GLACIERS: CARES AND DEVELOPMENT PROJECTS.

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¿WHAT IS A GLACIER?

A mass of land ice moving downhill (by internal deformation and sliding at the base) … maintained by accumulation of snow at high altitudes, balanced by melting at low altitudes or discharge into the sea…(GTOS, 2007)


Plomo Glacier, Chile

TYPES OF GLACIERS AS PER DEBRIS COVER, (EXTREMES):

Debris-free glacier: almost no debris coverage on glacier surface. Vulnerable to Climatic Change

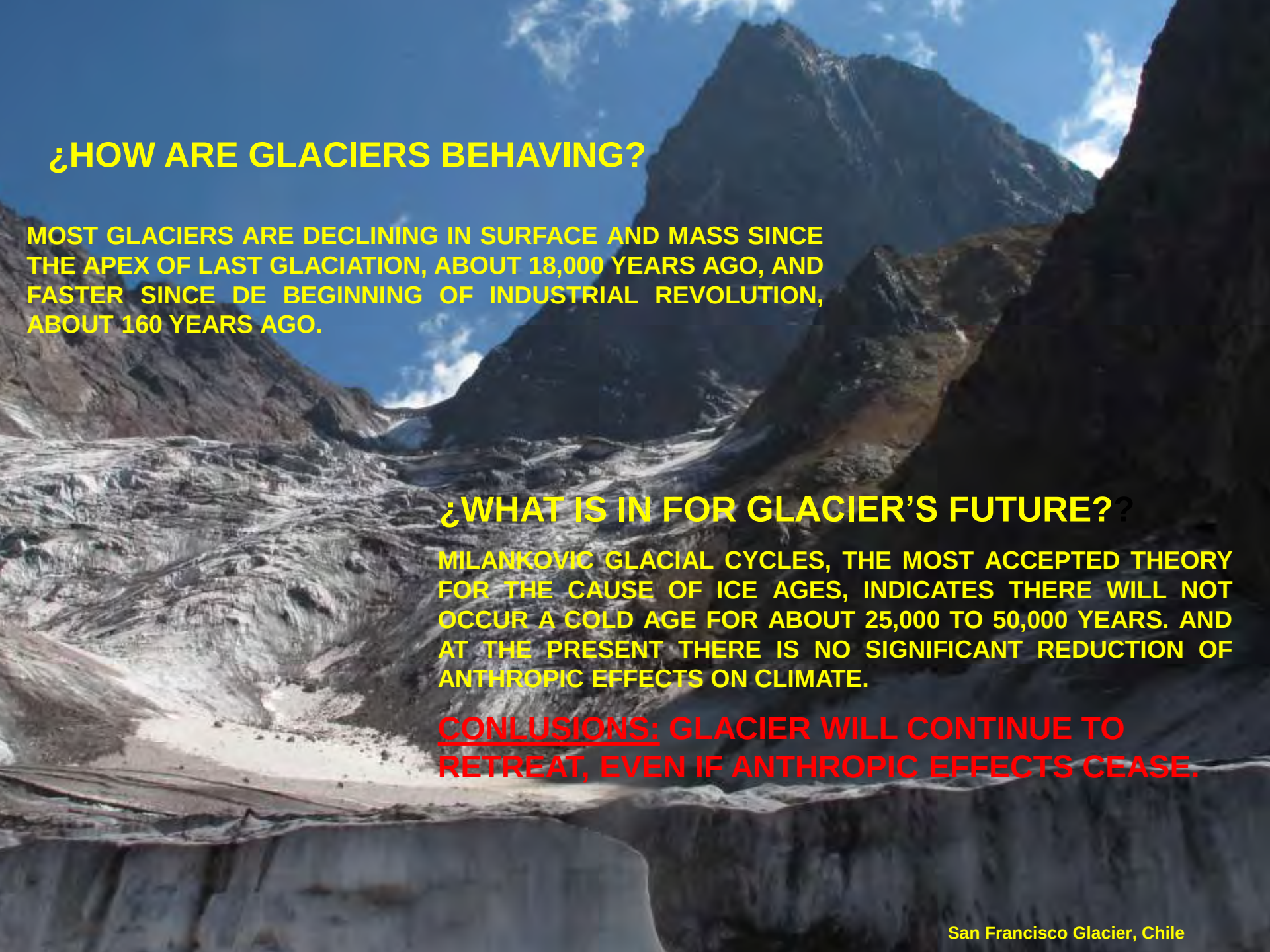
Carvajal Rock Glacier, Chile.

Rock glacier: all or most of its surface covered by rock debris, which acts as insulator. Less vulnerable to Climatic Change.


Monolito Rock Glacier, Chile

¿WHY GLACIERS MATTER?

WATER	❖ FRESH WATER RESERVE (temporary). ❖ RIVER-FLOW REGULATORS. ❖ SUPPORT WETLANDS AND ENHANCE BIODIVERSITY.
SCENERY	❖ SCENIC VALUE OF DEBRIS-FREE GLACIERS. ❖ (NOT SO FOR ROCK GLACIERS.)
CLIMATE	❖ CLIMATIC CHANGE INDICATORS. ❖ INFLUENCE CLIMATE.
RISKS	❖ ORIGINATE DANGERS AND RISKS.
CULTURE	❖ OF ANCIENT PEOPLE.



