Earth Observation for Weather

International trends & developments

Earth observation applications

Business development

Capacity building

0. Introduction

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HCP international:
consulting, marketing of earth observation

Project director EOPOWER:
project for promotion & capacity building of earth observation applications

Sequence:

- General assessment of the state-of-the-art of earth observation
- Major trends and developments in the application field
- Description of earth observation solutions
- Assessment of market potential for earth observation solutions and marketing instruments
- Capacity building for successful application of earth observation solutions

Earth Observation helps you:

save money

save lives

save the environment

Earth observation applications

- On the verge of reaching new user communities
- These new user communities need to be involved
- Weakest link / last mile aspects are important
- Marketing needed: promotion & capacity building

Life cycle of products & services

Initialization

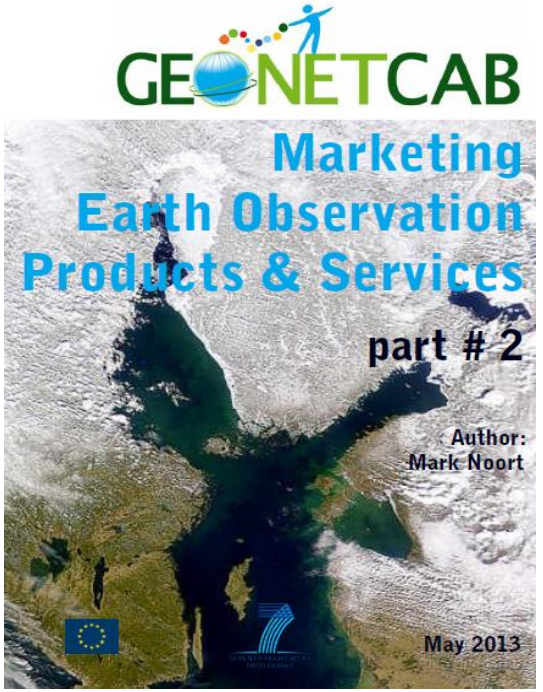
System analysis & design

Rapid prototyping

System development

Implementation

Post-implementation



Scope and definitions

Weather: state of the atmosphere, to the degree that it is hot or cold, wet or dry, calm or stormy, clear or cloudy.

Atmosphere: a layer of gases surrounding a planet or other material body of sufficient mass that is held in place by the gravity of the body.

Weather forecast / prediction: the application of science and technology to predict the state of the atmosphere for a given location.

Weather aspects are also covered in the disaster management toolkit, climate toolkit, energy and mining toolkit, environmental management toolkit and agriculture toolkit.

Assessment of business & funding opportunities

- Categories of weather products & services
- Life cycle phase of product or service
- Regional context, level of technological & economic development
- Optimum marketing mix

1. International trends & developments in weather

Issues & trends in weather

- Improvements in **weather forecasting accuracy and capability,** including high-impact weather prediction;
- Increased attention for **communication with stakeholders** and **support to decision-making**;
- Increased attention for **changes of weather patterns in different climate scenarios** (see also climate toolkit).

Drivers

- Importance of timely and accurate weather forecasts for all kinds of economic activity;
- Increased vulnerability (in terms of economic losses and lives lost) in relation to high-impact weather events (concentration of people and physical assets, especially in urban areas);
- Uncertainty about future weather with respect to climate change (trends, seasonal forecasts and deviations from “normal, expected” weather).

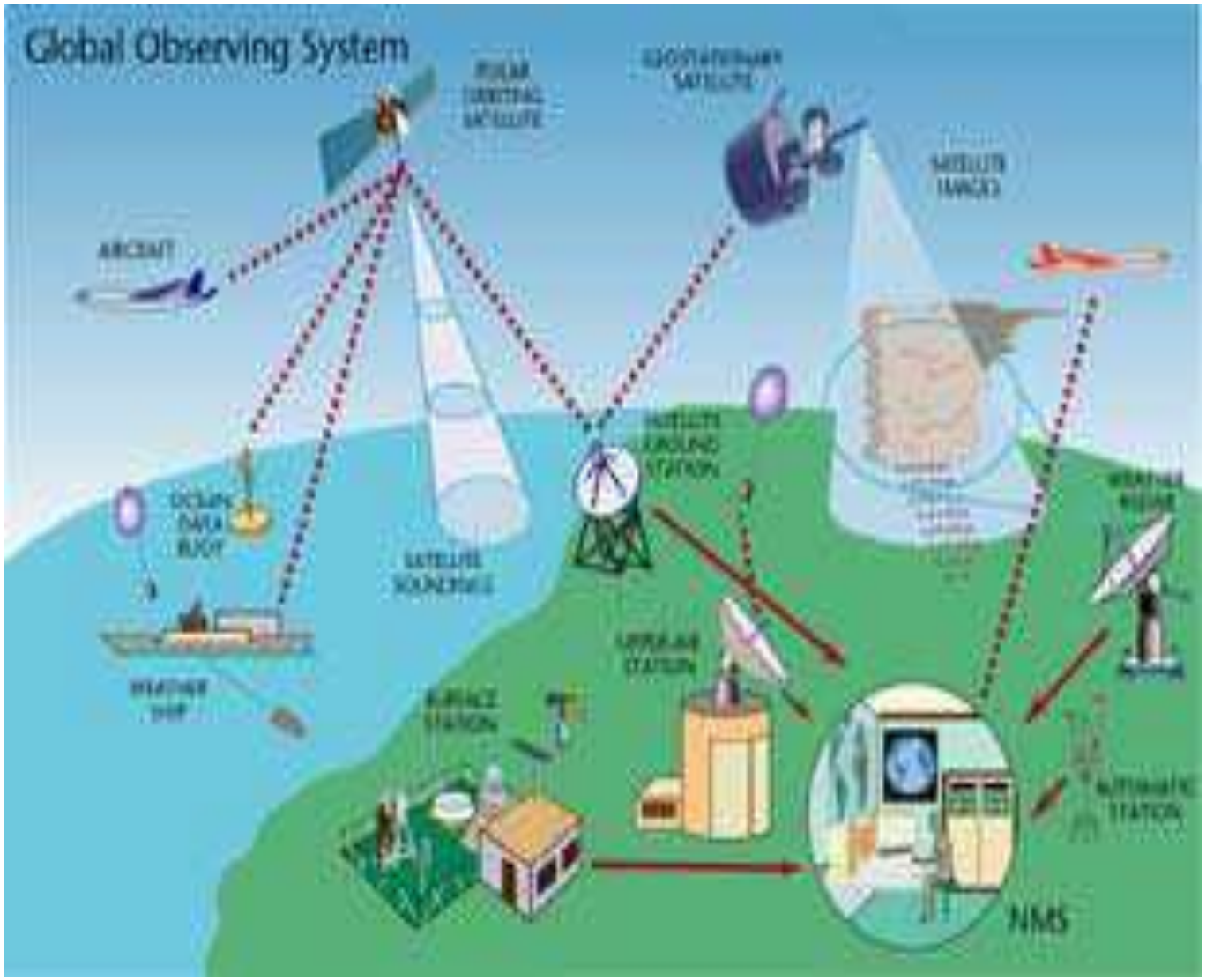
Weather forecasting accuracy and capability

- **Improvements in forecasting** related to: time range (nowcasting, short, medium, long), accuracy, probability, risk (possible damage / lives lost);
- **Numerical weather prediction** (NWP): application of model(s) using mathematical equations for weather prediction (divide the atmosphere in grid boxes, record data on processes for each grid box and then calculate the future state for that box);
- **Nowcasting**: technique for very short range forecasting (map the current weather, use the speed and direction of movement to forecast the weather a short period ahead);
- **Ensemble forecasting**: estimate risk of particular weather events, using multiple forecasts (by making small alterations to either the starting conditions or the forecast model, or both).

World Weather Research Programme:

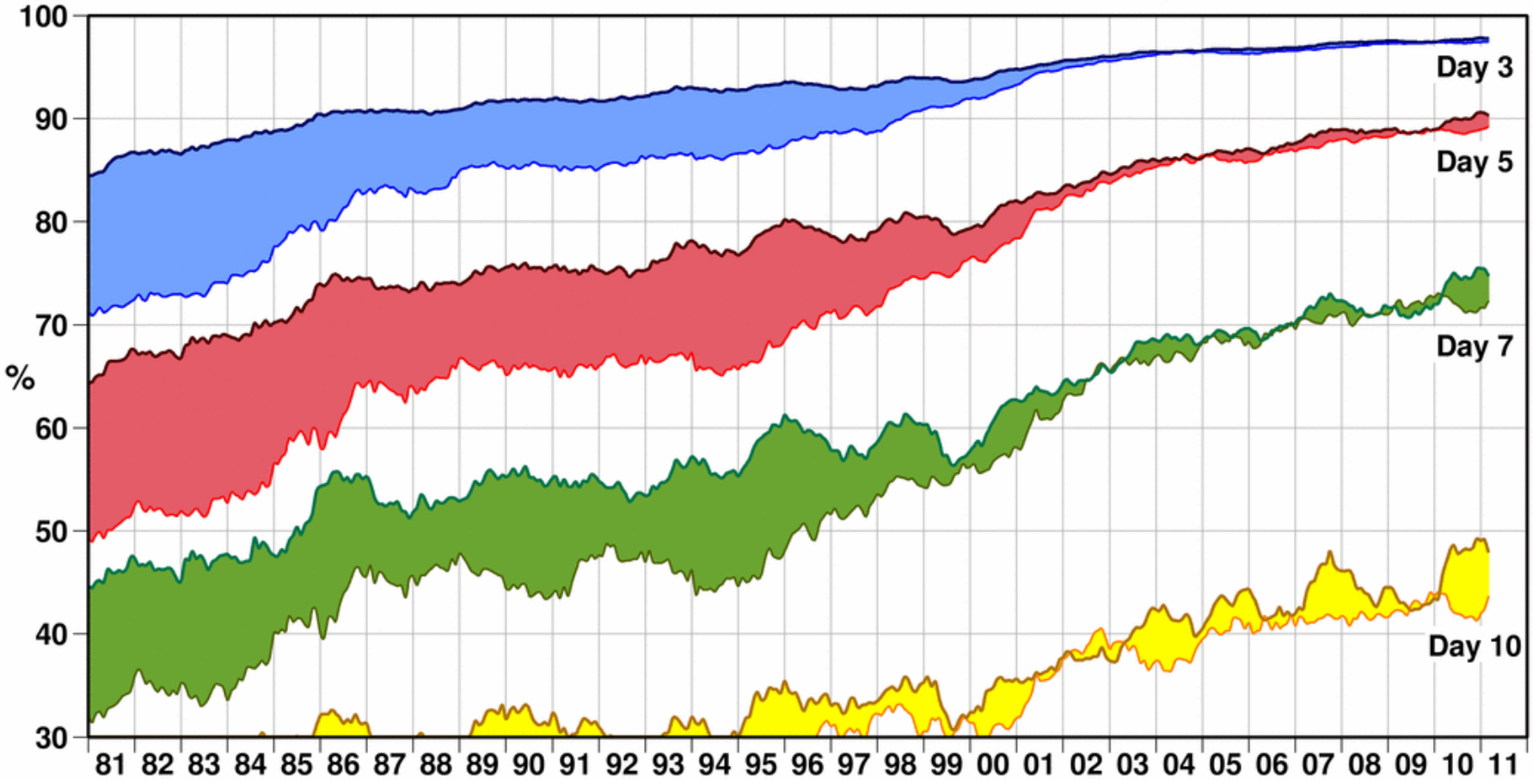
- ***Improvement of weather forecasts*** in the form of the THORPEX and TIGGE programmes (as part of THORPEX)
- ***THORPEX*** (THe Observing system Research and Predictability Experiment) is an international research programme to accelerate improvements in the accuracy and utility of high-impact weather forecasts up to two weeks ahead
- ***TIGGE*** (THORPEX Interactive Grand Global Ensemble) provides a data base of ensemble predictions from the leading global NWP centres, for scientific research on predictability and development of probabilistic weather forecasting methods

