

# A Hierarchical Prototypical Network for Few-Shot Remote Sensing Scene Classification

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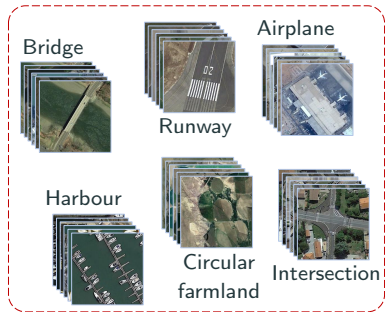
Manal Hamzaoui, Laetitia Chapel, Minh-Tan Pham, Sébastien Lefèvre

July 5<sup>th</sup>, 2022

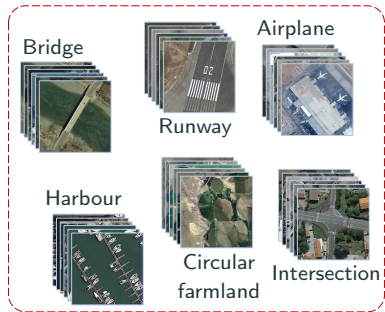
Université Bretagne-Sud, IRISA, MULTISCALE project

MACLEAN @ CAP/RFIAP Workshop 2022

# A Hierarchical Prototypical Network for FSRSSC

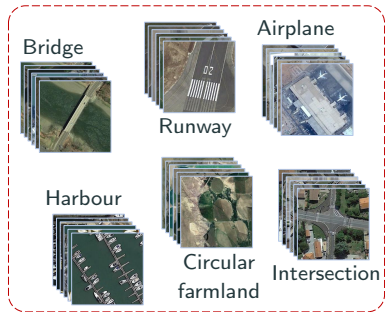


# A Hierarchical Prototypical Network for FSRSSC



Few images/class

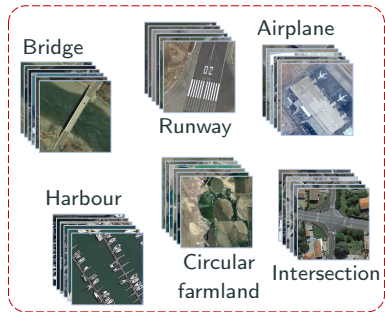
# A Hierarchical Prototypical Network for FSRSSC



