A simplified Approach to Cloud Masking with VIIRS in the S-NPP / JPSS Era

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Background

Obvious need for cloud detection with satellite imagery

- Improved real-time situational awareness
- Mask to support product generation
- Climate studies

Robust VIIRS Cloud Mask (VCM) produced by NOAA with confidence indicators, phase, presence of aerosols, smoke, or shadows, and more

- IR threshold tests, brightness temperature difference tests, solar reflectance tests, NIR and thermal IR thin cirrus tests
- Inputs - Tbbs for M12, M13, M14, M15, M16, I4, I5; reflectance for M1, M4, M5, M7, M9, M10, M11, I1 and I2
- Variety of dynamic ancillary data –surface T, PW and wind speed, snow/ice cover – hundreds of adjustable parameters
- Heritage - Saunders and Kriebel (1988), Stowe et al (1995) for AVHRR and Ackerman et al. (1997) for MODIS, and Gustafson et al. (1994), Hutchison et al. 2005 (for oceans)

Motivation

VIIRS cloud mask already exists So why another?

VCM design to meet NOAA needs, may not address broader community needs like:

- Easy to implement approach for application real-time and case study
- Tuning by user for better regional and local performance
- Cross platform (instrument) consistency of approach)

Two channel (11 μm and 3.7 or 3.9 μm) / three test with dynamic spatially and temporally varying thresholds may provide flexibility to the community

Approach adapted from that of Haines et al. 2005; Jedlovec et al., 2008; Jedlovec 2009

Drivers to the Approach with VIIRS

Easy to apply, accurate in variety of situations

Day and night applications for diagnostic and climate studies, tunability for local applications

Algorithm consistency between satellites

- **Rely on simple infrared threshold test in 11 μm window channel and emissivity differences between surface and various cloud types at 11 and 3 μm as represented in channel brightness temperatures**

  Tb11 – cold for high, thick clouds

- **Emissivity clouds is lower at 3 μm than 11 μm providing lower brightness temperatures at night but potentially larger (during day) when reflected solar radiation is present**

  Tb11 – Tb3 >> 0 clouds at night

  Tb11 – Tb3 << 0 clouds during day (solar illumination)

Cloud Tests

Split window spectral test

- **If {Tb11(x,y,t)-Tb3(x,y,t) < 0 and < [(CND(x,y,t')-ΔND]} ➡ CLOUD**
- **If {Tb11(x,y,t)-Tb3(x,y,t) > 0 and < [(CPD(x,y,t')+ΔPD]} ➡ CLOUD**

ΔND – negative difference adjustment factor (4.0)

ΔPD – positive difference adjustment factor (2.5)

Longwave infrared channel test

- **If {Tb11(x,y,t)-CWLW(x,y,t') < -ΔLW} ➡ CLOUD**

ΔLW – longwave IR adjustment factor (18.5)

Adjustment factors are subjectively determined to tune the algorithm performance for regional applications

Composite Thresholds

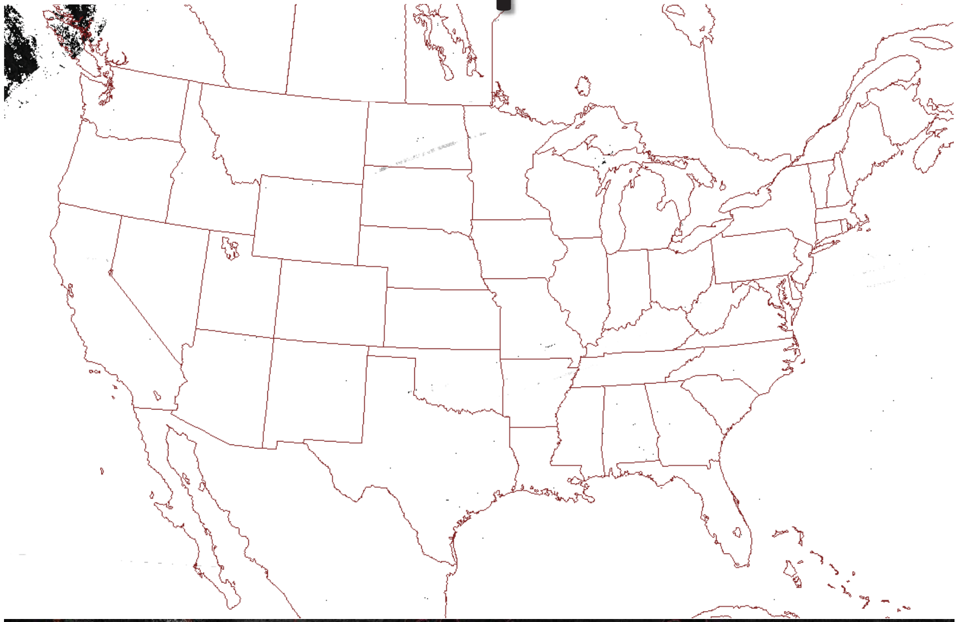
Appropriate thresholds often change with season, time day, and geographic region