THORPEX



Global observing system

Weather: improved forecasts



Improvement in accuracy of weather forecasts over a period of 30 years: upper line = northern hemisphere, bottom line = southern hemisphere (Source: ECMWF; 2013)

More information:

Subseasonal to seasonal prediction – research implementation plan (WWRP/WCRP/THORPEX; 2012) *research plan, with attention for climate change, disaster risk management and food security (food supply and markets)*

TIGGE – The THORPEX Interactive Grand Global Ensemble (THORPEX; 2010) *short description of the TIGGE programme*

User requirements specification for TIGGE archive functions and applications;
Products based on TIGGE ensembles delivered to SWFDP users;
Enhanced TIGGE archive functions available & demonstrated; data registered in GCI (GEOWOW; 2012)
enhancing TIGGE and making the results accessible to users

TIGGE website http://www.ecmwf.int , data archive available at http://apps.ecmwf.int/datasets/data/tigge/

Communication with stakeholders (1)

- High-impact weather: **accuracy and timing of forecast** should be **balanced against size of avoidable loss**;
- Communication of uncertainty: **decision makers are very sensitive to false alarms** and, at the same time, **have a strong need for a high detection rate**;
- Verification: verification results should be presented alongside the forecasts so that users can readily **understand the quality of the forecast** they are currently using.

Communication with stakeholders (2)

- Better **dissemination of forecast information** to reach end users;
- Improved insight into **how users do interpret and apply** (or do not apply) **forecast information**;
- **Integrate all stakeholders** through interaction to produce suitable information tailored to the user needs;
- Facilitate quantification and evaluation of **environmental, societal and economic benefits** by the end user;
- Find the **most cost effective combination of observing system, data assimilation, forecast and application procedures** (Early Warning System) to improve high impact weather forecasts from the user perspective.

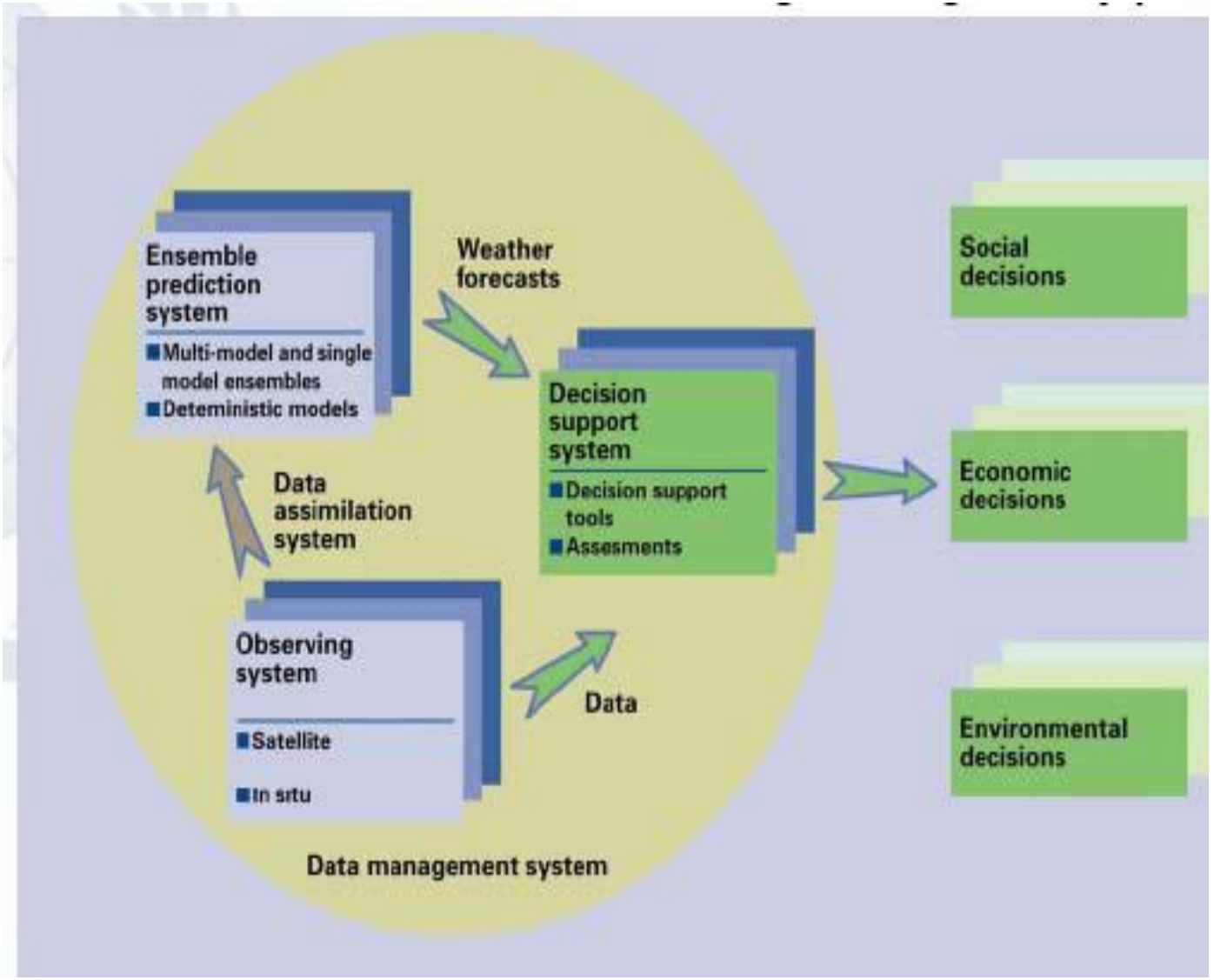
Example: Monsoon prediction and decision making

- Important for arranging cropping strategy and taking preventive action in **potential flooding zones**;
- Institutional mechanism for **communicating climate information** to various user departments and agencies is important;
- Forecasts should be released that **match the lead-time requirements** that are relevant to the end-users;
- Seasonal forecast products should **reflect local climatic zones** (rather than administrative regions);
- Governments should rethink the **value of climate prediction in societal and economic development**.

Example: Requirements for an effective community response to warnings

- Getting **free warning and hazard information**;
- Receiving **warning with sufficient lead time**;
- **Understanding the warning content**;
- **Believing the warning**;
- **Believing that the threat is real**;
- Knowing when and what **appropriate action** to take;
- Being in a **state of preparedness**.

THORPEX decision support



A global interactive end- to-end forecasting system for the 21st century

More information:

Weather research in Europe – a THORPEX European plan (WMO; 2010) *research plan for Europe and the Mediterranean, including section on decision making*

WWRP/THORPEX African science plan (WMO; 2008)
science plan for Africa, involving end-users

Global monsoon system – Research and forecast (World Scientific; 2011) *series of articles on monsoon system research, only some chapters are freely available: heaviest precipitation (ch2), intraseasonal variability (ch11), diurnal cycle (ch15), Taiwan monsoon (ch18), modelling monsoons (ch25), atmospheric and oceanic weather (ch29), oceanic processes (ch30)*

The global monsoon systems (WCRP) *introduction to monsoon systems and research efforts*

Changing weather patterns and climate

- Concerns about the **impact of global climate change**, in terms of weather and climate variability and associated effects such as sea-level rise;
- **Science and technology of weather forecasting and climate prediction** has been moving ahead rapidly;
- Need for **reduction of the uncertainty** about the relationship between weather and climate change, to predict changing weather patterns under different scenarios with the aim to **improve decision-making** for adaptation and mitigation.

More information:

Climate impacts on energy systems - Key issues for energy sector adaptation (World Bank; 2011) *how the changing climate impacts energy systems, including need for improved observation networks in developing countries + case studies from Albania and Mexico*

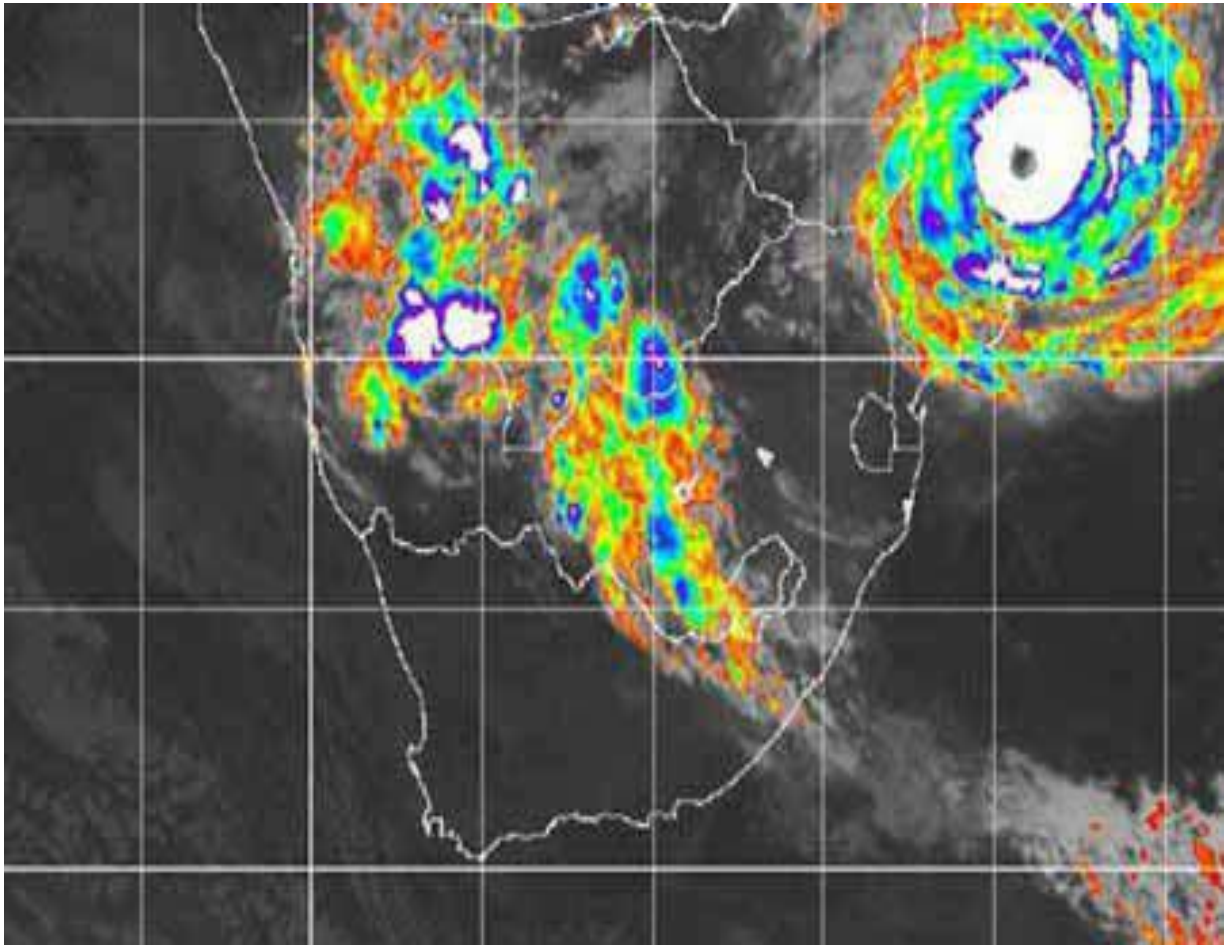
Frequently asked questions (IPCC; 2007) *answers on frequently asked questions on climate change, including the relation between weather and climate change*

