LA RECESIÓN DE LOS GLACIARES ANDINOS DESDE LA PERSPECTIVA DE LA GESTIÓN INTEGRADA DE LOS RECURSOS HÍDRICOS

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PRINCIPIOS DE LA GIRH

- Es un proceso para el desarrollo sostenible, la asignación y el control del uso de los recursos hídricos en el contexto de objetivos sociales, económicos y medioambientales
- Los usos del agua son interdependientes y se deben considerar conjuntamente, atendiendo al bienestar general y al uso sustentable de los recursos- Contrasta así con enfoques sectoriales.
- Integridad y globalidad de las distintas formas en que el agua se presenta en una cuenca.

EL CAMBIO CLIMÁTICO Y LOS RECURSOS HÍDRICOS

LOS RECURSOS HÍDRICOS SON EL PRIMER ESLABON AFECTADO EN LA CADENA DE IMPACTOS

Los glaciares dieron el primer aviso del CC

El CC y la GIRH

- El CC es un paradigma reciente para la planificación hídrica
- Está el CC presente en los planes estratégicos generales y sectoriales de cada Estado?
- Está realmente el CC en la agenda de la gestión?
- La GIRH debe contemplar estrategias de adaptación

VULNERABILIDADES

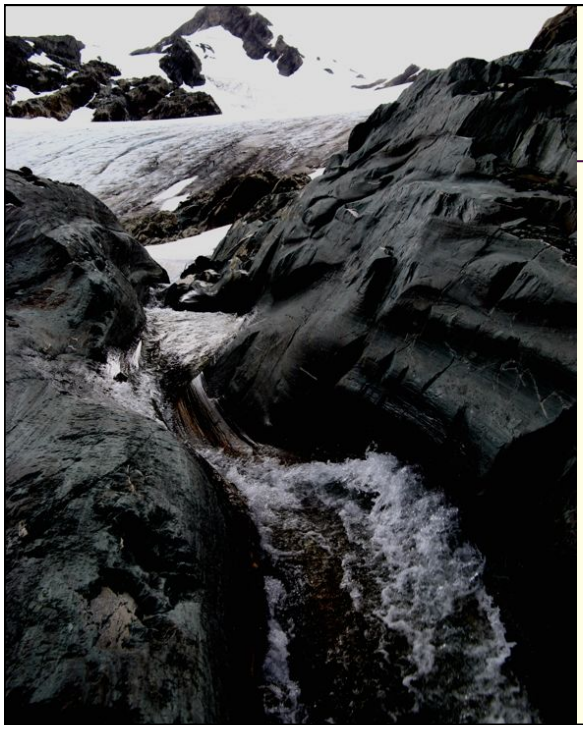
- Estamos en capacidad de identificar vulnerabilidades?
- Dónde - en qué medida?

El análisis de vulnerabilidad requiere de precisiones y de conocimiento

- CC: de qué estamos hablando exactamente?

- Vulnerabilidad a riesgos de origen glaciar
- Vulnerabilidad a eventos climáticos extremos

- Vulnerabilidad de los glaciares al CC
- Vulnerabilidad de los sistemas hidrológicos a la extinción de glaciares
- Vulnerabilidad a la reducción de los depósitos nivales
- Vulnerabilidad a la desaparición del permafrost



How will change the hydrological regimen of the rivers if glaciers disappear?

What is the magnitude of the net glacier contribution to the runoff?

What do we mind as "glacier contribution"?

