High Altitude Environment for Wx Balloons

Space Weather: Upper-atmospheric Space and Earth Weather eXperiment (USEWX)

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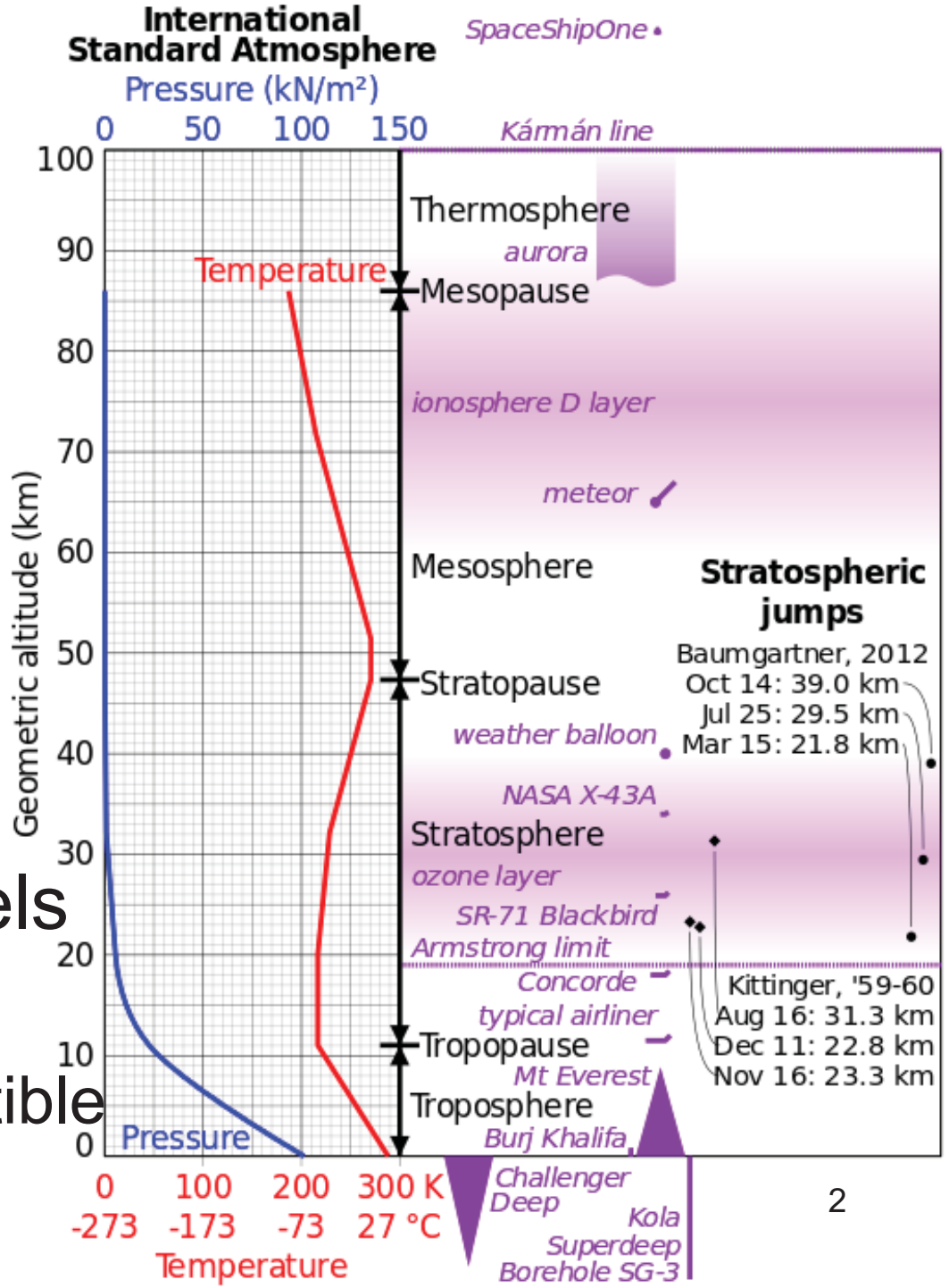
Jacobs Inc.

Teachers in Space Workshop

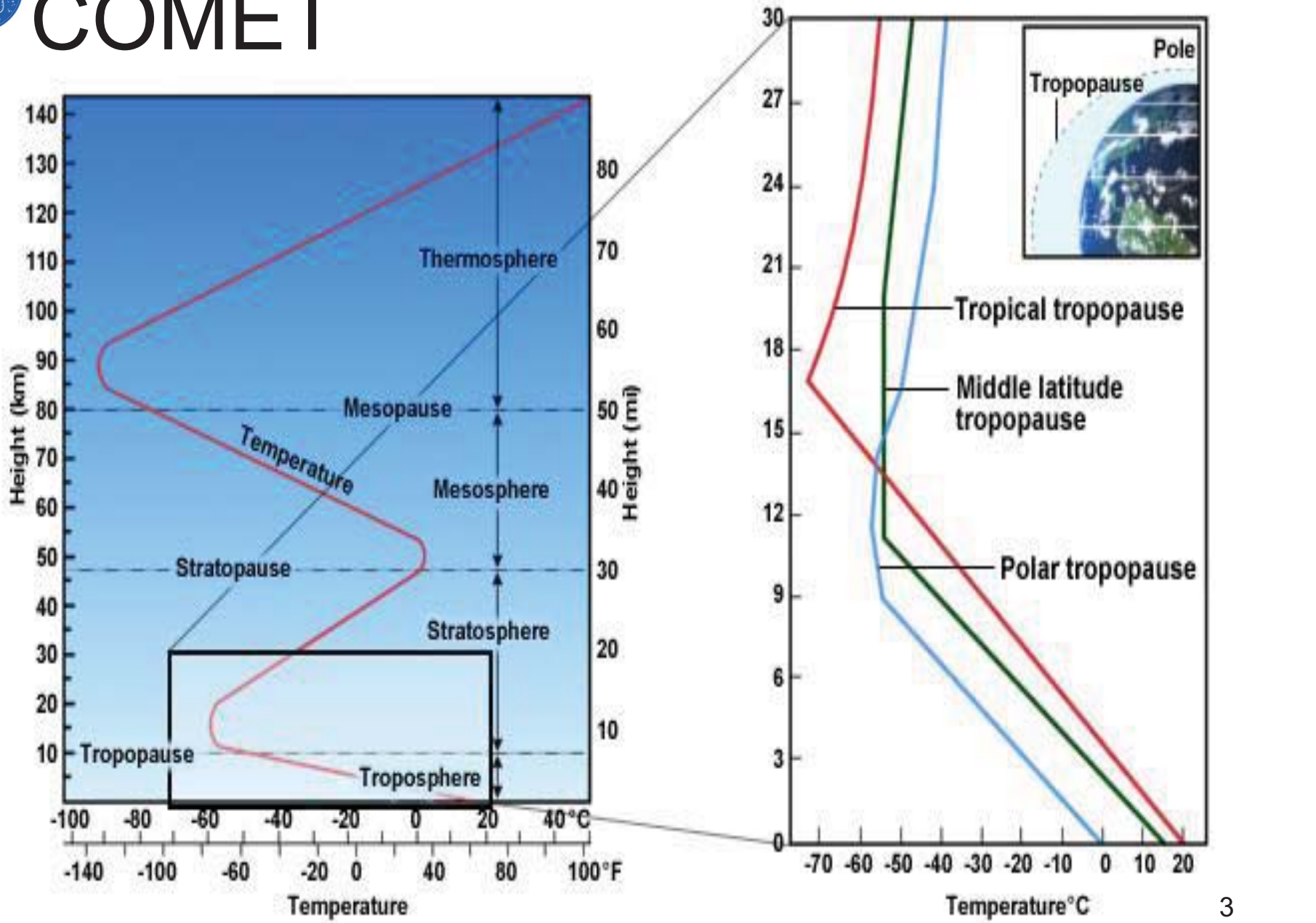
July 21-25, 2014

Standard Atmosphere

- Cold-battery life
- Low pressure-
  - Sealed containers
  - High pressure differential
- Dry-ESD
- High Radiation levels
  - Human dosing
  - Electronics susceptible to failures

