Atmospheric Radon in a marine environment: a novel approach based on Airborne Gamma-Ray Spectroscopy (AGRS)

Università degli Studi di Ferrara

Marica Baldoncini[a,b], Matteo Albéri[a,b], Carlo Bottardi[b,c], Brian Minty[d], Kassandra G. C. Raptis[a,b], Virginia Strati[b,c], Fabio Mantovani[b,c]

[a]INFN, Legnaro National Laboratories, Italy; [b]Department of Physics and Earth Sciences, University of Ferrara, Italy; [c]INFN, Ferrara Section, Italy; [d]Minty Geophysics, Australia.

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Photos are welcome!

INFN Istituto Nazionale di Fisica Nucleare

Please contact me:
baldoncini@fe.infn.it

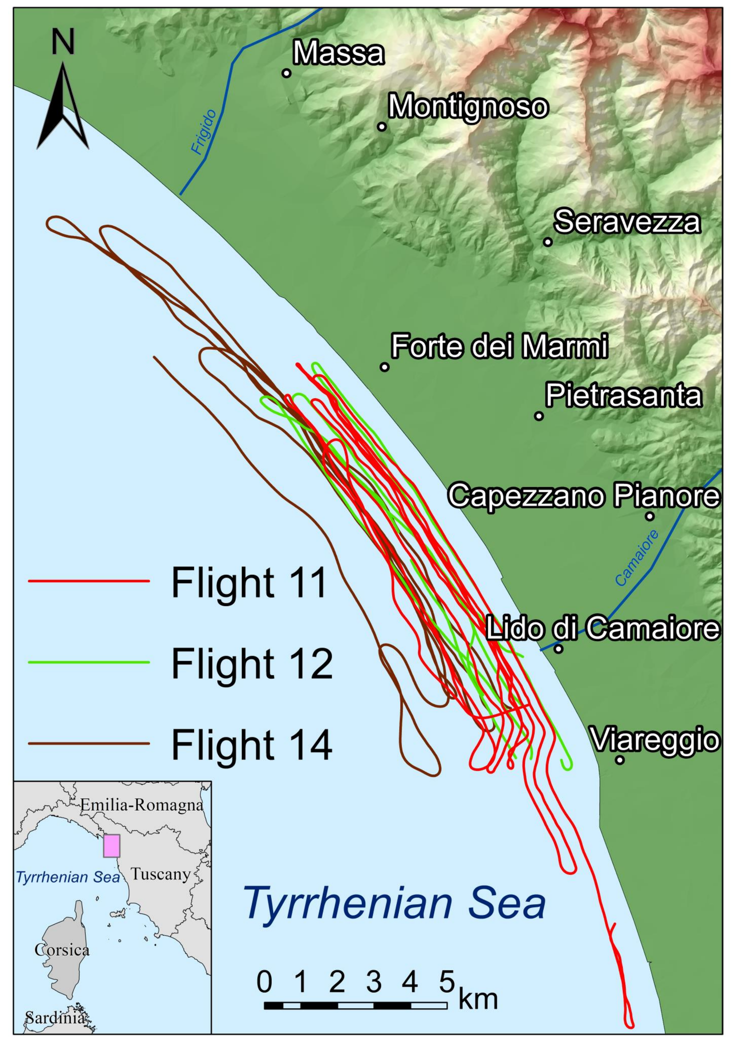
1 Scientific motivations and goal

- ^{222}Rn gas is responsible for ~43% of global human exposure to ionizing radiation
- ^{222}Rn is an atmospheric tracer used as a proxy for climate and pollution studies
- ^{222}Rn is a severe source of background in Airborne Gamma-Ray Spectroscopy (AGRS)
- The marine environment is ideal for tracing atmospheric ^{222}Rn via AGRS
- ^{222}Rn is a noise in monitoring for spent nuclear fuels and radioactive wastes carried in ships