- We can make measurements of total glacier contribution flowing down from a glacier (R)
- But the total annual run-off is the result of:

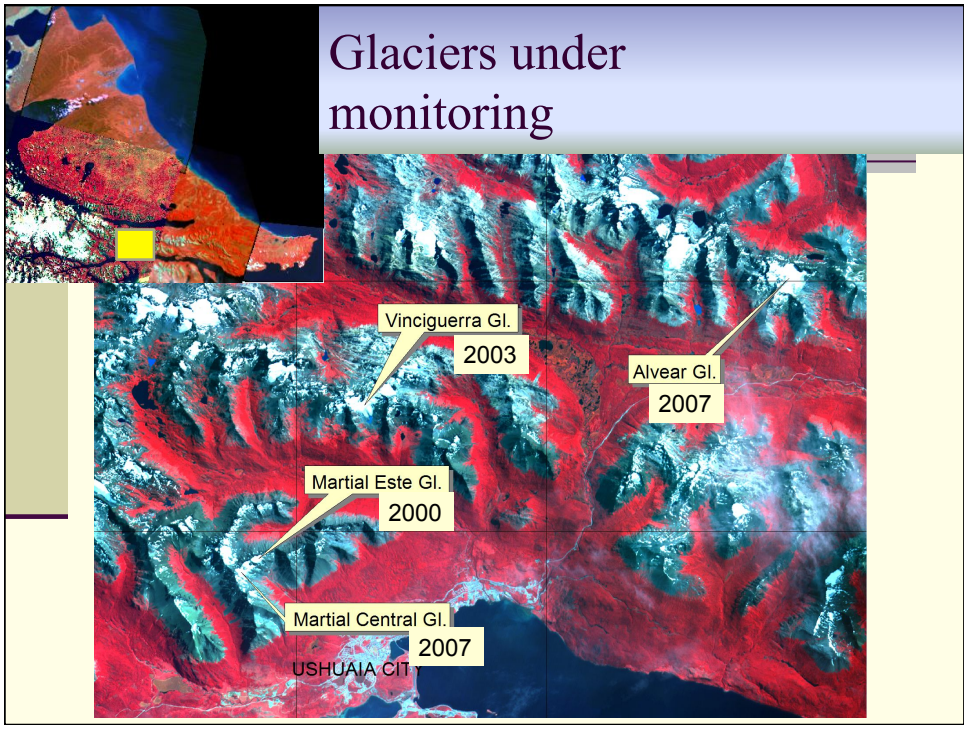
R= P – E - Su - ~~Δ Storage~~

MASS BALACE IS A USEFUL HYDROLOGYCAL TOOL

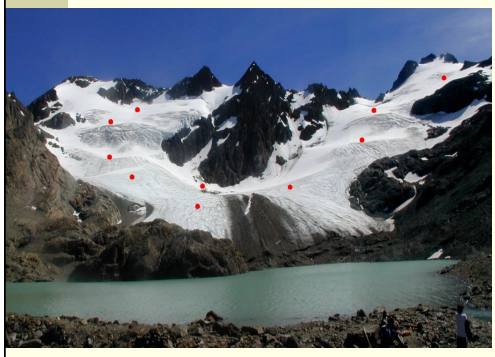
EVALUATION OF VULNERABILITY TO GLACIER EXTINTION IN TIERRA DEL FUEGO - ARGENTINA

- Mass Balance of pilot glaciers.
- Glacier inventory by water basin
- Evaluation of net glacier contributions by water basin
- Runnof meassuring and analysis
- Glacier contributions - summer runoff comparison
- Water basins are categorized according a method useful for snow-rain water basin regime and glacier contributions.

