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1 INTRODUCTION

1.1 Purpose of this document

This Statement of Work (SoW) establishes the tasks to be performed within the three thematic projects collectively referred to as Atmosphere-LANd Interaction Study (ALANIS), for which a single Invitation to Tender (ITT) is issued.

These activities are part of the Support to Science Element (STSE), whose main objective is the reinforcement of the scientific component within the ESA Living Planet Programme. STSE covers scientific support for both future and on-going missions, by taking a proactive role in the formulation of new mission concepts and of the related scientific agenda, by offering a multi-mission support to scientific use of ESA Earth Observation mission data and to the promotion of the achieved results.

ALANIS is carried out in collaboration with iLEAPS, the land-atmosphere core project of the International Geosphere-Biosphere Programme (IGBP). The scientific goal of iLEAPS is to provide understanding of how interacting physical, chemical and biological processes transport and transform energy and matter through the land-atmosphere interface [REF1].

This activity is jointly motivated by the growing importance of investigating land-atmosphere interface dynamics due to their capability of strongly affecting the Earth system, as well as by the increasing multi-mission observational capacity provided by existing and upcoming ESA EO and 3rd party (TPM) missions.

In this context, the attention will focus on the northern Eurasian boreal region, since it represents the world's largest terrestrial ecosystem and has recently experienced a noteworthy increase in greenhouse-gas and aerosol emissions [REF2]. In particular ALANIS is dedicated to three thematic areas:

- Theme 1: Boreal lake/wetland dynamics and methane emissions (referred to as ALANIS – Wetland Dynamics & CH_4 Emissions);
- Theme 2: Boreal forest fire plumes and greenhouse-gas/aerosol dispersion (referred to as ALANIS – Fire Plumes & Gas/Aerosol Dispersion);
- Theme 3: Natural and anthropogenic aerosol dynamics in the boreal region (referred to as ALANIS – Aerosols).

Note that Bidders may submit proposals that address solely a specific Theme from those described in this document (see Section 4). Bidders may also bid for more than one Theme or all three Themes but always via dedicated and independent proposals for each Theme.

The proposed activity is based on the scientific requirements expressed by the iLEAPS community. To consolidate those requirements, the European Space Agency (ESA) in collaboration with iLEAPS International Project Office (IPO), organized a scientific consultation workshop in Vienna on 20th April 2009. The outcomes of the workshop describe the preliminary observational and scientific needs identified by the iLEAPS community and represent the scientific basis for the ALANIS project (see Annex A).

1.2 Structure of this document

This document is organised into six Sections:

- Section 1 is this introduction; it outlines the scope of the procurement and the structure of the document;
- Section 2 lists the applicable and reference documents as well as the web sites that are relevant for ALANIS;
- Section 3 introduces the investigated problem and outlines the objectives of the project;
- Section 4 specifies the themes to be addressed;
- Section 5 provides a description of the required work to be performed;
- Section 6 describes some special conditions for the procurement and use of EO data in the framework of the ALANIS project and special requirements for team composition;
- Section 7 specifies acronyms and abbreviations;
- Annex A contains the Scientific Requirement Documents provided by the member of the iLEAPS International Project Office (iLEAPS IPO);
- Annex B summarizes significant activities and projects relevant to ALANIS;
- Annex C reports technical and management requirement matrices.

2 RELEVANT DOCUMENTS

2.1 Applicable documents

[APP1] Scientific Requirement Document – Annex A of this SoW.

2.2 Reference documents

[REF1] iLEAPS Science Plan and Implementation Strategy, IGBP Report 54, IGBP Secretariat, Stockholm, 2005.

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2.3 Relevant websites

[URL1]	ESA web site:	http://www.esa.int
[URL2]	ESA's Data User Programme:	http://earth.esa.int/DUP
[URL3]	ESA Category 1:	http://www.projects.esa-ao.org
[URL4]	iLEAPS web site:	http://ileaps.org
[URL5]	IGBP website:	http://www.igbp.net
[URL6]	GOSAT website:	http://www.jaxa.jp/projects/sat/gosat/index_e.html
[URL7]	GlobAerosol website:	http://www.globaerosol.info/
[URL8]	GlobCarbon website:	http://www.globcarbon.info
[URL9]	GlobCover website:	http://ionia1.esrin.esa.int/
[URL10]	PERMAFROST website:	http://dup.esrin.esa.it/projects/summaryp91.asp

3 PROJECT BACKGROUND AND OBJECTIVES

3.1 Background

Determination of the role of the Eurasian boreal region is essential in understanding the global Earth system as it represents the largest terrestrial ecosystem on Earth. In this context, boreal forests play a vital role in curbing global warming by storing in forest and peat ecosystems billions of tons of carbon formed since the Last Glacial Maximum around 20,000 years ago. Northern lakes and wetlands, instead, are important sources of carbon, partially released as methane and other trace gases to the atmosphere especially during spring and summer [REF3]. Furthermore, it has been observed that boreal forests are responsible for growing emissions of natural secondary organic aerosols. This, along with increased concentrations of long-range transported anthropogenic aerosols in northern Eurasia, is expected to trigger severe impacts on climate in the near future [REF4].

The size and remoteness of boreal Eurasia, however, pose a challenge to quantification of both terrestrial ecosystem processes and their feedbacks to regional and global climate. Furthermore, human activities and climate changes are thought to have altered the natural equilibrium of the whole region, thus strengthening the need for an effective mapping and monitoring of surface-atmosphere exchange interactions [REF5].

In such a complex framework, Earth Observation (EO) provides one of the main sources of information for estimating variables that can be employed as input to coupled models governing the land-atmosphere interface over the extremely wide and often unreachable areas of northern Eurasia.

To coordinate the efforts of the scientific community for improving the common knowledge of related surface and atmosphere dynamics, the International Geosphere-Biosphere Programme (IGBP) established in 2004 the integrated land ecosystem-atmosphere process study (iLEAPS), whose projects and activities are managed by the iLEAPS International Project Office (iLEAPS IPO) located in Helsinki.

iLEAPS investigates the role of human activities in affecting the land-atmosphere interface and the extent to which terrestrial vegetation determines the physical and chemical environment from local to global scales. In particular, the overall objective is to enhance the understanding of how interacting physical, chemical and biological processes transport and transform energy and matter through the land-atmosphere interface. Due to the complexity and wide range of scientific issues, iLEAPS stresses the need for increased integrative approaches and collaboration, connects scientists, experimentalists and modellers from various disciplines, and promotes international research projects.

Under the umbrella of STSE, ESA and iLEAPS IPO organized a scientific consultation workshop held on 20th April 2009 at the Austrian Academy of Sciences in Vienna for defining the preliminary research needs of the scientific communities investigating land and atmosphere dynamics in northern Eurasia.

During the workshop, scientists pointed out the potential offered by existing EO missions, which allow improved observations of several important variables. However, the need for additional research and synergistic use of multi-mission data was also stressed. The outcomes of the meeting (reported in Annex A) define the main research requirements for the iLEAPS community and represent the main scientific driver for the ALANIS project.

3.2 Objectives

ALANIS contributes to the STSE Science Partnerships, aiming at reinforcing the links between the Agency and major international scientific groups. It constitutes a collaboration between ESA and the iLEAPS project of IGBP. It aims at improving the understanding of coupled land-atmosphere interactions in northern Eurasia by exploiting and maximising the use of ESA EO missions.

In this context, short-term general objectives of the project include:

- To advance towards the development and validation of **novel advanced EO-based multi-mission based products**, **algorithms**, **models**, as well as **case studies** and **multi-temporal datasets** (maximising the use of ESA data) that may respond directly to the specific scientific requirements of the iLEAPS community for:
    - Improving the characterization of boreal Eurasian lake and wetland dynamics and reducing current uncertainties in related methane emissions (Theme 1);
    - Improving the estimation of plume injection height of biomass burning events occurred in boreal Eurasia and reducing current uncertainties in related greenhouse-gas and aerosol dispersion forecast (Theme 2);
    - Discriminating natural aerosols emitted by boreal Eurasian forests from long-range transported fine anthropogenic aerosols (Theme 3);
- To support iLEAPS efforts to improve the observation, understanding and prediction of land-atmosphere processes in boreal ecosystems at different spatial and time scales demonstrating the capability of ESA data in responding to the needs of the iLEAPS Science Community;
- To set up a solid scientific basis for the development of a robust consistent long-term data set of EO-based land and atmospheric geo-information products over the boreal area in support of the iLEAPS scientific efforts;
- To develop a Scientific Roadmap as a basis for further ESA activities in support of the iLEAPS community.

Moreover, in the long-term the project aims also at:

- Reinforcing the long-term strategic partnerships with IGBP and the iLEAPS community;
- Fostering the use of ESA data within the iLEAPS community for land-atmosphere processes studies;
- Fostering the scientific return of ESA missions in terms of novel scientific results and publications.

4 ALANIS THEMES

The following Themes have been selected to be investigated on the basis of the manifest interest of the iLEAPS community (see Appendix A) and supporting evidence from the scientific literature that EO may play a fundamental role for advancing scientific process studies in the related application domains:

- Theme 1: Boreal lake/wetland dynamics and methane emissions (referred to as ALANIS – Wetland Dynamics & CH_4 Emissions);
- Theme 2: Boreal forest fire plumes and greenhouse-gas/aerosol dispersion (referred to as ALANIS – Fire Plumes & Gas/Aerosol Dispersion);
- Theme 3: Natural and anthropogenic aerosol dynamics in the boreal region (referred to as ALANIS – Aerosols).

Note that, as indicated in the following Sections, the advanced level of maturity of current EO data and models will allow activities related to Theme 1 and Theme 2 to be tackled as research and development activities. Concerning Theme 3, instead, in the light of the intrinsic complexity of the problem, as well as the limited related literature, the activity shall be carried out as a feasibility study (this will imply a reduced number of tasks to be performed with respect to Theme 1 and Theme 2 as specified in Section 5).

4.1 Theme 1: ALANIS – Wetland Dynamics & CH_4 Emissions

4.1.1 THEME 1: PROBLEM STATEMENT

Boreal Eurasian lake and wetlands play an important dual role in the global carbon cycle as they represent both the largest natural methane source and one of the major net carbon sinks [REF6]. In these ecosystems, the combination of elevated water tables, high productivity and low decomposition has led to significant carbon storage, which has been also favoured by low temperatures and slow diffusion of oxygen into the soil (1000 times more slowly in water saturated soils than in dry soils). Under such anoxic conditions, methanogens produce CH_4 principally by the fermentation of acetate and/or oxidation of hydrogen using CO_2 as electron acceptor. Much of the CH_4 produced is subsequently oxidized by methanotrophic bacteria, but the remainder is transported to the atmosphere via bubbling and diffusion, or escapes through vascular plants [REF7].

Both lake/wetland dynamics and the balance between related methane emissions depend on climatological and hydrological factors, leading to potentially significant feedbacks to the global climate system [REF8]. Understanding and modelling the natural variability of CH_4 fluxes from wetlands constitute an important crosscutting topic. However, high spatial and temporal variability of methane emissions combined with patchy and incomplete information on their geographical dispersion makes it difficult to obtain reliable estimates. In fact, so far global CH_4 emissions from lakes/wetlands still have the largest uncertainty than any other natural (e.g., ocean, termites, hydrates) or anthropogenic (e.g., rice agriculture, ruminants, energy, landfills) source [REF2] (present estimates range between 92 [REF9] and 237 [REF10] Tg CH_4 per year). This is of concern because projections for the future suggest a rise in methane emissions and thus a positive feedback in climate change [REF11].

