Hydrothermal Inputs and Transient Tracers

What goes down must come up…

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Hydrothermal Inputs and Transient Tracers

1. **Remembering our objectives**
   - **Tracer tools at hand & how to use them**
2. Hydrothermal Inputs
   - Lessons learned and future strategies
3. Transient Tracers
   - Benefits and limitations

GEOTRACES Objectives

- Characterize the large scale distributions of the TEIs
- Identify their sources and/or sinks
- Quantify the rates, fluxes, and global/regional budgets of TEIs

Tracers* as Tools

- Identifying and characterizing water masses
- Outlining/highlighting pathways
- Quantifying dilution
  - Detecting non-conservative behavior
  - Flux gauges
- Estimating time-scales and rates

*Not just ***Transient*** tracers

Our Tracer Tool-Box [1]

- Temperature and Salinity, Geostrophy*
  - Conservative, largely non-transient
- Macronutrients (nitrate, phosphate, silicate) [2]
  - Non-conservative but commonly measured
  - Pseudo-conservative constructs sometimes used (*caveat emptor*)
- Helium-3
  - The non-atmospheric, non-tritiugenic part
  - Conservative, global hydrothermal inputs “known”
- Stable Isotopes & Provenance Tracers
  - Conservative, driven by hydrologic forcing
  - “Non-traditional” emerging as tools
- Transient and Radio-Tracers
  - Many conservative
  - Various time histories, time constants, and boundary conditions

[1] In order of decreasing quantity of measurements

[2] Are they the answer or the question?

*Not really a tracer, but computable from T, S, P

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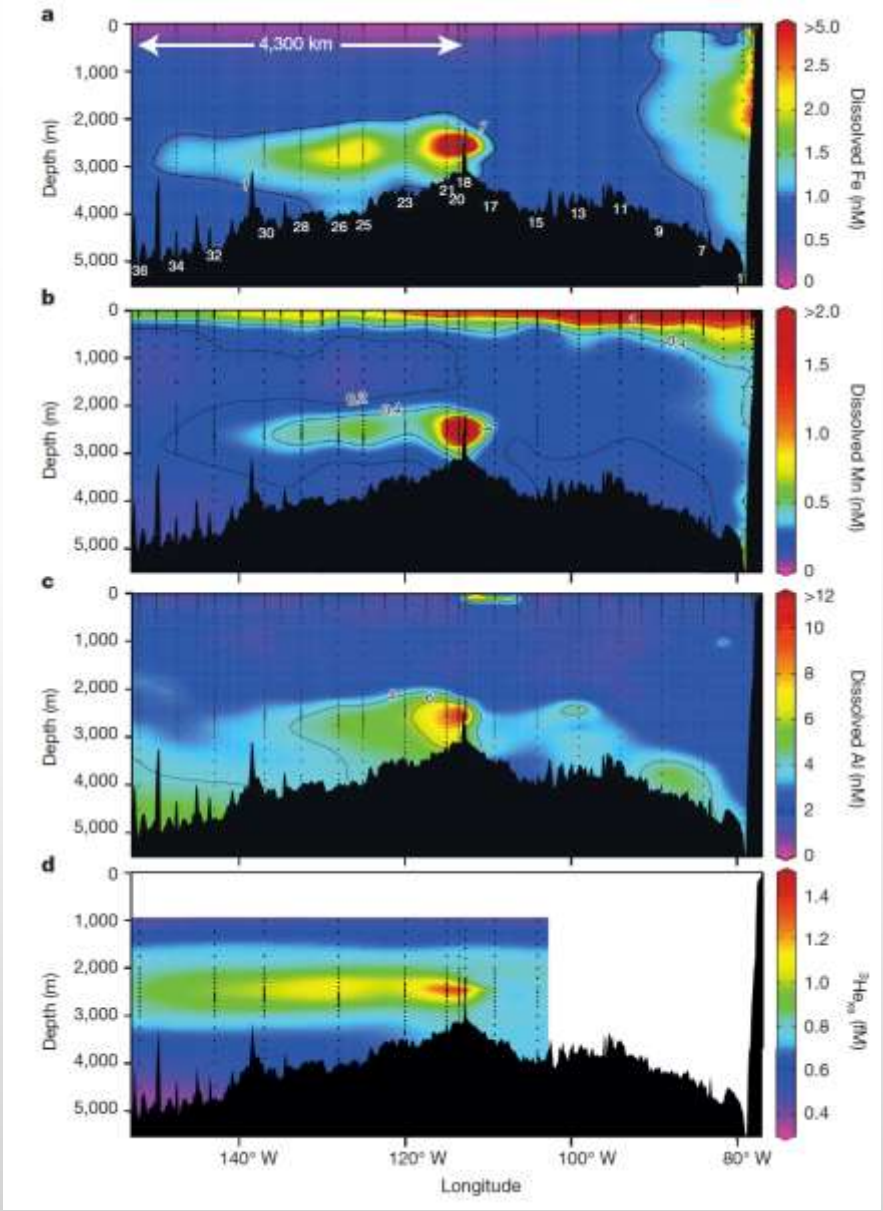
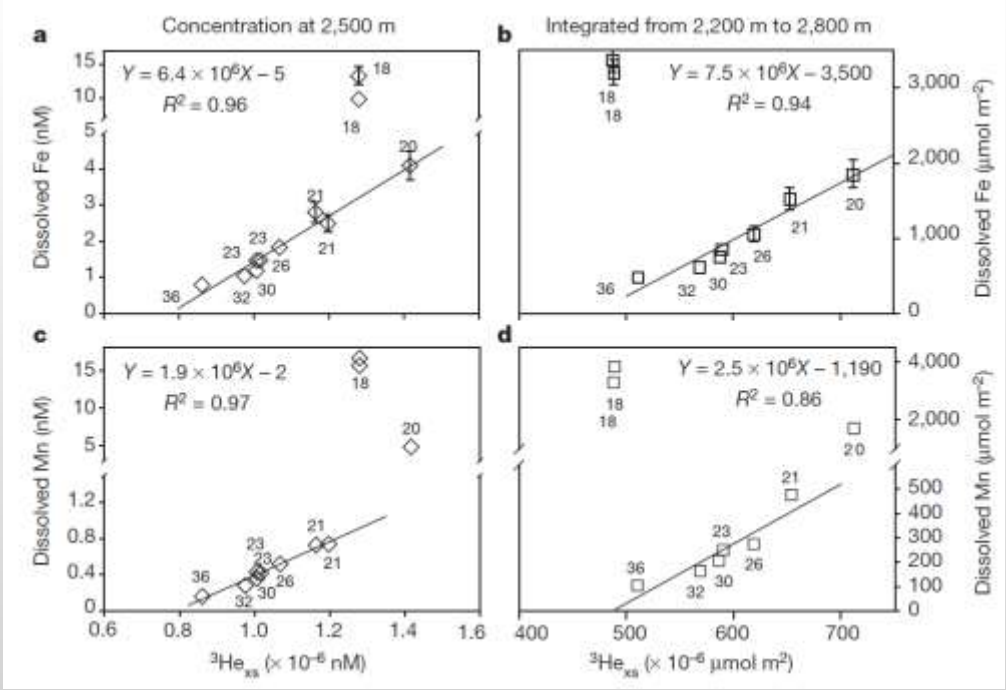
GP16 15°S Zonal Section (2013)

(Resing et al, 2014)



Global Metal Flux = Metal:^{3}He ratio X Global ^{3}He Flux ?

