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Exploring user needs for climate risk assessment in the transport sector: how could global high-resolution climate models help?

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Abstract

Climate change is an issue relevant for all modes of transport. The interconnected nature of transport systems – and their dependence on other key services such as energy – mean that the transport sector must account for both direct and indirect effects of climate change in sector-focused climate risk assessments.

To respond to sector-focused climate information needs in Europe, the “PRIMAVERA” project aims to provide useful and usable climate information, derived from *high-resolution*, *global* climate models. The model simulations will be evaluated to assess their ability to simulate key climate processes and hence to add value to existing climate risk assessment methods.

PRIMAVERA is engaging with users and stakeholders across sectors, including transport. Here we give information on transport users’ needs for climate risk assessment. We outline how PRIMAVERA could address these needs, and how it will share relevant outcomes with users and stakeholders, including those in transport.

Keywords: Climate change resilience; safe and resilient transport infrastructure; risk assessment; stakeholder engagement; end-user needs.

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1. Introduction

PRIMAVERA is a European Commission-funded project about designing and running new, high-resolution global climate models, and assessing their ability to simulate societally important processes and thereby providing climate information to support climate risk assessment activities across Europe. The project runs from 2015-2019 and is led by the Met Office (UK) and the University of Reading (UK), working with multiple partner organisations from across Europe.

The work streams in the project explore multiple themes, ranging from very technical elements (such as the representation of particular meteorological processes in the models) to understanding how the information from these new models can be used to assist people who use climate model information in decision-making and climate risk assessment. A key point about PRIMAVERA is the resolution of the models that are being run. An initial tranche of simulations are being run at moderately high resolution (~25km), and these will be followed by a further tranche at very high resolution (~6-15km). In addition, higher temporal resolution (sub-daily) is anticipated for some variables. For global climate modelling, these resolutions are particularly high; most models run at such resolutions are run over limited areas or time periods.

A specific project work package on user engagement has been in progress for just over one year (at the time of writing), and seeks to explore the ways in which climate information is currently used by a range of different end-users and stakeholders across sectors – including transport – and therefore how PRIMAVERA could address the needs of users in these sectors. Although there have been various European Commission funded projects in the recent years that have looked into the identification of user needs for climate information in a wide variety of sectors (e.g., CLIMB, http://www.climb-fp7.eu/home/home.php; WASSERMed, http://wassermed.cmcc.it/; SECTEUR, http://climate.copernicus.eu/secteur; COST-VALUE, http://www.value-cost.eu/; EUPORIAS, http://www.euporias.eu/), PRIMAVERA is unique amongst these projects. The planned second tier of higher-resolution simulations mentioned above, will be informed by the user needs identified by this work package and will specifically target key extreme events or processes that impact users significantly.

2. Approach to user engagement and dissemination

Research has long existed on the characteristics of weather and climate information that contribute to their potential for usability. Three main attributes have been established to play a role and to increase the usefulness and applicability of such information, specifically, its credibility, salience and legitimacy (Cash et al., 2002). Focusing specifically on the relevance (or salience) of climate information, existing research indicates that despite developments in technological and scientific capabilities in recent years, there are persistent barriers in the usability of climate information due to less attention being paid to its applicability and fit to user needs (Bruno Soares et al., 2017). Many users from a variety of sectors are indicating that the information could be better tailored to address their operational and strategic planning needs. To increase the usability of climate information, an important cornerstone in the process of its development is a joint and collaborative interaction and communication between users and providers (Jones et al., 2016; Rössler et al., 2017). Such interactions should not be infrequent or occur only in the beginning or at the end of a project, as established by Buontempo et al. (2017). User participation in the co-design of products improves the usability of climate predictions, increases the transparency of the information, allows the tailoring of information to respond directly to user needs, contributes to a better communication of uncertainty, and bridges the gap between state-of-the-art climate science projections and the readiness of users' to apply this information (Christel et al., 2017).

