Multi-sensor near-real time forest monitoring
- to address GOFC GOLD & GFOI RD interests -

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GOFC-GOLD
Global Observation of Forest Cover and Land Dynamics
Land Cover Project Office

GFOI
Global Forest Observations Initiative

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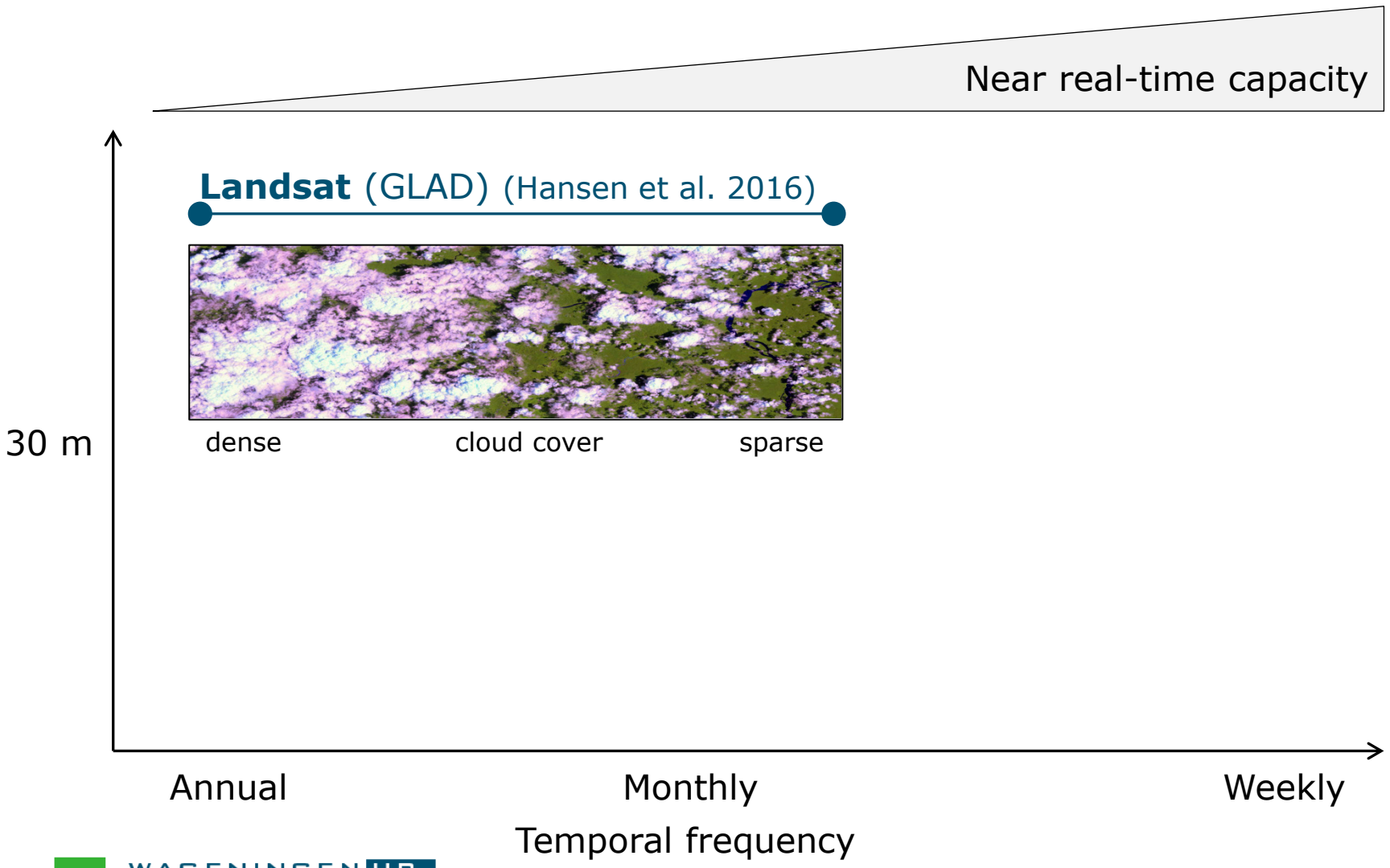
http://www.gofcgold.wur.nl/

GOFC GOLD & GFOI R&D interests

- GOFC-GOLD long-term objectives:
  - Sustained process of building an improved match between Observations, Data Products and User Needs
  - Ensure systematic and continuous program of space-based and on-the-ground forest and land cover observations
  - Promote transparency and free & open source data/tools

- For the case of near-real time forest change monitoring
  - Technological progress versus country/user need driven
    - User needs assessment for near real-time is required
    - Dense, regular and consistent sampling throughout time and space to increase robustness of early warning systems
    - Regional calibration to increase precision
    - Link to local/community-based monitoring on the ground
  - Aim to use open source methods and data systems
  - Assessing and understanding uncertainties and impact for users

Towards dense, regular and consistent sampling



Landsat observations for Peru, 2014 (Hansen et al, 2016)

