SPACE WEATHER INTRODUCTORY COURSE

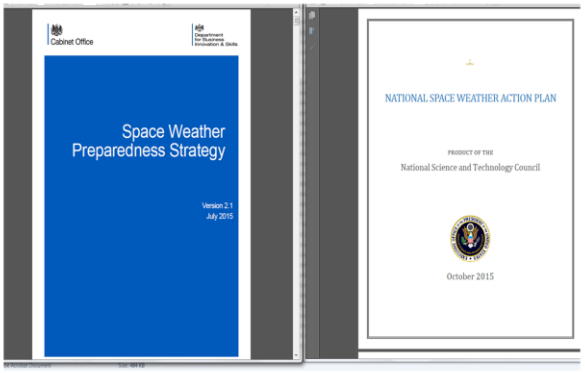
Collaboration of

Solar-Terrestrial Centre of Excellence

Koninklijke luchtmacht

Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

May 2017



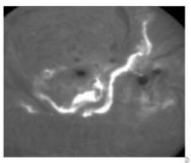
INSTITUTES AND POLICIES

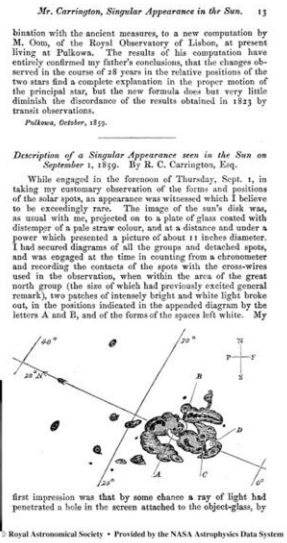
How is space weather organized?

Bert van den Oord

SOME HISTORY

- Event with notable impact on society: **Carrington event** in 1859
- Had strong impact on telegraph services
- Canonical name for a severe solar event





Mr. Carrington, Singular Appearance in the Sun. 13

bination with the ancient measures, to a new computation by M. Oom, of the Royal Observatory of Lisbon, at present living at Pulkowa. The results of his computation have entirely confirmed my father's conclusions, that the changes observed in the course of 18 years in the relative positions of the two stars find a complete explanation in the proper motion of the principal star, but the new formula does but very little diminish the discordance of the results obtained in 1823 by transit observations.

Pulkowa, October, 1859.

Description of a Singular Appearance seen in the Sun on September 1, 1859. By R. C. Carrington, Esq.

While engaged in the forenoon of Thursday, Sept. 1, in taking my customary observation of the forms and positions of the solar spots, an appearance was witnessed which I believe to be exceedingly rare. The image of the sun's disk was, as usual with me, projected on to a plate of glass coated with distemper of a pale straw colour, and at a distance and under a power which presented a picture of about 11 inches diameter. I had secured diagrams of all the groups and detached spots, and was engaged at the time in counting from a chronometer and recording the contacts of the spots with the cross-wires used in the observation, when within the area of the great north group (the size of which had previously excited general remark), two patches of intensely bright and white light broke out, in the positions indicated in the appended diagram by the letters A and B, and of the forms of the spaces left white. My

first impression was that by some chance a ray of light had penetrated a hole in the screen attached to the object-glass, by

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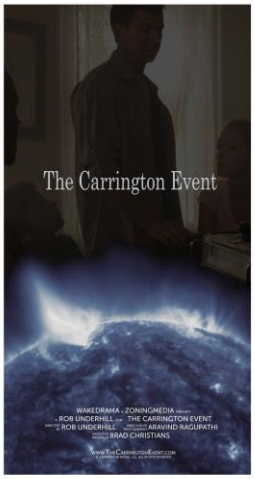
The way space weather is organized has a long history driven by astronomical research and military operational needs. Requirements aviation become important but last decade the need to protect society.

…..AND A BAD DISASTER MOVIE



https://www.youtube.com/watch?v=iAjtheYwXQk

News of a massive solar flare goes viral. Soon after, the power is out. Phone's dead. Water taps are dry. Radio is static. Days pass with no news, just people getting more crazy. A week later the fight for survival has already begun.