Biogeochemical land surface models can provide estimates of CH_4 fluxes [REF9],[REF12],[REF13],[REF14]. However, the lack of in situ measurements makes them difficult to parameterise, properly constrain and calibrate.

In this context, remote sensing represents a global and valuable source of information from which to obtain consistent data characterizing both lake/wetland dynamics as input to models, as well as reliable retrievals of atmosphere CH_4 concentration for constraining land-atmosphere coupled models.

4.1.2 THEME 1: SPECIFIC OBJECTIVES

The main objective of this Thematic Area is to reduce current uncertainties in CH_4 emissions in the boreal Eurasian region by integrating (i.e., assimilating) suitable EO-based land surface products and atmospheric CH_4 measurements into an advanced land-atmosphere coupled model.

To this end, the following priority activities shall be carried out:

- Investigate, develop and validate (maximizing the use of ESA data) a **set of novel target products** (see Section 4.1.3) suitable for characterizing the dynamics of boreal Eurasian lake and wetland ecosystems (*land component*) in relation to corresponding variations of atmospheric methane concentrations (*atmosphere component*);
- Investigate, develop (preferably adapting one of the models currently available in the literature, e.g. [REF9],[REF12],[REF13],[REF14]) and validate a suitable **land-atmosphere coupled model** capable of taking full advantage of satellite observations of atmospheric methane concentrations (see Table 4.2), as well as the whole set of aforementioned novel target products (to be both employed as inputs and/or constraints of the model) for reducing current uncertainties in methane emissions from boreal Eurasian lakes and wetlands;
- Generate an **experimental dataset** consisting of the entire set of novel target products engendered for a period of **two years** over the whole boreal Eurasian region, and then the corresponding methane emission estimations by employing the developed land-atmosphere coupled model.

The project does not start from scratch but it is based on a significant number of research and development activities demonstrating the value of ESA data to characterise both the land and atmosphere products of interest for this Thematic Area (a summary of some of these activities is provided in Annex B). It is worth noting that the Contractor is encouraged to maximise the use of these research results, as well as to coordinate with related existing project and initiatives.

4.1.3 THEME 1: BASELINE PRODUCT PORTFOLIO DESCRIPTION

The portfolio of EO-based products reported in Table 4.1 shall be used as a baseline for the novel set of target products to be developed for ALANIS Theme 1.

Table 4.1 - Portfolio of potential EO-based products suitable to be developed in the framework of ALANIS Theme 1.

Product	Description	Temporal Resolution	Spatial Resolution	Potential Suitable Sensors
Snowmelt Onset/Duration/End	Required for determining when wetland methane emissions restart after the winter season.	Daily within a suitable interval (e.g., April-July)	25 km	MetOp-A ASCAT
Ice Break-up Date	Required for determining when lake methane emission restart after the winter season.	Weekly within a suitable interval (e.g., April-July)	150 m ÷ 1 km	ENVISAT ASAR WS, ENVISAT ASAR GM
Freeze Onset Date	Required for determining when lake/wetland methane emissions stop after the summer season.	Daily within a suitable interval (e.g., August-October)	25 km	MetOp-A ASCAT
Lake and Wetland Extent Dynamics	Required for detecting spatial changes of lake and wetland surface over time at high / medium spatial resolution and low time frequency.	Twice a month during snow/ice free period	150 m	ENVISAT ASAR WS
Fractional Inundated Vegetation Dynamics	Required for detecting spatial changes of inundated areas over time at low spatial resolution and high time frequency.	Every 3 days during snow/ice free period	25 km	Multisensor approach: ENVISAT AATSR + MetOp-A ASCAT

The Contractor shall use this baseline portfolio during the initial phase of the project as a reference for:

- Consolidating the scientific requirements identified by the iLEAPS IPO;
- Delineating the final set of target products to be developed in the framework of the project (eventually including also products beyond the list in Table 4.1);
- Defining the specifications for the experimental data set to be developed in the final phase of the project (in terms of product definition, resolution, frequency, accuracy, etc.).

In order to perform the required work, additional data will be required (e.g., EO-based CH_4 concentrations). In this context, the Contractor shall exploit existing ESA data, as well as datasets from previous or on-going ESA (or non-ESA) activities available over the considered area that are relevant for the investigated Theme. In particular, the list of products reported in Table 4.2 must be taken into careful consideration (see also related technical notes in Annex B).

Table 4.2 – Currently available products that must be taken into consideration in the framework of ALANIS Theme 1.

Product	**Source Sensor / *External Source***	**Temporal Resolution**	**Spatial Resolution**
Atmospheric Methane Concentration	*University of Bremen, University of Heidelberg, Royal Dutch Meteorological Institute (KNMI)*	Monthly	60 x 30 km
	GOSAT TANSO (ESA TPM) [if available]	Every 3 Days	10 km
Land Surface Temperature	ENVISAT AATSR	At least every 3 Days†	1 km
Leaf Area Index	*GlobCarbon**	Monthly	1-10 km
Soil Moisture	MetOp-A ASCAT	Daily	25 km
	PERMAFROST [if available]	Weekly during snow/free period	1 km
	SMOS MIRAS [if available]	At least every 3 Days	40 km
Vegetation Cover Type	*GlobCover*	Once	300 m

4.2 Theme 2: ALANIS – Fire Plumes & Gas/Aerosol Dispersion

4.2.1 THEME 2: PROBLEM STATEMENT

Biomass burning events in boreal regions have proven a significant impact on atmospheric chemistry on regional to global scales. On the one hand, air pollution has increased due to direct emissions from fires or by trace species that are generated in the atmosphere from these direct emissions through chemical reactions or microphysical modifications [REF15]. On the other hand, intense burning has been causing a decrease of carbon storage in such ecosystems, which can be potentially converted from carbon sinks to net sources, in turn contributing to global warming [REF16]. All these issues are particularly evident in northern Eurasia [REF4].

Vegetation fires vertically displace their emissions (composed of around 90-95% of greenhouse gases and 5% of particulate matter) through convection induced by the heat and moisture released by the fire. Ambient meteorological conditions, fire released energy and moisture determine the injection height of fire plumes in the atmosphere [REF15]. It was shown that most fires deposit their emissions into the atmospheric boundary layer (i.e., below about 5 km [REF17],[REF18]). However, there is growing evidence that under favourable meteorological (high atmospheric instability) and fire conditions (high energy release), fire emissions can be injected into the upper troposphere (UT) or even the lower stratosphere (LS), especially at high latitude regions (pyro-convective

† It is worth noting that, due to cloud coverage such a frequency cannot be guaranteed at northern high latitudes.
* The global application of the GlobCarbon algorithm for Leaf Area Index (LAI) estimation is achieved by reference to the GLC2000 global land-cover map, which considers different information classes with respect to those taken into consideration in the GlobCover project.

events) [REF19]. The atmospheric lifetime of most fire released trace gases and aerosol particles is substantially enhanced in the UT/LS region and, hence, their atmospheric impact lasts longer and affects greater regions [REF2]. During dry weather condition, and in particular for significant injection heights, aerosol particles can be even transported over thousands of kilometres before they are removed from the atmosphere by wet deposition [REF19].

Understanding the impacts of fires on air quality and climate requires the use of transport models [REF16],[REF20],[REF21],[REF22],[REF23]. Observations of plume injection are necessary to initialize and validate these models and to develop relationships between injection height and greenhouse-gas and aerosol dispersion over time. However, due to the lack of auxiliary information on the altitude of fire plumes, arbitrary assumptions are currently used (e.g., fixed vertical injection levels [REF16]).

A reliable knowledge of plume injection height, as well as a proper tracing of related fire emissions into the atmosphere is mandatory for improving current large-scale predictions of greenhouse-gas and aerosol dispersion. To this aim, satellite remote sensing represents the unique mean for retrieving proper observations accounting for the widespread nature and variability of boreal fires, and regional to global dispersion of emitted aerosols and trace gases.

4.2.2 THEME 2: SPECIFIC OBJECTIVES

The main objective of this Thematic Area is to reduce current uncertainties in forecasting dispersion of greenhouse-gas and aerosol emissions due to forest fires occurred in the boreal Eurasian region by integrating (i.e., assimilating) suitable EO-based land surface products and atmospheric trace gas and aerosol measurements into an advanced land-atmosphere coupled model.

To this end, the following priority activities shall be carried out:

- Investigate, develop and validate (maximizing the use of ESA data) a **set of novel products** (see Section 4.2.3) suitable for estimating plume injection height (*land component*) of biomass burning events occurred in boreal Eurasia and tracking related greenhouse-gas and aerosol dispersion over time into the atmosphere at global scale (*atmosphere component*);
- Investigate, develop (preferably adapting one of the models currently available in the literature, e.g. [REF20],[REF21],[REF22],[REF23]) and validate a suitable **land-atmosphere coupled model** capable of taking full advantage of the whole set of aforementioned novel target products, including satellite observations of emitted greenhouse-gas and aerosol dispersion over time (to be employed as inputs and/or constraints of the model), for reducing current uncertainties in greenhouse-gas and aerosol dispersion forecasts from boreal Eurasian fires at global scale;
- Generate an **experimental dataset** consisting of the entire set of novel target products engendered for a consistent number of fire events occurred in a period of **three years** over the whole boreal Eurasian region, and then the corresponding greenhouse-gas and aerosol dispersion forecasts by employing the developed land-atmosphere coupled model.

The project does not start from scratch but it is based on a significant number of research and development activities demonstrating the value of ESA data to characterise both the land and atmosphere products of interest for this Thematic Area (a summary of some of these activities is provided in Annex B). It is worth noting that the Contractor is encouraged to maximise the use of these research results, as well as to coordinate with related existing project and initiatives.

4.2.3 THEME 2: BASELINE PRODUCT PORTFOLIO DESCRIPTION

The portfolio of EO-based products reported in Table 4.3 shall be used as a baseline for the novel set of target products to be developed for ALANIS Theme 2.

Table 4.3 - Portfolio of potential EO-based products suitable to be developed in the framework of ALANIS Theme 2.

Product	Description	Temporal Resolution	Spatial Resolution	Potential Suitable Sensors
Fire Injection Height	Required for characterizing the injection height of the considered fire event.	Event Dependent	300 m ÷ 1 km	ENVISAT AATSR, ENVISAT MERIS
Fire Emitted Green-house-gas and Aerosol Dispersion Tracking	Required for characterizing greenhouse-gas and aerosol spatial dispersion over time for the considered fire event.	Daily from event beginning to end	10 ÷ 20 km	MetOp-A IASI

The Contractor shall use this baseline portfolio during the initial phase of the project as a reference for:

- Consolidating the scientific requirements identified by the iLEAPS IPO;
- Delineating the final set of target products to be developed in the framework of the project (eventually including also products beyond the list in Table 4.3);
- Defining the specifications for the experimental data set to be developed in the final phase of the project (in terms of product definition, resolution, frequency, accuracy, etc.).

Please note that the employment of **ENVISAT AATSR and MERIS** for retrieving information about the fire injection height, as well as of **MetOp-A IASI** for tracking related gas and aerosol emissions is **mandatory**. Any other choice shall be formerly discussed and approved by ESA. Deviations from this requirement shall be clearly justified.

The Contractor is also encouraged to exploit existing ESA data, as well as datasets from previous or on-going ESA activities available over the considered area that are relevant for the investigated Theme. In particular, the list of products reported in Table 4.4 must be taken into careful consideration (see also related technical notes in Annex B).

Table 4.4 – Currently available products that must be taken into consideration in the framework of ALANIS Theme 2.

