ITALIAN REPORT ON THE VICTORIA LAND LATITUDINAL GRADIENT PROJECT

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The Victoria Land Coast (Ross Sea), including the Ice Shelf section south of McMurdo Sound, extends across nearly 18 degrees of latitude, from Cape Adare at 68 S to the La Gorce Mountains at 86 S and represents the most extensive latitudinal gradient along the Antarctic coastline that can be studied within the existing logistics of national programs. Recently, we have recognised the opportunity to develop a large-scale, multidisciplinary project to study the unique inland and marine communities along the Victoria Land Coast.

The Ross Sea region contains a number of environmental (ecological) spectra relating to cold, aridity, solar radiation, UV, light/dark conditions and highly variable sea ice dynamics including a major polynya. The land and coast within the Ross Dependency across this wide latitudinal range includes a variety of marine, terrestrial and freshwater habitats. Some of these systems are unique to the Antarctic.

Moving along the Victoria Land Coast, changes of environmental parameters affect all the inland and marine environments, starting from nutrient cycles and primary production to top predators, leading to strong changes in community structure and function at any trophic level. Overlapping the gradually changing variables, abrupt local transitions and peculiarities may occur, because of strong wind action, peculiar edaphic features, melt-water inputs, grain size and sea-bottom morphology. It is presumable the presence of critical depth/altitude, over which community structures and life cycles are affected, while, beyond these limits, communities features should maintain relatively homogeneous along the coast.

A comprehensive study of the Victoria Land Coast will yield invaluable information on the dynamic interactions between terrestrial and shallow water ecosystems, especially in light of current efforts to understand the impacts of climatic shifts in Antarctica.

This project would be conducted within a framework of international collaborations between PNRA (Italian Antarctic Research Programme) and other Antarctic research Institutions, at different locations (*e.g.* Cape Adare, Cape Hallett, Coulman Island, Kay Island, Cape Washington, Edmonson Point, Terra Nova Bay, Cape Russell, Cape Roberts, Marble Point, Dry Valleys, McMurdo Sound, Brown Hills, Beardmore Glacier and La Gorce Mountains).

Research priorities:

- **To evaluate the environmental gradients linked to latitude**
- **To relate community transitions along the Victoria Land Coast to geomorphological and hydrological features**
- **To evaluate biochemical, physiological and other adaptive responses of representative organisms across longitudinal and altitudinal/bathymetrical transects**
- **To estimate anthropogenic impact and the importance of the latitudinal gradient in the xenobiotic accumulation pattern in organisms**
- **To measure biodiversity at species and genetic level**
- **To test the progressive emergence of benthic assemblages**

Background

Environmental gradients linked to latitude

Significant differences in the marine and non-marine physical environment are found in temperature, wind stress, solar radiation, UV-B, humidity, melting and pack-ice coverage. They affect living organisms both in terms of their minimum and maximum values but also in their seasonal variability. Synoptic measurements of main parameters should be carried out and past data-sets should be analysed and modelled.

Environmental changes over such a wide latitudinal range at one point in time can be used to mimic environmental changes at one point in space over a long time span. A latitudinal gradient can therefore be used to study the effects of potential changes in regional climate that may or may not be associated with global change, as well as providing a range of environmental conditions for more fundamental studies. Underlying this is the phenomenon of "Polar focussing" whereby a given change in latitude in the Polar Regions is followed by a greater change in environmental variables than a similar latitudinal change in the temperate or tropical regions. Polar focussing provides an additional advantage to the use of a gradient approach to study environmental change in the Ross Sea region.

Three major systematic environmental gradients that are significant to understanding Victoria Land environments are latitude, altitude/depth and distance from the coastline. These three gradients have different spatial scales, environmental variables and environmental constants. None of these gradients alone are simple surrogates for environmental change. However, combining these will result in a better understanding of our current ecosystems and an increased predictive knowledge of the effects of future environmental change.

Community transitions and spatial variability related to geomorphological and hydrological features

Geographic and hydrological out-standings may constitute barriers affecting the distribution of inland and marine communities, causing patchiness and population isolation.

As much as it concerns water column communities, studies have been carried out regarding organic matter flux and fate, plankton biomass, krill and fish larvae distribution along the Victoria Land coast, in terms of species distribution, abundance and genetics.