Our strategy for user engagement comprises several complementary approaches. Our efforts are concentrating on two important tasks recommended by Bruno Soares et al. (2017) to facilitate and promote the uptake of climate information by users and decision-makers, i.e., addressing current gaps in the provision of climate information and increasing the understanding of that information, "including its parameters, limitations and scientific uncertainty". Learning from similar efforts in previous years, we are making use of established collaborative connections and will consider existing information on user needs gathered during these projects.

In summary, in PRIMAVERA, the following user engagement tools and processes have been / will be used:

- An initial online survey of user needs for weather and climate information, where over 200 people were invited to participate (concluded; >80 responses, including 32 transport sector respondents from 10

European countries). Stakeholder contacts were compiled by pooling existing contact lists from various institutions involved in PRIMAVERA, and these lists further augmented by online searches
- A series of 1:1 interviews, to follow up on particular responses from the survey (concluded; twelve interviews with transport sector stakeholders have been undertaken. Table 1 shows the spread of their roles and transport modes – not all possible combinations were found, but coverage is reasonable for the number of interviews)
- Webinars and workshops, to share outcomes from the survey and interviews, and to gather information from sector-focused groups of stakeholders (one webinar delivered; development of further webinars in progress)
- An online user interface platform (UIP; http://uip.primavera-h2020.eu/) to share sector-focused information from the project. This is a user-oriented area of the PRIMAVERA website and will be used to convey information in an accessible way to users from particular sectors
- Sector-focused fact sheets and case studies – a further way to engage with stakeholders on topics of general or sector-based interest – several fact sheets have been already developed, linking hazards with particular sectors (e.g. heatwaves and energy; windstorms and insurance; flooding and transport)
- An email distribution list (primavera_updates@bsc.es) and Twitter feed (@PRIMAVERA_H2020), to support the sharing of user-focused updates from the project

Table 1 Role type and transport mode(s) of focus of the transport sector interviewees (12 in total). The geographic scope of each interviewee's discussion (country level, Europe level, global level) is indicated in brackets.

	Transport mode			
Role type	*Land transport (road and/or rail)*	*Aviation*	*Marine / ports / waterborne transport*	*All modes*
User	2 (country)	3 (2 country, 1 Europe)	1 (country)	–
Consultant	1 (country and Europe)	1 (global)	–	1 (global)
Academic	2 (1 country, 1 global)	–	1 (country)	–

3. User needs for climate risk assessment: general observations

Topics covered by the survey and interview questions included: sectoral attitudes to climate change; weather management and climate change adaptation strategies; relevant hazards for sectors; current use of weather / climate data, information and tools; recording of weather impacts; metrics, indicators and thresholds related to weather / climate events; relevant gaps in understanding and available tools; and how PRIMAVERA could address current needs within sectors.

There was a wide range of responses, even within a comparatively small sample of survey returns and interviews. Users are interested in a wide range of meteorological or meteorologically-derived natural hazards, including windstorms, floods, heatwaves and cold snaps. Additionally, user needs are diverse, and there is no "one size fits all" approach to addressing them. Some factors which influence user needs are the user's (a) specific role or function within an organization (e.g. operational management vs. strategic planning); (b) existing level of knowledge about climate and climate modelling; and (c) level of scientific / technical capability. Similar findings have emerged from other studies of this type (e.g. the recent Copernicus Climate Change Service project "SECTEUR", http://climate.copernicus.eu/secteur).

4. User needs for climate risk assessment within the transport sector

4.1. Attitudes

All participants felt that their sectors / organisations are aware of, and acknowledge, climate change. However, there was variation in how organisations and sectors were acting upon it. Some perceived that this variation depended on legislative drivers (e.g. the existence or otherwise of laws requiring action on climate change, such as the UK Climate Change Act 2008) or economic drivers (e.g. the financial capacity of an organisation to act upon climate change, or the financial capacity of a country to support adaptation activities in that country). The challenge of incorporating climate change into existing economic decision making frameworks such as cost-benefit analysis was highlighted. The link between present-day experiences of extreme weather and the future impacts of climate change was discussed, with some participants noting that the former influenced the perceived importance of the latter. Asset life was also emphasized as an important factor in climate change impacts considerations, given the large variation in design life of transport infrastructure assets.

