Estrategias de vida al límite: LÍQUENES EN EXPERIMENTOS DE ASTROBIOLOGÍA

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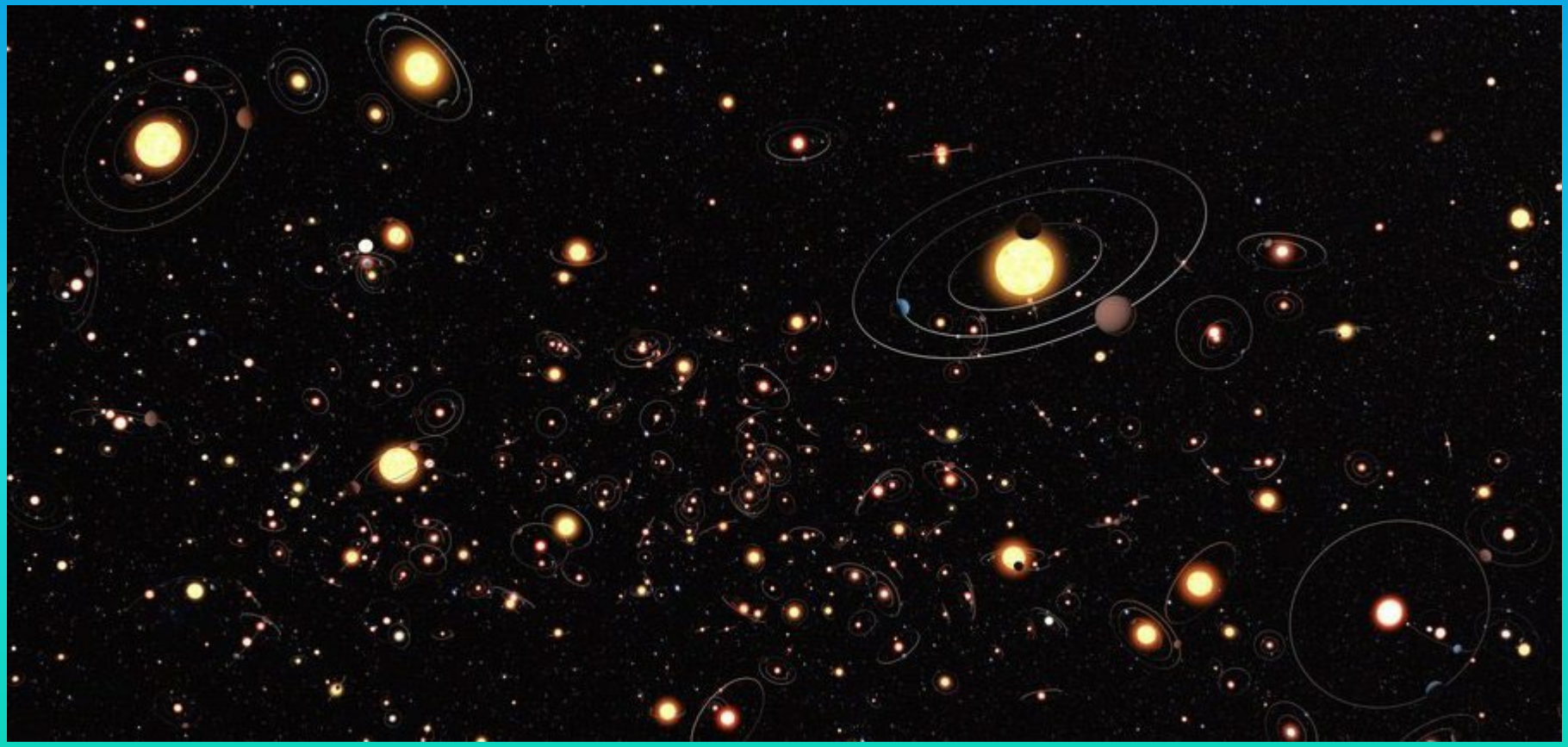
Madrid, Noviembre 2023

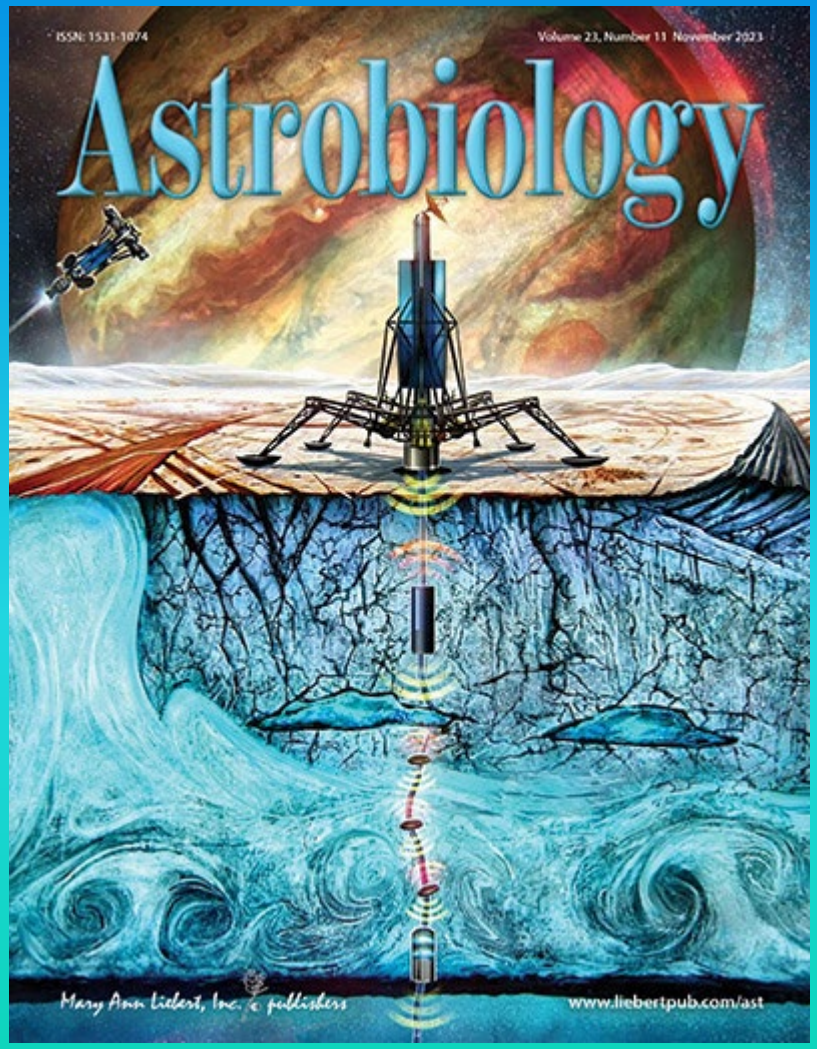
Life, Here and Beyond

Astrobiology is the study of the origin, evolution, and distribution of life in the universe.



OBJECTIVES:

- Discovering how biological systems respond, acclimate and adapt to the space environment
- Developing integrated physiological models for biology in space
- Identifying the underlying mechanisms and networks that govern biological processes in the space environment
- Developing cutting-edge biological technologies to facilitate spaceflight research
- Enabling the transfer of knowledge and technology to the understanding of life on Earth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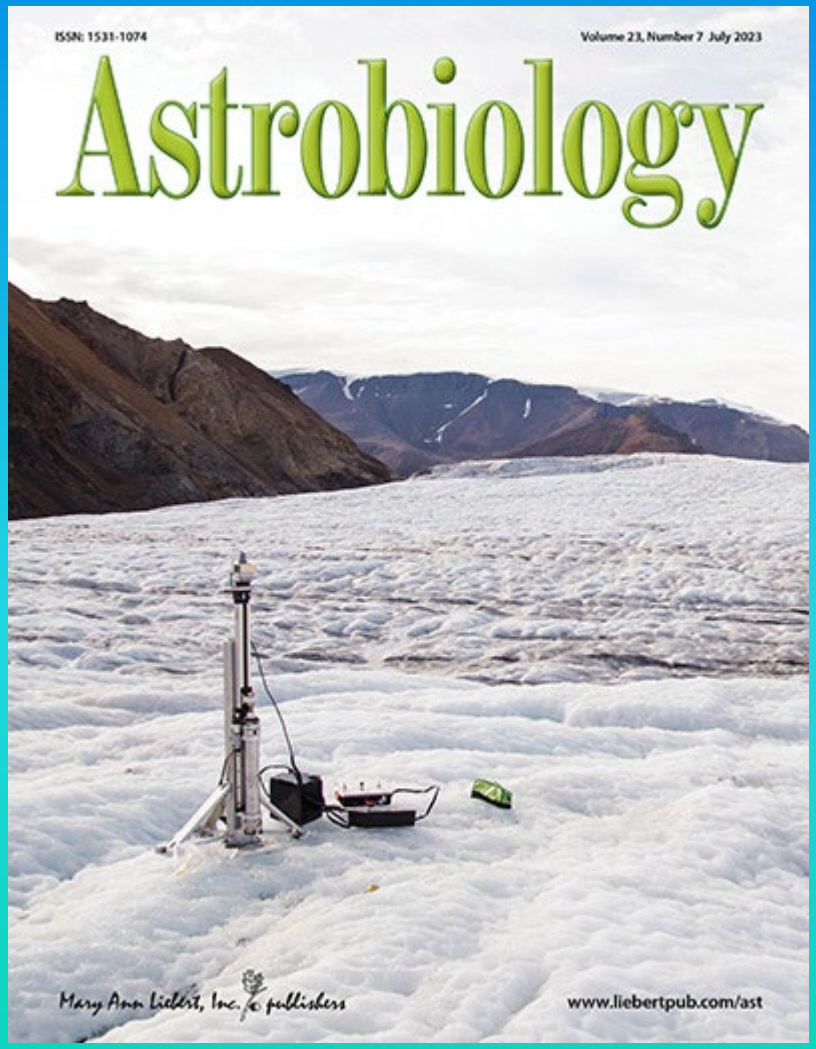
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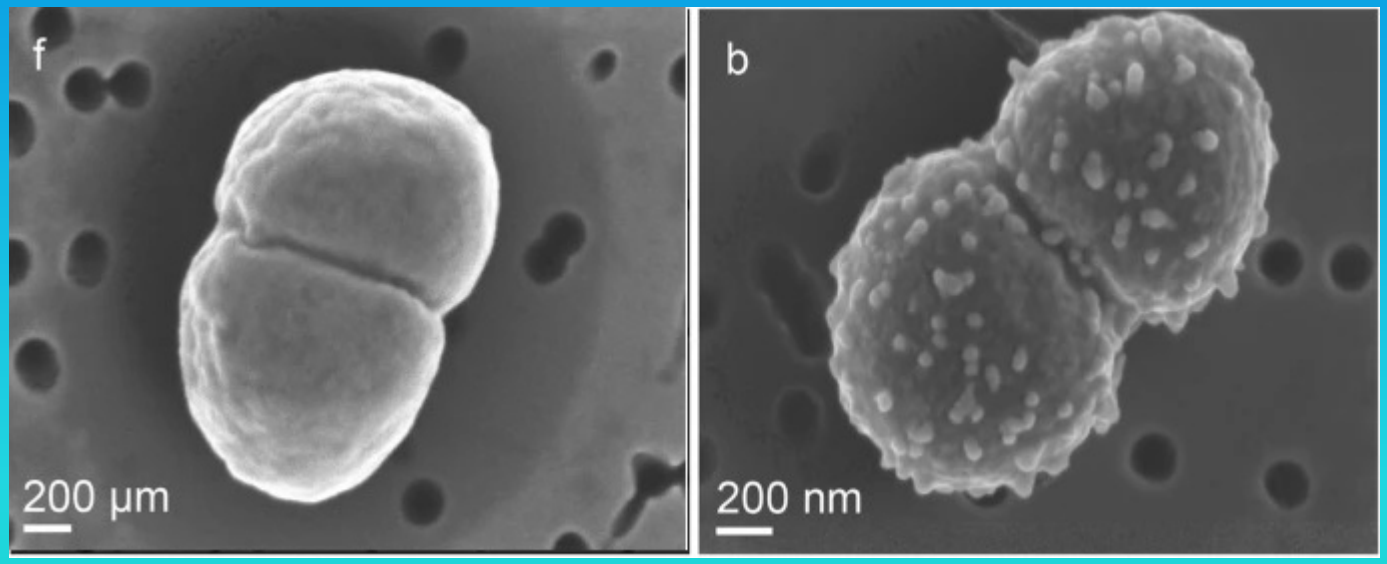


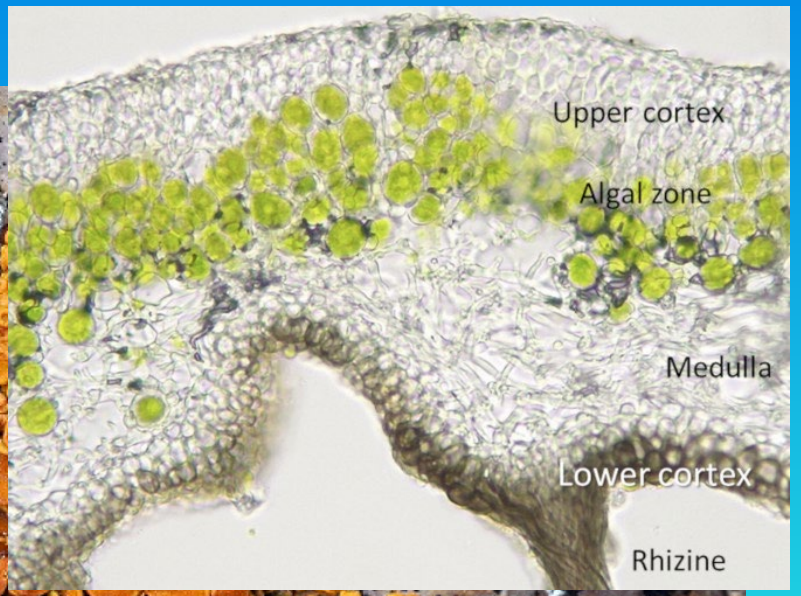
SEM images of *Deinococcus radiodurans* control (left), and after LEO exposure (right). (Ott et al., Microbiome, 2020)

TARDÍGRADOS

With a lack of moisture or in other unfavorable conditions, tardigrades lose up to 98 percent of their water and plunge into a state of anhydrobiosis, in which they can stay for years.

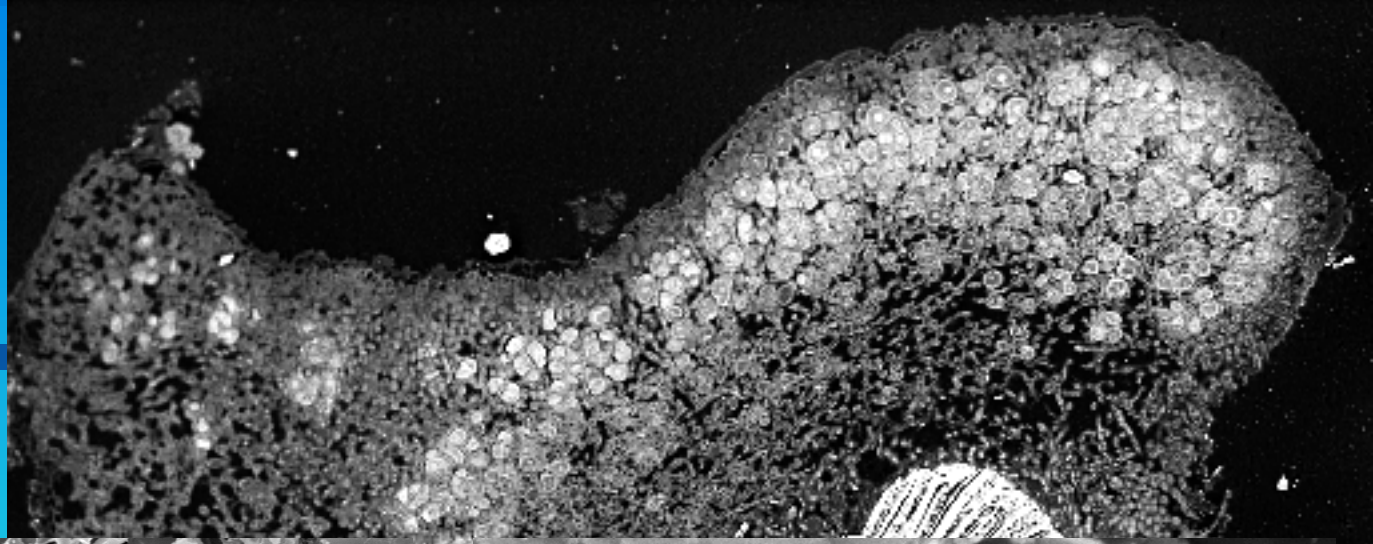
In this state, they can for a short time withstand temperatures from almost absolute zero to 100 degrees Celsius, pressures from practically zero to 600, and ionizing radiation of 5000 grays (a thousand times more than the lethal dose for most animals and humans).

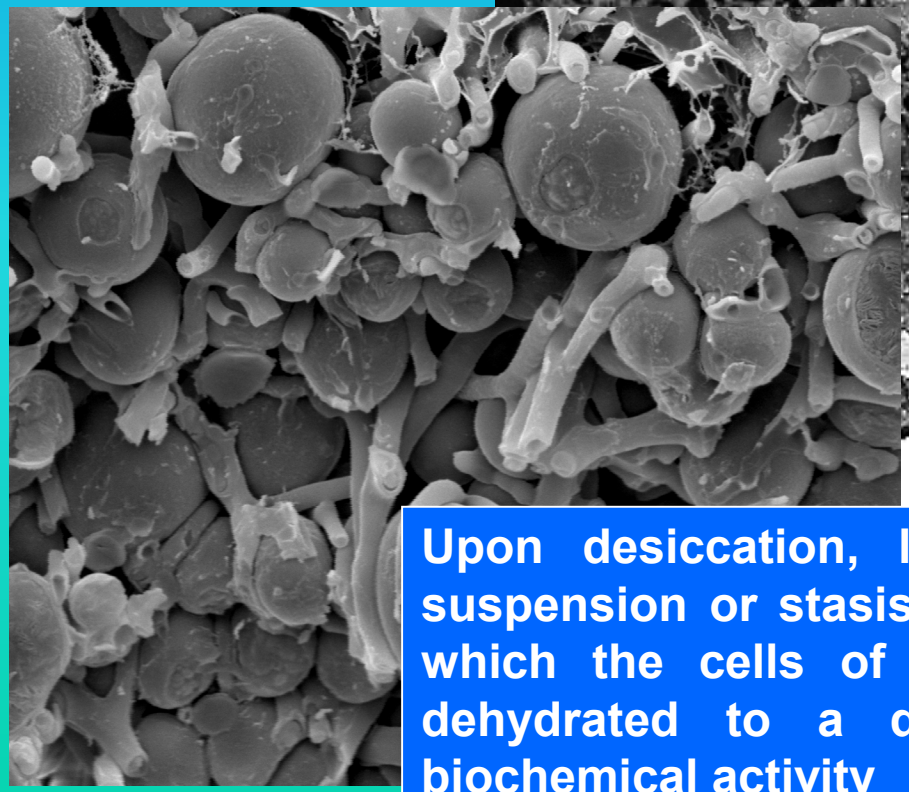
LÍQUENES

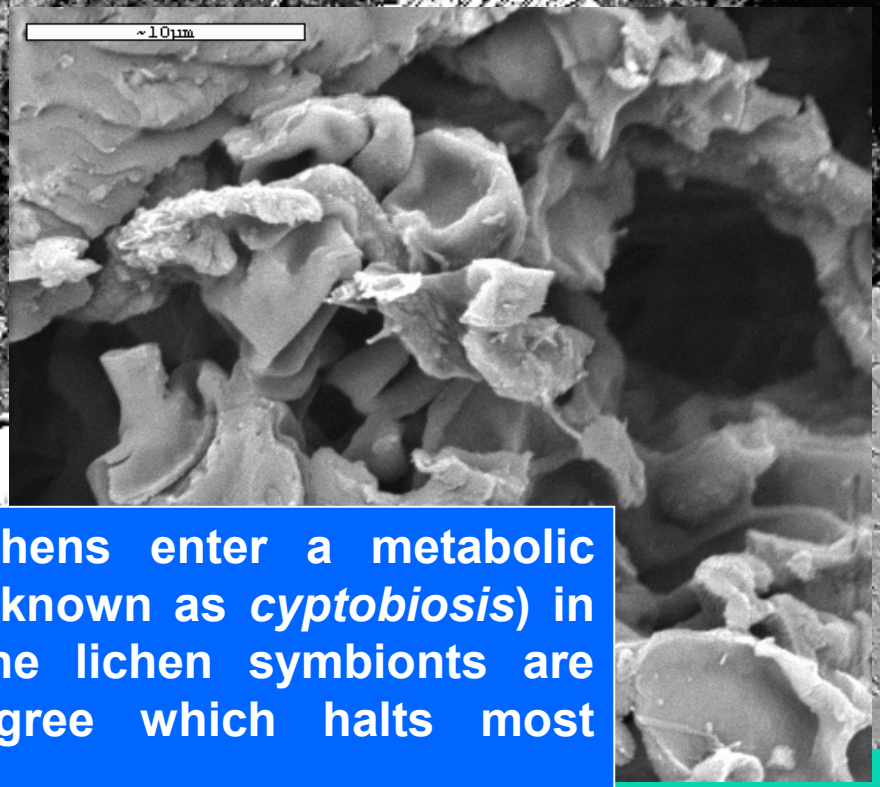


SEM-BSE

LTSEM







Upon desiccation, lichens enter a metabolic suspension or stasis (known as *cyptobiosis*) in which the cells of the lichen symbionts are dehydrated to a degree which halts most biochemical activity

The lithic form of life, a way to cope with the most extreme environments on Earth


Epilithic

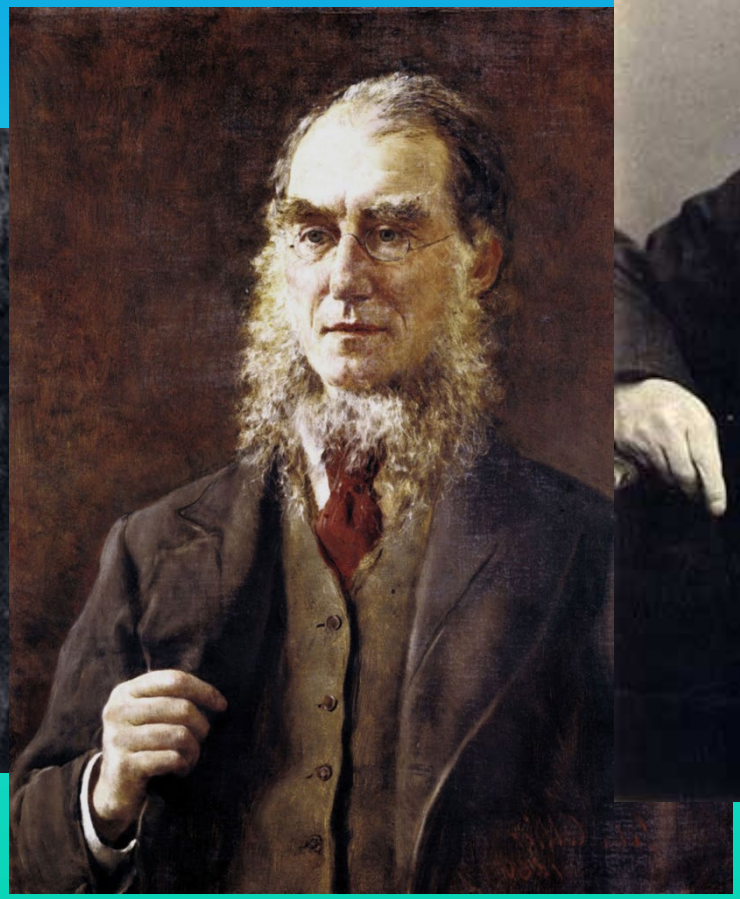

Epilithic


Hypolithic


Endolithic

Sir **Joseph Dalton Hooker (1817 – 1911)**

1844–1859: *Flora Antarctica: The botany of the Antarctic voyage*. 3 vols.



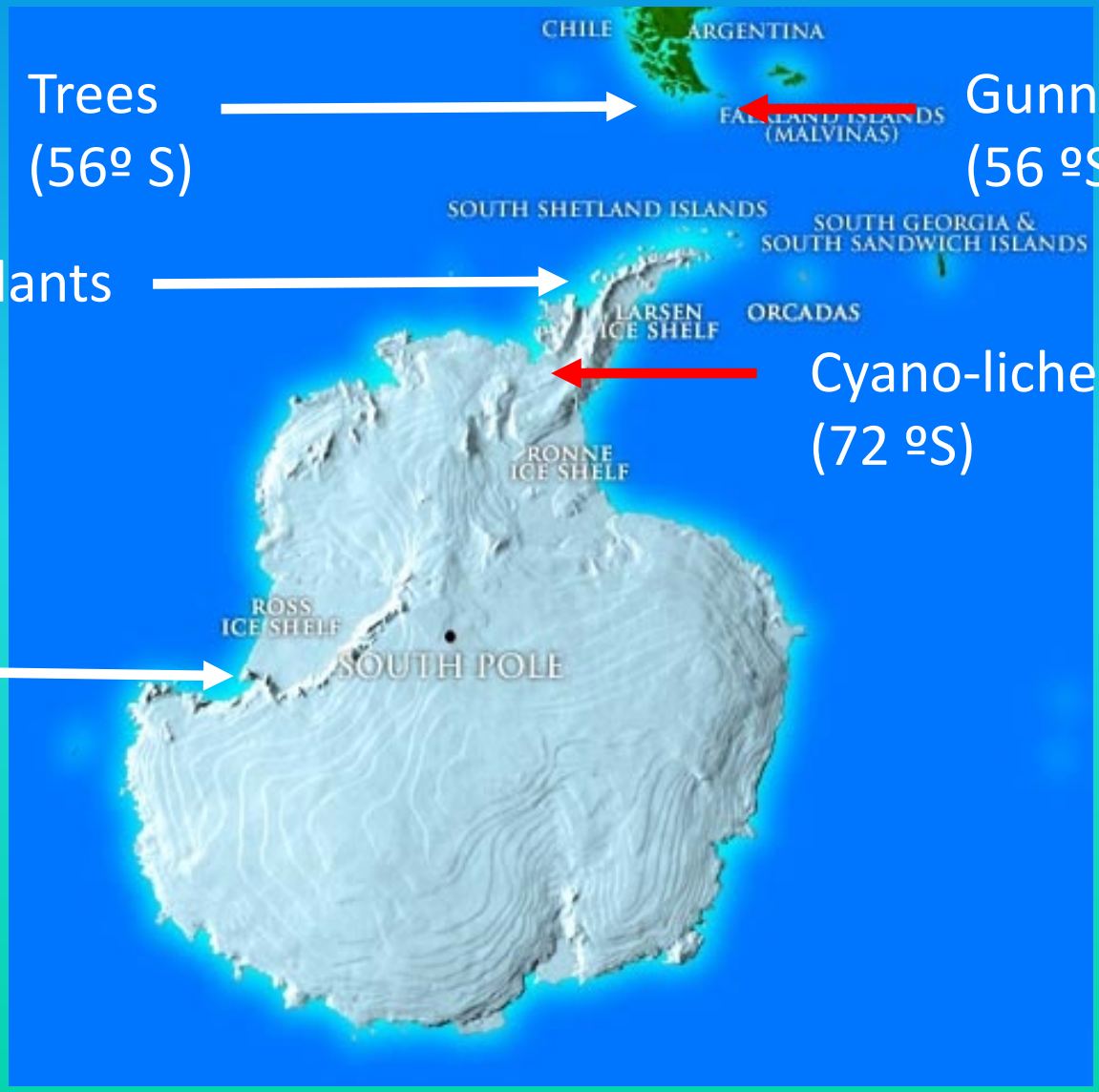
TIBET

ANTÁRTIDA

"Bipolarity"

"To find the identical plant forming the only vegetation at the two extreme limits of vegetable life is always interesting; but to find it absolutely in both instances painting landscape, so as to render its colour conspicuous in each case five miles off, is wonderful"

Natural boundaries in Subantarctic – Antarctic region



Trees
(56º S)

Gunnera
(56 ºS)

Vascular Plants
(68º S)

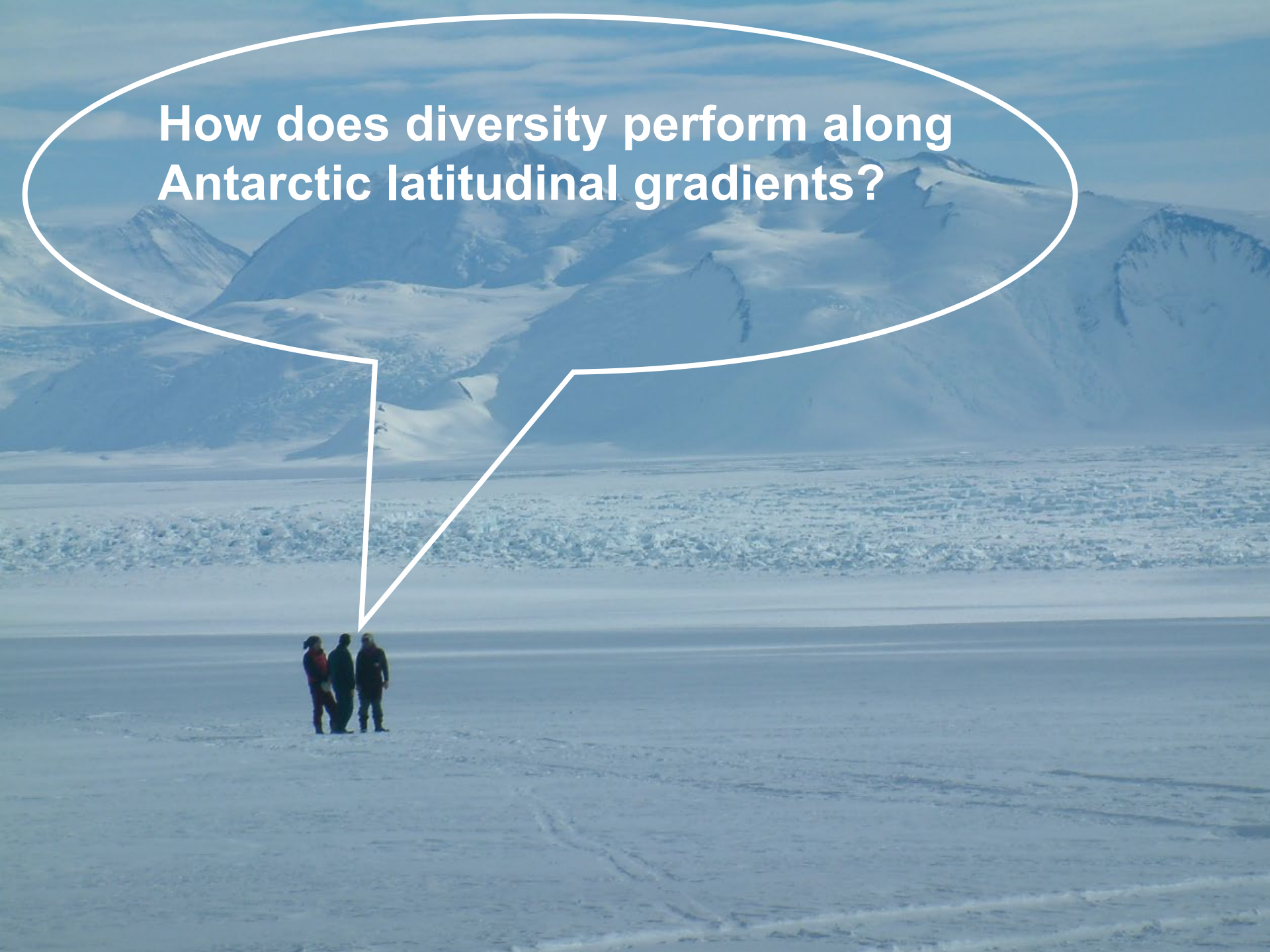
Cyano-lichens
(72 ºS)

Hepatics
(77 ºS)

Lichens are a major contributor to vegetation in Antarctica,
There is a cover gradient (low in the south, high in the north)

Rock surface

Livingston Island 63ºS


How does diversity perform along Antarctic latitudinal gradients?

