European Space Weather Modelling Activities:

A look at Current Capabilities and the Transition to Operational Services

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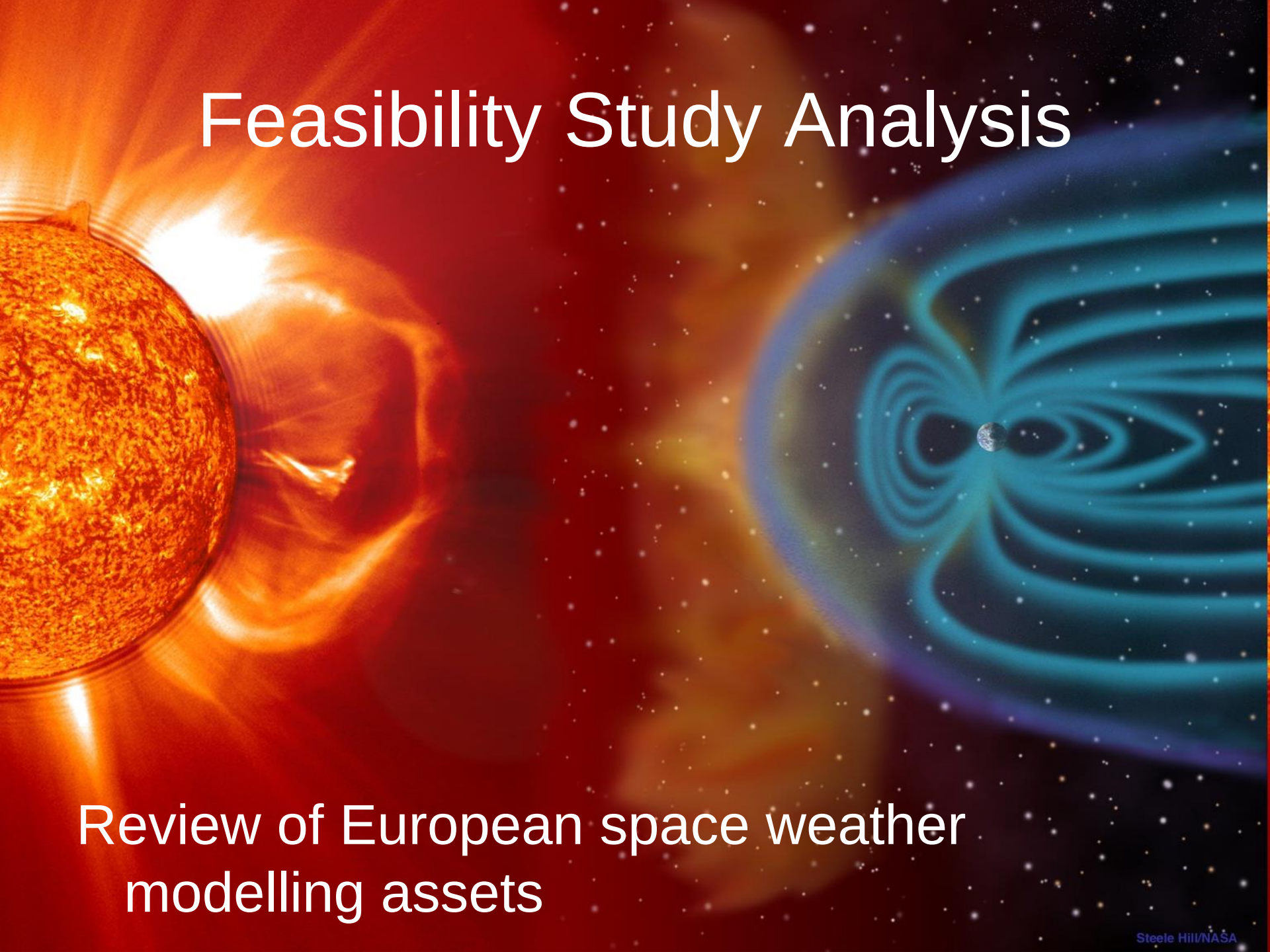
Overview

- Previous ESA studies that have reviewed European modelling assets
- SWENET pilot service use of models
- COST Actions, past and future activities
- Space Weather Warning for Space Systems
- Upcoming actions and interface with ESA-SSA

