Optimal adjustment of the atmospheric forcing parameters of ocean models derived from ERAinterim Reanalysis using sea surface temperature data assimilation in long term (1989-2007) simulations of the global ocean circulation.

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CONTEXT

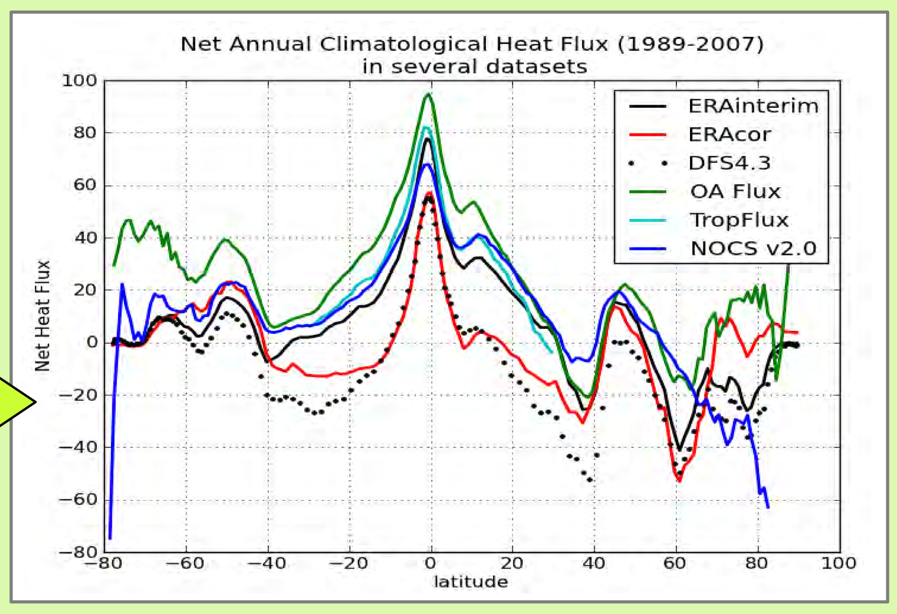
Sea surface temperature (SST) is more precisely observed from space than near-surface atmospheric variables and air-sea fluxes. But ocean general circulation models that carry out simulations of the recent ocean variability use, as surface boundary conditions, bulk formulae which do not involve the observed SST. In brief, **models do not take advantage directly in their forcing of one of the best observed ocean surface variable**, except when specifically assimilated.

The objective of this research is to develop new approaches based on ensemble data assimilation methods that use SST satellite observations (and when available SMOS or AQUARIUS satellite sea surface salinity data) to constrain (within observation-based air-sea flux uncertainties) the surface forcing function (**surface atmospheric input variables**) of long-term ocean circulation simulations.

The problem of the **correction of atmospheric fluxes by data assimilation** has already been approached in other studies and projects (Skachko et Al., 2009, Skandrani et Al., 2009). The main goal of this work is to adapt the methodology to a different experimental context.