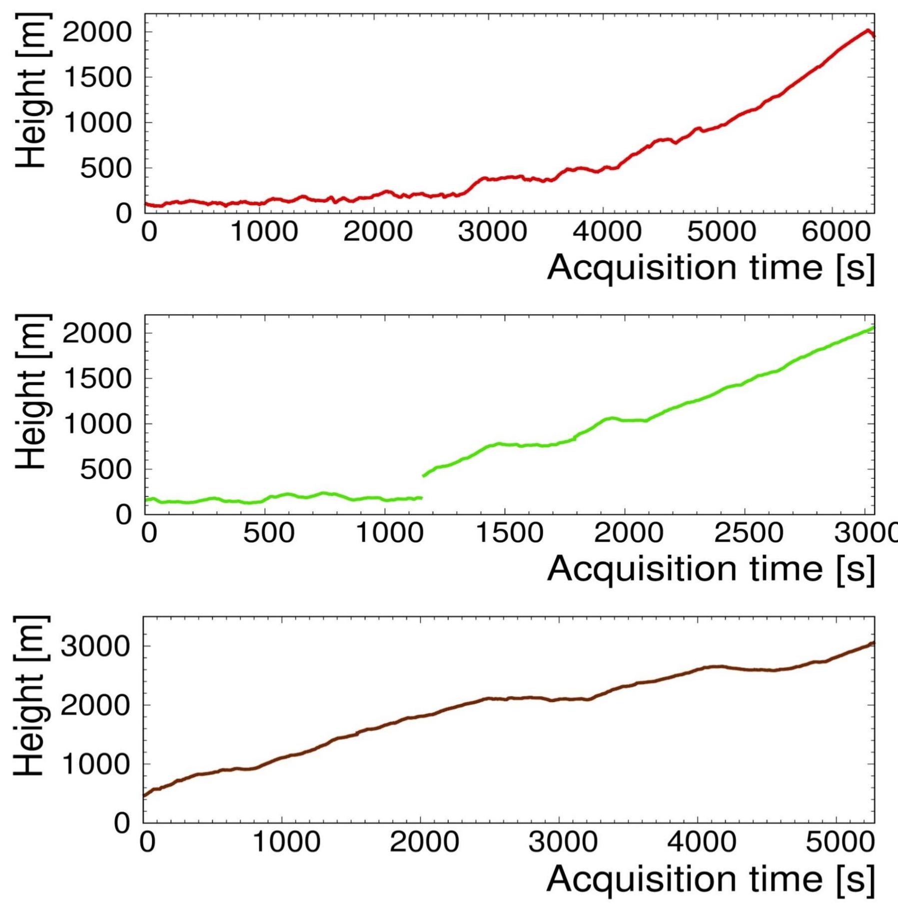
The goal of the study is to assess ^{222}Rn vertical profile by means of dedicated offshore AGRS surveys

2 AGRS surveys

Three offshore surveys were performed over the Tyrrhenian Sea (Italy)



