Hydrologic modelling at a continuous permafrost site using MESH

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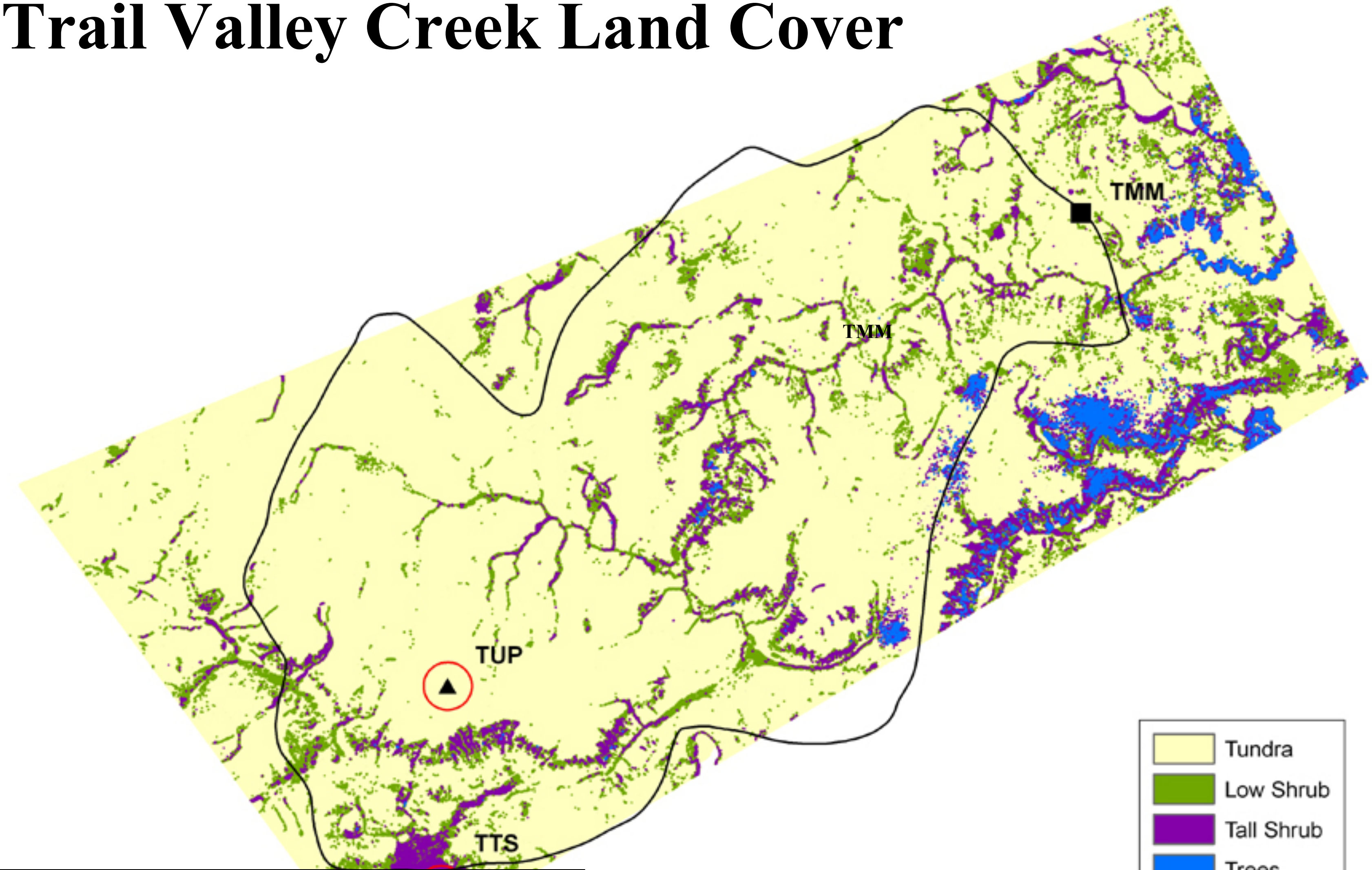
Purpose of Study

- Test the latest version of MESH at a continuous permafrost site
- Model performance will be evaluated against observed:
  - basin runoff
  - spatially distributed snow cover area
  - spatially distributed sensible and latent heat
- Problem areas of the model will be identified
- Approaches of including the spatial variability in snow cover and surface energy balance factors will be tested and their impact on model performance will be quantified

Model Runs

- MESH version 1.3 (released Aug 17, 2009) was run for TVC from 1996 to 2006
- Runs were conducted for the period May 1st to Sep 30th each year
- Model was run at resolution of 1 km
- Initial base case runs were carried out using “standard” vegetation based landcover classes:
  - tundra,
  - shrub tundra,
  - forest,
  - water