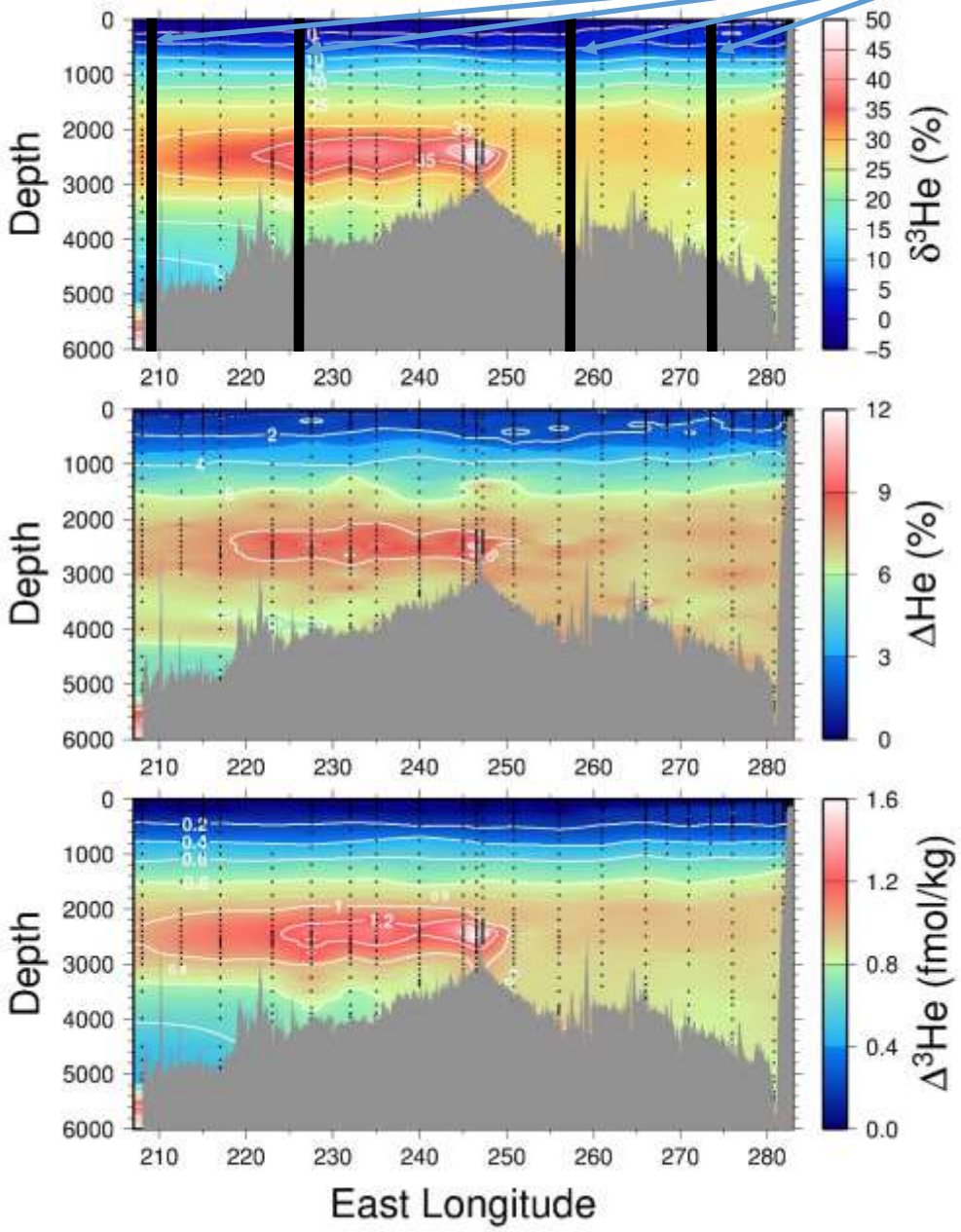
Global ^{3}He Flux = 480 ± 50 mol/year (Schlitzer, 2016; Bianchi et al, 2010)