Estrategias de vida al límite

* **Biodiversidad** Tierra del Fuego, Ant. Marítima, Ant. Continental.

* **Microclima**: Definir y comparar los factores abióticos.

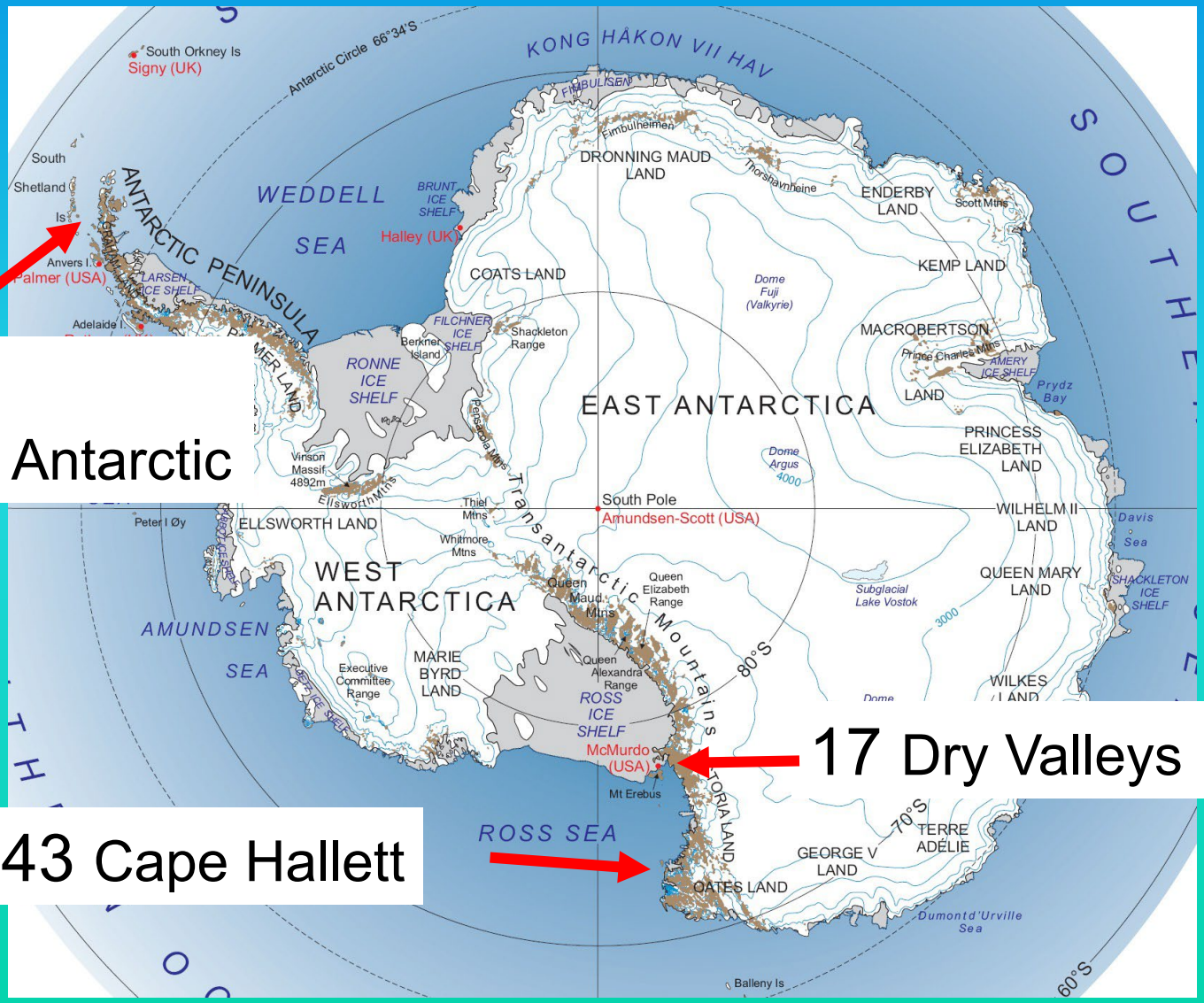
* **Crecimiento:** Características ambientales y productividad anual.

* **Adaptación:** Casos concretos.

* **Supervivencia:** Resistencia a condiciones excepcionales.

- *Gradientes climáticos / Relaciones biogeográficas*

There is a gradient in the number of lichen species, increasing from south to north.



Usnea aurantiaco-atra

Umbilicaria antarctica

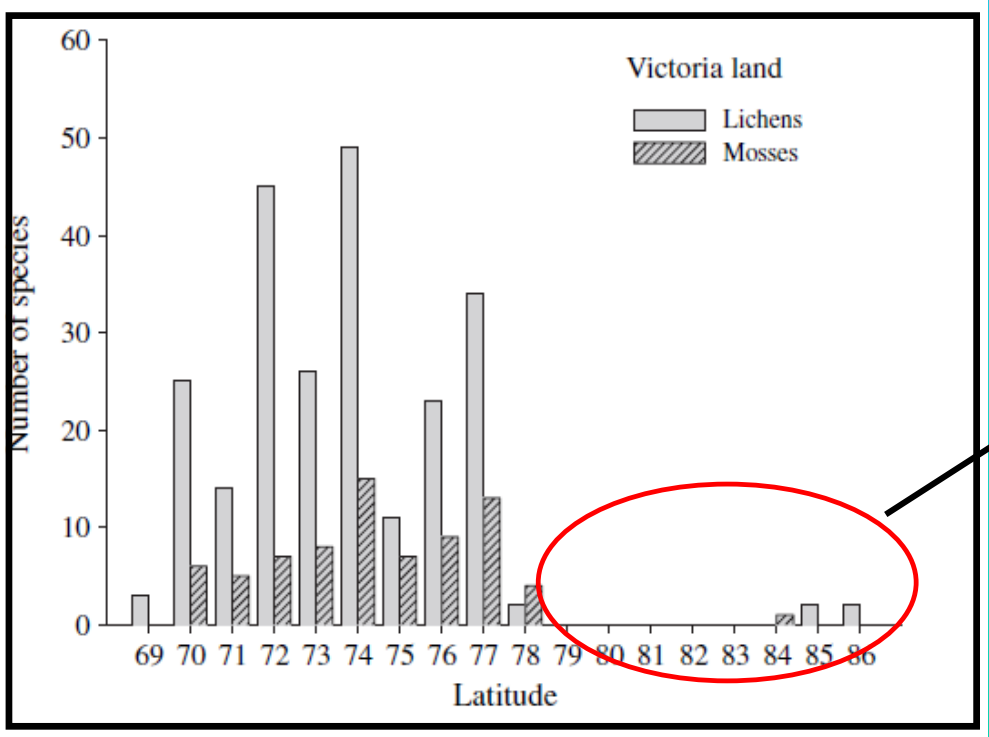
Placopsis contortuplicata

Journal of Biogeography (J. Biogeogr.) (2007) **34**, 132–146

ORIGINAL ARTICLE

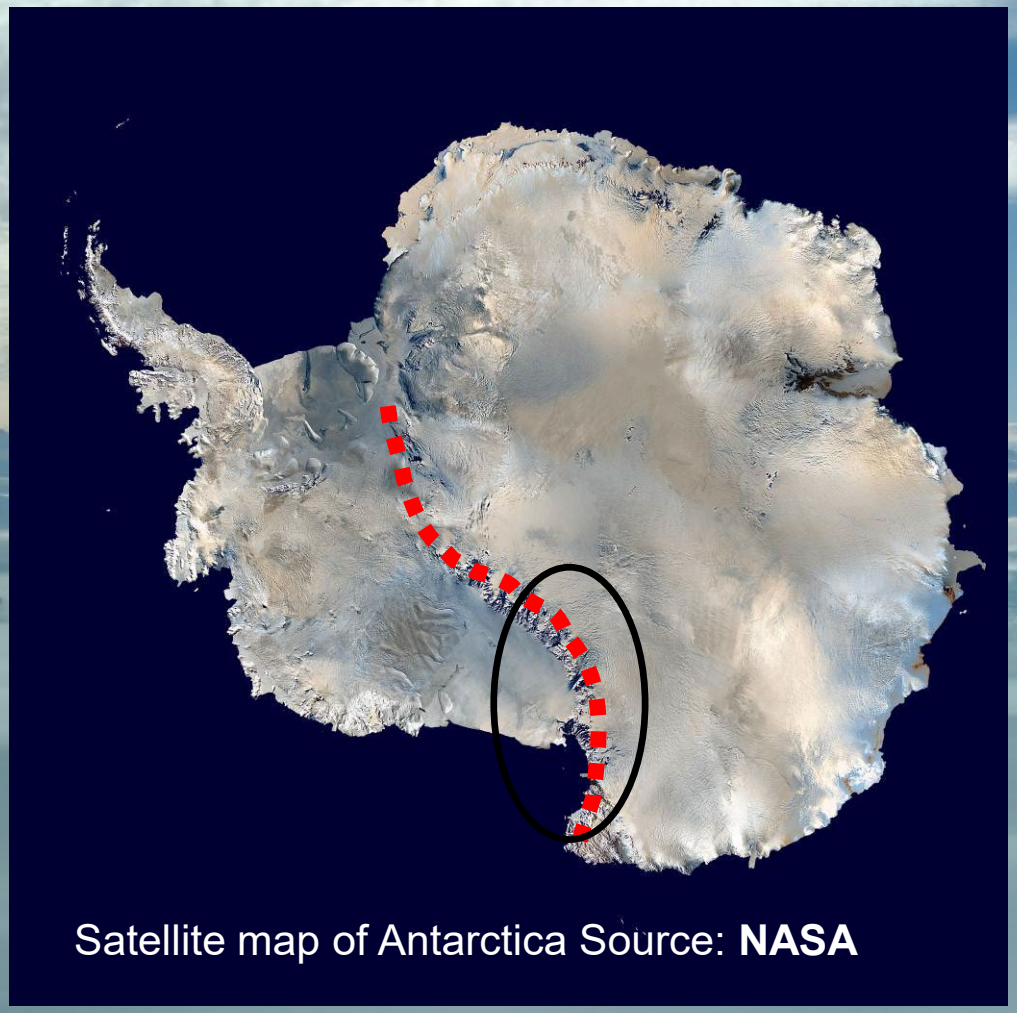
Diversity and biogeography of the Antarctic flora

Helen J. Peat*, Andrew Clarke and Peter Convey



Ross Sea region

The region may still not be sufficiently surveyed for terrestrial biota.



Satellite map of Antarctica Source: **NASA**

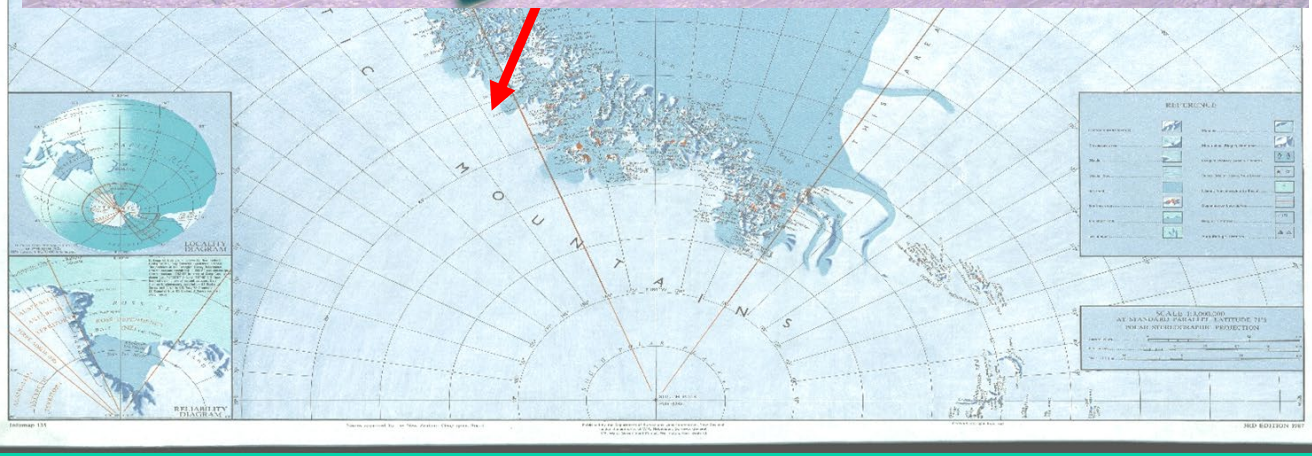
Transantarctic Mountains (TAM)

- One of the longest mountain range on Earth (3.500 km)
- Stretch from 72-87°S

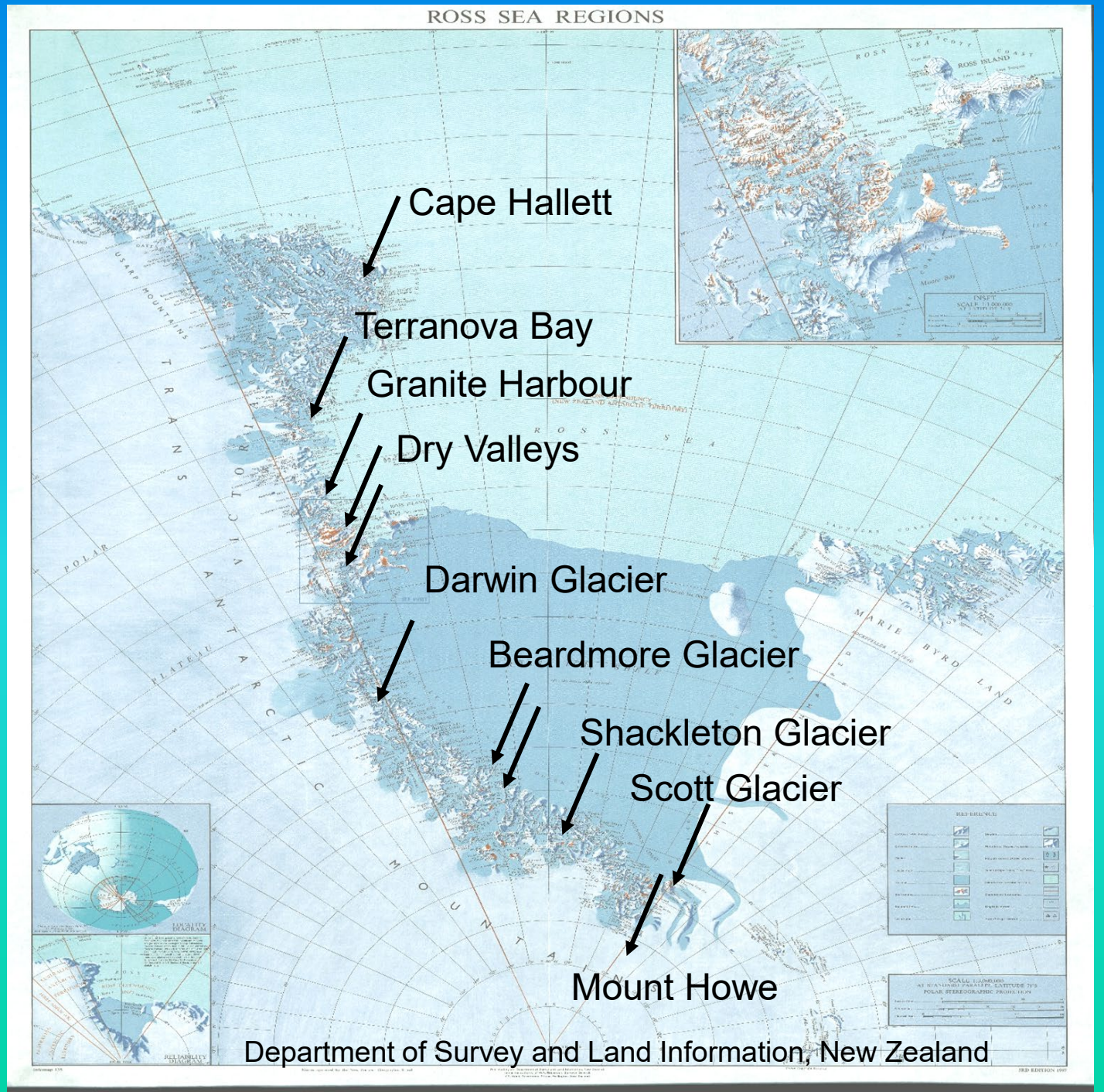
Diversity in TAM southern of Ross Island is still poorly known and many localities potentially available for vegetation development still remain unexplored.

The Latitudinal Gradient Project (LGP) project focused on the latitudinal gradient along the Ross Sea coastline and used it as a proxy for a climate gradient

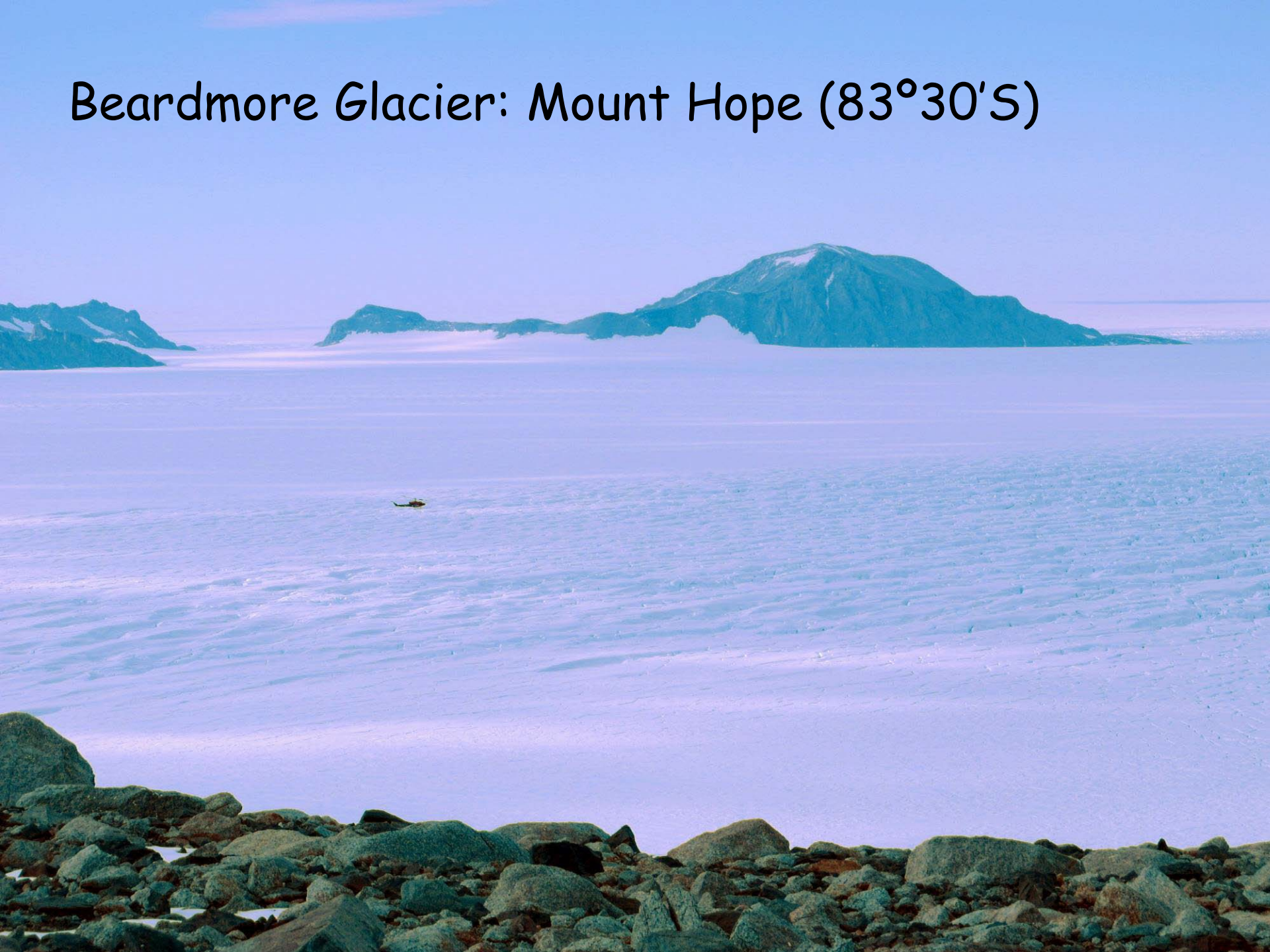
During the 2011 austral summer as part of the LGP (New Zealand) and with the assistance of the Central Transantarctic Mountain (CTAM) field camp (NSF, USA) we had the opportunity to explore the most southern parts of the Transantarctic Mountains reaching as far south as 87°S



Visited sites



Beardmore Glacier: Mount Hope (83°30'S)



Beardmore Glacier: Mount Kyffin – Ebony Ridge (83°48'S)

Fog over Beardmore Glacier

Mount Kyffin – Ebony Ridge (83°48'S)


Mount Howe (87°22'S)
Around 3000m a.s.l.


