Probabilistic approach to cloud and snow detection on satellite imagery

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Overview on classification approaches

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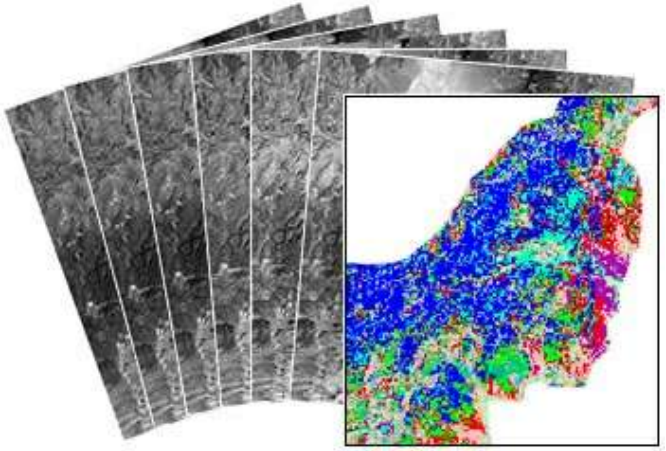
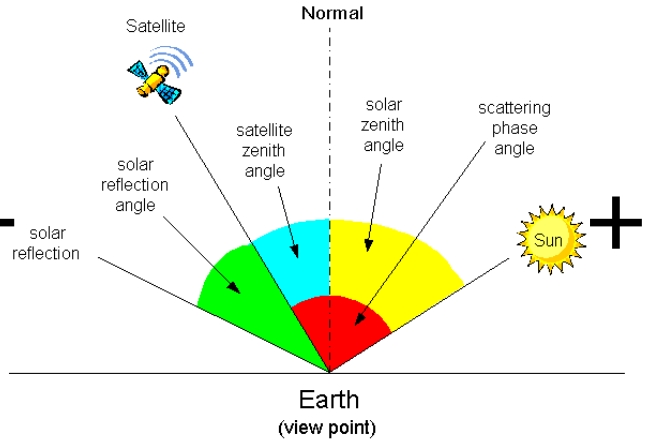
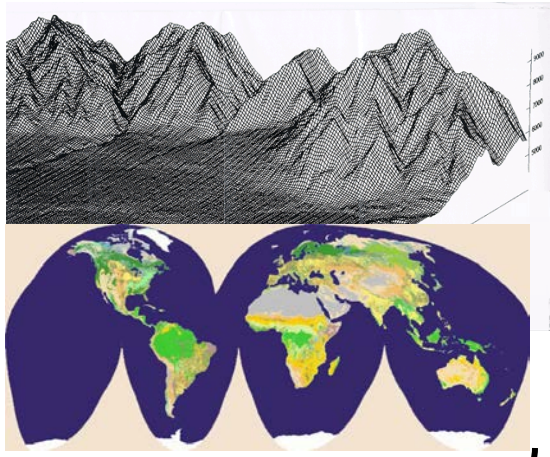
Multispectral imagery



Acquisition angles



Ancillary data



- Decision-tree analysis
- Bayesian classifiers
- Neural networks
- Support Vector Machines (SVMs)
- Expectation Maximization (EM)
- variety of clustering methods…….

Decision-tree classification

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tresholds: >0.2 >0.1 SKT – B11>10K

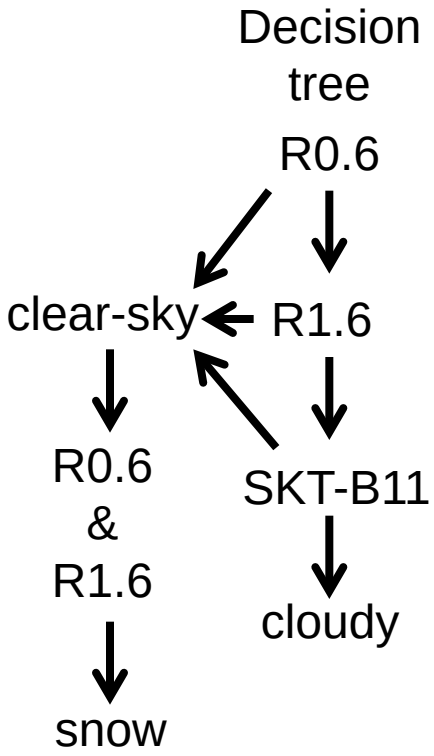
LAT	LON	R0.6	R1.6	B11	SKT	
4.5	34.5	0.04	0.01	268	270	confident clear
5.7	36.7	0.42	0.05	270	271	probably clear (snow)
6.2	39.2	0.10	0.04	260	275	probably clear
6.7	40.2	0.80	0.2	270	265	probably cloudy
7.3	44.8	0.20	0.11	272	277	probably clear
8.3	50.6	0.08	0.02	280	291	probably clear
10.2	55.2	0.12	0.11	275	272	confident clear
20.0	58.0	0.89	0.6	256	276	confident cloudy
……	……	……	……	……	……	

R0.6 – reflectance 0.6 um

R1.6 – reflectance 1.6 um

B11 – brightness temperature 11 um [K]

SKT – Skin Surface Temperature [K]



Why not to use all information at once?

Probabilistic Cloud Mask (PCM) approach

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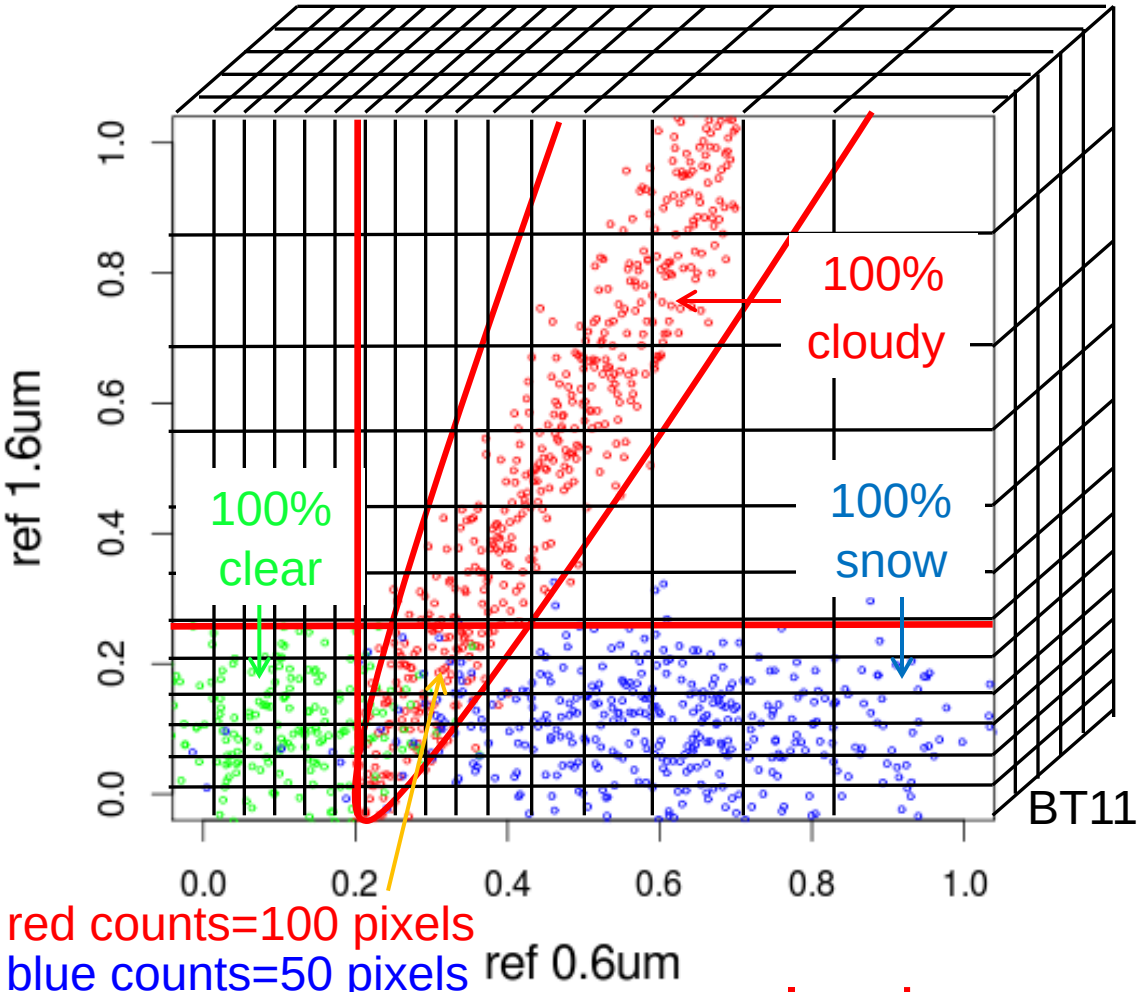

