ties to emphasize those measurements of our local astrophysical laboratory that will best illuminate how these fundamental cosmic entities operate. Moreover, observations to date already indicate that the Saturn system is literally changing before our eyes. We anticipate that even more dramatic transformations in our neighborhood's astrophysical laboratory will be monitored by Cassini's instruments over the next several years.

References and Notes

1. Special Issue on Cassini at Saturn, *Science* **307** (25 February 2005).
2. J. J. Lissauer, J. N. Cuzzi, in *Protostars and Planets II*, D. C. Black, M. S. Matthews, Eds. (Univ. of Arizona Press, Tucson, AZ, 1985), pp. 920–958.
3. Special Issue on Disks in Space, *Science* **307** (7 January 2005).
4. M. S. Tiscareno *et al.*, paper presented at the American Geophysical Union fall meeting, 5 to 9 December 2005, San Francisco (abstract FM-P33B0245T2005).
5. J. E. Colwell, personal communication.
6. J. E. Colwell, L. W. Esposito, M. Sremcevic, *Geophys. Res. Lett.* **33**, L07201 (2006).
7. M. M. Hedman, P. D. Nicholson, B. D. Wallis, paper presented at the American Geophysical Union fall meeting, 5 to 9 December 2005, San Francisco (abstract FM-P31D02H2005).
8. H. Salo, *Icarus* **117**, 287 (1995).
9. A. W. Harris, in *Planetary Rings*, R. J. Greenberg, A. Brahic, Eds. (Univ. of Arizona Press, Tucson, AZ, 1984), pp. 641–658.
10. M. S. Tiscareno *et al.*, *Nature* **440**, 648 (2006).
11. P. Kalas, J. R. Graham, M. Clampin, *Nature* **435**, 1067 (2005).
12. Support from the Cassini project is gratefully acknowledged. We thank M. Tiscareno, M. Hedman, and P. Nicholson for comments.

10.1126/science.1114856

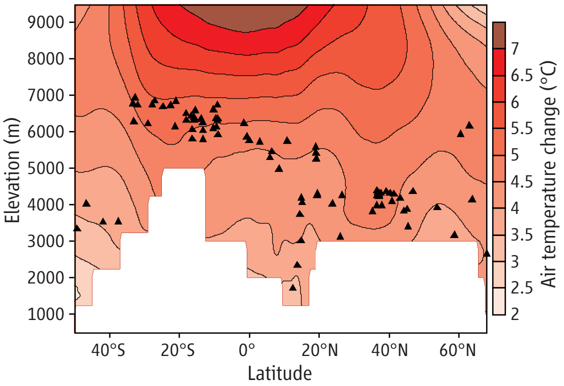
CLIMATE CHANGE

Threats to Water Supplies in the Tropical Andes

Climate models predict that greenhouse warming will cause temperatures to rise faster at higher than at lower altitudes. In the tropical Andes, glaciers may soon disappear, with potentially grave consequences for water supplies.

Raymond S. Bradley, Mathias Vuille, Henry F. Diaz, Walter Vergara

According to general circulation models of future climate in a world with double the preindustrial carbon dioxide (CO$_2$) concentrations, the rate of warming in the lower troposphere will increase with altitude. Thus, temperatures will rise more in the high mountains than at lower elevations (see the figure) (*1*). Maximum temperature increases are predicted to occur in the high mountains of Ecuador, Peru, Bolivia, and northern Chile. If the models are correct, the changes will have important consequences for mountain glaciers and for communities that rely on glacier-fed water supplies.



Global warming in the American Cordillera. Projected changes in mean annual free-air temperatures between (1990 to 1999) and (2090 to 2099) along a transect from Alaska (68°N) to southern Chile (50°S), following the axis of the American Cordillera mountain chain. Results are the mean of eight different general circulation models used in the 4th assessment of the Intergovernmental Panel on Climate Change (IPCC) (*15*), using CO$_2$ levels from scenario A2 in (*16*). Black triangles denote the highest mountains at each latitude; areas blocked in white have no data (surface or below in the models). Data from (*15*).

Is there evidence that temperatures are changing more at higher than at lower elevations? Although surface temperatures may not be the same as in the free air, in high mountain regions the differences are small (*2*), and changes in temperature should thus be similar at the surface and in the adjacent free air. Unfortunately, few instrumental observations are available above ~4000 m. The magnitude of recent temperature change in the highest mountains is therefore poorly documented. An analysis of 268 mountain station records between 1°N and 23°S along the tropical Andes indicates a temperature increase of 0.11°C/decade (compared with the global average of 0.06°C/decade) between 1939 and 1998; 8 of the 12 warmest years were recorded in the last 16 years of this period (*3*). Further insight can be obtained from glaciers and ice caps in the very highest mountain regions, which are strongly affected by rising temperatures. In these high-altitude areas, ice masses are declining rapidly (*4*–*6*). Indeed, glacier retreat is under way in all Andean countries, from Columbia and Venezuela to Chile (*7*).