4.2. Relevant hazards

Prior studies – e.g., Baker et al. (2010), Bles et al. (2016), Koetse and Rietveld (2009), Thornes et al. (2012), VTT (2011), Xia et al (2011) – have also examined the links between weather/climate and impacts on transport, and stakeholders in the sector are beginning to highlight these via their own channels to improve awareness both within the sector and for transport users. Examples include Network Rail's (UK) "Delays explained" pages (https://www.networkrail.co.uk/running-the-railway/looking-after-the-railway/delays-explained/), PIANC's "Navigating a Changing Climate" Action Plan (http://navclimate.pianc.org/about/action-plan), and EUROCONTROL's work within the aviation sector (Burbidge, 2016).

To optimize user-focused activities, in terms of addressing the hazards of greatest interest/impact, survey and interview participants were asked to rate a range of weather and weather-related hazards from 1 (lowest) to 5 (highest) according to the degree of impacts which these hazards caused for the transport sector (or, for those working in research-focused roles, the degree of research interest in the hazards). Table 2 summarizes the responses from the participants.

Table 2 Impacts of particular weather / climate (and related) hazards on transport subsectors.

Type of hazard	**Sub-sectors and impacts**		
	Road and rail	**Aviation**	**Marine / Waterborne transport and ports**[†]
Rainfall and rainfall-related flooding	Biggest issue. --Direct effects (flooding of railroads and roads; bridge scour) --Indirect effects (flooding of assets such as signalling equipment, depots and stations) --Spatial extent, frequency of occurrence of interest	Biggest issue. --Direct impacts: flooding impacts especially in tropical regions --Indirect impacts: disruption of access to airports by affecting the ground transport links to the airport locations	--Direct impacts: transit times may increase or decrease when travelling against or with the increased flow --Indirect impacts of flooding on navigation; increased difficulty in ship manoeuvring such as turning
Low temperatures	Highly rated. --Direct impacts: snow on tracks or roads; avalanches affecting roads/railways in mountainous regions; slip and fall hazards at stations; ; rail cracks/breaks; --Indirect impacts: freezing of points; icing of conductor rail disrupting the traction current; icing in tunnels;	See comments on snow/ice and frost	
Snow / ice and frost		Biggest issue. --Direct impacts: snow on runways; icing of aircraft --Indirect impacts: problems with accessing airports when there is a lot of snow on the ground	--Direct impact of sea ice on navigation in high latitudes --Indirect impacts on road and/or rail access to/from ports, which may lead to suspension of port operations
High winds	Highly rated. --Direct impacts: high-vehicles overturning on bridges and exposed roads; similarly for freight wagons on the railways; safety and disruption hazard from trees and debris --Indirect impacts –overhead line equipment (OLE) of electrified railways can be brought down; objects can be blown onto the OLE disrupting services	Biggest issue. --Direct impacts: on operations which leads to delays and diversions to alternative airports; risk to airport construction operations --Longer-term issue - changes in prevailing wind direction around an airport which can affect flights due to runway directionality	--Direct impacts: on manoeuvring of ships on and off berths; on approaching or leaving ports related to wind direction and port orientation --Indirect impacts: disruption of port operations conducted with large cranes *(table continues on next page)*

† No comparative rating is presented for the responses from the marine and waterborne sectors, due to the small number of respondents.