Product	**Source Sensor / *External Source***	**Temporal Resolution**	**Spatial Resolution**
Fire Affected Area	*GlobCarbon*	Monthly (1998-2007)	1 km
Fire Injection Height	TERRA MISR	Event Dependent	275 m
Fire Radiative Power	TERRA/AQUA MODIS	Daily	1 km
Fraction of Absorbed Photosynthetically Active Radiation	ENVISAT MERIS	At least every 3 Days	1.2 km
Land Surface Temperature	ENVISAT AATSR	At least every 3 Days†	1 km
Leaf Area Index	*GlobCarbon**	Monthly (1998-2007)	1-10 km
Vegetation Cover Type	*GlobCover*	Once	300 m

4.3 Theme 3: ALANIS – Aerosols

4.3.1 THEME 3: PROBLEM STATEMENT

Tropospheric aerosols play a crucial role in climate evolution [REF4]. In particular, it is now well established that their influence on the Earth's radiative budget is to cool the climate system by directly reflecting sunlight to space, and indirectly by increasing cloud cover and brightness (which in turn reflects more sunlight to space). However, depending on their composition, atmospheric aerosols can also absorb incoming sunlight, thus further cooling the surface but warming the atmosphere. The opposed effects of aerosol cooling and greenhouse gases warming imply that the amplitude of estimated future greenhouse warming will depend on the present aerosol cooling [REF24].

Assessing the aerosol effect on climate is of paramount importance. Nevertheless, it represents a very complex task. Aerosols, in fact, range from desert dust to urban pollution and fire smoke, thus exhibiting different chemical compositions which correspond to different optical properties. Moreover, also interactions with clouds and precipitation increase their variability over space and time.

Aerosols in the atmosphere are composed by particles of both natural (e.g., soil dust, sea salt and sulphates) and anthropogenic (e.g., pollutants by energy production, traffic and industrial activities) origin. However, since the lifetime of aerosol particles is comparable to the time scale of intra-continental and intercontinental transport (i.e., 3 to 10 days), anthropogenic aerosols are ubiquitous

† It is worth noting that, due to cloud coverage such a frequency cannot be guaranteed at northern high latitudes.
* The global application of the GlobCarbon algorithm for Leaf Area Index (LAI) estimation is achieved by reference to the GLC2000 global land-cover map, which considers different information classes with respect to those taken into consideration in the GlobCover project.

and the natural "background" aerosols are difficult to observe and quantify with confidence [REF25].

Atmospheric aerosols represent a kind of "external" cause of climate change with respect to natural aerosols that instead may provoke variations in the climate system as part of its feedback mechanism. Accordingly, the separation of anthropogenic from natural aerosols is essential for assessing human impacts. In particular, for properly assessing the effect of anthropogenic aerosols on the atmosphere, it is mandatory to effectively characterize the burden of natural aerosols, as it represents a reference level for inferring human-induced aerosol impact. This separation is also important for understanding the cloud-mediated effects of aerosols on climate, since cloud properties respond to aerosols in a nonlinear way and are most sensitive to the addition of particles when the background concentration is low [REF25],[REF26].

In this context, the interest in investigating anthropogenic in contrast to natural aerosol dynamics over boreal Eurasia stems from two main concepts. First, boreal forests directly modify atmospheric particles in several ways. In particular, besides emission of biogenic volatile compounds, it has been identified that a ubiquitous feature at boreal Eurasian forest sites is the regular occurrence of new particle formation events generating secondary organic aerosols [REF4]. Second, northern Eurasia due to particular wind circulation conditions is impacted periodically by long-range transported anthropogenic aerosols, such as those formed by energy production, traffic and industrial activities [REF27].

In recent years, there has been a growing interest towards the influence of aerosols on climate through both direct and indirect effects. Several extensive investigations and coordinated field campaigns have been carried out to assess the impact of anthropogenic aerosols *in situ* [REF28]. Nevertheless, due to the intrinsic complexity of the problem, very few studies have been conducted using remote sensing data. Present satellite remote sensing instruments, in fact, do not measure the aerosol chemical composition needed to discriminate anthropogenic from natural aerosol components (see Annex B). Accordingly, a complete picture cannot be obtained without integrated modelling capable of taking into consideration all main processes and components.

4.3.2 THEME 3: SPECIFIC OBJECTIVES

In the light of the scientific requirements provided by the iLEAPS community for this Theme (see Annex A), the Contractor shall investigate (maximizing the use of ESA data) the feasibility of discriminating with existing EO-based products long-range transported anthropogenic aerosols from natural aerosols emitted by boreal Eurasian forests.

To this end, the following priority activities shall be carried out:

- Investigate, develop and validate **novel algorithms solely exploiting as input currently available EO-based products** for discriminating natural from anthropogenic aerosols in boreal Eurasia;
- Investigate, develop and validate **novel strategies for assimilating already existing EO-based products into chemical transport models** (CTMs, e.g. [REF29],[REF30],[REF31])

currently available in the literature to discriminate natural from anthropogenic aerosols in boreal Eurasia (e.g., by identifying the source regions from the analysis of model back-trajectories);

- Investigate at least **three case studies** referring to as many sites with different characteristics located in boreal Eurasia for quantitatively and qualitatively evaluating, as well as cross-comparing the performances of both the aforementioned approaches.

The project represents a preliminary attempt to investigate the current capabilities offered by satellite data for discriminating natural and anthropogenic aerosols. However, despite the reduced literature available on this Thematic Area, the Contractor is encouraged to maximise the use of datasets and results available from past and current related ESA activities (see Annex B).

5 DETAILED DESCRIPTION OF THE STUDY TASKS

In this Section a detailed description of the Work Plan for ALANIS Themes is provided. In particular, the Work Plan for research and development activities associated with Theme 1 and Theme 2 is reported in Section 5.1, whereas a reduced Work Plan for the feasibility study associated with Theme 3 is described in Section 5.2.

5.1 Work Plan for Theme 1 and Theme 2

In the following, a detailed description for each of the tasks to be carried out in the context of ALANIS Theme 1 and Theme 2 is provided. The proposed tasks are common to both Themes. Any eventual change or modification shall be properly justified by the Contractor.

Tasks are distributed among three different phases.

Phase 1 – Requirement Consolidation
- Task 1: Scientific Requirement Consolidation;
- Task 2: Preliminary Analysis;
- Task 3: Technical Specifications.

Phase 2 – Development and Validation
- Task 4: Product Development and Validation;
- Task 5: Model Development and Validation.

Phase 3 – Dataset Generation, Model Processing and Phase Out
- Task 6: Experimental Dataset Generation;
- Task 7: Model Experimental Processing;
- Task 8: Scientific Roadmap;
- Task 9: ALANIS Final Workshop.

In the following, technical and management requirements are tagged within the text as [T.#.#] and [M.#], respectively. Furthermore, they are summarized and listed in corresponding matrices reported in Annex C.

5.1.1 PHASE 1 – REQUIREMENT CONSOLIDATION

In this phase, which will last up to 4 months, the Contractor shall consolidate the preliminary scientific requirements for the investigated Theme in collaboration with the iLEAPS IPO and define the characteristics of the target products, the coupled model and the experimental dataset to be developed.

In Phase 1, at least the following tasks shall be performed:

- Task 1: Scientific Requirement Consolidation;
- Task 2: Preliminary Analysis;
- Task 3: Technical Specifications.

At the end of Phase 1, a **Requirement Engineering Review (RER)** will take place in ESRIN.

Task 1: Scientific Requirement Consolidation
<u>Description:</u> In this task, the Contractor shall consolidate the preliminary scientific requirements identified by the iLEAPS IPO for the investigated Theme (see Annex A). This activity shall include the consultation with the iLEAPS scientific community [T.1.1] to derive an updated analysis of the major current needs [T.1.2] and characterize limitations and drawbacks of products and models already available related to the considered Theme [T.1.3]. On the basis of such analysis, the Contractor shall then derive a consolidated, coherent and complete view of the scientific requirements associated with the Theme into consideration. Accordingly, the Contractor shall describe into details the technical constraints for the target products, the coupled model and the experimental dataset to be developed [T.1.4].
<u>Deliverables:</u> **Requirement Baseline (RB)**: This document shall include a complete and detailed description of the information requirements concerning the investigated Theme identified by the iLEAPS IPO (see Annex A). The RB will represent the basis for all the activities to be carried out during the project.

Task 2: Preliminary Analysis
<u>Description:</u> In this task, the Contractor shall perform a comprehensive review of current initiatives, algorithms, models and EO-based products and datasets that are relevant in the context of the investigated Theme, mainly stressing the attention on ESA and European missions. This shall include: • An analysis of current ESA and non-ESA mission suitable EO data [T.2.1]; • A detailed review and assessment of existing algorithms, models, methods and EO-based products and datasets, as well as related limitations and drawbacks [T.2.2]; • A cross comparison of currently available products and models [T.2.3]; • A survey of all accessible ancillary data (e.g., in situ data, airborne campaigns data, reference data) [T.2.4] which could be of use in helping the Contractor to perform an adequate validation of both the target products and the coupled model to be developed, as well as an effective cross-comparison with available state-of-art results and a quantitative evaluation of uncertainties (problems such as the lack of sufficient ancillary data shall be inves-

tigated, the impact assessed, and practical solutions identified);

- A survey of current and upcoming initiatives and projects related to the investigated Theme [T.2.5].

In performing this analysis, the Contractor shall consider the most recent scientific publications, as well as researches and operational projects funded in the last few years by ESA, the EC and R&D national programmes.

Task 2 must be complemented by a proper risk analysis pointing out which risk areas could affect the final success of the project (as concerns the considered Theme) and the proposed solutions.

All the outcomes from this activity shall be reported in the Preliminary Analysis Report (PAR).

Deliverables:

Preliminary Analysis Report (PAR): This document shall describe the outcomes of the Preliminary analysis. The PAR must complement the RB and represent an input for completing the Technical Specifications (see Task 3).

Task 3: Technical Specifications

Description:

In this task, the Contractor shall provide a technical answer to the RB and define the technical specifications for the target products, the coupled model and the experimental dataset to be developed. In particular, the Contractor shall define, on the basis of both the product portfolio baseline description (provided in Section 4.1.3 and Section 4.2.3) and the direct consultation with users, the set of novel EO-based products that are most likely to be useful for improving the estimates of methane emissions from lakes and wetlands (Theme 1), as well as the forecast dispersion of greenhouse-gas and aerosol emissions due to vegetation fires (Theme 2) in boreal Eurasia. The corresponding coupled model to be developed shall be able of taking full advantage of the whole set of these products. The Contractor shall also specify the validation procedures to be then adopted for assessing the effectiveness of the target products and the coupled model, respectively. In both cases, at least three test sites (which may differently affect the respective performances) shall be specified, for which suitable ancillary data identified in Task 2 are accessible by the Contractor.

To this aim, the Contractor shall provide a description of:

- The technical specifications for each target product (defined on the basis of both the product portfolio baseline description provided in Section 4.1.3 and Section 4.2.3 and the direct consultation with users) in terms of accuracy, geographic/temporal coverage, and spatial/temporal sampling [T.3.1];
- The prototype methodological and validation approaches for implementing each target product and quantitatively estimating related uncertainties [T.3.2];
- The technical specifications for the land-atmosphere coupled model to be developed (preferably properly adapting one of the available models identified in Task 2) capable of

taking full advantage of the entire set of target products (to be employed as inputs and/or constraints of the model) [T.3.3]; • The prototype methodological and validation approach for implementing the coupled model and quantitatively estimating related uncertainties [T.3.4]; • The technical specifications of the final experimental dataset (to be generated in Phase 3) in terms of geographic/temporal coverage [T.3.5]; • All EO and non-EO data required in the framework of the project [T.3.6]; • At least three test sites for both the target products and the coupled model to be developed (which may differently affect the respective performances), for which suitable ancillary data identified in Task 2 are accessible by the Contractor [T.3.7].
Deliverables: **Technical Specifications (TS)**: This document shall describe the technical answer to the RB and shall provide a detailed and complete description of the target products, the coupled model and the experimental dataset to be developed. The TS shall represent the baseline for Phase 2. **Validation Plan (VP)**: This document shall describe and justify the validation protocol and measures to be employed in Phase 2 for assessing the effectiveness of both the target products and the coupled model to be developed.

