UK-Environmental Observation Framework (UK-EOF) Statement of Need

Atmosphere Observation Requirements

Alongside development of Towards a Statement of Need, the UK-EOF has also developed Observation requirements tables to capture more detailed information to help articulate:

- The UK's requirements for observing the natural environment
- The questions that we need to answer
- How close we are to being able to provide the evidence via a balanced suite of observations.

For ease, information gathering has been split into environmental domains and for each domain, what the specific issues or sub issues that are of importance for the headline issues identified in the UK-EOF Statement of Need.

Information has been gathered from experts in their field via correspondence, a workshop and open consultation. The tables are not final and some gaps exist in the information. The UK-EOF will work to fill these gaps and revise the tables accordingly.

Some of the sub-issues identified fall under several fundamental issues and there are key dependencies with other environmental domains.

Observation requirements captured within the tables have not been prioritised in any way, nor has current capability been identified. Prioritisation will be addressed via a decision support framework which is also being developed under the UK-EOF and capability or current activities are searchable within the UK-EOF Environmental Observation Activity Catalogue (www.ukeof.org.uk).

Other sources of useful information include: The Global Climate Observation System (GCOS[1]) & World Meteorological Organisation (WMO[2]), who have a set out user requirements (thus linking observations to users).

Summary of Requirements (under each UK-EOF headline issue)

Pressure on all environments in the light of Population Growth and associated pollution.

With an increase in population growth it is likely that the demand for energy will also increase. Linked to this is whether there will be an augmentation of emissions and atmospheric pollution, which could give rise to increased human health problems. Air quality information is currently collected and this could be enhanced by information from future satellites (GMES Sentinels 4 & 5). Guidance on requirements for atmospheric chemistry are given by the WMO, Global Atmosphere Watch (GAW) and also the Integrated Global Observing Strategy (IGACO).

Urban areas are often 'warmer' than surrounding rural areas and a question regarding whether the localised weather is affected by these 'urban heat islands' exists. To answer this question localised meteorological monitoring is needed.

[1] http://www.wmo.ch/pages/prog/gcos/index.php?name=ClimateObservationNeeds

[2] http://www.wmo.int/pages/index_en.html

Many of the requirements under this headline issue relate to climate and therefore links should be established with the UK Climate Impacts Partnership (UK-CIP). When considering climate for population growth, issues such as increased migration to coastal regions (despite increased risk of coastal flooding) and pressure on natural resources such as water also need attention. The UK does not currently have any desalination plants but they may have in the future. If this were to happen decisions on how they were fuelled and the emissions they may produce would need to be made.

Supporting economic growth reconciled with sustainable use of natural resources

Energy demands are likely to change in the future and there is a need to predict these demands, along with any associated emissions. This will also help to address whether the current energy supply is sustainable or whether further alternatives are required and if so, what their impact would be. Currently in UK there are surface networks which provide information on temperature, wind speed and solar radiation. This information can be used to determine alternative energy options, however current observation sites are insufficiently dense to meet all our information needs.

Predicting the demands and supply of water requires information on precipitation and the level of the water table on a real-time, medium-term and long-term basis. This information can be used to put management and policy regimes in place.

The relationship between air quality and transport requires observations for both monitoring and predication purposes. Measurements for transport have a dependency on the parameters for National Weather Prediction (NWP) and questions regarding whether severe weather events are linked to both land or air transport were posed. If relationships are found, information could be used to determine whether it is possible to minimise the impacts of weather events. With regard to aviation, emissions are not currently included in the Kyoto agreement however there is a need for their quantification. Noise pollution is also an effect of aviation and should therefore be included in relevant monitoring programmes.

Understanding future states of the Earth, particularly the Carbon Cycle (but not excluding other element cycles)

There is a need to understand the sources and sinks for carbon, nitrogen and sulphur so that atmospheric fluxes can be determined. This information is necessary if we are to understand climate feedbacks and validate the United Nations Framework Convention for Climate Change (UNFCCC) and Copenhagen processes. In relation to this there is a need to understand whether the strength of the sinks is changing and if so what the impacts will be. The UK has signed up to the Kyoto agreement and must therefore verify declared emissions. Therefore although not part of the natural cycle, emissions must also be monitored.

There is a national requirement to monitor greenhouse gases *in situ*, both in the UK and on remote islands. Key gases are CO_2 (carbon dioxide), CH_4 (methane, the main component of natural gas), N_2O (nitrous oxide), and so-called Montreal gases (CFCs). Monitoring is needed to contribute to the UN WMO Global Atmosphere Watch, to validate emission declarations under the UNFCCC, and to determine greenhouse gas emissions and uptakes. There is also a basic scientific requirement for observations to determine the relationship (including feedbacks) between increasing temperature, CO_2 and CH_4. Currently there is a lack of UK support for CO_2 measuring stations and often monitoring on UK territory is funded by the EU and

US. A proposal for the UK to participate in Europe's Integrated Carbon Observing System (ICOS) has been developed, but sustainable UK-source funding is required. Satellite data are also important in partnership with *in situ* measurements for CO_2 and CH_4 monitoring. Such satellite data should be integrated with ground measurements.

