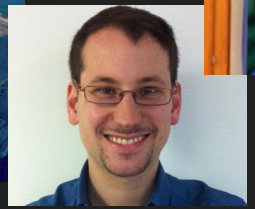
HighRes-net
MFSR by Recursive Fusion

ELEMENT AI

Mila

Michel Deudon (& deer)



Freddie Kalaitzis Julien Cornebise Zhichao Lin

Md Rifat Arefin Israel Goytom Kris Sankaran

Samira E. Kahou Vincent Michalski Yoshua Bengio

ESTEC – Noordwijk | Kelvins Day | September 11, 2019

About

01 Challenge, motivation & results

02 On Fusion & Registration

03 Applications & Future Work

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Challenge, motivation and results

The suspect was reported to
be somewhere in this city.

Low-resolution

Single Image Super-Resolution

High-res

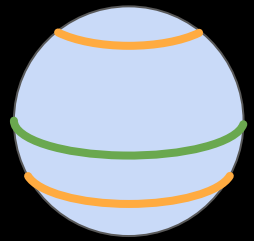
Low-res public satellites

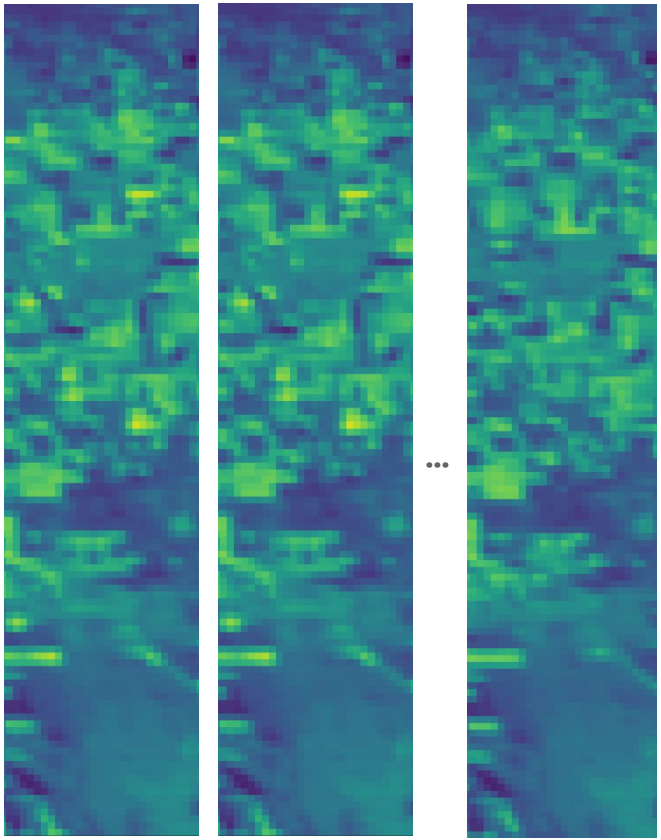
- Sentinel 2 10 m
- Landsat 30 - 15 m
- PROBA-V 300 - 100 m