Previous Studies & Resources

- SW feasibility studies (1999-2001):
  - Broad studies to evaluate European assets and to evaluate the need for and potential scope of a European Space Weather Programme
  - Identified modelling as a key strength in Europe
  - Catalogue generated
- Space Weather Pilot Projects (2003-2006)
  - Prototyped >20 individual service products, several based on existing modelling activities & transition to real-time operation
- COST 724 online catalogues (2003-)
  - EC funded coordination of research
  - Contacted many groups and provide online list of Euro resources
- Development so far as individual projects. No direct steps to develop framework in Europe for transitioning to operations. Individual services
- ESA-SSA will carry out an initial review of European assets in 2009 prior to embarking on main developments with a view to providing a European modelling framework

Feasibility Study Analysis

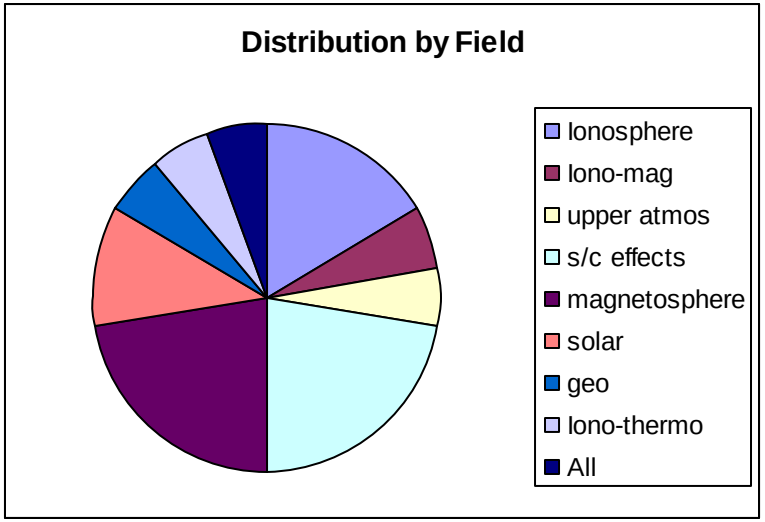


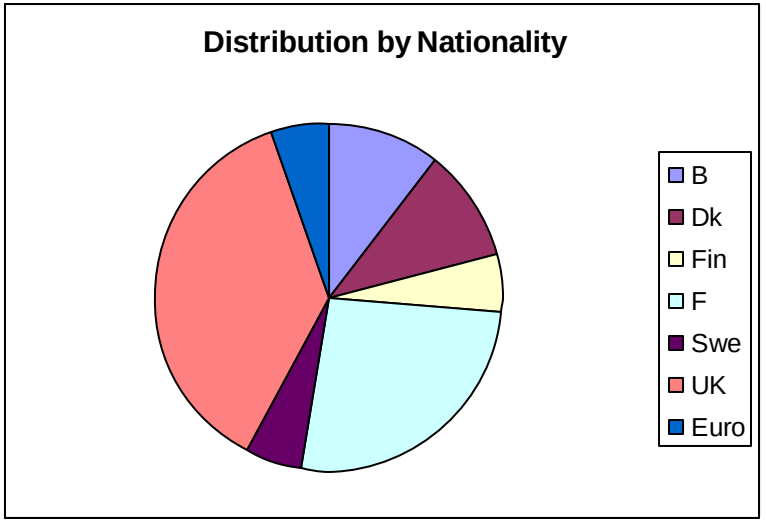
Review of European space weather modelling assets

Steele Hill/NASA

Feasibility Study Catalogues

- 2001 survey identified around 20 modelling assets
- Includes physical models such as GUMICS (FIN), Salammbo (F)
- Neural network based systems (e.g. IRF & BGS)





Model Maturity

- Models were given 3 categories of maturity:
  - Mature: *model or process has been created, although it may not have been implemented*.
  - Immature: *model or process are under development*.
  - Speculative: *the likelihood of success of the model or process is yet to be well-established*.

