GEO Initiative on Essential Variables – GEO-EVs

1. *Executive Summary* (2 pages)

Full title of the Initiative: GEO Initiative on Essential Variables
Short title or acronym: GEO-EVs
Proposed category: GEO Initiative
Overview:

The concept of Essential Variables (EVs) is increasingly used in Earth observation communities to identify those variables that have a high impact, high feasibility and relative low cost of implementation. The community of GCOS was the first to develop a full set of Essential Climate Variables (ECV). Other examples of communities applying the same concept are oceans (EOV-BluePlanet), biosphere (EBV-GEOBON), water cycle (GEOGLOWS), etc. ConnectinGEO illustrated that EVs can be a useful approach to several indicators for monitor SDGs. ERA-PLANET GEO-Essential proposes a need to review and extend the current EV framework and a priority assignment in designing, deploying and maintaining EV in connection with the responsible observation networks. At the same time, EVs should be promoted among all SBAs in GEO. The GEO-EVs initiative aims to be a panel of experts to discuss about the current status of the EVs, exchange knowledge, experiences and methodologies in EVs definition, analyse the usefulness of some of them in creating SDG indicators and the gaps to be solved in communities in the near future. This initiative does not have the intention to interfere in the on-going communities already working on the definition of the EVs, but to become a common point to share expertise and to have a single voice inside GEO regarding EVs.

Planned Activities:

- Meta-coordination in the elaboration of EVs among SBAs. Reduce the overlapping already between existing between and future EVs. Shared knowledge and processes for EVs definition.
- Gap analysis of EVs and observation networks.
- Convergence of the definition of EVs across SBAs.
- Expanding EVs to all relevant themes in Earth Observation.
- Relationship between EVs and SDGs. Further analyse the approximation of SDGs indicator's retrieval based on the use of EVs as a proxy.

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2. Purpose (3 pages)

Rationale (i.e. evidence of need) for the Initiative:

Sustainable development that preserves the capacity of the environment to sustain well-being of present and future generations can only be achieved through transformational pathways departing from the current unsustainable routes. Informed governance can lead to policies supporting best practices for sustainable development (Griggs et al., 2013; Griggs et al., 2014). Reaching the Sustainable Development Goals (SDGs), as adopted by the United Nations in 2015, should be constrained within stable and functioning life-support systems that define a safe operating space for humanity (Rockstrom et al., 2009; Steffen et al., 2015). Raworth (2012) is further defining a safe and just space by integrating the social boundaries. This means addressing biophysical and social targets in ways that incorporate synergies and tradeoffs. Griggs (Griggs et al. 2014; Griggs et al. 2013) also recommends working with quantifiable targets at multiple geographical scales and across sectors. For now, the Inter-Agency Expert Group on SDG Indicators provided a first set of indicators for consideration by the United Nations Statistical Commission. The International Council for Science (ICSU, 2015; Lu et al., 2015) has defined five priorities for science to measure progress towards the SDGs: i) design a set of practical indices; ii) set up a monitoring program for these indices; iii) evaluate the performance towards achieving the targets; iv) improve the observational infrastructures; and v) standardize the sources and quality of data. An additional recommendation is that the SDGs indicators are aligned with those of existing international agreements (e.g. UNFCCC for climate, CBD Aichi targets for biodiversity (Brooks et al., 2015)).

Indeed, the temptation is great, when defining SDGs or other integrated environmental indicators, to reinvent the wheel instead of using existing initiatives and data available –for instance through the Group on Earth observations (GEO) and its Global Earth Observation System of Systems (GEOSS) (GEO, 2017). From an Information, Communication and Technology (ICT) perspective, data interoperability and standardization of web services are critical to improve data access and exchange. Other sources of information than remote sensing are based on the aggregation of national statistics, including the statistical agencies, or on efforts from other scientific communities and data mediators, for example the Global Biodiversity Information Facility (Wheeler 2004) in the biological domain. This example demonstrates the importance of ICT solutions and calls for data interoperability. Integrated environmental policies (e.g. SDG) should be linked conceptually, operationally and institutionally to the present efforts to better fill the existing gaps between science and policy (Lehmann et al., 2017), and avoid unneeded confusion and redundancy.