Trail Valley Creek Land Cover

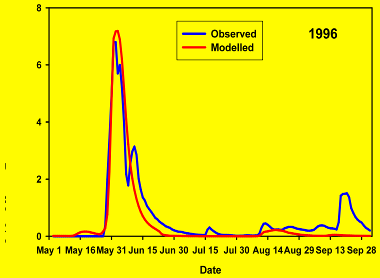


Landscape Type	Area (%)
Tundra	71
Shrub Tundra	24
Forest	2
Water	3

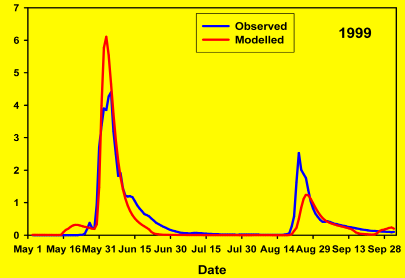
Calibration

- Initial model parameters were taken from Dornes et al. 2008
- MESH version 1.3 uses three new interflow parameters: Drainage Density, Average Overland Slope, and Hydraulic Conductivity of the Soil at a depth of 1m
- MESH appears to be is very sensitive to those three parameters
- 1996 and 1999 were used to calibrate these three parameters along with the closely related soil hydraulic conductivity at the surface.

Calibration Years



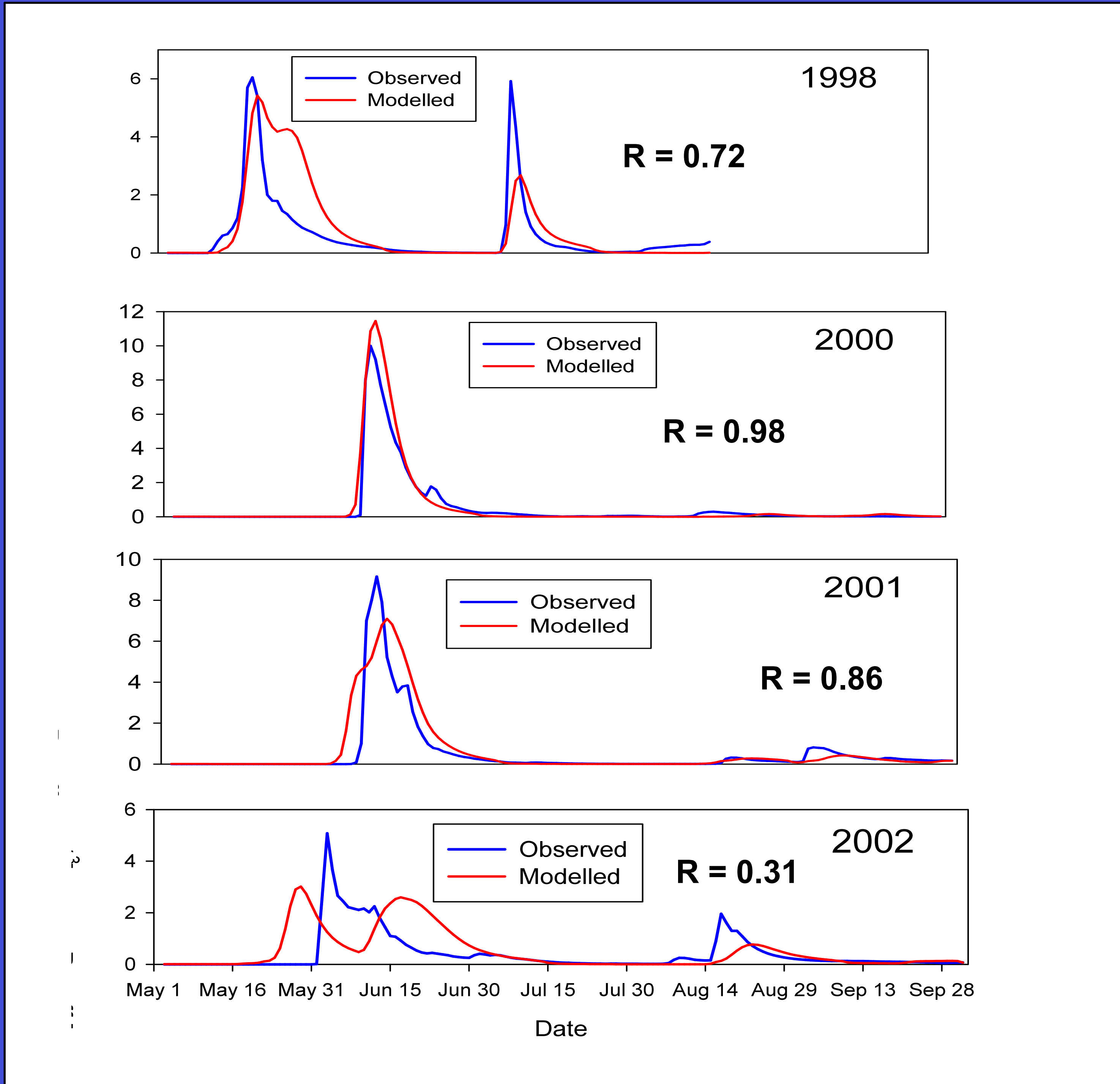
R = 0.94



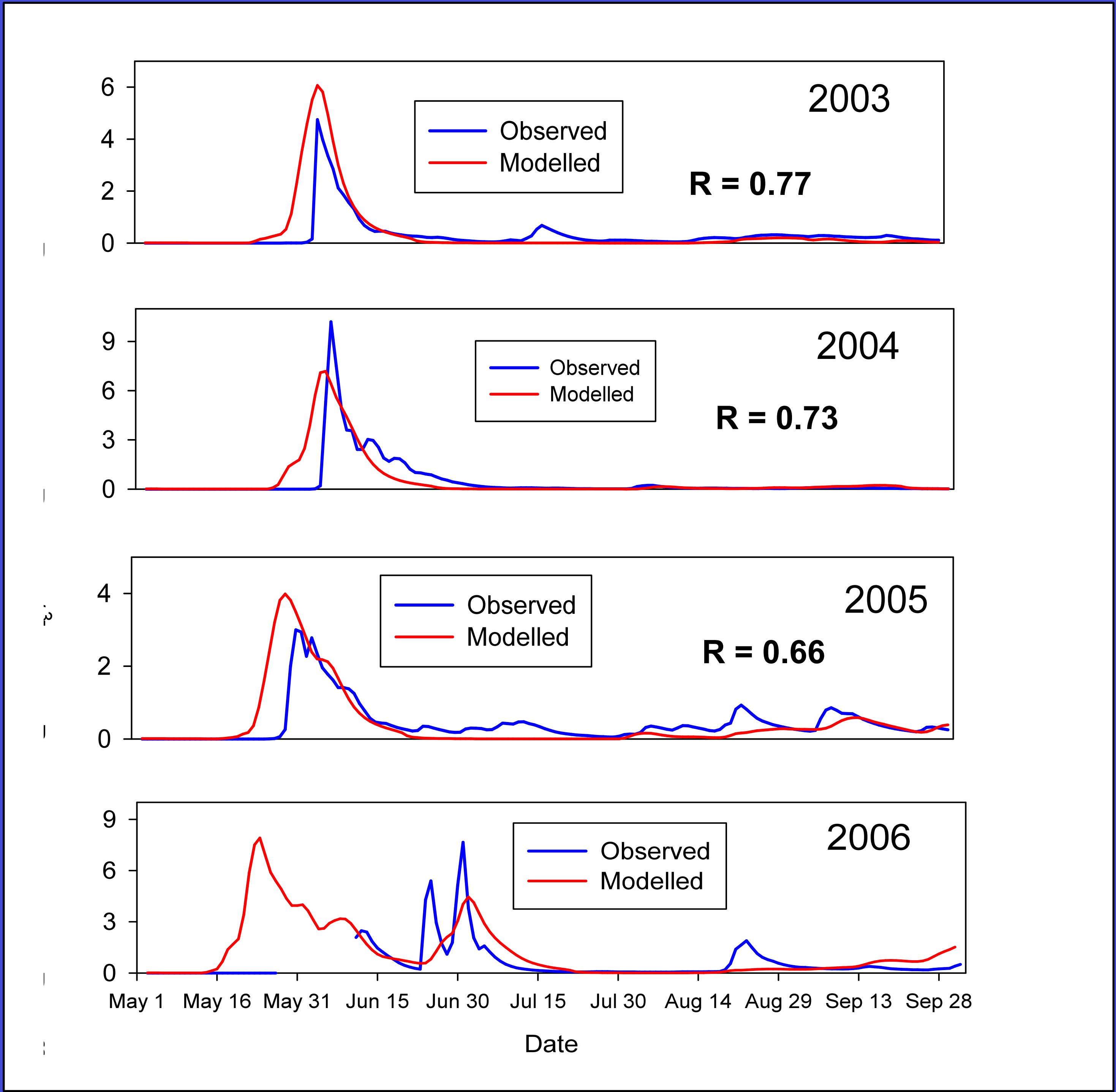
R = 0.92

Note: Dornes et al. 2008 model parameters used + calibration of 3 new parameters

Modelled Years 1998 and 2000 to 2003



Modelled Years 2003 to 2006