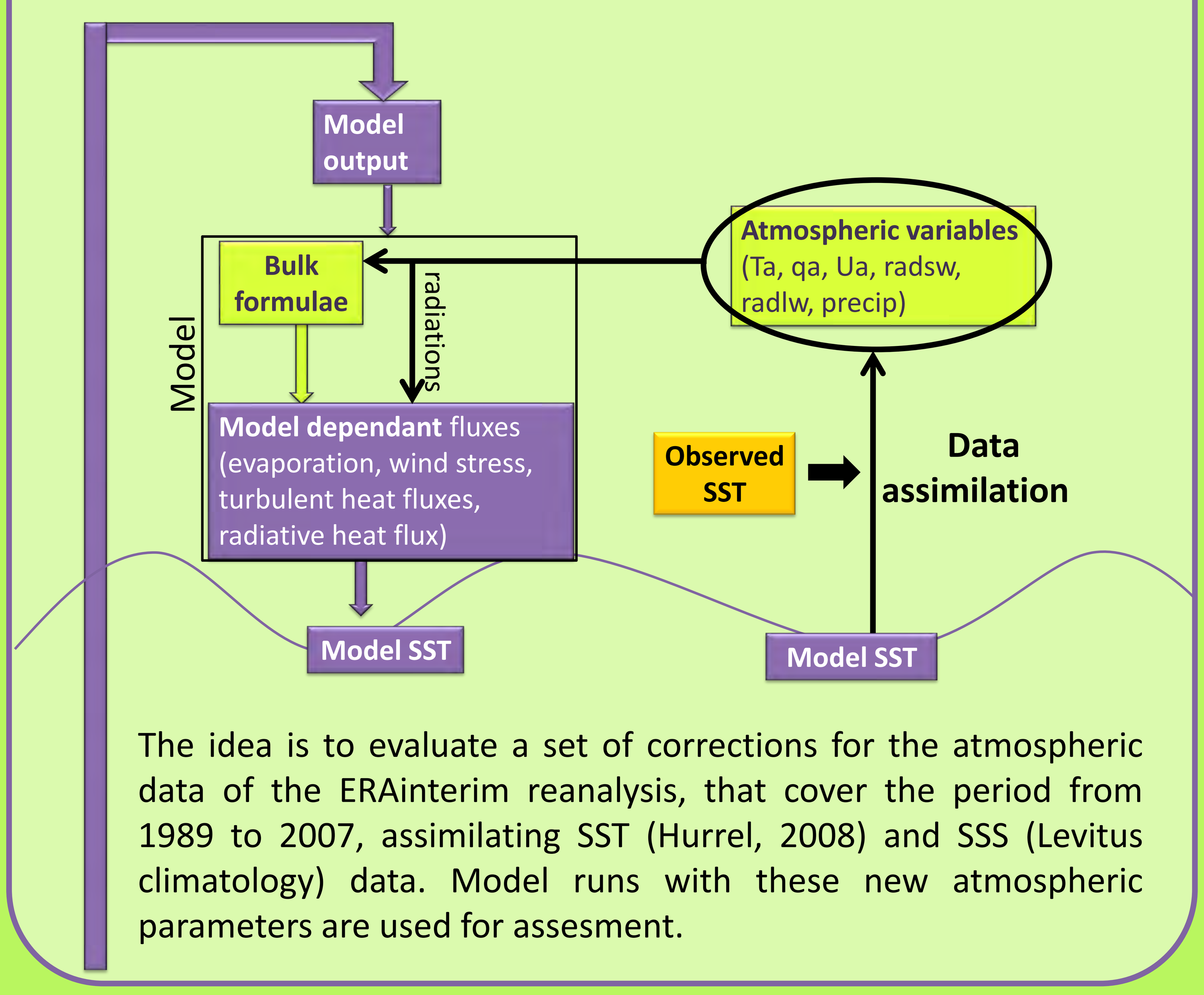
EXPERIMENTAL CONTEXT:
- **Model: NEMO, 2° global simulation ORCA2**
- **First guess forcing: ERAinterim reanalysis atmospheric parameters (1989-2007)**
- **Objective: monthly forcing corrections**

Large discrepancies between the different forcing/flux dataset : e.g. in the 20N-20S latitudes band: 20 to 40 W/m²



CONCEPT

Correct the forcing function by SST data assimilation

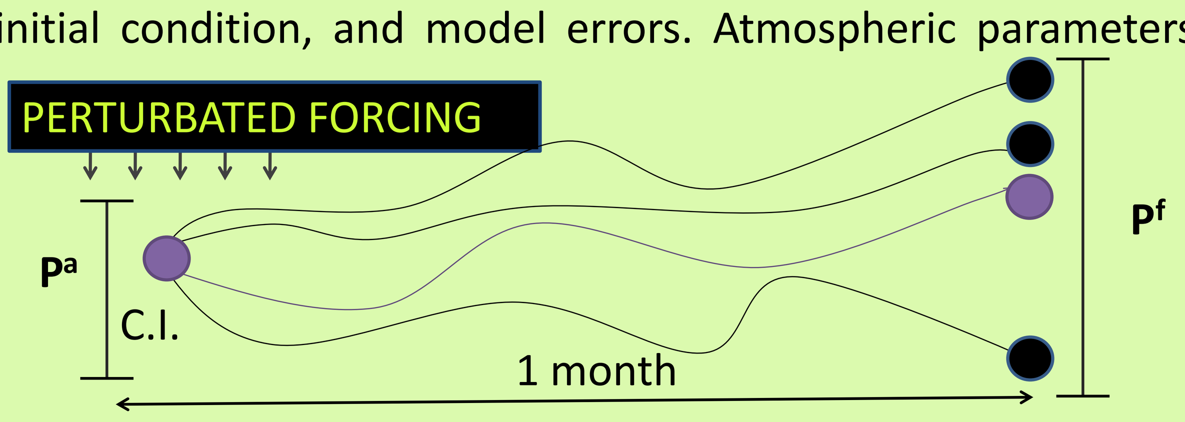


The idea is to evaluate a set of corrections for the atmospheric data of the ERAinterim reanalysis, that cover the period from 1989 to 2007, assimilating SST (Hurrel, 2008) and SSS (Levitus climatology) data. Model runs with these new atmospheric parameters are used for assesment.

