

PHD PROPOSAL FOR THE DOCTORAL SCHOOL « Ecologie, Géosciences, Agronomie, ALimentation »

GENERAL INFORMATION

Thesis title: Contribution of Artificial Intelligence to bedforms mapping and analysis
Acronym: AIBEDMAP
Disciplinary field 1: Geosciences Disciplinary field 2: Select an element
Three keywords: Geomorphology ; GIS ; Artificial intelligence
Research unit : LPG UMR 6112 Laboratoire de Planétologie et de Géodynamique
Name of the thesis director HDR (Habilitation thesis to supervise research) required: MOURGUES Régis Email address of the thesis director: regis.mourgues@univ-lemans.fr Name of the thesis co-supervisor 1 (if applicable): BESSIN, Paul Email address of the thesis co-supervisor 1 (if applicable): paul.bessin@univ-lemans.fr Name of the thesis co-supervisor 2 (if applicable): POCHAT, Stéphane Email address of the thesis co-supervisor 2 (if applicable): stephane.pochat@univ-nantes.fr
Thesis grant (funding origin and amount): Contrat Doctoral Etablissement (Institutional Doctoral Fellowship)
Contact(s) (mailing address and E-mail): paul.bessin@univ-lemans.fr
Recruitment process: Recruitment process depends on thesis funding. To select the corresponding recruitment process, please visit the EGAAL website here . This information is needed for proposal publication. <input checked="" type="checkbox"/> Doctoral school contest <input type="checkbox"/> Interview <input type="checkbox"/> Other (indicate) :

All sections must be filled. Once filled, please save the proposal form in pdf format using the following naming: Supervisor Name_Unit_Subject Acronym_EN.pdf

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SCIENTIFIC DESCRIPTION OF THE PhD PROJECT

Socio-economic and scientific context : (10 lines)

Based at Nantes, Angers and Le Mans (western France), the [Laboratory of Planetology and Geodynamics](#) (LPG – UMR 6112) organizes its research activities around 4 thematics. The PhD thesis will mainly take place at Le Mans (with regular visits and stays in Nantes) and will be mainly part of the "Planet Earth" thematics (possible openings towards the "Telluric planets" and "Icy worlds" thematics). The researchers involved in the supervision and the collaborations related to the thesis subject cooperate actively on different aspects: geomorphology, sedimentology and physics of the transfer processes through various projects (e.g. DEFORm 2015-2019, [ANR IceCollapse](#), 2019-2023; [Geoplanet](#) 2017-2019).

A recurrent point of these works is the need to map and analyze bedforms. Bedforms describe morphologies that develop at the interface between a fluid and a material due to fluid flow. Bedforms are typically clustered in large fields where they form assemblages of periodic patterns (Allen, 2004; Marshak, 2019). According to their occurrences and the nature of materials constituting the bedforms, different labels have are commonly used such as: ripples and dunes (loose sediment transported by water/wind), moraines and lineations (e.g. drumlins, flutes; loose sediment transported by water and ice), or sublimation waves (wind-driven ice sublimation/precipitation) on the ice surface (Figure 1). The large amount and the resolution of data now available to map these bedforms require the development of new mapping methods using Artificial Intelligence (Machine Learning, Deep Learning).