PCM's bins have 8 dimensions:

- Land cover/use
- Day time: day,twilight,night
- 3 x spectral features
- texture feature
- view angle & azimuth sectors

Each dimension is divided by several thresholds or categories which gives >60 mln possibilities.

Algorithm is trained against PPS cloud mask and MOD10A1 snow mask.

Features are localized within the array by the nearest neighbor technique.

All information is used in a single step to extract probabilities from LUTs.

Invariant Coordinate System (ICS) transformation

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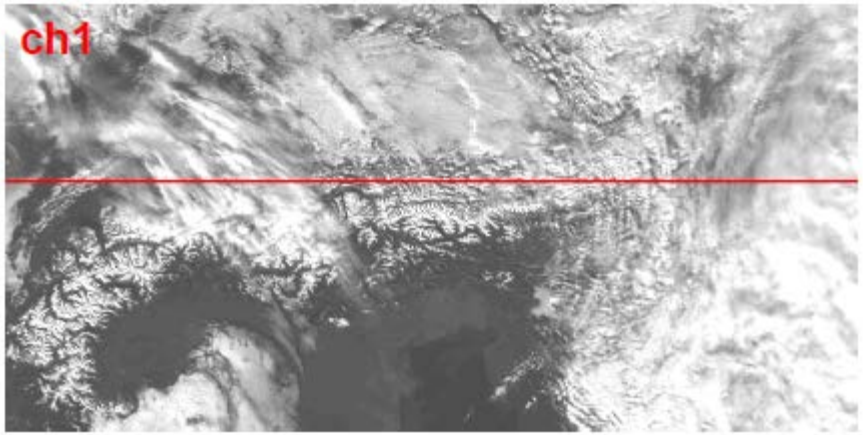
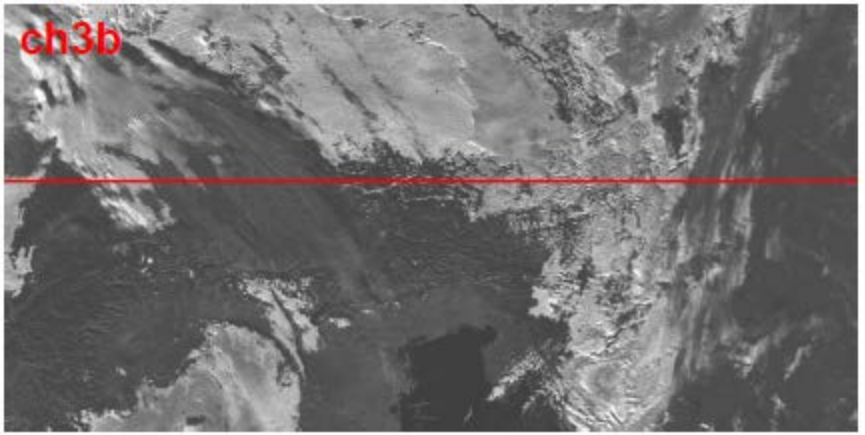
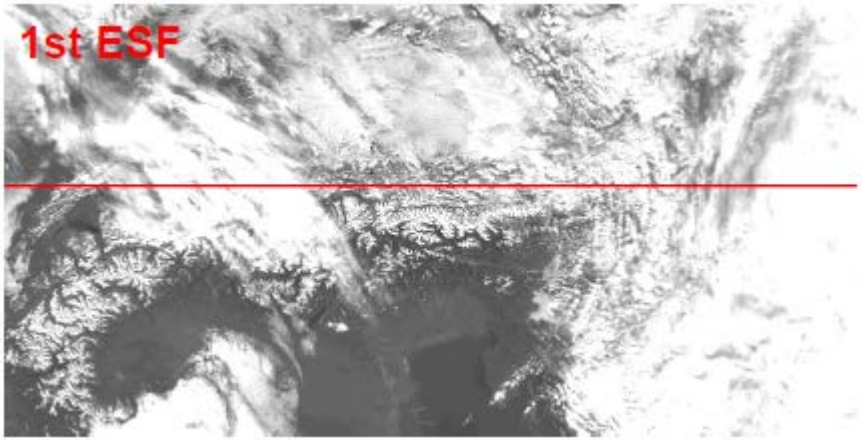
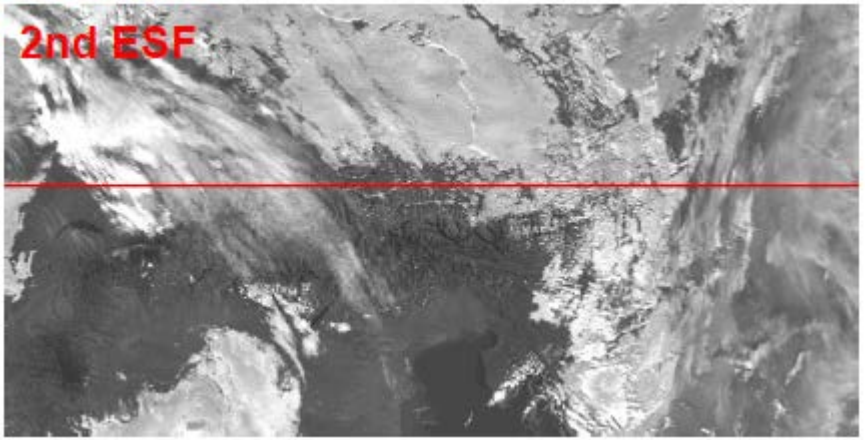
ICS is based on Principal Component Analysis and gives stable decomposition regardless the distribution mean. It is used to reduce the dimensionality of array.





