CARFFGS SCM4 Astana Kazakhstan, 31 October- 2 November 2017

Soil Moisture & FFG Models

Eylon Shamir, Ph.D.
Hydrologic Research Center
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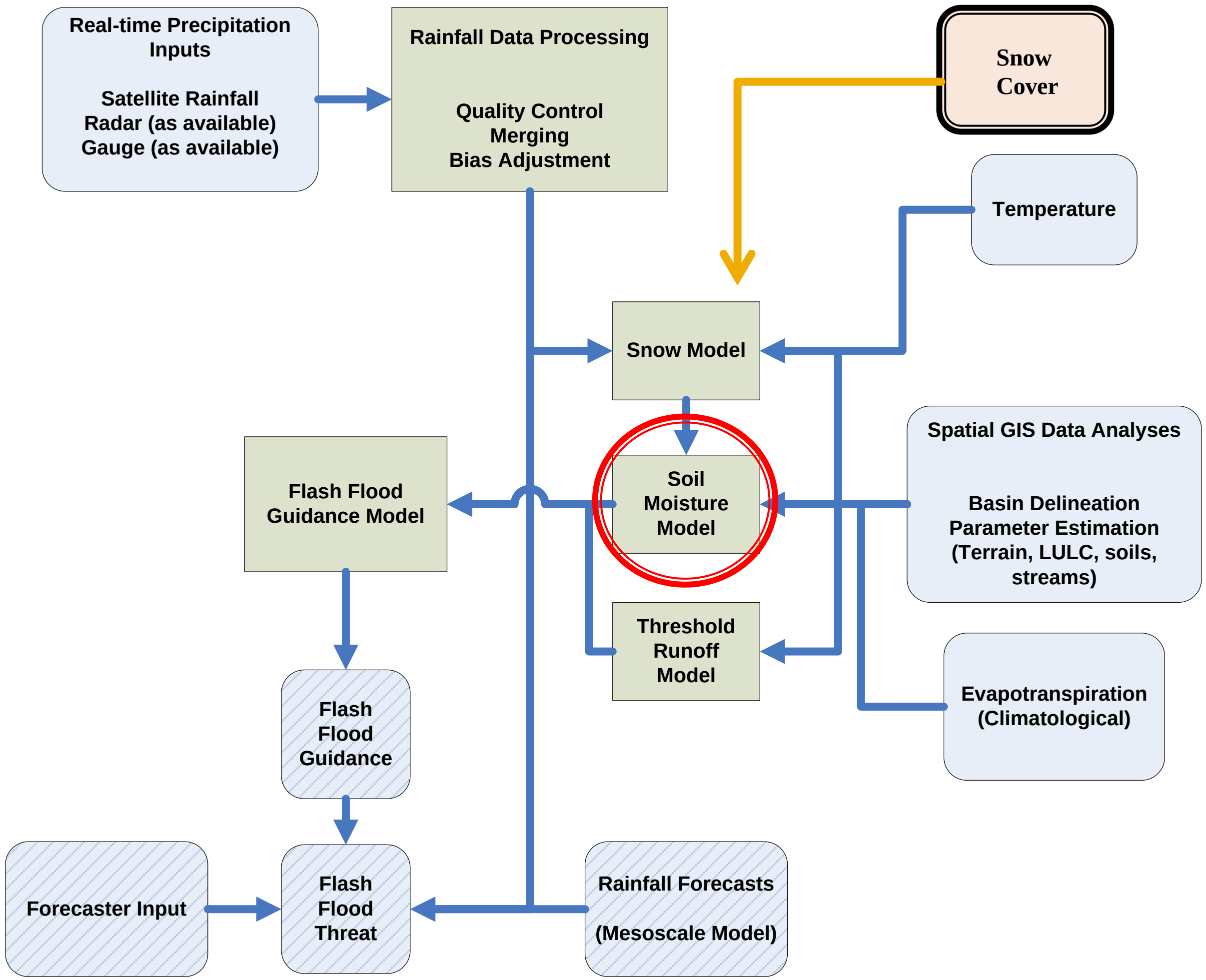
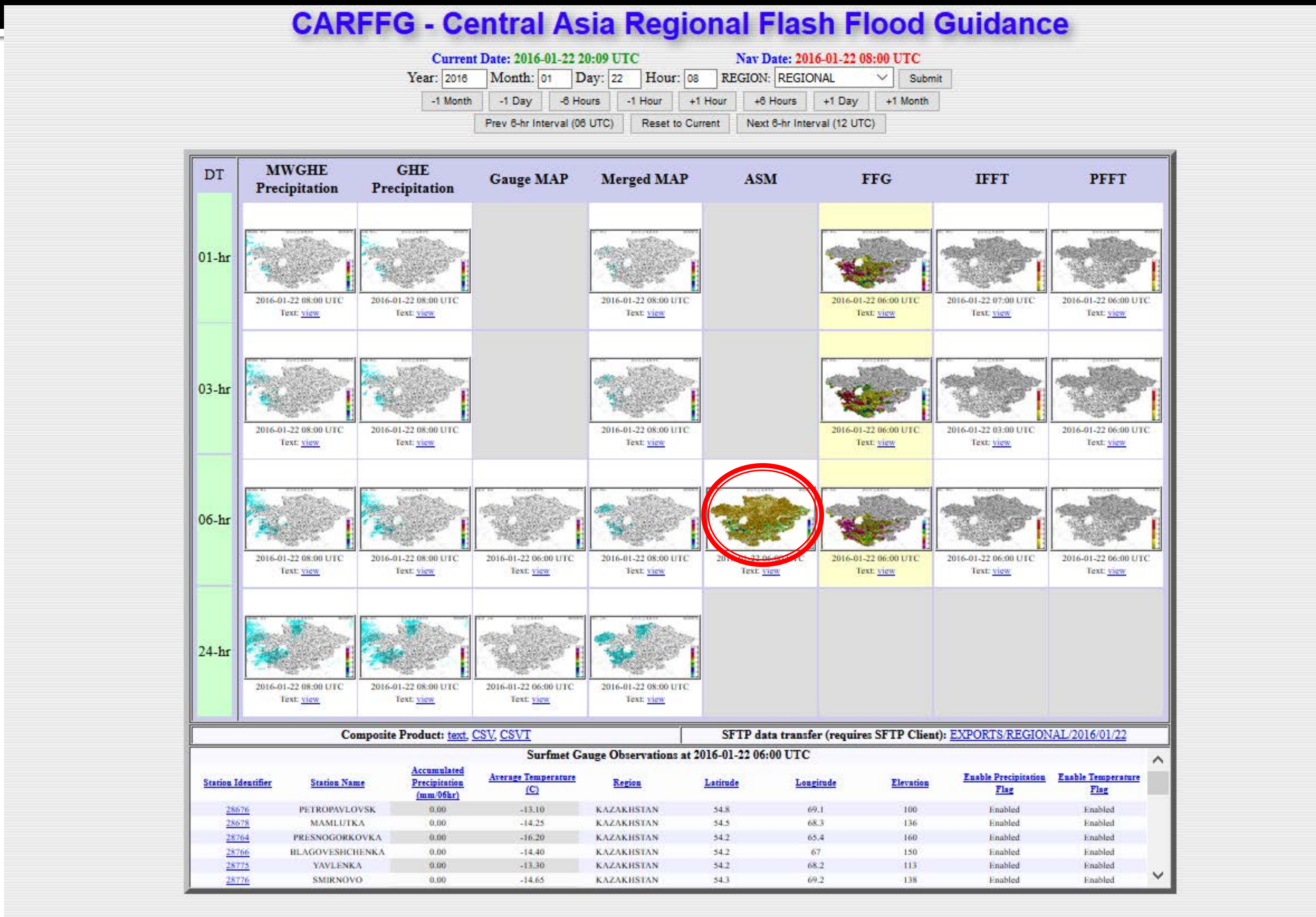
http://www.hrcwater.org

