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A sub-pixel resolution enhancement model for multiple-resolution multispectral images

Nicolas Brodu, Dharmendra Singh, Akanksha Garg

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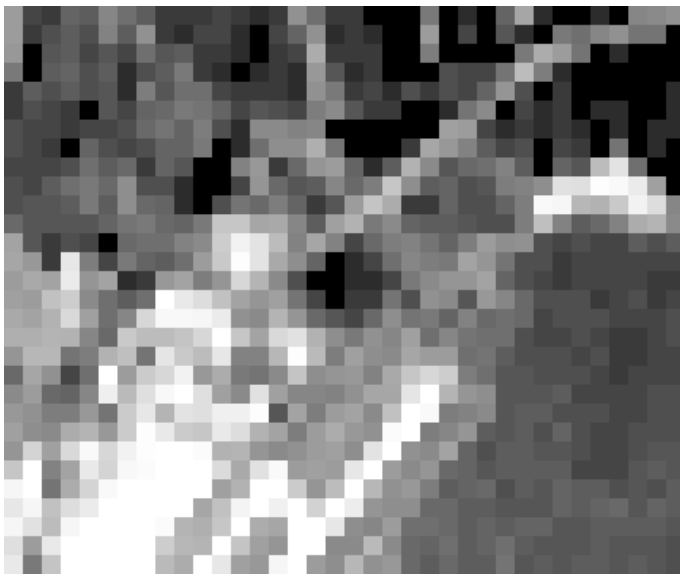
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SUPER-RESOLUTION OF SENTINEL-2 MULTISPECTRAL IMAGES

N. Brodu, Inria Bordeaux, France

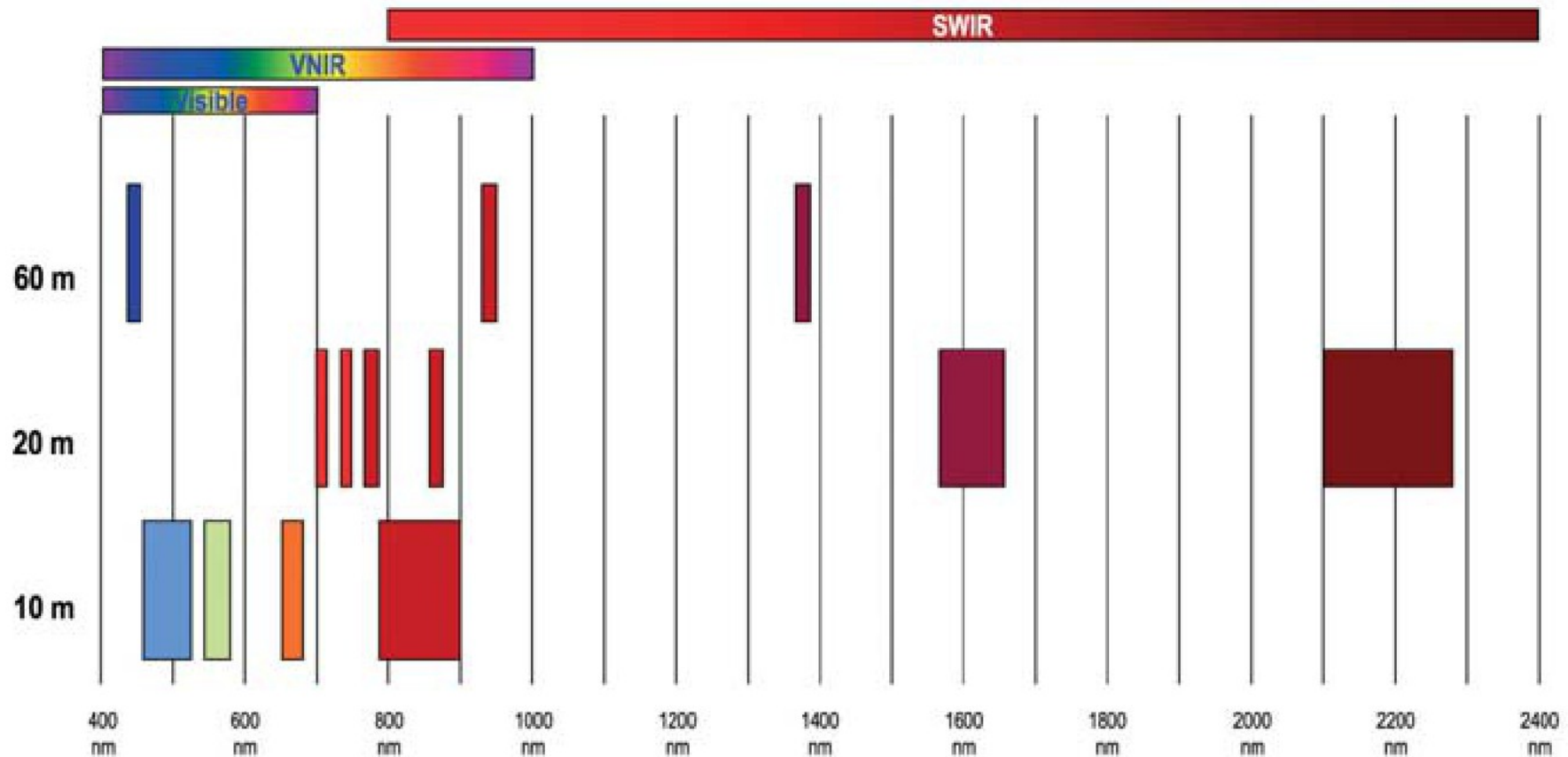
Classification of MODIS data with : A. Garg, D. Singh, IIT Roorkee, India