combined with SKT-T11





Example of the PCM classification

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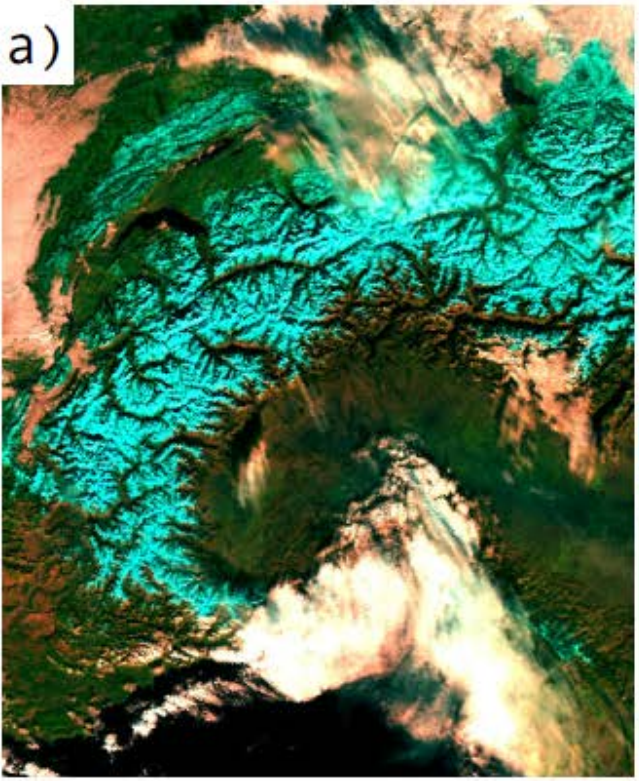
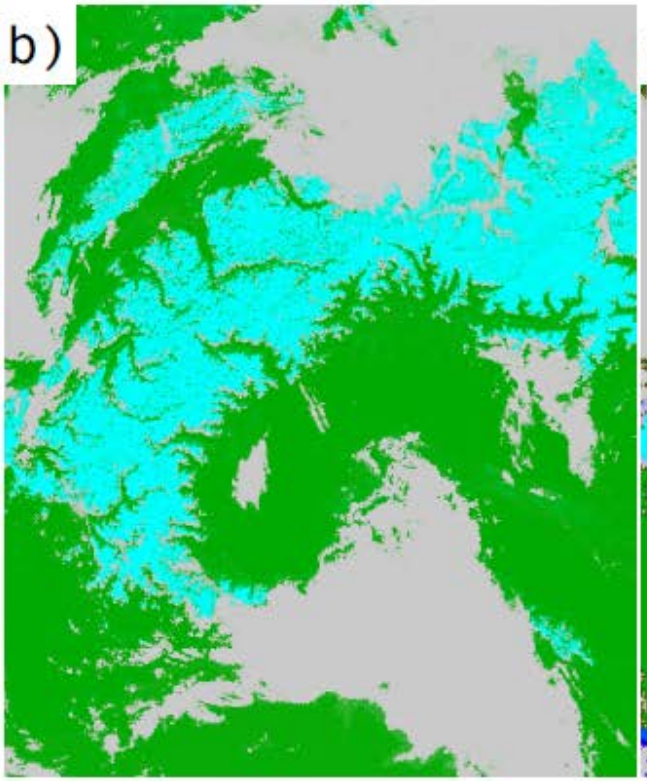
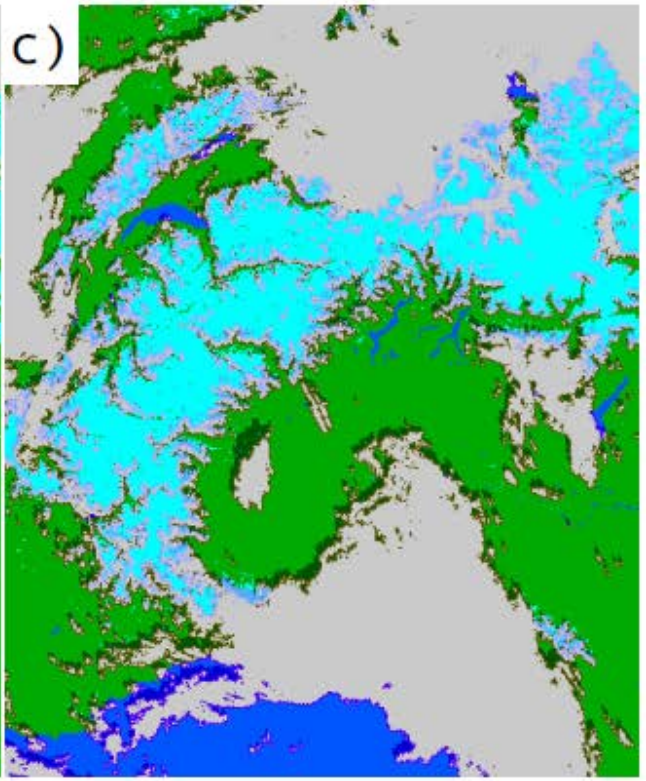
R:1.6 um,G:0.8 um,B:0.6 um



Probability clear/snow/cloud



Combined binary product with cloud shadow and land/water



Mean annual total cloud cover composites during the day from NOAA18

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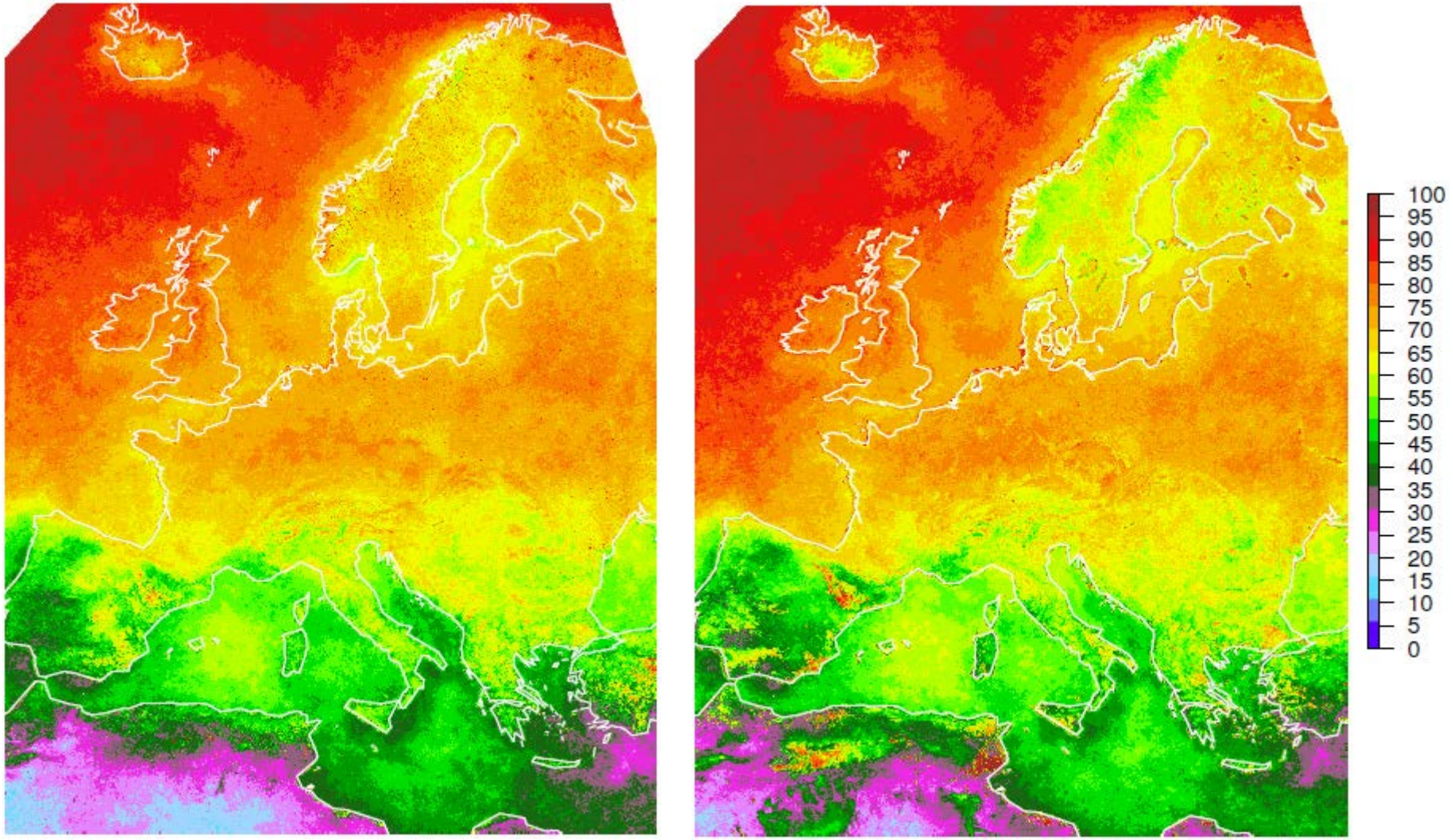
PCM