In this context, Essential Variables (EVs) are used in Earth observation to identify variables that correspond to high impact on the Earth system and should be a priority for monitoring. EVs assume that there is a limited number of variables that are essential to characterize the state in a system without losing significant information on its past and future trends. The identification of these variables should help supporting adequate observing systems in the context of restricted budgets. EVs are also thought to improve the definition and

maintenance of workflows from raw data to final end users' products. Indeed, EVs are being used by different communities to define the smallest number of variables describing a system allowing defining indicators for policy purposes. The review of the set of EVs, conducted by ConnectinGEO (www.connectingeo.net (ConnectinGEO, 2016a, b, c)) in several GEO communities, revealed that there exist different maturity levels and a considerable overlap between the EVs identified by the different communities considered. The community working on the Global Climate Observing System (GCOS) was the first to develop a full set of EVs, i.e. the Essential Climate Variables (ECV) (Bojinski et al., 2014; Hollmann et al., 2013; Szczypta et al., 2014). Presently, significant efforts are being made to define and monitor EVs in the areas of biodiversity and ecosystems (Pereira et al., 2013; Scholes et al., 2012), water (Lawford, 2014), oceans (Constable et al., 2016; Hayes et al., 2015) and more recently on SDGs themselves (Reyers et al., 2017). Some of the later efforts are still incomplete. In addition, there is a need to generalize and complete the definition of EVs the rest of Earth thematic areas to have a full description of the status and trends of the Earth System.

This initiative does not have the intention to interfere in the on-going communities already working on the definition of the EVs, but to become a common point to exchange procedures, experiences and challenges, know overlapping and gaps, and to have a single voice inside GEO.

Description of any direct policy mandate received from an international body

Recently, a side event (*Can we have a GEO Initiative on a common approach to Essential Variables?)* was organized by members of the H2020 ERA-PLANET GEOEssential project during the GEO week in Kyoto (29th October 2018) with the participation of GEOBON, GEOGLAM, GEOGLOWS, and the GEO secretariat, among others. On that event we stated the need of a common initiative for a better meta-coordination and understanding among communities and SBAs, sharing knowledge and processes and give integrated responses to interconnected challenges such as SDGs. This event was followed by a request of the Swiss delegation to include such an initiative in the GEO work plan during the GEO Plenary. This request was supported by the Greek, German, Italian and Spanish delegations.

Actual and/or planned outputs of the Initiative (i.e. data sets, open methods, information products or services, or other openly available results intended for external users) and their geographical scope.

These are the expected outputs of this initiative:

- Monitoring the evolution of the EV definition in different domains. Detect gaps and overlaps.
- Recommendations to consolidate the EV in the themes that has not completed a consolidated list of EVs
- Generate a roadmap to generalize and complete the definition of EVs to other EO communities to have a full description of the status and trends of the Earth System.

This roadmap is based on the knowledge of the process on defining EV's.

- Ensure that all the relevant SDG indicators are covered by the existence of future EVs framework and other policy frameworks and GEO engagement priorities.
- Collecting the Definitions of the spatial and temporal resolutions of EVs for different scopes.
- Serve as a forum to exchange experiences, best practices, and knowledge about EVs.

Actual and/or intended users of the outputs and the expected types of decisions these outputs are expected to inform.

The immediate users of this process are the scientists that are experts in the topic that will benefit from a framework that can be presented to the policy makers to request for the needed funding to ensure resources to measure the evolution of the selected variables.
Another user of this process is the UN SDG indicator framework and other policy frameworks. Thanks to the definition of EV's and a clear way to obtain them the UN ensures that it is possible to monitor the progress to the SDG.

Expected outcomes, impacts and beneficiaries from adoption of the outputs from the Initiative.

- "Outcomes" refer to changes in decisions by users based, in part, on the outputs of the Initiative. These decisions may relate to policy, operational, household or other contexts.
    - Meta-coordination in the elaboration of EVs among SBAs. Reduce the overlapping already between existing between and future EVs
    - A common frame on spatial and temporal resolutions of EVs for different scopes.
    - Shared knowledge and processes for EVs definition.
    - Complete the approximation to SDGs indicators' retrieval based on the use of EVs as a proxy.
- "Impacts" refer to the ultimate intended benefits expected to be realized as a consequence of the outcomes. These could include reduction of mortality, reduced financial costs, improvements in biodiversity conservation, etc.
    - The ultimate impact of this initiative concerns the efficiency of reporting on all SBAs for improved decision making. This is closely related to reporting on the SDGs as well. Also reduce the cost of the reporting process.
    - A better coordination on EVs across SBAs can help the implementation of Nexus approach, also across the SDGs.
    - Support the SDG work programme.
    - Support GEO Engagement Priorities.
- "Beneficiaries" refer to the human populations expected to benefit from the impacts of the Initiative. These are often not the same as the intended users.
    - The scientific community (that have better argumentation in from of the funding agencies).
    - The UN SDG framework and the national governments responsible for the

monitoring of SDGs.

