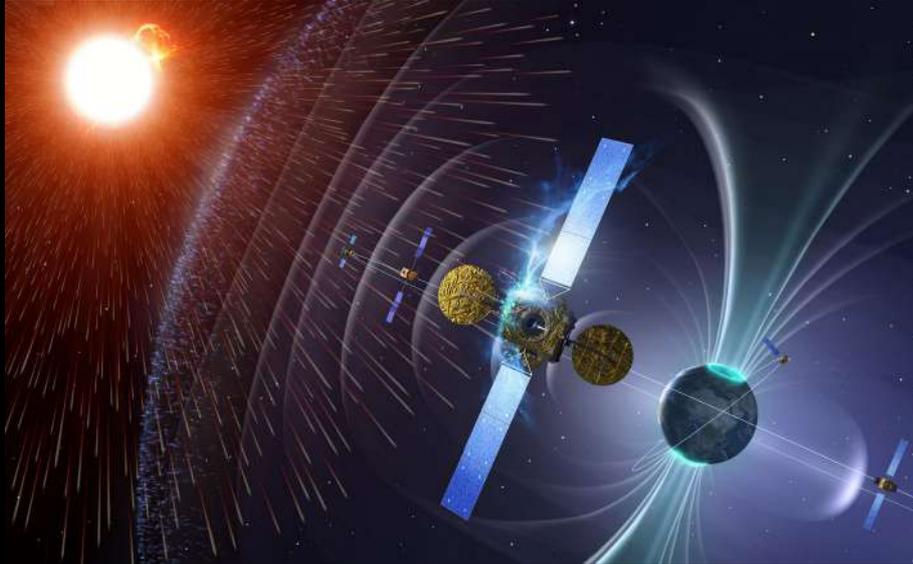


Sistema de Alerta Temprana de Clima Espacial



Dr. Ernesto Aguilar Rodríguez

UNAM
Instituto de Geofísica
Unidad Michoacán

ernesto@igeofisica.unam.mx



Curso Fenómenos Astronómicos

Centro Nacional de Prevención de Desastres (CENAPRED)
Escuela Nacional de Protección Civil (ENAPROC)



28 de mayo de 2021





UNDRR

Oficina de Naciones Unidas para la
Reducción del Riesgo de Desastres

Sistema de Alerta Temprana:

sistema integrado de vigilancia, previsión y predicción de amenazas, evaluación de los riesgos de desastres, y actividades, sistemas y procesos de comunicación y preparación que permite a las personas, las comunidades, los gobiernos, las empresas y otras partes interesadas adoptar las medidas oportunas para reducir los riesgos de desastres con antelación a sucesos peligrosos.

Elementos de un Sistema de Alerta Temprana:



UNDRR

Oficina de Naciones Unidas para la Reducción del Riesgo de Desastres

Tipos de Sistemas de Alerta Temprana:

1) Por tipo de amenaza o peligro:

- Amenazas o peligros geológicos como los maremotos o tsunamis, terremotos, actividad volcánica, y deslizamientos;
- Amenazas o peligros hidrometeorológicos incluyendo mal tiempo en tierra y en el mar, inundaciones, sequías, huracanes, tifones, ciclones, tornados, ondas heladas y de calor, etc.;
- Incendios forestales;
- Amenazas o peligros biológicos incluyendo plagas de insectos como la langosta y algas como la marea roja;
- Amenazas o peligros a la salud, incluyendo aquellas debido a vectores y virus;
- En caso de plagas en cultivos y enfermedades en ganado.



Tipos de Sistemas de Alerta Temprana:

2) De acuerdo al nivel en el que es operado:

- Sistemas comunitarios de alerta temprana.
- Sistemas nacionales de alerta temprana operados por entidades del Estado;
- Sistemas operados a nivel regional;
- Sistemas operados a nivel mundial por organizaciones internacionales;



¿Sistema de Alerta Temprana por Fenómenos de Clima Espacial?