SENTINEL-2

ESA Satellite, launched in June 2015

13 spectral bands at different resolutions : 60m/pixel, 20m/pixel, 10m/pixel



Goal : put all bands at 10m/pixel

AVAILABLE TEST DATA (FALL 2015)

R,G,B bands
at 10m/pixel

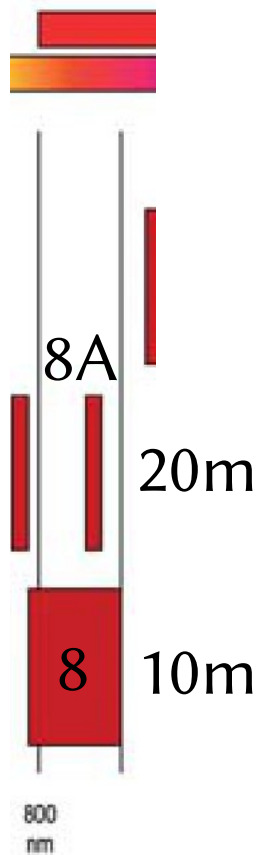
Around
Venice



RESULT 20M \rightarrow 10M

Example : Near infrared, Band 8A (20m), comparable to Bande 8 (10m)

Large band à 10m, narrow spectral band at 20m (targets vegetation)

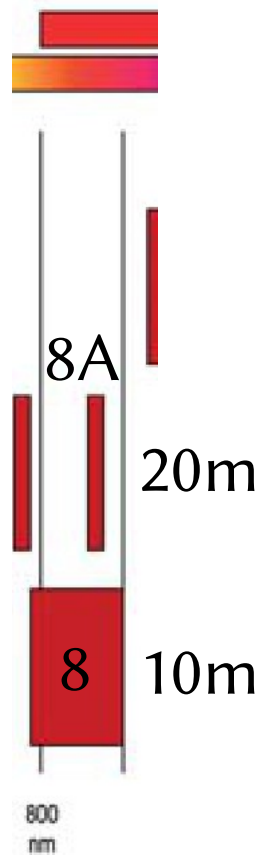


Original
Band 8A
(20m)

RESULT 20M \rightarrow 10M

Example : Near infrared, Band 8A (20m), comparable to Bande 8 (10m)

Large band à 10m, narrow spectral band at 20m (targets vegetation)

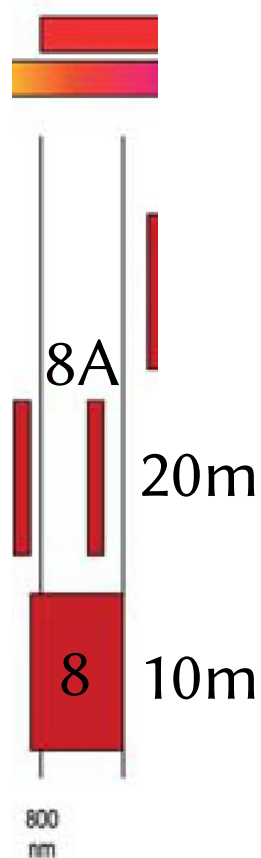


Bande 8A
résolue
à 10m

RÉSULTAT 20M → 10M

Example : Near infrared, Band 8A (20m), comparable to Bande 8 (10m)

