Tethered balloons for radio detection of UHE neutrinos in Antarctica: the RITA project

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Talk outline

Introduction

Russian/Soviet radio work in Antarctica, RAMAND

- Pilot experiments
- Knowledge accumulated

RITA: proposal for tethered balloon experiment

- Design
- Flux sensitivity projections

Introduction

Askaryan's idea (1961-1965):

detect coherent Cherenkov radio emission of E.M. cascades produced by cores of EAS and muons

Antarctic ice (very low RF absorption at -50C) is a natural large-scale dielectric neutrino target

– Gusev and Zheleznykh, 1983

Nearly 50 years of studies of radiowave neutrino detection and detection in ice

Russian (Soviet) radio ν work in Antarctica

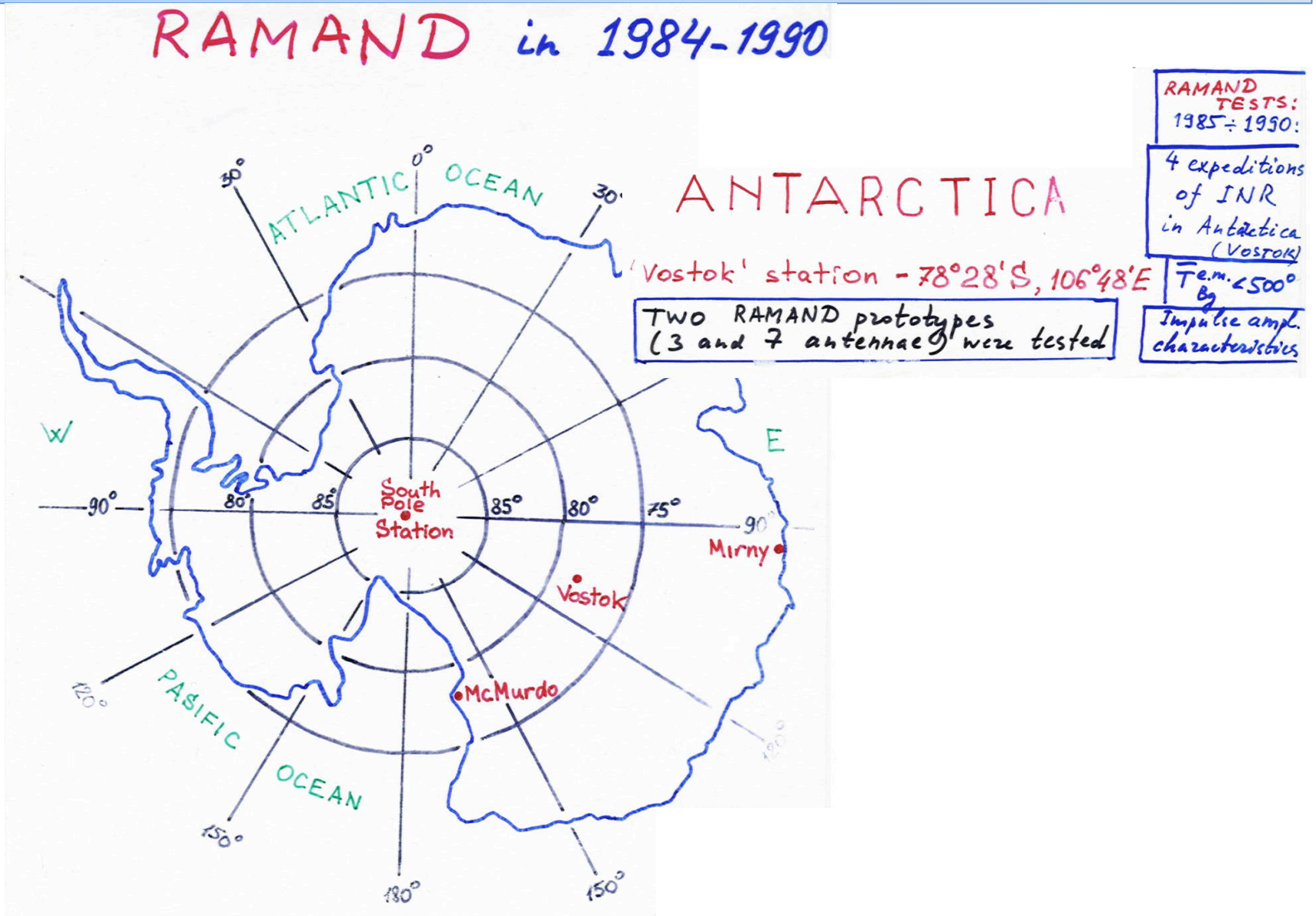
RAMAND experiments at Vostok and Mirny

4 Antarctic expeditions in 1985-1990

- Glaciology information
  - transparency of ice for radio waves of 100 MHz – 1 GHz for different temperatures
- 1985-1986:first experimental investigations
  - mean noise level, amplitude spectra of pulses in a single radio detector module 250–1000 MHz (G. Gusev et al.)
- 1986-1987: "Hydra" (3-channel installation)
  - investigation of pulse BG sources (A. Provorov et al.)
- 1988 and 1990: "Hydra-7" (7 channels)
  - RAMAND prototype