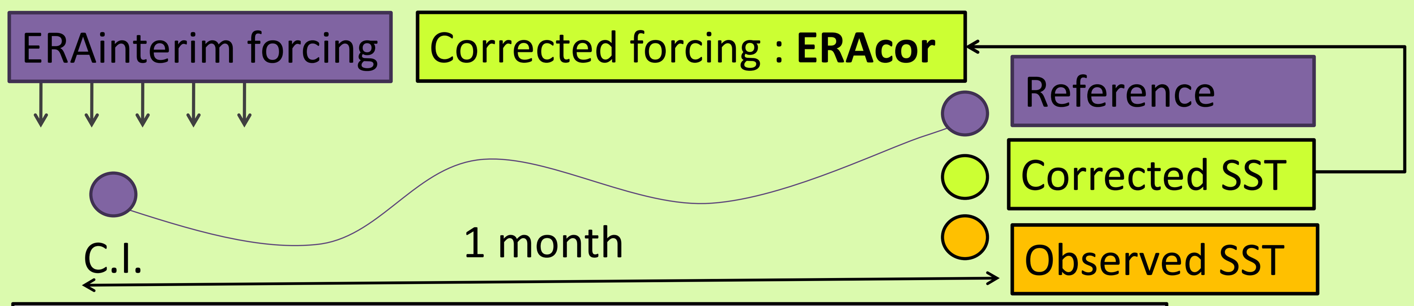
METHOD FOR ATMOSPHERIC PARAMETER ESTIMATION

We use a sequential method based on the SEEK filter, with an ensemble experiment of 200 members to evaluate parameter uncertainties. To better isolate forcing errors, we have to minimize the other sources of error such as initial condition, and model errors. Atmospheric parameters perturbations are calculated from multivariate EOF of monthly means parameters over the whole ERAinterim period.

The control vector is extended to correct forcing parameters (air temperature, air humidity, longwave and shortwave downward radiations, precipitation, wind velocity). The assimilation step is realized « off-line », that is to say that we don't correct the model state. We obtain atmospheric parameters corrections that we can apply to the model in free runs.

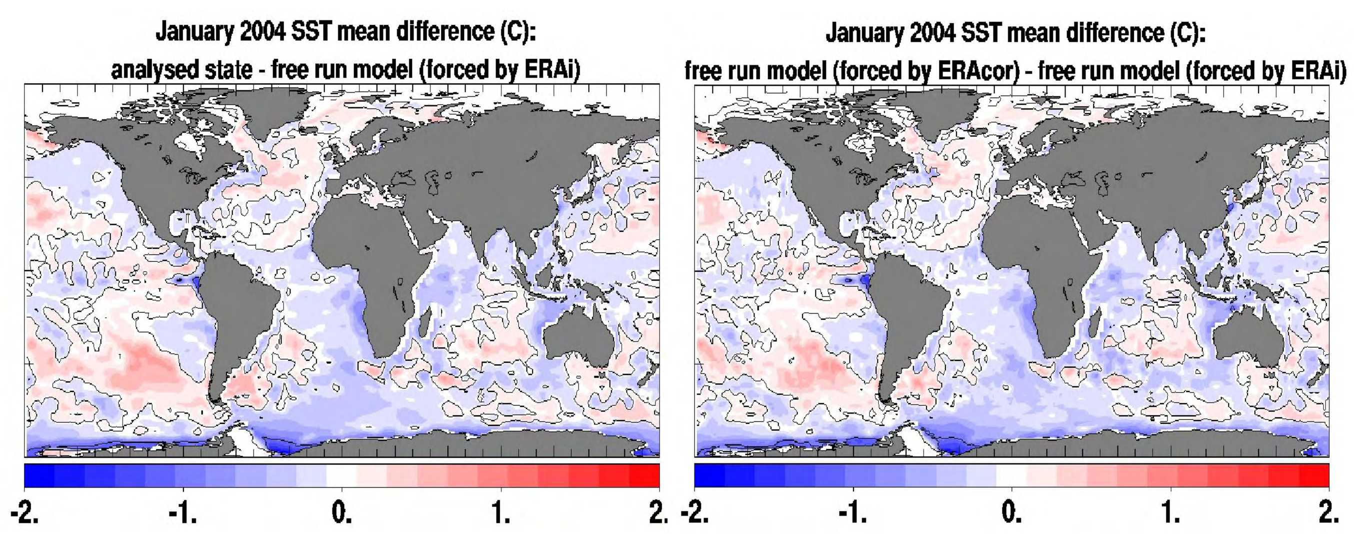


$$P^f = \underbrace{M P^a M^T}_{\text{C.I. ERROR}} + \underbrace{Q}_{\text{FORCING, MODEL ERRORS ...}}$$