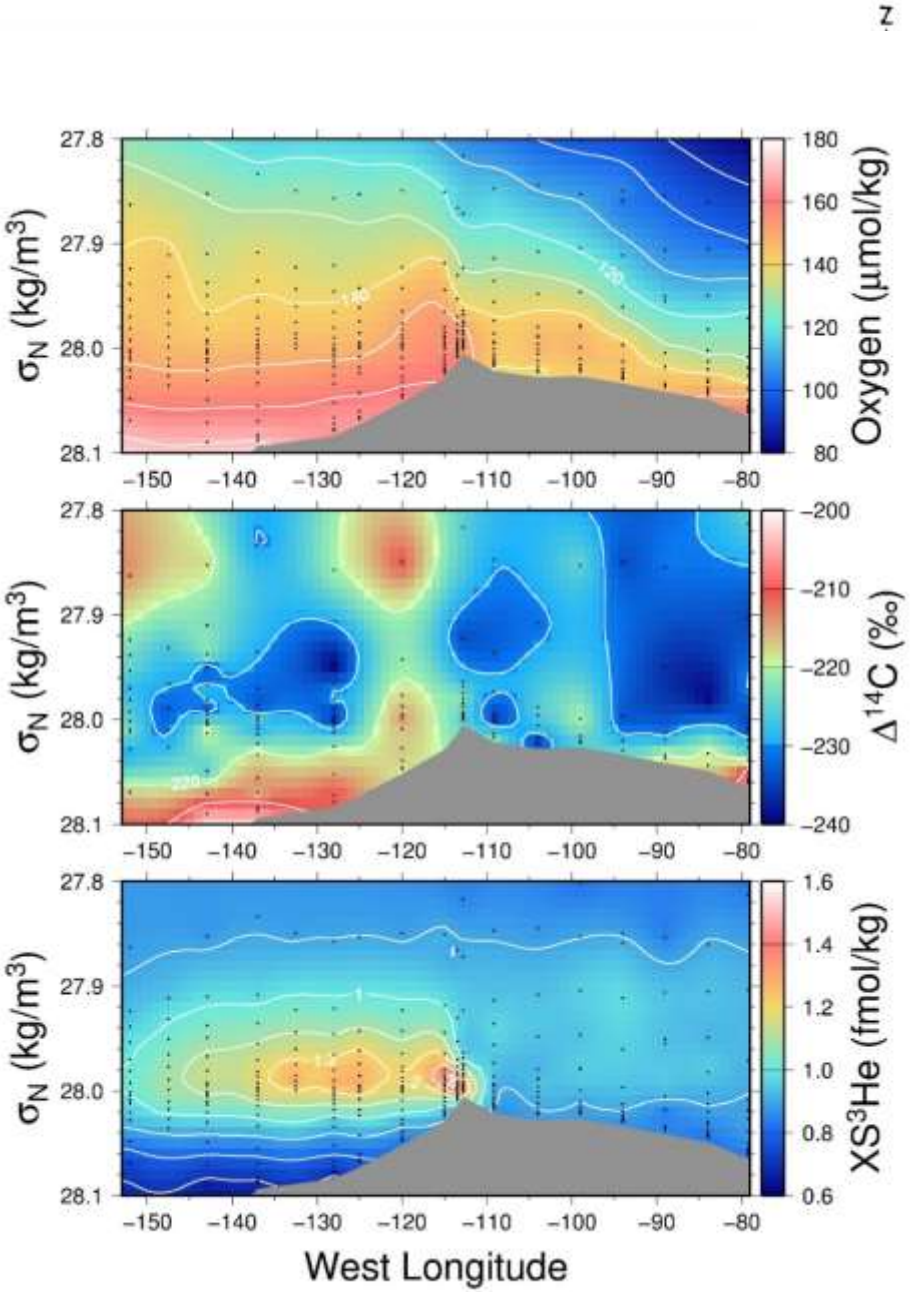


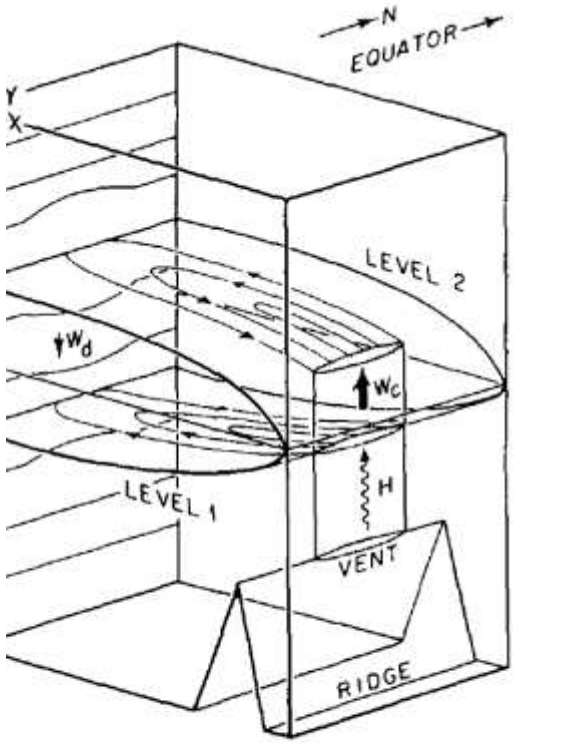
*Assumes we know the flux-weighted Metal:^{3}He ratios for all sources

The EPZT Hydrothermal plume

WOCE Meridional Lines





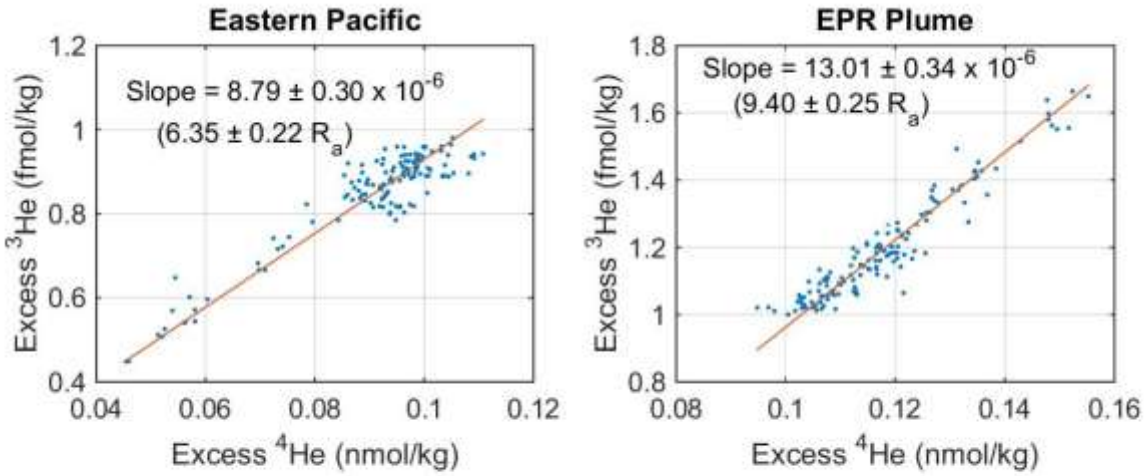


ppositely rotating superposed gyres at mid-depth
ge volume, w_c, of water entrained into hot vent
he lower level and released at higher level. Due to
e gyres extend westward from the crest of the

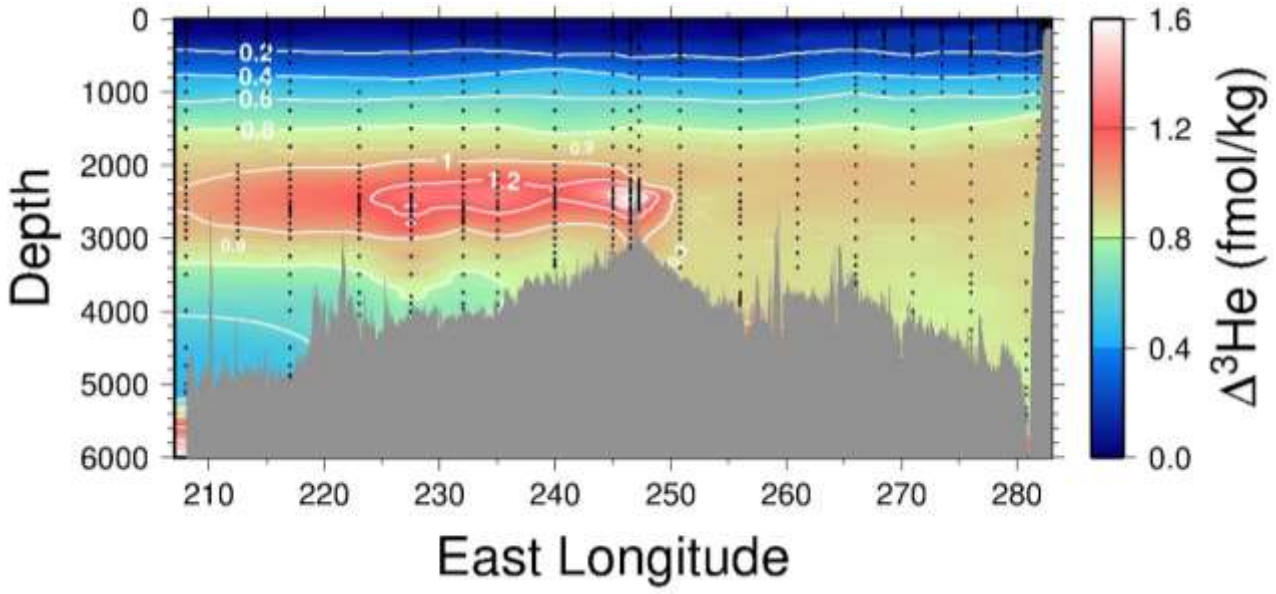
Volcanic

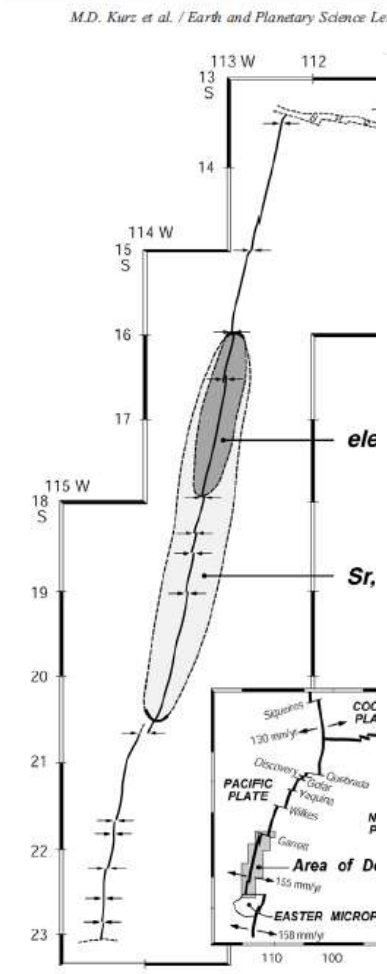
The Broader Scale Helium Isotope Balance…