- The humanity as a whole if the policy makers decide the right informed decisions to make the planet suitable.

List of objectives and planned way of attaining them

- Become a central point where to exchange experiences, methodologies and knowledge regarding the development of EVs in several GEO communities → Constitute a group with representatives from all domains with a collaborative platform to easy share knowledge. Regular telecons will be set up and collocated meetings will be planned within GEO meetings.
- Monitoring the evolution of the EV definition in different domains. Detect gaps and overlaps → All EVs will be plotted in the dynamic ENEON graph allowing to detect overlapping and gaps (http://www.eneon.org/graph-ev-sdg/index.htm).
- Recommendations to consolidate the EV in the themes that has not completed a consolidated list of EVs → Best practice and recommendation documents will be shared among the community.
- Generate a roadmap to generalize and complete the definition of EVs to other EO communities to have a full description of the status and trends of the Earth System → This roadmap will be based on the knowledge of the process on defining EVs.
- Ensure that all the relevant SDG indicators are covered by the existence of future EVs framework and other policy frameworks and GEO engagement priorities → Interlinkages between EVs and SDGs will be plotted in the dynamic ENEON graph allowing to detect overlapping and gaps (http://www.eneon.org/graph-ev-sdg/index.htm).
- Collecting the definitions of the spatial and temporal resolutions of EVs for different scopes → Definitions will be considered in best practice and recommendation documents shared among the community.

3. Background and Previous Achievements (3 pages)

This initiative comes from the previous work already done by GCOS, GEOBON and GEOWLOWS, among others, regarding EVs and the knowledge gathered in the H2020 ConnectinGEO project on their status particularly in the GEO community. Within ConnectinGEO a gap analysis in European EO in-situ data was performed under the umbrella of SDGs and EVs and among GEO SBAs. Now, this work continues under the ERA-PLANET GEOEssential project (H2020-SC5-15-2015), active from 2016 to 2021 collecting all this work and evolving the approach between EVs, SDGs, communities and framework policies (Lehmann et al. 2019)(Figure 1).