$ cheap / free

high revisit frequency

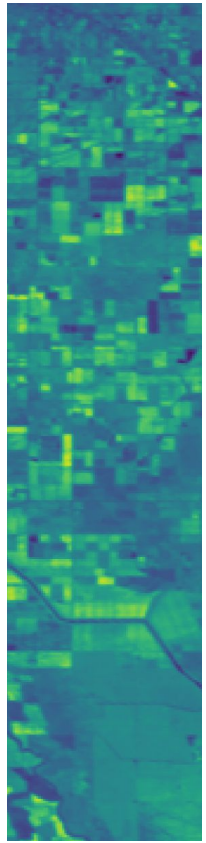
PROBA-V
2-daily
coverage



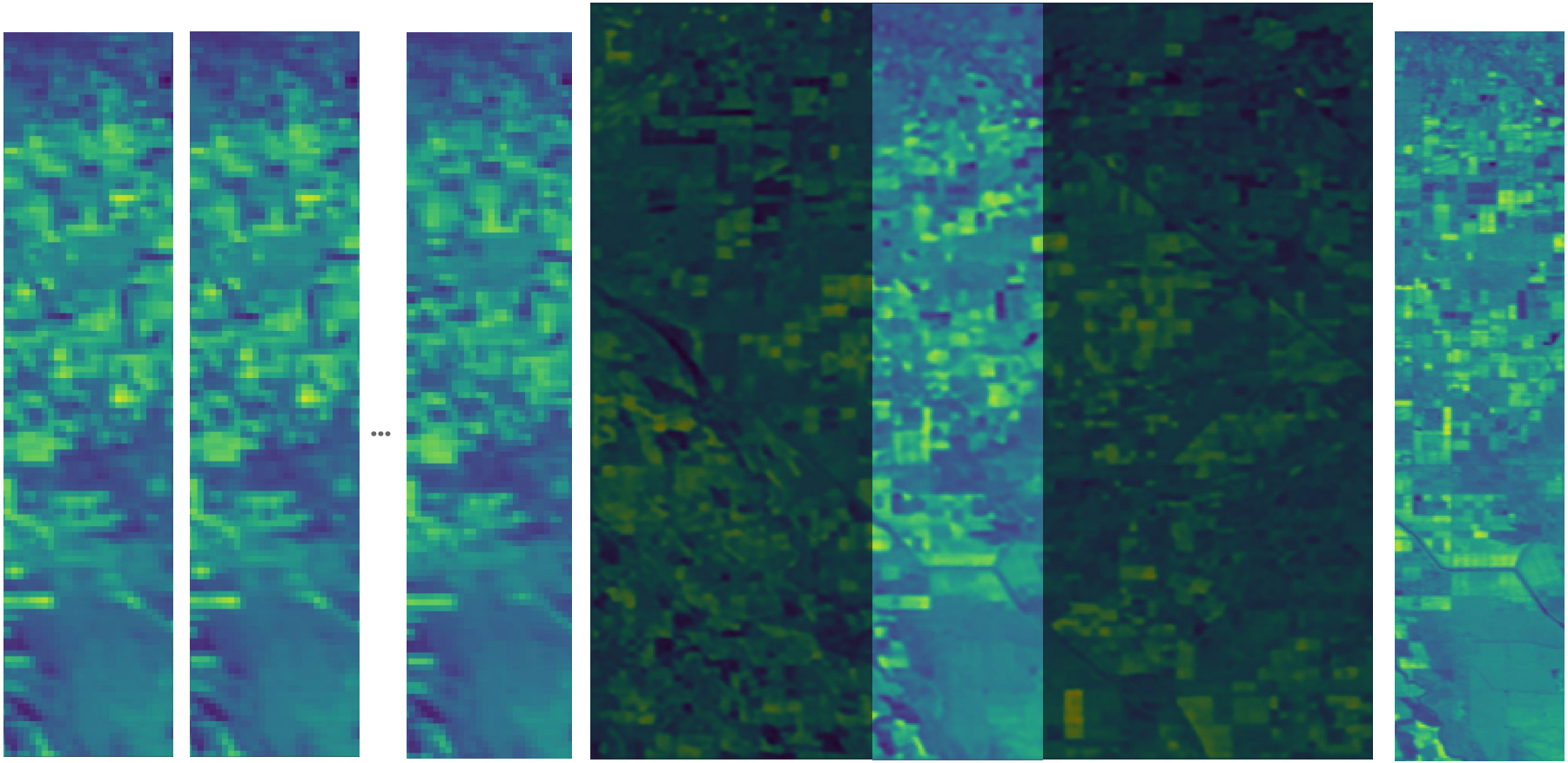


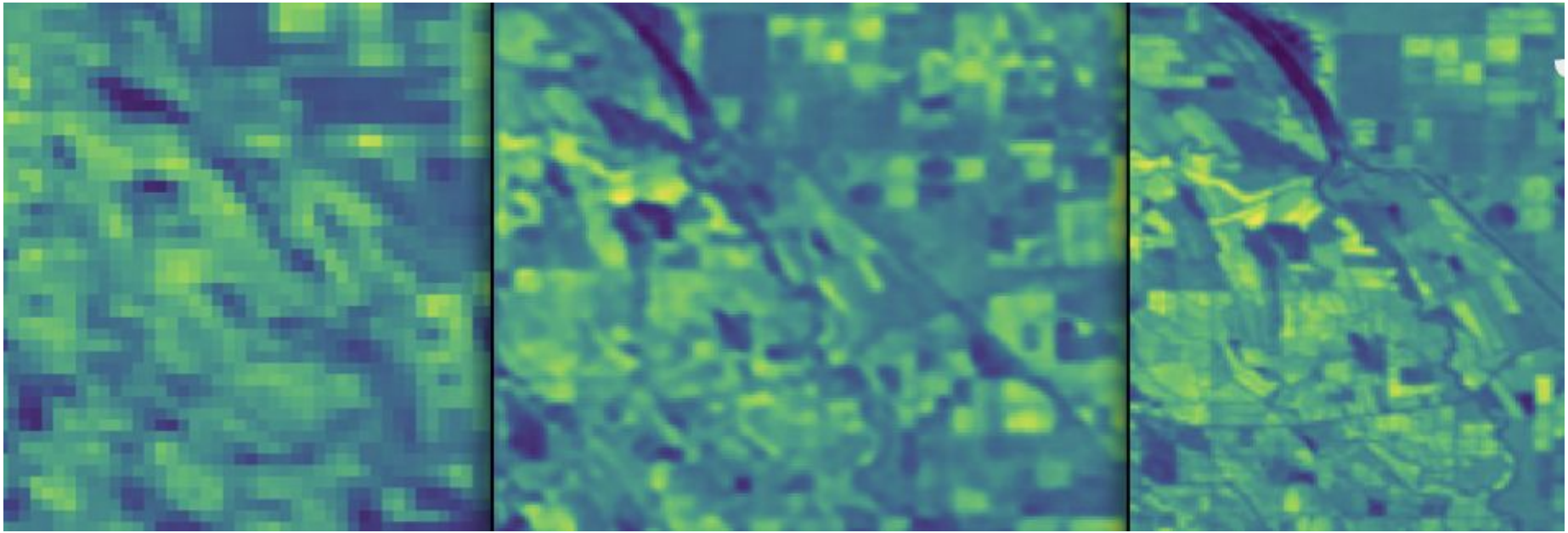
Low-res 1 Low-res 2 ... Low-res 9

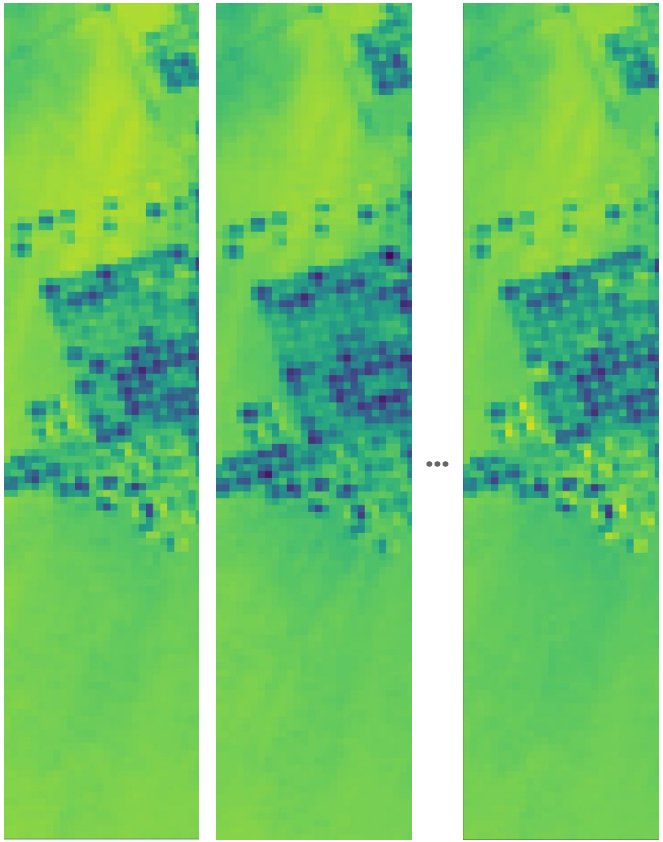
Super-res



High-res

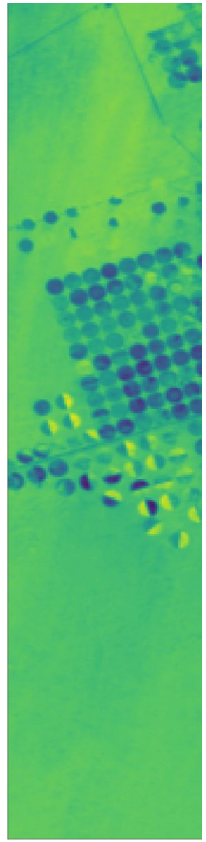

Low-res 1
Low-res 2
...
Low-res 9
Super-res
High-res



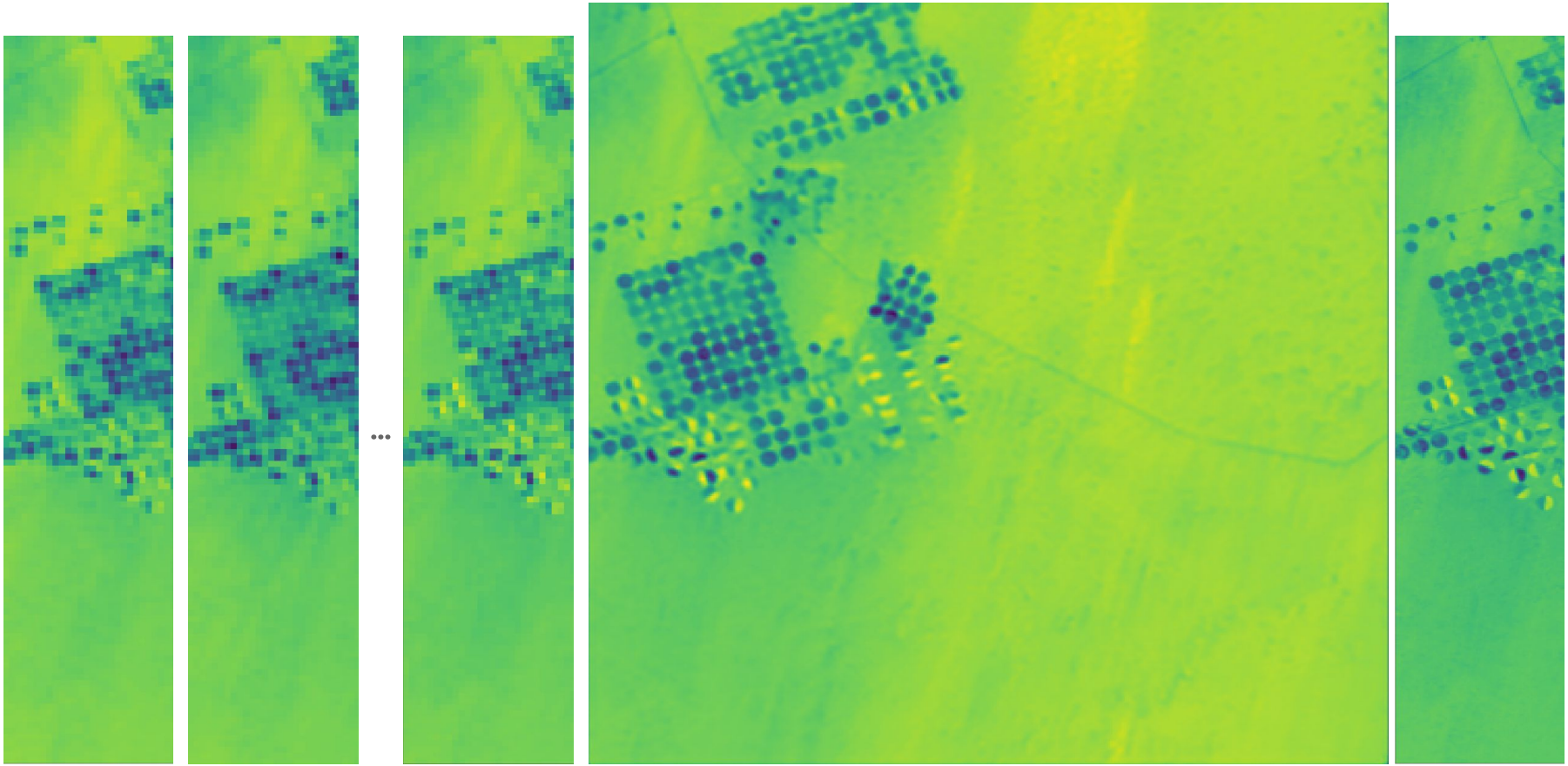


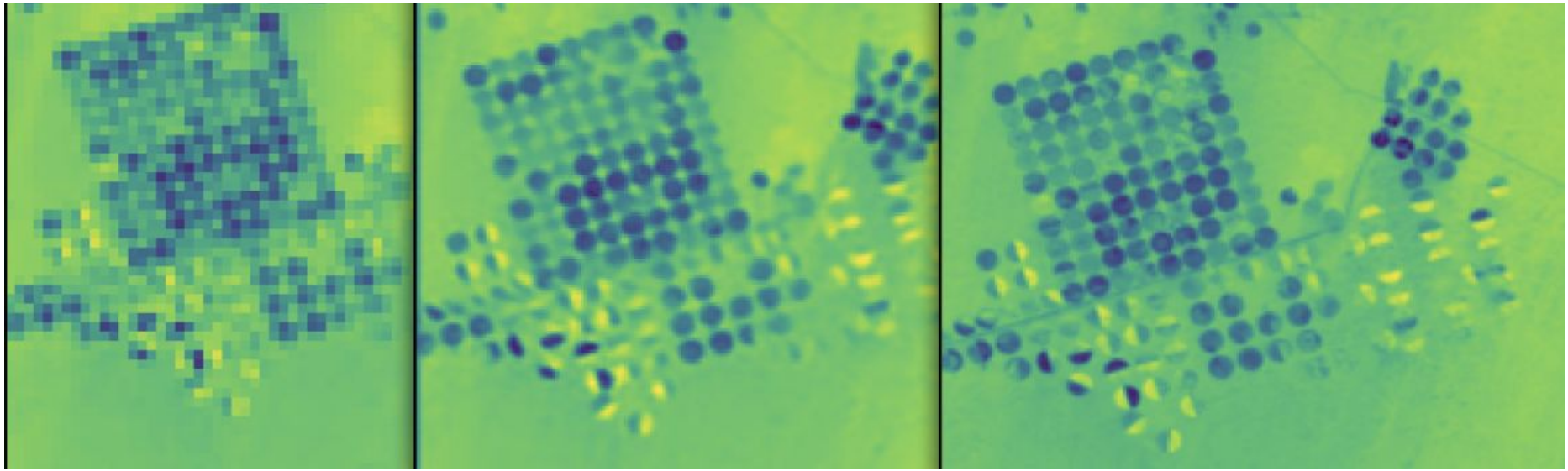
Low-res 1 Low-res 2 ... Low-res 9

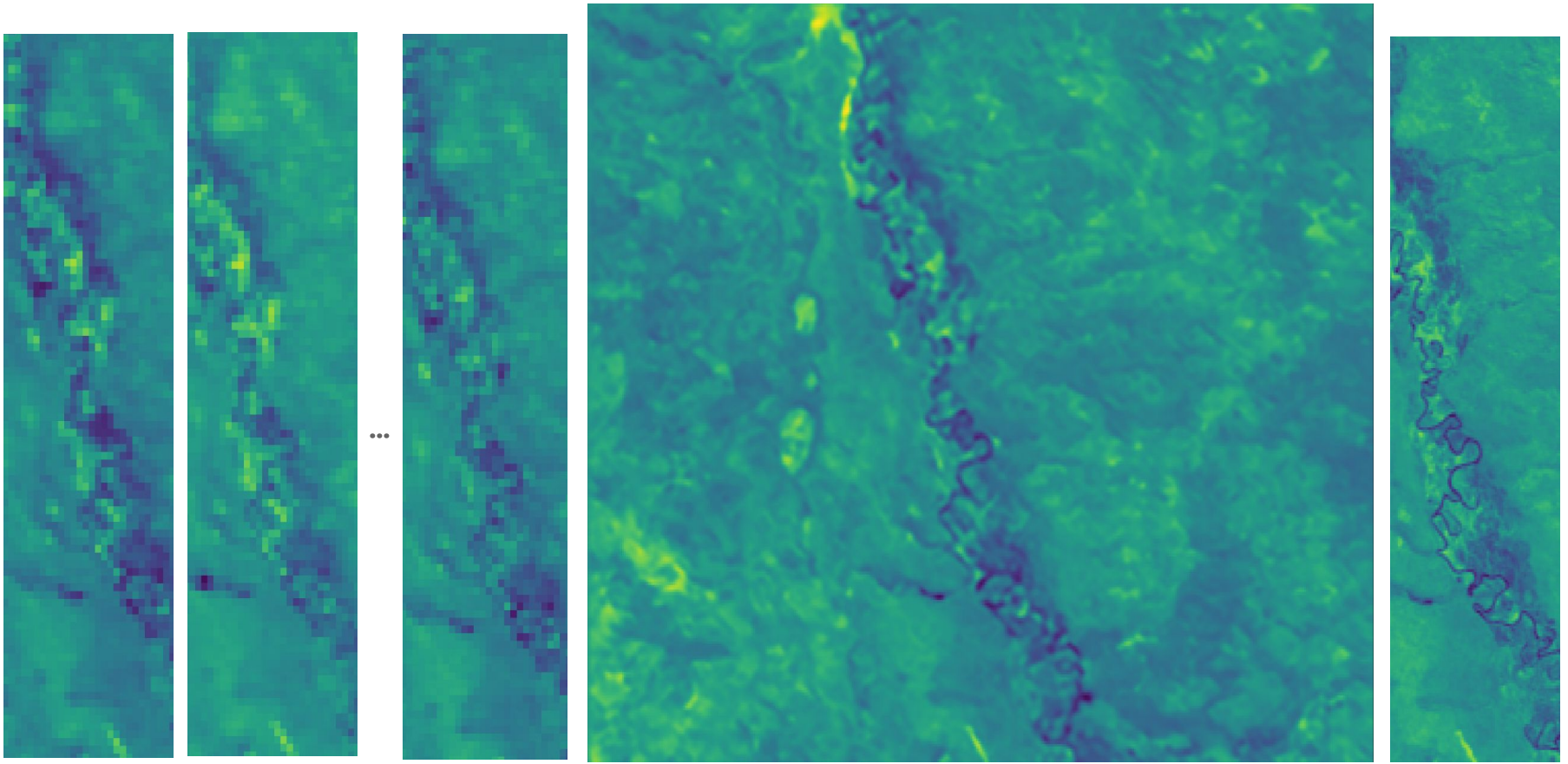