Few images/class



# A Hierarchical Prototypical Network for FSRSSC



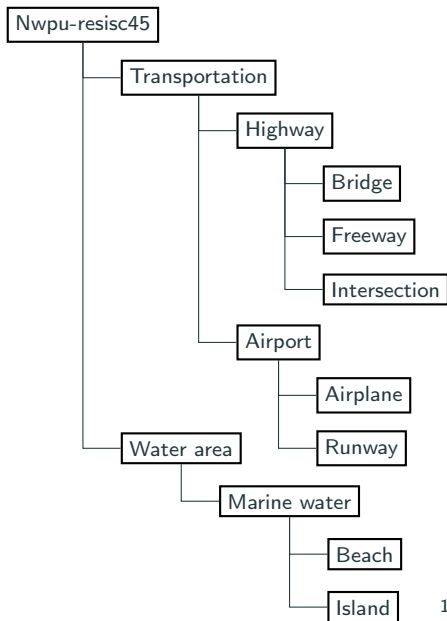
Few images/class



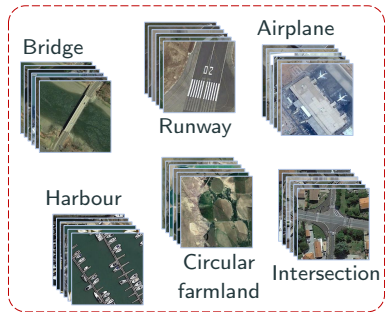
✓ Freeway

✓ Intersection or Bridge

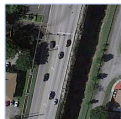
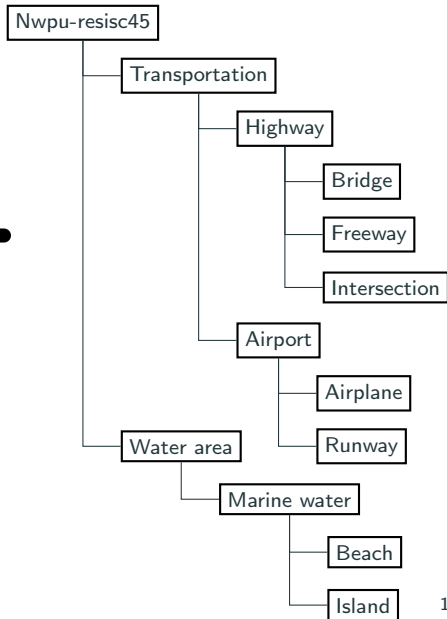
✗ Circular farmland



# A Hierarchical Prototypical Network for FSRSSC



Few images/class



✓ Freeway

✓ Intersection or Bridge

✗ Circular farmland

# Presentation outline

1. Introduction
2. Few-Shot Classification with Prototype Learning
3. A Hierarchical Prototypical Network for Few-Shot Image Classification
4. Experiments & results
5. Conclusion

# Introduction

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# Introduction

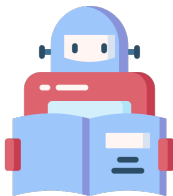


A tiger is a powerful big cat with a distinctive coat of dark orange with black stripes.

# Introduction



A tiger is a powerful **big** cat with a distinctive **coat of dark orange** with **black stripes**.





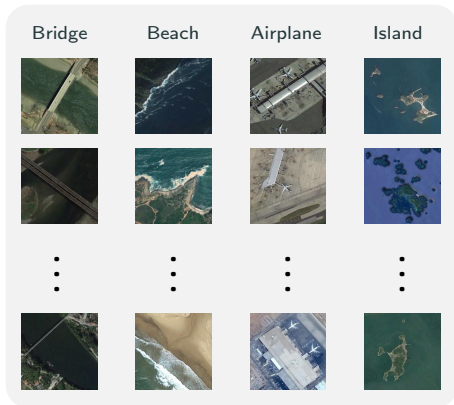
## Few-Shot Learning

A tiger is a powerful big cat with a distinctive coat of dark orange with black stripes.

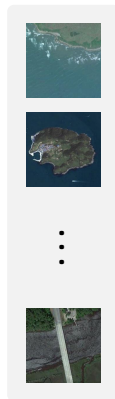


## Classical deep supervised learning

Train data



Test data



**Test classes = Train classes**

## Few-Shot Learning

Meta-Training

Episode 1

Episode 2

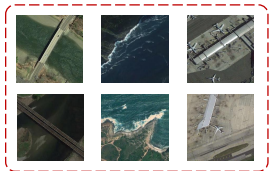
...

Meta-Testing

## Few-Shot Learning

Meta-Training

Episode 1



Episode 2

...

Meta-Testing



## Few-Shot Learning

Meta-Training

Meta-Testing

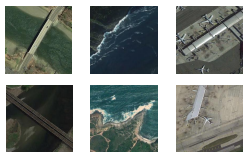
Episode 1

Episode 2

...

Support Set

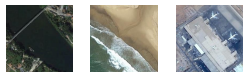
$K = 2$



$N = 3$

Query Set

$K' = 1$



## Few-Shot Learning

Meta-Training

Meta-Testing

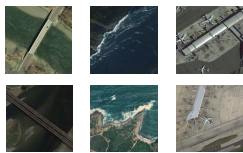
Episode 1

Episode 2

...

Support Set

$K = 2$

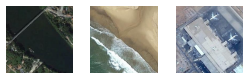


$N = 3$

3-way 2-shot

Query Set

$K' = 1$





## Few-Shot Learning

Meta-Training

Meta-Testing

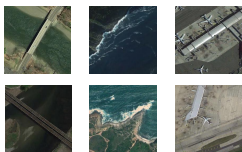
Episode 1

Episode 2

...

