Can we use Spot 5 Take 5 to monitor dissolved organic carbon in the Arctic river Yenisei ?

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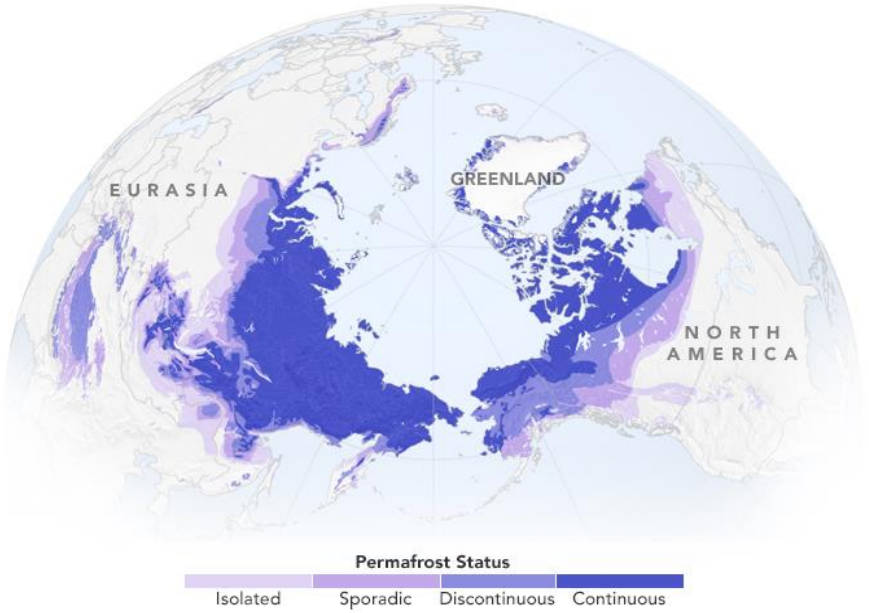
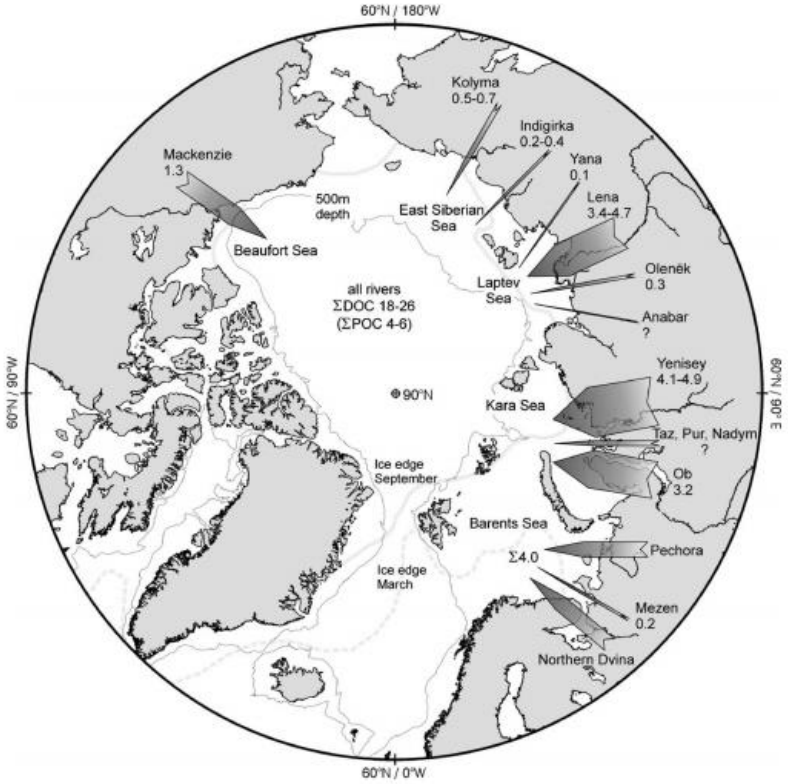
Context





✓ + 5°C in high-latitudes
✓1/3 of the organic carbon in permafrost

✓ organic carbon drained by great Arctic rivers → dissolved organic carbon (DOC)
✓Yenisei river is the greatest contributor to Arctic Ocean

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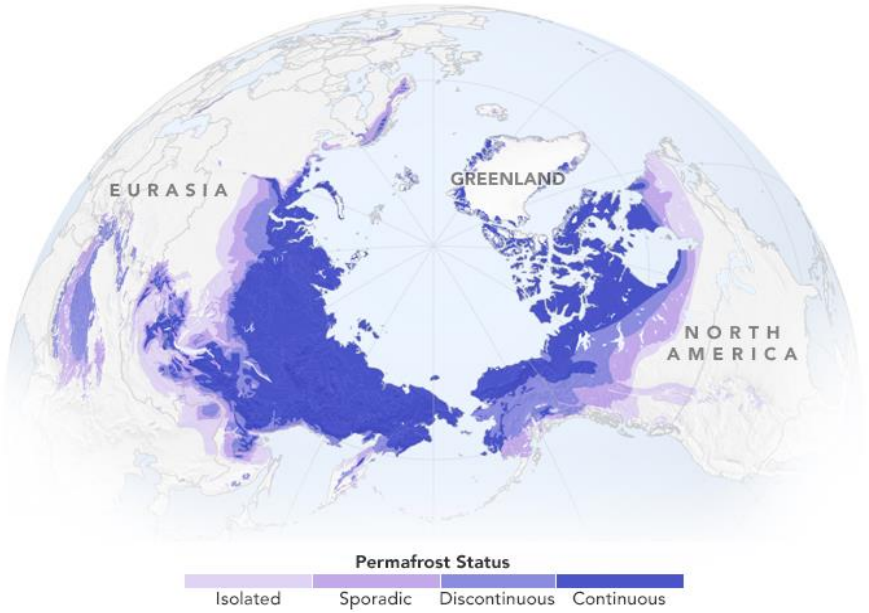

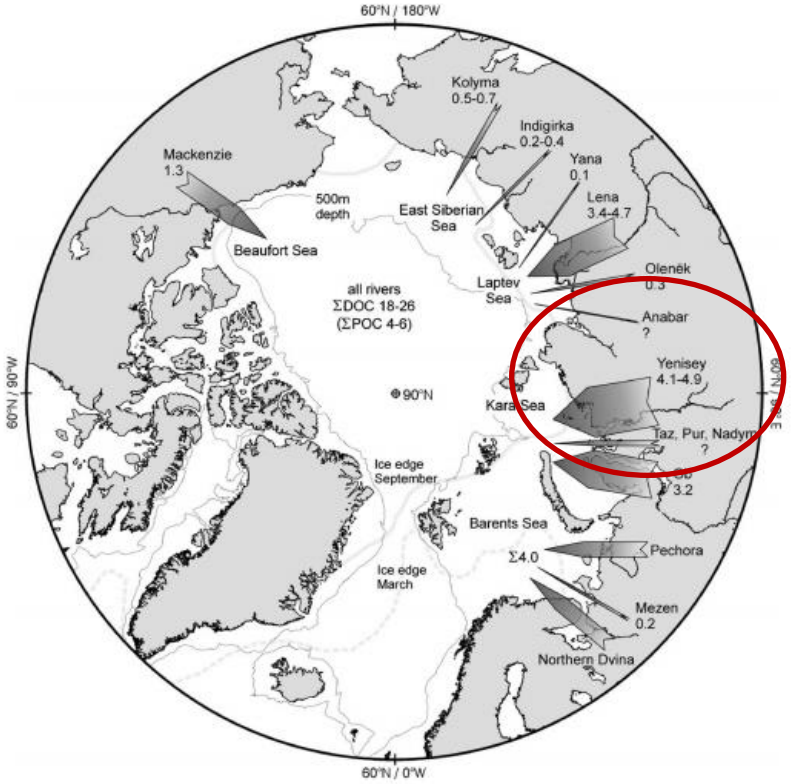

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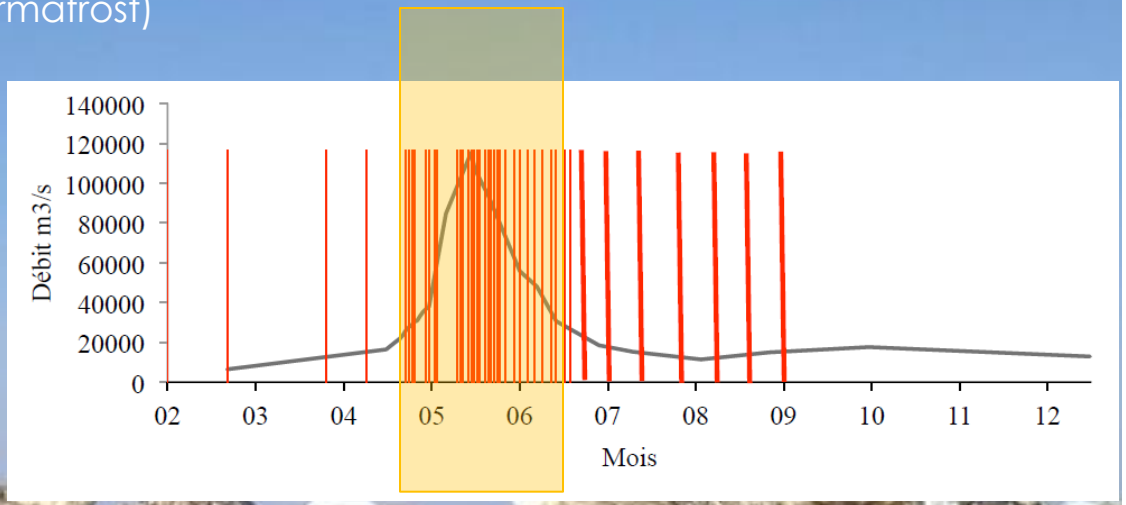