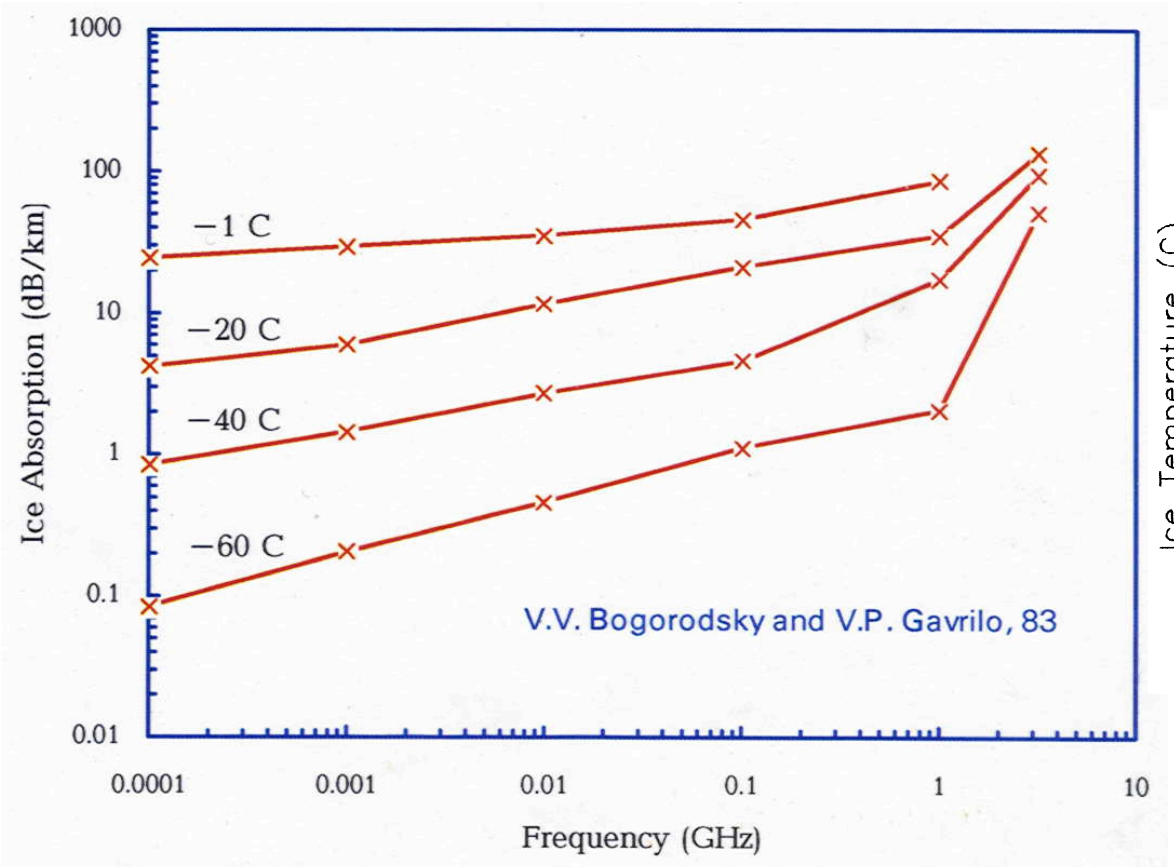
Some results also see in (A. Provorov et al., Proc. "Venice 1991, Neutrino telescopes", 337-355)