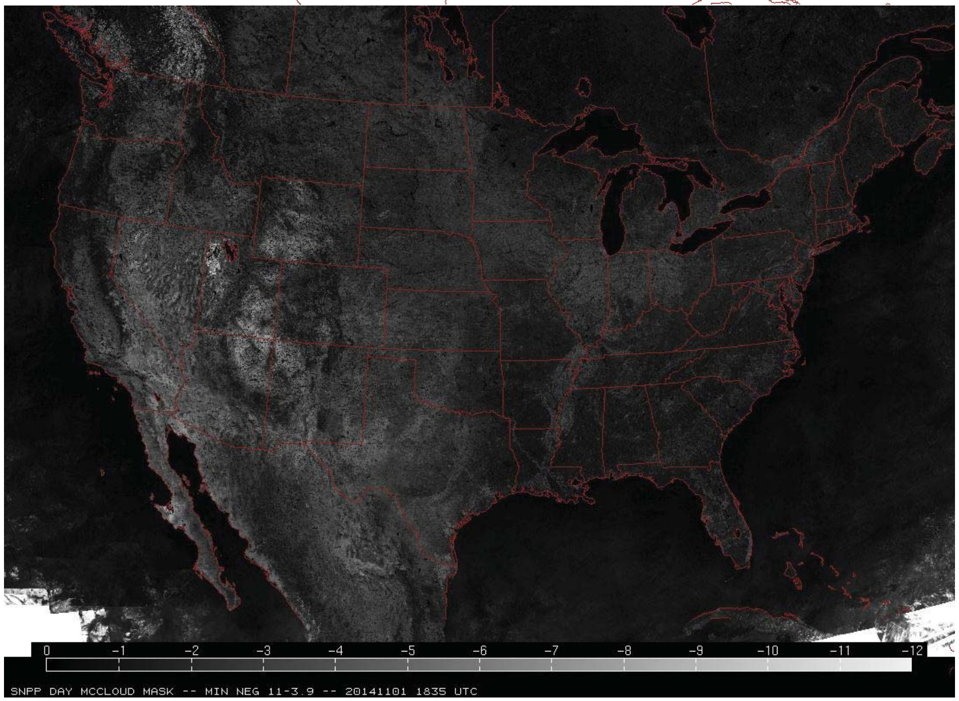
Use imagery over previous 7-20 to determine appropriate threshold on a pixel by pixel basis

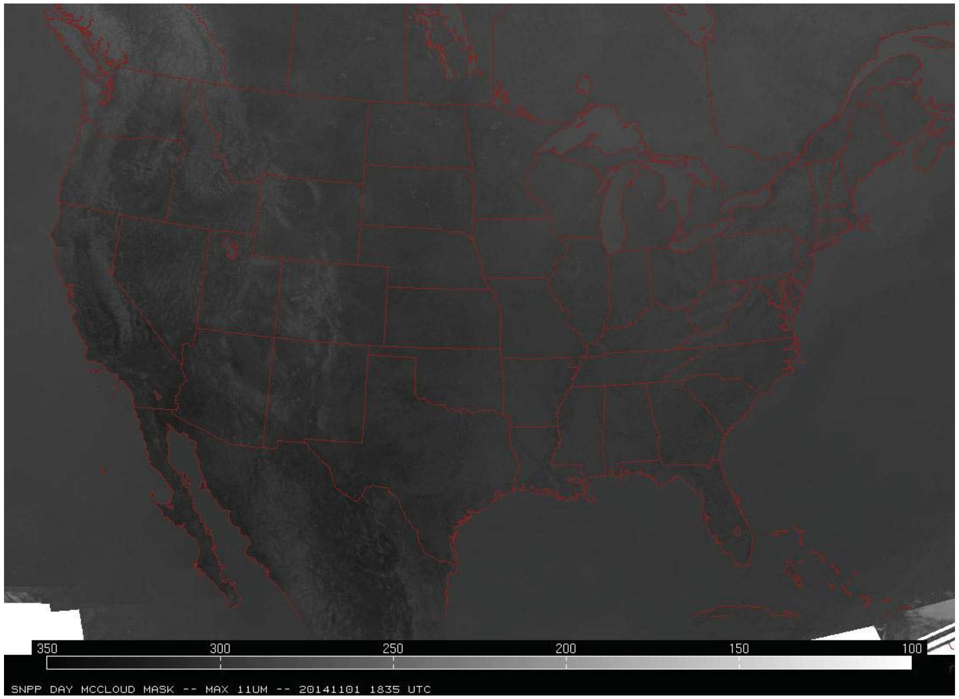
- Largest negative and smallest positive Tb11 - Tb3 μm difference image over the previous 20 days assumed to provide estimate of clear sky difference value – difference image values smaller than these thresholds probable correspond to cloud-free conditions
- Warmest Tb11 over previous 20 days at corresponding observation time represents cloud-free conditions

Resulting composite images form spatially and temporally (recalculated each day) varying thresholds for cloud detection

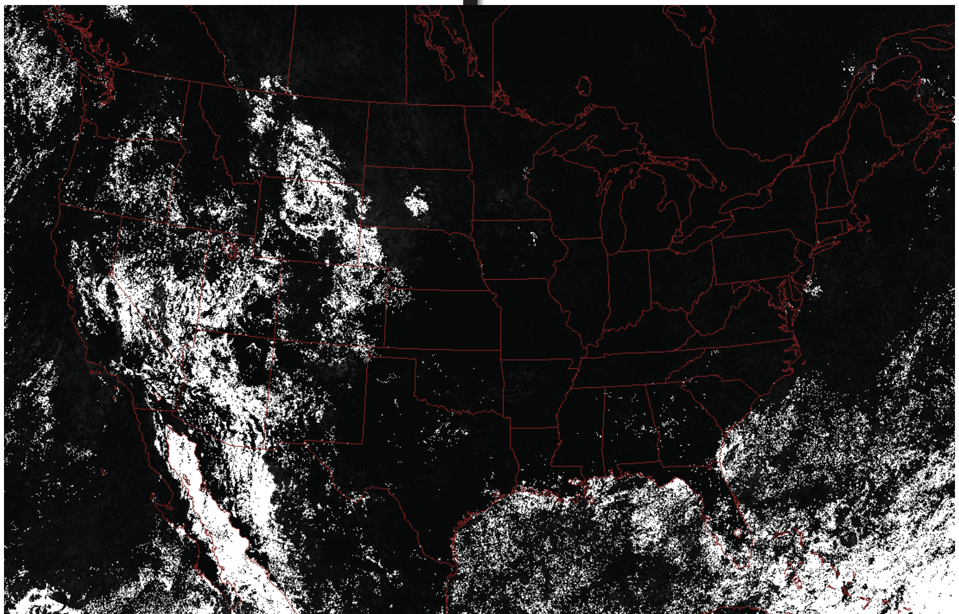
Composites Use in Tests (Day)