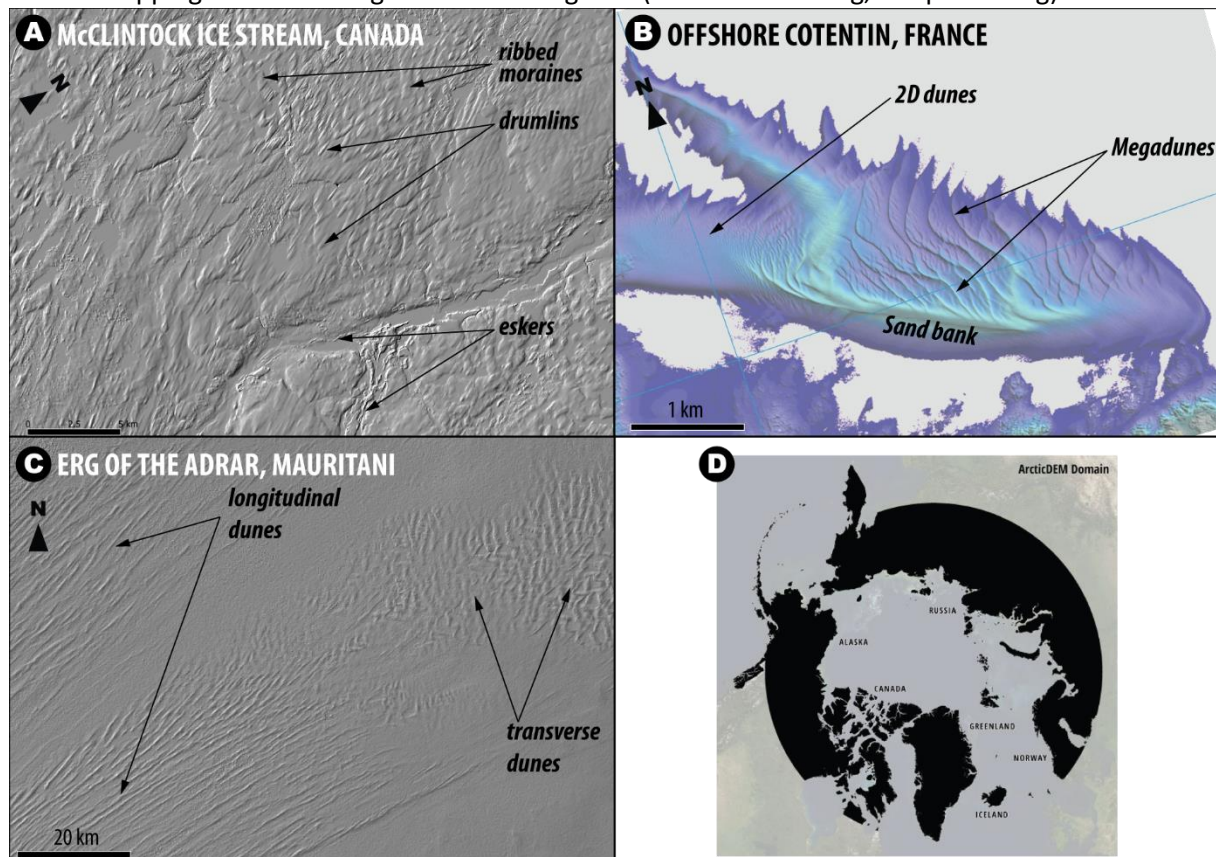


Figure 1 : Snapshots of bedforms within different geomorphological contexts (A : subglacial, B : submarine, C : eolian) on Hillshades derived from DEM (B : decreasing bathymetry from dark blue to cream) and (D) ArcticDEM dataset coverage at 2m resolution (Sources : A : ArcticDEM (Porter et al., 2018), C : Lidar Normandie Hauts-de-France 2016-2017 V.20180501 ; C : SRTM 1 arcsecond, Jarvis et al., 2008).

Thus, the thesis will focus on the development of a (semi-) automated protocol to map bedforms and apply this protocol to one or several bedform fields (e.g. [large Saharian erg](#); bedforms under paleo-ice caps, subaquatic dune field).

Assumptions and questions (8 lines)

Bedforms are of major scientific interest due to their ubiquitous occurrence on planetary surfaces, including Earth, and because their characteristics (e.g. shape, size, orientation, complexity) mainly depend on the features of the overlying fluid flow (e.g. velocity, direction(s), spatial and temporal variations, turbulence). Mapping fields of bedforms is therefore a way i) to determine the flow dynamics and to propose paleodynamic reconstructions (e.g. paleoglaciology) but also ii) to understand their modes of formation and their spatio-temporal relationships. Nowadays, topographic (Digital Elevation Models, DEM) and satellite imagery data are increasingly available with higher resolutions and larger geographical areas; constituting an extraordinary database to process (e.g. [ArcticDEM](#), 2 m and 10 m resolution; Figure 10 Porter et al., 2018; [RGE ALTI](#)®, IGN; [HiRISE](#) and [HRSC](#) data). However, bedform mapping is mostly performed through manual digitizing under Geographic Information System from DEM, satellite images and their derivatives (slope, curvature, etc.) or by basic pixel analysis protocols. The former method is very time consuming and induces cartographer mapping subjectivity while the latter produces noisy results and struggle to distinguish bedforms of different sizes (Hillier et al., 2015; Wagner, 2018). This PhD thesis aims i) to address these challenges by using Artificial Intelligence (AI) for geomorphological mapping and ii) to produce one to several studies of field(s) of bedforms on terrestrial to Martian sites using these new AI tools.