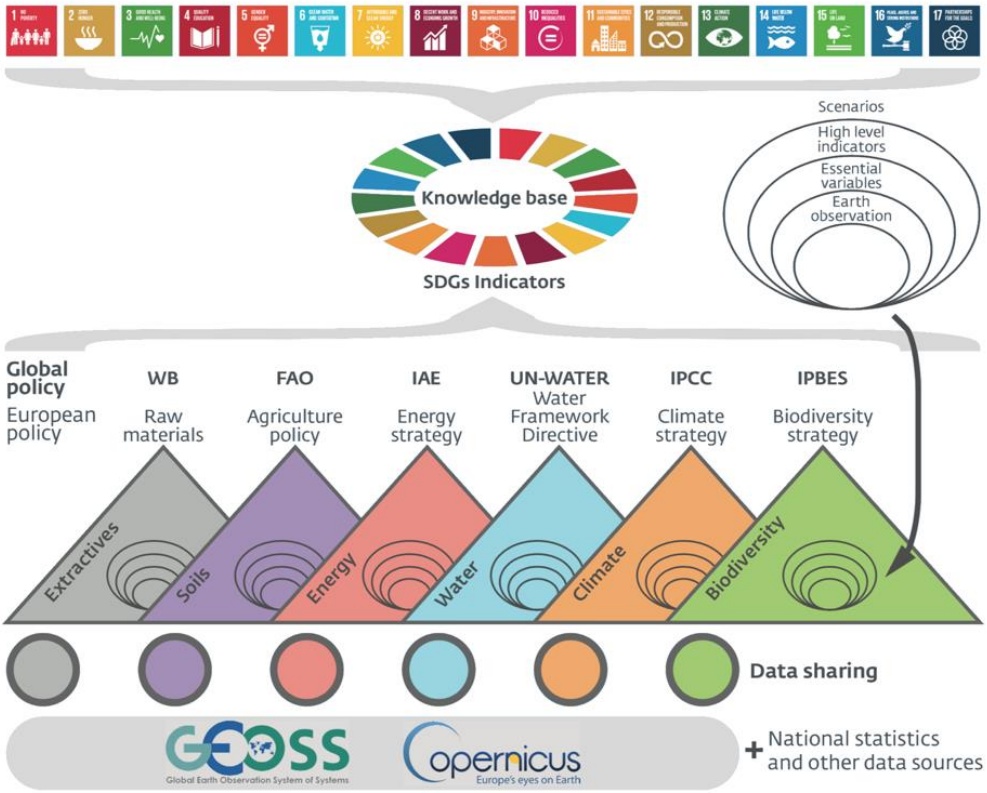

Figure 1. EVs conceptual approach in GEOEssential and basis for this initiative (from Lehmann et al. 2019)

According to ConnectinGEO experts, EVs can be defined as "the minimal set of variables that determine the system's state and developments, are crucial for predicting system developments, and allow us to define metrics that measure the trajectory of the system" (ConnectinGEO, D2.2). Moreover, some EVs could be a good starting point for SDG indicators. In this sense, some work has been done in connecting EVs with SDG indicators: ConnectinGEO *deliverable 2.3 Proposal of EVs for selected themes*; visually linking them in the ENEON graph (http://www.eneon.org/graph-ev-sdg/index.htm); and the special issue on EVs in the International Journal of Digital Earth, pushed by GEOEssential coordinators.

The first step on that work started with the workshop "*Towards a sustainability process for GEOSS Essential Variables (EVs)*" held in Bari on June 11-12, 2015. The workshop covered the status of EV discussions in the SBAs Agriculture, Biodiversity, Climate (and specifically Atmospheric composition, Carbon Cycle, and Greenhouse Gases), Disasters, Ecosystems, Energy, Health, Water (and River discharge), and Weather, and in the thematic areas Citizen Science, Human Settlements, Oceans (and Marine Ecosystems), and Solid Earth Science (including volcanology).

From that workshop, we learnt that in most SBAs and thematic areas, the development of sets of EVs is a community processes leading to an agreement on what is essential for the goals of that community. While there are many differences across the communities in the details of the criteria, methodologies, and processes used to develop sets of EVs, there is also a considerable common core across the communities, particularly those with a more

advanced discussion. Concerning inter-community differences of criteria, in particular, the feasibility to measure the EVs in terms of cost, effort, and impact plays a different role in different communities. There is some level of overlap between the EVs determined by different communities (e.g., Climate and Water), and there is a potential to develop an integrated set of EVs common to several or all SBAs, which then could be complemented with SBA specific EVs (Figure 2).

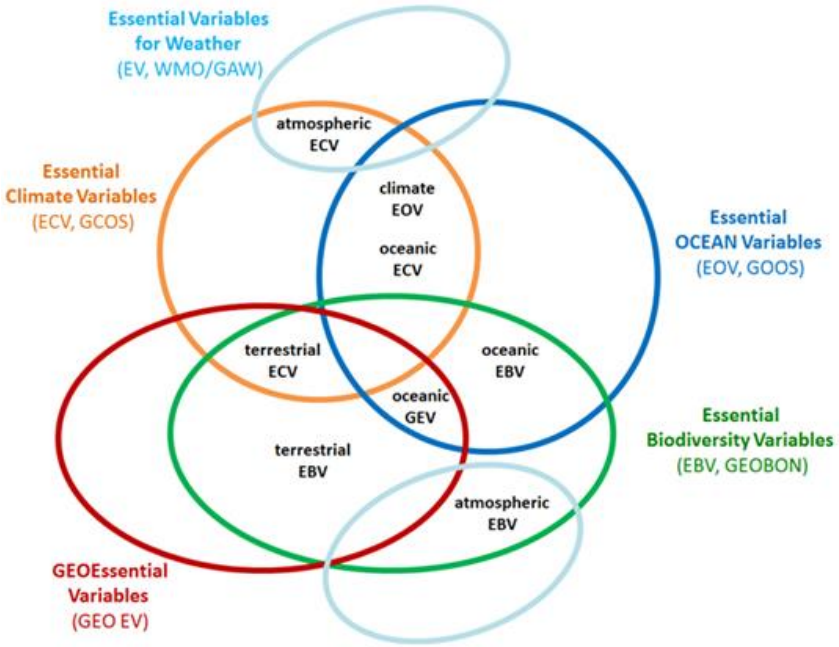

Figure 2. Conceptual overlap of all projects for defining Essential Variables (figure from (Lausch et al., 2018))