Reviewing weather and climate services in the Pacific (SPREP; 2010) *review of National Meteorological Services in the Pacific region (mainly small island states that are especially vulnerable to sea-level rise)*

Climate and ocean: Variability, predictability and change (CLIVAR; 2014) *brochure on the CLIVAR research programme*

2. Earth observation applications

Earth observation for weather



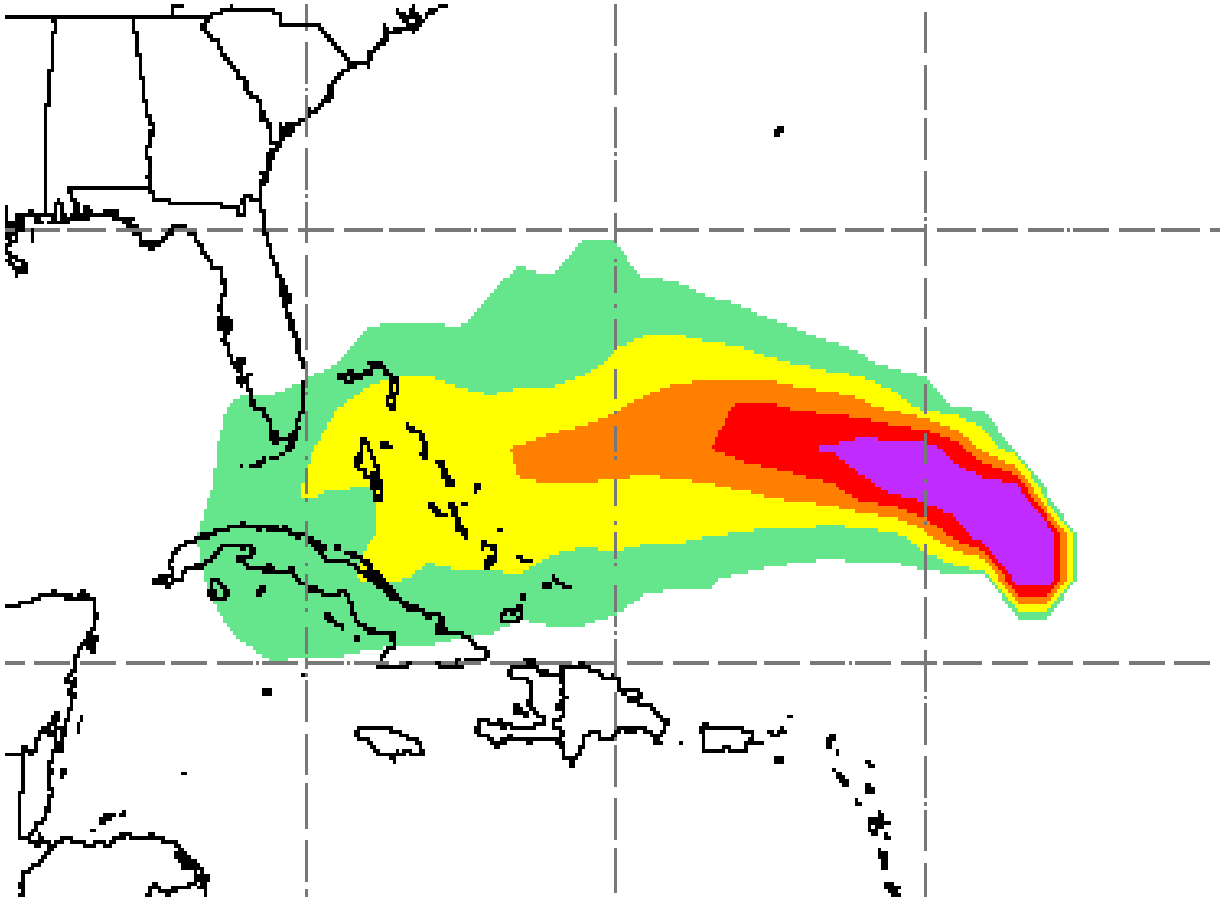
Tropical cyclone Eline provoking flooding in Mozambique and Madagascar

Earth observation contribution

- **High-impact weather prediction** (see also disaster management toolkit)
- **Precipitation (and general weather) forecasting and monitoring**
- **Earth observation for weather (-indexed) insurance** (in agriculture toolkit)

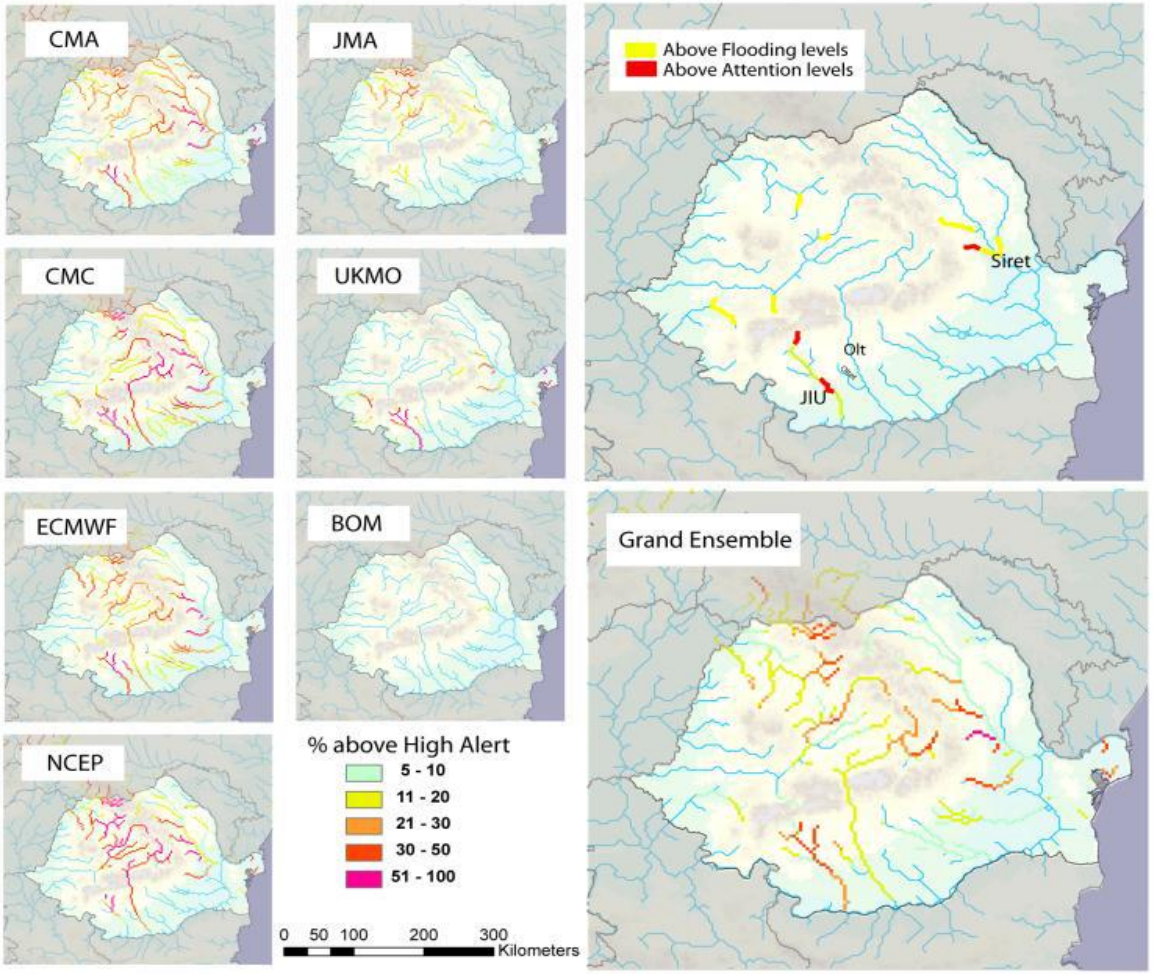
Weather products and services are linked to all GEO Societal Benefit Areas and provide input to products and services related to these SBAs

Example high-impact weather prediction



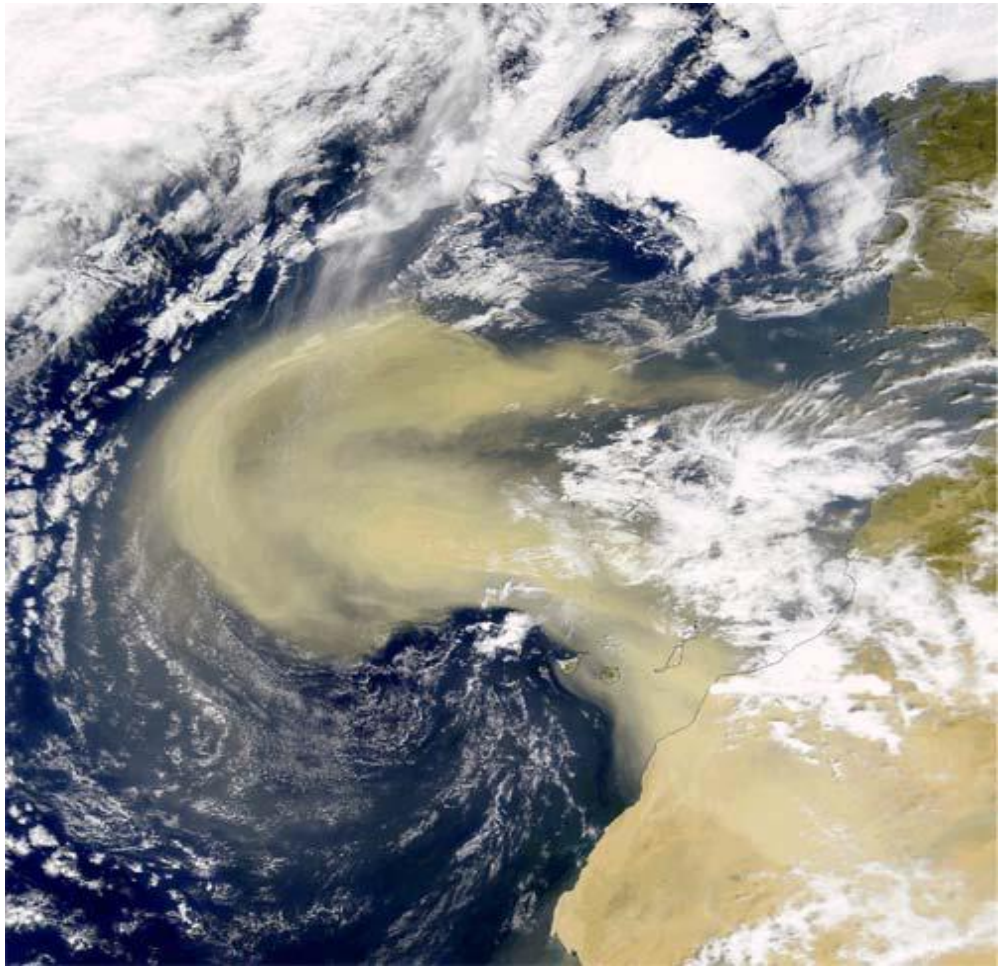
Forecasting strike probabilities for Hurricane Ike by combining two TIGGE ensembles

Example high-impact weather prediction (2)



Predicting flood alerts for Romania using TIGGE

Example high-impact weather prediction (3)



Massive sandstorm blows off the northwest African desert (February 26th, 2000)

High-impact weather prediction

- Earth observation supports high-impact weather prediction for disaster management, water management, agriculture, energy, health, fisheries, aviation / transportation, etc.;
- Data series are available for historical and statistical analysis and analysis of whole regions;
- Earth observation facilitates shortening of the warning time and the communication and decision-making process;
- Cost estimate: on case-by-case basis, meteorological satellite imagery is usually free;
- Main challenges: cost, complexity, business model, knowledge transfer.