Support Set

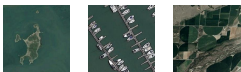
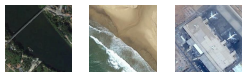
$K = 2$



$N = 3$

Query Set

$K' = 1$



## Few-Shot Learning

Meta-Training

Meta-Testing

Episode 1

Episode 2

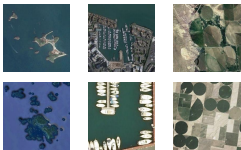
...

Episode 1

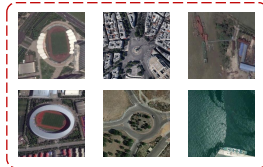
...

Support Set

$K = 2$

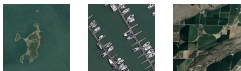
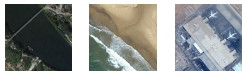


$N = 3$



Query Set

$K' = 1$



## Few-Shot Learning

### Meta-Training

### Meta-Testing

Episode 1

Episode 2

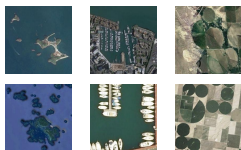
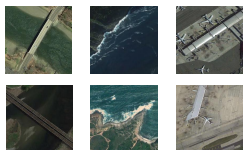
...

Episode 1

...

Support Set

$K = 2$

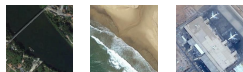


$N = 3$



Query Set

$K' = 1$



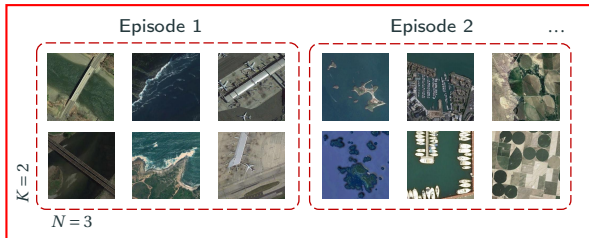
- 1 Episode = 1 classification problem

## Few-Shot Learning

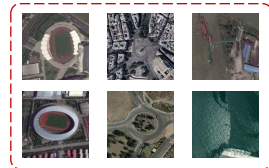
### Meta-Training

### Meta-Testing

Support Set



Query Set



- 1 Episode = 1 classification problem } - Support set  $\approx$  Train set.

## Few-Shot Learning

Meta-Training

Meta-Testing

Episode 1

Episode 2

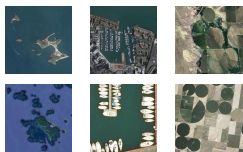
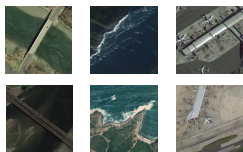
...

Episode 1

...

Support Set

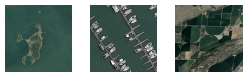
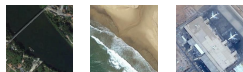
$K = 2$



$N = 3$

Query Set

$K' = 1$



- 1 Episode = 1 classification problem
- {
- Support set  $\approx$  Train set.
  - Query set  $\approx$  Test set.

## Few-Shot Learning

### Meta-Training

### Meta-Testing

Episode 1

Episode 2

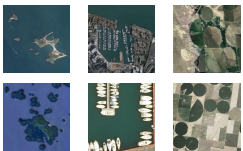
...

Episode 1

...

Support Set

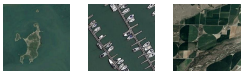
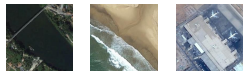
$K = 2$



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Query Set

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- 1 Episode = 1 classification problem  $\left\{ \begin{array}{l} - \text{Support set} \approx \text{Train set.} \\ - \text{Query set} \approx \text{Test set.} \end{array} \right.$
- **Train** → **Known** classes; **Test** → **Novel** classes.

## Few-Shot Learning

+ Focused only on visual information.