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This is a badly acted movie but the scenario is realistic. Coronal mass injections can lead to power outages. In case that a Carrington event occurs one hemisphere may be affected and a lot of transformers may be destroyed. The problem is that the lead time for these items is months while the stock is limited.

VITAL SECTORS

CATEGORY A	CATEGORY B
National transport and distribution electricity	Regional distribution electricity
National gas production and distribution	Regional distribution gas
Oil supplies	Aviation
Drinking water supplies	Shipping traffic main ports
Water management	(Petro) chemical industry and storage chemicals
Production and storage nuclear material	Retail payments/toonbank betalingsverkeer
Internet services	Cashless transactions/giraal betalingsverkeer
Cell phone communication	Inter-banking payments/hoogwaardig betalingsverkeer tussen banken
Satellite communication	Stock markets and stock trading/effectenverkeer
Fixed line communication	Communication emergency services
	Operational capabilities police
	Reliable information digital government services

All these vital sectors are directly or indirectly susceptible to space weather

SWIC 2017 – collaboration between STCE, Koninklijke luchtmacht, KNMI
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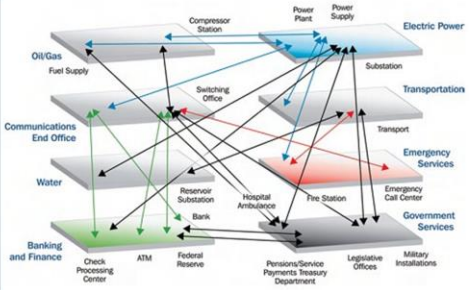
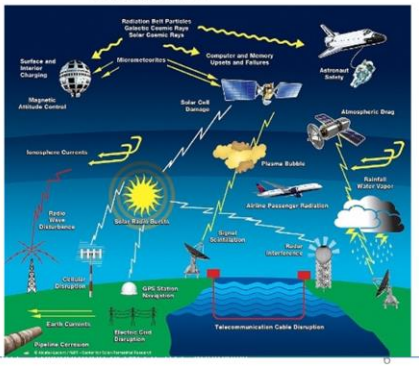
The vital sectors are applicable to every high tech society. Each sector can be affected in many ways (terrorism, human error, bad maintenance, etc) but space affects all.

SW EFFECTS ON CRITICAL INFRA STRUCTURES

- Chain effects
  - Note important role of electric power and communications



- Overview SW effects
  - Economic damage
  - Societal disruption
  - Casualties



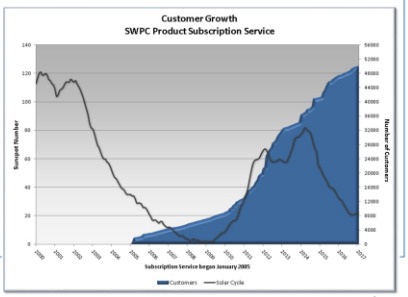
INCREASING INTEREST IN SPACE WEATHER AFTER WWII

The **International Space Environment Service (ISES)** has been the primary organization engaged in the international coordination of space weather services since 1962.

Prior to 1996, ISES was called the International URSIgram and World Days Service (IUWDS). The IUWDS was formed in 1962 as a combination of the former International World Days Service, initiated in 1959 as part of the International Geophysical Year (IGY), and the former URSI Central Committee of USRIgrams, which initiated rapid international data interchange services in 1928.

NOAA started in 1946 with space weather services

The Space Environment Forecasting Division focused its research on the effects of solar disturbances and how to predict them. This effort was a natural outgrowth of research on techniques to measure changes in the ionosphere which affect radio transmissions. Since most of such changes are the result of solar-associated disturbances, many of the same techniques could be used to study the nature of the disturbances themselves. Such investigations were critical to support for manned and unmanned space flights.



