Landsat Reference Data
Status, Validation Methods and First Results

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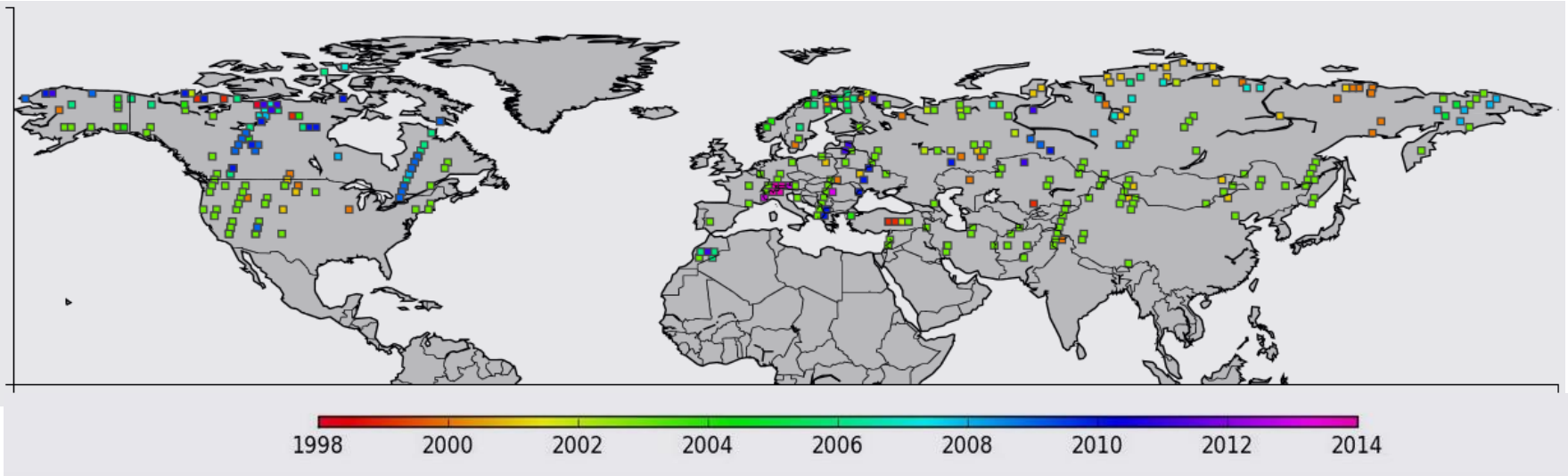
Overview Landsat Scenes

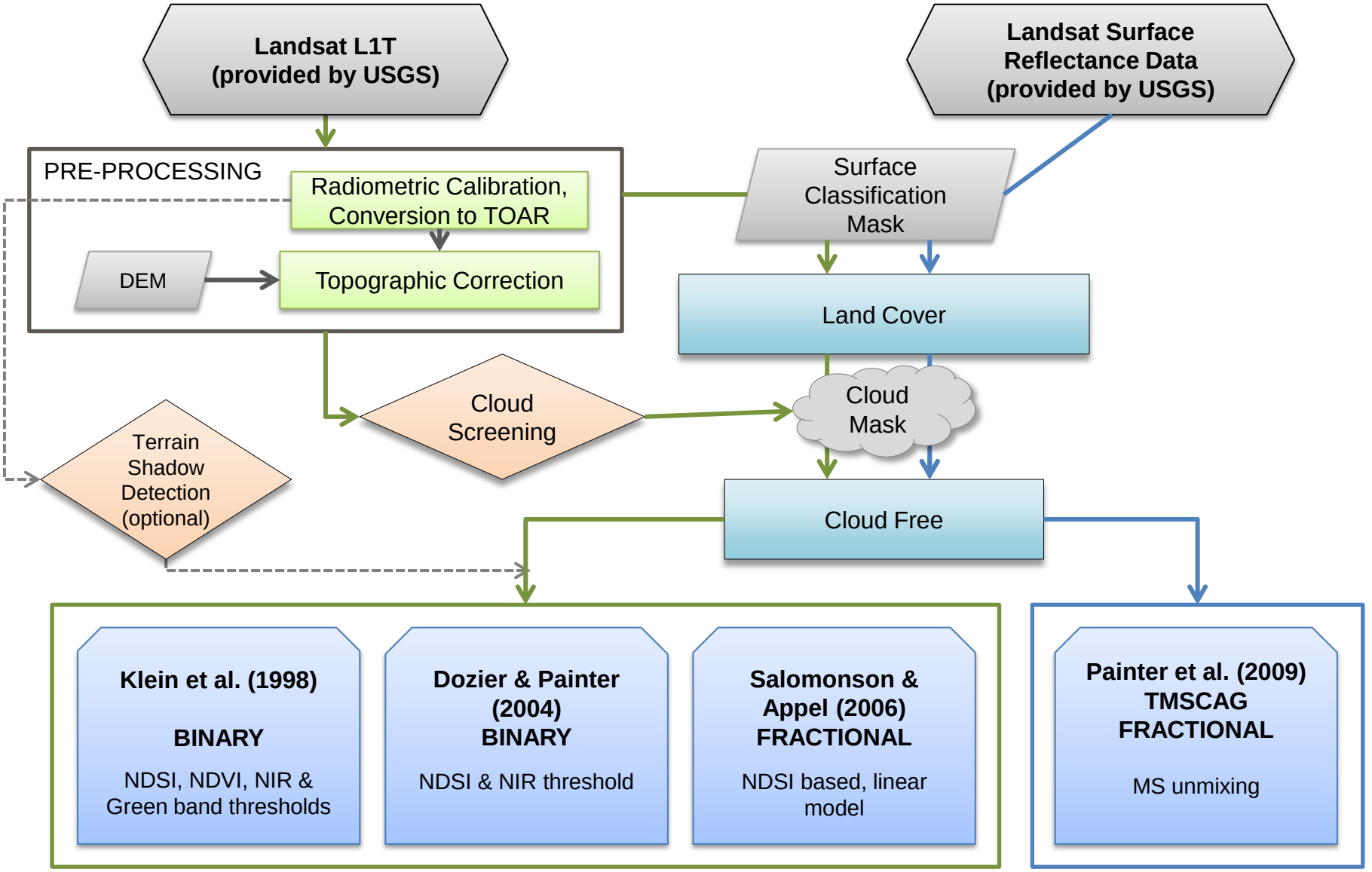
→ 459 Landsat scenes from Landsat-5 (188), Landsat-7 SLCon (255) and Landsat 8 (16) over the Northern Hemisphere



Intersection with snow extent products

ASNOW	CRCLIM	CRYOL	EURAC	GLSSE	HSAF	IMS01	IMS04	JXAM5	JXM10	M10C05	PATHF	SCAG
132	410	118	19	268	13	9	182	436	426	407	287	~100

Processing Line Landsat Reference Data



Snow Detection Algorithms - binary

Binary SE by adapted method after Dozier and Painter (2004)

Based on applying thresholds to the Normalized Difference Snow Index (NDSI) and to the near-infrared band at 0.85 µm:

$$NDSI = \frac{VIS - SWIR}{VIS + SWIR} = \frac{REF_{0.55\ \mu m} - REF_{1.6\ \mu m}}{REF_{0.55\ \mu m} + REF_{1.6\ \mu m}}$$

if ***NDSI > 0.40*** *and* ***$REF_{0.85\ \mu m}$ > 0.11*** *then* ***SNOW***

Binary SE by adapted method after Klein et al. (1998)

Thresholds to NDSI, Normalized Difference Vegetation Index (NDVI) and spectral query:

if ***$REF_{0.55\mu m}$ > 0.10*** *and* ***$REF_{0.85\mu m}$ > 0.11***
AND some of the following is true:
→ ***NDSI > 0.4*** *or*
→ ***NDVI ≥ 0.25*** *and* ***NDSI ≥ 0.0652 * EXP(1.8069 * NDVI)*** *or*
→ ***NDVI ≥ 0.1*** *and* ***NDVI < 0.25*** *and* ***NDSI ≥ (NDVI-0.2883)/-0.4828)***
THEN ***SNOW***
OTHERWISE pixel is ***SNOW FREE***

Snow Detection Algorithms - fractional

Fractional SE by adapted method after Salomonson and Appel (2006)

Is based on the Normalized Difference Snow Index (NDSI, Equ. 6.2). The approach uses a linear model to weight the binary snow classification derived by the NDSI:

FSC = -0.01 + 1.45 * NDSI

Fractional SE by method of Painter et al. (2009) - TMSCAG

The TMSCAG algorithm is a new version of the Rosenthal and Dozier (1996) spectral mixing model adapted to the ETM+ bandpasses and radiometric characteristics and retrieves fractional snow cover from the ETM+ and TM data (Painter et al., 2009).