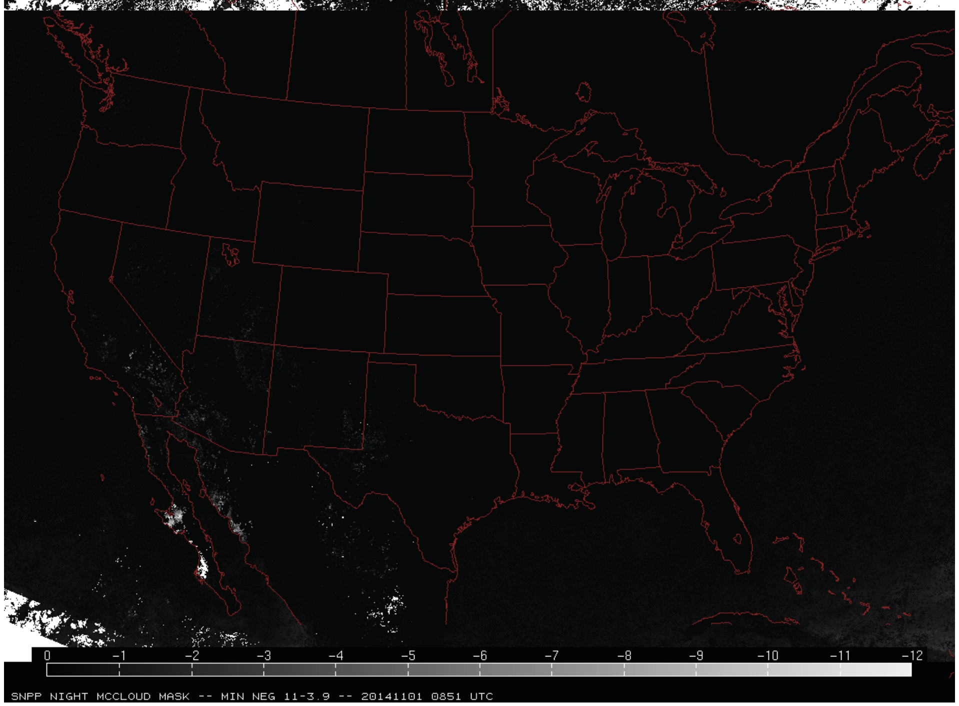


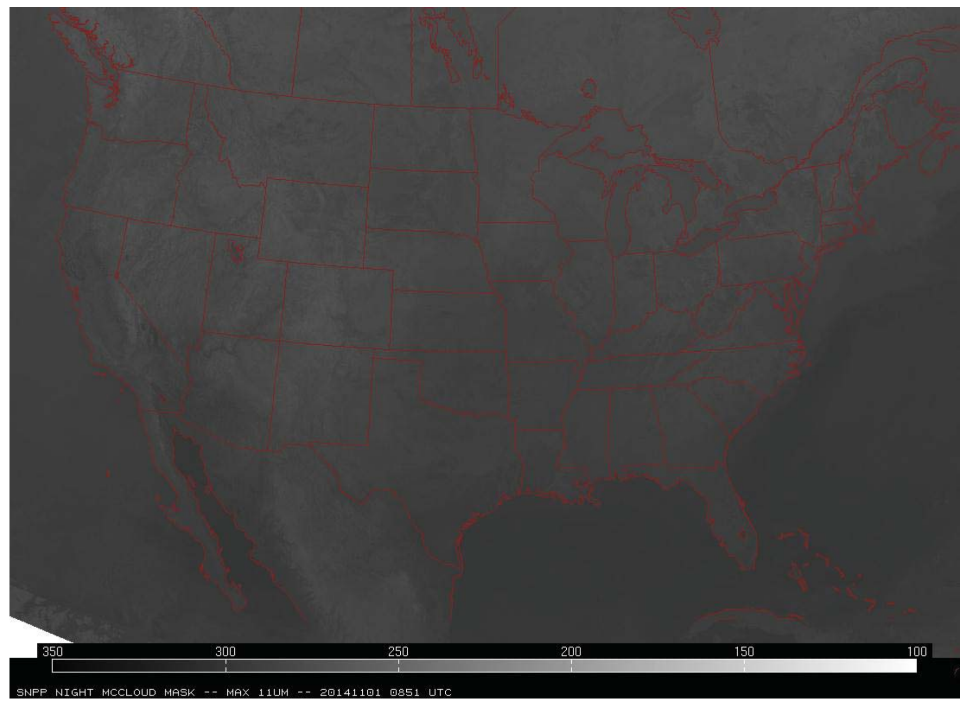




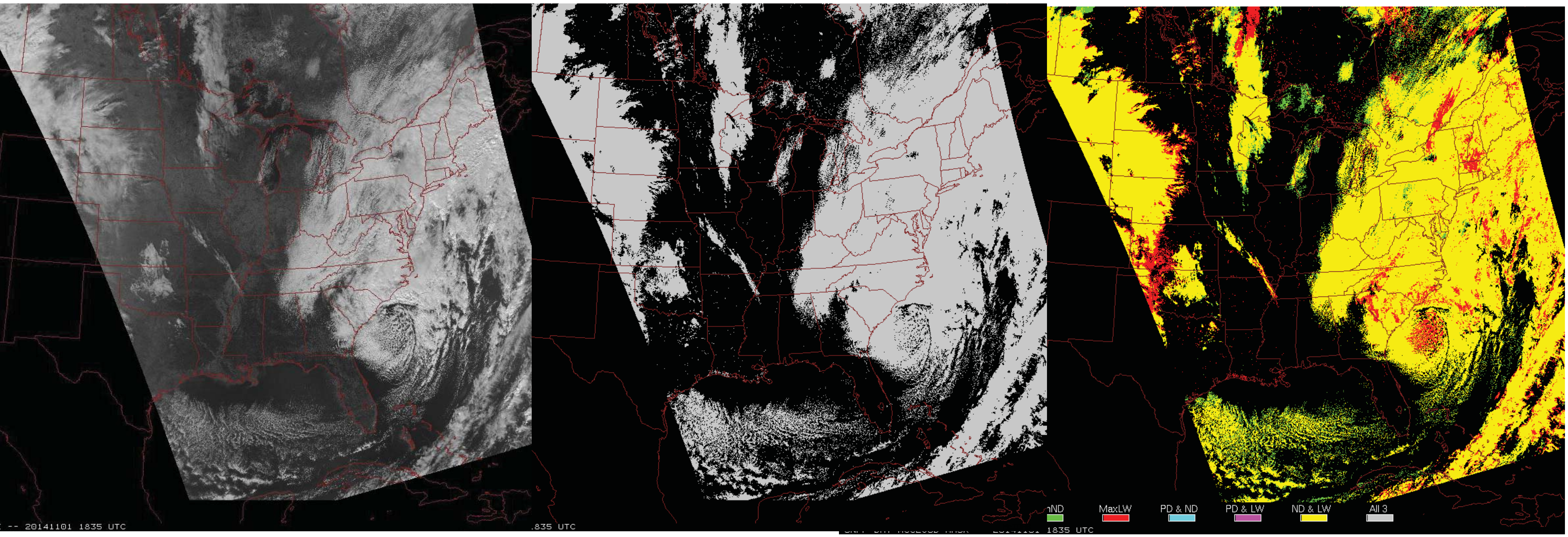
Composites Use in Tests (Night)