As much as it concerns benthic studies, after the pioneer works carried out by USA and New Zealand in the 50-70s, the attention of the researchers has been focused only on the structure and dynamics of shallow waters communities close to the bases. The comparison between the structure and composition of the communities, the life histories and the role of the main key species stresses relevant differences between McMurdo and Terra Nova Bay, whose patterns could be related to a gradual change along the latitudinal gradient or be the consequence of abrupt changes related to geomorphological and hydrological barriers. Strong gradients have been already documented along the Ross Sea as regards to fluxes at the water-sediment interface and biogenic sedimentation rates. These characteristics, coupled with complex geomorphological features, determine large spatial variability in benthic community composition, density and stratification pattern along the Victoria Land transect.

The Terra Nova Bay polynya, the Drygalski Glacier and the Ross Ice Shelf represent in fact significant physical features which could affect communities along the Victoria Land Coast, affecting community structure, genetic differentiation and adaptations.

These barriers could strongly influence the trophic dynamic of marine ecosystems, as strictly related to physical, chemical and biological processes occurring either in the water column and bottom sediments. Pelagic and benthic compartments are coupled in marine system and interact through the material and energy flows also determining the evolution of planktonic and benthic communities.

Recently, particular attention has been focused on the structure and dynamics of the sea-ice community which has a fundamental role in primary production processes.

The production of faecal material by the zooplankton communities is of interest in the evaluation of OM pool and total OM flux. A great role is played in this framework by the microbial community whose different metabolic pathways mainly concurred to the regeneration processes (mineralization) and the degradation of organic compounds.

Most of scientific activities on fish communities have been conducted at Terra Nova Bay and Dumont D'Urville. In addition, collaboration has been established with Australian researchers working at Casey Station. Particular attention has been given to reproduction, larval stages, recruitment (previous data stress strong latitudinal variations in reproductive strategy of some species) and predator-prey relationships.

Till now, population genetic studies have been carried out on plankton and nekton species, in terms of analysis of inter- and intra-specific genetic diversity. Investigations have been performed by means of molecular markers such as sequence polymorphism at mitochondrial DNA, amplified fragments length polymorphism (AFLPs) and microsatellite nuclear loci. The results obtained so far indicate the existence of distinct genetic pools in the different areas of the Southern Ocean for both fish and krill species. Such genetic heterogeneity is more pronounced in the two fish species studied (*Pleuragramma antarcticum* and *Chionodraco* spp.) as compared to the Antarctic krill *Euphausia superba*.

Biochemical, physiological and other adaptive responses

The biology of Antarctic organisms is strongly affected by temperature, light, food and water availability most of which change with latitude. Anyway, seasonal and interannual variations may complicate the comprehension of the latitudinal gradient effect on community structure, but this variability itself may be a feature of latitude.

Moreover some terrestrial features vary in a non-linear manner to latitude, such as the extent of freeze/thaw cycles which impart considerable stresses on organisms, the oceanic influence, affected by pack-ice persistence and wind action, and, finally, the altitude which has a marked bearing on temperature, ands can mimic the solar radiation effects along the latitudinal gradient.

Baseline information on the ecology and biology of terrestrial and marine organisms is important for interpreting possible community responses to fluctuating environmental parameters and in the perspective of evaluating possible effects of global change. Moreover differences in distribution, abundance and growth rate of $CaCO_3$ utilising organisms (algae, molluscs and echinoderms) may be hypothesised, due to the influence of latitudinal changing or edaphic parameters on biocalcification.

Water is the principal limiting factor in terrestrial ecosystems and eventual climatic shifts (temperature and precipitation) could strongly affect water availability and element (essential and toxic) leaching.

Inland, most research was performed within the SCAR- RiSCC (Regional Sensitivity to Climate Change) in Antarctic Terrestrial and Limnetic Ecosystems, focusing on survival strategies, genotypic and phenotypic plasticity, inter-specific competition and community dynamics,

biogeochemical cycles (carbon and nutrients, growth and primary production, organic matter decomposition, bioavailability of essential and toxic elements).

Continental Antarctica presents only few non-marine environments suitable for life. Microbial flora and fauna (cyanobacteria, tardigrades, nematodes, rotifers) have several strategies (e.g. anhydrobiosis) that allow them to be dispersed by wind and to establish in some of the most extreme environments on earth. However, local soil conditions or water conditions (salinity, anoxia) can result in local patchiness in community structure and composition.