Sunspots
Sunspots are concentrated, cool areas at up to 7,000° F and show the location of strong magnetic fields protruding through what we see as spots on the Sun's surface. A sunspot's surface is generally the source of solar and space weather.

Coronal Mass Ejections (CMEs)
Large portions of the corona, or outer atmosphere of the Sun, can be explosively blown into space, sending billions of tons of plasma, or superheated gas, Earth's direction. These CMEs have their own magnetic field and can slam into and interact with Earth's magnetic field, resulting in geomagnetic storms. The fastest of these CMEs can reach Earth in under a day, with the slowest taking 4 or 5 days to reach Earth.

Solar Wind
The solar wind is a constant outflow of electrons and protons from the Sun, always present and buffeting Earth's magnetic field. The background solar wind flows at approximately one million miles per hour.

Sun's Magnetic Field
Strong and ever-changing magnetic fields drive the life of the Sun and create sunspots. These strong magnetic fields are the energy source for space weather and their twisting, shearing, and reconnection lead to solar flares.

Solar Radiation Storms
Charged particles, including electrons and protons, can be accelerated by mass ejections and solar flares. These particles bounce and gyrate their way through space, roughly following the magnetic field lines and ultimately bombarding Earth from every direction. The fastest of these particles can reach Earth tens of minutes after a solar flare.

Geomagnetic Storms
A geomagnetic storm is a temporary disturbance of Earth's magnetic field associated with enhancements in the solar wind. These storms are created by the solar wind and its magnetic field interacting with Earth's magnetic field. The primary source of geomagnetic storms is CMEs, which stretch the magnetic field on the right side, causing it to release energy through magnetic reconnection. Disturbances in the ionosphere (a region of Earth's upper atmosphere) are usually associated with geomagnetic storms.

Solar Flares
Reconnection of the magnetic fields on the surface of the Sun drive the biggest explosions in our solar system. These solar flares release immense amounts of energy and result in electromagnetic emissions spanning the spectrum from gamma rays to radio waves. Traveling at the speed of light, these emissions make the 93 million mile trip to Earth in just 8 minutes.

Earth's Magnetic Field
Earth's magnetic field, largely like that of a bar magnet, gives the Earth some protection from the effects of the Sun. Earth's magnetic field is constantly compressed on the day side and stretched on the night side by the ever-present solar wind. During geomagnetic storms, the disturbances to Earth's magnetic field can become extreme. In addition to some buffering by the atmosphere, this field also offers some shielding from the charged particles of a radiation storm.

Diagram Labels: Corona, Earth, Earth's magnetic field, CME plasma, Compression on the day side, Reconnection region, Stretching on the night side.