Super-res

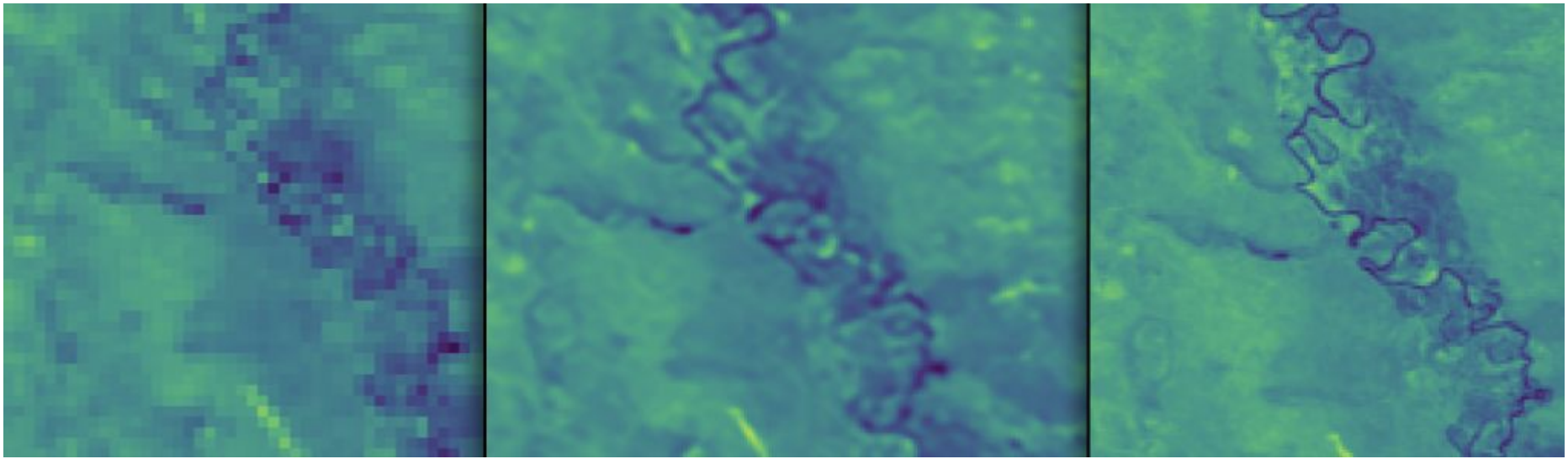


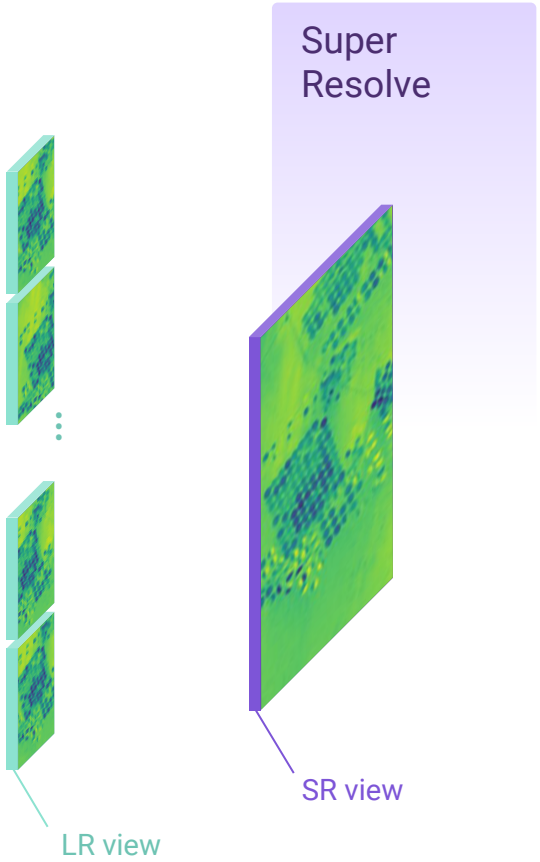
High-res

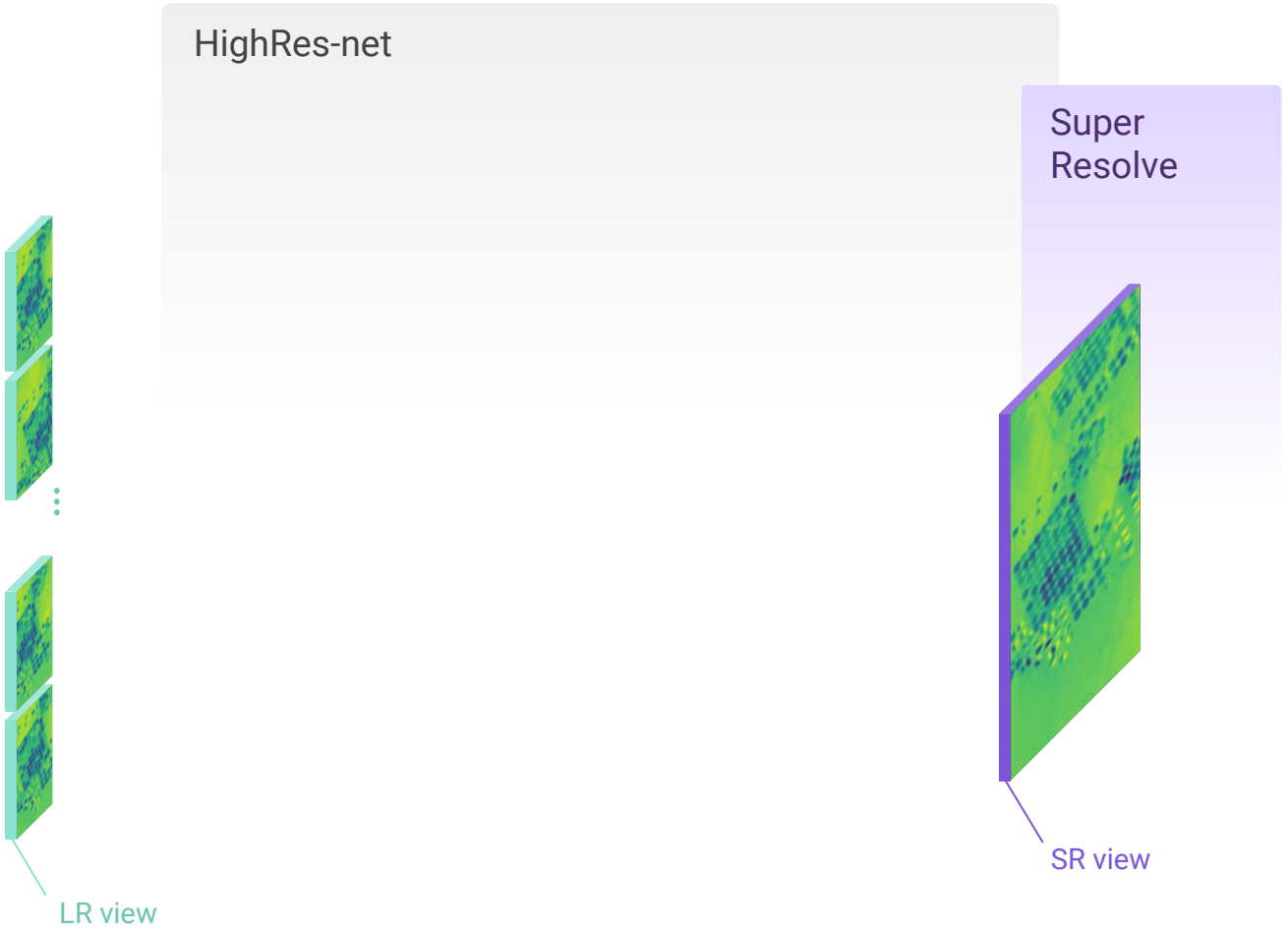

Low-res 1
Low-res 2
...
Low-res 9
Super-res
High-res

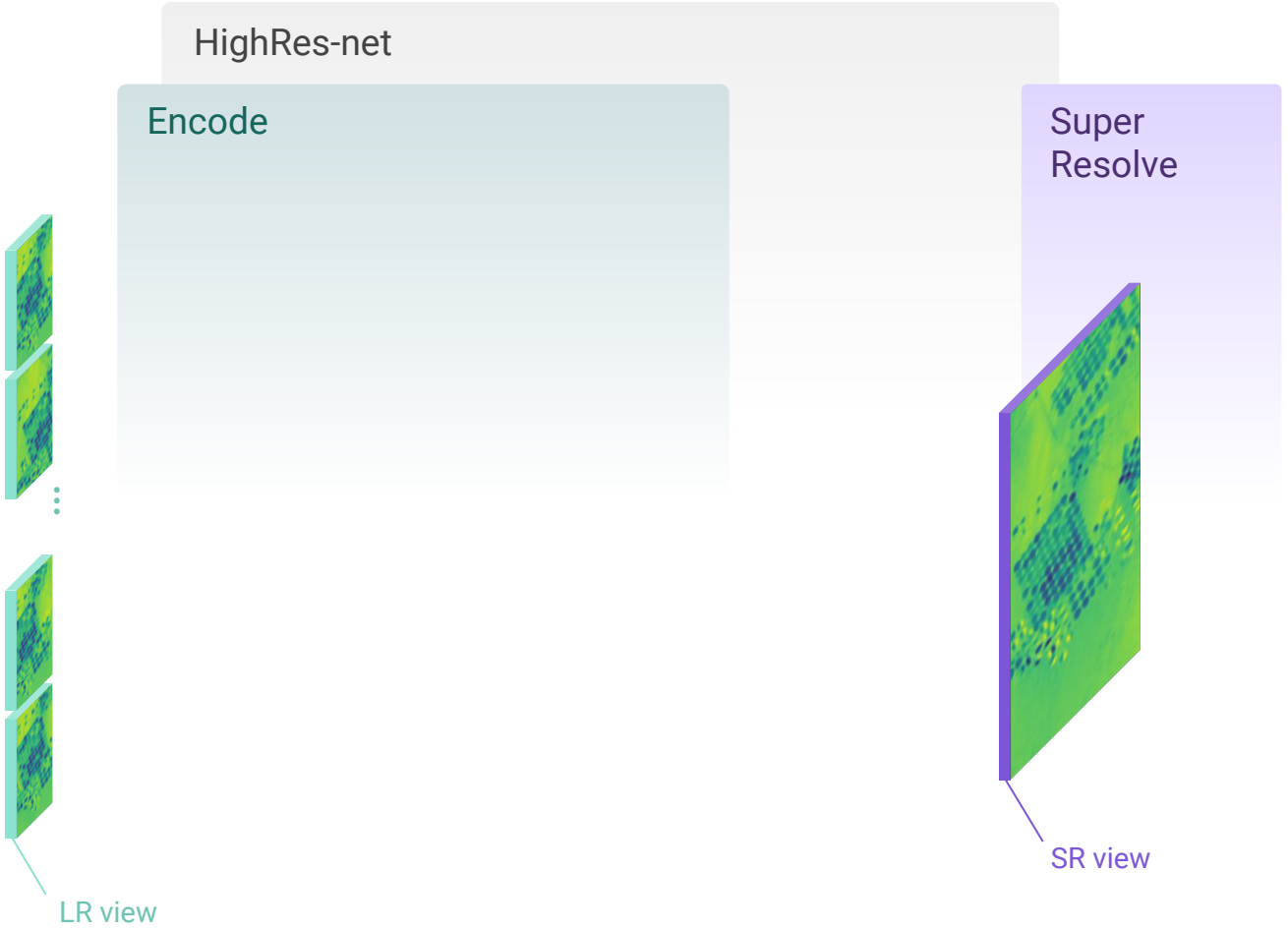


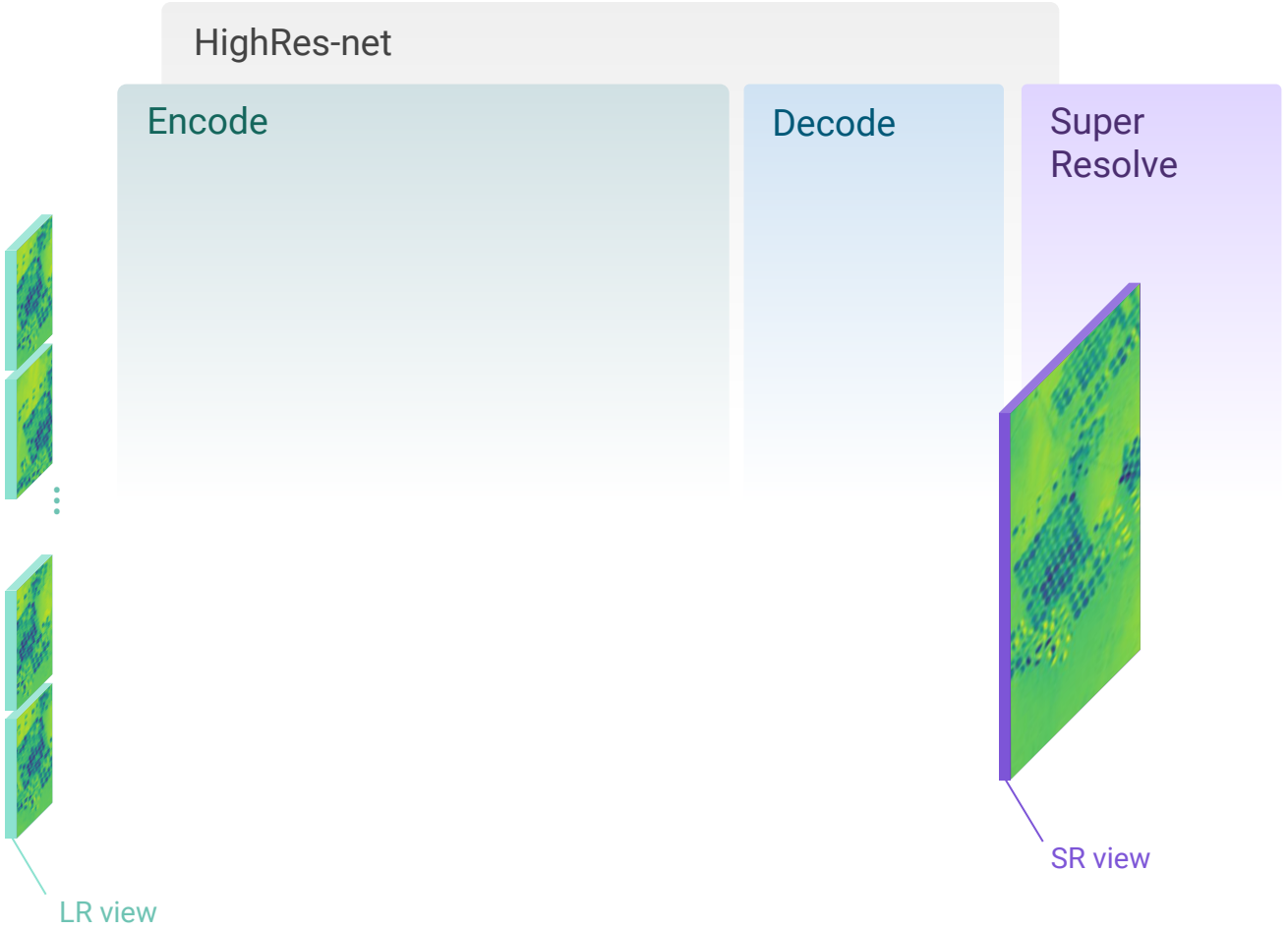

Low-res 1
Low-res 2
...
Low-res 9
Super-res
High-res

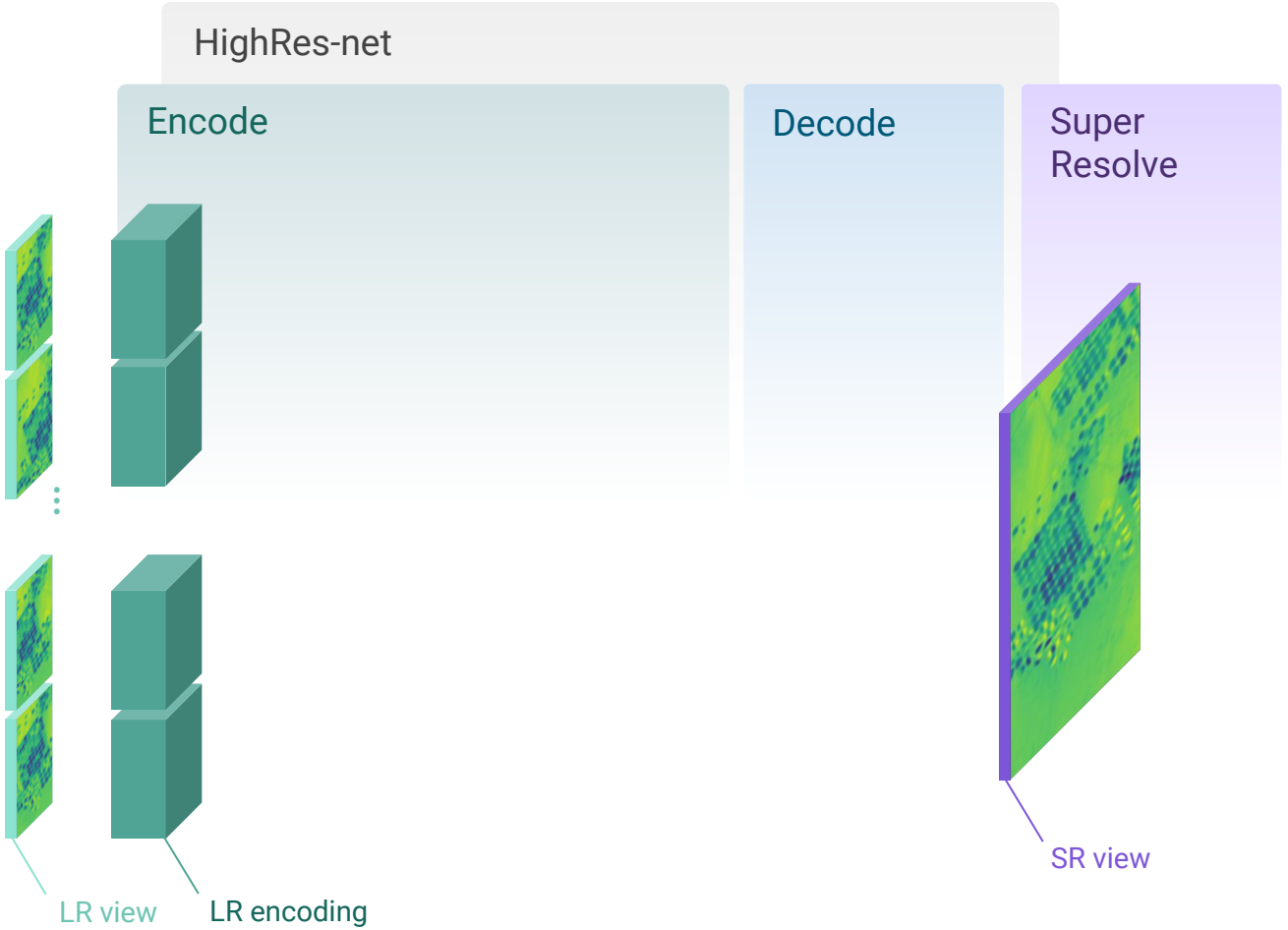


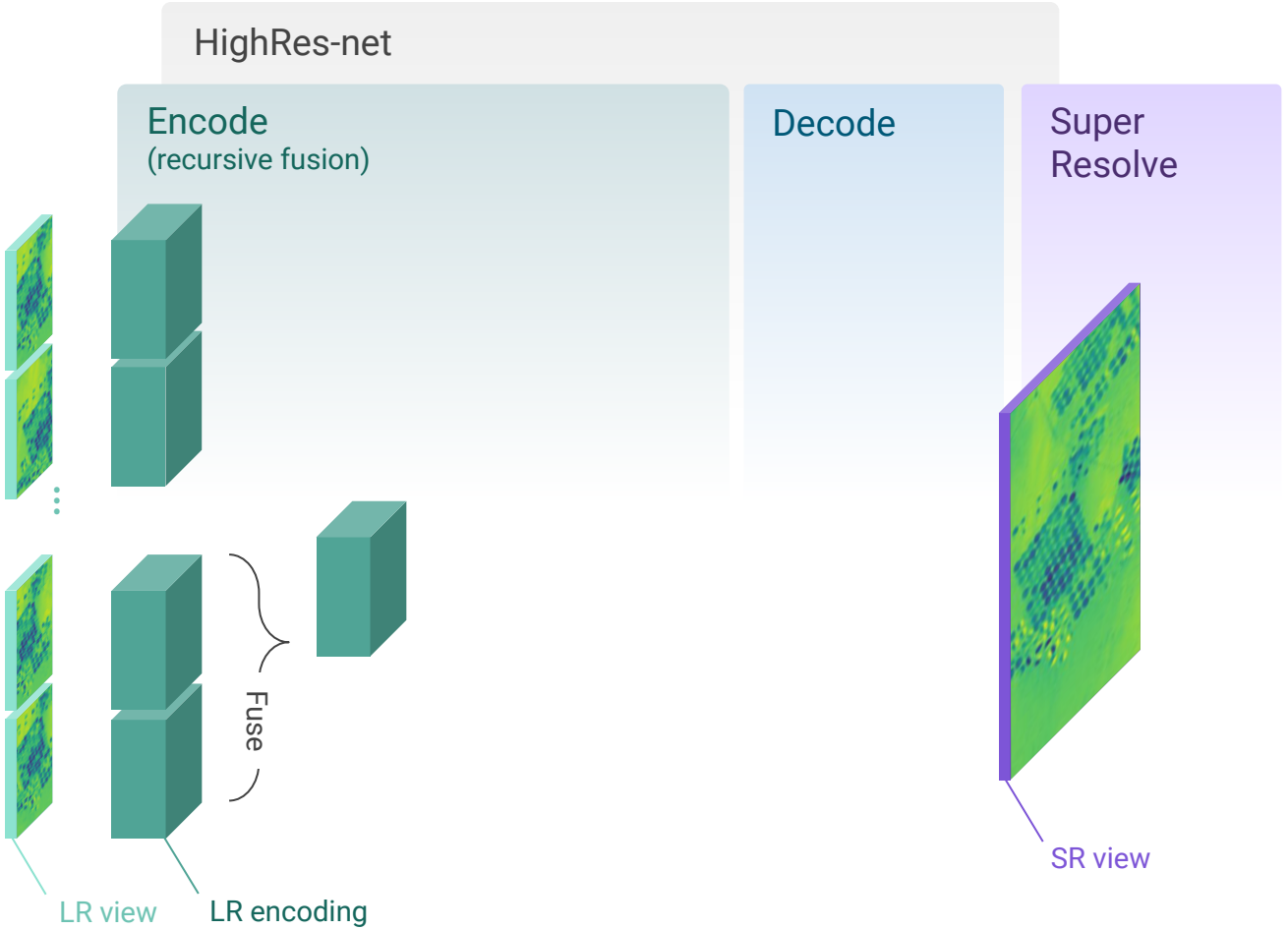

Super
Resolve
SR view
LR view

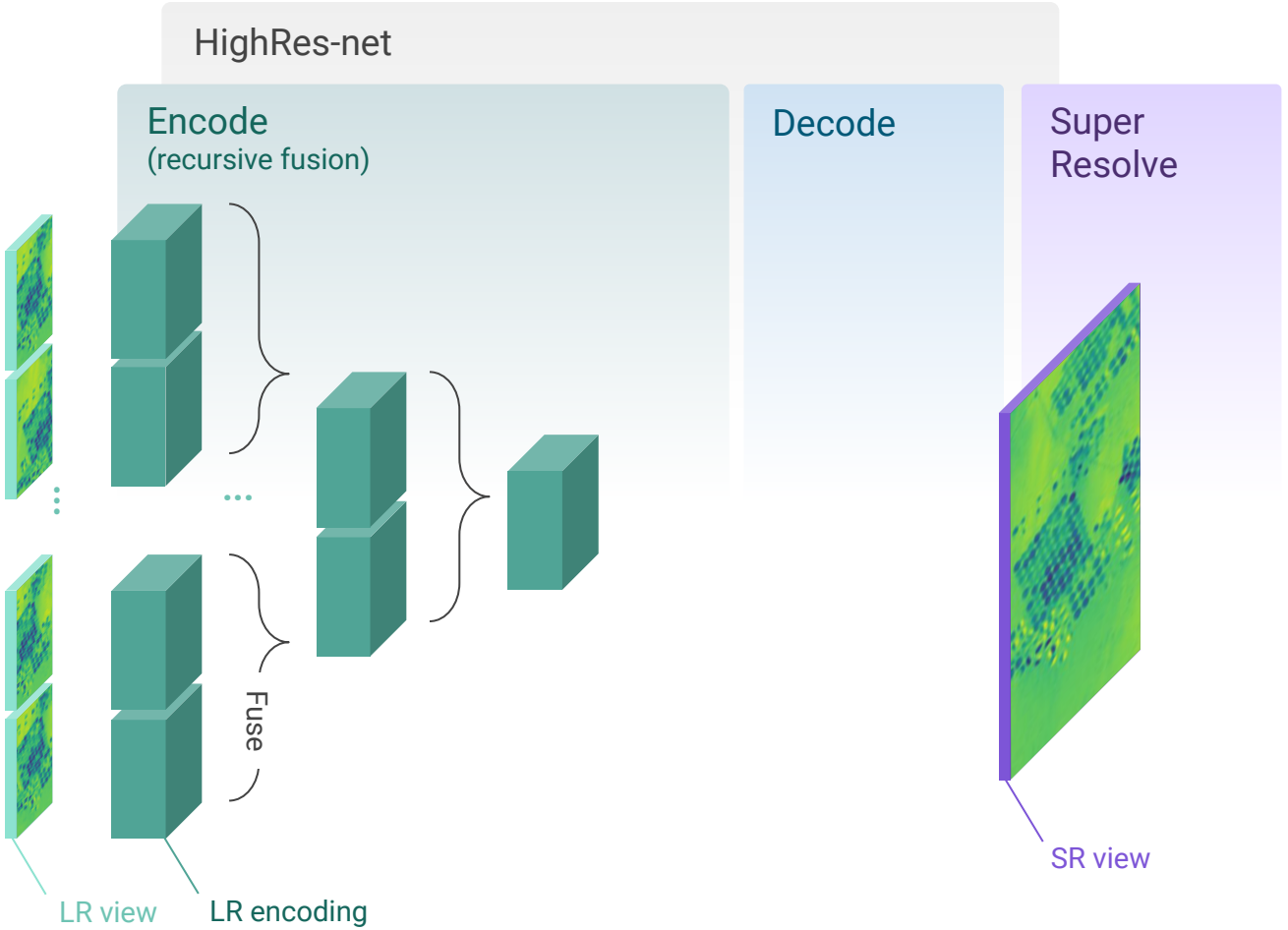

HighRes-net
Super
Resolve