¿HOW ARE GLACIERS BEHAVING?

MOST GLACIERS ARE DECLINING IN SURFACE AND MASS SINCE THE APEX OF LAST GLACIATION, ABOUT 18,000 YEARS AGO, AND FASTER SINCE DE BEGINNING OF INDUSTRIAL REVOLUTION, ABOUT 160 YEARS AGO.

¿WHAT IS IN FOR GLACIER'S FUTURE?

MILANKOVIC GLACIAL CYCLES, THE MOST ACCEPTED THEORY FOR THE CAUSE OF ICE AGES, INDICATES THERE WILL NOT OCCUR A COLD AGE FOR ABOUT 25,000 TO 50,000 YEARS. AND AT THE PRESENT THERE IS NO SIGNIFICANT REDUCTION OF ANTHROPIC EFFECTS ON CLIMATE.

CONLUSIONS: GLACIER WILL CONTINUE TO RETREAT, EVEN IF ANTHROPIC EFFECTS CEASE.

San Francisco Glacier, Chile

EVENTS IMPACTING GLACIERS, in order of importance:

1. **NATURAL EVENTS, SLOW OR VIOLENT: climatic variations, volcanism, seismicity, others.**

2. **DISTANT ANTHROPIC ACTIVITY: global Climatic Change, thermal umbrella of large urban centers, deforestation, dust, others. Commonly associated to population growth.**

3. **NEAR-BY ANTHROPIC EFFECTS – "DEVELOPMENT PROJECTS": public and private.**

Snow penitents on Rinconada West Glacier, Chile

¿HOW CAN A PROJECT IMPACT GLACIERS?

- **By direct contact**: excavations, dumps, tunnels, roads, cavities, others.
- **Changes of glacier surface properties:** most common by deposition of anthropic dust which increases ablation rate.
- **Changes in characteristics of local climate:** modifiying temperature, cloudiness, wind, relative humidity, etc.
- **Changes in local topography**: altering wind, snow, avalanches, insolation patterns, etc.
- **Changes in the drainage patterns:** entering a glacier, intra-glacial, sub-glacial, supra-glacial, or issuing from a glacier.
- **Induced ground accelerations:** blastings, heavy equipment, etc.

Neumayer Channel glaciers, Antarctica

¿HOW TO PROCEED WITH A PROJECT WITHIN A GLACIATED AREA?

A) EVALUATE POSSIBLE IMPACTS ON GLACIERS:

DEFINE A PRELIMINARY PROJECT INFLUENCE AREA, mínimum 20 km radius from all works

INVENTORY ALL GLACIERS WITHIN INFLUENCE AREA

MAKE A PRELIMINARY EVALUATION OF LIKELY IMPACTS

MAKE BASE-LINE STUDIES OF PRESUMABLY IMPACTED GLACIERS

EVALUATE EFFECTS ON IMPACTED GLACIERS, include dust dispersion models

B) IF IMPACTS EXISTS:

CHANGE PROJECT

MITIGATE AND REPAIR

- With glacier-management techniques
- Compensate with other resources

C) PERMANENTLY:

GLACIERS AND SOURROUNDINGS CONTROL AND MONITORING PROGRAMME for project duration and closure.

Southern Patagonian Ice Cap, Chile

¿WHAT SHOULD A STATE DO IF PROJECTS INTEND TO OCCUPY GLACIATED AREAS

1. DEFINE WHAT IS CONSIDERED A GLACIER:
   using definitions of international organizations.
2. MAINTAIN AN UPDATED GLACIER INVENTORY.
3. PRODUCE RECOMMENDATIONS FOR IMPACT EVALUATIONS:
   a) TO DEFINE A PROJECT PRELIMINARY INFLUENCE AREA.
   b) FOR A PRELIMINARY EVALUATION OF LIKELY IMPACTS ON GLACIERS.
   c) FOR GLACIER BASE-LINE STUDIES.
   d) TO EVALUATE IMPACTS.
4. ASSES THE MERITS OF IMPACTS STUDIES AND OF THE PROPOSALS FOR MITIGATIONS-REPAIRS-COMPENSATIONS.
5. ISSUE RECOMMENDATIONS ON:
   a) GLACIERS CONTROL AND MONITORING PLAN.
   b) PLANS TO MONITOR ENVIRONMENTAL PARAMETERS IN GLACIER'S VICINITY.

CONTENT OF A GLACIER BASE LINE:

1. GENERAL DESCRIPTION: classification, temperature, stratigraphy (in rock glaciers).
2. ICE/SNOW (MASS) BALANCE.
3. HEAT BALANCE.
4. WATER BALANCE.
5. VELOCITIES OF MOVEMENT AND STRESSES.
6. THICKNESS.
7. GENERAL STABILITY: geotechnical stability analysis methods.
8. BIODIVERSITY: within the glacier and its surroundings.
9. VARIATIONS: Recent and Quaternary (as per terrain evidence).