PPS



Mean annual total cloud cover composites during the night from NOAA18

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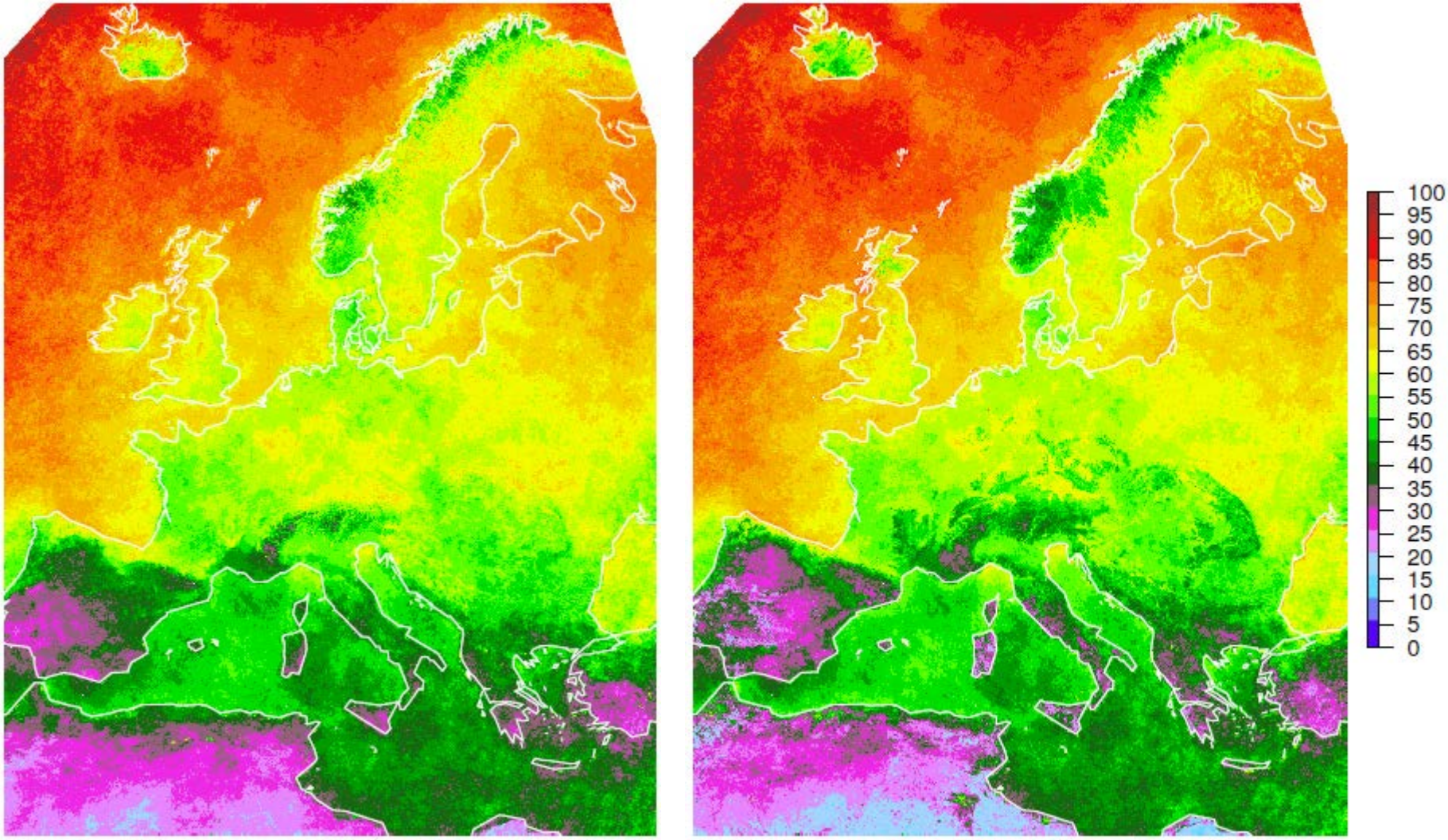
PCM

PPS



Total cloud cover PCM vs PPS/MODIS

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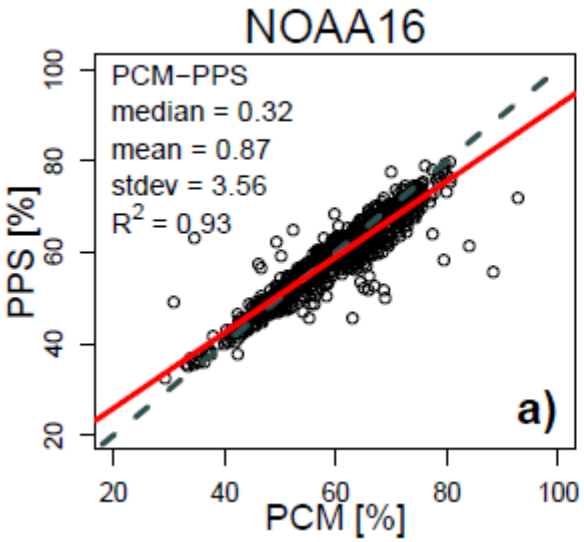