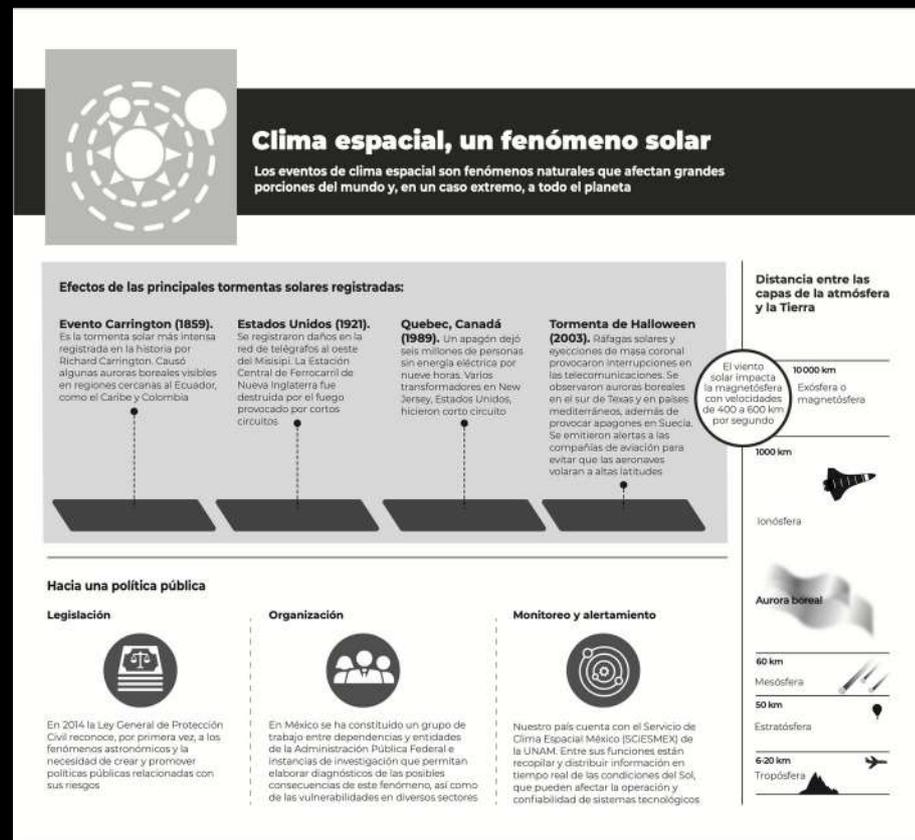
Source: Images: NOAA, NASA, ESA

Space Weather

Forecasting, Tracking, and Effects of Earth Directed Solar Phenomena

Logos: NASHUA REGIONAL HIGH SCHOOL, CFA, NASA/Goddard Space Weather Research Center

Infografía de Clima Espacial de México



Estrategia para mitigar los efectos de los riesgos derivados del clima espacial



Detección: identificación de posibles eventos y difusión rápida de la alerta.