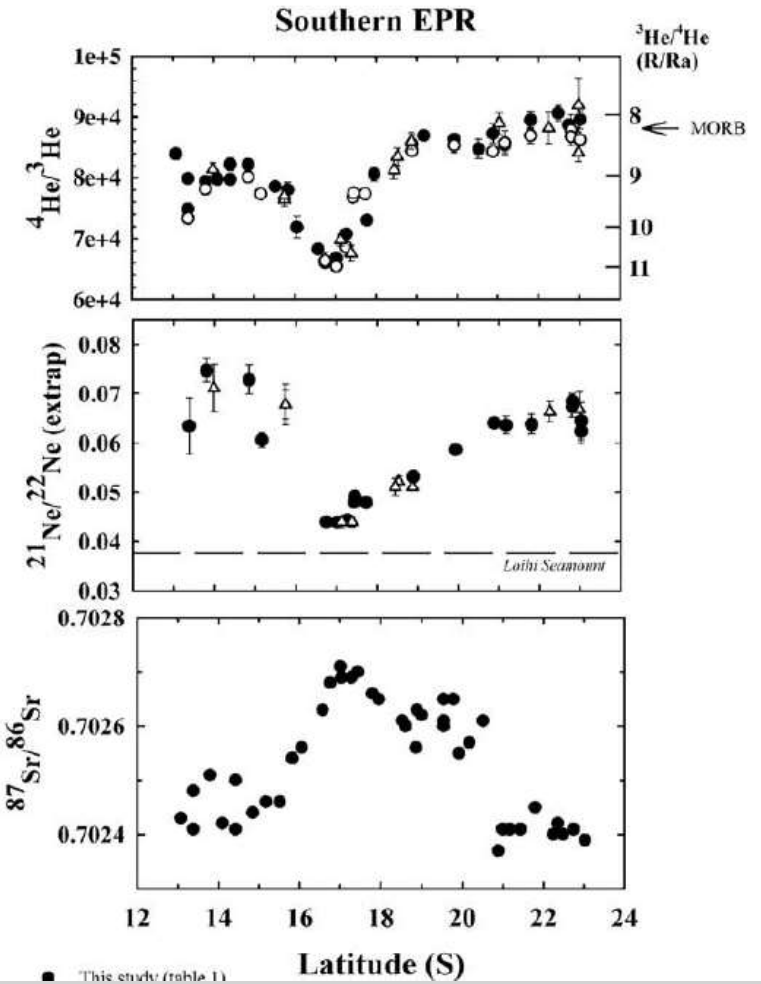
Basin "background" $^{3}He/^{4}He$ significantly lower than MORB inputs:
A "diffuse" *radiogenic* (U-Th) He flux
- residual MORB degassing
- sedimentary efflux