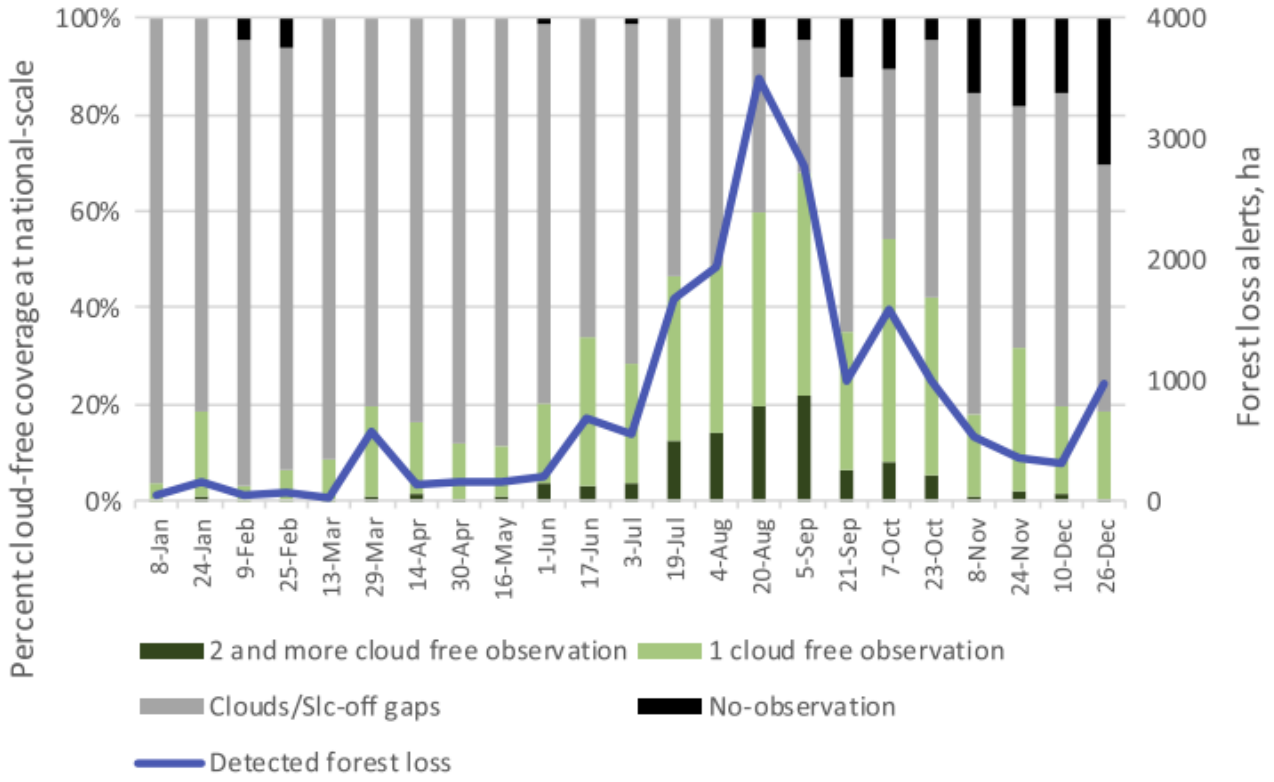
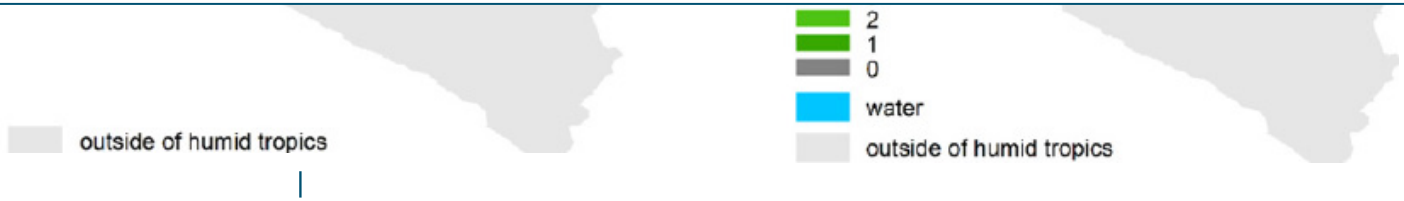
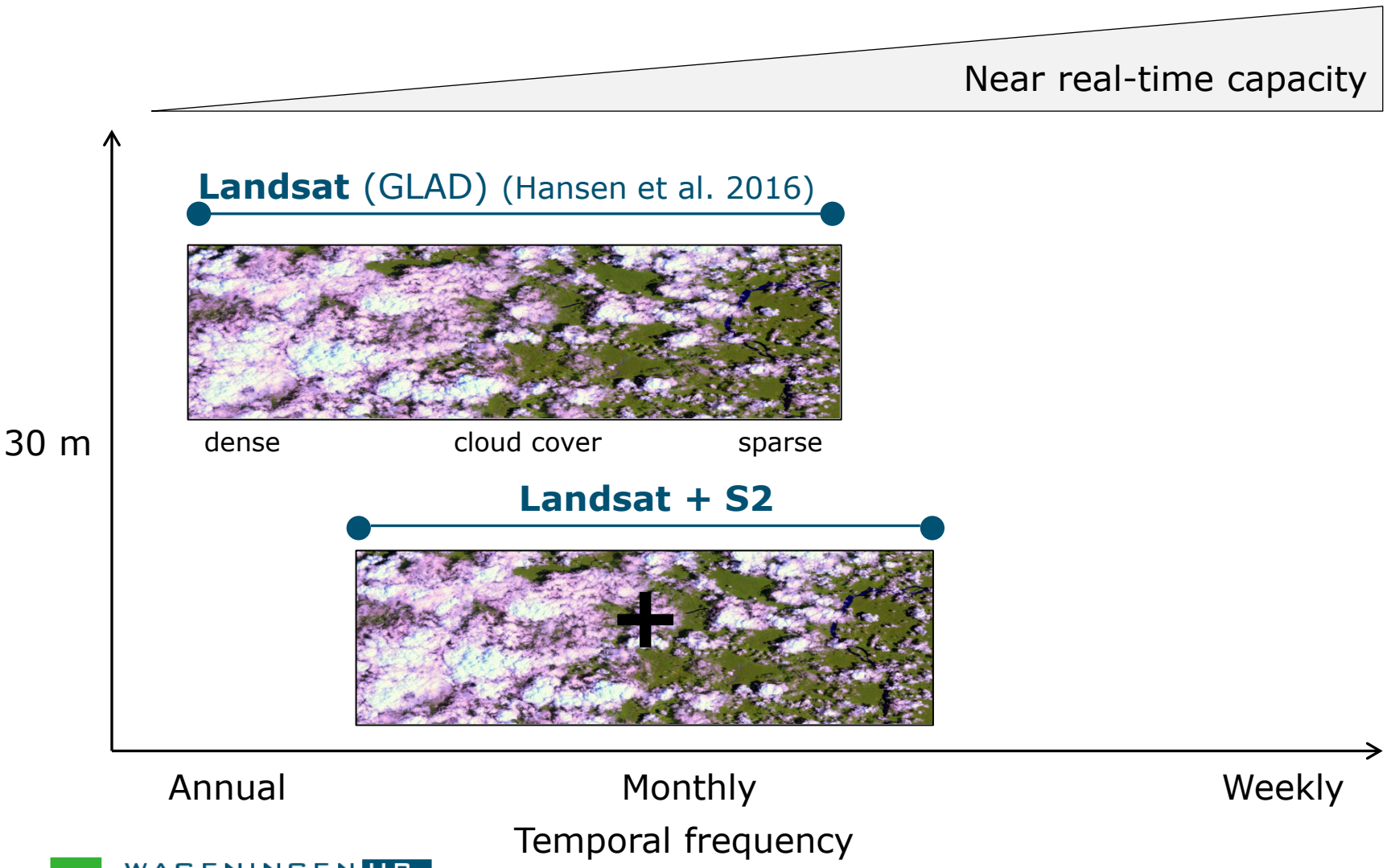


Figure 9. Cloud free observations and forest loss detection by 16 day period for Peru in 2014.



Towards dense, regular and consistent sampling



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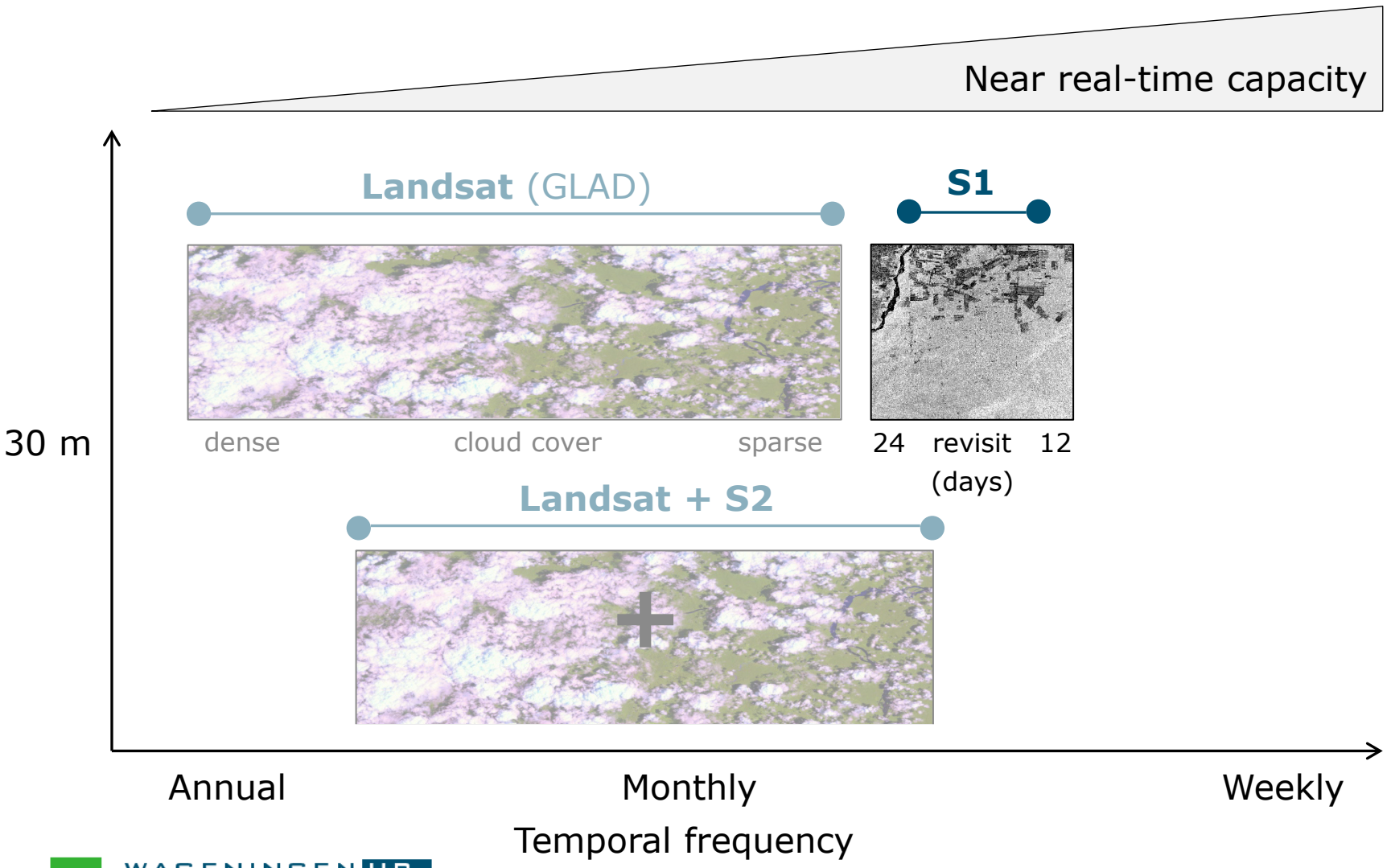