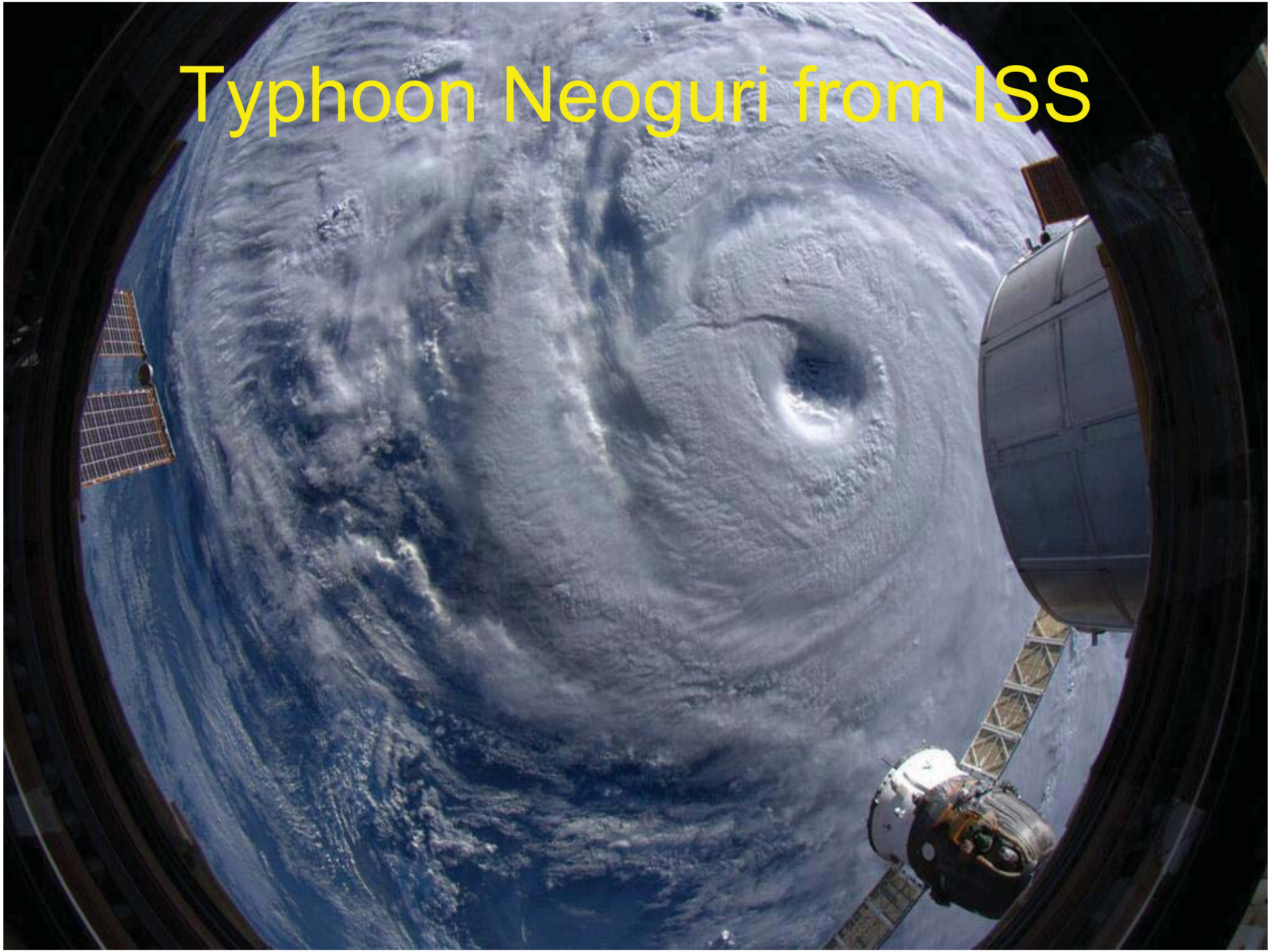


COMET



AFRC/NWS Radiosondes

Typhoon Neoguri from ISS



What is Space Weather?

- **Two sources of space weather**

1. **Inside Our Solar system: a known source direction**

   Our Sun emits:

   - **Photons**
   - **X-rays**
   - **Solar Energetic Particles (SEPs)**
   - **Solar radiation**
     - **Protons, electrons, ions (p, a, Fe^{+})**
   - **The Sun's Magnetic field varies considerably**

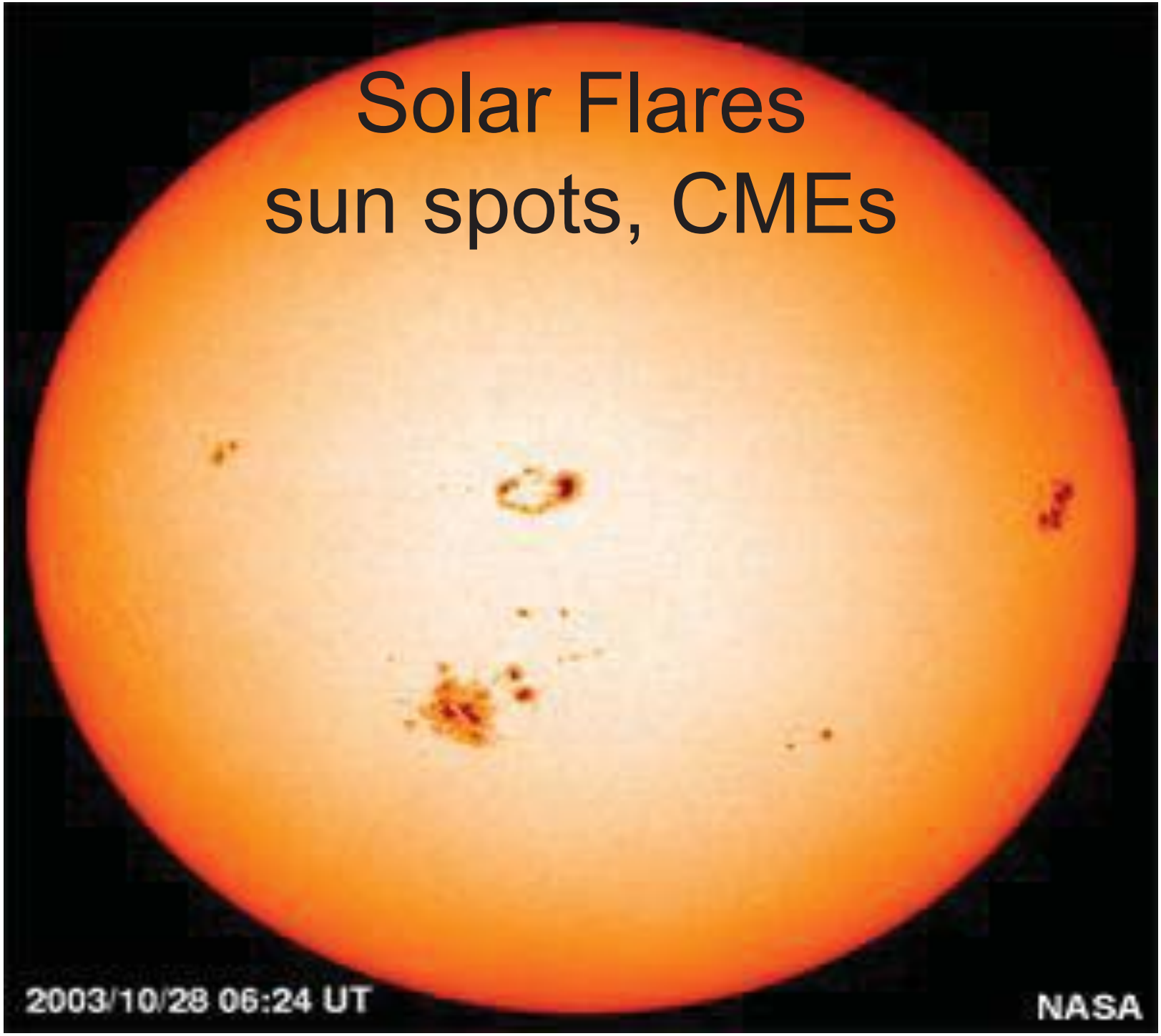
2. **Outside our solar system: an unknown source direction**