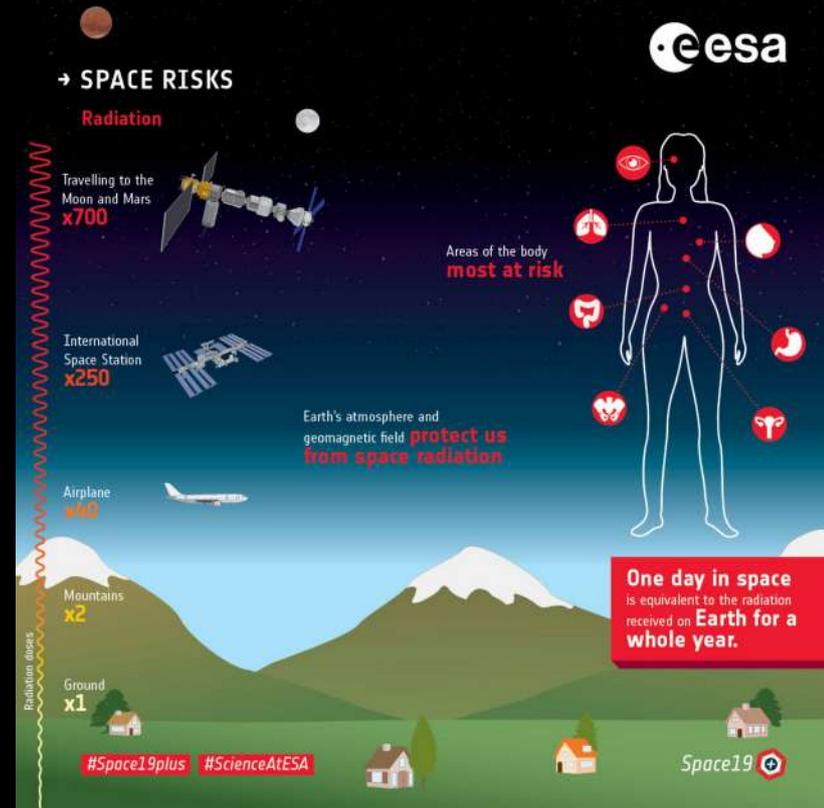
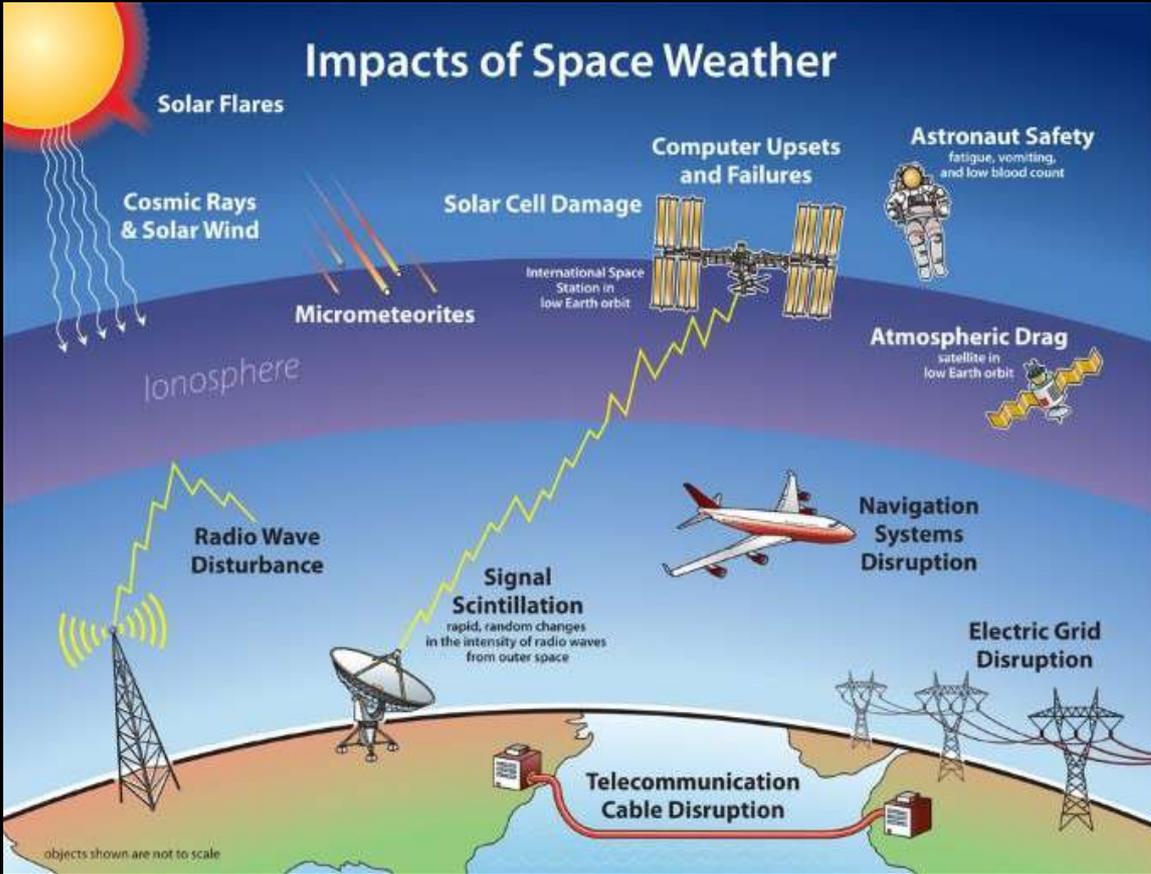
Defensa: protección de la infraestructura que potencialmente puede ser afectada, ya sea directamente o retrasando o reduciendo los efectos sobre redes y sistemas.

Mitigación: minimizar el posible impacto, mediante la introducción de redundancia en los sistemas, reducción de la dependencia entre sistemas y contención del problema entre sistemas interdependientes.

Respuesta: preparación de actividades diseñadas para potenciar la respuesta rápida y de emergencia ante los posibles incidentes, como la realización de planes y ejercicios o la disposición de equipamiento.