5.1.2 PHASE 2 – DEVELOPMENT AND VALIDATION

In this phase, which will last maximum 12 months, the Contractor shall develop, implement and validate the target products and the coupled model defined in Phase 1. This shall be supported by a verification analysis justifying the implementation choices.

In Phase 2, at least the following tasks shall be performed:
- Task 4: Product Development and Validation;
- Task 5: Model Development and Validation.

A **Preliminary Development Review (PDR)** will take place at the Contractor premises at the half of Phase 2. During this meeting, the Contractor shall report the preliminary outcomes of Task4 and Task 5. Potential modifications and improvements identified and agreed with ESA during the PDR shall be implemented and properly validated by the Contractor before the end of Phase 2.

Phase 2 will end on ESA acceptance of all the deliverables scheduled for Task 4 and Task 5. In particular, at the end of Phase 2 a **Qualification Review (QR)** will take place in ESRIN to review the progress of activities and results obtained. During the QR, the adequacy, reliability and accuracy of the target products and the coupled model developed shall be reviewed and evaluated. Also deliverables produced in Phase 2 will be considered in the review process, as well as validation results. A special attention will be devoted to cross-comparison activities to be carried out for assessing the effectiveness of the developed products and models with respect to currently available counterparts.

On the basis of the outputs of the QR, the Agency reserves the right to revise successive tasks of the activity and a contractual go/no-go decision shall be made by ESA on whether to continue to Phase 3. The decision will be based on:

- Timely delivery of all deliverables;
- Scientific and technical quality of deliverables;
- Assessment of deliverables against the requirements specified in the SoW;
- Feasibility of remaining activities.

Task 4: Product Development and Validation
<u>Description:</u> In this task, on the basis of the PAR and the TS, the Contractor shall develop and validate the entire suite of target products identified in collaboration with the iLEAPS IPO in the RB. For each target product, an end to end suitable algorithm should be implemented [T.4.1]. Then, the Contractor shall carry out a detailed experimental analysis for testing and verifying all the different implementation choices [T.4.2] and ultimately evaluate the effectiveness of the developed products according to the VP [T.4.3]. In particular, the experimental analysis shall be carried out on at least three different test sites (already identified in Task 3) with characteristics that could differently affect the performances, for which suitable ancillary data shall be accessible by the Contractor. A detailed description of the final version of the algorithms (including related data sources, processing steps and output data) shall be reported by the Contractor into the Product Development Definition File (DDF-P) [T.4.4]. Moreover, a scientific analysis of the results driving to specific development choices and trade-offs (including technical considerations justifying the selected methodologies) shall be provided by the Contractor into the Product Development Justification File (DJF-P) [T.4.5]. The Contractor shall also report a detailed description of the validation analysis into the Product Validation Report (VR-P) [T.4.6], which shall also include a cross-comparison against currently available alternative products derived from both ESA and non-ESA missions. Moreover, the VR-P shall also include a quantitative assessment of the uncertainties associated with each target product, which shall demonstrate and emphasize their improved capabilities.
<u>Note:</u> As concerns Theme 2, cross-comparison between the fire injection height product to be developed from ENVISAT AATSR/MERIS data and the TERRA MISR counterpart currently available product is **mandatory**.
<u>Deliverables:</u> **Product Development Definition File (DDF-P)**: This document shall describe into details all the algorithms implemented for developing the whole suite of target products, as well as related data sources, processing steps and output data. In particular, the DDF-P shall include both a Data

Processing Model (DPM) and a Product Description Manual (PDM) providing a complete description of all the algorithms (both theoretical and technical) and corresponding input/output data flows, respectively.

Product Development Justification File (DJF-P): This document shall report a scientific analysis of the results driving to specific development choices and trade-offs for all the algorithms implemented for developing the whole suite of target products. Technical considerations justifying the selected methodologies shall be also provided.

Product Validation Report (VR-P): This document shall describe all the experimental validation activities carried out according to the procedure specified in the VP for assessing the effectiveness of the developed target products. The VR-P shall compare final products against the TS. Moreover, a detailed cross-comparison with already existing similar products shall also be included, as well as a quantitative assessment of the uncertainties associated with each product.

Task 5: Model Development and Validation

Description:

In this task, on the basis of the PAR and the TS, the Contractor shall develop and validate a suitable land-atmosphere coupled model identified in collaboration with the iLEAPS IPO in the RB capable of taking full advantage of the whole set of novel target products developed in Task 4 (to be employed as inputs and/or constraints of the model) [T.5.1].

In particular, besides developing a coupled model *ex-novo*, the Contractor is encouraged to properly adapt one of the models currently available in the literature (among those already identified in Task 2).

The Contractor shall carry out a detailed experimental analysis for testing and verifying all the different implementation choices [T.5.2] and ultimately evaluate the effectiveness of the developed model according to the VP [T.5.3]. In particular, the experimental analysis shall be carried out on at least three different test sites (already identified in Task 3) with characteristics that could differently affect the performances, for which suitable ancillary data shall be accessible by the Contractor.

A detailed description of the final version of the model (including a description of all the configuration parameters and a summary assessment of their function, sensitivity, value range and likely impact on model outputs) shall be reported by the Contractor into the Model Development Definition File (DDF-M) [T.5.4]. Moreover, a scientific analysis of the results driving to specific development choices and trade-offs (including technical considerations justifying the selected methodologies) shall be provided by the Contractor into the Model Development Justification File (DJF-M) [T.5.5].

The Contractor shall also report a detailed description of the validation analysis into the Model Validation Report (VR-M) [T.5.6], which shall also specify any deficiencies, problems and known configuration limitations of the model, as well as describe the domain of validity of the model in terms of space and time scales and range of physical parameters. Moreover, the VR-M shall also include a quantitative assessment of the uncertainties associated with model outputs, which shall demonstrate and emphasize the improved capabilities of both the model and the suite of target products developed in the framework of the project.

Note:

Employing the entire suite of target products as inputs and/or constraints of the coupled model to be developed might entail the use and/or implementation of proper inverse modelling techniques:

- As concerns theme 1, the ensuing coupled model should be capable of improving methane emission estimations from boreal Eurasian lakes and wetlands at a regional scale also directly exploiting satellite observations of atmospheric methane concentrations;
- As concerns theme 2, the ensuing coupled model should be capable of improving estimations of greenhouse-gas and aerosol dispersion forecasts due to biomass burning events occurred in boreal Eurasia at a global scale also directly exploiting satellite observations of greenhouse-gas and aerosol dispersion over time.

Deliverables:

Model Development Definition File (DDF-M): This document shall provide a description of the final version of the model (both theoretical and technical), as well as of all the configuration parameters for the model and a summary assessment of their function, sensitivity, value range and likely impact on model outputs. Moreover, the DDF-M shall properly report how to configure the model and how to read and interpret model outputs.

Model Development Justification File (DJF-M): This document shall report a scientific analysis of the results driving to specific development choices and trade-offs for the developed coupled model. Technical considerations justifying the selected methodologies shall be also provided.

Model Validation Report (VR-M): This document shall describe all the experimental validation activities carried out according to the procedure specified in the VP for assessing the effectiveness of the developed model. The VR-M shall describe the domain of validity of the model in terms of space and time scales and range of physical parameters. Moreover, the VR-M shall also include a quantitative assessment of the uncertainties associated with model outputs, which shall demonstrate and emphasize the improved capabilities of both the model and the suite of target products developed also with respect to already existing similar products.

5.1.3 PHASE 3 – DATASET GENERATION, MODEL PROCESSING AND PHASE OUT

In this final phase, which will last up to 4 months, the Contractor shall generate the experimental dataset as well as the corresponding model experimental outputs (obtained by processing the experimental dataset into the coupled model developed in Phase 2). Moreover, the Contractor shall also set up solid bases for further developments of the project and identify potential follow-up activities. In particular, the attention shall be focused on identifying potential scientific developments within the STSE and demonstration activities for dedicated large scale information services within the Data User Element.

In Phase 3, at least the following tasks shall be performed:

- Task 6: Experimental Dataset Generation;
- Task 7: Model Experimental Processing;
- Task 8: Scientific Roadmap;
- Task 9: ALANIS workshop.

At the end Phase 3, a **Final Review (FR)** will take place in ESRIN to review with the Contractor the experimental datasets, the model experimental outputs and the proposed Scientific Roadmap. The Contractor shall provide the final datasets and outputs, as well as Phase 3 deliverables within the FR.

Task 6: Experimental Dataset Generation
Description: In this task, the Contractor shall generate an experimental dataset consisting of the entire set of novel target products (developed and validated in Task 4) engendered for a reference period over a specific area of interest [T.6.1]. In particular: • As concerns Theme 1, the experimental dataset shall cover a period of two years over the whole boreal Eurasian region; • As concerns Theme 2, the experimental dataset shall refer to a consistent number of fire events occurred in a period of three years over the whole boreal Eurasian region. The experimental dataset shall be complemented by proper documentation and metadata [T.6.2] and then delivered to the scientific community for: i) fostering additional validation activities and further cross-comparisons; and ii) supporting user acceptance. Both the experimental dataset and related documentation and metadata shall be available on-line and promoted within potential user communities [T.6.3]. To this aim, the Contractor shall guarantee free access for consolidating the dataset within the iLEAPS scientific community and promote its employment to potential future users (e.g., key institutions). In this context, synergies with modellers and users shall be developed for testing the effectiveness of target products in the framework of other state-of-art coupled models.
Deliverables: **Experimental Dataset**: An experimental dataset consisting of the entire set of novel target products (developed and validated in Task 4) engendered for a reference period over a specific area of interest (defined in accordance with ESA) as well as related documentation and metadata shall be provided.

Task 7: Model Experimental Processing
Description: In this task, the Contractor shall process the experimental dataset generated in Task 6 into the

coupled model developed and properly validated in Task 5 [T.7.1]. This will allow to obtain the following experimental output products:

- Theme 1: estimates of methane emissions from northern lakes and wetlands over the entire boreal Eurasian region for a period of two years;
- Theme 2: greenhouse-gas and aerosol dispersion forecasts for a consistent number of fire events occurred in a period of three years over the whole boreal Eurasian region.

The Contractor shall also perform an impact analysis for investigating the sensitivity of the experimental output products [T.7.2], as well as properly estimating their uncertainties and characterizing their effectiveness with similar products currently available (among those already identified in Task 2) [T.7.3]. These activities shall be described into details in the Impact Assessment Report (IAR).

Model experimental output products shall be available on-line and promoted within potential user communities [T.7.4]. To this aim, the Contractor shall guarantee free access for consolidating the outputs of the model experimental activity within the iLEAPS scientific community and promote their employment to potential future users (e.g., key institutions).

Deliverables:

Model Experimental Outputs: Output products obtained by processing the experimental dataset generated in Task 6 into the coupled model developed and validated in Task 5 shall be provided.

