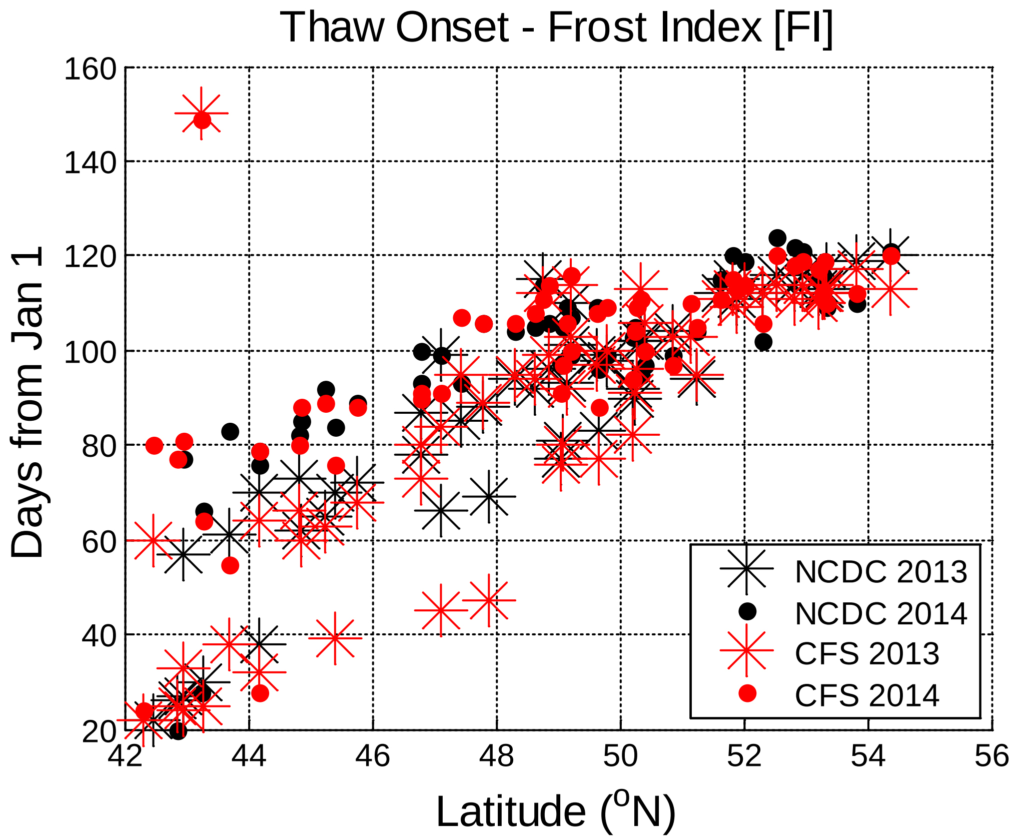


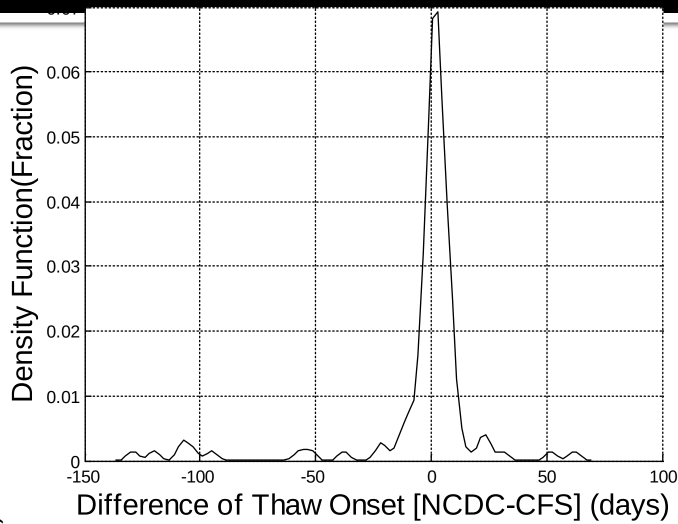
Land cover map: Klein et al., 2012

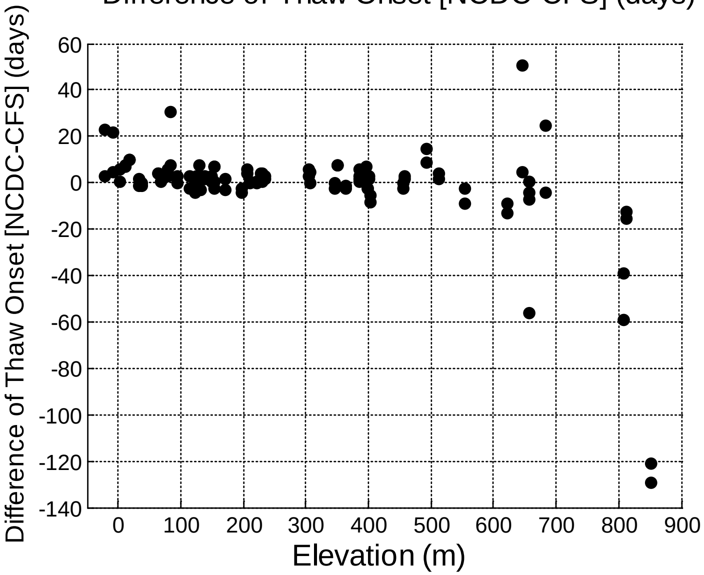