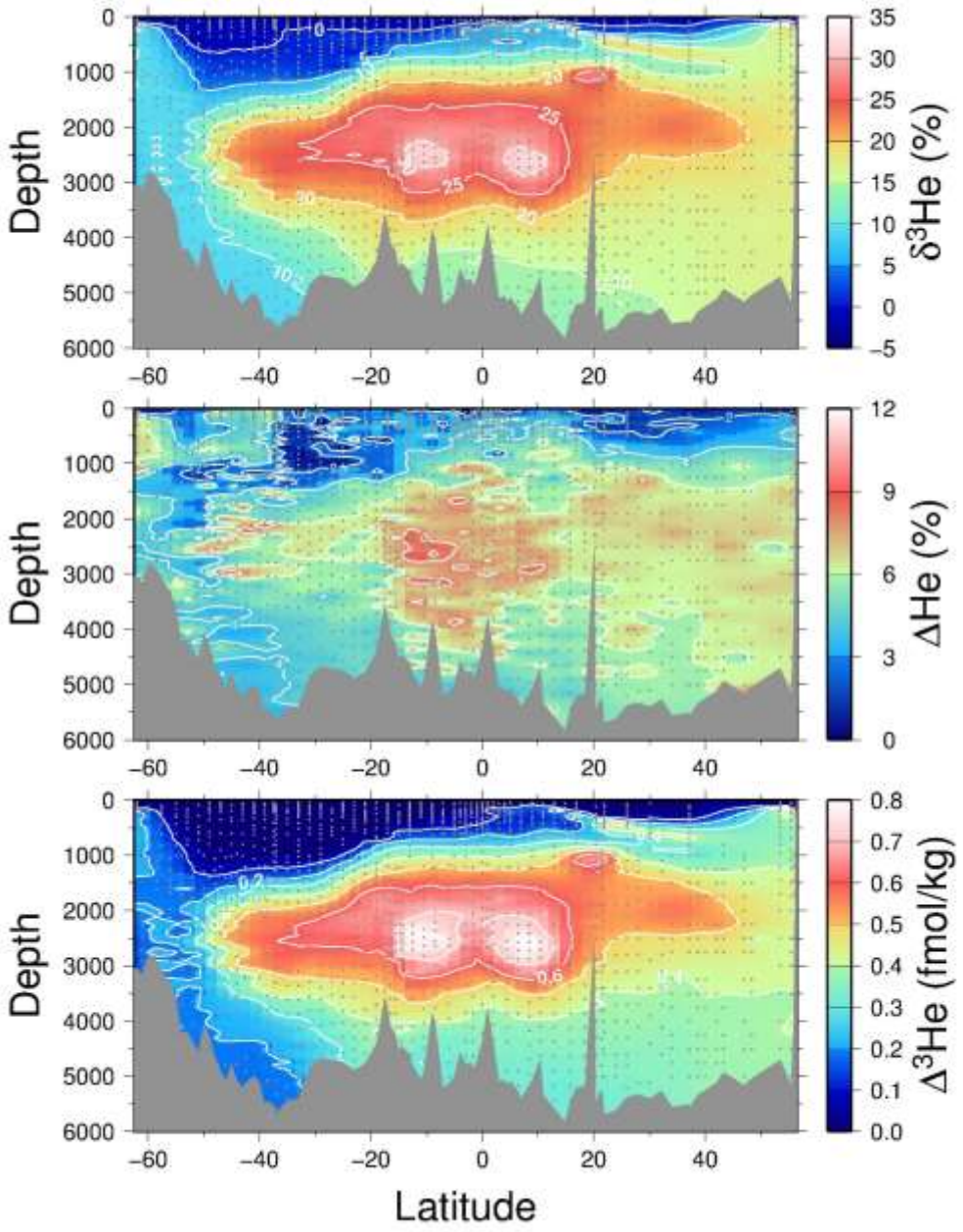
Typical MORB $^{3}He/^{4}He$ = 8 R_a

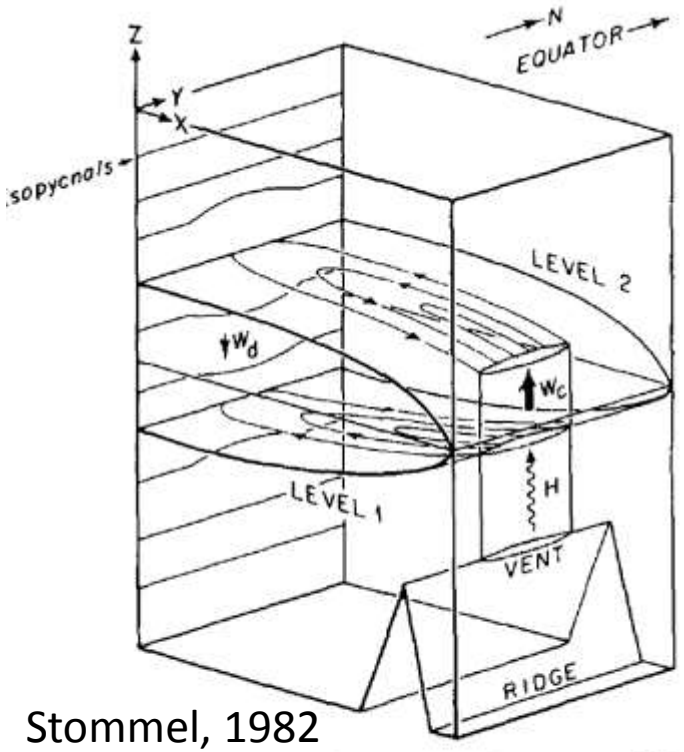






The Planned Section



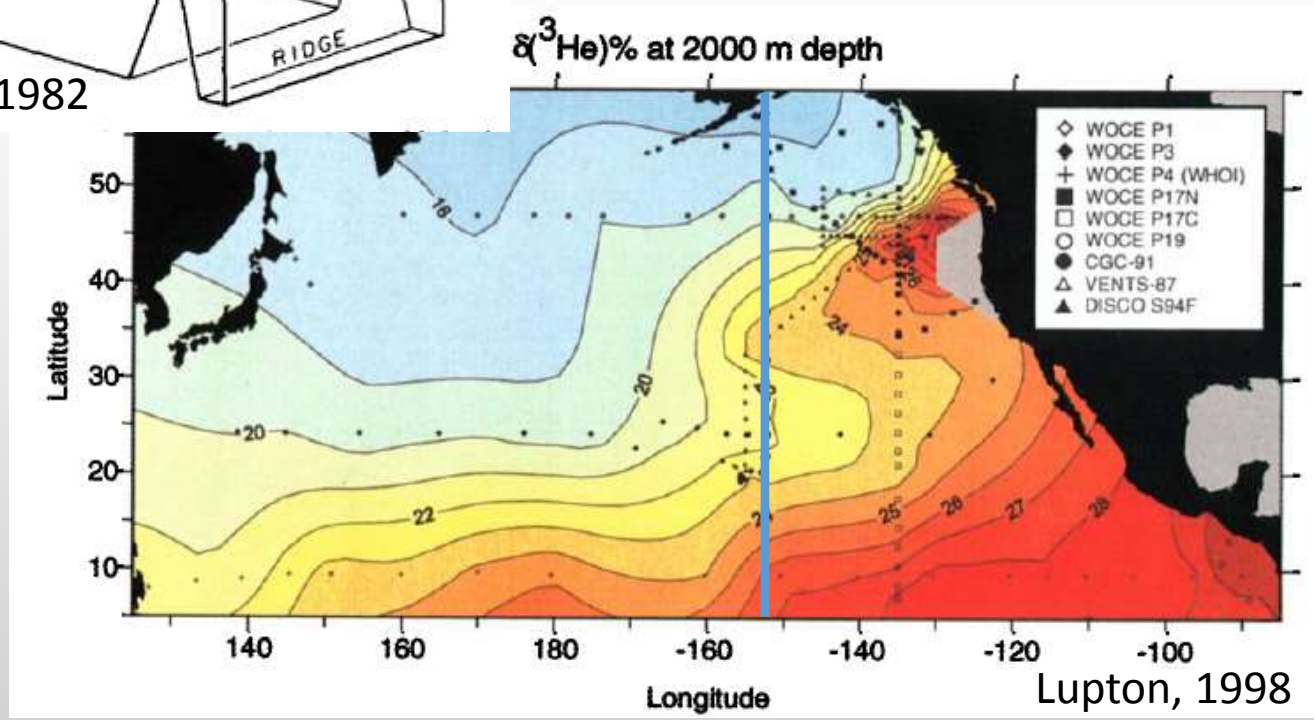


Stommel, 1982

1. Shallower Loihi (high $^3He/^4He$) plume

2. Multi-source, multi-layer plumes emanating westward from EPR and subducting plate boundaries

3. Conflated with β-Plume dynamical circulation patterns



Lupton, 1998

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   - **Benefits and limitations**