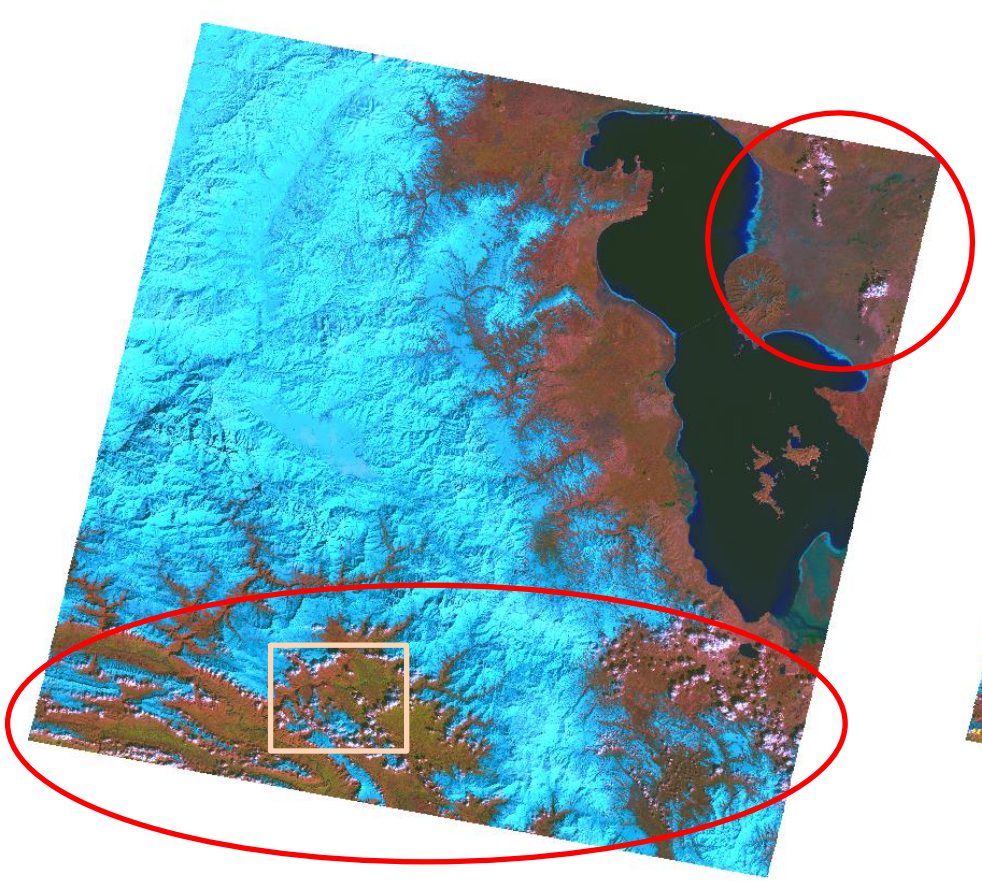
Cloud Screening

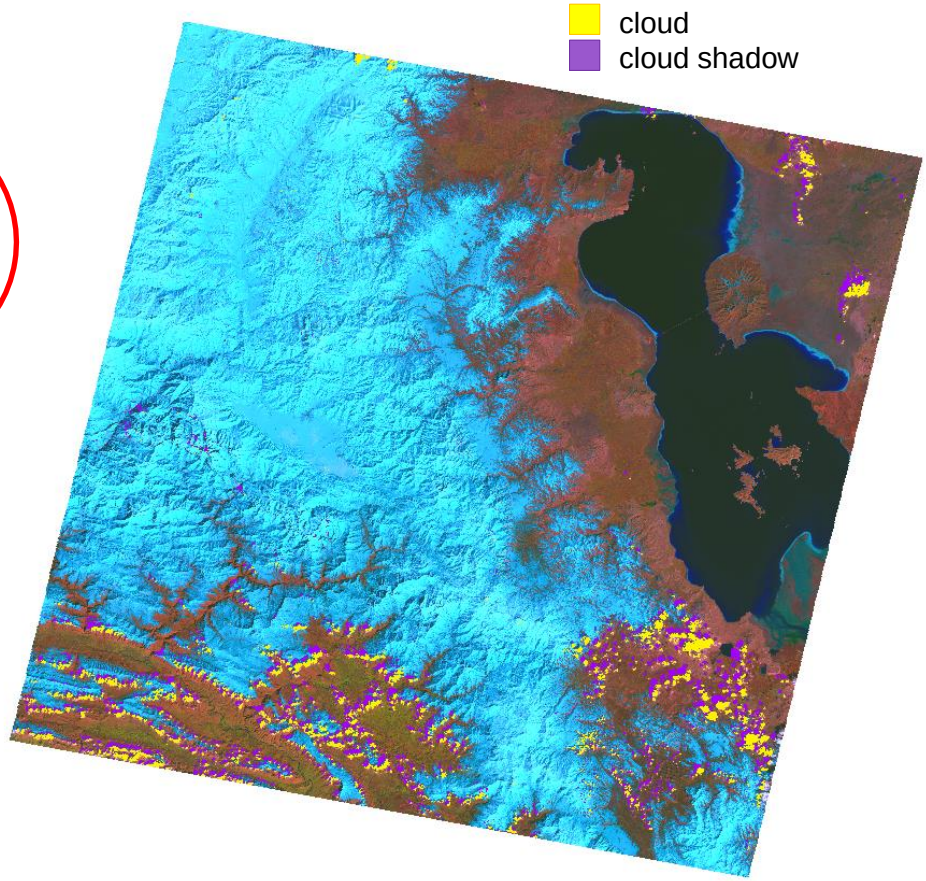
Clear sky scenes: 205 (LS5 → 62, LS7 SLCon→140, LS8 →3)
Scenes with clouds: 254 (LS5 →126, LS7 SLCon →115, LS8 →13)

Cloud Classes		Scenes	Method
0	completely clear-sky; no need for cloud masking	205	-
1	clouds concentrated in a certain part of scene area; masking by hand easy (and necessary)	137	**Manual Cloud Masking/ACCA.SEAS**
2	very few scattered clouds; masking a bit laborious; however if not done, does not affect the result very much	39	**Manual Cloud Masking/ACCA.SEAS**
3	scattered clouds and shadows; masking laborious but has to be done if using the scene	78	**Manual Cloud Masking/ACCA.SEAS**
4	too cloudy for intercomparison / cloud masking very laborious	-	-

Cloud Screening ACCA.SEAS

LS7 P169/R34 8 Mar 2003 over Turkey/Iran





Cloud Screening ACCA.SEAS

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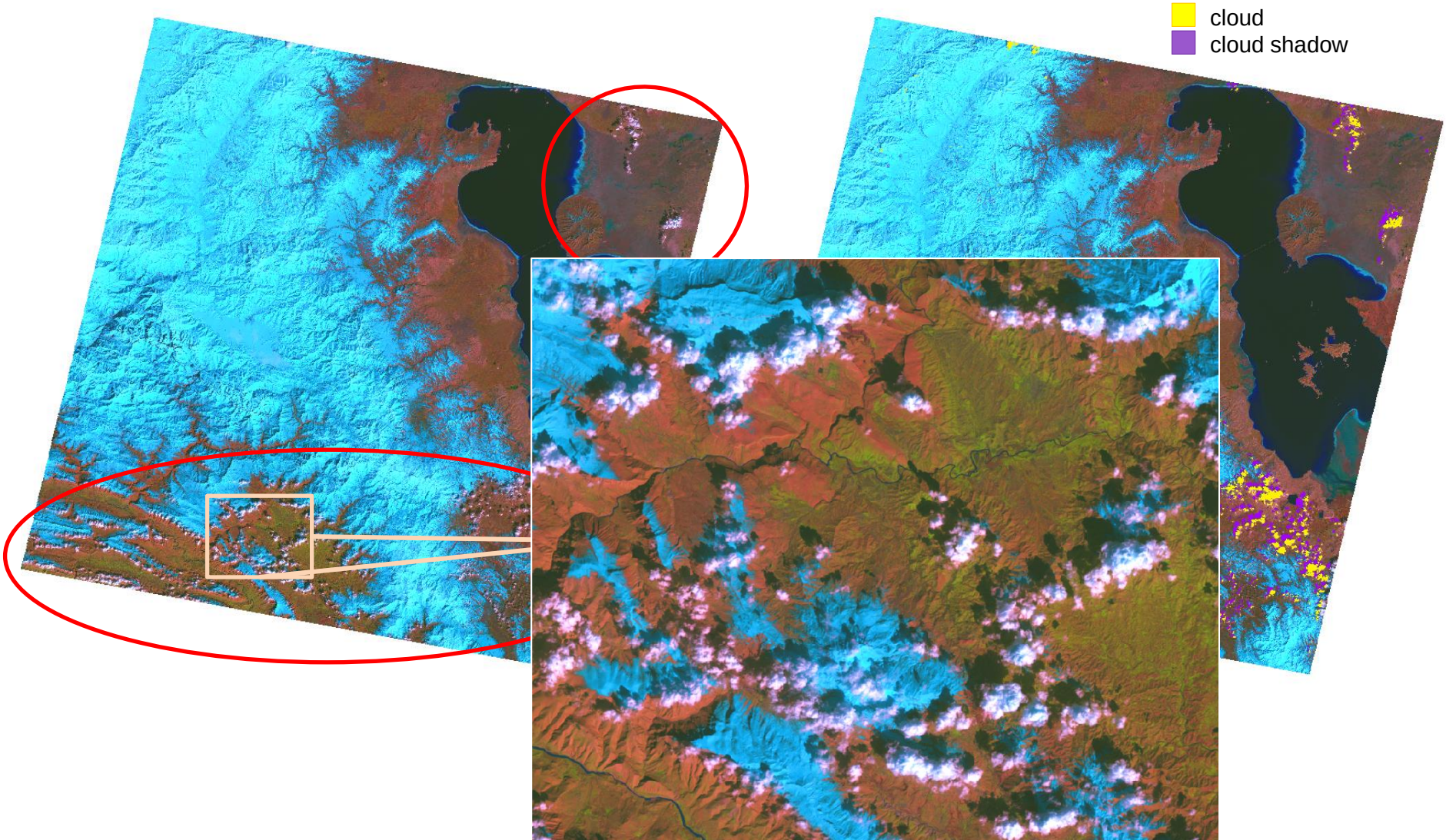
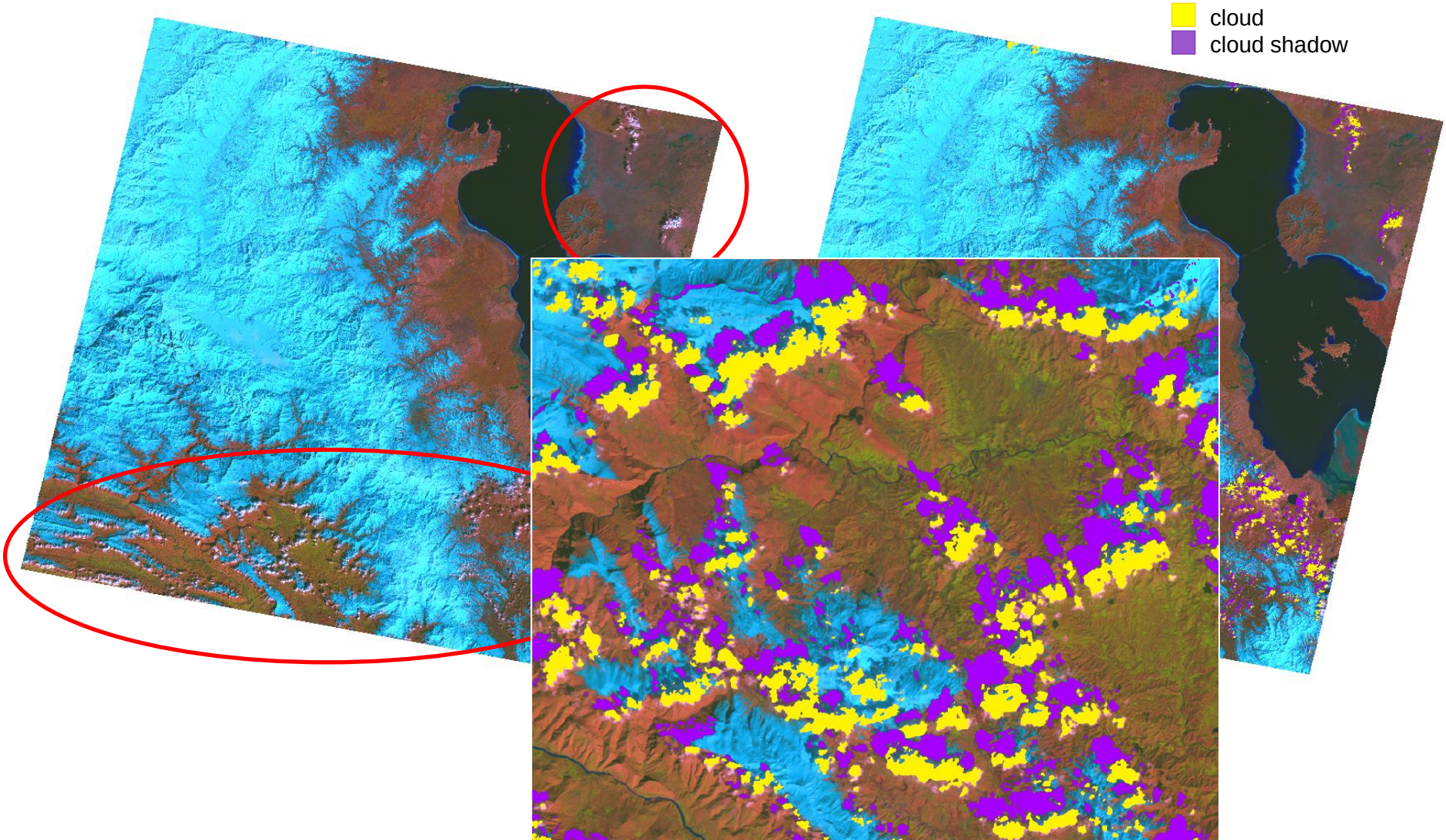


