SQL & DataFrames

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Google Cloud

Agenda

Course Intro

Beam Concepts Review

Windows, Watermarks, and Triggers

Sources and Sinks

Schemas

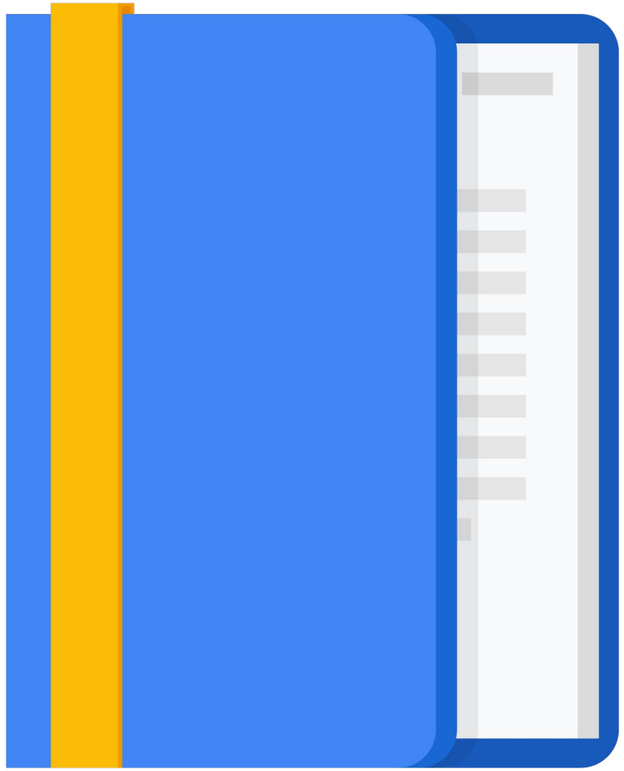
State and Timers

Best Practices

SQL and DataFrames

Beam Notebooks

Summary



SQL and DataFrames

Agenda

Dataflow and Beam SQL

Windowing in SQL

Beam DataFrames

Schemas+SQL to the rescue!

By understanding the structure of a pipeline's records,
we can provide much more concise APIs for data processing.

What is SQL?

- SQL is a domain-specific language used in:
  - RDBMS
  - Stream processing

```
SELECT SUM(foo) AS baz, end_of_window
FROM my_topic WHERE something_is_true(bizzle)
GROUP BY TUMBLING(timestamp, 1 HOUR)
HAVING baz > my_magic_number LIMIT 3;
```

What is SQL?

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- Relational algebra:
  - Projection
  - Filter
  - Aggregation

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What is SQL?

- SQL is a domain-specific language used in:
  - RDBMS
  - Stream processing
- Relational algebra:
  - Projection
  - Filter
  - Aggregation
- Syntax to operate on nested structures.

```
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FROM my_topic WHERE something_is_true(bizzle)
GROUP BY TUMBLING(timestamp, 1 HOUR)
HAVING baz > my_magic_number LIMIT 3;
```

A join in Java

```
package org.apache.beam.examples.cookbook;

import com.google.api.services.bigquery.model.TableRow;
...


public class JoinExamples {

 /** Join two collections, using country code as the key. */
 static PCollection<String> joinEvents(
   PCollection<TableRow> eventsTable, PCollection<TableRow> countryCodes) throws
Exception {

  final TupleTag<String> eventInfoTag = new TupleTag<>();
  final TupleTag<String> countryInfoTag = new TupleTag<>();

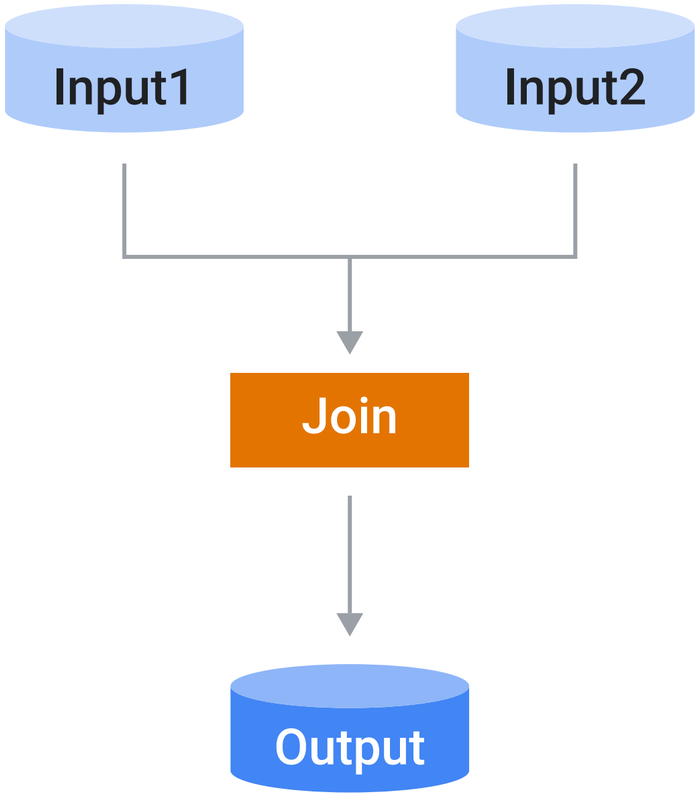
  // transform both input collections to tuple collections, where the keys are
country
  // codes in both cases.
  PCollection<KV<String, String>> eventInfo = eventsTable.apply(ParDo.of(new
ExtractEventDataFn()));
  PCollection<KV<String, String>> countryInfo = countryCodes.apply(ParDo.of(new
ExtractCountryInfoFn()));

  // country code 'key' -> CGBKR (<event info>, <country name>)
  PCollection<KV<String, CoGbkResult>> kvpCollection =
    KeyedPCollectionTuple.of(eventInfoTag, eventInfo)
      .and(countryInfoTag, countryInfo)
      .apply(CoGroupByKey.create());

  // Process the CoGbkResult elements generated by the CoGroupByKey transform.
  // country code 'key' -> string of <event info>, <country name>
  PCollection<KV<String, String>> finalResultCollection =
    kvpCollection.apply("Process",
      ParDo.of(
        new DoFn<KV<String, CoGbkResult>, KV<String, String>>() {
         @ProcessElement
         public void processElement(ProcessContext c) {
          KV<String, CoGbkResult> e = c.element();
          String countryCode = e.getKey();
          String countryName = "none";
          countryName = e.getValue().getOnly(countryInfoTag);
          for (String eventInfo : c.element().getValue().getAll(eventInfoTag)) {
           // Generate a string that combines information from both collection
values
           c.output(KV.of(countryCode,"Country name: " + countryName + ", Event
info: " + eventInfo));
          }
         }
        }));
```

```
  // write to GCS
  PCollection<String> formattedResults =
    finalResultCollection.apply("Format",
      ParDo.of(
        new DoFn<KV<String, String>, String>() {
         @ProcessElement
         public void processElement(ProcessContext c) {
          String outputstring = "Country code: " + c.element().getKey() + ", " +
c.element().getValue();
          c.output(outputstring);
         }
        }));
  return formattedResults;
 }

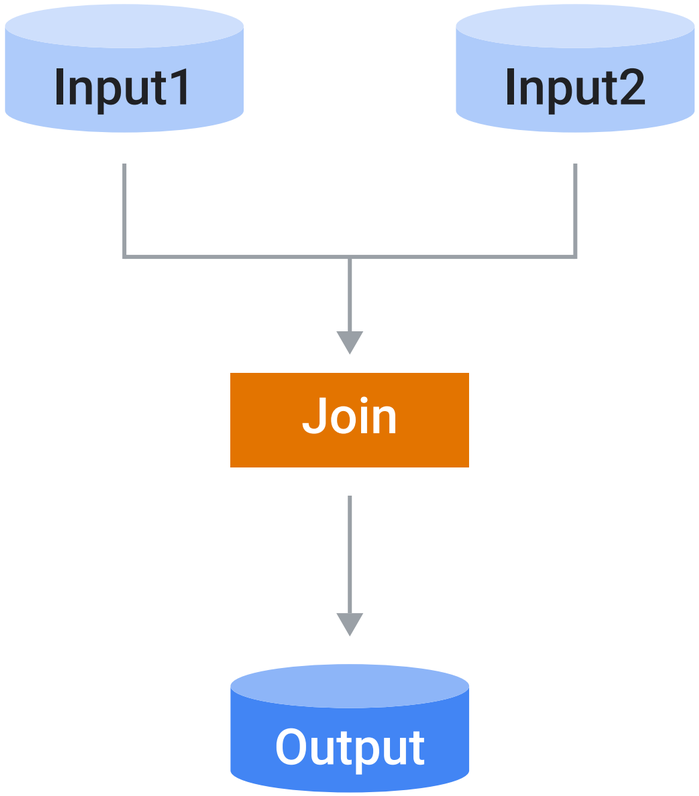
 ...
 public static void main(String[] args) throws Exception {
  Options options =
PipelineOptionsFactory.fromArgs(args).withValidation().as(Options.class);
  Pipeline p = Pipeline.create(options);
  // the following two 'applys' create multiple inputs to our pipeline, one for
each
  // of our two input sources.
  PCollection<TableRow> eventsTable =
    p.apply(BigQueryIO.readTableRows().from(GDELT_EVENTS_TABLE));
  PCollection<TableRow> countryCodes =
p.apply(BigQueryIO.readTableRows().from(COUNTRY_CODES));
  PCollection<String> formattedResults = joinEvents(eventsTable, countryCodes);
  formattedResults.apply(TextIO.write().to(options.getOutput()));
  p.run().waitUntilFinish();
 }
}
```



A join in Scala (using Scio)