$$\underbrace{X^a}_{\text{SST and forcing parameters}} = X^b + K (Y - HX^b)$$

METHOD STEPS :
1. **Ensemble forecast : model response to parameters uncertainties**
   - **Using reduced initial condition error**
   - **Using reduced model error**
   - ➡ **Forecast error covariance in augmented space**
2. **Parameter estimation : Kalman Filter for an augmented control vector**
   - **Small observation error**
   - **Truncation of the prior gaussian distribution**
   - ➡ **Correction of atmospheric parameters**
3. **Model run with new parameters : model response vs analysis efficiency**



The method permits to isolate the forcing errors minimizing other error sources.

Analysis step and direct application of corrected parameters in the model

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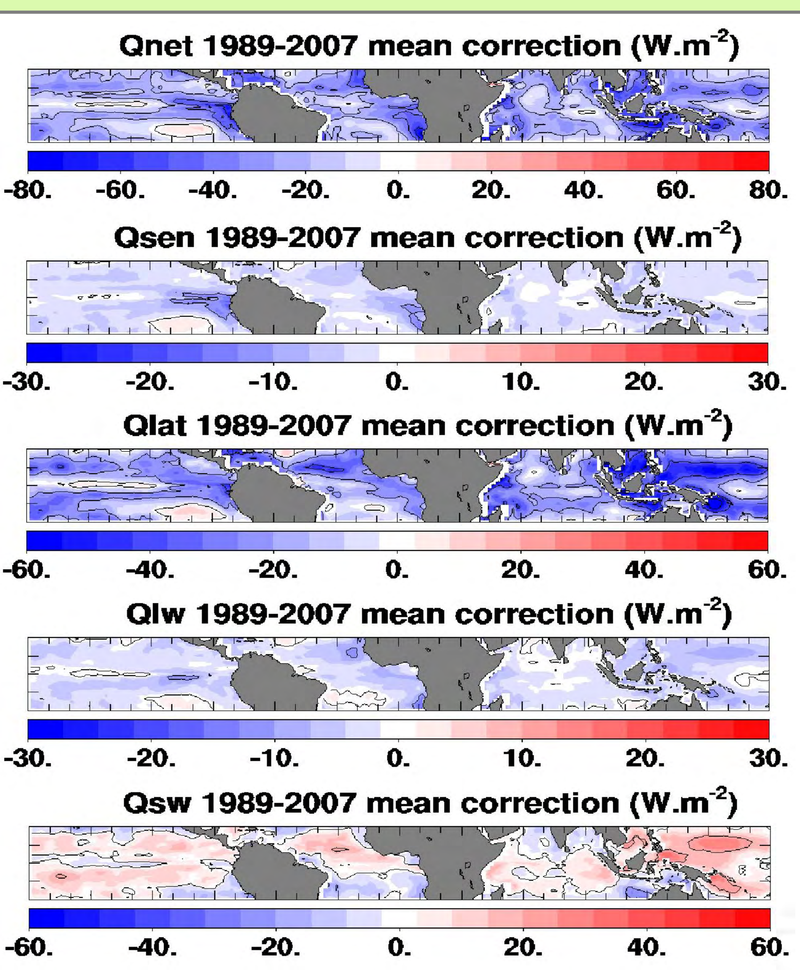
Comparable effects

RESULTS AND CONCLUSIONS



The heat excess observed in ERAinterim is reduced by increasing turbulent heat losses.

Mathematically optimal method

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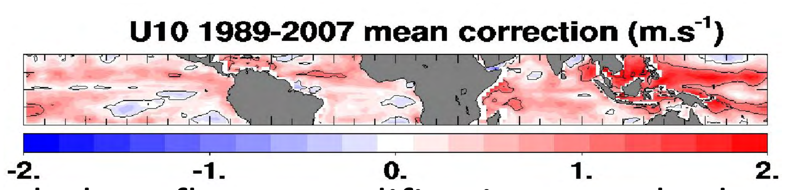
To guide classical empirical corrections