Although not the primary focus of the requirements tables (which is the collection and primary use of the information), analysis products, which can be used to interpret and carryout reanalysis and or post processing are integral to the taking of observations and should therefore be considered.

Fisheries, Agriculture, Food Security and Water Supply

Many decisions made for crop management are reliant on observations for agricultural meteorology (guidance for which is giving by the WMO). In the future, as the environment changes decisions will need to be made on planting regimes, which pesticides should be used and harvesting options all of which will require agricultural meteorology observations. Information on land management, drainage, drought prediction etc are also associated with this.

In addition, information on air pollution, climate variables and their effects on crop yield will also be important when planting and planning for the future. Environmental impacts on pollinators or destructive insects will need to be considered, along with links to disease spread via aerosols or airborne vectors. This information can be used to inform agricultural and livestock management. Crops or forests may also be affected by acid rain and aquaculture by eutrophication. To answer questions regarding the extent and potential increase of these issues in surface waters and other natural ecosystems, both ground and satellite observations could be used.

The burning of biomass and other agricultural activities could lead to increased releases of aerosols and photo-oxidants, there is a need to monitor these events and assess the impacts that they may have on the environment. Some relevant measurements are taken by satellite & other air quality measurements from tall towers.

Human Health, Wealth and Wellbeing

Poor air quality can have adverse effects on human health (e.g. Chronic Obstructive Pulmonary Disease), therefore this and associated issues are the main focus under this headline issue. For example, issues related to the presence and release of fine particles from industry or volcanoes and summer smog.

For policy, key observations and forecasting are related to emissions - Defra have a network for observing air quality parameters and pollutants, however there is a need for integration across the different networks (which are currently supplying data to different places e.g. European Monitoring and Evaluation Programme (EMEP), Eureopean Environment Agency (EEA) etc. Scales also need to be considered; satellites are capable of providing information on a global scale but are not good for local scale issues such as Particulate Matter (PM_{10}). Such integration could be used to help determine the extent, areas and hence people at most risk from long range transport of air pollution.

The global decrease in stratospheric ozone and the corresponding increase in ultraviolet radiation raises health issues for humans and also questions regarding feedback to climate change. Extreme weather can also cause health risks, for example heat waves or extreme cold spells, the occurrence and prediction of these events needs to be monitored along with prediction of the impacts.

Environmental change could lead to the emergence or changing ranges of environmentally sensitive diseases. Environmental observations, coupled to disease research could identify emerging diseases, predict their spread and provide information for their containment or management options.

Understanding, avoiding and mitigating the effects of Extreme Events and Disasters

Extreme weather events have implications for both human health and infrastructure. Measurements for extreme weather have a dependency on the parameters needed for NWP. These measurements are also required (along with some other parameters such as tide gauge information and satellite data) for other weather related events such as storm surges (which have impacts on flood defences), wind storms, fluvial and pluvial flooding and winter weather. All of these events could increase in severity with our changing environment therefore the measurements are required for use in predicting frequency, severity and identifying areas at risk. Measurements for NWP can also be used to understand whether there are links to air quality and extreme events.

To fully understand and be able to predict the dispersion of toxic plumes, further information is required on the boundary layer heights. This information, along with observations for NWP and various emissions, could be used to inform models that can predict toxic plume dispersion. Similar information (boundary layer height, NWP and surface temperature & humidity) can be used to inform questions surrounding the frequency and density of fog and low clouds.

With the development of alternative energies, the risk of increased nuclear events could be possible. Observations are required to ensure that the UK has the relevant contingency planning in place to be able to respond to extreme events & disasters.

Understanding and reducing the impacts of environmental change on marine and terrestrial biological diversity, ecosystems & services

There is a need for better understanding of the boundary layer in the biosphere, this could have affects on both weather and climate prediction. Biomonitoring of habitats and species is an area that requires observations; however this is something that may be covered in more detail within the Biosphere domain.

Changes occurring within the Arctic ecosystem may have profound effects on global climate and the atmosphere; this includes issues related to methane, clathrates and gas fields, which are covered in more detail under the cryosphere domain.

Understanding climate variability and climate change within Earth System Science.

It was asked whether this section should refer to catastrophic climate change, as change does not occur linearly – if so the focus should be what are the 'tipping points' or threshold effects.