The main steps of the thesis and scientific procedure (10-12 lines)

To develop and apply one or several (semi-)automatic bedform mapping protocol(s), the PhD candidate will perform the development of AI protocols and apply those to several bedform fields according to the following steps:

- ✓ Bibliographic synthesis of mapping protocols using AI and training in Machine Learning and Deep Learning;
- ✓ Development of a protocol to map bedform contours and ridges (choice of: aeolian, subglacial, aquatic) using Machine Learning (or Deep Learning);
- ✓ Application of the developed protocol to a selected field of bedforms to produce mapping and morphometric analysis i) to understand and quantify the spatial relationships between the morphologies (e.g. amplitudes, wave lengths, angles) and/or ii) to propose an interpretation of the fluid flow dynamics;
- ✓ Reproducibility analysis of the developed mapping protocol on other fields of bedforms from a similar dataset;
- ✓ Depending on the results, the protocol could be adjusted for bedforms i) to analysis time series of data and/or ii) to produce a comparative analysis between terrestrial and planetary morphologies.

At the beginning of the thesis, the PhD candidate will build on the work and results of two Master 2 internships carried out in Le Mans. They have initiated the development of mapping protocols based on the segmentation-classification of DEM and derivatives (e.g. slope, curvature, etc.) to map subglacial morphologies.

Methodological and technical approaches considered (4-6 lines)

The protocol of bedform mapping will be based on AI, specifically on Machine Learning. It will involve the segmentation of pixel data (DTM and satellite images) and the classification of the segmented objects based on their characteristics (OBIA (Object-Based Image Analysis) approach, Figure 2). Preferably, this development will be carried out on the eCognition developer software (Le Mans) which proposes powerful segmentation algorithms (e.g. Multiresolution segmentation, Multi-threshold segmentation; e.g. Eisank et al., 2014; Middleton et al., 2020) that can be associated with a Deep Learning approach (Convolutional Neural Network, CNN; Robson et al., 2020). Various classification algorithms (e.g. Random Forest, K-mean, SVM, Decision Tree) will also be tested. Depending on the student's skills in programming, remote sensing and GIS, a development and an integration of an innovative protocol under Python and QGIS (by integrating libraries and tools such as Orfeo) could be considered.

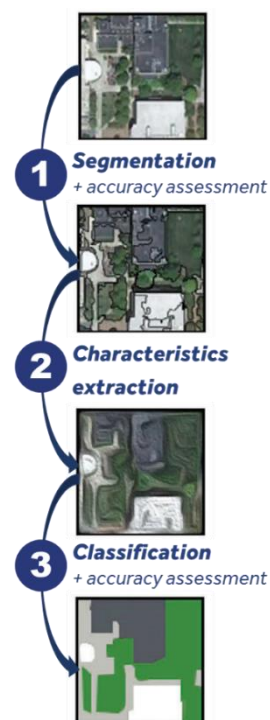


Figure 2 : Main step of an Object-Based Image Analysis protocol on a satellite image.

Scientific and technical skills required by the candidate

- ✓ Master degree (or equivalent) in one or several of the following fields is mandatory : GIS, Earth Sciences, Topography, Physical Geography;
- ✓ A background knowledge in GIS (QGIS or ArcGIS) is mandatory ;
- ✓ A background knowledge in programming (Python) will be appreciated;
- ✓ A background knowledge in geomorphology, sedimentology and/or fluid mechanics will be appreciated;
- ✓ A good level in English (spoken and written) recommended;
- ✓ Driving license recommended.

