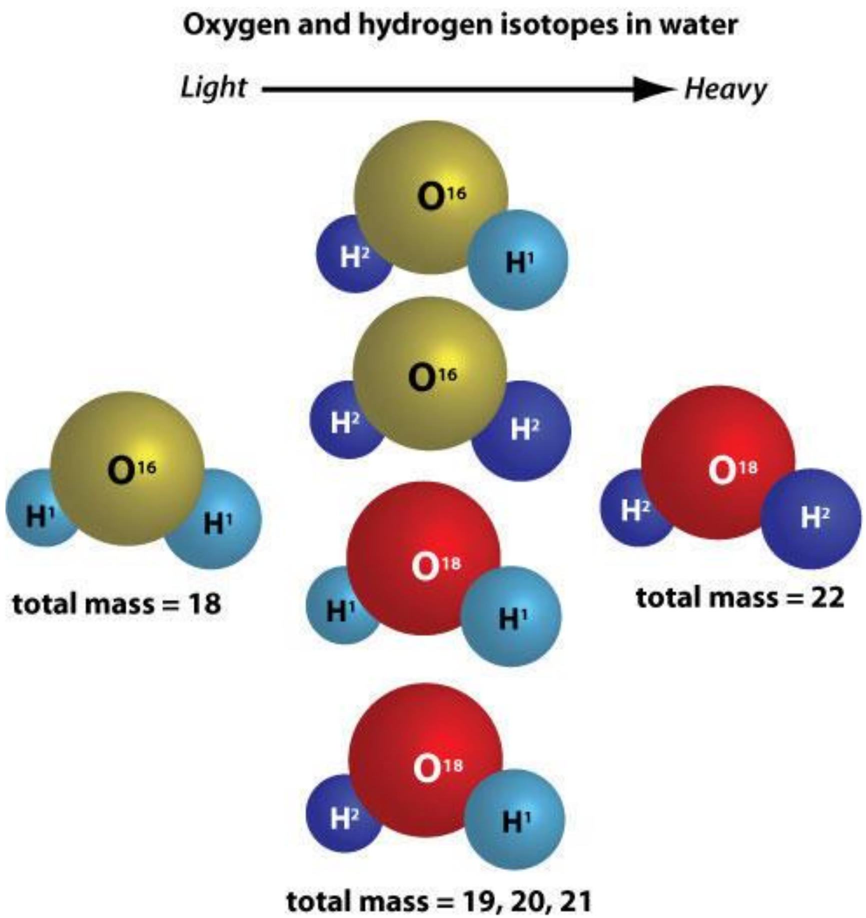
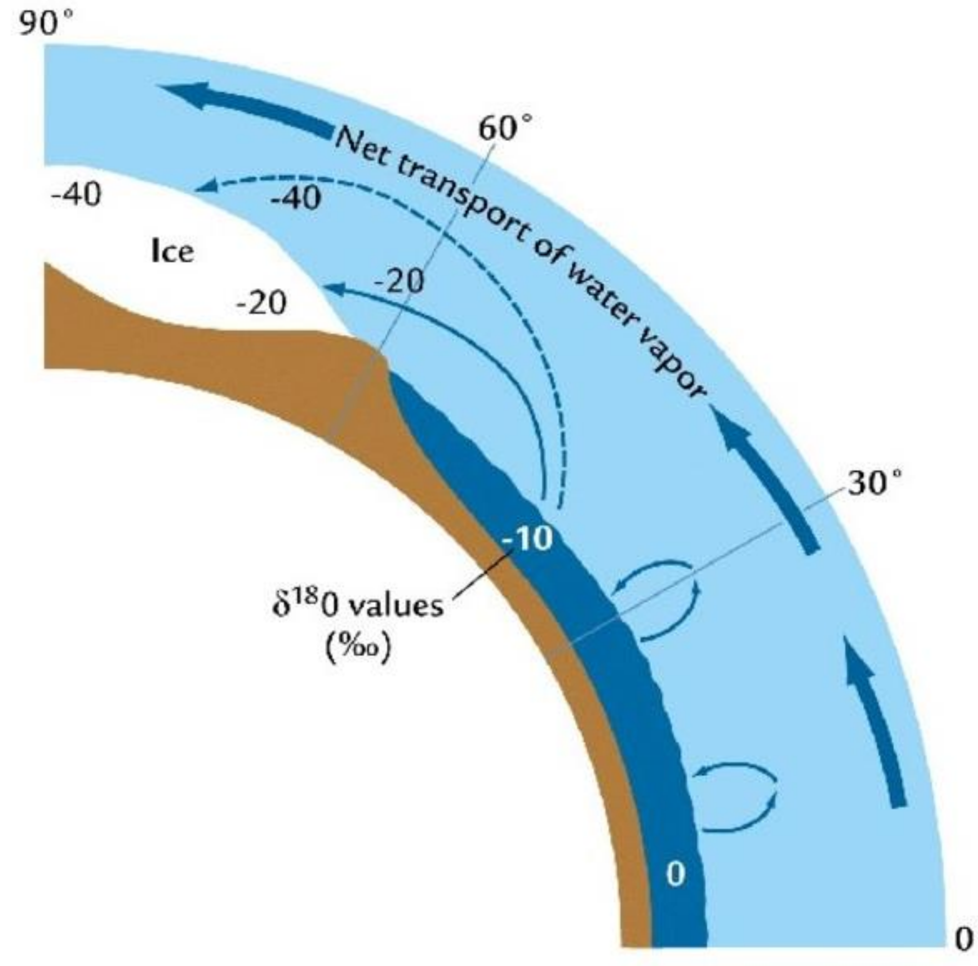
Les isotopes dans IPSLCM