Currently within the requirements table the GCOS goals for Climate are listed, these are thought to represent the issues - however they could be expanded. Further information could be gathered from the Intergovernmental Panel for Climate Change (IPCC) document to the UNFCCC (needs for measurements). There is a need for both regional and global impacts, each of which requires different measurement strategies. Current national networks are thought to be (just about) adequate;

however it is uncertain whether we have the correct measurements for future adaptation strategies.

The oceans and atmosphere have many linkages and cross cutting questions include whether the oceans moderate increases in atmospheric temperature, and how and at what rate, are the oceans warming? Observations of Argon and Nitrogen ratios are needed to answer these questions.

Scientific and Technological Advancement/Innovation

Several of the technological issues relate to alternative power generation. Such as whether wind or solar energies would be reliable for long term energy production and also whether current technologies can be improved to efficiently harness these energy sources in variable conditions.

With increasing research and the likelihood of carbon capture and storage, technology to provide safety monitoring of CO_2 from storage sites will become a requirement. This will involved localised observations of seismology and the measurement of atmospheric CO_2. Although this issue was raised under technological development, carbon capture and storage could also sit under both the Earth System Cycles (Carbon Cycle) or Climate Change.

Other Requirements and General Comments

Understanding the constraints and limitations of both our measurements and our ability to take observations are important. Any constraints should be built into conclusions and the assumptions declared.

There is a lack of measurements of atmospheric chemistry in the tropics to determine tropical sources and sinks was raised. This is relevant to UK overseas territories such as the Ascension Islands or Diego Garcia, which are ideally placed to undertake continuous observations. Information could be used to verify emissions from India and Asia and could contribute to global carbon budgets.

Atmosphere Observation Requirements Table

Information captured in the table will help to articulate what the UK's requirements are for observing the natural environment, what the questions are that we need to answer and how close we are to being able to provide that evidence via a balanced suite of environmental observations.

For each environmental domain information has been collected on the specific issues or sub issues that are of importance for the headline issues identified in the UK-EOF Statement of Need.

Consultation with the community has led to the population and validation of the following table. The tables are currently 'work in progress' and will continue to be revised as requirements and priorities change. The requirements captured have not been prioritised in any way.

Specific/Sub issue	**What are the key questions that require answering in order to address the specific/ sub issue?**	**Measurement Type** (variables that would need to be measured to provide evidence to address the specific issues)	**Frequency of collection** e.g. A continuous measurement for 1 week in Spring, repeated every 2 years. Or A spot measurement, once a week, every week throughout the year. Or Irregular measurements as required i.e. extreme event monitoring.	**What geographic coverage do we need?** A) UK B) England C) N. Ireland D) Scotland E) Wales F) Localised UK G) Europe (non UK) H) Global I) Other (please specify) J) Ocean/Sea (please specify	**What is the primary use for the data?** A) Basic Science B) characterising environmental issues/solutions (influencing policy) C) Direct env. Management D) Modelling & Prediction E) Complying with Legislation F) Development & Growth	**Are the current actions / measurements sufficient to provide the evidence needed to address the issue?** If known, please list the current programmes/sensors which are capable of providing the evidence (e.g. for Sea Surface Temperature AATSR, SLSTR. AVHRR, AMSR and Modis satellites are capable of measuring SST).
Population Growth (Pressure on all environments in the light of population growth and associated pollution.)						
Water Supply	What are the likely affects on human population increase on water supply?	Insitu monitoring of key pollutants	spot measurements, throughout the day	Mostly urban with a few key rural stations A, G, J, G (including	C, D, E (?)	Monitoring by Defra/Local Councils Air Quality data: • Improved portal for air quality data • Improved near real-time and offline delivery of data with quality control

				developing world)		• City-scale monitoring of air quality with use of remote sensing. • Future satellites such as GMES sentinels 4 & 5, following on from ENVISAT & OMI. Atmospheric chemistry requirements Statement of Guidance: http://www.wmo.int/pages/prog/sat/documents/SOG-06_Aero.doc Global Atmosphere Watch (GAW) strategy: http://www.wmo.int/pages/prog/arep/gaw/gaw_homes_en.html Integrated Global Observing Strategy: Atmosphere Chemistry IGACO: http://ioc.unesco.org/igospartners/Atmosphere.htm
Energy Supply	What are the likely affects of human population increase on energy supply?	Insitu monitoring of key pollutants Emission monitoring - CO_2/CH_4	spot measurements, throughout the day	Mostly urban with a few key rural stations A, G, J, G (including developing world)	C, D, E (?)	(see comments above for Water Supply)
	Will energy requirements increase if alternative energies are provided?					
	Is there an increased risk of nuclear accidents?					
Increasing Pollution	How will levels of atmospheric pollution increase with population					