References

- Allen, J.R.L., 2004. Bedform, in: Goudie, A.S. (Ed.), Encyclopedia of Geomorphology. Routledge - Taylor and Francis Group, London and New-York, p. 110.
- Eisank, C., Smith, M., Hillier, J., 2014. Assessment of multiresolution segmentation for delimiting drumlins in digital elevation models. *Geomorphology* 214, 452–464. <https://doi.org/10.1016/J.GEOMORPH.2014.02.028>
- Hillier, J.K., Smith, M.J., Armugam, R., Barr, I., Boston, C.M., Clark, C.D., Ely, J., Frankl, A., Greenwood, S.L., Gosselin, L., Hättestrand, C., Hogan, K., Hughes, A.L.C., Livingstone, S.J., Lovell, H., McHenry, M., Munoz, Y., Pellicer, X.M., Pellitero, R., Robb, C., Roberson, S., Ruther, D., Spagnolo, M., Standell, M., Stokes, C.R., Storrar, R., Tate, N.J., Wooldridge, K., 2015. Manual mapping of drumlins in synthetic landscapes to assess operator effectiveness. *J. Maps* 11, 719–729. <https://doi.org/10.1080/17445647.2014.957251>
- Jarvis, A., Reuter, H.I., Nelson, A., Guevara, E., 2008. Hole-filled SRTM for the globe, Version 4. CGIAR-CSI SRTM 90m Database. Int. Cent. Trop. Agric. Cali, Columbia. <http://srtm.csi.cgiar.org>.
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- Middleton, M., Nevalainen, P., Hyvönen, E., Heikkonen, J., Sutinen, R., 2020. Pattern recognition of LiDAR data and sediment anisotropy advocate a polygenetic subglacial mass-flow origin for the Kemijärvi hummocky moraine field in northern Finland. *Geomorphology* 107212.
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- Robson, B.A., Bolch, T., MacDonell, S., Hölbling, D., Rastner, P., Schaffer, N., 2020. Automated detection of rock glaciers using deep learning and object-based image analysis. *Remote Sens. Environ.* 250, 112033. <https://doi.org/https://doi.org/10.1016/j.rse.2020.112033>
- Wagner, K., 2018. Geographic information systems and glacial environments, in: Past Glacial Environments. Elsevier, pp. 503–536.

THESIS SUPERVISION¹

Unit name: Laboratoire de Planétologie et de Géodynamique LPG UMR 6112	Team name: Géosciences Le Mans
Unit director name: MOCQUET Antoine	Team director name: ZANELLA Alain
Mailing address of the unit director: antoine.mocquet@univ-nantes.fr	Mailing address of the team director: alain.zanella@univ-lemans.fr
Thesis director Surname, first name: MOURGUES Régis Position: Professeur Obtained date of the HDR (Habilitation thesis to supervise research): 2012 Employer: Le Mans Université Doctoral school affiliation: EGAAL Rate of thesis supervision in the present project (%):40 % Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%):80 % Number of current thesis supervisions/co-supervisions: 2	
Thesis co-supervisor 1 (if applicable) Surname, first name: BESSIN, Paul Position: Maître de conférences (Assistant professor) Habilitation thesis to supervise research <input type="checkbox"/> yes <input checked="" type="checkbox"/> no If yes, date diploma received: Employer: Le Mans Université Doctoral school affiliation: EGAAL Rate of thesis supervision in the present project (%):30 % Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%):0 % Number of current thesis supervisions/co-supervisions: 0	
Thesis co-supervisor 2 (if applicable) Surname, first name: POCHAT, Stéphane Position: Maître de conférences (Assistant professor)	

¹ In EGAAL Doctoral School, if only one scientist in thesis supervision = 100% of supervision rate; if 2 people involved in thesis supervision = from 50% to 70% of supervision rate for the director; if 3 people involved in thesis supervision = 40% / 30% / 30% of supervision rate distribution among supervisors.