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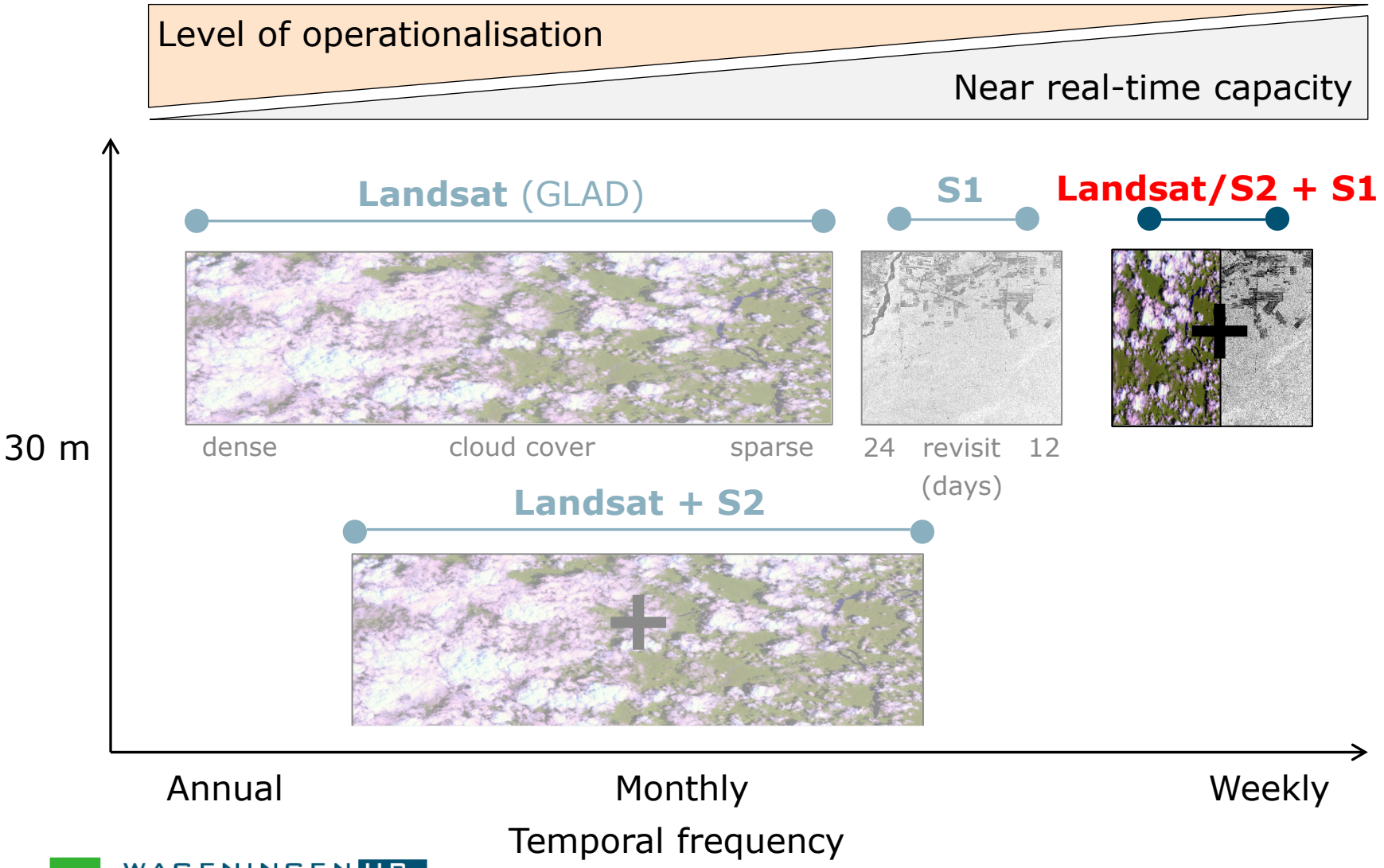
Towards dense, regular and consistent sampling



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Multi-sensor near real-time deforestation monitoring

(Reiche et al., under review)

Study site

- Santa Cruz, Bolivia
- Tropical dry forests

Data

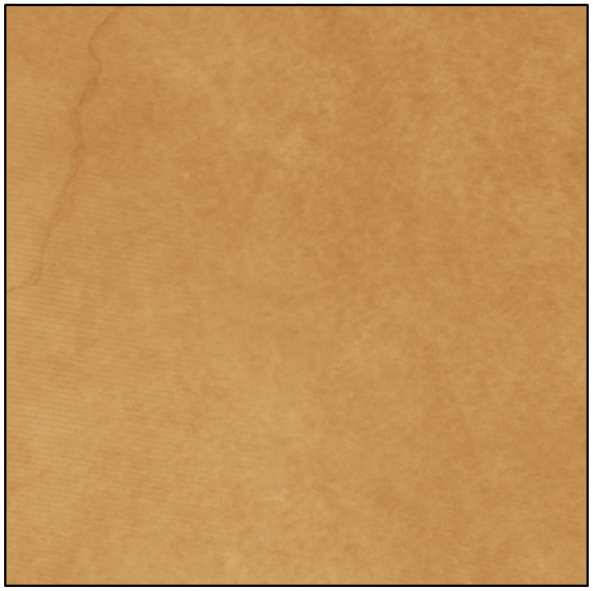
- Sentinel-1, PALSAR-2, Landsat-7/8

Methods

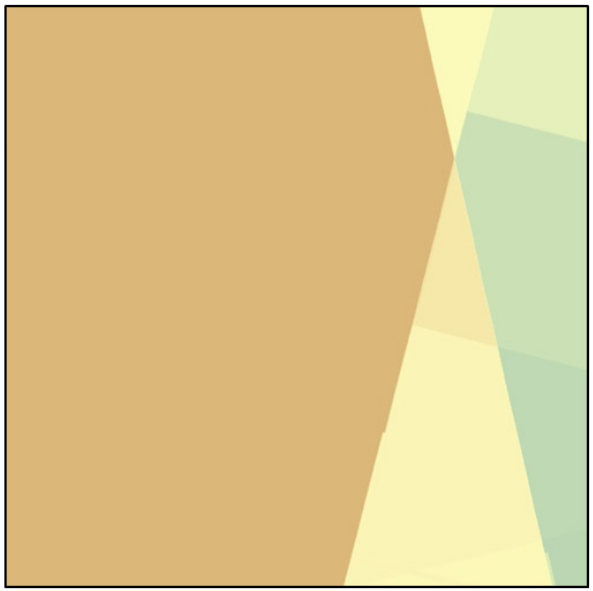
- Time series processing & co-registration
- Deseasonalisation (Hamunyela et al., 2016)
- Probabilistic approach for time series combination and NRT change detection (Reiche et al., 2015)

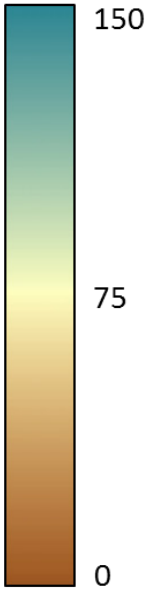
Valid (cloud-free) observation (10/2014 – 10/2016)

Landsat [min:13; **mean: 30**; max:44]

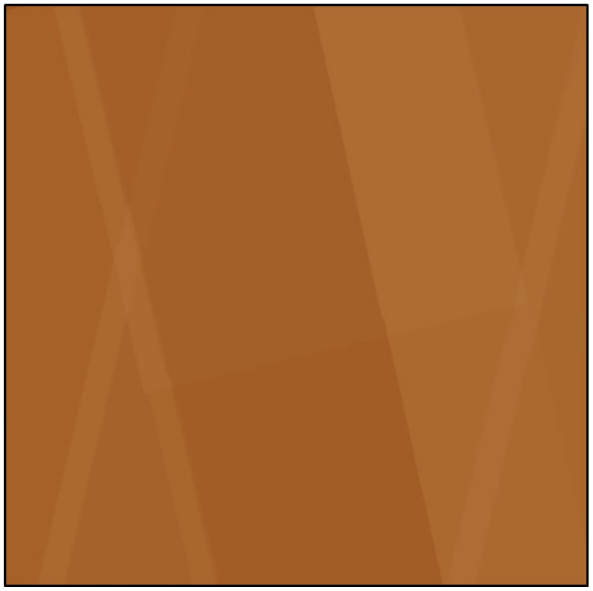


Sentinel-1 [min:47; **mean:57**; max:98]