   Black Holes, Supernovas, higher energy particles plus other stars

   - **Galactic Cosmic radiation (n, p, e, a, $\pi, m, \ \Gamma - rays$)**

- **Space weather is the dynamical variability of the Sun's photons, particles, and fields and they interact with the Earth's near-space environment and our technology.**

Solar Flares
sun spots, CMEs



COMET: Timeline of a Solar Storm

SWPC Space Wx Scales

Radio Blackouts R scale

- First to arrive (2-30 min)
- Radiation: X-rays
- High Frequency (HF) radio blackouts for 1 hour
- Navigation Errors
- # of occurrences in 11 yr. solar cycle:
- R-1 2000
- R-2 350
- R-3 175
- R-4 8
- R-5 <1

Solar Radiation Storm S scale

- Second to arrive (1-3 hours)
- Radiation: High energy Particles-Protons, high energy gamma rays, ions (Fe,O,Ur)
- Humans:Bio-mutations, cancer, DNA damage, HF, Nav, satellite damage
- Duration 42 hrs. # occurrences:
- S-2 25
- S-3 10
- S-4 3
- S-5 <1

SWPC Space Wx Scales (cont.)

Geomagnetic Storms G scale

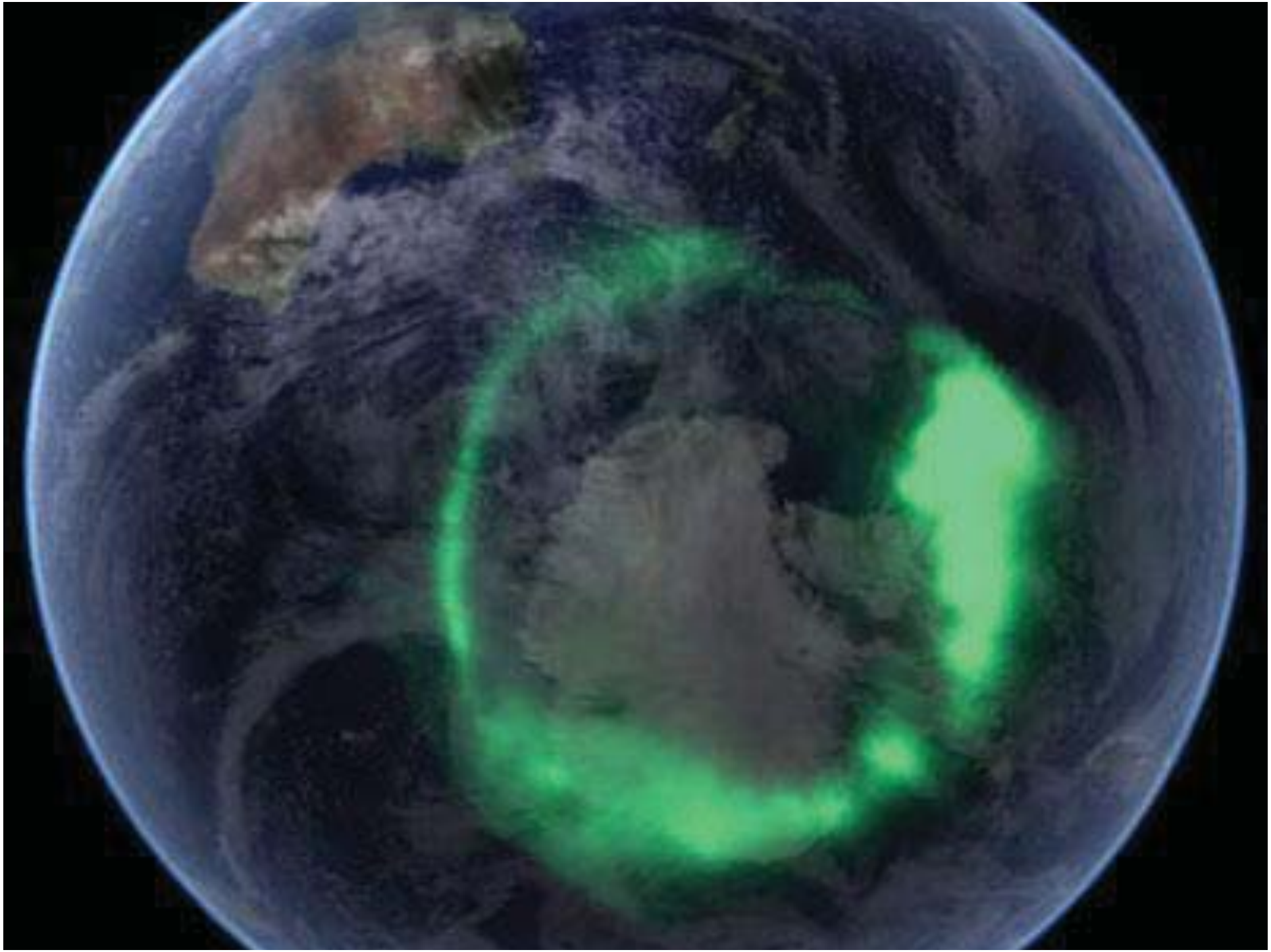
- Third to arrive (30-50 hours)
- Radiation: Kp
- Power companies experience high currents-transformer damage, protective trips, electrical grid impact/blackouts
- HF, LF, Navigation systems/GPS, Oil Pipeline high current
- Spacecraft/Satellite operations: safe mode to prevent losses, ISS crew to most shielded section of ISS
- G-1 1700
- G-2 600
- G-3 200
- G-4 100
- G-5 4

Space weather evolution

- Geomagnetic Storms are created as space weather interacts with a planet's magnetic field and their atmosphere.
- Magnetic poles are the focus for higher particle and radiation events. They follow the magnetic field lines down
- Charged particles in the solar wind interact with atoms and ions through collisions with atmospheric atoms
- Atmospheric molecules become "excited" through collisions and outer electrons jump to higher energy orbits. As the electrons move back to lower energy orbits the molecules give off light
- This causes the aurora. Aurora colors are dependent on what elements are involved. Green=Excited O2, Blue=Ionized N2, Red=Excited N2 and O2