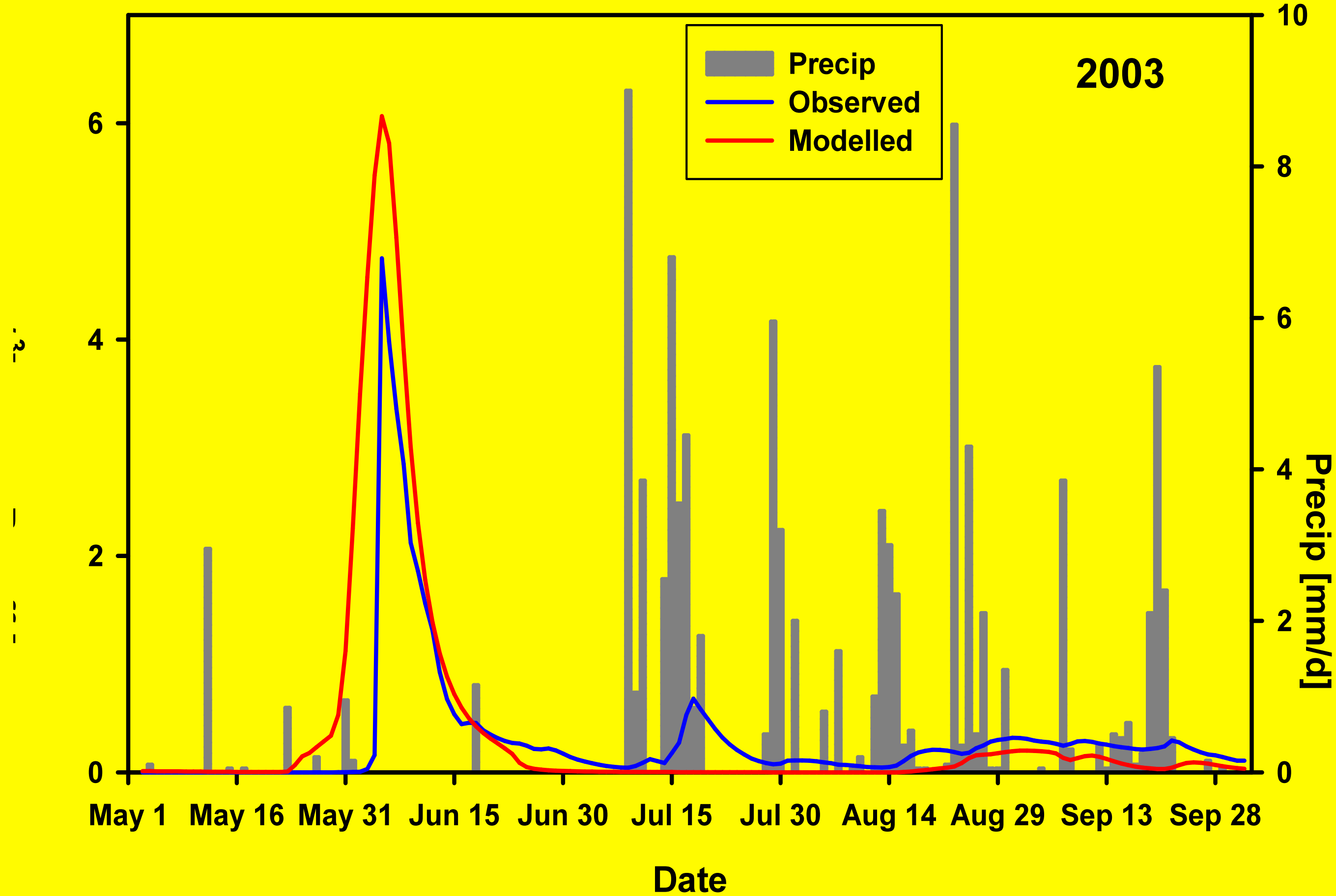


Model Base Case Run Statistics

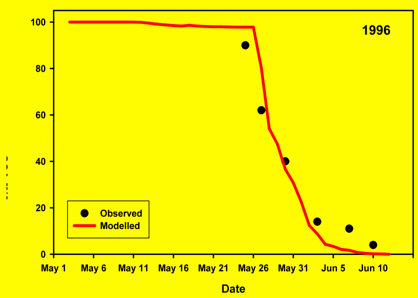
	Modelled Peak Volume %	Modelled Total Flow Volume %	Modelled Spring Flow Volume %	R
1996	106	72	94	0,94
1998	90	132	159	0,72
1999	139	89	102	0,92
2000	114	111	116	0,98
2001	79	122	134	0,86
2002	59	123	151	0,31
2003	128	124	186	0,77
2004	70	108	110	0,73
2005	133	99	144	0,66
AVG	102	109	133	0,77
AVG without Cal. Years	96	117	143	0,72