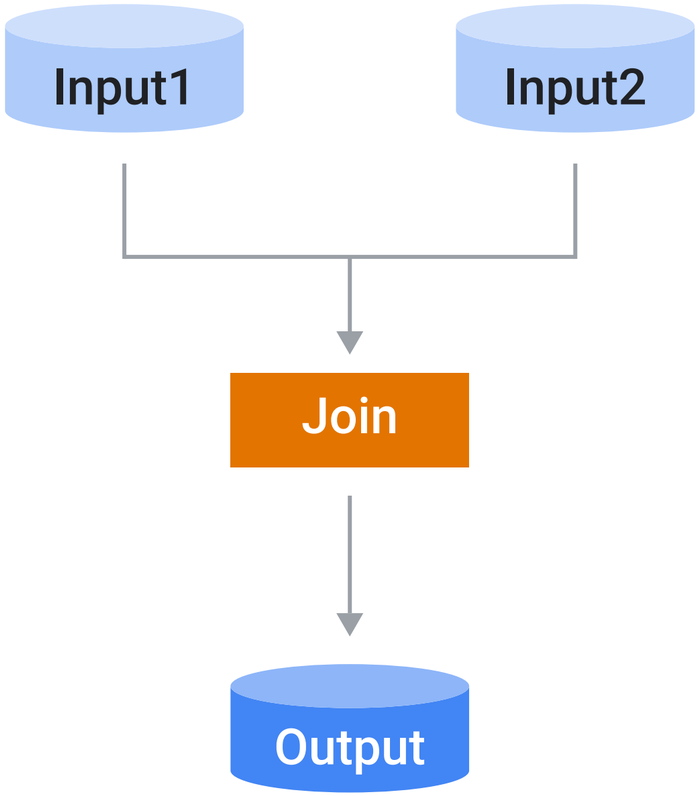
```
import com.spotify.scio._

object Join {
 def readInput(sc: ScioContext, path: String) = {
  val KeyLen = 10
  sc.textFile(path)
   .map((x: String) => (x.substring(0,KeyLen),
x.substring(KeyLen)))
 }
 def main(cmdlineArgs: Array[String]): Unit = {
  val (sc, args) = ContextAndArgs(cmdlineArgs)
  val left = readInput(sc, args("input1"))
  val right = readInput(sc, args("input2"))
  left.leftOuterJoin(right).saveAsTextFile(args("output"))
  sc.close()
 }
}
```



Why SQL?

```
SELECT input1.*, input2.*
FROM input1 LEFT OUTER JOIN input2
   ON input1.Id = input2.Id
```



SQL—Translated to PTransform

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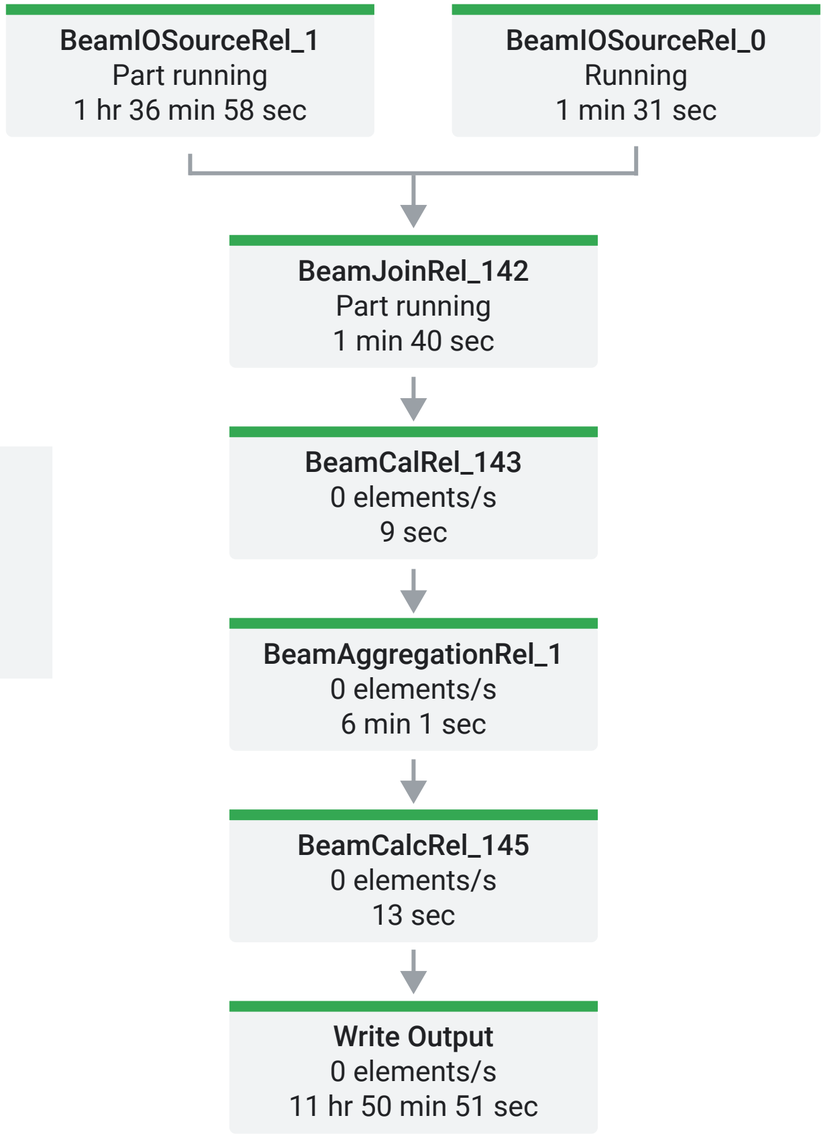


Explaining components

Input	Input	Input
BigQuery UI	Analytical queries over historical data	Data analyst

Explaining components

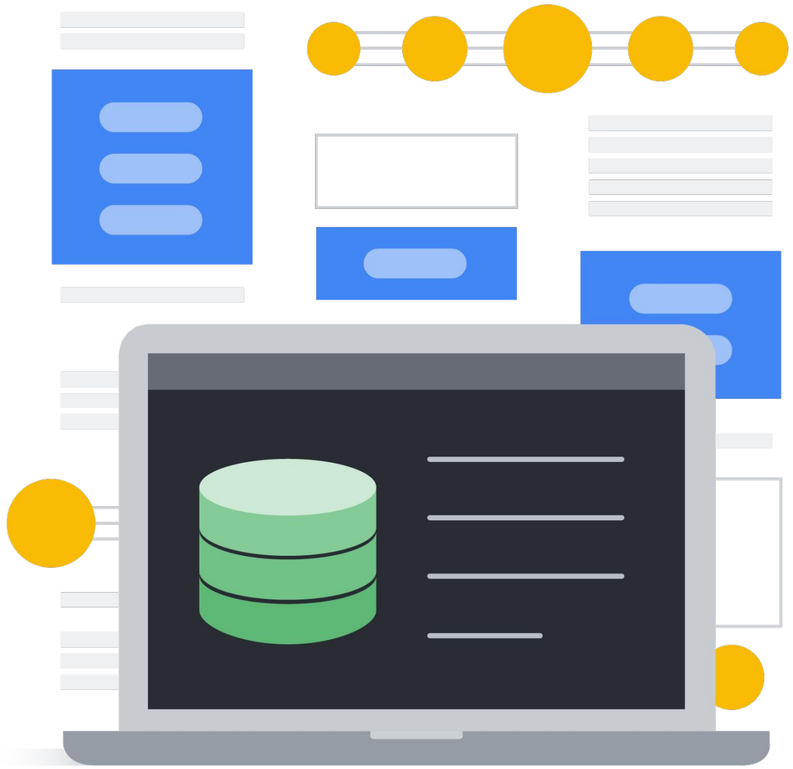
Input	Input	Input
BigQuery UI	Analytical queries over historical data	Data analyst
Dataflow SQL UI	**Analytical queries over real-time data**	**Data analyst**

Explaining components

Input	Input	Input
BigQuery UI	Analytical queries over historical data	Data analyst
Dataflow SQL UI	Analytical queries over real-time data	Data analyst
Beam SQL	**Integrating SQL within a Beam pipeline**	**Data engineer**

Beam SQL

- Works with stream and batch inputs.



Beam SQL

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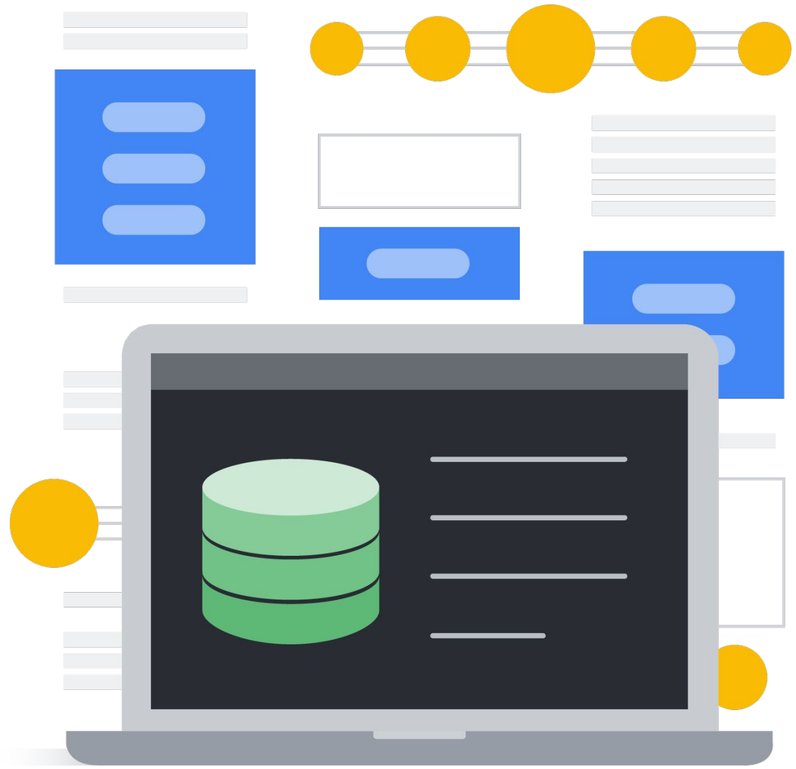
- Can be embedded in an existing pipeline using SqlTransform, which can be mixed with PTransforms.