- Models that appear mature:
  - Solar wind and CME propagation
  - Forecast geomagnetic indices from upstream solar wind parameters based on neural network techniques
  - Climatic Ionospheric density profile modelling
  - Substorm modelling based on solar wind parameters

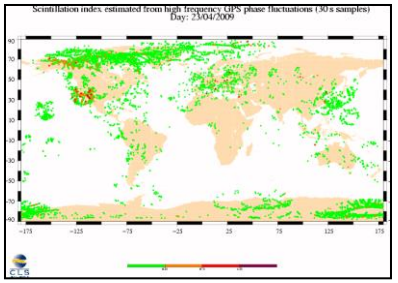
Example for Ground Effects

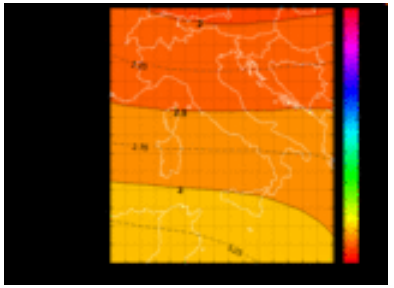
	Mature	Immature	Speculative
Rate of Change of B field - forecast	forecast indices using propagation of L1 data	Numerical Kp forecasts geoeffectiveness of solar wind structures	Physical models based on solar structures Physical models based on CME data
Rate of Change of B field - nowcast	interpolation in time from observations using neural networks	physical modeling (including based on indices)	
Storm and substorm events - forecast	physical models based on solar wind physical model based on indices and L1 data	physical model based on solar features geoeffectiveness of solar wind structures	

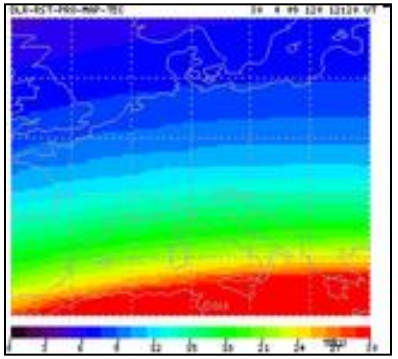
SWENET: Space Weather Euro Network

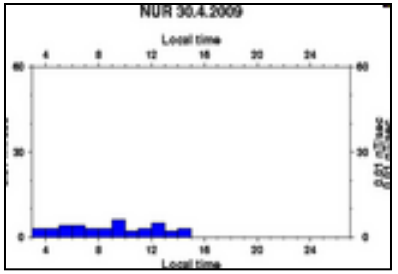
- Aim to support investigation of maturity of the “market”
- ~30 CO-FUNDED services established