LR view
SR view

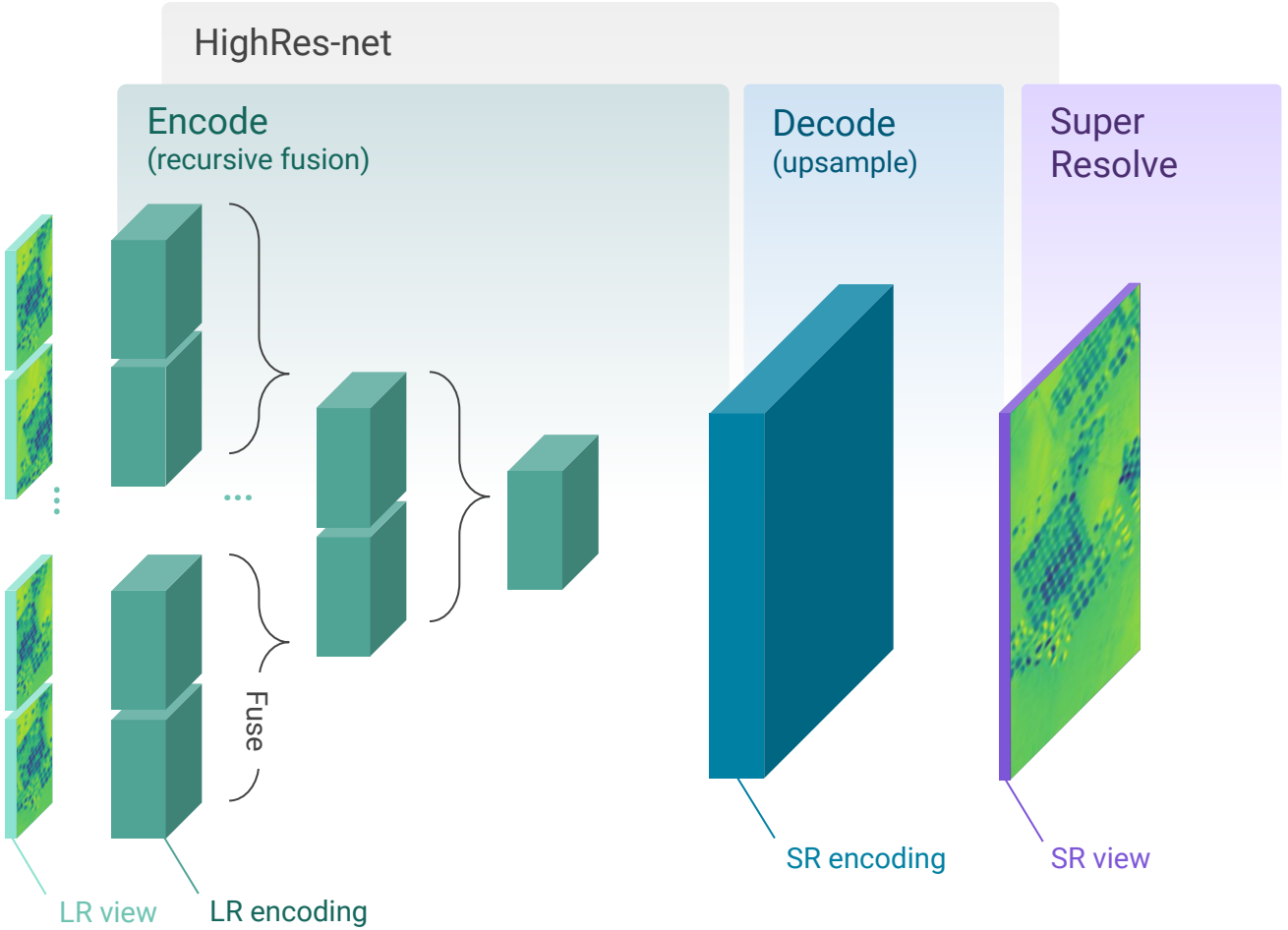

HighRes-net
Encode
Super
Resolve
LR view
SR view

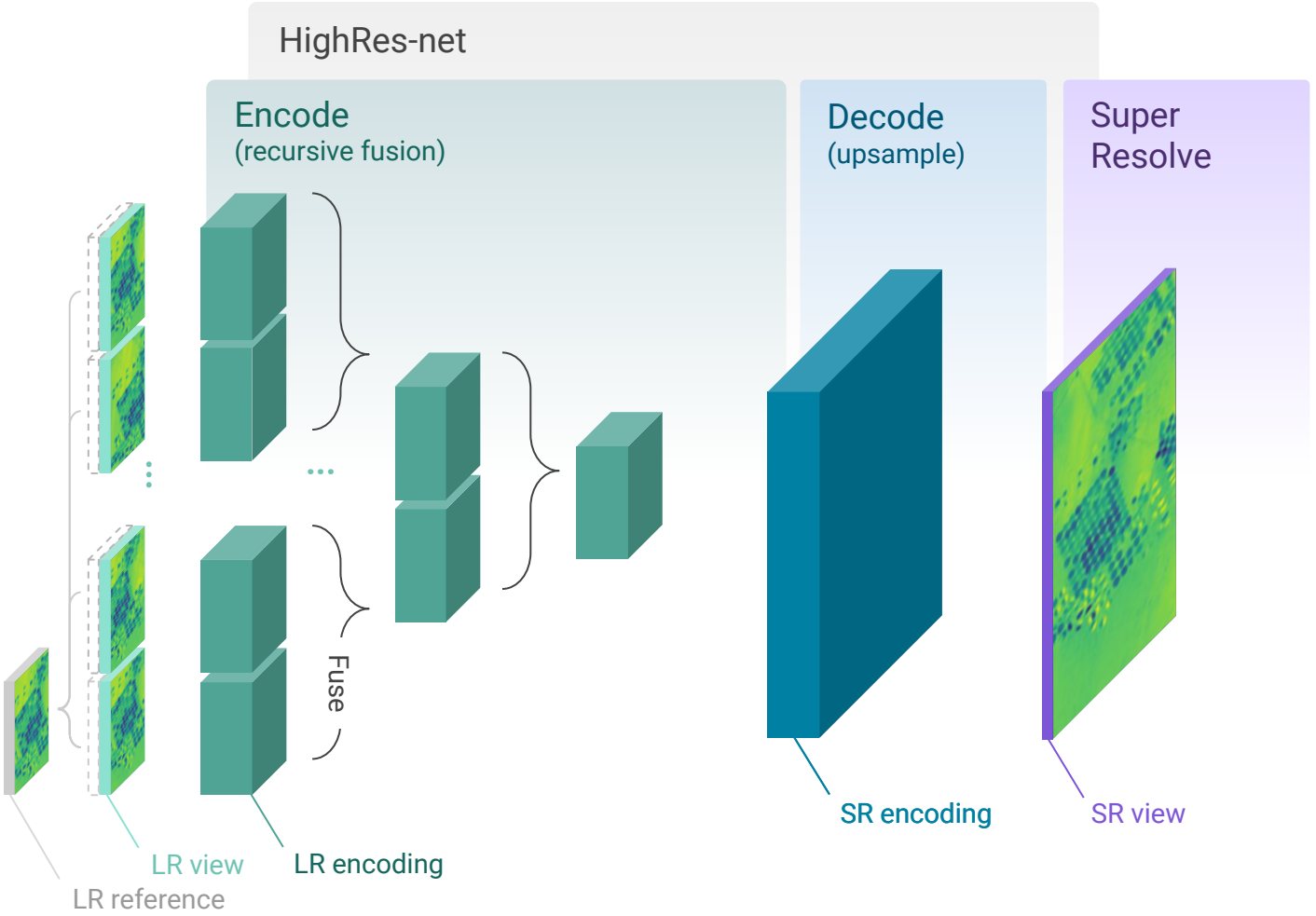

HighRes-net
Encode
Decode
Super Resolve
LR view
SR view

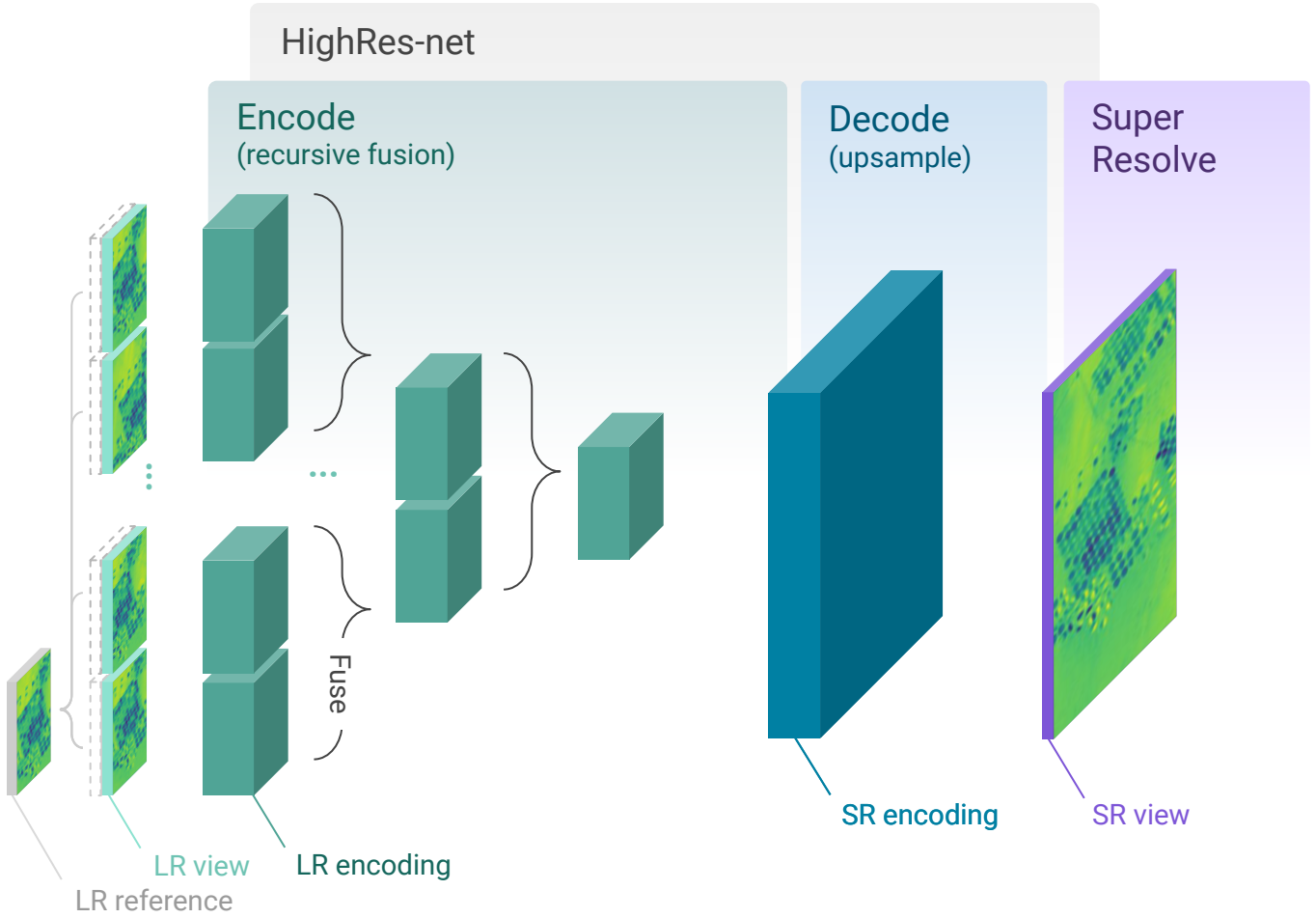

HighRes-net
Encode
Decode
Super Resolve
LR view
LR encoding
SR view


HighRes-net
Encode
(recursive fusion)
Decode
Super
Resolve
Fuse
LR view
LR encoding
SR view


HighRes-net
Encode
(recursive fusion)
Decode
Super
Resolve
Fuse
LR view
LR encoding
SR view

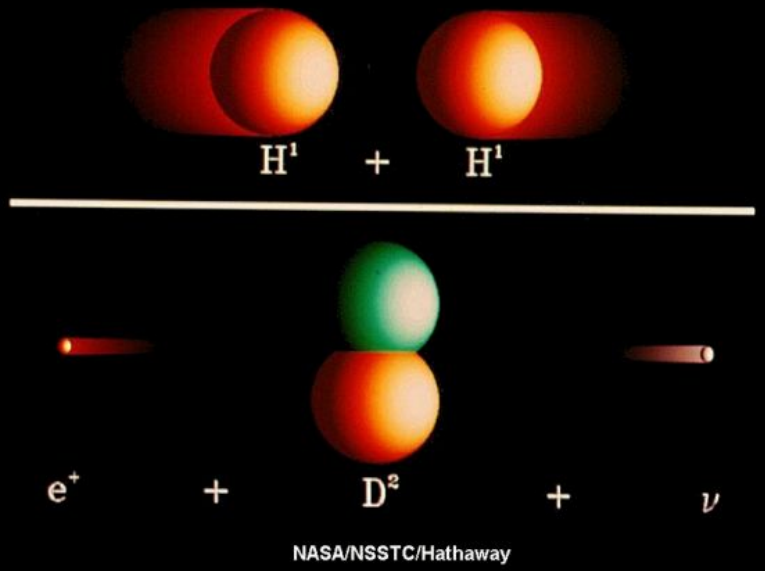

HighRes-net
Encode
(recursive fusion)
Decode
(upsample)
Super
Resolve
Fuse
LR view
LR encoding
SR encoding
SR view


HighRes-net
Encode
(recursive fusion)
Decode
(upsample)
Super
Resolve
Fuse
LR reference
LR view
LR encoding
SR encoding
SR view


HighRes-net
Encode
(recursive fusion)
Decode
(upsample)
Super
Resolve
Fuse
LR reference
LR view
LR encoding
SR encoding
SR view

On Fusion

What is *Fusion*?



“A nuclear reaction in which atomic nuclei of low atomic number fuse to form a heavier nucleus with the release of energy.”