Key Components of FFGS



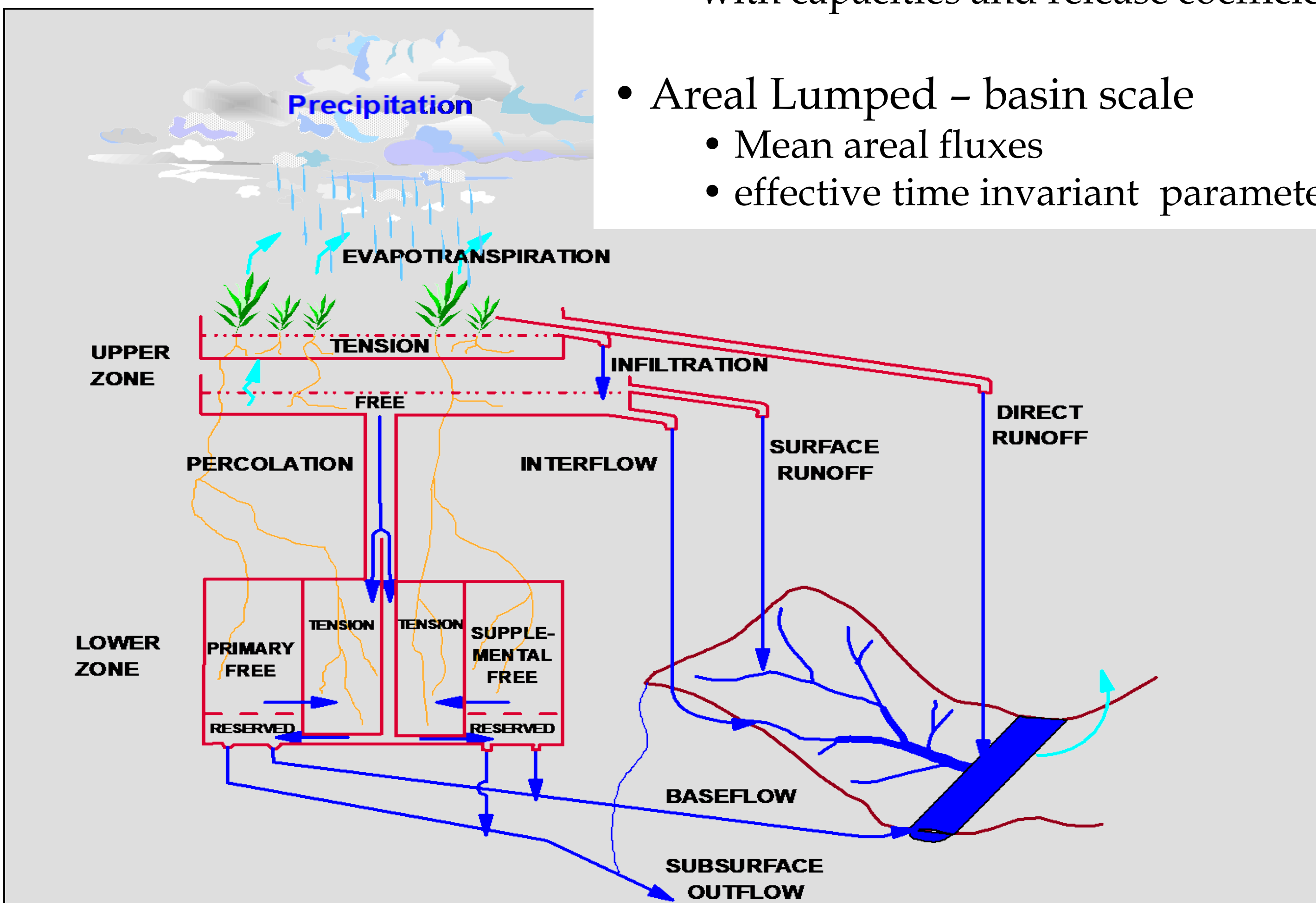
CARFFGS


CARFFG - Central Asia Regional Flash Flood Guidance
Current Date: 2016-01-22 20:09 UTC
Nav Date: 2016-01-22 08:00 UTC
Year: 2016 Month: 01 Day: 22 Hour: 08 REGION: REGIONAL Submit
-1 Month -1 Day -6 Hours -1 Hour +1 Hour +6 Hours +1 Day +1 Month
Prev 6-hr Interval (06 UTC) Reset to Current Next 6-hr Interval (12 UTC)
DT
MWGHE Precipitation
GHE Precipitation
Gauge MAP
Merged MAP
ASM
FFG
IFFT
PFFT
01-hr
03-hr
06-hr
24-hr
Composite Product: text, CSV, CSVT
SFTP data transfer (requires SFTP Client): EXPORTS/REGIONAL/2016/01/22
Surfmet Gauge Observations at 2016-01-22 06:00 UTC
Station Identifier | Station Name | Accumulated Precipitation (mm/06hr) | Average Temperature (C) | Region | Latitude | Longitude | Elevation | Enable Precipitation Flag | Enable Temperature Flag
28676 PETROPAVLOVSK 0.00 -13.10 KAZAKHSTAN 54.8 69.1 100 Enabled Enabled
28678 MAMLUTKA 0.00 -14.25 KAZAKHSTAN 54.5 68.3 136 Enabled Enabled
28764 PRESNOGORKOVKA 0.00 -16.20 KAZAKHSTAN 54.2 65.4 160 Enabled Enabled
28766 BLAGOVESHCHENKA 0.00 -14.40 KAZAKHSTAN 54.2 67 150 Enabled Enabled
28775 YAVLENKA 0.00 -13.30 KAZAKHSTAN 54.2 68.2 113 Enabled Enabled
28776 SMIRNOVO 0.00 -14.65 KAZAKHSTAN 54.3 69.2 138 Enabled Enabled

Sacramento Soil Moisture Accounting SAC-SMA Model

- Process based conceptual model
  - A simplified description of physical processes:
  Mass balance - soil profile as a series of connected reservoirs with capacities and release coefficients

- Areal Lumped – basin scale
  - Mean areal fluxes
  - effective time invariant parameters



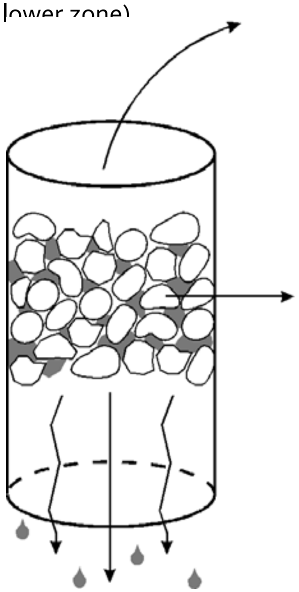
SAC-SMA Principles

Three general type of soil water content that influence the runoff

- Tension water
  - The part that can be separate from the soil and returned to the atmosphere through ET
  - Water that is held against gravity due to force attraction by the soil molecules
  - Depend on soil climate and land cover

- Free water
  - Water in the liquid state that is free to travel
  - This is the water that will supply all the deficiencies in the model compartments (i.e., tension, percolation into the lower zone)
  - The lateral flow is generated from the free water
  - When rainfall intensity is larger than the percolation rate than the excess rain will generate surface flow.

- Interception
  - The potion of rain that is remained on the vegetation
  - A moisture storage that affect the rainfall-runoff regime
  - The intercepted water is temporarily interfere with the ET from the tension water storage.
  - Form modeling perspective the intercepted water is included in the tension storage.
  - Problem might occur in areas with large annual variability in interception



In general:

Smaller soil particles (clay) have larger tension water storage

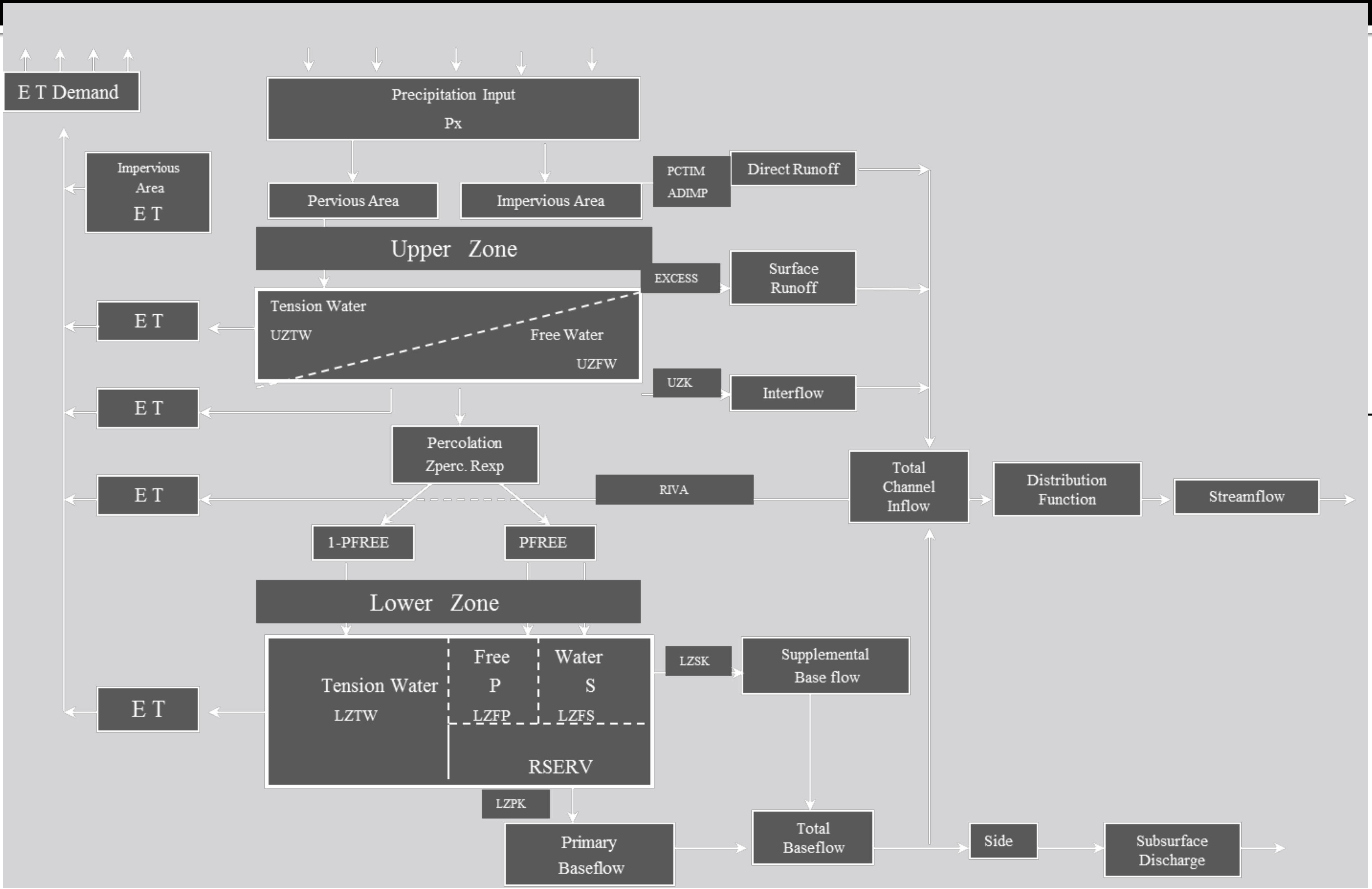
Large soil particles (sand) have larger free water storage

References:

