Controls on Turbidity Current Flow Modes: New Insights from Direct Measurements Worldwide*

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Abstract

New technology now enables high-resolution measurement of turbidity currents. New data can answer key questions, such as what flow modes exist for field-scale turbidity currents? How important is the trigger in controlling flow behaviour compared to grain size? We analyse direct measurements of turbidity currents from eight locations worldwide (water depths: 65-2300 m). We test whether commonalities in flow mode exist, independent of location, thickness, velocity and duration. Normalised time-velocity plots reveal three distinct flow modes. Type 1 is a rapid increase in velocity (first 5-10% of the flow) followed by an exponential deceleration. Type 2 is a steady increase in velocity (first 30-50% of the flow), followed by a similar waning decline. Like Type 1, Type 3 exhibits a rapid peak in velocity; however, the exponential decline is interrupted by a near-constant velocity for c.80% of the flow, which then drops off.

Canyons with coarse axial sediments (<10% mud) and oceanographic-triggers feature Type 1 flows. Canyons directly linked to hyperpycnal rivers feature Type 2 flows, where sediments comprise c.10-40% mud. Type 3 flows are also linked to rivers, but are not directly fed by sediment-laden river water. Unlike Type 1 and 2 flows which are <22 hours long, Type 3 flows last several days. High mud contents (>60%) permit Type 3 flows to sustain at low velocities (0.2-0.8 m/s). We suggest that triggers and grain size are equally important controls on setting up flow mode, but that the latter is more significant further away from the source.

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Controls on turbidity current flow modes: New insights from direct measurements worldwide

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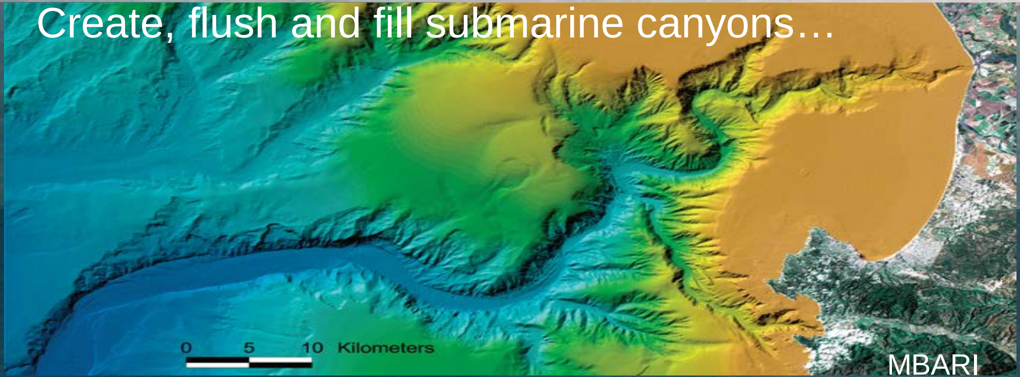
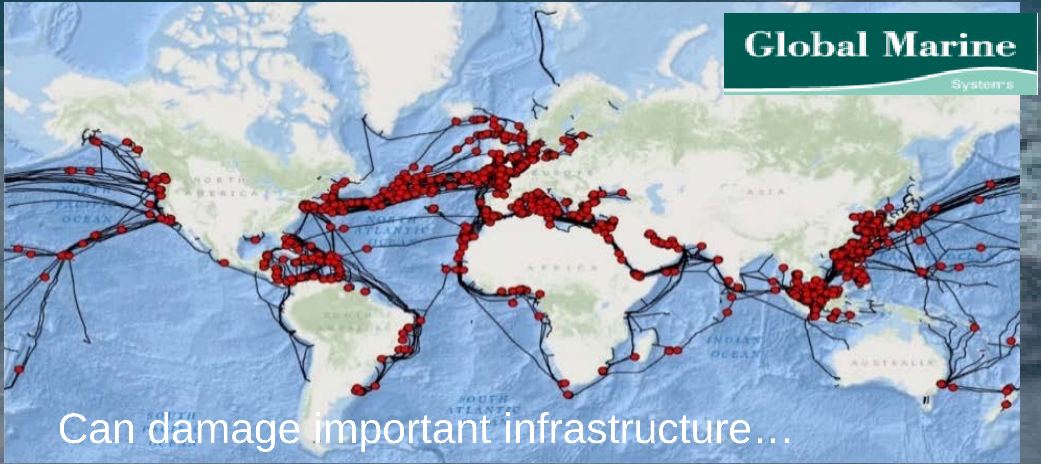
Turbidity currents: powerful avalanches of sediment in the ocean

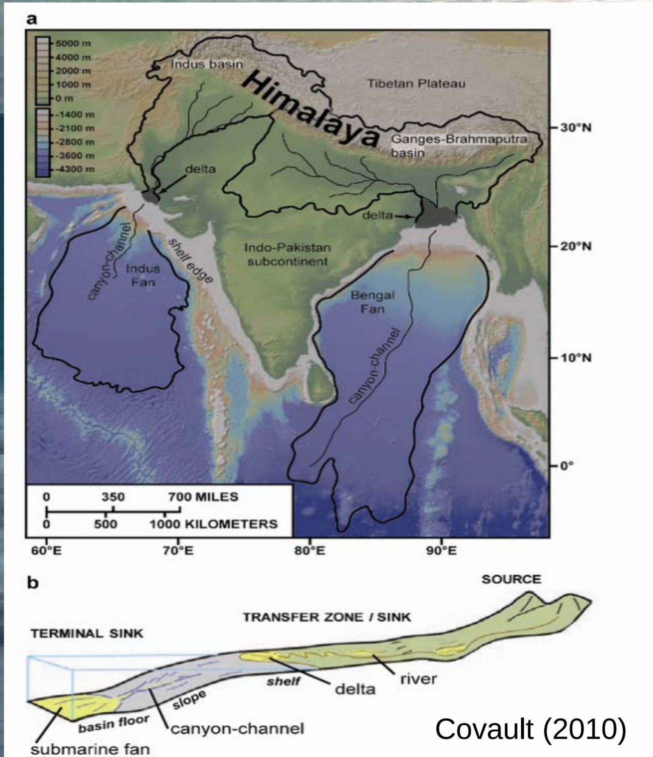
Create, flush and fill submarine canyons…