Four Glaciers Pass, Chile

MANAGEMENT OF MOUNTAIN GLACIERS: ¿WHY?

- GLACIERS ARE AN IMPORTANT ENVIRONMENTAL RESOURCE, BUT CONDEMNED TO EXTINTION (BECAUSE OF NATURAL AND ANTHROPIC CAUSES) UNLESS MANAGED.

- GLACIERS MUST BE SAVED, IF POSSIBLE.

- RISKS THAT GLACIER ORIGINATE (glacier slides, lahars, glofs, etc) MUST BE PREVENTED OR REDUCED.

¿HOW?

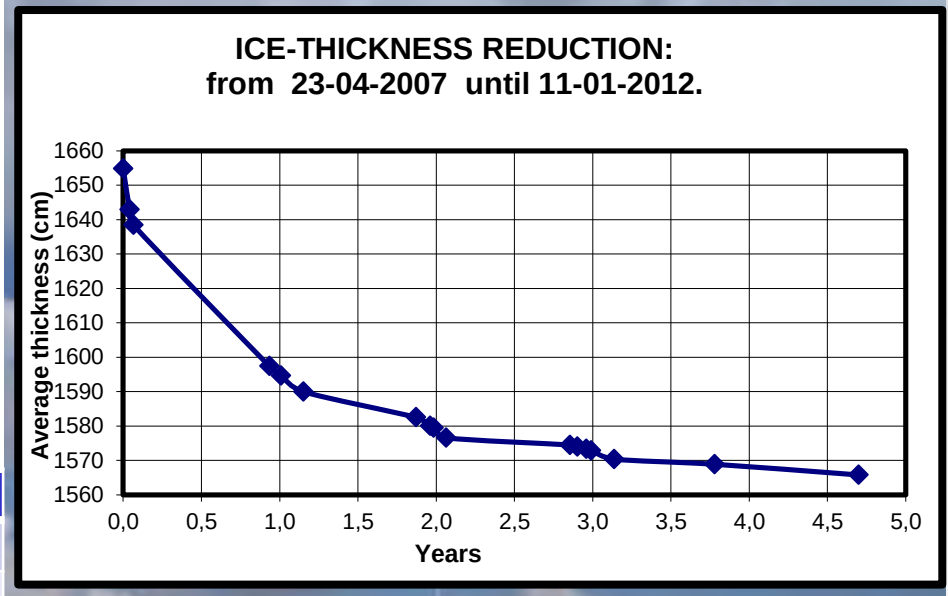
- NEW GLACIER-MANAGEMENT TECHNIQUES ARE BEING CREATED:
  a) Artificial increase of snow or ice accumulation.
  b) Reduction of surface ablation.
  c) Relocating ice masses to special deposits for a longer existence.
  d) Generating new self sustainig glaciers (tests so far).
  e) Improving the knowledge of glacier's characteristics.

- COLABORATION FROM ALL PARTIES IS REQUIRED.

A RELOCATED-ICE SPECIAL DEPOSIT: improving the persistence of an ice mass extracted from a rock-glacier terminus.

- The goal: To achieve an ice-melting rate lower than in its original site, which is 15 cm/a.
- The pickup stands on a 32.000 ton ice deposit, 16 m deep, 2.400 m^2 surface area, covered with 1 m of "inert" rock-debris.
- The deposit rests on a 1 m thick "inert" rock-debris layer.
- Temperature sensors in post-deposition drill holes, and ablation stakes resting at the base.
- No "hot spots" developed. Flows as a glacier.
- Less than 1% of initial ice mass lost during relocation.

ANNUAL SURFACE DESCENT				
2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
48,2 cm	16,0 cm	6,6 cm	5,1 cm	3,1 cm



A NEW MINI-ROCK-GLACIER TO LAST FIVE CENTURIES INSTEAD OF ONLY ONE IN ITS ORIGINAL SITE.

SOURCE: CODELCO-CHILE, Andina Division.

ARTIFICIAL SNOW ACCUMULATION TO CONVERT A SNOW FIELD INTO A GLACIER: WITH A SNOW-FENCE.

Snow fence:

- at Salvadora, Chile, 4,100 m.a.s.l.
- installed April 2010,
- L = 60 m, H = 4 m,
- permeability 40%,
- free foot 0.5 m.

Average snow accumulation in area ~ 1.8 m

Maximum accumulation behind fence ~ 4.1 m

SOURCE: CODELCO-CHILE, Andina Division

"… we can do much more than what we think we can do." *M. Gandhi*

END

THANK YOU

PRESENT-DAY QUESTIONS FOR GLACIOLOGY:

a) ¿HOW TO SAVE GLACIERS, AND CAN WE GENERATE NEW SELF- SUSTAINING GLACIERS?

b) ¿CAN GLACIERS AND DEVELOPMENT CO-EXIST?
Wrong question:
¿WHAT ARE WE WILLING TO DO TO CO-EXIST WITH GLACIERS?

Torres del Paine National Park, Chile