http://www.nws.noaa.gov/oh/hrl/nwsrfs/users_manual/htm/formats.php

Burnash, R.J.C., 1995

Model Structure



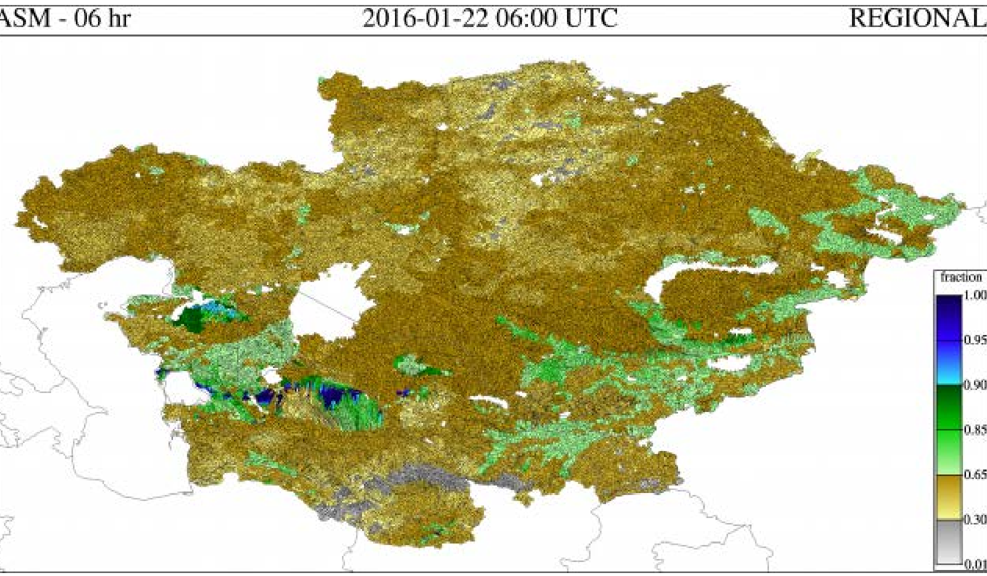
SAC-SMA Parameters

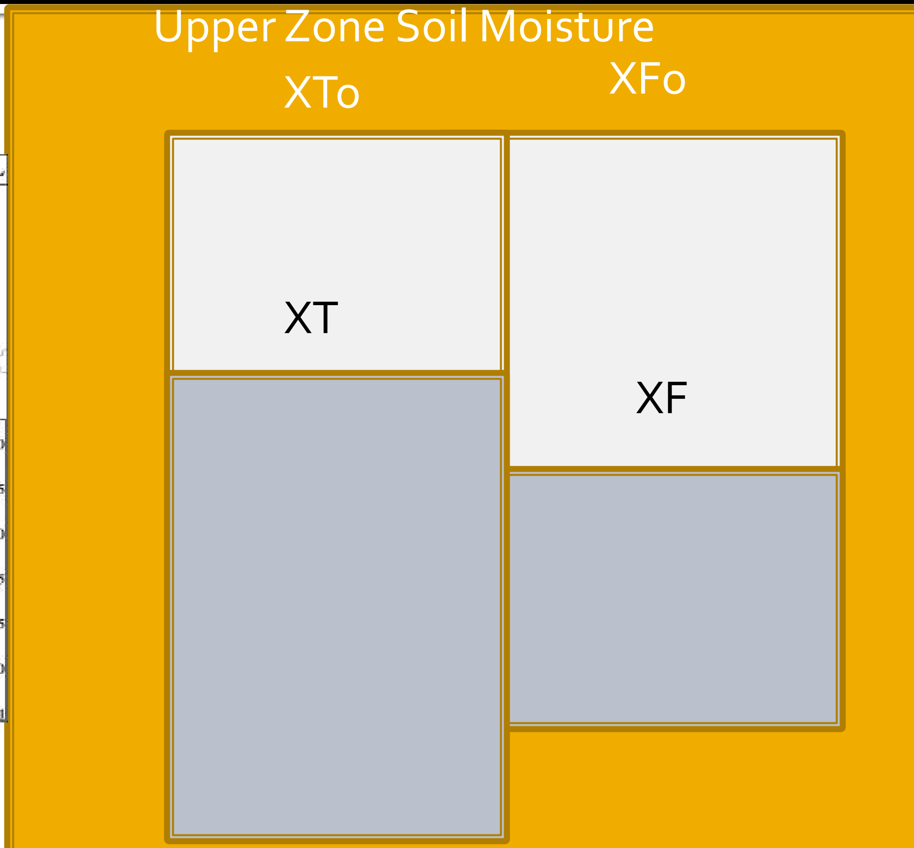
PXADJ	Precipitation adjustment factor
PEADJ	ET-demand adjustment factor
UZTWM	Upper zone tension water capacity (mm)
UZFWM	Upper zone free water capacity (mm)
UZK	Fractional daily upper zone free water withdrawal rate
PCTIM	Minimum impervious area (decimal fraction)
ADIMP	Additional impervious area (decimal fraction)
RIVA	Riparian vegetation area (decimal fraction)
ZPERC	Maximum percolation rate coefficient
REXP	Percolation equation exponent
LZTWM	Lower zone tension water capacity (mm)
LZFSM	Lower zone supplemental free water capacity (mm)
LZFPM	Lower zone primary free water capacity (mm)
LZSK	Fractional daily supplemental withdrawal rate
LZPK	Fractional daily primary withdrawal rate
PFREE	Fraction of percolated water going directly to lower zone free water storage
RSERV	Fraction of lower zone free water not transferable to lower zone tension water
SIDE	Ratio of deep recharge to channel baseflow
ET Demand	Daily ET demand (mm/day)
PE Adjust	PE adjustment factor for 16th of each month

State Variables

ADIMC	Tension water contents of the ADIMP area (mm)
UZTWC	Upper zone tension water contents (mm)
UZFWC	Upper zone free water contents (mm)
LZTWC	Lower zone tension water contents (mm)
LZFSC	Lower zone free supplemental contents (mm)
LZFPC	Lower zone free primary contents (mm)

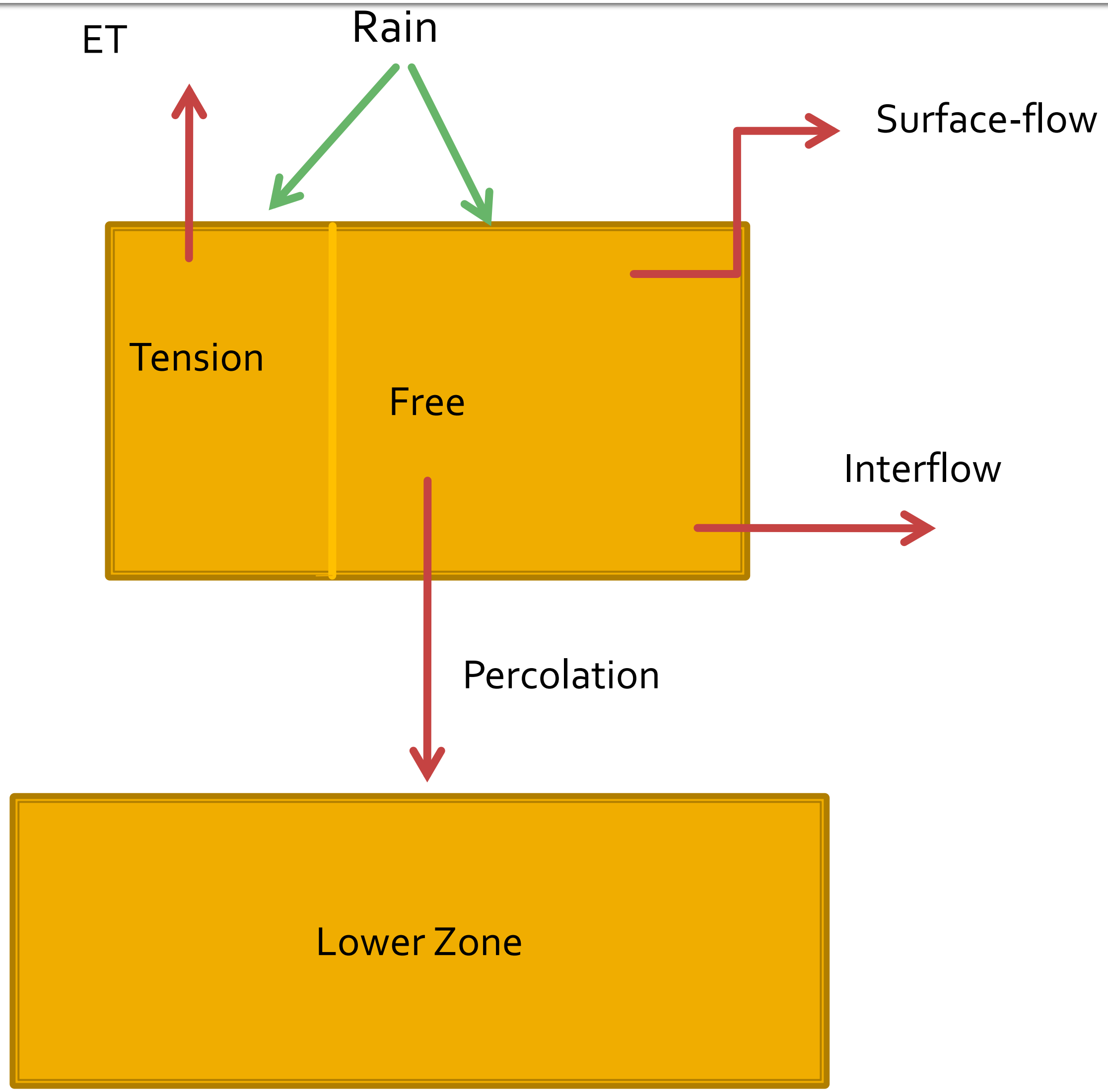
Average Soil Moisture [ASM]





ASM = (XT + XF) / (XTo + XFo)

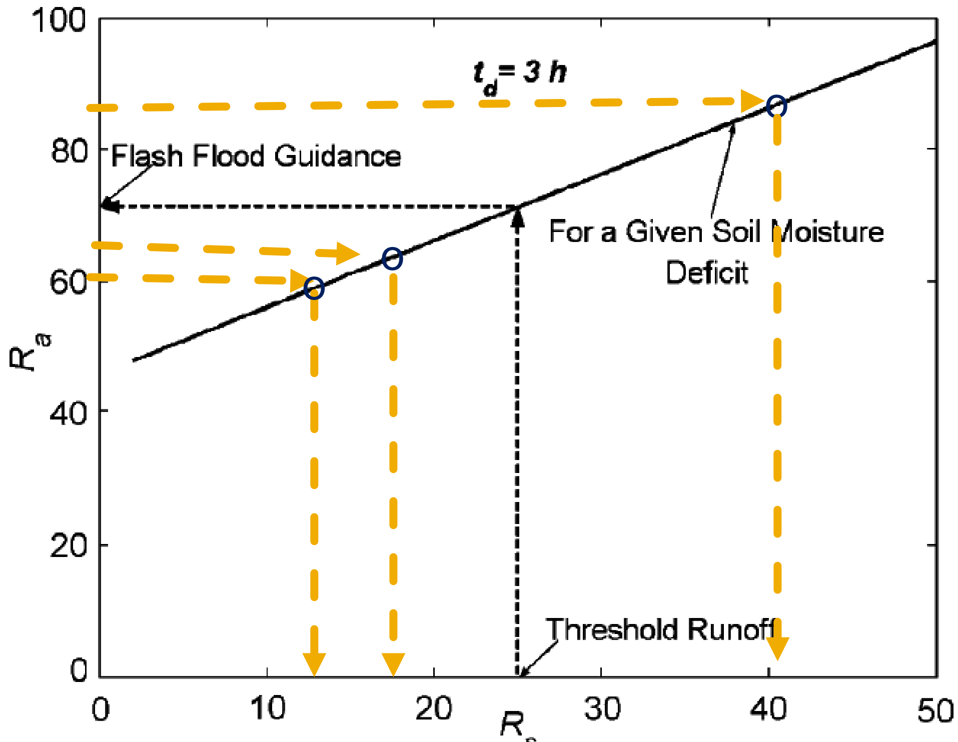
Flash Flood Sensitive Parameters



Determination of FFG using thresh-R and rainfall –runoff curve

FFG

Rainfall Depth



Rainfall depth \ surface runoff

Fig. 2. Model relationship (solid line) between a given volume of rainfall, R_a, of duration t_d and the model-generated runoff R_s for a given soil moisture deficit. The relationship is used to translate the surface runoff that is just enough to cause flooding of the draining stream at the watershed outlet (called threshold runoff) to the required volume of rainfall over a given duration t_d (called flash flood guidance of duration t_d).

Georgakakos 2006 JH 317:81-103

Relationship of Threshold Runoff to FFG

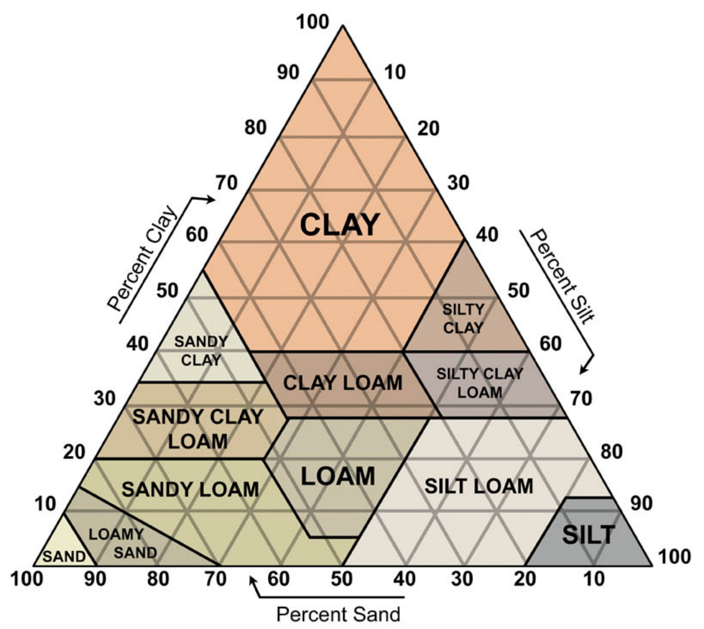
- Effective rainfall is the residual amount after accounting for all losses such as interception and soil moisture storage
- FFG is the amount of actual rainfall of a given duration falling over the watershed that causes flooding at the outlet of the drainage stream.