Aurora
NASA


limb
star

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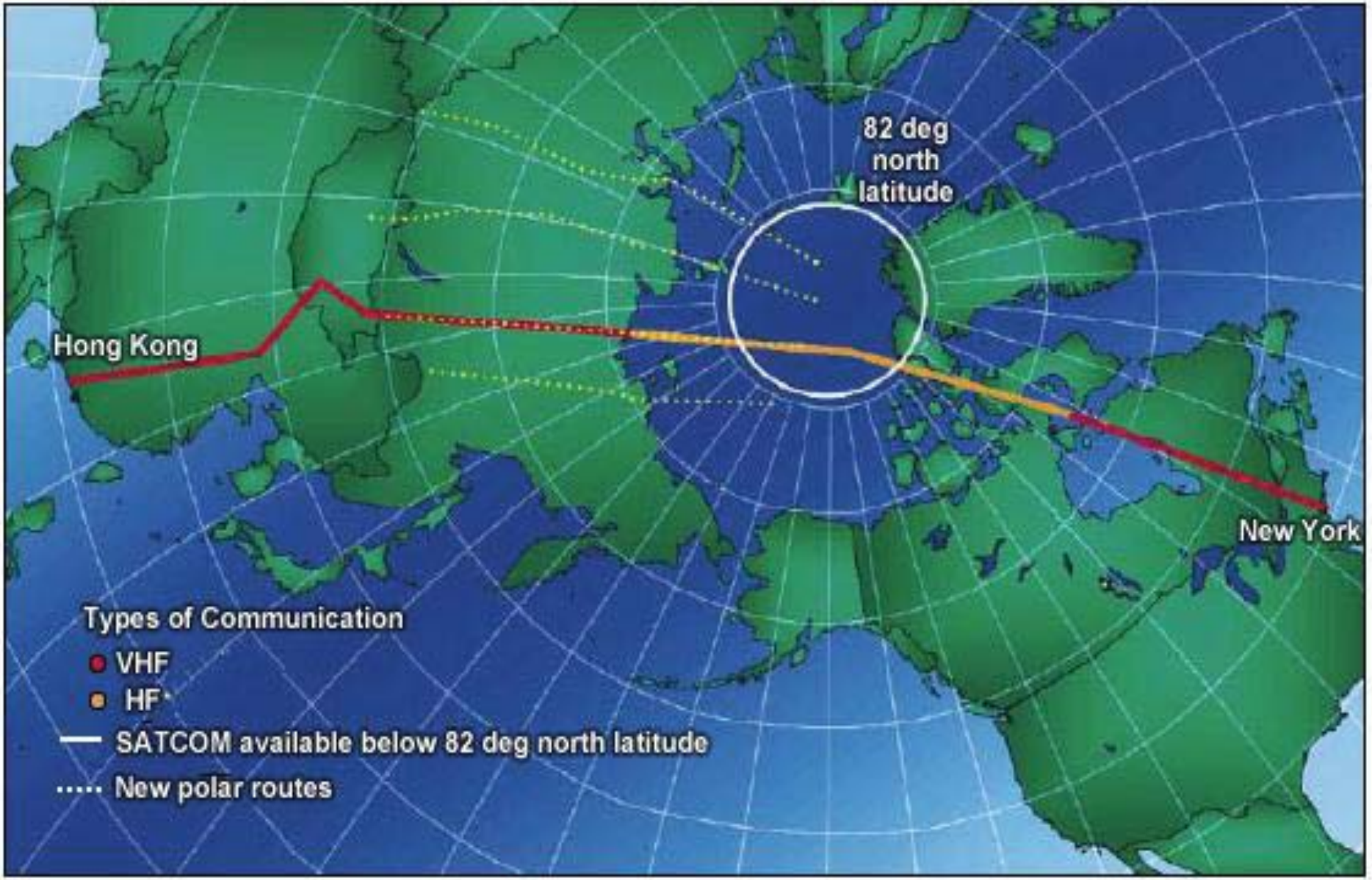
Space Weather in 3D

- http://iswa.gsfc.nasa.gov/downloads/20130709_203400_anim.tim-den.gif
- http://www.swpc.noaa.gov/
- http://spacewx.com/Space_Weather_Now.html
- Space Weather Impacts on Aviation
- http://www.spaceweather.com/


82 deg
north
latitude
Hong Kong
New York
Types of Communication
VHF
HF
SATCOM available below 82 deg north latitude
New polar routes

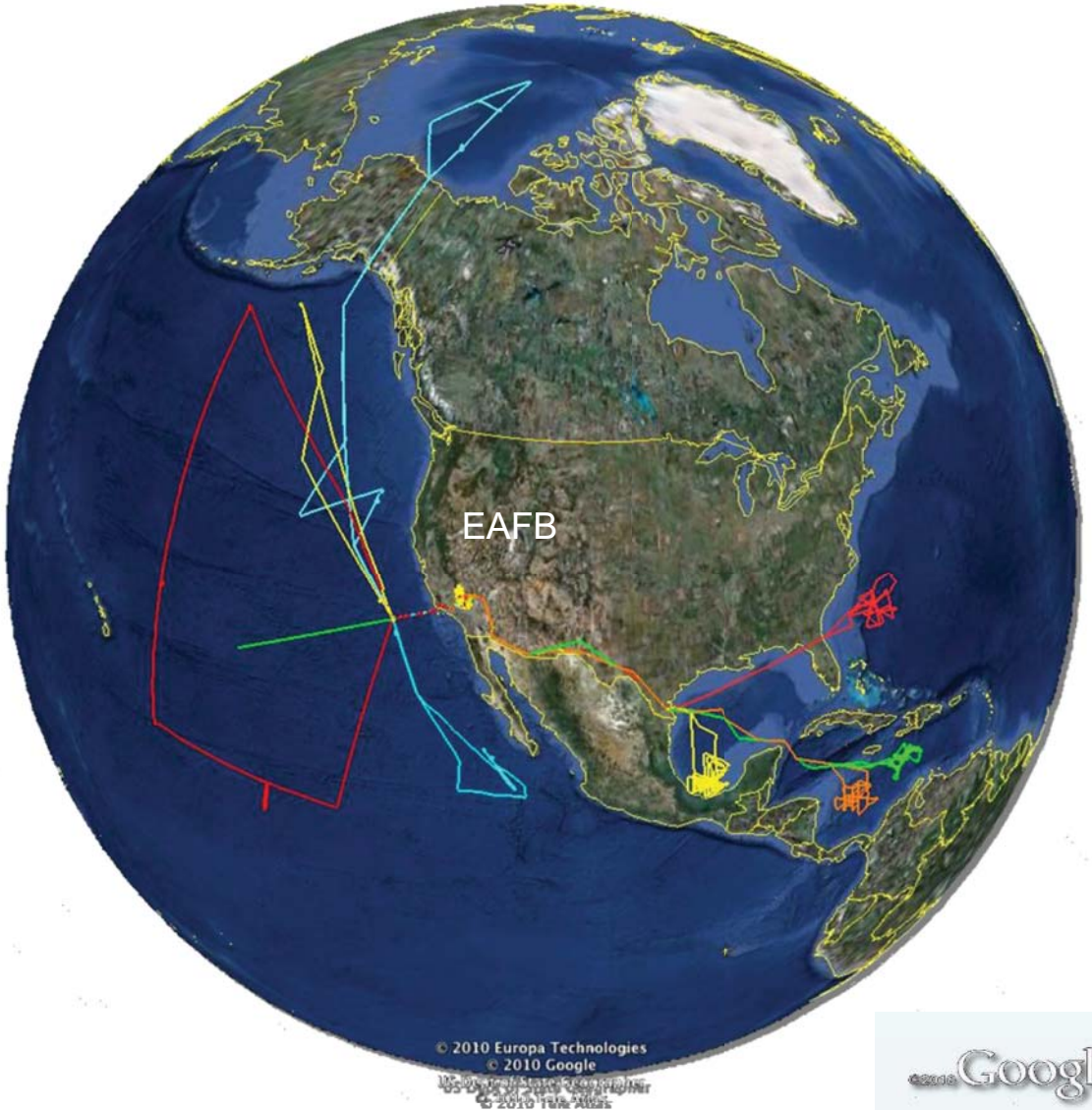
NOAA/NWS

COMET: GPS errors over US

- Arctic/Antarctic areas of high scientific value
- High radiation Earth/Sun interaction

- Human Radiation Dosing (flight crews/PAX)
- Radio Blackouts, GPS Navigation Errors
- **Single Event Effects (SEEs) can damage Integrated circuits and software (bit flipping)**
- **USEWX dosimeters on ICE Bridge in Oct-Nov 2014**

Why is NASA AFRC concerned about Space Weather?



Flights are:
Polar and Equatorial
ER-2 and Global Hawk fly very high above the protective levels in the Earth's atmosphere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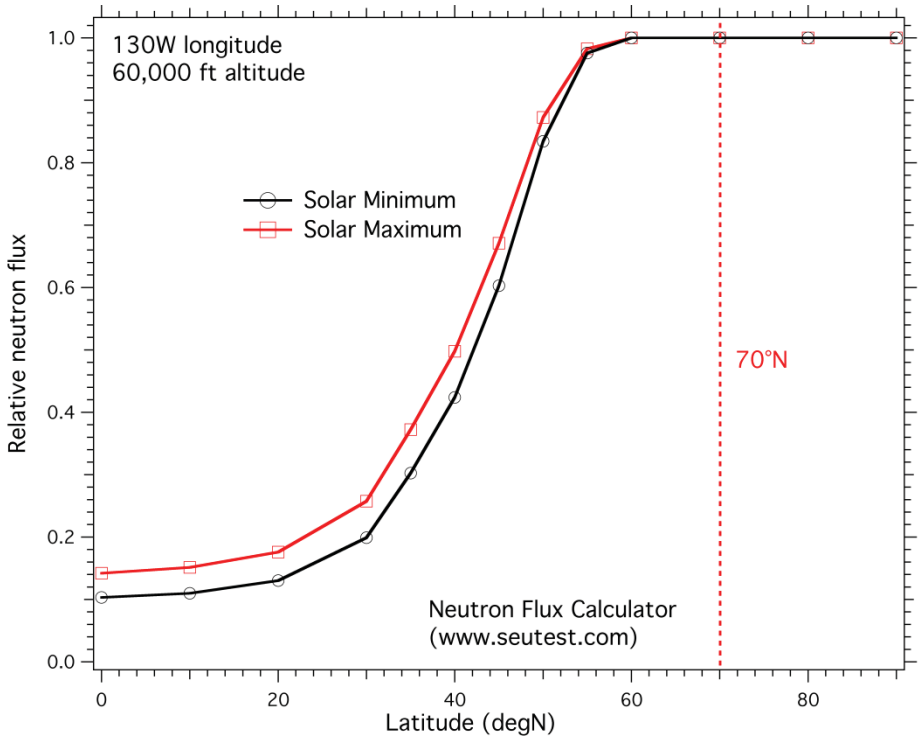
NORTHROP GRUMMAN
DRYDEN FLIGHT RESEARCH CENTER