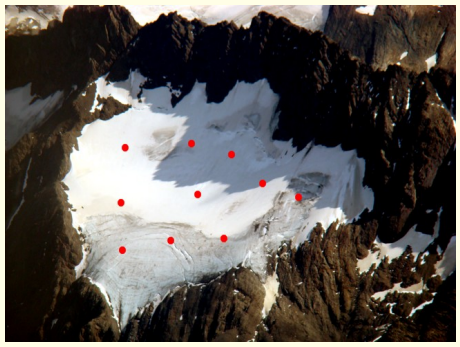
Glaciers under monitoring



Ablation and accumulation stakes



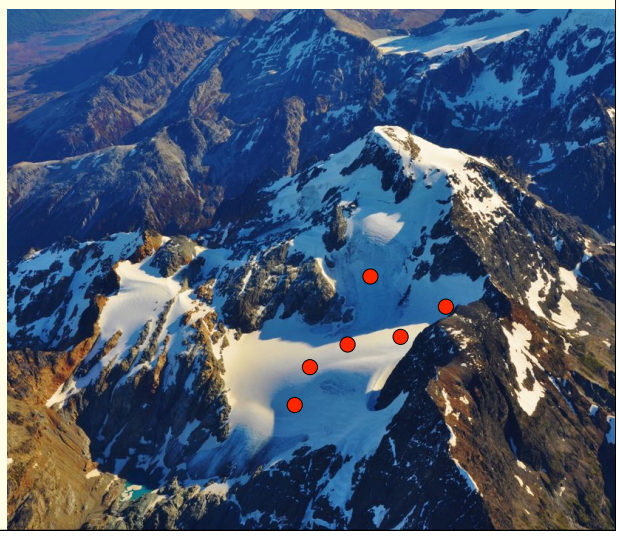
Vinciguerra



Martial Este

Ablation and accumulation stakes

Alvear|

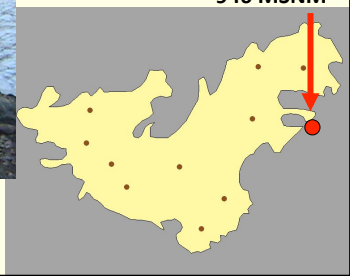


- Mass balance , glacier topography and and thikness

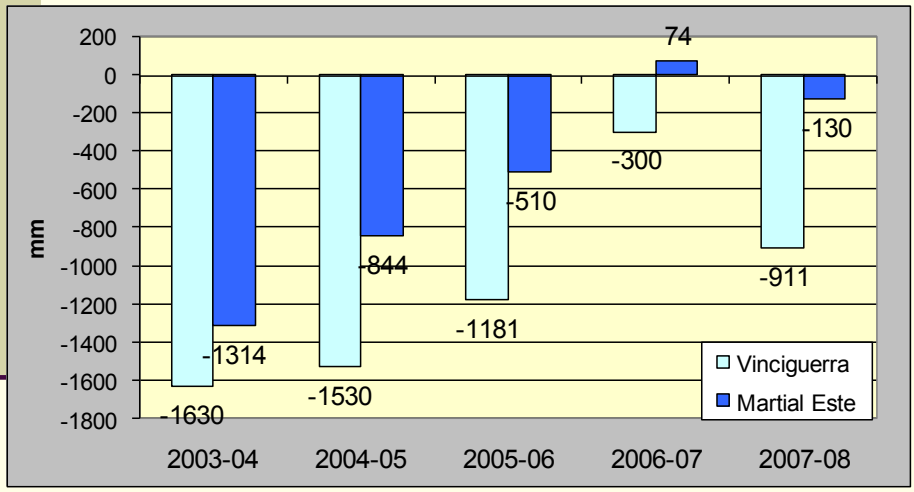
Climate monitoring

Vinciguerra

946 MSNM

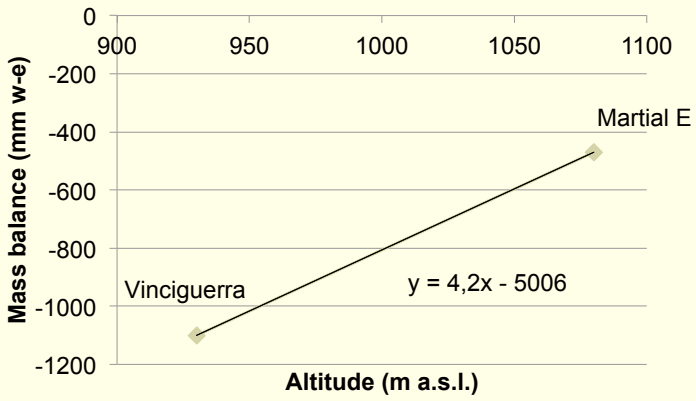


Mass balance results



Vinciguerra: - 1110 mm we **Martial E: - 545 mm**

Mass balance depends on glacier medium altitude



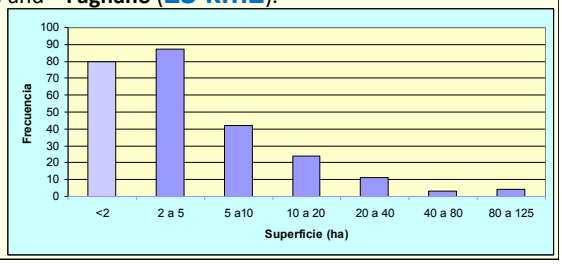
Short summary of the 2002 Glacier inventory for the Argentinean basins of Tierra del Fuego

105.64 km2 is the **total surface** of glaciers which contribute to the runoff of the Argentinean basins of Tierra del Fuego, including the Chilean glaciers of the bi-national basins.

Only **19.6 km2** (18.6%) correspond to **Argentinean** glaciers of the Tierra del Fuego

Most of the rest of the area is located on the Chilean sector of two big water basins: **Lapataia** (**65.2 km2**) and **Fagnano** (**23 km2**).

15 Are the Argentinean or bi-national basins including glaciers



Glacier Area by Water Basin