Recuperación: posibilitar la restauración de las actividades comerciales y gubernamentales, de forma rápida y eficiente.

Riesgos por Efectos Fenómenos de Clima Espacial



¿Cómo cuantificar los Riesgos por Efectos Fenómenos de

Clima Espacial?

Tormentas de radiación

Radio blackouts (apagones)

R5	Extreme	HF Radio: Complete HF (high frequency*) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector.	HF Radio: Complete HF (high frequency*) radio blackout on the entire sunlit side of the Earth for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector. Navigation: Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 (2 x 10 ⁴)	Less than 1 per cycle
R4	Severe	HF Radio: HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time.	HF Radio: HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time. Navigation: Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.	X10 (10 ³)	8 per cycle (8 days per cycle)
R3	Strong	HF Radio: Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth.	HF Radio: Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth. Navigation: Low-frequency navigation signals degraded for about an hour.	X1 (10 ¹)	175 per cycle (140 days per cycle)
R2	Moderate	HF Radio: Limited blackout of HF radio communication on sunlit side, loss of radio contact for tens of minutes.	HF Radio: Limited blackout of HF radio communication on sunlit side, loss of radio contact for tens of minutes. Navigation: Degradation of low-frequency navigation signals for tens of minutes.	X5 (5 x 10 ²)	350 per cycle (300 days per cycle)
R1	Minor	HF Radio: Weak or minor degradation of HF radio communication on sunlit side, occasional loss of radio contact.	HF Radio: Weak or minor degradation of HF radio communication on sunlit side, occasional loss of radio contact. Navigation: Low-frequency navigation signals degraded for brief intervals.	X1 (10 ⁰)	2000 per cycle (950 days per cycle)

44	Colombia	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours. HF radio contact may be degraded or lost for a number of hours.	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours. HF radio contact may be degraded or lost for a number of hours.	X1	1000000 per cycle
44	Spain	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours.	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours.	X1	1000000 per cycle
44	France	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours.	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours.	X1	1000000 per cycle
44	Germany	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours.	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours.	X1	1000000 per cycle
44	Italy	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours.	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours.	X1	1000000 per cycle
44	Japan	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours.	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours.	X1	1000000 per cycle
44	USA	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours.	Blackout: Emergency services communication may be degraded or lost. This may depend on type and distribution of infrastructure. Spacecraft operations: Low Earth orbit satellite operations may be degraded or lost. This may depend on type and distribution of infrastructure. Aviation operations: Some general aviation systems may experience loss of HF radio contact for a number of hours. HF radio contact may be degraded or lost for a number of hours.	X1	1000000 per cycle