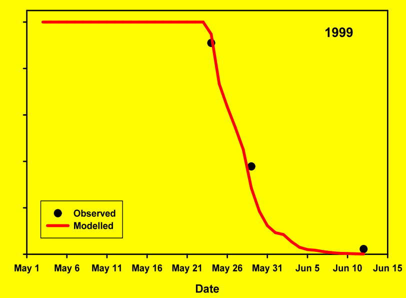
Major Problems with the Model Simulation

- Early rise to the snowmelt peak
- Summer runoff events are under predicted



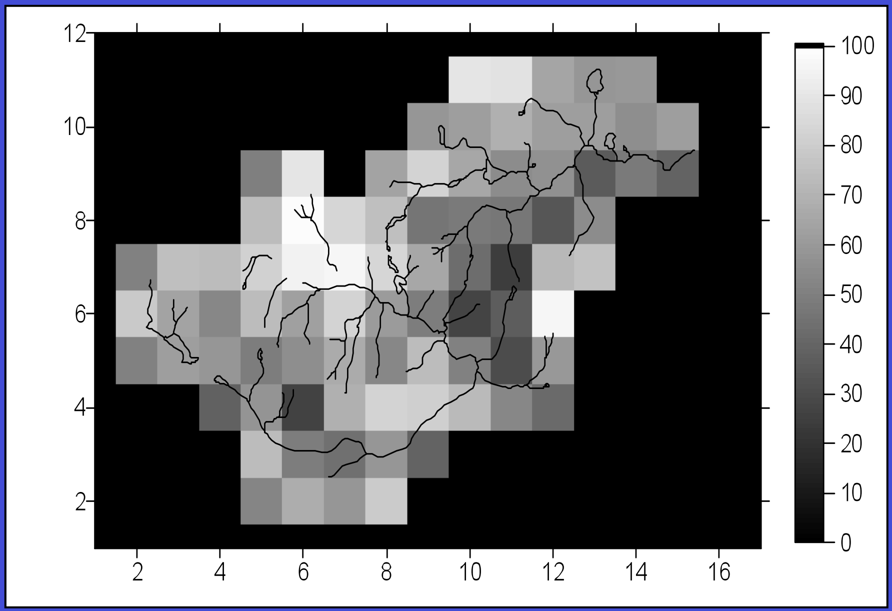
Model Results: Basin Average SCA





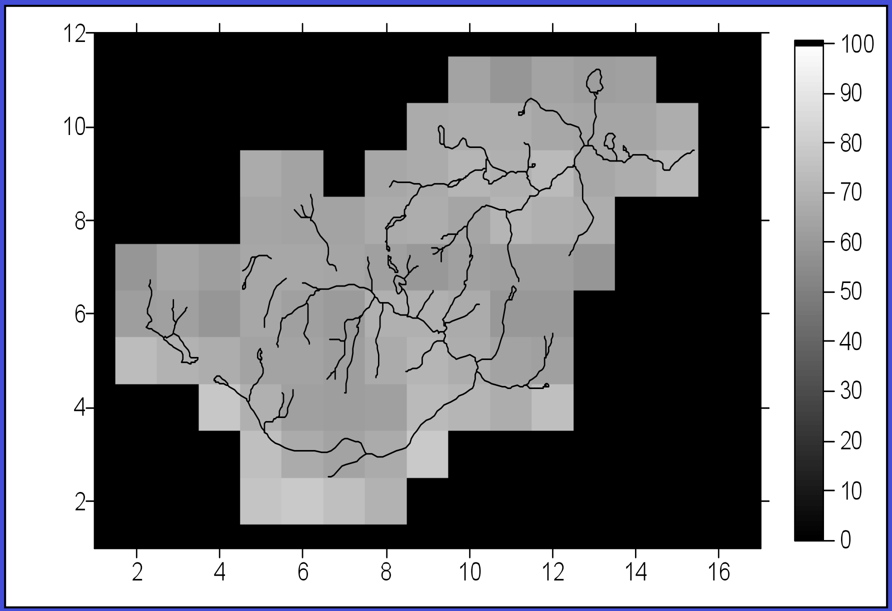
Model Results: Spatial Variability of SCA