	growth?					
Coastal flooding	What is the likely extent of impacts from disproportional population increase in coastal regions?	- Marine Tidal range - River run-off - Precipitation rates				
Desalination Plants	How and what will be the impact of powering them (in the future)?	GHG emissions				
Urban Heat Islands	How will localised weather be affected?	Local meterologogy				
	What building materials are needed to keep cities cooler? (See Scientific and Technological Advance Table). ***Is this an R&D question/issue rather than observations?***	Thermal infrared radiation				
Economic Growth and Sustainability (Support economic growth whilst reconciling with sustainable use of natural resources)						
Energy Supply See also Population Growth and Economic Development.	Is the current energy supply sustainable?	Primarily surface temperature and wind speed. Solar radiation Cloud cover Plus site specific forecasts	Daily and continuous. (Hourly to real-time)	Currently 26 UK sites (Insufficient)?	Specific services	Surface networks are currently insufficiently dense. Better interface to satellite products for solar radiation.
	How can we better forecast energy demands?					
	What are the emission levels and are CO_2 and CH_4 emissions increasing?			H - Global		

	Is there an increased risk of nuclear accidents? Is there radioactive leakage from nuclear power plants?	Radionuclide monitoring around nuclear power plants.		F – localised UK H - Global		
Water Supply See also Population Growth	Is the current water supply sustainable?	Precipitation Water Tables Water Demand				
	How can we better forecast water demands	(As above)				
Land Transport (& links to air quality)	By prediction, can we minimise the impacts of severe weather events?	Parameters required for National Weather Prediction including: - surface pressure and wind, - 2-D wind field, (measured) - 3-D temperature field, - 3-D humidity field, - Clouds (cover, base & top) High density network of roadside / rail track automatic weather stations typically observing: a. Surface and ground temperature b. Surface state c. Surface wind d. Surface humidity/dew pt	Continuous	A (UK & regional) H (Global)	Modelling, prediction & monitoring. B, C, D, E?	**All transport applications** have a dependency on the parameters required to support global, regional and mesoscale numerical weather prediction (**NWP**), information for which is collected/provided by the Met Office.

	With increasing usage demand, can we minimise the associated pollution from roads/motorways etc	As above	Continuous	A (UK & regional) H (Global)	B, C, D, E?	
Aviation	By prediction, can we minimise the impacts of severe weather events?	In additional to numerical weather prediction dependencies, particular focus on: - convective activity, icing, heavy precipitation, high winds & visibility. - Cloud and liquid / ice water content - Visibility & cloud ceiling height- Volcanic ash and dust- Aerodrome specific observations - Lightning detection	Continuous	A (UK & regional) H (Global)	Modelling, prediction and monitoring	See the Critical atmospheric variables for Global, Regional and nowcasting outlined in the Extreme Events table. Global WP variables (see Extreme Weather & Events section) **and Aeronautical forecast specific req'ts**:- - satellite imagery combined with lightning detection systems to determine location, intensity of strong convective activity: Meteosat Second Generation (MSG) next generation of Geo (MTG) satellites with new

	Can we increase efficiency at airports with increased knowledge / prediction of weather events?	As Above (?)	Continuous	A (UK & regional) H (Global)	D, economic gains F- development and growth (planning for airports etc)	scanning strategies will get closer to meeting requirements. Met Office ATDNet System (long range lightning detection) - ground-based turbulence and wave detection instruments are not currently available in sufficient density across the globe. - Further remote sensor technology required for Air Terminal areas - Lack of info for visibility and ceiling height for low cloud (although research satellites with this capacity will be monitored for operational usability in next few years). See Statement of Guidance for Aeronautical Meteorology (http://www.wmo.int/pages/prog/sat/documents/SOG-06_Aero.doc) for further details
Carbon Capture and Storage – see Earth System Cycles (Carbon cycle) below.						
Carbon Cycle (Future States of the Earth and particularly the Carbon Cycle)						
Carbon Capture and storage	Can we minimise leakage from CCS plants? Are there systems in place to provide adequate warnings should there be an incident? (Safety monitoring	- Seismology - Atmospheric Carbon Dioxide leakage	Regular	F – local to storage site BUT monitoring should occur globally where the sites exist		Much work has been done in Norway