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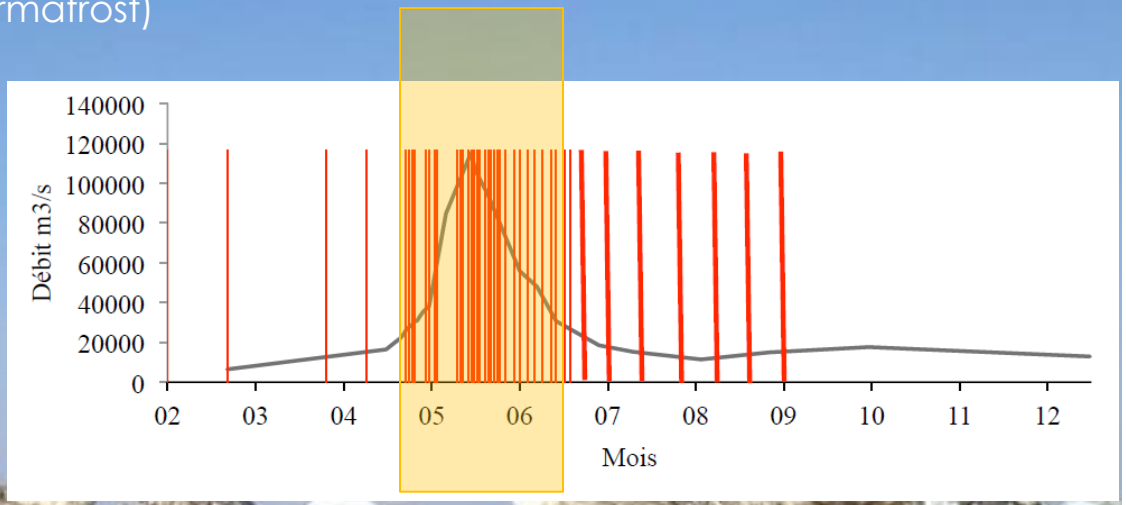

- ✓ 80 % of DOC fluxes in the peakflow period
- ✓ Logistical problems to sample DOC
  - ✓ Remaining ice-breaks
  - ✓ Very short-period (a few weeks in May and June)

- ✓ Lack of knowledge on DOC spatial patterns at largest scales and on DOC temporal dynamics

Context – Remote sensing could be a precious tool

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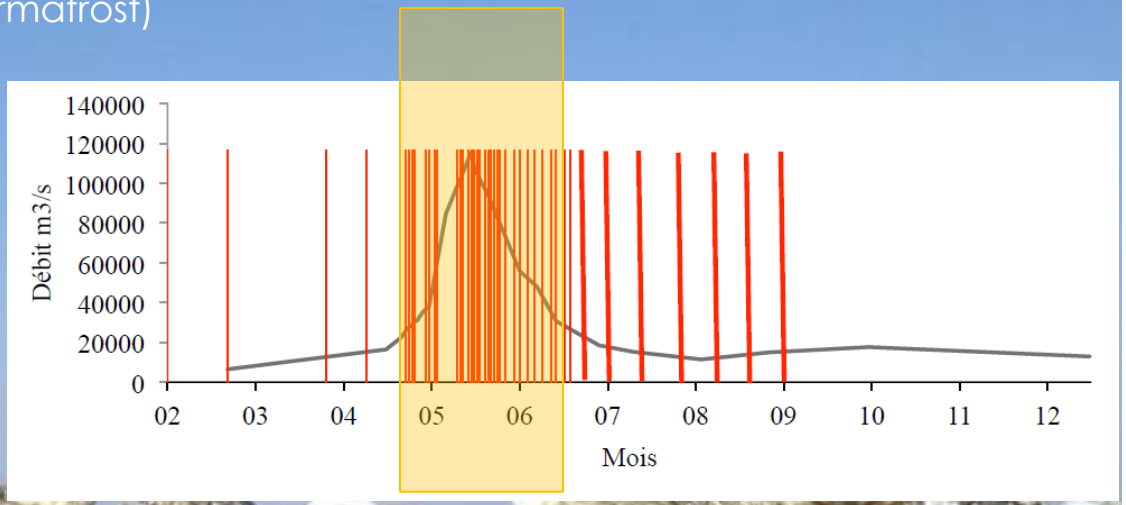

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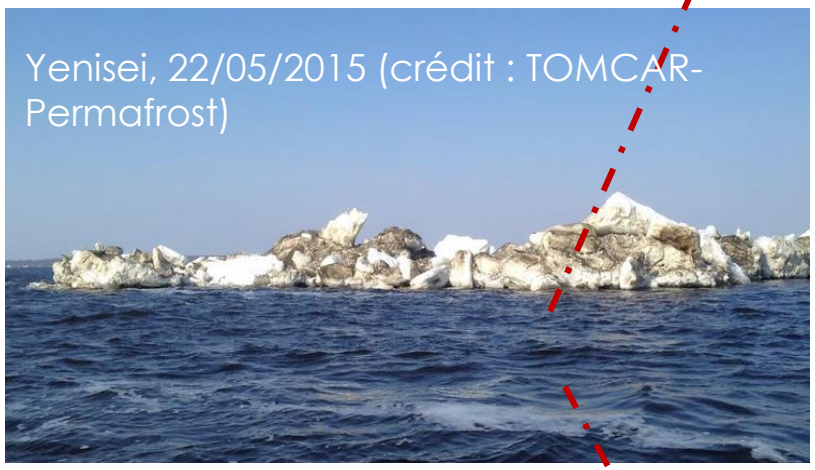
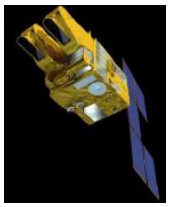
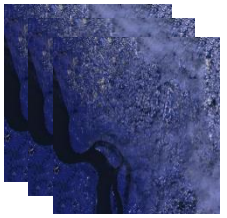


Satellite acquisitions



Optical satellite images

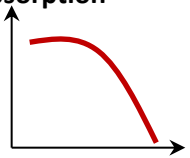


DOC retrieval

2nd statistical relationship

1st statistical relationship

In situ DOC measurements



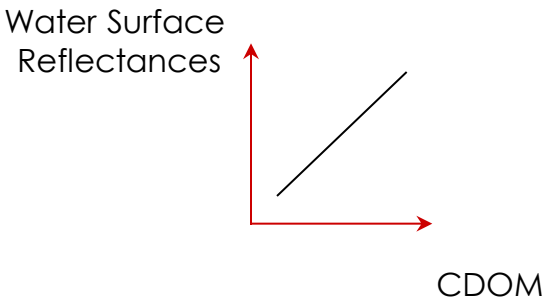
CDOM measurements

Background

✓ Numerous CDOM retrieval algorithm have been developed in oceans, lakes and more recently on Arctic rivers (for a review : Zhu et al, 2014; Brezonik et al, 2015)

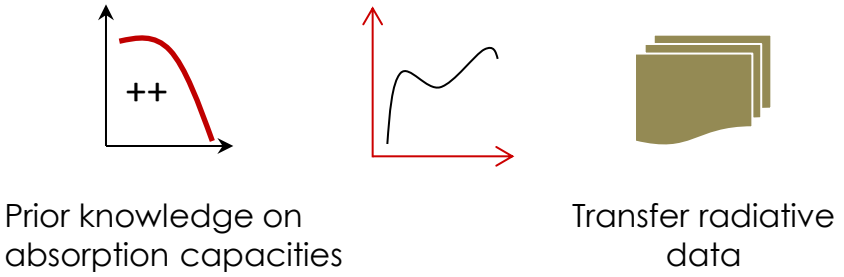
✓2 major approaches to explore relationships between CDOM and optical signal

Empirical models



✓Easy to calibrate
✓Current problems of linear regression(outliers, overfitting)

Process-based model



✓ Best description of the processes
✓ Input data rarely available

Background

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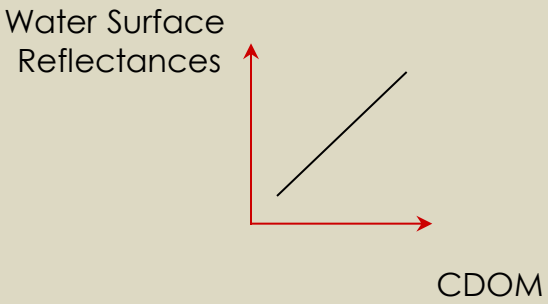
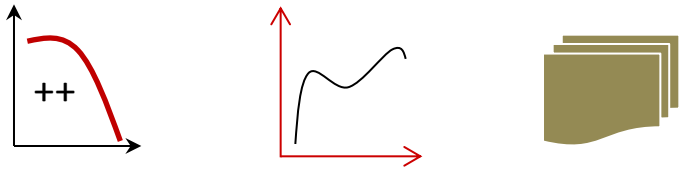
Empirical models



✓ Geographic-area dependent
✓ Spectral band combinations are effective (band ratio or band multiplication)
✓ namely shorter and longer wavelengths combination

Process-based model



Prior knowledge on absorption capacities

Transfer radiative data

Issues

✓ Low- spatial resolution sensors are effective to monitor CDOM in oceans or lakes but high-spatial sensors are more suited for Arctic rivers :