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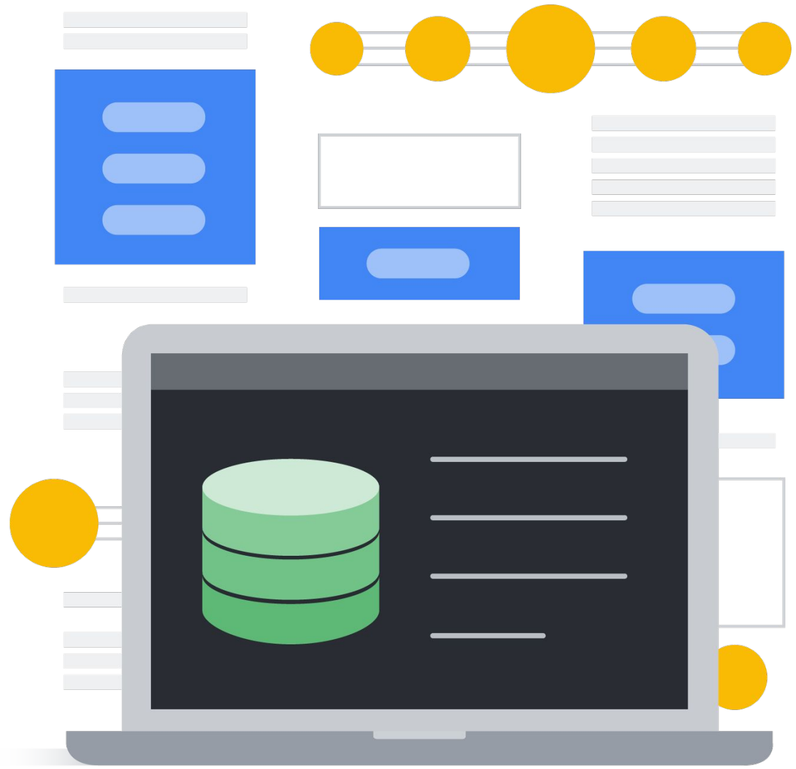

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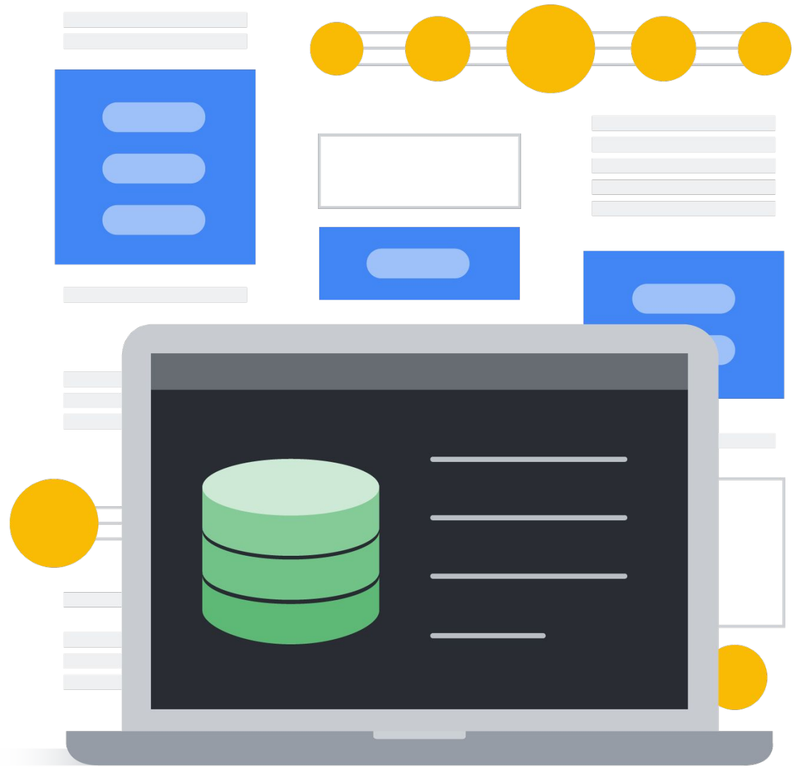
- Supports UDFs in Java.
- Supports multiple dialects
  - Beam Calcite SQL
  - Google ZetaSQL



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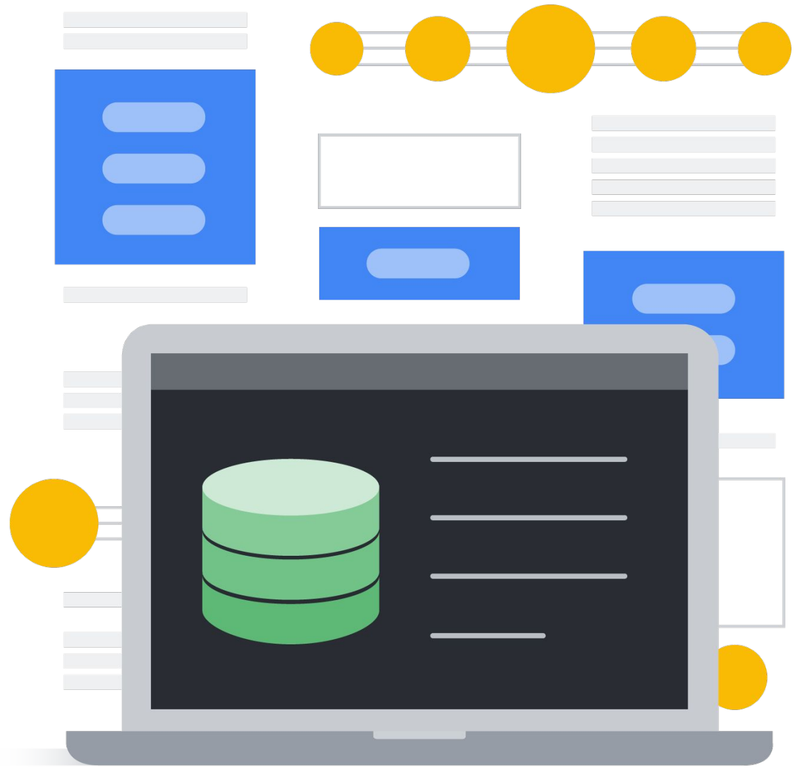
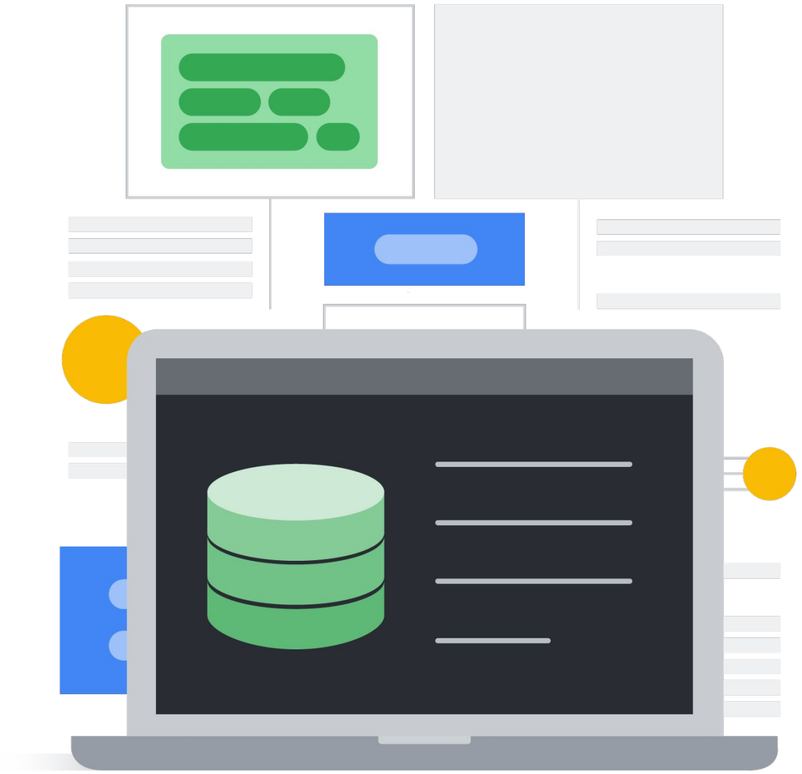
- Integrates with Schemas
  - Uses Row
- Stream aggregations support windows.



Beam SQL dialects

Apache Calcite

- Provides compatibility with other OSS SQL dialects (e.g. Flink SQL)
  - Copy-paste queries may require changes to table names, array indexing
- More mature implementation
  - Supports Java UDFs



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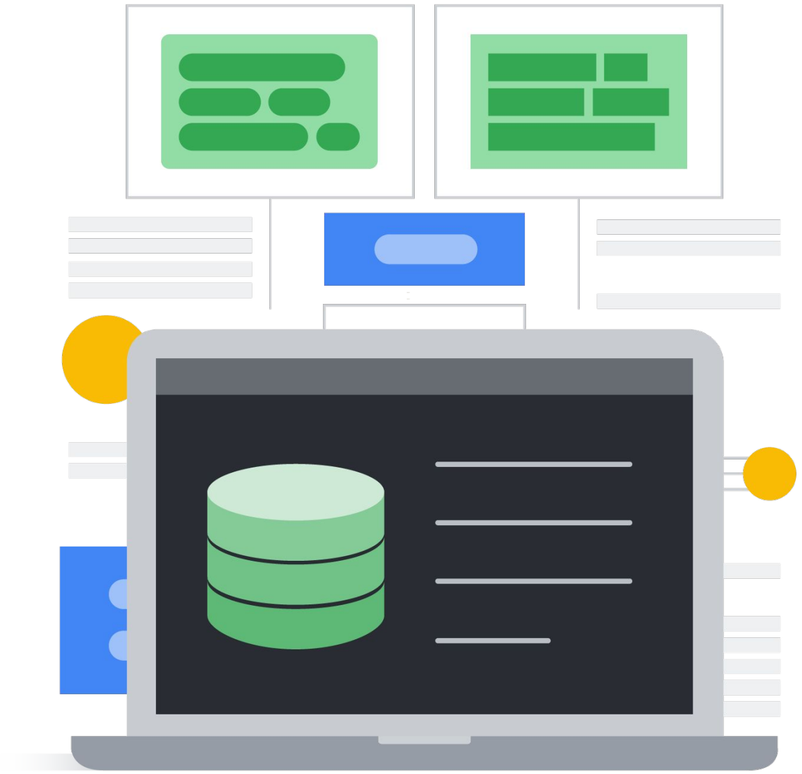
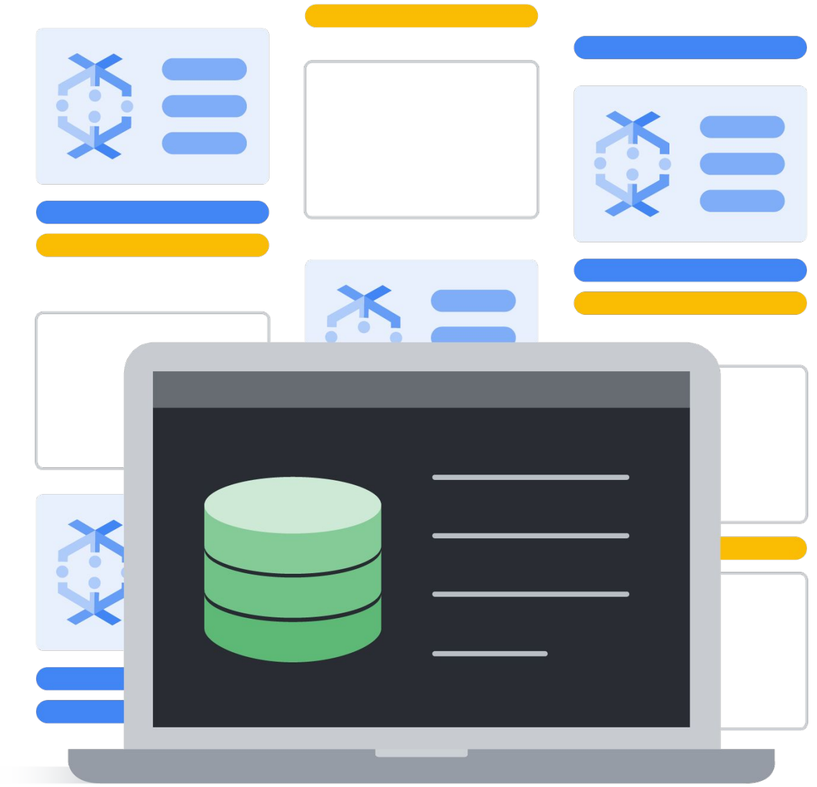
ZetaSQL

- Provides BigQuery compatibility
  - Copy-paste queries may require changes to table names



Dataflow SQL

- It’s a Beam ZetaSQL SqlTransform in a Dataflow Flex Template!