- Zhang et al.[1] proposed a pre-training step + cosine distance metric.
- Cheng et al.[2] proposed a Siamese-prototype network (SPNet) with prototype self-calibration (SC) and intercalibration (IC).

## Few-Shot Learning

- + Focused only on visual information.
- Semantic knowledge.

### Text[3]

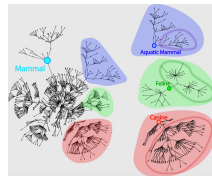
A tiger is a powerful big cat with a distinctive coat of dark orange with black stripes ...

### Attributes

#### Polar bear

Black:	no
White:	yes
Brown:	no
Stripes:	no
Water:	yes
Eat fishes:	yes

### Knowledge Graph[4]





## Objectives:

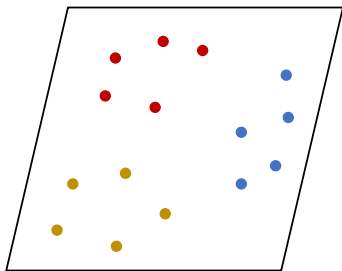
- Few-shot Remote Sensing Scene Classification.
- Semantic knowledge: class hierarchy.

# Few-Shot Classification with Prototype Learning

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# Few-Shot Classification with Prototype Learning[5]

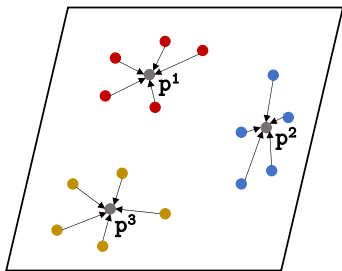
3-way 5-shot



Feature space

# Few-Shot Classification with Prototype Learning[5]

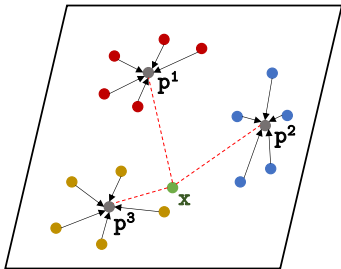
3-way 5-shot



$$p^c = \frac{1}{K} \sum_{(x,y) \in S^c} f_{\Phi}(x)$$

# Few-Shot Classification with Prototype Learning[5]

3-way 5-shot



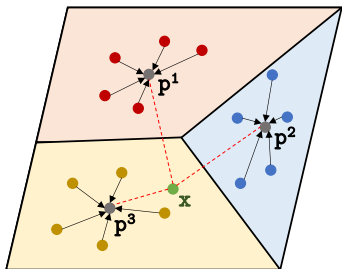
$$p^c = \frac{1}{K} \sum_{(x,y) \in S^c} f_{\Phi}(x)$$

Prediction probability:

$$p_{\Phi}(y_q = c | x_q) = \frac{\exp(-d(f_{\Phi}(x_q), p^c))}{\sum_{c' \in C_e} \exp(-d(f_{\Phi}(x_q), p^{c'}))}$$

# Few-Shot Classification with Prototype Learning[5]

3-way 5-shot



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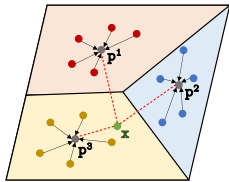
Function to be optimized:

$$\mathcal{L} = -\frac{1}{N \times K'} \sum_{c \in C_e} \sum_{(x_q, y_q) \in Q^c} \log p_{\Phi}(y_q = c | x_q)$$

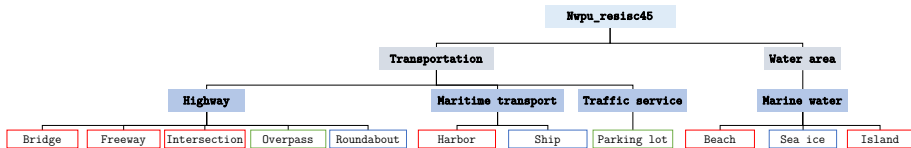
# A Hierarchical Prototypical Network for Few-Shot Image Classification

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# A Hierarchical Prototypical Network for FSIC