In these environments, biological communities microalgae are ever present. In some cases, they represent the main component both quantitatively and qualitatively (for example benthic and floating algal mats). During the last decade (1989-1999) samples were collected from different Antarctic non-marine habitats: lakes and ponds, meltwaters, mosses, ornitogenic soil, ahumic soil, snow and rock, covering most of deglaciated zones of northern Victoria Land (from 72°36' S to 75° 46' S).

Studies have been performed about elementary composition, relation with substrate and distribution of lichenes according to latitude, altitude, distance from the coast, birds presence and other environmental features.

Regarding the extremophilic microorganism (thermophiles, alophiles and psychrophiles), several species of thermophiles (one of which, *Bacillus thermoantarcticus*, is a novel species) and alophiles have been isolated from Mount Melbourne and Edmonson Point. Taxonomical work has been carried out, as well as characterisation of enzyme content and membrane lipids. A psychrophile (*Psychrobacter* sp. TAD1) has been isolated from fresh continental water. Two glutamate dehydrogenases, each specific for either NAD or NADP, have been purified and characterised, with respect to cold-adapted features.

A great bulk of data has been collected about sea-ice microalgal communities and their adaptations in relation to temperature, salinity and light. These organisms produce secondary metabolites, among which carotenoids, of relevant interest, as they represent "fine chemicals" of commercial interest.

At sea, researches were carried out focusing mainly on fish respiration rate and metabolism. Primarily attention was given to differences in structural and functional characteristics of haemoglobin in half of the total species number of the sub-order Notothenioidea and in other sub-orders (Zoarcoidea), giving particular attention to thermodynamic oxygen binding properties and to tri-dimensional crystallographic structure in species having functionally different haemoglobins.

Secondarily, studies were performed on metabolism (enzymatic systems playing a key role in the metabolic pattern), in particular on blood red cell glucose-6-phosphate dehydrogenase, liver L-glutamate dehydrogenase, muscle phosphorilase, blood and gills carbonic anhydrase, in terms of structure and catalytic behaviour at changing temperatures. Some of these enzymes are studied relative to different physiology of species with and without haemoglobin.

Studies regarding reproductive adaptations have been performed on some of the most conspicuous benthic species, stressing relevant changes in tempos and timing of spawning, that can be related to latitude, although interannual and local changes occur, which may mask latitudinal effects.

Ecotoxicology

The long distance transport of air borne chemicals (such as some persistent organic pollutants), the impact of increasing levels of UV radiation (due to the stratospheric ozone depletion) and focal sources of physical-chemical disturbance associated with scientific bases and tourism depict the opportunity of developing integrated ecotoxicological studies.

The Southern Ocean isolates Antarctica from other oceans and lands therefore volatile contaminants can reach it mainly via the transport of air mass. Furthermore, the southern

hemisphere is mainly occupied by oceans and land is relatively less populated than the northern hemisphere so that the contamination pattern from the Northern high latitudes to the Southern high ones follows a latitudinal gradient.

Remote areas including the Polar regions were considered to be pristine until contamination was first documented in the 1970's.

Global contamination by persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs) and organochlorine pesticides has been well documented. Oceans are a major sink for persistent chemicals, which are transported from continental areas by atmosphere and oceanic currents. Global distillation or fractionation by condensation in cold polar environments has been proposed as a mechanism whereby the polar regions may become sinks for some POPs. They vaporize from source areas in the mid-latitudes and are transported to the high latitudes by air mass movements. In relation to the volatility of the various POPs, they condense at different ambient temperatures and fall out on the earth surface again. Condensation and falling out depend on physicochemical properties of molecules and air temperature so chemical deposition is strictly correlated to them and the process has been defined as "global distillation".

This is why it is expected that the presence of POPs may follow a latitudinal gradient. Due to the low temperatures, POPs degradation is very slow in the polar regions. Ice is a cold trap for POPs and it can release them thus these compounds may enter in the trophic webs where they bioaccumulate and biomagnify. Migratory animals, especially top predators (such as South Polar skua and other birds, whales), may be another source of pollutants with their excrements and carcasses.