Observed



May 25, 1996: SCA Mean = 62%
Range 24% - 99%

Simulated



May 25, 1996: SCA Mean = 64%
Range 55% - 90%

Spatial Variability in SCA (1996)

	Observed SCA				Modelled SCA			
Date	AVG %	Max %	Min %	Range %	AVG %	Max %	Min %	Range %
23-May	90	100	55	45	90	97	81	16
25-May	62	99	24	75	65	90	55	35
28-May	40	89	13	76	38	74	27	47
1-Jun	14	40	2	38	8	23	1	22
5-Jun	11	32	0	32	3	0	8	8
8-Jun	4	15	0	15	0	0	0	0

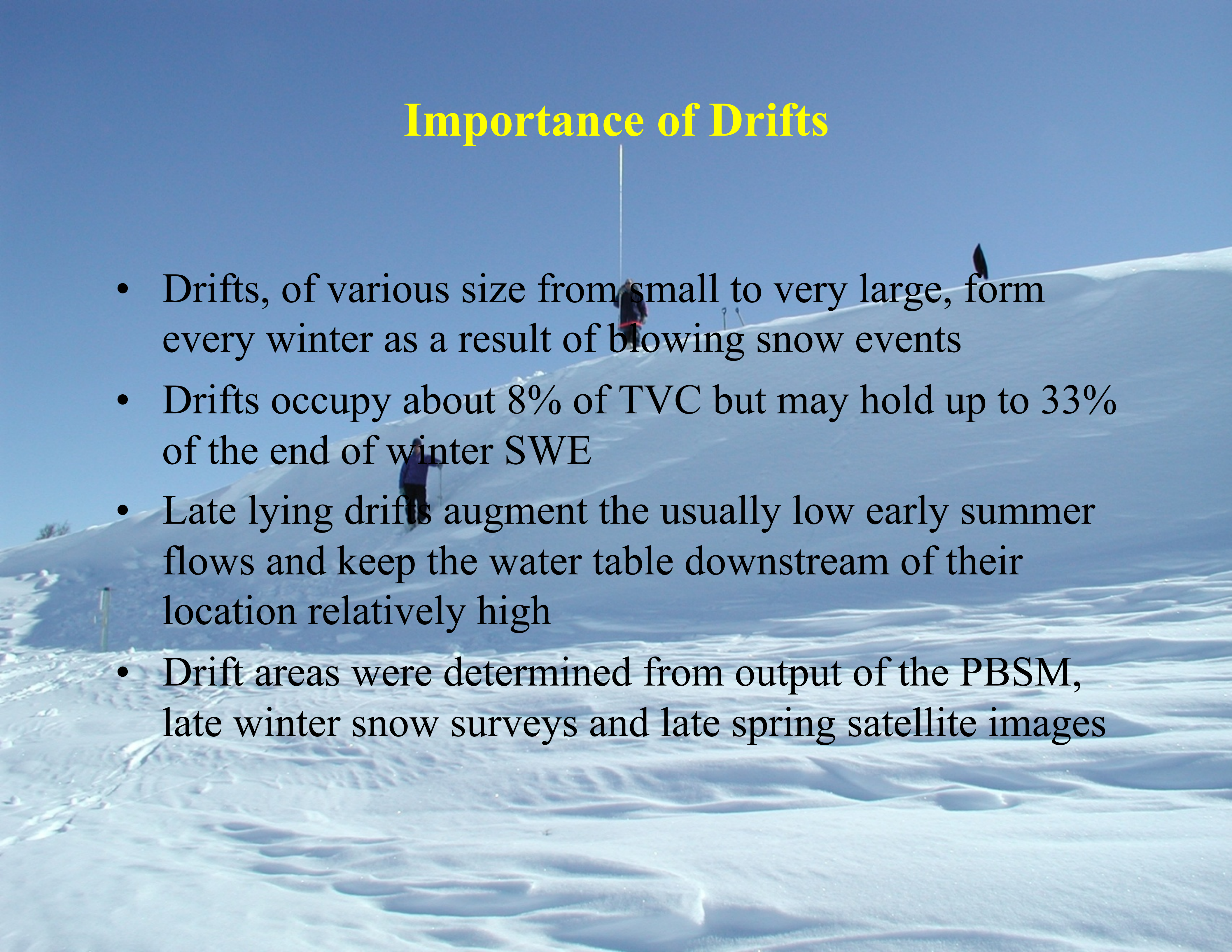
Spatial Variability in SCA

- Spatial variability of SCA during melt is under predicted by the model
- Naturally occurring spatial variability can be attributed to two factors:

  - Spatially variable end of winter snow cover due to re-distribution from blowing snow
  - Spatial variability in the snowmelt energy balance (radiation and turbulent fluxes)