MODIS/Terra 8day LST vs. SCA 2000-2014



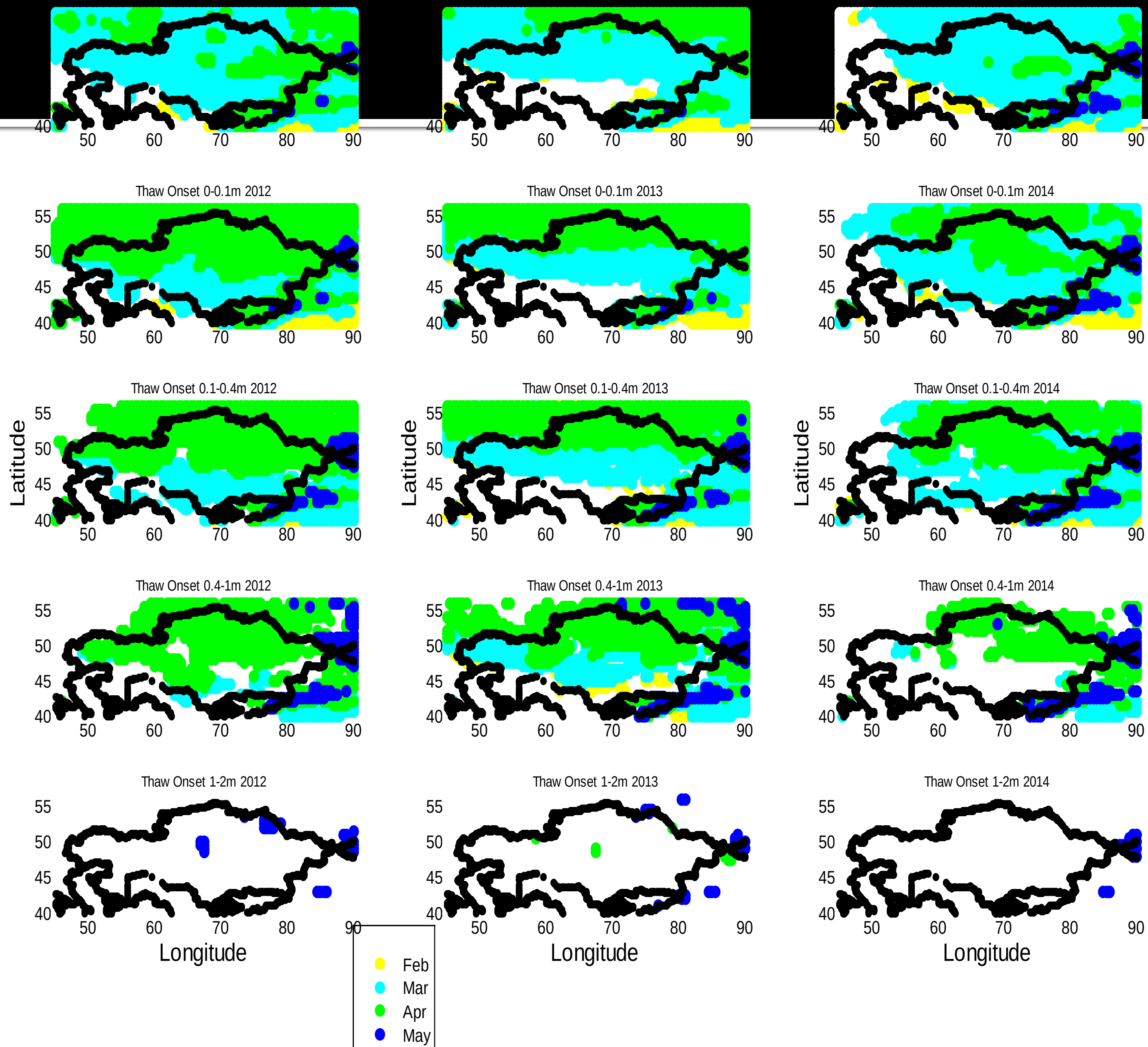
Thaw Onset calculated with Temperature data from NCDC and CFS