Among POPs, polychlorinated biphenyl (PCBs), polychlorinated-dibenzo-*p*-dioxins (PCDDs), polychlorinated-dibenzofurans (PCDFs), polychlorinated-naphthalenes (PCNs) and chlorinated pesticides (i.e. *p,p'*-DDE) have already been detected in Antarctic organisms. All these compounds are industrial chemicals that exhibit several common properties such as high lipophilicity (increasing with chlorination), high stability to breakdown by acids, bases, heat, hydrolysis.

The use of key species as sentinels (bioindicators) for monitoring environmental changes around Antarctica has been stressed by SCAR programs, such as EASIZ. However, very limited investigations have dealt with the development and validation of biomarkers in Antarctic organisms, based on responses at different level of biological organization, for early detection and prediction of environmental changes. Thus the improvement of our knowledge about the biochemical, molecular, genetic and physiological responses to a changing environment along a north - south continuum appears to be a significant issue to be addressed.

Among the numerous biological responses described as biomarkers in the last two decades, those based on the cellular antioxidants and on the susceptibility to oxidative stress are of increasing interest for ecotoxicologists, since several physical and chemical perturbations are known to exert their toxic effects through the enhancement of intracellular generation of reactive oxygen species. Antioxidant defenses of Antarctic key species were shown as useful biomarkers for detecting pollutant effects under both field and laboratory conditions; moreover, variations of the redox status appeared closely related to other important damages including lysosomal membrane destabilization. The antioxidant system is also strictly involved with the impact of UV radiation on biota. In fact, despite many invertebrates are partially protected from the direct effects, the indirect effects associated with enhanced UV radiation mainly include an elevated production of oxyradicals both in sea water and in the cell cytoplasm.

Biodiversity

Our knowledge of the Ross Sea and Victoria Land biota is limited to occasional and spatially limited collections, and is thus incomplete. A comprehensive survey is fundamental to the

understanding of the biogeography of this area, as well as regional biodiversity. A check-list of the recorded species is available on the web-site www://mna.it.

Data regarding species richness and distribution are available for lichenes, microalgae (lakes, ponds, ice), fungi, protozoans, oligochaetes and insects.

At sea, in the framework of the study of phytoplankton (diatoms and dinoflagellates) and zooplankton studies, protozoans, crustaceans (copepods, euphausids, ostracods, mysidaceans), fish larvae and microzooplankton have been intensively investigated along the western side the Ross Sea.

Within benthic communities, attention was focused, mainly in the area of Terra Nova Bay, on sponges, bryozoans, molluscs, echinoderms and polychaetes.

Among top predators, data are available on diversity, distribution and biomass of fish, birds, mammals in the western Ross Sea.

Particular attention was focused on fish communities, which have been studied also in terms of cytogenetics. Patterns of chromosomal differentiation have been described and interpretation of the karyological data attempted. The monophily of the Notothenioidea is still an unproven hypothesis, that merits further investigations, as phylogenetic data are still limited.

The knowledge of the ecology of seabirds and marine mammals is essential for the management of marine resources and for the assessment of changes due to natural or man made causes. Climate, presence of polynyas, pack ice or fast ice may influence the presence and breeding success of marine mammals and birds.

Along the Victoria Land, data were collected by ship surveys, which gave an important contribution to understand their biogeography, as well as the regional biodiversity. Observations on seabirds (*Pygoscelis adeliae*, *Aptenodytes forsteri*, *Pagodroma nivea*, *Oceanites oceanicus*, *Catharacta maccormicki*) and their breeding locations started to be recorded since 1996/97 summer season.

Progressive emergence of benthic assemblages

At sea, in areas not exposed to disturbance due to anchor ice formation or iceberg scouring, marine benthic communities are typically highly structured by biological interactions. Environmental conditions are relatively consistent, although in coastal benthic systems decadal scale oceanographic variations can result in major shifts in trophic interactions and the structure of benthic communities. Similar to other marine systems, fluxes play an important role in influencing local ecosystem and community structure and functioning. This is clearly illustrated by the role of advected primary production in the structure of coastal benthic communities in McMurdo Sound. These features emphasise the importance of local biotic processes and broad-scale oceanographic variation, the interaction of which are likely to result in environmental gradients markedly different from those apparent in terrestrial ecosystems.