Satellite Imagery / Cloud Mask (Day)



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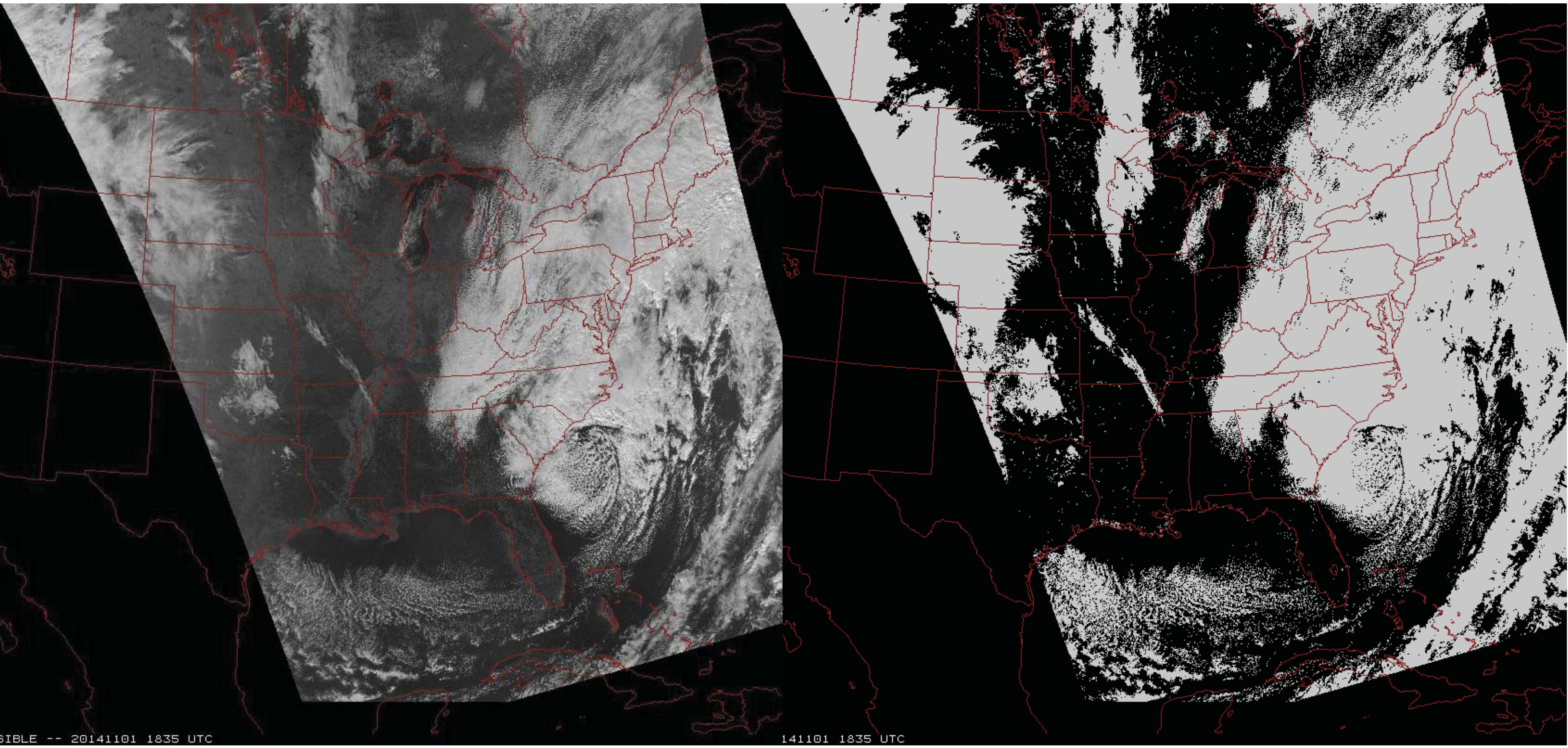