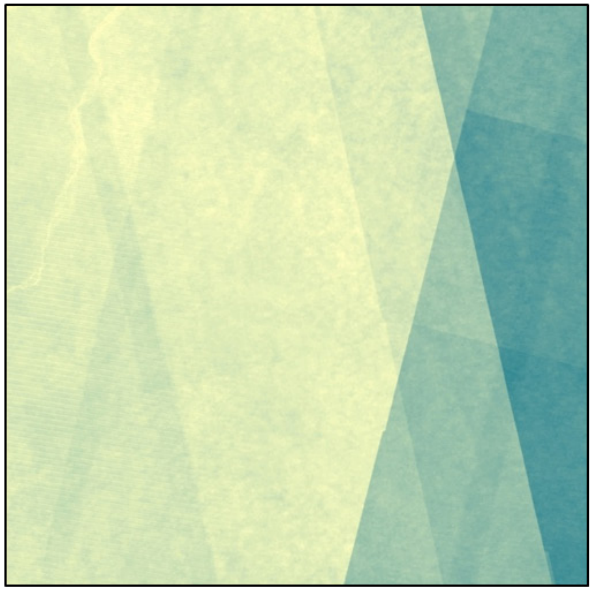




PALSAR-2 [min:4; **mean: 8**; max:15]

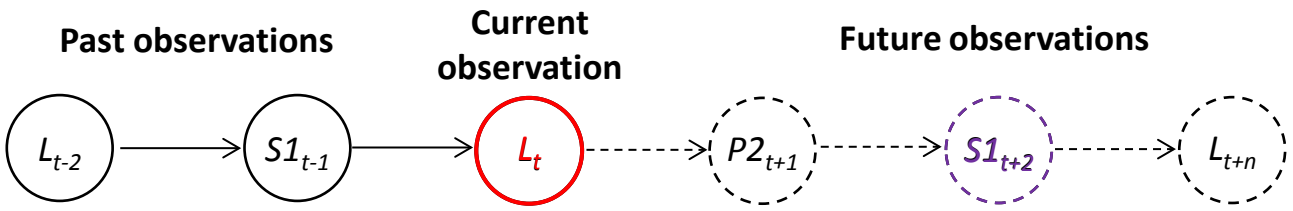


Multi-sensor [min:65; **mean:96**; max:147]



Probabilistic approach to multi-sensor time series for NRT deforestation detection (Reiche et al., 2015/2017)

Input: Spatially normalised Landsat NDVI, Sentinel-1 and PALSAR-2 time series observations in NRT environment



Multi-sensor time series observations

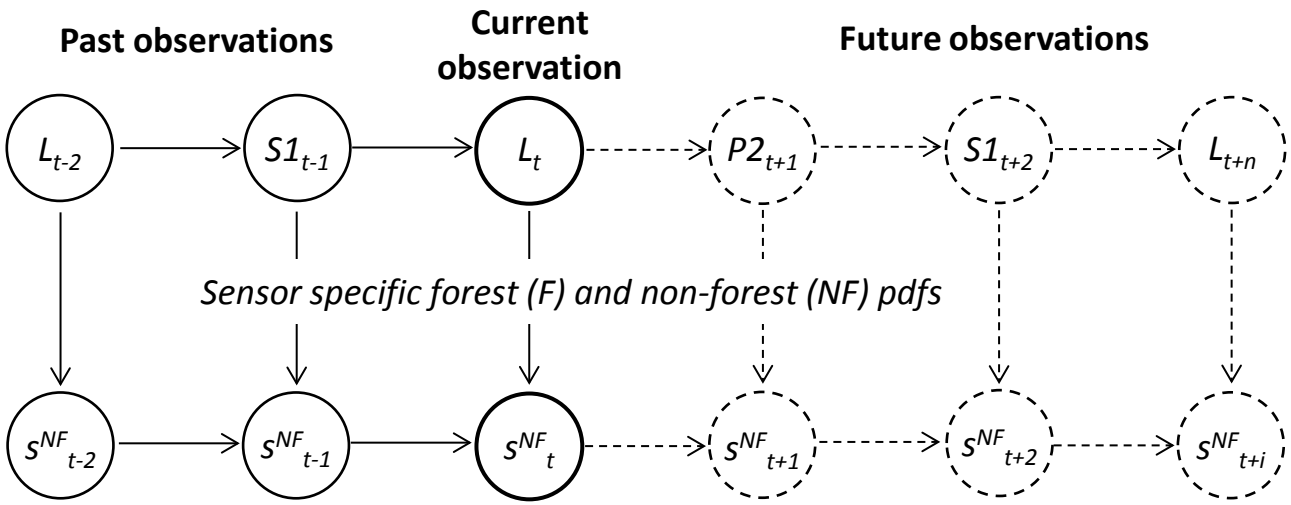
Landsat obs. at time = t *(current observation)*