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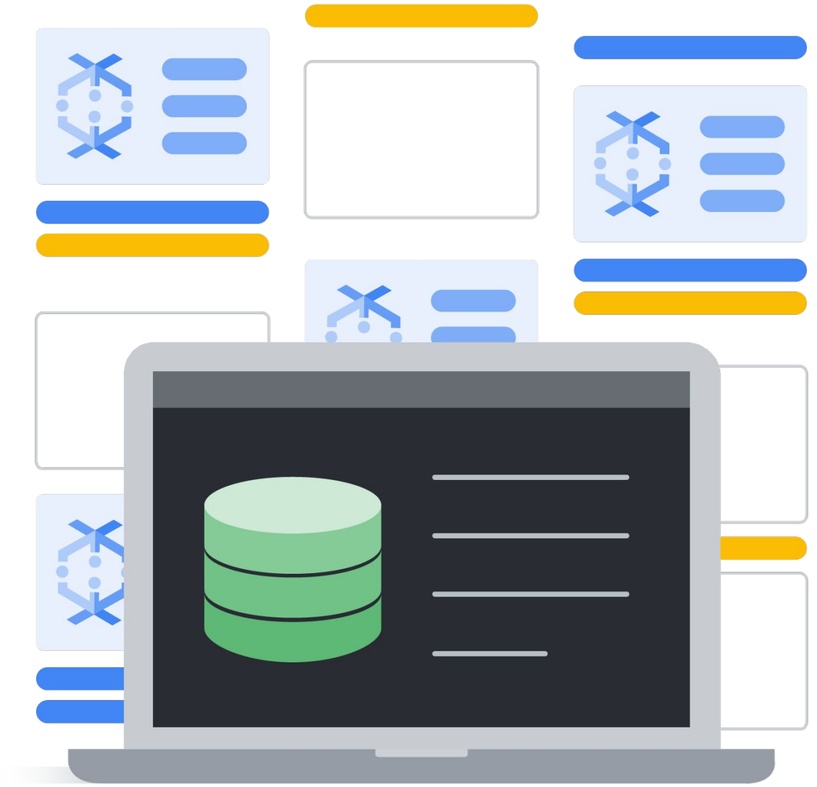
- Write Dataflow SQL queries in the BigQuery UI or gcloud CLI.



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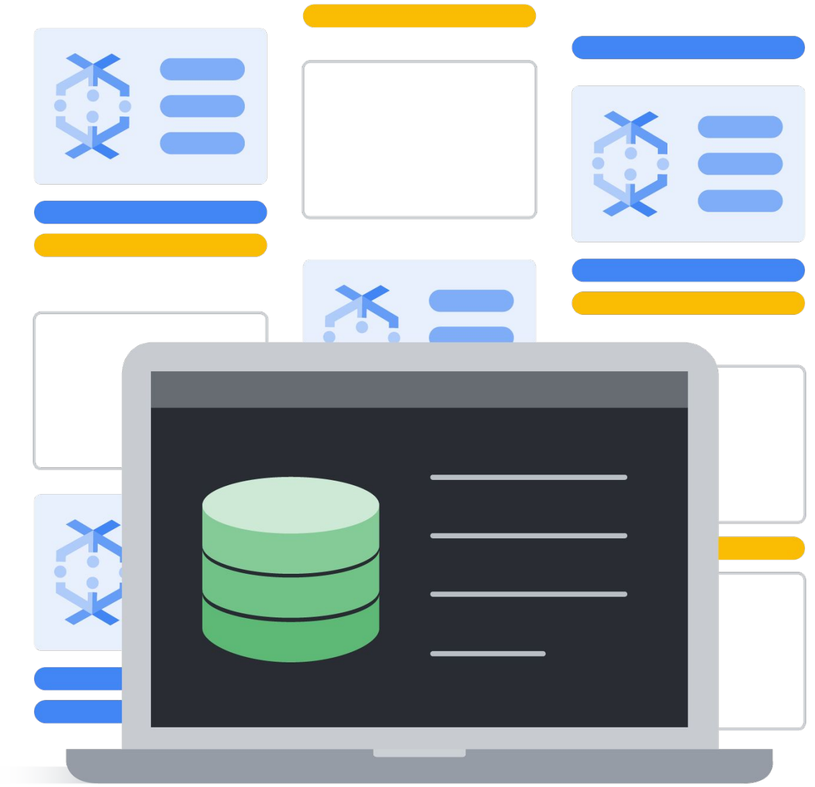

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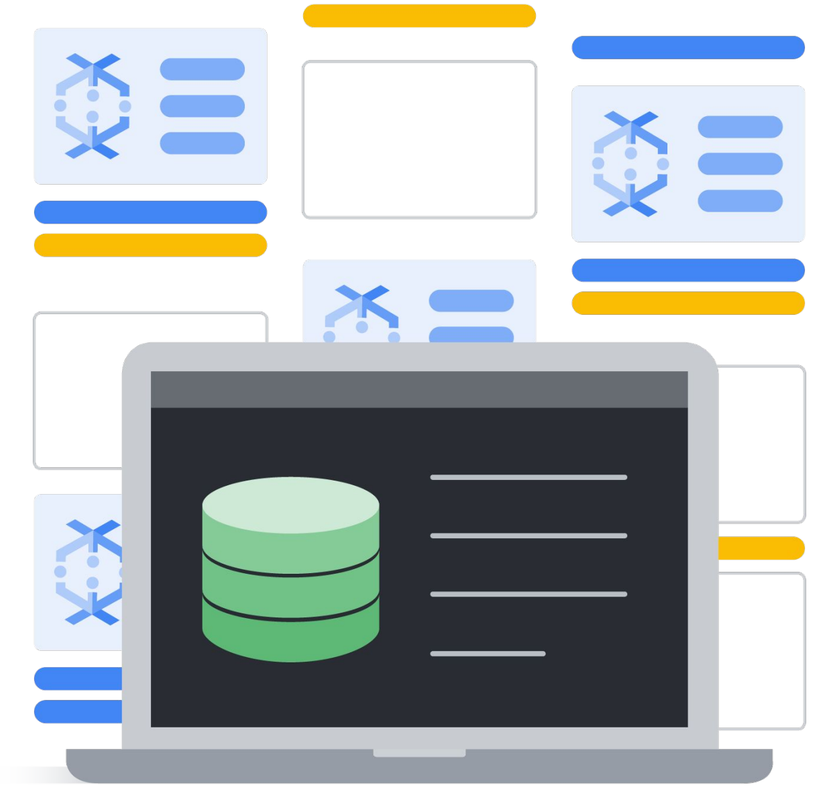
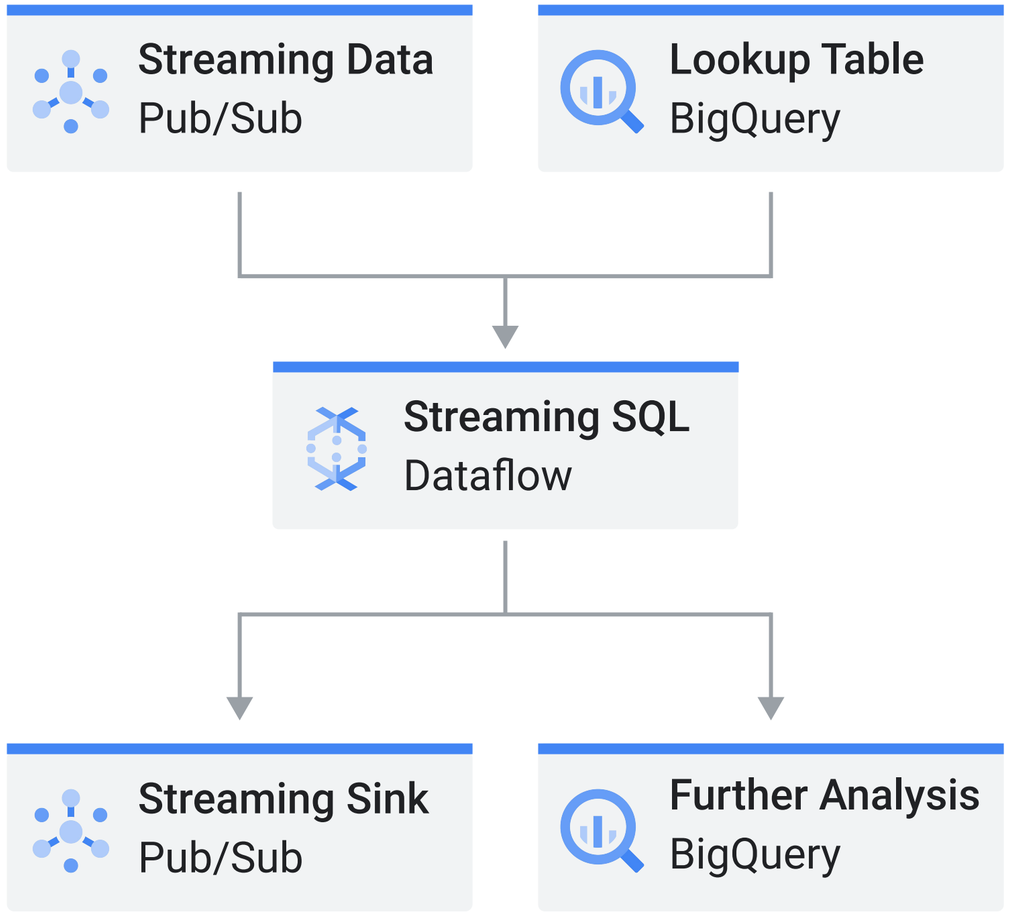
- Write Dataflow SQL queries in the BigQuery UI or gcloud CLI.
- Uses ZetaSQL, the same dialect as BigQuery Standard SQL.
- Optional engine for long running batch jobs.