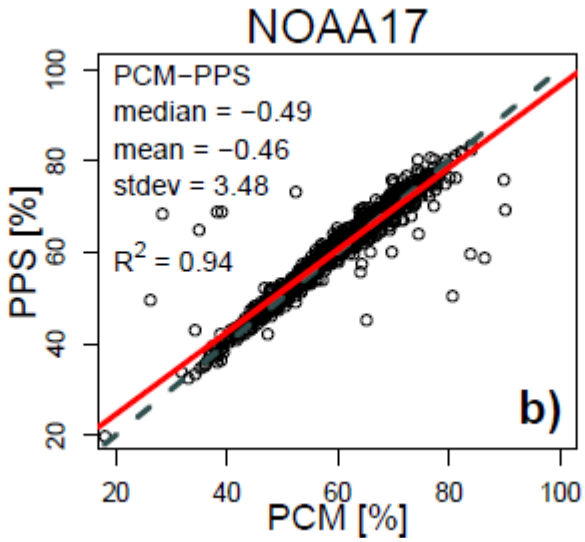

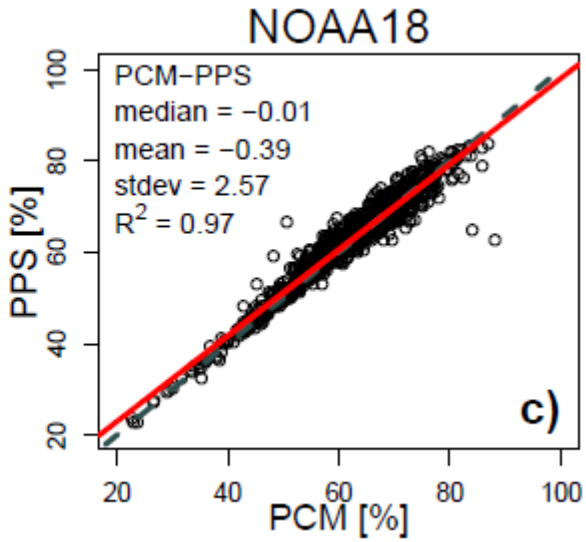

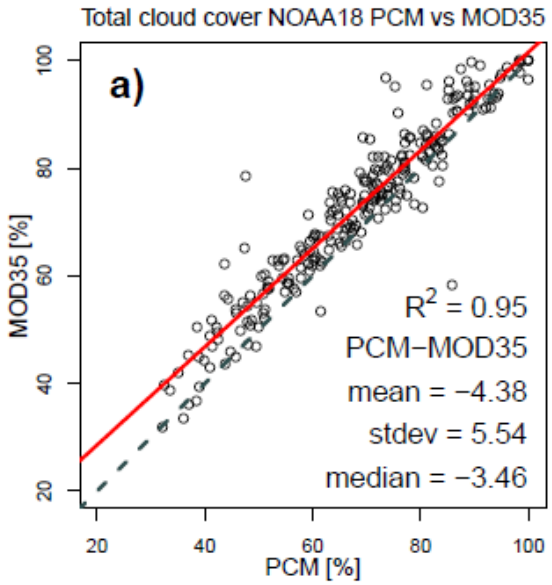

Annual mean probability distribution as a function of SYNOP cloud amount

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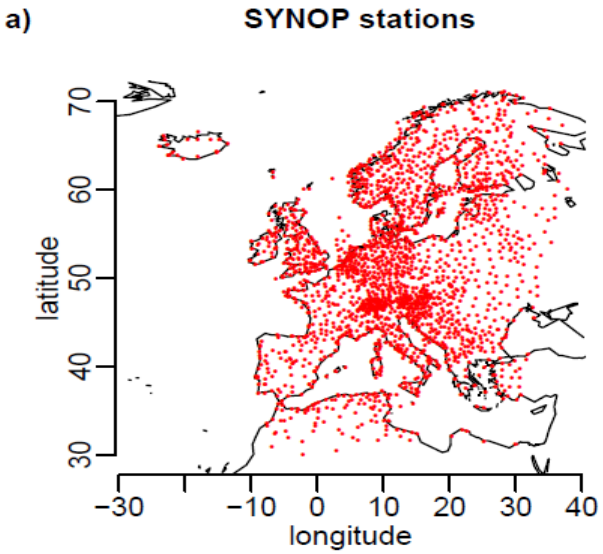