Space weather started getting more and more attention after the second World War because of the (miliatry) interest in good radio transmission: NOAA.
ISES started from the need of datastandards (like METAR, BUFFR,…)
The interest in warnings increased strongly theend of the last century

USER FREQUENCY NOAA SERVICES

SCHRIJVER AND RABANAL: SPACE WEATHER CUSTOMER SURVEY

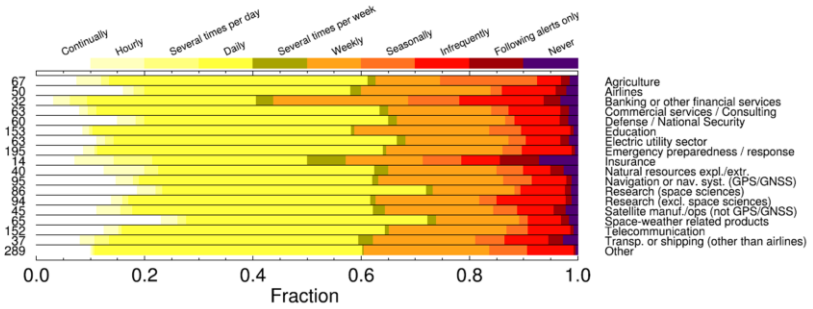


Figure 5. Monitoring frequency of space weather resources by societal sector.

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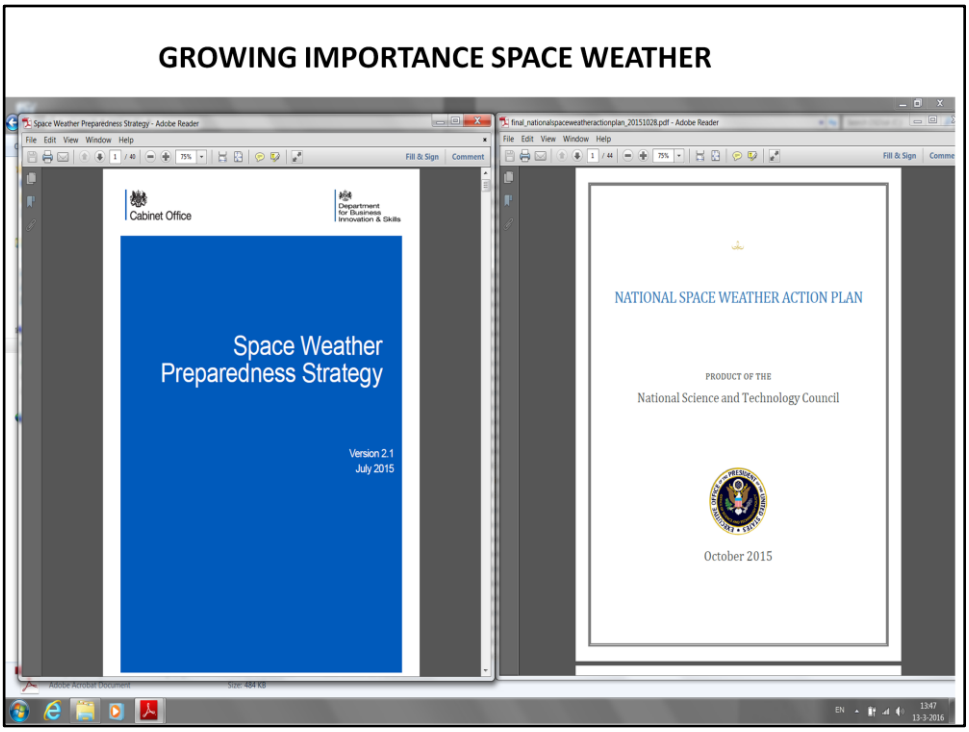
A study on how often NOAA services are consulted per sector: 2013 DOI: 10.1002/swe.20092

The distribution is almost identical for all sectors; this is caused by chain effects.