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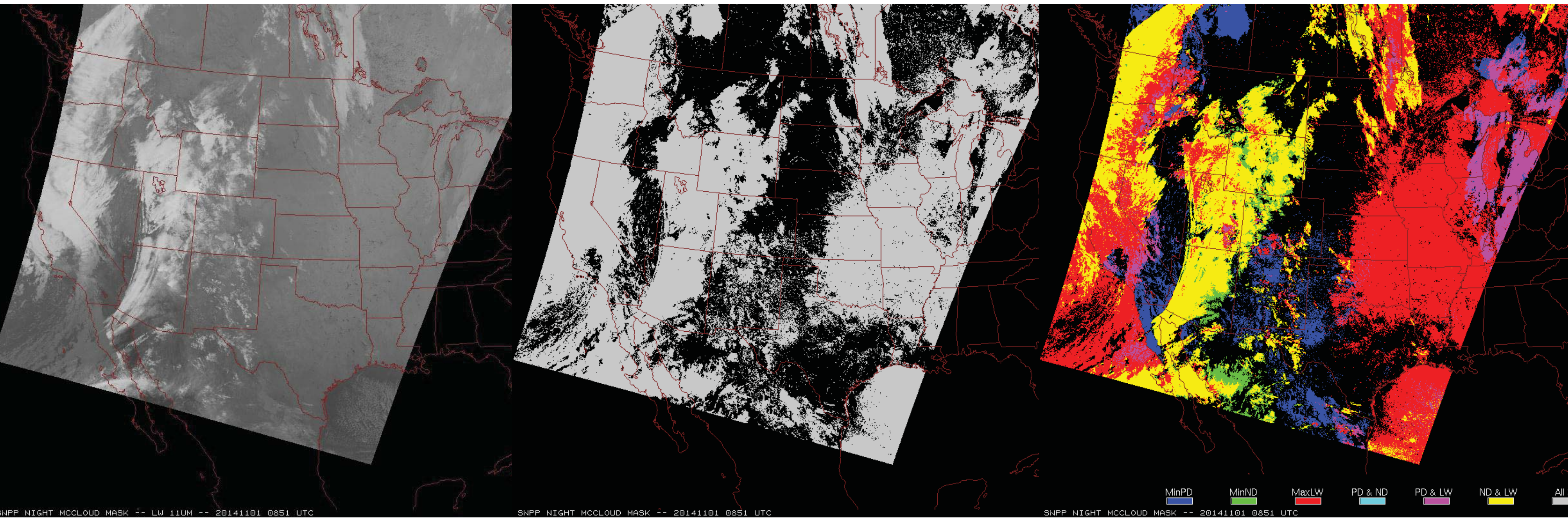