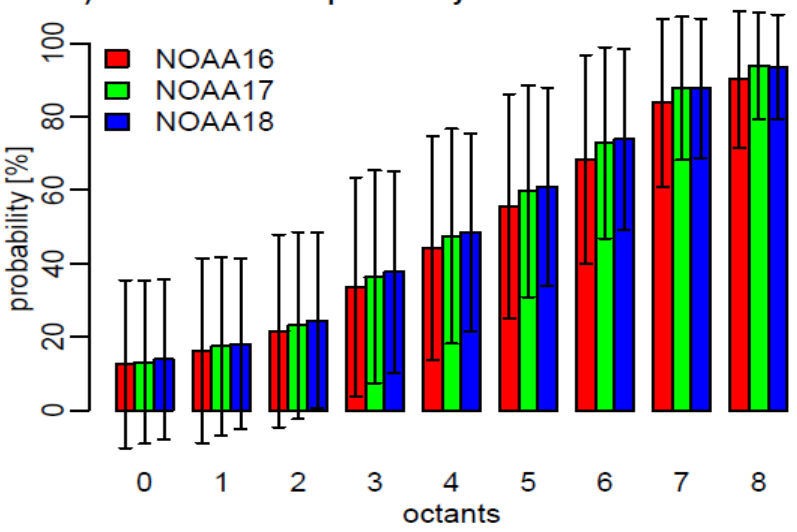

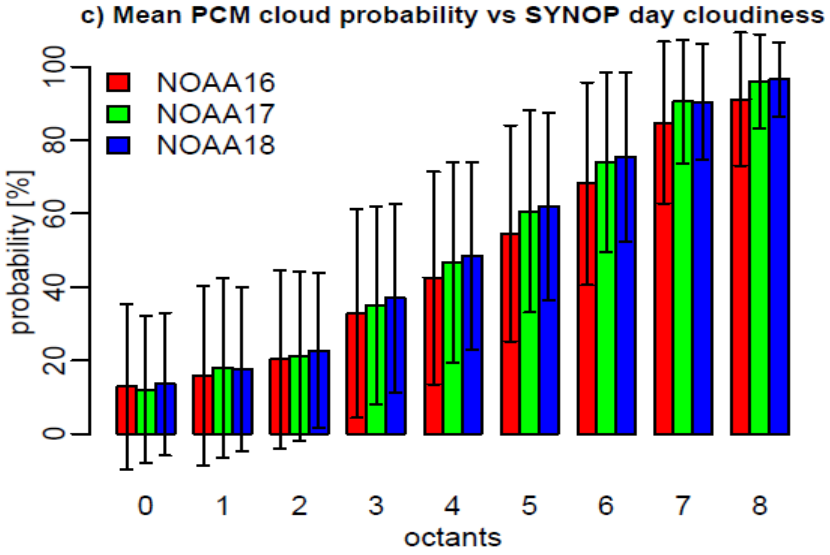

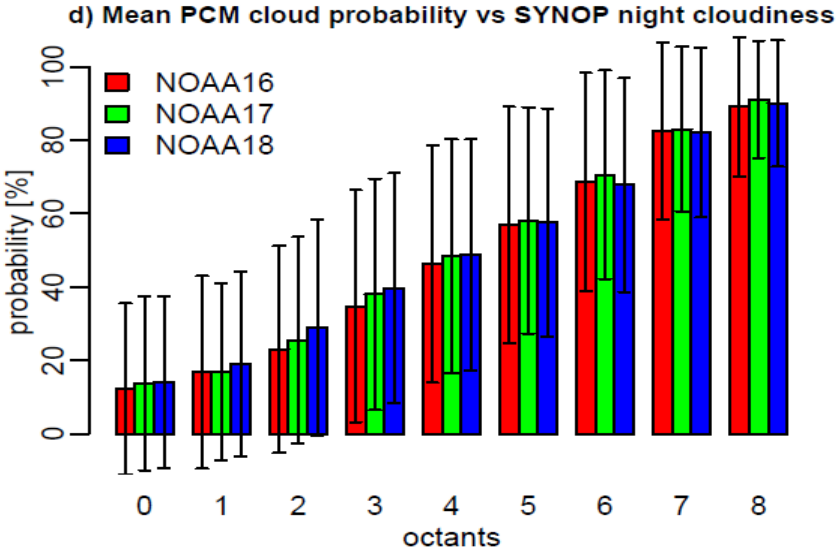

Validation PCM & PPS against SYNOP

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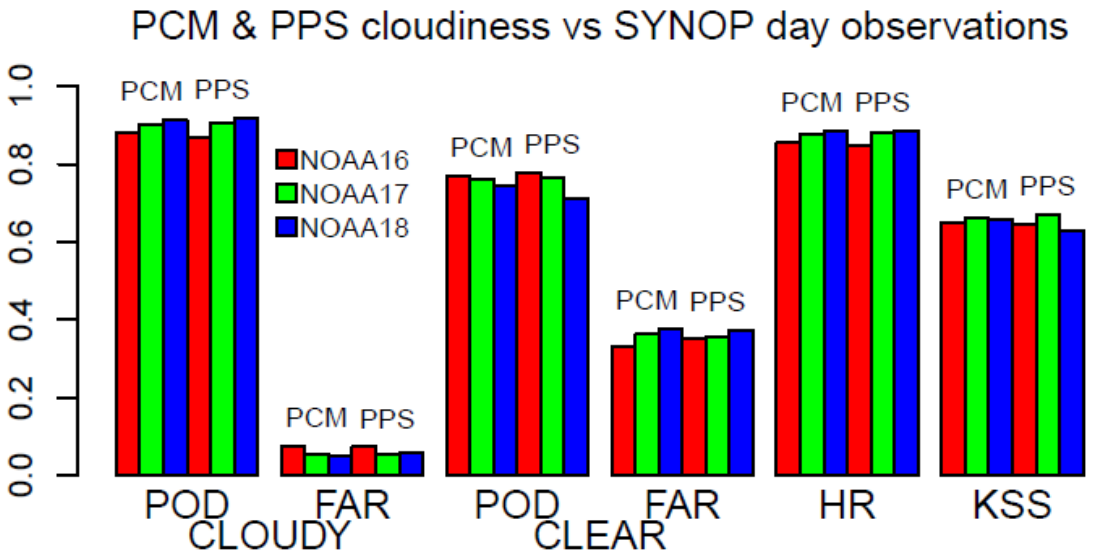
Quality indicators:

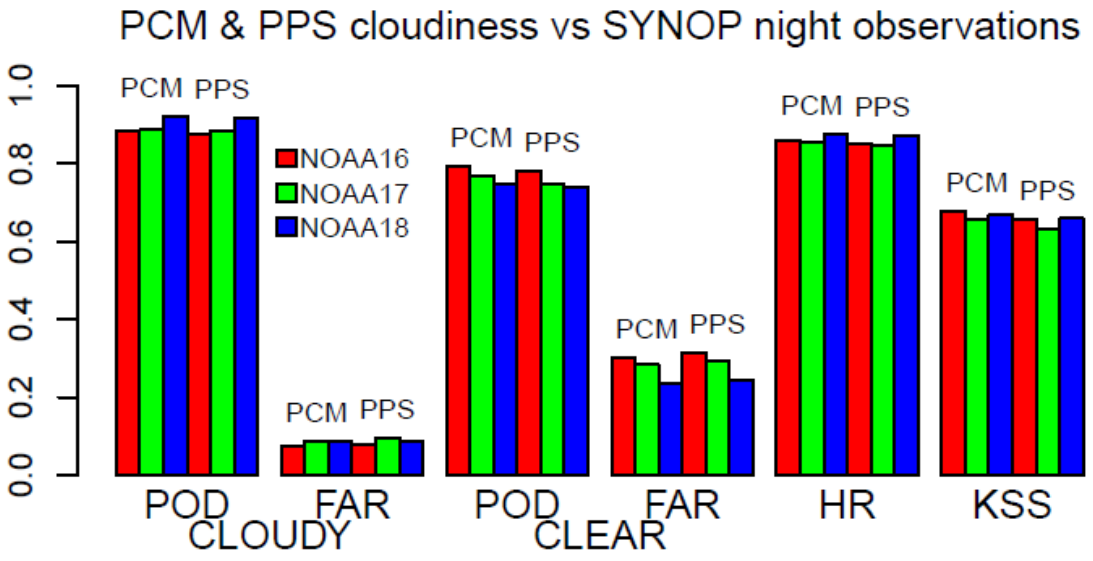
POD – Probability Of Detection

FAR – False Alarm Rate

HR – Hit Rate

KSS – Kuiper Skill Score





Validation PCM & PPS against CALIPSO

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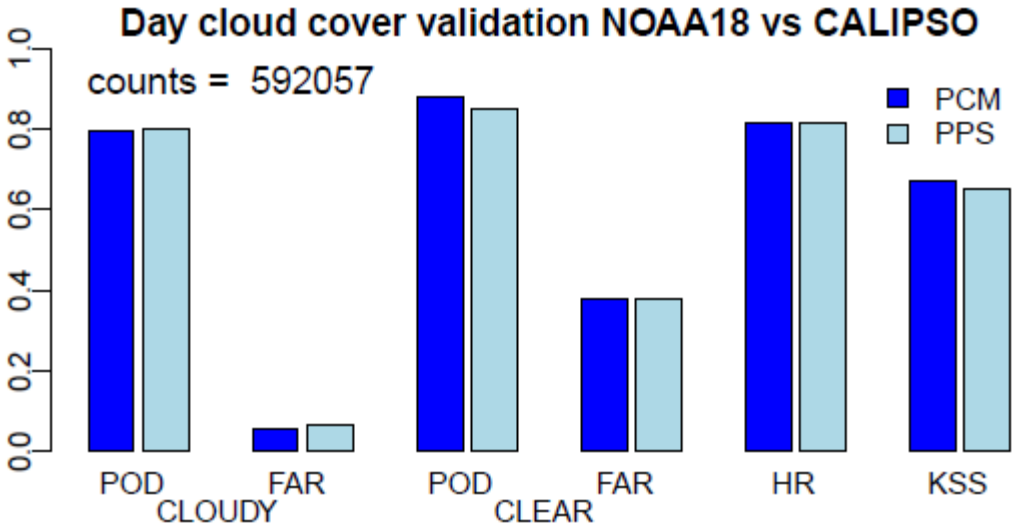