TRANSANTARCTIC MOUNTAINS
Dry Valleys, 100 a.s.l.
Latitude 77° S

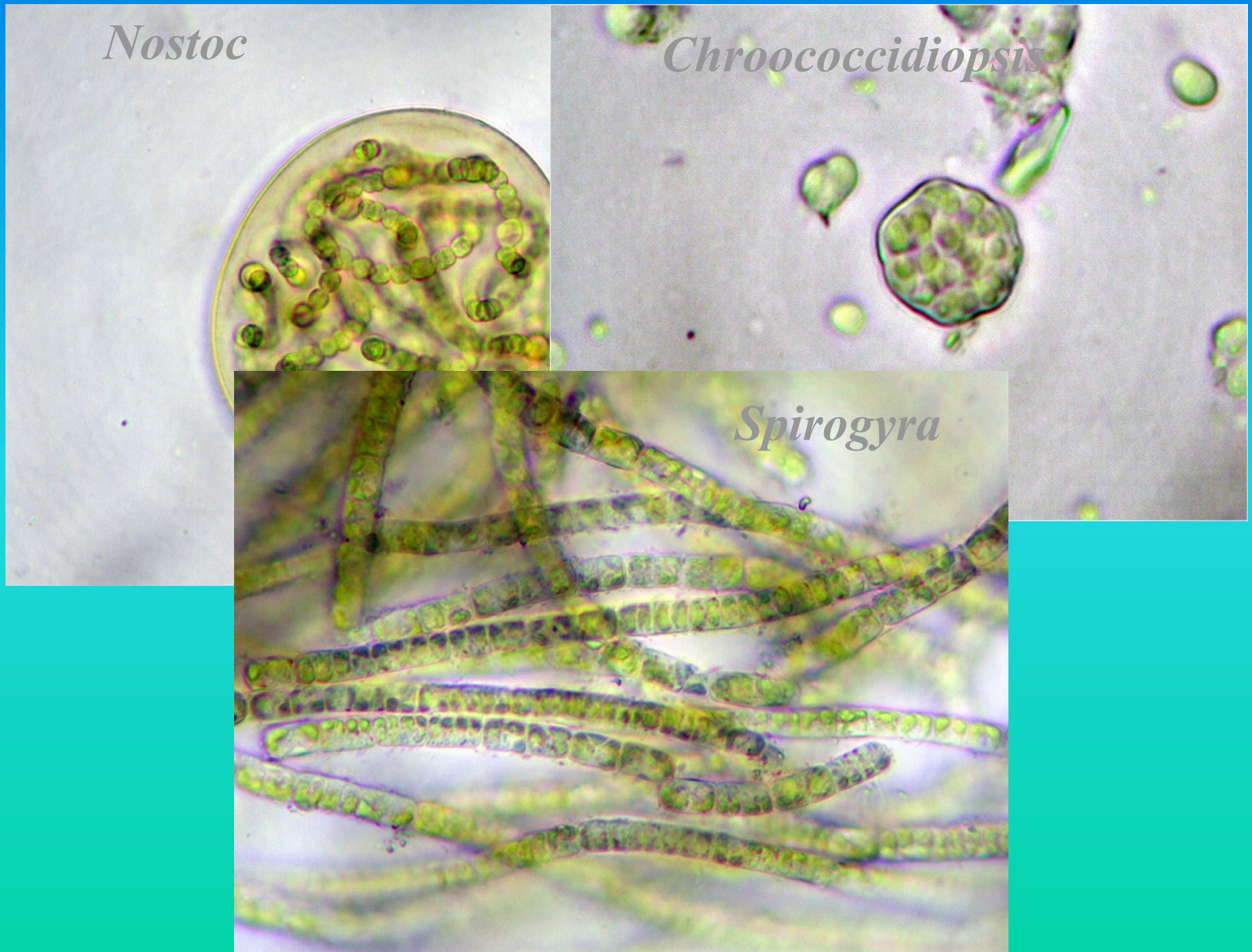
- Very low temperatures
- Extremely dry
- High UV radiation

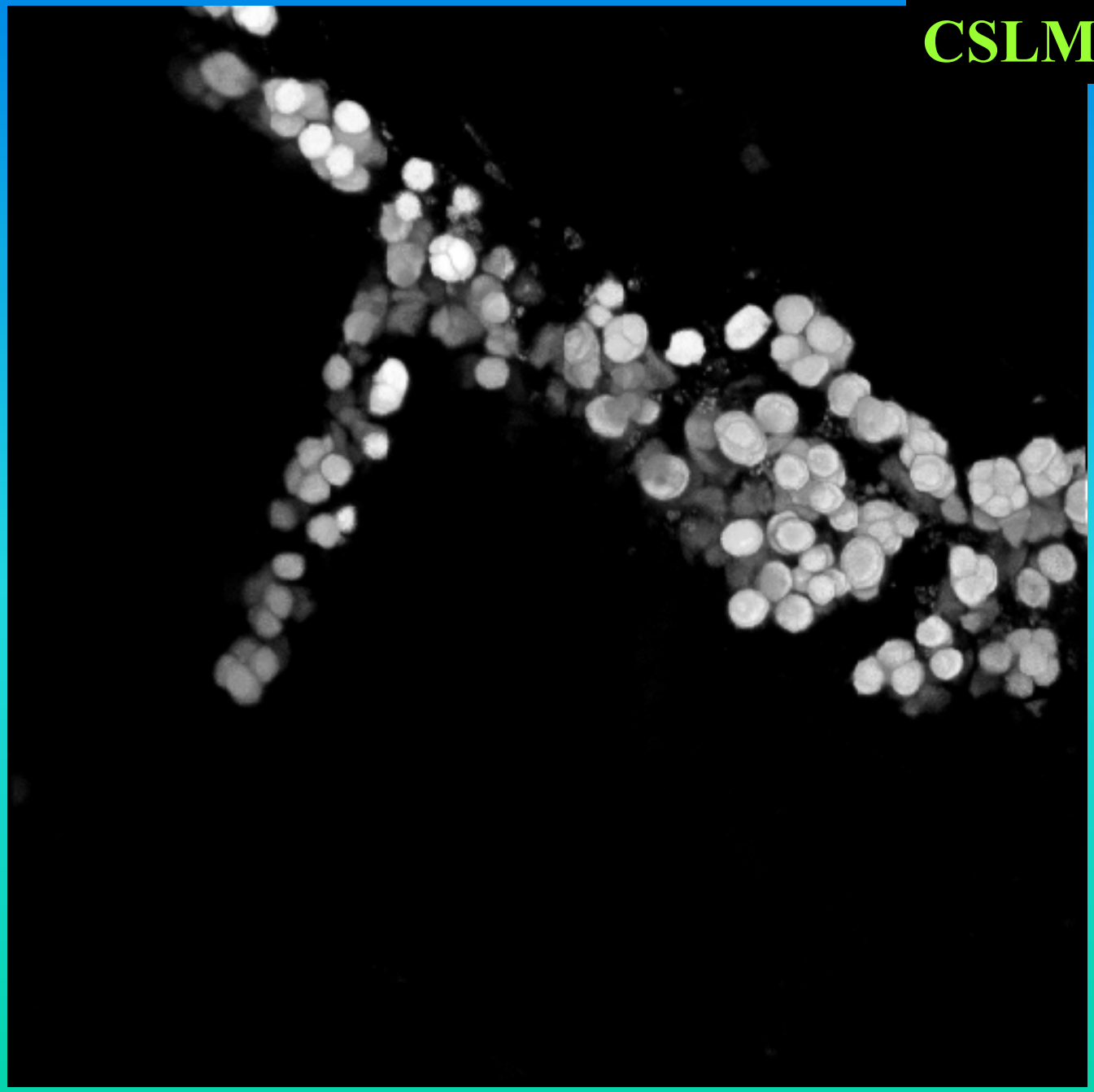

Umbilicaria aprina
Habitat:
Runoff (W)
2 cm


Buellia frigida
1 cm

Líquenes endolíticos en areniscas

Líquenes endolíticos en areniscas


Nostoc
Chroococcidiopsis
Spirogyra


CSLM


Pseudephebe minuscula
1 cm


Umbilicaria decussata
1 cm

Individualidad de las localidades:
Número de especies liquénicas en cada loc.:

Cape Hallett - 26

Botany Bay - 34

Dry Valleys - 31

Mount Kyffin - 27

Edmonson Point - ~50

Individualidad de las localidades:
Número de especies liquénicas en cada loc.:

Cape Hallett - 26

Botany Bay - 34

Dry Valleys - 31

Mount Kyffin - 26

73 especies

Edmonson Point - 50

Individualidad de las localidades:
Número de especies liquénicas en cada loc.:

Cape Hallett - 26

Botany Bay - 34

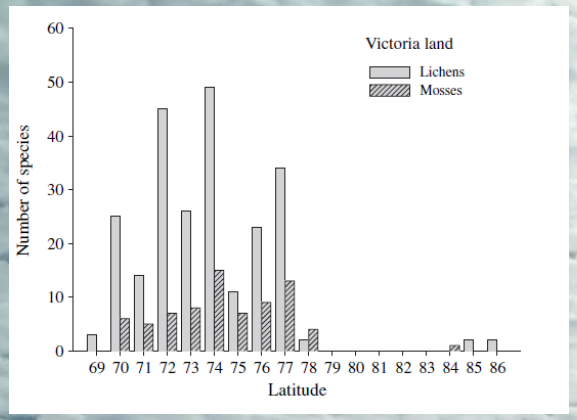
Dry Valleys - 31

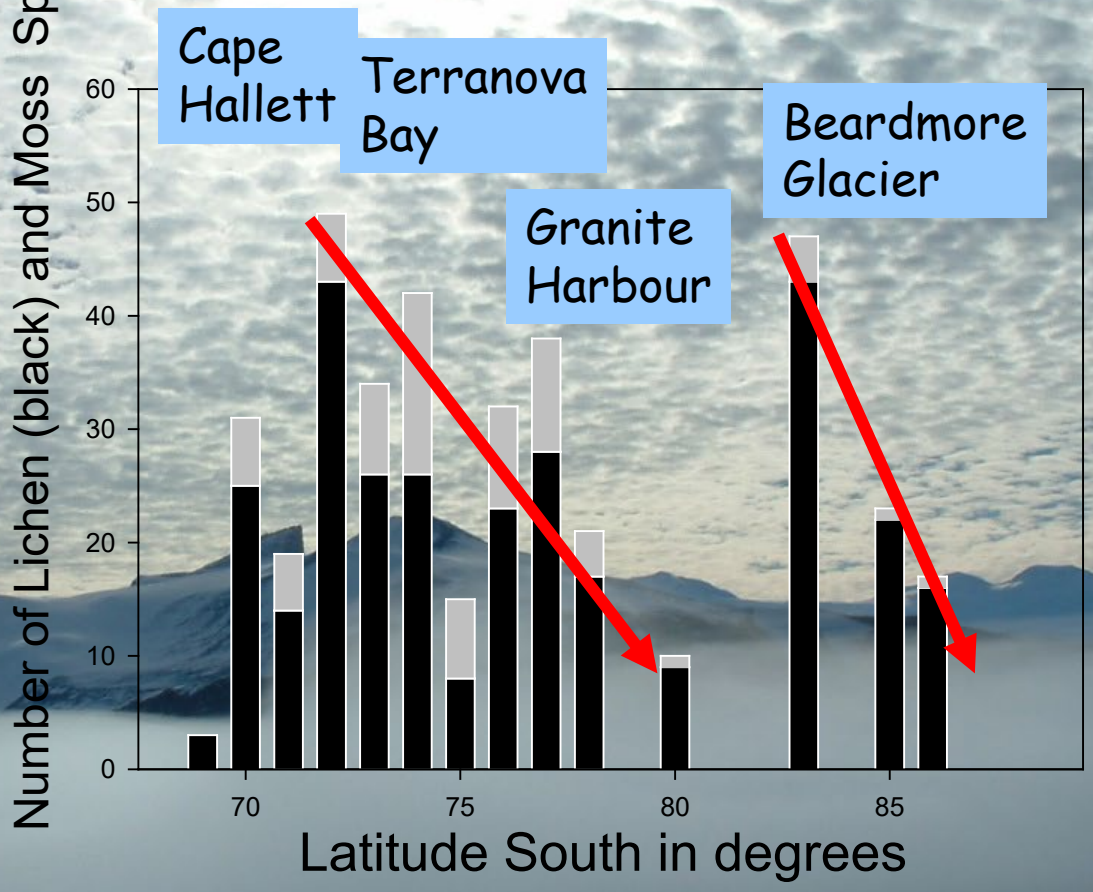
Mount Kyffin - 26

73 especies

Edmonson Point - 50

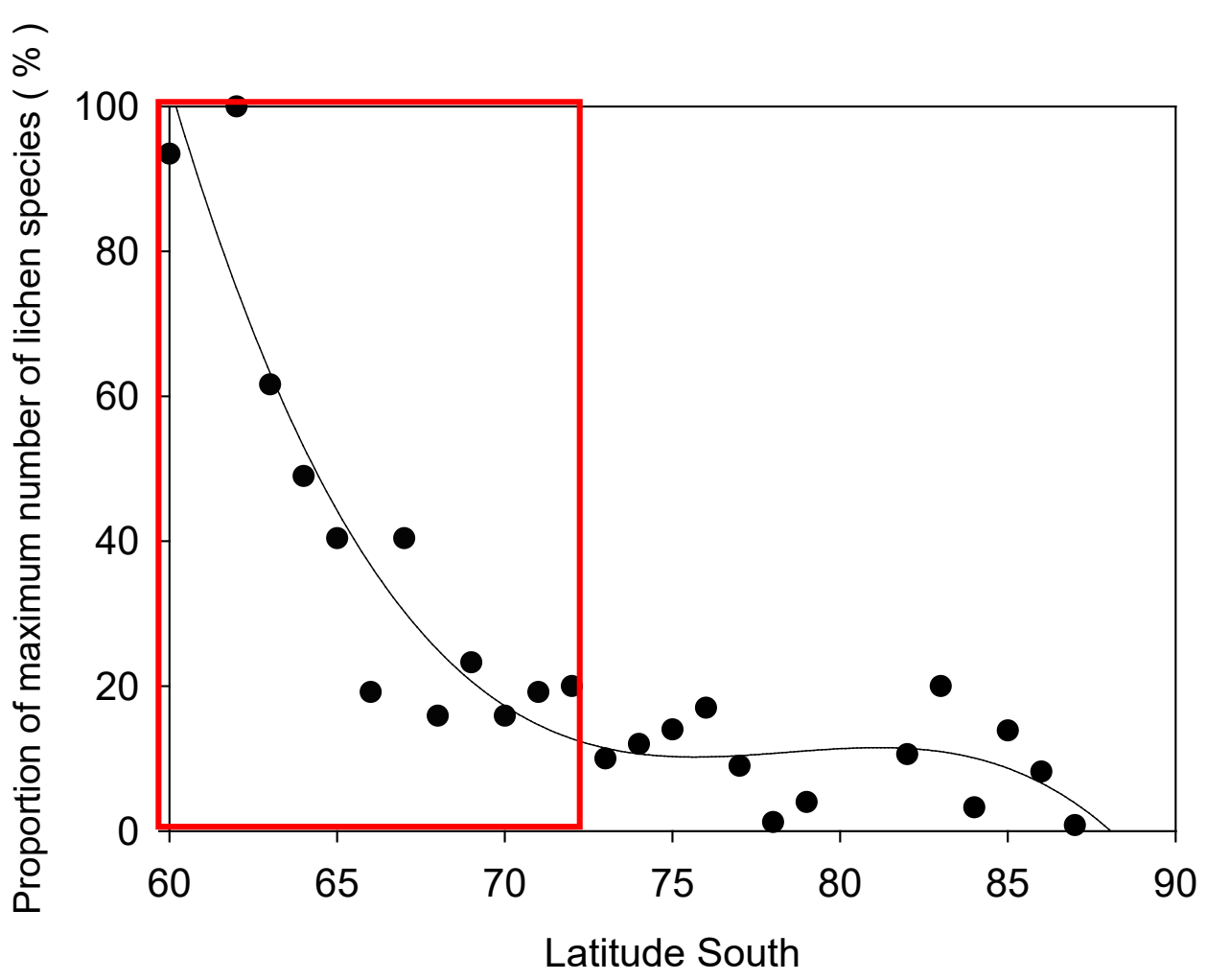
>100 especies



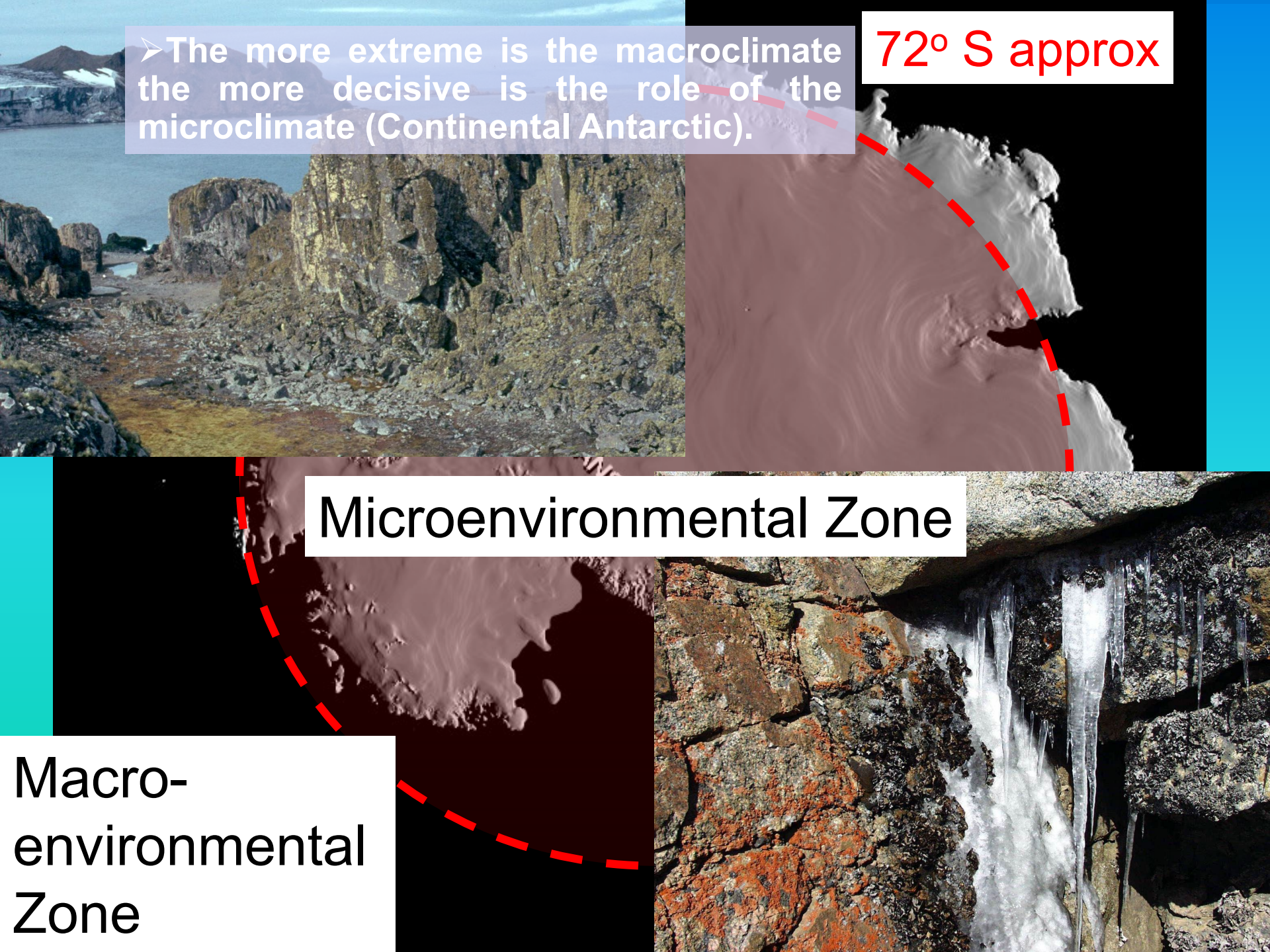


Cape Hallett and Beardmore Glacier emerge as the richest localities of the TAM.There appear to be two latitudinal gradients.

A regression of lichen diversity in relation to latitude until 72° S aprox.




MICROCLIMA
Umbilicaria aprina
**Habitat:
Runoff**


➢The more extreme is the macroclimate the more decisive is the role of the microclimate (Continental Antarctic).
72º S approx
Microenvironmental Zone
Macro-environmental Zone

Estrategias de vida al límite

* **Biodiversidad** Tierra del Fuego, Ant. Marítima, Ant. Continental

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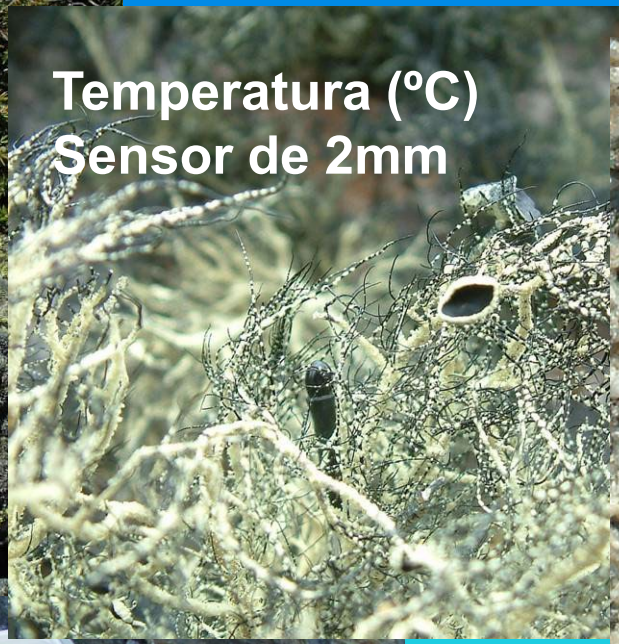
* **Adaptación:** Casos concretos.

***Supervivencia:** Resistencia a condiciones excepcionales.

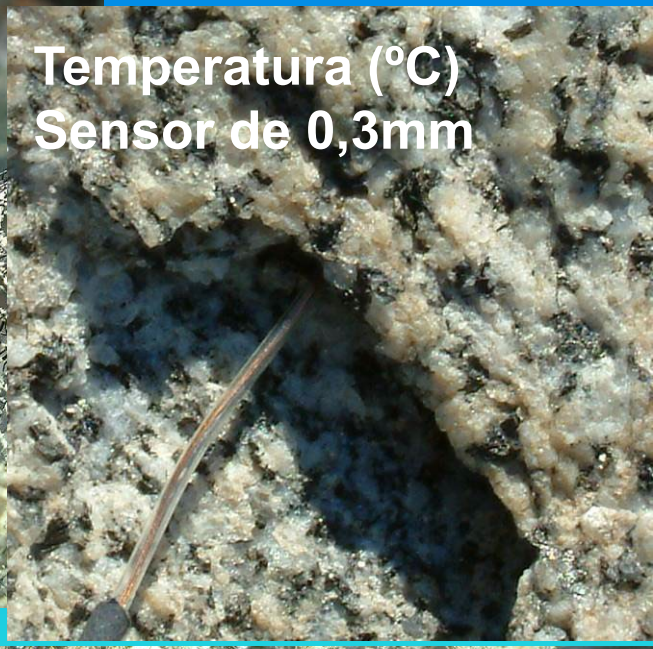
- *Microecología*

Radiación (PAR)

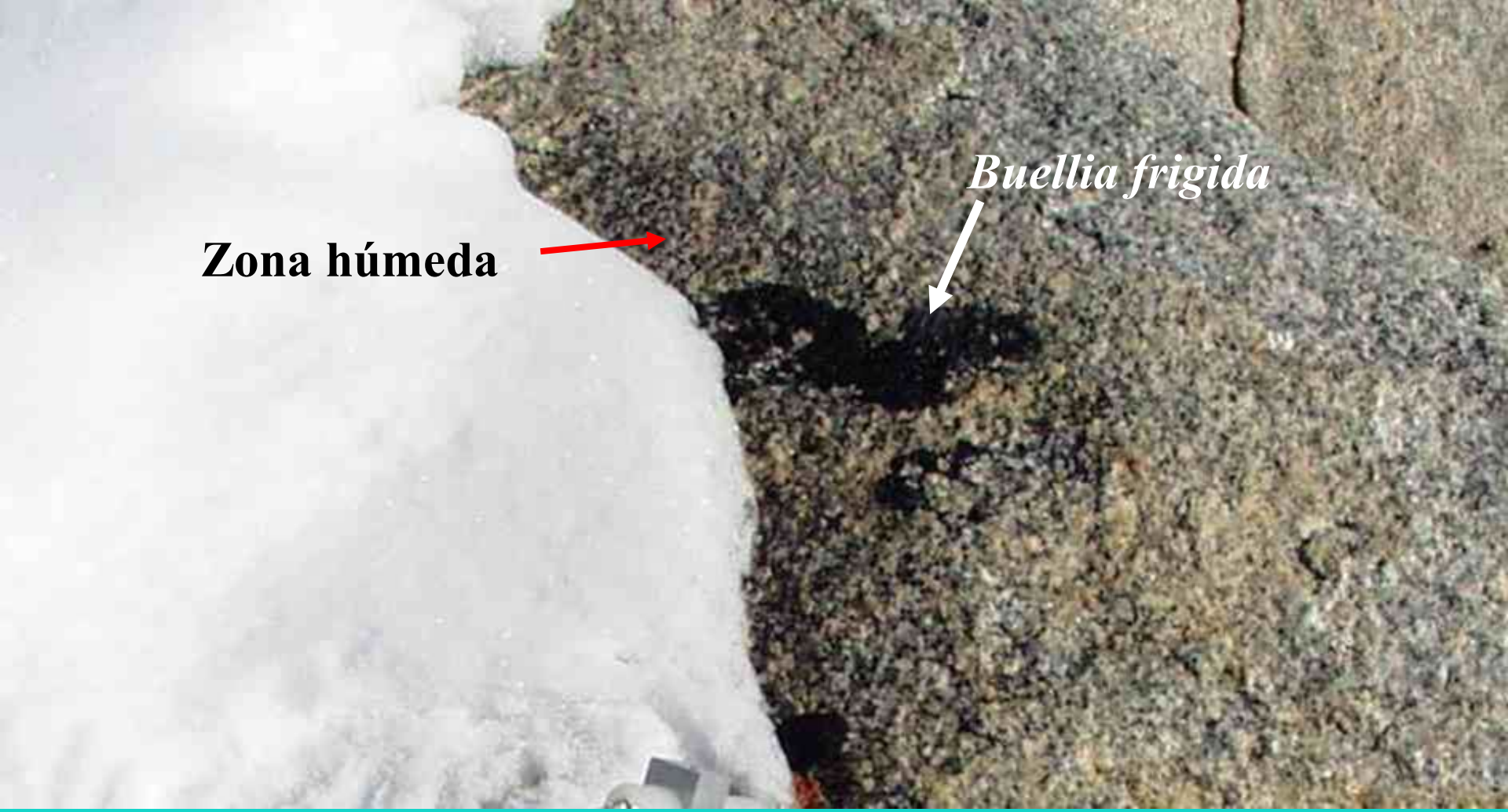
Temperatura (ºC)
Sensor de 2mm



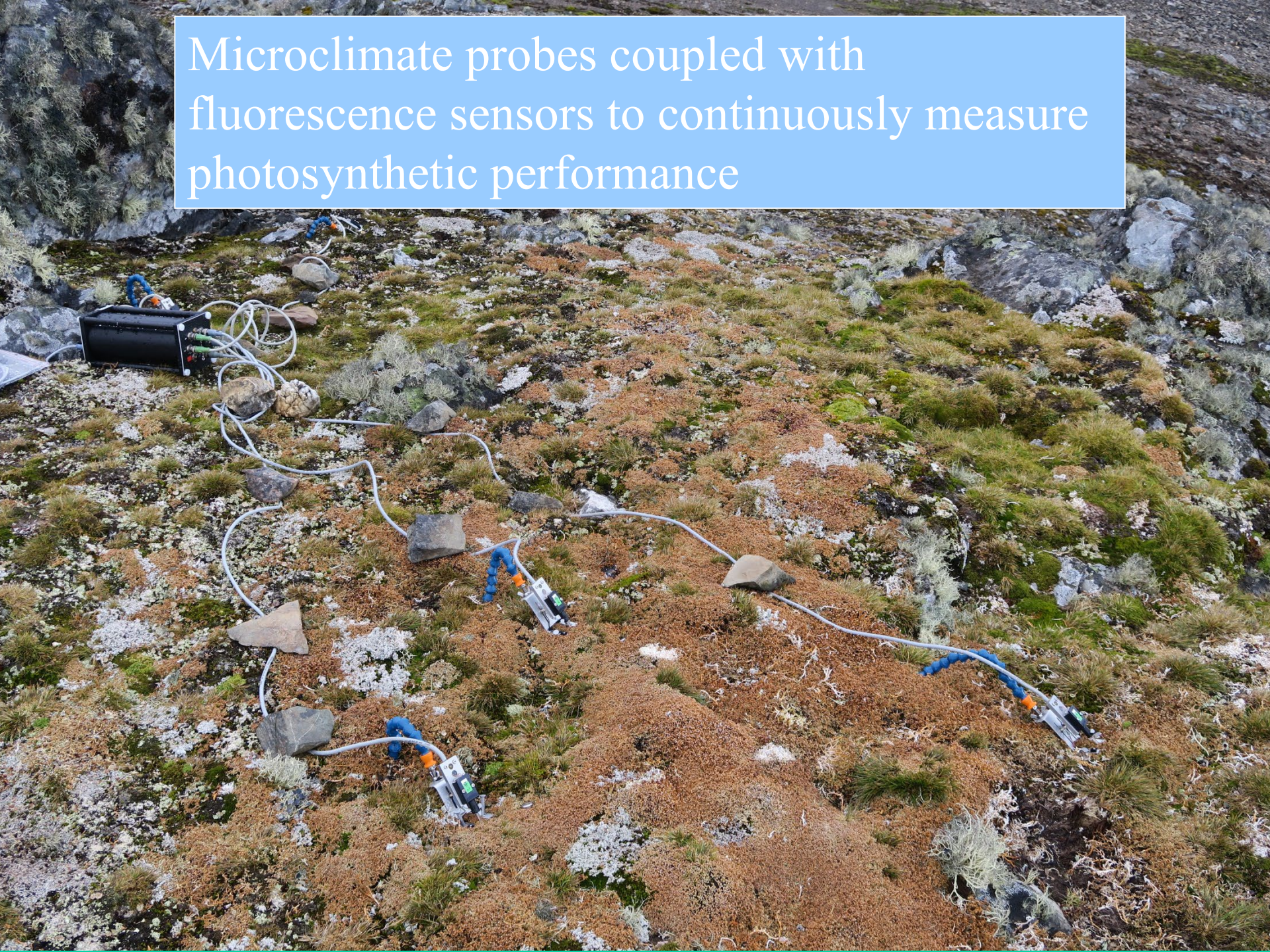
Temperatura (ºC)
Sensor de 0,3mm

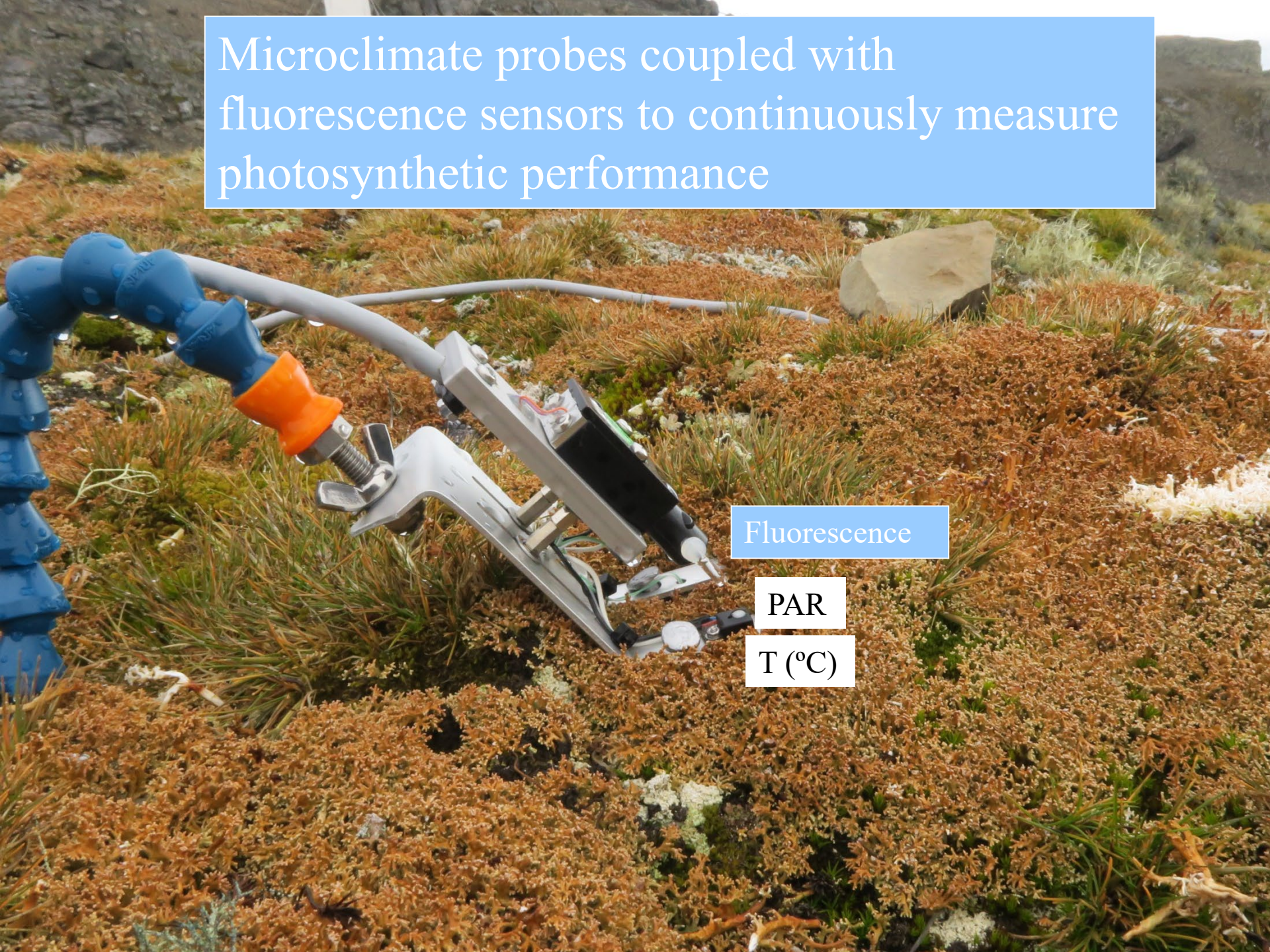


Humedad relativa (%)