H min [m]	H max [m]	Total time [s]
77	3066	14688



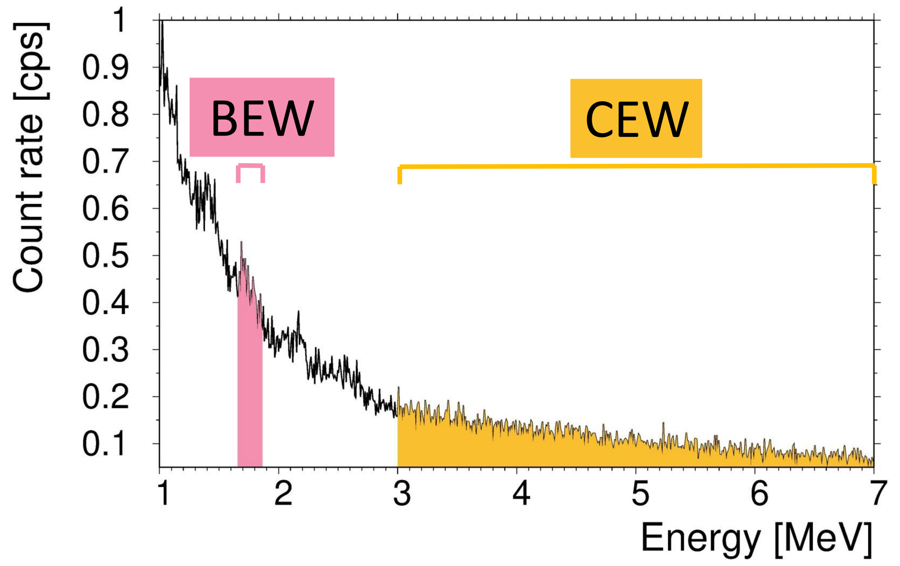
3 Experimental setup

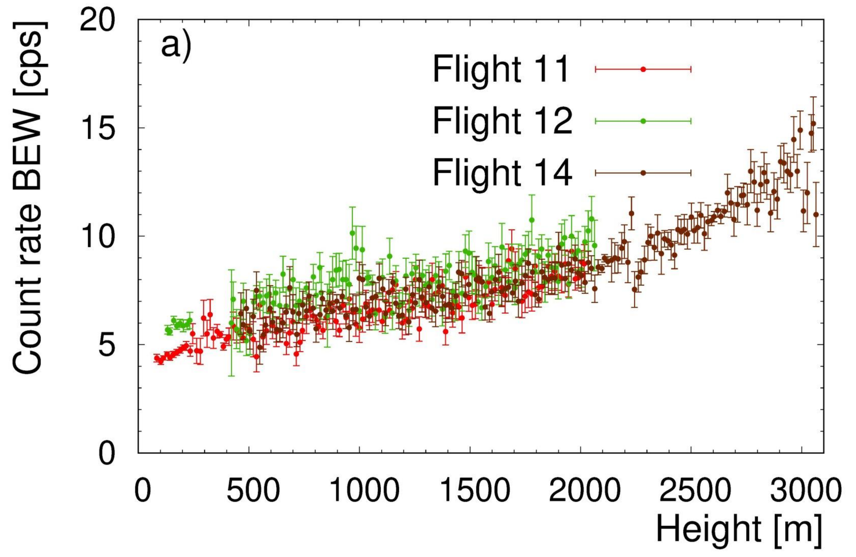
The Radgyro is a prototype aircraft for multiparametric airborne surveys

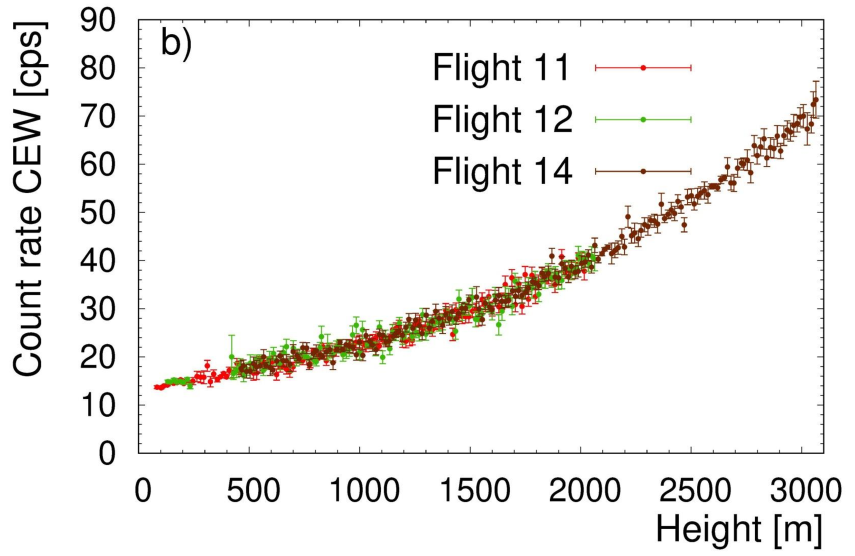
AGRS spectra are acquired with a 16 liter NaI detector

Flight altitude is measured with 7 different altimetric sensors

4 Experimental data







- Two energy ranges: ^{214}Bi energy window (BEW, 1.66-1.86 MeV) and cosmic energy window (CEW, 3.0-7.0 MeV)
- In CEW only gammas with cosmic origin are detected
- ^{214}Bi is a ^{222}Rn daughter: the count rate in the BEW allows for inferring ^{222}Rn concentration