Dataflow SQL

Streaming pipelines made easy

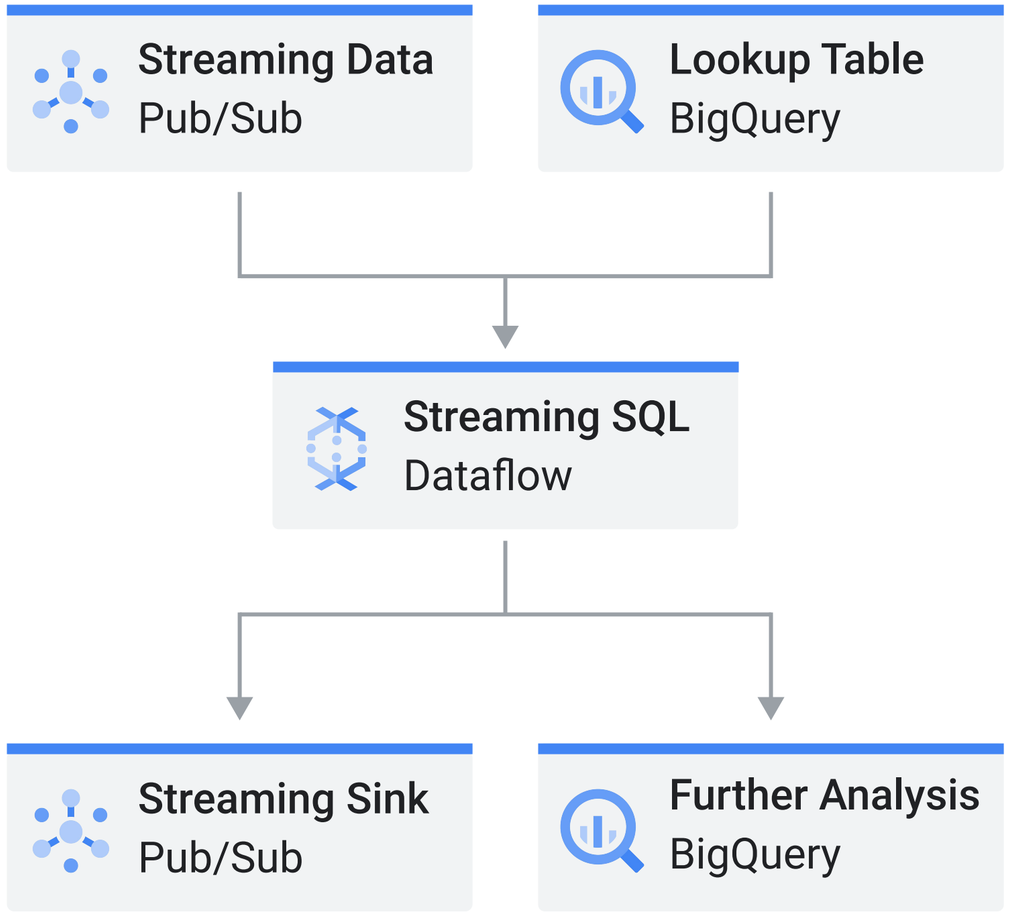
- Target of Dataflow SQL!



Dataflow SQL

Streaming pipelines made easy

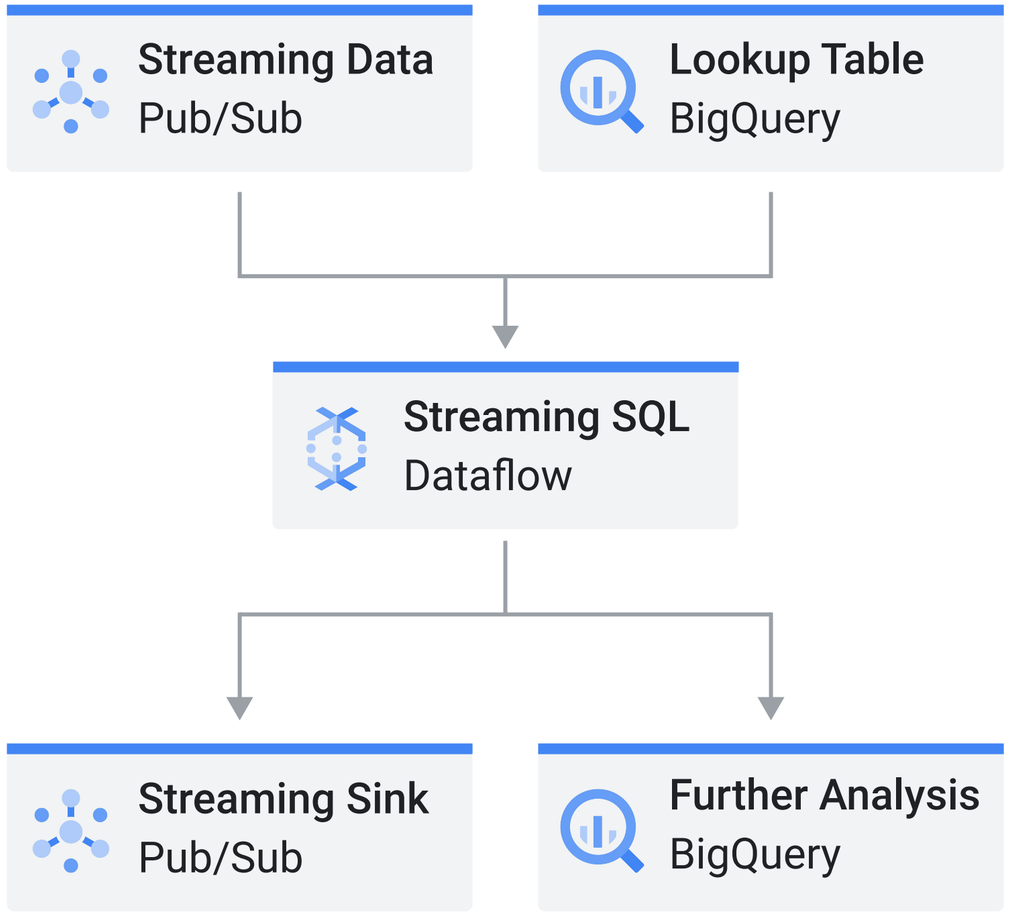
- Target of Dataflow SQL!
- An example use case would:
  - Select from PubSub
  - Join with batch data
  - Aggregate over Window
  - Publish to BigQuery or PubSub



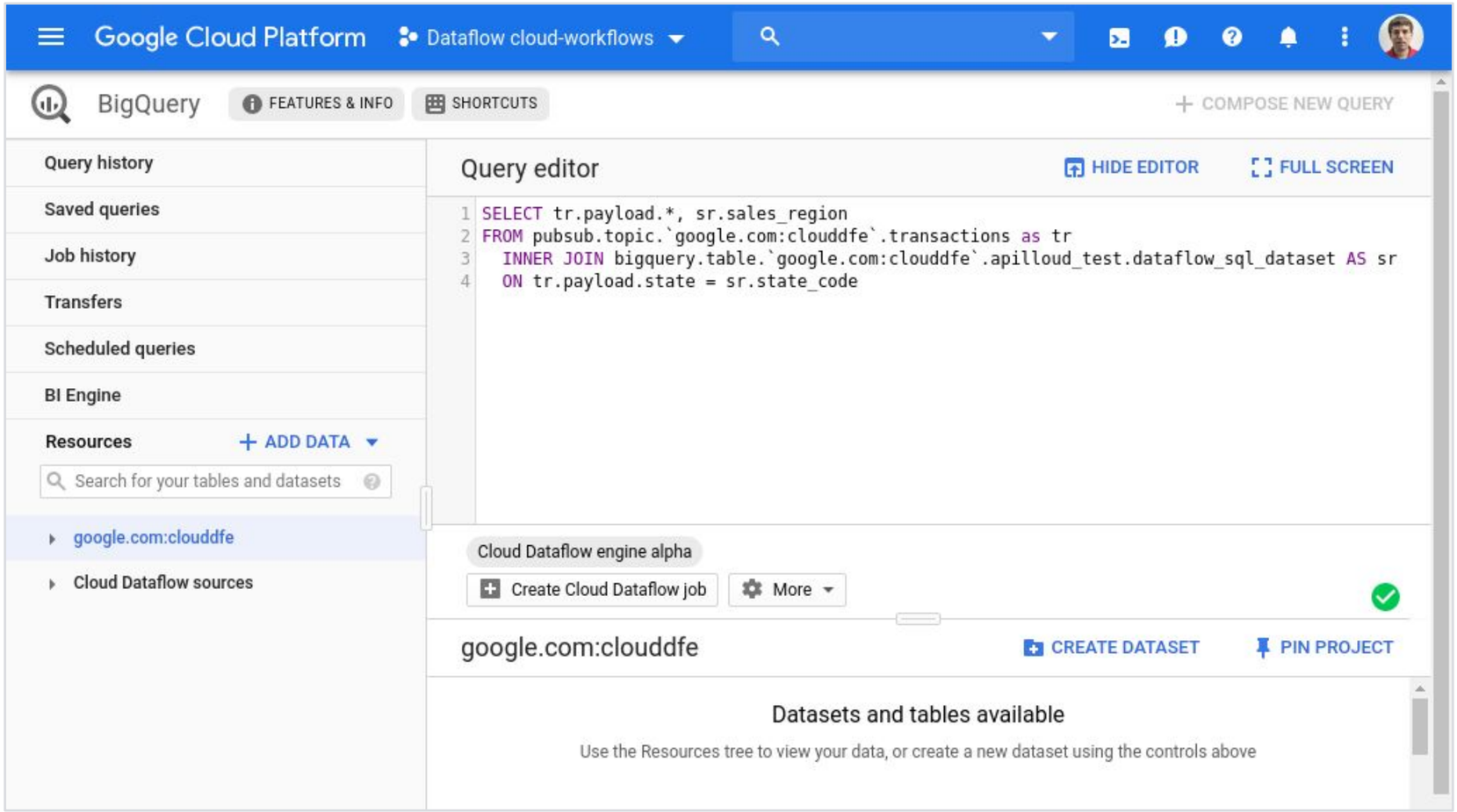
Dataflow SQL

Streaming pipelines made easy

- Target of Dataflow SQL!
- An example use case would:
  - Select from PubSub
  - Join with batch data
  - Aggregate over Window
  - Publish to BigQuery or PubSub
- Open framework with more connectors coming like Kafka and Bigtable.