Cloud Screening ACCA.SEAS

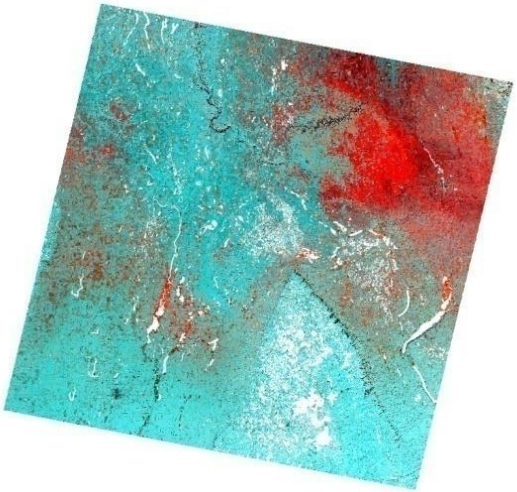
LS7 P169/R34 8 Mar 2003 over Turkey/Iran



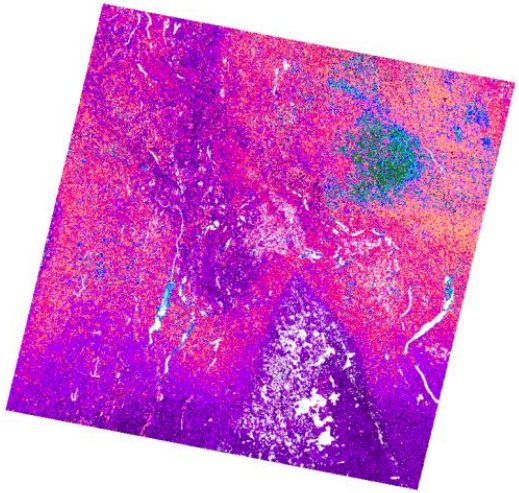
Snow algorithm intercomparison (flat/unforested)

LS7 P030/R028, 6 Feb 2003 North Dakota/US

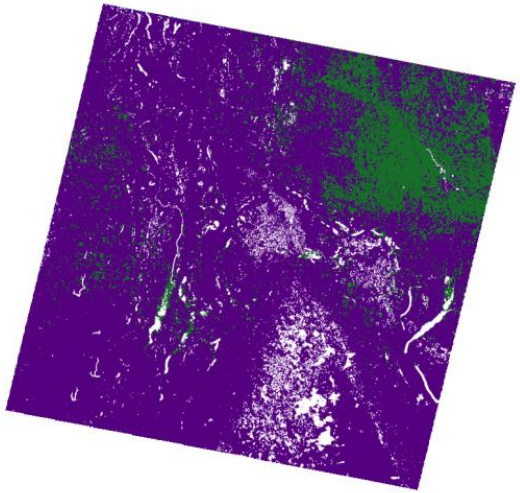
False color composite



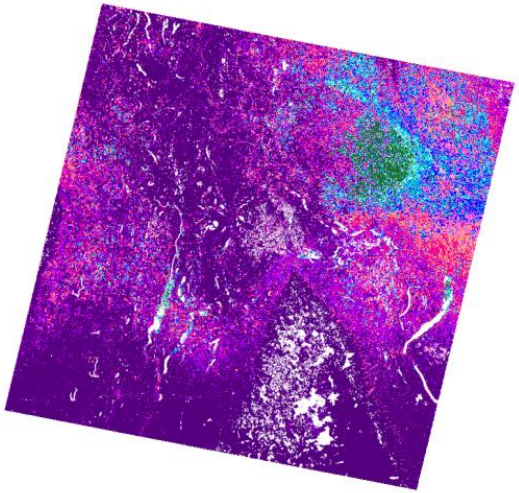
TMSCAG



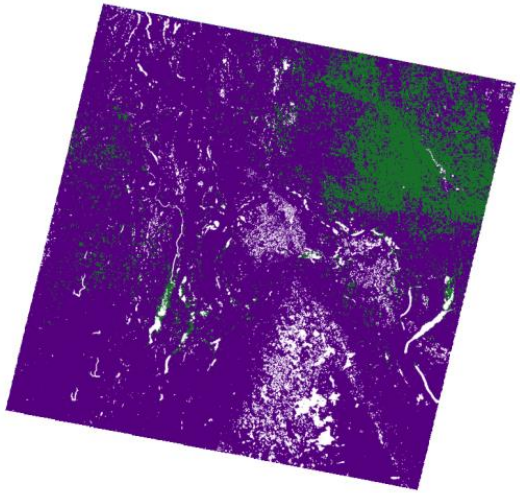
Dozier

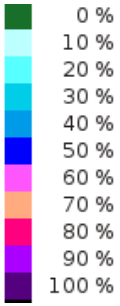


Salomonson



Klein

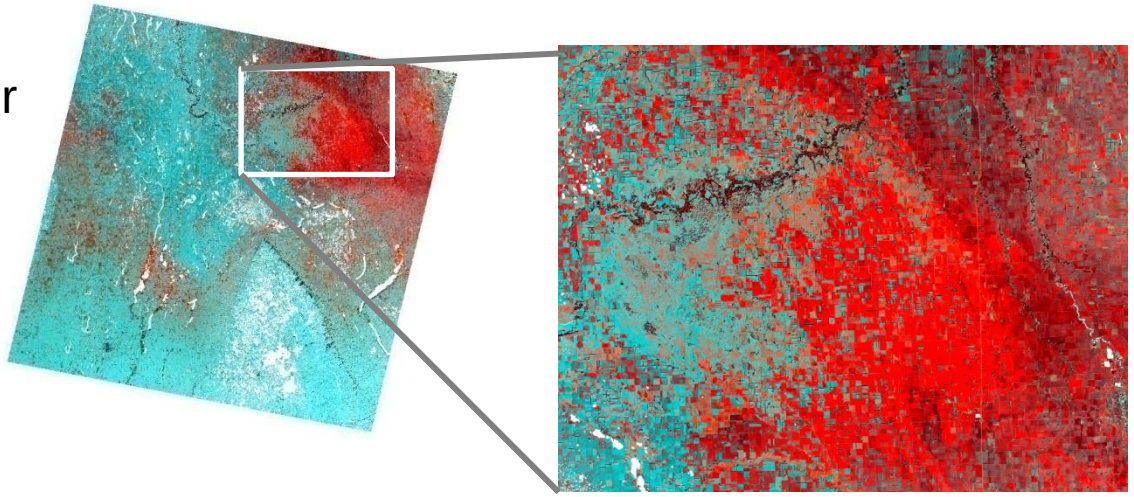


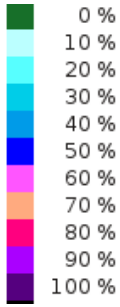


Snow algorithm intercomparison (flat/unforested)