Can damage important infrastructure…

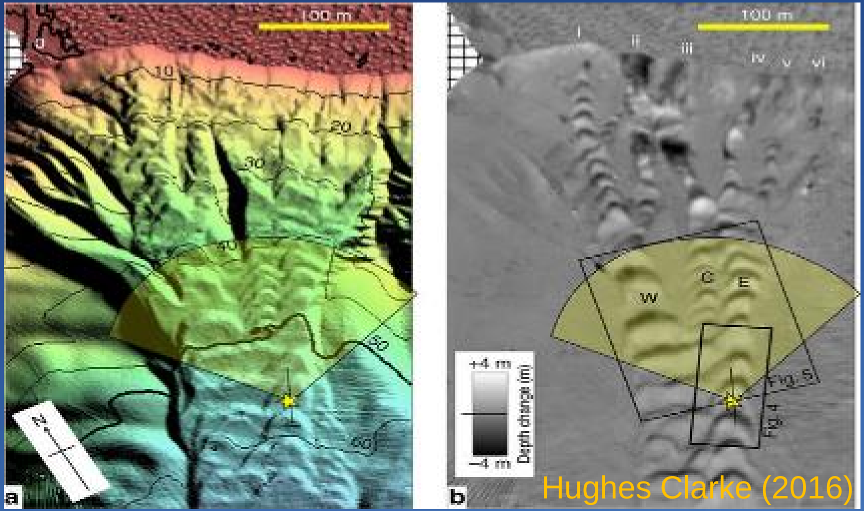


Deposit globally important amounts of sediment…

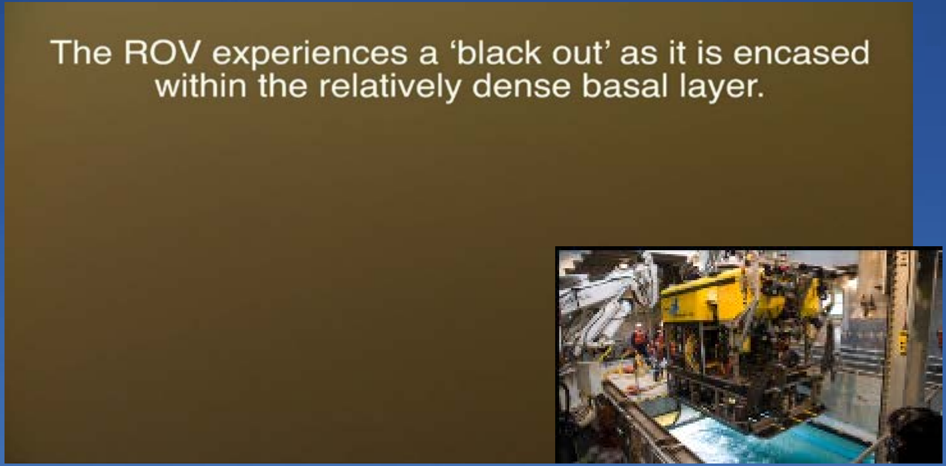


Covault (2010)

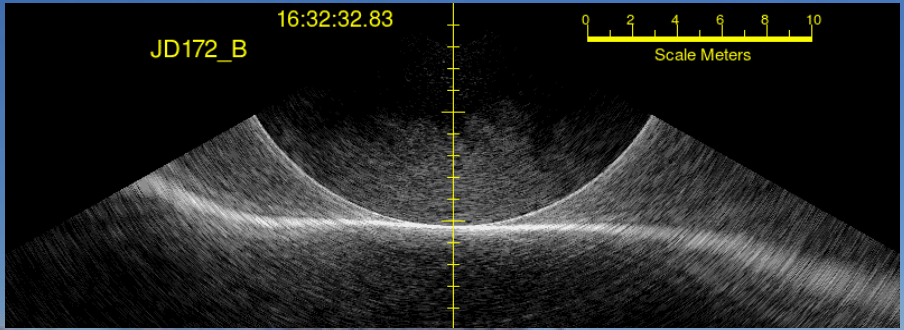
Repeat mapping shows interaction of flows with the seafloor

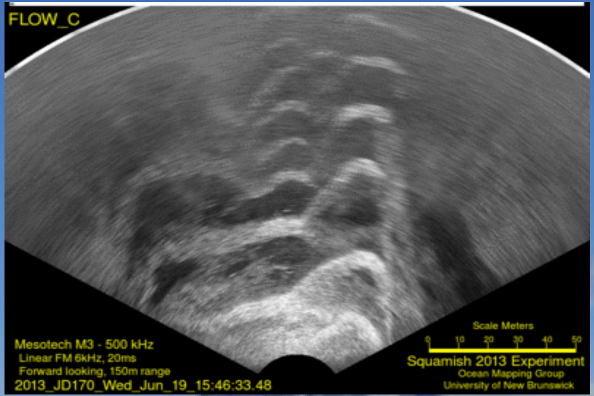


Sumner and Paull (2014) flew an ROV through a flow!