Basin name	Basin surface (ha)	Glaciers Surface (ha)	Gl. Coverage ratio %
Guanaco	2856	1.1	0.04
Varela	16074	9.0	0.06
Elder	1327	1.72	0.13
R. de la Turba	122153	43.0	0.04
S/N(E de Guanaco)	2472	12.8	0.52
2 de Mayo	1712	12.0	0.70
Lasifashaj	42118	170.4	0.40
Encajonado	6183	46.0	0.74
Pipo	15813	148.6	0.94
Fagnano	347691	2368.0	0.68
Pta Segunda	3047	44.0	1.45
B Esperanza	1656	46.6	2.81
Olivia	20924	638.2	3.05
A.Grande	12538	499.4	3.98
Lapataia	56147	6523.5	11.62

Estimating the net glacier contribution

The net annual glacier contrib. to the Runoff from a single glacier ¨$_0$¨ is:

Net Gl. Flow $_0$ = S_0 x (Mass balance) $_0$ = S_0 x Mb_0

At the basin level :

Total Net Gl. Flow = ∑ Net glacier Flow$_i$ =∑ S_i x Mb_i

Mb_i = f (S_I , h_i)
Then Total Net Gl Flow in the basin = f (S , H)
S= total surface glacier in the basin
H= Weighted mean of h_I for glaciers in the basin

The seasonal net glacier contribution index (SNGCI)

Because the low representation of glacier in the basin, the Net Glacier Flow/ Total yearly Runoff ratio is insignificant for most of the basins.

However, ice melting occurs in a short summer period - about 60 days- after seasonal snow disappears of the glacier ablation zone .

Glacier contribution is significant at this time in some water basins.