Carbon, Sulphur and Nitrogen Sources and Sinks	Does the UK have a full understanding of sources and sinks? (Currently No)	CO_2, CH_4, C isotopes, CO, HFCs, PFCs, N_2,, N_20, H_2, O_2 (monitoring and emissions). Surface flux changes and concentrations towers	Continuous operation to WMO Standards, or weekly flask samples.	Surface in situ network (UK sites and S. Atlantic network) ~ 1000Km A (UK: tall towers) J North Atlantic F UK remote territories	A, B, D Understanding Climate Feedback Validate UNFCCC & Copenhagen Process	UK needs to provide integrated component of ICOS Sustainable funding required for key elements of in situ network: In situ CO_2 stations More flux towers required in England Integrated plan for UK CO_2 measurements and ICOS contributions Hydrogen and isotope measurements
		Satellite		H global		Currently ENVISAT, GOSAT in commissioning. Satellites a likely gap in CO_2 from space in 2013+
		CH4 measurements (monitoring and emissions)		A, H Surface in situ network including UK sites and S. Atlantic network, flux towers. Part of global network		More stations for global network. Stations in hot spot regions such as permafrost, northern latitudes (Ocean – clathrates), rice paddy areas, wetlands.
		Satellite				Currently ENVISAT and IASI. GOSAT in commissioning. Sentinels 5p & 5 will have CH_4 monitoring capability. CH_4 research requirements many need further capability.
	Can we predict biomass growth/loss?	Above measurements required				See above

Carbon, Sulphur and Nitrogen Sources and Sinks continued…	Are carbon sink strengths changing? Is it leaking?	As above (?) O_2/CO_2 ratios in atmosphere				Only a leak can decrease this ratio
	UK Energy Emissions	Satellites			E - verifying Kyoto declared emissions (self certified by emitters)	
	How is CO_2/CH_4 etc related to temperature?					
	Are the oceans warming? To what extent? And at what rate?	Ar/N_2 ratios				Currently no UK monitoring.

FISHERIES, AGRICULTURE, FOOD SECURITY & WATER SUPPLY (The effects of environmental change)						
Crop management	How will environmental change effect application of pesticides, planting and harvesting options?	Short range weather forecasting products have a dependency on the following key atmospheric data: - surface pressure & wind, - 3-D wind field, - 3-D temperature field, - 3-D humidity field, - Clouds (cover, base, top) - Precipitation - Solar radiation - Soil measurements - Ozone Agricultural meteorology needs, - soil moisture and temp. data at strategically located stations to help monitor droughts - aeolian sedimentation loads along with comprehensive analysis of wind for sand storm impacts - leaf area index and land cover measurements (higher spatial resolution) - polar satellite instruments should be enhanced to deliver this.	Continuous	A, H National and Global		Much of this information is provided by the Met Office See Agricultural Meteorology Statement of Guidance http://www.wmo.int/pages/prog/sat/documents/SOG-09_Agriculture.doc for further details

		- multi-frequency synthetic aperture radar systems - for canopy structure & water content determinations				
Crop Management Cont….	How will environmental change affect insect pollinators/destructive insects?					
	Howe does air pollution affect crop yield?					
	How will crop yield respond to climate change?					
	How will weather events influence harvesting, growth cycles etc?					
Informing & support of livestock farming	Howe ill environmental change effect disease management / airborne transport?	Requirements span those parameters necessary to support short range NWP (see above) to multi-seasonal forecasting.	Continuous	Primarily Regional and UK A		
Land Management	How will environmental change effect crop selection, drainage & adaptation strategies (cultivation of new environmentally resilient crop varieties)	Requirements span those parameters necessary to support seasonal to decadal forecasting. Dependant on the global atmospheric observing systems since seasonal and inter-annual systems are driven by winds and in several cases heat flux products				

Aerosol & photo-oxidant levels	What are the likely impact of enhanced biomass burning and other agricultural activity?	Satellite – UK AATSR, Eumetsat SEVIRI and NASA MODIS See Air Quality measurements of pollutants and fires. VOCs Ozone Particles Nox In situ Co H_2	Continuous but overpass night time frequency for UK needs to be checked Regional and global is fine. High quality continuous	National, Regional & Global A, F, H	A, B, C	
	To what extent are these levels likely to rise				D	Tall Towers
Acid Rain & Eutroph-ication	What is the likely extent and of increased acid rain and eutrophication in a)surface waters b)other natural ecosystems?	- Wet and dry deposition - Flux rates - Ammonia - Nitric acid - Sulphates etc - NOx - SO_2	Continuous Annual	National	A, C, D	Effect on crops and biodiversity
Increased pressure on water resources - See other tables.						
Stratosphere ozone (O_3)	UV impact on crops?					
Biomass burning	What are the global impacts of tropical biomass burning in Africa, S.E. Asia etc	Plumes		I – Other: Ascension – mid trophosphere Africa – Diego Garcia trophosphere		