- FFG is derived from threshold runoff through soil moisture modeling and accounting for all losses in the transformation of rainfall to runoff

- Threshold Runoff is a one-time calculation for a given watershed whereas FFG is computed on a real-time basis

Soil Moisture Accounting Model A priori Parameter Estimation

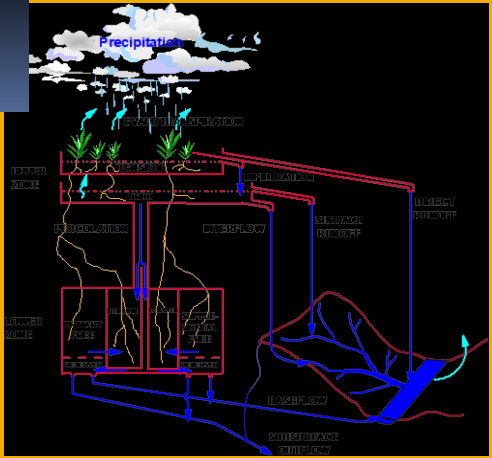
Soil Texture → Soil Hydraulic Properties(moisture content in wilting point , field capacity and saturation and Ks) → SMA model parameters



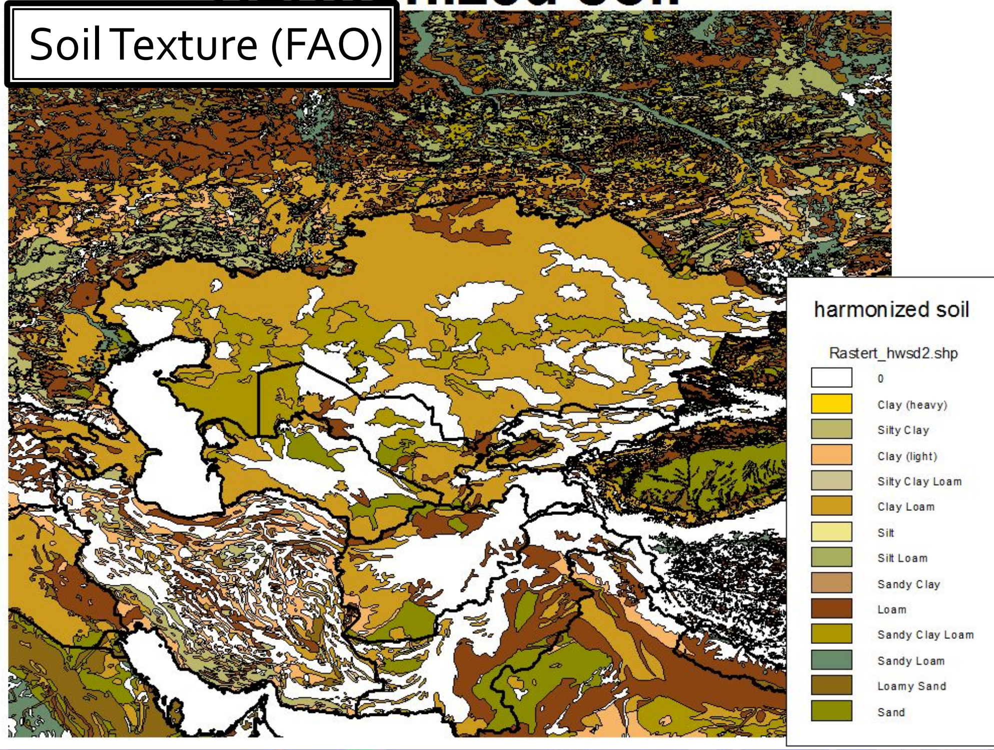
Soil Texture and Hydraulic Properties

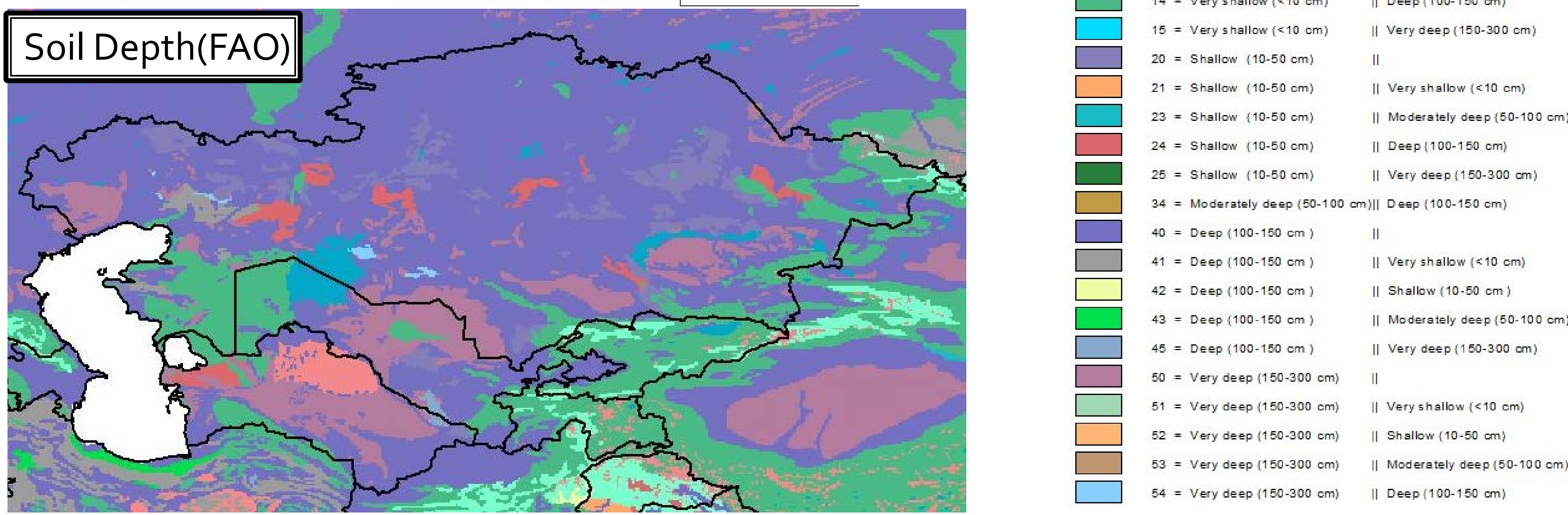
Soil Class	$\theta_s (m^3/m^3)$	$\theta_f (m^3/m^3)$	$\theta_m (m^3/m^3)$	$K_s (m/h)$	α	$\sigma_{Ks} (m/h)$
Sand	0.34	0.09	0.015	0.168	2.79	0.062
Loamy Sand	0.42	0.16	0.05	0.050	4.26	0.082
Sandy Loam	0.43	0.21	0.07	0.019	4.74	0.119
Loam	0.44	0.25	0.095	0.012	5.25	0.108
Silty Loam	0.48	0.29	0.11	0.010	5.33	0.090
Sandy Clay Loam	0.40	0.24	0.11	0.016	6.77	0.088
Clay Loam	0.47	0.32	0.17	0.009	8.17	0.099
Silty Clay Loam	0.46	0.33	0.19	0.007	8.72	0.103
Sandy Clay	0.41	0.29	0.18	0.026	10.73	0.054
Silty Clay	0.47	0.35	0.21	0.005	10.39	0.124
Clay	0.47	0.36	0.24	0.004	11.55	0.106