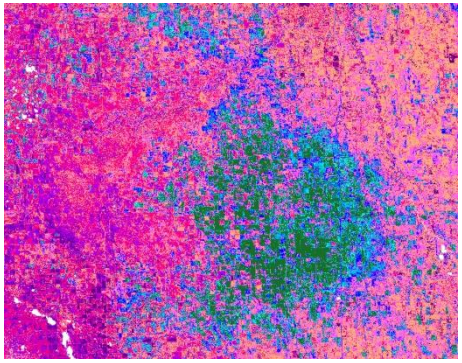
LS7 P030/R028 6 Feb 2003 North Dakota/US

False color composite

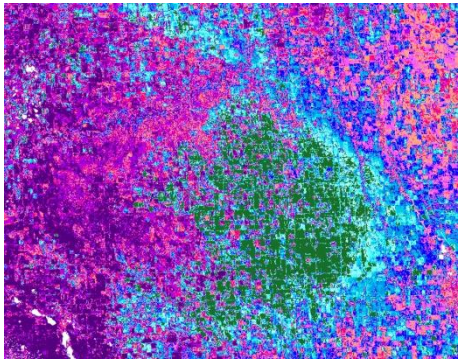




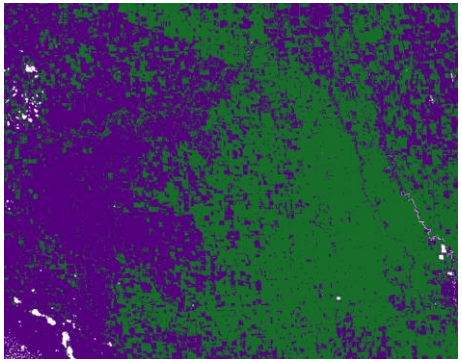
TMSCAG



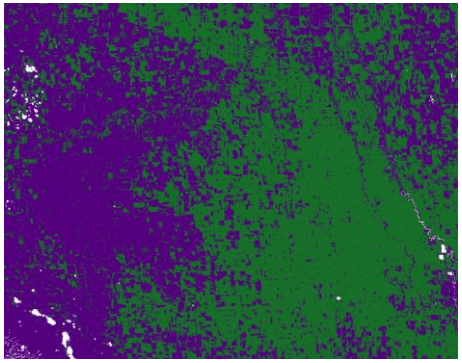
Salomonson



Dozier



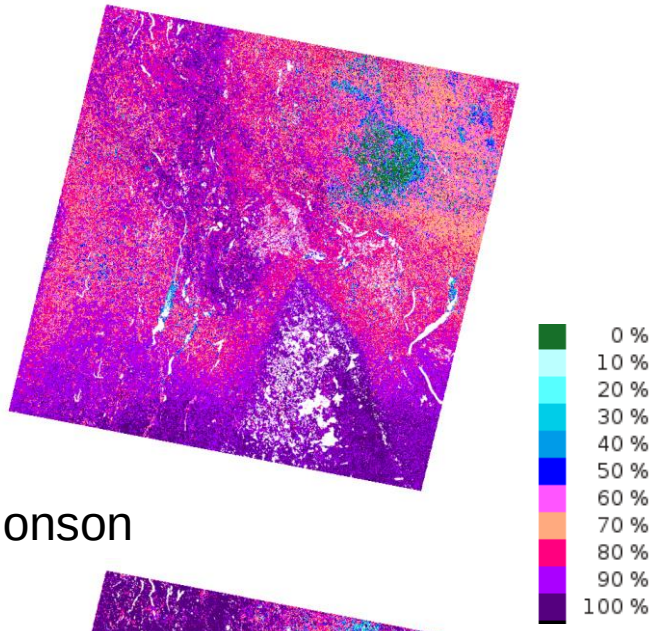
Klein



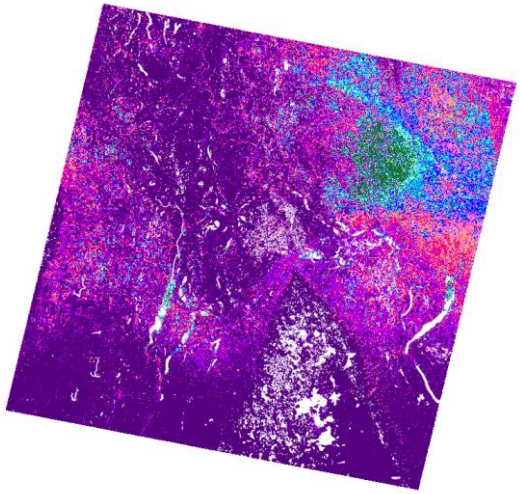
FSC snow algorithms intercomparison (f/uf)

LS7 P030/R028 6 Feb 2003, North Dakota/US

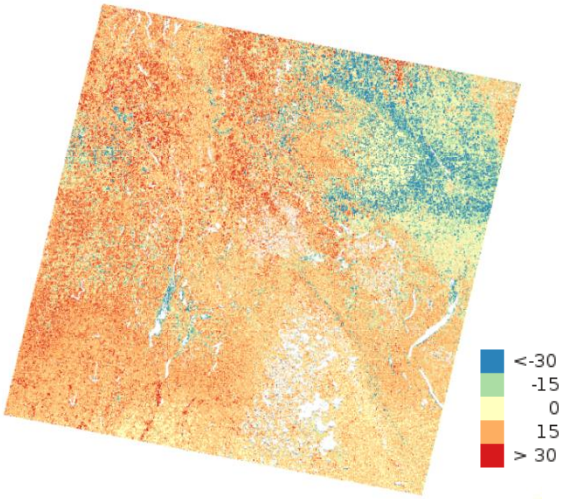
TMSCAG

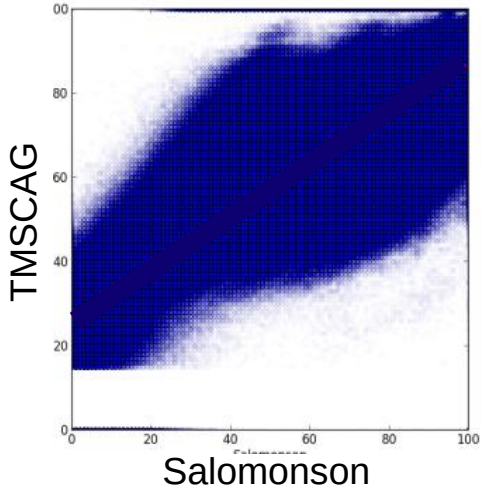


Salomonson



Difference Map: Salomonson vs. TMSCAG

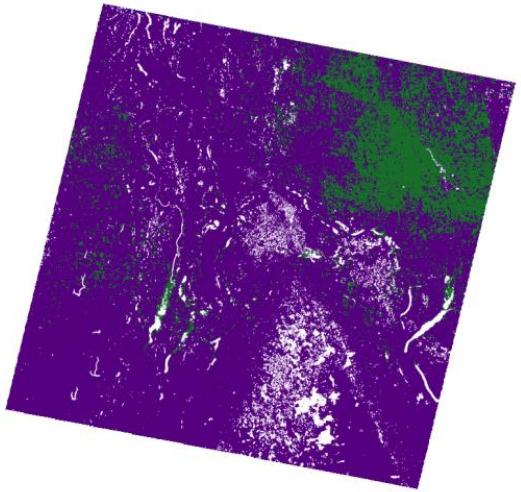




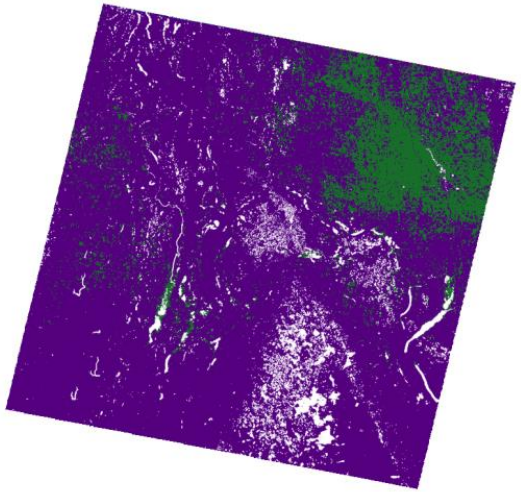
BIN snow algorithms intercomparison (f/uf)

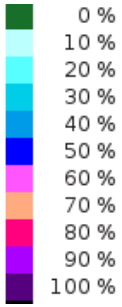
LS7 P030/R028 6 Feb 2003, North Dakota/US