Earth Movements (landslides)	Highly rated. Typically arising from excessive rainfall --Direct impacts: In mountainous regions rockfalls due to freeze-thaw cycles --Indirect impacts in countries with ageing infrastructure slopes	Little relevance.	
High temperatures	Moderately rated. --Direct impacts: changes to railway track geometry (rail buckling); on passenger/ staff thermal comfort at stations and on board trains; degrading of road surfaces --Indirect impacts on maintenance schedules for ballasted tracks; operation of electronic equipment (for signalling) inside small buildings or lineside cabinets	Highly rated. --Direct impacts: heat stress risk to personnel working on exposed parts of airports, such as apron; issues with aircraft takeoff and climb due to the air being less dense in extreme high temperature conditions, which impedes the lift of the aircraft	
Drought	Moderately rated. --Indirect impacts on infrastructure built on some substrates (peatland or clay soils), which may dry out or shrink exposing foundations or causing structural degradations or instabilities	Little relevance.	--Direct impacts on inland waterways transport due to decreasing water levels
Lightning / convective storms	Moderately rated. Lightning not a hazard for roads. --Indirect impacts on electronic equipment used in railway signalling; vegetation fires starting at the lineside.	Highly rated. --Direct impacts – safety risk for air travel; some airspace regions may be closed in severe convection conditions; risk for on the ground personnel.	--Indirect impacts on sensitive electronic navigation systems
Coastal hazards including coastal flooding and erosion	Lowest rated. A lot of variation in ratings; Highly-location specific depending on intersection of road and railway assets with the coast.	Impactful only for coastal assets.	--Direct impacts: floods can damage coastal assets and disrupt port access of ships --Indirect impacts: flooding impacts on links to other transport modes; changes of clearance under structures such as bridges due to sea level changes; changes in coastal morphology due to erosion
Other hazards	--Vegetation related issues when considering planting choices for infrastructure slopes (for stabilization and for biodiversity) and future suitability of the chosen plants under a changing climate -- Disruptions during annual leaf fall season	--Northern Hemisphere polar jet stream affects transatlantic flights routing	--Visibility: zero visibility increases the difficulty of navigation and manoeuvring of ships alongside an installation in busy shipping areas or in areas that are difficult to navigate --Tidal flows/currents have similar impacts to high/low river flows described above

4.3. Resolution and scale

Most participants felt that information at a higher spatial resolution would be useful. Many drew parallels with their spatial scale of interest, referring to specific locations (usually ports and airports), or to the spatial heterogeneity of road/rail infrastructure (long in one dimension, short in the other). Some referred explicitly to higher-resolution information being better for decision-making/targeting of resources, and indicated the need for the resolution to be as high as possible; others were more circumspect, noting that increased resolution was a step in the right direction but that there were limits on how useful repeated increases in resolution could be in practice.

Spatial scales of interest varied considerably. Participants discussed these in terms of both their own sectoral interests (e.g. location of infrastructure) and more geographic terms (e.g. scale of weather phenomenon or geographic feature):

- Small scale: localised infrastructure (e.g. ports, airports, railway track sections, road sections...); specific types of weather event (e.g. squalls, thunderstorms...)
- Moderate scale: sub-country scale organisational sub-units (e.g. regional units of a country-wide company); sub-country scale river catchments; small units of airspace ("sectors")
- Large scale: whole countries or country-wide organisations; whole seas or regions of ocean; large-scale regions of airspace; river catchments spanning multiple countries

Some participants' roles also involved the consideration of multiple different spatial scales.

The response regarding the increased **spatial resolution** of the PRIMAVERA models was positive, but some noted that even what is termed "high" resolution in PRIMAVERA was far from what they needed. For example, participants reported a need for very high resolution (~tens of centimetres to tens of metres) for some applications, like understanding wind loading on cranes or modelling flooding of particular roads. There were also comments on the challenge of linking this kind of extremely fine scale modelling to coarser scales (e.g. specific road to city-scale). A question was posed whether increased resolution would add any further information in the countries where there was little geographic variation in topography. Participants from countries which have their own country-level climate projections were sometimes doubtful that PRIMAVERA would add value in terms of spatial resolutions. Finally, one participant from the aviation sector highlighted that aviation was interested in spatial resolution not only horizontally, but also vertically through the atmosphere.

With regard to **temporal resolution**, participants often confused this with lead time (i.e. the time between the issue date of the prediction/projection and its validity period). There was again a wide range of responses. References were made to the use of real-time information and hourly data in weather forecasting to support operational activities. In terms of climate timescales, many people felt that the general guidance offered by projections/trends at a seasonal or annual scale, and/or multi-year/multi-decade averages, was sufficient for their purposes (this was true across subsectors). One person did not think that anyone in their organisation would use daily (and it is assumed, by extension, sub-daily) climate projection data for their work. Another participant highlighted the "jump" between commonly-used baselines for climate projections (e.g. 1971-2000) and projection information (often starting around ~2020s), which could lead to information that looks unrealistic and also to potentially inappropriate use of the data to make predictions at shorter lead times than climate projections allow.