4. *Relationship to GEO Engagement Priorities and to other Work Programme Activities (3 pages)*

Description of which activities or outputs of the Initiative, if any, are expected to inform the achievement of SDG targets and/or the measurement of SDG indicators. Identify which targets and/or indicators are implicated. (See Appendix 1 for a table of SDG targets and indicators that have been identified as most relevant to Earth observations. Other SDG targets and indicators not included in the table may also be identified.)

Work done in ConnectinGEO concluded that 231 of the 240 indicators can be calculated with socio-economic data, but 30 can be extracted with the combination of socio-economic data and Earth observation (in-situ, airborne or remote sensing) and 9 indicators by Earth observation alone. In one document, GEOSS is specifically mentioned for the Goal 6: Ensure availability and sustainable management of water and sanitation for all. This is considerably lower than in the previous version of the indicators for the old collection of the SDGs candidates released in February 14th, 2014 by the Sustainable Development Solution Network. One of the reasons is the way Climate Change is considered in Goal 13: Take urgent action to combat climate change and its impacts. This goal has to consider that the UNFCCC is the primary international, intergovernmental forum for negotiating the global response to climate change and also the overlap with the IPPC. The approach taken to Goal 13 is avoiding

consideration of climate change monitoring and rather focusing on monitoring the impact of governmental decisions and policies for mitigation, adaptation, impact reduction and early warning for climate change. This moves Goal 13 and its targets and indicators away from the Earth observation domain. As discussed in Section 3, there is a need for a complementary set of indicators for sustainable development that links environmental changes to an overall sustainability metrics. For these indicators, EOs will be crucial.

ConnectinGEO considered that EO can be used in the indicators for the following SDGs and targets (deliverable 2.3 ConnectinGEO Proposal of EVs for selected themes), see *Figure 3*. Visually, an effort has been done to link EVs and SDGs in the ENEON graph (http://www.eneon.org/graph-ev-sdg/index.htm) within the GEOEssential project. For the moment, this exercise has only been done for SDG2, SDG6, SDG7, SDG13, and SDG15 (Masó et al. 2019).