5 Theoretical model

The count rate in the BEW is the sum of:

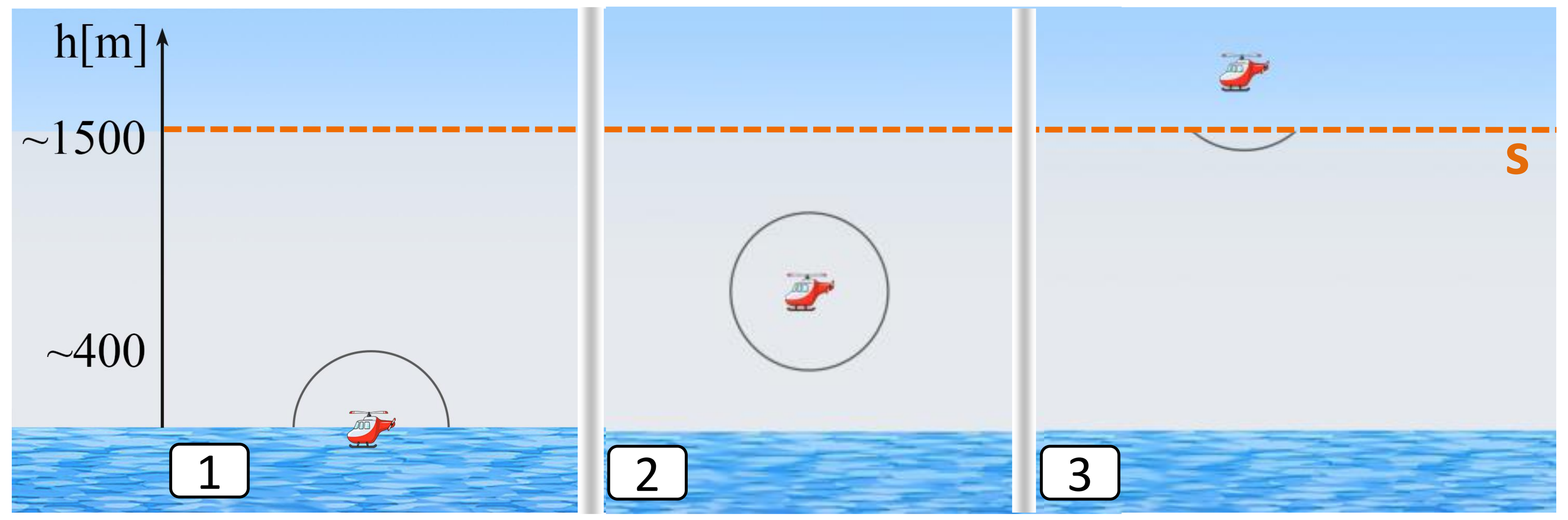
- cosmic component, exponentially increasing with flight height
- constant component, due to the radioactivity of the aircraft and of the equipment
- atmospheric ^{222}Rn altitude dependent component, reflecting ^{222}Rn distribution in the atmosphere