In general, it was the most technically-minded participants who noted any potential value of sub-daily information from PRIMAVERA, and these people tended to be the ones who were already using daily data. These participants linked temporal resolution with the relevant timescale of the processes and/or impacts concerned (e.g. sub-daily and even sub-hourly data were needed for extreme precipitation / surface water flooding; perhaps daily/weekly information for open water storage and processes related to river flooding – but this was not at all important for longer-timescale processes such as those related to groundwater). Only one person explicitly stated that their work had been constrained by existing data resolution limitations, and that they had worked with daily data because sub-daily had not been available. Another noted that some countries have access to sub-daily climate data, but others do not.

4.4. Existing management of weather and climate impacts

For most in the transport sector, weather management is "business as usual"; as such, it was not surprising that interviewees felt that weather/climate hazards would become more important in future, under a changing climate. By extension, understanding the effect of climate change on existing management practices will also become more important, and adaptation to these effects will need to be considered. Figure 1 shows the time horizons of interest for weather/climate data/information and related business activities.

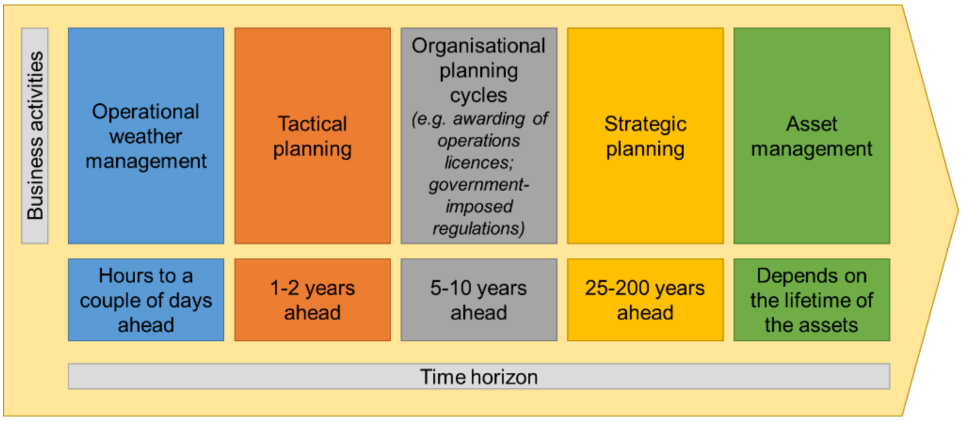

Fig. 1 Time horizons of interest for weather and climate data and information, as discussed by survey and interview participants

4.4.1. Weather timescale

Specific **weather management** activities cited by participants included:

- Use of real-time and forecast data and information in operational decision-making – for example, use of closed-circuit television (CCTV) cameras to identify flooded roads so diversions can be put in place
- Development of operational management plans for severe weather events (e.g. ceasing or not commencing a particular operation if particular weather thresholds are forecast to be exceeded)
- Hazard-specific management plans (e.g. reducing the safety risk from possible rail buckling in hot weather)
- Development of seasonal strategies for managing different weather throughout the year
- Use of bespoke warning systems at known weather-sensitive locations
- Use of traffic management systems
- Creation of criteria (either subjective or objective) defining “normal” and “abnormal” weather conditions
- Logging weather-related incidents in formal or informal databases, to monitor their number and severity
- Ensuring good asset management processes are in place

Many of these have also been discussed in previous projects, such as MOWE-IT (http://www.mowe-it.eu) and EWENT (http://ewent.vtt.fi/).