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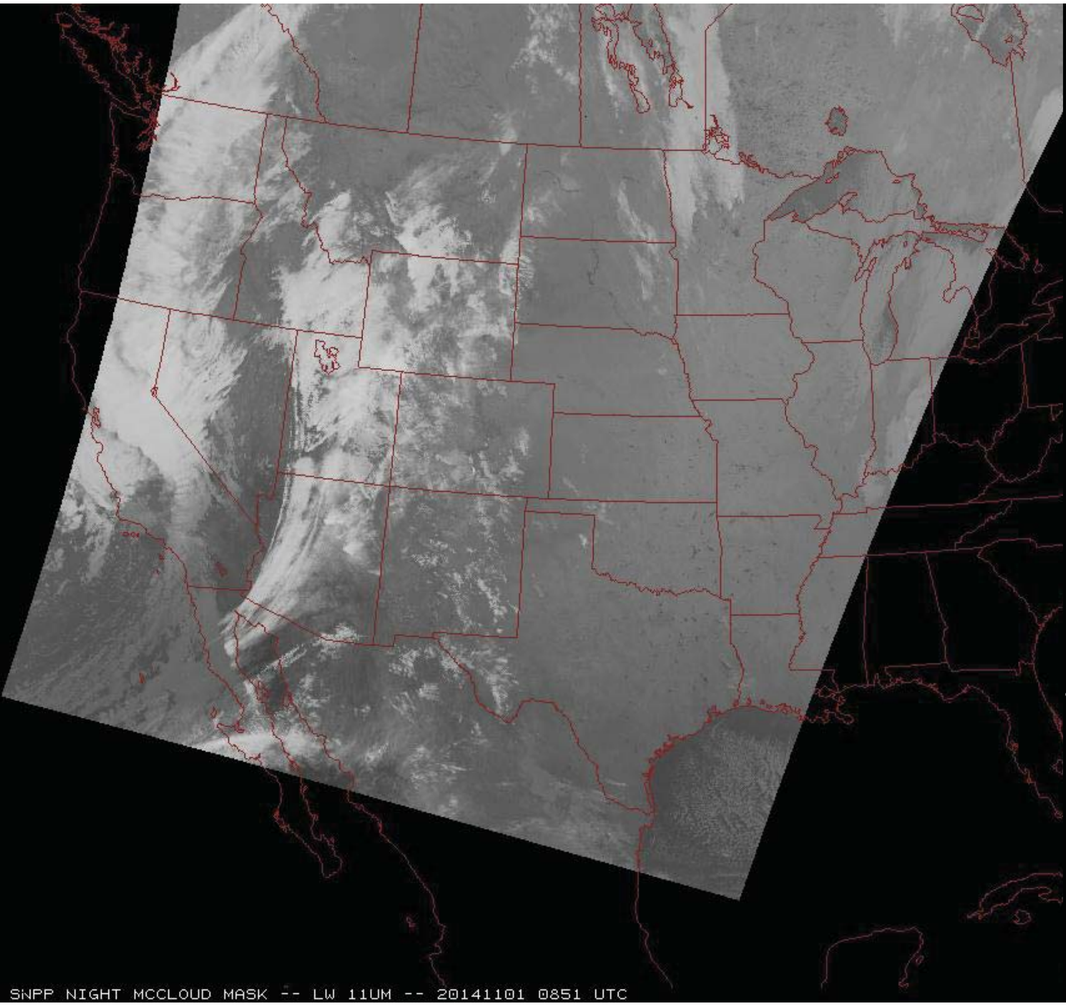
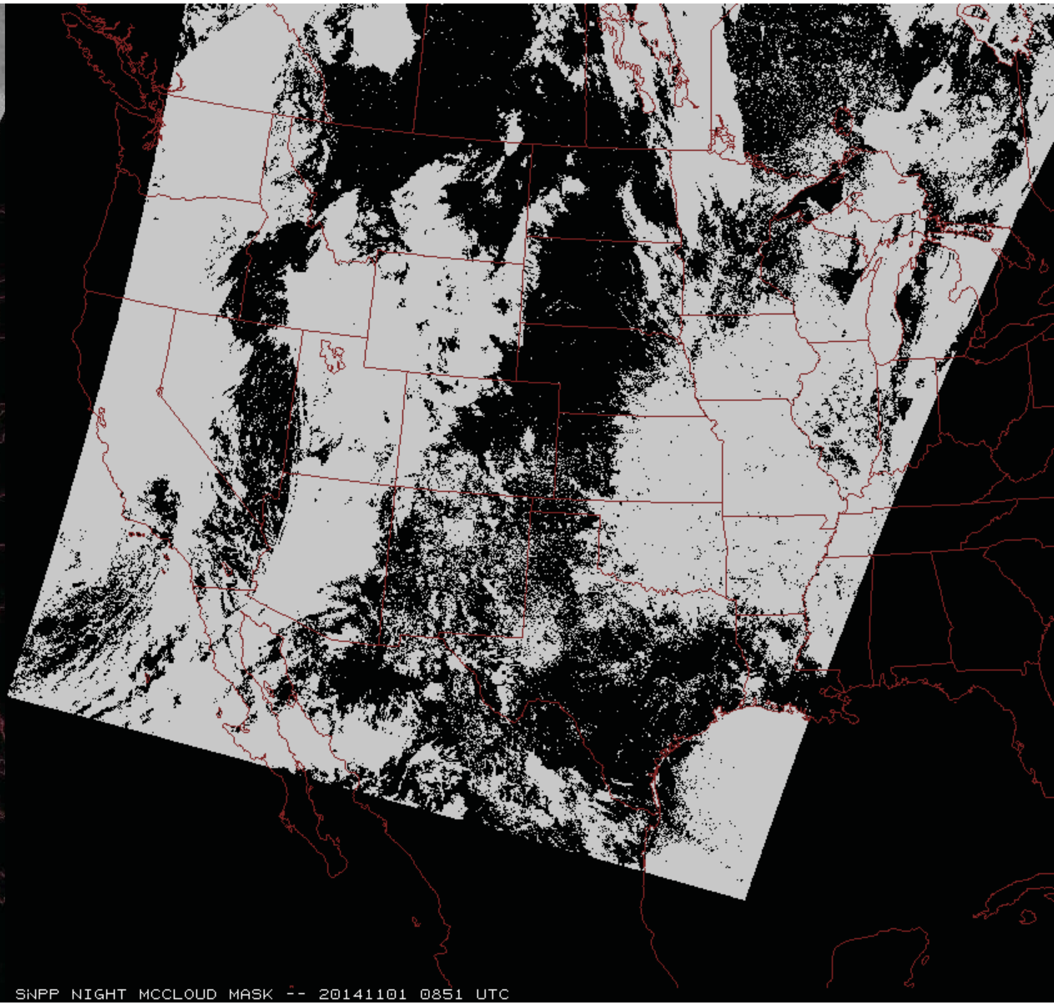




Verification / Validation

How good / accurate is the cloud mask?

Compare with other cloud masks, other satellite sensors (e.g., Calipso) and / or against ground truth