Impact Assessment Report (IAR): This document shall describe the analysis carried out for evaluating the sensitivity of the model experimental outputs. The IAR shall also include a proper assessment of their uncertainties and a suitable comparison with similar products currently available (among those already identified in Task 2).

Task 8: Scientific Roadmap

Description:

In this task, the Contractor shall define a Scientific Roadmap for fostering future developments in support of the iLEAPS community and transferring the outcomes of the ALANIS project (as concerns the investigated Theme) into operational activities. In particular, attention shall be focused on advancing toward maximizing the use of ESA data. Note that at least the following issues shall be considered:

- Providing a critical analysis of all the feedbacks from scientists and institutions that have accessed the experimental datasets [T.8.1];
- Identifying potential strategies for integrating target products into other existing models at different scales for demonstrating their improved effectiveness for science and applications [T.8.2];
- Defining a scientific development strategy for establishing long-term multi-mission data records responding to the needs consolidated in the RB as a support to scientists and users involved in investigating the considered Theme [T.8.3];

• Defining a potential plan for fostering a transition from research to operational activities (a demonstration end-to-end system shall be proposed) [T.8.4]; • Identifying scientific priority areas to be addressed in future STSE projects in support of the iLEAPS community as a follow up activity of the ALANIS project (as concerns the investigated Theme) [T.8.5]; • Recommending further advances in other potential relevant areas (e.g., future missions, in-situ validation, etc.) [T.8.6].
Deliverables: **Scientific Roadmap (SR)**: This document shall define strategic actions for fostering a transition of the target products and the coupled model developed in the project from research to operational activities. In particular, the SR shall describe potential developments for establishing long-term multi-mission data records, as well as identifying further relevant issues (related to the investigated Theme) to be addressed by future STSE projects in support to the iLEAPS community.

Task 9: ALANIS Final Workshop
Description: In this task, the Contractors of each ALANIS theme shall integrate and cooperate for organizing a final workshop in collaboration with the iLEAPS IPO [T.9.1] aimed at: • Presenting and promoting the outcomes of the ALANIS project to the iLEAPS community; • Discussing the proposed scientific roadmap; • Collecting feedback and deriving recommendations for further related ESA activities.
Deliverables: **Final Workshop**.

5.2 Workplan for Theme 3

In Table 5.1, a description of the tasks to be carried out in the context of ALANIS Theme 3 is provided. Any eventual change or modification shall be properly justified by the Contractor. The project shall last up to 20 months.

Note that at least the following tasks shall be performed:

- Task 1: Preliminary Analysis;
- Task 2: Development and Validation;
- Task 3: Scientific Roadmap.

Table 5.1 - Description of the tasks to be carried out in the context of ALANIS Theme 3.

Task	Description	Deliverables
1. Preliminary Analysis	The Contractor shall perform a comprehensive review of current initiatives that are relevant in the context of the investigated Theme. This shall include: • A detailed assessment of existing products, datasets, models and algorithms, as well as related limitations and drawbacks; • An analysis of current ESA and non-ESA mission suitable EO data; • A survey of all accessible ancillary data (e.g., in situ data, airborne campaigns data, reference data) which could be of use in helping the Contractor to perform adequate validation activities; • A survey of current and upcoming initiatives and projects related to the investigated Theme. In performing this analysis, the Contractor shall consider the most recent scientific publications, as well as researches and operational projects funded in the last few years by ESA, the EC and R&D national programmes.	**Preliminary Analysis Report**: This document shall describe the outcomes of the Preliminary analysis.
2. Development and Validation	The Contractor shall develop and validate: • Novel algorithms solely exploiting as input currently available EO-based products for discriminating natural from anthropogenic aerosols in boreal Eurasia; • Novel strategies for assimilating already existing EO-based products into chemical transport models currently available in the literature to discriminate natural from anthropogenic aerosols in boreal Eurasia. The Contractor shall implement at least three different case studies for evaluating the performances of both the developed algorithms and models. Experimental activities shall be carried out on different test sites with characteristics that could differently affect the performances, for which suitable input and ancillary data shall be accessible by the Contractor. Moreover, the Contractor shall perform detailed quantitative and qualitative analysis and cross-comparison of the final output products obtained by both the approaches.	**Feasibility Study Report**: This document shall provide a description of the final version of the developed algorithms and models, related validation, as well as a detailed analysis of the output products and comprehensive cross-comparison activities. **Case Studies:** The Contractor shall provide at least three case studies consisting of: o Input data for both the developed algorithms and models; o Final output products; o Related documentation.
3. Scientific Roadmap	The Contractor shall define a Scientific Roadmap for fostering future developments in support of the iLEAPS community and transferring the outcomes of the project into research and development activities. In particular, attention shall be focused on advancing toward maximizing the use of ESA data.	**Scientific Roadmap**: This document shall describe potential developments for identifying further relevant issues to be addressed by future STSE projects in support to the iLEAPS community.

5.3 Horizontal activities

Two horizontal activities shall be addressed in the framework of the ALANIS project for all the Themes:

- Promotion;
- Management and coordination.

5.3.1 PROMOTION

The Contractor shall define and implement a Promotion Plan (as concerns the investigated Theme) [M.1] for:

- Providing evidence of submitted papers on the results of the ALANIS project in relevant peer-reviewed international science journals;
- Establishing connections between ALANIS and other relevant projects within iLEAPS and IGBP;
- Promoting the results of the ALANIS project within the iLEAPS and IGBP communities, maximising the visibility of ESA into their individual programmes;
- Promoting the ALANIS results and distributing free experimental output data to scientific and user communities;
- Representing ALANIS in scientific conferences, meeting and workshops through scientific presentations and exhibitions.

This Promotion Plan shall be submitted to ESA for approval before the end of Task 1 and shall be executed during and after the project lifetime.

The Contractor shall set up (before the end of Task 1) a web site for the project, which shall be maintained up to at least two years after the end of the project [M.2]. The web site shall provide a direct access to different products and data sets developed during the project. Contents of the web site shall require the ESA approval before being published.

5.3.2 MANAGEMENT AND COORDINATION

The Contractor shall provide at least the following deliverables:

- Project Management Plan (due within the first month of the Project), which shall include both a Quality Management Plan (applied during the project lifetime) and a Working Plan (describing the intended approach to work with users) [M.3];
- Project Technical Deliverables (specified in Section 5.1 and Section 5.2) [M.4];
- Monthly Progress Reports [M.5];
- Final Report for public access (executive summary of the project summarising relevant achievements) [M.6].

The Project Management Plan shall present the objectives of each deliverable, describe major elements and include a preliminary Table of Content. Moreover, it shall be updated during the whole project (at least at the end of each Task).

As concerns Theme 1 and Theme 2, the schedule of planned activities shall comply with the milestones reported in Table 5.2. In addition, a Progress Meeting (PM) will take place every 3 months at the Contractor premises (except for those coinciding with one of the reviews).

For Theme 3, the Contractor shall propose a different reduced scheduling.

Table 5.2 - List of Milestones for ALANIS Theme 1 and Theme 2.

Phase	Review	Milestone	Place
1	RER	End of Phase 1	ESRIN
2	PDR	End of Preliminary Development	Contractor Premises
	QR	End of Phase 2	ESRIN
3	FR	End of Phase 3	ESRIN

Tables 5.3 and 5.4 provide the list of deliverables for Themes 1 and 2, and Theme 3, respectively.

Table 5.3 - List of deliverables for ALANIS Theme 1 and Theme 2.

Activity	Deliverable
Scientific Requirement Consolidation	Requirement Baseline (RB)
Preliminary Analysis	Preliminary analysis Report (PAR)
Technical Specifications	Technical Specifications (TS) Validation Plan (VP)
Product Development and Validation	Product Development Definition File (DDF-P) Product Development Justification File (DJF-P) Product Validation Report (VR-P)
Model Development and Validation	Model Development Definition File (DDF-M) Model Development Justification File (DJF-M) Model Validation Report (VR-M)
Experimental Dataset Generation	Experimental Datasets
Model Experimental Processing	Model Experimental Outputs Impact Assessment Report (IAR)
Scientific Roadmap	Scientific Roadmap (SR)
ALANIS Final Workshop	ALANIS Final Workshop
Promotion	Project web site Publications Presentations
Management	Standard ESA documents Final Report

Table 5.4 - List of deliverables for ALANIS Theme 3.

Activity	Deliverable
Preliminary Analysis	Preliminary analysis Report
Development and Validation	Feasibility Study Report Case Studies
Scientific Roadmap	Scientific Roadmap
Promotion	Project web site Publications Presentations
Management	Standard ESA documents Final Report

As concerns Theme 1 and Theme 2, the project manager shall ensure that the following coordination activities are implemented:

- Ensuring and coordinating the synergy with relevant national and European projects and programmes [M.7];
- Coordinating the effective access to all the data required in the framework of the project (as concerns the investigated Theme), with a special attention to those necessary for validation activities [M.8];
- Coordinating the collection and the analysis of the scientific requirements (and corresponding feedback) from the iLEAPS community [M.9].

6 ADDITIONAL ISSUES

6.1 EO Data Procurement

The Contractor shall use suitable ESA data to the largest extent [M.10]. To this aim, the Contractor shall be entitled to acquire any ESA data required at conditions and prices for Category-1 use [URL 3].

It is worth noting that all the products and related algorithms, as well as models to be developed shall require input EO products derived from different sources of EO data. Accordingly, the Contractor is encouraged to exploit both ESA and non-ESA EO mission data when appropriate to the work to be performed.

Moreover, the Contractor is also encouraged to exploit ESA historical archives.

Data procurement can be quoted, but all the procurement with the ESA budget will be property of ESA and will only be given at the disposal of the Contractor in the framework of the project. Terms and conditions from the Data Distributors are to be fully understood and strictly fulfilled.

Due to Research and Development (R&D) nature of the present contract, the contractor shall explore the possibility of acquiring non-ESA data required for the project at an R&D compatible price.

6.2 Special Requirements for Team Composition

Since the subject of the present ITT requires to combine complementary skills and expertise, the Contractor shall team up a consortium capable of allocating the tasks to be performed to staff that are qualified and well-experienced in the various relevant fields of the project [M.11]. In particular, for each Thematic Area the team shall include:

- Scientific groups and/or value adding companies with a strong experience in EO data and applications;
- Environmental organizations and/or scientific groups with a strong experience in land-atmosphere processing and modelling.

Bidders shall provide evidence of team expertise in their proposals specifying, in particular, scientific specialisation and involvement in other initiatives relevant to the ALANIS project for each member.

7 ACRONYMS AND ABBREVIATIONS

ALANIS	Atmosphere-LANd Interaction Study
AOD	Aerosol Optical Depth
APP	Applicable Document
CAT1	Category 1 (Data Policy for ESA EO data procurement)
CTM	Chemical Transport Model
EO	Earth Observation
DDF-M	Model Development Definition File
DDF-P	Product Development Definition File
DJF-M	Model Development Justification File
DJF-P	Product Development Justification File
DPM	Data Processing Model
fAPAR	fraction of Absorbed Photosynthetically Active Radiation
FR	Final Review
IAR	Impact Assessment Report
IGBP	International Geosphere-Biosphere Programme
iLEAPS	Integrated Land Ecosystem-Atmosphere Processes Study
IPO	International Project Office
ITT	Invitation To Tender
LAI	Leaf Area Index
LCCS	Land Cover Classification System
LS	Lower Stratosphere
PAR	Preliminary Analysis Report
PDM	Product Description Manual
PDR	Preliminary Development Review
PM	Progress Meeting
QR	Qualification Review
R&D	Research & Development
RB	Requirement Baseline
RER	Requirement Engineering Review
TPM	Third Party Mission
TS	Technical Specifications
SoW	Statement of Work
SRD	Scientific Requirement Document
STSE	Support To Science Element
UT	Upper Troposphere
VGC	Vegetation Growth Cycle
VP	Validation Plan
VR-M	Model Validation Report
VR-P	Product Validation Report

ANNEX A ALANIS SCIENTIFIC REQUIREMENT DOCUMENT

1 Introduction

The European Space Agency (ESA) and the Integrated Land Ecosystem-Atmosphere Processes Study (iLEAPS) as part of the International Geosphere-Biosphere Programme (IGBP) organized a Scientific Consultation Workshop, held on the 20th April 2009 and hosted by the Austrian Academy of Sciences in Vienna for setting up the basis of a joint activity aimed at improving the common knowledge about land-atmosphere dynamics in Northern Eurasia.