Tormentas geomagnéticas

G5	Extreme	Power systems: Localized voltage control and protective system problems may occur leading to potential for localized loss of power. Transformers may experience damage. Spacecraft operations: may experience extensive surface charging, drag may increase on low-Earth-orbit satellites, problems with orientation, uplink/downlink and tracking satellites. Other systems: HF (high frequency) radio communication may be impossible in many areas for one to two days. GNSS/GPS satellite navigation may be degraded for days with possible effects on infrastructure reliant on GNSS/GPS for positioning or timing. Low-frequency radio navigation can be out for hours, and aurora may be seen across the whole of the UK.	Power systems: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. Spacecraft operations: may experience extensive surface charging, drag may increase on low-Earth-orbit satellites, problems with orientation, uplink/downlink and tracking satellites. Other systems: pipeline currents can reach hundreds of amps. HF (high frequency) radio propagation may be impossible in many areas for one to two days. Satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.).	Kp = 9	4 per cycle (4 days per cycle)
G4	Severe	Power systems: No significant impact on UK power grid likely. Spacecraft operations: may experience surface charging and tracking problems, drag may increase on low-Earth-orbit satellites, corrections may be needed for orientation problems. Other systems: HF radio propagation sporadic, GNSS/GPS satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora may be seen across the whole of the UK.	Power systems: possible widespread voltage control problems and some protective systems will probably trip out key assets from the grid. Spacecraft operations: may experience surface charging and tracking problems, corrections may be needed for orientation problems. Other systems: induced pipeline currents affect protective systems, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.).	Kp = 8, including a 9	100 per cycle (60 days per cycle)
G3	Strong	Power systems: No significant impact on UK power grid likely. Spacecraft operations: Surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. Other systems: Intermittent GNSS/GPS satellite navigation and low-frequency radio navigation problems may occur. HF radio may be intermittent, and aurora may be seen in Scotland and Northern Ireland and as low as Mid-Wales and the Midlands.	Power systems: voltage corrections may be required, false alarms triggered on some protection devices. Spacecraft operations: surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. Other systems: intermittent satellite navigation and low-frequency radio navigation problems may occur. HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.).	Kp = 7	200 per cycle (130 days per cycle)
G2	Moderate	Power systems: No impact on UK power grid. Spacecraft operations: Corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. Other systems: HF radio propagation can fade at higher latitudes, and aurora may be seen across Scotland.	Power systems: high latitude power systems may experience voltage alarms, long duration storms may cause transformer damage. Spacecraft operations: corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. Other systems: HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.).	Kp = 6	600 per cycle (360 days per cycle)
G1	Minor	Power systems: No impact on UK power grid. Spacecraft operations: Minor impact on satellite operations possible. Other systems: aurora may be seen as low as Northern Scotland.	Power systems: weak power grid but business not at risk. Spacecraft operations: minor impact on satellite operations possible. Other systems: irregular aurora; not affected at mid and higher levels; aurora is commonly visible at high latitudes (southern Michigan and Maine).	Kp = 5	1000 per cycle (900 days per cycle)

Semáforo de nivel de riesgo: Servicio de Clima Espacial México (SCiESMEX)

Color de Semáforo	Condiciones Necesarias	Nivel y Descripción
Amarillo 2	<ul style="list-style-type: none"> Atmósfera solar: $M1 \leq$ Flujo de Rayos X suaves $< X20$ de lado noche. Medio interplanetario: Detección de EMC, posiblemente dirigida a la Tierra, con $v0 > 1000$ km/s. Velocidad de viento solar in-situ > 800 km/s. Magnetosfera terrestre: $7 \leq Kp \leq 8$ y/o $-150 \text{ nT} \geq Dst > -250 \text{ nT}$. Ionosfera terrestre: Reportes de ionosfera significativamente perturbada de otras regiones del planeta. Posibles auroras boreales vistas en latitudes altas y medias (55°N-45°N). Rayos cósmicos: Flujo de Rayos X suaves $\leq M8$ 	<p>Precaución</p> <p>Detección de evento intenso, sin afectaciones significativas en México.</p>
Amarillo 3	<ul style="list-style-type: none"> Atmósfera solar: $M1 \leq$ Flujo de Rayos X suaves $< X20$ de lado día. Medio interplanetario: Se confirma EMC dirigida al entorno terrestre a menos de 0.5 UA de distancia a la Tierra. Magnetosfera terrestre: $8 \leq Kp \leq 9$ y/o $-250 \text{ nT} \geq Dst > -450 \text{ nT}$ Ionosfera terrestre: $dTEC > 350\%$. Posibles auroras boreales vistas en latitudes medias (45°N-36°N) Flujo de Rayos X suaves $> M8$ 	<p>Alerta</p> <p>Evento intenso con afectaciones en México.</p>
Rojo	<ul style="list-style-type: none"> Atmósfera solar y Rayos cósmicos: Flujo de Rayos X suaves $\geq X20$ Medio interplanetario: Detección in-situ de arribo de EMC y/u onda de choque. Magnetosfera terrestre: $Kp = 9$ y $Dst \leq -450 \text{ nT}$ Ionosfera terrestre: $TEC \geq 250 \text{ TECU}$. Posibles auroras boreales vistas en latitudes de México (menores a 35°N) 	<p>Grave</p> <p>Posible evento catastrófico (Carrington).</p>
No Aplica	<p>Cuando las condiciones a reportar:</p> <ul style="list-style-type: none"> no se recomienda un semáforo superior o igual a Amarillo 2, se presenta una cancelación o conclusión de evento. 	No Aplica