→ to evaluate **the spatial heterogeneity of DOC**

→ to characterize the river **during the ice-break period or between clouds**

→ for **their atmospheric corrections**

✓ Available high- spatial resolution sensors (Landsat, Spot) have a too low repeat-cycle orbite :

→ to evaluate **DOC dynamics in the freshest period**

→ to have an **acceptable number of spatial acquisitions**

Goals

✓ Developing a CDOM algorithm retrieval at high spatial and temporal resolution to :

→ to evaluate the **DOC dynamics during the open water season** with a special focus on **the freshest period**

→ to evaluate **the spatial heterogeneity of DOC** in the river channel

✓ Specific objectives are :

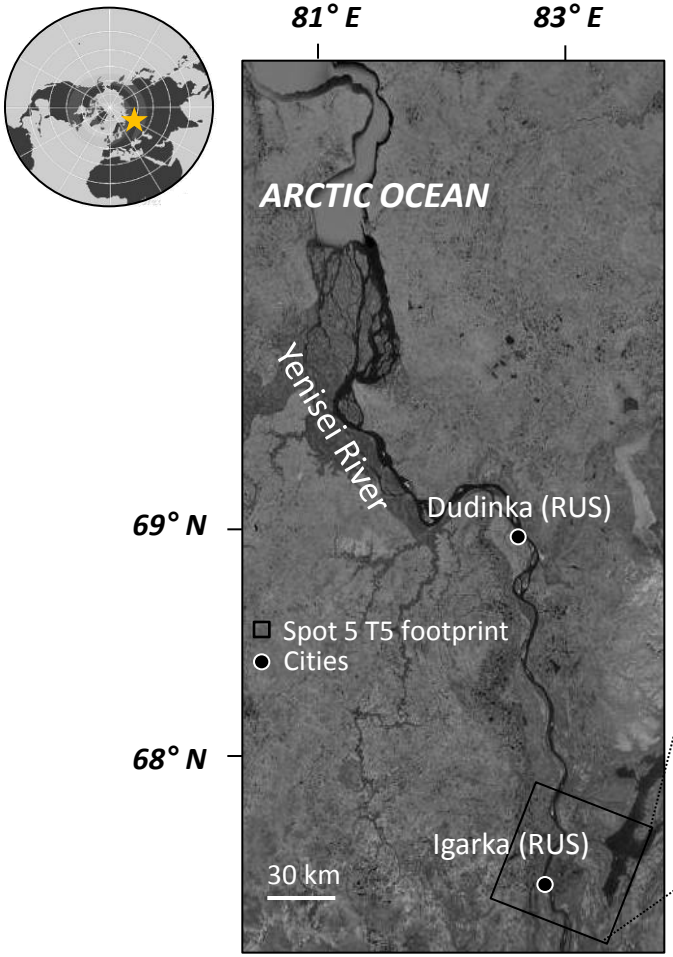
→ finding an optimal **spectral bands configuration**

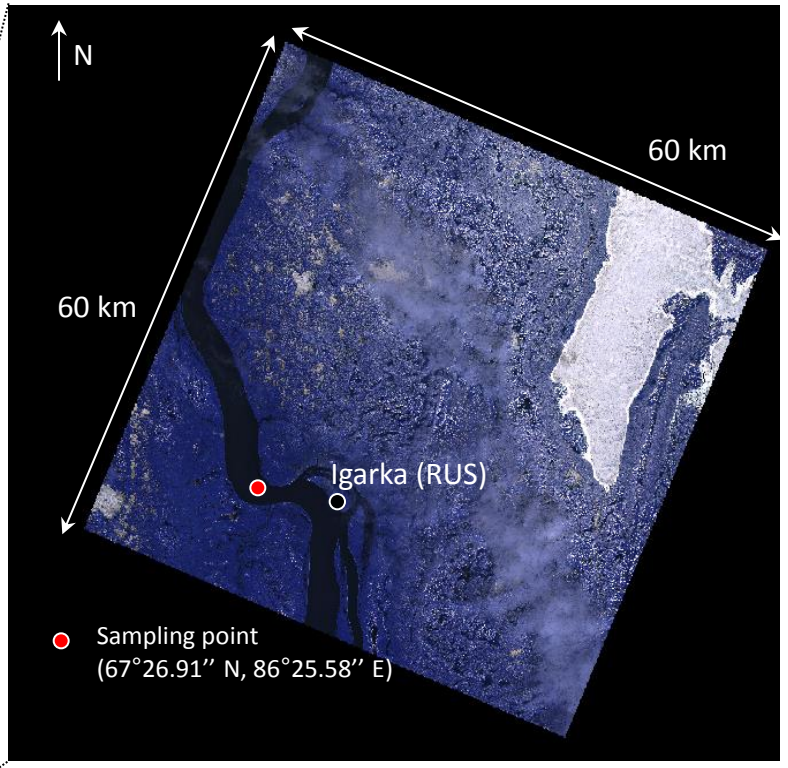
→ evaluating **the predictive performance** of the developed model

→ discussing **the potentiality of high spatio-temporal optical remote sensing**

→ Preparation for Sentinel 2 data

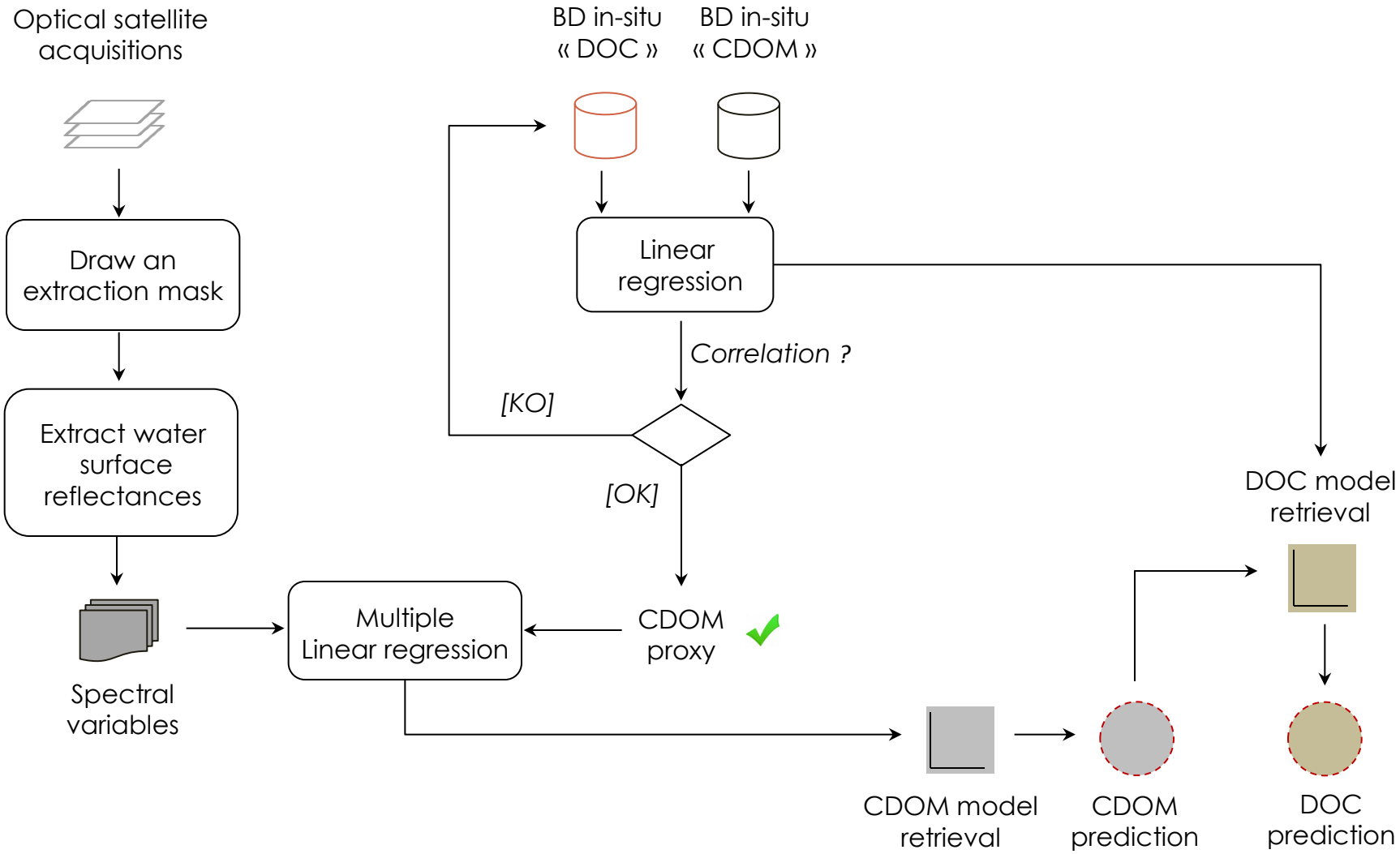
Study site – Yenisei river (Igarka – Take 5 Site)





- ✓ discontinuous permafrost
- ✓ high-flow period lasts from mid-May to mid-July
- ✓ Peak-flow period in late May-early June