Habilitation thesis to supervise research yes no If yes, date diploma received:

Employer: Université de Nantes

Doctoral school affiliation: EGAAL

Rate of thesis supervision in the present project (%): 30 %

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 0 %

Number of current thesis supervisions/co-supervisions: 0

Professional status of previous PhD students supervised by both director and co-supervisors (from 5 years)

Please provide the following information for each PhD students supervised

Surname, first name: LELANDAIS, Thomas

Date of PhD beginning and PhD defence: 01/10/2015 – 19/12/2018

Thesis supervision: MOURGUES Régis

Professional status and location: Ingénieur, ALTRAN, Brest

Contract profile (post-doc, fixed-term, permanent): CDI

List of publications from the thesis work:

Lelandais, T., Mourgues, R., Ravier, É., Pochat, S., Strzeczynski, P., Bourgeois, O., 2016. Experimental modeling of pressurized subglacial water flow: Implications for tunnel valley formation. J. Geophys. Res. Earth Surf. 121, 2022–2041. <https://doi.org/10.1002/2016JF003957>

Lelandais, T., Ravier, É., Pochat, S., Bourgeois, O., Clark, C., Mourgues, R., Strzeczynski, P., 2018. Modelled subglacial floods and tunnel valleys control the life cycle of transitory ice streams. Cryosph. 12, 2759–2772. <https://doi.org/10.5194/tc-12-2759-2018>

Surname, first name: LARMIER, Salomé

Date of PhD beginning and PhD defence: 01/10/2016 – 30/06/2020

Thesis supervision: MOURGUES Régis

Professional status and location: Looking for a job

Contract profile (post-doc, fixed-term, permanent):

List of publications from the thesis work:

Larmier, S., Zanella, A., Lejay, A., Mourgues, R., Gelin, F., Geological parameters controlling the bedding-parallel veins distribution from Vaca Muerta Formation cored data, Neuquén basin, Argentina. AAPG bulletin, accepted

Five main recent publications of the supervisors on thesis subject:

Vérité, J., Ravier, É., Bourgeois, O., Pochat, S., Lelandais, T., Mourgues, R., Clark, C.D., Bessin, P., Peigné, D., Atkinson, N., 2020. Ribbed bedforms in palaeo-ice streams reveal shear margin positions, lobe shutdown and the interaction of meltwater drainage and ice velocity patterns. Cryosph. Discuss. 2020, 1–31. <https://doi.org/10.5194/tc-2020-336>

Lelandais, T., Ravier, É., Pochat, S., Bourgeois, O., Clark, C., Mourgues, R., Strzeczynski, P., 2018. Modelled subglacial floods and tunnel valleys control the life cycle of transitory ice streams. Cryosph. 12, 2759–2772. <https://doi.org/10.5194/tc-12-2759-2018>

Le Cadre, A., Bessin, P., Kravitz, K., Braun, J., 2019. Think objects, not pixels! Semi-automated object-based analysis for geomorphic identification and mapping from digital elevation data: the case of planation

surfaces, in: ASF Association Des Sedimentologues Francais. 17ème Congrès Française Sédimentologie, Beauvais.

Bordiec, M., Carpy, S., Bourgeois, O., Herny, C., Massé, M., Perret, L., Claudin, P., Pochat, S., Douté, S., 2020. Sublimation waves: Geomorphic markers of interactions between icy planetary surfaces and winds. Earth-Science Rev. <https://doi.org/10.1016/j.earscirev.2020.103350>

THESIS FUNDING

Origin(s) of the thesis funding:

Salary : Institutionnal Doctoral Fellowship (Le Mans Université) 2021-2024 ;

Working environnement : BPGO project (2021, P. Bessin) ; ANR IceCollapse (2019-2023, E. Ravier) ; LPG (Le Mans) ; additional project proposals (e.g. INSU, ANR) ;

Gross monthly salary: 1769 €/month – 1950 €/months with teaching duties

Thesis funding state : Acquired

Salary : funded

Working environnement : partly funded (Projet BPGO, ANR IceCollapse)

Funding beginning date/Funding ending date: 10/01/2021 to 09/30/2024 – 36 months

Date: 03/24/2021

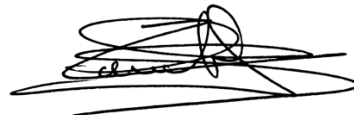
Name, signature of unit director:

Antoine MOCQUET



Name, signature of team director:

Alain ZANELLA



Name, signature of thesis project director:

Régis MOURGUES