GROWING IMPORTANCE SPACE WEATHER



In 1980 not a lot of attention for space weather but in 2015 it becomes part of government policy

However there is a lot of money involved in space weather services

SPACE WEATHER INFRASTRUCTURE

We see a transition from scientific instrumentation to operational space weather instrumentation

UV, röntgen, ϒ

radioburst

visible

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In the past most (groundbased and spaceborn) instrumentation was for (astrophysical) research. Later semi-operational satellites were developed like SOHO and the last decades operational satellites like SDO. The cost of this observing infrastructure requires collaboration and therefore joint policies

De Air Force Weather Agency, tegenwoordig 557th Weather Wing, is het weerbureau voor de Amerikaanse krijgsmacht. Naast verwachtingen voor gewoon weer, maken zijn 24/7 verwachtingen voor ruimteweer. Ze maken analyses van de zon en vertalen events naar de impact op (militaire) technologieën. AFWA is het oudste bureau voor ruimteweersverwachtingen. Hun geschiedenis gaat terug tot 1948. Vanaf 1965 maken zij 24/7 verwachtingen. In hetzelfde jaar werd het Space Disturbances Laboratory opgericht, waarin ook het Space Disturbances Forecast Center. Daaruit ontstond later NOAA's SWPC. Tegenwoordig worden de ruimteweerverwachtingen door AFWA en SWPC samen gemaakt. AFWA is gevestigd op Offutt AFB in de omgeving van Omaha, Nebraska. Ze onderhouden verschillende sensoren, zowel op de grond (RSTN, SOON, SCINDA) als in de ruimte (DMSP), al worden de meeste waarnemingen tegenwoordig door civiele instanties (NASA/ESA/NOAA/etc.) gedaan. AFWA produceert een indrukwekkende verzameling producten, variërend van waarnemingen, verwachtingen, modelleringen en waarschuwingen. Een deel van deze producten wordt gedeeld met NATO-partners. AFWA is 'assisting nation' v.w.b. Space Weather in NATO-operaties. Zodoende beschikt de Koninklijke Luchtmacht over een aantal van hun producten.

AFWA, NOAA, ESA, ISES services deliverers
ICAO user requirements; WMO regulatory body
EU has space strategy and funds programs H2020/ FP7

AND OTHER INITIATIVES

International Union of Radio Science (URSI)
International Telecommunication Unit (ITU)
International Living with a Star (ILWS)
International Space Weather Initiative (ISWI)
International Union of Geodesy and Geophysics (IUGG)
International Association of Geomagnetism and Aeronomy (IAGA)
ICSU World Data System
Scientific Committee on Solar-Terestrial Physics (SCOSTEP, ICSU)
NASA
EUMETSAT
CESRA
……

POLICIES

- COSPAR roadmap
- WMO strategic plan
- ICAO conops for space weather information in support of international air navigation
- US strategy and action plan
- UK strategy
- EU Space strategy

There are more national policies bu US/UK are best developed

THE INTERNATIONAL SPACE ENVIRONMENT SERVICE (ISES)

A **collaborative network** of space weather service-providing organizations around the globe. Their mission is to improve, to coordinate, and to deliver operational space weather services. ISES is organized and operated for the benefit of the international space weather user community.

ISES currently includes **16 Regional Warning Centers**, **four Associate Warning Centers**, and **one Collaborative Expert Center**. ISES is a Network Member of the International Council for Science World Data System (ICSU-WDS) and collaborates with the World Meteorological Organization (WMO) and other international organizations.

http://www.spaceweather.org/

Oldest service

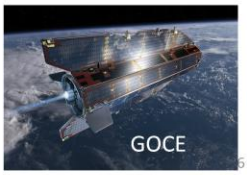
ESA SSA PROGRAMME

http://www.esa.int/Our_Activities/Operations/Space_Situational_Awareness

- Space Weather (SWE): monitoring conditions at the Sun and in the solar wind, and in Earth's magnetosphere, ionosphere and thermosphere, that can affect spaceborne and ground-based infrastructure or endanger human life or health
- Near-Earth Objects (NEO): detecting natural objects that can potentially impact Earth and cause damage
- Space Surveillance and Tracking (SST): watching for active and inactive satellites, discarded launch stages and fragmentation debris orbiting Earth