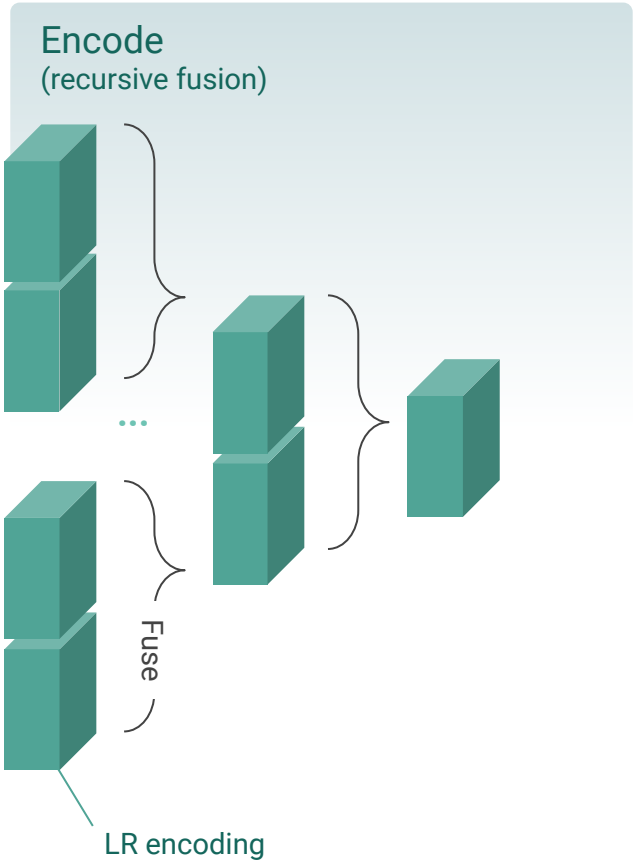
Oxford dictionary

What is *Fusion*?

“Referring to food or cooking which incorporates elements of both Eastern and Western cuisine.”

Oxford dictionary

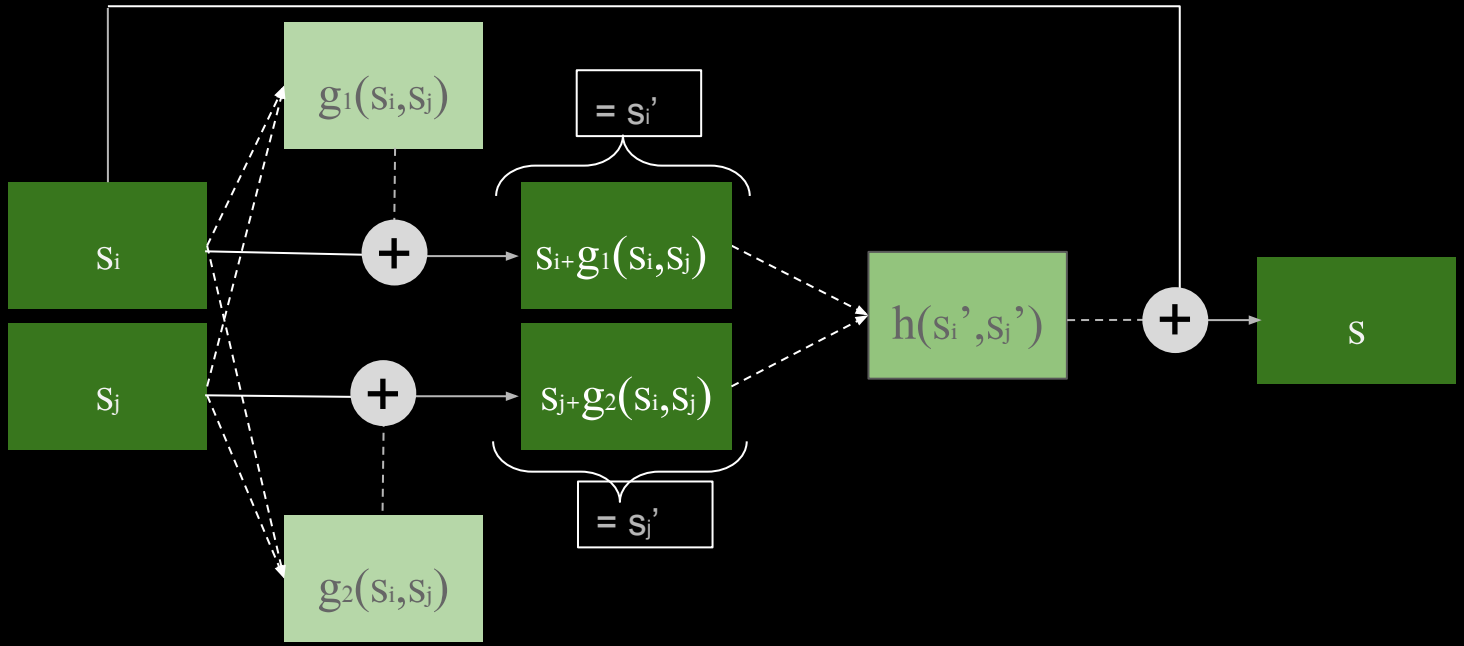
What is *Fusion*?



“the process or result of joining two or more [representations] together to form a [new representation] ”

Oxford dictionary

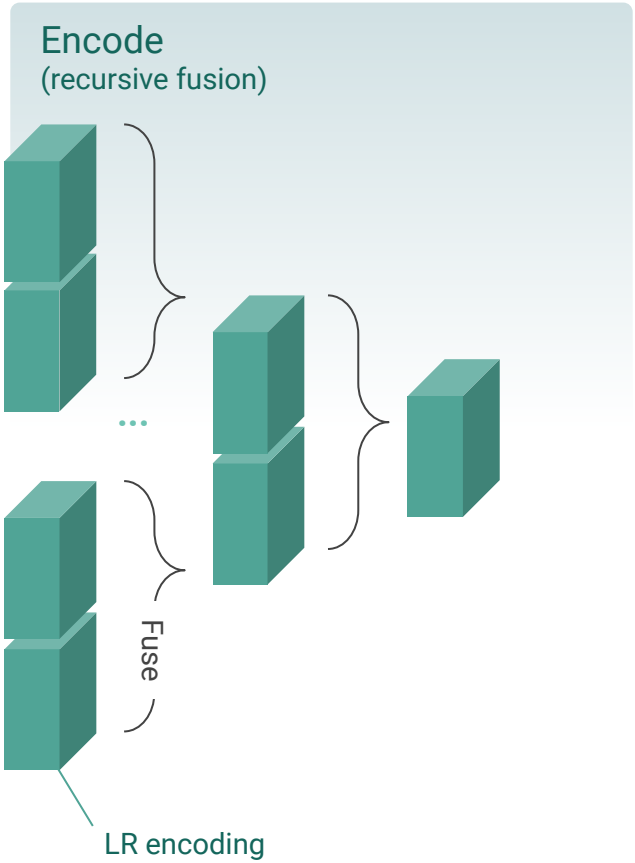
Fusion - under the hood



Fusion - under the hood

Fused *representation* contains
more information
than individual *representations*

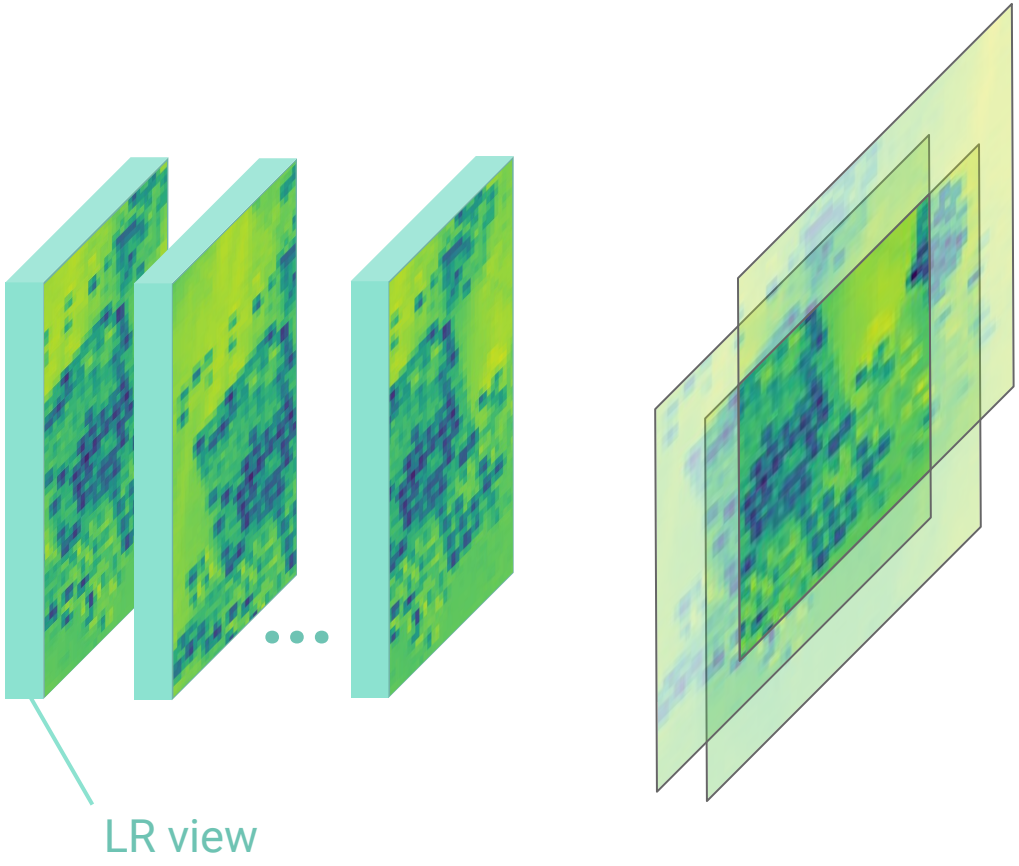
Recursive Fusion



Low-memory & **fast** fusion, by design

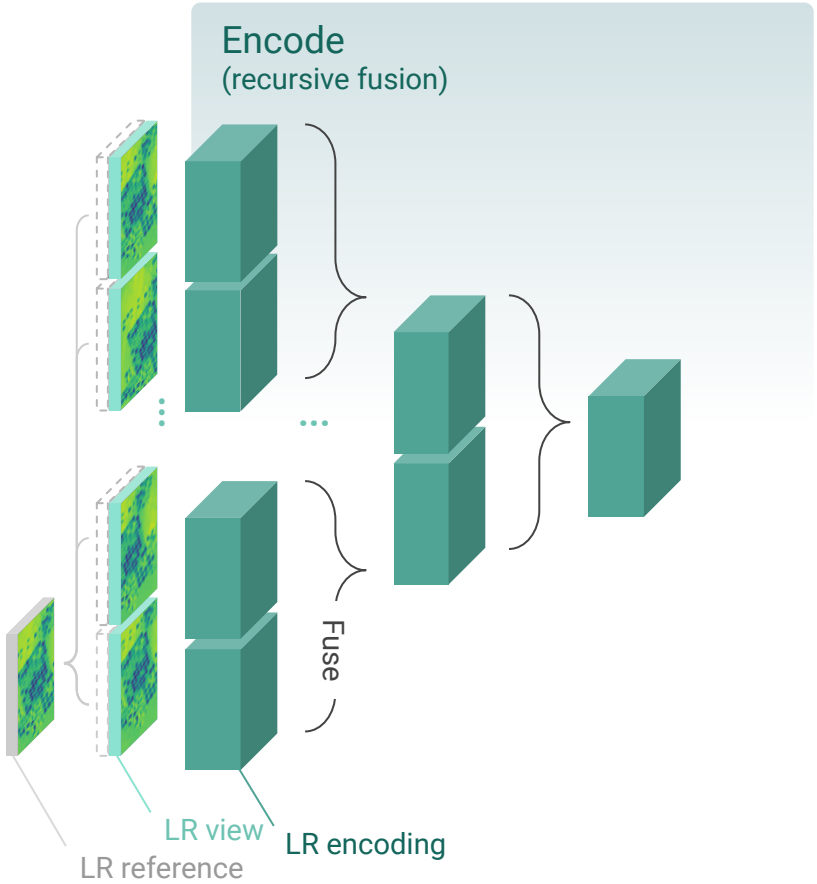
- Fusion in LR space
- $O(\log_2 k)$ fusion layers
- $O(k)$ fusions

Registration matters!