Human Health, Wealth and Wellbeing (Consequences of environmental change for Human health, wealth and wellbeing)						
Air Quality	How will these factors effect human health; -Increase in fine particulate content in regions of industrial development and population growth. - Increased occurrence of summer smog over most cities in the world, including the developing countries, and the increased ozone background in the northern troposphere? -Global decrease in stratospheric ozone, attendant increase in surface ultraviolet radiation, feedback on climate change - Ozone recovery - Anthropogenic Chlorine loading - Trends in source gases (replacements for CFCs – also greenhouse gases) - Volcanic impacts - Change in solar	Monitoring of key pollutants ***What are the key pollutants?***	Spot measurements, daily, throughout the day; Mostly urban with a few key rural stations	UK, Europe, and Atlantic (for transport and for policy Access to global data for science/climate EU, Global	A, B, C, D, E	Defra/Local council networks Integration of frequency across scales is critical Must be embedded in EMEP/EEA and SAW like Structures
		Trace gases, particles, VOCs, toxic organics, heavy metals, POPs, PM measurements	In general, range from 30 min to monthly	Global		Defra network. Basic system in place but needs the following improvements: - Inter-calibration of in situ sensors - Improvement of NOx, NOy insitu sensors (NO_2 and HNO_3) - More rural stations - Gaps for VOC measurements - City-scale coverage lacking & no use of remote sensing - Well instrumented city test-bed; 5 sites in more than 1 city. Clearer interface/portal for all Defra, NERC and other air quality systems. Near real-time delivery for all networks with quality control. For breakthrough, need low cost, rapid response sensors linked to remote sensing.

Air Quality continued…		Atmospheric composition including CFCs/HCFCs	High frequency to monthly			AGAGE - source gas network for ground measurements (www.agage.eas.gatech.edu/) Clean Air Stations: Mace Head, Weybourne, Cape Verde ***(Are these sites sufficient?)*** CARIBIC aircraft (civil aircraft with instrumentation - http://www.caribic-atmospheric.com/) ESA, EUMetsat, NL/NASA satellite instruments on ENVISA, Metop, Aura. Satellite AQ now promised but needs continued support for UK to ensure GMES provision and UK needs met. Requires GMES Implementation of Sentinels 5 Precursor / full 5 (for continuity) and 4 (for diurnal) to complement Metop. No limb sounding from satellites in 2013+ to deliver transport at middle to high altitudes in the trophosphere.
		Dust monitoring	Satellite passes: AATSR, Eumetsat SEVIRI and NASA MODIS Daily	A – UK H - Global		Environmental Satellite data for: Pollution Tracking Detection and monitoring of airbourne pollutants including: smoke plumes, dust storms and volcanic ash. Need GMES Sentinel-3 to provide this from 2013 (currently not output products) and also Sentinel 5/Eumetsat post-EPS from 2020. Need to make regular use of Eumetsat MSG/Metop. NPOESS can also be used.

Air Quality continued…		Fire monitoring (data to support fire scale prediction of events)	Satellite passes: AATSR, Eumetsat SEVIRI and NASA MODIS	A – UK H - Global		ENVISAT to 2013. GMES Sentinel-3 from 2013. Sevir/MTG continuous. VIRS on NOAA/NASA NPOESS. Developments of Europe-Specific fire sensors should be checked.
		Dispersion modelling				Dispersion information to provide advice for airborne diseases – detailed wind flows (such as those expected from Meteosat Third Generation Satellites (MTG).
		Ozone	Ozone stations are UK contribution to global monitoring of ozone recovery ***What frequency are observations recorded from these stations?***	A National H Global	E - Change of emissions of CFCS/NCFCS i.e. compliance Montreal Protocol	Dobson stations & sonde stations Mace Head (continuous) Global system for monitoring ozone is good. No ground based FITR station for monitoring ozone or source gases. Satellites. Currently Aura, Eumetsat, Metop system for total ozone and vertical profiles.

Air Quality Continued….		Chlorine	Continuous			No ground based FITR station for Chlorine. Chlorine loading can be monitored from satellites until 2010+ Satellite system post 2010 for chlorine loading may be possible but not defined up to now. Likely to be some gaps after NASA Aura, SDA ACE, ENVISAT MIPAS as limb sounding capability. Satellite system post 2013 – has not been defined up to now.
		Solar radiation; (cloud cover / depth)				mesoscale modelling Cloud condensation (Mace Head) Better interface to satellite produces to solar radiation.
		Emissions ***Are these covered by entries above?***	National and Global			
		Surface Metrological Observations				Mace Head

High Impact Weather Events	What will be the impacts of increased occurrence of high impact weather events? There is a need for products to mitigate the risks associated with specific health related problems such as: - surface temperature extremes (heat wave & cold weather services) - Chronic Obstructive Pulmonary Disease (COPD)	Monitoring land surface temperature Some of the above measurements will cover this issue.				Satellites: Infrared (see also extreme events table)
Environment-ally sensitive diseases	How will the current ranges of environmentally sensitive disease alter with environmental changes?	Some of the above measurements will cover this issue. See also Agriculture table				
Long range transport of air pollution	What is the likely extent of long range air transport? What areas of the UK are likely to be affected?	Upper Air 3D winds Precipitation Some of the above measurements will cover this issue.				Satellites