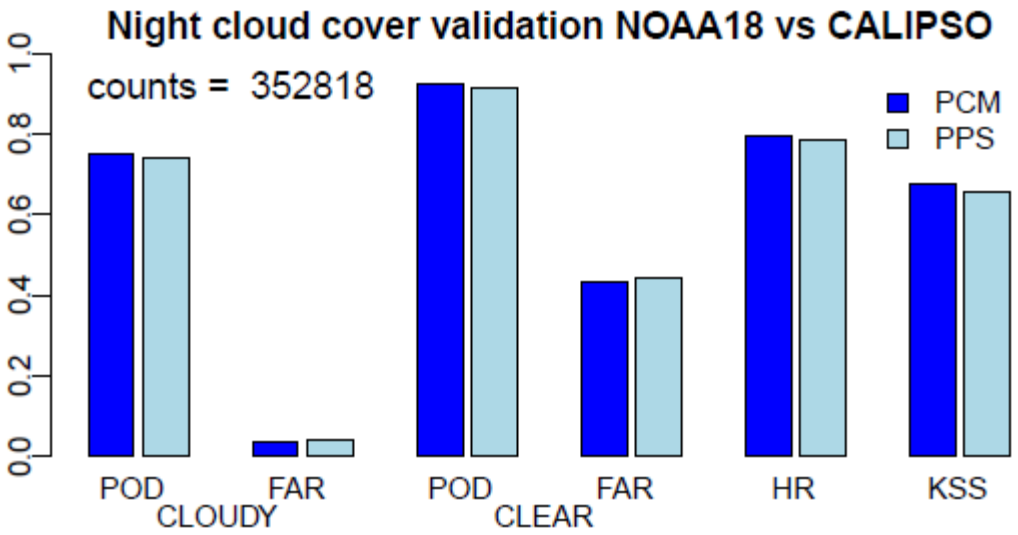

Total snow cover PCM vs MOD10A1

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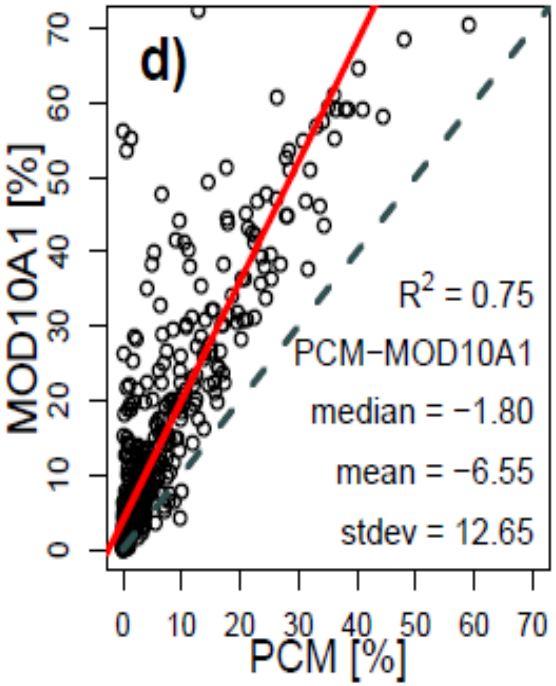
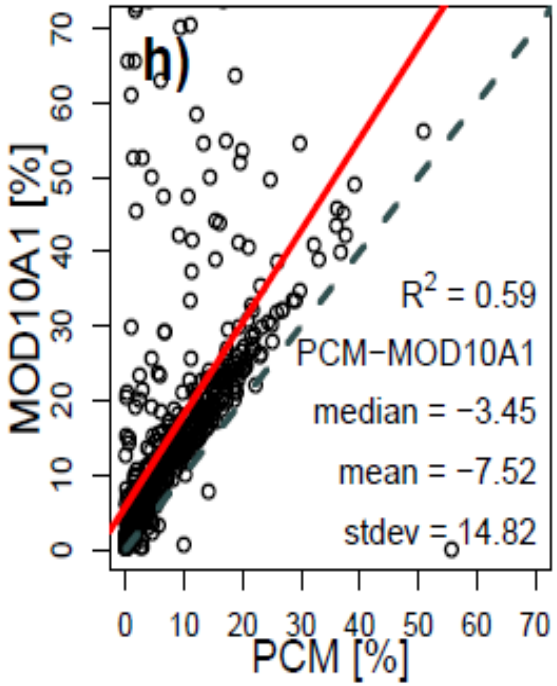
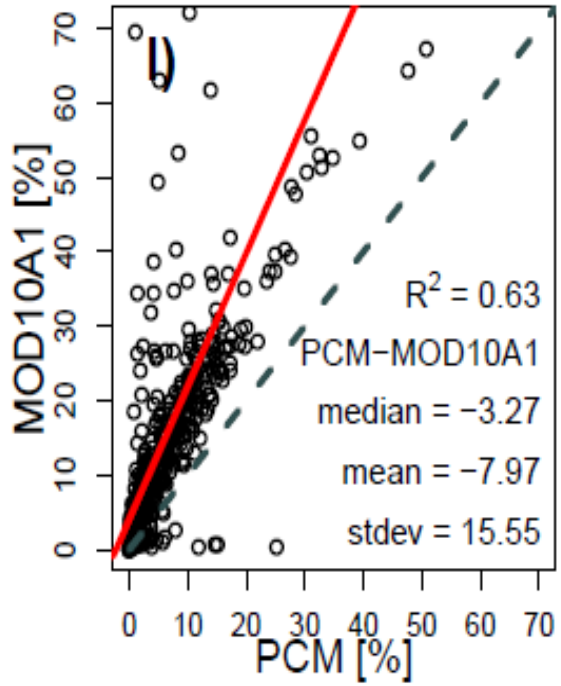
NOAA16



NOAA17



NOAA18



Validation PCM against MOD10A1

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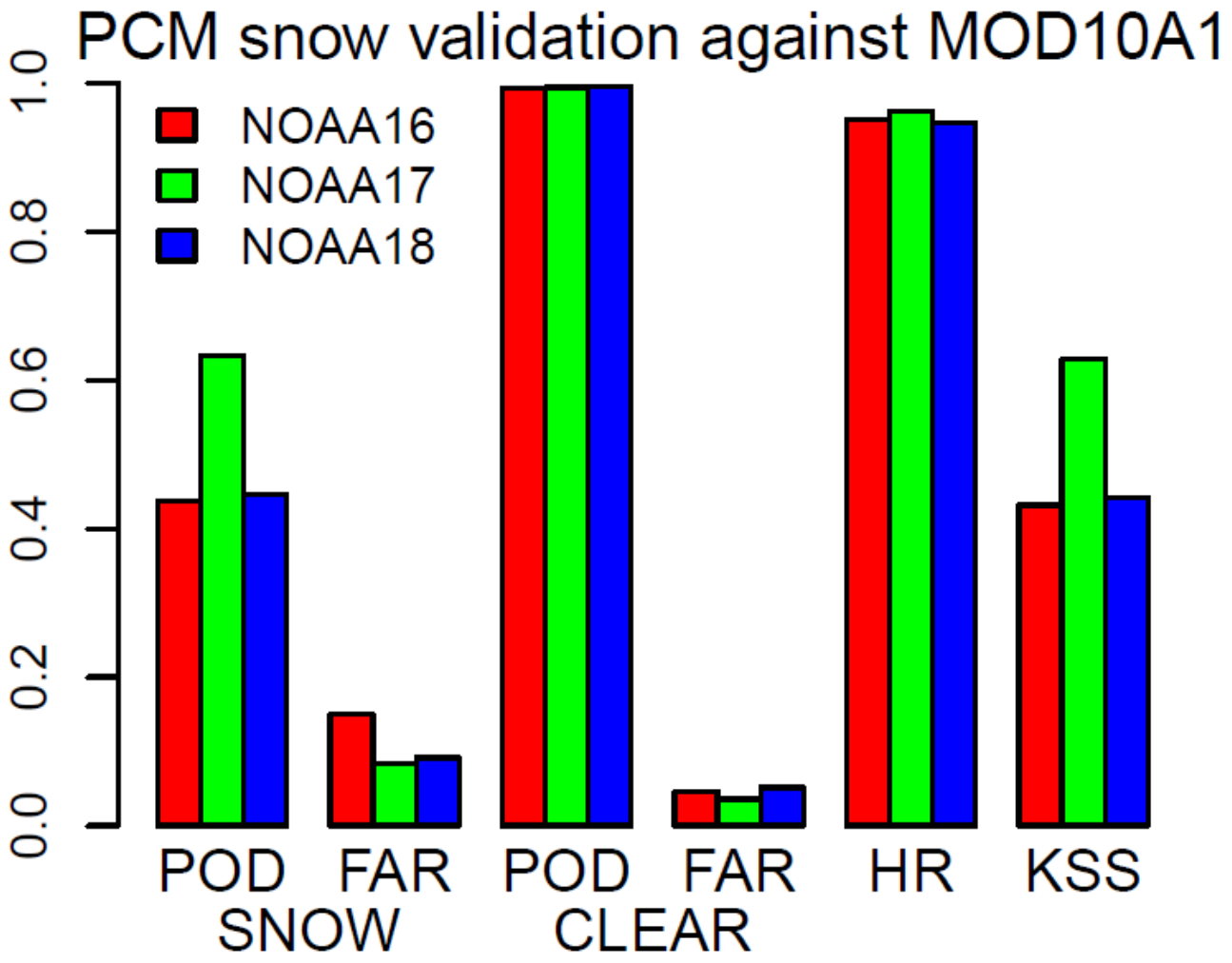