Examples:

The European Centre for Medium-range Weather Forecasts – European co-operation at its best (ECMWF; 2012) *describes improvements in medium-range forecasts, with some examples of high-impact weather prediction*

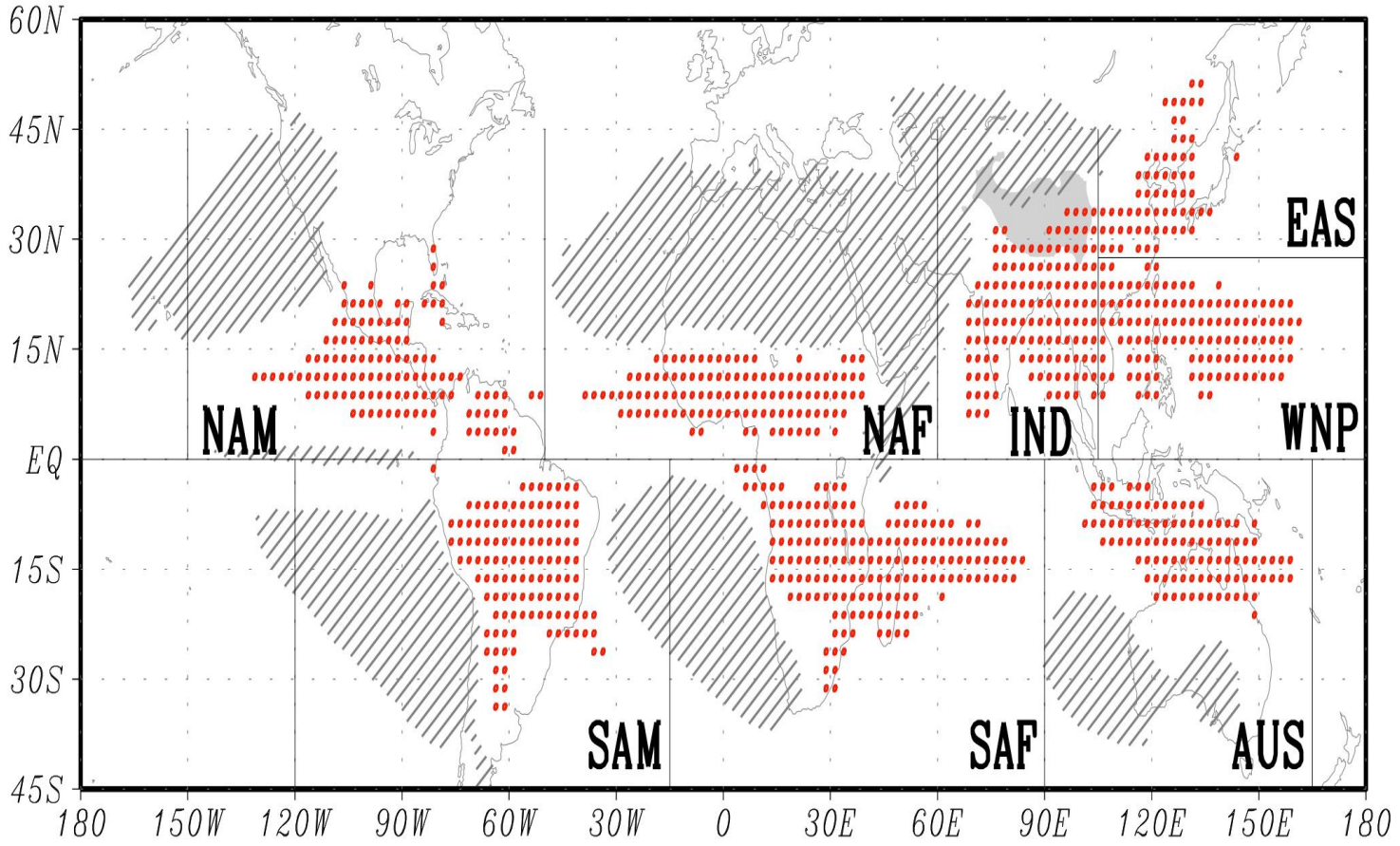
Weather satellites: Critical technology in an uncertain environment (Space Solutions; 2013) *overview of weather satellites and their benefits (US perspective)*

NOAA knows… Earth observation satellites (NOAA; 2011) *factsheet on the use of earth observation for a 'weather-ready nation'*

Heaviest precipitation events, 1998 – 2007: a near global survey (Mapes; 2011) *chapter 2 of 'The global monsoon system': Analysis of and attempts to understand extreme rainfall events over a 10-year period*

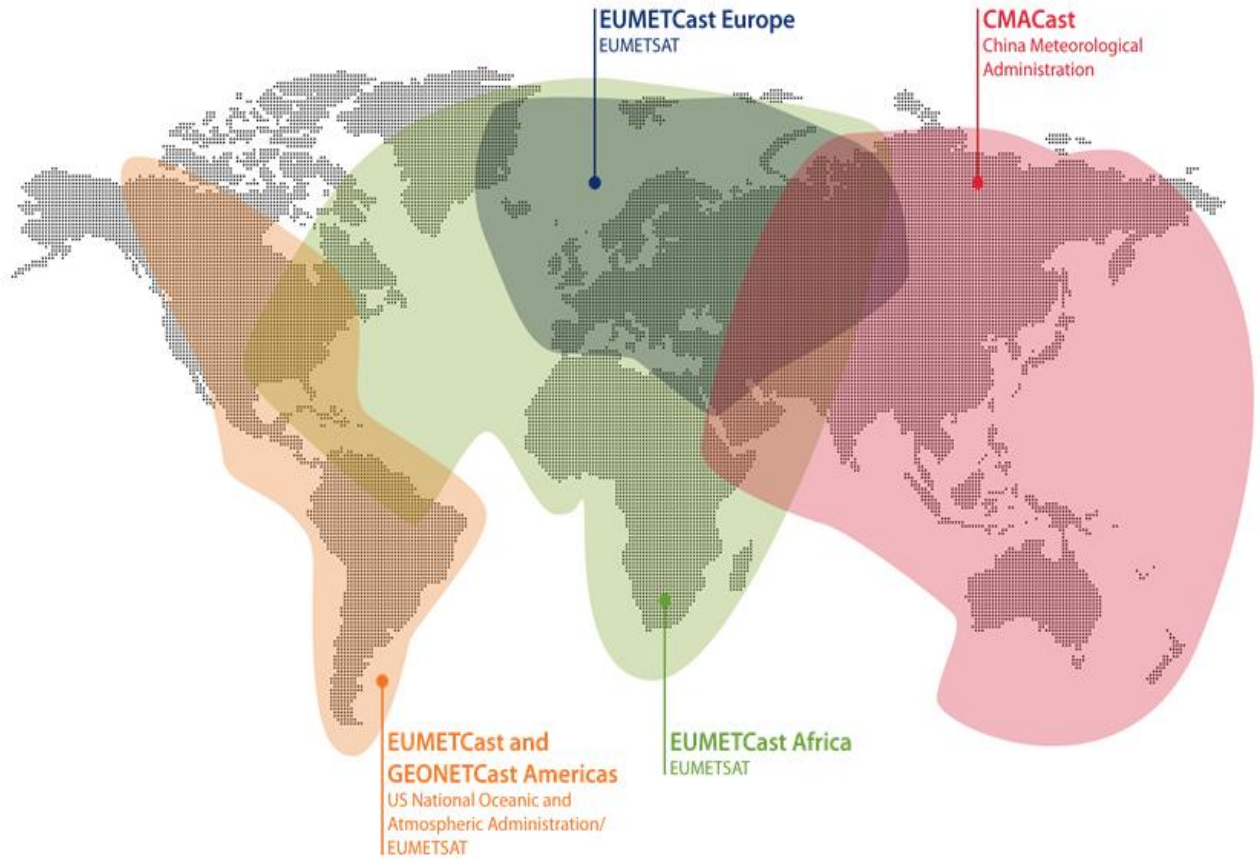
Predicting and managing extreme weather events (NOAA; 2012) *description of state-of-the-art in understanding and prediction extreme weather events and requirements for managing these events in the US*