4.4.2. Climate timescale

There was consensus among interviewees on the need for the transport sector to adapt to climate change. There were differing views on adapting to existing hazards being sufficient, vs. a need to be aware of other hazards which had not previously been an issue but which climate change could cause to become one. This linked to participants’ descriptions of current weather management activities – for some, the management of particular “typical” hazards was a business-as-usual activity, with the rarer and/or more extreme events creating bigger problems, due to lack of preparedness. One participant referred to the effect of “institutional memory” on weather management and risk perception, stating that the perceived biggest issue for their organisation varied in time according to what had been experienced most recently (for example, cold winters vs. mild/wet ones).

Relative **times of emergence** for hazards were referenced by some participants. One participant felt that climate change was incremental and that adaptation could be achieved through existing weather management processes. Another noted that sea level rise was a slowly evolving hazard and that there was therefore more time to adapt to it than to other hazards.

Specific **climate management** activities cited by participants included: undertaking vulnerability / risk assessment; development of organisational plans, strategies and roadmaps for climate change adaptation and mitigation, either proactively or in response to legal / regulatory requirements; reviewing operational and design standards containing weather/climate-related elements to check whether they could still be appropriate in future; using historical weather data together with future projections to determine whether new assets need to be built differently from existing assets.

4.5. Climate data or climate information?

Almost all interviewees said that their focus was less on using climate *data* (raw/direct model outputs) and more on using climate *information* (processed/tailored data, or products derived from such data). Reasons cited for this largely focused on a lack of appropriate skills for working with data, and a lack of available resource to do the more intensive work perceived to be necessary for using data directly. It was also felt that information was easily available, so there was no need to work with data; and that data was less useful for the higher-level stakeholders, who needed materials to be in an accessible and simple format. The few interviewees who used data were those working in academic roles rather than in consultancy or end-user roles.

4.5.1. Historical data / information

Participants were asked about their use of historical (past) climate data and/or information. They focused mostly on the data element here. Most participants stated that they use historical climate data, with some using data in very specific cases rather than routinely. Historical data was commonly sourced from a country's / city's official meteorological service, or from another meteorological provider, with some organizations also collecting their own meteorological data. Quoted uses of historical climate data included:

- Deriving thresholds for impacts
- Informing decision-making / understanding how such data can support decision-making
- Informing new infrastructure builds
- Logging past events to see how often action is taken
- For planning / "lessons learned" purposes
- Exploring trends and relating the norms from last century to new norms

4.5.2. Future data / information

Most participants said that they used future climate data and/or information. One participant wished to use future data/information, but felt that it was too early in the evolution of their climate change adaptation strategy to be doing so yet. Data and information were sourced from scientific journal articles, online material, IPCC climate projections, and country-level climate projections and associated reports. Quoted uses of future climate data and information included:

- As a topic of interest only
- Raising awareness and understanding
- Improving the specification of a future investment
- Planning significant capital projects
- As part of a climate change adaptation study (either planned or completed)

4.6. Gaps and issues

4.6.1. Access to, and comprehension of, climate data and information

There were diverse opinions about whether organisations had sufficient **access to information** on climate change. Some felt that relevant information was lacking, with one person explicitly citing resolution as an issue. Others felt that access was available to those who required it; and some felt that knowing what to do with the available information, rather than having access to it, was the bigger issue.

4.6.2. Understanding and knowledge translation

The following gaps in understanding and/or knowledge were identified:

- A gap in knowledge (in a specific transport subsector) of what climate change information is available and to what extent it is relevant.
- Gaps for specific hazards were identified:
  - At the weather timescale, the uncertainty of cumulonimbus forecasting, and forecasting of thunderstorms/lightning.
  - At the climate timescale, research on the projected changes to the jet stream.
- How to move from having access to and/or understanding of climate projections towards understanding their implications for the transport organisation in question, and for its role in the wider transport system.
- How to move from having a good qualitative understanding of impacts towards a quantitative evaluation of these, e.g. financially or operationally.