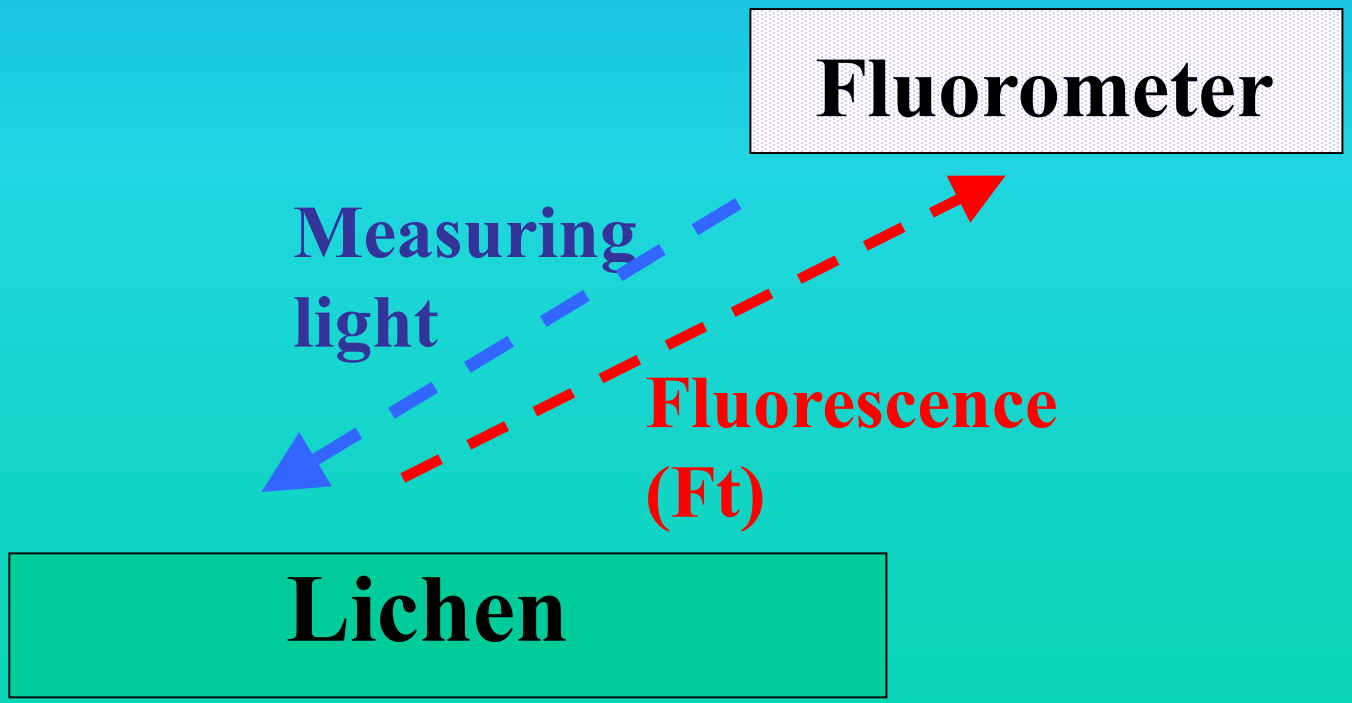
Hidratación de los líquenes tras el retroceso nival


Microclimate probes coupled with fluorescence sensors to continuously measure photosynthetic performance


Microclimate probes coupled with fluorescence sensors to continuously measure photosynthetic performance
Fluorescence
PAR
T (ºC)

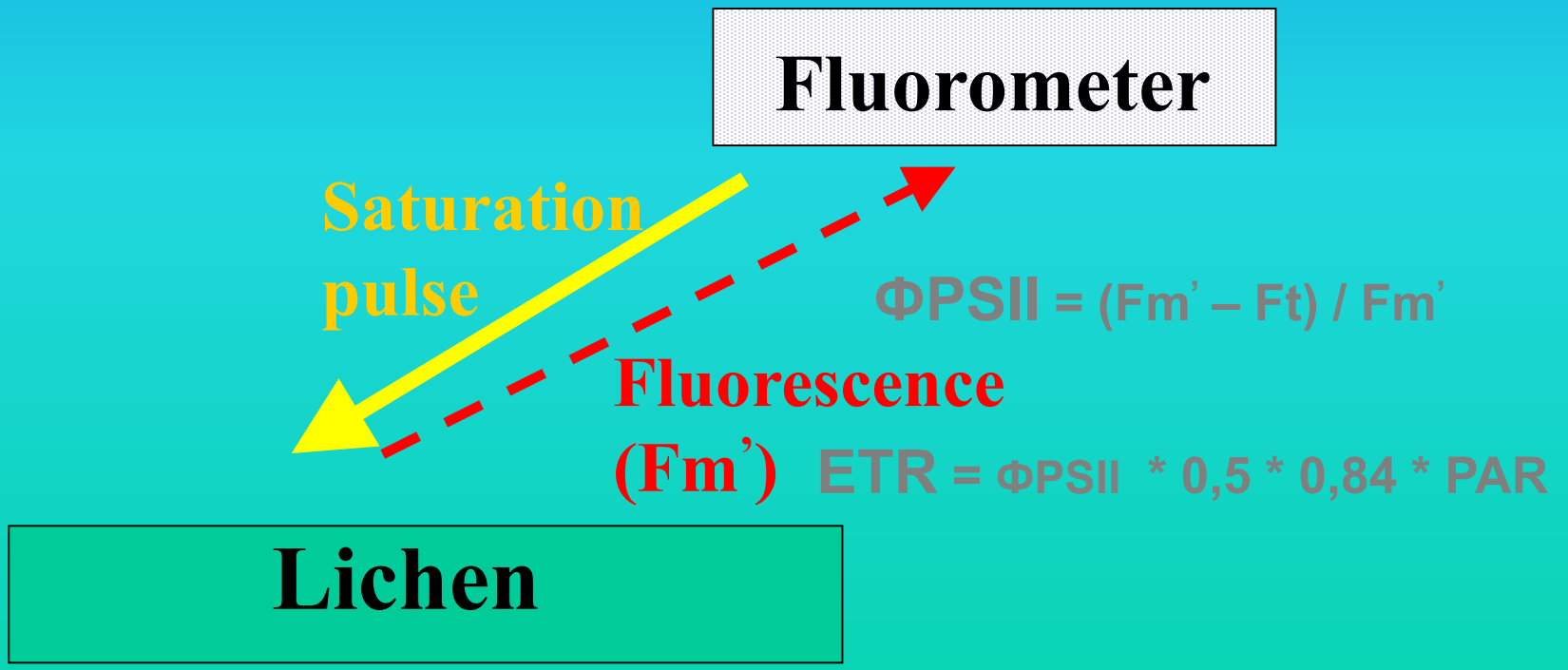
Chlorophyll *a* fluorescence

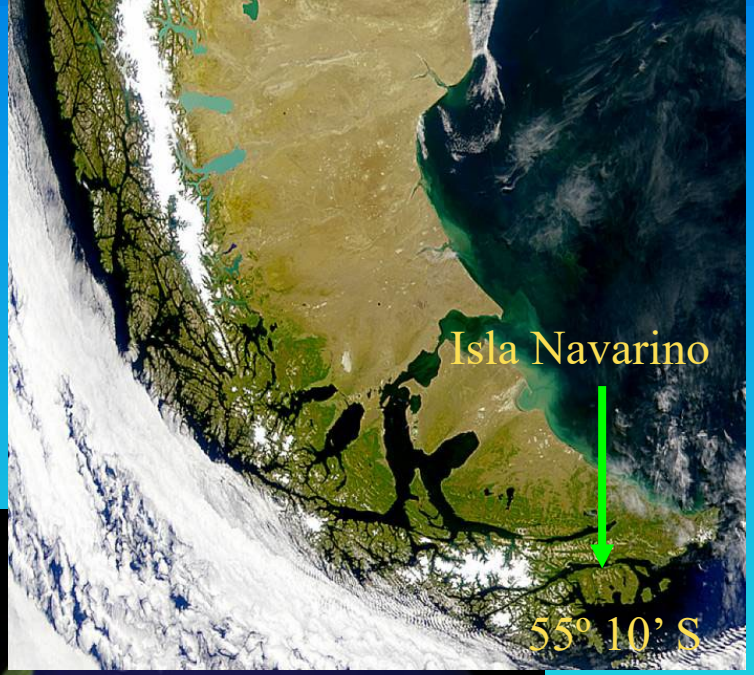
- an indicator of photosynthetic performance

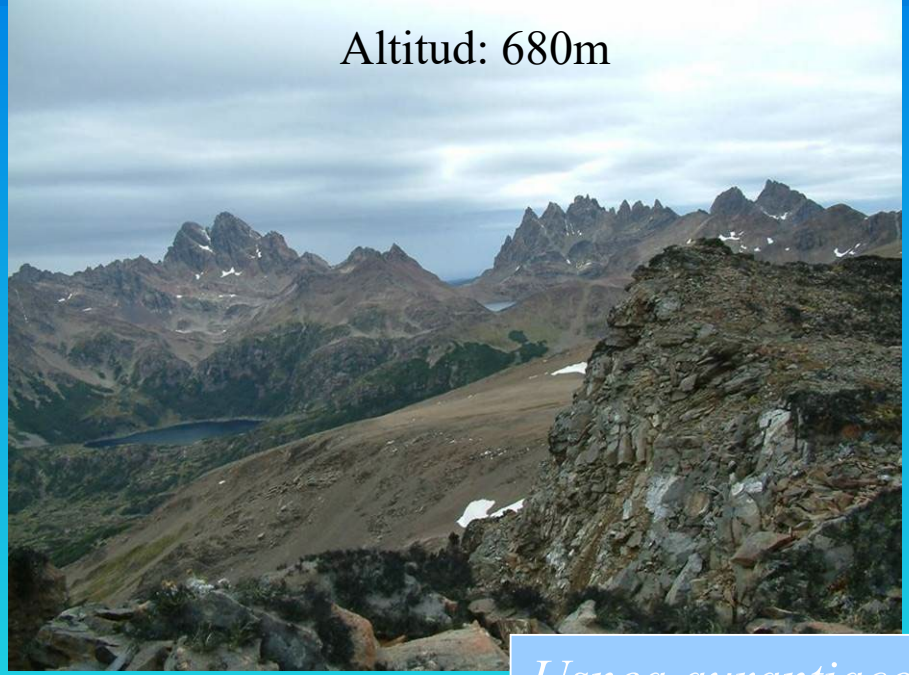


Chlorophyll *a* fluorescence

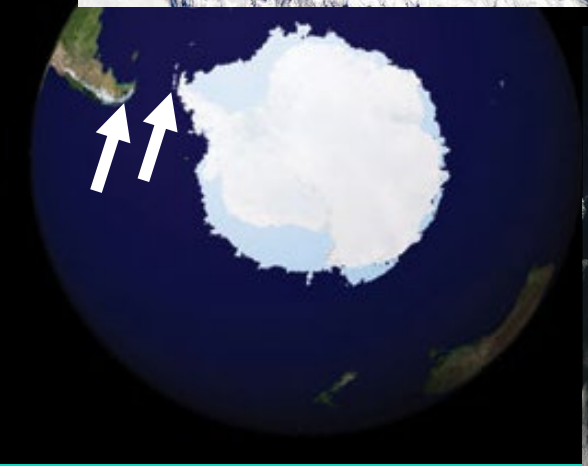
- an indicator of photosynthetic performance



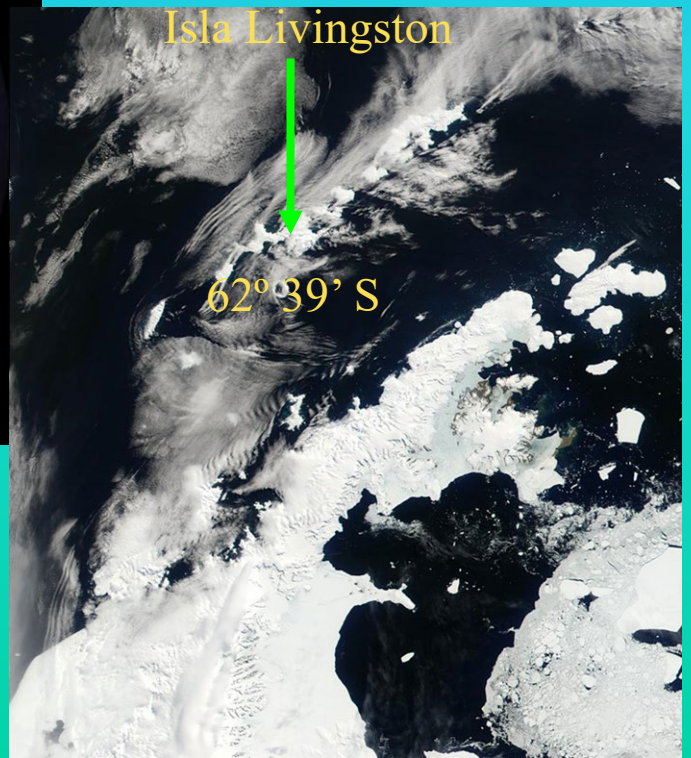


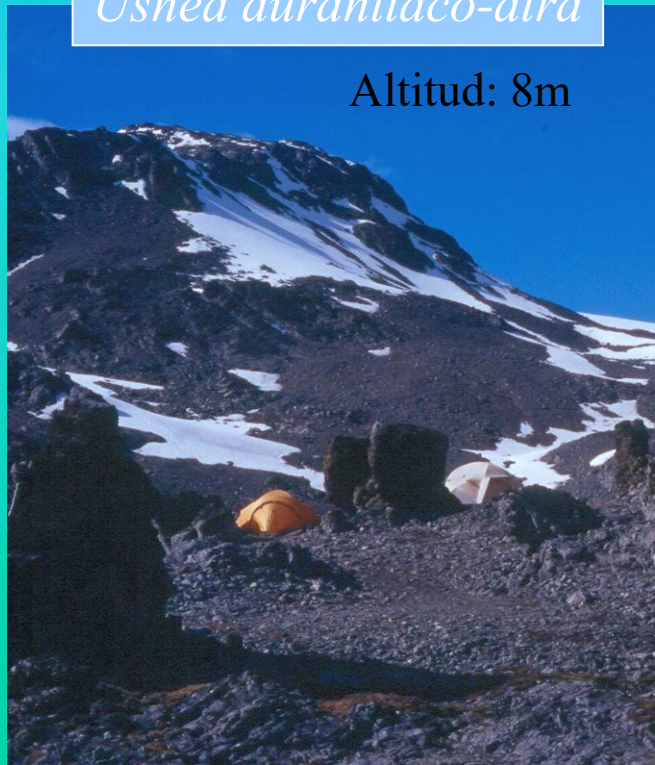


Usnea aurantiaco-atra

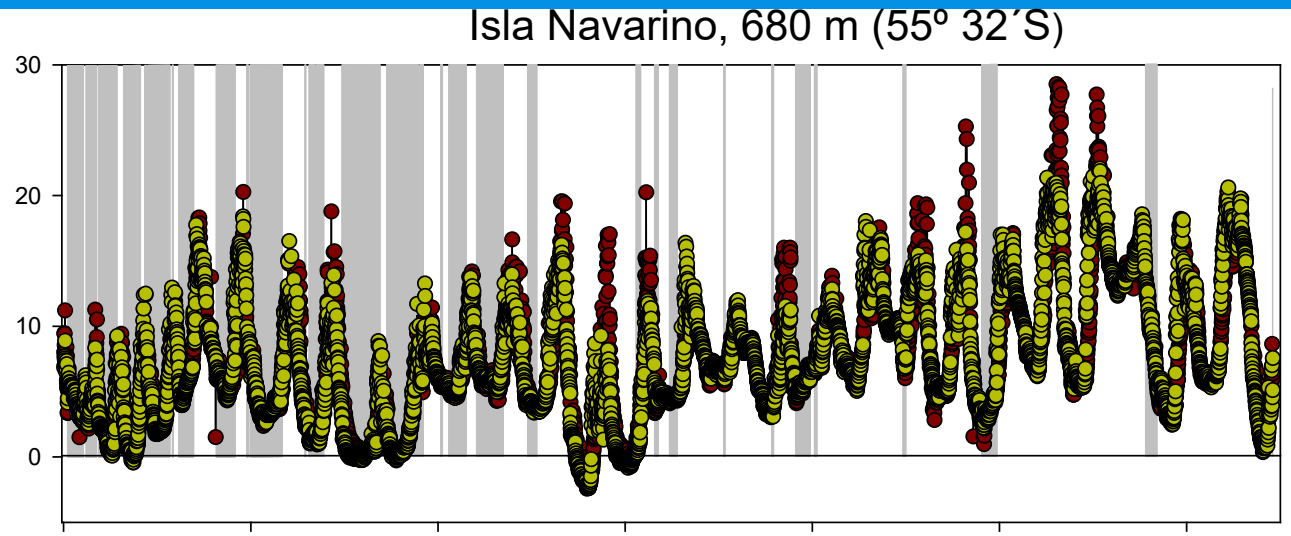


Medidas microclimáticas simultáneas Enero-Febrero 2005



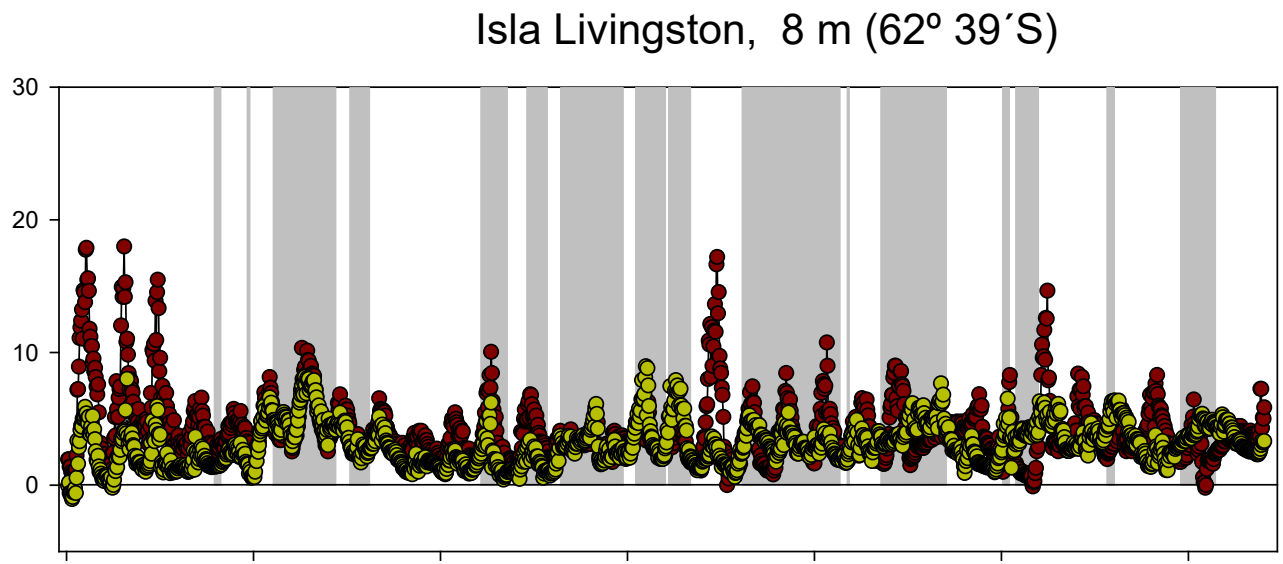


Medidas a medio plazo del microclima



MEDIAS de T (ºC)

Aire: 7,1±4,8
Talo: 7,5±4,9
Talo act.: **3,9±2,4**
Periodo act.: 34,9%



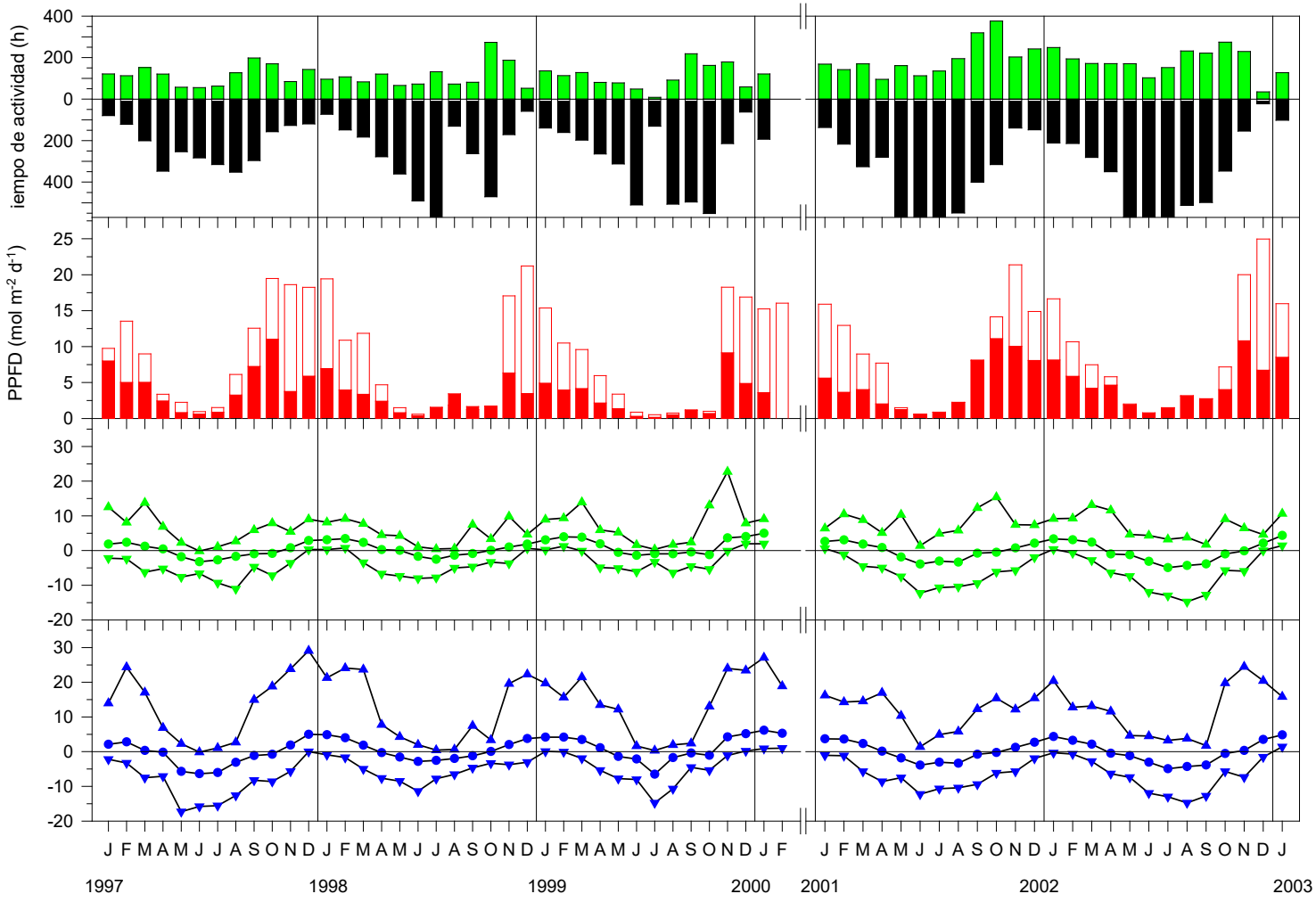
Aire: 2,9±1,6
Talo: 4,0±2,47
Talo act.: **3,6±1,8**
Periodo act.: 34,4%

Usnea aurantiaco-atra

Periodo de actividad
T del talo
T del aire

Medidas a largo plazo del microclima

Isla Livingston (62º 39´)



MEDIAS ANUALES

38%

3,8±2,3

1,1±1,3

-1,7±1,9

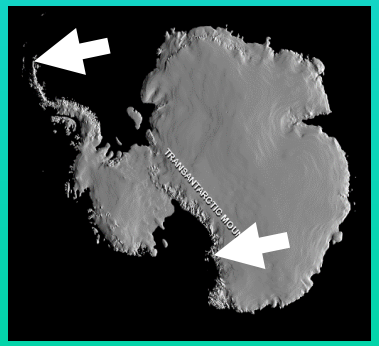
Medidas de larga duración de microclima y fotosíntesis. Medias de temperatura del aire y del talo

	Guadarrama Cumbre (2000m, 40º 47'N) *Lasallia hispanica* (T y t absolutas)	Guadarrama Bosque (1450m, 40º 47'N) *Lasallia hispanica* (T y t absol.)	Almería Tabernas (305m, 37º 00' N) *Diploschistes diacapsis* (T y t absol.)	Antártida Isla Livingston (10m, 62º 39' S) *Usnea aurantiaco-atra* (T y t absol.)	Antártida Granite Harbour (10m, 77º 00' S) *Umbilicaria aprina* (T y t absol.)
T media del aire (ºC)	6,4 (Navacerrada)	9,3 (ElVentorrillo)	18,2 (Tabernas)	-2,3 (Rey Jorge)	-21,5 (Scott Base)
Temperatura media del talo (ºC)	9,7 ± 5,8 (58,5/-10,8)	12,2 ± 5,4 (48,0/-6,2)	18,6 ± 7,6 (**63,5**/-5,0)	-2,2 ± 2,3 (30,0/-18,5)	-9,74* (29/**-33,5**)
Temperatura media del talo en actividad (ºC)	4,5 ± 3,6 (1 año)	7,2 ± 2,9 (1 año)	8,6 ± 2,8 (1 año)	0,9 ± 1,4 (14 años)	0,1 ± 1,7 (3 años)

Lichen activity monitoring at Botany Bay (77°S) and Livingston Island (62°S)

Temperatures when lichens are active are identical at these sites which are 15 degrees of latitude apart.