Sentinel-1 obs at time = t+2 *(2nd future observation)*

https://github.com/jreiche/bayts

Probabilistic approach

Step 1: Deriving and combining TS of conditional non-forest (NF) probabilities

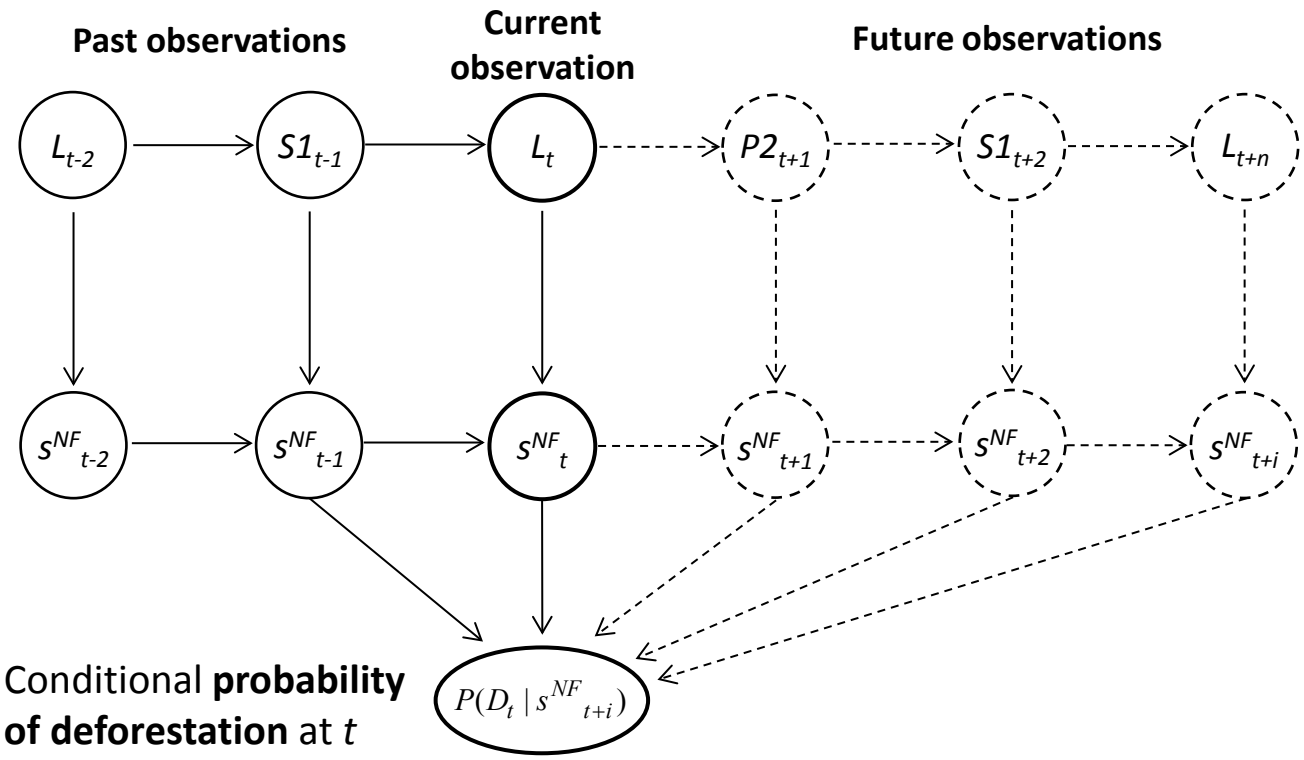


Multi-sensor time series observations

Conditional non-forest probabilities

Probablistic approach

Step 2: Iterative Bayesian updating of the probability of deforestation



Multi-sensor time series observations

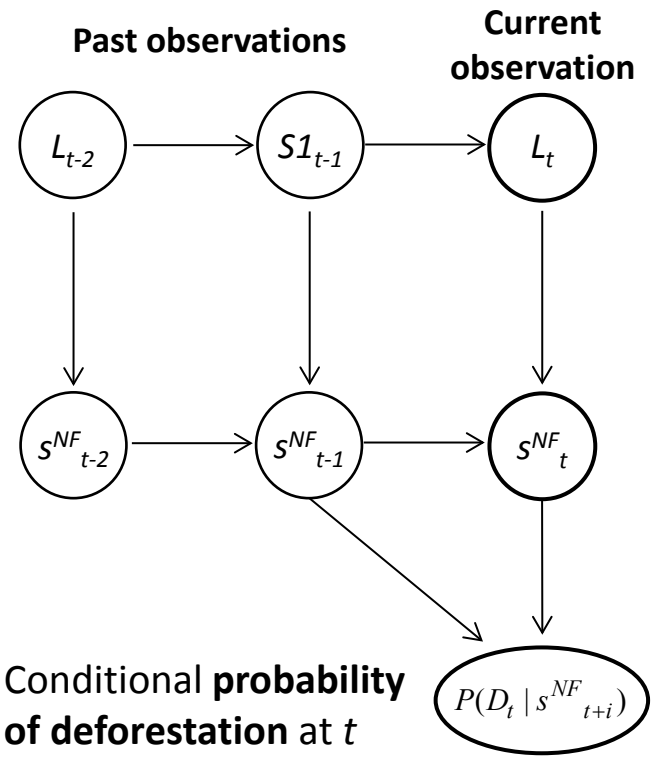
Conditional non-forest probabilities

Conditional **probability of deforestation** at *t*

https://github.com/jreiche/bayts

Probabilistic approach

Step 2a: Flag potential changes and calculate probability of deforestation



Conditional **probability of deforestation** at *t*

- If conditional NF probability (s^{NF}) > 0.5
  --> Flag potential deforestation
  --> Calculate conditional probability of deforestation, $P(D_t \mid s^{NF}_{t+i})$

Bayesian probability updating

$$P(D_t \mid s^{NF}_{t+i}) = \frac{P(s^{NF}_{t+i} \mid D) P(D_t \mid s^{NF}_{t+i-1})}{P(s^{NF}_{t+i})}$$

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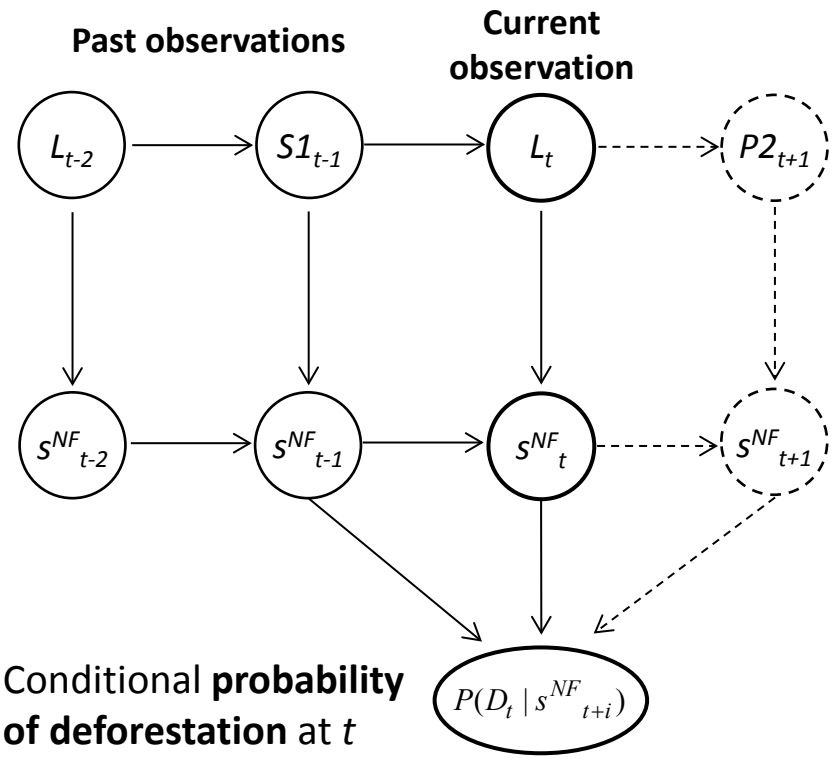
Probabilistic approach

Step 2b: Iterative Bayesian updating using upcoming observations



Conditional **probability of deforestation** at *t*

- If conditional NF probability (s^{NF}) > 0.5
  --> Flag potential deforestation
  --> Calculate conditional probability of deforestation, $P(D_t \mid s^{NF}_{t+i})$

Bayesian probability updating

$$P(D_t \mid s^{NF}_{t+i}) = \frac{P(s^{NF}_{t+i} \mid D) P(D_t \mid s^{NF}_{t+i-1})}{P(s^{NF}_{t+i})}$$

- Future observations used as new evidence to update $P(D_t \mid s^{NF}_{t+i})$ and to confirm or reject the deforestation event by exceeding a threshold

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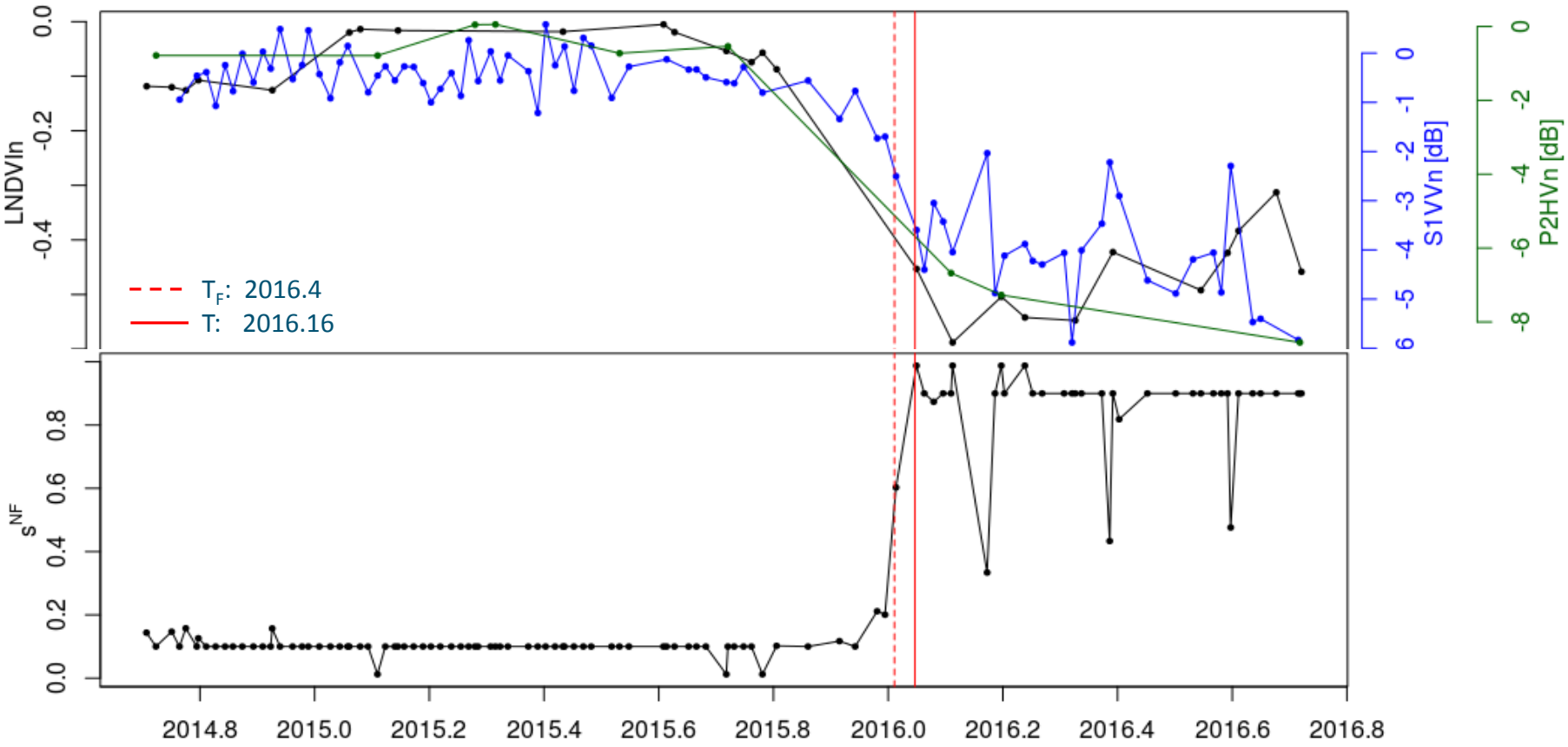
Results I: Single-pixel example