Dozier

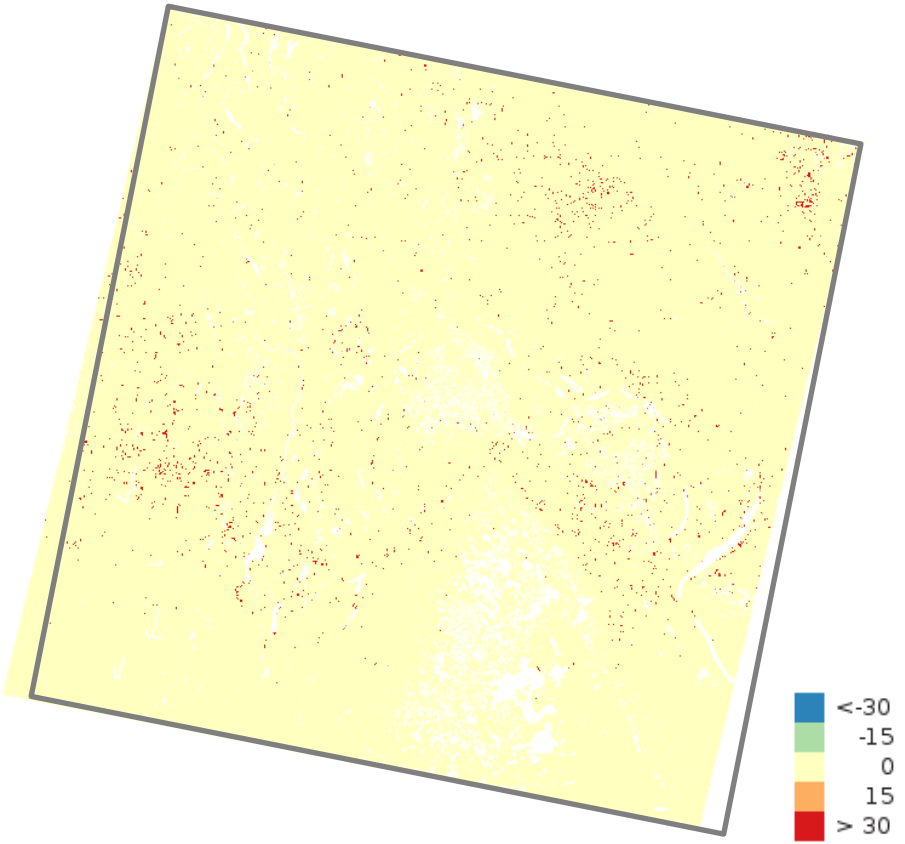


Klein





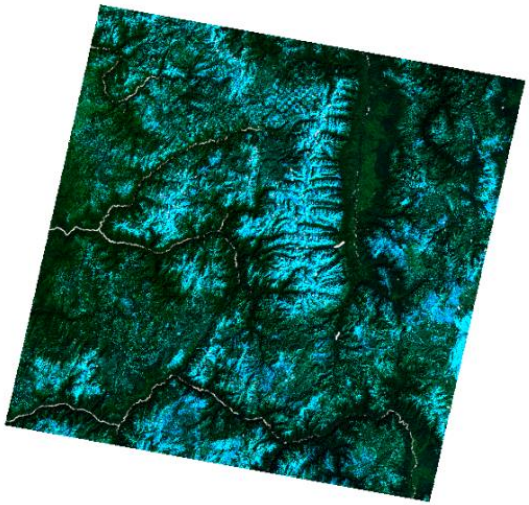
Difference Map
Dozier vs. Klein

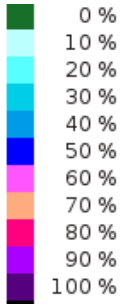


Snow algorithms intercomparison (forested mountains)

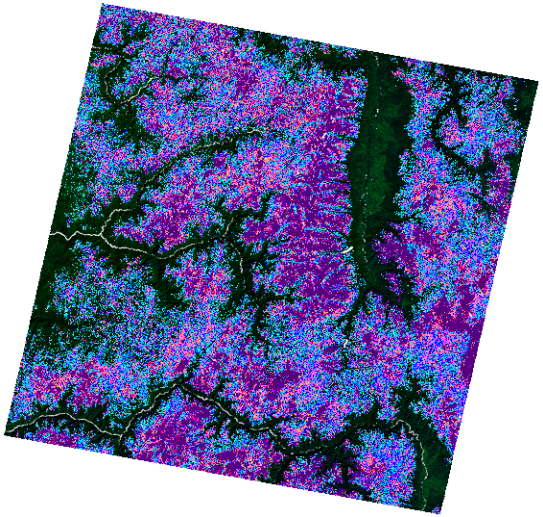
LS7 P041/R028, 8 Apr 2003 Idaho/US

RGB 5-4-3

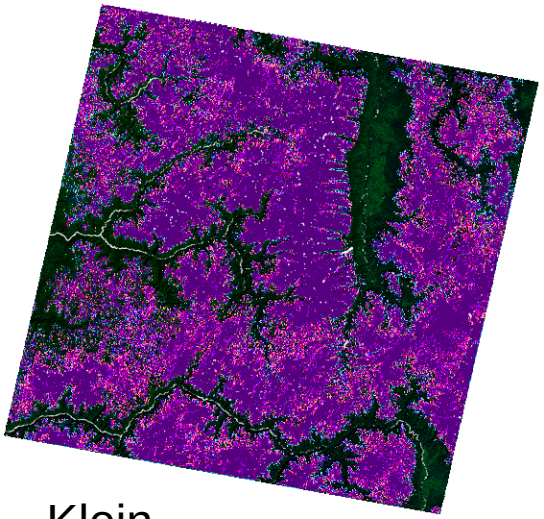




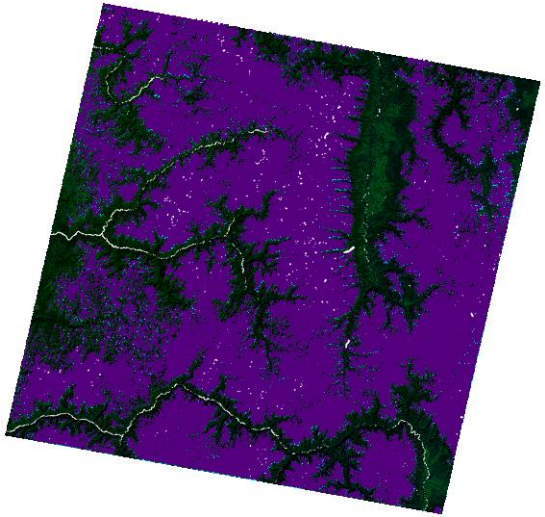
TMSCAG



Salomonson



Dozier



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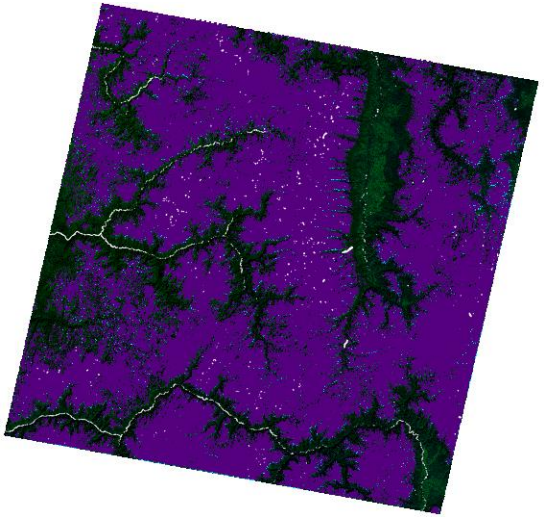
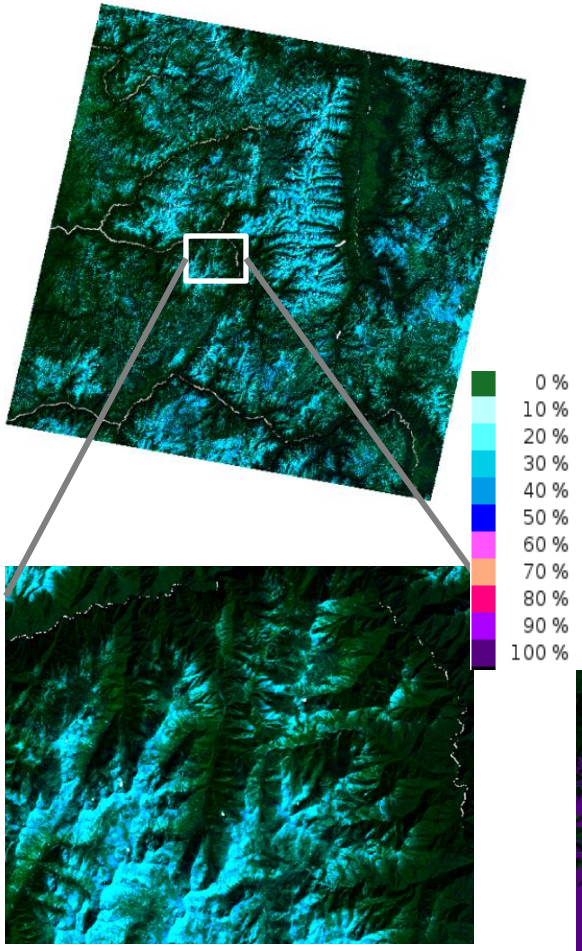


Snow algorithms intercomparison (forested mountains)