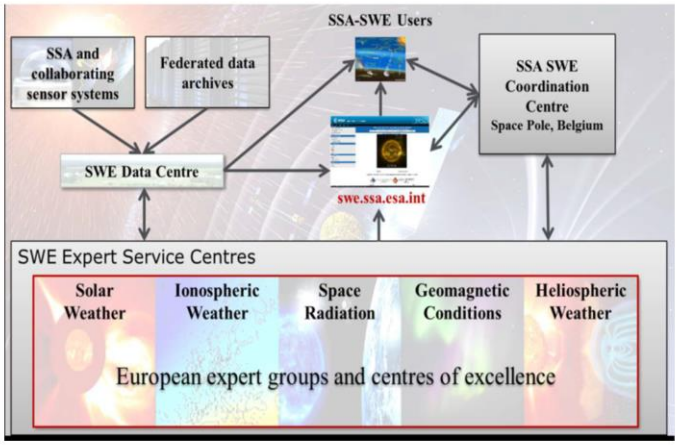
- ESA has a long term development plan for space weather services
- ESA also has an **Earth Explorer programme** with scientific missions

oration between STCE, Koninklijke luchtmacht, KNMI



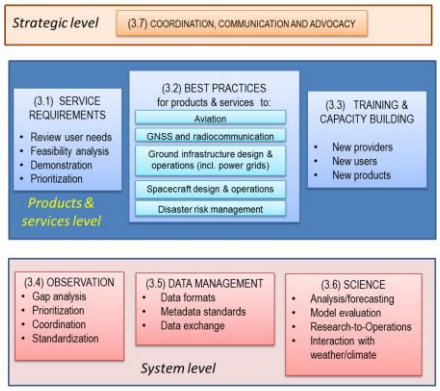
ESA has a Space Situatinal Awareness programme that currently starts phase 3 (3 out of 4)
ESA also operates scientific satellites like SWARM and GOCE