+

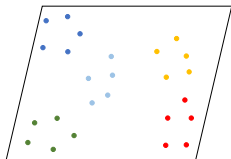
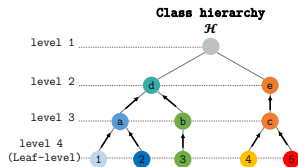


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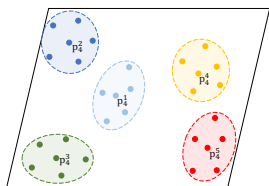
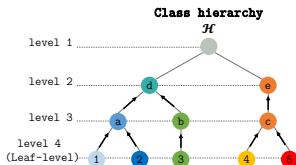


# A Hierarchical Prototypical Network for FSIC

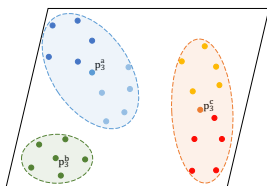
5-way 5-shot



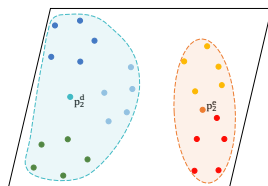
# A Hierarchical Prototypical Network for FSIC



Level 4



Level 3

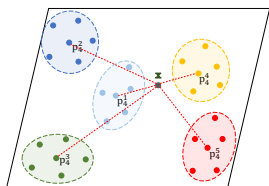
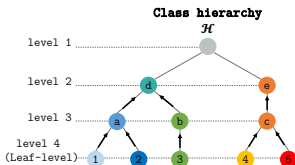


Level 2

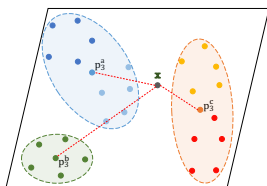
Hierarchical prototypes:

$$p_{\ell}^c = \frac{1}{|S_{\ell}^c|} \sum_{(x_i, y_i) \in S_{\ell}^c} f_{\Phi}(x_i)$$

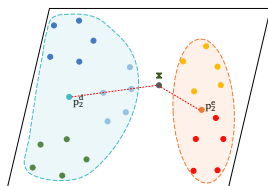
# A Hierarchical Prototypical Network for FSIC



Level 4



Level 3



Level 2

Hierarchical prototypes:

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Function to be optimized:

$$\mathcal{L}_{\mathcal{H}\text{-proto}} = \sum_{\ell=2}^L \lambda_{\ell} \mathcal{L}_{\ell} ; \quad p_{\Phi}(y_q^{\ell} = c | x_q) = \frac{\exp(-d(f_{\Phi}(x_q), p_{\ell}^c))}{\sum_{c' \in C_{\ell}^c} \exp(-d(f_{\Phi}(x_q), p_{\ell}^{c'}))}$$

# Experiments

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- 5-way 5-shot classification.
- Remote sensing dataset (NWPU-RESISC45):
  - 45 classes.
- Feature extractor: ResNet12.
- Evaluation metrics:
  - Accuracy per level.
  - Hierarchical precision:

$$hp = \frac{\sum_i |\hat{Y}_i \cap Y_i|}{\sum_i |\hat{Y}_i|}$$

**Table 1:** 5-shot classification results computed on the test set of the NWPU-RESISC45 dataset at different levels of the class hierarchy.

Method	hyp-param	overall acc	L3-acc	L2-acc	hp
ProtoNet [5]	/	83.76 ± 0.13	84.80 ± 0.04	85.62 ± 0.09	84.72 ± 0.08
c-ProtoNet [1]	10	80.21 ± 0.59	82.11 ± 1.80	84.81 ± 4.08	82.38 ± 2.16
Soft-labels [6]	4	84.22 ± 0.25	85.35 ± 0.23	86.19 ± 0.23	85.25 ± 0.23
h-ProtoNet (ours)	0.5	84.90 ± 0.25	86.01 ± 0.22	86.72 ± 0.23	85.88 ± 0.22
h-ProtoNet (ours)	1	<b>85.11 ± 0.23</b>	<b>86.10 ± 0.22</b>	<b>86.81 ± 0.22</b>	<b>86.01 ± 0.21</b>
h-ProtoNet (ours)	2	<u>84.95 ± 0.23</u>	85.93 ± 0.22	86.65 ± 0.20	85.85 ± 0.22