Methodological flowchart



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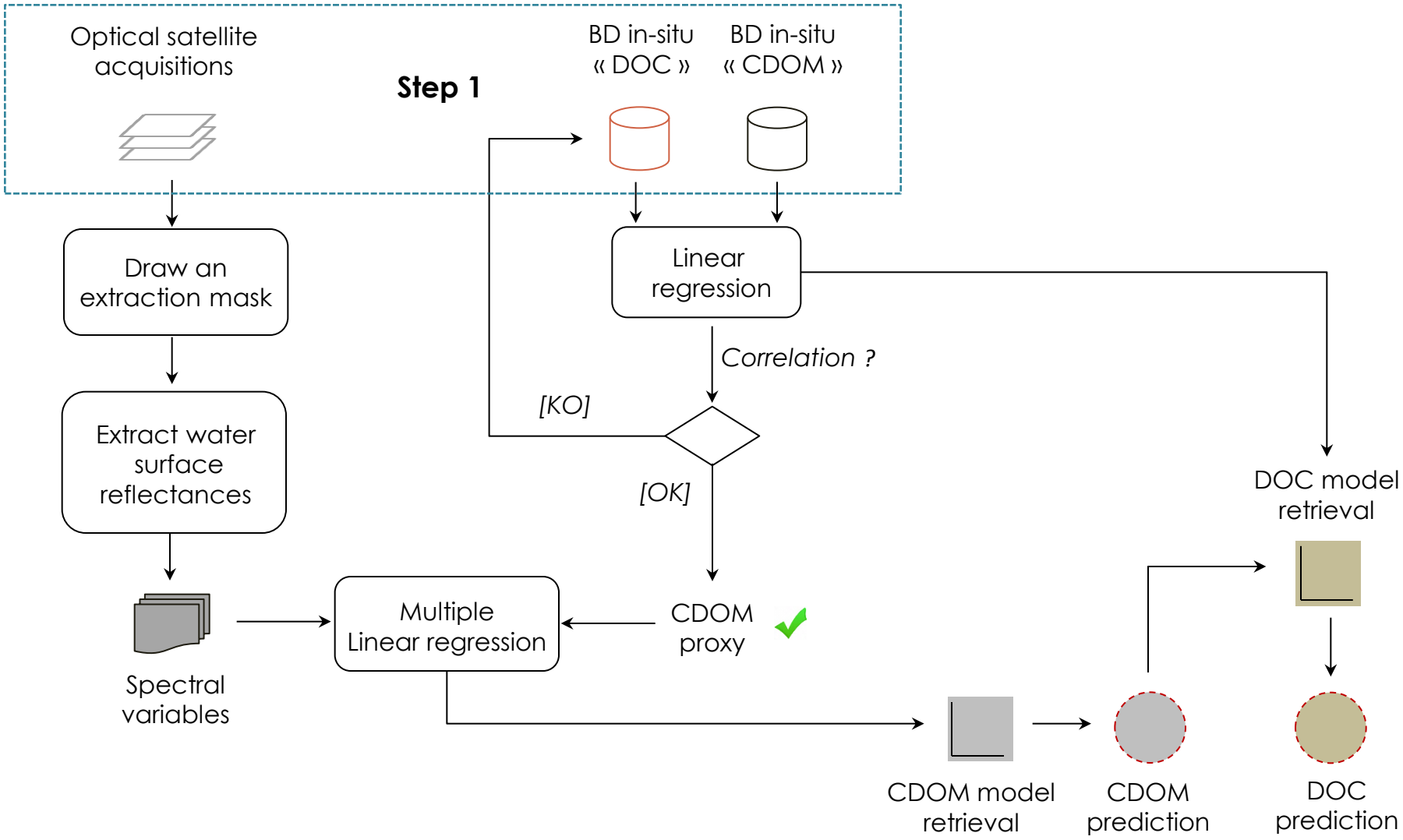

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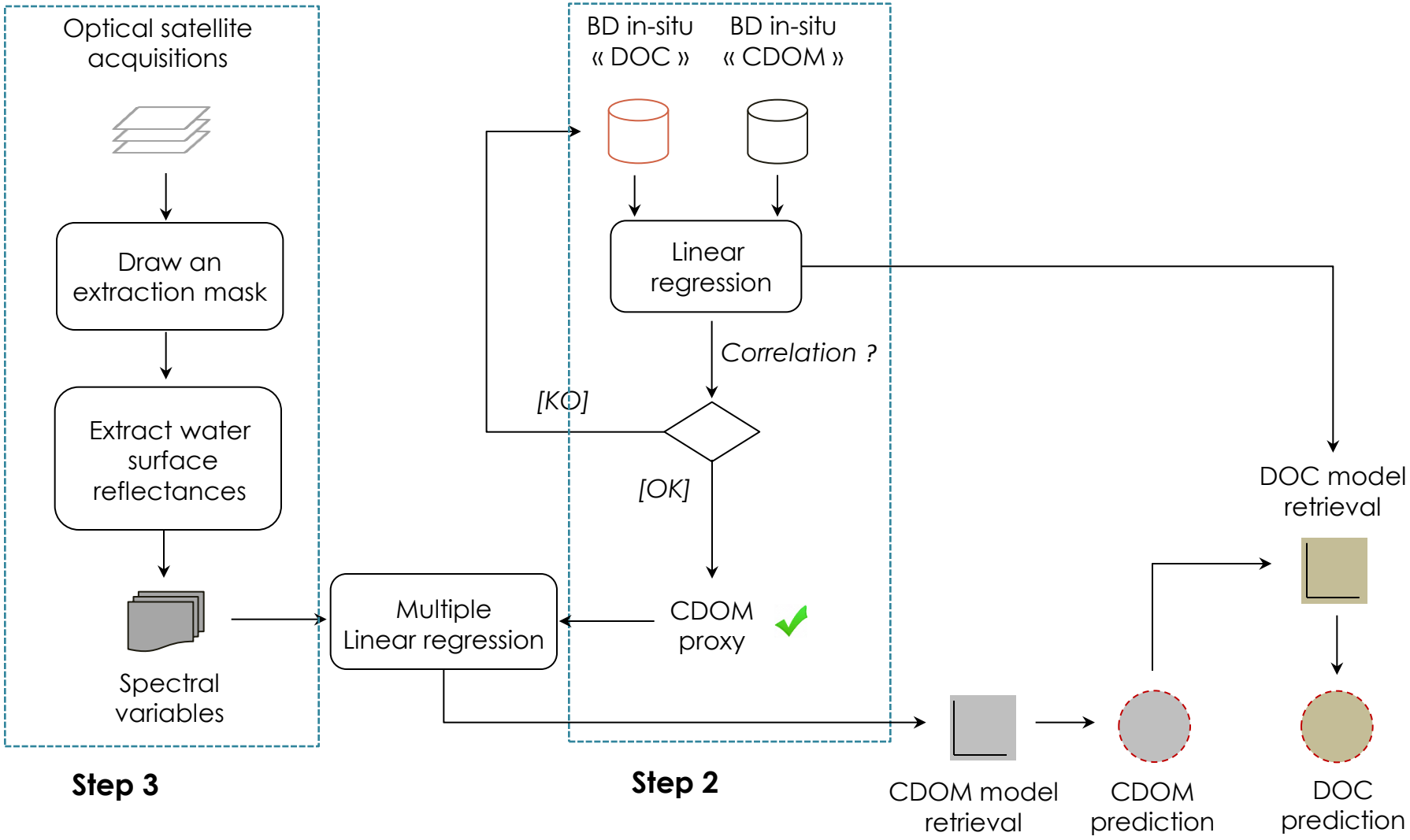

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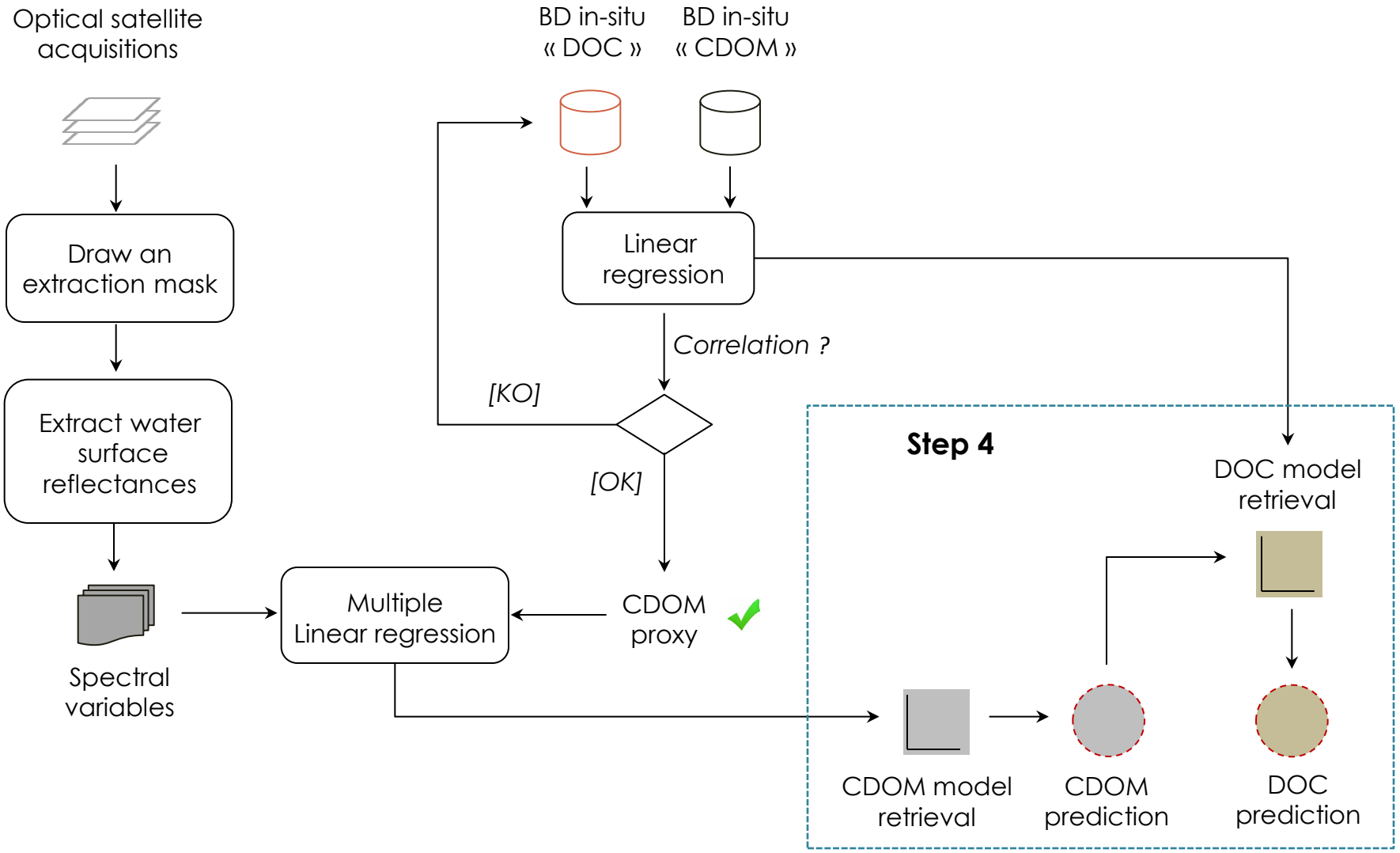