Values are from Cosby et al. 1984

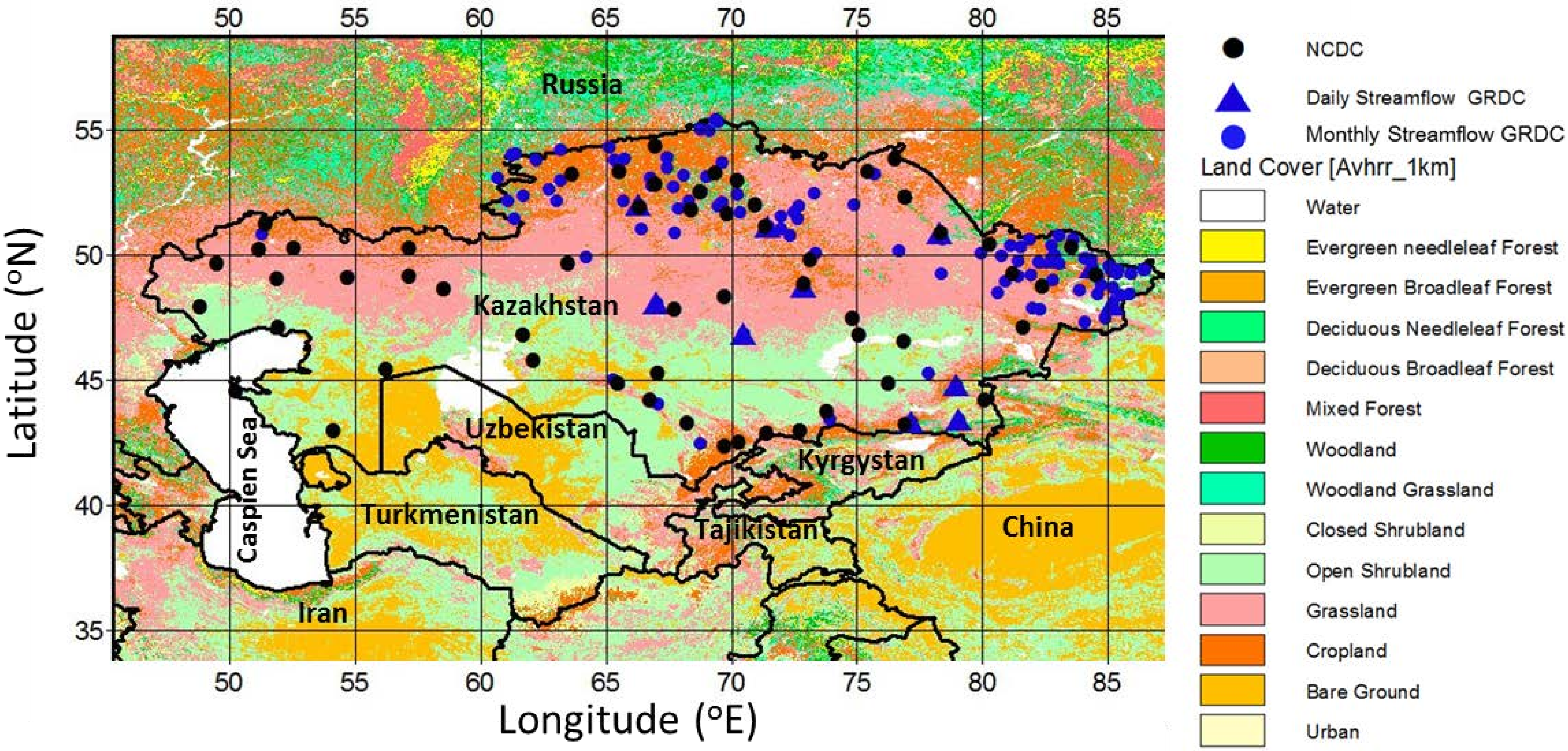


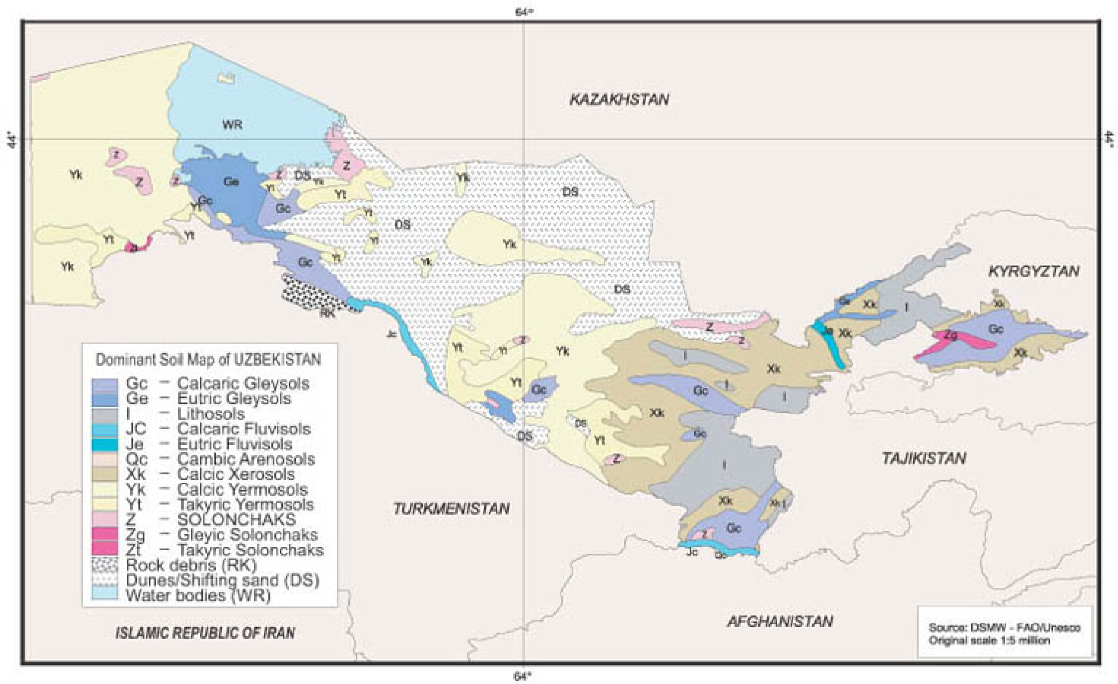
Harmonized soil



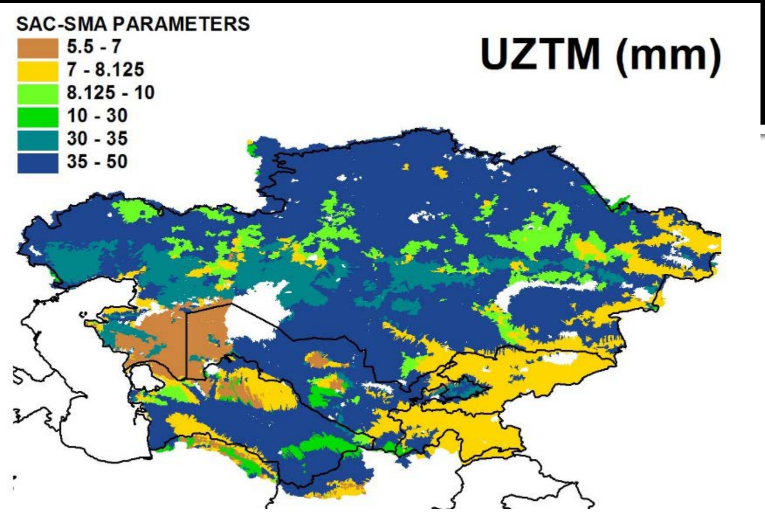


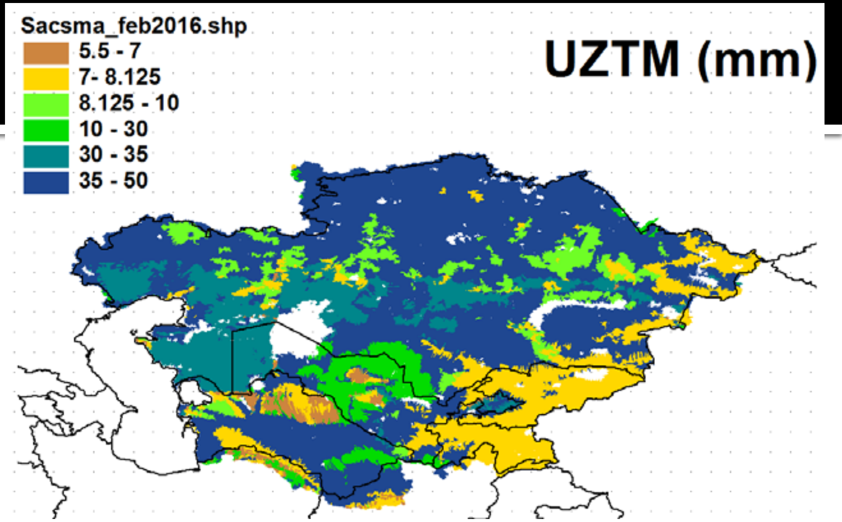
AVHRR-USGS (1-km) Land Cover Map

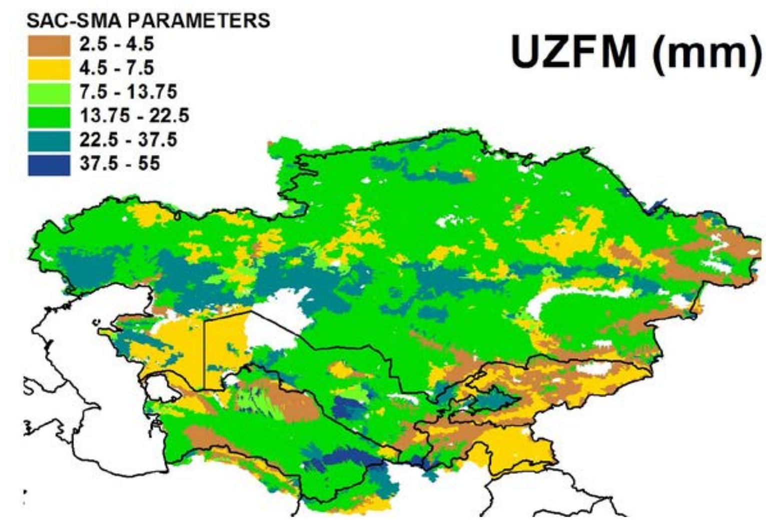


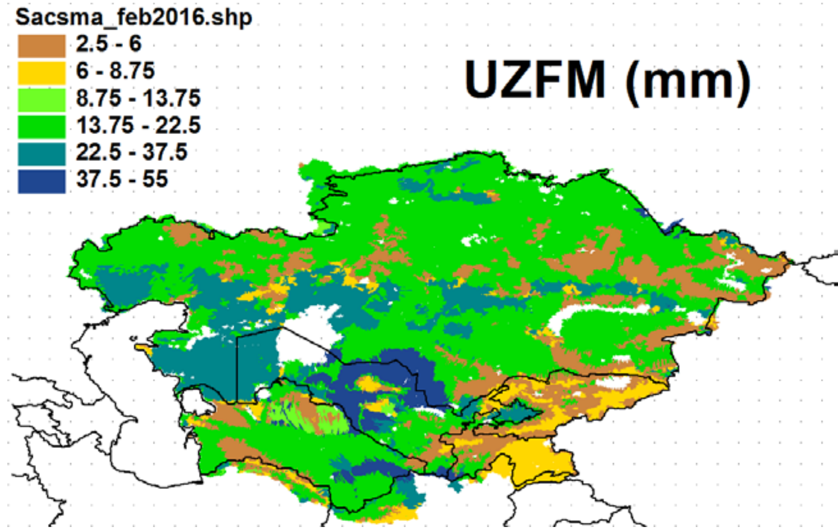


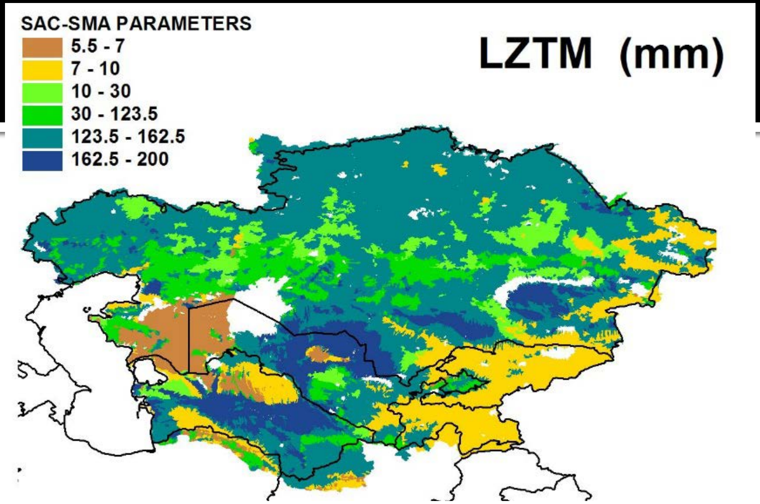
64°
44°
KAZAKHSTAN
KYRGYZTAN
TAJIKISTAN
TURKMENISTAN
AFGHANISTAN
ISLAMIC REPUBLIC OF IRAN
Dominant Soil Map of UZBEKISTAN
Gc – Calcaric Gleysols
Ge – Eutric Gleysols
I – Lithosols
JC – Calcaric Fluvisols
Je – Eutric Fluvisols
Qc – Cambic Arenosols
Xk – Calcic Xerosols
Yk – Calcic Yermosols
Yt – Takyric Yermosols
Z – SOLONCHAKS
Zg – Gleyic Solonchaks
Zt – Takyric Solonchaks
Rock debris (RK)
Dunes/Shifting sand (DS)
Water bodies (WR)
Source: DSMW - FAO/Unesco
Original scale 1:5 million

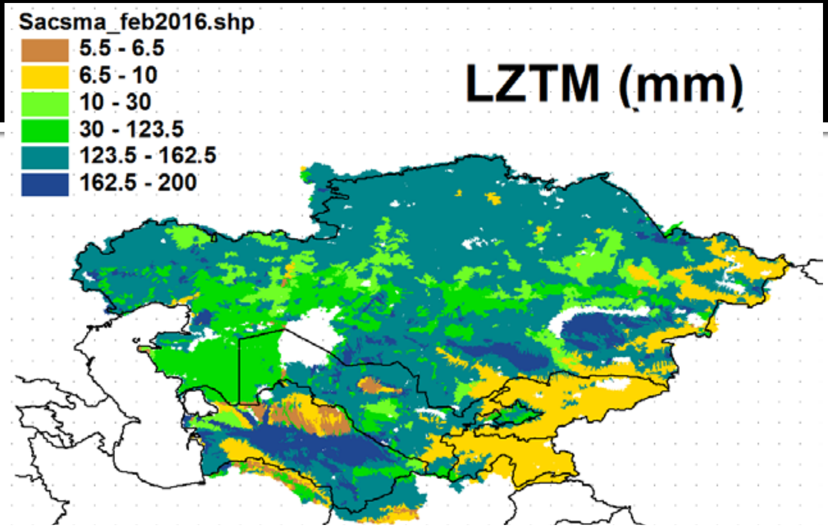

SAC-SMA PARAMETERS
5.5 - 7
7 - 8.125
8.125 - 10
10 - 30
30 - 35
35 - 50
UZTM (mm)