- ***http://esa-spaceweather.net/swenet***

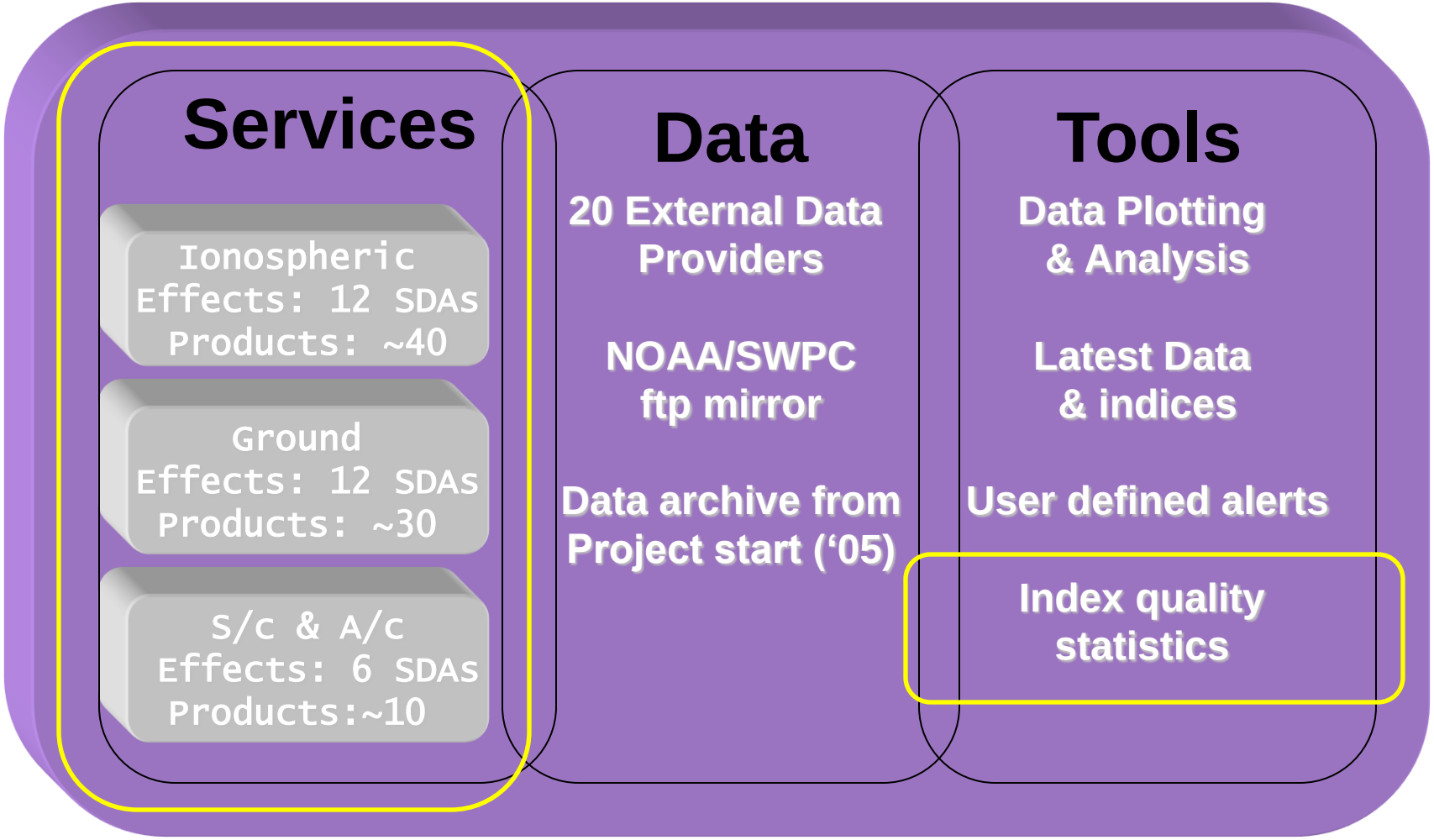








The Space Weather European Service Network: SWENET



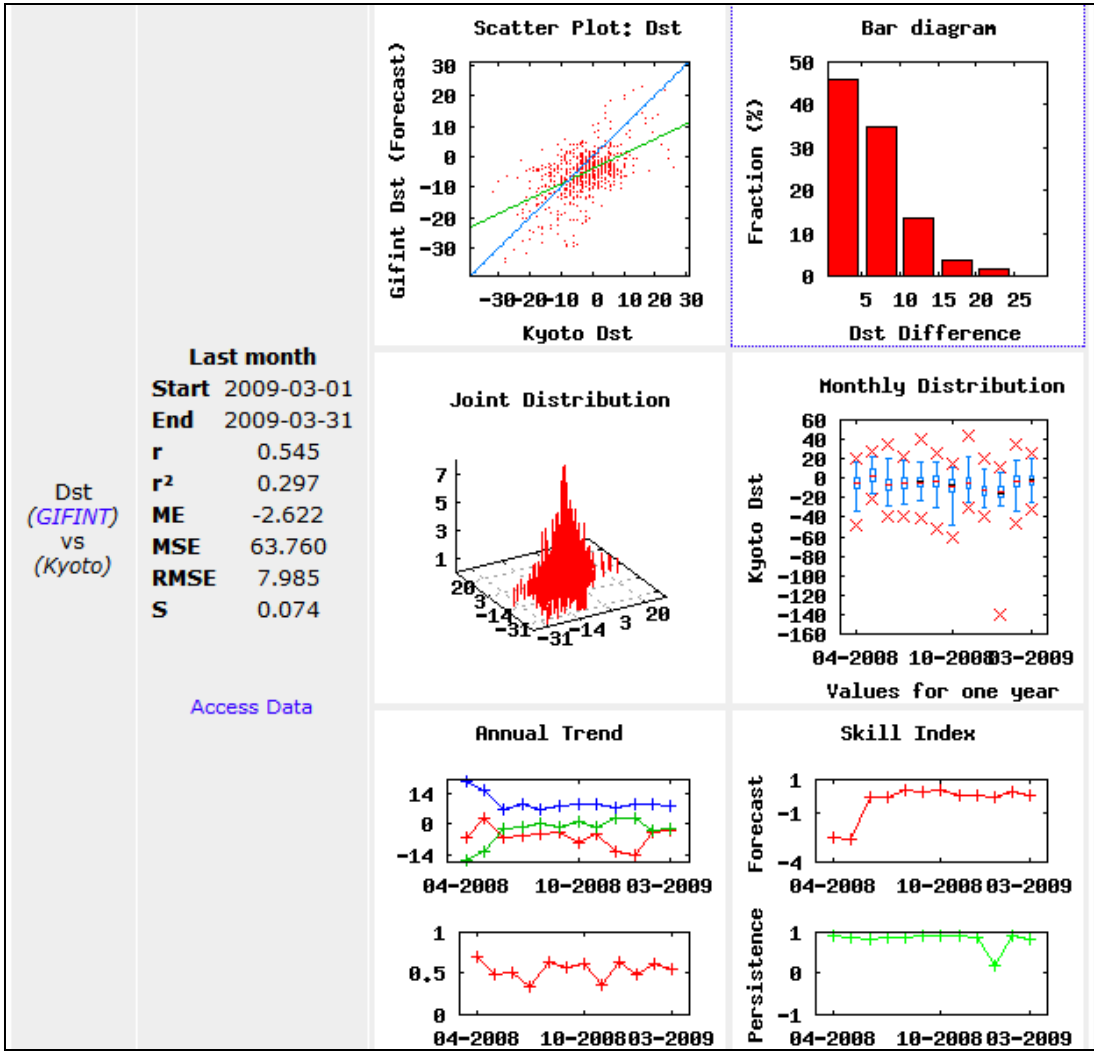
Space Weather European NETwork

SWENET Service Model Use

- Combined existing pilot services with real-time implementation of (new and) existing models
- Example existing models implemented in pilot services:
  - DICTAT internal charging code
  - Salammbo radiation belt model
  - Neural network forecast of geomagnetic indices
  - IRI 2001 reference ionospheric model
  - NeQuick ionospheric electron density model
- Example new developments:
  - Dst forecast based on solar wind data

Preliminary Product Verification: SWENET Metrics