Dataflow SQL UI



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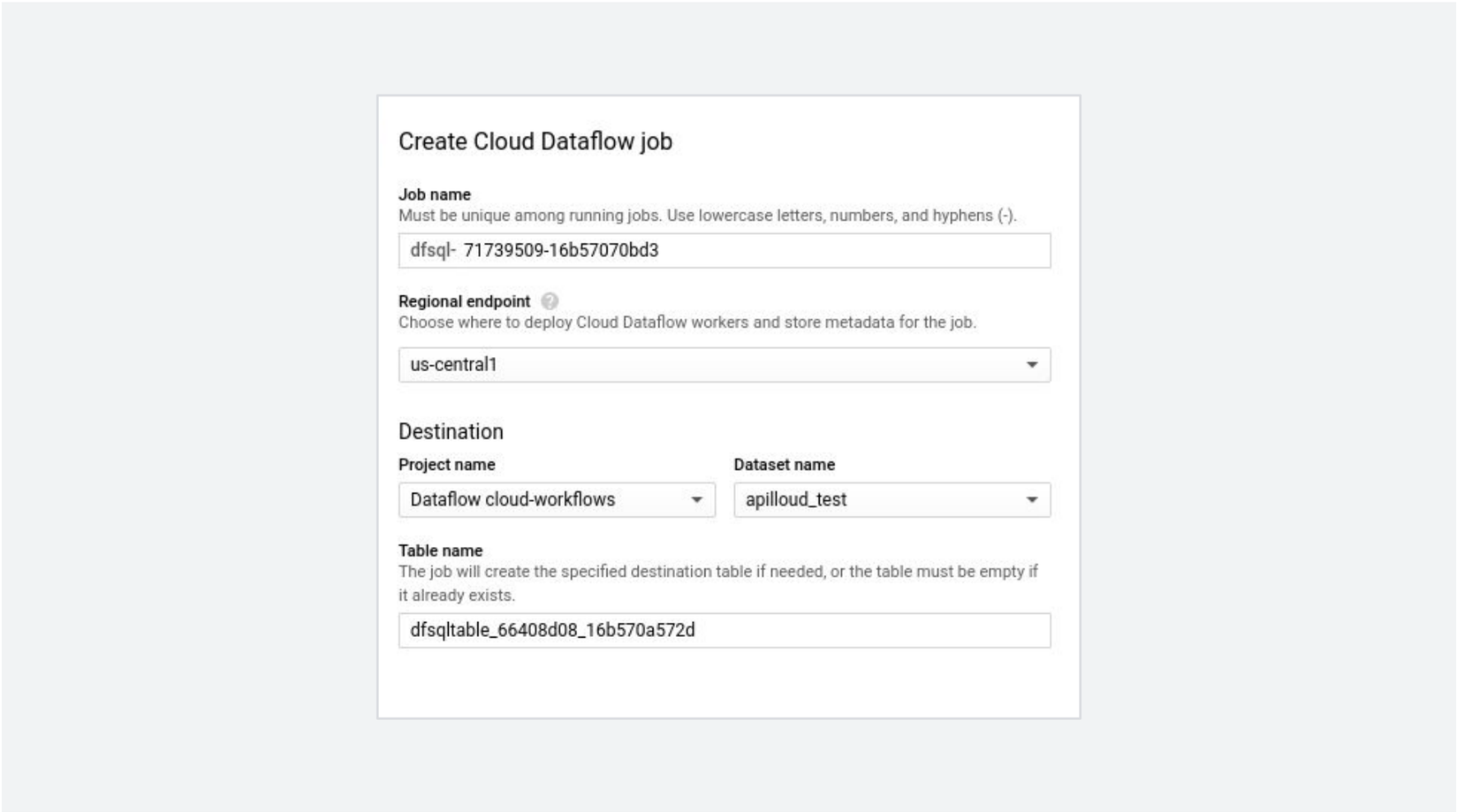

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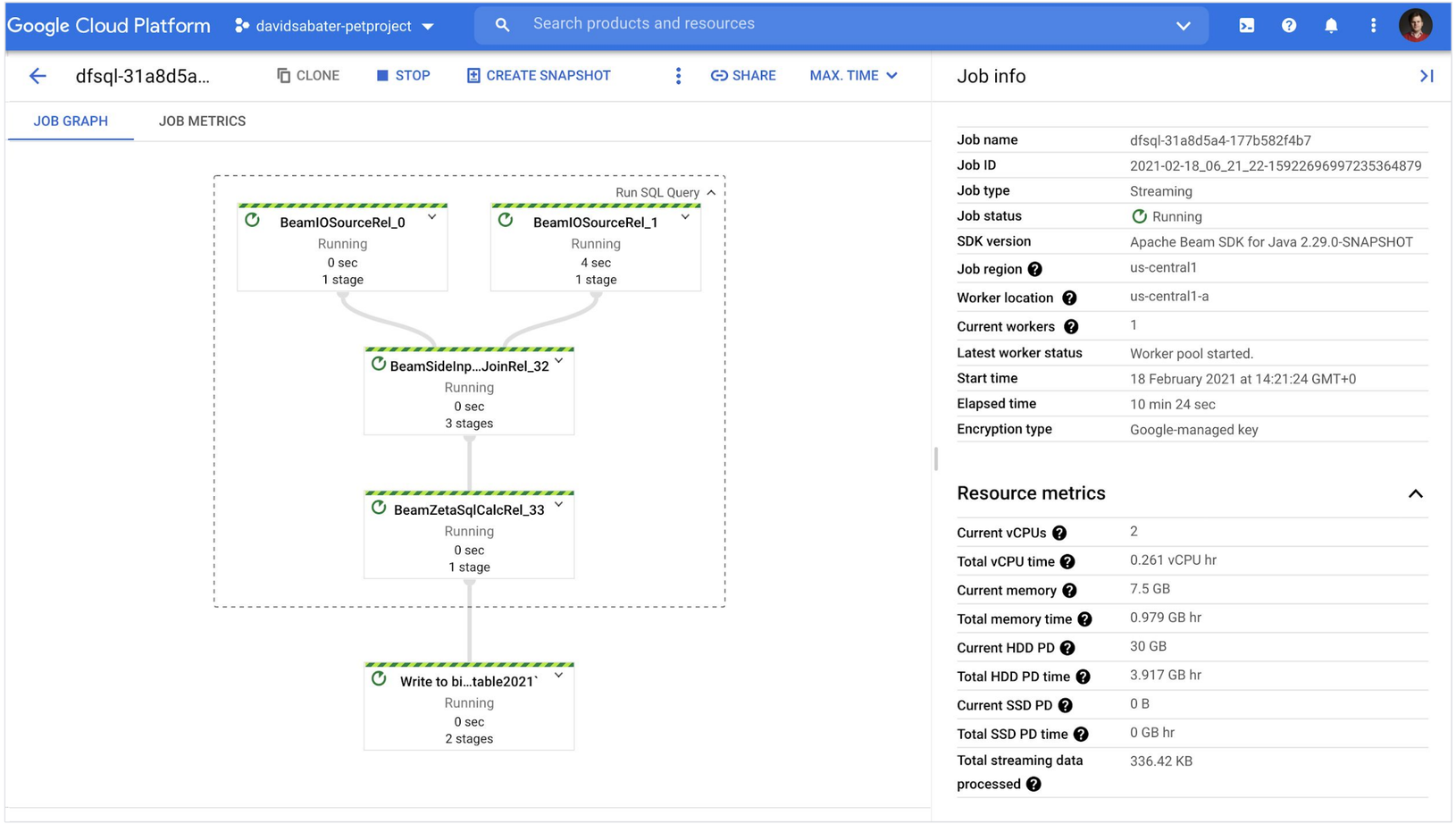


Dataflow SQL CLI

```
$ gcloud dataflow sql query ‘SELECT SUM(foo) AS baz, end_of_window
         FROM my_topic WHERE something_is_true(bizzle)
         GROUP BY TUMBLING(timestamp, 1 HOUR)’
```

Using SQL statements within existing pipelines

```
//run a simple query, and register the output as a table in BeamSql;
 String sql1 = "select MY_FUNC(c1), c2 from PCOLLECTION";
 PCollection<Row> outputTableA = inputTableA.apply(
    SqlTransform
        .query(sql1)
        .addUdf("MY_FUNC", MY_FUNC.class, "FUNC");
```

Dataflow SQL template

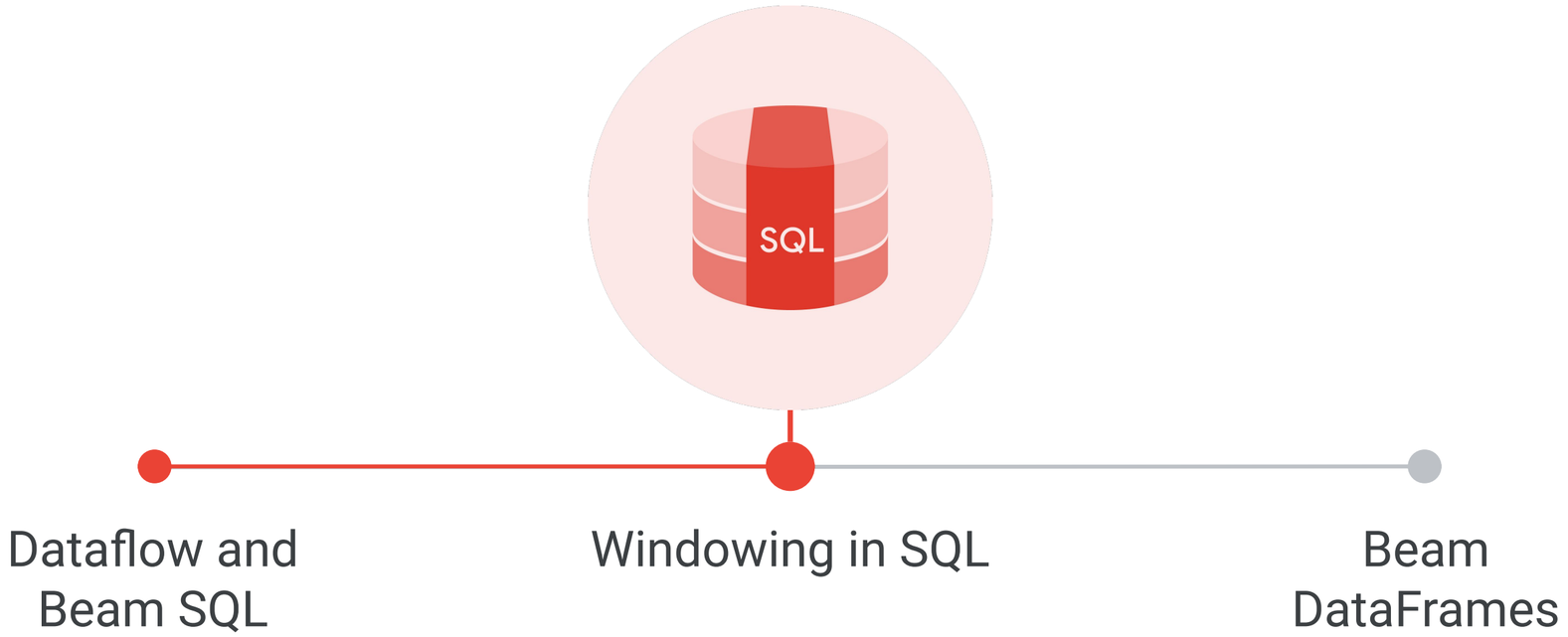
```
/** A simplification of the Dataflow SQL template. */
Pipeline pipeline = Pipeline.create(options);

DataCatalogTableProvider tableProvider =
  DataCatalogTableProvider.create(options);

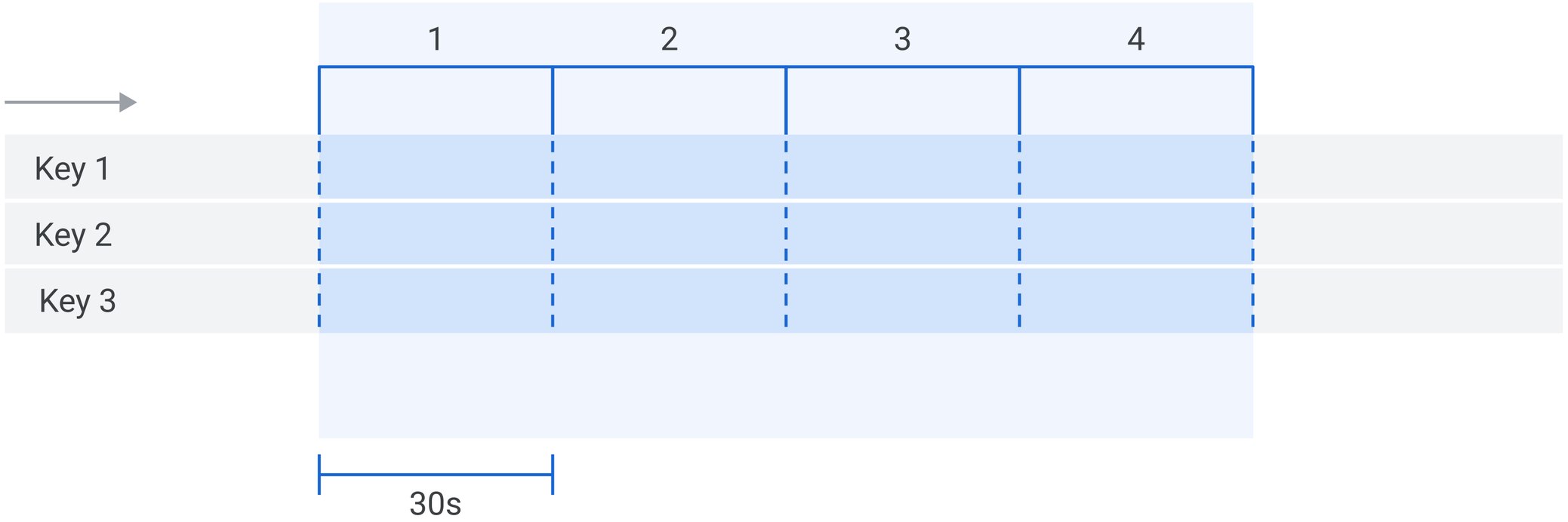
SqlTransform queryResult =
  p.apply(SqlTransform.query(options.getQueryString())
   .withDefaultTableProvider(tableProvider));
for (Output output : options.getOutputs()) {
  queryResult.apply(createSink(output, tableProvider));
}
pipeline.run();
```