Large band à 10m, narrow spectral band at 20m (targets vegetation)

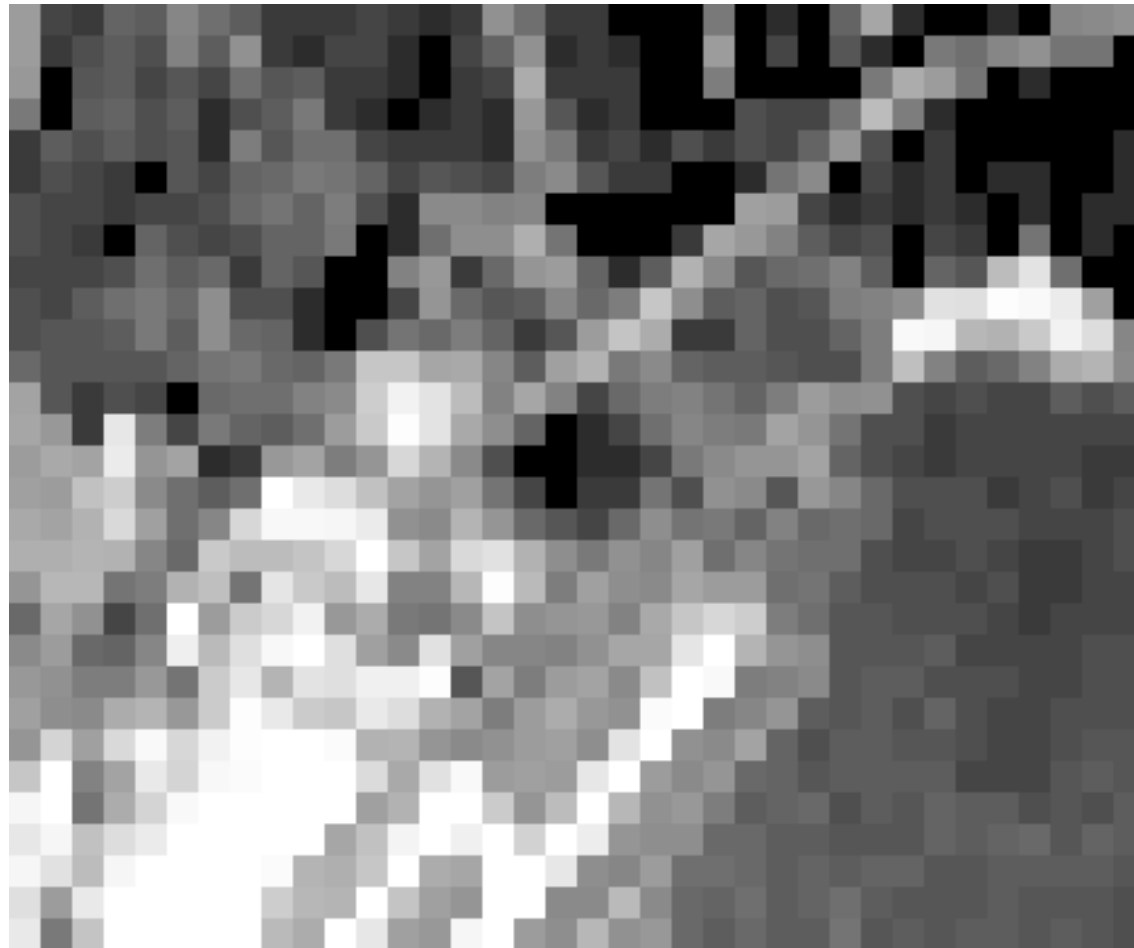
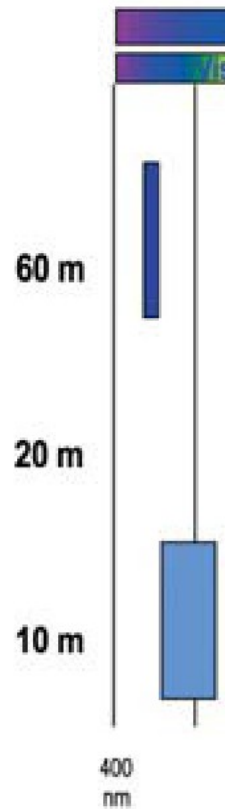


Bande 8
at
10m

RÉSULTAT 60M \rightarrow 10M

Example : Visible light, Bande 1 (60m, violet),

To compare with band 2 (10m, blue) ?