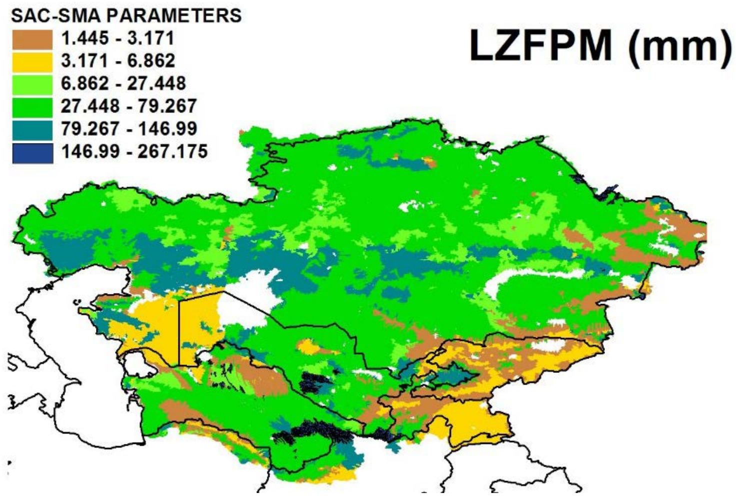

Sacsma_feb2016.shp
5.5 - 7
7- 8.125
8.125 - 10
10 - 30
30 - 35
35 - 50
UZTM (mm)

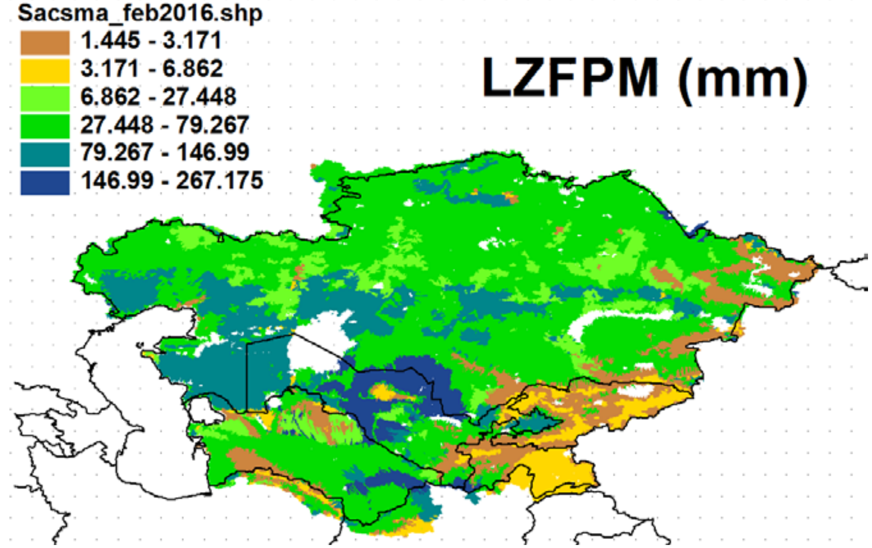

SAC-SMA PARAMETERS
2.5 - 4.5
4.5 - 7.5
7.5 - 13.75
13.75 - 22.5
22.5 - 37.5
37.5 - 55
UZFM (mm)

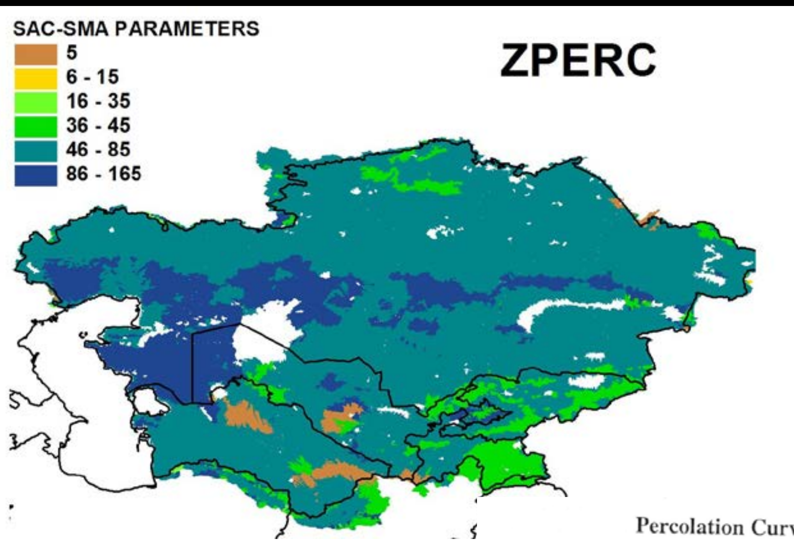

Sacsma_feb2016.shp
2.5 - 6
6 - 8.75
8.75 - 13.75
13.75 - 22.5
22.5 - 37.5
37.5 - 55
UZFM (mm)

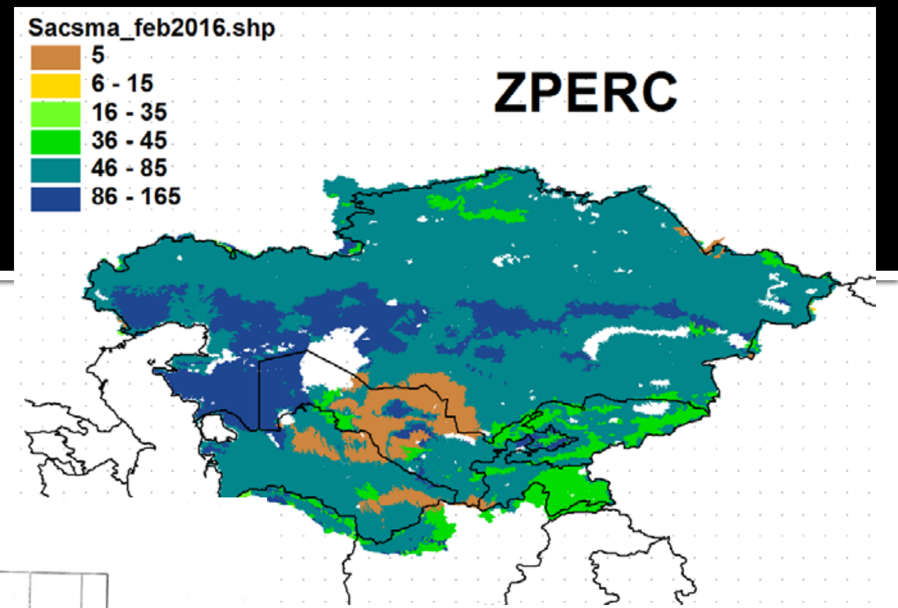

SAC-SMA PARAMETERS
5.5 - 7
7 - 10
10 - 30
30 - 123.5
123.5 - 162.5
162.5 - 200
LZTM (mm)


Sacsma_feb2016.shp
5.5 - 6.5
6.5 - 10
10 - 30
30 - 123.5
123.5 - 162.5
162.5 - 200
LZTM (mm)


SAC-SMA PARAMETERS
1.445 - 3.171
3.171 - 6.862
6.862 - 27.448
27.448 - 79.267
79.267 - 146.99
146.99 - 267.175
LZFPM (mm)


Sacsma_feb2016.shp
1.445 - 3.171
3.171 - 6.862
6.862 - 27.448
27.448 - 79.267
79.267 - 146.99
146.99 - 267.175
LZFPM (mm)





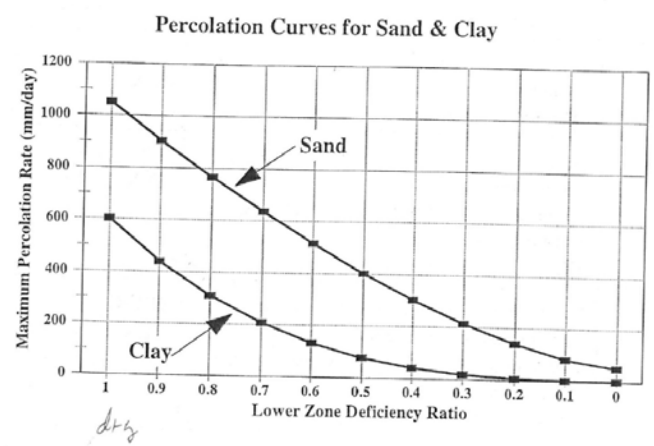
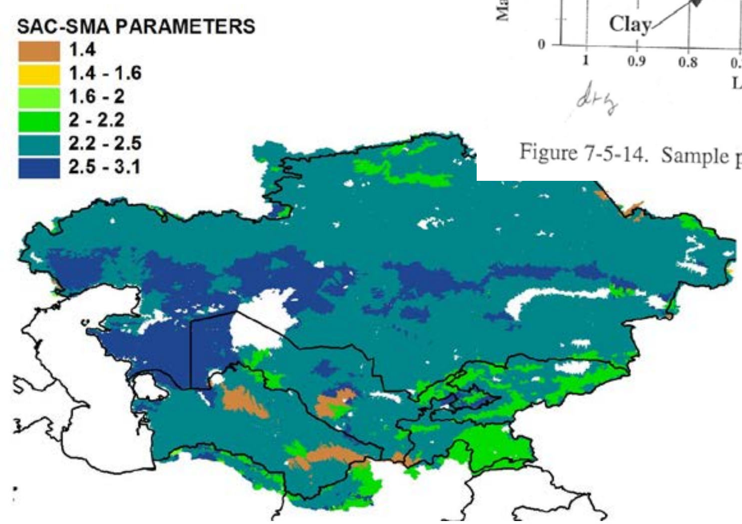
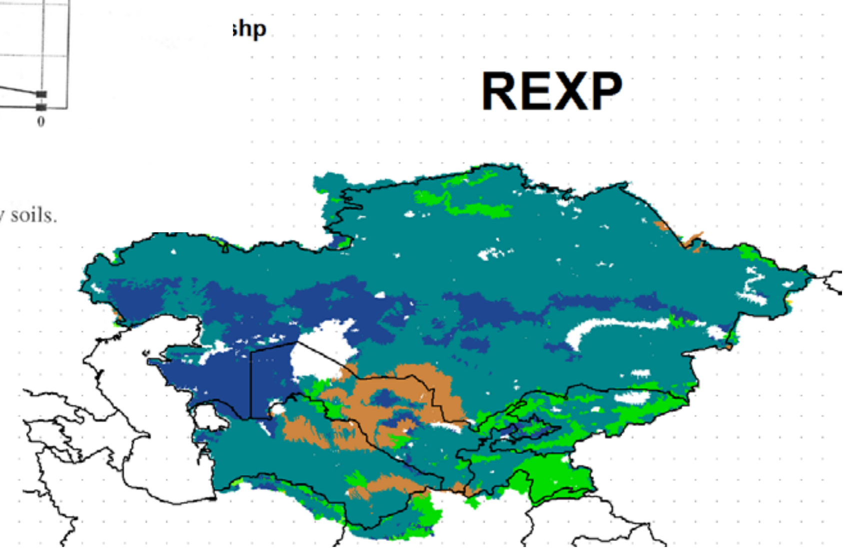
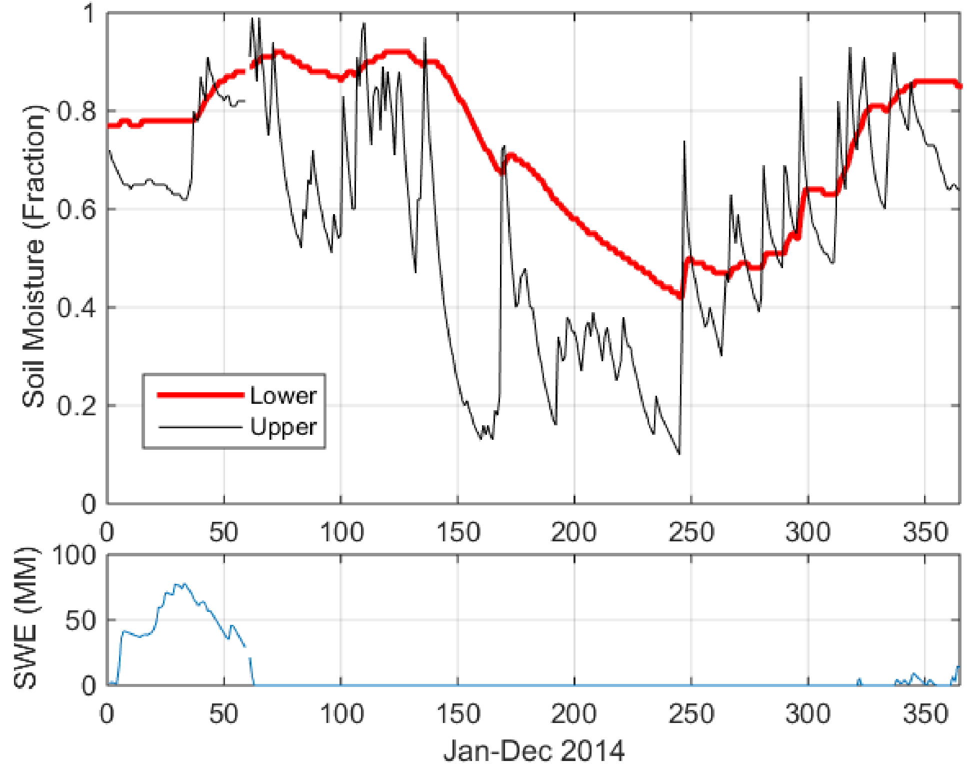