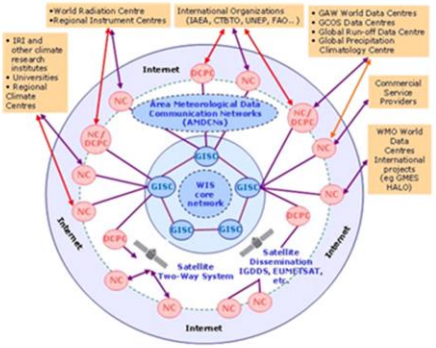
ESA-SSA-SWE SYSTEM



http://www.esa.int/Our_Activities/Operations/Space_Situational_Awareness

WMO (VN, ICAO): WORKPLAN 2015-2019





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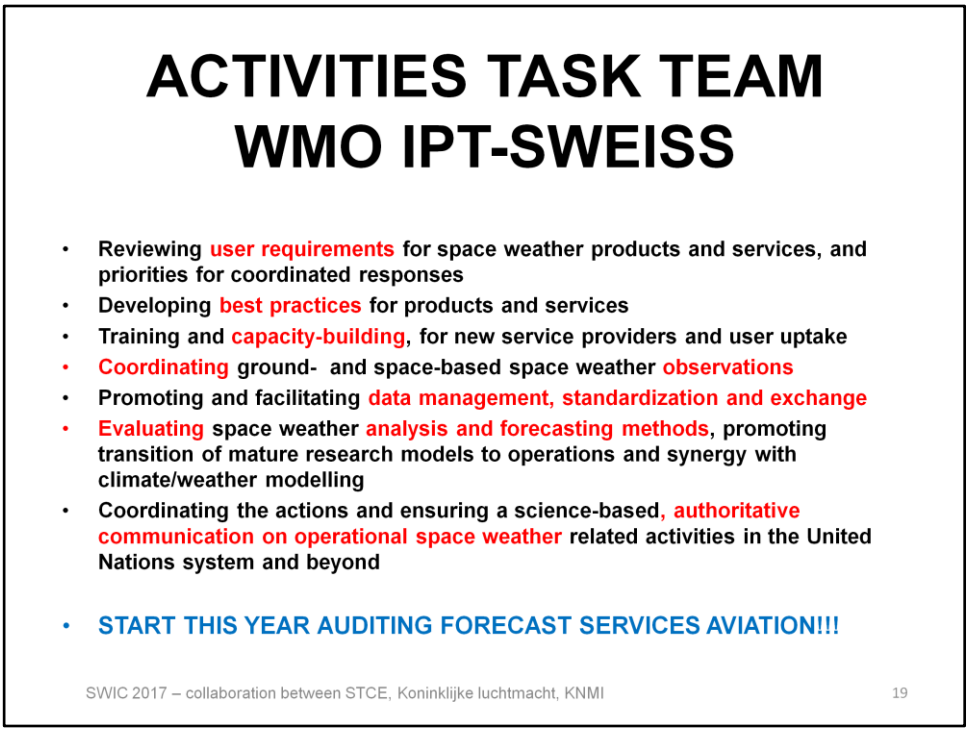
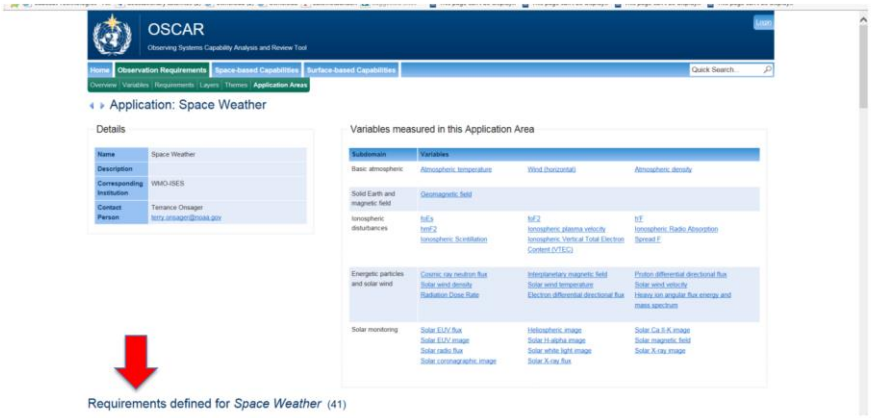
ICAO has asked WMO to regulate space weather services and to start using meteorological infrastructure for exchange of space weather products



There is a special WMO task team for space weather activities. WMO regulates and advises on behalve of United Nations

WMO – RRR - OSCAR



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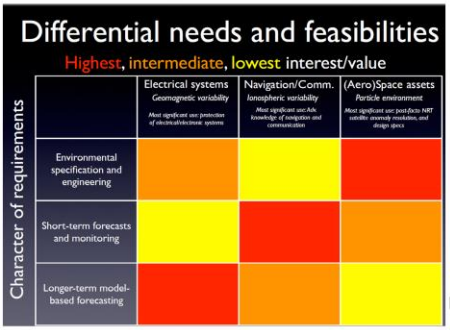
WMO will start collecting requirements for space weather products

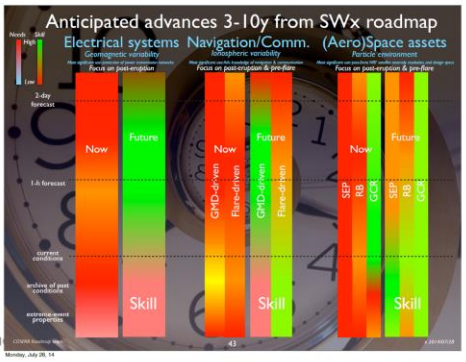
COSPAR ROADMAP

http://www.sciencedirect.com/science/article/pii/S0273117715002252

This roadmap describes which observations, models and infrastructures are needed to improve the forecasts. It puts these requirements in a roadmap, provides priorities for different activities and predicts how skills will improve.

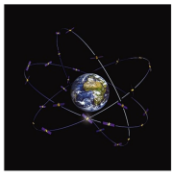
This roadmap is a leading document for international developments of space weather services





Committee on Space Research has produced a roadmap with advises how forecasting can be improved

EUROPEAN UNION



- Has independent space strategy
- Operates COPERNICUS and GALILEO
- Collaboration with ESA for developing services
- Funds development of tools, services, data management via 7th Framework Programme (FP7) in the past and presently via Horizon 2020 Space and Secure Societies Calls.

See http://www.spaceweather.eu/nl/eu-fp7

http://www.spaceweather.eu/nl/eu-h2020