A convergence of factors contribute to these changes. Rising freezing levels (the level where temperatures fall to 0°C in the atmosphere) (*8*, *9*) lead to increased melting and to increased exposure of the glacier margins to rain rather than snow (*10*). Higher near-surface humidity leads to more of the available energy going into melting snow and ice, rather than sublimation, which requires more energy to remove the same mass of ice. Therefore, during humid, cloudy conditions, there is often more ablation than during drier, cloud-free periods (*6*). In some areas, changes in the amount of cloud cover and the timing of precipitation may have contributed to glacier mass loss through their impact on albedo (surface reflectivity) and the net radiation balance (*11*). As these processes continue and snow is removed, more of the less reflective ice is exposed and absorption of the intense high-elevation radiation increases, thus accelerating the changes under way through positive feedbacks.

The processes involved in mass-balance changes at any one location are complex, but temperature is a good proxy (*12*) for all these processes, and most of the observed changes are linked to the rise in temperature over recent decades (*5*). Further warming of the magnitude shown in the figure will thus have a strong negative impact on glaciers throughout the Cordillera of North and South America. Many glaciers may completely disappear in the next few decades, with important consequences for people living in the region (*7*).

Although an increase in glacier melting initially increases runoff, the disappearance of glaciers will cause very abrupt changes in streamflow, because of the lack of a glacial buffer during the dry season. This will affect the availability of drinking water, and of water for agriculture and hydropower production.

In the High Andes, the potential impact of such changes on water supplies for human con-

---

R. S. Bradley and M. Vuille are at the Climate System Research Center, Department of Geosciences, University of Massachusetts, Amherst, MA 01003, USA. H. F. Diaz is at the Earth System Research Laboratory, National Oceanic and Atmospheric Administration, Boulder, CO 80303, USA. W. Vergara is in the Latin America Environment Department, World Bank, 1850 I Street, NW, Washington, DC 20433, USA. E-mail: rbradley@geo.umass.edu (R.S.B.)

sumption, agriculture, and ecosystem integrity is of grave concern. Many large cities in the Andes are located above 2500 m and thus depend almost entirely on high-altitude water stocks to complement rainfall during the dry season. For example, Ecuador's capital Quito currently receives part of its drinking water from a rapidly retreating glacier on Volcano Antizana. Other cities, like La Paz in Bolivia and many smaller population centers, likewise partially depend on glacier sources for drinking water. In many dry inter-Andean valleys, agriculture relies on glacier runoff; for instance, ~40% of the dry-season discharge of the Rio Santa, which drains the Cordillera Blanca in Peru, comes from melting ice that is not replenished by annual precipitation (*13*). As these water-resource buffers shrink further (and, in some watersheds, disappear completely), alternative water supplies may become very expensive and/or impractical in the face of increased demand as population and per-capita consumption rise.

Furthermore, in most Andean countries, hydropower is the major source of energy for electricity generation. As these water resources are affected by reductions in seasonal runoff, these nations may have to shift to other energy sources, resulting in large capital outlays, higher operational and maintenance costs, and—most probably—an increased reliance on fossil fuels.

We have focused here on changes taking place in the mountains of the tropical Andes, but the same situation prevails in high mountain regions elsewhere in the Tropics. Glaciers are disappearing rapidly in East Africa and New Guinea, though there is far less reliance on glacier-fed water supplies in those regions. It is in the tropical Andes that climate change, glaciers, water resources, and a dense (largely poor) population meet in a critical nexus. Some glaciers have already reached the threshold at which they are destined to disappear completely; for many more, this threshold may be reached within the next 10 to 20 years. Therefore, governments must plan without delay to avoid large-scale disruption to the people and economy of those regions (*14*).

Practical measures to prepare for, and adapt to, these changes could include conservation of (or price controls on) water supplies in urban areas, a shift to less water-intensive agriculture, the creation of highland reservoirs to stabilize the cycle of seasonal runoff, and a shift to power generation from resources other than hydropower. At the same time, more detailed scenarios of future climate change in these topographically complex regions are urgently needed. High-resolution regional climate models allow for a better simulation of climate in mountain regions than do general circulation models. Coupled with tropical glacier–mass balance models, these regional models will help us to better understand and predict future climate changes and their impacts on tropical Andean glaciers and associated runoff.

Recent high-resolution (grid size ~10 km) regional climate simulations for the Colombian Andes indicate that even at relatively low altitudes, projected temperature increases and changes in rainfall patterns have the potential to disrupt water and power supplies to large segments of the population (*14*). Such simulations must be used to inform decision-makers of the steps they need to take to avoid a very problematical future in the region.