Camille Risi, Masa Kageyama, Pierre Sepulchre, Jean-Claude Dutay, Cécile Agosta…



credit: USGS



credit: University of Washington

Isotopes de l’eau dans IPSLCM

Modéliser les isotopes, pourquoi ?

- Ils sont sensibles à tous les changements de phase de l’eau, en particulier dans les systèmes convectifs
- Ce sont des traceurs des circulations atmosphérique et océanique, et de l’eau dans les sols
- On les retrouve dans de nombreuses archives climatiques: glaces, spéléothèmes, cellulose des arbres, coquilles des foraminifères, dents
- Pour l’époque actuelle, ils sont mesurés au sol, par avion, par satellite

➔ Essentiels pour la compréhension du cycle hydrologique actuel et pour caractériser les changements climatiques passés

RESEARCH ARTICLE SUMMARY

TECTONICS

Revised paleoaltimetry data show low Tibetan Plateau elevation during the Eocene

Svetlana Botsyun*, Pierre Sepulchre, Yannick Donnadieu, Camille Risi, Alexis Licht, Jeremy K. Caves Rugenstein

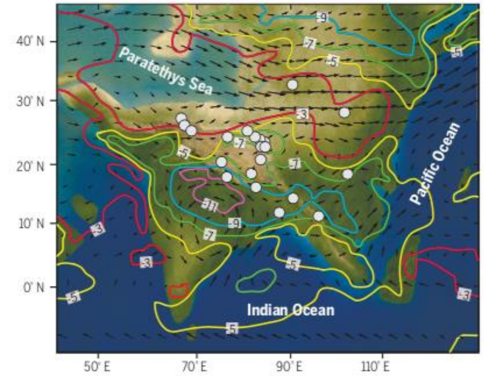
INTRODUCTION: The uplift history of the Tibetan Plateau (TP) is critical for understanding the evolution of the Asian monsoons and the geodynamic forces involved in collisional orogens. The early topographic history of the TP is uncertain, and the timing of the initiation of uplift remains controversial. The majority of studies that find evidence for an old plateau (as early as the Eocene, ~40 million years ago) rely on stable isotope paleoaltimetry. This method is based on observations and models that show depletion in heavy oxygen isotopes in rainfall during orographic ascent. Ancient carbonates of the TP record past rainfall isotopes; when available, their isotopic signature can be compared with isotopic lapse rates in order to estimate at what elevation they grew in the past, but the use of this method in deep time has many uncertainties.