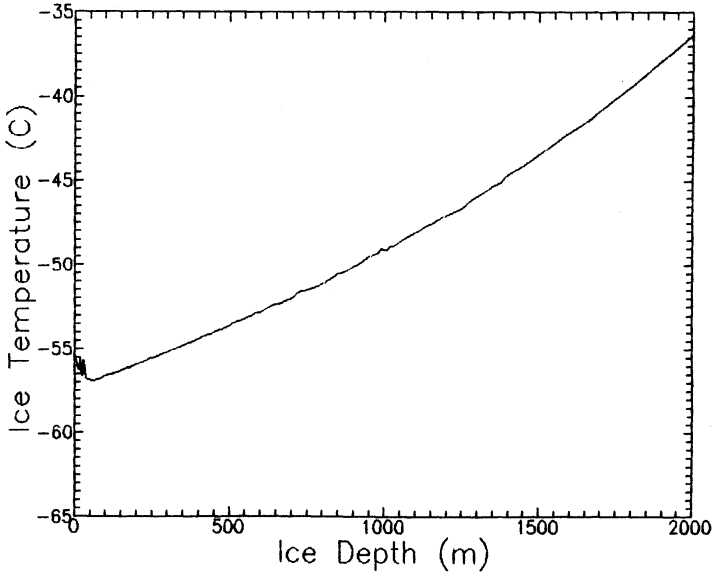
Stations in Antarctica



Polar ice properties

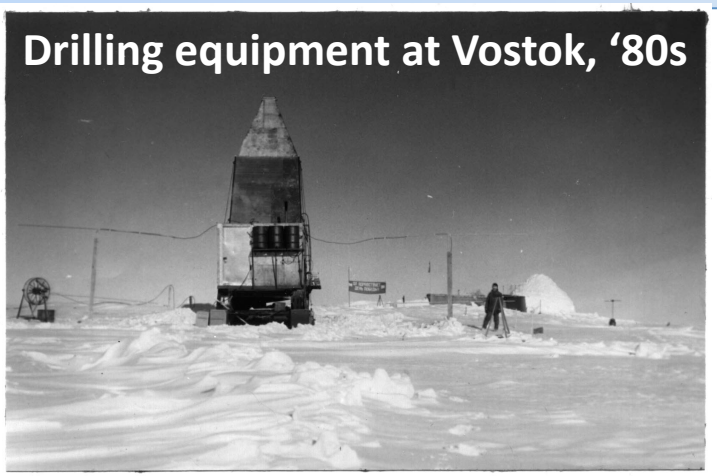
Ice absorption vs frequency at different temperatures

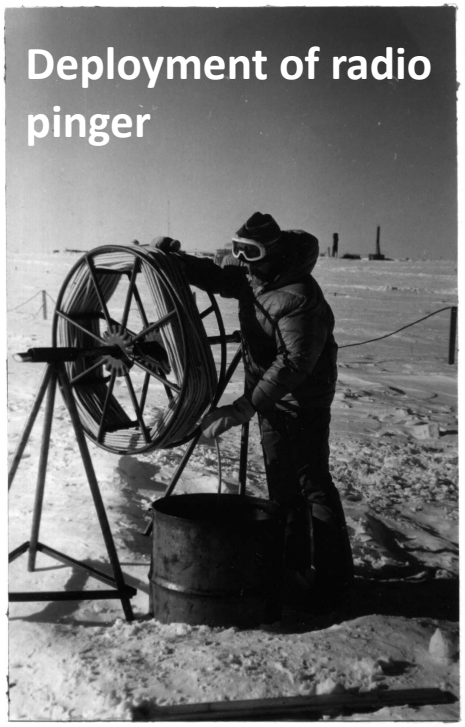


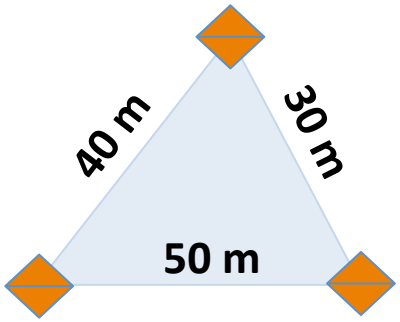


First background studies and Hydra

- 1985-1986:
  - noise studies w/ single module
- 1986-1987: Hydra
  - 3 broadband receiver channels
  - Pinger locations reconstructed
  - Man-made backgrounds investigated (sources coincide with station objects)
  - Upper limit on flux of impulse pulses from ice obtained