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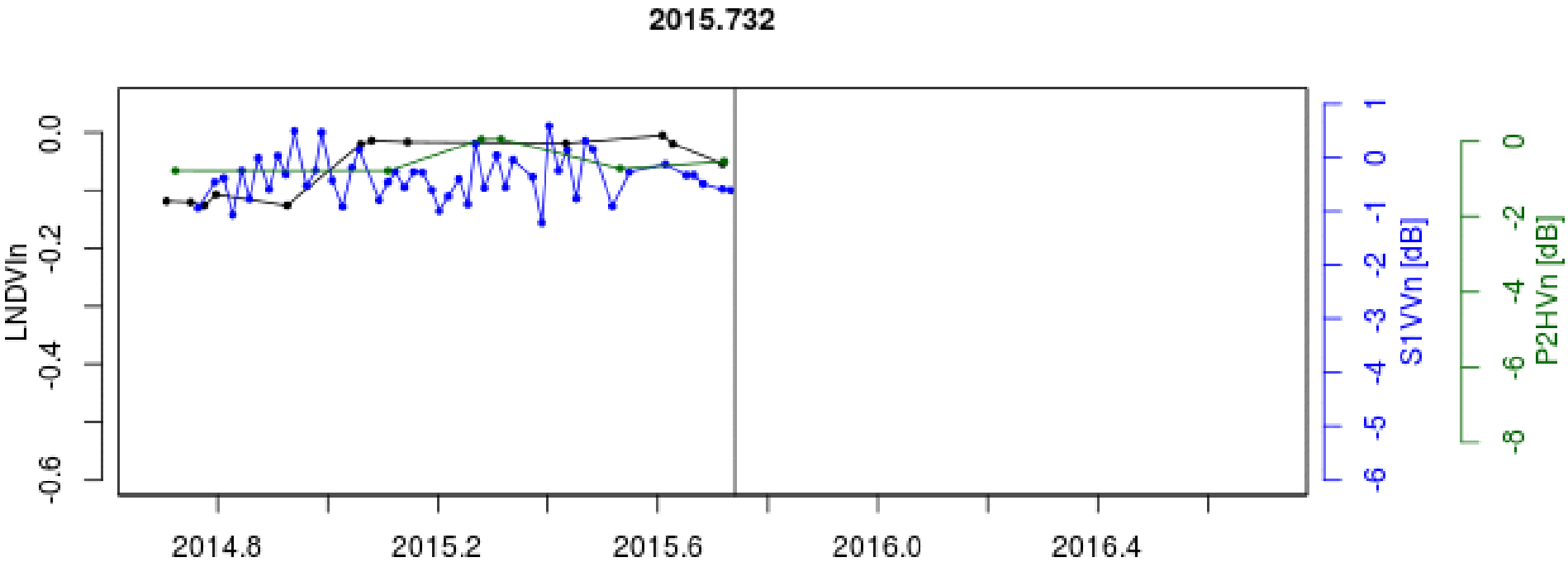
(Reiche et al. under review)

Results I: Single-pixel example



- Landsat
- Sentinel-1
- PALSAR-2

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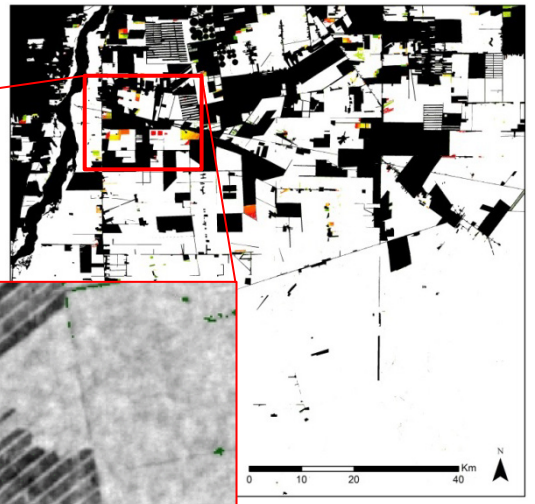
(Reiche et al. under review)

Detected deforestation
(10/2015 - 09/2016)

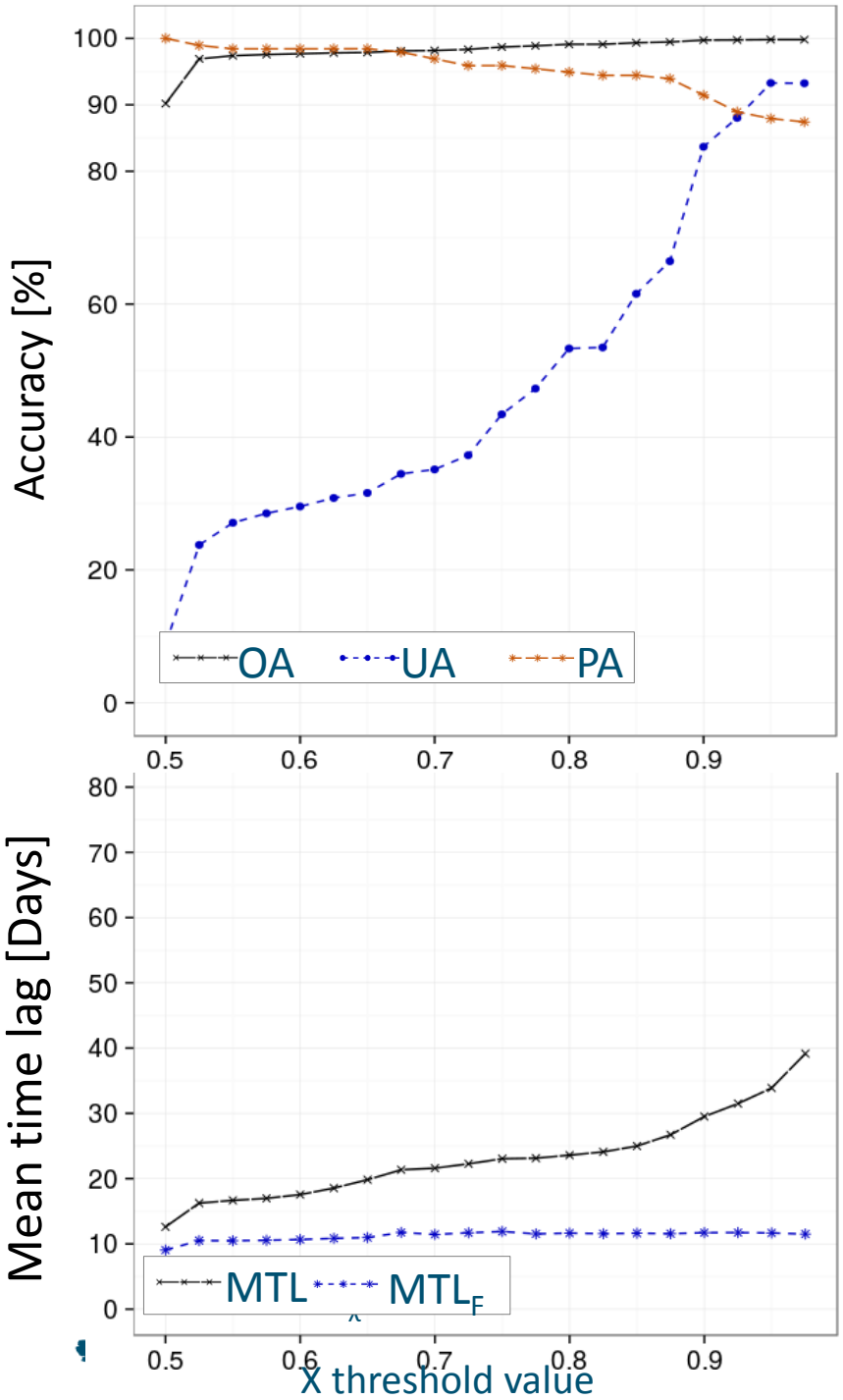


Temporal accuracy

(Mean time lag of confirmed changes)

Landsat	=	78 days
Sentinel-1	=	39 days
Multi-sensor	=	31 days

(Reiche et al. under review)