Global biosphere and climate change processes manifest themselves at most in the boreal regions, and particularly in Eurasia. Indeed, the role of Eurasian boreal ecosystems is essential in global climate regulation. On the one hand, northern forests are pools of terrestrial carbon and constitute a global sink of atmospheric carbon dioxide (CO_2), thus contributing to the attenuation of greenhouse effects. On the other hand, boreal lakes and wetlands store large amounts of carbon, partially released as methane (CH_4) and other trace gases to the atmosphere during spring and summer.

The extent and remoteness of Boreal Eurasia, however, pose a challenge to quantification of both terrestrial ecosystem processes and their feedbacks to regional and global climate conditions. Moreover, human activities and climate changes occurred in the last few years have altered the natural equilibrium in that region, thus strengthening the need for an effective mapping and monitoring of surface-atmosphere exchange interactions. Satellite remote sensing observations allow a regular monitoring of key characteristics of both the state and time course of changes in boreal ecosystems, thus being particularly useful for estimating climatic and biospheric changes, as well as for understanding their mechanisms and forecasting their future trends.

In this complex framework, the ESA-iLEAPS joint initiative is motivated, on the one hand, by the increasing need for multi-source datasets required by scientists, modellers and institutions involved in investigating boreal ecosystems, and, on the other hand, by the growing potentialities offered for investigating northern high latitudes by existing (and upcoming) ESA and non-ESA missions (thus allowing unprecedented availability of satellite Earth observation (EO) data for a variety of key parameters over boreal regions).

This document will describe the preliminary observational requirements needed for identifying key variables characterizing land-atmosphere dynamics over boreal regions and will serve as the basis for ESA to launch a dedicated activity (the Atmosphere-LANd Interaction Studies - ALANIS) within the context of the new program Support to Science Element (STSE). iLEAPS will provide the scientific input and coordination based upon its current state-of-art global data products.

2 The ESA-iLEAPS ALANIS project Objectives

The ALANIS project aims at supporting iLEAPS research for setting up the scientific grounds for:

1) Advancing towards the development and validation of novel advanced EO-based multi-mission products, improved data sets and enhanced applications that may respond directly to the specific scientific requirements of the iLEAPS community;
2) Improving the observation, understanding and prediction of land-atmosphere processes in boreal ecosystems at different spatial and time scales;
3) Setting up a solid scientific basis for further ESA activities in support of the iLEAPS community;
4) Defining a scientific roadmap to advance the establishment of long-term common activities.

3 Potential themes for ALANIS

During the ALANIS consultation workshop hosted by the Austrian Academy of Sciences in Vienna on April 20th 2009, four potential topics preliminary identified together with the iLEAPS International Project Office (IPO) have been discussed:

- Monitoring northern high latitude lake/wetland dynamics and methane emissions;
- Aerosol dynamics in boreal ecosystems;
- Boreal forest vegetation dynamics and carbon fluxes;
- Biomass burning plume detection and injection height determination.

These four themes refer to the most important areas of research currently carried out by the iLEAPS community involving issues mainly related to the Northern Eurasia region.

In the following, for each of these topics we will summarize the most relevant outcomes of both keynote speakers' presentations and open discussions. In particular, the attention will be focused on briefly characterizing the problems and pointing out current status and major needs identified during the workshop.

Monitoring northern high latitude lake/wetland dynamics and methane emissions

Methane (CH_4) is one of the most dangerous greenhouse gases and plays an important role in atmospheric chemistry; in particular, its contribution to the current greenhouse effect is about 22%. Evidence has been found that boreal lakes and wetlands, due to peat accumulation, currently constitute the biggest methane source on Earth, even in comparison to anthropogenic emissions. Accordingly, monitoring their dynamics represent a central issue to be investigated for obtaining reliable estimates of future emissions.

Besides natural lakes fed by rivers, boreal thaw lakes (over 8ha) and wetlands (below 8ha) form in regions where ice-bearing permafrost warms and thaws due to a local change in ground conditions and/or regional climate change. Generally, they tend to be relatively small but numerous, and may cover 20-40% of the land surface in certain regions (i.e., notably the unglaciated terrain of Northeast Siberia), often undergoing a dynamic cycle of formation and drainage. Once formed, they expand with continued thawing of surrounding soils until the following freezing season.

Interactions of CH_4 between water and the atmosphere are key factor for understanding the biological and chemical dynamics of northern lakes and wetlands. A relatively small proportion of the total amount of methane dissolved in water is input from external sources. Instead, although some CH_4 may be dissolved in groundwater and surface-water inflow, the majority of dissolved methane is produced by anaerobic decomposition in sediment. This CH_4 moves upward to the water column, where it is ultimately converted to biomass and CO_2 by methanotrophic bacteria or emitted to the atmosphere via plants, molecular diffusion and ebullition.

In order to obtain regional estimates of methane emissions more reliable than those currently available, nowadays there is a significant need for:

- A combined monitoring of different variables that can be provided as input to existing land-surface models capable of simulating methane production;
- Direct measurements of CH_4 emissions to be employed for validation purposes.

In this context, it is largely partaken that only remote sensing provides both the necessary inputs and reference values to verify the models at the required temporal and spatial scales.

So far, the most relevant parameters to be monitored have been identified as the following:

- Lake and wetland extent;
- Soil moisture;
- Surface temperature;
- Vegetation type;
- Snowmelt;
- Freeze/thaw transition.

It is worth noting that the development of long-term datasets of products referring to these variables would allow sensible improvements in current estimates.

Assessing long-term changes in the extent of boreal lakes and wetlands can be performed by means of optical satellite data, which proved effective discrimination capabilities (i.e., they also allow to properly identify different types of inundated vegetation) but generally suffer from high cloud coverage at northern latitudes (preventing their employment for short-term changes). SAR data, instead, are particularly suitable for identifying daily to seasonal changes due to their all-weather monitoring capabilities.

Since lakes and open waters can be easily identified with microwave data with a proper spatial resolution, their dynamics can be monitored through the analysis of multitemporal series. In such framework, ENVISAT ASAR GM and WS data have proven to be a valuable source of information to this purpose. However, as concerns wetland monitoring, due to their complex nature, the integration of further information is mandatory for obtaining reliable discrimination. In particular, accounting for soil moisture will allow differentiating between different sub-types, to which specific amounts of methane emissions correspond. This could be possible for instance by employing active microwave data derived from scatterometers (e.g., ERS series scatterometers, METOP ASCAT), that permit a reliable retrieval of surface wetness. This type of data, due to the sensitivity to dielectric properties, is also useful for determining the start/end of thawing/freezing period, which is directly related to snowmelt and, thus, helps identifying inundated vegetation areas. As concerns surface temperature, both optical and passive microwave sensors can be used for an effective retrieval.

In the challenging task of monitoring northern lakes and wetlands, it must be taken into account that different information classes are characterized by specific spatial and temporal dynamics. Peatlands and fens may vary from an extent of few squared meters to several squared kilometres, but generally experiment long-term changes (i.e., annual to decadal). Tundra ponds, instead, are smaller (at maximum few hectares) but often vary on a weekly to annual scale. Seasonal floodings even exhibit a higher temporal variability (i.e., weekly to monthly), with a spatial extent from few hundreds of squared meters to some tens of squared kilometres.

Due to the lack of input data for some of the aforementioned parameters at proper scale, current methane-emission estimates derived from different land-surface models exhibited large uncertainties. To this aim it would be important to obtain regular direct measurements of methane emissions at regional scale (even characterized by a reduced spatial resolution with respect to the extent of boreal lakes and wetlands) for validation purposes. This has been proven to be feasible through the employment of ENVISAT SCIAMACHY data. A proper long term analysis of this type of data would help the improvement of existing models that can benefit from the use of several remote sensing data as assessed above.

Aerosol dynamics in boreal ecosystems

Atmospheric aerosols play a key role in the Earth's climate system by scattering and absorbing solar radiation and by acting as cloud condensation nuclei (CCN).

Northern latitudes are affected by both natural and anthropogenic aerosols. On the one hand, natural aerosols over the continental boreal environment are mostly generated as secondary organic aerosols from biogenic emissions of boreal forests (especially during the biogenically active part of the year). On the other hand, high northern latitudes are impacted periodically by long-range transported anthropogenic aerosols, such as those formed by energy production, traffic and industrial activities.

Quantifying the effects of atmospheric aerosols requires detailed information on their physical and chemical properties as well as on their spatial distribution and temporal variability in the atmosphere. Detailed physic and chemical properties can only be measured *in situ*, and a few networks of ground measurement sites have already been established for this purpose (e.g., AERONET). Aerosol vertical distributions, instead, can be effectively determined with lidar, aircraft or balloon measurements. As concerns satellites, they provide aerosol data with a high spatial coverage, but they are mainly confined to a few column-integrated properties such as the aerosol optical depth (AOD) and the Ångström parameter (which characterizes the shape of the size distribution). This is generally carried out by employing optical sensors (e.g., ENVISAT MERIS and ASAR, TERRA/AQUA MODIS, NOAA AVHRR, MSG SEVIRI, etc.). However, disturbing effects by the varying surface albedo and clouds make such data inaccurate at low aerosol concentrations.

In this complex framework, it has become clear that assessing the various effects of atmospheric aerosols at a regional and global scale requires a synergic complementary use of surface measurements, remote sensing techniques and proper transport and atmospheric models. Such a concept has already been applied when trying to reduce the existing uncertainties in the direct radiative forcing by anthropogenic aerosols, when determining ground-level aerosol concentrations over large geographic scales, and when analysing and predicting regional air pollution episodes caused by aerosols.

Nowadays, one of the primary objectives for researchers involves the possibility of effectively characterizing both the spatial distribution and temporal variability of natural and anthropogenic aerosols at high northern latitudes and estimating their implications on air quality and climate change.

Related to these goals, the following aspects are also of major concern:

- Characterizing the AOD associated with natural aerosols emitted by boreal forests;
- Deriving a statistically significant relationship between AOD and the concentration of both natural and anthropogenic aerosols at high northern latitudes;
- Evaluating the contribution of natural aerosol loading over boreal forests in aerosol-cloud-climate interactions;
- Predicting particulate air pollution episodes over high northern latitudes;
- Estimating the nucleation and Aitken mode particle concentrations.

Boreal forest vegetation dynamics and carbon fluxes

Boreal Eurasian forests are assumed to store more carbon than any other terrestrial ecosystem on the planet (i.e., around 20–25% of the total carbon stored on Earth). Accordingly, due to both their sensitivity to change and their size, they are likely to affect the global climate system by modifying the global carbon budget altering its release and sequestration.