Modified MESH Runs

- Additional topography based land classes (GRU's) will added:
  - windswept tundra and snow drifts;
  - These are aimed at improving the representation of the end-of-winter snowcover
- Existing land classes will be divided according to slope and aspect in order to enable appropriate input of incoming solar and long wave radiation
- Energy inputs will be pre-processed and representative values chosen from detailed small scale GEOtop model runs

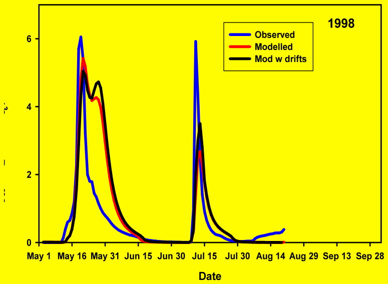


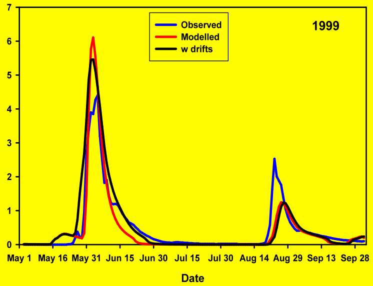
Importance of Drifts

- Drifts, of various size from small to very large, form every winter as a result of blowing snow events
- Drifts occupy about 8% of TVC but may hold up to 33% of the end of winter SWE
- Late lying drifts augment the usually low early summer flows and keep the water table downstream of their location relatively high
- Drift areas were determined from output of the PBSM, late winter snow surveys and late spring satellite images

MESH Modelled Runoff including Drifts

- Additional runoff occurred during the receding portion of the snowmelt peak
- As a result, early summer runoff events are slightly higher, but the simulation of late summer runoff events is not improved

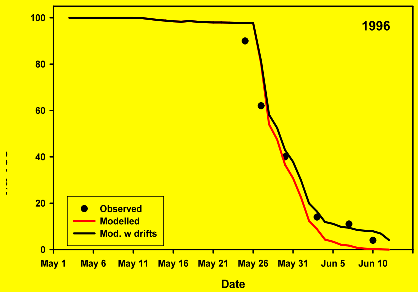


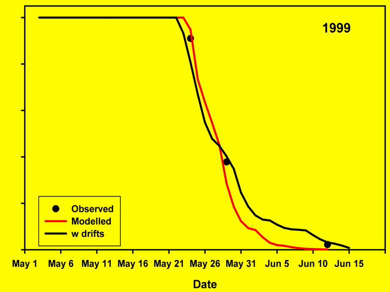


Model Statistics with Drifts

	Modelled Peak Volume no drifts %	Modelled Peak Volume with Drifts %	Modelled Total Flow Volume no drifts %	Modelled Total Flow Volume with Drifts %	Modelled Spring Flow Volume no drifts %	Modelled Spring Flow Volume with Drifts %	R no drifts	R with Drifts
1996	106	66	72	69	94	88	0,94	0,93
1998	90	83	132	139	159	168	0,72	0,68
1999	139	124	89	113	102	138	0,92	0,91
2000	114	90	111	121	116	125	0,98	0,96
2001	79	79	122	128	134	140	0,86	0,83
2002	59	76	123	150	151	192	0,31	0,4
2003	128	124	124	147	186	225	0,77	0,81
2004	70	65	108	126	110	129	0,73	0,74
2005	133	111	99	104	144	153	0,66	0,71
AVG	102	91	109	122	133	151	0,77	0,77
AVG without Cal Years	96	90	117	131	143	162	0,72	0,73

Basin Average SCA with Drifts





Spatial Variability in SCA with Drifts

	Observed SCA		Modelled SCA without drifts		Modelled SCA with Drifts	
Date	AVG	Range	AVG	Range	AVG	Range
	%	%	%	%	%	%
23-May	90	45	90	16	91	13
25-May	62	75	65	35	68	36
28-May	40	76	38	47	43	58
1-Jun	14	38	8	22	14	38
5-Jun	11	32	3	8	9	26
8-Jun	4	15	0	0	6	19

Future Work with MESH

- MESH output of surface energy balance (especially turbulent fluxes of sensible and latent heat) will be compared to MAGS aircraft data
- Available aircraft data consists of basin averages and 3-km gridded datasets. Both datasets will be compared to MESH output data
- GEOtop output data will be used to find optimal MESH setup that includes as much spatial information on surface energy fluxes as possible while retaining computational efficiency

GEOtop Runs mirroring MESH

Fully distributed at 10 m resolution

↓

Matching MESH using several slope and aspect classes per landcover (i.e. steep, average, moderate south facing tundra etc.)