IKHANA

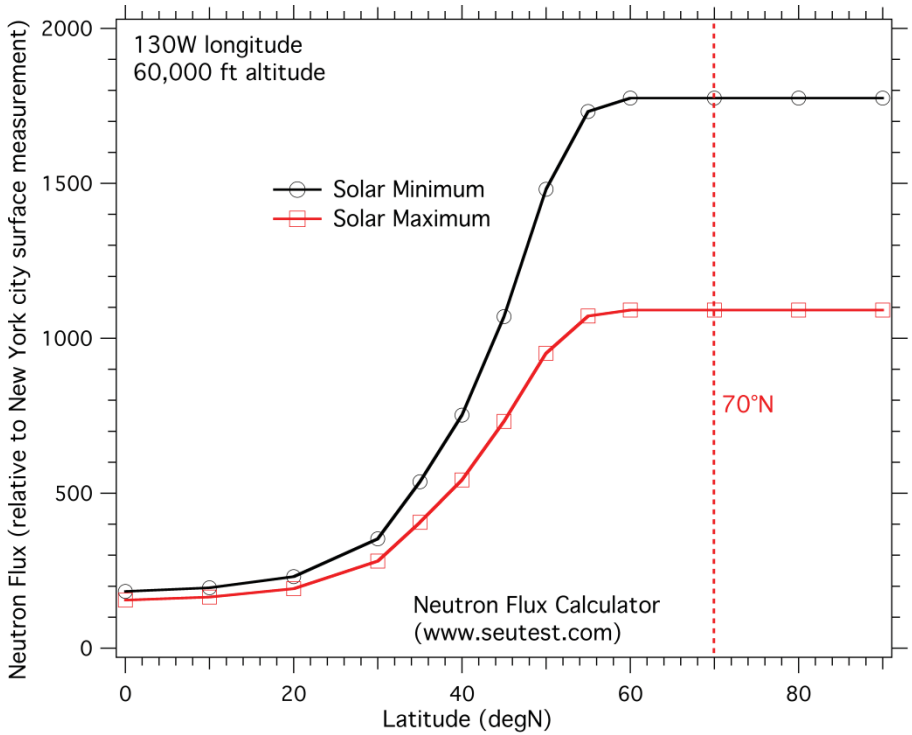
Calculations of the latitude dependence of neutron flux

Neutron flux normalized to 90° N



- Flux values are normalized to the value at 90° latitude.
- The variation in latitude gradient is less than 10% between solar min and max.
- Normand and Baker results (Fig. 2) match the latitude dependence at solar maximum.
- No change in flux occurs above 70° N.

Neutron flux relative to NYC



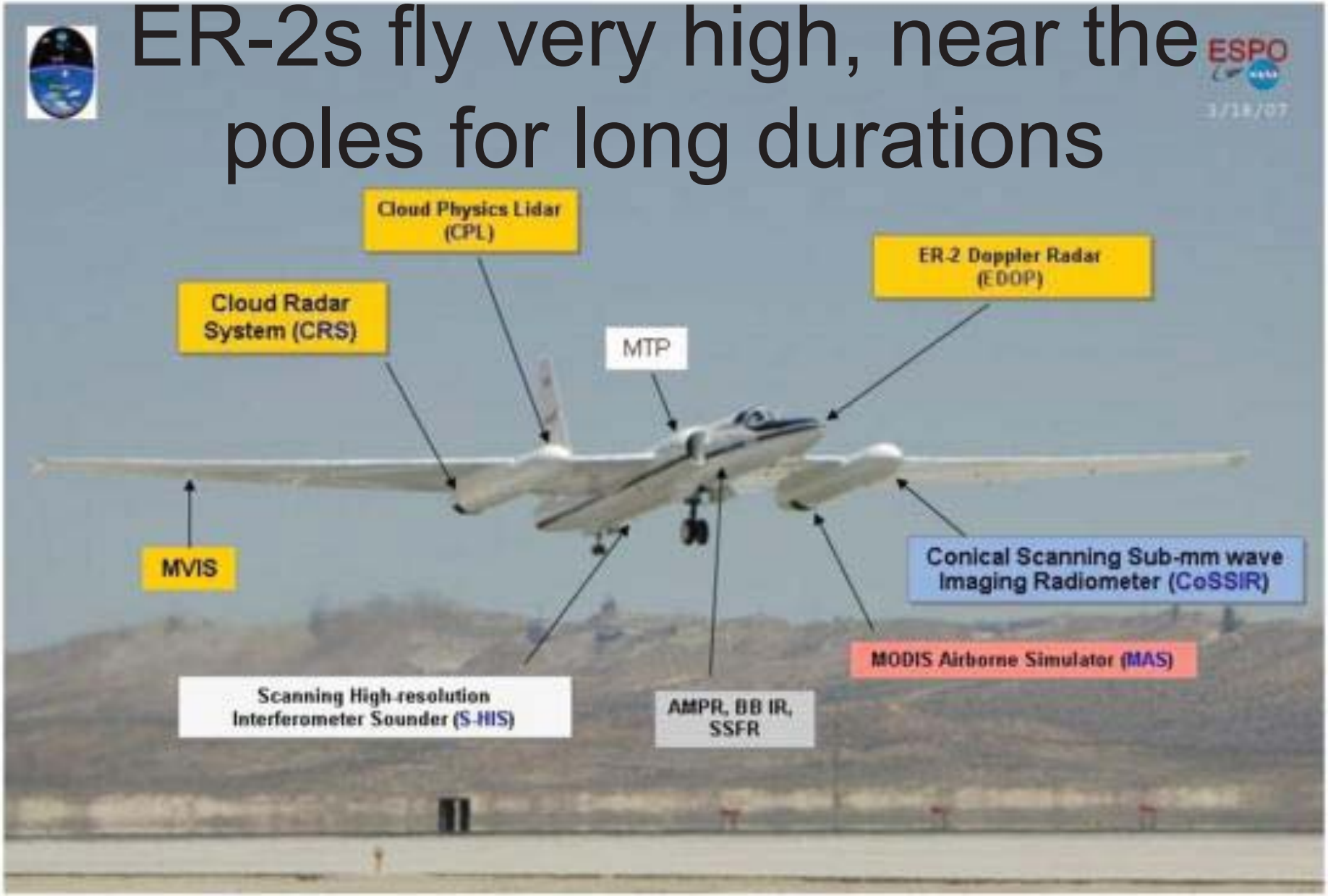
- Flux values are referenced to the value measured in New York City at the surface.
- The flux changes by a factor of 1.6 between solar minimum and solar maximum.
- No change in flux occurs above 70° N.

(www.seutest.com calculations represent the most current scientific understanding of the dependences of neutron flux on altitude, latitude, and solar cycle.)