Extreme Events and Disasters						
High impact weather events	Can we predict high impact weather events to safeguard loss of human life and the UK's infrastructure? Includes: 1) Public weather forecasting 2) Prediction of extremes (heat waves/cold) 3) Defence 4) UK citizens overseas	All sub-issues listed below have a dependency on the parameters required to support global and regional scale numerical weather prediction (NWP). These including the following key atmospheric data: - surface pressure and wind, **- 3-D wind field,** - 3-D temperature field, - 3-D humidity field, - Clouds (cover, base & top) - precipitation Nowcasting and very short range forecasting (VSRF) bring additional requirements associated with the need to understand in detail the current state of the atmosphere and how it will develop in the short term. These results in a requirement for high resolution (spatial & temporal); - satellite imagery;	Continuous Many parameters required every 12 hours (threshold), hourly (optimal)	H Global, B, C, D, E Regional, A National Network resolution increasing as spatial scale reduces	D. Modelling, prediction and monitoring	As described in the relevant WMO Statements of Guidance http://www.wmo.int/pages/prog/sat/RRR-and-SOG.html#SOG Full details of the requirements for Global NWP, Regional NWP, Nowcasting the Very Short Range Forecasting (VSRF) together with other WMO application areas available at: http://192.91.247.60/sat2/aspscripts/UserBT.asp?AFF_SHORT_NAME=WMO For the UK the Met Office is a key contributor to the WMO Global observing system (as part of its mandate as the UK's national meterological service). land surface temperature – Satellite infrared.

		In addition to the above: - solar radiation - weather radar imagery; - surface observations; - lightning event detection;				
Storm surges	Flood Defence				D	
	How will frequency of Storms increase?	In addition to the above (see high level impacts entry): - Tide Gauge data - Satellite ocean altimetry products - Rainfall rate	Continuous	H (global) A (National Network) F (Regional)	D	Storm tide forecasting service for the EA/SEPA National network resolution increasing as spatial scale reduces.
Toxic Plume dispersion modelling (for Chemical, Biological, Radiological or Nuclear incidents)	What is emitted? Where will the plume go? How concentrated will it be?	In addition to the above (see high level impacts entry): Pollutants and contaminants: Petroleum Products Pathogens, Airborne Toxic Material Radionuclide CO, NO, NO2, CH2O, PM10 Aerosol, Black Carbon & Volatile Organic Compounds – which are required at the same resolution & cycle times as the meteorological parameters. Boundary layer height	Basic network: continuous Enhanced monitoring as required	Global, Regional, National Network resolution increasing as spatial scale reduces	D	Dispersion modelling is provided by the Met Office Emergency monitoring and Response Centre (EMARC)
Windstorms	How will frequency increase?	All parameters listed under High level impacts	Continuous. High temporal frequency	Global, Regional, National	D Nowcasting research.	

Windstorms Continued…	What will be the severity and impact of events?		observations. Shorter timescales other than synoptic required to study meso-scale features.	Network resolution increasing as spatial scale reduces	D	
	What are the substructures in storms and their generating mechanism?				D	
	Do we have suitable building designs to cope with increased windstorms ***Research Question? Which may require long term observations?***				D	
Fluvial & Pluvial flooding	How will frequency increase?	In addition to the above (see high impact weather events): - Surface precipitation rate and type; - Hi-resolution weather radar imagery	Continuous	Global, Regional, National Network resolution increasing as spatial scale reduces		
	How will the severity of events change? (Probability distributions)					
Winter time severe weather	How will frequency increase? Blizzards, snowstorms, ice etc	All parameters listed under high weather impact events at high resolution (particularly in the boundary layer) and: - Weather radar imagery - Lightening detection	Continuous (winter months)	As above		

	How ill the severity of events change? Probability distributions (EPS)			As above		
Convective Scale storms	- How will frequency increase? (gust fronts, hail, intense precipitation, lightning, tornadoes)	In addition to parameters under high impact weather events: - Surface temperature & humidity - Cloud height	Continuous	As above	D, B Saving human life	
	Early detection precursors				D	
Fog and low clouds	How will frequency/density increase?	In addition to parameters under high impact weather events: - Surface temperature & humidity - Cloud height - Boundary layer height - Atmospheric composition	Continuous	As above	D	
	How will the severity of events change? Probability distributions (EPS)			As above	D	
Air Quality	How will emissions change?	Air chemistry		As above	D	