Warming in the northern high latitudes has been extremely rapid in recent decades and it is projected to considerably exceed global average rates in the next future. Changes in precipitation patterns, instead, are less certain, but for large boreal regions, soil moisture is projected to decline as increased evaporative demand exceeds possibly enhanced precipitation. Such estimated trends fuel debate on the associated medium- to long-term changes in boreal Eurasian carbon pools. In particular, the possibility for substantial carbon cycle feedbacks in the climate system has been recently identified in a number of modelling studies.

Complex interactions with natural disturbance regimes (e.g., fire events and insect outbreaks) have demonstrated their effects on accelerating transient of carbon. However, the boreal region may not be uniformly vulnerable to climate change in terms of net carbon loss. In fact, warming is expected to stimulate mineralization and hence to enhance nitrogen availability for plant growth. Considering the strong nitrogen limitation observed in many boreal forest soils makes also this process crucial for projecting climate-carbon cycle interactions in the future.

A number of important scientific questions arise from boreal land-atmosphere interactions in the light of rapid climate change. In particular, main research themes involve the study of:

- Vegetation structure/type changes and related effects on carbon cycle;
- Effects of climate change on carbon-water-nutrient cycle and subsequent effects of carbon-water-nutrient cycle changes on terrestrial climate;
- Effects of climate and atmospheric changes in albedo associated with vegetation cover changes;
- Current status and recent trends of boreal Eurasian forests, not only in terms of total geographic extent but also in terms of relative proportions of major vegetation types (deciduous vs. evergreen forest, forest vs. wetland) and canopy structure (height, density);
- Effects of climate change on carbon cycle, water cycle, and disturbances in permafrost regions;
- Extent and effects of disturbances (e.g., logging; insect outbreaks, fire events) on climate feedbacks.

It is worth noting that, small errors in spatial characterisation of boreal Eurasian forests can rapidly cause large errors in overall carbon budget estimations. Therefore, ecosystem response to climate change in such region must be carefully taken into consideration. As an example, increased greening has already been documented from remote sensing (e.g., migration on larch forests into the tundra in Siberia). However, a more general picture on vegetation dynamics is still missing. Equally important is to detect traces of changes along the southern transition between forest into steppe or even in the most central areas which may by vulnerable to increased evaporative demand and changed vegetation patterns. At the same time the translation of vegetation changes into alterations of biosphere-atmosphere exchanges of carbon (and water) is a crucial ingredient for understanding the feedbacks of climate change on the carbon cycle. Eddy covariance flux tower provide an excellent and non-destructive tool for this purpose. In fact, if cross-site analyses and integration with remote sensing data are performed, it is possible to generalize and up-scale from single-site observations in space and time.

In the last decade, remote sensing has made a big progress towards specific land-surface observation and retrieval of biophysical quantities such as albedo and fraction of absorbed radiation (fAPAR), which have been effectively employed for continental-scale estimates of vegetation productivity. Promising attempts have been also carried out not only to infer the vegetation radiation absorption, but also its photochemical state through the estimation of the photochemical reflectance index (PRI). Moreover, land surface temperature is operationally derived both from geostationary and polar-orbiting satellites. A considerable improvement has been obtained by introducing passive and active microwave sensors, which are not affected by cloud cover or other atmospheric disturbances and yield information both on vegetation structure/biomass and soil water status. Even more detailed information of canopy structure is expected from lidar applications, which are not yet operational at continental scale.

Terrestrial models are rapidly improving their ability of representing canopy structure, vegetation dynamics, disturbance events and associated links to carbon pool changes. In this framework, remote sensing information is vital for model evaluation. However, remote sensing data can be even directly integrated into the models themselves for obtaining an analysis of climatic change impacts on future carbon fluxes. In particular, they can be used even to impose further model constraints complementing ground observations.

For addressing these issues, the following remote sensing derived products are required at present:

- Continuous fields of canopy cover for major vegetation types;
- Seasonal to interannual changes and trends in canopy leaf area index, fAPAR and albedo;
- Land surface temperature;
- Snow cover extent and thickness;
- Soil moisture;
- Frozen soil extent;
- Continuous fields of growing stock volume or stem density and canopy height;
- Defoliated area (e.g., due to insect attacks).

Biomass burning plume detection and injection height determination

Boreal fires play a major role in carbon dynamics as they can determine the magnitude of net biome productivity through combustion (most direct carbon loss during fire events is usually from below-ground fuel), decomposition of fire-killed vegetation and stand renewal (i.e., young successional stands have potential to be greater sinks than mature stagnant forests). These events are particularly stressed up in Eurasia, where the number and extent of boreal forest fires is dramatically increasing (e.g., catastrophic fires cover approximately some millions of hectares annually in Russia alone, but it is a general assumption that Russian statistics may be underestimated). Furthermore, trend observations let us expect an increase in fire activity in the next few years as well as longer fire seasons. Warmer conditions caused by increased greenhouse gases will make the weather more conductive to fires, and, thus, will cause a further increase in greenhouse gases due to greater carbon release.

Biomass burning events represent an important source of gases and particles released into the atmosphere; in particular, a wide variety of species are emitted, including mainly carbon dioxide (CO_2), carbon monoxide (CO) and methane (CH_4). In general, a large amount of thermal energy is released creating a strong updraft. For most fires, the plume initially rises no further than the boundary layer; then, after some time, it can be transported zonally as well as vertically into the free and eventually the upper troposphere. In other cases, instead, the species are injected directly into the upper troposphere or even the stratosphere (e.g., pyro-convective events). This has a strong impact on pollutant dispersion, since in the troposphere the pollutants are advected away faster from the source region and can extend even over several thousand kilometres. As it is crucial for understanding how the smoke will disperse, the accurate estimate of injection heights for biomass burning emissions is of fundamental importance for aerosol transport modelling.

In this context, there have been numerous studies on the chemical characterization of biomass burning plumes at different stages of their evolution. Measurements have been made from the ground or from aircrafts using a variety of techniques and modelling of transport and photochemistry have been carried out. Nevertheless, up to now it has not been possible to obtain precise estimations of injection height; therefore, a common assumption in global models is to assume a constant injection height, which results in sub-optimal performances.

The employment of satellite-based instruments in recent years has helped in the analyses of the chemical composition of plumes from large fires, providing a better spatial and temporal sampling of the burning events. Infrared and UV-visible nadir sounders have provided a wealth of data, enabling the concentration distributions of several important biomass burning products to be derived. However, these measurements lack vertical resolution thus still avoiding precise estimation of injection height. Recently, automatic plume detection has been pioneered by exploiting both NASA's AVHRR (advanced very high resolution radiometer) and MISR (multiangle imaging spectroradiometer) sensors. In particular, the MISR sensor has revealed the capability of effectively estimating plume heights using multiple view observations by exploiting a method developed for cloud top-height determination (i.e., plume height and movement are retrieved by matching the same plume at three different angles) which is independent from radiometric calibration, atmospheric temperature profile and plume emissivity. With respect to techniques based on lidar sensors (e.g., CALIPSO), this stereo approach does not rely on any external information or assumptions concerning the aerosols or plumes.

In the light of: i) their dual view stereo scanning capability (i.e., nadir 0°-22° and forward 55°-52°); and ii) the long-term availability of data (i.e., continuous records are available since 1991), in the scientific community there is an increasing need for developing techniques based on ATSR sensor series (ERS-1 ATSR-1, ERS-2 ATSR-2 and ENVISAT AATSR) similar to that developed for the MISR sensor.

To obtain an accurate large-scale prediction of biomass smoke distribution, a proper combination of models is necessary (i.e., emission models, injection models, transport models and chemical process models). In such context, there is a significant need for obtaining datasets of remote sensing products which can be then effectively employed for improving current estimates. In particular information related to fire radiated energy, fire geometry, fire weather and synoptic meteorology and emitted species (e.g., CO, aerosol, particle size spectrum, optical properties, CO_2, etc.) is needed.

ANNEX B TECHNICAL NOTES

For properly addressing the ALANIS project, the Contractor is encouraged to take into consideration research and development advances recently proposed in the literature, as well as existing data sets available from previous or on-going relevant ESA initiatives. A summary of the most significant activities is provided in the following.

Technical Notes relevant to Theme 1

ALANIS Theme 1 involves the estimation of methane emissions (*atmosphere component*) from Eurasian boreal lakes and wetlands (*land component*). In the literature, ESA data have already been employed in the context of different studies for retrieving useful information about the EO-based products included into the baseline portfolio described in Section 4.1.3 for this Thematic Area. In particular:

Promising works accounting for C-band ENVISAT ASAR (Advanced Synthetic Aperture Radar) data time series have recently proved their effectiveness in estimating variations of boreal lake/wetland spatial extent at different scales in Global (i.e., 1 km spatial resolution) [REF32] or Wide Swath mode (i.e., 150 m spatial resolution) [REF33];

The ERS-1 and ERS-2 C-band scatterometers have been proven useful for globally deriving relative soil moisture with 50 km spatial resolution since 1992 [REF34]. Nowadays, continuation is ensured by the ASCAT (Advanced SCATterometer) instrument mounted on board of MetOp-A (an ESA-EUMETSAT joint mission), which provides even shorter revisit intervals and increased spatial resolution (i.e., 25 km). In particular, it has been demonstrated that near surface soil moisture can be determined by means of a time series analysis [REF35],[REF36]. The ENVISAT Radar Altimeter 2 (RA-2), which is the improved follow-on to earlier radar altimeters on the ERS-1 and ERS-2 spacecrafts, has instead demonstrated a good capability of detecting changes in water table levels [REF37];

C-band as well as Ku-band scatterometers proved suitable for detecting snowmelt events. In this framework, C-band MetOp-A ASCAT as well as Ku-band SeaWinds Quickscat (ESA's third party mission) provides useful measurements (both with 25 km spatial resolution) for identifying the exact day of the year of beginning/end of thaw-freezing cycle (large changes in backscatter between morning and evening acquisitions are characteristic for the snowmelt period, when freezing and thawing take place during night and daily hours, respectively) [REF38];

Significant works have been carried out also for assessing the validity of the Land Surface Temperature (LST) product generated from data acquired by the ENVISAT Advanced Along-Track Scanning Radiometer (AATSR), which provides the opportunity to measure LST on a global scale with a spatial resolution of 1 km. In particular, the target accuracy of the LST product, which exploits nadir data from the AATSR thermal channels at 11 and 12 µm, has demonstrated its reliability, varying between 1.0 K at night and 2.5 K for daytime retrievals [REF39];

As concerns vegetation cover, several studies proved the effectiveness of the ENVISAT Medium Resolution Imaging Spectrometer (MERIS) in identifying different land-cover types at 300 m resolution [REF40]. However, at high latitudes significant cloud cover may prevent the employment of most of the acquisitions, thus making it necessary to take into consideration long-term mosaics, which may prevent a good discrimination between different information classes. Recently other strategies have been also proposed for reliably classifying major vegetation classes on the basis of the analysis of ENVISAT ASAR data time series [REF41], [REF42];

ENVISAT SCIAMACHY (SCanning Imaging Absorption SpectroMeter for Atmospheric CartograpHY) has been the first satellite instrument capable of measuring the global distribution of methane with high sensitivity down to the Earth surface where methane sources are located. This is due to its near-infrared detectors which can identify those colours which methane molecules absorb. Methane retrievals from SCIAMACHY have proven to be very successful, especially if concurrent retrievals of carbon dioxide are used as proxy for the light path [REF43]. However, poor spatial resolution is sometimes excessively impacting the retrieval precision and accuracy. In this context, improvements could be obtained by utilising upcoming data from the TANSO (Thermal And Near-infrared Sensor for carbon Observation) sensor mounted on the GOSAT satellite (ESA's third party mission) which will permit to obtain methane concentration estimates with a finer spatial resolution (i.e., 10 km) [URL6].