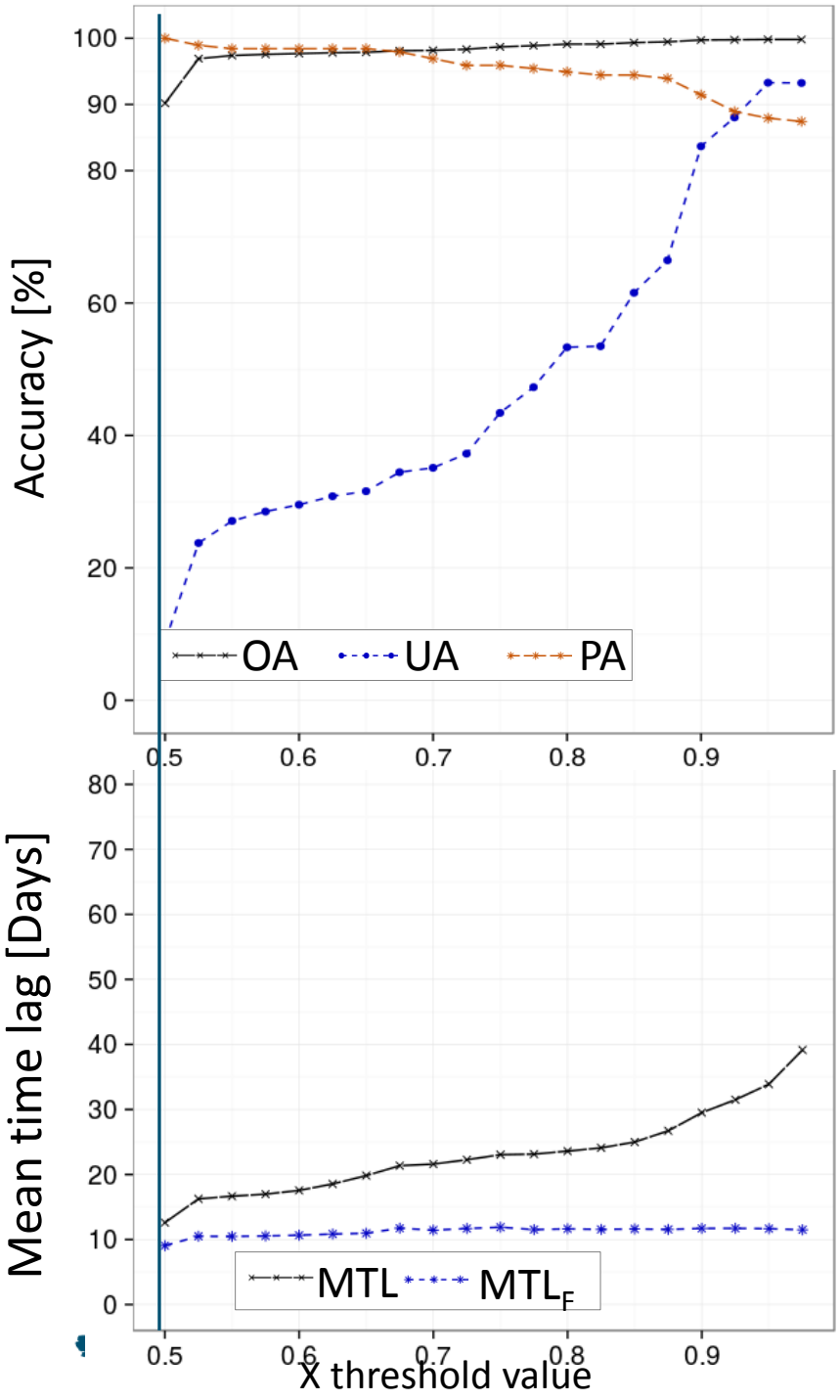


Assessing and understanding uncertainties and impact for users

- Spatial accuracy:
  - Overall accuracy (OA)
  - User accuracy (UA) & Producers accuracy (PA) of deforested class
- Temporal accuracy:
  - Mean time lag of flagged (MTL_F) and confirmed changes (MTL)

Which threshold value to select?