Biological Diversity, Ecosystem & Services (Impacts of environmental change on biological diversity, ecosystems and ecosystem services)						
Surface/boundary later	***What are the questions/issues that need to be answered?***	Various physical parameters including surface rainfall, temperature, humidity, solar radiation Soil moisture Surface and boundary layer measurements				
Acid deposition & Eutroph-ication **See also agriculture table**	How is the ecosystem changing?		Annual	A National F Local		
Biomonitoring	How are habitats and species changing?	- Individual species Earth Observation (Chlorophyll, leaf index etc) - Bio Aerosol	Annual or seasonal	A National F Local		Issues covered more fully in Biosphere tables
Arctic Change	How is the ratio between C^{13} and CH_4 changing?	CH_4 C^{13} Budgets Clathrates	Regular	Arctic (wetlands, gasfields)	D	Gasfields – could affect EU main supply. An issue covered in the cryosphere requirements tables.

CLIMATE CHANGE: (Variability & Climate Change: Challenges in Earth System Science).						
GCOS goals and National/ Regional needs; specifically of impact related variables	1. To characterise the state of the global climate system & its variability 2. To monitor the forcing of the climate system, including both natural and anthropogenic contributions 3. To support the attribution of the causes of climate change	Atmospheric Essential climate variables & metadata; **Key Surface** Air temperature, precipitation, air pressure, surface radiation budget, wind speed and direction, water vapour **Key Upper-Air** Earth Radiation budget (including solar irradiance), upper-air temperature, wind speed and direction, water vapour, cloud properties **Composition** Carbon dioxide, methane, ozone, nitrous oxide,	**Continuous sustained measurement** over long timescales. Temporal resolution requirements vary with specific application, although most parameters are needed daily (3-hourly often desirable in many cases).	Global (contributions) and Regional and sub-regional scale network enhancements necessary for many applications	**Multiple uses:** A) Basic Science B) characterising environmental issues/ solutions C) Direct env. Management D) Modelling & Prediction E) Complying with Legislation	UK composition measurements should be strengthened Within the UK the Met Office (amongst others) contributes to WMO initiatives with long term monirotinf of Essential climate variables.

	4. To characterise extreme events important in impact assessment and adaptation, and to assess risk & vulnerability 5. To support the prediction of global climate change (mean and variability) 6. To project global climate change information down to regional and national scales	Chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, sulphur hexafluoride & perfluorocarbons, Aerosol properties (optical and composition). **Other parameters** listed in the detailed GCOS requirements, including Albedo and aerosols (other parameters are relevant to other environmental domains such as Sea Surface Temperature, permafrost, snow cover etc.	Precipitation required hourly to characterise variability & extremes			
Atmosphere/ Ocean interaction	Is atmospheric temperature moderated by the oceans?	Atmospheric Ar/N2 ratios (There are no Ar sources except from ocean warming)				
Scientific & Technological Advancement/Innovation (Stimulation of Scientific & Technological Advance and Innovation)						
Development of improved WIND powered energy generation (Also see	How reliable is the wind as a resource? (vis a vis the technological capability to harness very light and very strong winds)	Winds at 5-1000m above the surface: a. speed b. direction	At least 10 mins (depending on technological advances in energy storage)	A (UK) 10Km resolution to allow local/city-scale generation	B, D, E, F	Assessment of viability and cost benefit ratio; input to validation of models of future climate for assessment of future costs and benefits.

economic growth)	Can the UK provide wind power in UK remote territories	Wind speed and direction (hilltops)	Continuous	I. UK overseas territories e.g. Falklands, S. Georgia	B, F	Assessment of viability and cost benefit ratio; input to validation of models of future climate for assessment of future costs &benefits.
Solar power generation	Can we improve the efficiency of solar power generation?	- solar irradiances - cloud cover	Hourly Daily	A – UK F – Localised		
Alternative Energy Solutions	Does the technology exist to meet demands for increasing use of alternate energies?	- Biofuels - Wind				
Keeping cities cool	What building materials are need to reduce urban heat islands? ***Research question that requires observational information?***	Infrared radiation (from satellites or towers_	Integrated over 26 hour periods for assessment of heat storage	A UK cities and towns at <10m resolutions to resolve effects of a variety of existing materials	B, F	Use results to guide development of new materials.
OTHER REQUIREMENTS						
Constraints of measurement systems	Need to understand the limitations of measurement system in deriving observations					
Lack of tropical data for Atmospheric chemistry	Tropical sources and sinks are very poorly understood		Continuous in situ FTIR total column …scale?	H Tropics. e.g. Diego Garcia (Monsoon), Ascension	A, B, E Verifying emissions from India, Asia etc	
Virus/ pathogen spread (Also see biosphere tables)						