¿Cómo Alertar a la Población Sobre los Riesgos por Efectos Fenómenos de Clima Espacial?

Antes de dar una alerta temprana...

¿qué ocurrió?

¿qué está pasando?

y ¿qué se puede esperar en las próximas 12, 24, 48 y 72 horas?

¿cuáles son sus posibles efectos?

¿ya ocurrieron?

Si no, ¿cuándo se presentarán?

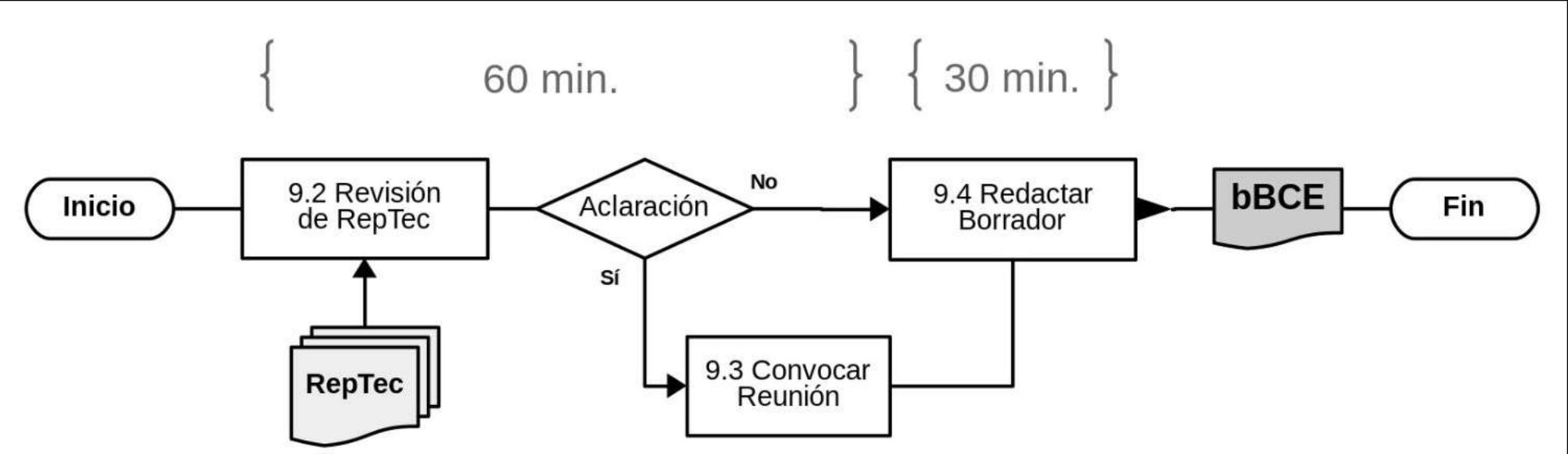
¿por cuánto tiempo?

¿qué regiones de México se verían afectadas?

¿de qué forma podrían ser afectadas?

¿impacto en la salud?

Procedimiento



Boletín de Clima Espacial (BOCE) del Servicio de Clima Espacial México

Boletín de Clima Espacial :: Seguimiento

Emisión: 14/03/2019 - 12:34 BOCE/01/2019-04#

Ing. Israel Santacruz Isunza
Subdirector del Plan de Emergencias Radiológicas
Dirección General de Protección Civil
Secretaría de Gobernación

Estimado Ing. Santacruz, me permito enviarle el Boletín de Clima Espacial, el cual es resultado de el seguimiento realizado al fenómeno detectado el día 28 de octubre a las 06:00 horas en tiempo local.