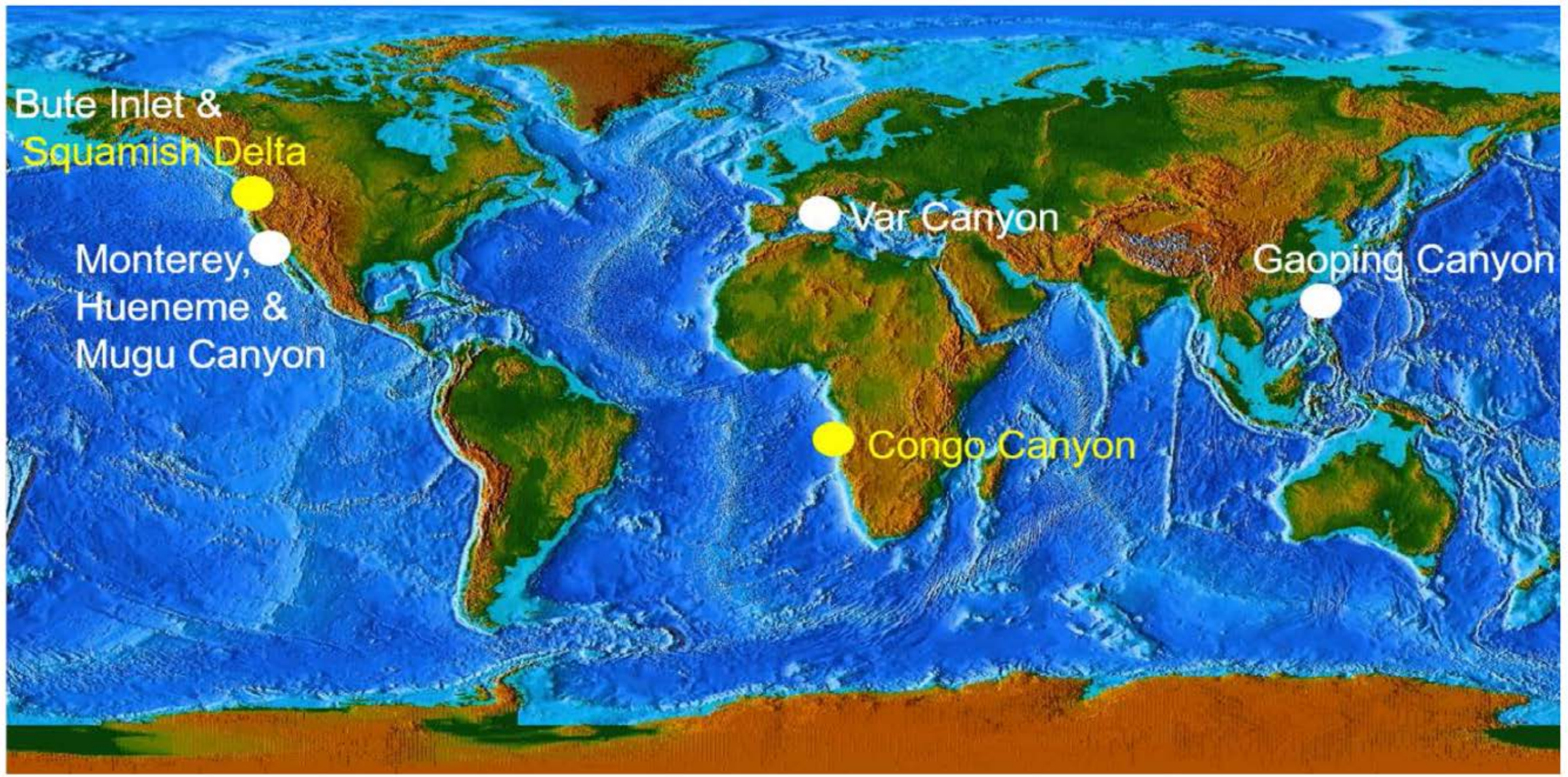


Multibeam sonars image the flows themselves…



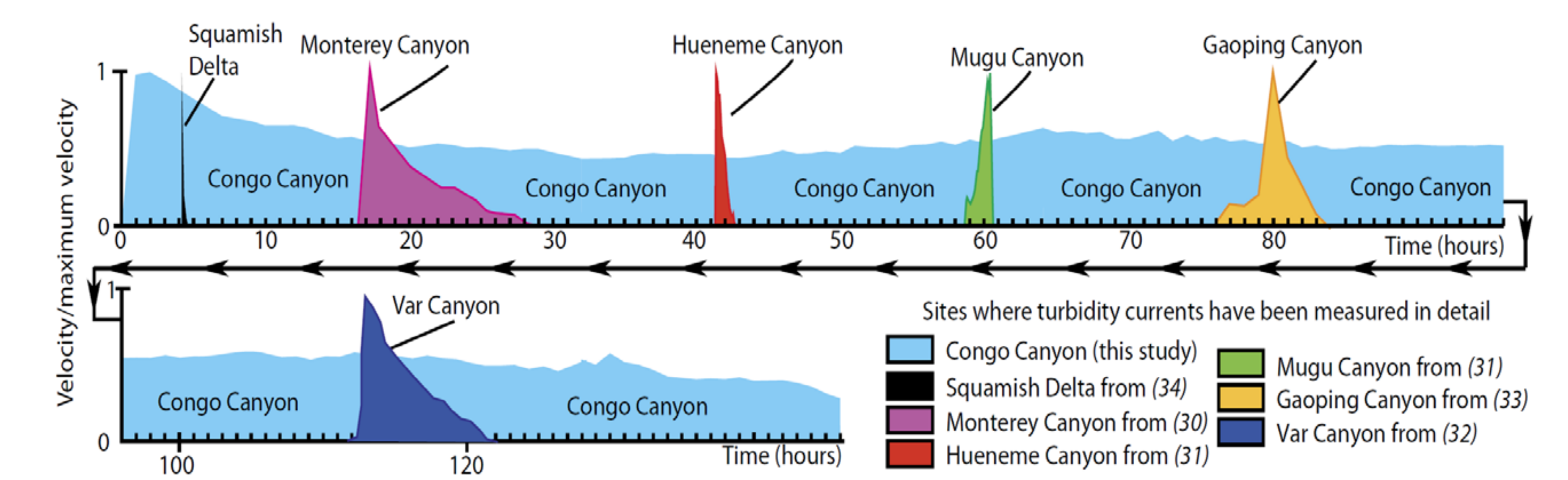


Sites where turbidity currents have been measured



… from direct measurements of turbidity currents at water depth from 65 m to 2300 m