RATIONALE: Applying stable-isotope paleoaltimetry in greenhouse climates makes the implicit assumption that the factors that control atmospheric distillation and rainfall oxygen isotopic composition ($\delta^{18}O_w$) have remained constant over millions of years. However, the impact of past climate change on $\delta^{18}O_w$ values is unclear. In particular, for the Eocene, higher atmospheric CO_2 concentration (P_{CO_2}) and markedly different Asian paleogeography, including a wide and shallow Paratethys Sea in central China and a latitudinal shift of the southern Tibet margin ~10° to the south, have been hypothesized to modify the Asian climate and regional $\delta^{18}O_w$ values. In addition, the carbonate formation temperature is often unknown, increasing the uncertainty in the reconstructed $\delta^{18}O_w$.

RESULTS: We ran climate simulations with Eocene boundary conditions and varying TP elevation. We accounted for changing P_{CO_2}, land surface albedo, orbital variation, and sea-surface temperatures, which potentially cause shifts in $\delta^{18}O_w$, by changing the relative contribution of different air masses and the local hydrological cycle—the evaporation-to-precipitation ratio and the fractioning between convective and large-scale rainfalls. In our simulations, the south-shifted location of the entire Indian foreland induces strong convection over the southern flank of the TP and a radically different pattern of water recycling compared with that of present day. Our simulations reproduce monsoonlike seasonal precipitation over the Indian foreland, with summer convective rainfall reaching the TP. An intense anticyclonic circulation during summer months induces widespread aridity on the northern part of the Plateau. This peculiar atmospheric circulation, together with intensified water recycling and multiple moisture sources, results in a reversed isotopic lapse rate across the southern flank of the TP, with the most negative $\delta^{18}O_w$ over northern India and increased $\delta^{18}O_w$ northward. On the basis of Eocene experiments with varied boundary conditions, we argue that this is a robust feature of Eocene climate over the region. Furthermore, this pattern is the opposite of the present-day $\delta^{18}O_w$ over the Himalayas, which decreases with elevation, driven by orographic rainout following a Rayleigh distillation process. Last, using our simulated temperatures and $\delta^{18}O_w$, we derived virtual carbonates $\delta^{18}O$ for different elevation scenarios and compared them with the geological record. Statistical analysis shows that a low TP topography during the Eocene is the scenario that provides the best match between model and data.

ON OUR WEBSITE

Read the full article at http://dx.doi.org/10.1126/science.aaq1436



Simulated stable oxygen isotope composition of summer precipitation for the Eocene (42 million years ago) Asia. The combination of changes in water recycling and the source of air masses induces the reversal of isotopic lapse rate. Summer winds trajectories highlight intense westerlies and easterlies at each border of the TP. Circles indicate localities of paleoaltimetry sites used in this study.

CONCLUSION: Our simulations indicate that standard stable isotope paleoaltimetry methods are not applicable in Eocene Asia because of a combination of increased convective precipitation, mixture of air masses of different origin, and widespread aridity. In the Eocene, the presence of a reversed isotopic lapse rate precludes use of any of the previously developed $\delta^{18}O_w$-elevation relationships for estimating the Eocene elevation of the TP. Rather, a model-data comparison on the carbonates $\delta^{18}O$ suggests that the TP reached only low to moderate (<3000 m) elevations during the Eocene, reconciling oxygen isotope data with other proxies of elevation and with geodynamic models that propose a recent (Neogene) uplift. More generally, we suggest that using climate models in conjunction with stable isotope data from the geological archives provides a powerful tool to incorporate climatic changes into the analysis of paleoelevations. ■

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Où en est-on ?