DFRC C-20 over Iceland


NASA
DLR
SOFIA

ER-2s fly very high, near the poles for long durations

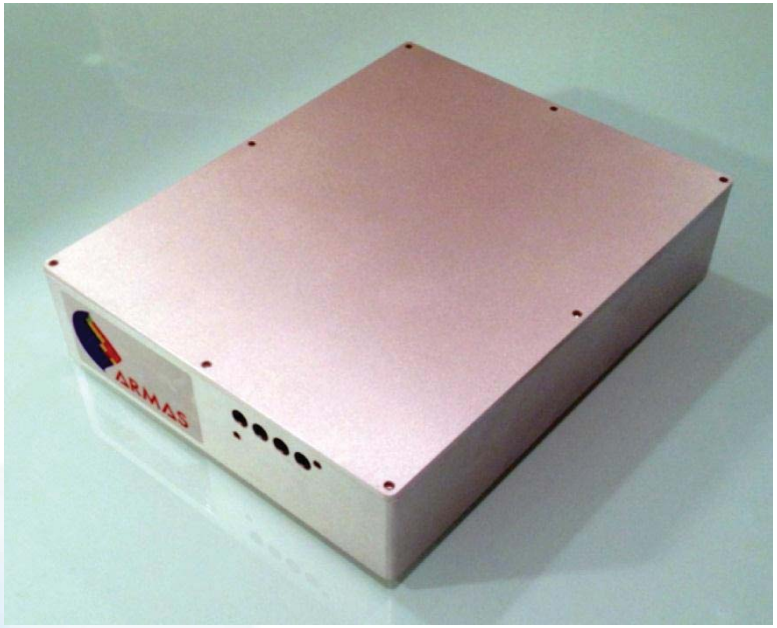


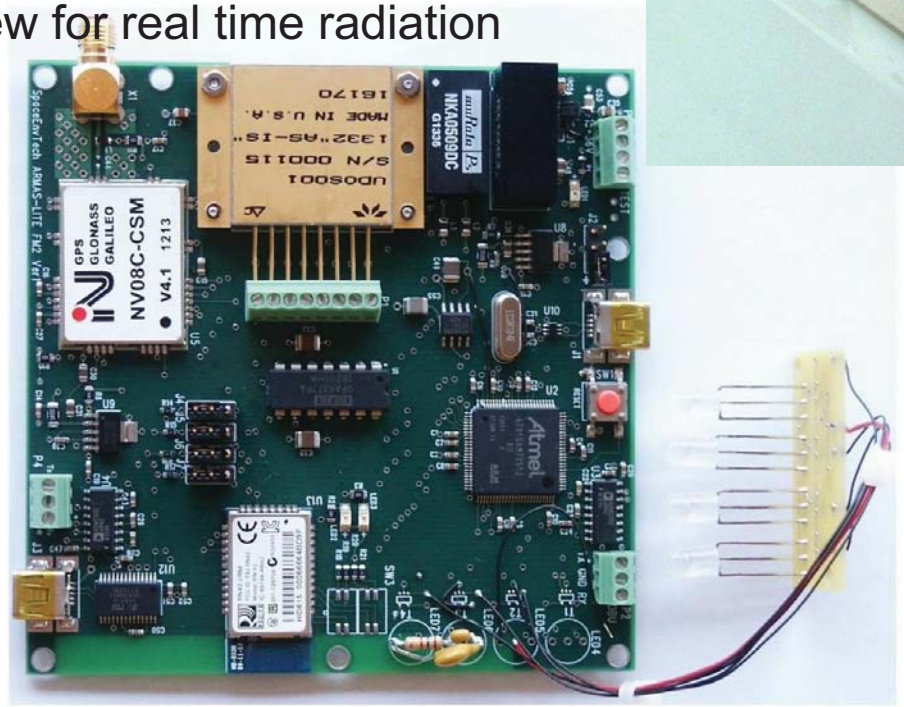
Hawk TEPC Dosimeter

- TPEC-Tissue Equivalent Proportional Counter (human dosing)
- Passive-measures neutrons and gamma radiation
- Flew on DFRC/Lockheed ER-2 1990s
- 20 year old technology
- Must be pressurized to prevent elect. arcing
- Large, bulky, expensive $25K
- In process to fly on SOFIA B747-SP
- Flown on United and Virgin Atlantic
- Polar routes

USEWX Commercial Partner: Space Environmental Technologies (SET)

- Silicone based micro-dosimeter
- Tremendous potential to fly due to size
- Still costly $40-50K
- Too expensive to launch on a weather balloon
- Commercial space vehicles, Aircraft, High altitude balloons (drifters), ISS
- Expandable, customizable, GPS/Blue tooth
- Direct data to crew for real time radiation decision making!



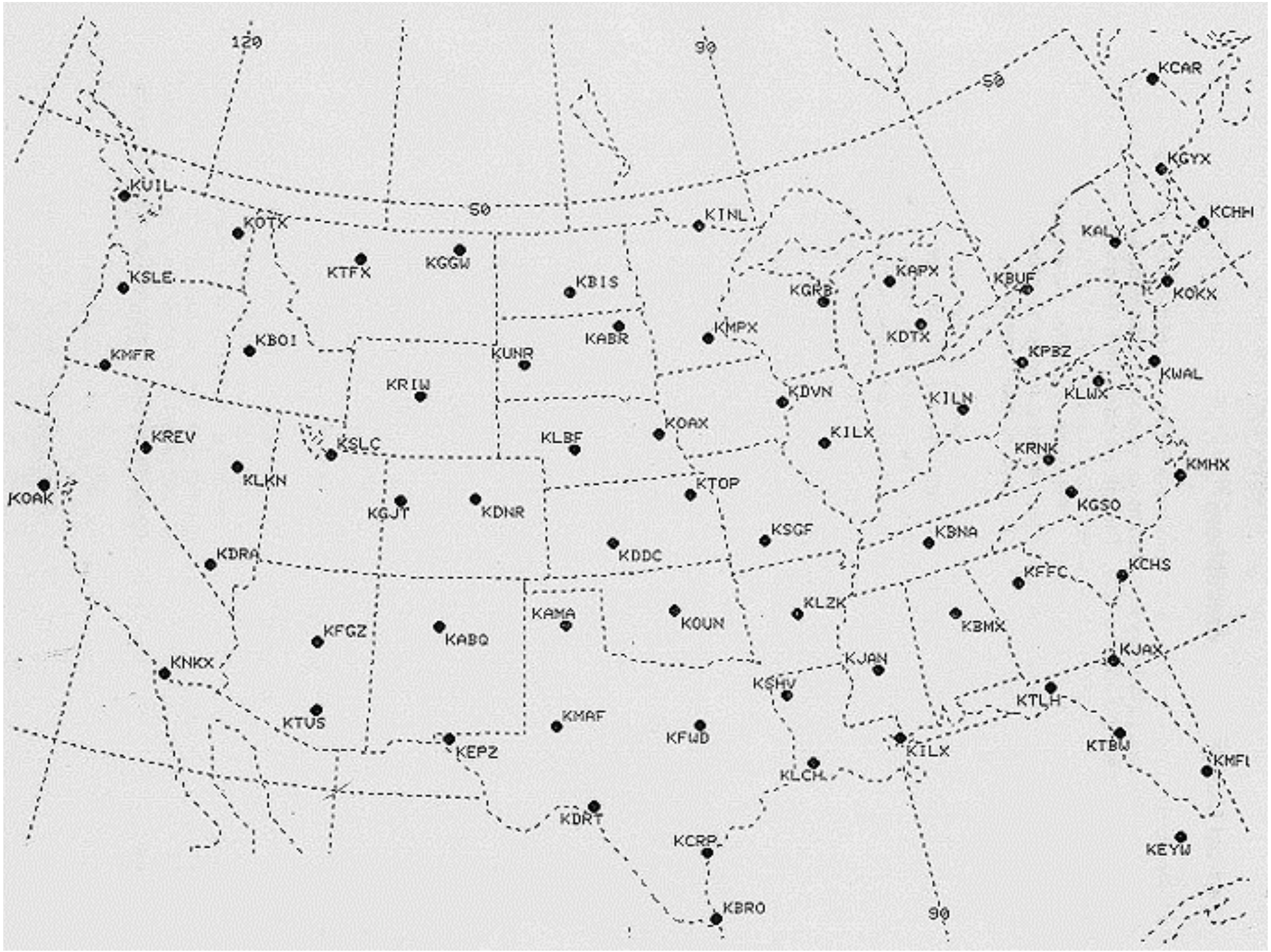


Weather Balloon Launch in support of flight testing

- AFRC Radiosonde equipment
- AFRC Research Instrumentation
- Work to develop cheaper radiation sensors example: medipix
- Ground test to compare/calibrate in ground particle accelerators
- Flight test cheaper dosimeter package with Vaisala Radiosonde interface