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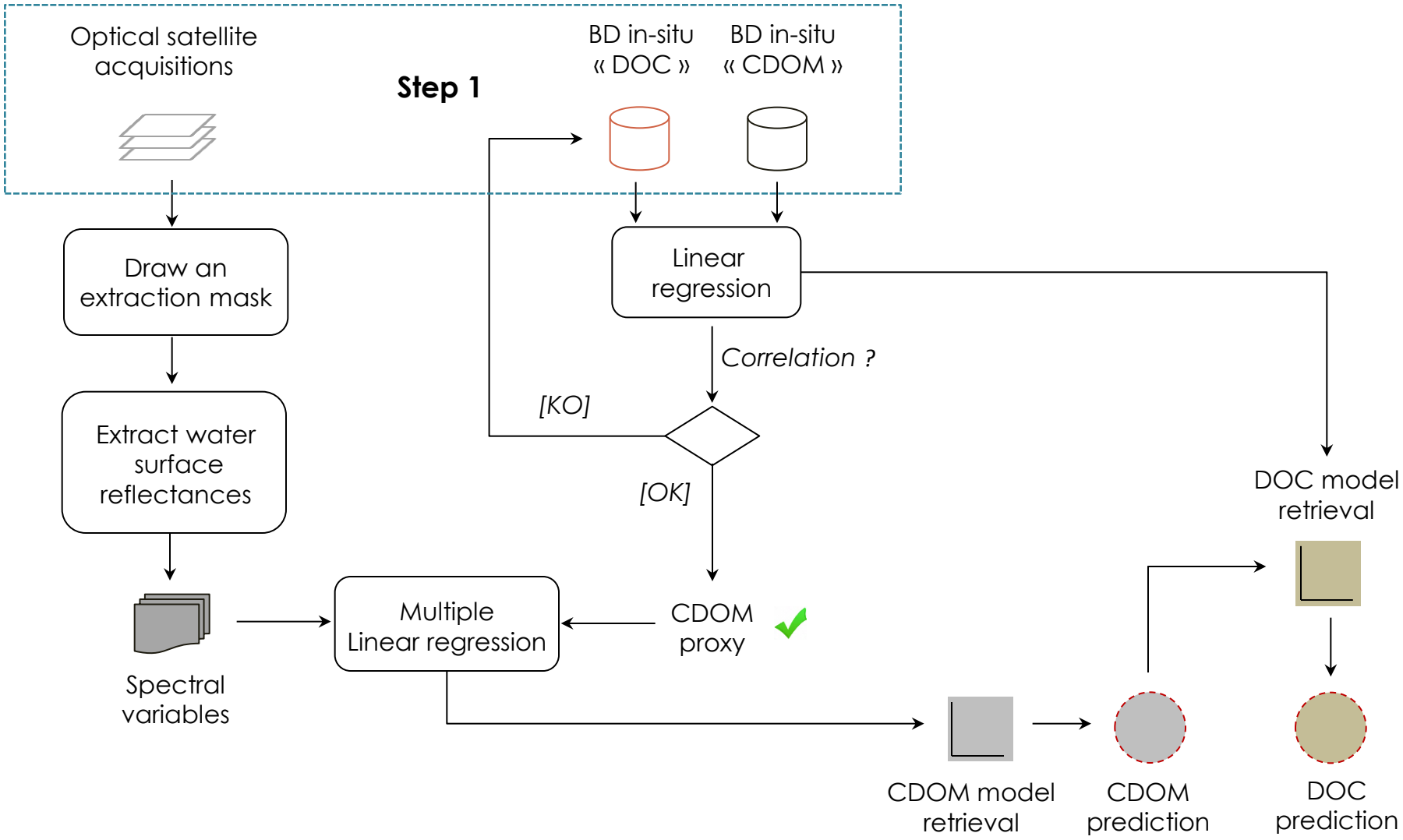
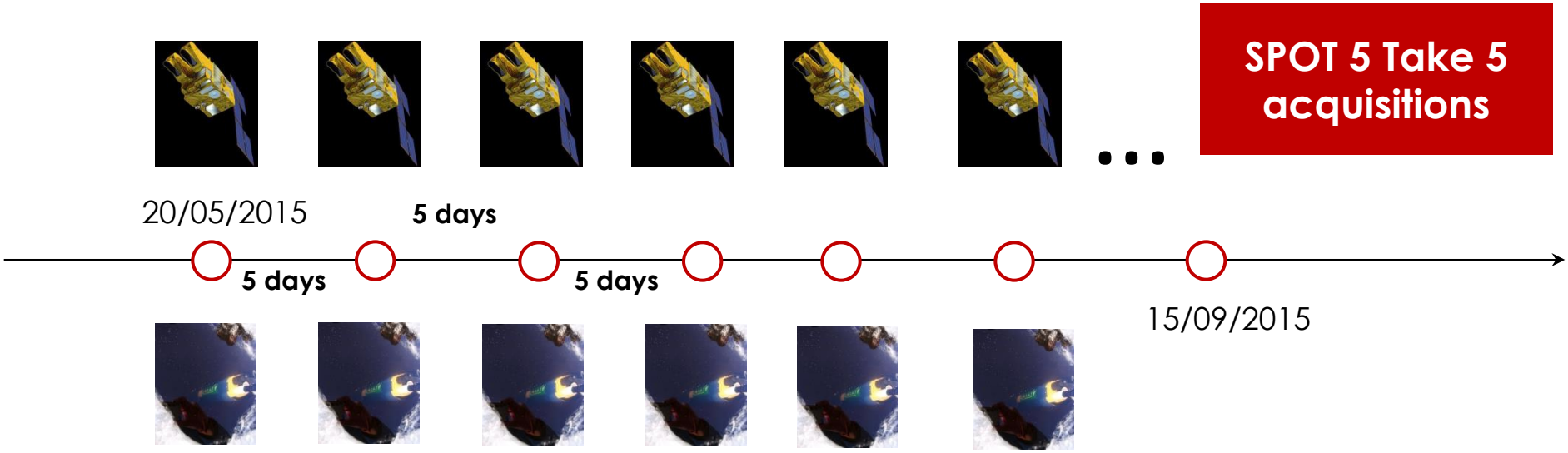


Synchronisation of in-situ measurements and Spot 5 Take 5 acquisitions



- ✓ 25 ST5 scenes from 09/04/2015 to 06/09/2015
- ✓ 41 field-samples in 2014 and 28 in 2015 (DOC, CDOM, TSS)

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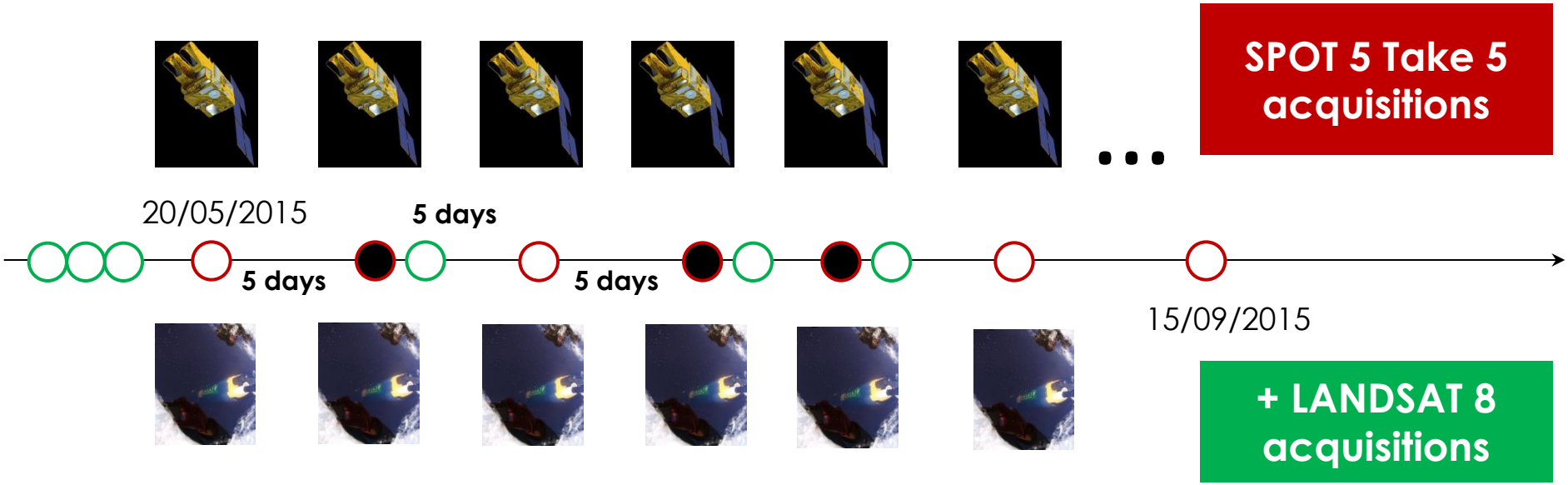