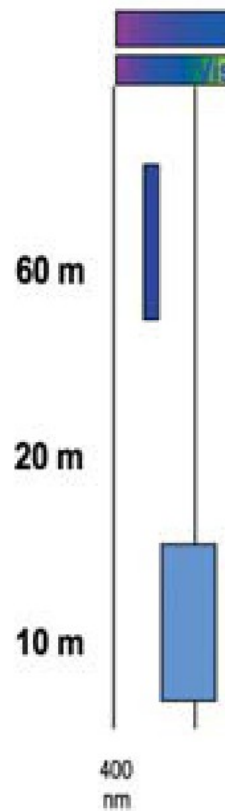


Original
Band 1
60m

RÉSULTAT 60M → 10M

Example : Visible light, Bande 1 (60m, violet),

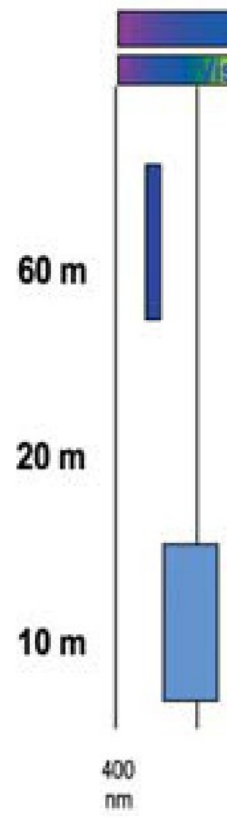
To compare with band 2 (10m, blue) ?



Super-resolved
Band 1
at 10m

RÉSULTAT 60M → 10M

Example : Visible light, Bande 1 (60m, violet),
To compare with band 2 (10m, blue) ?



Original
Bande 2
at 10m
(blue, not
violet)



Original 60m band 1



Super-resolved 60m band 1

An aerial photograph showing a road that curves from the bottom left towards the center. The landscape is divided into various fields and patches of vegetation. The image has a grainy, high-contrast appearance, typical of a satellite or aerial photograph. The road is a prominent dark line against the lighter, textured ground.