Conclusions

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- PCM provides classification probability between clear/cloudy/snow classes.
- All spectral, angular and ancillary information is used is a single step to extract probabilities from LUTs.
- Spectral contrast of thin ice clouds is enhanced by ICS transformation.
- PCM cloud detection skills are on the same level or better than the training PPS cloud masks.
- PCM snow detection skills are in good agreement for instruments with the 1.6 um channel operating. For instruments with 3.7 um channel the classification accuracy is lower.

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Thank you for you attention

PCM is available for free on:
http://r-forge.r-project.org/projects/pcm/

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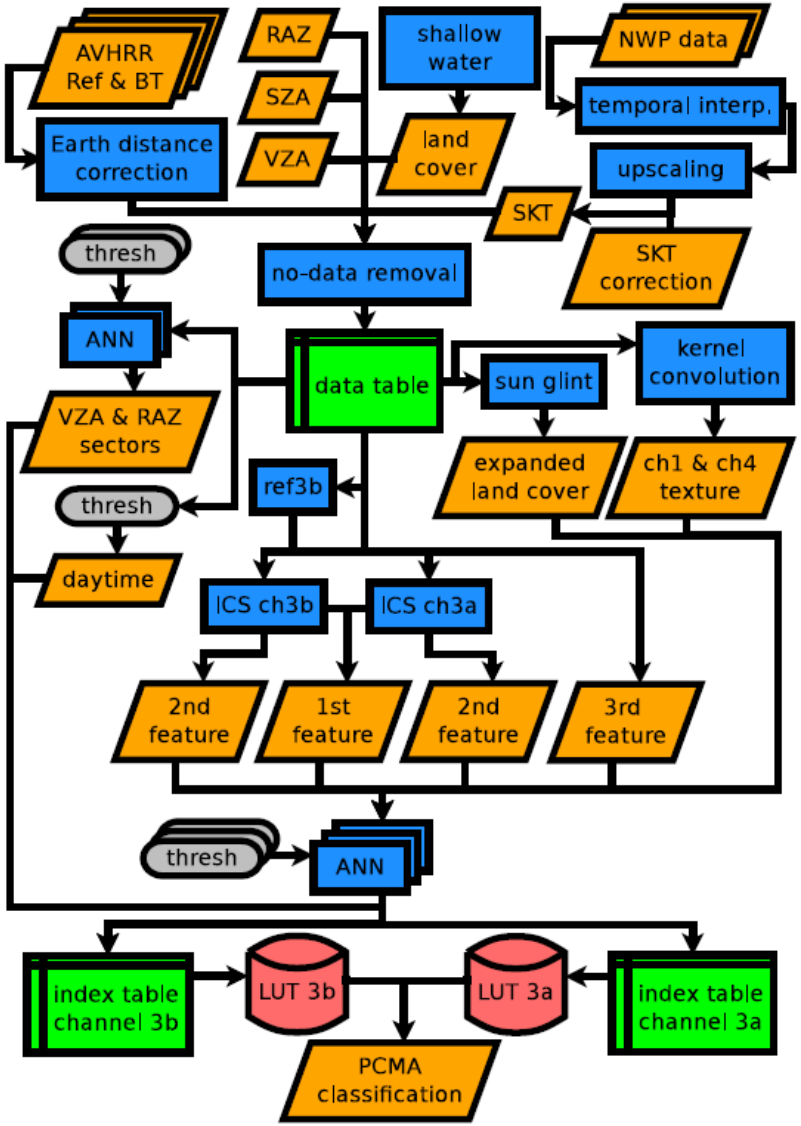
PCM work-flow



Mean latitudinal PCM-PPS differences

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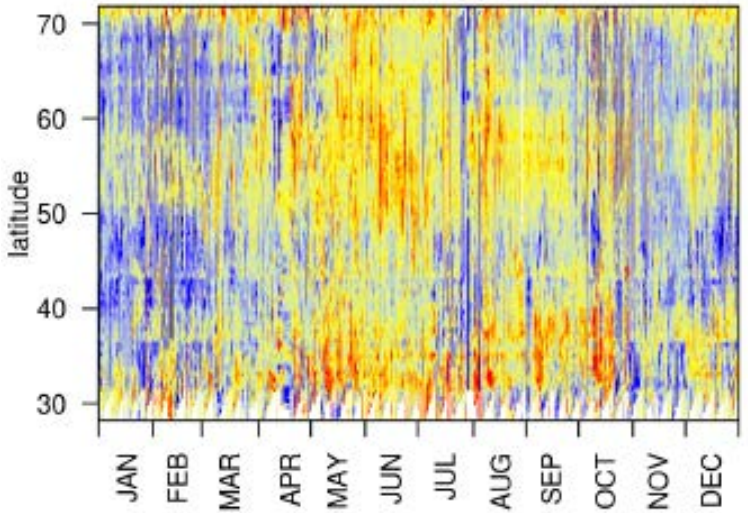
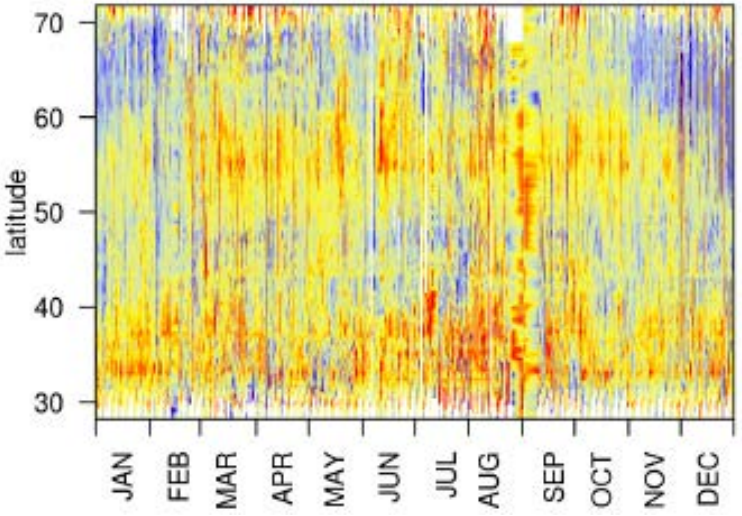
a) NOAA16 PCM-PPS total cloud cover in 2011



b) NOAA17 PCM-PPS total cloud cover in 2008



c) NOAA18 PCM-PPS total cloud cover in 2008