Dataflow SQL and DataFrames

Agenda



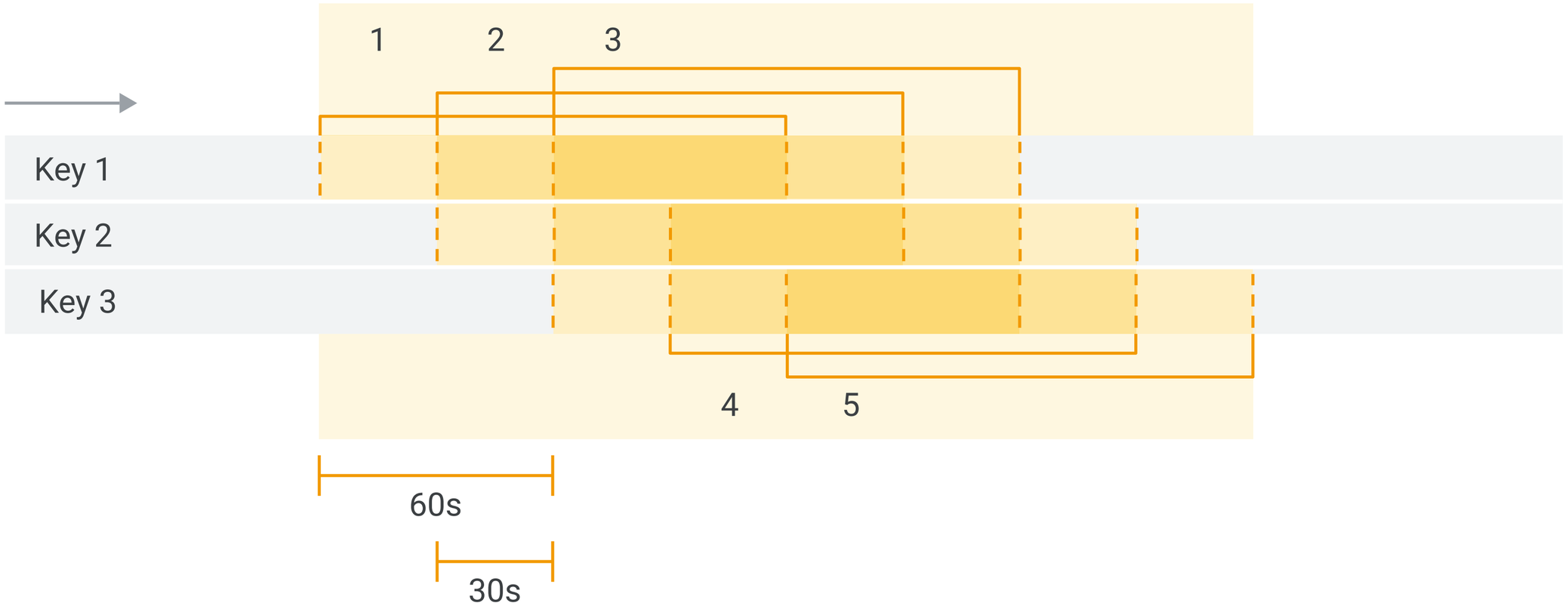
Windows—Tumbling windows (fixed windows)



Use case: Total purchases per product

```
SELECT productId,
TUMBLE_START("INTERVAL 10 SECOND") as period_start,COUNT(transactionId)
AS num_purchases
FROM pubsub.topic.`instant-insights`.`retaildemo-online-purchases-json`
AS pr
GROUP BY productId,
         TUMBLE(pr.event_timestamp, "INTERVAL 10 SECOND")
```

Windows—Hopping windows (sliding windows)



Use case: Total purchases per product

```
SELECT productId,
       HOP_START("INTERVAL 10 SECOND",
                 "INTERVAL 30 SECOND") as period_start,
       HOP_END("INTERVAL 10 SECOND",
                "INTERVAL 30 SECOND") as period_end,
       COUNT(transactionId) AS num_purchases
FROM pubsub.topic.`instant-insights`.`retaildemo-online-purchases-json`
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GROUP BY productId,
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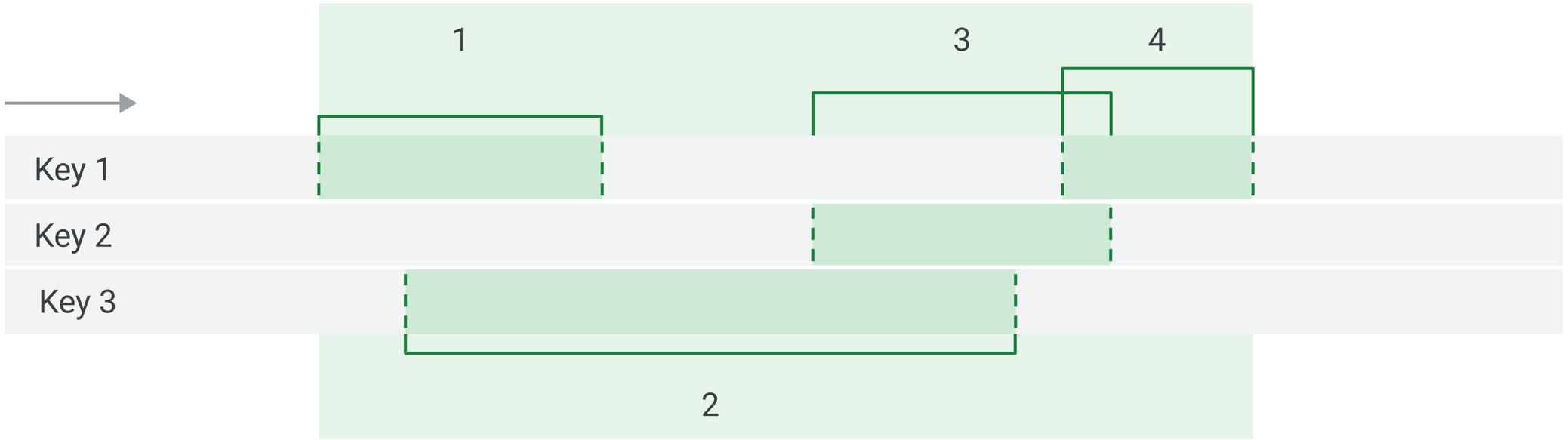
             "INTERVAL 10 SECOND",
             "INTERVAL 30 SECOND")
```