LS7 P041/R028, 8 Apr 2003 Idaho/US



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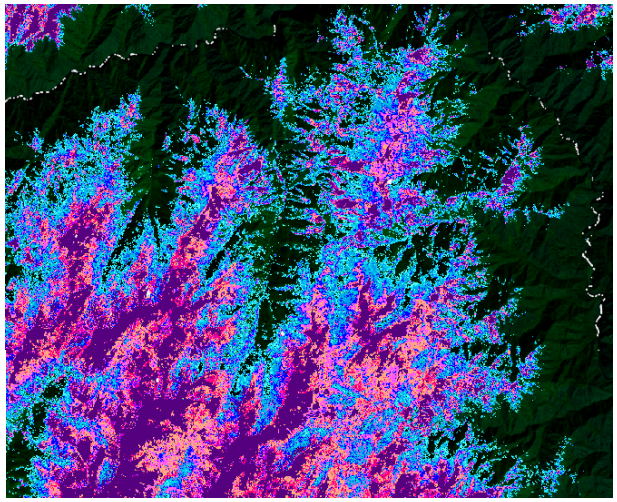
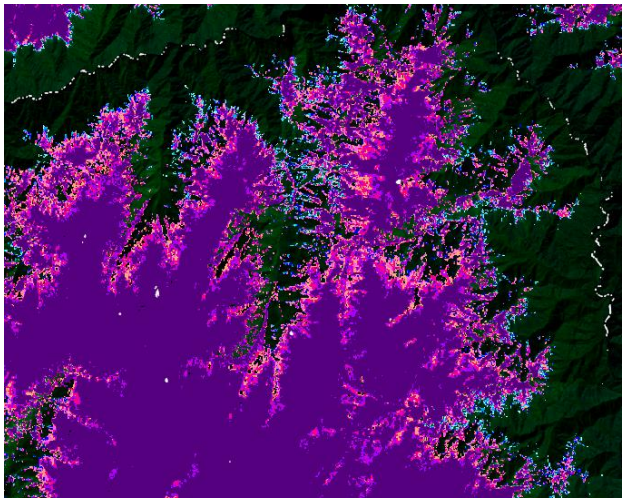
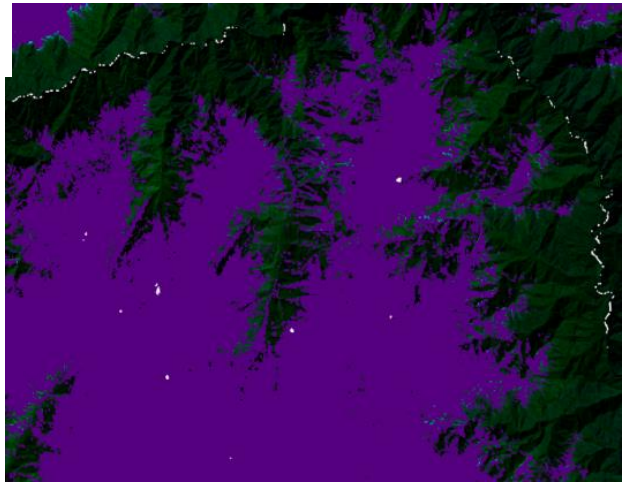


Salomonson



Dozier



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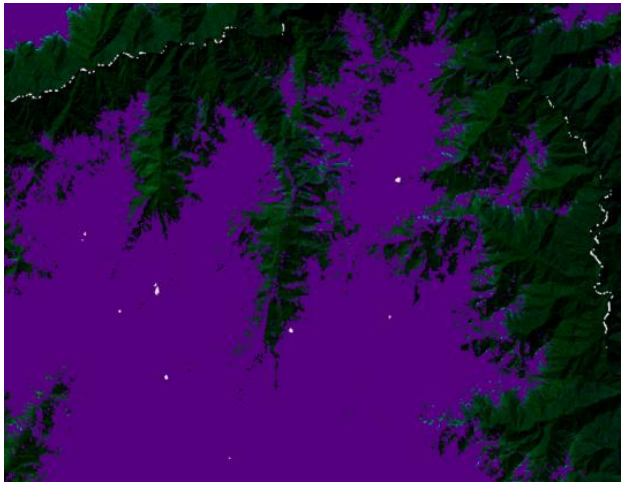
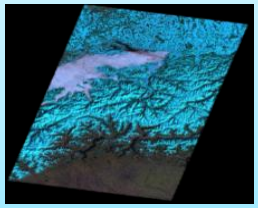
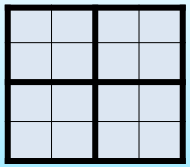


Validation Concept for SE Products

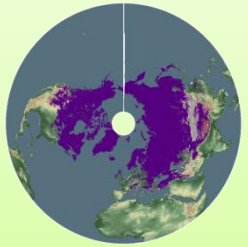
Landsat BIN or FSC HR snow maps in SE product projection





Aggregation to FSC at **original resolution & projection** of SE product

SE Products (original projection & resolution)

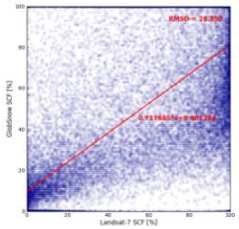


Exclude invalid areas:
no-data, clouds, open water

Separate validation for:
Different surface classes: **mountains, forest**
LS FSC range: **0-25 %, 26-50 %, 51-75%,76-100%**

Fractional & Binary SE Products

- Pixel by Pixel
- Number of snow pixels
- RMSE, Bias, Correlation Coefficient
- Fraction of total SE
- Scatterplot

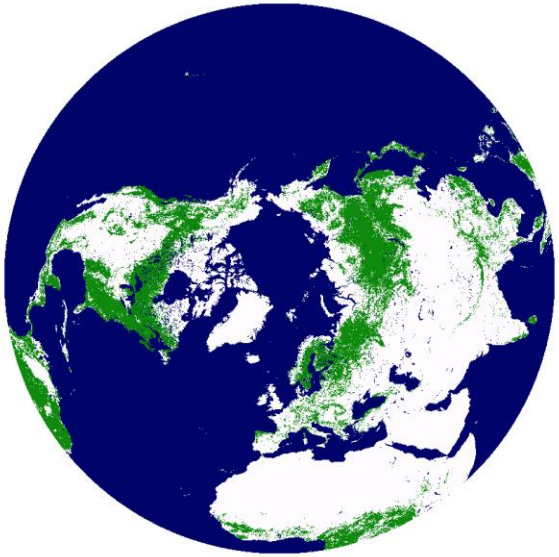


Binary SE Products

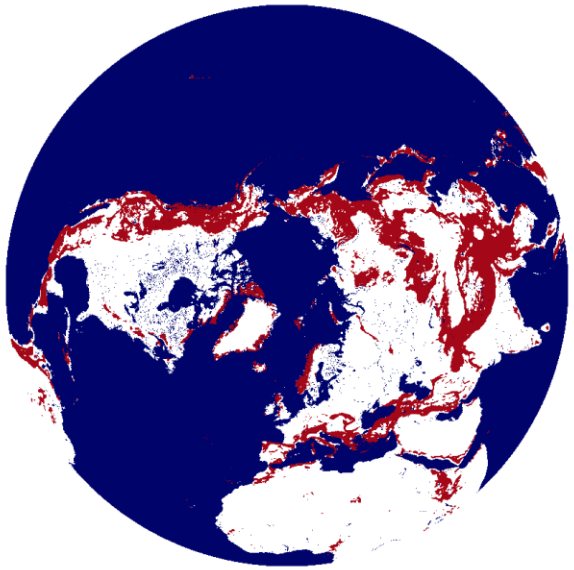
- for Landsat fsc to bin: **≥0.15, ≥0.25, ≥0.50**
- Validation metrics:
  - Precision
  - Recall
  - Accuracy
  - F factor

Surface Classes for Validation

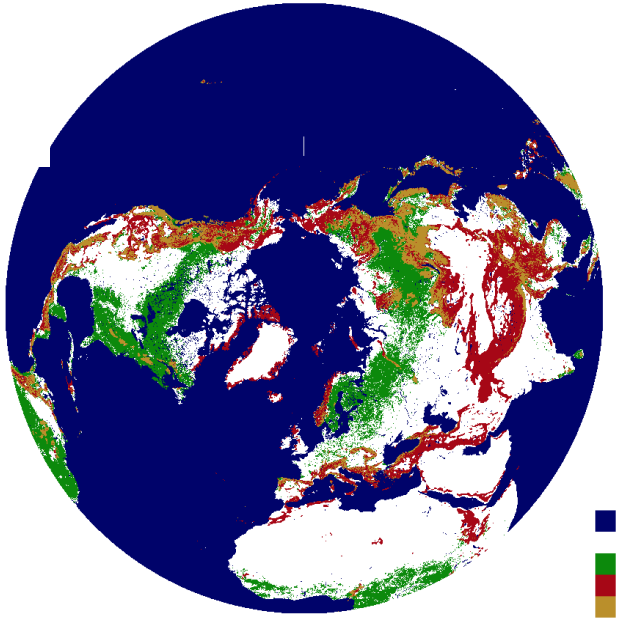
Forest Mask from GlobCover V2.3



Mountain mask (slope >2°) from GETASSE30



SnowPEx Validation Mask



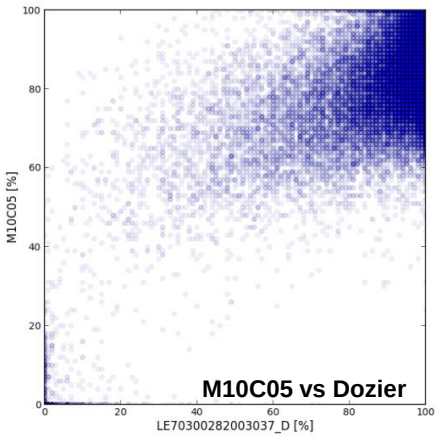
Validation Results

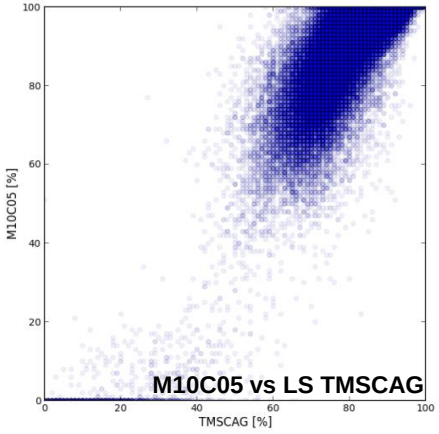
LS validation of fractional & binary SE products

6 Feb 2003 LS7 SLCon P030/R028, North Dakota/US (flat/unforested)

SE PRODUCT	NUI	LS ALG	CORR COEFF	BIAS	Unbiased RMSE	Max-Min RMSE
CRCLIM 5 km	1320	D	0,10	-14,01	23,50	11,29
		K	0,10	-13,23	23,32	
		S	0,11	-17,19	18,67	
	1312	T	0,12	-23,35	12,21	
JXAM5 5 km	1163	D	0,49	-5,00	10,41	0,9
		K	0,51	-4,31	9,90	
		S	0,39	-9,37	10,59	
	928	T	0,27	-18,52	9,69	
JXM10 5 km	1033	D	0,73	-4,74	9,83	0,49
		K	0,74	-4,07	9,52	
		S	0,69	-9,34	9,84	
	814	T	0,67	-18,84	9,35	
M10C05 500 m	120111	D	0,79	5,19	8,88	3,28
		K	0,78	5,80	8,78	
		S	0,91	0,06	5,60	
	95193	T	0,86	-9,64	7,14	