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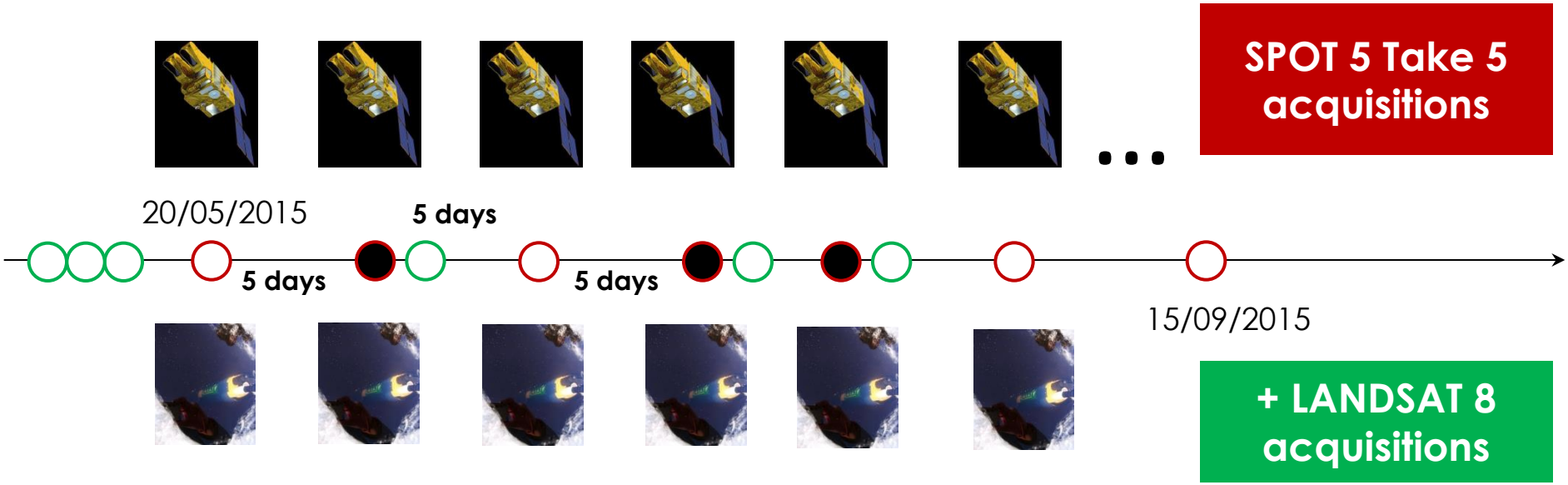


- ✓ 25 ST5 scenes from 09/04/2015 to 06/09/2015
- ✓ 41 field-samples in 2014 and 28 in 2015 (DOC, CDOM, TSS)

- ✓ Only 6 ST5 scenes and 6 L8 scenes selected (clouds, hazing effects, acquisitions during the ice-period, too large gaps)
- ✓ 6 dates during the peakflow period (namely 22/05)

Time-series

L8 (22/05) ST5 (03/06) ST5 (18/06) ST5 (11/07) L8 (22/07) L8 (08/08) L8 (08/09)

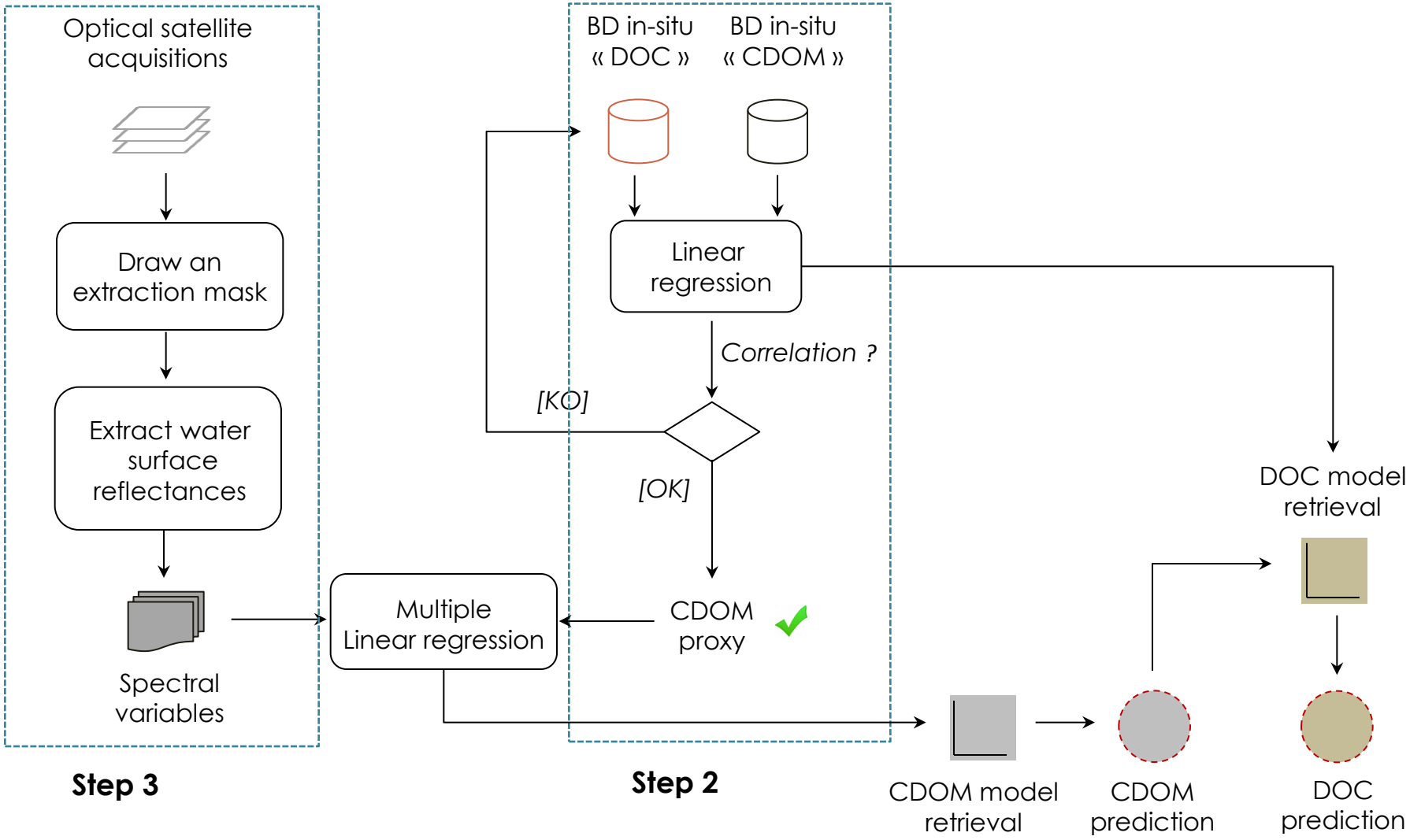
Image corrections

- ✓ Surface reflectance products were used
  - ✓ MACCS processor (Hagolle et al, 2015)
  - ✓ L8SR (L8SR Product Guide)

Field sample treatments

- ✓ Field measurements concern DOC (mg/L), CDOM (m^{-1}) and TSS (mg/L)
- ✓ Absorbance at 440 nm was chosen (Brezonik et al, 2015)

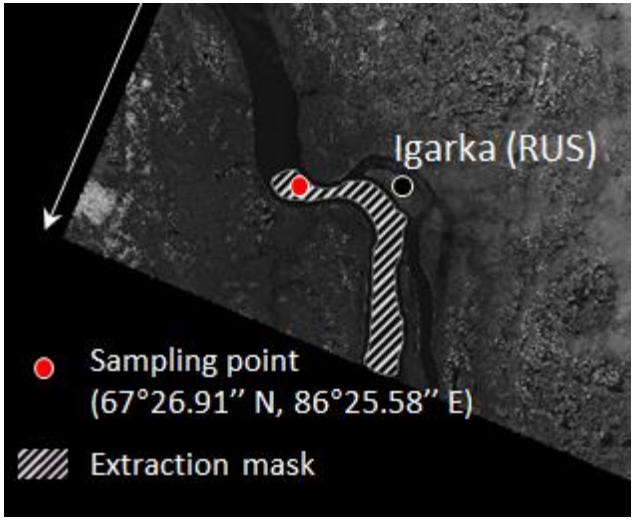
Methodological flowchart



CDOM as a proxy to retrieve DOC concentrations ?