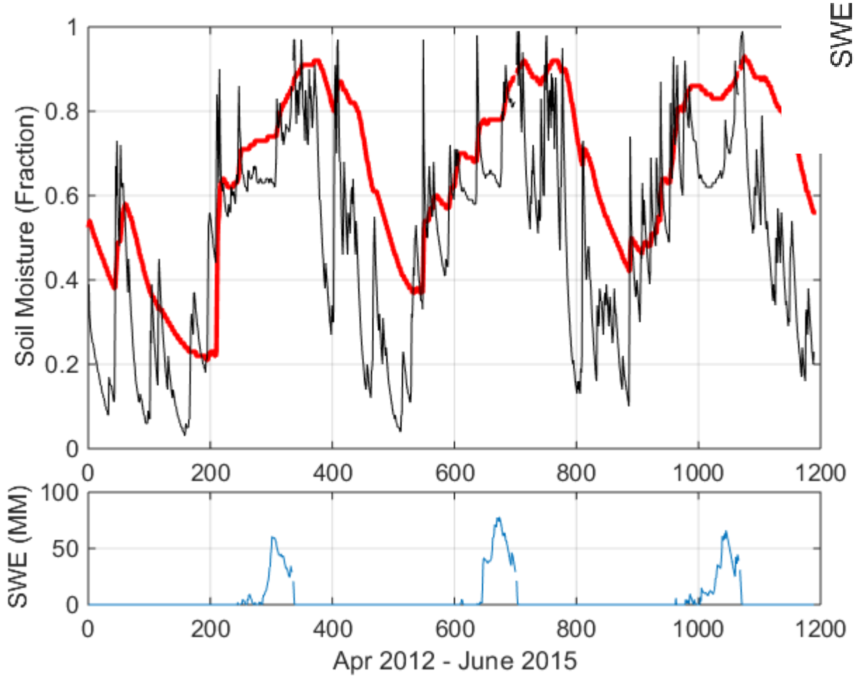
Figure 7-5-14. Sample percolation curves for sand and clay soils.



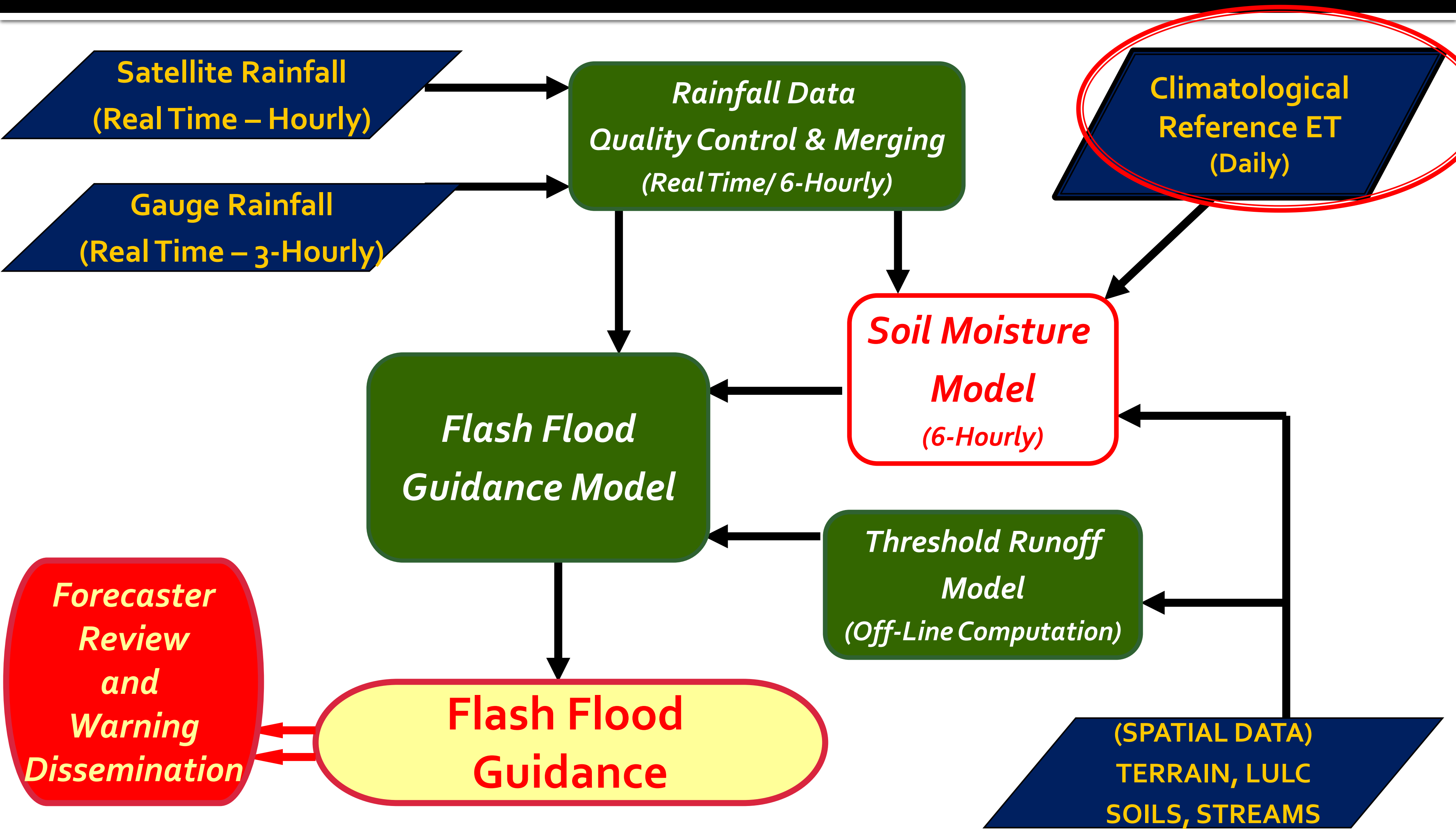


Soil Moisture Time series



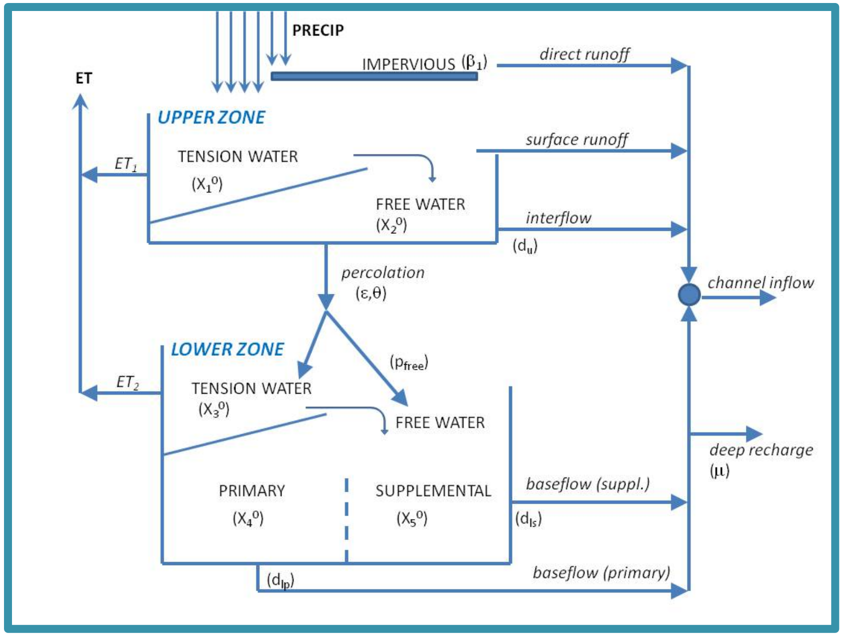


BSMEFFG Model Components



Potential Evapotranspiration Input

- PET used to determine soil moisture loss to evaporation/vegetation.
- Implementation is data driven:
  - Daily or climatological (monthly)
  - Pan Evaporation Data
  - Temperature-index methods (require temperature data)
  - Radiation based methods (require solar radiation/wind obs)



Potential vs. Actual ET

Water Availability: PET vs. AET

- PET (potential ET) is the expected ET if water is not limiting
  - Given conditions of: Wind, Temperature, Humidity
- AET (actual ET) is the amount that is actually abstracted (realizing that water may be limiting)
  - $AET = \alpha * PET$
  - Where α is a function of soil moisture, species, climate
  - In Florida, ~ α is unity for the summer, 0.75 otherwise
- ET:PET is low in arid areas due to water limitation
- ET ~ PET in humid areas due to energy limitation

Calculation of PET

Detailed dynamic energy and aerodynamic equation (e.g. Penman-Monteith)