Technical Notes relevant to Theme 2

ALANIS Theme 2 involves the estimation of plume injection height (*land component*) of biomass burning events occurred in boreal Eurasia and the forecast of related greenhouse-gas and aerosol dispersion over time into the atmosphere at global scale (*atmosphere component*).

As regards the *land component*, in the literature pioneer studies using stereo-height retrievals have been recently proposed. In particular, data obtained from the Multiangle Imaging SpectroRadiometer (MISR) mounted on board of the Terra satellite have provided promising results, making possible unique plume identification and injection height retrieval [REF17] using methods developed for cloud-top-height determination [REF44]. The use of oblique-angle imagery from MISR (which acquires in nine different view zenith angles in four spectral bands in the visible and near-infrared spectrum) enhances plume sensitivity because of the longer optical path through the atmosphere, and the combination of multi-angle multi-spectral information assists in distinguishing smoke from clouds or other types of aerosols and, thus, to infer about its height. In such context, due to: i) their dual view stereo scanning capability; and ii) the long-term availability of data (i.e., continuous records are available since 1991), in the scientific community there is an increasing need for developing techniques based on ATSR sensor series (ERS-1 ATSR-1, ERS-2 ATSR-2 and ENVISAT AATSR) similar to those developed for the MISR sensor.

However, recently a novel interesting methodology has been presented in [REF45] also for MERIS data. In particular, the proposed technique has demonstrated the capability of inferring the altitude of aerosol plumes over the ocean from reflectance measurements in the window channel and the O_2 absorption A-band (i.e., 759 to 770 nm). In particular, similarly to what is done for generating the

MERIS Cloud Top Height (CTP) product, a reflectance ratio is computed between the reflectances measured in the spectral channel cantered at 753.75 nm (15 nm wide), strongly attenuated by O_2 absorption, and the spectral channel cantered at 760.625 nm (7.5 nm wide), minimally attenuated by O_2. For a given surface reflectance, simple relations are established between the reflectance ratio and the altitude of an aerosol layer as a function of atmospheric conditions and the geometry of observation. The simulations show that the method is accurate over dark surfaces when aerosol optical thickness at 765 nm is relatively large (i.e., > 0.3). In this case, the expected accuracy is on the order of ±0.2 km.

In this framework, it is worth also mentioning that information related to past fire events is already available in terms of the longest current record of active fire monitoring [REF45] and for burned area detection within the framework of the GlobCarbon project [REF46].

Concerning the *atmosphere component*, several satellite missions measuring the thermal infrared radiation in a nadir viewing geometry from low orbiting satellites have recently demonstrated the capability of identifying (and quantifying) a range of chemical species associated with fire emissions. In particular, the Infrared Atmospheric Sounding Interferometer (IASI) mounted on the MetOp-A satellite (a joint ESA-EUMETSAT mission) proved its effectiveness in capturing and tracking the dispersion of reactive trace species (i.e., CO, NH_3, CH_3OH, C_2H_4) in biomass burning plumes over space and time taking advantage of its spatial resolution (i.e., 25 km), coverage (i.e., global) and sampling (i.e., twice daily) [REF47]. This high spatial and temporal sampling capability along with the spectral and radiometric performances of the Fourier transform spectrometer (FTS) sensor, offer a unique support for identifying local and sudden emissions at the surface and for following the fate and transport of the resulting smoke plumes.

Technical Notes relevant to Theme 3

ALANIS Theme 2 investigates the feasibility of discriminating with existing EO-based products long-range transported anthropogenic aerosols from natural aerosols emitted by boreal Eurasian forests.

In the last few years, several efforts have been carried out for improving the quality of aerosol products derived from ESA sensors. In particular, in [REF48] a simple physical model of light scattering has been developed that is pertinent to the dual-view-angle sampling of the AATSR instrument and can be used to retrieve surface bi-directional reflectance and atmospheric aerosol properties without recourse to *a priori* information of the land surface properties. From the dual-angle top-of-atmosphere reflectances both the spectral and angular information can be used solve the inverse problem and enable separation of the atmospheric and surface scattering contributions to the observed signal.

Substantial success has been obtained previously by a number of studies involving also MERIS aerosol retrieval using spectral methods over known targets. However, since MERIS and AATSR provide similar resolution and swath but complementary information, encompassing different spectral domains and viewing geometries, novel researches are exploring the advantages offered by using information from both instruments simultaneously to constrain atmospheric profile [REF49].

Despite these promising advances, at present satellite remote sensing instruments do not allow measuring the aerosol chemical composition required to discriminate anthropogenic from natural aerosol components. Accordingly, so far a unique method has been developed [REF50] to this purpose. In particular, the proposed technique exploits the capability of the MODIS sensor to distinguish fine (submicron) from coarse (supermicron) aerosols, which serves as a signature of the anthropogenic component and can be used to estimate the fraction of anthropogenic aerosols. Nevertheless, despite the technical soundness of the method, due to several heuristics that must be taken into consideration, current uncertainties are around ±30% [REF50].

Relevant ESA projects

The Bidders should make themselves familiar with and take careful consideration of datasets available from past and current ESA initiatives relevant to the ALANIS project. However, none of such activities shall be duplicated in the framework of ALANIS. In the following, a brief description of the most significant ESA projects related to ALANIS is provided.

GlobAerosol

The ESA GlobAerosol project aims at providing a 10 year aerosol climatology from European satellite radiometers [URL7]. The project is making use of the ERS-2 ATSR-2, the ENVISAT AATSR and MERIS, and the MSG SEVIRI sensors. The data products to be produced are: i) aerosol optical depth at 550 and 870 nm; ii) Ångstrøm coefficient; and iii) aerosol speciation (from a selection of 5 pre-defined types, i.e. maritime, continental, desert, urban/polluted and biomass burning). Data will be produced on a 10x10 km sinusoidal grid on both a daily and monthly composite basis, and will be available for each individual instrument and as a combined product. The dataset will run from 1995 until the end of 2007 and products will be generated at the nominal overpass time of ENVISAT (from 2002 onwards) or ERS-2 (until 2001).

GlobCarbon

The ESA GlobCarbon project was initiated to generate fully calibrated estimates of at-land products quasi-independent of the original EO source, for use primarily in Dynamic Global Vegetation Models [URL8],[REF46]. In particular, the GlobCarbon initiative features estimation of burned areas, the fraction of absorbed photosynthetically active radiation (fAPAR), leaf area index (LAI) and Vegetation Growth Cycle (VGC) for 10 complete years, from 1998 to 2007 when overlap exists between ESA EO sensors (i.e., ERS-2 ATSR-2, ENVISAT AATSR and ENVISAT MERIS) and the French SPOT VEGETATION sensor at 1 km spatial resolution.

GlobCover

The ESA GlobCover project has developed a service capable of delivering global composite and land-cover maps using as input 300m observations from the ENVISAT MERIS sensor [URL9], [REF40]. The GlobCover service has been demonstrated over a period of 19 months (i.e. from December 2004 to June 2006), for which a set of MERIS Full Resolution (FR) composites (bi-monthly and annual) and a global land-cover map have been produced. The GlobCover composites have been derived from a set of processing made on the MERIS FR images such as cloud detection, atmospheric correction, geolocalisation and re-mapping. The GlobCover land-cover map is compatible with the UN Land Cover Classification System (LCCS). In particular, considered thematic classes include main types of vegetation cover, water bodies, artificial surfaces, bare and cultivated areas, as well as permanent snow and ice.

PERMAFROST

The objective of the oncoming ESA PERMAFROST project is the demonstration of the capabilities offered by EO-based data to identify, monitor and assess permafrost related geo-hazards as a complementary tool to existing practice, such as terrain analysis, permafrost science and geotechnical engineering [URL10]. The end users to this proposal require deformation and geohazard maps to determine the existence and extent of permafrost instability to reduce risk to resource development and production. At a regional scale, land surface temperature, surface soil moisture and water bodies products are planned to be implemented.

ANNEX C REQUIREMENT MATRICES

Technical Requirement Matrix for Theme 1 and Theme 2

Task	Requirement Code	Requirement Description
1	T.1.1	Consultation with the iLEAPS Scientific Community
	T.1.2	Updated analysis of major current needs
	T.1.3	Characterization of limitations and drawbacks of products and models currently already available
	T.1.4	Description of technical constraints for target products, models and experimental datasets to be developed
2	T.2.1	Analysis of current ESA and non-ESA mission suitable EO data
	T.2.2	Review and assessment of current relevant algorithms, models, methods and EO-based products and datasets
	T.2.3	Cross comparison of currently available products and models
	T.2.4	Survey of all accessible useful ancillary data
	T.2.5	Survey of current/upcoming related initiatives and projects
3	T.3.1	Technical specifications for target products to be developed
	T.3.2	Description of methodological and validation approaches for implementing target products and estimating related uncertainties
	T.3.3	Technical specifications for the coupled model to be developed
	T.3.4	Description of methodological and validation approach for implementing the coupled model and estimating related uncertainties
	T.3.5	Technical specifications of the final experimental dataset
	T.3.6	Description of EO and non-EO data required in the framework of the project
	T.3.7	Description of test sites for both the target products and the coupled model to be developed
4	T.4.1	Implementation of an end to end suitable algorithm for each target product
	T.4.2	Experimental analysis for testing/verifying the implementation choices
	T.4.3	Evaluation of the effectiveness of the developed products
	T.4.4	Description of the final version of the algorithms
	T.4.5	Analysis of the results driving to specific development choices and trade-offs
	T.4.6	Description of the validation analysis
5	T.5.1	Implementation of a suitable land-atmosphere coupled model
	T.5.2	Experimental analysis for testing and verifying the implementation choices
	T.5.3	Evaluation of the effectiveness of the developed model
	T.5.4	Description of the final version of the model
	T.5.5	Analysis of the results driving to specific development choices and trade-offs
	T.5.6	Description of the validation analysis
6	T.6.1	Generation of the experimental dataset
	T.6.2	Description of the experimental dataset and related metadata
	T.6.3	Free on-line access to the experimental dataset and metadata
7	T.7.1	Processing of the experimental dataset into the coupled model
	T.7.2	Impact analysis of the experimental output products
	T.7.3	Detailed description of the impact analysis
	T.7.4	Free on-line access to the experimental output products
8	T.8.1	Analysis of the feedbacks from scientists and institutions that have accessed the experimental datasets

8	T.8.2	Identification of potential strategies for integrating target products into other existing models at different scales
	T.8.3	Definition of a scientific development strategy for establishing long-term multi-mission data records
	T.8.4	Definition of a potential plan for fostering a transition from research to operational activities
	T.8.5	Identification of scientific priority areas to be addressed in future STSE projects in support of the iLEAPS community
	T.8.6	Recommendations for further advances in other potential relevant areas
9	T.9.1	Final workshop organization

Management Requirement Matrix for Theme 1 and Theme 2

Requirement Code	**Requirement Description**
M.1	Definition and implementation of the Promotion Plan
M.2	Set-up and maintenance of a free-access project website
M.3	Definition of the Project Management Plan (including both the Quality Management Plan and the Working Plan)
M.4	Drawing up of Project Technical Deliverables
M.5	Drawing up of Monthly Progress Reports
M.6	Drawing up of the Final Report for public access
M.7	Coordination with relevant national and European projects and programmes
M.8	Coordination of the access to all the data required in the framework of the project
M.9	Coordination of the collection and the analysis of the scientific requirements
M.10	Employment of ESA data to the largest extent
M.11	Team up of a consortium capable of allocating the tasks to be performed to qualified and well-experienced staff