References and Notes

1. R. S. Bradley, F. T. Keimig, H. F. Diaz, *Geophys. Res. Lett.* **31**, L16210 (2004).
2. D. J. Seidel, M. Free, *Clim. Change* **59**, 53 (2003).
3. M. Vuille, R. S. Bradley, M. Werner, F. T. Keimig , *Clim. Change* **59**, 75 (2003).
4. E. Ramirez *et al.*, *J. Glaciol*. **47**, 187 (2001).
5. B. Francou, M. Vuille, P. Wagnon, J. Mendoza, J.-E. Sicart, *J. Geophys. Res*. **108**, 4154 (2003).
6. G. Kaser, C. Georges, I. Juen, T. Molg, in *Global Change and Mountain Regions: A State of Knowledge Overview*, U. Huber, H. K. M. Bugmann, M. A. Reasoner, Eds. (Kluwer, New York, 2005), pp. 185–195.
7. A. Coudrain, B. Francou, Z. W. Kundzewicz, *Hydrol. Sci. J.* **50**, 925 (2005).
8. J. F. Carrasco, G. Casassa, J. Quintana, *Hydrol. Sci. J.* **50**, 933 (2005).
9. H. F. Diaz, N. E. Graham, *Nature* **383**, 152 (1996).
10. B. Francou, M. Vuille, V. Favier, B. Cáceres, *J. Geophys. Res.* **109**, D18106 (2004).
11. P. Wagnon, P. Ribstein, B. Francou, J.-E. Sicart, *J. Glaciol*. **47**, 21 (2001).
12. From 1999 to 2002, some glaciers had neutral or slightly positive mass balance as a result of a prolonged La Niña episode. Since 2002, glaciers are again retreating everywhere, and temperatures have rebounded upwards.
13. B. G. Mark, J. M. McKenzie, I. J. Gómez, *Hydrol. Sci. J.* **50**, 975 (2005).
14. W. Vergara, *Adapting to Climate Change. Latin America and Caribbean Region Sustainable Development Working Paper 25* (World Bank, Washington, DC, 2005).
15. www-pcmdi.llnl.gov/ipcc/about_ipcc.php
16. Nebojsa Nakicenovic, Rob Swart, Eds., *Special Report on Emissions Scenarios* (Cambridge Univ. Press, Cambridge, U.K., 2000).
17. We acknowledge the international modeling groups for providing their data for analysis; the Program for Climate Model Diagnosis and Intercomparison (PCMDI) for collecting and archiving the model data; the Johnson Space Center/Climate Variability and Predictability (JSC/CLIVAR) Working Group on Coupled Modelling (WGCM) and their Coupled Model Intercomparison Project (CMIP) and Climate Simulation Panel for organizing the model data analysis activity; and the IPCC WG1 Technical Support Unit for technical support. The IPCC Data Archive at Lawrence Livermore National Laboratory is supported by the Office of Science, U.S. Department of Energy (DOE). This research was supported by the Office of Science (Office of Biological and Environmental Research), U.S. DOE, grant DE-FG02-98ER62604 and NSF grant EAR-0519415.

10.1126/science.1128087

CELL SIGNALING

A New Way to Burn Fat

Jaap G. Neels and Jerrold M. Olefsky

Acetyl-CoA carboxylase controls fat storage and utilization in adipose cells. An important regulator of this enzyme modulates its degradation and is a potential therapeutic target for treatment of insulin resistance and obesity.

Storage of body fat creates an energy reserve for times of starvation, but excess body fat, or obesity, substantially increases the risk for diabetes, cardiovascular disease, and other disorders. So the appropriate balance between fat storage and utilization is clearly important. Adipose tissue acetyl–coenzyme A (CoA) carboxylase (ACC) plays a crucial role in maintaining this balance, and regulation of this enzyme is tied to the overall control of energy metabolism. On page 1763 of this issue, Qi *et al.* (*1*) show that the mammalian protein TRB3 mediates degradation of adipose tissue ACC, providing a new level of metabolic regulation for this key enzyme.

ACC regulates lipid storage and overall energy metabolism by catalyzing the formation of malonyl-CoA from acetyl-CoA (*2*). In turn, malony-CoA has two important functions with respect to overall triglyceride storage (see the figure). It serves as the essential substrate for fatty acid synthesis, but it also blocks the uptake of fatty acids from the cytosol into the mitochondria, where they undergo oxidative metabolism to generate adenosine 5′-triphosphate (*2*). Through these effects, malonyl-CoA is a key control point for fat metabolism in peripheral tissues, including adipose tissue, suggesting that it may also have central effects within the hypothalamus to regulate energy balance (*3*).

There are two major isoforms of ACC in rodents and humans, each the product of a separate gene. ACC1 is highly expressed in lipogenic tissues such as liver, adipose, and lactating mammary gland, whereas ACC2 is predominantly expressed in heart and skeletal muscle and, to a lesser extent, in the liver (*2*). ACC1 is a cytosolic enzyme and ACC2 is associated with the mitochondria. The tissue distribution and intracellular localization of each isoform suggest that mitochondrial-associated ACC2 generates the malonyl-CoA that is

---

The authors are in the Department of Medicine, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093–0673, USA. E-mail: jolefsky@ucsd.edu