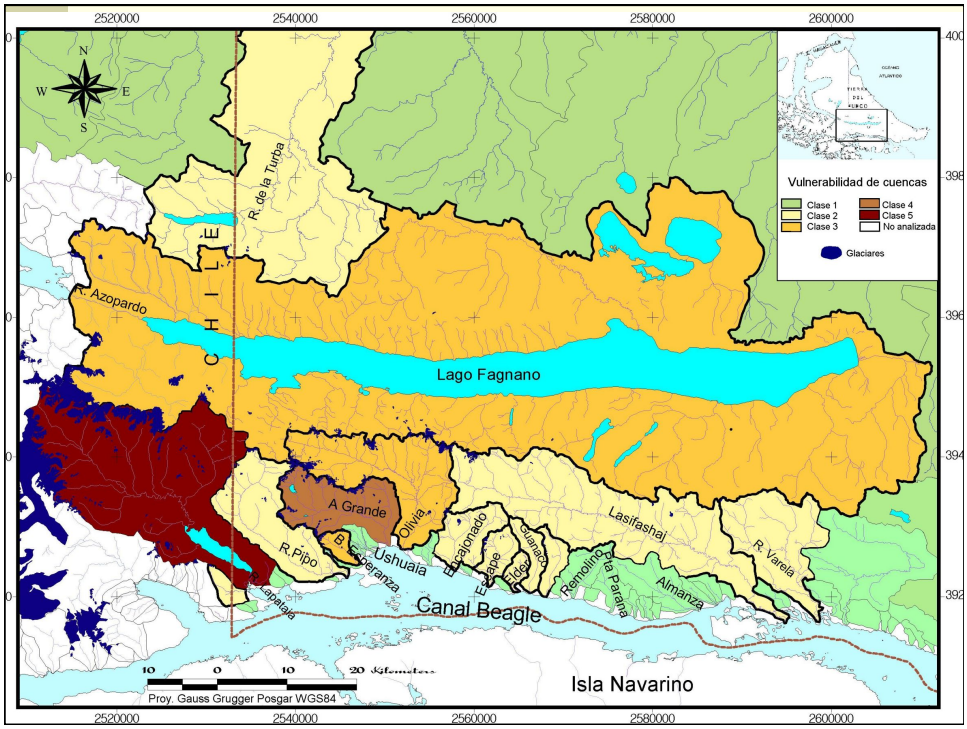
The SNGCI is the ratio between Net glaciers contribution and the total runoff volume in the basin for the matching seasonal period. (The last one is low because the seasonal snowpack is extinct.)

Cathegorizing basins by using the seasonal net glacier contribution index

Class	SNGCi	Glacier area %	Explanation
1	0	0	No vulnerability to glacier disappearing. Hydrological changes produced by climate change will depend only on effects of temperature increasing over the seasonal snowpack.
2	> 0 and < 6	>0 and < 1.2%	Low vulnerability .Glacier contribution is only perceptible in the glacial and periglacial basin environments, and occasionally at the basin level during very dry and warm episodes.
3	6 to 12	1.2% to 3.5%	Moderately vulnerability to the glacier recession , especially in dry and warm summers, when glacial water compensate drought
4	12 to 24	3.5% to 7%	Marked vulnerability. Glacier influence is normally appreciable in summer time Daily runoff variability is appreciable also after seasonal snow extinction.
5	24 to 40	7% to 14%	High vulnerability. Glacier contribution is significant in summer at the level of the whole basin.
6	>40	>14 %	Very high vulnerability. The hydrological regime in the basin depends strongly on the glacial flow . Temperature is more determinant on floods than precipitation.