- Trade-off between UA, PA & MTL
- Strongly user driven choice

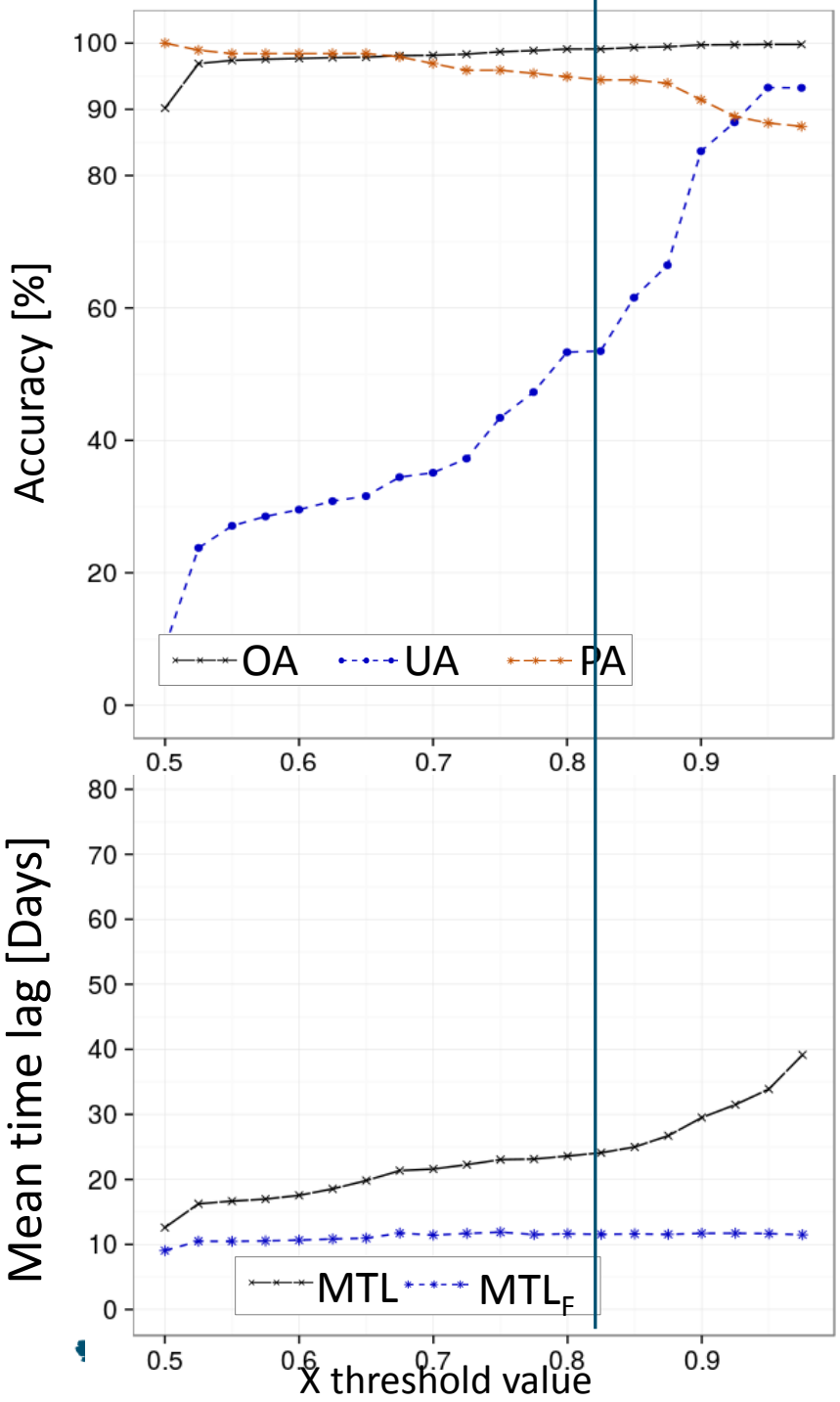


Use case I

Fast alerting

- Threshold value = 0.5

- Users A. = 9%
- Producers A. = 100%
- MTL = 12 days
- Area bias = +755 km²

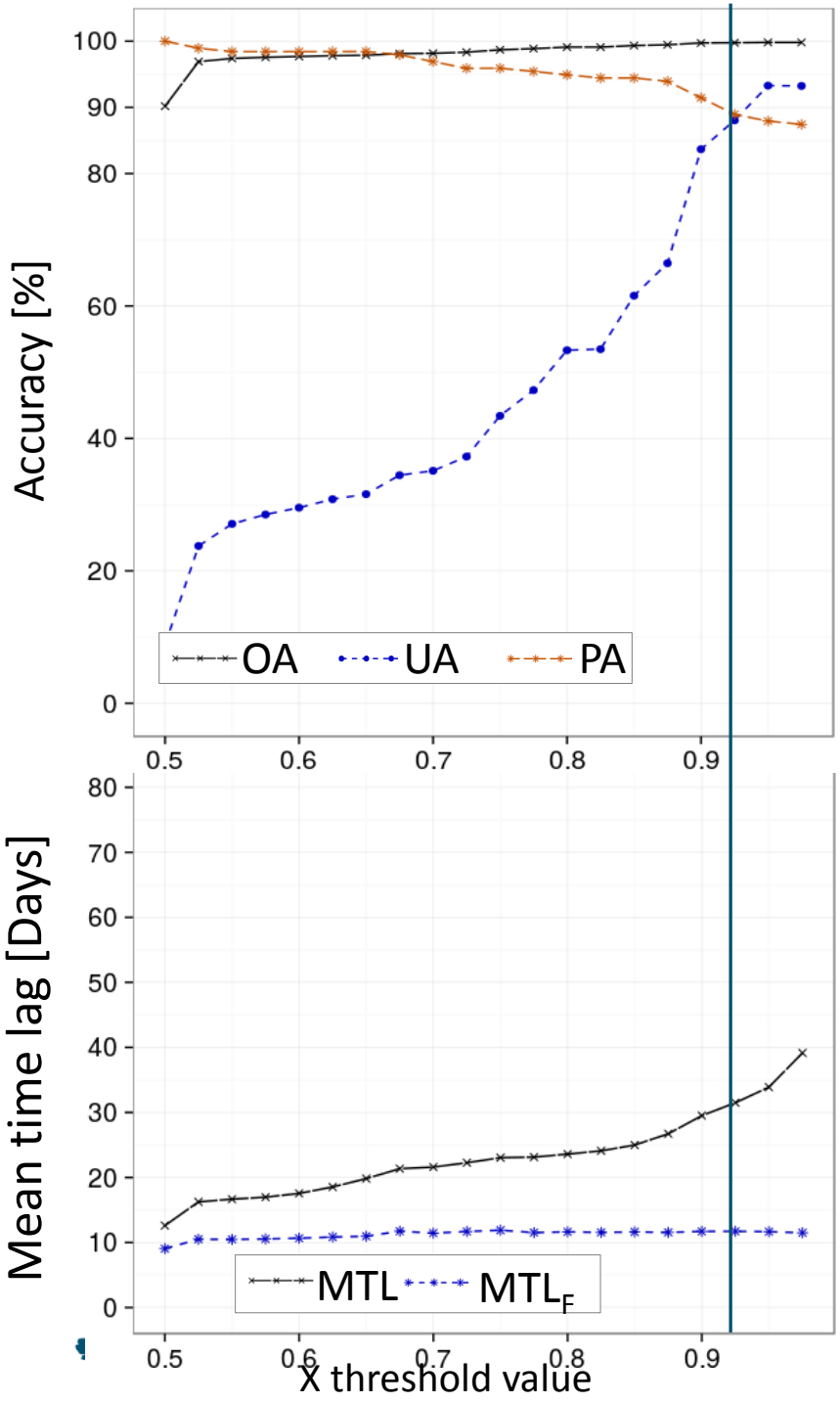


Use case II

Confident alerting

- Threshold value = 0.825

- Users A. = 54%
- Producers A. = 95%
- MTL = 22 days
- Area bias = +50 km²

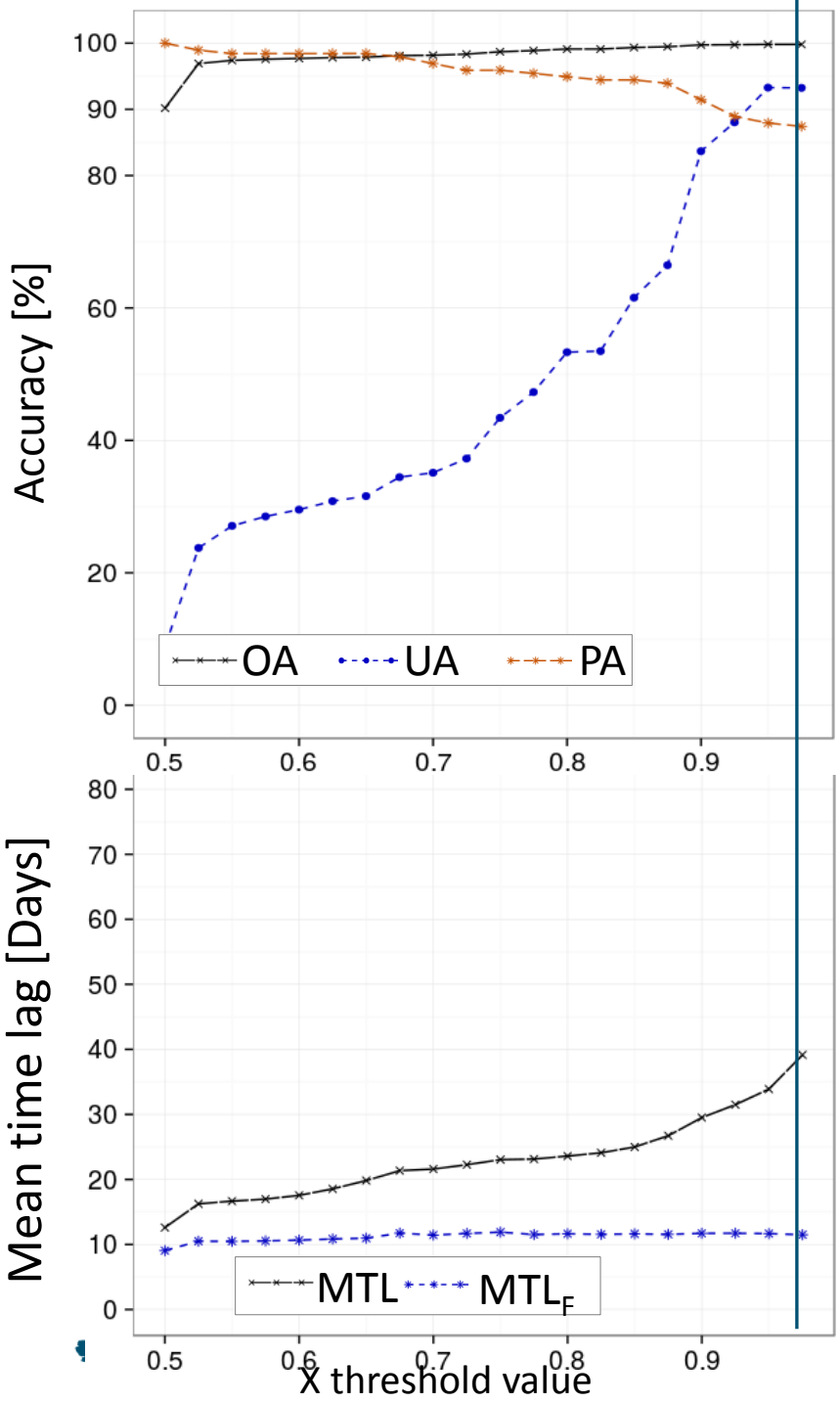


Use case III

Accounting of changes

- Threshold value = 0.925

- Users A. = 88%
- Producers A. = 89%
- MTL = 31 days
- Area bias = +0.4 km²



Use case IV

Target field surveys

- Threshold value = 0.975

- Users A. = 93%
- Producers A. = 88%
- MTL = 39 days
- Area bias = -9 km²

Some priorities

- Sensor interoperability & comparison work
  - Dense Sentinel-1 time series across tropics show great potential for regular and consistent sampling
  - Use of optical and SAR data in combination (the more observations the higher the temporal precision)
  - Integration with higher-resolution data (targeted sampling) i.e. Planet, TerraSAR-X etc.
- Development and integration of open-source tools in operational environments (i.e. GFW)
  - Rapid development for Radar pre-processing (i.e ESA-SNAP)
  - Open source near-real time algorithms (i.e. Bayts package on github)
- Ambitions for a GFOI ALERT activity
  - Moving targeted R&D into operational practice
  - Synthesis of various data sources and approaches available
  - Use-case driven analysis of uncertainties towards specific solutions