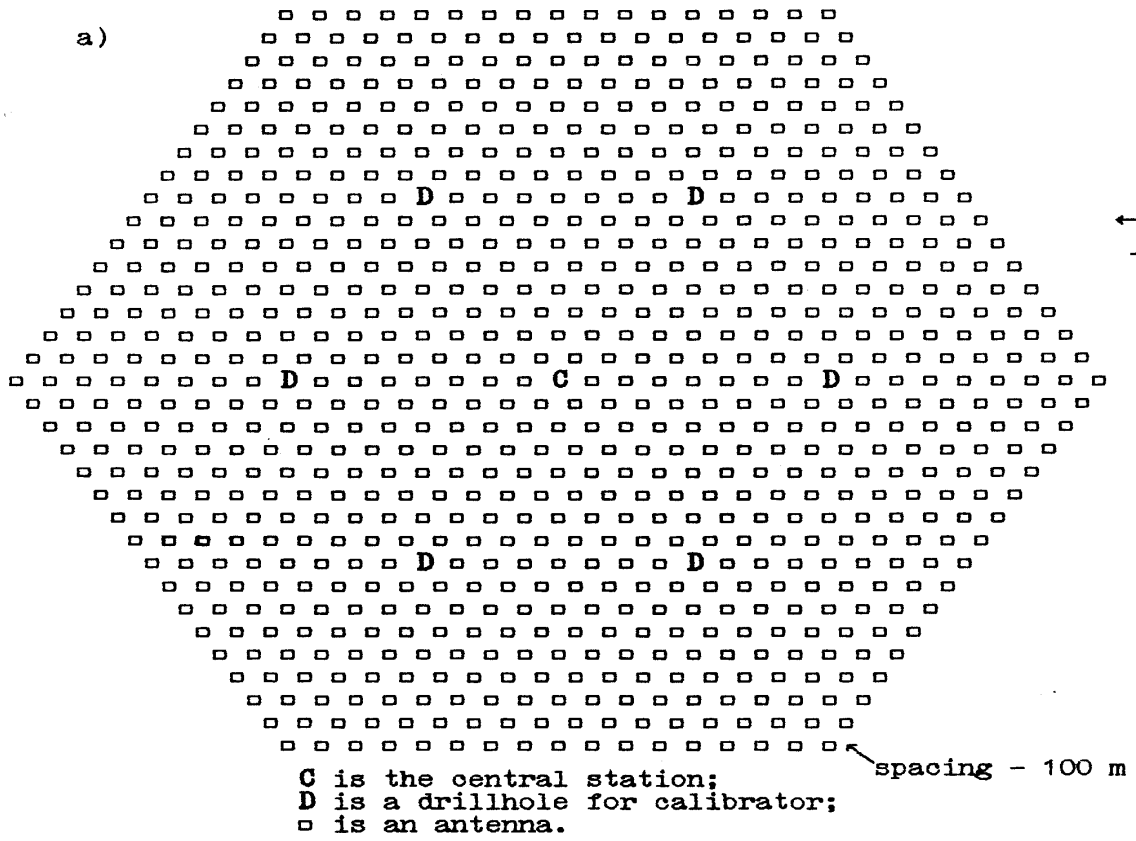


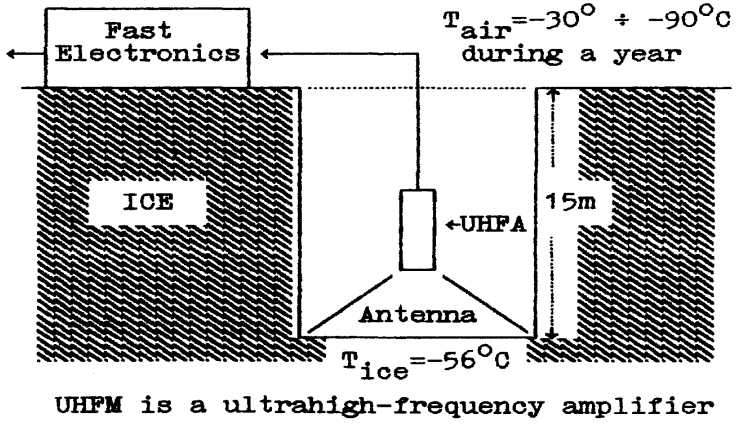




Proc. 20th Inter. Cosmic Ray Conference. Moscow, “NAUKA”, 1987, vol. 6, pp. 472-275.

RAMAND concept





Radiowave detector of UHE ν with V_{eff}≈10km^3

- Hexagonal antenna field, shallow deployment (15m)
- Approved in 1988 by Soviet authorities

RAMAND pilot: Hydra-7

- Prototype Hydra-7
- 7-channel installation
- Deployed and tested at Vostok in 1988 and 1990