Example precipitation monitoring and forecasting



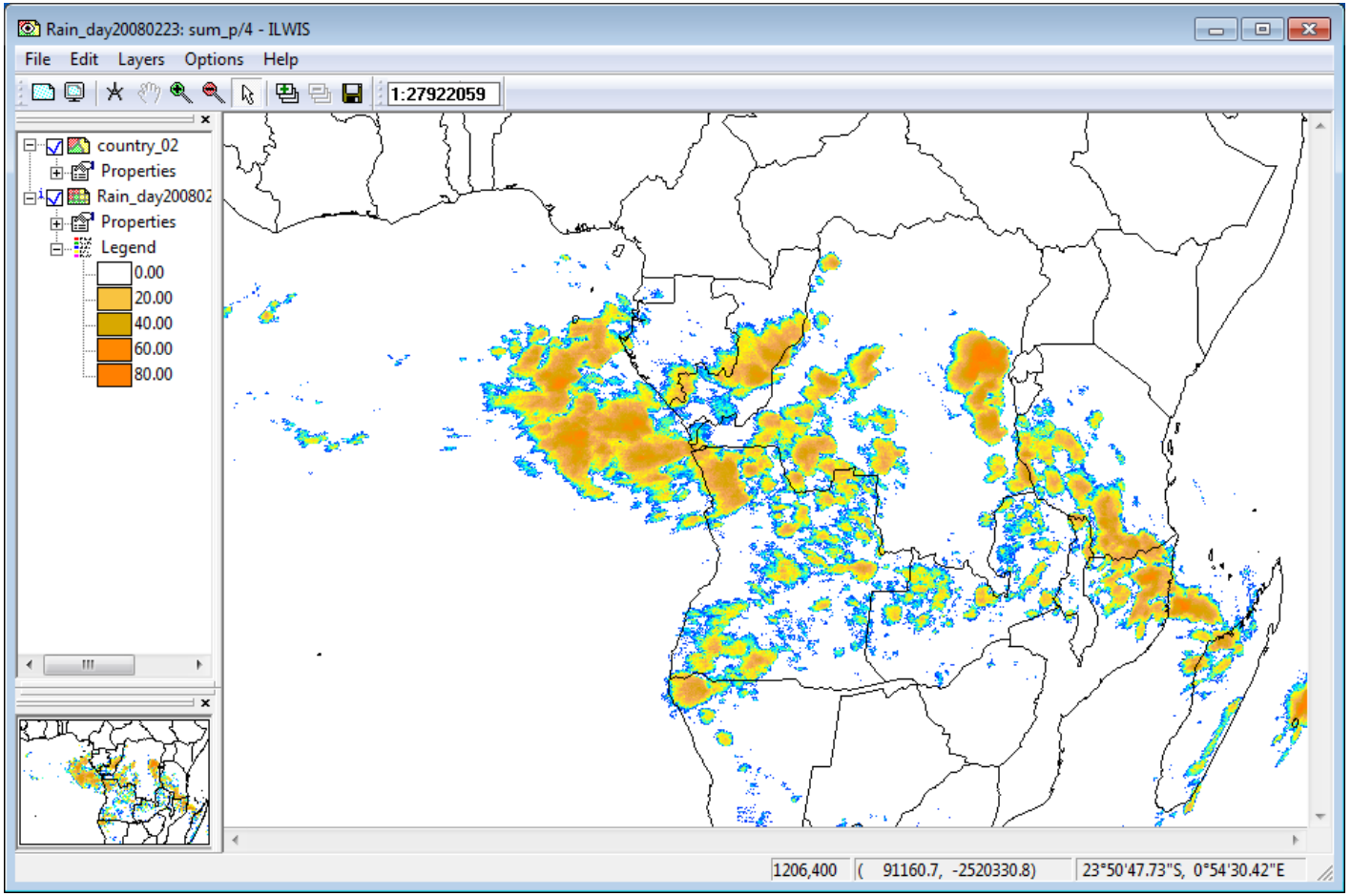
Approximate location of monsoons across the globe

Example precipitation monitoring and forecasting (2)



GEONETCast coverage

Example precipitation monitoring and forecasting (3)



Precipitation calculated over central Africa for 23/02/2008 (Source: DevCoCast

Precipitation monitoring and forecasting

- All aspects of the high-impact weather prediction apply;
- Services, such as GEONETCast (service that delivers meteorological products and services to end-users, among other services) make weather information accessible and affordable to all kinds of users;
- Cost estimate: on case-by-case basis, setting up a GEONETCast station costs about € 1,500, satellite imagery distributed through GEONETCast is free;
- Main challenges: acceptance, knowledge transfer.

Examples:

Statements of guidance (WMO; 2012) *on: global numerical weather prediction, high-resolution numerical weather prediction, nowcasting and very short range forecasting, seasonal to inter-annual forecasts, aeronautical meteorology, atmospheric chemistry, ocean applications, agricultural meteorology, hydrology, climate monitoring, climate applications and space weather*

How Sentinels can support space-based weather predictions (Copernicus; 2013) *description of support to weather forecasts through the Sentinel satellites programme*

Examples (2):

GEONETCast – DevCoCast application manual (DevCoCast; 2012)
description of how to use the system and software with application examples on meteorology, agriculture and water quality

GEONETCast toolbox – installation, configuration and user guide of the GEONETCast toolbox plug-in for ILWIS
http://52north.org/downloads/earth-observation/geonetcast/geonetcast-toolbox/52n-eo-gnc-toolbox-1-4

GEONETCast toolbox factsheet XML version 1.2 *description of all the products and data that can be received and of the features of the GEONETCast toolbox*

Demonstration of GEONETCast technology (Maathuis; 2015)
presentation on the state-of-the-art of GEONETCast applications

Growth potential for earth observation

- Mainly a **public good**, provided by national meteorological organizations (NMOs) and international specialized organizations;
- Research topics in meteorological phenomena require specialization and are best studied in an international context;
- Gains can be obtained by **improving management** of the whole **communication chain** between specialized meteorological agencies and beneficiaries (think of timely warning for flooding or agricultural management);
- The **envisaged role for business** (SMEs) consists primarily in the delivery of meteorological products and services of specialized agencies to end users and/or using these as input for other products or services (think of agriculture, water management, health, energy, etc.).

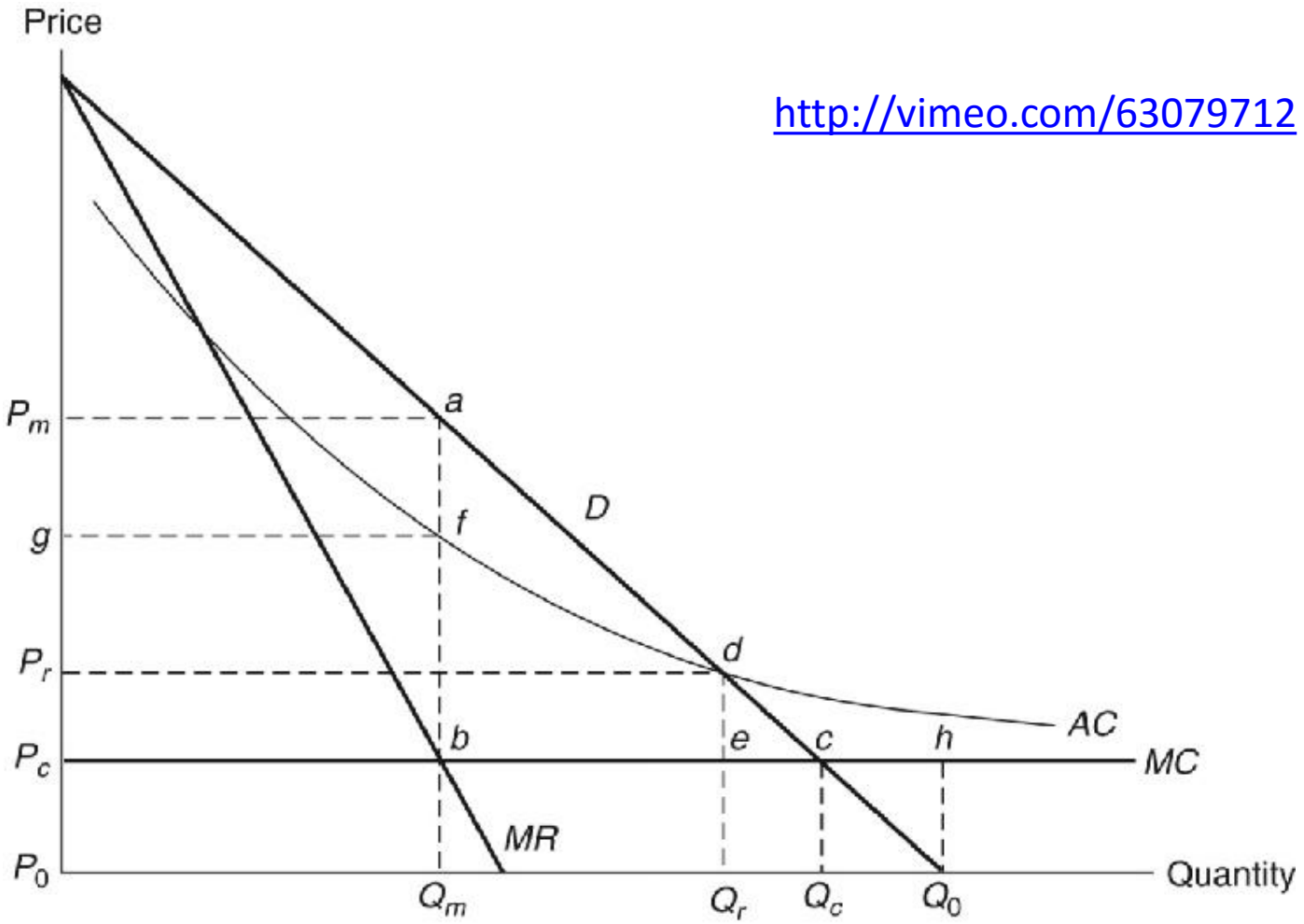
3. Business development

Why is marketing / promotion of earth observation needed?

- Public sector information (PSI)
- Externalities (environmental accounting & payment for ecosystem services)
- Global datasets, open access, data sharing, compatibility (GEO)

If public sector information is made available free-of-charge, demand will increase and, in the end, government revenue also, as companies will derive income from value-added products and services, and consequently pay more taxes (see figures in following slides).

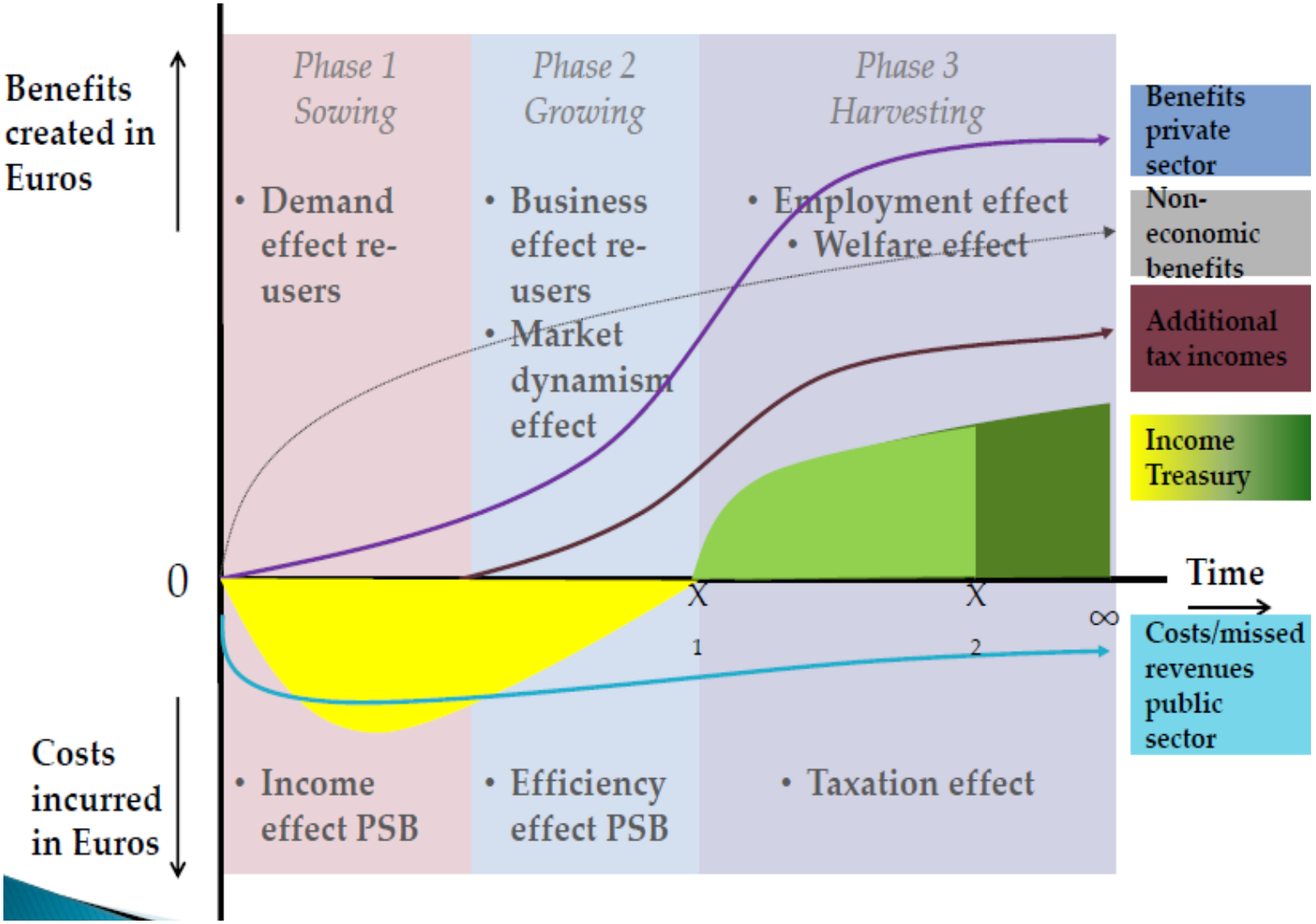
Supply & Demand Public Sector Information