The hypothesis of “polar emergence” has never been tested other than with incidental collections of species which appear to co-occur in the deep sea and shallow Antarctic coastal areas. Recent studies on algal zonation have stressed the disappearance of kelp (occurring in Adelie Land at Dumont d'Urville french station) and the narrower depth distribution of frondose red algae while moving southward from Cape Adare to McMurdo Sound. Similarly, *Adamussium* bed bathymetric distribution shows an up-welling moving from Terra Nova Bay to McMurdo Sound area.

Moreover relevant changes occur in spawning occurrence of this species along the Victoria Land Coast. Finally, being the communities emergence linked to the light availability, the different persistence of ice coverage could, locally, mimic a possible latitudinal gradient.

Working hypotheses

- **The physical environment**
  The physical measurements needed are:

1. air, soil, soil moisture, freshwater temperature
2. solar radiation and UV-B intensity
3. tide and sea currents vectors and magnitudes
4. ocean temperature and salinity
5. topography and bathymetry
6. sea-ice conditions
7. wind vectors and magnitudes
8. lake levels and stream and ice flows

- **Structure and functioning of inland, pelagic (holoplankton and meroplankton), benthic and nekton communities, identifying key species and their ecological relevance (distribution, abundance and role)**

  Biological aspects which could be affected by the latitudinal gradient are:

  1- for communities:
  structure (composition and biomass)
  carbon and nutrient cycles
  variations in primary and secondary productions
  food chains (structure and complexity, feeding guilds etc),

  2- for key species:
  population structure (density, depth/altitudinal distribution)
  changes in trophic needs
  top predators role
  symbiotic relationships
  breeding, reproductive strategy, periodicity and effort
  influence of edaphic parameters (water availability, substrate type etc)

- **Biochemical, physiological and other adaptive responses of key species**

  Adaptive and physiological studies should particularly focus on:

  1- genotypic and phenotypic plasticity
  2- bacterial standing stock, production and enzymatic activity
  3- energy flow in the first compartment of the lower food web
  4- biomolecular adaptations of extremophilics
  5- respiration rates and metabolism in Notothenioidea
  6- adaptive biomolecular mechanisms to small environmental changes
  7- fish citogenetics to evaluate possible chromosomal intraspecific variations and genomic structural changes

- **Xenobiotic compounds, biomarkers and biological indicators**
  Studies will include:

1- baseline data for POPs in organisms of the Ross Sea/Victoria Land coasts
2- evaluation of the relationship between the latitude and the type and amount of POPs accumulated by organisms, accordingly to the cold fractionation theory
3- biomagnification processes and assessment of risk for most exposed species
4- identification of local sources of pollution (i.e.: scientific stations)
5- assessment of the eventual role of migratory and non migratory habits in the tissue residue pattern
6- identification of sentinel species for biomonitoring studies
7- characterisation of basal biological responses at molecular, cellular and physiological level
8- investigation of the adaptive role of some biological responses and their variability along environmental gradients
9- evaluation of UV-B effects on non marine microalgae

- **Biodiversity**

Biodiversity will be studied at community, species and genetic levels:

1- Community studies will be performed to evaluate:
their distribution
environmental complexity
species richness
functional group diversity
size spectra

2- Species level:
inland taxonomy: lichenes, microalgae, microfungi, protozoans, oligochaetes, collembola, tardigrades;
marine taxonomy: microalgae, macroalgae, protozoans, sponges, cnidarians, annelid polychaetes and oligochaetes, molluscs, crustaceans, echinoderms, fishes

3- Genetic level:
attention will be focused on the population genetic variability of key species (in benthic and pelagic domains) due to the presence of geomorphological or hydrological barriers and, in particular, goals will be:

to extend the analysis of spatial and/or temporal variation at polymorphic loci;
to infer the genetic population structure (in relation to biology);
to estimate the migration rates (in relation to biology);
to test the effect of oceanographic factors on genetic diversity (micro- macro-geographic scale).