- Visual comparison of forecast vs. measured value for the last month.
- RMS Error
- Skill index: The average accuracy of a forecast method relative to a forecast produced with a reference method (forecast accuracy over a year)
- Monthly and annual performance trends



EC COST Activites

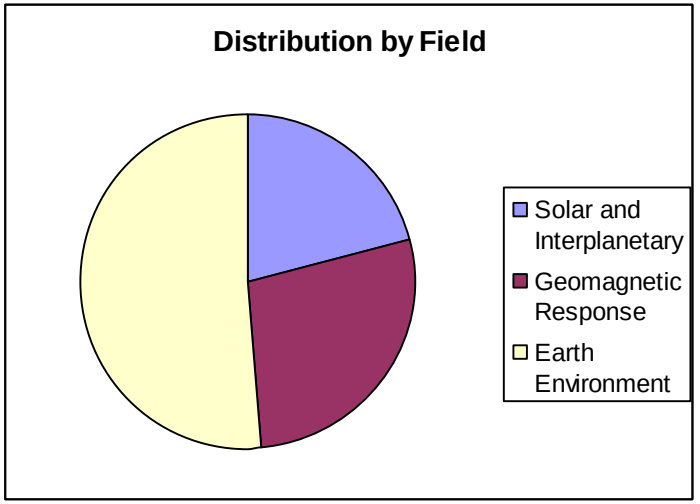
- EC funded intergovernmental network for coordination of nationally funded research activities
- **34 member states:** Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, Serbia, Former Yugoslav Republic of Macedonia and
- **One cooperating state:** Israel

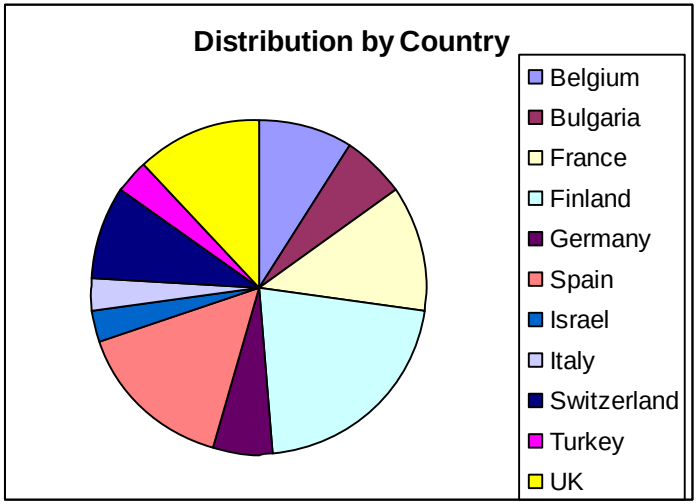
- Supports cooperation among scientists and researchers across Europe