Net Glacier Contributions and Water Resources Vulnerability by basin

Basin	Basin Area	Glaciers Area	Gl. Ratio	Yearly mass loss	Yearly NGC	NGC distributed on the year	NGC distributed on 60 daysr	Yearly average Runoff Basin	Seasonal runoff Basin	Gl Net Cont in the year	SNGCI =	Clase vulnera-bilidad
	a		b	$c=a.b.10^4$		$d=\frac{c}{86400.365}$	$e=\frac{c}{86400.60}$	f	g	d/f . 100	e/ g .100	
	Ha	Ha	%	m	m3	m3/s	m3/s	m3/s	m3/s	%	%	
Guanaco	2856	1.1	**0.04**	0.65	702	0.0002	0.001	0.75	0.82	**0.03**	**0.16**	**2**
Varela	16074	9.0	**0.06**	0.65	5824	0.002	0.011	4.3	4.73	**0.04**	**0.24**	**2**
Elder	1327	1.72	**0.13**	0.65	1118	0.0004	0.002	0.3	0.33	**0.12**	**0.65**	**2**
R. de la Turba	122153	43.0	**0.04**	0.60	25800	0.008	0.050	6	5.5	**0.14**	**0.90**	**2**
S/N(E de Guanaco)	2472	12.8	**0.52**	0.65	8346	0.003	0.016	0.66	0.73	**0.40**	**2.22**	**2**
2 de Mayo	1712	12	**0.70**	0.60	7200	0.002	0.014	0.44	0.48	**0.52**	**2.89**	**2**
Lasifashaj	42118	170.4	**0.40**	0.70	119280	0.038	0.230	9	9.9	**0.42**	**2.32**	**2**
Encajonado	6183	46.0	**0.74**	0.65	29874	0.009	0.058	1.5	1.65	**0.63**	**3.49**	**2**
Pipo	15813	148.6	**0.94**	0.60	89136	0.028	0.172	4.01	4.73	**0.70**	**3.63**	**2**
Fagnano	347691	2368	**0.68**	0.60	1420800	0.451	2.741	48	**54**	**0.94**	**5.08**	**2**
Pta seg	3047	44.0	**1.45**	0.65	28626	0.009	0.055	0.9	1.08	**1.01**	**5.11**	**2**
B Esperanza	1656	46.6	**2.81**	0.56	26073	0.008	0.050	0.37	0.44	**2.23**	**11.33**	**3**
Olivia	20924	638.2	**3.05**	0.60	382896	0.121	0.739	5.4	**6.4**	**2.25**	**11.54**	**3**
A.Grande	12538	499.4	**3.98**	0.67	334571	0.106	0.645	3.2	**3.8**	**3.32**	**16.98**	**4**
Lapataia	56147	6523.5	**11.62**	0.55	3587936	1.138	6.921	19	24	**5.99**	**28.84**	**5**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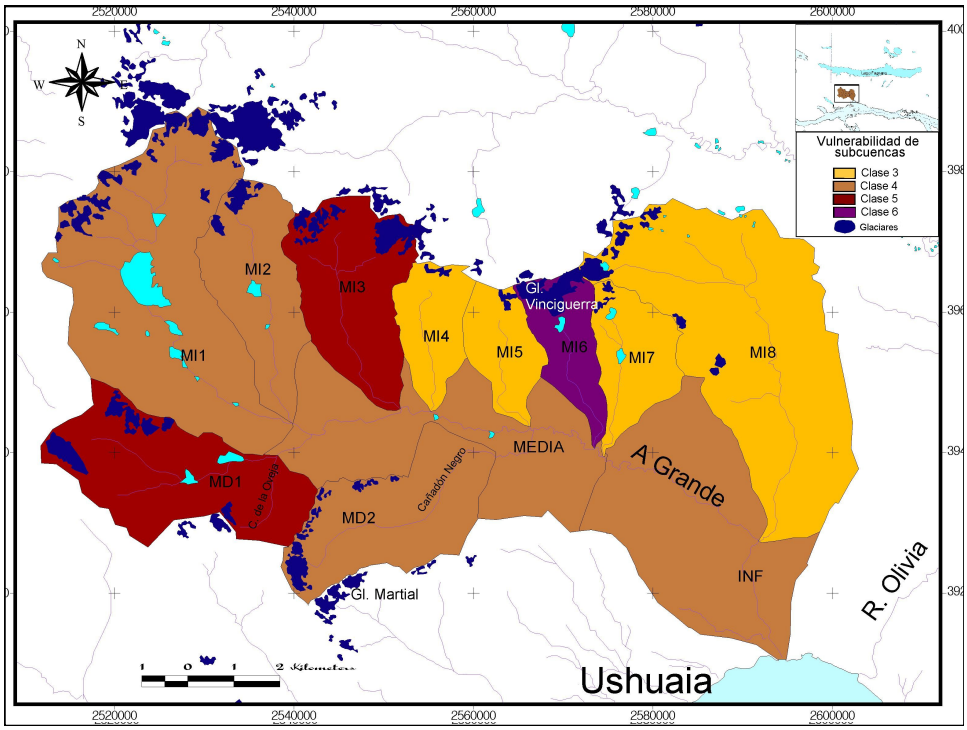
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Vulnerabilidad de subcuencas
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Clase 4
Clase 5
Clase 6
Glaciares