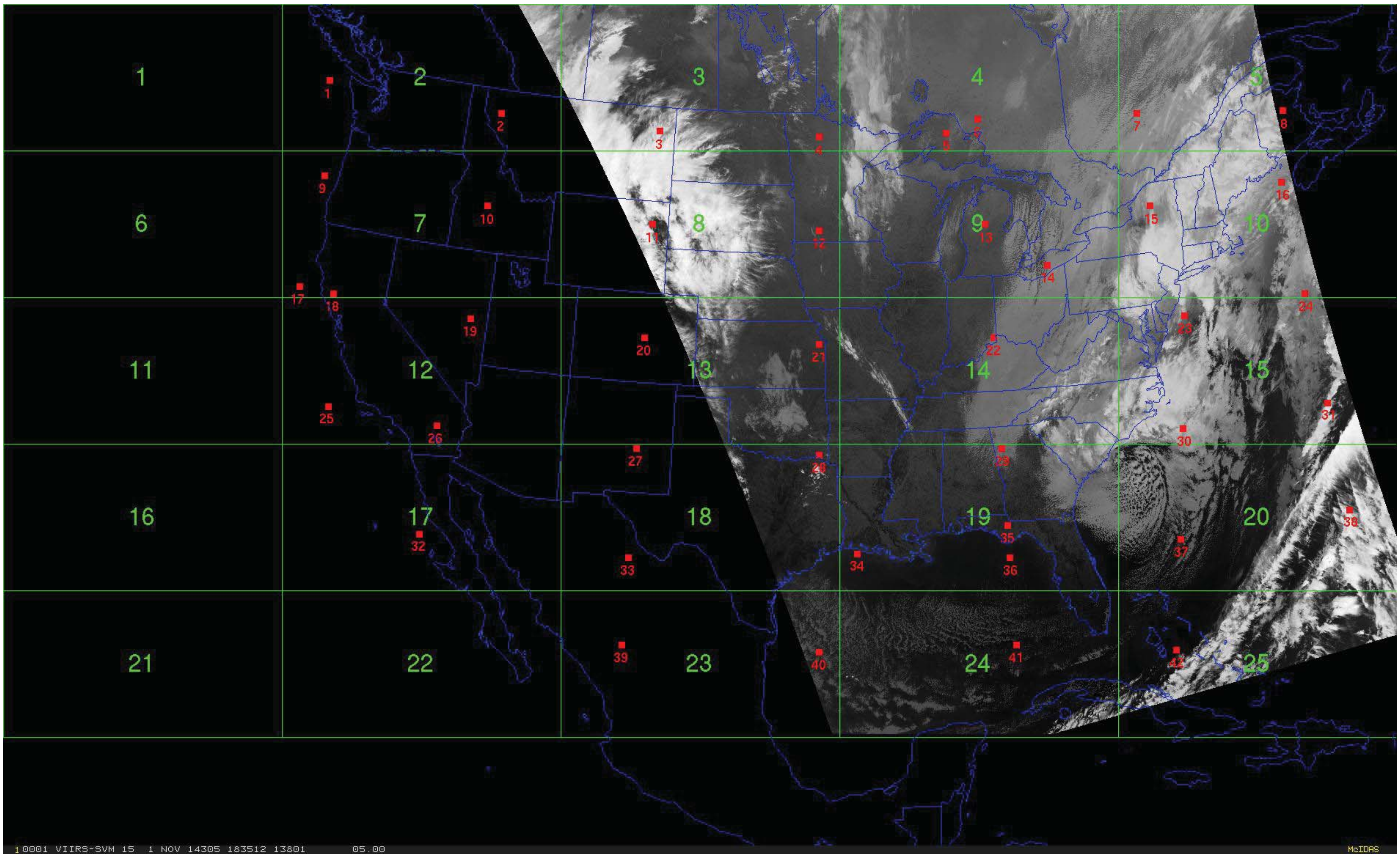
Ground truth is difficult to obtain

Develop ground truth data set for specific regions with trained remote sensing scientists / students

- 5 weeks (October-Nov) , day / night passes over CONUS, total number of images and points
- 3-5 satellite remote sensing experts manually look at imagery to determine % cloud cover, 30x30km (pixel) region – used visible and infrared imagery

Cloud Mask Validation Points

CONUS satellite image with validation points



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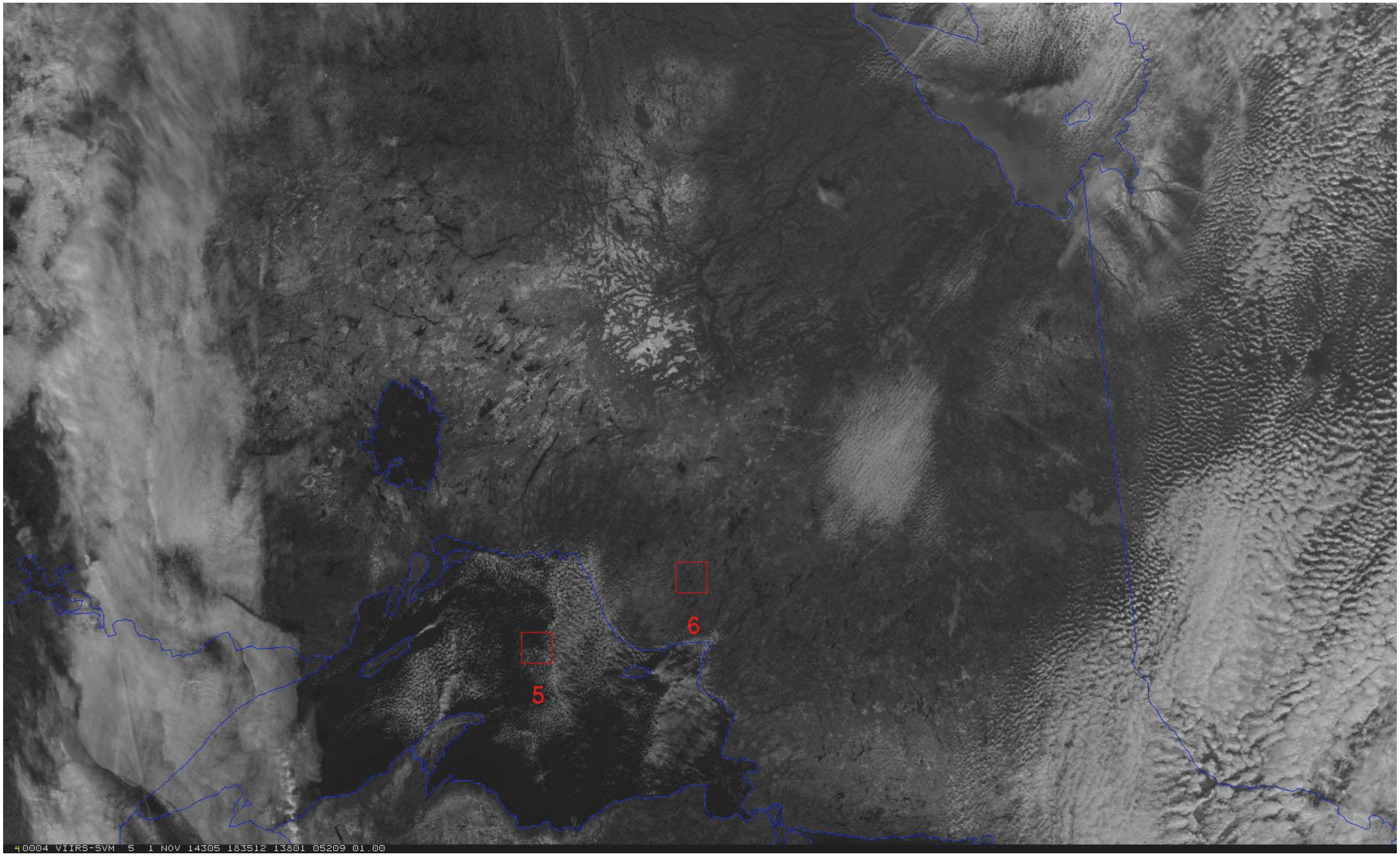
CONUS satellite image with validation points