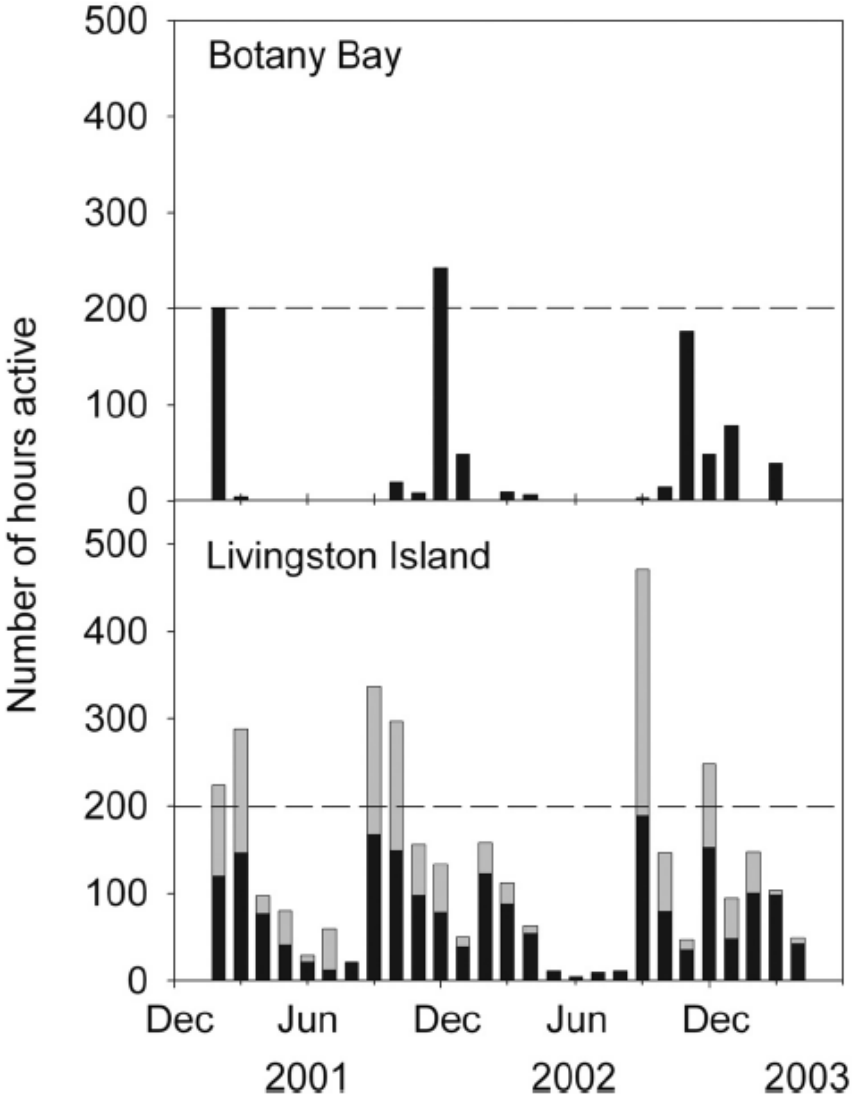
	Livingston Island	Botany Bay
Mean temperatures (°C)		
Air……..	-1.5	-17.0
Lichen when active…….	0.9	0.1
Lichen when active, November to February...	2.9	2.6



Fourteen degrees of latitude and a continent apart: comparison of lichen activity over two years at continental and maritime Antarctic sites

BURKHARD SCHROETER[1], T.G. ALLAN GREEN[2,4*], STEFAN PANNEWITZ[3], MARK SCHLENSOG[3] and LEOPOLDO G. SANCHO[4]

Lichen activity monitoring at Botany Bay (77°S) and Livingston Island (62°S)



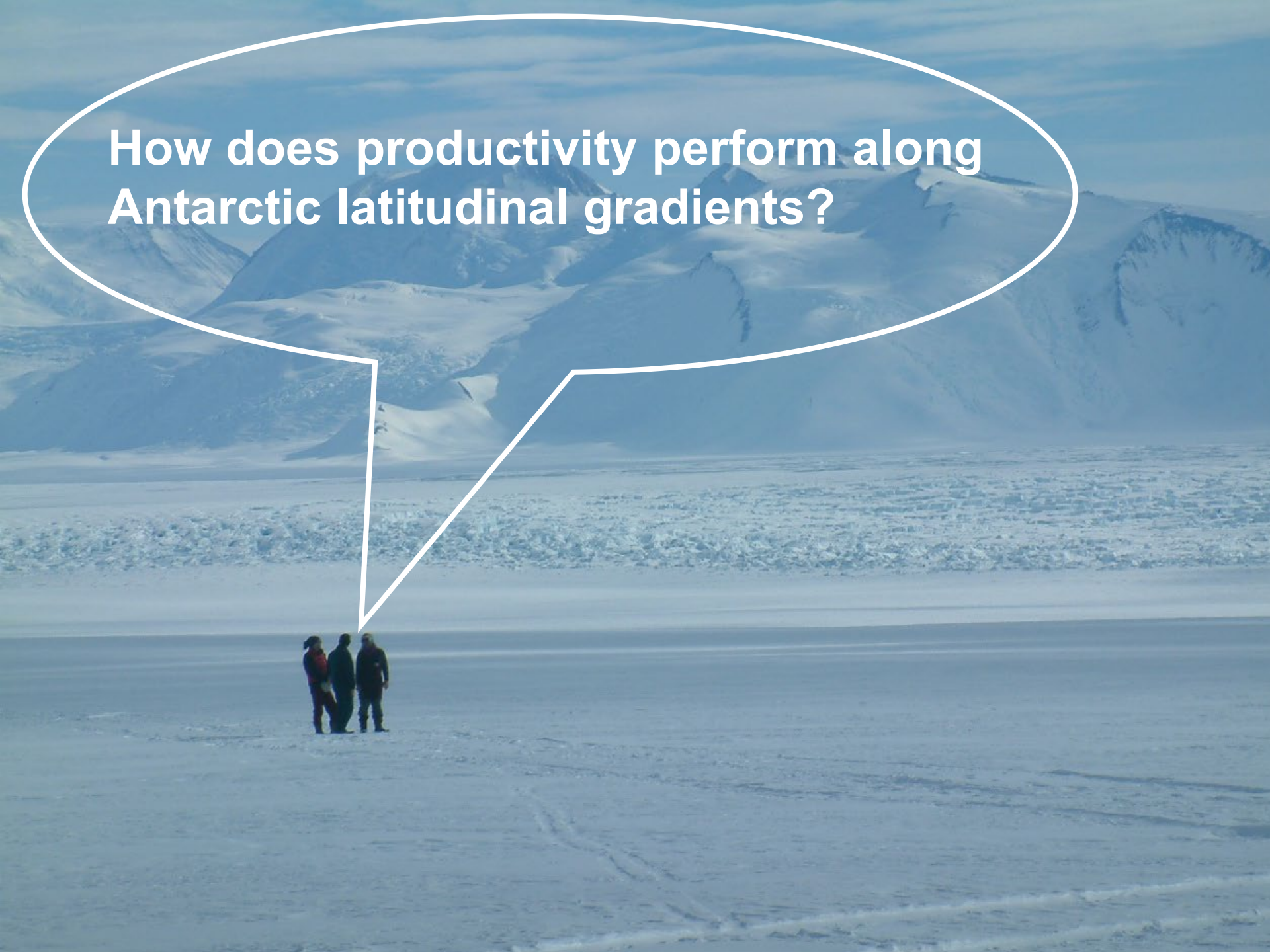
What is very different is the number of hours that the lichens are active

February 2001 to April 2003

	Total active hours	(% of Time)
Botany Bay	897	(4.6%)
Livingston I.	3694	(18.6%)

Fourteen degrees of latitude and a continent apart: comparison of lichen activity over two years at continental and maritime Antarctic sites

BURKHARD SCHROETER[1], T.G. ALLAN GREEN[2,4]*, STEFAN PANNEWITZ[3], MARK SCHLENSOG[3] and LEOPOLDO G. SANCHO[4]


How does productivity perform along Antarctic latitudinal gradients?

Estrategias de vida al límite

*** Biodiversidad**
Tierra del Fuego, Ant. Marítima, Ant. Continental

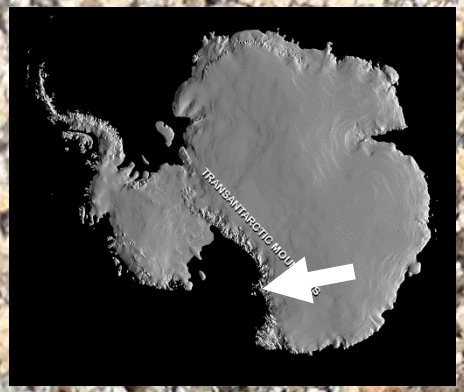
*** Microclima**: Definir y comparar los factores abióticos.

*** Crecimiento:** Características ambientales y productividad anual.

*** Adaptación:** Casos concretos.

***Supervivencia:** Resistencia a condiciones excepcionales.

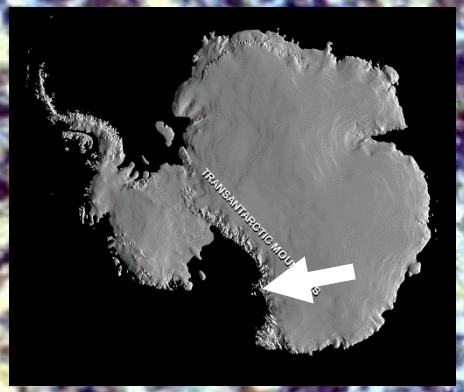
- *Liquenometría*



Buellia frigida

77-78º S

1 cm



Buellia frigida

1985

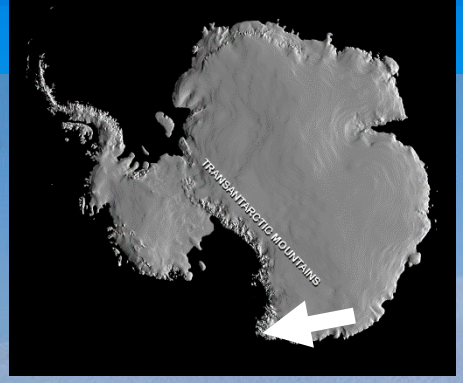
Extremely slow

2002

2008

1 cm

Annual Diameter Growth Rate: 0.02mm



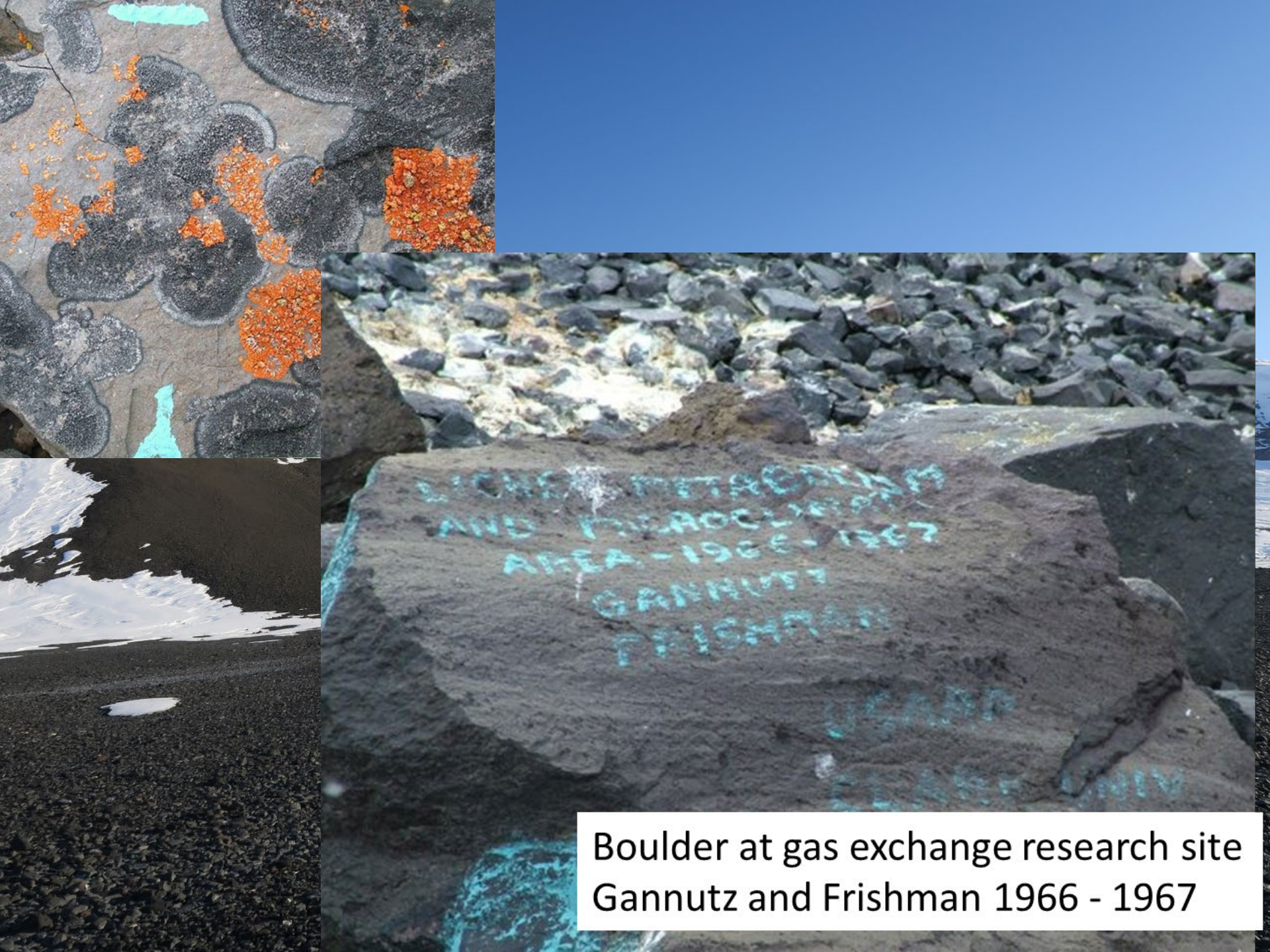
Cape Hallett

Summit at around 700m

Scree slope

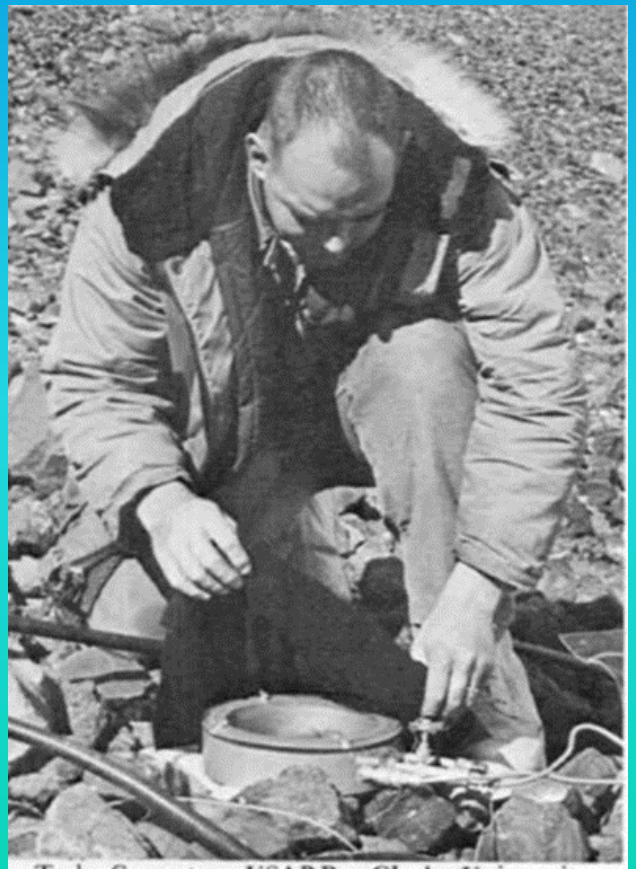
Flat outwash area
Rudolph site 1962

Seabee Hook
with Adelie Penguin colony



Boulder at gas exchange research site
Gannutz and Frishman 1966 - 1967

Theodore Gannutz and Steve Frishman
Cape Hallett. October to December, 1966;
First field gas exchange measurements (O.L. Lange assisting)

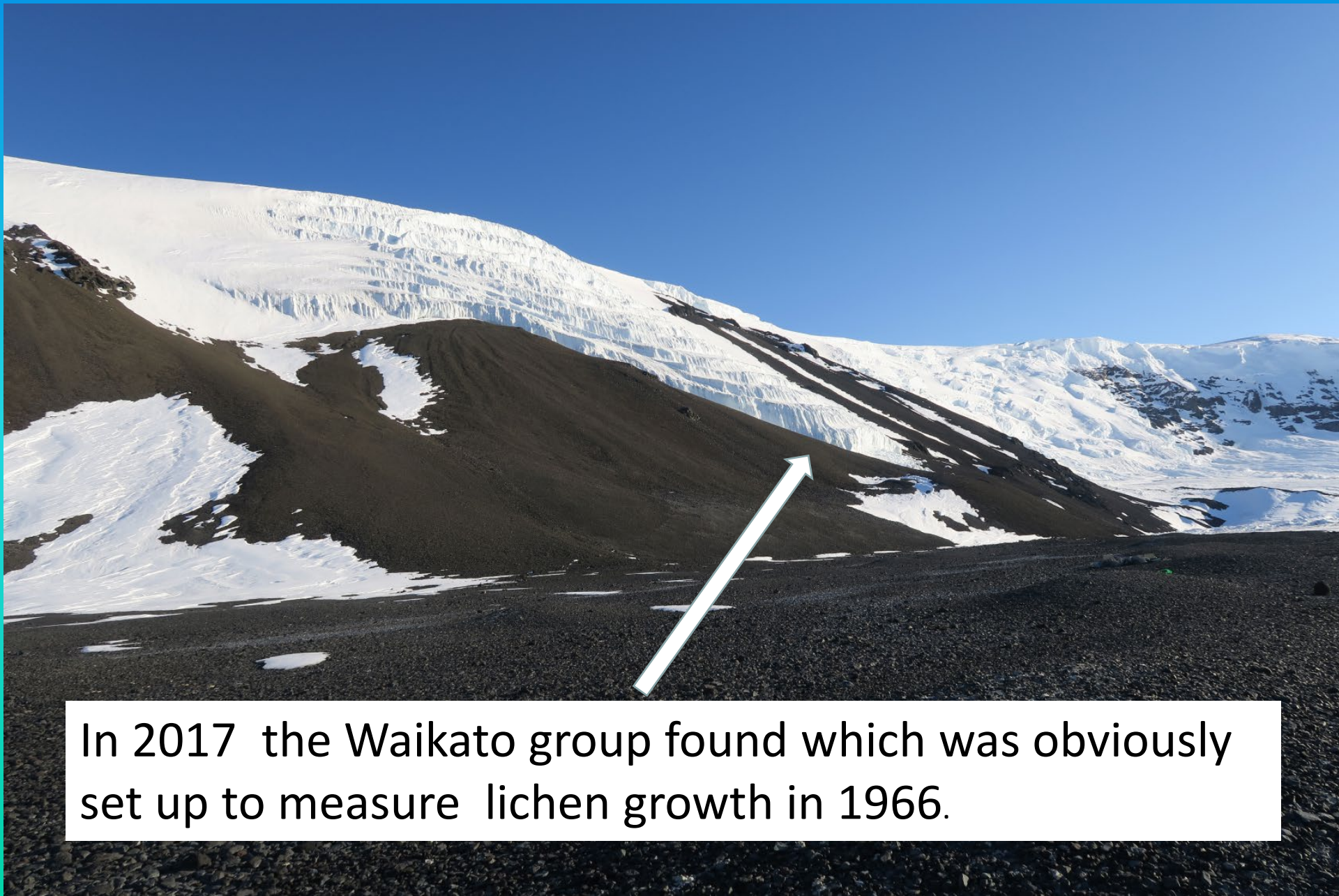


Ted Gannutz, USARP, Clark University, conducts lichen photosynthesis experiments with the aid of a respiration chamber.

Steve Frishman at the field laboratory

Única expedición a la Antártida en 1966

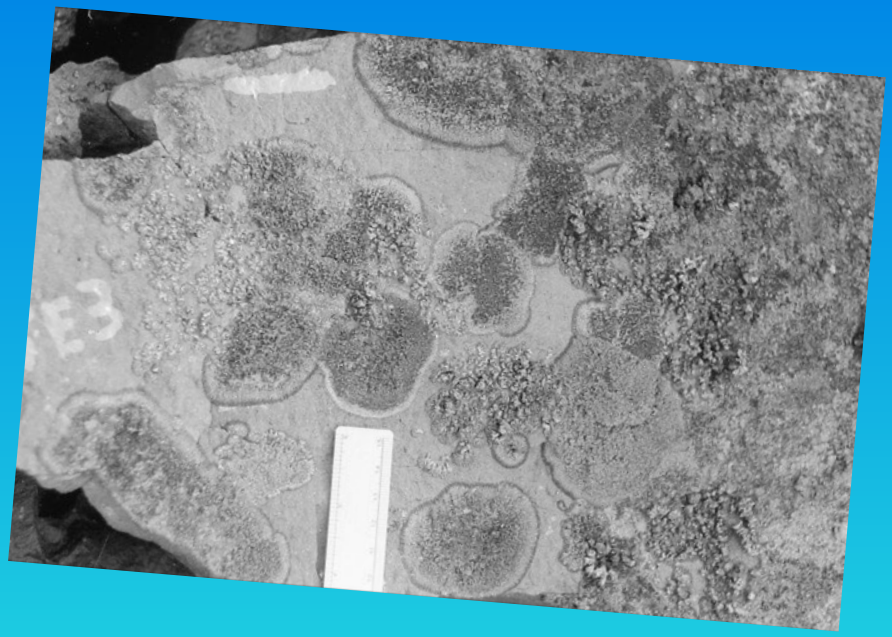
Cape Hallett, view of scree slope, looking south from Seabee Hook.



In 2017 the Waikato group found which was obviously set up to measure lichen growth in 1966.

Theodore Gannutz and Steve Frishman
Established the lichen monitoring site;
13 sites photographed - 1966.
Photographed again by Leopoldo Sancho, 2017 (51 thalli measured).

Original photographs are available from Ted Gannutz



1966

2017

51 years


TRANSANTARCTIC MOUNTAINS
Isla Livingston
Latitud 62º S

Look at the effects of the major environmental factors:

	Mean temperatures				
Location	Growth rate diameter (mm y^{-1})	Warmest month (mean T°C)	Coldest month (mean T°C)	Annual mean T°C	Precipitation (mm rain equivalent)
Dry Valleys (*)	**0.02**	**-4.8**	**-30.5**	**-20.0**	**50**
Cape Hallett (*)	**0.14**	**-1.4**	**-26.4**	**-15.0**	**120**
Signy Island (**)	**0.50**	**1.3**	**-9.0**	**-3.3**	**400**
Livingston Island (**)	**0.88**	**1.3**	**-7.0**	**-1.5**	**800**

(**Buellia frigida*, ***Buellia latemarginata* (from Hooker 1980)

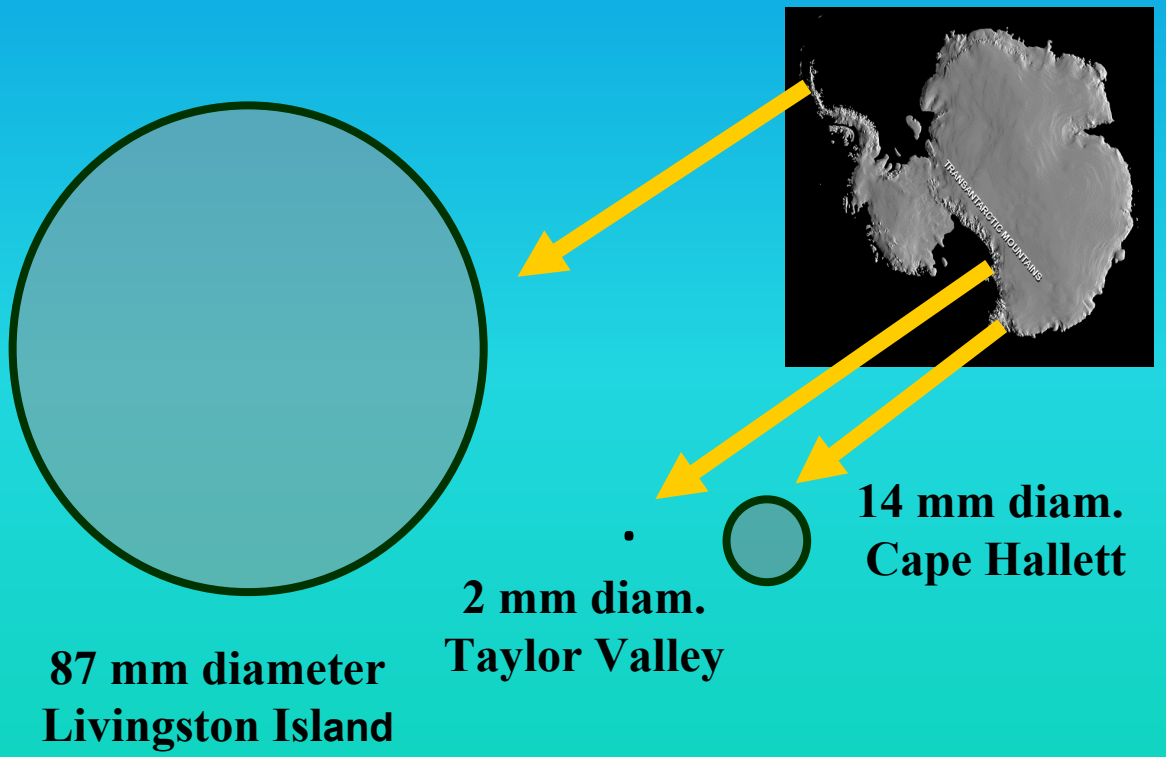
Growth rate of *Buellia* in 100 years

What actually drives the changes in growth rates and species numbers?