Original 60m band 9



Super-resolved 60m band 9

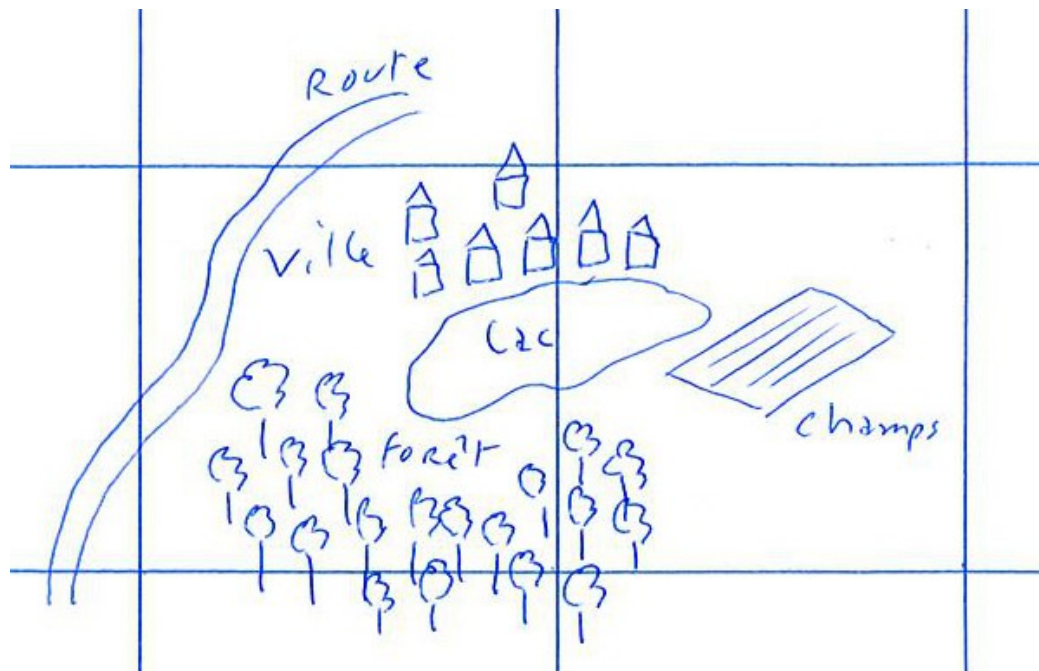
METHOD

Separating color from geometry

- Pixel = mix of different elements
- Mixing information = independent from the spectral band
- Color information information = specific to each band

Pixel boundaries are arbitrary

- Some information is also shared between nearby neighbors.

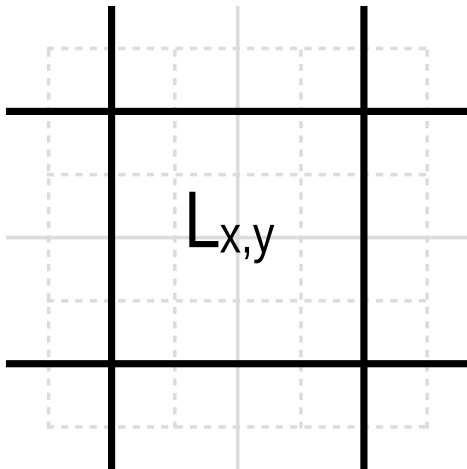


Too much pixel variability
⇒ no long-distance information
for inferring sub-pixels
⇒ Local model, ≠ wavelet for ex.

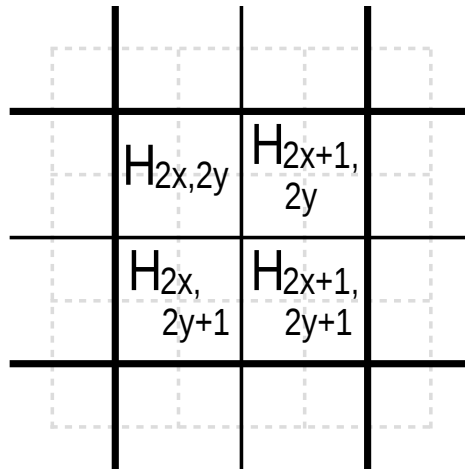
FOR 20M \rightarrow 10M

The problem

Available
low-resolution
pixel



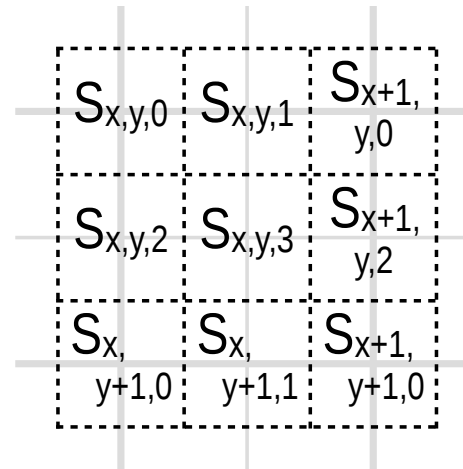
To divide in 4
pixels of higher
resolution