D...Dozier K…Klein
S…Salomonson T…TMSCAG





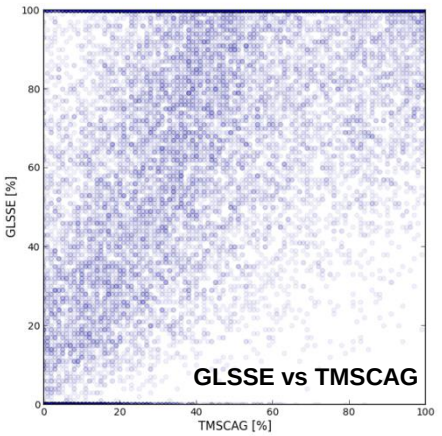
Validation Results

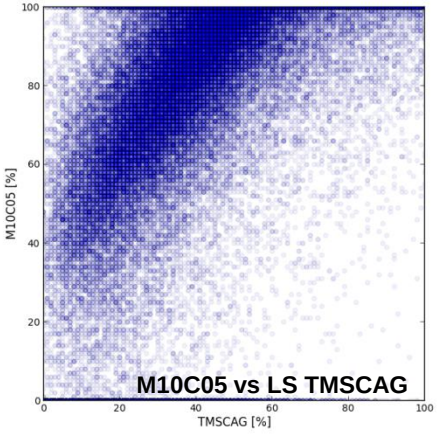
LS validation of fractional & binary SE products

8 Apr 2003 LS7 SLCon P041/R028, Idaho/US (forested mountains)

SE PRODUCT	NUI	LS ALG	CORR COEFF	BIAS	Unbiased RMSE	Max-Min RMSE
GLSSE 1km	31936	D	0,85	-1,09	22,19	6,21
		K	0,85	0,42	22,12	
		S	0,84	-5,57	22,62	
	31320	T	0,71	-25,23	28,40	
JXAM5 5 km	1561	D	0,71	10,93	35,12	2,08
		K	0,71	13,11	35,48	
		S	0,73	6,81	34,49	
	1558	T	0,71	-11,84	36,57	
JXM10 5 km	1552	D	0,75	10,74	33,27	3,06
		K	0,73	12,91	34,28	
		S	0,75	6,60	33,35	
	1549	T	0,72	-12,12	36,33	
M10C05 500 m	155576	D	0,92	2,20	16,97	8,45
		K	0,91	4,34	18,18	
		S	0,92	-1,94	17,17	
	151448	T	0,82	-21,35	25,42	
PATHF 5 km	1339	D	0,23	50,60	38,26	8,05
		K	0,22	52,76	37,35	
		S	0,24	46,46	36,33	
	1334	T	0,29	27,84	30,21	

D...Dozier K…Klein
S…Salomonson T…TMSCAG





Validation Results

LS validation of binary SE products

Transforming LS fractional to binary snow extent: Thresholds >=15%, 25%, 50%

27 May 2007 LS5 132/010 over North-East Russia

LS binary (≥15%) intercomparison

SE PRODUCT	LS ALG	Precision	Recall	Accuracy	F-factor
CRCLIM 5 km	D	0,83	0,97	0,87	0,90
	K	0,84	0,97	0,87	0,90
	S	0,93	0,94	0,91	0,93
IMS 4 km	D	0,95	0,76	0,83	0,84
	K	0,95	0,75	0,83	0,84
	S	0,97	0,68	0,77	0,80
JXAM5 5 km	D	0,91	0,88	0,87	0,89
	K	0,91	0,88	0,87	0,89
	S	0,97	0,82	0,86	0,89
JXM10 5 km	D	0,96	0,87	0,90	0,91
	K	0,96	0,86	0,90	0,91
	S	0,98	0,80	0,85	0,88

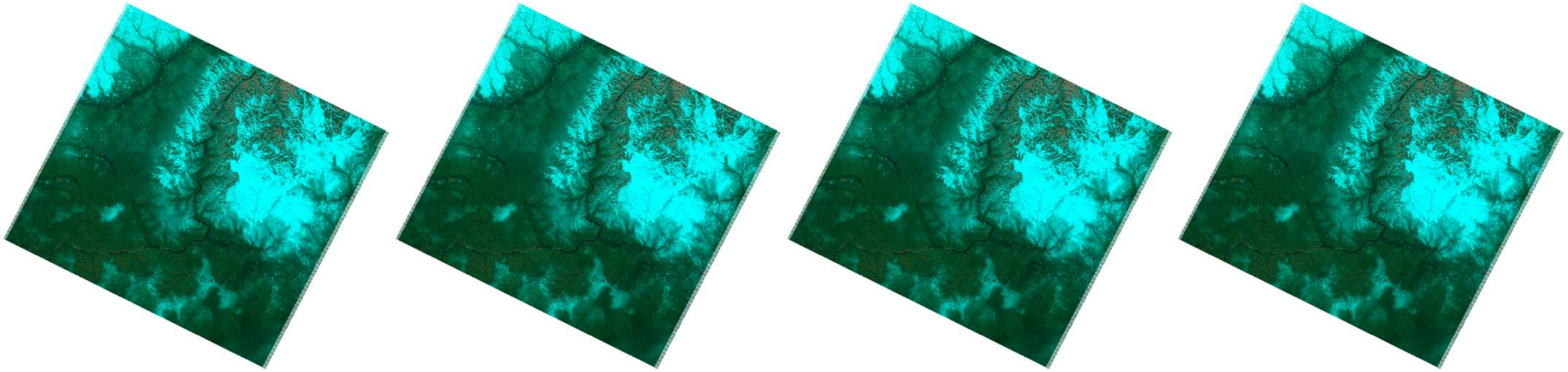
LS binary (≥ 50%) intercomparison

SE PRODUCT	LS ALG	Precision	Recall	Accuracy	F-factor
CRCLIM 5 km	D	0,57	0,99	0,70	0,72
	K	0,58	0,99	0,70	0,73
	S	0,60	0,99	0,72	0,75
IMS 4 km	D	0,74	0,90	0,84	0,82
	K	0,75	0,90	0,84	0,82
	S	0,78	0,90	0,85	0,84
JXAM5 5 km	D	0,67	0,98	0,80	0,79
	K	0,67	0,98	0,80	0,80
	S	0,69	0,98	0,81	0,81
JXM10 5 km	D	0,79	0,97	0,87	0,87
	K	0,79	0,97	0,87	0,87
	S	0,82	0,97	0,89	0,88