Growth rate gradient:

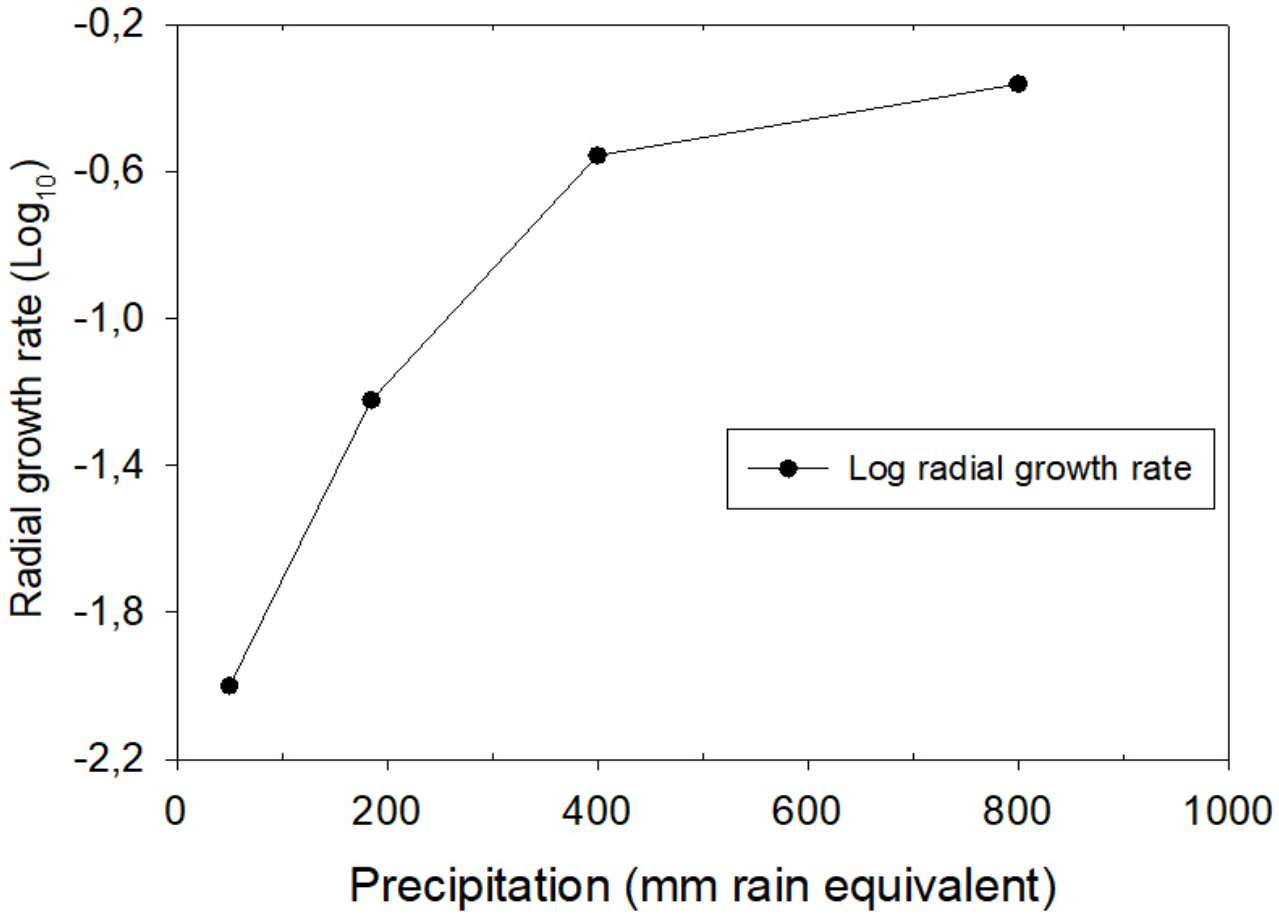
about 50 times for lichens

across Antarctica

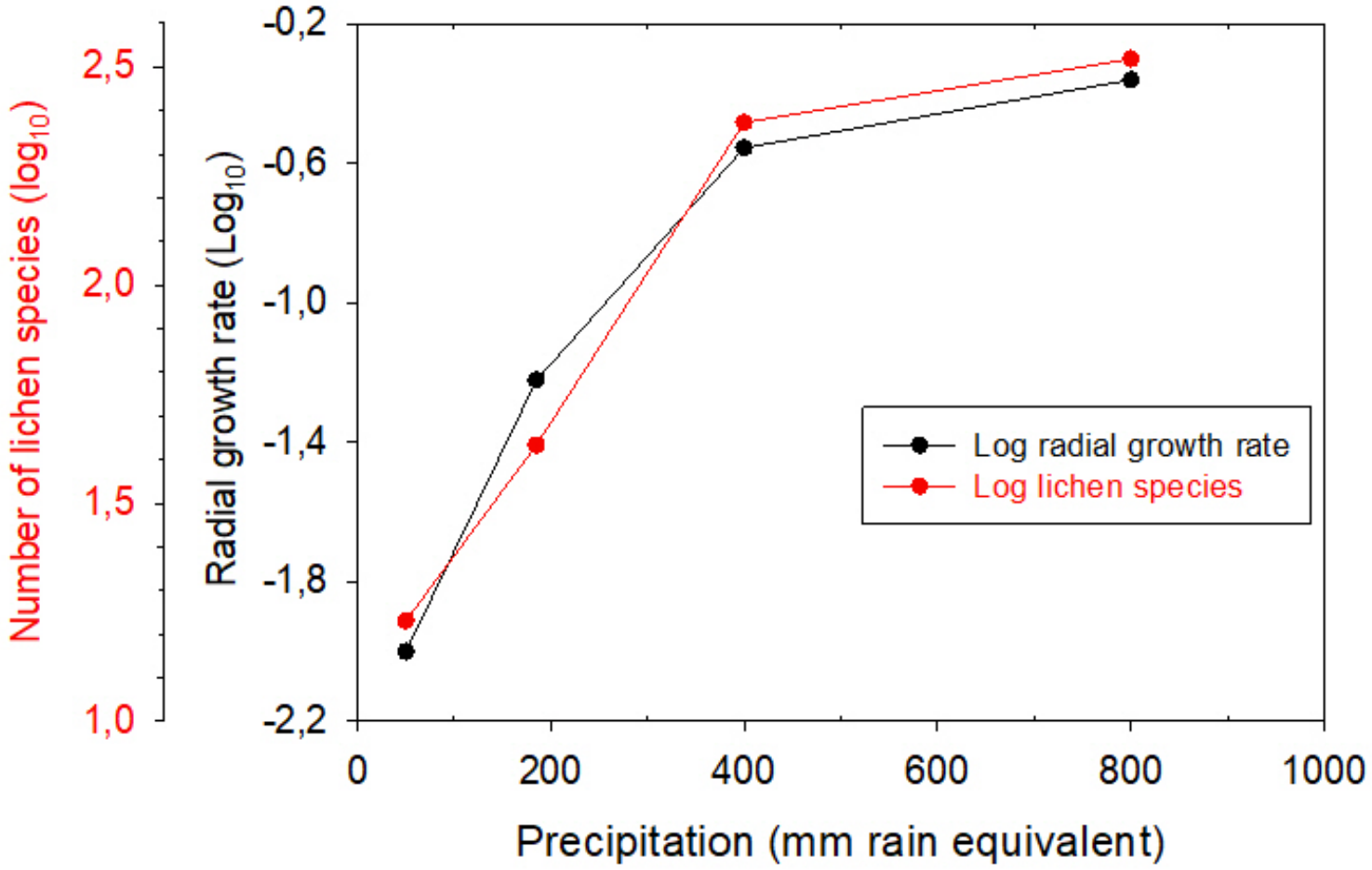


Potentially a good indicator/monitor for climate change

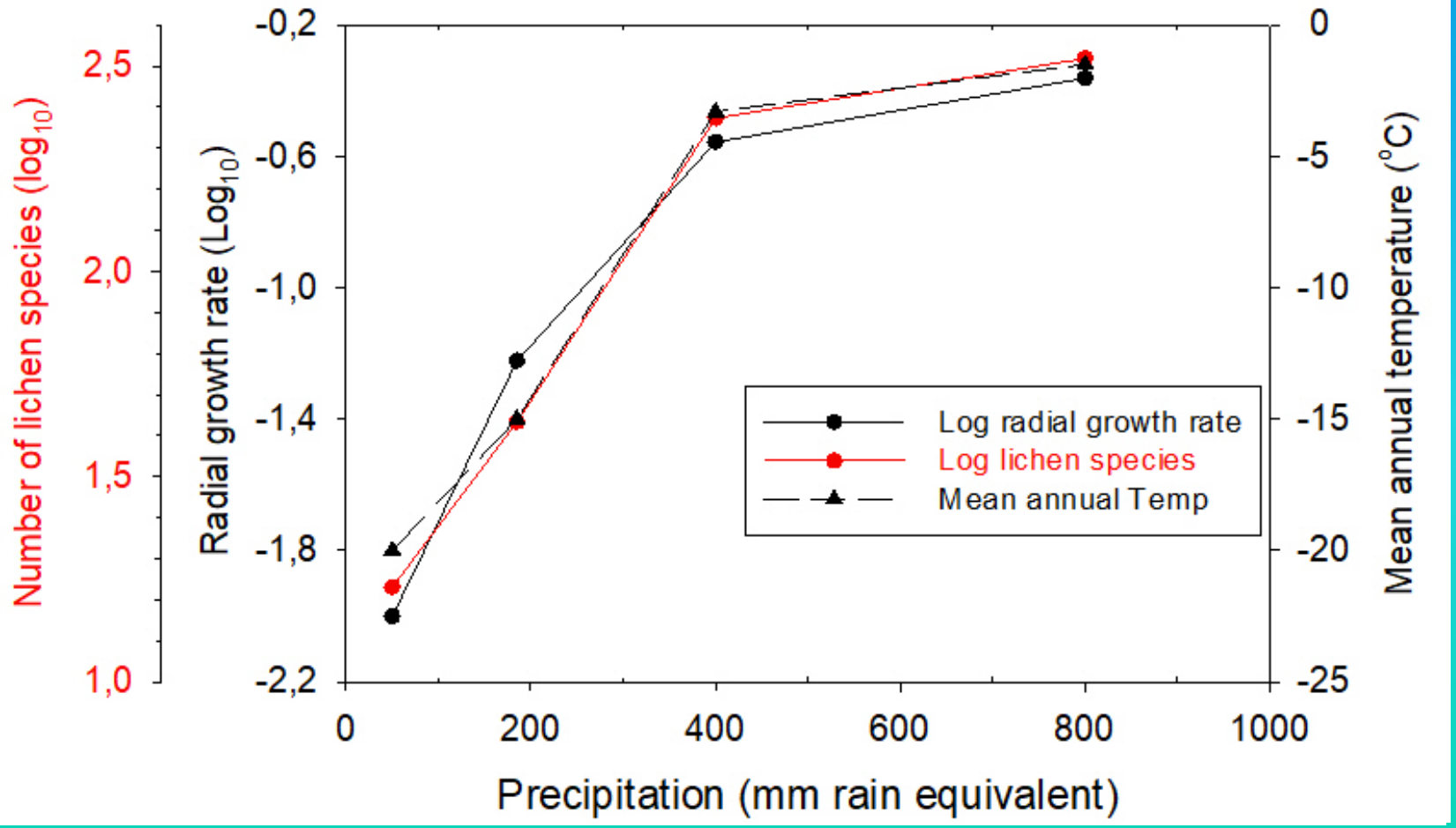
Environmental effects on growth



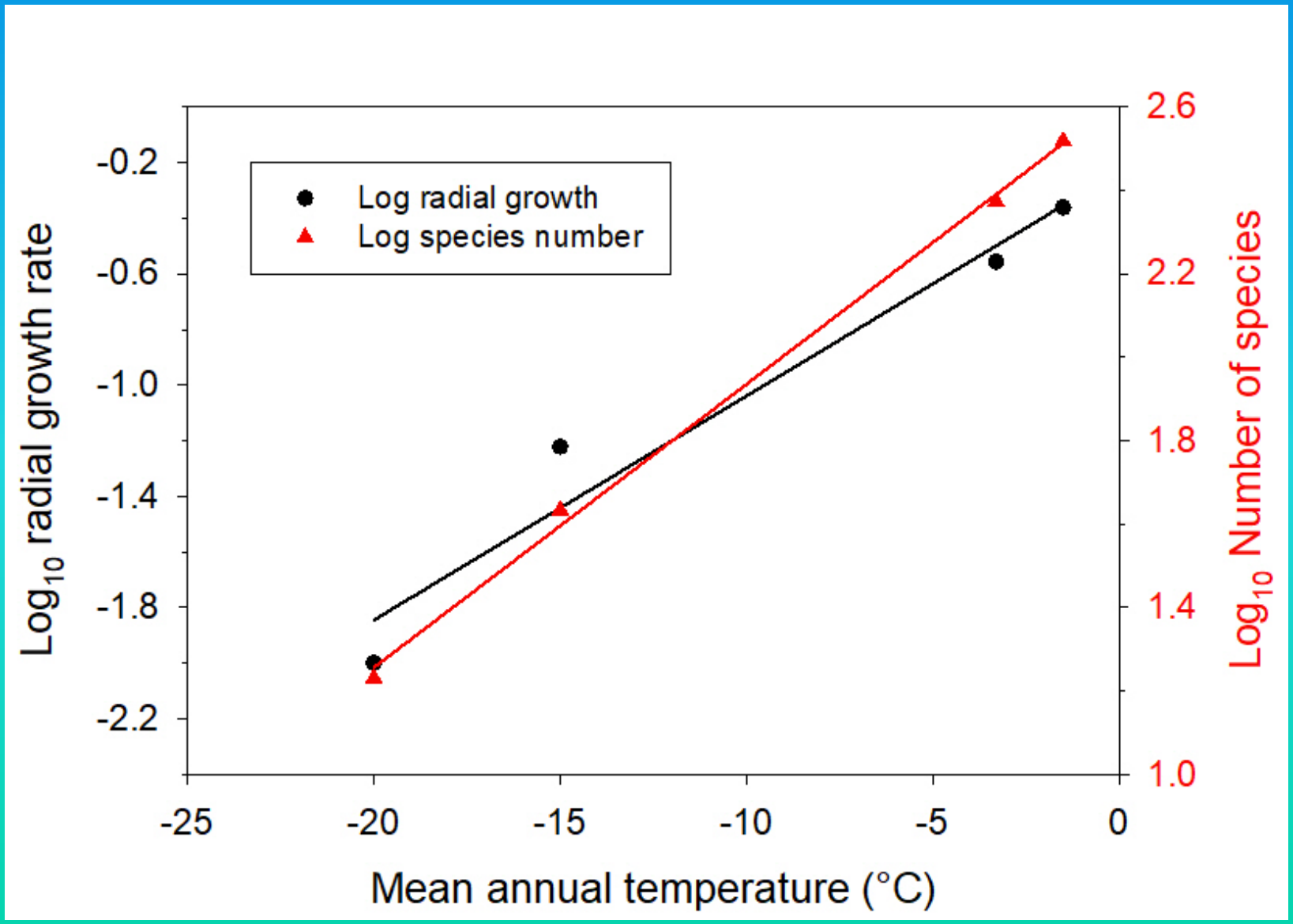
Environmental effects on growth



Environmental effects on growth



Growth and numbers versus mean annual temperature




Are the growth rates of each species genetically fixed or are they the result of environmental conditions?

Estrategias de vida al límite

- *Ecofisiología*

*** Biodiversidad**
Tierra del Fuego, Ant. Marítima, Ant. Continental

*** Microclima**: Definir y comparar los factores abióticos.

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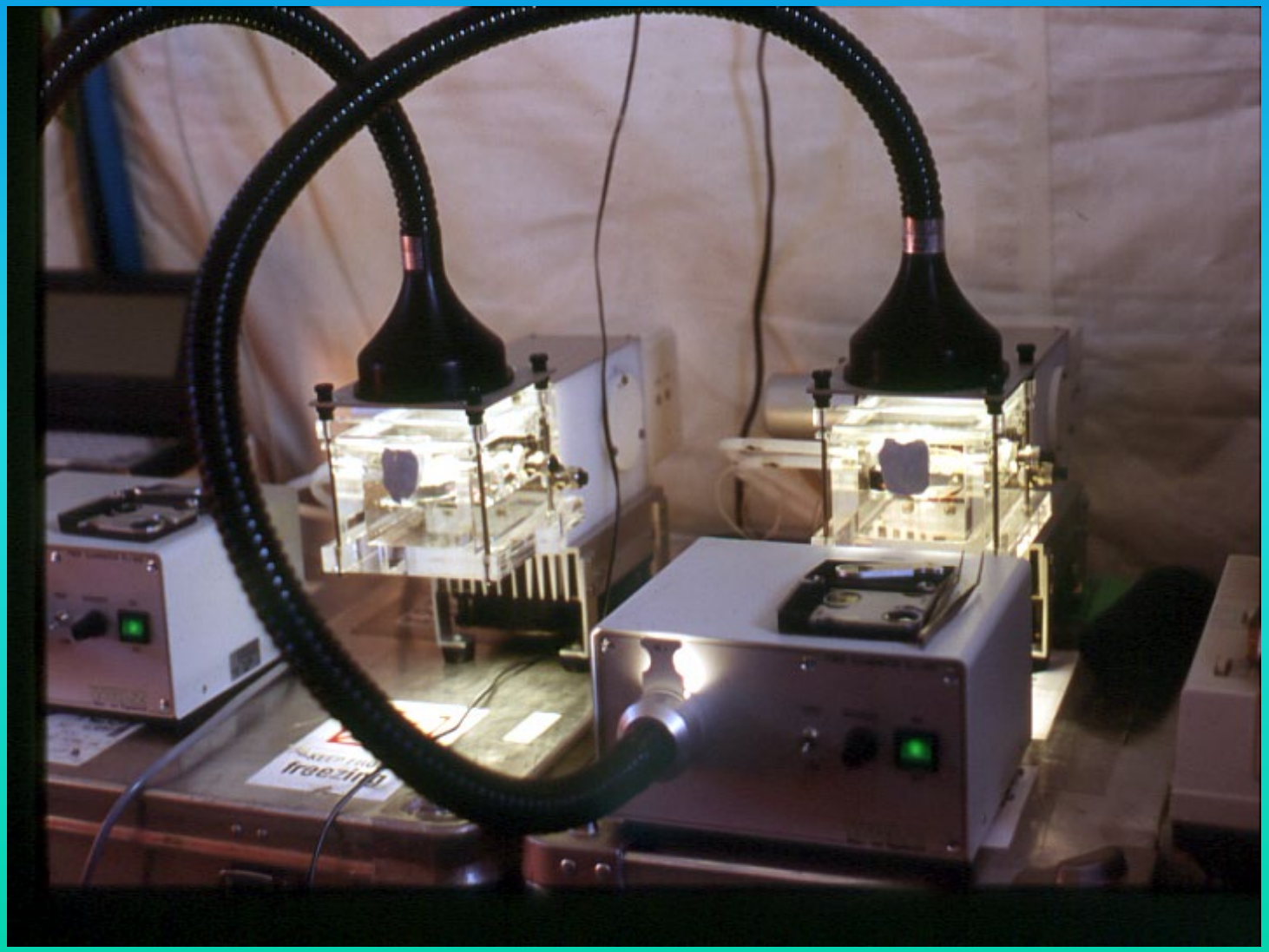
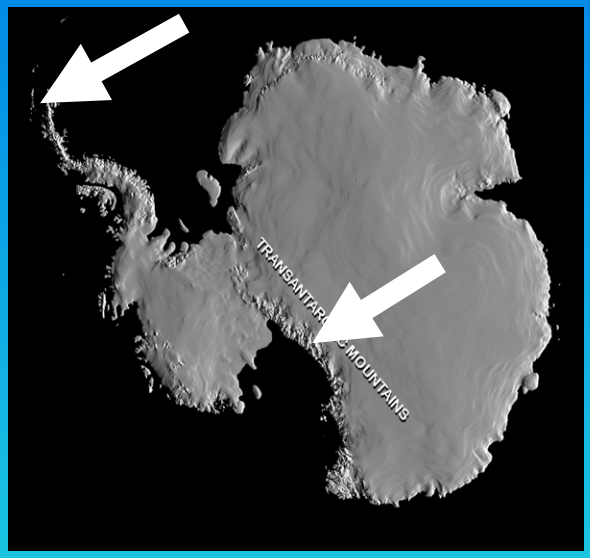
* **Adaptación:** Casos concretos.

***Supervivencia:** Resistencia a condiciones excepcionales.

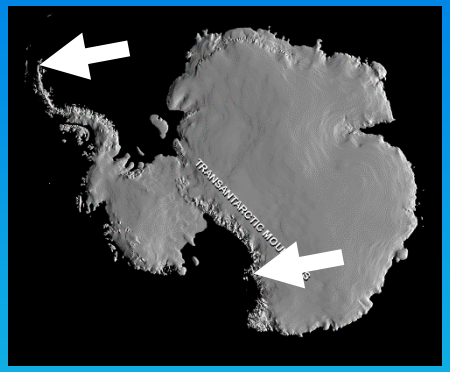


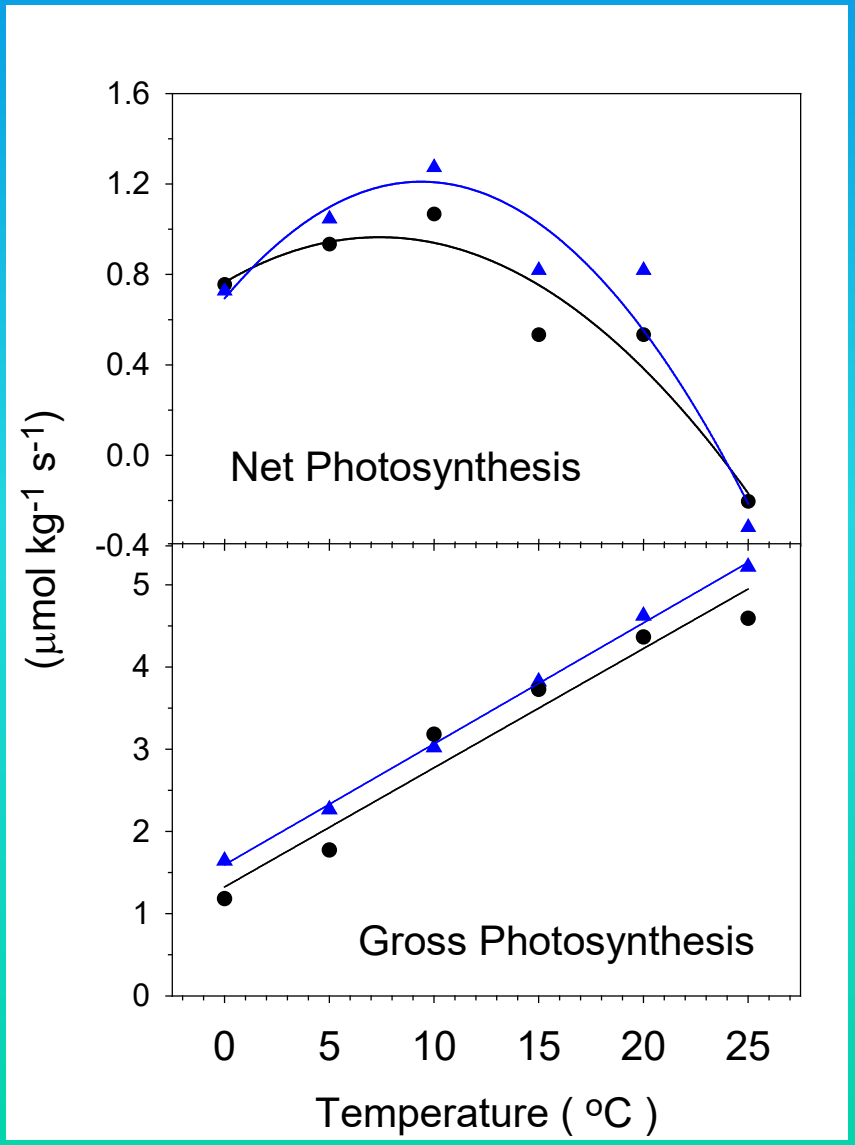


Livingston Island
(Latitud 62º39´S)

Mount Kyffin
(Latitud 83º40´S)

Adaptation of photosynthesis of the lichen *Umbilicaria decussata* to temperature.





▲ Livingston Island – 62°S

● Mt Kyffin - 84°S

22 degrees Latitude apart

Samples collected at exactly same time.

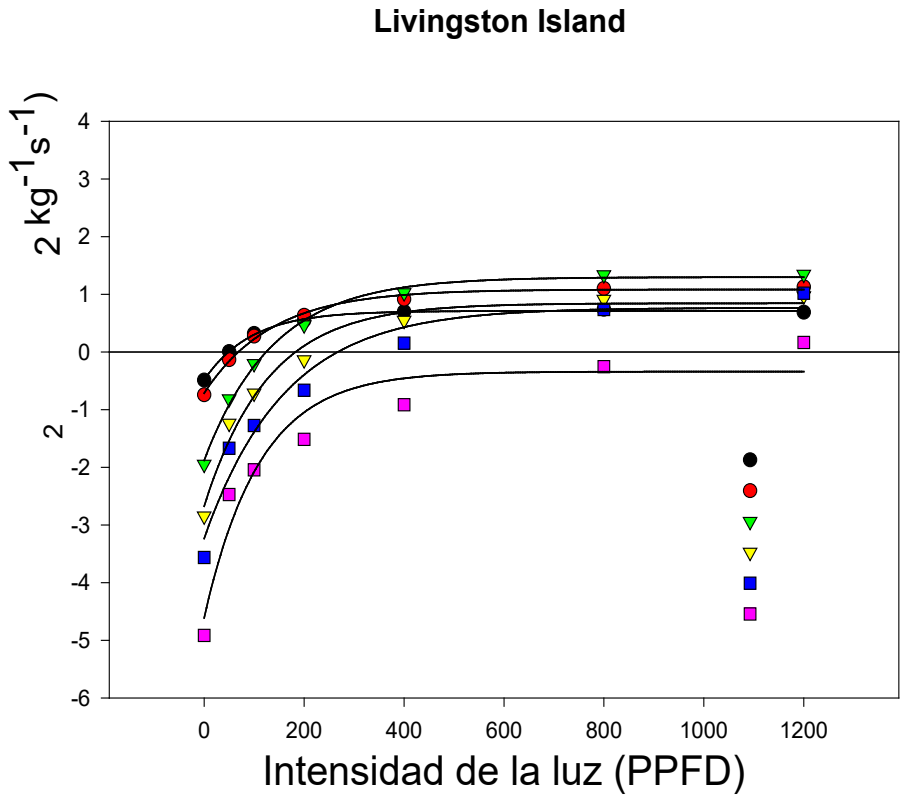
Identical optima

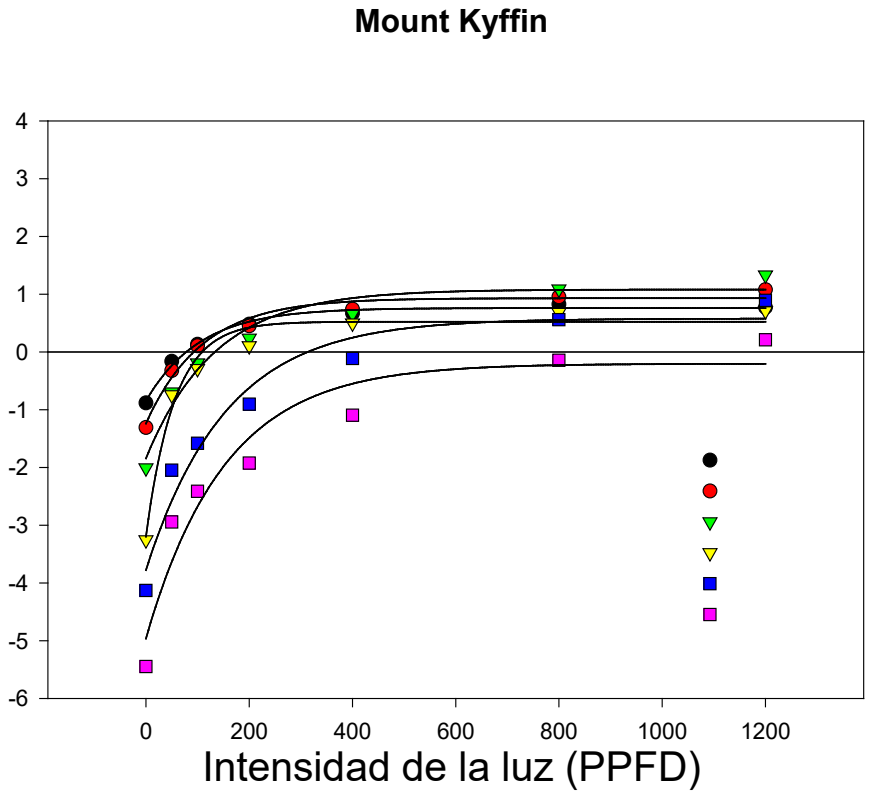
NO Adaptation

Umbilicaria decussata

Óptimo de T para NP: 0-10ºC (Latitud 62º39´S)

Óptimo de T para NP: 0-10ºC (Latitud 83º40´S)





Tasa máxima de asimilación ($\mu molCO_2\ kg\ DW^{-1}$) **de *U. decussata* de la Antártida**

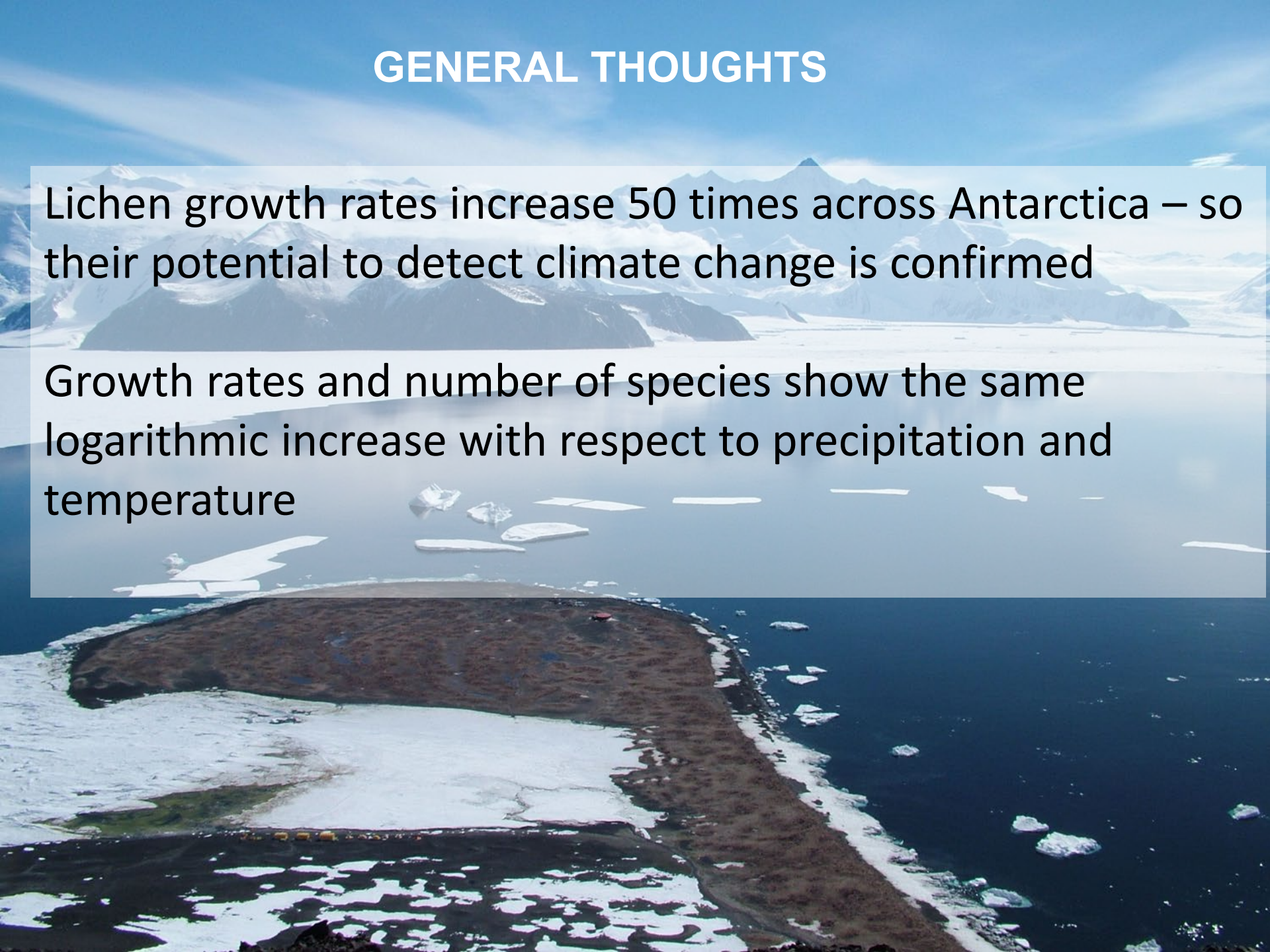
Livingston Island,	**62º S Latitud**	**1,3**
Casey Station,	**66º S Latitud**	**1,3**
Mount Kyffin,	**84º S Latitud**	**1,1**

Diferencias en la velocidad de crecimiento son debidas a las condiciones externas (ambientales), no internas (genéticas)

GENERAL THOUGHTS

Lichen growth rates increase 50 times across Antarctica – so their potential to detect climate change is confirmed

Growth rates and number of species show the same logarithmic increase with respect to precipitation and temperature



GENERAL THOUGHTS

Causes of the response

NOT due to changes in photosynthetic rates.