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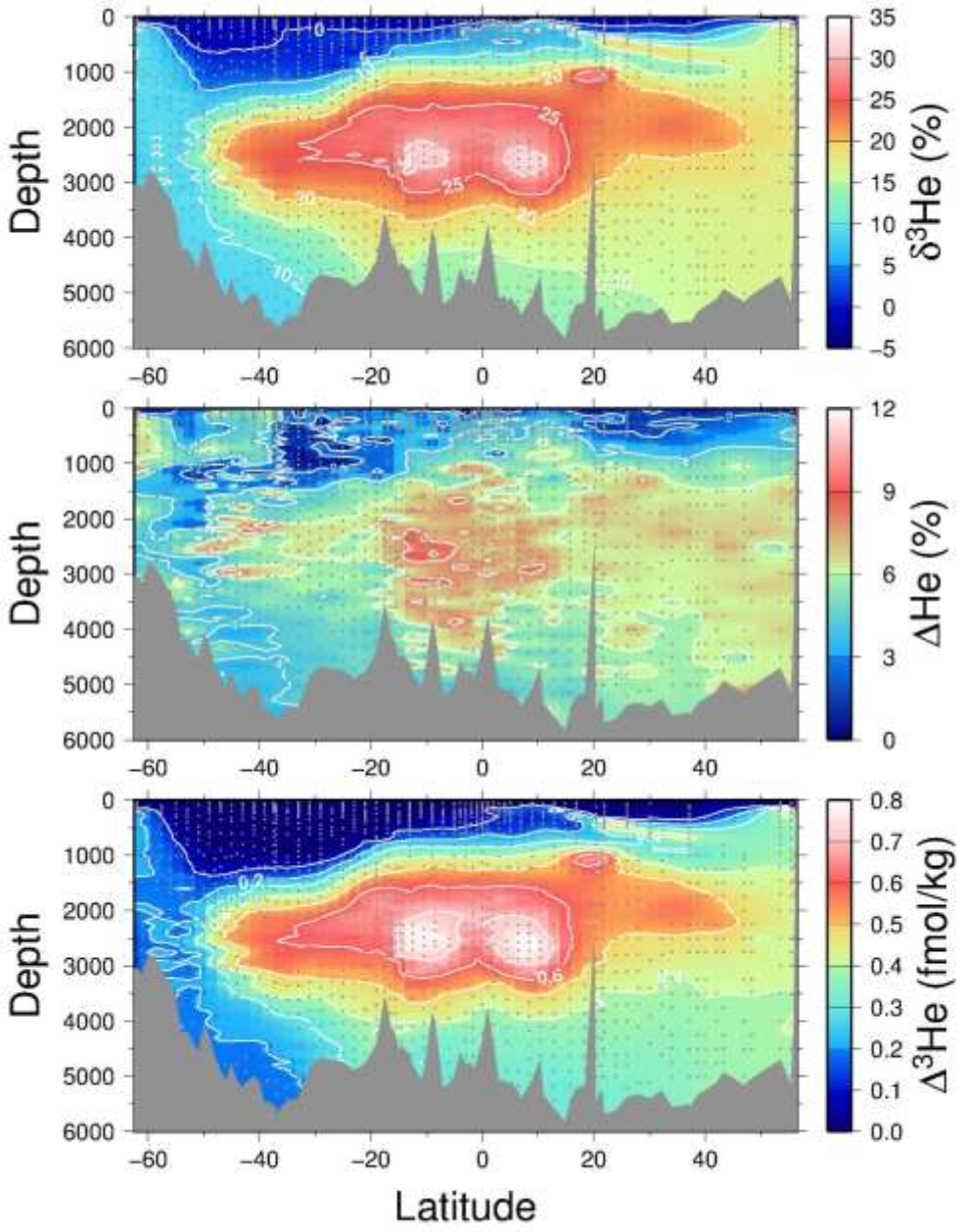
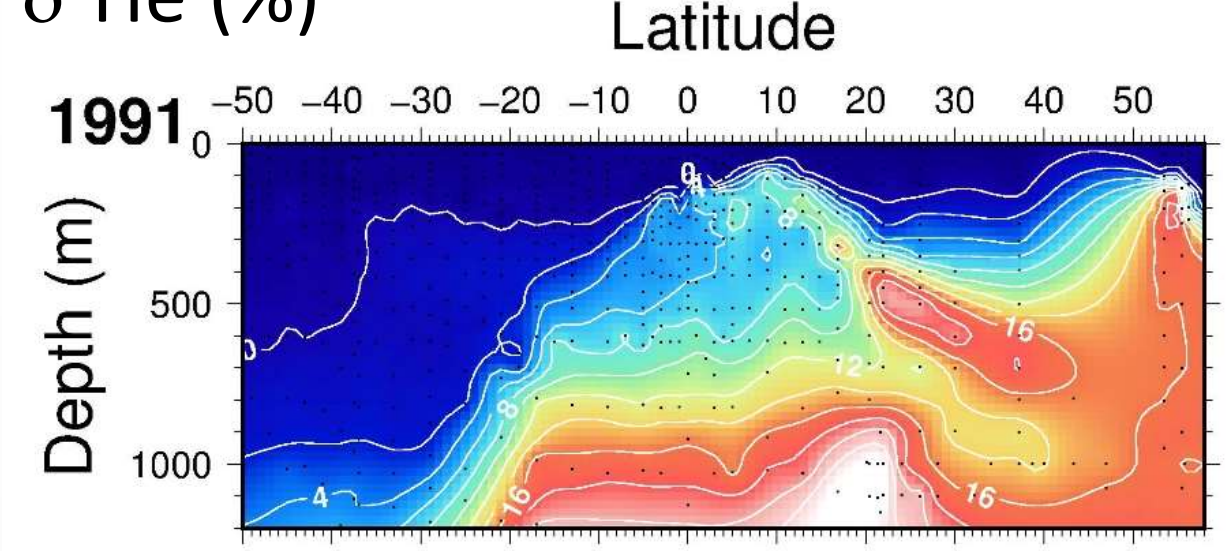
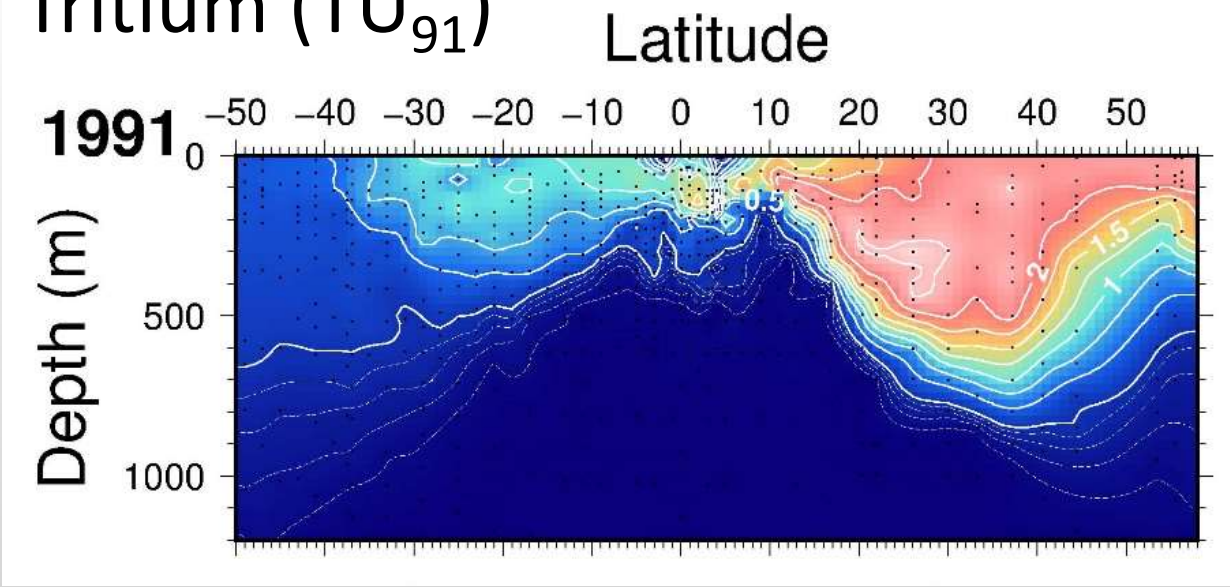


δ^3He (%)



Tritium (TU_{91})



Subtropical-Tropical Interaction

Subsurface tongues of subducted subtropical waters drawn into divergent equatorial flow

^{14}C is ~symmetric

CFC-11 less so…

^{3}H & ^{3}He not so…

Entry route into tropics constrained by LPS-type circulation

(McPaden and Fine, 1988)