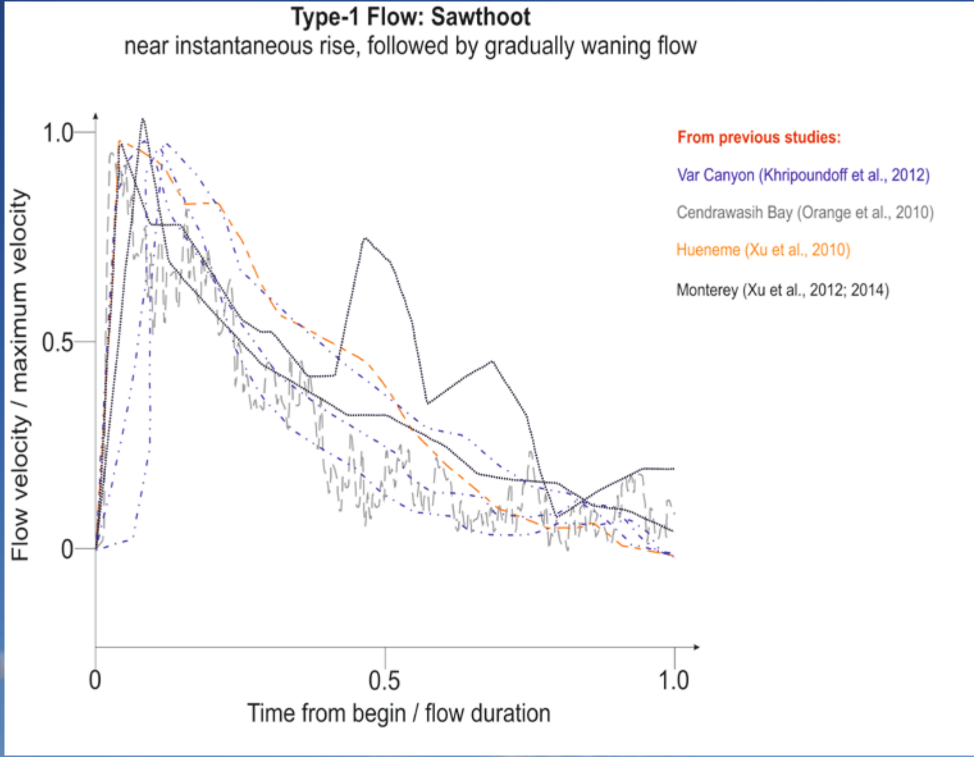
Azpiroz-Zabala et al., 2017

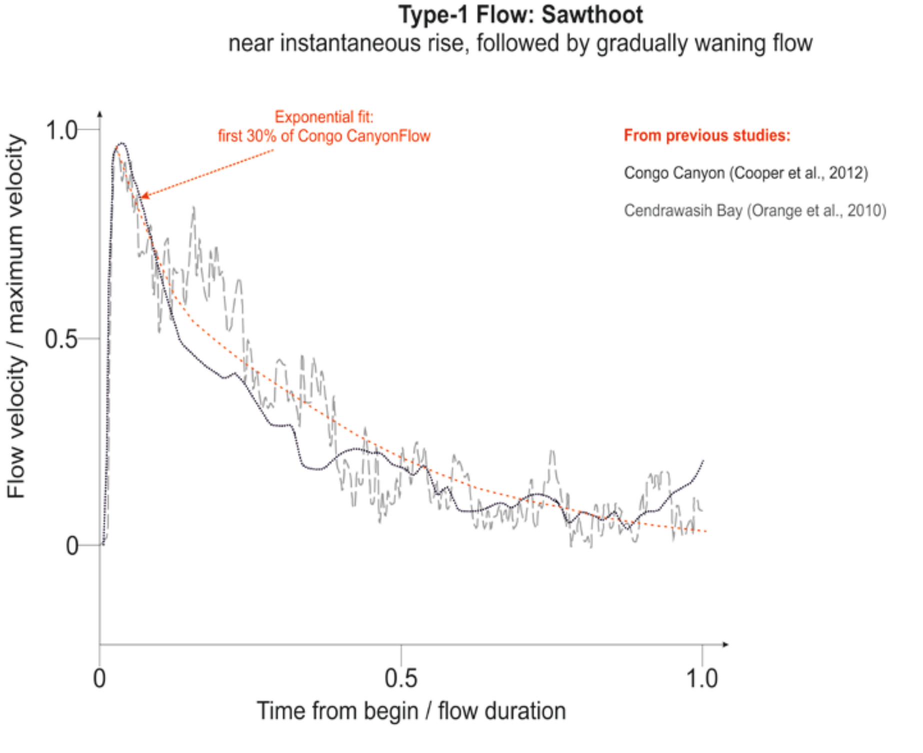


.. any commonalities in flow modes: location, flow thickness, velocity and duration?

.. How important is the trigger in controlling flow behaviour compared to grain size?

… Normalised time-velocity plots reveal three distinct flow modes

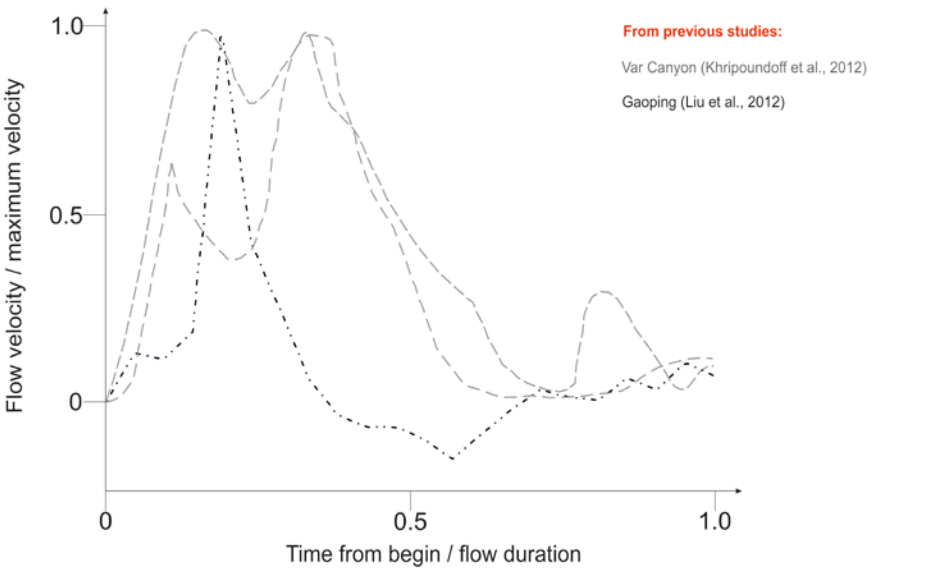




Type 1 is a rapid increase in velocity (first 5-10% of the flow) followed by an exponential deceleration