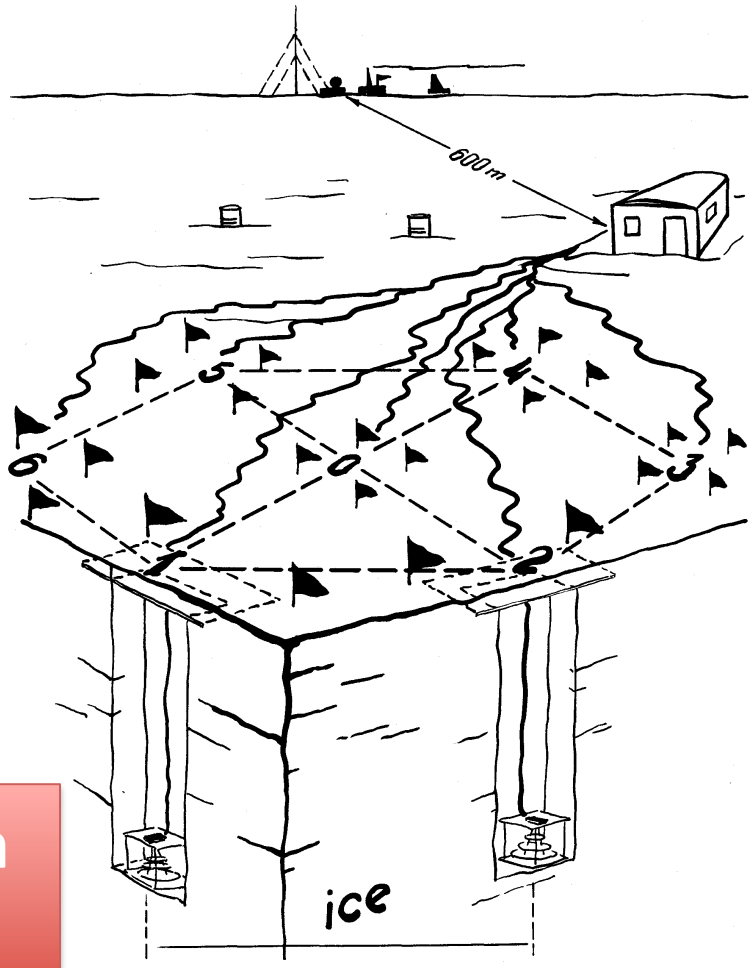


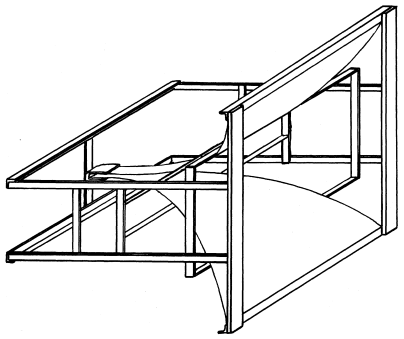
FIGURE 6

Unfortunately, this work has been abruptly discontinued in 1991

RAMAND antennas

TEM horn:

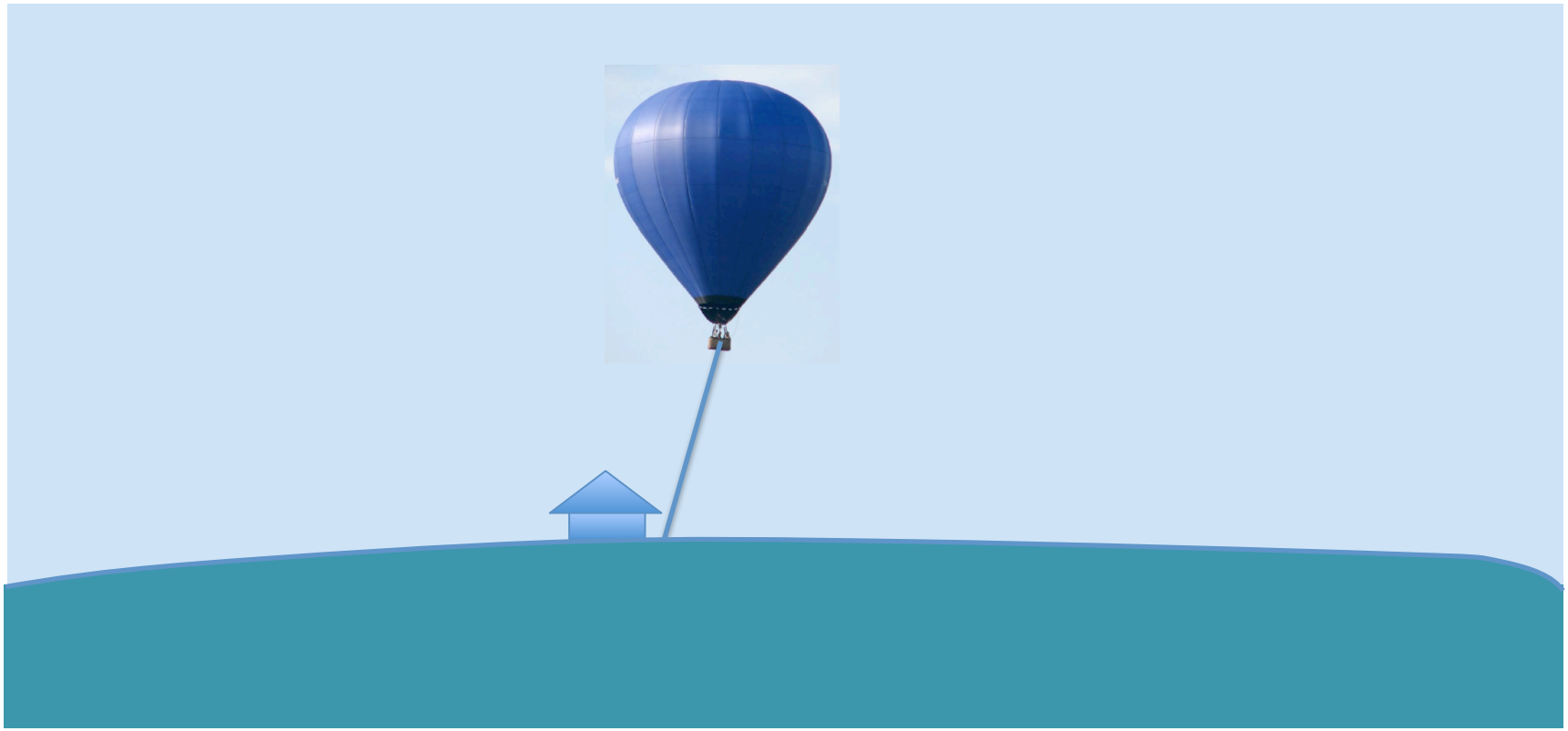
- Broadband antenna well suited for impulsive field measurements
- Planned for RAMAND, used in Hydra-7: 1m × 1m arcsine TEM horn, reception transfer function R_A=0.14 V/(V/m)
- Total 1280 antennas intended