http://vimeo.com/63079712

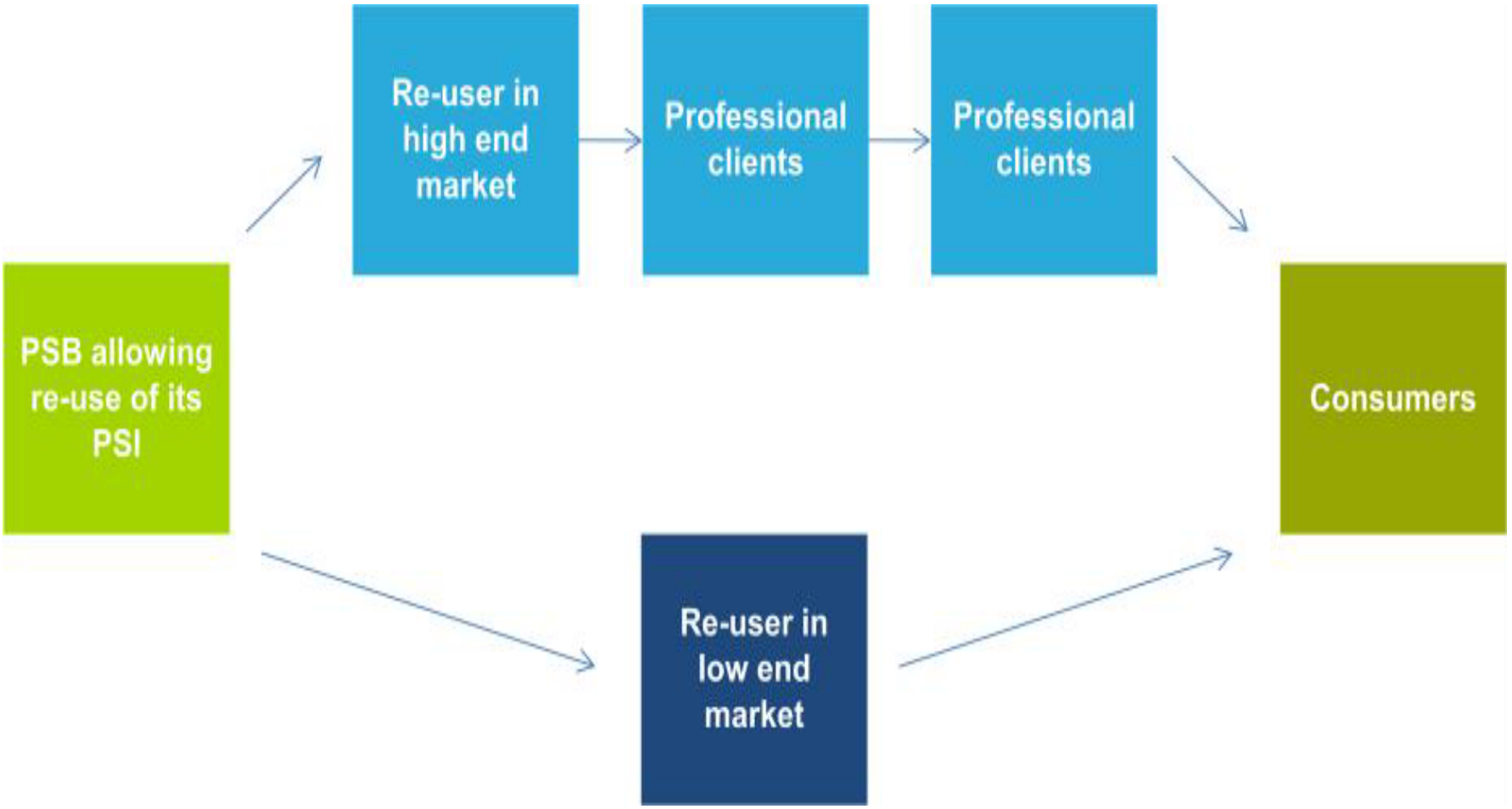
Source: About GMES and data: geese and golden eggs (Sawyer, de Vries 2012)

Cost-benefit Public Sector Information



Source: About GMES and data: geese and golden eggs (Sawyer, de Vries 2012)

Re-use of Public Sector Information



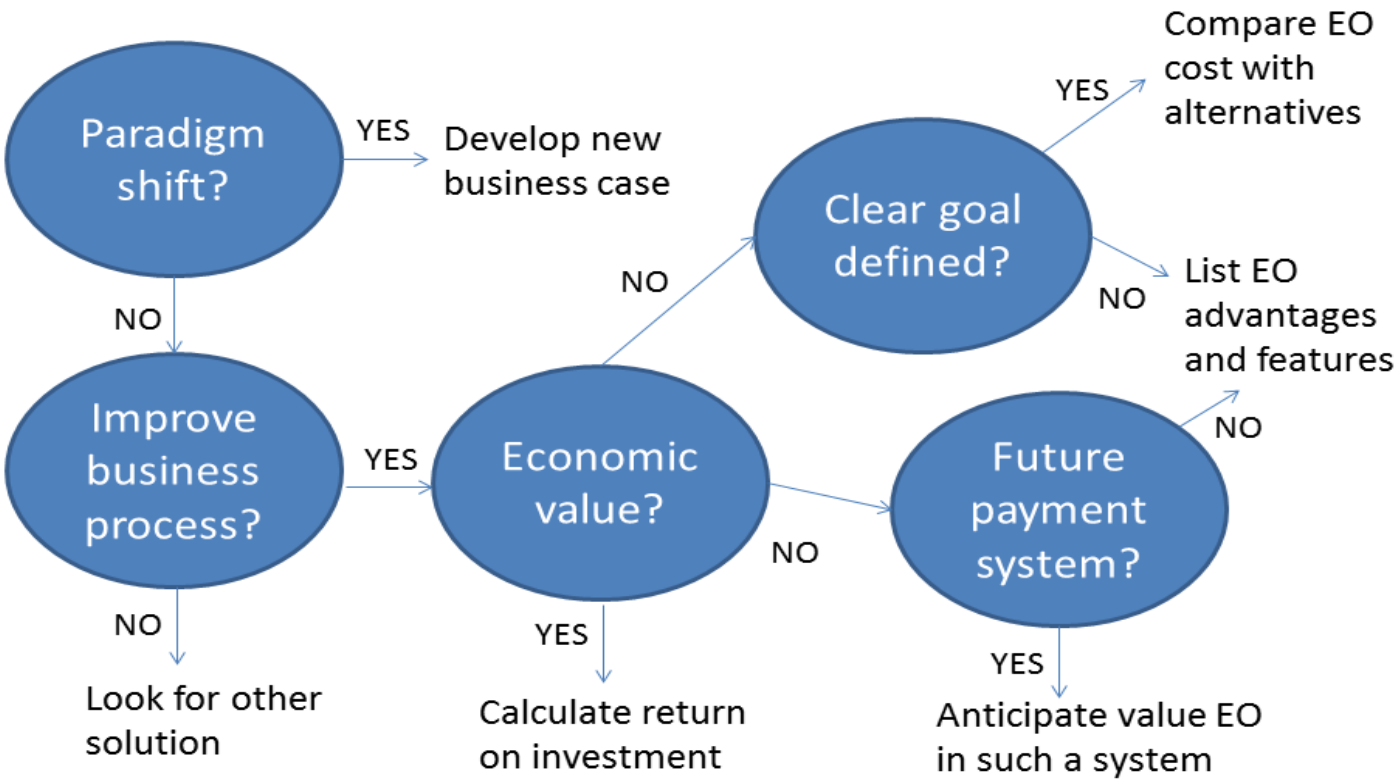
Source: About GMES and data: geese and golden eggs (Sawyer, de Vries 2012)

Most earth observation applications deal with so-called externalities, such as impact on the environment.
It is difficult to capture these in terms of conventional cost-benefit models.

To tackle this, the following framework for analysis of earth observation applications is developed:

Framework for analysis

Step-by-step benefit EO



Step-by-step analysis of the benefits of earth observation (source: GEONetCab, 2013)

Key questions

- Does the new application cause a paradigm shift?
- Is the current business or organization process improved?
- Does the application provide economic value that can be quantified?
- Is a clear measurable goal defined to which the earth observation application contributes?
- Is a future payment scheme or other economic mechanism foreseen in which the earth observation application fits?

Assessment of geospatial solutions

Rating of **characteristics** of geospatial solutions:

- fit-for-purpose
- comparative advantage
- complexity to user / ease- of-use
- elegance
- cost-benefit,
- sustainability
- resilience
- reproduction capacity / flexibility
- acceptance
- level of knowledge transfer required
- ethics, transparency, public accountability, objectivity & impartiality

Rating of **business environment**:

- **Willingness to pay** (by clients)
- **Embedding** (in organizational processes)
- **Openness** (transparency and ease of doing business, access to markets)
- **Institutions** (is the institutional environment conducive to doing business, acceptance of new solutions?)

Fit-for-purpose

An important, but often forgotten requirement:
Does the product or service do what it is supposed to do to solve a certain problem?

In other words: is it really a solution or just an attempt towards a solution?

- Quantitative: not applicable
- Qualitative (on scale of 1 to 5): based on description of what the EO solution actually does

Comparative advantage

What it does significantly better than other solutions to the same problem.

For earth observation usually the comparative advantages of greater accuracy, better resolution in time and space, comprehensive overview of large areas and near real-time information provision are mentioned as comparative advantages.

- Quantitative: calculation of degree in which the EO solution is better than alternatives
- Qualitative (on scale of 1 to 5): based on listing of comparative advantages

Complexity (to user) / ease-of-use

At all levels in the value chain the users (professionals and end-users) are able to work with the product or service.

- Quantitative: not applicable
- Qualitative (on scale of 1 to 5): based on user testimonials and user surveys

Elegance

Once you get the idea behind this product or service, you want to be part of the community that uses it.

This sense of belonging facilitates the formation of user groups that provide valuable feedback.