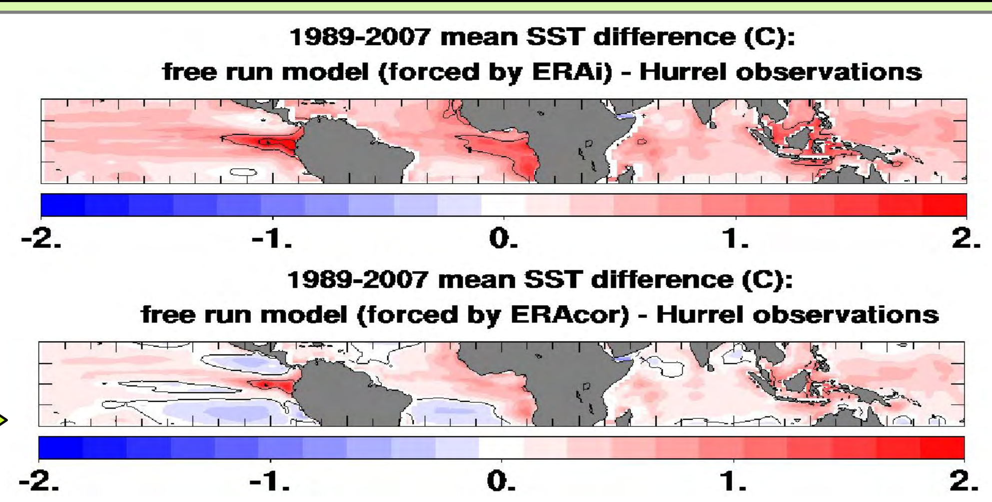


Turbulent fluxes modification mostly due to wind speed correction.

- **Consistence of fluxes correction with uncertainty characterized by heat fluxes datasets discrepancies.**
- **Forcing the model with corrected parameters (estimated for each month of 1989-2007) : reduced warm bias in the intertropical band with respect to observations.**
- **Diagnostic of the net heat flux computed with observed SST : sensible reduction as expected to correct ERAinterim forcing set, correction of the negative trend observed in ERAinterim dataset, better heat balance over the 1989-2007 period.**
- **An objective method to correct atmospheric reanalysis variables by taking advantage of their consistency with ocean dynamics: an alternative to « ad hoc » forcing corrections.**

Partitioning of the correction over the different fluxes

Impact in the model : Better agreement with SST observations.



Our method reduces significantly the intertropical band warm bias classically observable in forced simulations like the one forced by ERAinterim data.

Consistence with ocean dynamics

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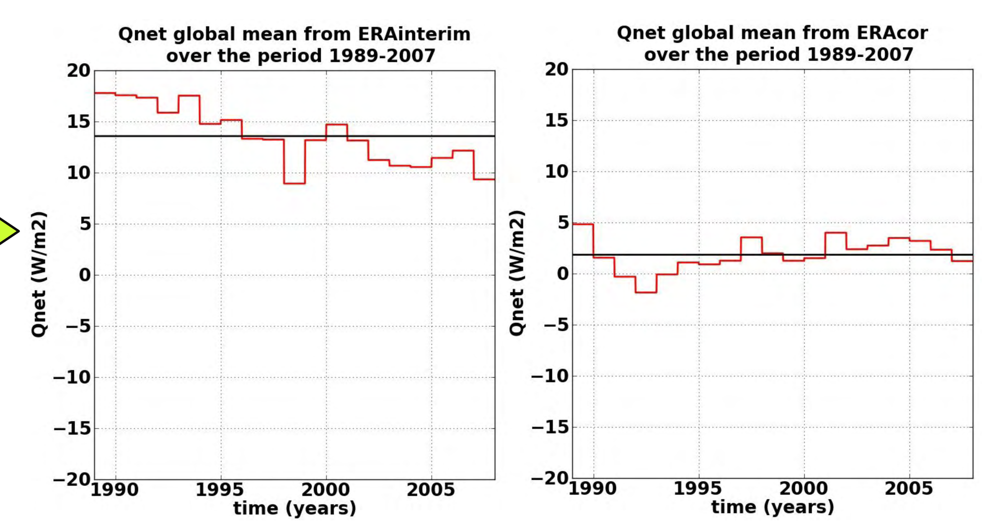
Valuable information to correct atmospheric variables

Net heat flux balance: Equilibrated budget



(Monthly mean in red, 1989-2007 mean in black)

An negative trend (over -1W/m²) is observed in ERAinterim net heat flux timeseries. It is unconsistent with the global warming observed in the 90s. Our method equilibrates the heat budget and detrends the net heat flux.

Objective not explicitely prescribed in the method itself.

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More realism in the forcing data

References : C. Skandrani et al., 2009 : Controlling atmospheric forcing parameters of global ocean models : sequential assimilation of sea surface Mercator-Ocean reanalysis data, Ocean Sci., 5,403-419.

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