TEM horn antennas made Russian collaborators are also part of the RICE experiment

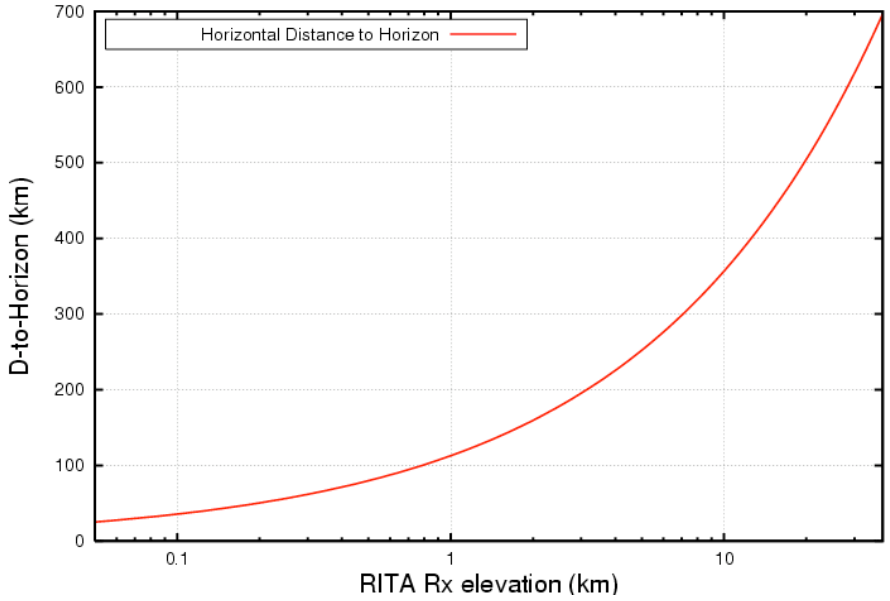
RITA concept

- Broadband radio receivers mounted on a balloon at a few km above the ground
- Tethered above ice, which serves as ν target



Advantages of tethered balloons

- Elevated strategy affords larger field of view



- Tethered scheme (compare to ANITA):
  - High duty cycle
  - Can carry power to the balloon (not limited to solar)
  - Data transferred in real time
  - Run in coincidence with ground antennas (a la' RAMAND)

Balloon specs/operating parameters

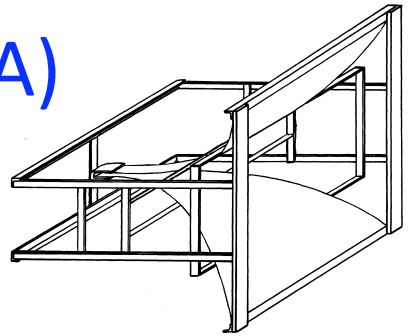
- Altitude:
  - Ice crystal formation on electronics favors >1.5km
  - Technologically, up to 2.5-3km appears feasible
  - Higher altitude is better: larger aperture
- Payload:
  - 500-550 kg capacity for considered options
  - Tether: ~300kg (polystyrene rope + signal cable)
- Fillant:
  - Helium
  - Heated air (electric, w/solar battaries, or gas-jet)

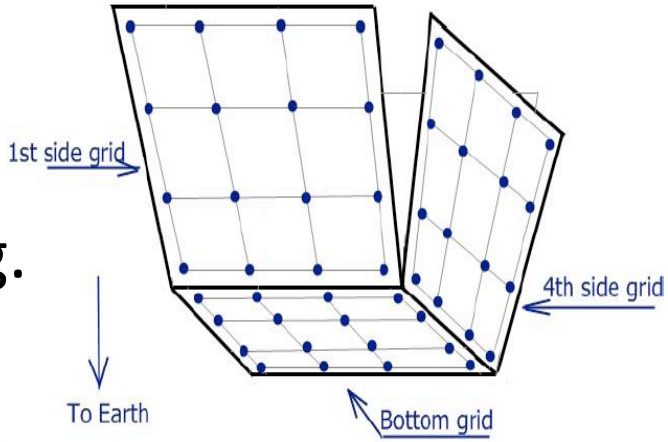
Specs, continued

- Size:
  - About 20 m diameter, 24 m height
- Environmental specs:
  - Operating temperatures -20 to 40 C
  - Winds <7 m/s