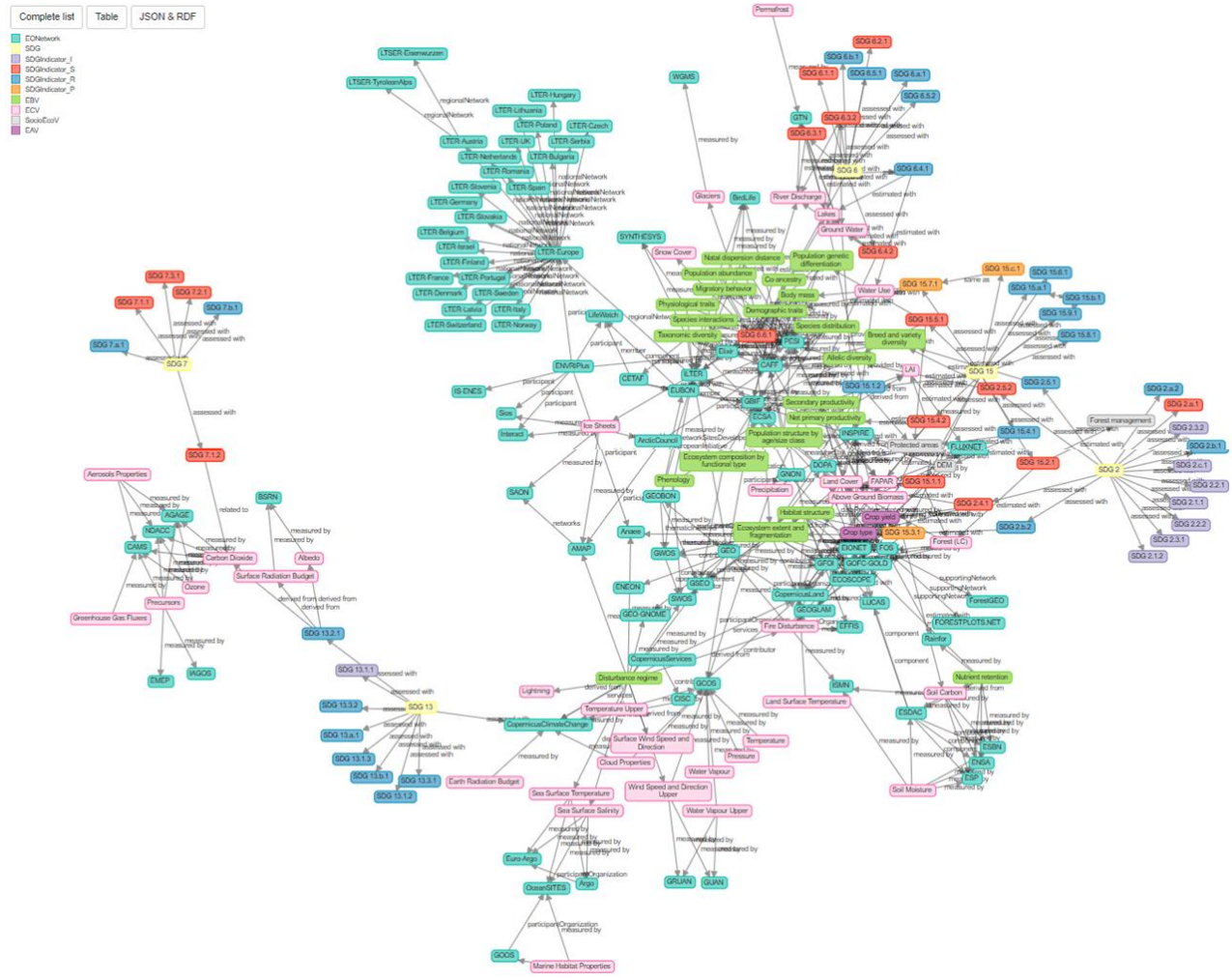

Figure 3. Link of EVs and SDGs in the ENEON graph

Description of which activities or outputs of the Initiative, if any, are expected to support the Paris Agreement and identify which pillars are implicated. (See Appendix 2 for the five pillars of the Paris Agreement where potential for contribution by Earth observations has been identified.)

Climate is the topic that has more experience with the definition of EVs. For that reason, support to the Paris Agreement it is not expected here (as ECVs are the more mature ones), although this activity will take great advantage from everything learnt by ECVs.

Description of which activities or outputs of the Initiative, if any, are expected to support achievement of the targets of the Sendai Framework and which targets are implicated. (See Appendix 3 for the Sendai Framework Targets.)

Disasters was one of the areas explored in the workshop "*Towards a sustainability process for GEOSS Essential Variables (EVs)*" held in Bari on June 11-12, 2015. If the work on the definition of EVs to measure EVs that help on the disaster prediction, or mitigation, then, this activity could impact on the Sendai Framework Targets.

List of Flagships, Initiatives and Community Activities in the 2017-2019 GEO Work Programme that are relevant to this Initiative and a brief description of the relationship or plans for future engagement/collaboration.

Related GEO Flagships:

- GEO Biodiversity Observation Network (**GEOBON**) → developers of the EBVs.
- GEO Global Agricultural Monitoring (**GEOGLAM**) → in relation to the future EVs on Agriculture.
- Global Forest Observation Initiative (**GFOI**) → possible relation with the EBVs.

Related GEO Initiatives:

- **Earth Observations in Service of the 2030 Agenda for Sustainable Development** → in relation to the connection between EVs and SDG indicators.
- **EuroGEOSS** → in relation with several EVs.
- **GEO Carbon** and GHG Initiative → in relation to ECVs.
- Geo Global Ecosystem Initiative (**GEOECO**) → in relation to EBVs.
- Geo Global Network for Observation and Information in Mountain Environments (**GEO-GNOME**) → in relation to EBVs.
- GEO Global Water Sustainability (**GEOGLOWS**) → in relation to the future EVs on Water.
- GEO Vision for Energy (**GEO-VENER**) → in relation to the future EVs on Energy.
- **GEOSS-EVOLVE** → in relation with several EVs.
- Oceans and Society (**Blue Planet**) → in relation to the Ocean EVs.
- Other **regional GEOSS** initiatives such as AFRIGEOSS, AMERIGEOSS and AOGEOSS → in relation with several EVs.