Validation Results

27 May 2007 LS5 132/010, North-East Russia

LS composite RGB 5-4-3 30 m

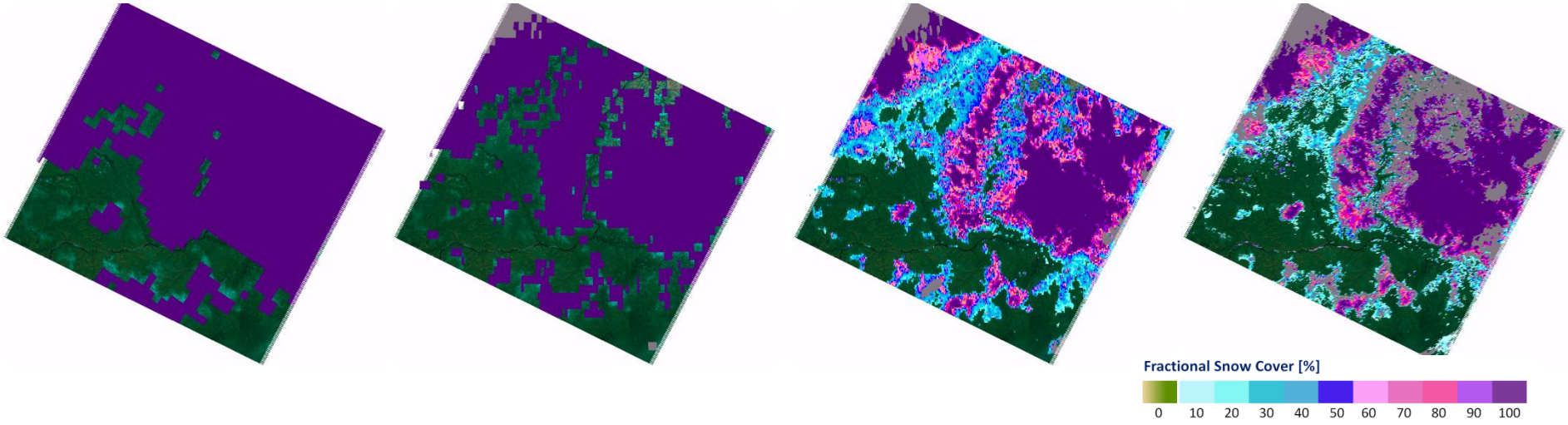


CRCLIM
5 km

JXAM5
5 km

GLSSE
1 km

M10C05
500m

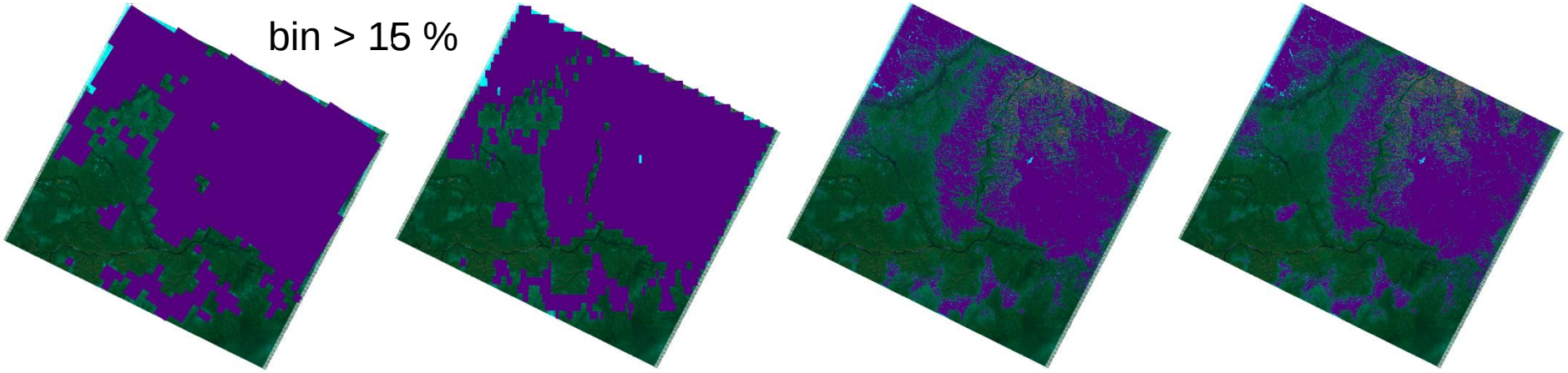


Validation Results

27 May 2007 LS5 132/010, North-East Russia

LS Klein Allg 30 m

bin > 15 %

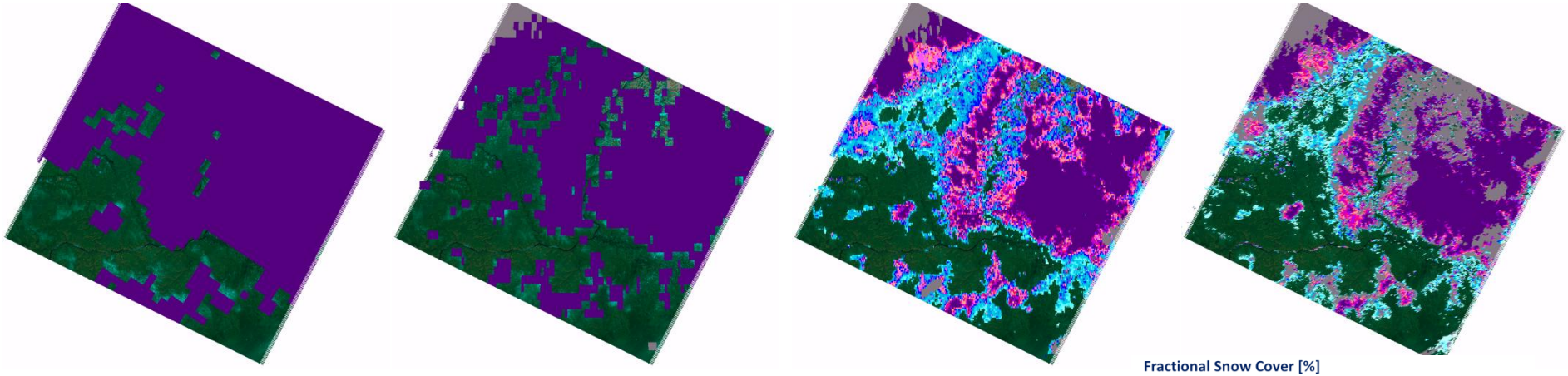


CRCLIM
5 km

JXAM5
5 km

GLSSE
1 km

M10C05
500m

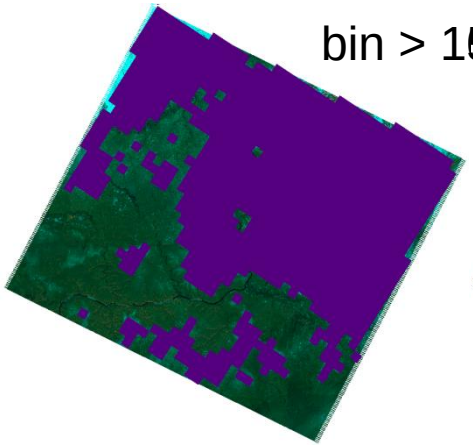


Validation Results

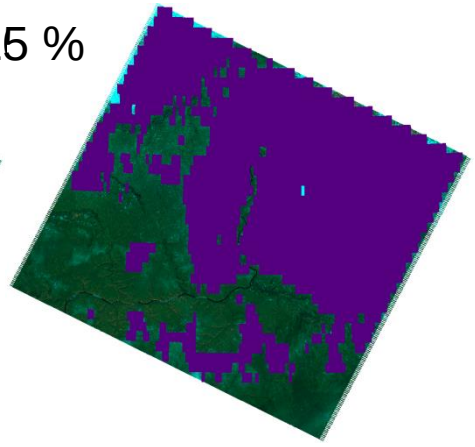
27 May 2007 LS5 132/010, North-East Russia

5 km EASE2

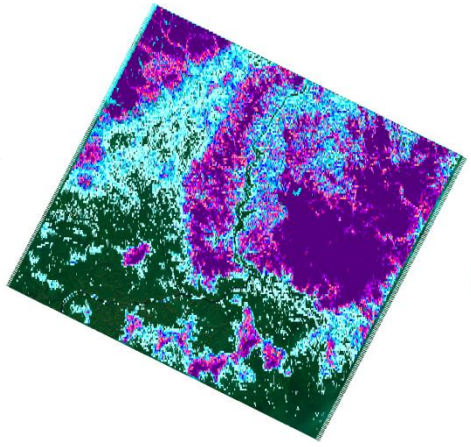
bin > 15 %



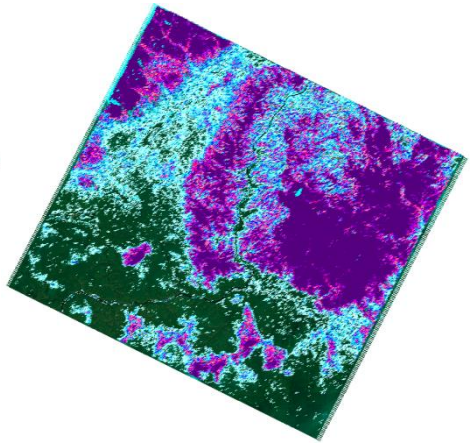
5 km LatLon



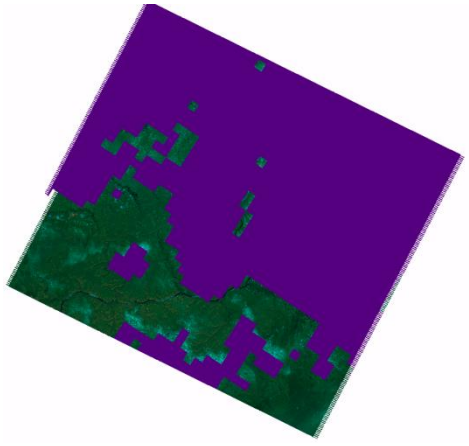
1 km LatLon



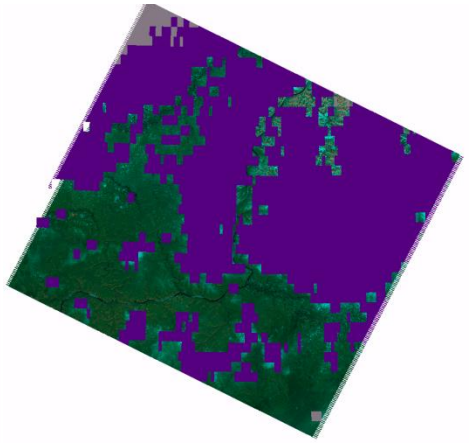
500 m Sin



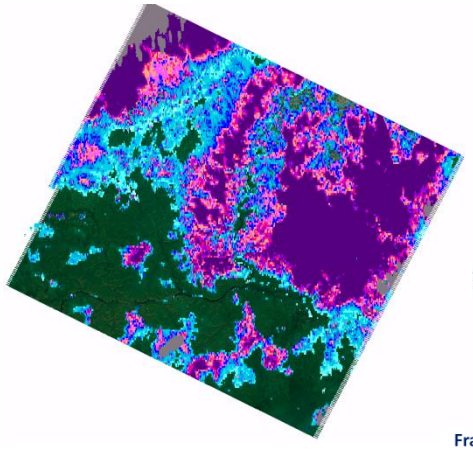
CRCLIM
5 km



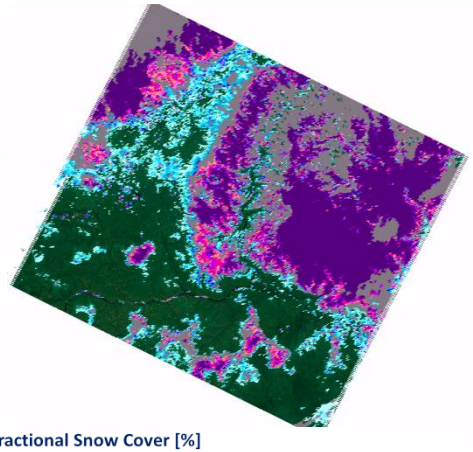
JXAM5
5 km

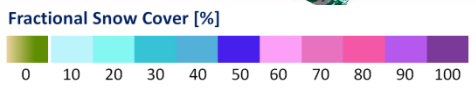


GLSSE
1 km



M10C05
500m





Next steps and discussion points

<u>To be discussed in Splinter Sessions:</u>

- Refinement of validation protocol
    - Use of 4 Landsat snow classifications for validation

- SCF threshold for all binary snow products required for validation (information on product provider)

<u>Next steps:</u>

- Completion of Landsat reference data set

- Perform validation of all products with all Landsat reference data