Radio receivers

- Horn antennas (as in RAMAND or ANITA)
- Planar dipole grid
  - Each dipole read out independently
  - 16 (4x4) orthogonal dipole array
    - Receive both linear polarizations
  - Active dipoles->amps->ADC->FPGA
  - Angular resolution of array ~23 deg.
  - Each array covers ~90×90 deg.
  - Total 4-5 such arrays, designed for λ=40cm
    - (have experience with 16-element λ=1m arrays)



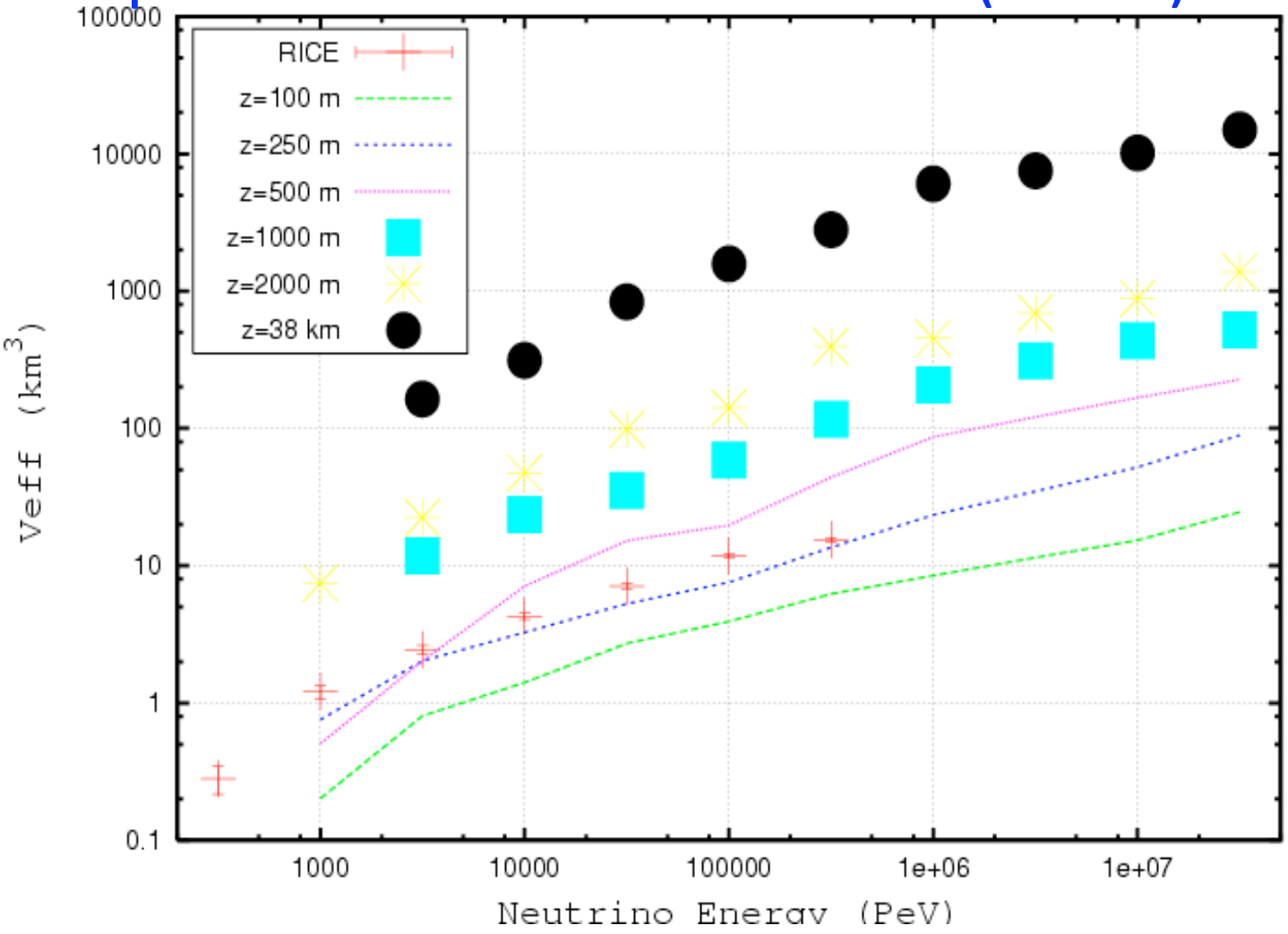


RITA sensitivity estimates

- Use RICE simulation, with the additions:
  - Updated local ice properties (at Vostok, ice is deeper and colder)
  - Assumed ANITA-like antenna configuration with full 2π coverage and 200-1200 MHz bandwidth
  - Add Fresnel coefficients for signal transmission through surface
  - Assume perfect trigger @5σ
- NB: as Z_{Rx} increases, more ice visible, but <R> to vertex also increases, pushes thresholds up