Constraint: $\langle H \rangle = L$
 \Rightarrow 3 free paramters
/ pixel

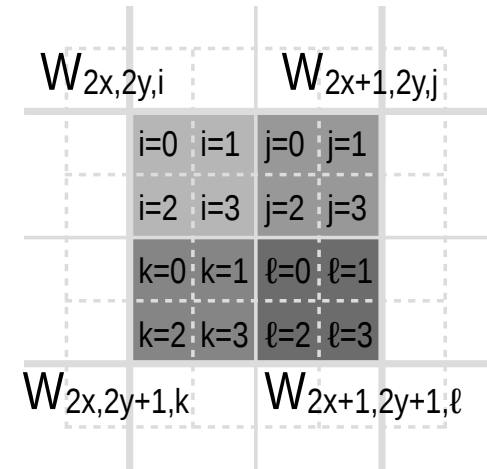
The model

Shared values
between neighbor
pixels



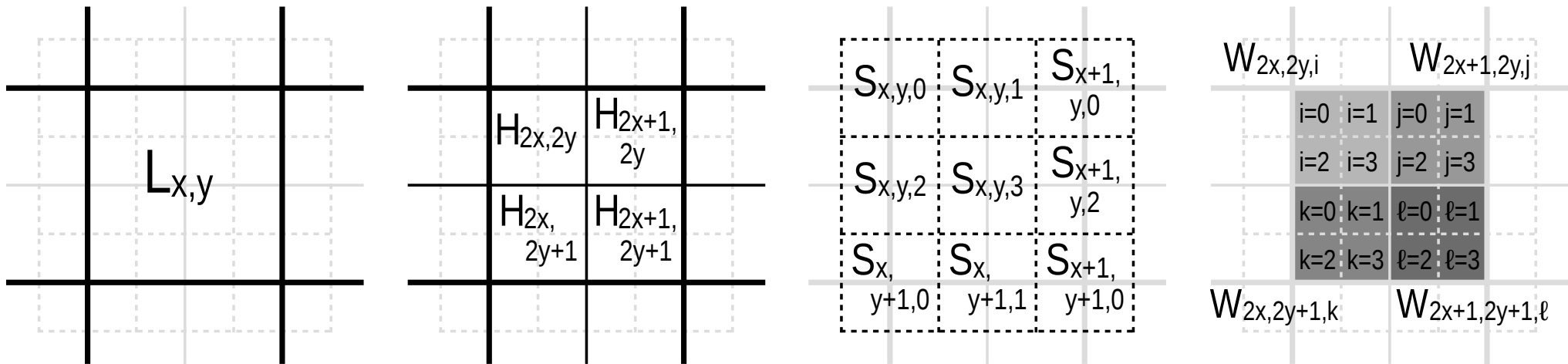
Depend on
the spectral
band

Weights = proportion
of these shared values
comprising the pixel



Shared between
spectral bands
Constraint: $\sum w = 1$

POUR 20M \rightarrow 10M



Step 1: Fit S , W using the 4 band at 10m

- H available \Rightarrow 1 parameter S / pixel at 10m is fixed \Rightarrow no free parameter for S
- 4 W per pixel at 10m, but 3 free parameters and 4 band \Rightarrow Least squares OK

Step 2: Find S for the 20m bands, W being fixed (band-independent)

- 2.1 (learning inter-pixels): Fit $S_L = \sum p_L \times L$, using neighbors on averaged 10m bands
- 2.2 (apply inter-pixels): Propagate $S_L = \sum p_L \times L$ on 20m bands
- 2.3 (apply details): Propagate S/S_L of 10m bands \rightarrow initial S value for 20m bands
- 2.4 (apply weights): $H = W * S$ for 20m bands (+ renormalization $\langle H \rangle = L$)

FOR 60M \rightarrow 10M

Method cannot be applied as such: 36 sub-pixels at 10m / pixel at 60m!

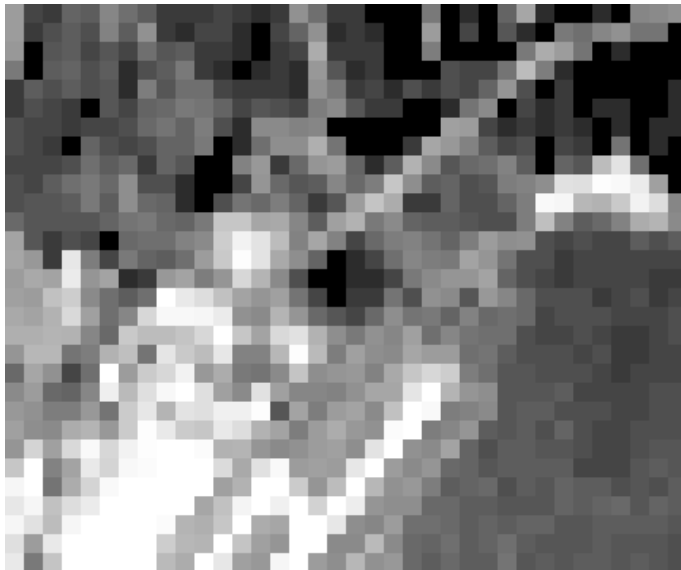
Solution : Intermediate 60m \rightarrow 20m step