- Quantitative: none, or it should be the size of the user community
- Qualitative (on scale of 1 to 5): based on user testimonials and user surveys

Cost-benefit

The cost-benefit of the product or service is quantified and sufficiently attractive, also in the long-term.

- Quantitative: cost-benefit calculation
- Qualitative (on scale of 1 to 5): based on quantitative assessment

Sustainability

The product or service can be delivered when it is needed.
There is a long-term perspective that guarantees delivery.

Sustainability concerns the following aspects:

- ✓ Long-term data availability
- ✓ Availability of finance/funds to provide the solution continuously for present and future use
- ✓ Long-term institutional / governmental interest and support
- ✓ Long-term user interest for a solution that addresses real needs

- Quantitative: not applicable
- Qualitative (on scale of 1 to 5): based on sensitivity analysis of the EO solution

Resilience

In case of extremes or breakdown in the value chain, the product or service can still be delivered at an acceptable level. Alternatives (plan B) are available (and developed).

- Quantitative: cost-benefit calculation of plan B
- Qualitative (on scale of 1 to 5): based on risk analysis of the EO solution

Reproduction capacity / flexibility

The product or service can be easily applied or adapted for use in another region or another situation, while still providing the solution without (too much) extra cost.

- Quantitative: calculation of reproduction costs for application in other regions or situations; measurement of spreading of actual use
- Qualitative (on scale of 1 to 5): based on quantitative assessment and description of EO solution

Acceptance

The users intuitively get what the product or service is about and are interested. They accept it as a solution to their problem.

- Quantitative: none, or survey results about acceptance. After introduction of the solution: number of clients and/or users
- Qualitative (on scale of 1 to 5): based on user testimonials and user surveys

Level of knowledge transfer required

The training requirements for professionals and other users along the value chain are clear and associated costs and efforts are acceptable.

- Quantitative: cost and time required to get the users at the desired knowledge and skill level
- Qualitative (on scale of 1 to 5): based on knowledge transfer plans and evaluation of training activities

Ethics, transparency, public accountability, objectivity & impartiality

Application of Earth observation increases the level of objectivity and impartiality in decision-making processes, including conflict resolution. The application improves transparency and public accountability. It raises no ethical issues or if it does, as in the case of privacy concerns, these are resolved in a satisfactory way for all parties concerned.

- Quantitative: not applicable
- Qualitative (on scale of 1 to 5): based on user testimonials and user surveys

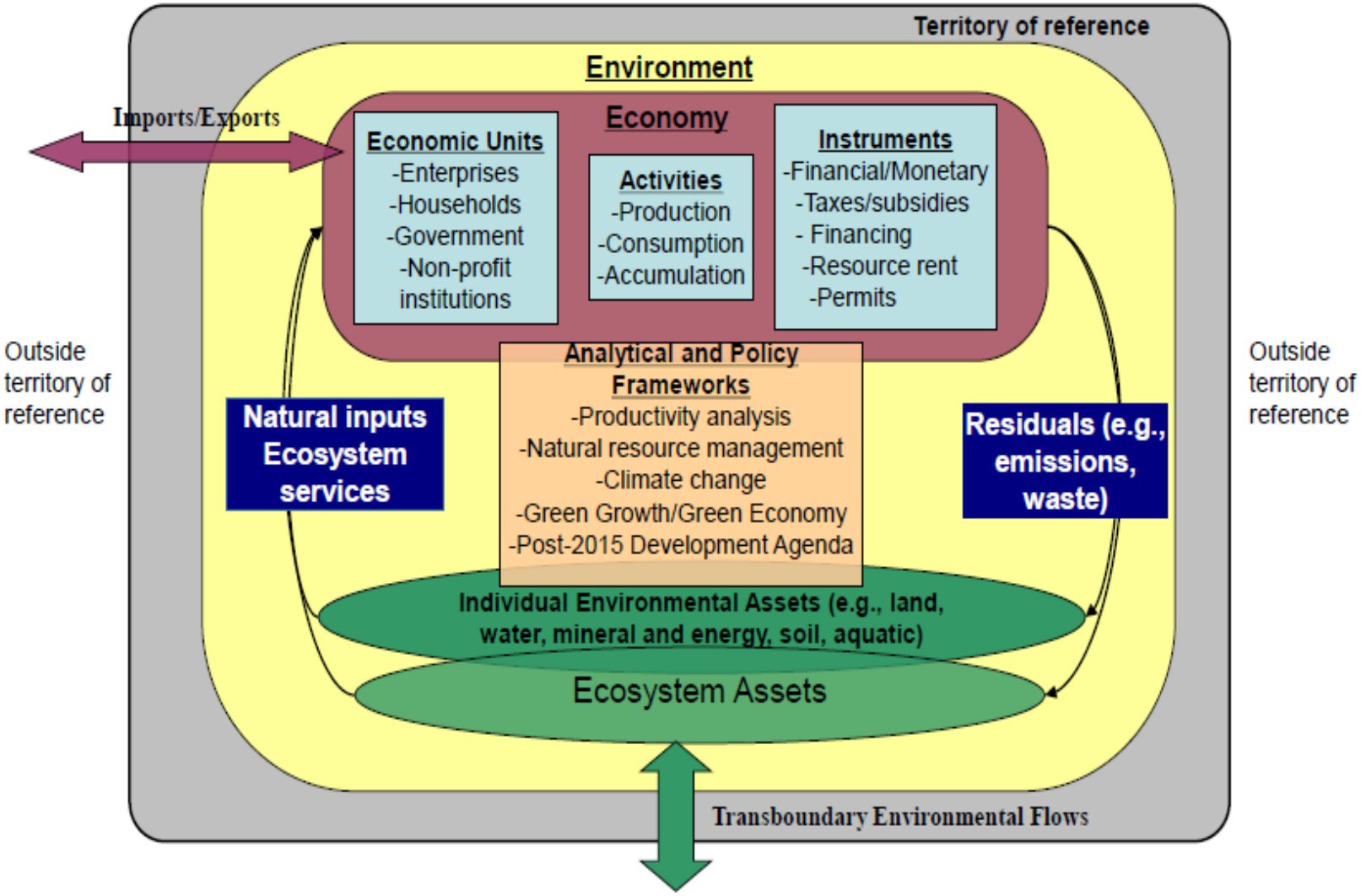
Several attempts have been made to introduce environmental accounting and to enlarge the sphere of the conventional economy to include and quantify impact on ecosystems.

The following slides give some examples:

Environmental accounting & payment for ecosystem services

- **SEEA:**
  System of Environmental-Economic Accounts
  (EC, FAO, IMF, OECD, UN, WB)
- **WAVES:**
  Wealth Accounting and the Valuation of Ecosystem Services (global partnership, led by World Bank)
- **TEEB:**
  The Economics of Ecosystems and Biodiversity
  (group led by UNEP)

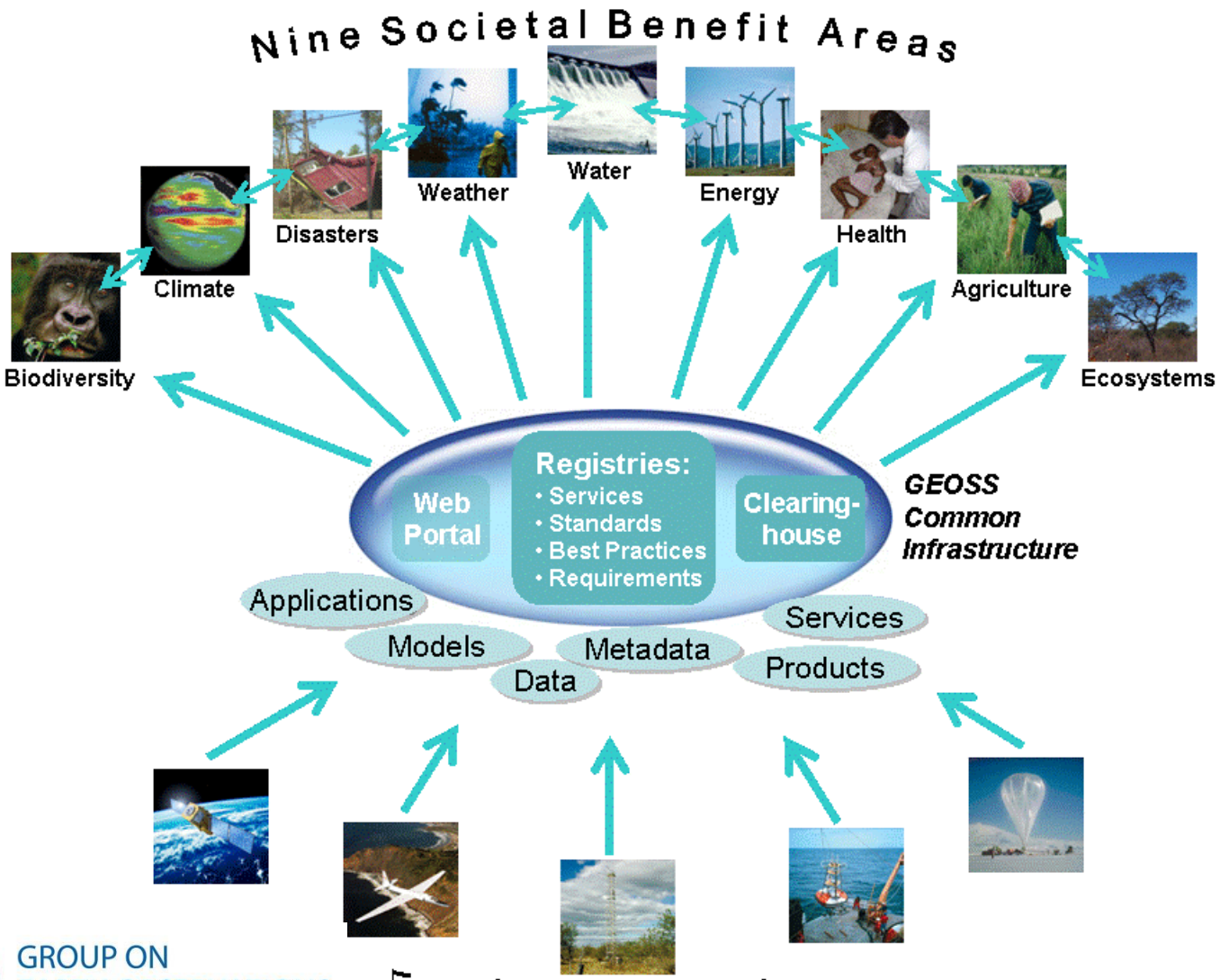
SEEA Conceptual Framework



Source: SEEA conceptual framework report (EC, FAO, IMF, OECD, UN, WB 2012)

For earth observation the work of the Group on Earth Observations (GEO) is essential to achieve the goal of a Global Earth Observations System of Systems (GEOSS), resulting in the shared GEO common infrastructure (GCI):

Group on Earth Observations



GROUP ON EARTH OBSERVATIONS

Marketing elements

- Customer value propositions
- Crossing the technology chasm
- Creating shared value
- Promotion tools

Customer value propositions capture the unique value of a product or services as perceived and appreciated by the customer.