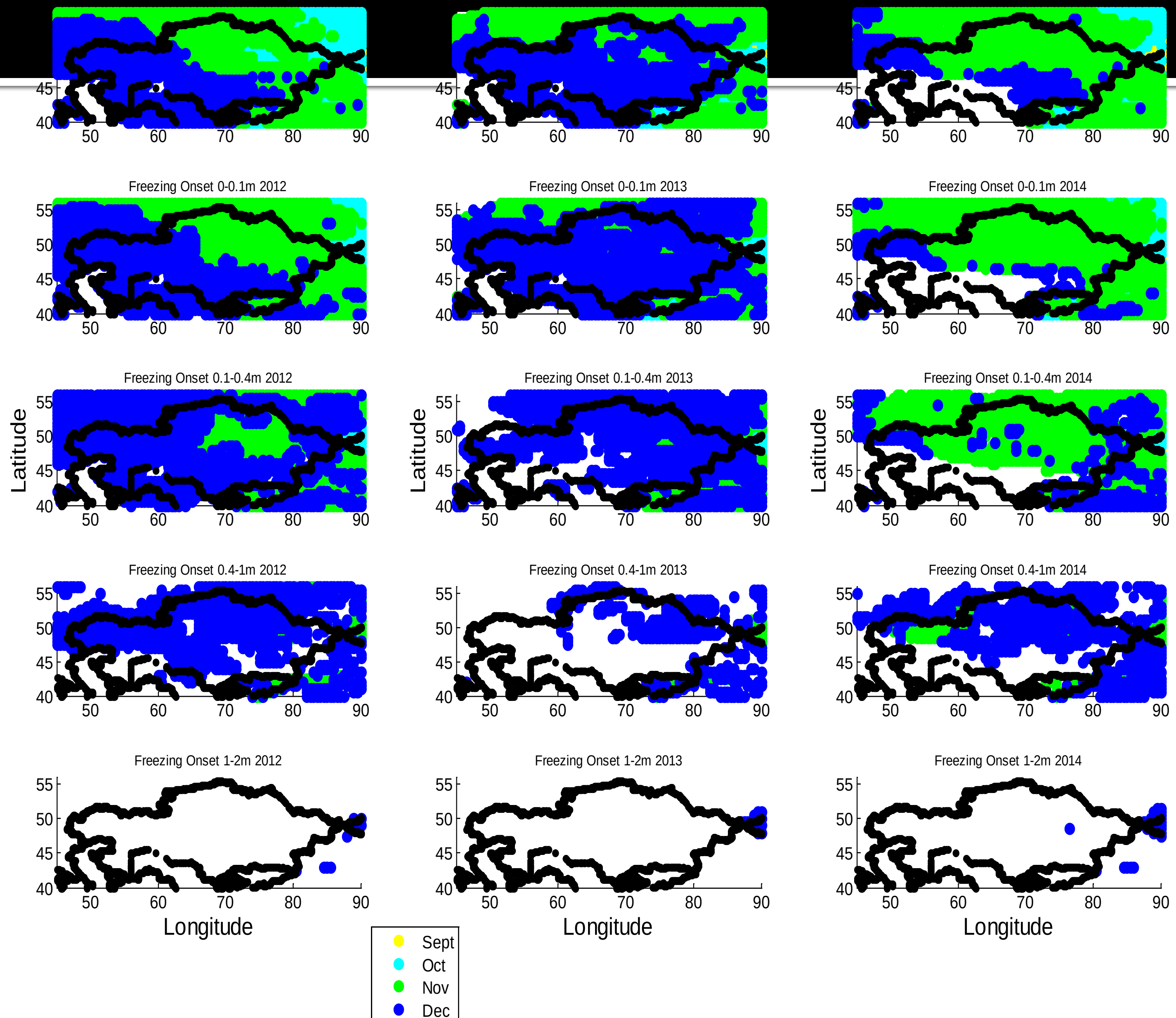


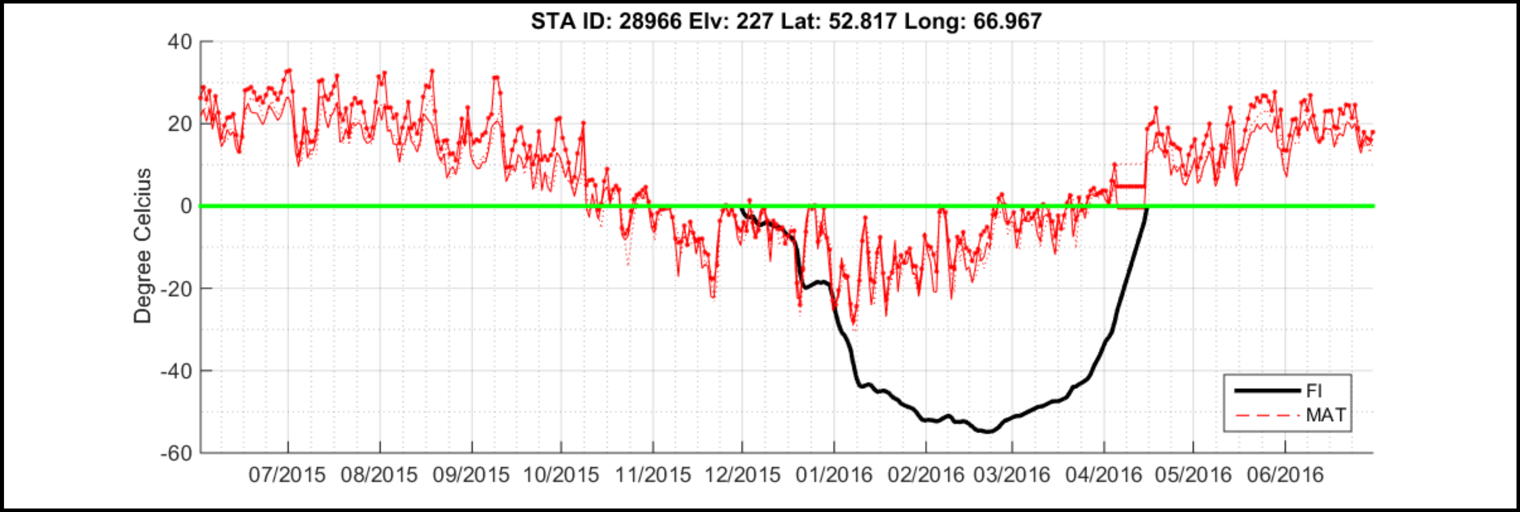


Thaw Onset [CFS 6-hr Forecast]



Freezing Onset [CFS 6-hr Forecast]