- Quick analysis:
 - 9 sub-pixels at 20m, fixed average \Rightarrow 8 free parameters / pixel
 - 6 bands at 20m + 4 at 10m \Rightarrow 10 constraints (≈ 9 with similar B8/B8A)
 - + 3 free parameters per W, shared /10 bandes ≈ 0.3 param/pixel
 - \Rightarrow Global least square fit for S,W on 10 bands OK ($\approx 8.3/9$ param/pixel)
- + Same method for splitting geometry/color : Fit S, W at 20m, then S_L , then details.

60m original

20m intermediate

10m final



MODIS DATA

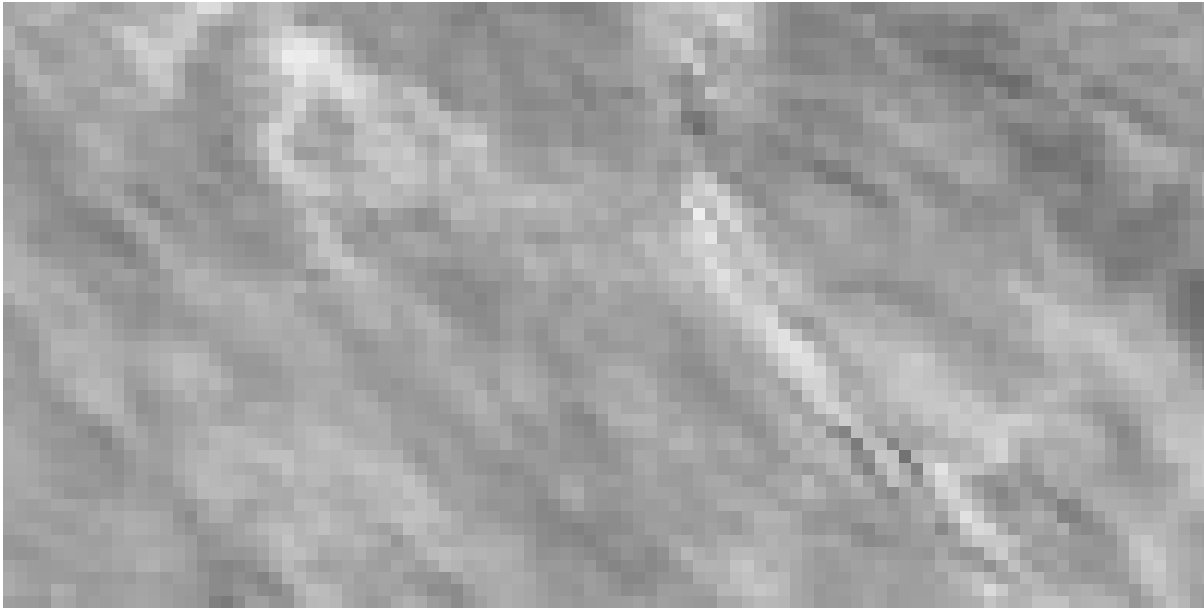
2 NASA satellites, cloned

- Visible/infrared
- 2 bands at 250m/pixel, 5 bands à 500m/pixel
- 2 acquisitions / day (final Sentinel-2 scenario = 1 acquisition every 3-4 days)

Method adaptation

- 2 bands of “high” resolution are not sufficient to fix the mixing weights W
- Hypothesis : The mixing geometry information (W) is unchanged over short times
 - ⇒ Fix S , W over several acquisitions (min=2, more are best for clouds)
- E.g. using cloud-free bottom of atmosphere images processed with 16 day data, with overlapping 8-days windows

EXAMPLE



Original (infrared 1628-1652 nm)