- *COST 724 (2003-2007)*: Developing the Scientific Basis for Monitoring, Modelling and Predicting Space Weather
- *COST ES0803 (2008-2012):* Developing space weather products and services

COST 724 SW Catalogues

- Catalogues identified ~33 individual modelling assets: significantly more than were available in 2001
- Model description, inputs-outputs and limitations
- See full catalogue (including data assets): http://ca724wg1.ts.astro.it/mod_data.php





COST 724: Space Weather Portal

- Space weather portal with focus on on-demand model access and outreach including introduction to space weather in 25 different languages

- Models hosted by ESWeP:
  - geomagnetic cutoff calculations (K. Kudela (IEP/SAV) & M. Storini (IFSI/CNR), COST724)
  - SOLPENCO (A. Aran, B. Sanahuja and D. Lario, University of Barcelona, COST724)
  - Exospheric solar wind model (H. Lamy and V. Pierrard, BISA, COST724)
  - Plasmapause location (V. Pierrard, BISA, COST724)
  - Magnetocosmics cutoffs (L. Desorgher, University of Bern, COST724)
  - Magnetocosmics trajectories (L. Desorgher, University of Bern, COST724)

- http://spaceweather.eu

COST ES0803 Focus on Services

- Inventory of current capabilities including modelling resources
- Cartography of European market and assessment of key user requirements to be addressed
- Development of models towards space weather goals through targeted workshops
- Foster cooperation leading to development of codes for new space weather products and services
- Feasibility study of new products and services. Ranking according to:
  - Short-term: Can be implemented with existing measurements and model
  - Medium-term: Need to deploy existing instrument types at new locations, need to improve timeliness or cadence of measurements, need to adapt models to the new application
  - Long-term: Requires new measurement techniques or systems, requires major improvements or fundamentally new concepts in modelling

Looking Towards Operational Services: Model Evaluation

- COSTES0803 will access the European research modelling community and help provide information on
  - Performance
  - Dependencies (data, models)
- Work will focus on reviewing current practice and developing appropriate
  - Metrics
  - Methods of comparison
- provide formal recommendations by which research models can be validated for eventual operational use.

Space Weather Warning for Space Systems

- ESA Technology Research Programme study (2yrs, expected KO Q2/2009)
- Main Objectives:
- provide user-tailored centralized access to distributed:
  - real-time and historical space environment data from ground and space-based sensors
  - outputs from numerical models of the space environment running in near-real time driven by data assimilated from these distributed resources
- to develop and demonstrate a distributed system, allowing coupling of these products in order to provide warnings of a sub-set of space weather hazards for space systems.

- Prototype environment called ***ViSpaNeT (Virtual Space weather Applications Network of Tools)*** that will focus on technology demonstration in the context of space weather service provision for the space sector.

Inputs to Space Situational Awareness

- Review existing European modelling Assets
  - Performance
  - Dependencies
  - Availability
- Assess requirements for transition into (pre-)operational framework
- Review will identify targeted areas for investment and input into design of prototype services
- ViSpANet will prototype technologies for accessing remote assets in near-real time

- Looking towards an operational service models must also be subject to appropriate standardisation: ISO, ECSS

Summary

- Europe has a wide and growing range of modelling capabilities distributed widely across the Memberstates
- European Modelling activities an essential part of the review of existing assets for SSA-SWE during 2009
- Space Weather Warning for Space Systems will start to prototype technologies geared towards remote model access that may be adopted by SSA-SWE
- Coordination within Europe is strong through the ESA Space Weather Working Team with COST, SOTERIA, HELIO and others
- International cooperation with our partners including NOAA/SWPC and ISES will continue to grow and is crucial

- Next European Space Weather Week: Brussels: 16-20th November 2009: http://sidc.oma.be/esww6