Three are the principal investigation sectors:

1. **Atmosphere and environmental gradients**
2. **Inland communities**
3. **Marine communities**

Sector	Research topics	Italian Principal Investigators
Atmosphere and environmental gradients	1. Analysis of climatic time series and of sea-ice coverage; 2. Modelling 3. Planning	**Coppola** (Italian Airforce) **Pellegrini** (ENEA)
	4. Synoptic measurements of environmental parameters	**Pellegrini** (ENEA-PNRA)
Inland communities	1. Inland and freshwater communities (production, biomass, processes and diversity)	**Andreoli** (Padova Univ.: microalgae biodiversity) **Bargagli** (Siena Univ.: processes in inland vegetal organisms) **Carchini** (Roma Univ: animal biodiversity, biomass, size spectra in freshwater communities) **Ciardiello** (CNR-Napoli: bacterial enzymes) **Fumanti, Cavacini** (Roma Univ.: microalgae biodiversity, UV effects) **Luporini** (Camerino Univ.: ecology and biogeography of ciliate protozoans) **Monticelli** (CNR-Messina: bacterial production)
	2. Sea-birds and marine mammals ecology	**Corsolini** (Siena Univ.: xenobiotic compounds monitoring and toxicity) **Nigro** (Pisa Univ.: bioindicator species, biomarkers) **Olmastroni** (Siena Univ.: ecology of sea-birds and marine mammals) **Regoli** (Ancona Univ.: bioindicator species, biomakers)

Marine communities	1. Water column: production, processes, phytoplankton, zooplankton, ichtyoplankton	**Andreoli** (Padova Univ.: microalgae biodiversity) **Guglielmo** (Messina Univ.: zooplankton distribution) **Monticelli** (CNR-Messina: bacterial production) **Patarnello** (Padova Univ.: krill population genetics) **Povero** (Genova Univ.: organic particulate and dissolved matter) **Sertorio** (Genova Univ.: zooplankton biodiversity) **Vacchi** (ICRAM-Roma: ichtyoplankton distribution and biodiversity)
	2. Benthic communities	**Albertelli** (Genova Univ.: soft-bottom communities) **Bavestrello** (Ancona Univ.: inter-specific relationships) **Cattaneo-Vietti** (Genova Univ.: hard-bottom communities) **Chiantore** (Genova Univ.: trophic and reproductive ecology) **Ciardiello** (CNR-Napoli: bacterial enzymes) **Corsolini** (Siena Univ.: xenobiotic compounds monitoring and toxicity) **Gambi** (SZ-Napoli: ecology and reproductive biology of polychaetes, and ecology of algal) **Luporini** (Camerino Univ.: ecology and biodiversity of protozoans) **Monticelli** (CNR-Messina: bacterial production) **Nigro** (Pisa Univ.: bioindicator species, biomarkers) **Patarnello** (Padova Univ.: benthic population genetics) **Regoli** (Ancona Univ.: bioindicator species, biomarkers)
	3. Fish communities: diversity, ecology, physiological adaptations and phylogenesis	**Di Prisco** (CNR-Napoli: fish adaptations) **Focardi** (Siena Univ.: xenobiotic substances accumulation) **Nigro** (Pisa Univ.: bioindicator species, biomarkers) **Patarnello** (Padova Univ.: fish population genetics) **Pisano** (Genoa Univ.: cytogenetics and genomic variability) **Vacchi** (ICRAM-Roma: biodiversity and distribution)

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Background of Italian events leading up to the Workshop

The idea to plan a multidisciplinary project focused to evaluate the role of latitudinal gradient on the Victoria Land and Ross Sea communities matured at Terra Nova Bay in the framework of the PNRA project "Structure and dynamics of the coenoses at Terra Nova Bay" between Paul Berkman and Mariachiara Chiantore (austral summer 1998-99). A first proposal was discussed at Bremerhaven during the EASIZ Workshop and Symposium (June 1999).

Further discussions were held in Italy during a workshop organised at the Siena University (with the presence of Berkman) (July 2000) and a first draft was presented at the Accademia dei Lincei (Rome, October 2000).

Guido Di Prisco discussed this project during the 24° SCAR Meeting held in Tokyo (August 2000), while Roberto Bargagli introduced the idea in South Africa during the organisation of the Regional Sensitivity to Climate Change in Antarctic Terrestrial Ecosystems (RiSCC) project which has close affiliations with the Victoria Land project. In fact, in this occasion, it was stressed that "one way of examining the predicted consequences of climate change is to investigate latitudinal gradients as an analogy for future climate change".

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