A continuación encontrará información que espero le sea de utilidad.

A SEMÁFORO

Color Sugerido			
No Aplica	Amarillo 2	Amarillo 3	Rojo

Justificación:
 GRAVE. Posible evento Carrington. Tormenta geomagnética extrema.

DESCRIPCIÓN

Seguimiento al BOCE/01/2019-04i

Desde hace una semana sol presenta dos regiones activas (0484 y 0486) que han producida una serie de fulguraciones intensas y extremas (tipo M y X) y eyecciones de masa coronal muy rápidas (velocidades mayores de 1000 km/s) en dirección a la Tierra.

Se reporta la detección de una tormenta geomagnética extrema clase G5. La tormenta inicio aproximadamente a las 02:00 tiempo local y al momento de la redacción de este reporte alcanza un Kp=9 y un Dst=-150 nT. La tormenta geomagnética no ha alcanzado la etapa de recuperación por lo se espera que su fase principal se extienda varias horas y su duración se extienda por varios días. La ionosfera sobre el territorio nacional se también se encuentra perturbada y seguirá la evolución de la tormenta magnética. No se detectan efectos de partículas energéticas solares en este momento sobre el territorio nacional.

Extracto de un simulacro

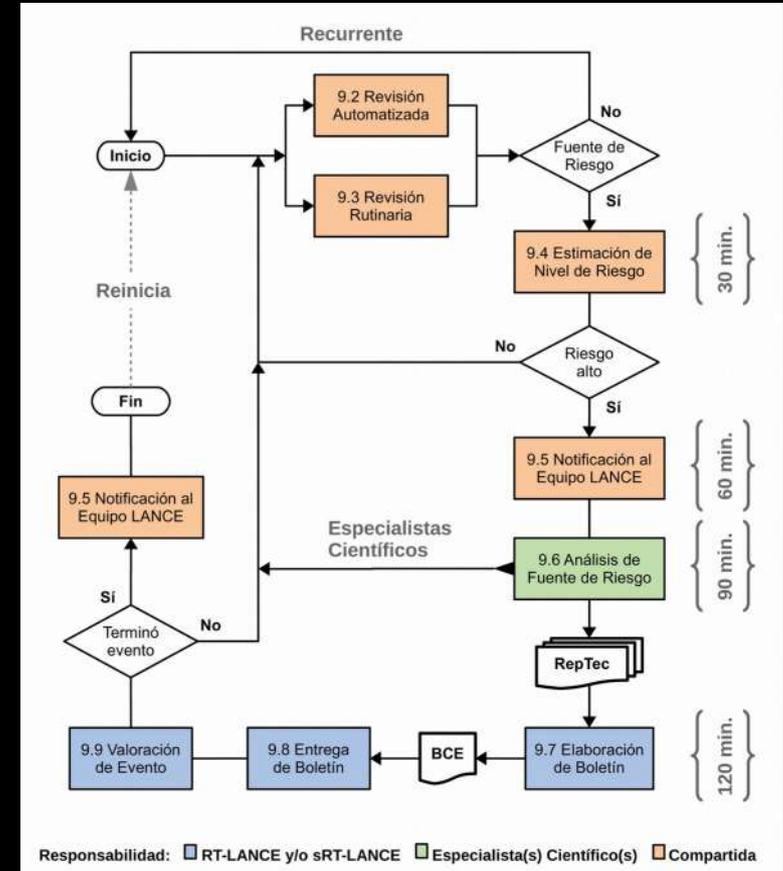


Diagrama para elaborar el BOCE



SCiESMEX

Servicio de Clima Espacial – México

<http://www.sciesmex.unam.mx>



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Laboratorio Nacional
de Clima Espacial