Related Foundational Tasks:

- **GEOSS In-Situ Earth Observation Resources** → in relation with the monitoring networks for several EVs.
- **GEOSS Satellite Earth Observation Resources** → in relation with the remote sensing products that can deliver several EVs.

Related Community Activities:

- Access to climate data in GEOSS
- Airnow International: Expanding Networks and Integrating Methods for Air Quality and Health Data → in relation to the future EVs on Health.
- Copernicus Atmospheric Monitoring Service (CAMS) → in relation to ECVs.
- Copernicus Climate Change Service (C3S) in relation with several EVs.
- Earth Observations and Citizen Science
- Earth Observations for Health (EO4HEALTH) → in relation to the future EVs on Health.
- Earth Observations for the Water-Energy-Food (W-E-F) Nexus
- Earth2Observe → in relation to the future EVs on Water.
- Geodata for Agriculture and Water (G4AW) → in relation to the future EVs on Water and EVs on Agriculture.
- Global Agricultural Drought Monitoring → in relation to the future EVs on Agriculture.
- Global Ecosystems and Environment Observation Analysis Report Cooperation (GEOARC) → EBVs?
- Global Marine Ecosystem Monitoring (GMEM) → in relation to EBVs
- In-Situ Observations and Practices for the Water Cycle → in relation to the future EVs on Water.
- Land Cover and Land Cover Change → in relation with several EVs; in particular with the ECVs.
- Socio-Economic Benefits of Earth Observations → in relation with several EVs.

5. Stakeholder Engagement and Capacity Building (2 pages)

Key stakeholders are:

- The Global Climate Observing System (GCOS) has been a pioneer in the development EVs for the Climate (gcos.wmo.int/en/essential-climate-variables).
- The GEO Biodiversity Observing Network (GEOBON) is developing EVs for Biodiversity (geobon.org/tag/ebv).
- GEO Global Water Sustainability (GEOGLOWS) has taken recently the lead on EVs on Water (www.earthobservations.org/activity.php?id=118).
- The Global Ocean Observing System (GOOS) is working on EVs for Oceans (www.goosocean.org/index.php?option=com_content&view=article&id=14&Itemid=114)
- Other SBAs on Energy, Agriculture, Health, Urban Development, Infrastructure and Transport, Disasters, still need to identify a key groups to further define their EVs.
- The UN SDG framework.

These Systems and Networks will be invited to join the GEO-EVs initiative by taking place in regular meeting and teleconferences. The next occasions to interact with these groups will be during the GEO work plan meetings and during the GEO annual meeting.

6. Governance (2 pages)

A very simple governing structure is proposed with two chair persons and an advisory committee.

The two co-chairs are responsible for the management of the activity (e.g. organizing regular meetings with the Advisory Board and with the Stakeholders) and to organize the execution of the decisions that the Advisory Board recommends by consensus.

The Advisory Board is composed of selected experts on EVs coming from the different EV initiatives.

Regular communications about the Initiative will be organized where stakeholders will be invited. Main opportunities will be the GEO meetings and the GEO Essential plenary meetings. Following the advice of the board, regular telecons will be organized to monitor the progress of the internal tasks and towards the expected outcomes. If necessary, dedicated telecons or face-to-face meeting will be organized to make progress toward a particular outcome.

7. Resources (1 page)

The main resources put in place are linked to the H2020 ERA-PLANET GEOEssential project running until August 2020. After that some resources of from the H2020 project E-SHAPE (formerly known as EuroGEOSS showcases) could be redirected to this activity if the coordinator of the project allows it.

In kind contribution will be made by the two proposed initial co-chairs.

8. Technical Synopsis (2 pages)

- Monitoring the evolution of the EV definition in different domains: this will be achieved by taking the ConnectinGEO reports and monitoring the literature to learn about extra progress made.
- Recommendations to consolidate the EV in the themes that have not been completed and consolidate the list of EVs. We will find the relevant stakeholders for each topic and guide them or help them in the process to define EVs by community consensus.
- Generate a roadmap to generalize and complete the definition of EVs the rest of Earth thematic areas: consolidate the methodology towards the definition of EVs based on the EBV literature and our own experience. Publish the methodology as a best practice document.
- Ensure that all the relevant SDG indicators are covered by the existing of future EV's framework: a gap analysis need to be conducted to ensure that all relevant SDG are covered.