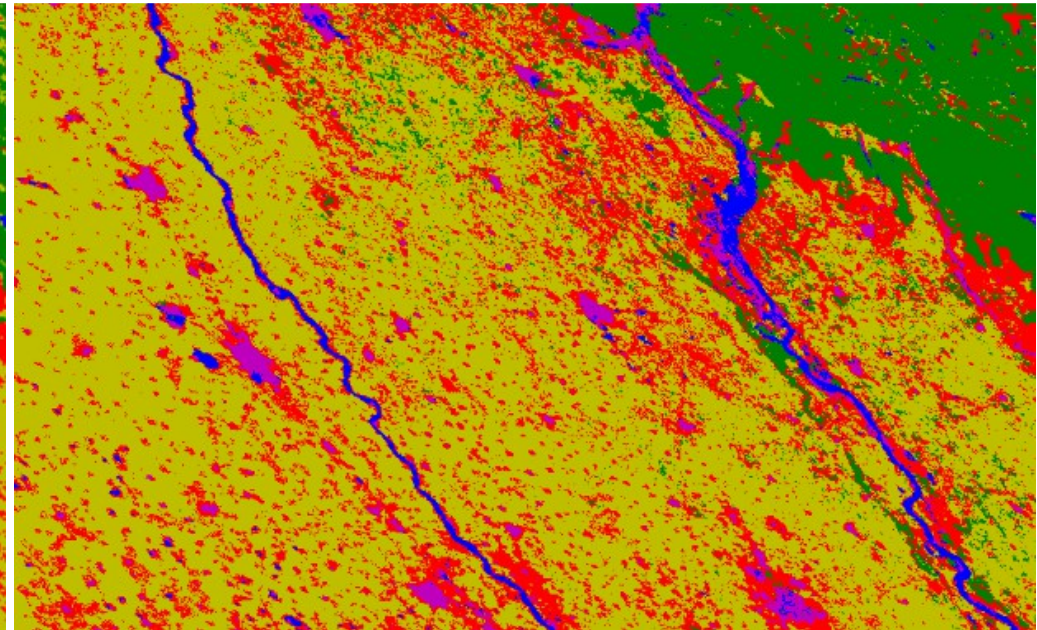
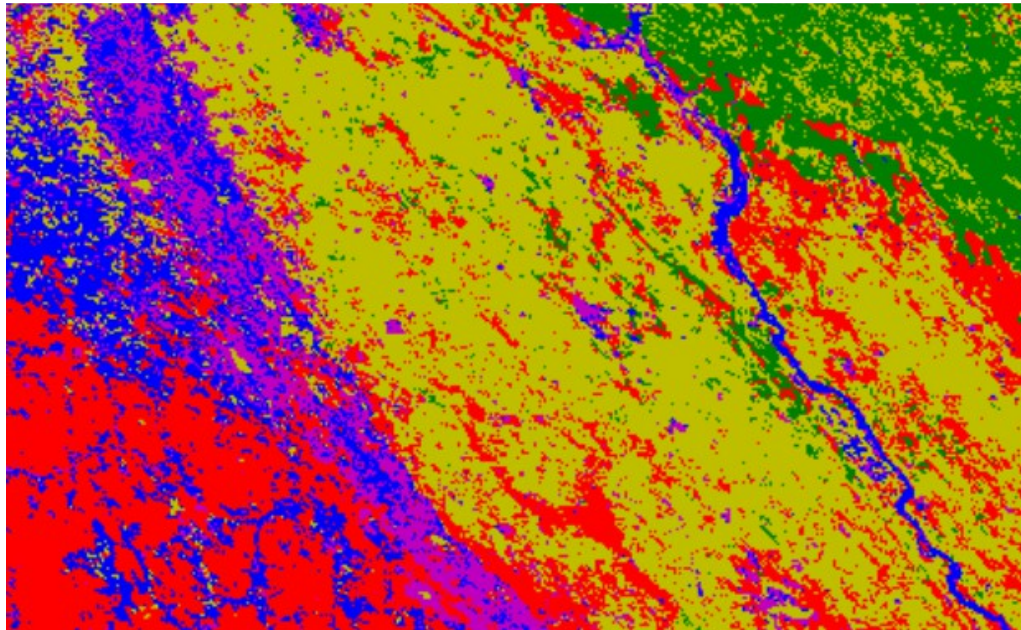
Super-resolution 500m => 250m

LAND OCCUPATION

Study zone around Roorkee, 200km north of Delhi

classification with original 500m data

with 250 super-resolved data



Blue : water Purple : urban Green : Forest Yellow : Fields Red : bare soil