Radiation fluxes

Meteorological variables

$$ET_d = \lambda^{-1} \frac{\Delta(R_n - G) + \frac{187200\gamma(e_a - e_d)}{r_a(T + 273)}}{\Delta + \gamma(1 + \frac{r_c}{r_a})}$$

Vegetation (canopy) Characteristics
Wetness Dependence

Evapotranspiration Demand ETD
Jensen-Haise: Radiation-based method with two parameters

For basin scale hydrologic models and operational environments, ETD procedures that are based on extraterrestrial radiation and climatic surface temperature outperform more complex models (e.g., Penman Monteith)

J-H Evapotranspiration Demand in a given location (mm/day):

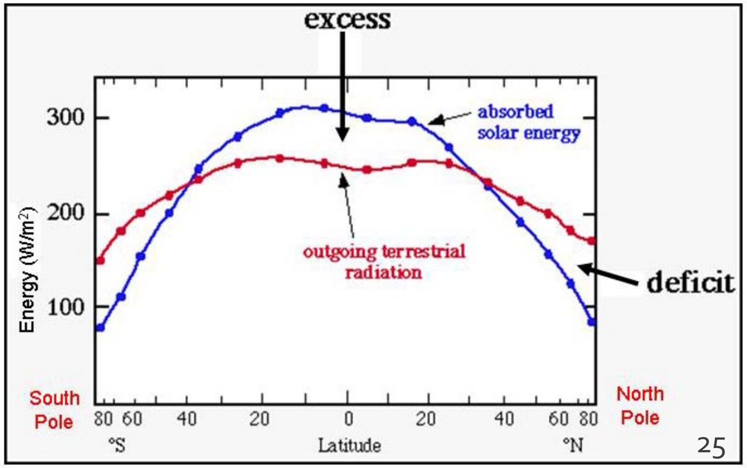
$$PE = [Re\,(Ta - K2)]/K1(\lambda\,\rho)$$

for Ta > K2

- Re - Daily potential Incoming extraterrestrial radiation (Mj m^{-2} d^{-1});
  - f{latitude, Julian date)
- Ta- Long term daily averages of surface temperature (minT+maxT)/2
  - f{Julian date, elevation)
- K2 (°C) – minimum temperature for which PE=0 (~5 °C)
- K1 (°C) – scale parameter (75-130) (assigned to 90)
- λ – Latent heat of water (Mj kg^{-1})
- ρ - density of water (kg m^{-3})

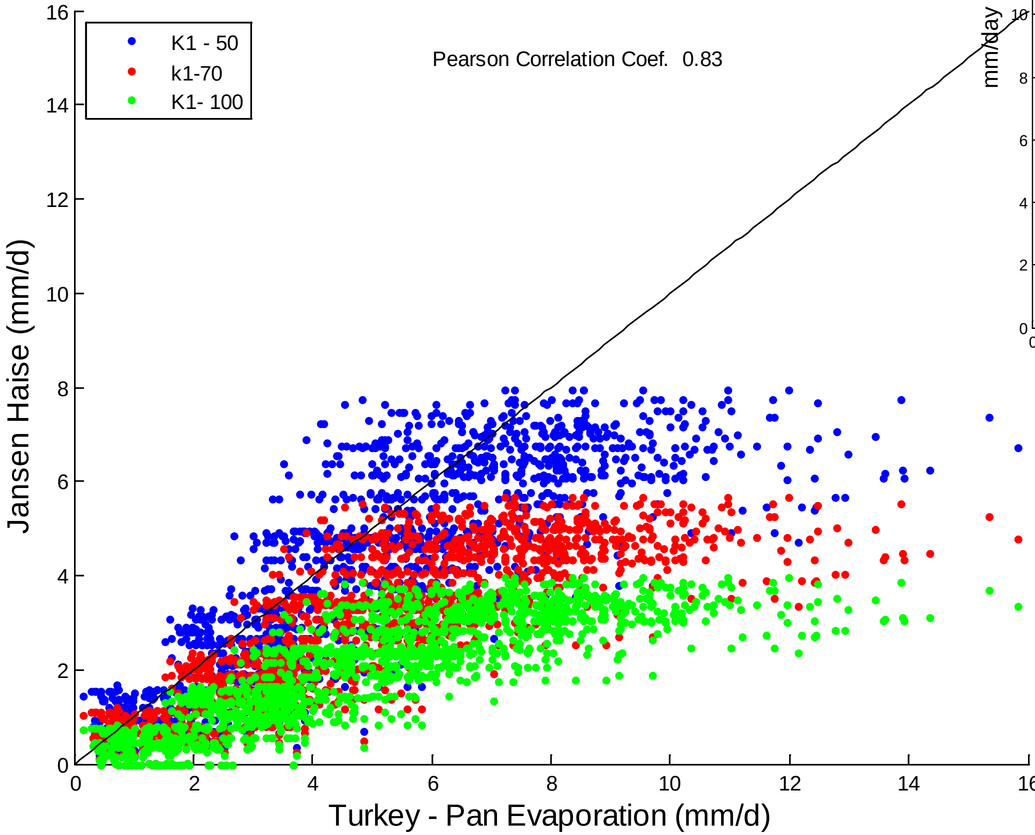
Jensen & Haise 1963
McGuinness & Borden 1973
Oudin et al 2005

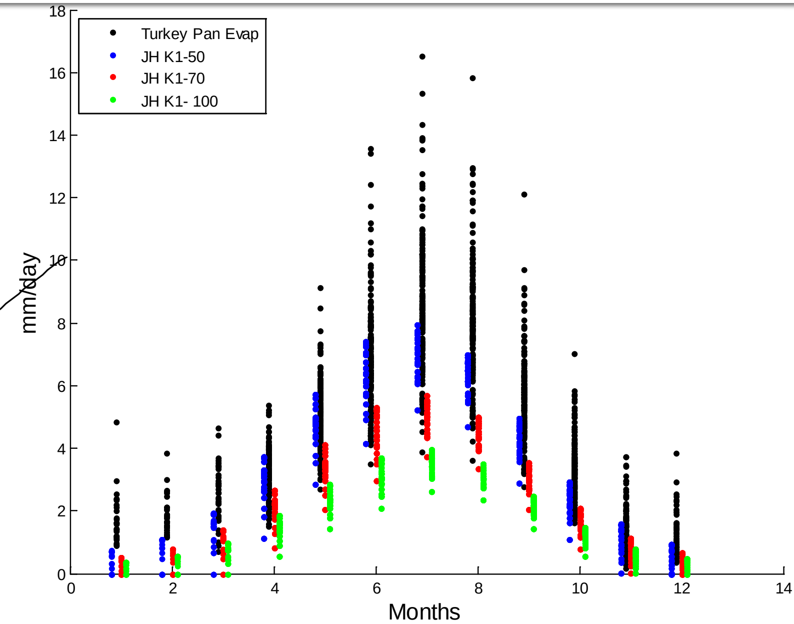
CRU-U of East Anglia, UK
Monthly climatology of mean daily Ta and diurnal Ta range
(1961-1990; 10 min scale)
New et al. 2002

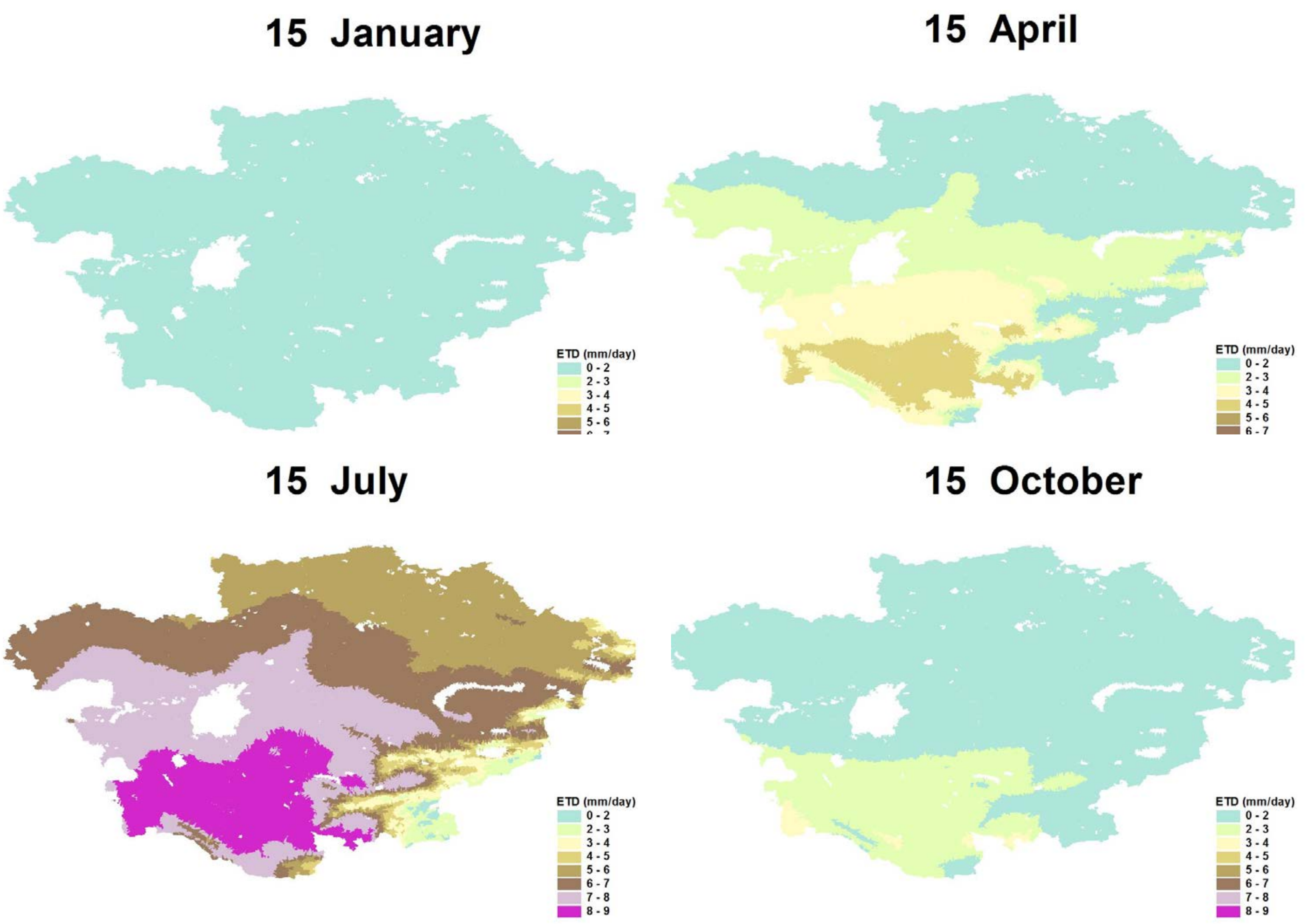


PET Comparison with Pan Evaporation Turkey

179 station with climatological Pan evap monthly values. About 26 year per stations






15 January
ETD (mm/day)
0 - 2
2 - 3
3 - 4
4 - 5
5 - 6
15 April
ETD (mm/day)
0 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
15 July
ETD (mm/day)
0 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
15 October
ETD (mm/day)
0 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9