Atmospheric Effects

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Presented by

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Lead Scientist
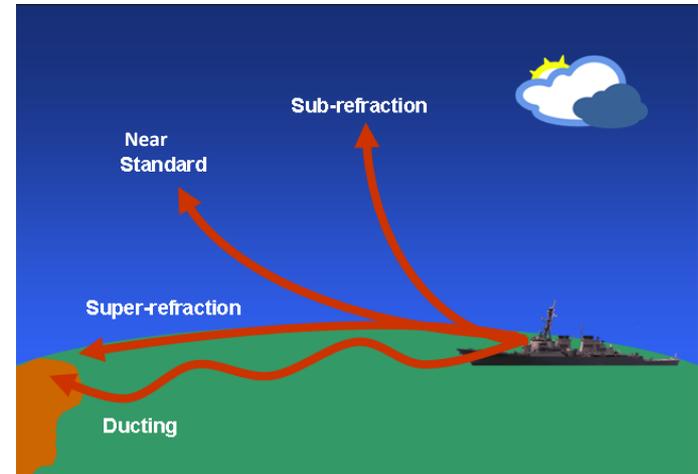
Propagation Measurements and Analysis Group

Sensor Data Collection and Analysis Branch

Types of Propagation

- Propagation environments are typically defined as
  - Free space (F = 1)
  - Near standard
    - "Standard" does not mean common
  - Sub-refractive
  - Super-refractive
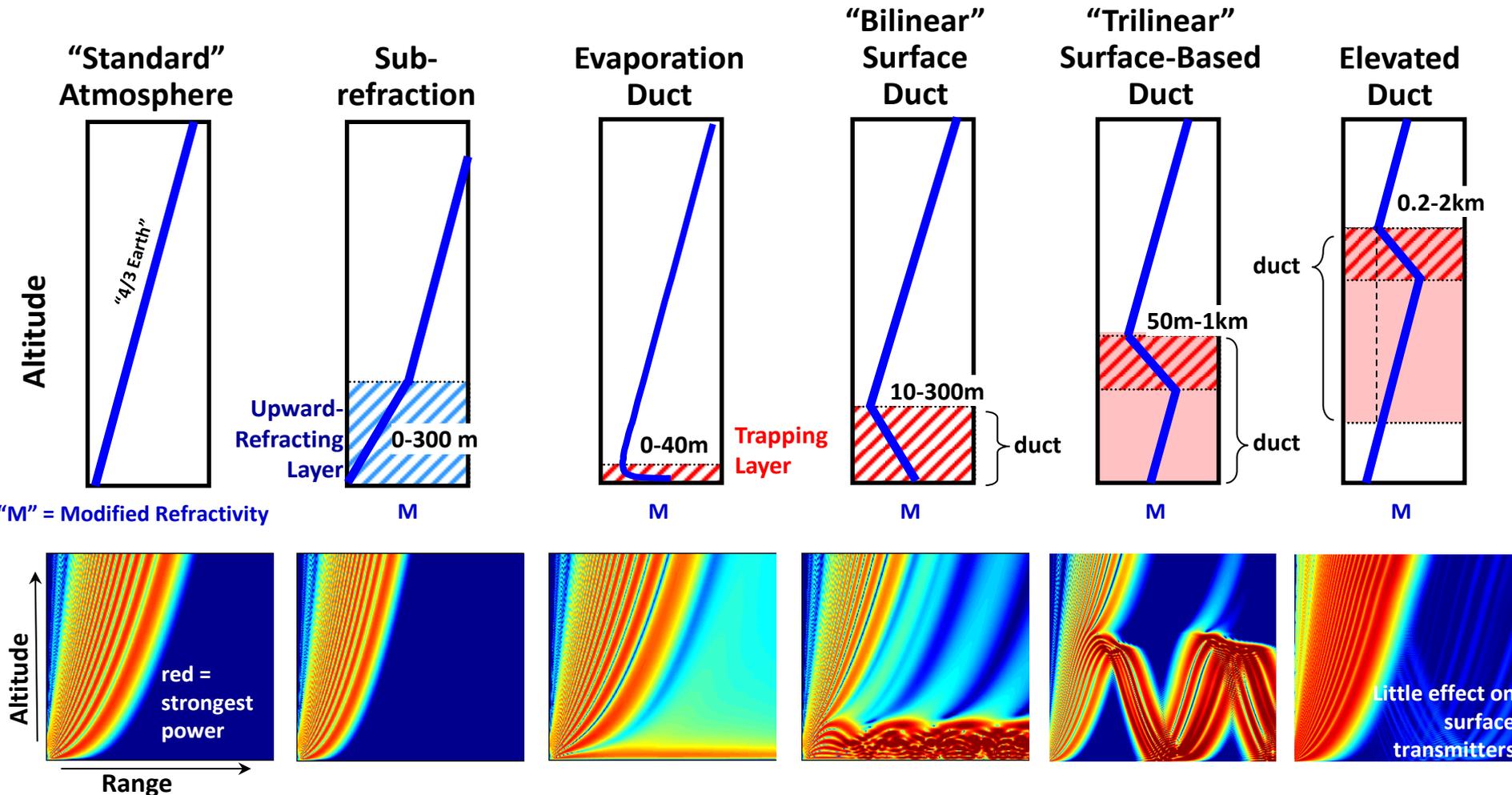 - Ducting, also known as trapping