Sensitive volume projections

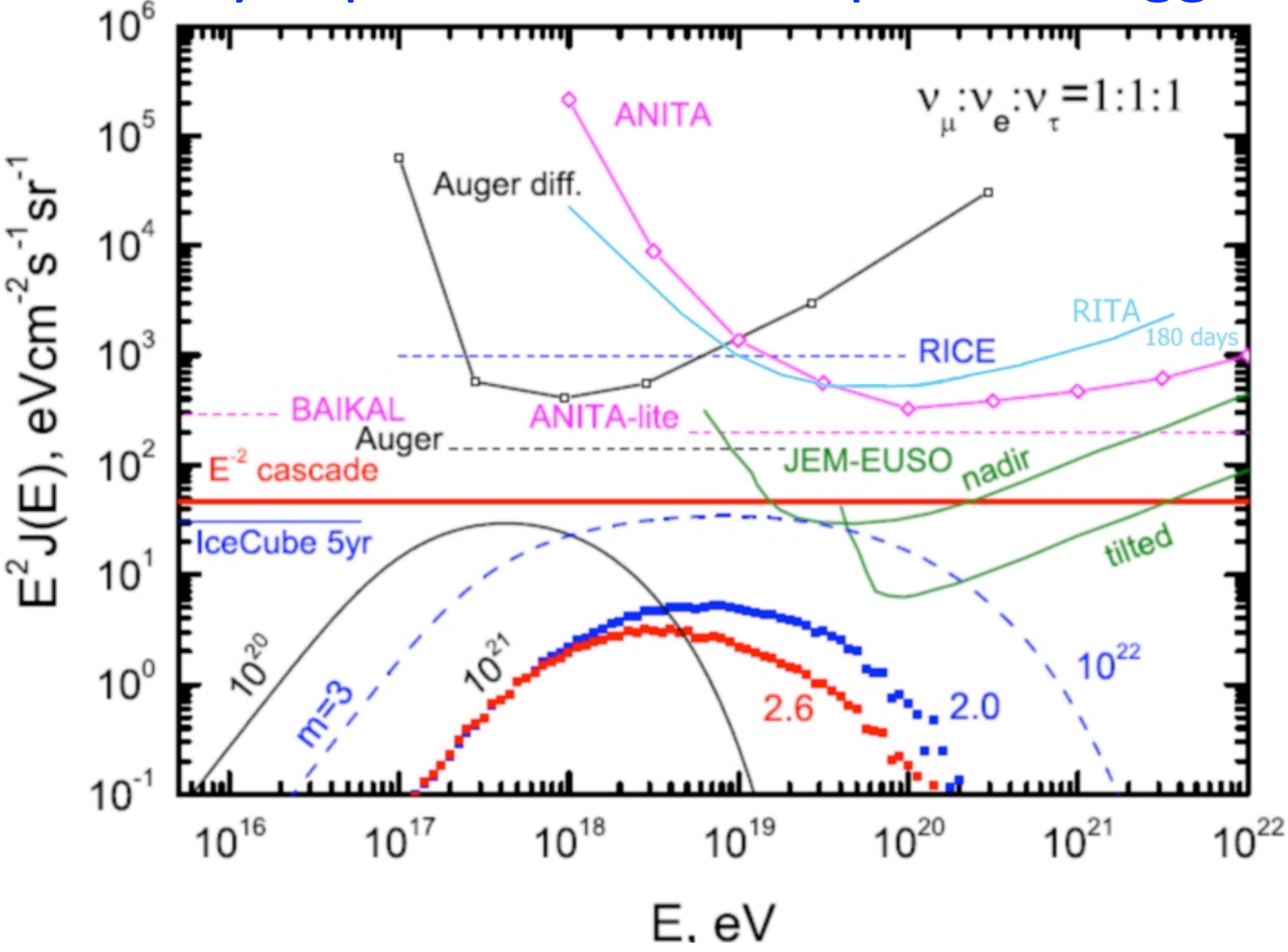
- Compare: RICE vs RITA vs ANITA (38km)



RITA vs ANITA: x10 less V_{eff}, BUT exposure can be much longer

Neutrino flux limit projections

RITA 180 day exposure, assumes perfect trigger @5σ



Summary

- Long history of Russian radio studies in Antarctica
- Significant expertise built within Hydra/ RAMAND projects
- Proposed low cost - high sensitivity RITA experiment
  - Large effective volume
  - Flux limit projections: promising