✓ All field-samples were used (N = 69)

✓ Goal : More robust statistical relationship



Extraction of water surface reflectances

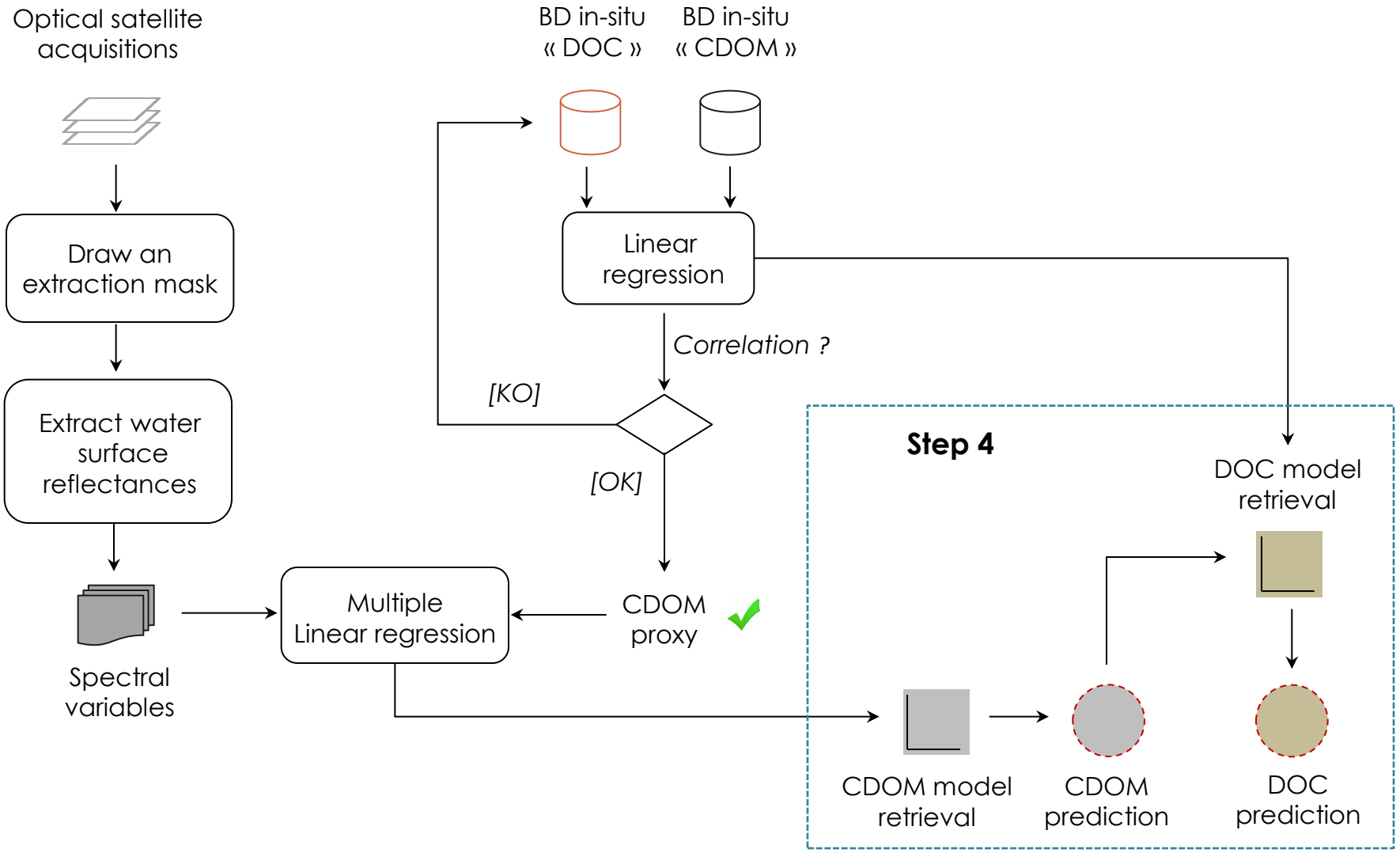
✓ A water extraction was defined :

- ✓ 15 km North-South
- ✓ from 300 m to river banks

✓ Goal : increasing the possibility to have cloud-free pixels

✓ [Min, max, mean, std] in Green and Red channels of each spatial scene

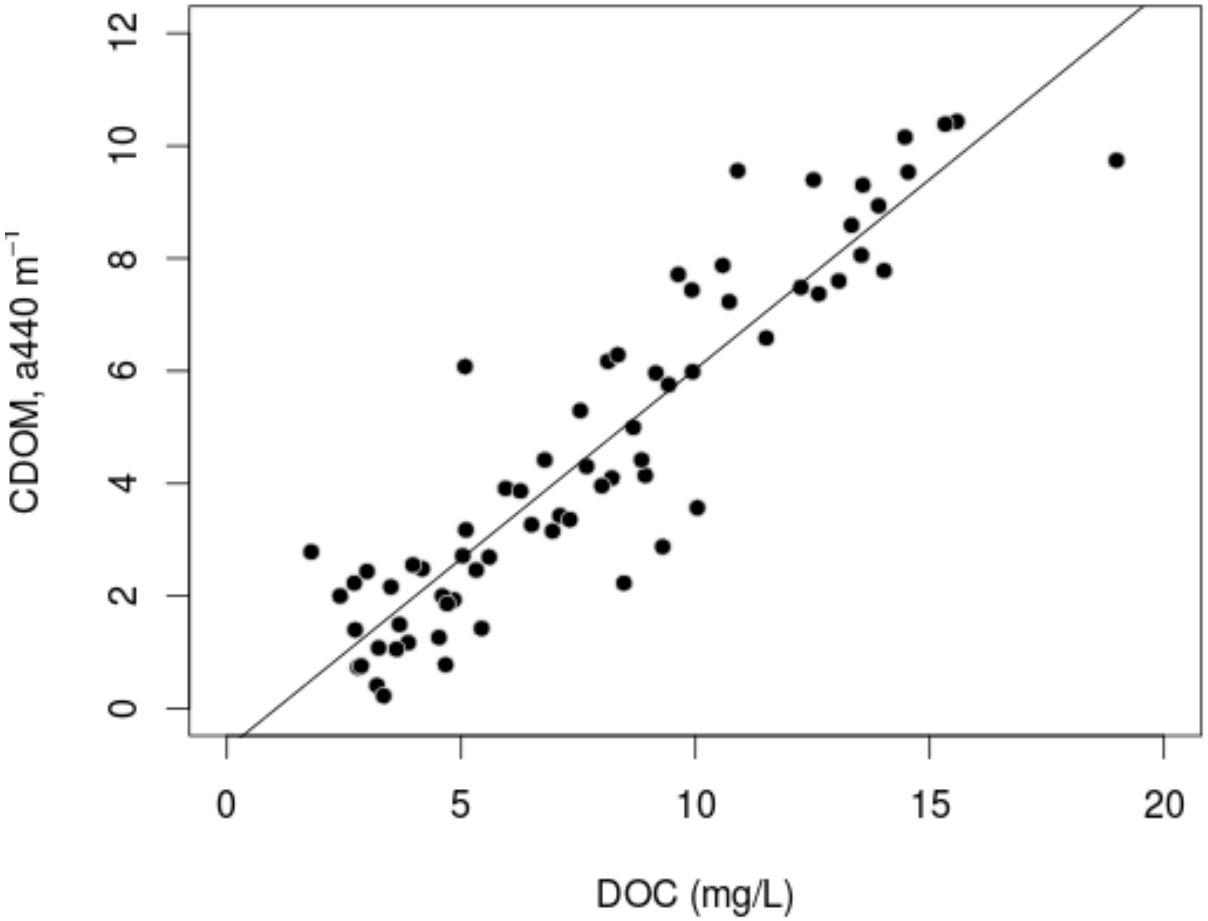
Methodological flowchart



CDOM algorithm development and statistical analyses

- ✓ Based on existing models developed for oceans, lakes or rivers
  - ✓ Kutser (2005) on Swedish lakes
    - → green-red ratio
  - ✓ Griffin (2011) on Kolyma river (Northern-Siberia)
    - → green-blue ratio + red
- ✓ Spectral band multiplications were also tested (interaction term)
- ✓ Goodness of fit was examined with R^2 and Root Mean Square Error (RMSE)