- Sub-refractive environments typically lead to a reduction in radio horizon
- Super-refractive environments typically lead to an increase in radio horizon
- Ducting can lead to significant increases in radio horizon

1976 US Standard Atmosphere

- Idealized, steady-state representation of the Earth's atmosphere from the surface to 1000km during periods of moderate solar activity

- Originally developed as a National Advisory Committee for Aeronautics flight standard

Categories of Refractive Conditions Explained

"Standard" Atmosphere — "4/3 Earth"

Sub-refraction — Upward-Refracting Layer — 0-300 m — M

Evaporation Duct — 0-40m — Trapping Layer — M

"Bilinear" Surface Duct — 10-300m — duct — M

"Trilinear" Surface-Based Duct — 50m-1km — duct — M

Elevated Duct — 0.2-2km — duct — M

"M" = Modified Refractivity

Altitude

red = strongest power

Range

Little effect on surface transmitters

Altitude

"M" is a function of atmospheric pressure, temperature, humidity and altitude

Credit: Tom Hanley, JHU APL

- **Radiosondes (Weather Balloons)**
  - Launch twice per day from hundreds of stations around the world and have been for decades per World Meteorological Organization standards

  - Measure temperature, pressure, and humidity as a function of altitude from the surface up to an altitude of 30 km (100 kft)
    - Everything we need to calculate refractivity

Atmospheric Data Sources
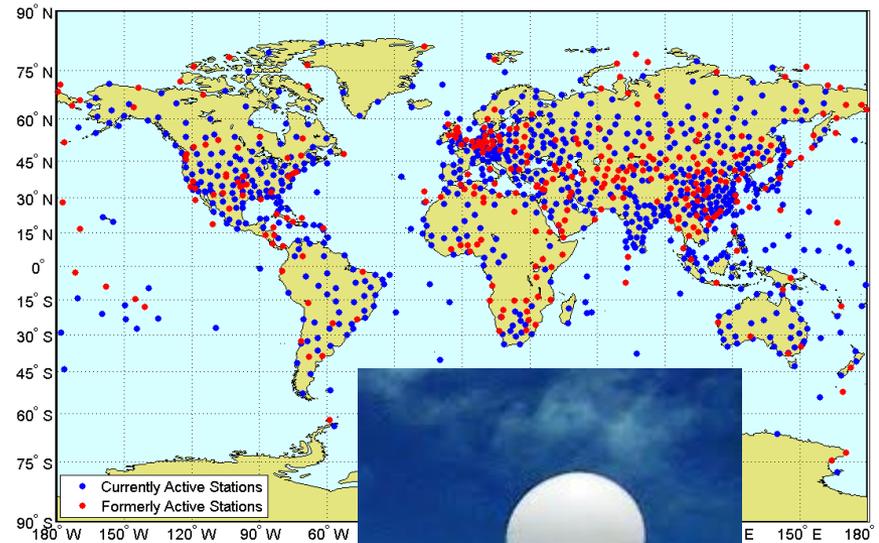
- Numerical Weather Prediction (NWP) Models
  - Computer models that ingest measured meteorological data and apply complicated algorithms and equations to solve for the temporal and spatial distributions of various parameters (temperature, humidity, winds, etc.)
  - Input data sets are assimilated from multiple sources: Radiosondes, satellites (Including Global Positioning System occultation constellations), aircraft, buoys, ships, surface stations, etc.
  - NWP models can also be run in a "Reanalysis" mode using quality-controlled historical data sets and the latest algorithms

Statistical Atmospheric Databases

- 1966, Bean et al. "A World Atlas of Atmospheric Radio Refractivity"
- 1987, Patterson, "Historical Electromagnetic Propagation Conditions"
- 2012, Radiocommunication Sector of the International Telecommunications Union (ITU-R), Recommendation P.453-10 "The radio refractive index: its formula and refractivity data" (In force Feb 2012)
- European Centre for Medium-Range Weather Forecasts Reanalysis
  - Europe's mesoscale NWP model run in a "reanalysis" mode
- Naval Postgraduate School Evaporation Duct Climatology Database
- Naval Postgraduate School Upper Air Climatology Database