Carbon gain increases due to longer active periods as one moves north.

Longer activity is driven by greater water availability which is linked to temperature.

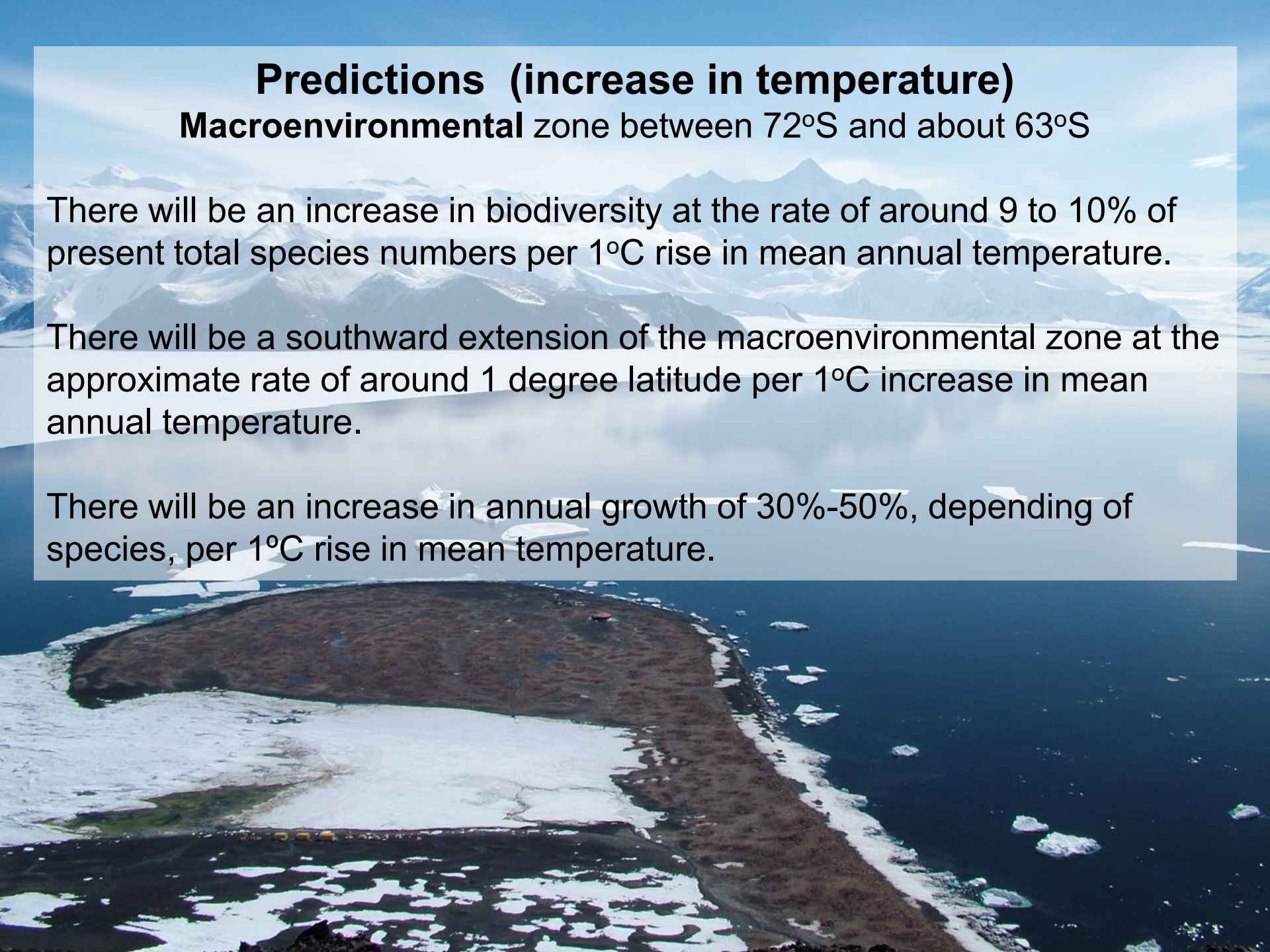
Predictions (increase in temperature)

Macroenvironmental zone between 72°S and about 63°S

There will be an increase in biodiversity at the rate of around 9 to 10% of present total species numbers per 1°C rise in mean annual temperature.

There will be a southward extension of the macroenvironmental zone at the approximate rate of around 1 degree latitude per 1°C increase in mean annual temperature.

There will be an increase in annual growth of 30%-50%, depending of species, per 1ºC rise in mean temperature.




To what extent are these bipolar lichens able to tolerate extreme conditions?

Estrategias de vida al límite

* **Biodiversidad** Tierra del Fuego, Ant. Marítima, Ant. Continental

* **Microclima**: Definir y comparar los factores abióticos.

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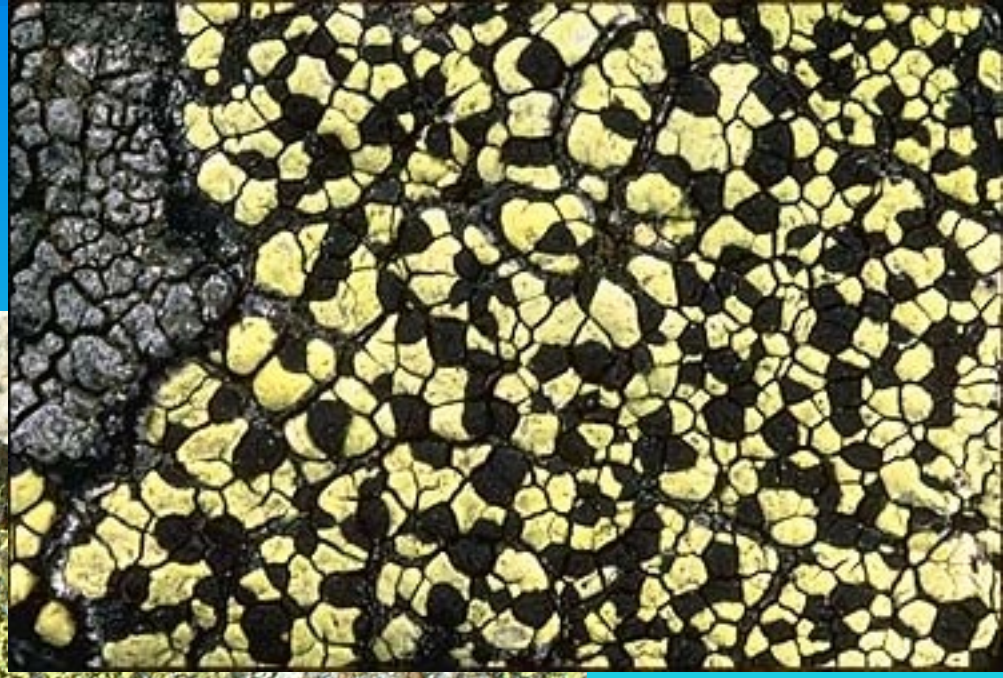
* **Adaptación:** Casos concretos.

***Supervivencia:** Resistencia a condiciones excepcionales.

- *Astrobiología*

Rhizocarpon geographicum



Xanthoria elegans

(Escala = 1 cm)

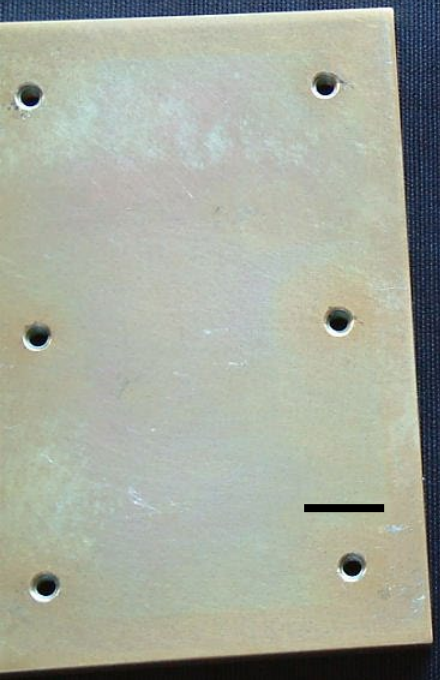

Dry Valleys, 100 m
Latitud 77° S

Líquenes endolíticos

UCM-INTA

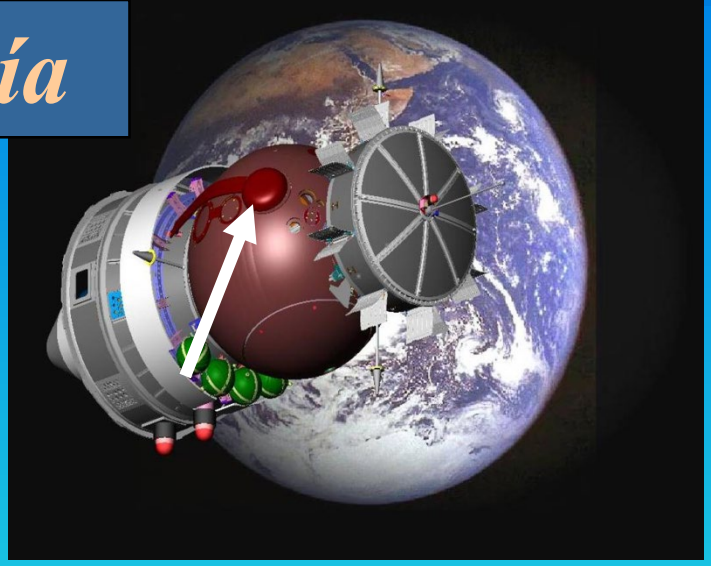
Experimento BIOPAN

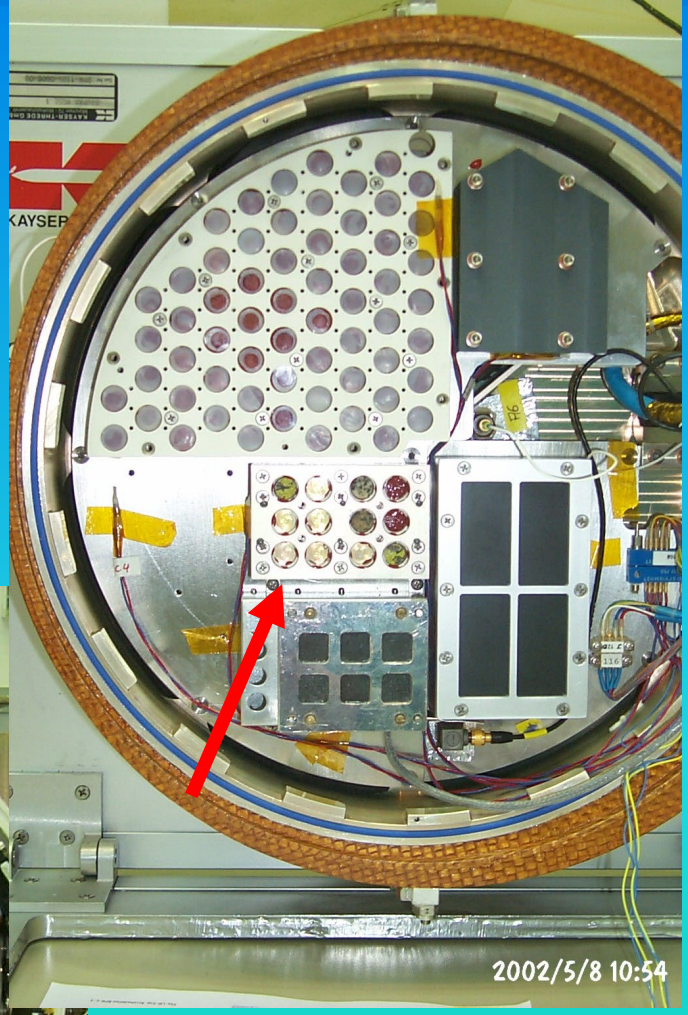
Hardware - LICHENS

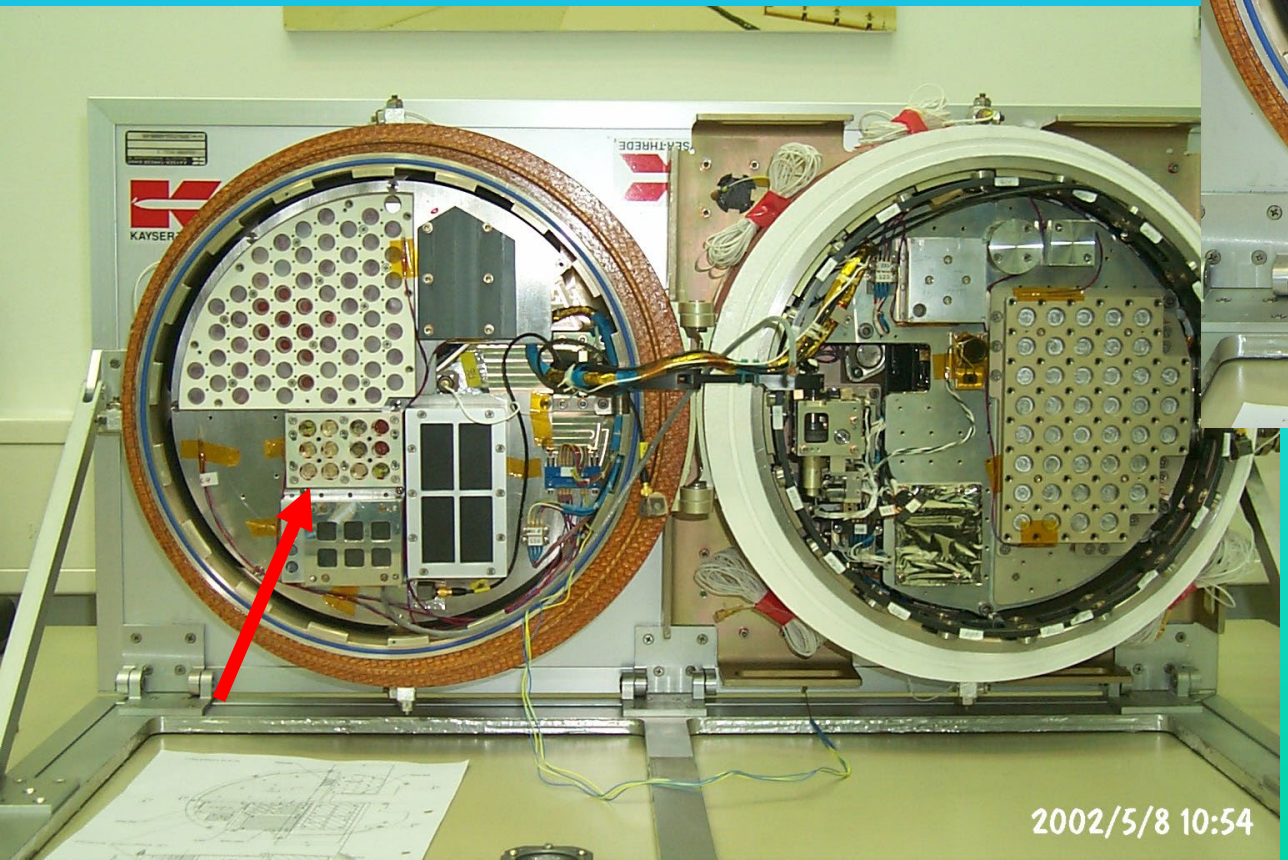


Astrobiología

Experimento BIOPAN



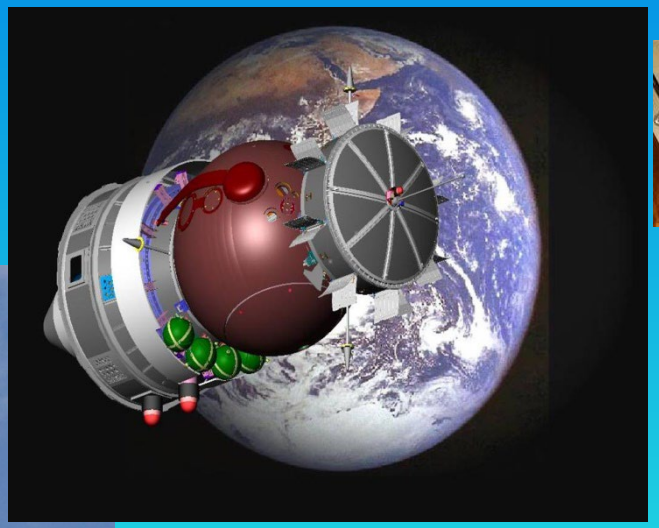




Localización del experimento en el sistema BIOPAN

Astrobiología

Misión Foton M2



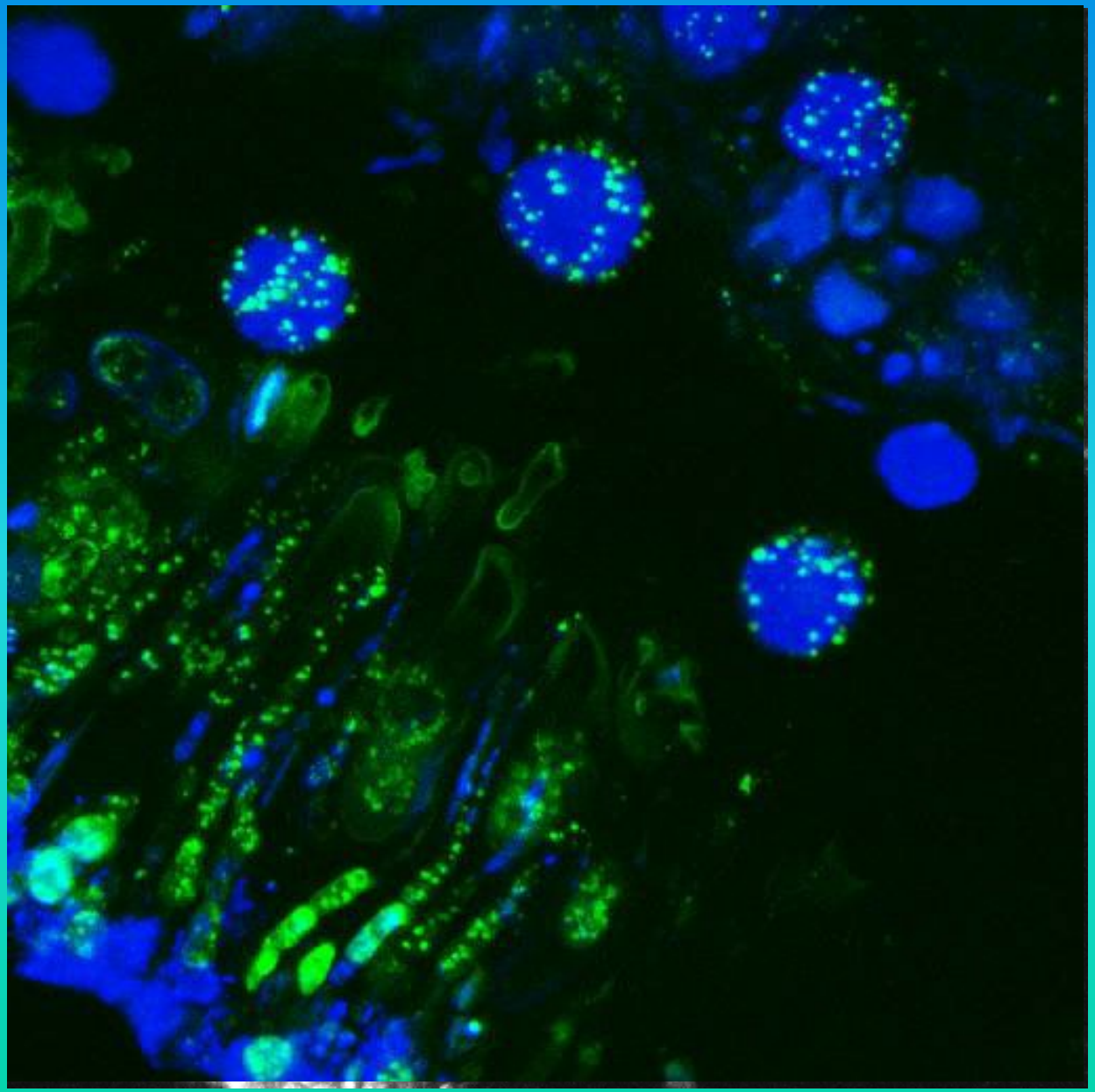
Lanzamiento: 31-05-05, Baikonur, Rusia.

Recuperación: 16-06-05, Samara, Rusia

BIOPAN

Apertura de BIOPAN en las instalaciones de ESA-ESTEC en Nordwijk (Holanda)

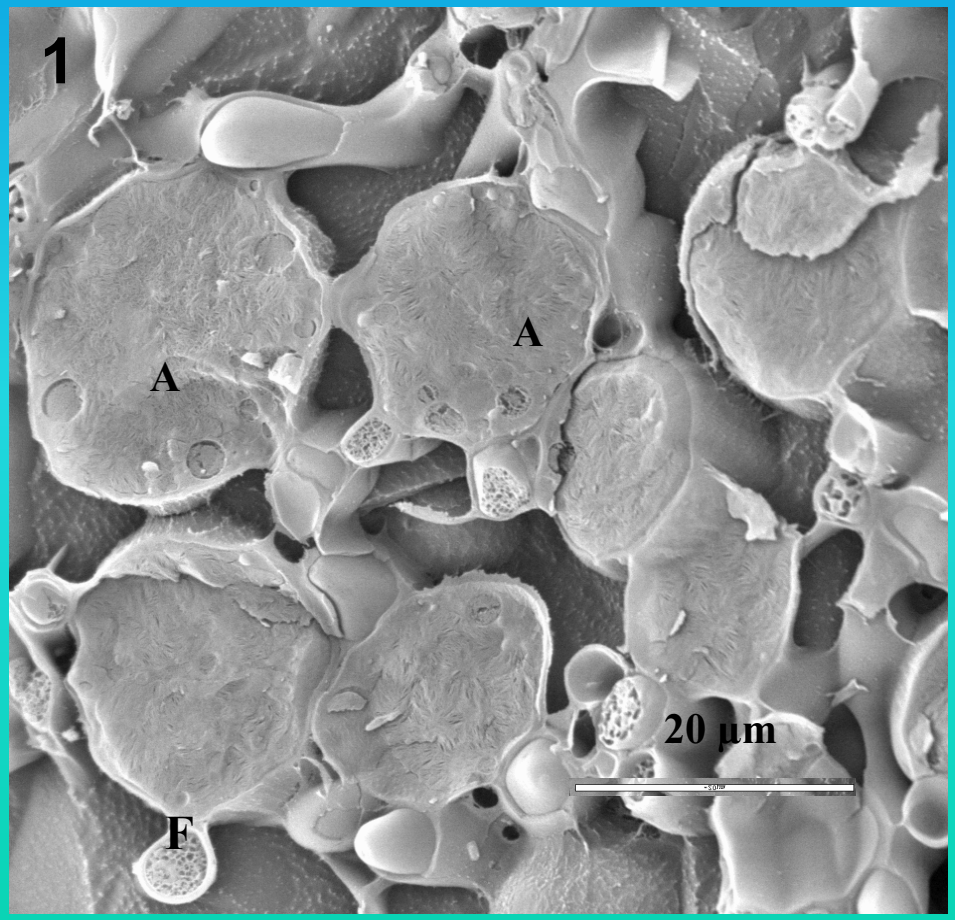
19 de Junio de 2005

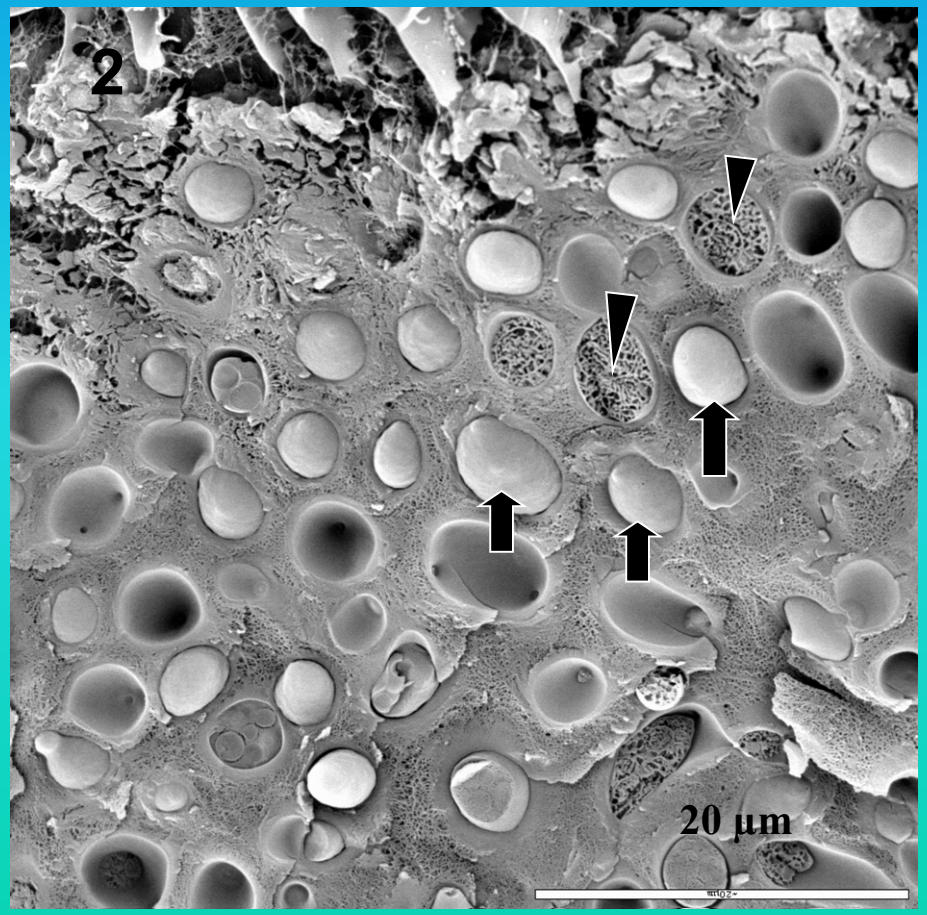


Microscopía
Laser confocal

Tinción
Diferencial de
ácidos
nucléicos

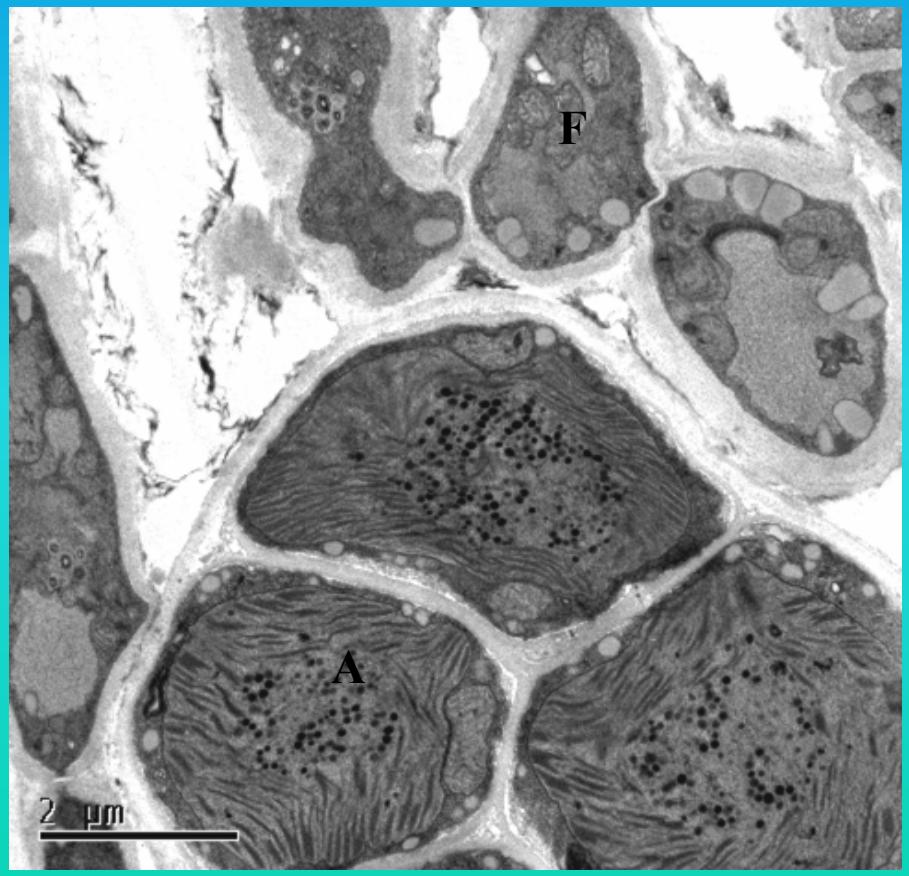
1- LTSEM image of the algal layer from *Xanthoria elegans* thallus after the flight (under neutral glass window) showing cellular integrity in algal and fungal partner.
2- LTSEM of the upper cortex from *Xanthoria elegans* thallus after the flight. Non fracturated cells (arrows) show the cellular membrane integrity and fracturated cells (arrowheads) permit to visualize the lack of signs of plasmolysis.