Statistics (VIIRS)

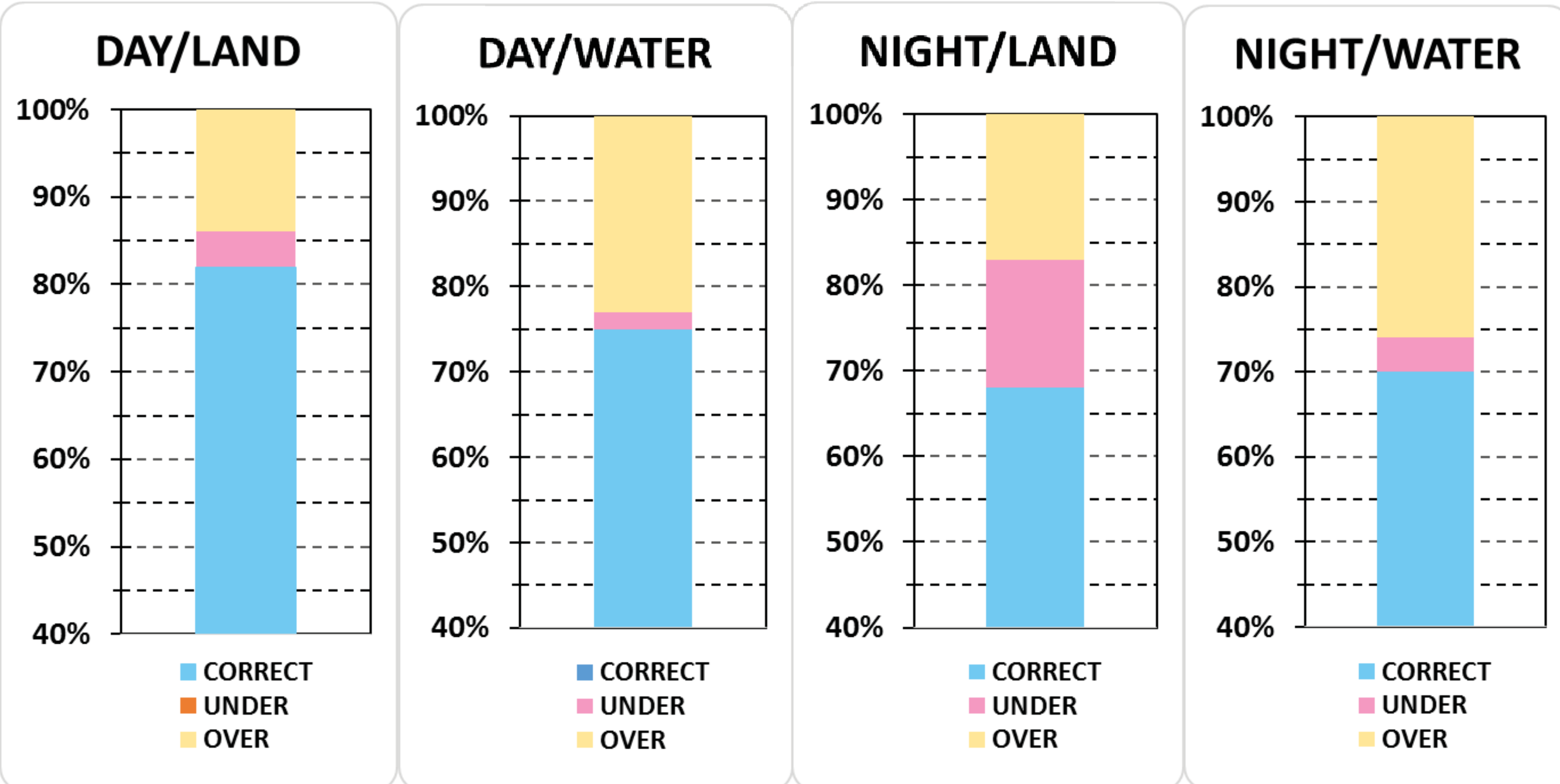
Performance against 42 validation points over from
October 1 – November 5, 2014

	OBS	C	I	F	U	Z	H
NUMBER	**3893**	**2892**	**1001**	**771**	**230**	**993**	**1899**
PERCENT	**100%**	**74%**	**26%**	**20%**	**6%**	**26%**	**48%**

C (correct) – total points and percent correct
I (incorrect) – total points and percent incorrect
F (false alarms) – the clear points identified as cloudy or the over-determination of clouds
U (misses) – undetected cloud points or an under-determination of clouds
Z (correct clear) – the points correctly determined to be cloud-free
H (hits) – the points correctly determined to be cloudy

			VIIRS
HR (hit rate)	= H / (H + U)	=	89.1%
FAR (false alarm rate)	= F / (F + Z)	=	43.7%
SS (skill score)	= HR – FAR	=	0.455

Performance



Spatially and temporally varying thresholds provide situational …

Tuning parameters – land water, etc.

Summary / Next Steps

- Verification results for 5 weeks in Fall 2014 indicate an overall hit rate of 89.1%, however, the false alarm rate is quite high at 43.1% suggesting a substantial over-determination of clouds
- Preliminary results suggest that “adjustment factors” need tuning to meet past algorithm performance with MODIS imagery

<u>Next steps</u>

- Tune adjustment parameters
- Validate in multiple seasons
- Compare to NOAA VCM with external validation
- Extend beyond CONUS
- Global verification

Backup Charts