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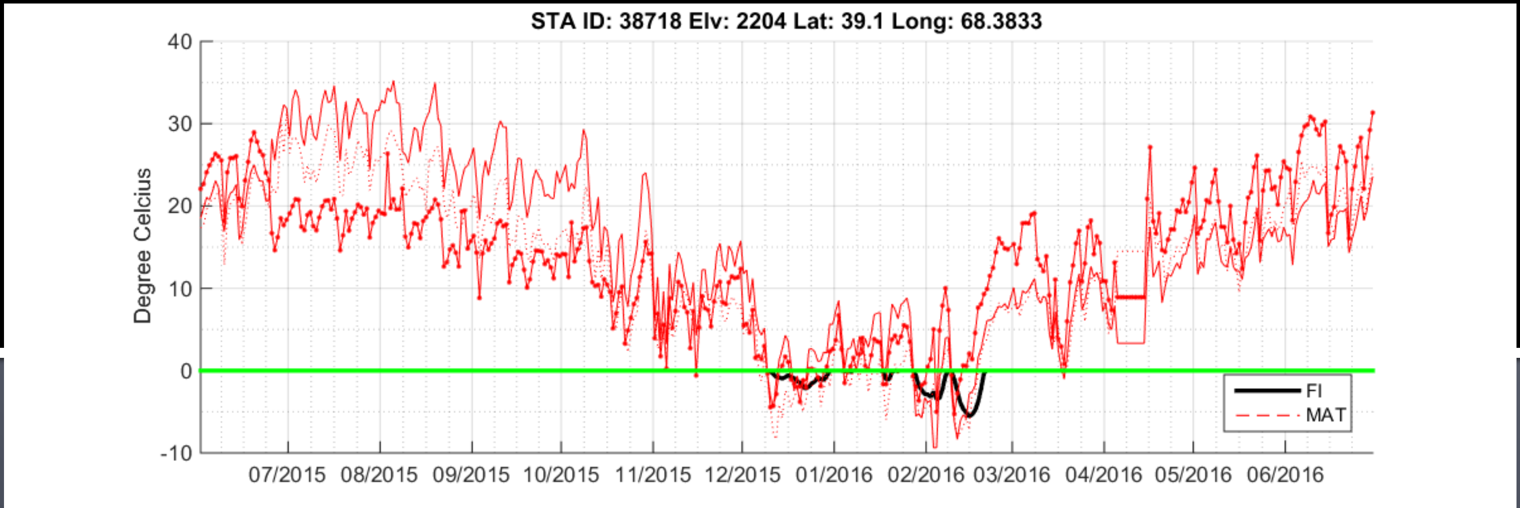
FI
MAT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FI
MAT

SWE from Real Time Run at KAZHYDROMET