CDOM can be used as a proxy to retrieve DOC concentrations in the Yenisei river

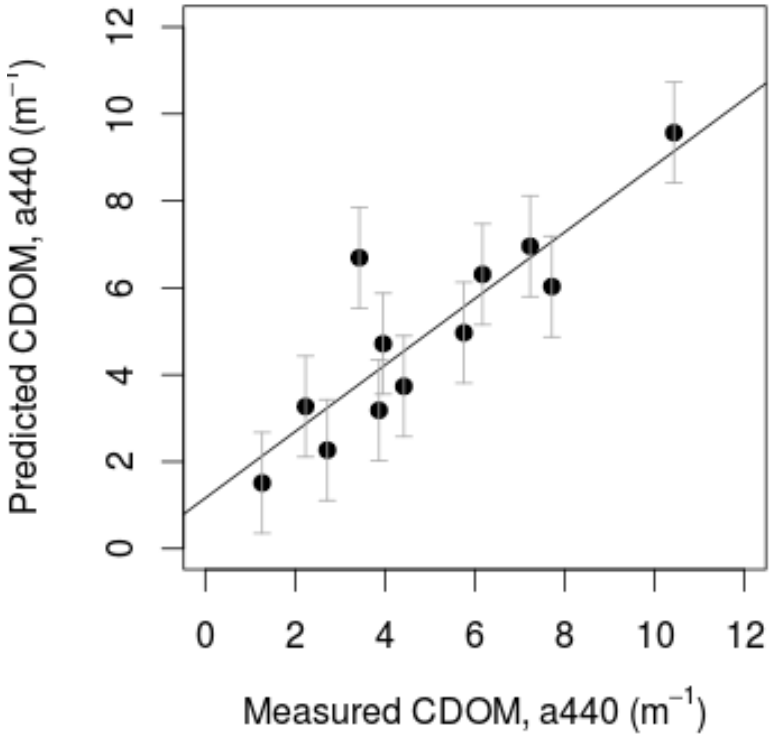


R2 = 0,84
$p < 0,001$
N = 69

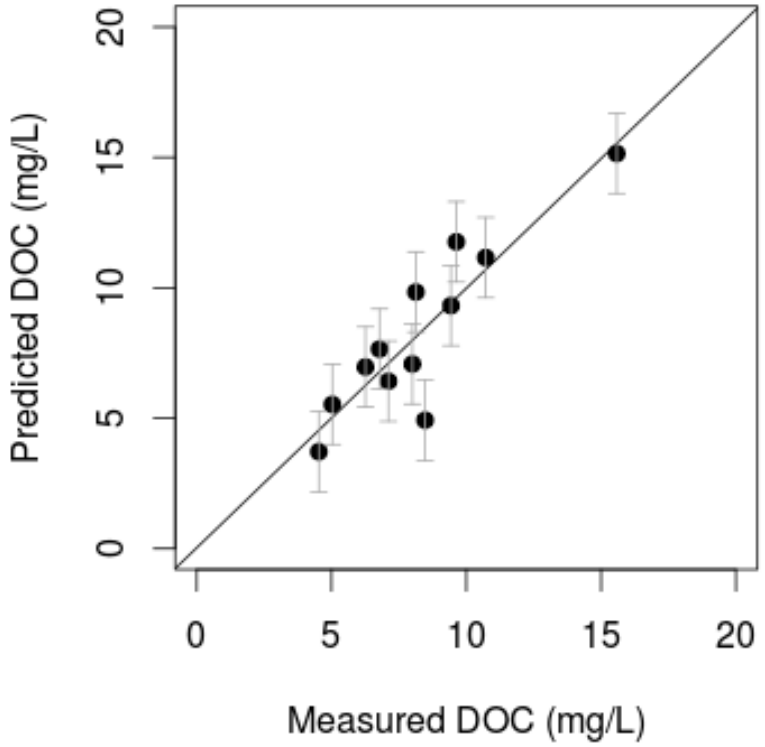
The CDOM model developed shows high performances

CDOM = -681,4*[Green] + 16410,9*[Green:Red]

R2 = 0,76 $p < 0,001$
RMSE = 1,2 N = 12



R2 = 0,79 $p < 0,001$
RMSE = 1,4 N = 12



Shorter and longer wavelengths interaction to retrieve DOC concentrations

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- ✓ TSS strongly reflects light in red band

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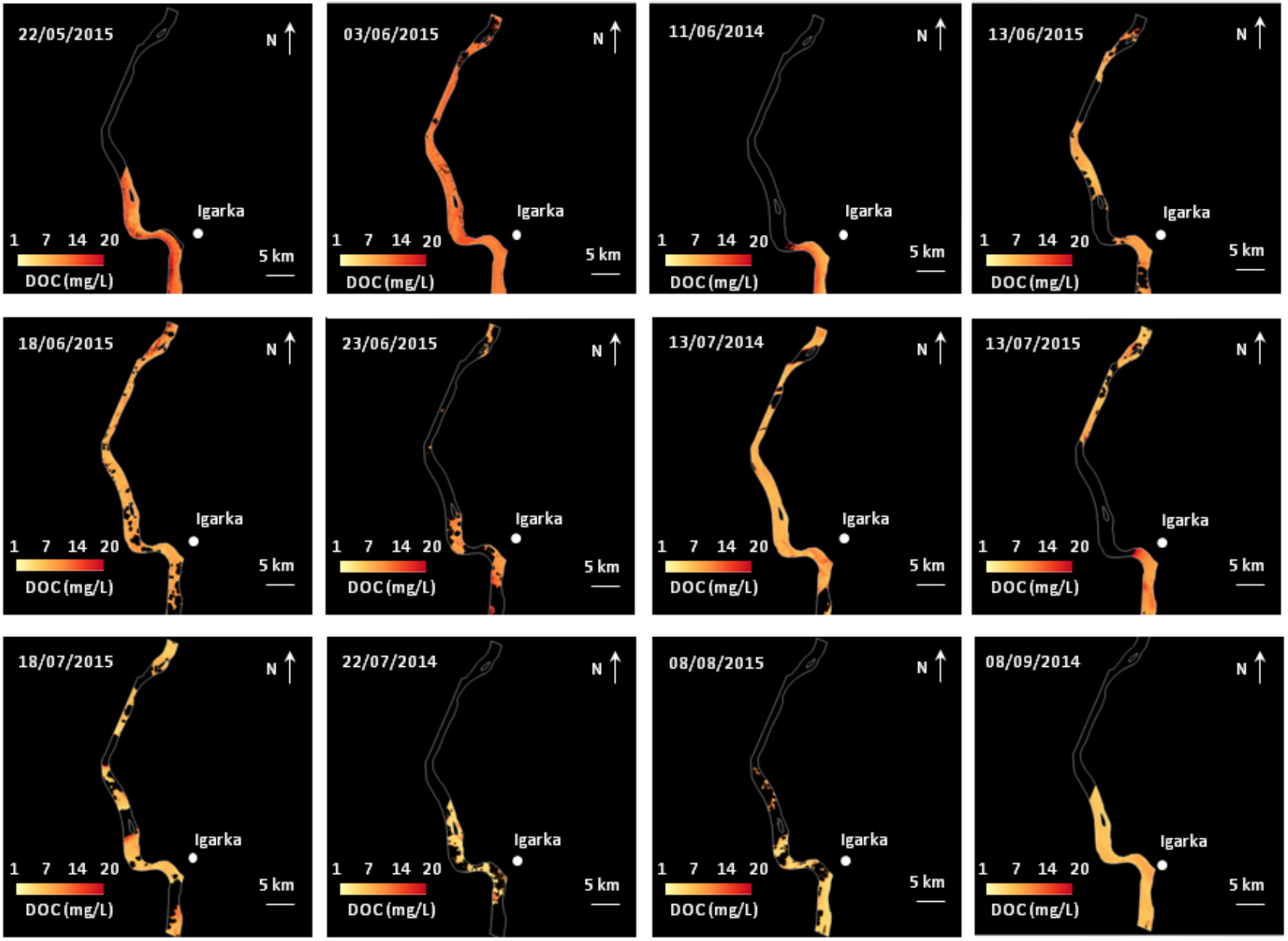
- ✓ TSS strongly reflects light in red band

→ For high values of TSS (> 15 mg/L) , statistical relationship between shorter wavelengths and CDOM is noised


22/05/2015
03/06/2015
11/06/2014
13/06/2015
18/06/2015
23/06/2015
13/07/2014
13/07/2015
18/07/2015
22/07/2014
08/08/2015
08/09/2014
N
Igarka
1 7 14 20
DOC (mg/L)
5 km

If combined with high-spatial resolution, multi-temporal remote sensing data are precious to retrieve DOC in Arctic rivers

- ✓ DOC evaluations :
  - ✓ To evaluate DOC in a hot-moment
  - ✓ To evaluate the spatial variability of DOC at largest scales
- ✓ Methodologically
  - ✓ To increase the possibility to have cloud-free scenes
  - ✓ To select pixels between cloud or ice-breaks
  - ✓ To apply more accurate atmospheric corrections

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Sentinel 2/Landsat 8 synergies are promising to retrieve DOC in Great Arctic Rivers

Conclusion

- ✓ An effective CDOM retrieval algorithm with six dates in the freshest period
- ✓ Additional dates in the model will be needed (only 12 dates)

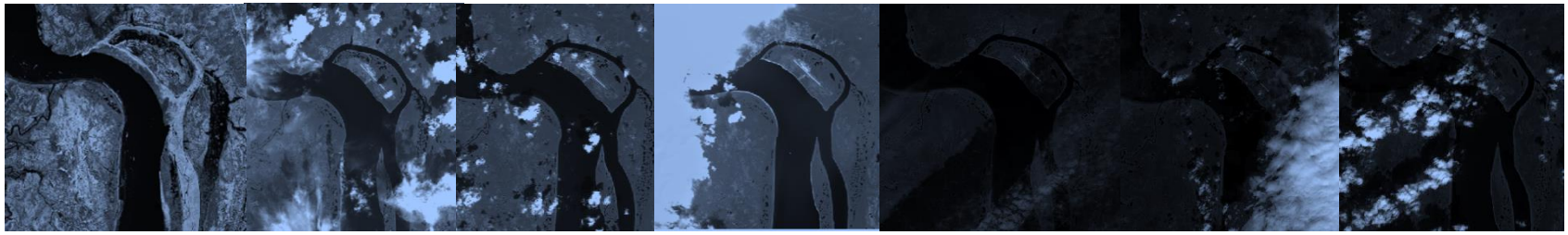
- ✓ Shorter and longer wavelengths combinations are powerful
- ✓ Potential TSS perturbations have to be taken into account

Perspectives

- ✓ Low and High spatial resolution could be complementary
- ✓ Sentinel 2 acquisitions in Igarka :

→Surface reflectance products will be delivered
→New field campaigns will be drived
→Further studies are coming…

Thanks!



Questions ?