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h-ProtoNet (ours)	2	<u><math>84.95 \pm 0.23</math></u>	$85.93 \pm 0.22$	$86.65 \pm 0.20$	$85.85 \pm 0.22$

**Table 1:** 5-shot classification results computed on the test set of the NWPU-RESISC45 dataset at different levels of the class hierarchy.

Method	hyp-param	overall acc	L3-acc	L2-acc	hp
ProtoNet [5]	/	$83.76 \pm 0.13$	$84.80 \pm 0.04$	$85.62 \pm 0.09$	$84.72 \pm 0.08$
c-ProtoNet [1]	10	$80.21 \pm 0.59$	$82.11 \pm 1.80$	$84.81 \pm 4.08$	$82.38 \pm 2.16$
Soft-labels [6]	4	$84.22 \pm 0.25$	$85.35 \pm 0.23$	$86.19 \pm 0.23$	$85.25 \pm 0.23$
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Regularization of  
the feature space

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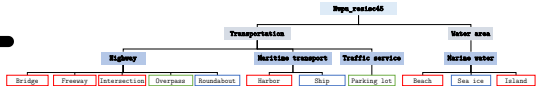
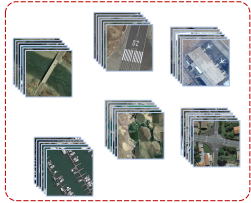
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# Conclusion

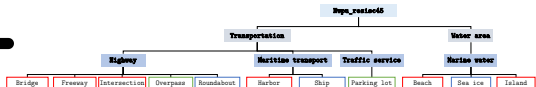
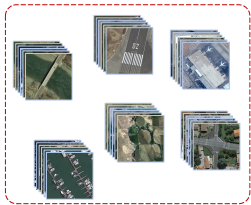
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# Conclusion & Perspectives



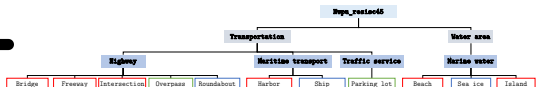
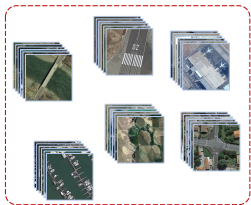
# Conclusion & Perspectives



**PERFORMANCES**

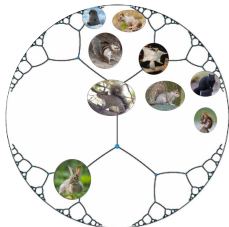
- + Overall Accuracy
- + Higher Level Accuracy

# Conclusion & Perspectives



**PERFORMANCES**

- + Overall Accuracy
- + Higher Level Accuracy



**Hyperbolic geometry[7]**

- [1] Zhang, P., Bai, Y., Wang, D., Bai, B., Li, Y.: Few-shot classification of aerial scene images via meta-learning. *Remote. Sens.* 13(1), 108 (2021).
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- [3] Chen, Z., Fu, Y., Zhang, Y., Jiang, Y., Xue, X., Sigal, L.: Multi-level semantic feature augmentation for one-shot learning. *IEEE Trans. Image Process.* 28(9), 4594–4605 (2019)
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- [6] Bertinetto, L., Müller, R., Tertikas, K., Samangooei, S., Lord, N.A.: Making better mistakes: Leveraging class hierarchies with deep networks. In: *CVPR*. pp. 12503–12512. Computer Vision Foundation/IEEE (2020).
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# A Hierarchical Prototypical Network for Few-Shot Remote Sensing Scene Classification

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July 5<sup>th</sup>, 2022

Université Bretagne-Sud, IRISA, MULTISCALE project

MACLEAN @ CAP/RFIAP Workshop 2022