Interestingly, they can differ completely from the features that the provider considers most important:

Customer Value Propositions

VALUE PROPOSITION	ALL BENEFITS	FAVOURABLE POINTS OF DIFFERENCE	RESONATING FOCUS
Consists of:	All benefits customers receive from a market offering	All favourable points of difference a market offering has relative to the next best alternative	The one or two points of difference whose improvement will deliver the greatest value to the customer
Answers the customer question:	"Why should our firm purchase your offering?"	"Why should our firm purchase your offering instead of your competitor's?"	"What is *most* worthwhile for our firm to keep in mind about your offering?"
Requires:	Knowledge of own market offering	Knowledge of own market offering and next best alternative	Knowledge of how own marketing offering delivers value to customers, compared with next best alternative
Has the potential pitfall:	Benefit assertion	Value presumption	Requires customer value research

Source: Customer value propositions in business markets (HBR 2006)

Buyer behaviour & motivation

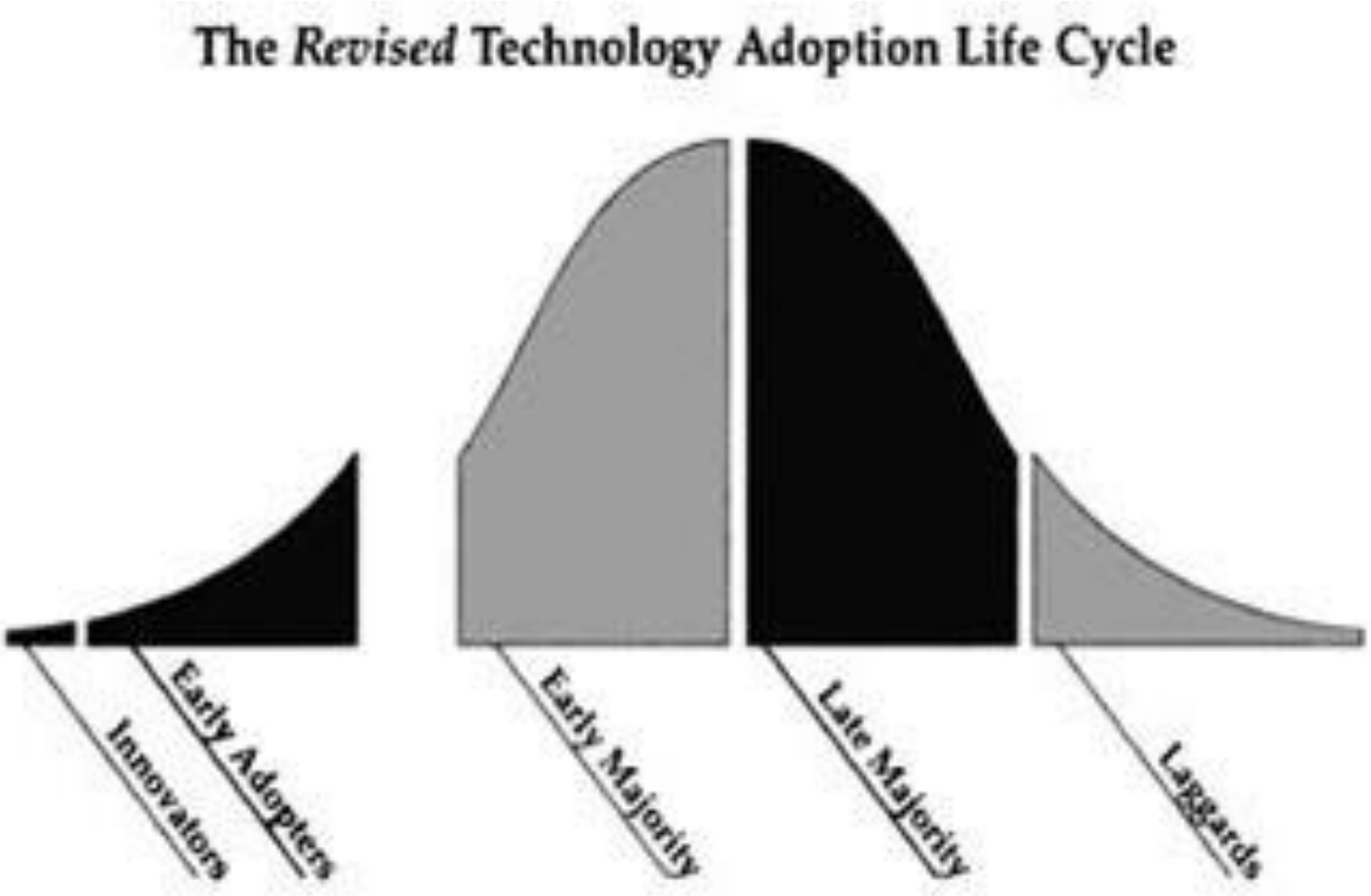
Type	Buyer behaviour	Motivation
Transactional sales	Intrinsic value buyers: “keep it cheap and easy to do business”	Understands the product Perceives it as substitutable Cost focus Resents time ‘wasted’ with sales people
Consultative sales	Extrinsic value buyers: “I don’t know the answer: help me analyse and solve the issue	Focus on how the product is used Interested in solutions and applications Values advice and help Needs the sales person

Source: Rethinking the sales force (Rackham, de Vincentis 1999)

Even when customer value propositions are well captured and formulated, introduction of solutions that involve new technology will have to overcome some hurdles.

This is called “crossing the technology chasm”:

Crossing the technology chasm



Source: Crossing the chasm (Moore 1991)

Crossing the technology chasm

- Most clients of EO products and services belong to the early and late majority,
- They are pragmatists and are not prepared or willing to take substantial risk: the solution should work and be reliable.
- Once convinced, the pragmatists will be long-term clients.

Source: Crossing the chasm (Moore 1991)

More information:

Creating & delivering your value proposition
– managing customer experience for profit
(Barnes, Blake, Pinder; 2009)

Customer value propositions in business markets
(Anderson, Narus, van Rossum [Harvard Business Review]**; 2006)**

Rethinking the sales force:
refining selling to create and capture customer value
(Rackham, de Vicentis; 1999)

Crossing the chasm
– marketing and selling high-tech products to mainstream customers
(Moore; 1991)

Creating shared value is a key element of successful implementation of earth observation solutions.

To achieve this, in most cases earth observation applications have to be integrated into more general (business or organizational) processes:

Create shared value

Involves cooperation between:

- **Public sector**
- **Private sector**
- **Social sector**

Opportunity for earth observation (integrated) solutions:

- Integrate EO in general business / organizational process
- Integrate different EO (and GIS and navigation) functionalities

Based on all considerations dealt with in the previous slides, there are some practical approaches that can be applied in combination to promote earth observation applications:

Tools for earth observation marketing:

- Success stories (in non-technical language, feasible, replication capacity, sustainable)
- Marketing toolkits (international trends, earth observation examples, references)
- Pilot projects, innovation funds, quick-wins (demonstration that EO actually works)
- Promotion outside EO community (fairs, seminars, lunch-bag meetings, magazines)
- Resource facilities for reference and capacity building (distributed, but connected, in different languages)

Source: Marketing earth observation products and services (Noort 2013)

Business elements

Business elements:

- **Proposal writing**
- **Business procedures**

Proposal writing is an art in itself.

During the GEONetCab and EOPOWER projects templates have been developed for writing successful proposals:

Proposal outline

1. Introduction / relevance
2. Objective(s)
3. Activities
4. Output
5. Management & evaluation
6. Risk assessment
7. Time schedule
8. Budget

Annexes

(more detailed version in separate document,
see www.eopower.eu or www.hcpinternational.com)

Other guides that may be useful:

- Civicus: writing a funding proposal
- Michigan State University: guide for writing a funding proposal
- ESRI: writing a competitive GRANT application
- REC: project proposal writing

If you run a company, compete for assignments and manage projects, a structured approach towards responsibilities, tasks, implementation and documentation is needed.

The following business procedures may be helpful:

Business procedures

1. On acquisition
2. On offers
3. On negotiation
4. On contracts
5. On project management
6. On travel & deployment
7. On deficiencies & complaints
8. On internal organization
9. On finance

(more detailed version in separate document,
see www.eopower.eu or www.hcpinternational.com)

Again:

- **SHARED PROBLEM**
- **SHARED LANGUAGE**
- **SHARED SOLUTION**

4. Capacity Building

General

Marketing is promotion + capacity building.

Especially for the introduction of new technologies capacity building is important at all levels.

Capacity building is the instrument to increase self-sufficiency and make solutions work.

General references for capacity building, open data and success stories

GEO Portal: www.earthobservations.org

Capacity building resource facility www.geocab.org
compilation of tutorials, references, open-source software, etc.

Satellites going local: *share good practice* **(Eurisy handbooks)**
www.eurisy.org

Earth observation for green growth (ESA; 2013)

General references for capacity building, open data (2)

Bringing GEOSS services into practice:
how to use data from the GEO portal and how to provide input
www.envirogrids.net

Science education through earth observation for high schools:
basic tutorials on all kind of subjects
www.seos-project.eu

Copernicus briefs:
information on satellite applications for different topics
http://www.copernicus.eu/main/copernicus-briefs

MetEd: *tutorials and courses on meteorology and related subjects*
https://www.meted.ucar.edu/training_detail.php

More references open data

Open data for sustainable development (World Bank; 2015)
description of the benefits of open data for a wide range of development goals, including the SDGs
http://pubdocs.worldbank.org/pubdocs/publicdoc/2015/8/904051440717425994/Open-Data-for-Sustainable-development-Final-New.pdf

Terms and conditions for the use and distribution of Sentinel data (European Parliament and European Commission; 2014)
standard stipulations related to free and open access to Sentinel data
http://www.demarine.de/lr/c/document_library/get_file?uuid=c5067655-b7ad-4d71-b07b-6111808f4abd&groupId=13521

Towards a thriving data-driven economy (European Commission; 2014) *policy document on the use of (open) data for a knowledge economy and society*
http://ec.europa.eu/information_society/newsroom/cf/dae/document.cfm?doc_id=6210

Capacity building resources for weather:

User guide to ECMWF forecast products (ECMWF; 2011)
overview of models, forecasts and products

Numerical Weather Prediction (Colorado State)
lecture in presentation form on numerical weather prediction

Link to **UCAR weather tutorial (2003)** -> 10 lectures in presentation form: http://www.rap.ucar.edu/general/weathercourse/

Link to **NavCanada local area weather manuals (2000)**
general introduction on meteorology (for aviation) + description of weather phenomena for different regions in Canada:
http://www.navcanada.ca/EN/media/Publications/Forms/AllItems.aspx?RootFolder=%2fEN%2fmedia%2fPublications%2fLocal%20Area%20Weather%20Manuals&FolderCTID=0x01200021B720762C66F0408AF378DB2B47FAAF

Capacity building resources for weather (2):

Remote sensing applications – Chapter 10: atmosphere **(NRSC; 2010)**

Remote sensing applications – Chapter 11: cyclones **(NRSC; 2010)**

GEONETCast – DevCoCast application manual (DevCoCast: 2012) *description of how to use the system and software with application examples on meteorology, agriculture and water quality*

From cloud top temperature to rainfall
Blending TRMM and MSG **(ITC; 2015)**
3-day EOPOWER (self-study) course for professionals
http://menhir.itc.utwente.nl:5000/fbsharing/KGKOZXKU/

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