- Define the spatial and temporal resolutions of EVs for different scopes: this will be done by collecting the necessary information from the experts on each theme.

9. Data Policy (2 pages)

- Adherence to GEOSS Data Sharing Principles and Data Management Principles.
- Use of the GEOSS Mirror on EVs (under development from the GEOEssential Project).

A. Individual Participants
   - CREAF: Joan Masó
   - University of Geneva: Anthony Lehmann, Gregory Giuliani
   - CNR: Paolo Mazzetti (TBC)
   - JRC: Stefano Nativi (TBC)
   - NOA: National Observatory of Athens: Evangelos Gerasopoulos (TBC)
   - IIASA: Ian McCallum
B. Confirmed Contributions
   - CREAF
   - University of Geneva
C. Task / Work Package Structure. There will be only one WP with the following tasks:
   1. Observatory of the EVs and ENEON. Gap analysis of EVs and observation networks. In this WP we will consolidate the observatory of EV and related networks initiated by ENEON.
   2. Convergence of the definition of EVs across SBAs. This WP is responsible for formulating the roadmap for elaborating EVs using a consensus process.
   3. Expanding EVs to all relevant themes in Earth Observation. This WP will support the process of consolidating the formulation EVs for some themes that the process is not completed of has not started.
   4. Relationship between EVs and SDGs. This WP will analyse the relation between the SDGs and the EVs and will define the necessary spatial and temporal scale for them
D. Deliverables / Milestones
   - Deliverables:
      a. Publication of a Special Issue on EVs and SDGs (2019)
      b. Report on Gap analysis of EVs and observation networks (2020)
      c. Recommendations to consolidate the EV in the themes that has not completed a consolidated the list of EVs (2020)
      d. Report on Convergence of the definition of EVs across SBAs (2021)
      e. Roadmap to generalize and complete the definition of EVs the rest of Earth thematic areas (2021)
      f. Collecting the Definitions of the spatial and temporal resolutions of EVs for different scopes necessary for the SDG (2022)

- Milestones:
  a. Annual GEO weeks
  b. Annual GEO Work plan meetings
  c. End of the GEOEssential project in August 2020

Annexes (additional annexes may be added as required)

I. Acronyms and abbreviations

CBD: Convention on Biological Diversity
ENEON: European Observatory of Earth Observation Networks
EV: Essential Variable
EBV: Essential Biodiversity Variable
ECV: Essential Climate Variable
EOV: Essential Ocean Variable
EV: Essential Variable
EWV: Essential Water Variable
GCOS: Global Climate Observing System
ICT: Information and Communication Technology
SBA: Societal Benefit Areas
SDG: Sustainable Development Goals
UNFCCC: United Nations Framework Convention on Climate Change

II. List of key scientific references describing the basis for the work of the Initiative

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III. Brief CV of Project Leader(s)

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2-Education

- PhD (Biology), University of Geneva, 1997
- Post-graduate master in Statistics, University of Neuchâtel, 2006
- MSc, Biology, University of Geneva, 1992
- BSc, Biology, University of Geneva, 1990

3-Employment history

- Since 2012: Associate Professor 100%, Head of enviroSPACE lab at the Institute for Environmental Sciences (ISE) and member of the Section of Earth Sciences and Environment, University of Geneva, Switzerland
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- 2006-2011: Seconded scientist 50%, Head of Environment monitoring and modeling unit, UNEP/GRID-Geneva
- 2001-2006: Scientific collaborator, Swiss Center for Mapping Fauna, University of Neuchâtel
- 1999-2001: First Assistant, Fellowship from Academic Society of Geneva, Aquatic Biology, University of Geneva
- 1998: Postdoc, SNF fellowship, Landcare Research, Hamilton, New Zealand
- 1993-1997: Assistant, PhD candidate, Aquatic Biology, University of Geneva

4-Insitutional responsibilities

- From August 2017: Vice-director of the Institute for Environmental Sciences at the University of Geneva.

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- MSc, Physics, Universitat Autonoma de Barcelona, 1994
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3-Employment history

- Since 1995: Researcher at CREAF
- 1995-2000: Part time Collaborator, Physics, Universitat Autonoma de Barcelona
- 1992-1995: Assistant, PhD candidate, Physics, Universitat Autonoma de Barcelona

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- From January 2019: Lead of the CREAF component of the GRUMETS research group