Windows—Session windows



Use case: Transactions per user session

```
SELECT userId,
       SESSION_START("INTERVAL 10 MINUTE") AS interval_start,
       SESSION_END("INTERVAL 10 MINUTE") AS interval_end ,
       COUNT(transactionId) AS num_transactions
FROM pubsub.topic.`instant-insights`.`retaildemo-online-purchases-json`
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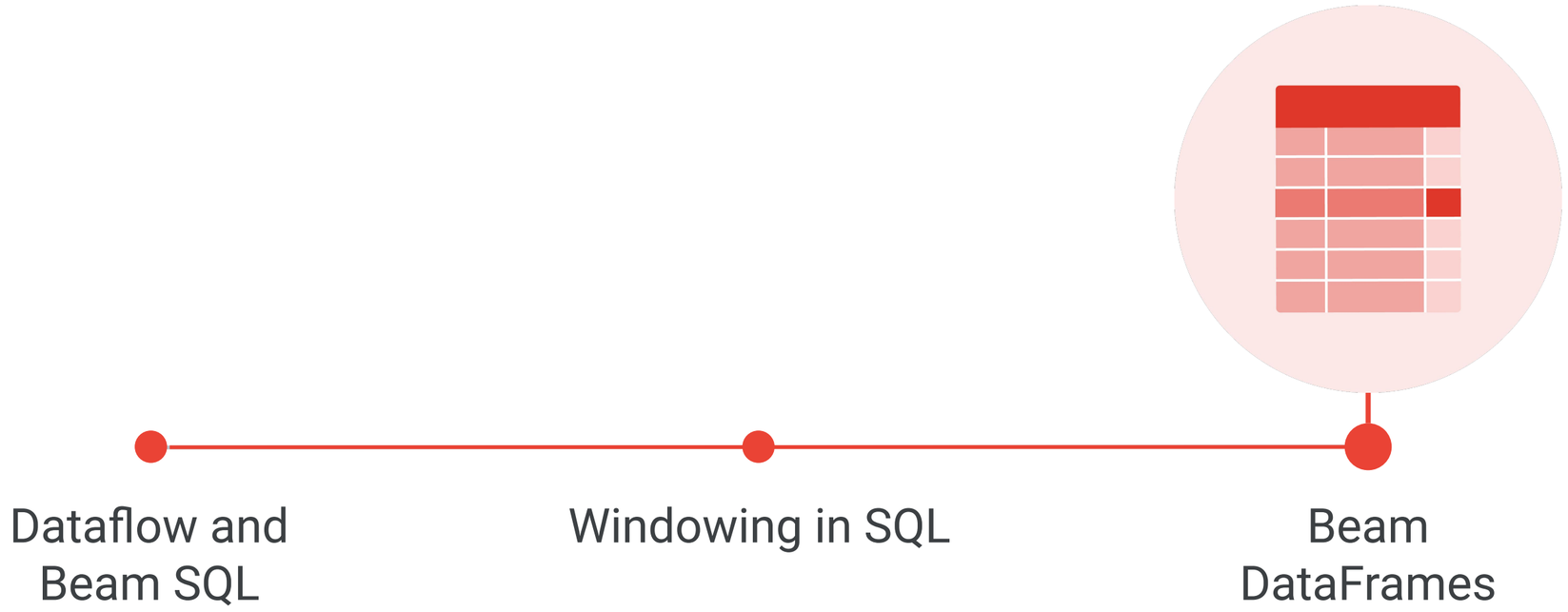
```

Dataflow SQL and DataFrames

Agenda



Beam DataFrames overview

- A more Pythonic expressive API compatible with Pandas DataFrames.

recipe	fruit	quantity	unit_cost
pie	strawberry	3	$1.50
pie	raspberry	1	$3.50
pie	blackberry	1	$4.00
pie	blueberry	2	$2.00
muffin	banana	3	$2.00
muffin	blueberry	2	$2.00

recipe	is_berry	total_quantity	total_price
pie	True	7	$16.00
muffin	False	3	$6.00
muffin	True	2	$4.00

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- Parallel processing with Beam model.

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- Think of Beam DataFrames as a domain-specific language (DSL) for Beam pipelines.

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Beam DataFrames overview

- A more Pythonic expressive API compatible with Pandas DataFrames.
- Parallel processing with Beam model.
- Think of Beam DataFrames as a domain-specific language (DSL) for Beam pipelines.
- Provides access to familiar programming interfaces within a Beam pipeline.

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recipe	is_berry	total_quantity	total_price
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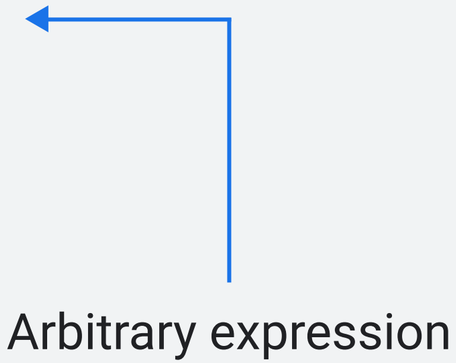
Using DataFrames—GroupBy

```
pc = p | beam.Create(['strawberry', 'raspberry', 'blackberry',
                      'blueberry', 'banana'])

pc | GroupBy(lambda name: name[0])
```



Using DataFrames—GroupBy

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pc | GroupBy(lambda name: name[0])
```

```
('s', ['strawberry'])
('r', ['raspberry'])
('b', ['blackberry', 'blueberry', 'banana'])
```

Using DataFrames—Transform

```
def my_function(df):
    ...
    return result


output = input | DataframeTransform(my_function)
```

Using DataFrames—Transform

```
def my_function(df):
    df['C'] = df.A + 2*df.B
    result = df.groupby('C').sum().filter('A < 0')
    return result


output = input | DataframeTransform(my_function)
```

Non-functional APIs
are supported as well.

DataFrame/PCollection conversion

```
with beam.Pipeline() as p:
  pc1 = ...
  pc2 = ...

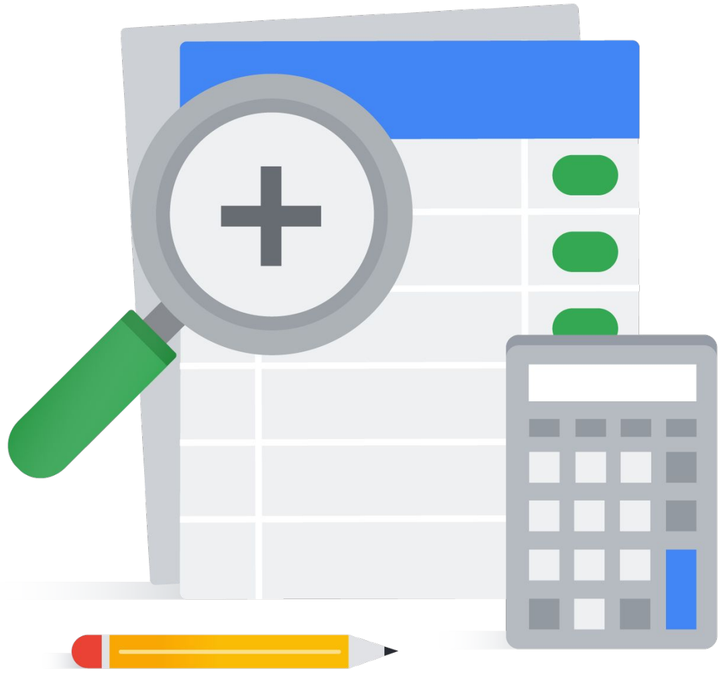
  df1 = to_dataframe(pc1)
  df2 = to_dataframe(pc2)
  ...
  result = ...

  result_pc = to_pcollection(result)

  result_pc | beam.WriteToText(...)
```

Differences from standard Pandas

- Operations are deferred, and the result of a given operation may not be available for control flow or interactive visualizations. For example, you can compute a sum, but you can’t branch on the result.



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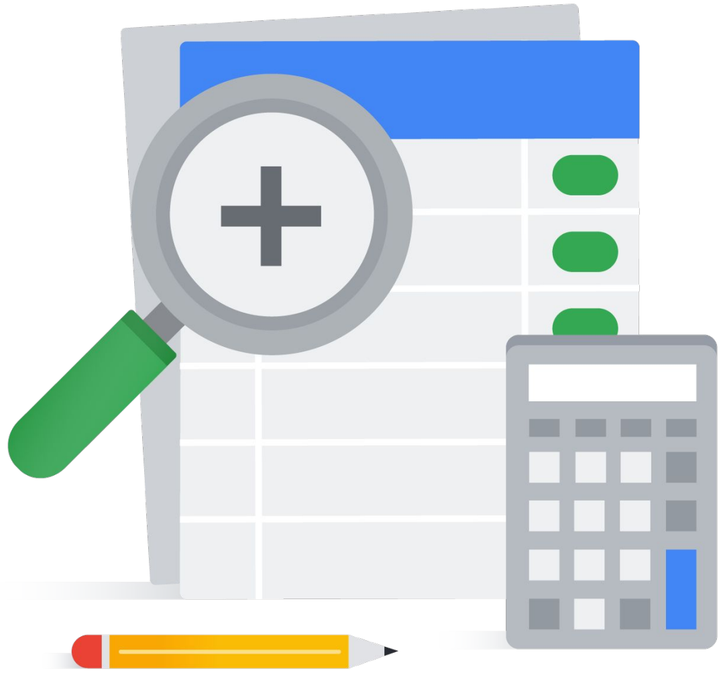

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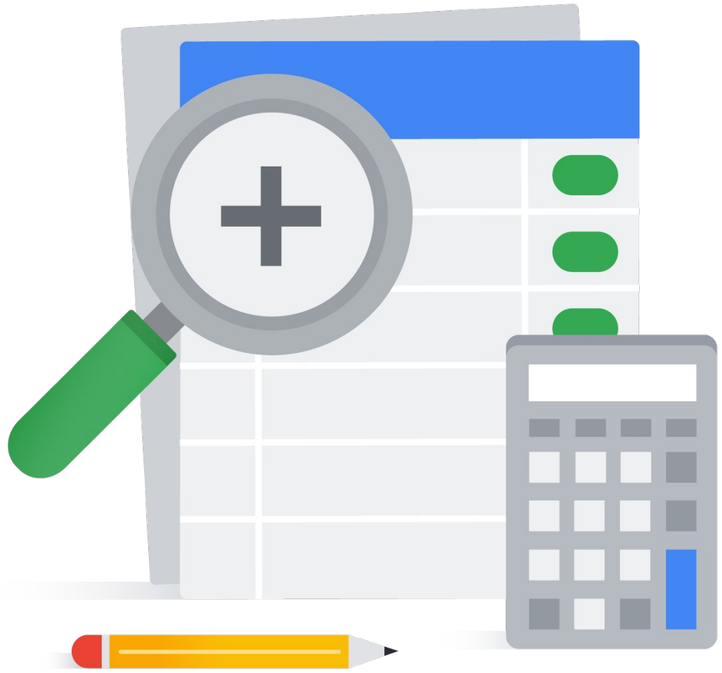
- Result columns must be computable without access to the data. For example, you can’t use transpose.
- PCollections in Beam are inherently unordered, so Pandas operations that are sensitive to the ordering of rows are unsupported. For example, head and tail are not supported.



Use case: Count words

```
words = (
lines
   | 'Split' >> beam.FlatMap(
      lambda line: re.findall(r'[\w]+', line)).with_output_types(str)
   # Map to Row objects to generate a schema suitable for conversion
   # to a dataframe.
   | 'ToRows' >> beam.Map(lambda word: beam.Row(word=word)))

df = to_dataframe(words)
df['count'] = 1
counted = df.groupby('word').sum()
counted.to_csv(known_args.output)
```

Use case: Count words

```
# Deferred DataFrames can also be converted back to schema'd PCollections
counted_pc = to_pcollection(counted, include_indexes=True)

# Print out every word that occurred >50 times
_ = (
   counted_pc
   | beam.Filter(lambda row: row.count > 50)
   | beam.Map(lambda row: f'{row.word}: {row.count}')
   | beam.Map(print))
```