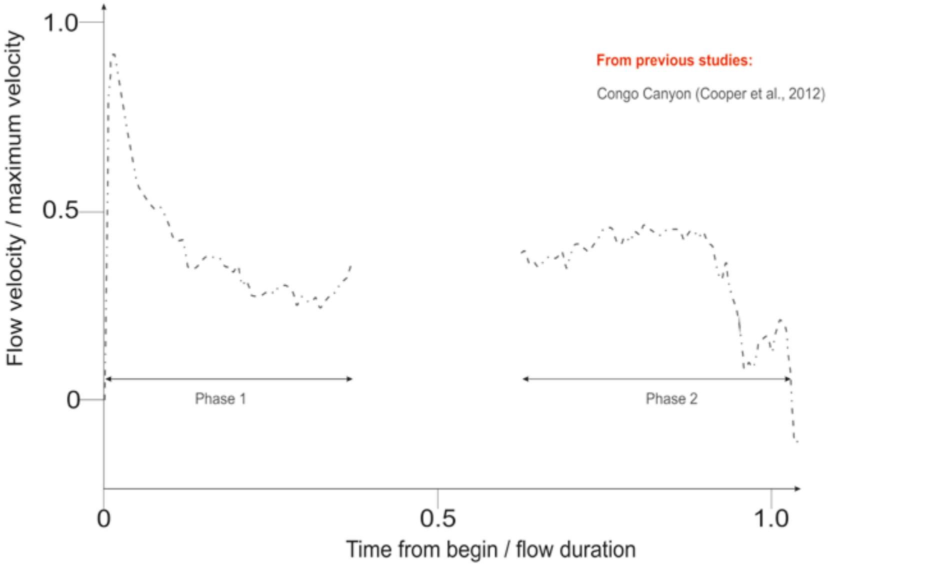
....

Type-2 Flow: Symmetric
rapid rise mirrored by a rapid decline



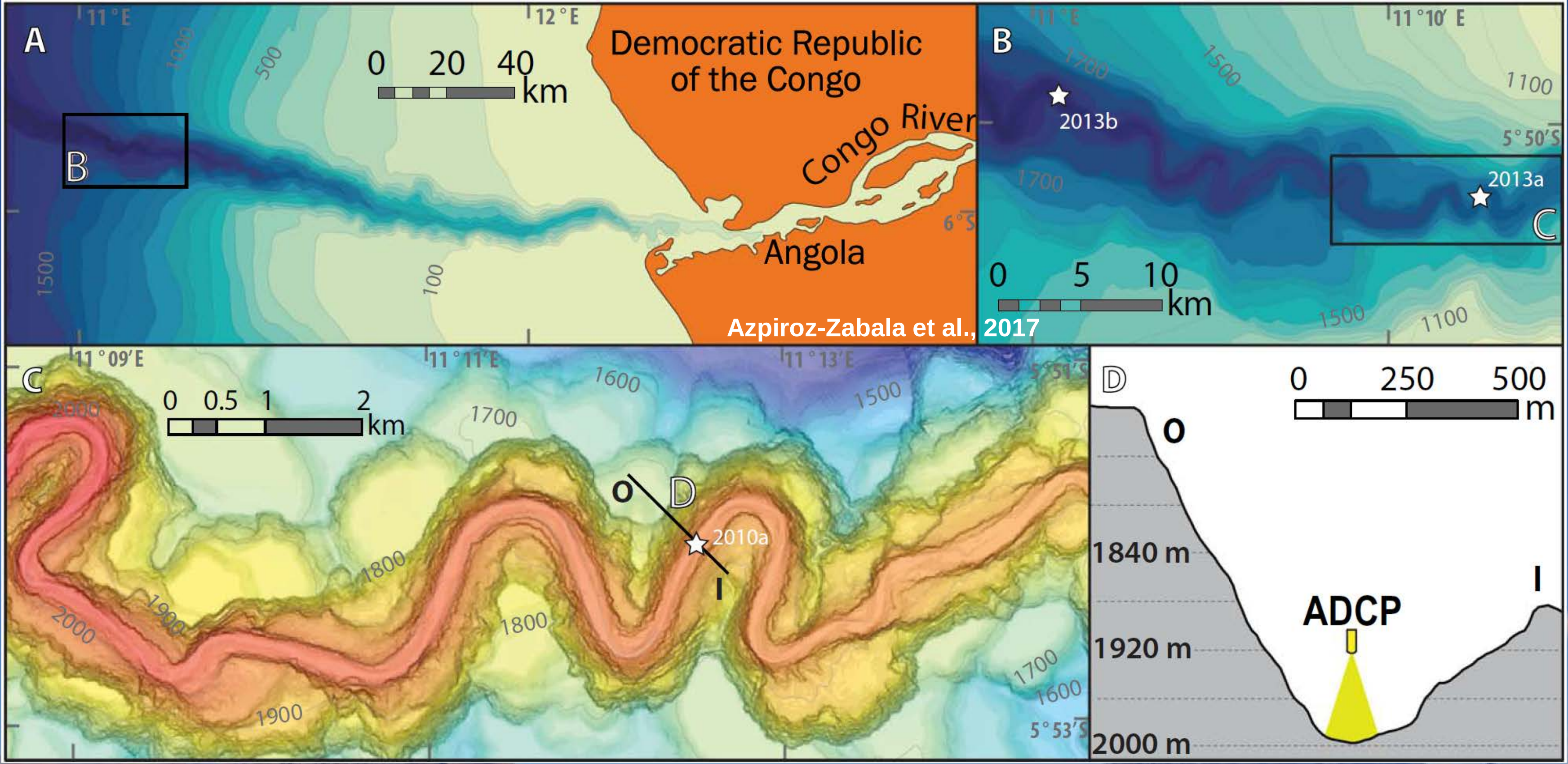
Type 2 is a steady increase in velocity (first 30-50% of the flow), followed by a similar waning decline

Type-3 Flow: Plateau-Like
near instantaneous rise, followed by steady plateau and then rapid decline



Like Type 1, Type 3 exhibits a rapid peak in velocity; however the exponential decline is interrupted by a near-constant velocity for c.80% of the flow, which then drops off

The most detailed direct measurement of velocities within oceanic turbidity currents