4.6.3. Tools and information

The following gaps in tools/information were identified:

- Scale and resolution – lack of data at an appropriate scale, e.g.:
  - At the weather timescale, the use of regional-scale forecasts/warnings for a specific site can result in reduced trust when the events that are warned about do not happen at the site.
  - At the climate timescale, lack of appropriate scale information necessitates the use of low-resolution climate model data or regional summary projections for a point location.
- Translation from averages to extremes – many climate projections provide information presented as averages, whereas most users are interested in extremes
- Language and applicability – publicly-available tools are often by definition generic rather than tailored to a specific need or sector, and use generic language that can be interpreted differently by different users (e.g. one person's "very high risk" is another's "medium risk").
- Tools for vulnerability assessment and adaptation – while generic risk assessment / adaptation resilience planning information is available in some sectors, there is limited information on what the specific issues are, and how to manage these.
- Tools for economic impact – these are rarely constructed in such a way as to be able to take climate change into account.

5. How could PRIMAVERA address the transport sector's needs?

5.1. Users' opinions on useful PRIMAVERA outputs

Users were asked, through the survey and interviews, to offer their views on what PRIMAVERA could provide in terms of guidance/descriptive information, data and technical information, visualisations, and training.

5.1.1. Guidance and descriptive information

Fact sheets and web-based materials were requested; as stated above, these are already planned/being delivered. There was agreement that data-focused guidance would be useful – including what data are available; what is (and is not) represented well within the data; information about uncertainties; and guidance on how to use uncertain information for planning purposes. Advice on acceptable (and non-acceptable) uses of the data was also suggested.

5.1.2. Data and technical information

In terms of data, some users wanted access to the data directly; others were happy to receive derived/post-processed products/information. A large proportion of the PRIMAVERA data will ultimately be available to all, but at present there is a focus on collaborative use of the data between scientists and users. Among technically-minded users, quantitative data for extremes was a commonly-requested item; other users took a "what if" approach that could be serviced by scenarios. Data for particular locations was mentioned by those whose interests were site-specific (rather than interests at the country or European level). Technical information about how to translate climate data/information into operational/infrastructure impacts was also suggested; this links back to the "knowledge translation" gap.

5.1.3. Visualised information

Standard visualizations such as timeseries of how variables change over time, and maps of geographic variations in projections of particular parameters – ideally comparing the present day and the future projections – were requested. Geospatial information that can be integrated into GIS was also encouraged. Infographics were highlighted as a quick and accessible method of disseminating information visually.

5.1.4. Training

Many participants felt that training was useful but that it needed to be tailored to specific audiences, discussing the difference between high-level and/or generic training, which would be suitable for senior managers, and more detailed and/or focused training, which would be welcomed by (for example) engineers and designers working in a particular sector or subsector.

The format of training materials / activities was considered important. For high-level stakeholders, "away days" were proposed as a way of focusing attention, and briefing notes were suggested as useful for people whose time was limited. For specialist users, seminars and face-to-face workshops were highlighted as helpful, since these allow two-way communication and questions. Online training/courses, videos and Powerpoint slides were cited as formats that were useful across multiple types of user. It was suggested that any PRIMAVERA activities that could tie in with formal reporting cycles (e.g. country-level risk assessment deadlines) would likely encourage user participation in workshops.

6. Conclusions and next steps

A wealth of information about user needs for climate information has been gathered to date via PRIMAVERA's user engagement activities – in transport as well as other sectors. For transport, many of the findings reinforce those from previous projects that explored weather/climate impacts on the sector, but useful additional insights have been gained regarding how PRIMAVERA could support transport users by providing appropriate guidance, products and training. Pleasingly, some of the materials requested by users – including web-based resources, fact sheets and briefing notes – were planned, or are being delivered, already during the project.

As stated above, the modelling approach in PRIMAVERA has been uniquely designed, in that a first stream of global climate modelling simulations will be conducted at moderately high horizontal resolution (~25km), and a second stream will follow, conducted at very high horizontal resolution (~6-15km). The intention is that some elements of the Stream 2 simulation configuration will be influenced by users' feedback on the design of products and visualisations from Stream 1. Work is now commencing to prepare user-focused materials based on Stream 1 outputs, so that this feedback can start to be gathered. The bespoke nature of this feedback will require different methods of engagement from those used so far, being better suited to sector-focused, small-group approaches like webinars and workshops. These activities are planned for later in the project.

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