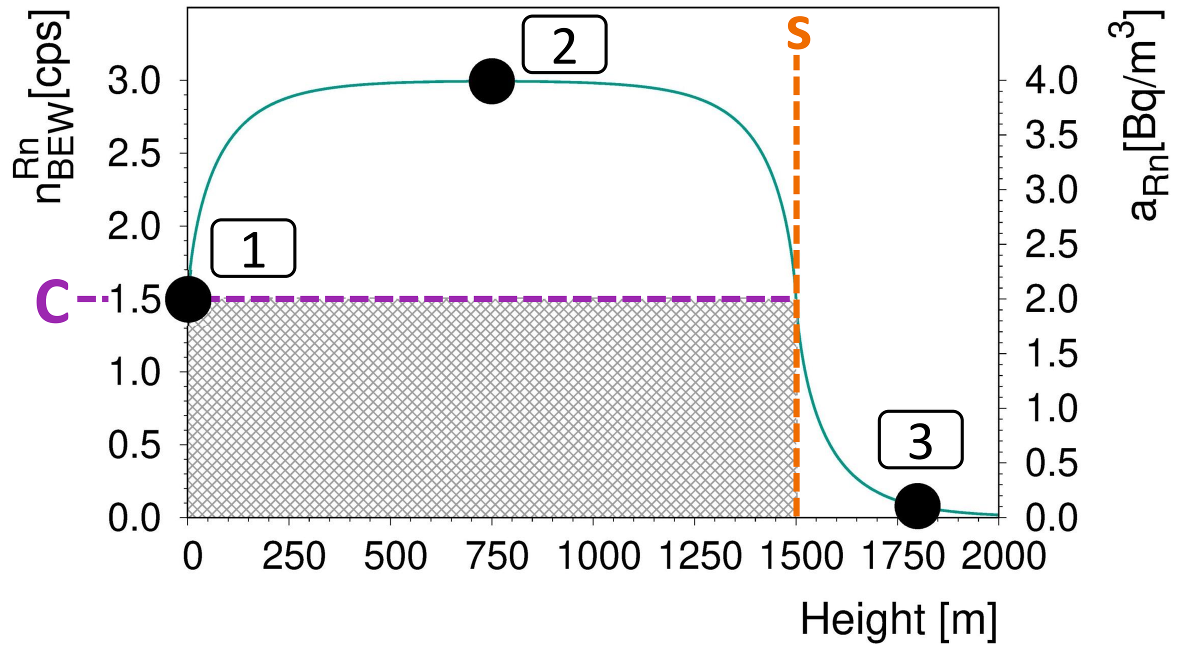
Atmospheric ^{222}Rn count rate is modeled on the basis of:

- ^{222}Rn concentration vertical profile. Constant for height < s and 0 for height > s
- Mean free path of ^{214}Bi photons. The AGRS detector field of view is approximable to a sphere of r ~400 m

The atmospheric ^{222}Rn count rate

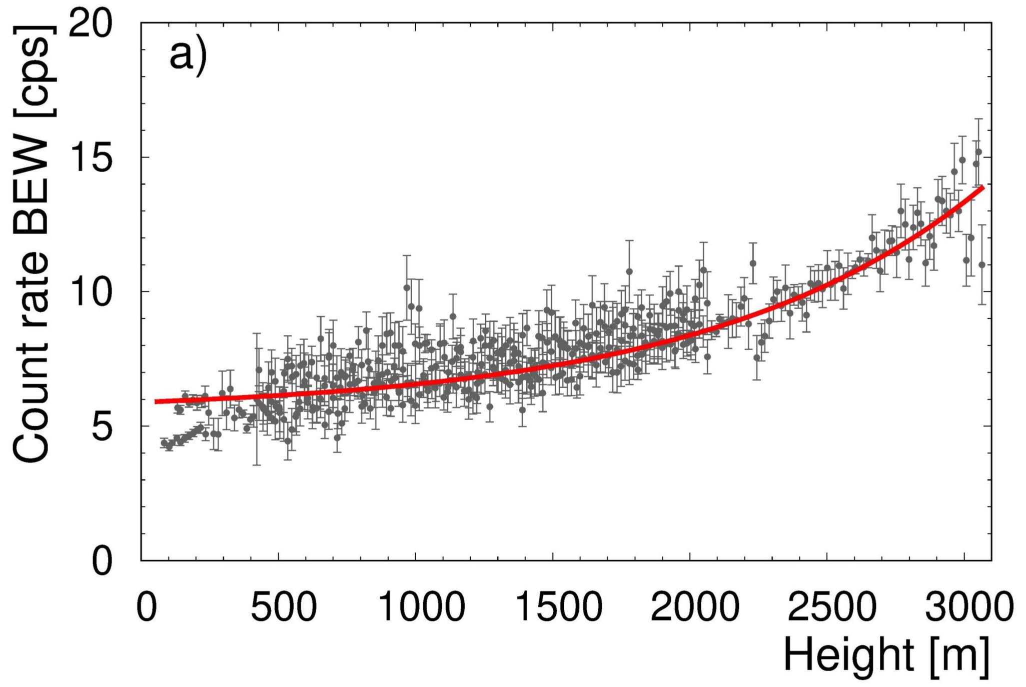
- is equal to C at sea level and at height s, corresponding to the half sphere field of view
- saturates to 2C, when the full sphere field of view is enclosed within the ^{222}Rn layer
- exponentially approaches 0 for flight altitudes greater than s