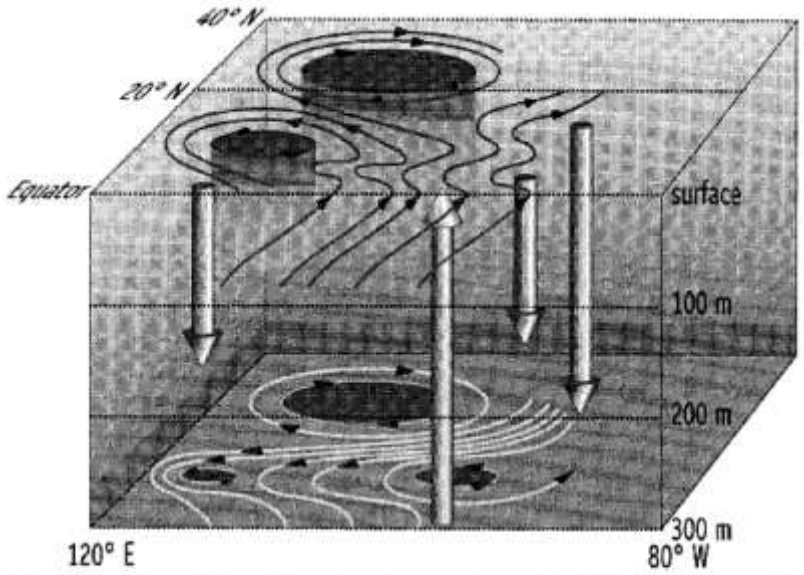
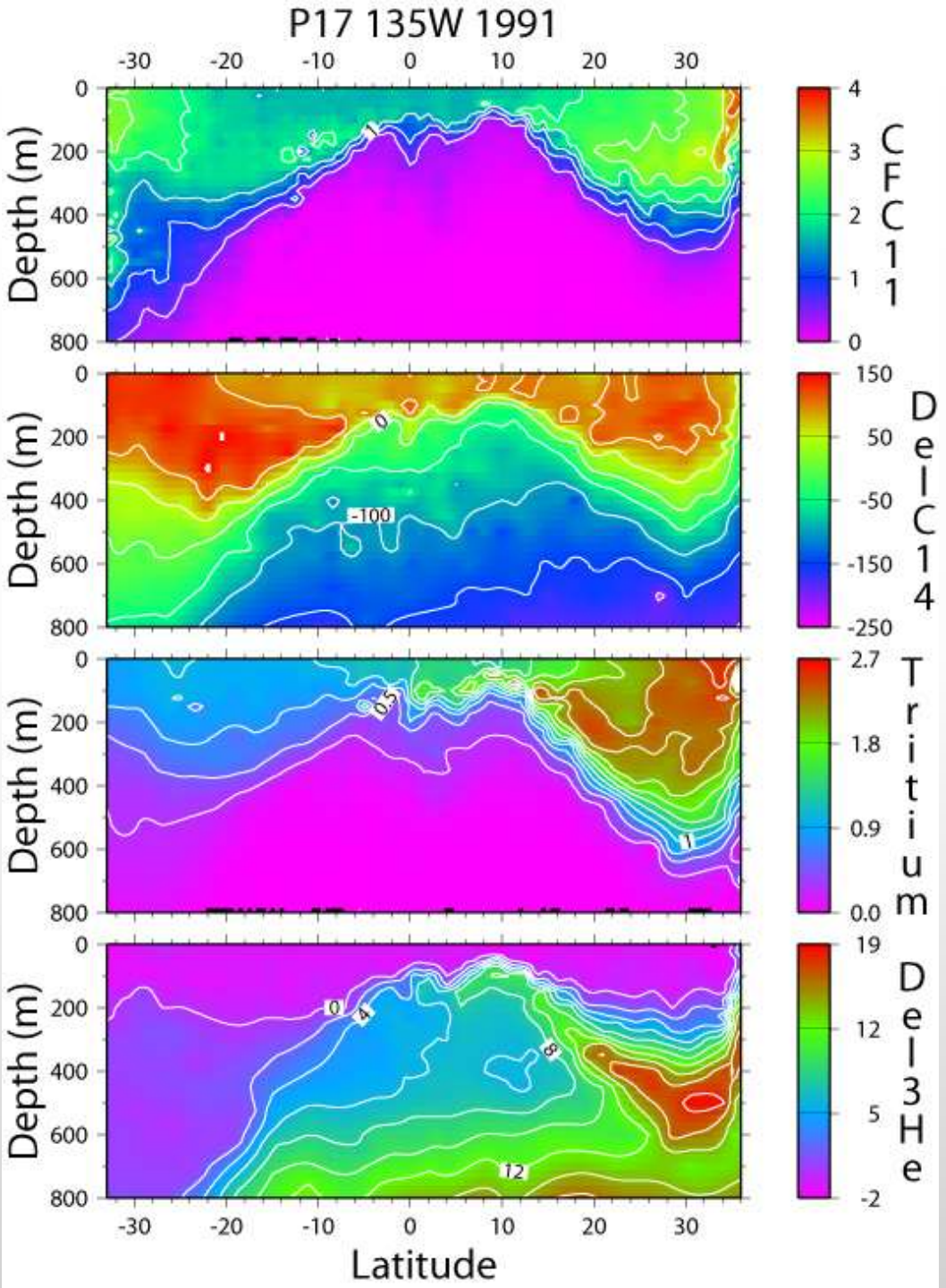


FIG. 11. A schematic diagram illustrating the water pathways in the North Pacific subtropical/tropical upper ocean, as well as the main horizontal gyres and meridional–vertical cells of the ocean circulation. The shading regions with thin arrows indicate horizontal gyres: the subtropical gyre and the Mindanao eddy in the surface layer, and the additional tropical northeastern gyre at depth. The big arrows indicate vertical motions: the equatorial upwelling in the central and eastern Pacific, downwelling in the far western equatorial Pacific and in the off-equatorial North Pacific along 3°–4°N, and the subduction in the broad subtropics.