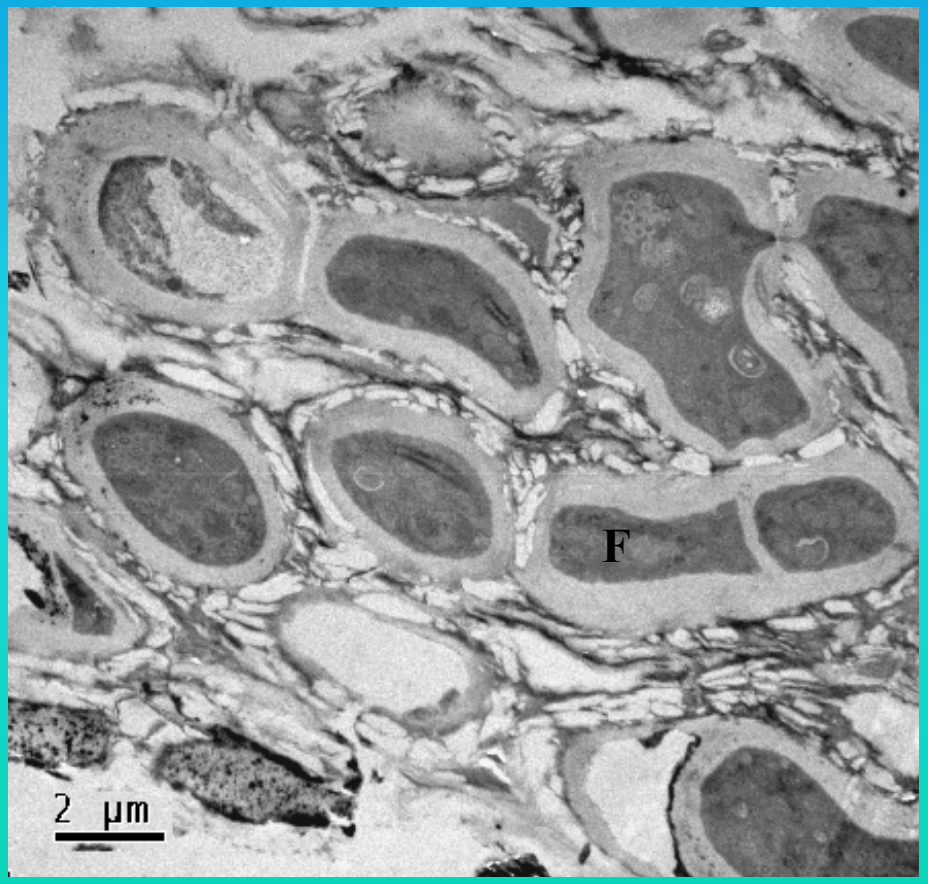




A, algal cells; **F**, fungal cells

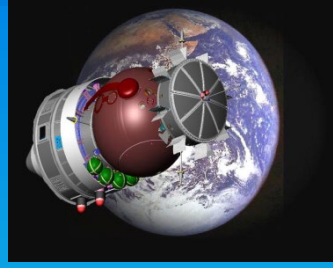
1, 2- TEM images of *Rhizocarpon geographicum* thallus after the flight (under neutral glass window) showing lack of ultrastructural damage in fungal and algal cells of the algal layer and in fungal cells of the upper cortex .



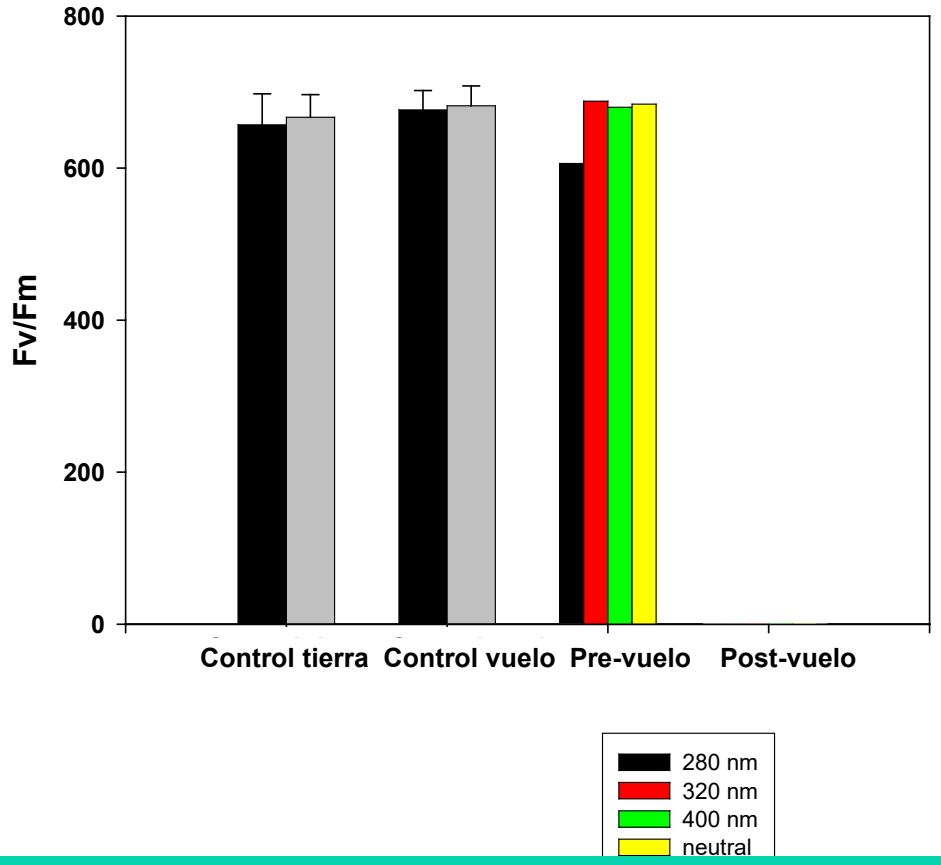


A, Algal cells; **F**, fungal cells

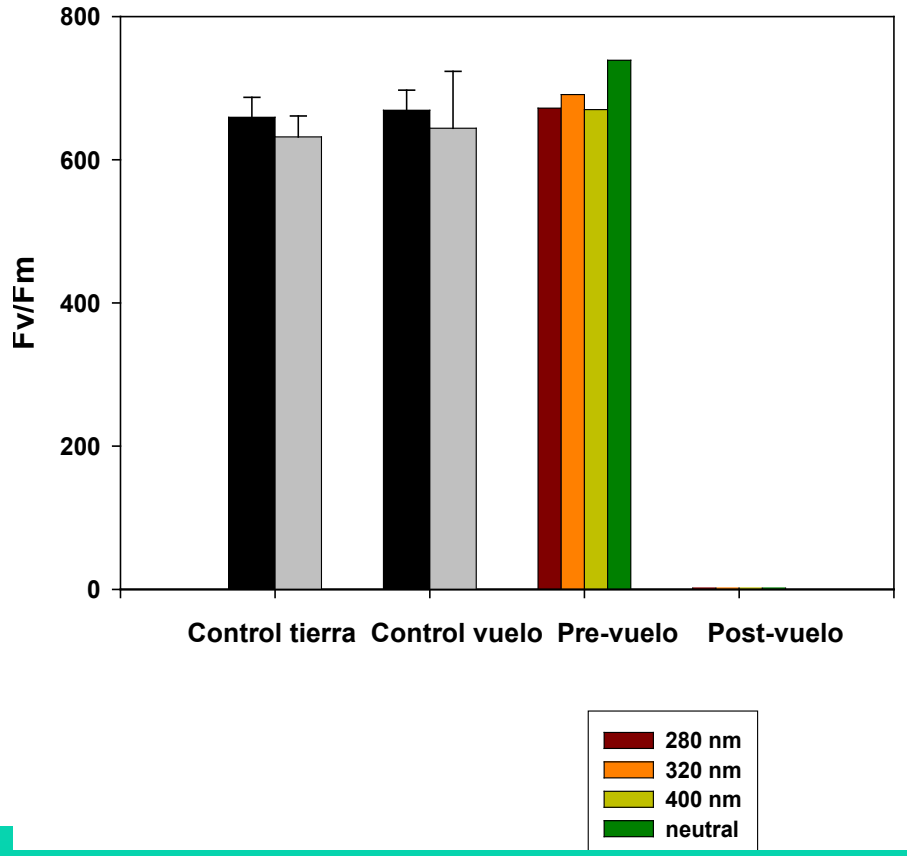
BIOPAN-5: Primeros resultados del experimento LICHENS



Rhizocarpon geographicum



Xanthoria elegans



Yied activity of Photosystem II of lichens on natural rock substrates before and after exposure to space during the BIOPAN 5 mission. Measurements after flight were taken after 24h of revitalization process.

Lichen species	Lab control (before flight)	Lab control (after)	Flight-dark control (before)	Flight-dark control (after)	Flight exposed (before)	Flight exposed (after)
Rhizocarpon geographicum	668.5 ± 20.0	671.5 ± 26.9	657.5 ± 40.7	674 ± 22.1	684	690
Xanthoria elegans	695.7 ± 26.1	688.7 ± 49.7	659.2 ± 22.8	663.5 ± 23.9	739	738

All exposed lichens, independent of the filters used, showed after the flight nearly the same photosynthetic activity as measured before the flight. Likewise, the photosynthetic activity of the exposed lichens was also similar to those showed by the Flight control and Earth controls

Conclusions

- Lichens have demonstrated to be the organism with the highest capacity to resist real space conditions, specially high UV radiation

- These results suggest that complex life forms adapted to tolerate extreme conditions on a certain planet, could resist an interplanetary transfer through space

ASTROBIOLOGY
Volume 7, Number 3, 2007

DOI: 10.1089/ast.2006.0046

Research Paper

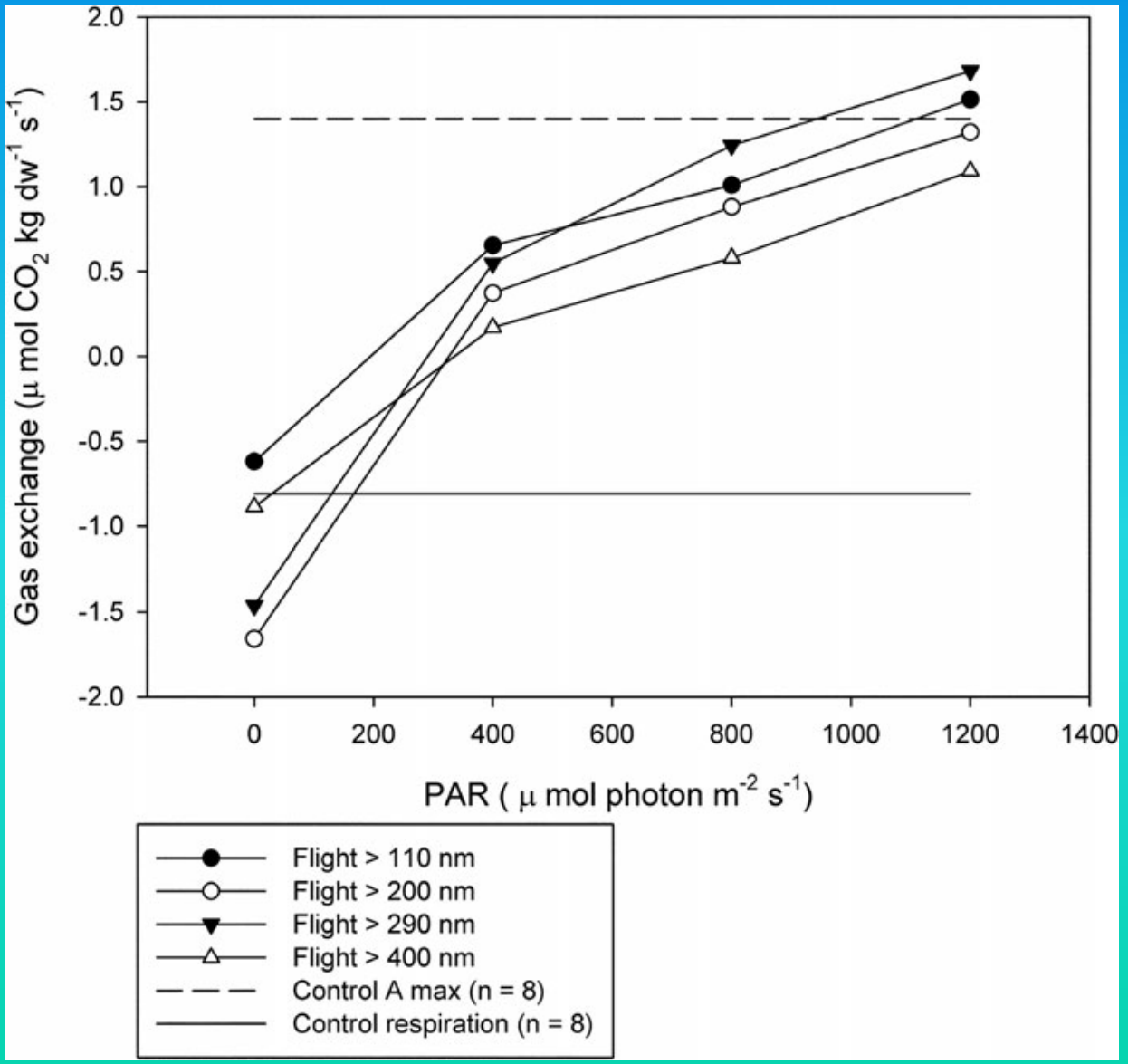
Lichens Survive in Space: Results from the 2005 LICHENS Experiment

LEOPOLDO G. SANCHO,[1] ROSA DE LA TORRE,[2] GERDA HORNECK,[3] CARMEN ASCASO,[4] ASUNCIÓN DE LOS RIOS,[4] ANA PINTADO,[1] J. WIERZCHOS,[5] and M. SCHUSTER[6]

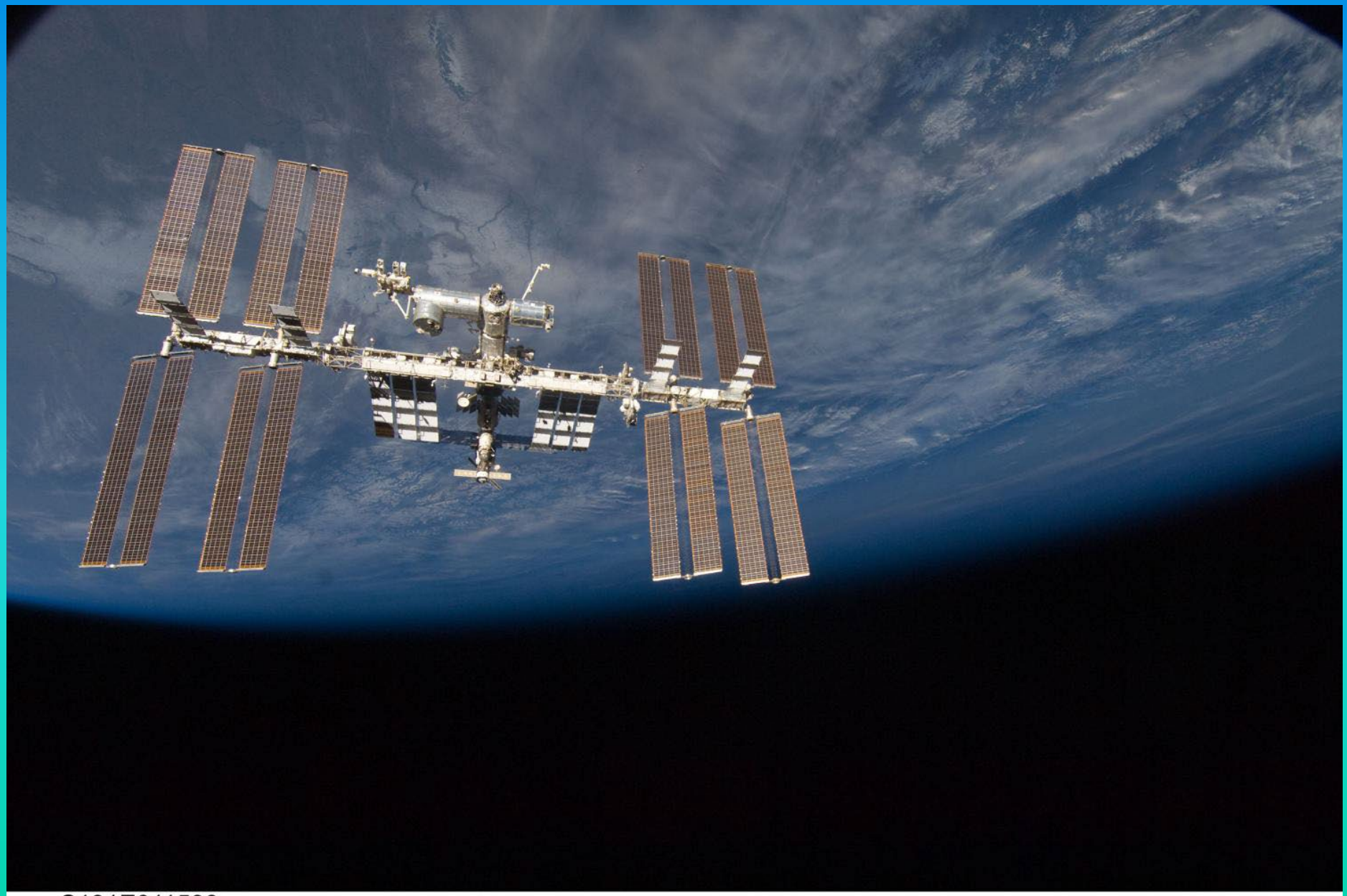
LITHOPANSPERMIA

Circinaria gyrosa

ASTROBIOLOGY
Volume 11, Number 4, 2011



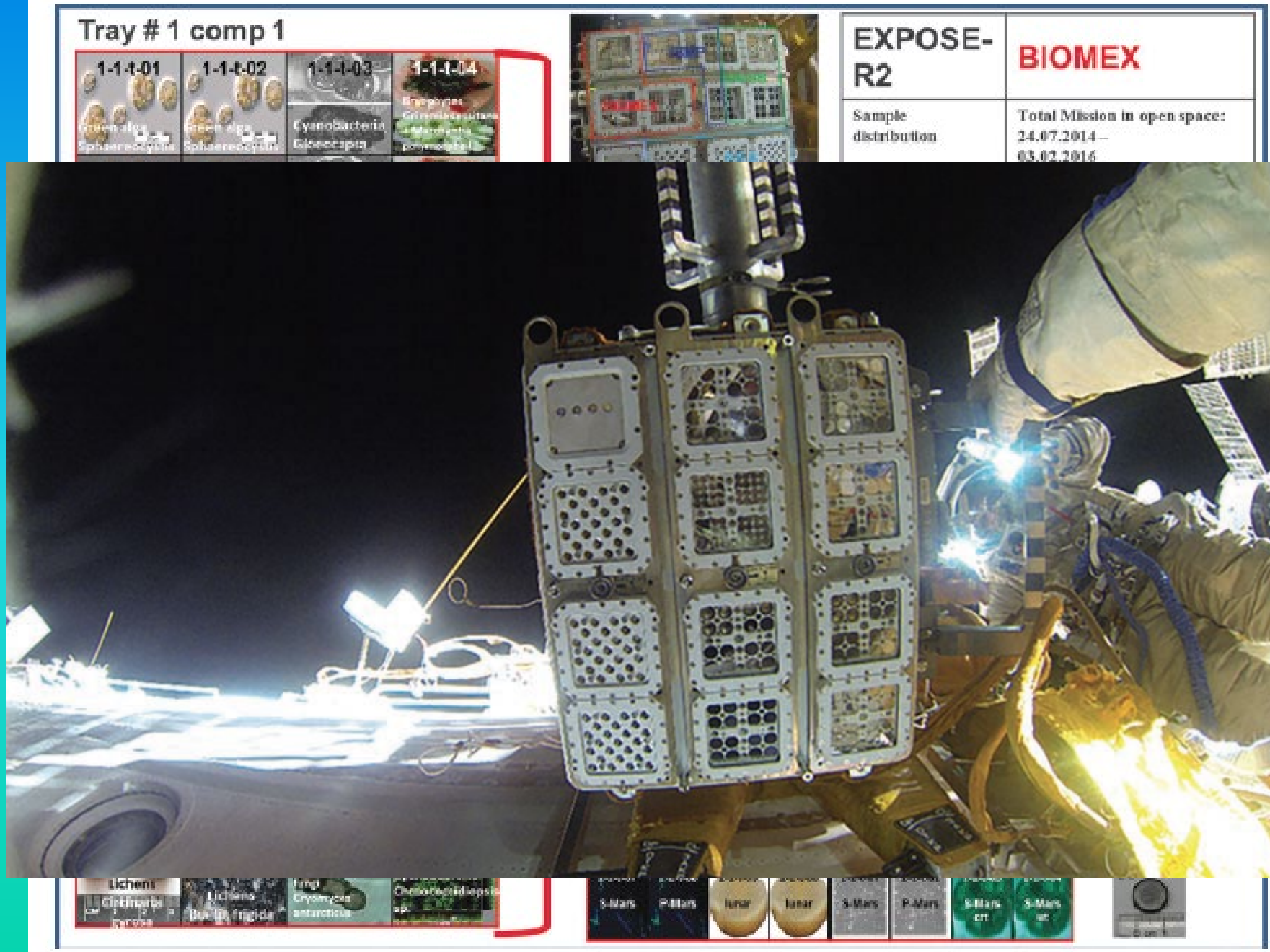
International Space Station (ISS)



S131E011590

The ESA Space Experiment BIOMEX on the ISS

ASTROBIOLOGY
Volume 19, Number 2,
2019 Mary Ann Liebert,
Inc. DOI:
10.1089/ast.2018.1897


Tray # 1 comp 1
1-1-t-01
1-1-t-02
1-1-t-03
1-1-t-04
Cyanobacteria
Gloeocapsa
EXPOSE-R2
BIOMEX
Sample distribution
Total Mission in open space:
24.07.2014 –
03.02.2016
Lichens
Cladonia
Xanthoria
Lichens
Buellia frigida
Fungi
Cryomyces antarcticus
Chroococcidiopsis sp.
S-Mars
P-Mars
lunar
lunar
S-Mars
P-Mars
S-Mars
S-Mars

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/icarus

Survival of lichens and bacteria exposed to outer space conditions – Results of the *Lithopanspermia* experiments

Rosa de la Torre [a,*], Leopoldo G. Sancho [b], Gerda Horneck [c], Asunción de los Ríos [d], Jacek Wierzchos [d], Karen Olsson-Francis [e], Charles S. Cockell [e], Petra Rett, Jean-Pierre P. de Vera [i], Sieglinde Ott [f], Jesus Martinez Frías [g], Pablo Gonz, Maria Mercedes Lucas [d], Manuel Reina [a], Ana Pintado [b], René Demets [h]

AST-2010-0588-Raggio_TP
Type: research-article

Research Article

ASTROBIOLOGY
Volume 11, Number 4, 2011

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Whole Lichen Thalli Survive Exposure to Space Conditions: Results of Lithopanspermia Experiment with *Aspicilia fruticulosa*

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UV-C tolerance of symbiotic *Trebouxia* sp. in the space-tested lichen species *Rhizocarpon geographicum* and *Circinaria gyrosa*: role of the hydration stat and cortex/screening substances

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Introduction

Limits of Life and the Habitability of Mars: The ESA Space Experiment BIOMEX on the ISS

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¡Desde la Antártida al espacio exterior!

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Antártida

Ciencia y aventura en los confines del mundo

LEOPOLDO GARCÍA SANCHO

Prólogo de Eduardo Martínez de Pisón

PIRÁMIDE

Leopoldo García Sancho, doctor en Biología por la Universidad Complutense de Madrid (1986), realizó estudios posdoctorales durante varios años en Alemania y en otros países europeos. Ha realizado dieciséis expediciones a diferentes regiones de la Antártida, bajo la supervisión de España, Nueva Zelanda, Estados Unidos y Chile.

Fue el investigador responsable del primer experimento con líquenes en el espacio exterior (2005), coordinado y financiado por la Agencia Espacial Europea. Es representante español en el grupo de Ciencias de la Vida, dentro del Comité Científico de Investigaciones Antárticas (SCAR), Premio Príncipe de Asturias de Cooperación Internacional en 2002. Ha publicado más de ciento cincuenta artículos científicos en revistas internacionales, muchos de ellos a partir de sus investigaciones en la Antártida. Actualmente es catedrático de Botánica en la Facultad de Farmacia de la Universidad Complutense y miembro correspondiente de la Real Academia de Ciencias de España.

1 El descubrimiento y la exploración de la Antártida

2 Un continente para la ciencia. Sistemas de organización y gestión internacional para estudiar, preservar y divulgar la Antártida

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8 Las amenazas del futuro. La Antártida ante el cambio global

9 El espíritu antártico. Vida y convivencia en la Antártida

ciencia hoy

El continente antártico y sus mares circundantes constituyen un lugar excepcional en el mundo: un inmenso espacio sin fronteras dedicado a la ciencia y a la conservación. El enorme esfuerzo de exploración e investigación iniciado hace más de un siglo está totalmente justificado por el papel crucial que la Antártida desempeña en el equilibrio ambiental de nuestro planeta. Especialmente ahora, en plena fase de calentamiento global, nuestro futuro dependerá, en gran medida, de lo que ocurra en el gran continente austral. Pero la Antártida es más que un enorme regulador climático; sus formas de vida, tanto vegetales como animales, son asombrosas y muestran la capacidad de la evolución para generar especies únicas y perfectamente adaptadas a un medio tan inhóspito.

Este es un libro de divulgación científica y que, por tanto, se propone ser objetivo. Sin embargo, inevitablemente está cargado de sentimientos y vivencias. Las dieciséis expediciones a la Antártida en las que ha participado el autor se han convertido en la médula de su vida profesional como científico y además han supuesto una intensa experiencia personal. Para el autor, ser biólogo en el Polo Sur es un privilegio y un maravilloso desafío, y en este libro trata de mostrar los principales avances científicos que se han producido en la investigación antártica en los últimos años, pero también comunicar la intensidad de la experiencia que supone trabajar en este lugar extraordinario. Aunque centrada en la biología vegetal, esta obra ofrece también una perspectiva más amplia que abarca otros campos científicos e incluso la reciente historia antártica y sus inusuales mecanismos de gestión internacional. Uno de los aspectos más notables de la Antártida, su belleza, es también el más difícil de reflejar en un libro, aunque ojalá sirva de estímulo al lector para adentrarse en la ingente cantidad de imágenes y vídeos disponibles a golpe de ratón. En un mundo que enfrenta multitud de amenazas e incertidumbres, la Antártida es un motivo de esperanza que merece la pena ser conocido y valorado.

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