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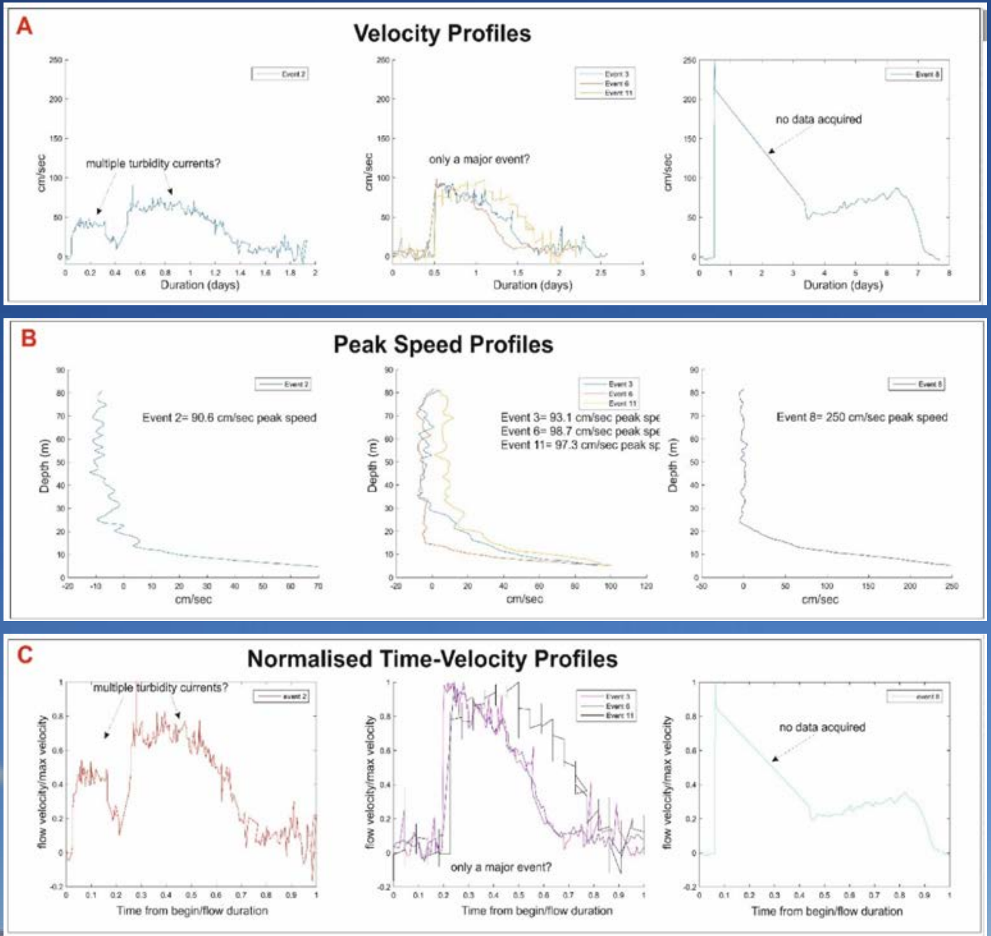
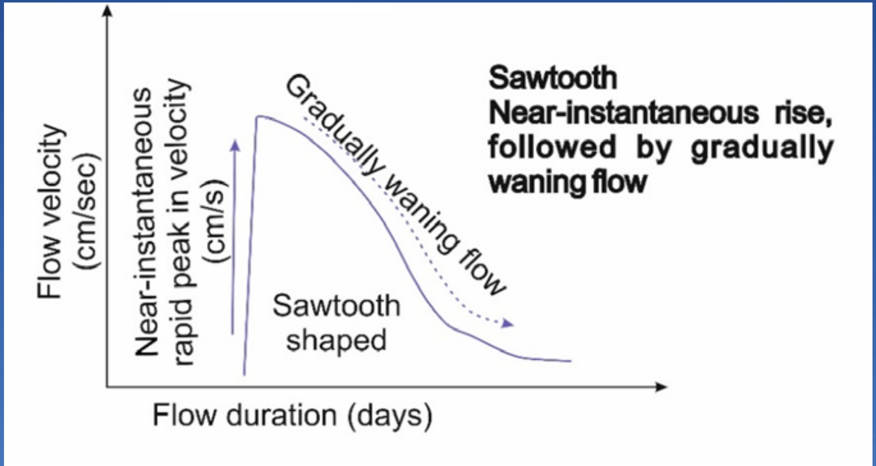
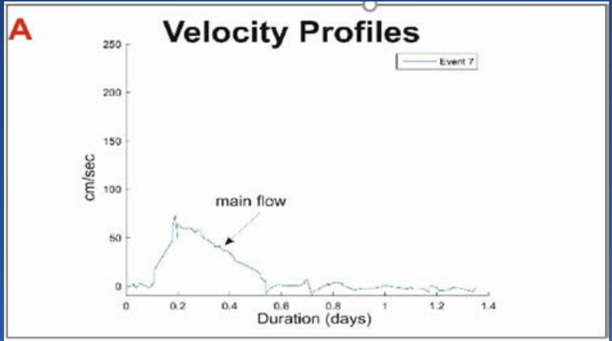
Introduction | Context and aim | Dataset and methodology | Initial results | Further steps

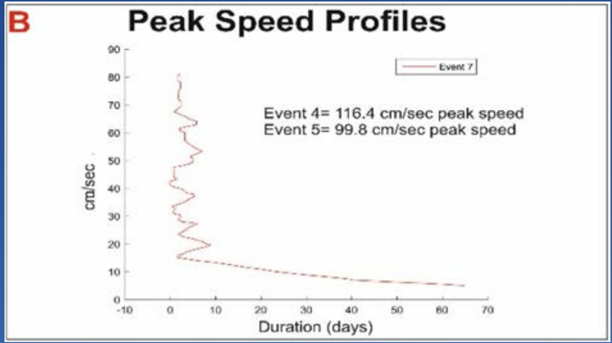

A
Velocity Profiles
multiple turbidity currents?
only a major event?
no data acquired
cm/sec
Duration (days)
B
Peak Speed Profiles
Event 2= 90.6 cm/sec peak speed
Event 3= 93.1 cm/sec peak spe
Event 6= 98.7 cm/sec peak spe
Event 11= 97.3 cm/sec peak sp
Event 8= 250 cm/sec peak speed
Depth (m)
cm/sec
C
Normalised Time-Velocity Profiles
multiple turbidity currents?
only a major event?
no data acquired
flow velocity/max velocity
Time from begin/flow duration

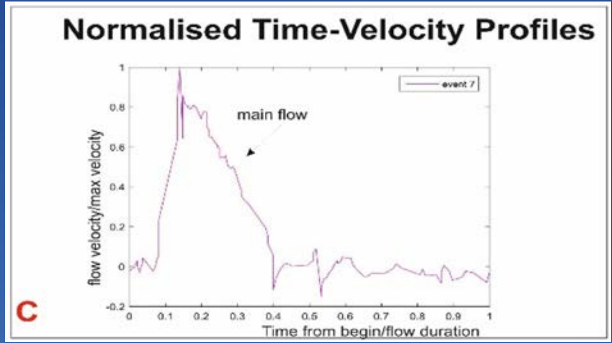

Sawtooth
Near-instantaneous rise, followed by gradually waning flow
Flow velocity (cm/sec)
Near-instantaneous rapid peak in velocity (cm/s)
Gradually waning flow
Sawtooth shaped
Flow duration (days)