Implicit co-registration

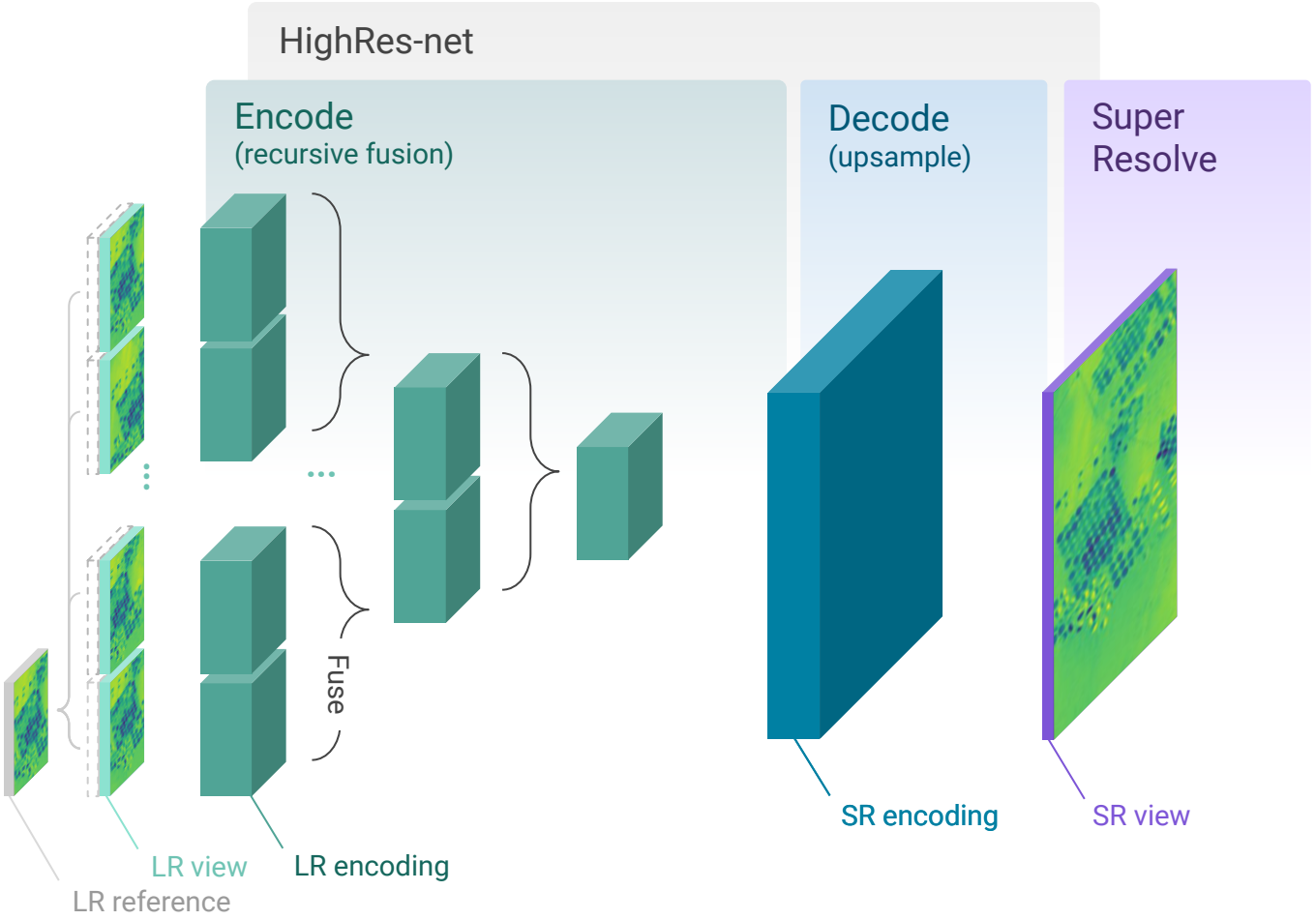
Co-registration



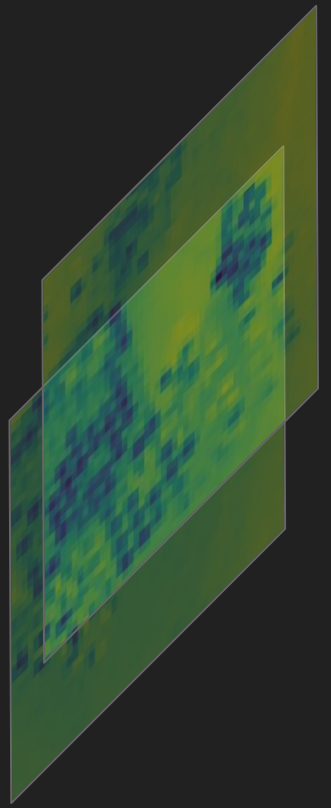
Ablation study - choice of reference frame

Reference	train score	test score
None (no co-registration)	1.0131	1.0088
Mean of 9 LRs	0.9636	0.9690
Median or 9 LRs (base)	**0.9501**	**0.9532**

HighRes-net in a nutshell



Registration in the loss

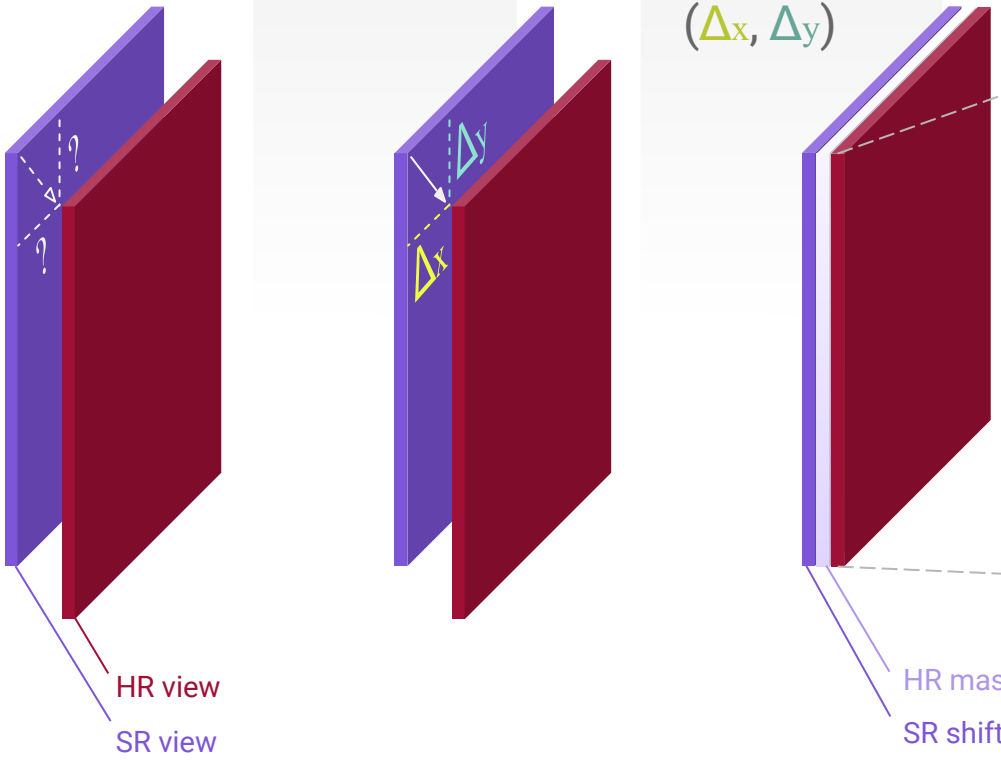


ShiftNet-Lanczos component

ShiftNet
(register)

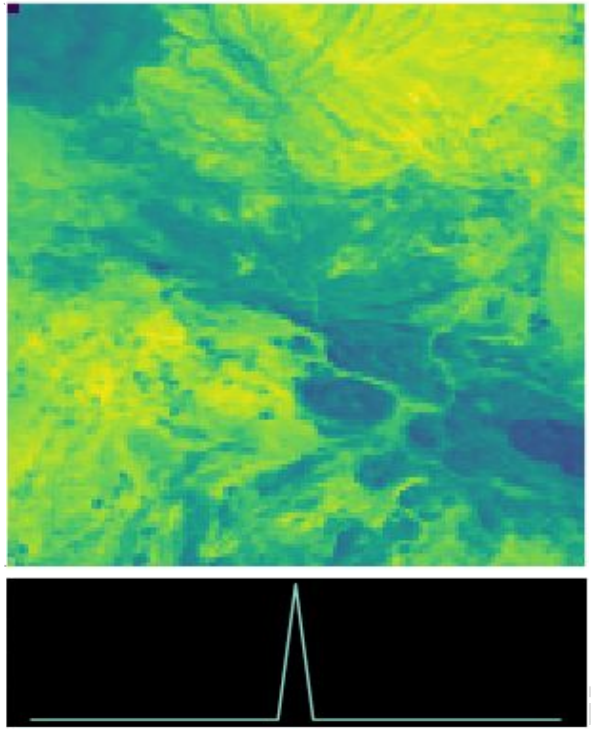
Lanczos
resampling
(shift & interpolate)

$(\Delta x, \Delta y)$

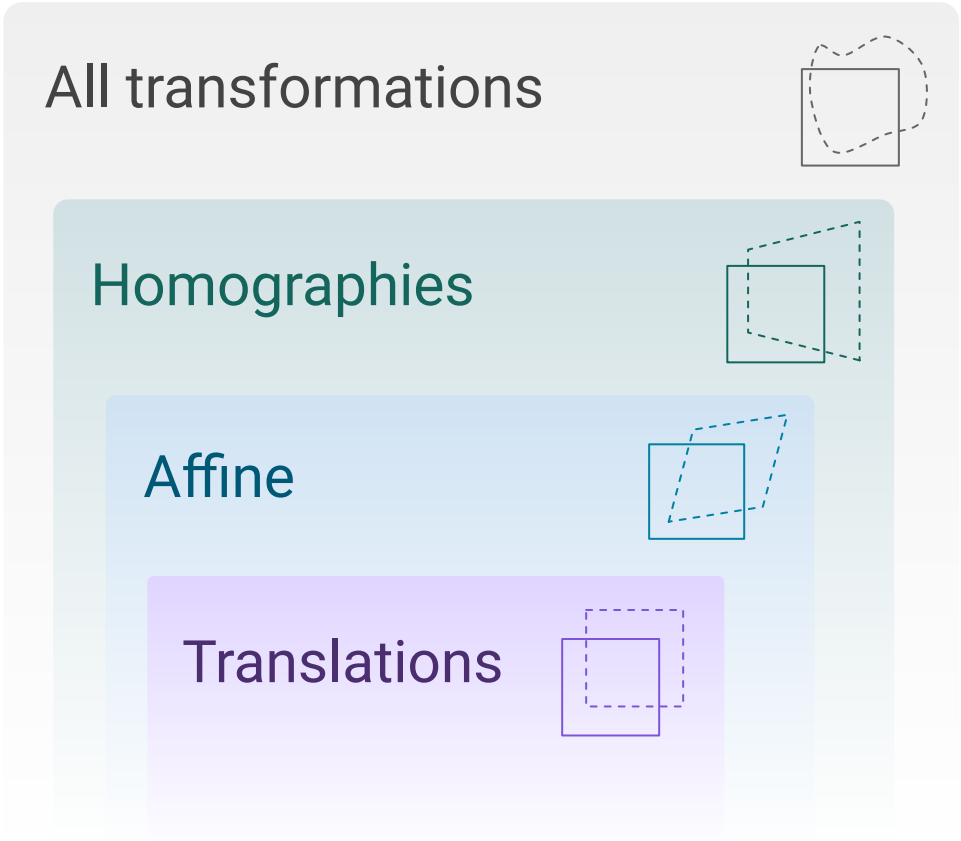


Ablation study: Registered loss

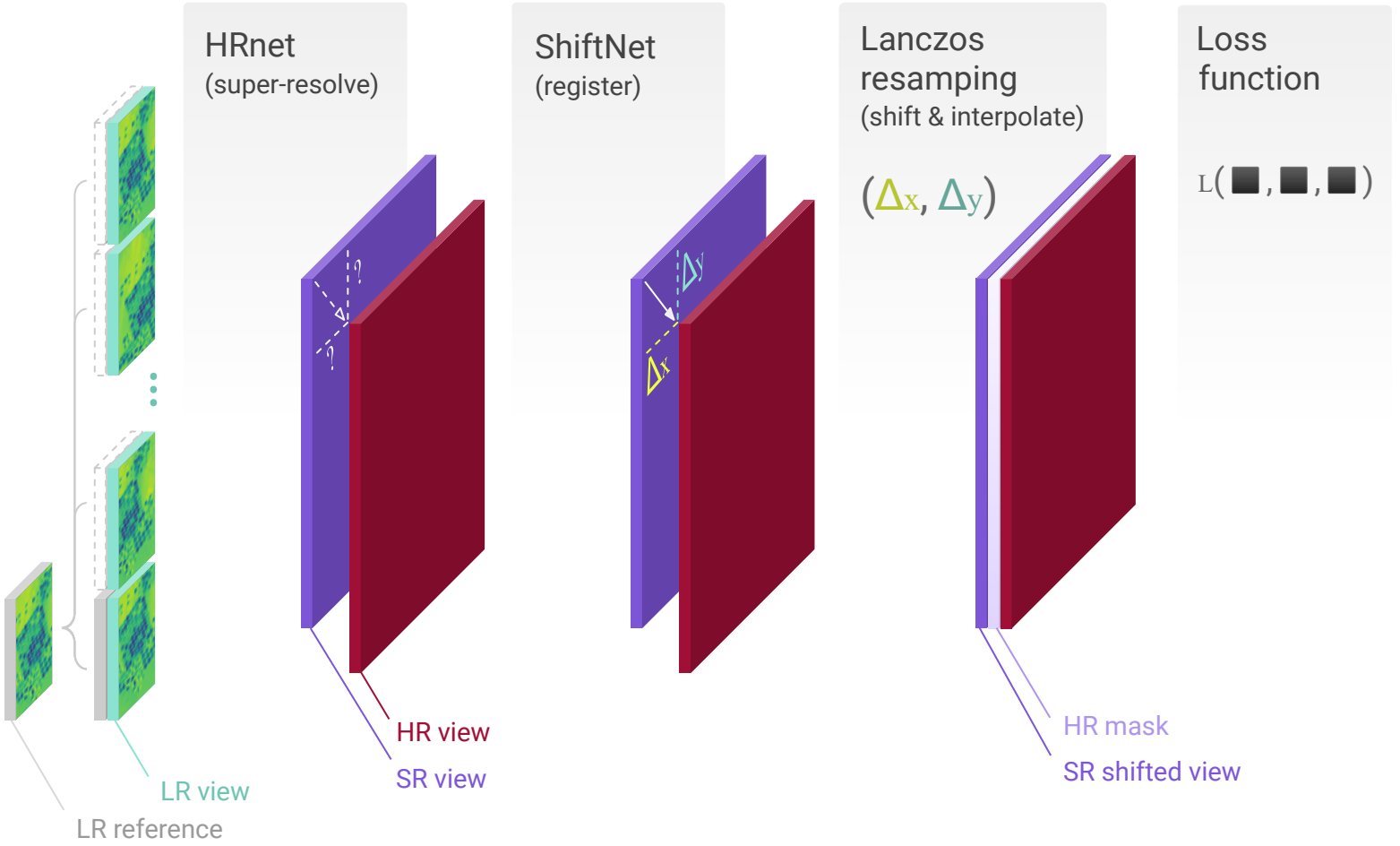
HighRes-net +	train score	test score
w/o registration	0.9616	0.9671
shiftNet + Lanczos	**0.9501**	**0.9532**