Medipix sensor with USB port

- Inexpensive
- New Technology
- Small, Portable
- Easily Interfaced
- Integrate with a weather balloon instrumentation
- Standardized: selected to fly on Orion
- Provide radiation data in real time to Pilots, UAV Operators, Teachers, Students, Partners, Researchers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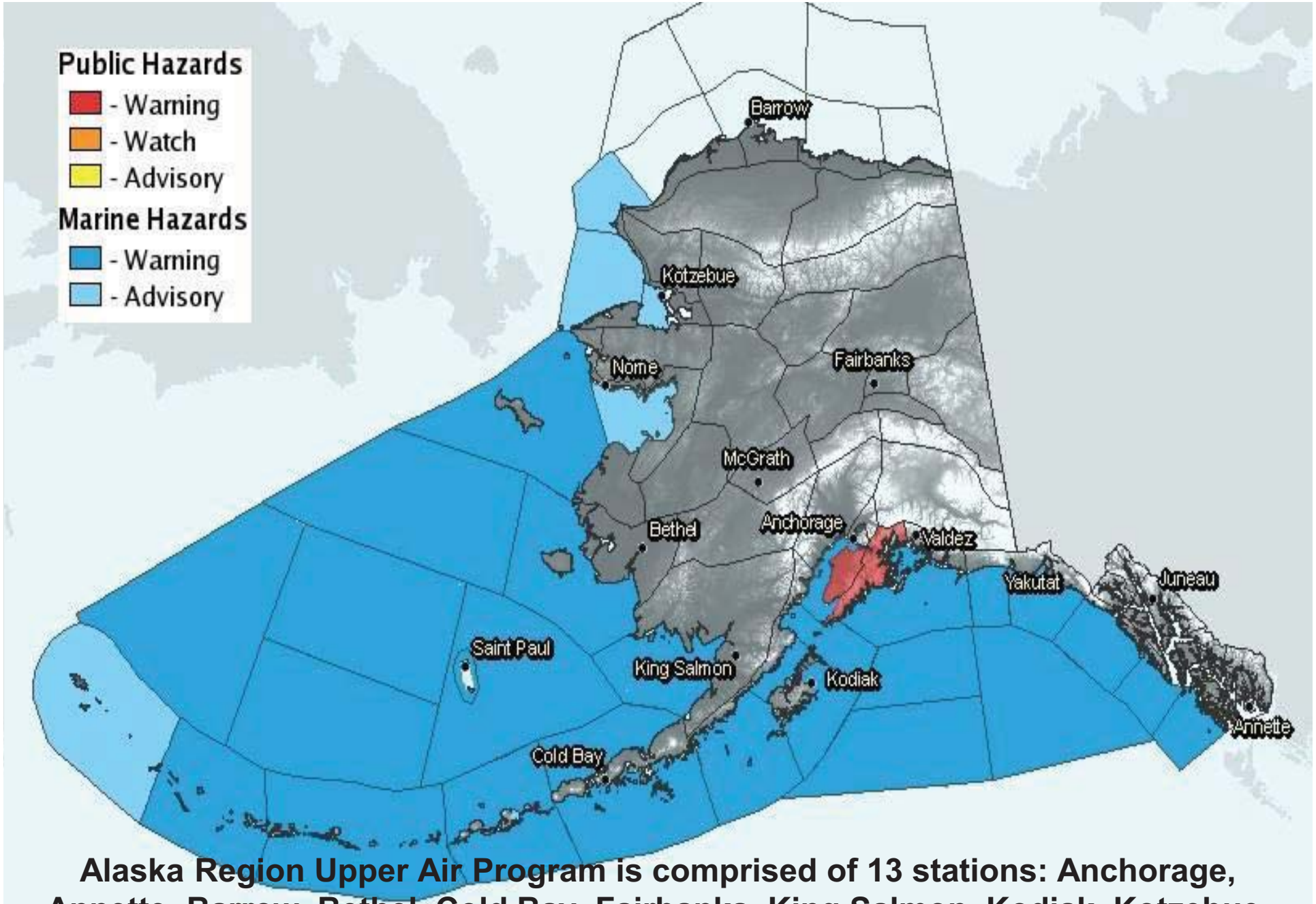


Alaska Region Upper Air Program is comprised of 13 stations: Anchorage, Annette, Barrow, Bethel, Cold Bay, Fairbanks, King Salmon, Kodiak, Kotzebue, McGrath, Nome, Saint Paul Island, and Yakutat.

Partners/Potential Partners

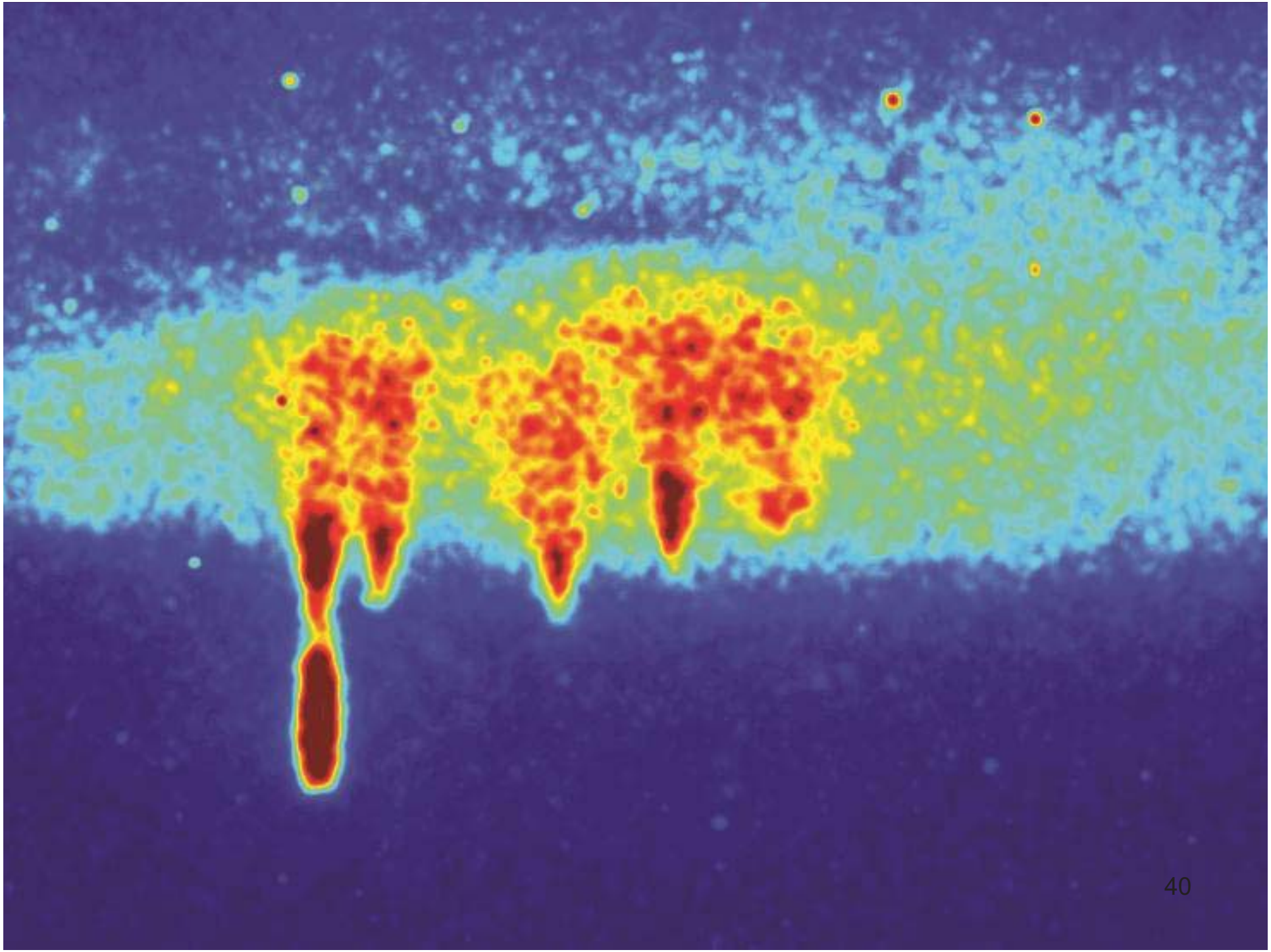
- NASA: AFRC, GSFC, JPL, JSC, KSC, Wallops, Teachers in Space (TIS), STEM
- NOAA: Space Weather Prediction Center (SWPC), National Weather Service (NWS)
- Education: U of Oklahoma/OK State, U of Houston, Prairie View A&M, Irvine Valley College, Edwards AFB 412th STEM outreach
- International: DLR, CERN
- Commercial Space, FAA, Boeing, Northrop Grumman, General Atomics, other UAV platforms