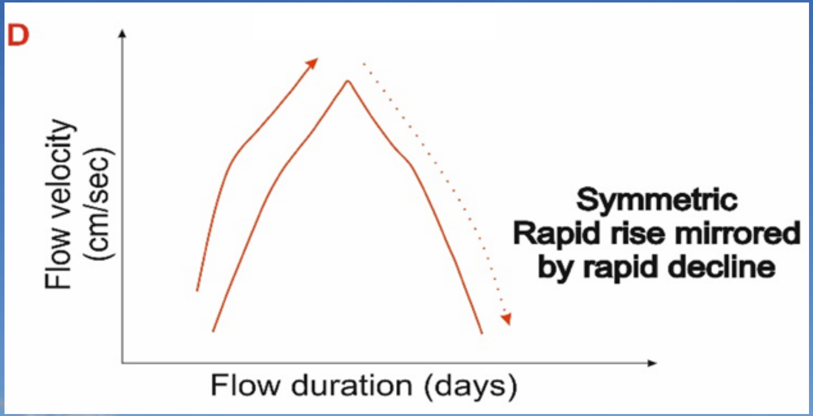
…

TYPE-1 FLOW?


A
Velocity Profiles
Event 7
cm/sec
main flow
Duration (days)

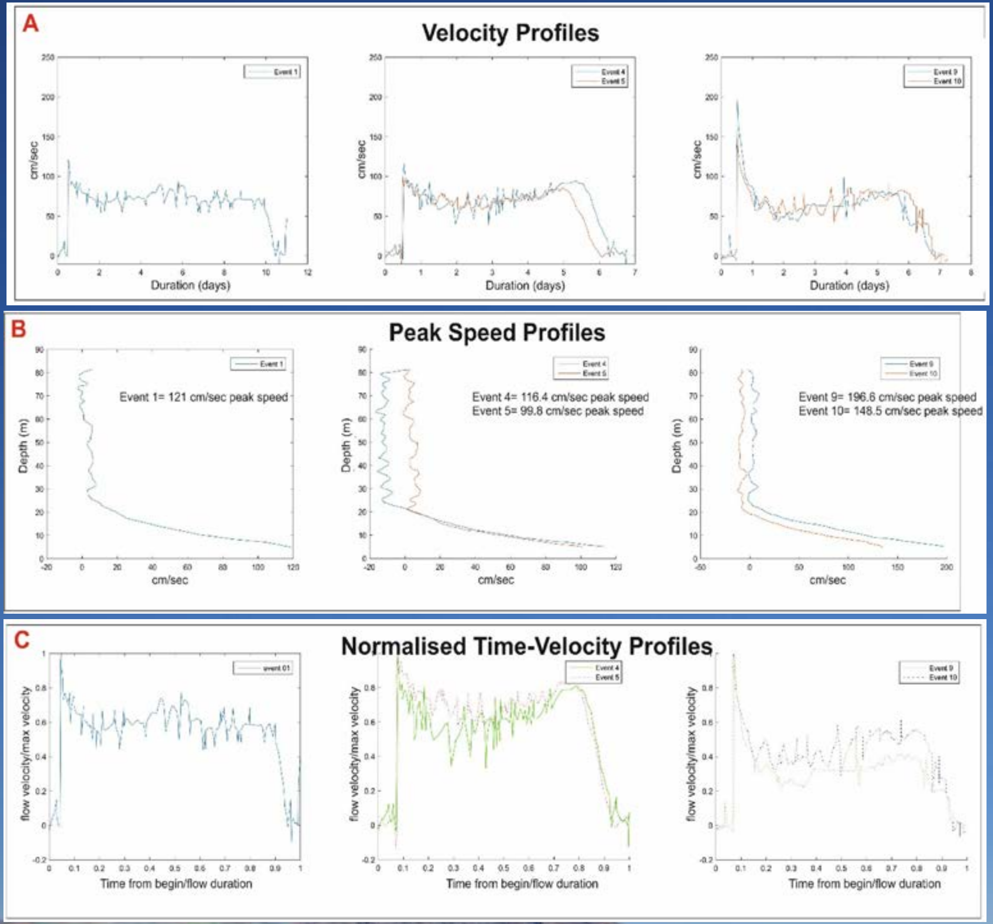

B
Peak Speed Profiles
Event 7
Event 4= 116.4 cm/sec peak speed
Event 5= 99.8 cm/sec peak speed
cm/sec
Duration (days)

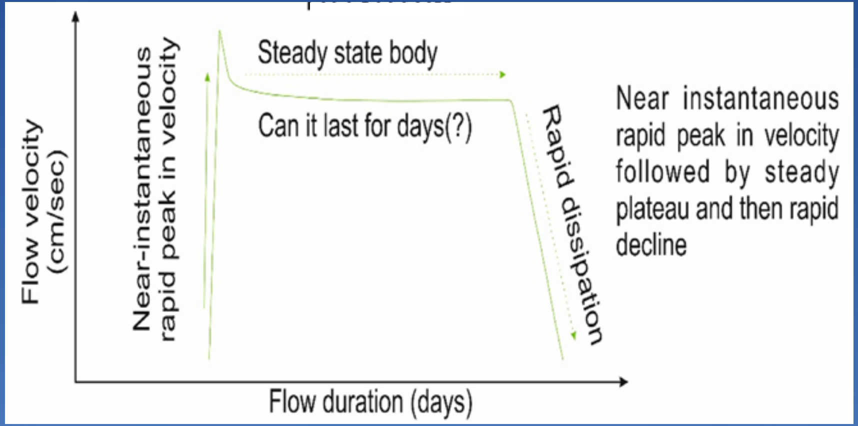

Normalised Time-Velocity Profiles
event 7
main flow
flow velocity/max velocity
C
Time from begin/flow duration


D
Flow velocity (cm/sec)
Symmetric
Rapid rise mirrored by rapid decline
Flow duration (days)

…

TYPE- 2 FLOW?