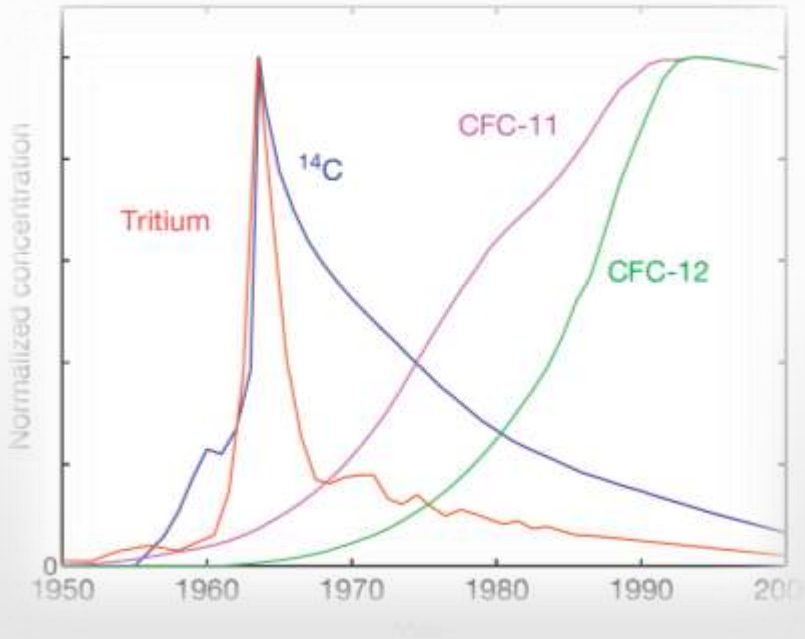
Rothstein et al, 1998

A delay path for ENSO modulation?
Alexander et al, 1999,
Capotondi et al, 2005



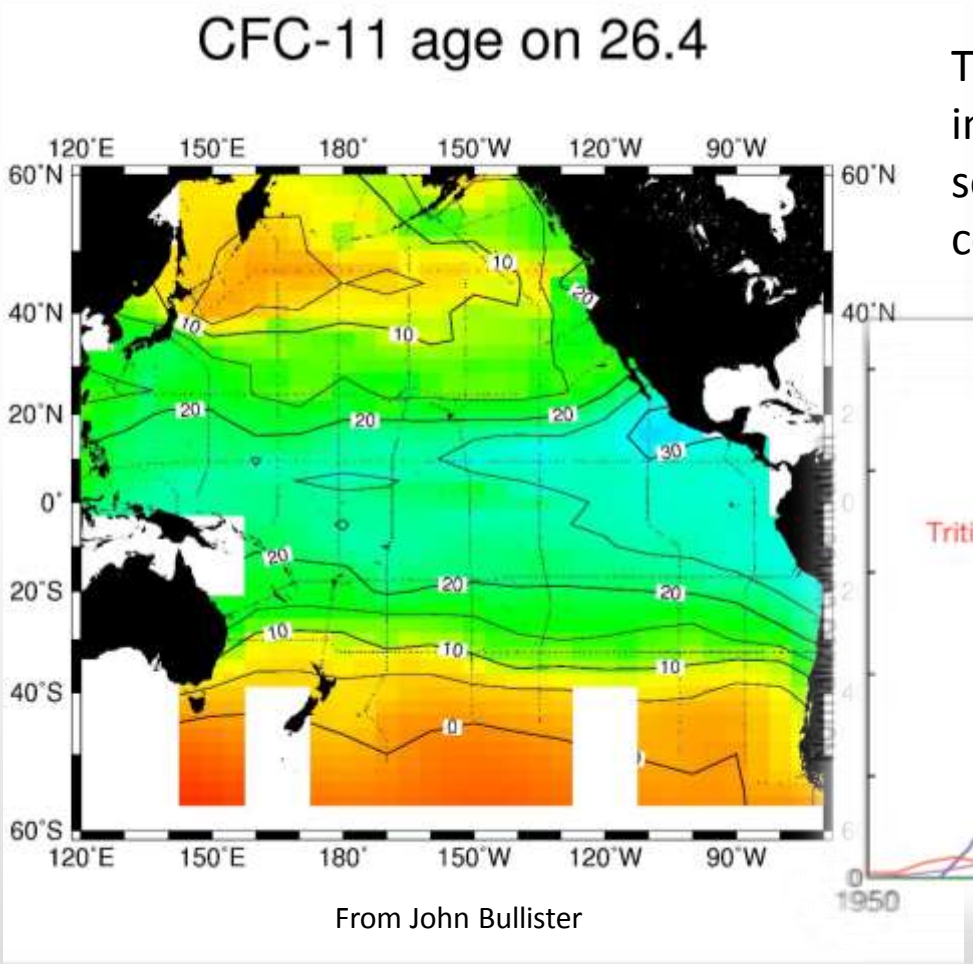
Our Transient Tracer Toolbox

- Outline pathways
  - Ventilation tracers, e.g., CFCs, SF_6, ^{3}H, bomb-^{14}C, ^{129}I, ^{137}Cs, ^{90}Sr, *etc.*
    - *Highlight pathways into the ocean*
    - *Range of characteristic time scales and boundary conditions*
  - Nutrient tracers, *e.g.,* Tritiugenic ^{3}He
    - *Highlight pathways back out of the ocean*
- Quantify chronologies (*caveat emptor!*)
  - "Age" is in the eye of the beholder…
    - Beware of
      - Transit-time distribution and boundary condition subtleties
      - Mixing non-linearities *(extrinsic and intrinsic)*



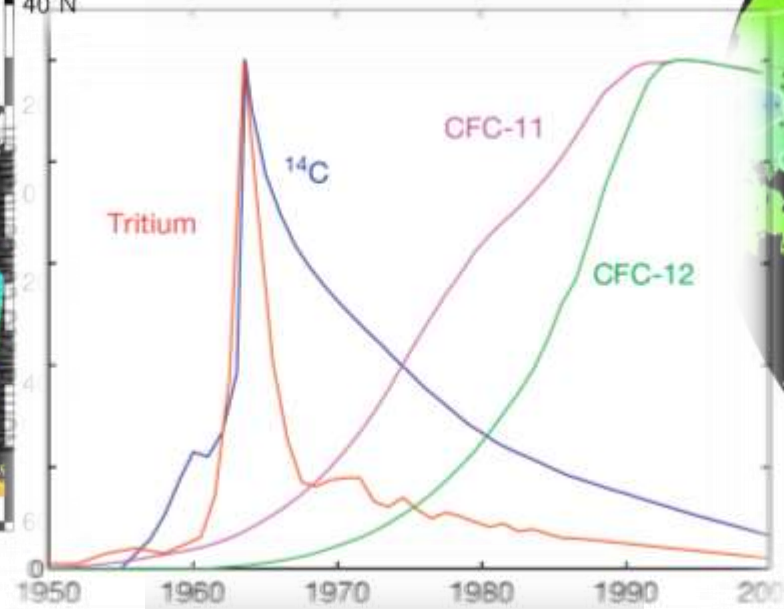
Global *vs.* Regional,
Hemispheric contrast,
Spiked *vs.* ramped

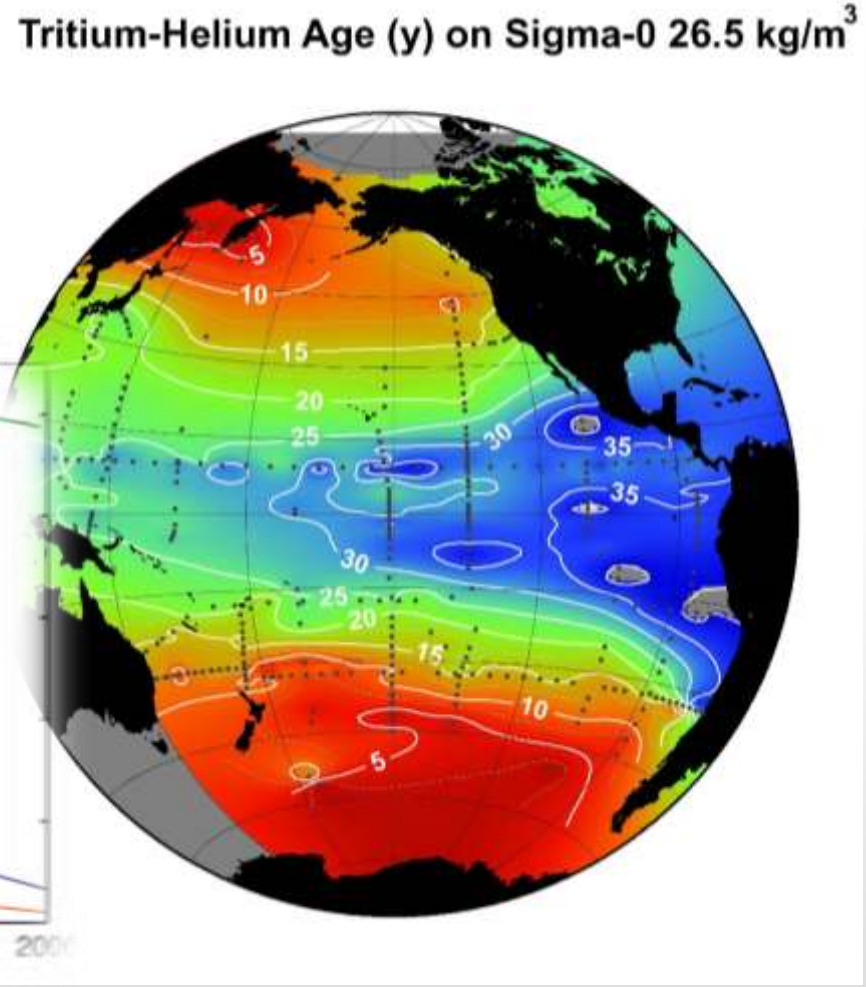
Transient tracer ages show ventilation and shadow zones in shallow circulation



From John Bullister

Tracer ages are colored by intrinsic/extrinsic time scales and boundary conditions (e.g., TTDs)





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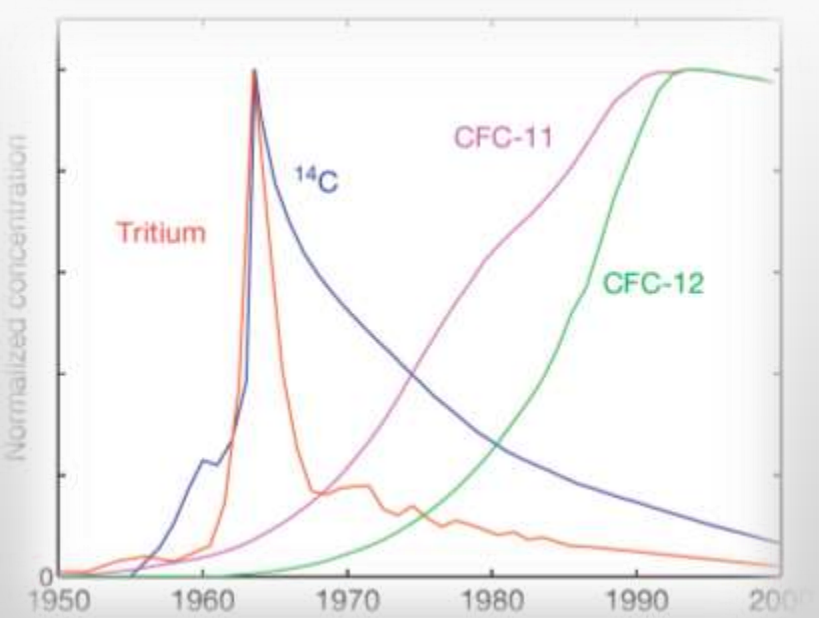

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