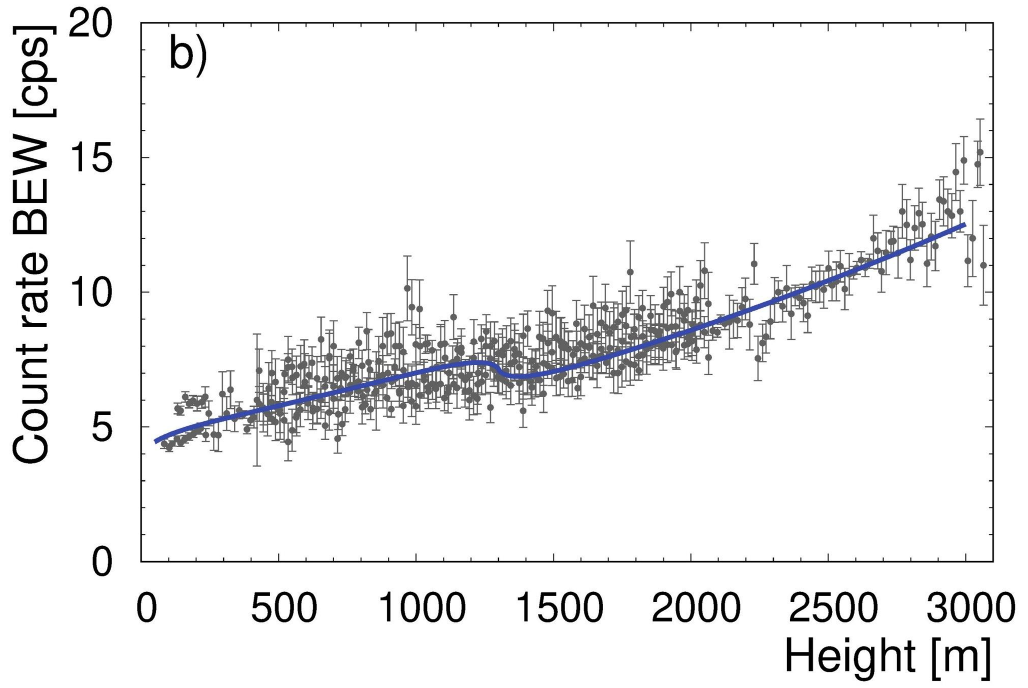




6 Results

- The **new model**, accounting for the presence of a homogeneous ^{222}Rn layer, provides a better fit compared to the ^{222}Rn free **standard model**
- The best fit curve models the count rate due to a ^{222}Rn layer having a_{Rn} = (0.96 ± 0.07) Bq/m^3 homogeneously distributed up to s = (1318 ± 22) m
- The mean ^{222}Rn concentration and mixing layer depth are in agreement with literature data: a_{Rn}~1 Bq/m^3, s ~1500 m





$$n(h)_{BEW}^{AIRCRAFT+COSMIC} = A_{BEW} e^{\mu_{BEW} h} + B_{BEW}$$

$$n(h)_{BEW} = n(h)_{BEW}^{AIRCRAFT+COSMIC} + n_{BEW}^{Rn}(s, C, h)$$

	$A_{BEW} \pm \delta A_{BEW}$ [cps]	$\mu_{BEW} \pm \delta\mu_{BEW}$ [m^{-1}]	$B_{BEW} \pm \delta B_{BEW}$ [cps]	s ± δs [m]	C ± δC [cps]	Reduced χ^2
Standard model	0.39 ± 0.07	(2.01 ± 0.1)·10^{-3}	5.5 ± 0.3	/	/	5.0
New model	8.2 ± 0.2	(2.54 ± 0.06)·10^{-4}	-4.9 ± 0.2	1318 ± 22	0.68 ± 0.05	2.1

Baldoncini M et al. *Exploring atmospheric radon with airborne gamma-ray spectroscopy*. Atmospheric Environment 170, 259-268. (2017).