ALGUNAS CONCLUSIONES

- As a consequence of glaciers recession , changes on hydrological regime will be perceptive in summer, especially in dry and warm periods.
- The water sources of Ushuaia (Ao Grande and Buena Esperanza) have moderated and marked vulnerability to loss net glacier flow, nevertheless the principal water restriction for water supply to the population occurs in winter, when glaciers don´t provide water. Glaciers extinction will impact on other water uses which could demand resources nowadays available in summer, like hydropower and irrigation.
- This basin vulnerability classification is useful to compare estimated effects from the glacier recession. It is relatively easy to determine and admit a reasonable error margin on the estimation of the total net glacier contribution . It is applicable to other regions located at medium to high latitude.
- Impacts on Water Resources produced by effect of the globall warming on the snowpack stability should be evaluated separately-

Diseñando estrategias para reducir vulnerabilidades

- Hemos considerado exhaustivamente las medidas no estructurales?

REDUCIENDO VULNERABILIDADES

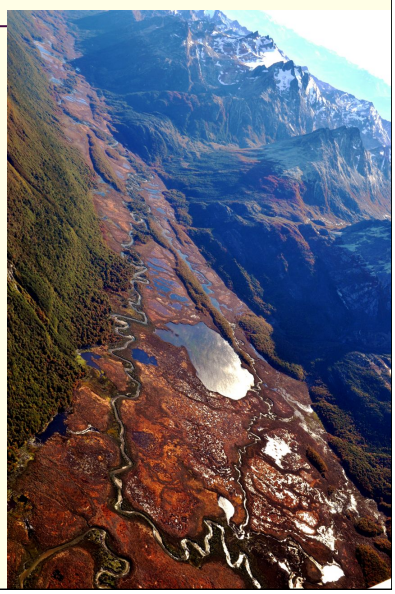
- LA PROTECCION DE ECOSISTEMAS REGULADORES. Cuáles pueden retener agua cuando hay excedentes y recargar el sistema de drenaje cuando hay déficit? Se encuentran amenazados?

HUMEDALES

Páramos

Turberas

Sistemas lagunares



REDUCIENDO VULNERABILIDADES

- Monitoreo y conservación de las fuentes prístinas:

  Manantiales, arroyos, vertientes y lagunas en cabeceras de cuencas

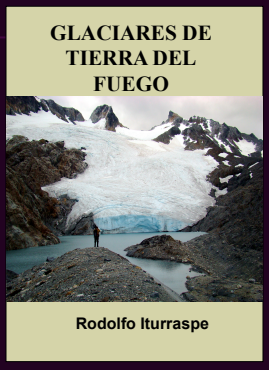
REDUCIENDO VULNERABILIDADES: otros ejes

- Planificación hídrica basada en la optimización de usos del agua.
- Promoción de la mejora en la eficiencia de los usos consuntivos del agua.
- Planificación territorial y desarrollo urbano
- Educación
- Legislación

El CC debería ser abordado integralmente con otros problemas que amenazan la sustentabilidad

- El CC no viene sólo sino en el contexto de la presión sobre el ambiente que generan el incremento demográfico y del desarrollo de capacidades técnicas para la explotación económica de los R.N.
- Desde la GIRH Hay que vincular estas perspectivas. Considerar al CC en forma aislada es incurrir en un sesgo que le resta realismo al problema.

Thanks for your attention!!!



This Article is result of the projects:

Glaciological Studies for the planning of water uses on escenarios of climate change (GEF-UNEP)

Monitoring of glaciers linked to water sources of Ushuaia City UNPSJB

Glaciology, Hydrology and Hydro-informatic applied to the study of effect s of climatic change on Water Resources (UNPSJB)