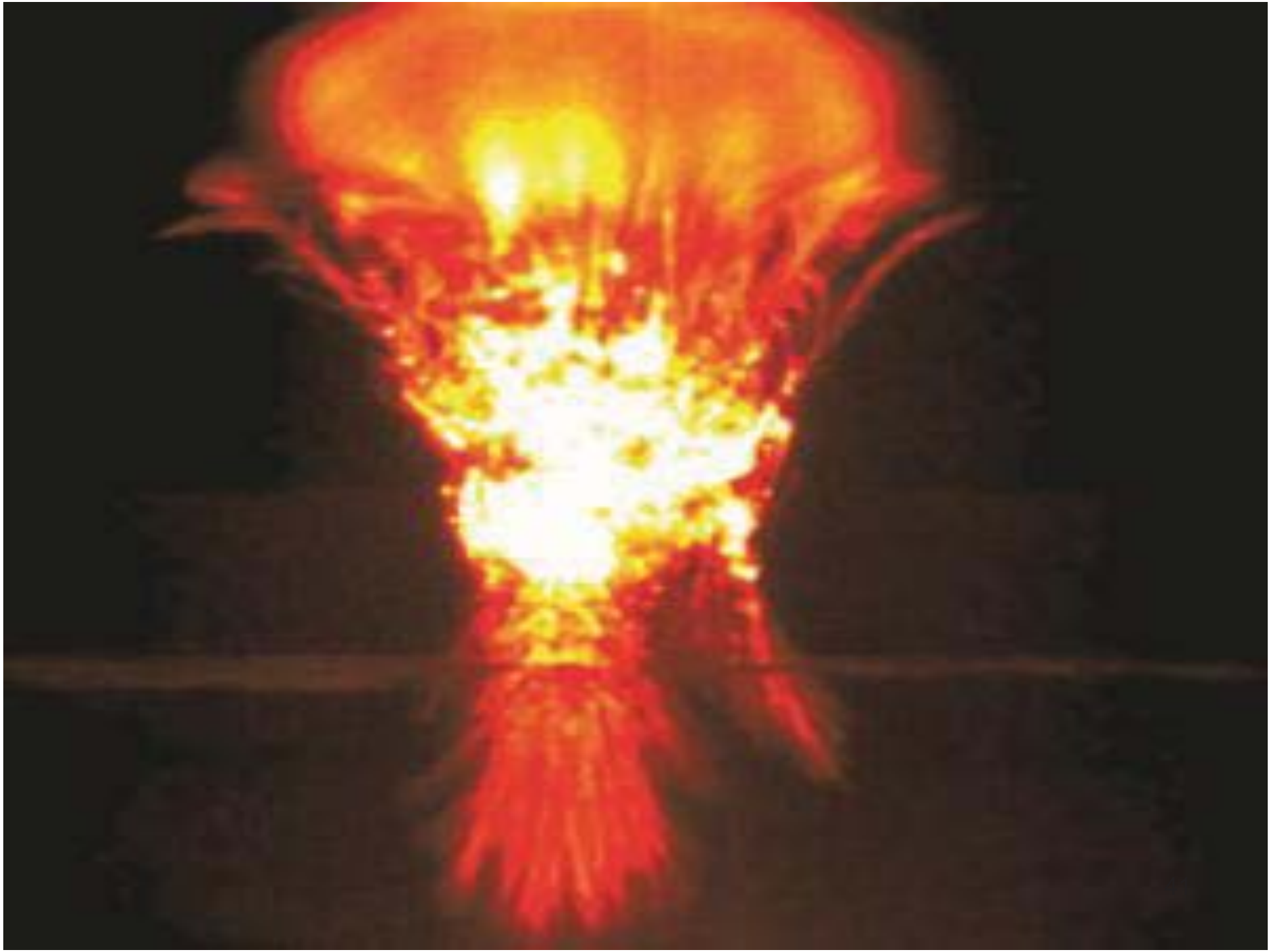
USEWX Phase I

- Ground calibrate new Teledyne micro-dosimeter with linear accelerators
- Suite of dosimeters, Thermal Neutron detector(s) on AFRC flight assets with priorities ER-2, Global Hawk, DC-8, others
- Compare data looking for correlations between high and low energy particles, galactic cosmic radiation, human dosing
- Real time radiation data to ER-2 pilot via Bluetooth or hardwire to cockpit

USEWX Phase II

- SET builds additional micro-dosimeters for Global Hawk, DC-8, others
- Develop an inexpensive dosimeter possibly kit built by students
- Integrate a weather sensor package to include dosimeter radiation instrumentation
- Distribute Medipix/interface to partners/teachers
- SWPC/NASA GSC forecast Space Weather Day of interest for coordinated flights and launches
- TIS, STEM, Discovery visit launch sites, chase and recover payloads for reuse
- Worldwide coordinated effort-SWPC , TIS, CERN, NWS, AFRC, DLR
- Balloon launches NWS, TIS, AFRC, CERN, Dr. Phillips's group
- Dosimeter data from: ISS, Satellites, Curiosity module to be added to USEWX database on SPACE (UCLA) and i(GSC)





Weather Hazard Awareness and Alert Technology WHAAT?

- Weather (WX) is a cause or factor in 50% of all aviation fatalities
- Weather delays cost billions a year and drive higher fuel/ticket costs
- Aircraft share WX data
- FAA nextgen solution
- Safety and efficiency improves
- Temperature, Humidity, Turbulence, Icing, wind data taken now, but not provided to Pilots in real time (TAMDAR/AMDAR), just used for input into WX models

- A 20% improvement in weather forecast accuracy by using this WX data
- Integrate improved Collision Avoidance Technology (iCAT) with onboard weather sensor data to process looking for WX hazard signatures/collisions with terrain
- PHASE I- Fly into WX hazards determine signature of hazard (Mtn Waves at EDW)
- Develop algorithms to recognize hazards and warn the pilot before experiencing it!
- Develop pilot data and alert interface, automated pilot reports (PIREPs)
- Develop communication method to warn other nearby aircraft that a hazard has been detected (ex. ADS-B, Iridium, Inmarsat, etc.)

WHAAT Phase I

- iCAT gives us terrain information and avoidance abilities. We develop algorithms for efficient and safe flight by Weather Advantage Routing (WAR).
- Utilize pilot/aircraft limitations for all weather hazards and account for downdrafts based on terrain/wind connections
- Develop dosimeters and Weather instrumentation for aircraft, Radiosondes and commercial space payloads i.e. merge USEWX and WHAAT
- Populate a database for all partners to use
- FAA NEXTGEN solution

Benefits

- **Aircraft accident reductions, Increased flight safety**
- **Better understanding of Space Weather, modeling and development of radiation exposure reduction techniques**
- **Pilots would have onboard data to use for weather hazard avoidance, changing altitudes or route to minimize radiation exposure during solar events and weather hazards (ex. Thunderstorms, Icing, Turbulence, etc.)**
- **Better Weather forecasts (Space and flight weather), model improvements, larger volume weather/space observations**
- **STEM partnerships promoting both Space Weather/Weather projects for students involving cutting edge research**
- **Develop procedures to minimize harmful radiation exposure to astronauts on ISS, Mars, and Asteroid missions**

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Questions?