↓

Matching MESH using one slope and aspect class per landcover (i.e. south and north facing tundra etc.)

↓

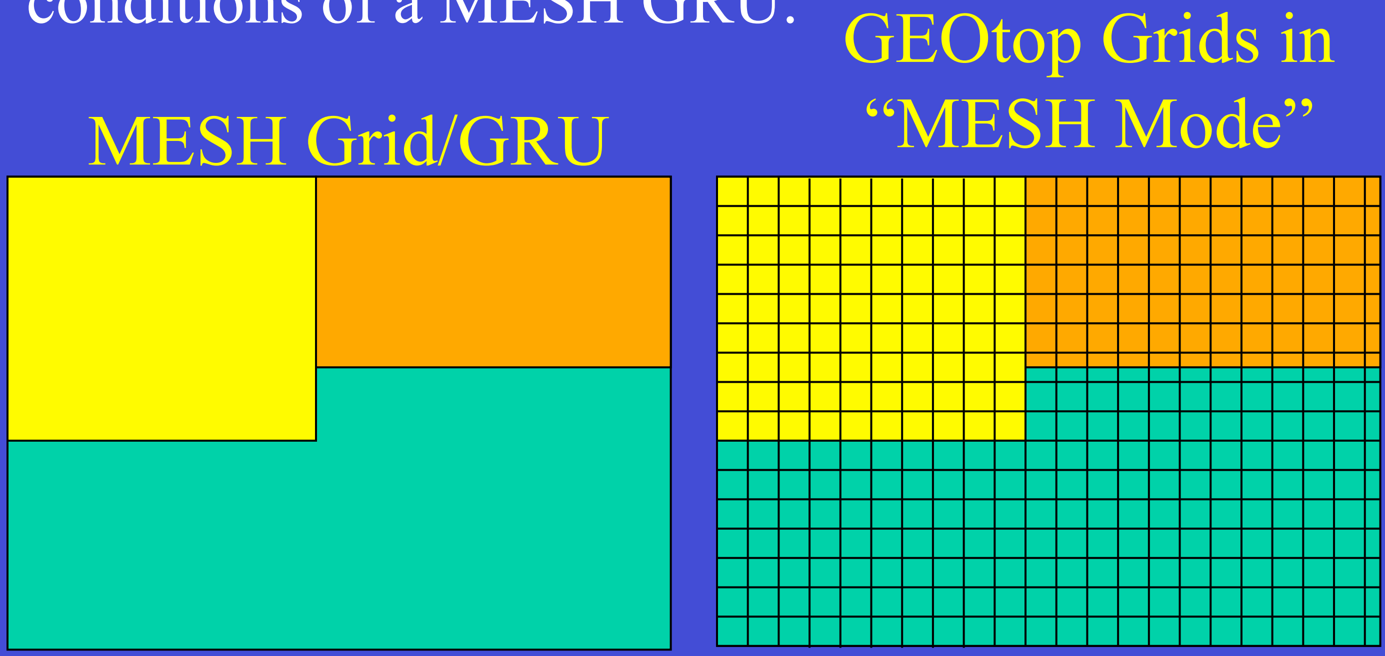
Matching MESH using vegetation based land cover classes

Computational Efficiency

Information on spatial distribution

Using GEOtop to simulate GRUs at same scale as MESH

- For each MESH grid, we will:
  - Run GEOtop at several resolutions ranging from high resolution (10m) to a resolution that would equal the conditions of a MESH GRU.



This will allow us to test a variety of GRU configurations before running MESH. Various combinations of slope/aspect and vegetation, and their impact on SCA and turbulent fluxes, for example, can be tested this way.

Summary

- MESH was able to simulate the spring snowmelt runoff rather well
- Summer rainfall induced runoff events seemed to be underpredicted
- Average basin SCAs were forecast well but the spatial variability of the SCAs within the basin was considerably under predicted
- The inclusion of drifts improved the simulation of late season average SCAs and their spatial variability
- Future work will be particularly aimed at improving the simulation of the spatially variable surface energy balance within MESH

Data available for inclusion in the IP3 data repository

- Data to enable the user to run MESH from 1996 to 2006 from May 1st to Sep 30th for TVC will be made available
- Data consists of: hourly air temperature, humidity, station air pressure, precipitation, windspeed, incoming solar radiation and incoming long wave radiation
- End of winter, landcover based, snow surveys to enable the construction of an initial snow cover
- Parameter files and output files from our MESH runs can also be added to the archive (if desired) to enable the reconstruction of MESH runs in the future

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Thank you very much