- Dans LMDZ6 :
  - Tourne en séquentiel ou MPI_OMP sur Jean-Zay, ancienne ou nouvelle physique
  - Pas encore fait : développements récents liés à la glace, 1D
  - Pérenne dans dyn3dmem (juste quelques bugs à corriger)
  - Non-pérenne dans physiq → besoin de mises à jour régulières ?

- Dans ORCHIDEE :
  - Pas de nouveau depuis 2012 (isotopes dans MICT-Choisnel)
  - A faire : mise à jour + implémenter dans hydrologie multi-niveaux → 1 an de travail ?

- Dans NEMO :
  - implantés dans NEMO3.6 par Anne Mouchet, mais pas dans le trunk

- Dans le couplé : rien de fait !

Des opportunités

- ORCHIDEE: Jérôme Ogée est prêt à encadrer un étudiant sur ce sujet (info Philippe Peylin)

- Post-doc IPSL de 2 ou 3 ans pour inclure les isotopes dans le couplé

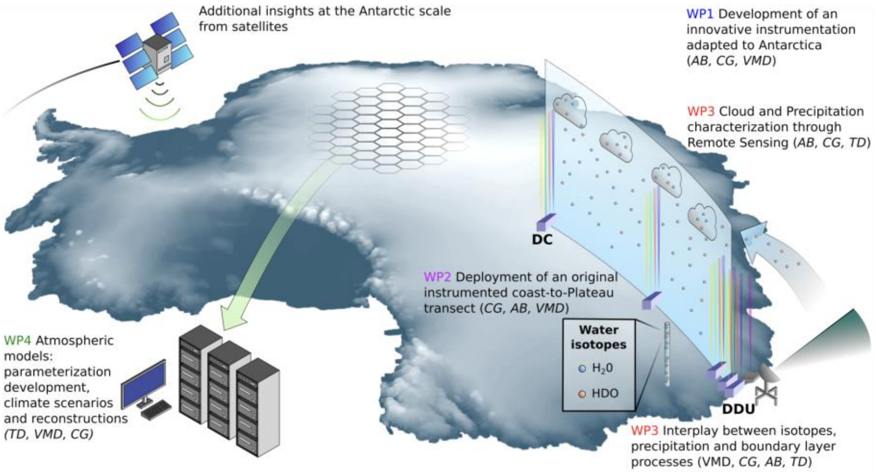
- Embauche de Sébastien Nguyen au LSCE
- Projet AWACA

ERC Synergy AWACA (2021-2027)

Atmospheric WAter Cycle over Antarctica: Past, Present and Future

PIs
Alexis Berne (EPFL, Suisse) : remote sensing
Thomas Dubos (LMD) : DYNAMICO-LMDZ / DYNAMICO-MAR
Christophe Genthon (LMD) : logistique, mesures
Valérie Masson-Delmotte (LSCE) : isotopes

et forte implication de Cécile Agosta



Objectifs :

- Comprendre le cycle de l'eau Antarctique (atmosphère)
- **Nuages, précipitations, isotopes**, en dehors des stations
- ⟹ Reconstructions 2000 ans, projections 21ème siècle

Modélisation atmosphérique avec isotopes

Configurations :

- DYNAMICO-LMDZ avec isotopes
- Modélisation régionale DYNAMICO-MAR avec isotopes
- Modélisation régionale DYNAMICO-LMDZ avec isotopes

Physique :

- Couplage avec modèle de neige (SISVAT puis CROCUSiso)
- Nouvelle microphysique froide avec isotopes (nuages, précipitations)

3 modules autonomes entre DDU et Dome C

- Surface meteorology (wind, temperature, humidity, blowing snow, turbulent fluxes)
- Water isotopes : SARA-H2O + snowflakes
- Clouds and precipitation (tropospheric column) : Rada + Lidars

La suite ?

- Jean-Baptiste Ladant va organiser une réunion en janvier avec les représentants « isotope » de chaque composante pour prendre des décisions sur la suite du développement/maintien etc.

⇒Envoyez un message si vous êtes intéressés !

MERCI de votre attention !