A
Velocity Profiles
cm/sec
Duration (days)
B
Peak Speed Profiles
Depth (m)
cm/sec
Event 1= 121 cm/sec peak speed
Event 4= 116.4 cm/sec peak speed
Event 5= 99.8 cm/sec peak speed
Event 9= 196.6 cm/sec peak speed
Event 10= 148.5 cm/sec peak speed
C
Normalised Time-Velocity Profiles
flow velocity/max velocity
Time from begin/flow duration

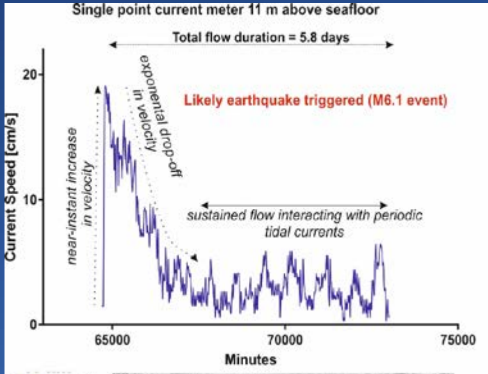

Flow velocity (cm/sec)
Near-instantaneous rapid peak in velocity
Steady state body
Can it last for days(?)
Rapid dissipation
Flow duration (days)
Near instantaneous rapid peak in velocity followed by steady plateau and then rapid decline

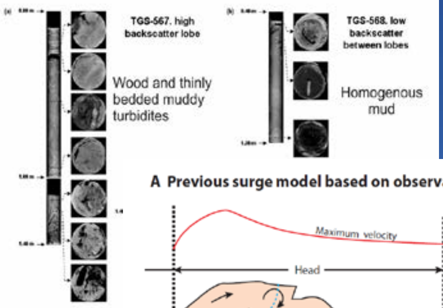
...

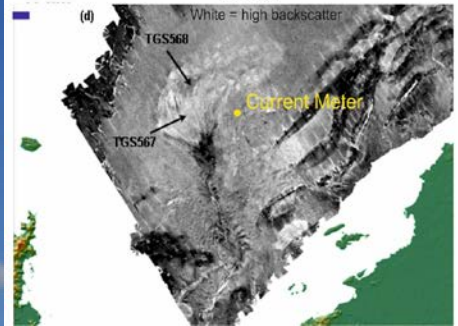
TYPE- 3 FLOW?

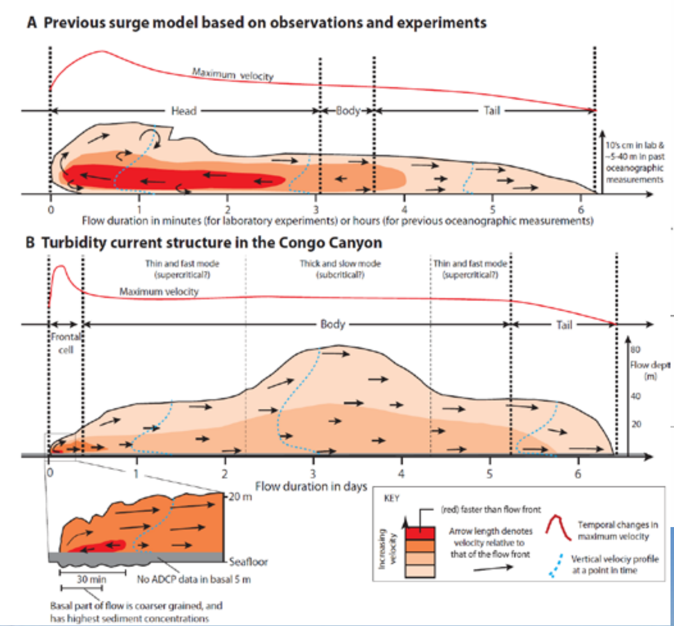
West Papua: non-normalised plot

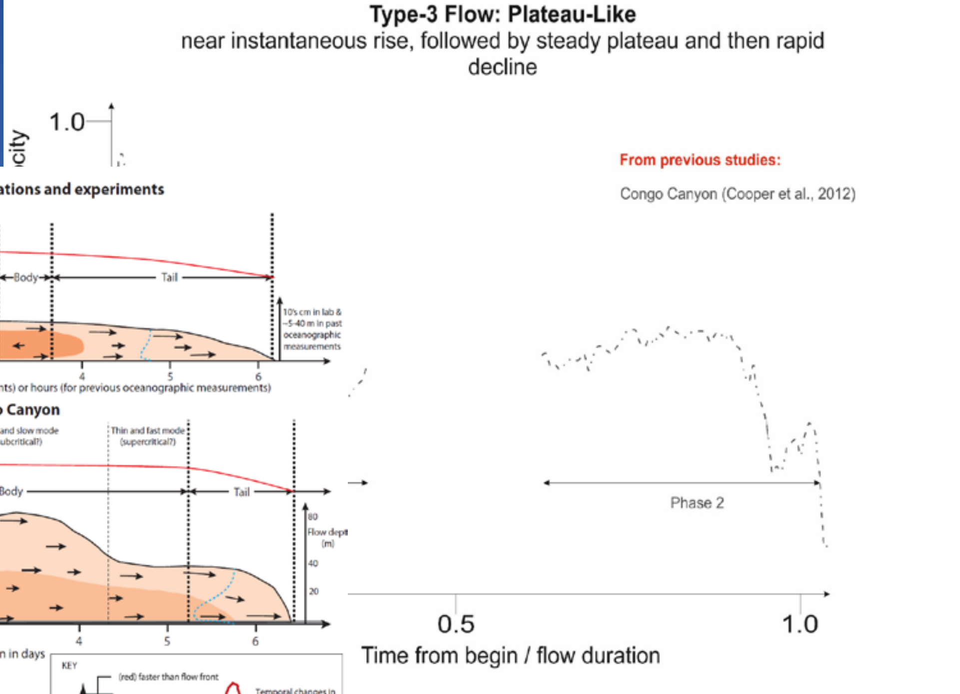
…any *similarities*?











1) instantaneous trigger
2) dominantly muddy system

may validate flow-stretching hypothesis?

- Non-normalised vs normalised time-velocity at different locations worldwide for different settings

- canyons with coarse axial sediments (<10% mud) and thought to by oceanically triggered;
- canyons directly linked to hyperpycnal rivers where sediments comprise mud and sand in different percentage;
- canyons linked to rivers, but not directly fed by sediment-laden river water.

- triggering mechanism of turbidity currents;
- grain size of the deposits transported by turbidity currents;
- thickness, velocity and density of turbidity currents.


Thank you!
DPI