Transformation space



End-to-end training

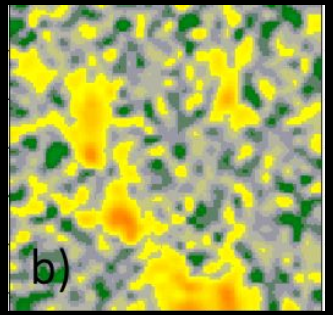


Applications / Future work

01 Now - Space weather (NASA Frontier Development Lab)

02 Future - Calibrate hallucinations

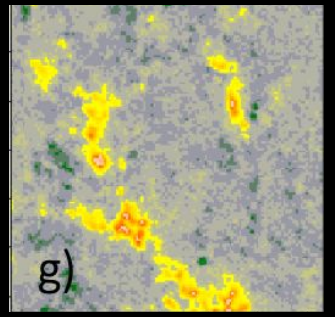
03 Future - Human Rights (Amnesty International / HRW)

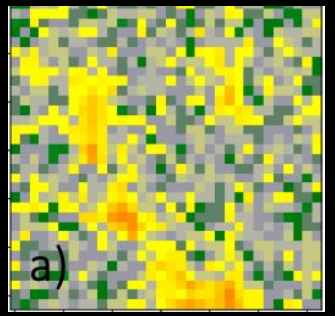


bi-cubic

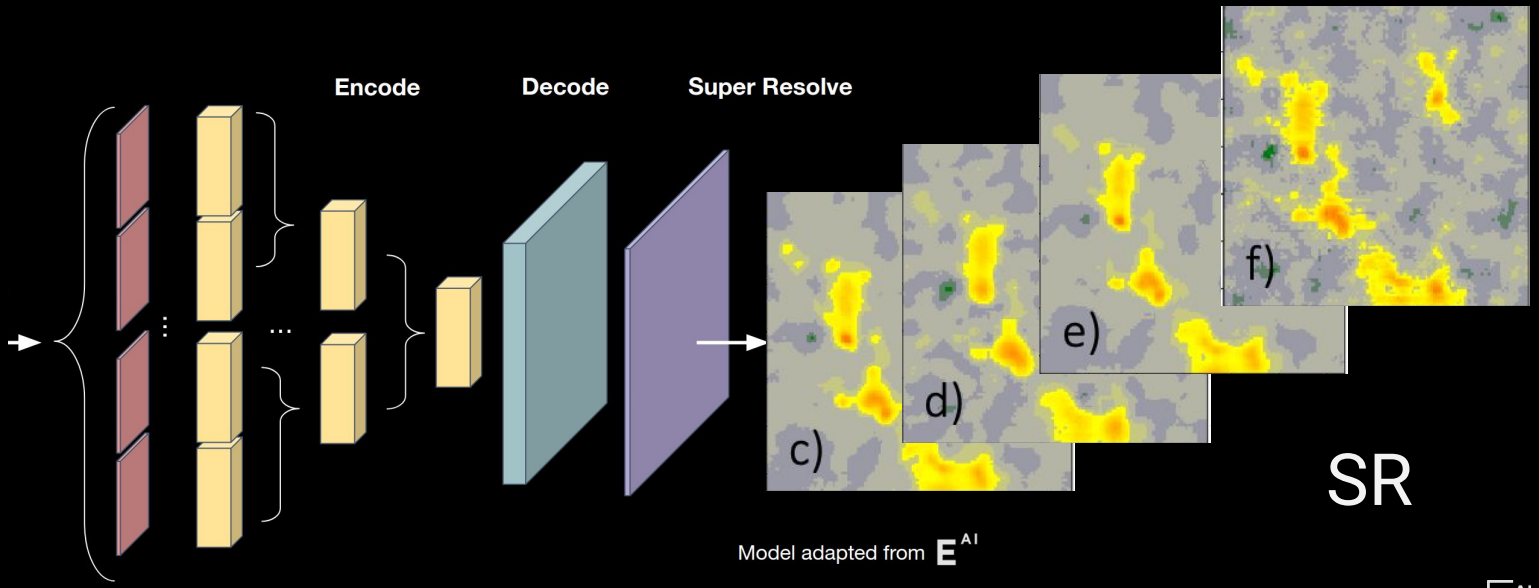
HR

ground truth





LR input

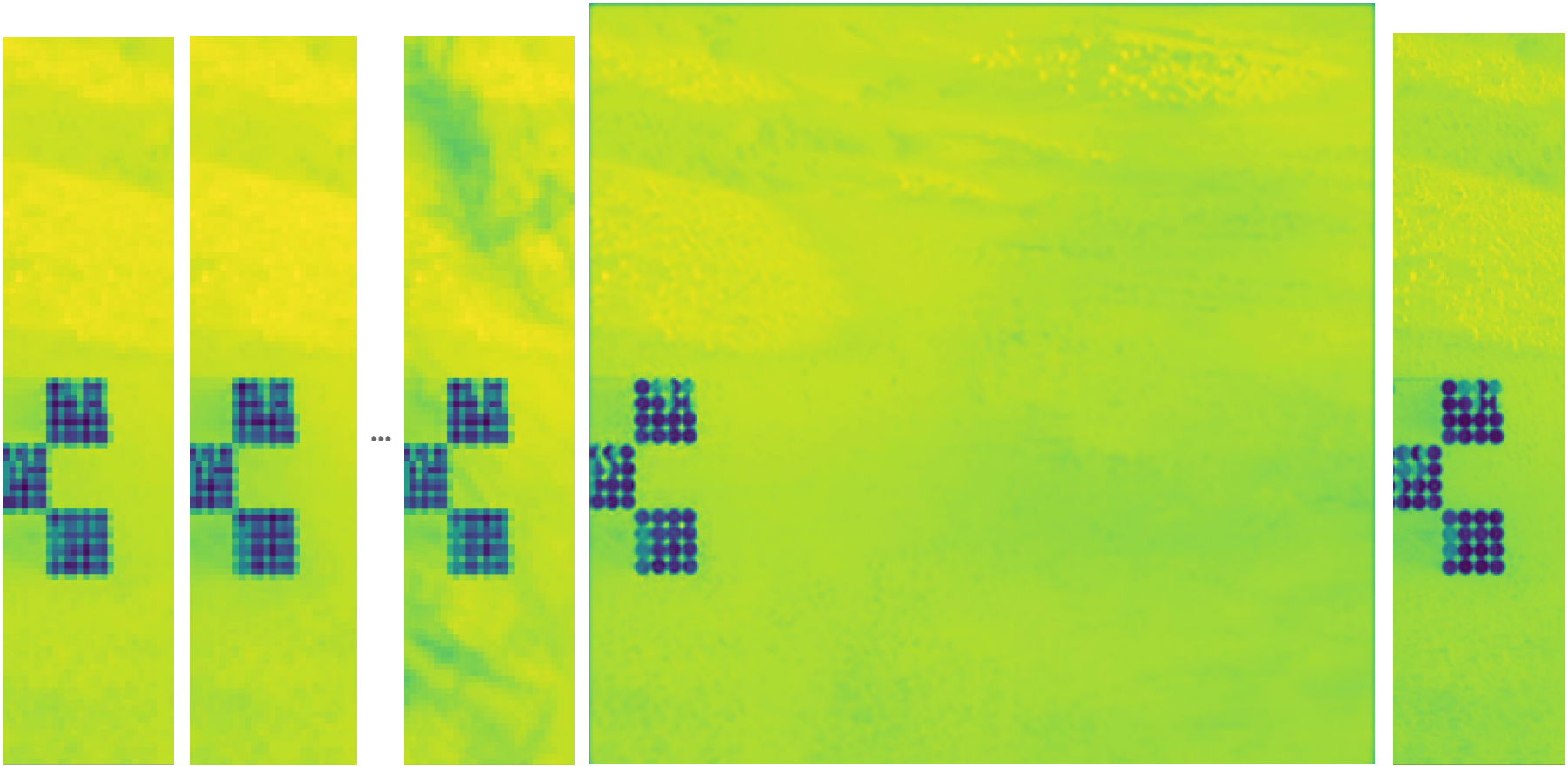


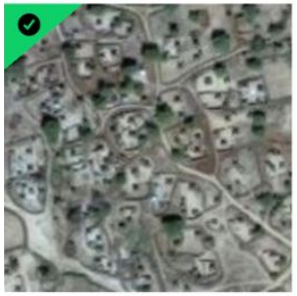
SR

Model adapted from E AI

Google Cloud intel AI LUXEMBOURG SPACE AGENCY Hewlett Packard Enterprise IBM kx LOCKHEED MARTIN nvidia ELEMENT AI USGS SETI INSTITUTE

E AI


Low-res 1
Low-res 2
...
Low-res 9
Super-res
High-res



✓ Metal roofs or other unnatural colour (can be isolated or in groups)

✓ Linear or circular features that enclose other objects

✓ Shadow (darkness) from the linear or circular features

✓ Many similar features clustered together

✘ Round, sporadic features, not enclosed, sometimes green

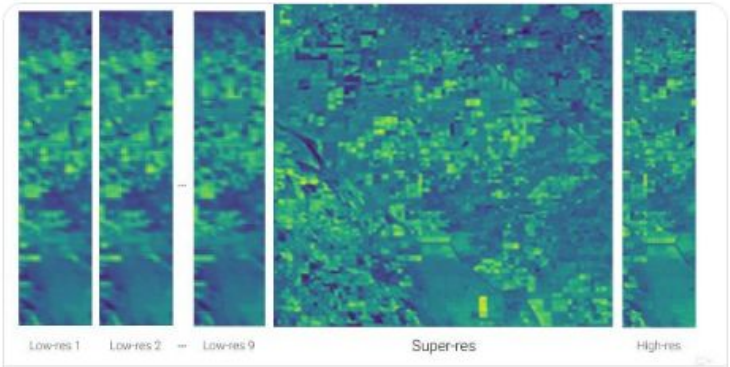
Destroyed: missing roofs, smaller shadows

Freddie Kalaitzis
@alkalait

Super-resolution matters.

It can help to monitor human rights and the environment from space, so with Michel Deudon, Zhichao Lin, @JCornebise, partnered with @MILAMontreal to nail the @esa SR challenge.

We also wrote a blog.
#AIforGood @element_ai elementai.com/news/2019/comp…



Computer, enhance please!
We believe super-resolution technology has a pivotal role to play in solving important problems for society and the environment.
elementai.com

♡ 31 3:40 PM - Jul 3, 2019

04

Q&A

ai4good@elementai.com
@alkalait

References

- http://ec.europa.eu/DocsRoom/documents/686/attachments/1/translations/en/renditions/native

ESA Super-Resolution challenge

Results

Name	Final Score
SuperPip	0.9474466476281652
rarefin	0.9477450367529225
ledzeppelin	0.9576339586408439
luis	0.9626599626701344
PIC4SeR	0.9721971077481462
EscVM	0.9785367146826757
SuperDeep	0.9807595119230784

Leaderboard

Name	Submissions	Best Score
rarefin	46	0.947388637793901
SuperPip	43	0.948844910272775
ledzeppelin	86	0.955016888143629
luis	9	0.964599100320855
PIC4SeR	15	0.971175807378147
EscVM	20	0.976616253152054
SuperDeep	38	0.981791472111074